SHEET METAL WORKERS' MANUAL

BROEMEL

Sheet Metal Workers' Manual

A Complete, Practical Instruction Book on the Sheet Metal Industry, Machinery and Tools, and Related Subjects, Including the Oxy-Acetylene Welding and Cutting Process

By

L. BROEMEL

With a Special Course in Elementary and Advanced Sheet Metal Work and Pattern Drafting for Technical and Trade School Instructors and Students; Also for Reference and Study by Sheet Metal Workers and Apprentices

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PREFACE

This book has been written in response to a widespread demand for a comprehensive work on the machinery, tools, and methods employed in sheet metal working. This demand comes from the trade, as well as from manual-training and technical schools.

Realizing the need for a correlated course in practical sheet metal and pattern drafting in text form, Professor J. S. Daugherty, Instructor in Sheet Metal Work in the School of Applied Industries, Carnegie Institute of Technology, Pittsburgh, Pa., has rendered valuable assistance by the preparation of such a course, with pen drawings and illustrations of actual problems, along the lines of the best shop methods, derived from years of experience in teaching the subject and as a practical sheet metal worker. The course is outlined and the problems are presented in such sequence that the processes and machine operations are reviewed with each new problem.

It is not expected that all the problems given by Professor Daugherty will be strictly copied, but rather that they will make clear the methods and processes that may be applied in the construction of similar problems in actual practice. The proper sequence, so necessary for successful instruction in sheet metal pattern drafting, is an important feature of this course. Many of the problems are only partly solved, which prevents the student from copying from the text and compels him to develop his power to think as well as to draw. It is desired that this course may be regarded as presenting the essentials of sheet metal work, rather than as an attempt to produce a series of models.

After a perusal of the correlated course in sheet metal working and pattern drafting, attention may well be directed to the chapters in this book on Oxy-Acetylene Welding and Cutting, Electric Welding, Hand Forging and Welding, and other information that does not directly deal with sheet metal work and pattern drafting, but includes subjects intimately connected with sheet metal working practice. These subjects are having extensive introduction in the modern sheet metal shop. Schools teaching sheet metal working as an industrial art should therefore in the preparation of their courses, arrange for lectures that will convey to the mind of the student that there are other methods for joining together sheet metals besides riveting and soldering. Any one school term does not permit extensive practice of these processes, but the student should know something about them, to qualify him for a place abreast of his fellow-workmen on establishing himself in the industrial shop. If the time for lectures on these subjects is not afforded, it can be suggested that the student read up on the same.

The principal author of this book has been for many years active with The Peck, Stow & Wilcox Co., of Southington, Conn., foremost manufacturers of sheet metal working machinery. He presents a collection of data on the construction and application of modern sheet metal working machines and tools, describing their purposes and uses with pen drawings and other illustrations in as practical and non-technical a manner as possible, making the instruction given easy to follow. During eighteen years of service with the manufacturers named, he has gained a broad experience in sheet metal working machinery development, and offers here a source of information of great value to all those interested in sheet metal work, and the labor and time saving equipment so necessary for bringing to a finished stage of completion the many problems that daily confront the sheet metal worker in the shop.

The author, having spent a lifetime with the tinsmith and sheet metal worker, during that time has visited many shops the country over. It is surprising to observe how limited is the knowledge of a large percentage of apprentice and advanced sheet metal workers regarding the essentials of machine and tool construction and application. Therefore, the subject of sheet metal working machinery and tool construction, their uses and application, is treated in these pages in an extensive way. It is suggested that the school instructor make the student fully acquainted with all equipment used, pointing out the adjusting features in such machines, and fully explaining their operation.

It is also recommended that the student educate himself on machines and tools that are not used in the school classroom, so that he will not feel awkward or embarrassed when entering the commercial field in pursuit of his trade, to find in the shop where he is employed equipment with which he is not familiar, and different from similar machines and tools on which he received his school training.

An examination of the Table of Contents will show that the range of other subjects covered is such as will make a valuable and well-rounded course of instruction.

The author is greatly indebted to The Prest-O-Lite Company, Indianapolis, Ind., for the instructive course given on oxy-acetylene welding and cutting; and he feels grateful indeed to the Buffalo Forge Company, Buffalo, N. Y., for exercises given on hand forging and welding, which were prepared with the assistance of Professor L. E. Nollau, of Kentucky State University; Professor James Littlefield, of the Cleveland Technical High School, and Mr. Robert M. Smith, Supervisor of Technical Work in the High Schools of Chicago.

Acknowledgments are also due, and are hereby tendered, to The Metal Club, Philadelphia; The Art Metal Construction Company, Jamestown, N. Y.; The Peck, Stow & Wilcox Company, Southington, Conn.; Follansbee Brothers Company, Pittsburgh, Pa.; and the Federal Board for Vocational Education, Washington, D. C., for various courtesies in connection with the preparation of this volume.

The manufacturers mentioned above are all well known in technical school and industrial fields, and a cordial invitation is extended to our readers to communicate with them or visit their large manufacturing plants, in pursuit of further knowledge on any of the subjects covered in this book, or equipment relating thereto.

It is hoped that this work, the first of its kind ever attempted in one complete volume, will prove helpful to industrial teachers, students, apprentices, sheet metal workers, and all others interested in sheet metal work. Its great advantage is that all information of interest to the industrial sheet metal worker is contained in a single comprehensive volume; and as the ambition of the student develops he will find all these things of great importance for a practical worker to have at his command.

L. B.

CONTENTS

IX

X

XI

XII

XIII

XIV

XV

SHEET METAL WORKERS' MANUAL

I

SHEET METAL INDUSTRY

Extensive Use of Sheet Iron and Steel.—The greater part of the iron tonnage of the many mills all over the world is rolled into sheets and sold to manufacturers using sheet metal. Sheet metal has qualities that make it the best material for numerous products used in the home, office, and factory, on the farm, in railroad rolling stock, automobiles, pleasure boats, merchant vessels, etc. Stringent fire laws are rapidly replacing wood with sheet steel in many structures. It is more economical than wood; it is indestructible, fireproof, light in weight, and very durable, and the finished product presents a pleasing appearance.

Sheet Metal Products.—The list of manufacturers using sheet steel and iron in their products is long and ever increasing. A few of their products are named below:

Acetylene gas machines
Advertising signs
Agate and enamel ware
Ash cans
Automobiles
Bakers' and confectioners' utensils
Bar fixtures
Bedsteads
Blower systems
Blower and power fans
Building lath
Caskets
Clothes driers
Commercial automobile trucks
Cornice and skylights
Culverts
Dairy and creamery machinery
Electric advertising signs
Elevators
Factory equipment — Benches, hand trucks, lockers, stools
Fireless cookers
Fire extinguishers
Fireproof doors
Feed troughs

Freight cars
Gaskets
Heater pipe
Hospital furniture
Incubators and brooders
Kodaks
Lamps
Laundry machinery
Locomotives
Metal barrels
Metal stampings
Milk cans
Motor boats
Oil tanks
Pipe elbows
Portable garages
Portable hen houses
Railroad passenger cars
Refrigerators
Refrigerating and ice machinery
Rowboats
Silos
Soda fountains and apparatus
Steamships
Steel furniture and cabinets
Store bins
Store fronts
Stoves, ranges and furnaces
Tinware
Toys
Ventilating systems
Ventilators
Washing machines
Wash tubs
Water coolers
Watering troughs
Window sashes

The Tin Roof.—A roof of tin protects our nation's most treasured buildings and safeguards its priceless treasures and relics. America's foremost residence, the White House, is roofed with tin, also the adjoining executive offices. Needless to say, critical discrimination—taking into account effect and appearance, as well as protection from the elements, durability, and real economy—led to the adoption of this type of roofing for the President's home.

Tin is not combustible. A tin roof is an unbroken sheet of metal, with no cracks or openings of any kind to admit fire.

In a fire at Scranton, Pa., flames swept across the roofs of three adjoining buildings on Lackawanna Avenue. The center building had a tin roof. Those on either side were roofed with slag. Both of these slag roofs caught fire and burned through, communicating the fire to the interior of the building. But the building in between them—covered with tin—was uninjured.

Such instances may be multiplied hundreds of times and are a matter of common knowledge. The fire-resist-ing properties of tin roofs are amply attested by fire departments, and by the insurance underwriters in the more favorable rates granted on buildings covered with tin.

Sheet Metal Furniture.—Sheet metal is now extensively used for office furniture. Of great importance in every business are the records, letters, contracts, and other papers which insurance cannot replace. Sheet metal furniture and files afford protection from fire.

A fire test conducted by a congressional committee at Washington, D. C., proved conclusively that fire severe enough to slightly char the edges of papers in a metal vertical file unit will totally destroy a similar cabinet of wood.

At the time of the great Baltimore fire the Baltimore Trust Company had four metal steel cabinets in use in their banking room, and the canceled checks, books, vouchers, coupons, etc., contained in the steel cases were found intact and perfectly preserved.

Metal desks represent the best architectural taste in their quiet dignity and correct proportion. They are very substantial, but not cumbersome; designed on straight simple lines, faultless in detail. They can be finished to match any wood trim and are a distinct addition to the finest interiors.

Building Trim of Metal.—The New York Municipal Building is probably the most complete and handsome in the world. It is fireproof throughout, with all trim of sheet metal, and in this "age of steel" it is worthy of note that there is steel office equipment on twenty-two floors, in twenty-five departments of the municipal service.

Architects more and more specify sheet metal in place of wood trim for buildings. Contractors have come rapidly to see the advantage of sheet steel over wood, as it adds an extra quality to their work at no increase in labor cost. It gives them the prestige that comes with having the good condition of a building observed and remarked upon after years of use.

Sheet metal is an essential in constructing buildings of every description. The appearance test is a time test—a question of durability.

It is interesting to observe that metal lath, sash, and trim were used exclusively in the Woolworth Building in New York City.

Steel Boats and Cars.—Steel has replaced wood in the motor boat, passenger coach, electric car, and subway coach. It is in general use in the manufacture of automobiles and goes into the interior equipment of battleships and steamships. During the great World War tons of sheet steel have been purchased by the United States Government and its manufacturers for use in marine construction.

A Government contract was recently awarded for 38,800 tent stoves. This was but the beginning of buying for this purpose, and it seemed probable that eventually the Government orders would exceed 300,000 stoves. For the contract named, about 550 tons of sheets were required.

ADVANTAGES OF ROOFING TIN

Something like a hundred years ago America began the use of roofing tin—imported from Europe. Domestic tin plate first was made in 1830, in Philadelphia.

Durability.—So far, nobody has undertaken to fix a limit on the durability of the tin roof. The National Association of Master Sheet Metal Workers is authority for the statement that where good tin is used, and good workmanship, the roof can be expected to last as long as the building stands, with no further attention except painting.

Philadelphia's oldest tin roof dates back to 1835, according to information in the files of the Philadelphia

Sheet Metal Workers' Association. It is on the Horace Binney residence, 243 South 4th Street, now owned by the Pennsylvania Railroad and used for office purposes. The present roof is believed to be the same as was laid, over shingles, by the late Jos. Trueman, Quaker tinsmith, in 1835 or thereabouts. The records of the Association show many instances of tin roofs laid thirty, forty and fifty years ago, which remain in good condition today.

At Bethlehem, Pa., the Moravian Seminary was roofed with tin, in 1836. The roof is still in good condition, at this writing—over eighty years afterwards.

In New York state, at Cherry Valley, stood Judge Morse's office building, until 1908, when this building was taken down. The tin roof was found to be in good condition after ninety-five years' service.

Many notable roofs furnish testimony on the durability of tin as a roofing material. Everywhere roofs of tin, in service for a half-century, are to be found in excellent condition and apparently good for an indefinite period.

Lightness.—Besides affording long-time protection from the elements, roofing tin, being light in weight, imposes no unusual strain on supporting walls. In this way, the tin roof adds to the durability of the building itself. In Jersey City a large church was condemned as unsafe, because of the heavy weight of its slate roof. The slate was removed, roofing tin put on, and the structure saved from demolition.

Repairs Easily Made.—Roofing repairs are easily and economically made, when the roof is tin. They can be made in any kind of weather—regardless of rain, snow or temperature. And a repair in a tin roof is permanent. With other forms of roofing, almost without exception, repairs require removal and replacement of large areas—usually involving considerable expense and generally leaving the roof in an imperfect condition, which becomes a source of future trouble. With the use of roofing tin, properly laid, future trouble and expense are practically eliminated at the very beginning.

Base Plates for Roofing Tin.—For a roofing tin to wear well, the base on which it is made must be protected by a properly applied coating of tin and lead. The base plate must be free from chemical elements which cause corrosion or pinholing, and must be soft, pliable, and ductile. All these necessary qualities are determined or governed by the process by which the base plate is made from the raw materials, and its subsequent treatment.

Practically all the high-grade roofing tin plates manufactured in this country today, are based on the mild, soft steel produced by the open-hearth process. This steel, being hammered into billets and cut into convenient sizes for handling, is rolled down into "tin bars," 8 inches wide by 20 to 30 feet long. The bars in turn are cut into certain sizes to correspond to the sizes of base plates desired. These pieces then go through the following operations to reach the stage of finished plate:

First, they are hot rolled into plates of the size and gauge desired. Then they go through the successive processes of pickling, washing, first annealing, cold rolling, second annealing, and second pickling. They are once more thoroughly washed, and are then ready for tinning.

VARIOUS KINDS OF SHEET METAL

Special reference has been made to roofing tin, because of its importance to the sheet metal worker in the average shop. Bright charcoal tin for tinware manufacturing and other purposes, galvanized sheets, and sheets having a coppered, nickeled, or polished finish, all go through the same process of manufacture as the roofing tin plate. They all have their origin in the base plate material.

Charcoal tin has a dead black finish before it is dipped in pure tin, while the roofing tin plate is dipped in a mixture of tin and lead; and the galvanized sheet, so extensively used in the sheet metal shop, is dipped in spelter. Other finishes are treated by special methods and dipped in their own solutions. But if we could take any of these plates or sheets and scrape their surfaces down to the base plate, we would find that all of them, no matter how finished, originate from the black sheet.

Steel sheets for special uses in press work, etc., are produced through special annealing.

Among the "Useful Tables" at the end of this volume, complete information will be found on weights and standard gauges of tin plate and galvanized sheets, as well as other data of interest to the student.

The sheet metal working industry today also employs very extensively aluminum, brass, copper, and zinc sheets, all of which are easy working materials, except what is termed "hard" and "half hard" brass. When attempting to apply sheet metal working machinery to operations in brass, where the brass is hard or half hard, it is always advisable to confer with the machinery manufacturer, to secure an expert decision as to whether the machine is well adapted for the working of brass in its special degree of hardness.

The student, after leaving the school and establishing himself in a sheet metal shop, is often called upon to make a recommendation of the best equipment and material the market affords for operations in sheet metal work. It is suggested, therefore, that the student should familiarize himself with the different grades and kinds of materials, so as to be able to specify the gauge and special grade of material to which particular machines or tools should be applied.

In our chapter on sheet metal working machinery, the capacities of all machines given apply to iron or soft steel; and as sheet steel is manufactured in different degrees of hardness, this has a great effect on all machinery made for sheet metal working operations. Where material is used outside of the average soft-grade stock, the machinery manufacturer should receive this information, on which to base his recommendations.

IMPORTANCE OF SHEET METAL WORK

Sheet metal work is an increasingly important cog in the wheels of industry. Before the Great War it had become an essential factor in practically every branch of the metal trades. During the war this industry has suddenly sprung into greater prominence, but has been seriously handicapped by the lack of skilled mechanics. After the war the work of restoration will undoubtedly bring with it a tremendous need for men skilled in all sheet metal trades.

Automobile, aeroplane, and truck makers, as well as metal furniture, metal ceiling, and metal roofing manufacturers, are now looking to the technical schools for assistance. Sheet metal working is now, indeed, a most fertile vocation.

That this opportunity is recognized by school officials and instructors is evidenced by the number of technical and high schools now adding sheet metal courses.

A Growing Industry.—Sheet metal work is a large and growing industry. It is intimately connected with the building trades and an increasing proportion of the costs of building are spent for cornice work, roofing, skylights, ornamental ceilings, ventilating, heating, etc. The rapid growth of the automobile industry requires the labor of thousands of men on bodies and radiators, and the invention of sheet metal boats and a large line of metal furniture are opening up new fields every day. Today more than ever, the sheet metal working trades offer unusual opportunities to young men who possess the necessary training. The work is not confining, not unhealthful, and not dangerous, and the wages paid to the competent man in the sheet metal trades compare favorably with the wages paid in any similar skilled occupation.

This brief outline of the sheet metal industry shows a wide field of opportunity for the student and apprentice, as well as the tinsmith who complains that his trade is of less importance, owing to the introduction of modern methods, which now produce rapidly and in great quantities the tinware he used to turn out with great skill by hand.

It may not be amiss to mention here to the ambitious student who has selected sheet metal working as a vocation best suited to his qualifications, that early ambitions are very beautiful and alluring, but if they are not followed up and realized in actions—if our efforts to make our dreams come true are postponed—they will begin to fade, and our purpose will not prove quite so forceful, our desire to achieve will not be quite so insistent—and before we know it our ambition is dead.

Multitudes of young people who are eager to get an education to build up an honorable career go to the trade school and work hard, but after graduation slacken their efforts. They think that they are going to retain all they have acquired, and that their education is complete, not realizing that in reality it is only the beginning. The young man whose mind is constantly reaching up for something higher and better, always trying to inform himself, who is ever eager to absorb knowledge from every possible source, is made of winning material.

If you are studying to be a machinist, engineer, or sheet metal working contractor, make yourself a first-class one—king in your line, whatever it is. There is a great demand for sheet metal workers who are experts in this art. Some percentage of this demand is supplied by men who profess mastership of their trade, but are slow to think, having hands that do not move in unison with their minds. Manufacturers are compelled to send these men, at a late date of life, to our evening trade schools to improve their skill and enable them better to cope with ordinary shop problems.

A noted school instructor conducting evening classes in sheet metal work has stated that many men enter his class claiming years of experience in the trade, and do not know of the existence of many common, ordinary tools and machines used in daily shop practice, an essential form of knowledge for successful sheet metal working practice. As a consequence, the school instructor is forced to give a great deal of valuable time to a subject that might be self-taught, with a loss of many valuable hours during the school term, which could be better applied to the actual work of developing the many problems in these pages.

With this in mind, no efforts have been spared in the preparation of the information given in these pages pertaining to shop equipment. The author has attempted to qualify his reader to handle such equipment with good judgment as he goes from the school into the commercial world and moves from one shop to another. The trade school which he attended may have had one type of machine and when the student enters the shop as an apprentice he may find a different machine, the operation and adjustment of which he is not familiar with. It is urged upon the student to carefully peruse the valuable information given in these pages pertaining to machinery and tools and other subjects which are intimately connected with sheet metal working. No instructor during any one school term has the time to review these matters in detail, but the presentation of this complete work permits of acquainting our readers with these mechanical appliances, so that they may teach themselves.

Subscribe to any one or more of the good trade journals on sheet metal working. Keep in touch with the development of the industry in which you are striving to gain or to hold your place as a master. Follow the progress of the manufacturer who makes your favorite tools or machines. Maintain a catalog library of your own. Read mechanical books intimately connected with your trade. Welcome the ideas of others, and try to improve upon them. Experiment with the many formulas given in these chapters. These things will all help to make you an expert sheet metal worker.

Sheet metal working is not the vocation of a "jack of all trades," but an art that if once acquired and practiced with an ambition that does not die on the threshold when leaving the school, will develop trained workers fully qualified to solve the sheet metal problems that arise in every shop.

II

SHEET METAL WORKING MACHINERY

SQUARING SHEARS

Many kinds of shears are manufactured for cutting sheet metals in various shapes. But although confined in their work to squaring and trimming, no other shears prove so valuable and have such an important function in mills and in the shops of the small and large sheet metal worker and manufacturer as the *squaring shears.* When tin plate, sheet iron, brass, copper, or aluminum is ordered from the mill in sheets of large size, they must be sheared, or cut and trimmed, to a desired size for the article manufactured. We cannot start the progress of the material that is to be utilized on its way through the shop before it is properly cut to accurate size for the forming and shaping operations to follow.

The squaring shears, whether foot operated or driven by power with a belt or through a direct-drive motor, are alike in their operating principles and practicability, except that the crosshead or gate to which the upper cutting blade is fastened on the foot power squaring shears is drawn down through pressure brought to bear on a foot treadle, while the power squaring shears are driven with a belt from a line shaft and sometimes with a motor fitted in direct connection with the driving gears. On power squaring shears the stroke of the crosshead or gate is controlled by means of an automatic positive clutch. The clutch in the power squaring shears is tripped with a slight depression of a foot treadle, and unless the treadle is kept depressed the motion of the crosshead or gate will stop automatically at its highest point after making one cut, without any stoppage of the flywheel.

Foot Power Squaring Shears.—When using the foot power squaring shears it is the usual practice to insert the material between the cutting blades from the front of the machine, although it is customary in some shops to feed from the rear of the machine. The latter method of cutting with the squaring shears is more usually practiced when short pieces are to be cut from sheets of great

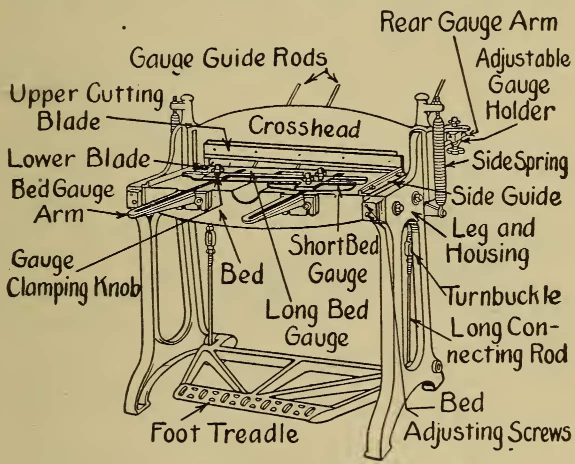


Figure 1.—Foot Power Squaring Shears.

length, for the purpose of allowing more freedom in operating the foot treadle; but when the sheet can be handled conveniently, the best results are secured when it is inserted in the usual way, from the front of the machine. When entering the sheet from the rear of the machine, the front bed gauges are used, and where the piece to be cut is larger than the bed in the machine, the bed gauge is carried out on the front bed gauge arms, provided for gauge extension. In squaring and trimming small pieces, the material is inserted in the machine between the cutting blades from the front of machine, gauging the work on the bed with either the short or the long bed gauge, or with the rear gauge, suiting the work that is to be sheared.

A rear gauge attachment, furnished with the squaring shears, consists of two rods which are fastened to the crosshead or gate of the machine and to which two adjustable gauge holders are attached. Through these gauge holders the gauge is adjusted to suit the size of strip to be cut, by moving the gauge to and from the lower cutting blade; and after the correct position of the gauge

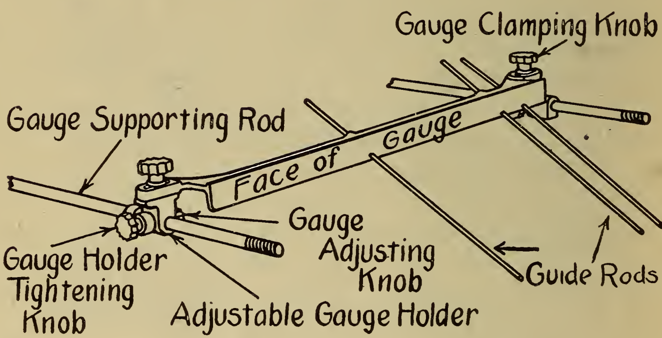


Figure 2.—Rear Gauge Attachment for Squaring Shears.

is secured it is made tight through hand wheels in the gauge holders. Gauge holders are provided with means for accurate and fine adjustment of the gauge. The gauge guide rods are intended to assist very light sheets to find their way to the face of the gauge; otherwise, the material might slip under the gauge, which would result in the making of a false or inaccurate cut. Sheets with usual stiffness will strike the rear gauge straight and true without the aid of any guide rods. Squaring shears are fitted with side guides, fastened on each end of the bed to facilitate more accurate squaring; a true cut being impossible unless the sheet to be squared or trimmed is pressed firmly against the side guides, at the same time allowing it to strike evenly with the rear or front gauge, whichever may be used.

A graduated scale in fractions of inches is cut in the bed of the squaring shears along the slot in which the bed gauge bolts move. This scale, when setting the bed gauges, may be depended upon as accurate until the cutting blades are ground, when the accuracy of this scale is lost and it is advisable to secure all gauge settings, measuring from the cutting edge of the lower cutting blade to the face of the bed gauge with an ordinary rule; and after correct alignment of the gauge is secured clamp the gauge securely by the gauge clamping knobs.

Foot power squaring shears are manufactured in a wide variety of sizes and capacities. Where the material to be cut is not heavier than No. 20 gauge iron (U. S. Standard), the market offers a light weight squaring shears with cutting blades measuring 30 inches in length. The foot power squaring shears shown in Figure 1 has a capacity for cutting No. 18 gauge iron and lighter (U. S. standard), and is manufactured in several sizes, the cutting blades measuring 22, 30, 36, 42, and 52 inches, respectively. Larger squaring shears of the same capacity, though somewhat different in construction, are also offered in sizes 62, 72, 96, and 120 inches. Heavier types of foot power squaring shears are manufactured for cutting as heavy as No. 16 gauge iron (U. S. Standard), in sizes 30, 36, 42, and 52 inches. When the material to be cut is heavier than No. 16 gauge iron, a power squaring shears should be used.

Squaring shears cut fully the lengths mentioned and overrun about 1 inch, and the housings are far enough apart that sheets in width equal to the cutting length can be passed through from front to back without obstruction. The capacities given apply to iron or soft steel. In cutting steel running higher in carbon, the hardness of the stock must be taken into consideration and the extreme thickness reduced accordingly. Squaring shears should never be used for material exceeding the extreme thickness given by the manufacturer, even if the pieces to be cut are narrow. In selecting a squaring shears it is always well to figure on ample leeway, as the capacity of the machine is influenced by the sharpness of the cutting blades and by the care with which adjustments are kept up by the operator.

"Hold Down" Attachment.—Foot power squaring shears in all sizes for cutting No. 16 gauge iron, and those for No. 18 gauge iron, 36 inches and larger, have a "hold down." (See Hold Down, Figure 4.) According to the style of the squaring shears, the hold down operates automatically with the stroke of the gate or crosshead (see Figure 4), and on some types of squaring shears the hold down operates independently by hand. In either case the hold down causes a uniform pressure to bear upon the sheet of metal while the cut is being made, preventing the drawing of the sheet from between the cutting blades. Without the hold down the pressure on the material is influenced with the hands and usually allows the material to draw away from between the cutting blades when making the cut, causing very inaccurate and unsatisfactory cutting. Therefore, according to the size of the machine and the gauge of material to be cut, the hold down has an important part. On very light material accurate cutting is possible without the hold down, particularly on squaring shears of short length.

Foot Power Gap Squaring Shears.—I have described the squaring shears (Figure 1) as having housings far enough apart that sheets in width equal to the cutting length can be passed through from front to back without obstruction,—a cutting feature which is also practical with the foot power gap squaring shears (Figure 3). The construction of gap shears gains for them an additional cutting advantage for cutting sheet of any length and of a width limited by the throat or gap in the housings or frame. A very convenient slitting gauge is attached to the right-hand housing for use in slitting sheets longer than the cutting blades. After the first cut the edge obtained at the previous stroke serves as a guide for the succeeding cuts and in this manner alignment of the successive cuts is obtained.

Foot power gap squaring shears are manufactured in

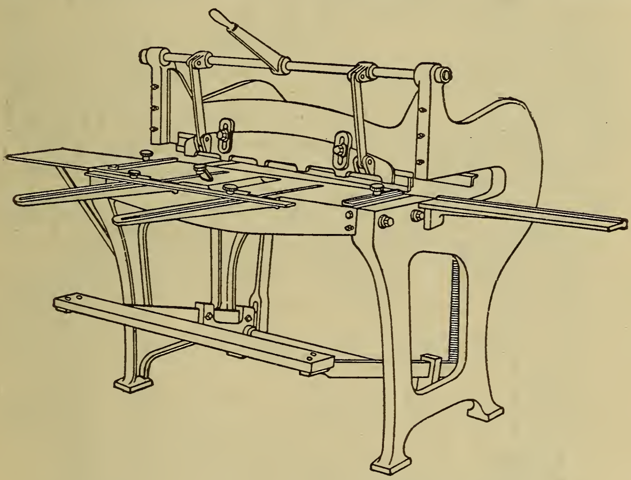


Figure 3.—Foot Power Gap Squaring Shears.

cutting lengths 36, 42, and up to 52 inches for special requirements, with a maximum capacity for cutting No. 16 gauge iron (U. S. Standard), and are made with a throat or gap of 18 inches.

Power Squaring Shears.—Figure 4 shows a power squaring shears of modern design with the driving mechanism overhead, out of the way of the operator and free from the dirt and scale that usually fall from the sheet metal that is being cut. The housings have a gap of 1 inch to the edge of the cutting blade to permit of trimming sheets of any length before squaring. The gap referred to also allows for sheets to be moved into cutting position sidewise without obstruction. The power squaring shears, overhead drive, are manufactured in lengths 30, 36, 42, 48, 60, 72, 96, 120, and 144 inches, and in a wide range of capacities.

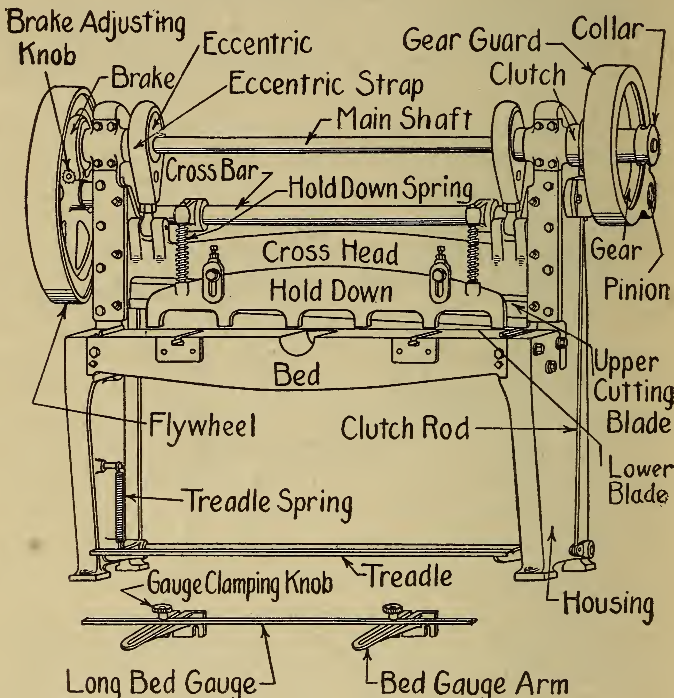


Figure 4.—Power Squaring Shears, Overhead Drive.

The machine shown in the illustration has a capacity for cutting No. 14 gauge iron and lighter.

Power Gap Squaring Shears.—Figure 5 illustrates a power gap squaring shears of new design, with the driving mechanism overhead. The same advantages already described as applying to foot power gap squaring shears (see Figure 3) are true with power gap squaring shears, but they are made with a depth of throat or gap in the housings of 15 and 18 inches, and in a range of sizes and capacities as mentioned under power squaring shears, overhead drive, Figure 4.

The machine illustrated (Figure 5) has a capacity for cutting No. 14 gauge iron and lighter (U. S. Standard).

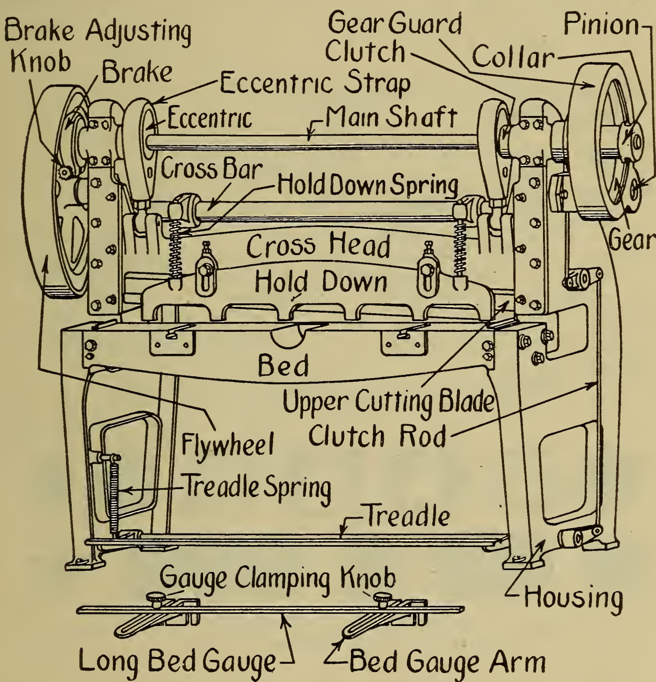


Figure 5.—Power Gap Squaring Shears, Overhead Drive.

LEVER SLITTING SHEARS

Sheet metal cutting lever shears are manufactured in various designs, intended for general shearing, trimming, and cutting, each claiming their particular advantages. The lever shears which I am about to describe may be summed up in three classes, namely, the combined bench and slitting shears, the scroll shears and the lever slitting shears.

Bench and Slitting Shears.—Figure 6 illustrates a general utility shears surpassing all other shears in the variety of work performed, and which often proves a desirable substitute where the work is too large or not of sufficient quantity to warrant the use of costly dies. The lower cutting blade is stationary, so that when cutting to line the mark may be easily followed with accuracy; and the line scribed is always exposed to the view of the operator, permitting of outside cutting, straight, or irregular cutting. It also allows for inside cutting on a sheet of metal, making a straight or irregular cut along a scribed line, avoiding the cutting of the outer edge of the sheet.

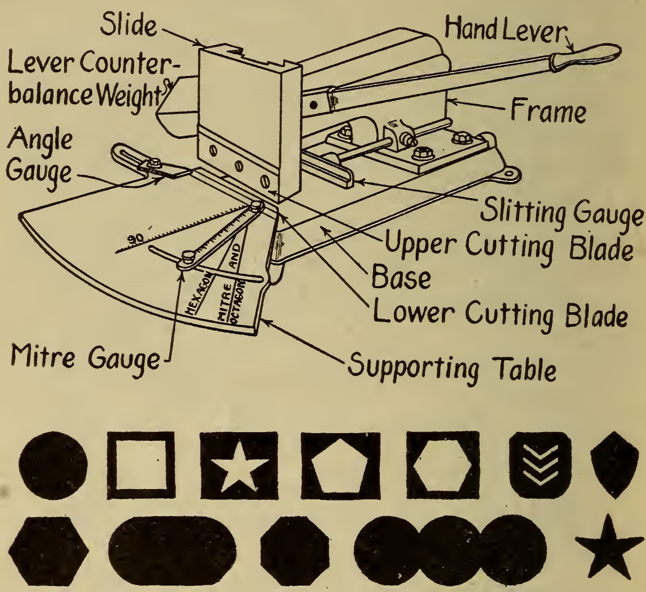


Figure 6.—Combined Bench and Slitting Shears, with Illustrations of Work Cut from Blanks to Line.

The upper cutting blade is fastened to a slide which moves in guideways parallel to the lower cutting blade by means of a counterbalanced hand lever, and is provided with a suitable table and adjustable angle and miter gauges, in addition to having a gauge in the cutting head or frame for straight slitting.

The combined bench and slitting shears are manufactured with cutting blades measuring 6½ and 9 inches,

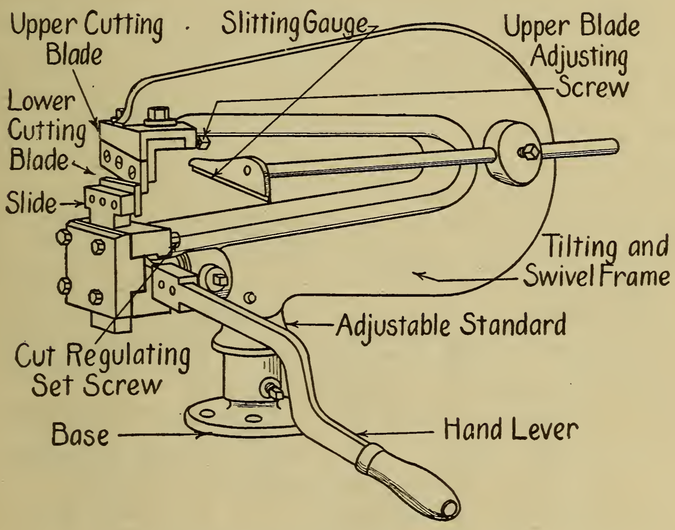


Figure 7.—Scroll Shears.

with a depth of throat in the cutting head or frame of approximately 9½ and 19¼ inches respectively; and with a maximum capacity for cutting No. 18 gauge iron and lighter (U. S. Standard), using the smaller machine, and 12 gauge iron and lighter (U. S. Standard) when the larger machine is used.

Scroll Shears.—The scroll shears, Figure 7, has the same cutting utility, and in many ways it resembles the combined bench and slitting shears, Figure 6. But it has a smaller cutting blade and differs in respect to adjust-

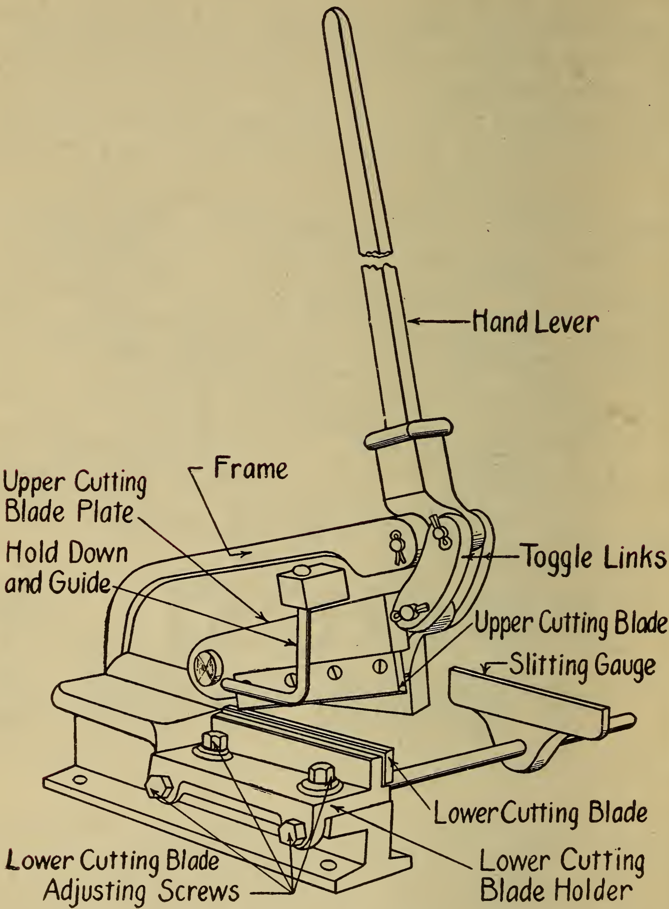


Figure 8.—Lever Slitting Shears.

ment and operation of the cutting blades, claiming an additional feature over the combined bench and slitting shears in having a tilting and swivel frame. The lower cutting blade in the scroll shears is fastened to a slide, which moves in guideways parallel to a fixed and stationary upper cutting blade by means of a hand lever. A set screw in the frame back of the lower blade regulates the length of cut, and through easy manipulation of this adjustment the benefit of a full cut or a fraction thereof is secured. The scroll shears is very useful in cutting circles, ovals, irregular curves, and such work, and its construction allows for cutting on the inside of a sheet of metal without cutting the outer edge. The frame will revolve in the standard and is adjustable to any angle required to suit the cutting in progress.

The scroll shears are manufactured in two sizes, with cutting blades measuring 4 and 4¼ inches, with a depth of throat in the cutting head or frame of approximately 10¾ and 17 inches respectively; and with a maximum capacity for cutting No. 20 gauge iron and lighter (U. S. Standard).

Lever Slitting Shears.—Unlike the shears already described (Figures 6, 7) lever slitting shears will not cut on the inside of a sheet without cutting the outer edge, but they have their advantages for general straight slitting and are so patterned as to allow of the slitting of sheet iron in any length or width.

A serviceable and useful lever slitting shears is shown in Figure 8. A lower cutting blade of 8 inches is fastened to a holder which is adjustable for taking up the wear of the cutting blades; and an upper cutting blade of the same length is fastened to a plate reinforced by the frame, the cut on a sheet of metal being made by means of a hand lever. In addition to having an adjustable slitting gauge, an angular shaped rod fastened to the frame serves as a guide and hold-down, which facilitates the cutting of sheets of any length.

The maximum capacity of the lever slitting shears described is No. 12 gauge iron and lighter (U. S. Standard).

ROTARY SLITTING SHEARS

Rotary slitting shears are extensively in use and offered in a variety of sizes and capacities, but in principle they are nearly all the same. Their construction consists of a frame with a deep throat fitted with parallel cutter shafts connected by gears, and the slitting is done by means of a hand crank, or with a belt when the machine is fitted with pulleys and arranged for power drive.

As with all shears having a throat, the depth of the throat is the determining factor as to the width of a sheet of iron that the shears will cut. The rotating of the cutters draws the material through the machine, and if the sheet of metal during the progress of cutting is pressed firmly against the slitting gauge, a clean straight cut is assured. The fact must not be overlooked that, when shearing very narrow strips, rotary cutters have a tendency to curl and twist the material out of shape; and when the shearing of perfect narrow strips is most important, the squaring shears with a hold-down are the only shears that are so constructed as to make a clean cut without twisting or buckling the material.

In the rotary slitting shears provision is made for taking up the wear of the cutters, and in setting the cutters care and good judgment should be exercised, so as to allow them to rotate freely; and they should not bind or rub against each other too hard.

The rotary slitting shears affords a rapid means for slitting sheet iron used in cornice, furnace, blow pipe, ventilation work, etc., and may be utilized for conveniently cutting irregular curves and circles of a large radius when following a scribed line, in a fraction of the time it takes to do the work with the ordinary hand snips or with the bench shears.

Figure 9 shows a rotary slitting shears mounted on heavy cast iron legs, intended for floor use. The rotary cutters have two cutting edges, making them reversible. The hand crank is adjustable to different leverages, shortening the leverage for speed when cutting very light material; a longer leverage being necessary when cutting

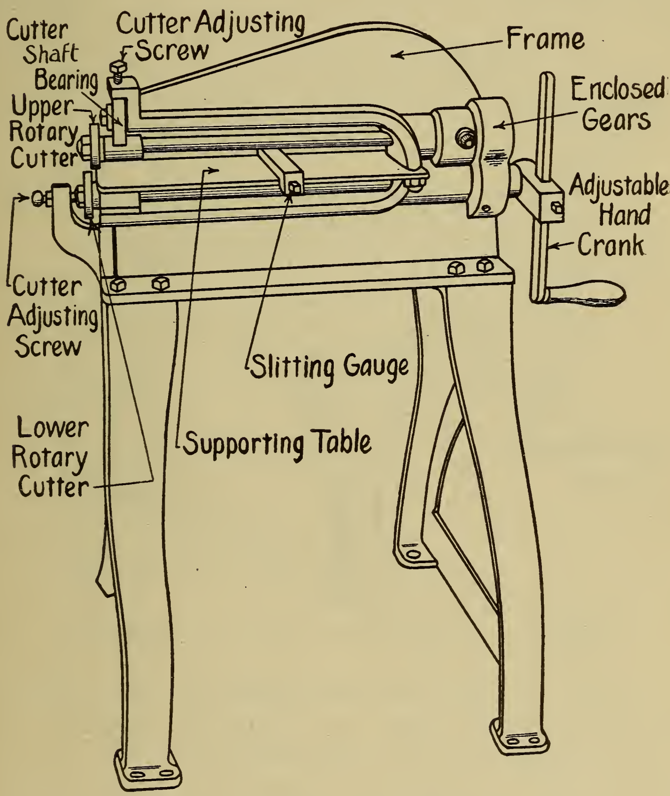


Figure 9.—Rotary Slitting Shears.

heavy sheet iron. Having a depth in the throat of 18 inches, the shears will slit a sheet 36 inches wide. Where floor space in a shop is limited, this machine offers a splendid substitute for the long length squaring shears.

The capacity of the rotary slitting shears, Figure 9, is No. 16 gauge iron and lighter (U. S. Standard).

Figure 10 illustrates a useful bench rotary slitting shears having a depth of throat of 9 inches and a capacity for cutting No. 20 gauge iron and lighter (U. S. Standard).

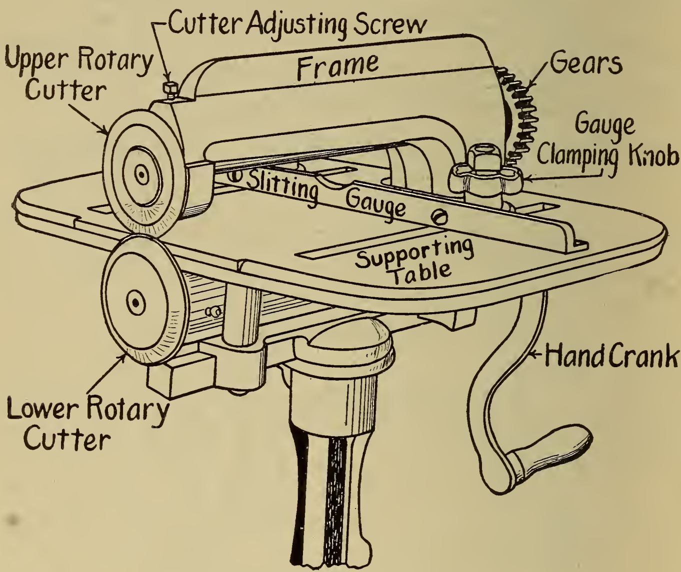


Figure 10.—Rotary Slitting Shears for Bench Use.

Angular Cutters.—Another type of rotary slitting shears is shown in Figure 11. Unlike the machines illustrated in Figures 9 and 10, the cutters in these shears are fitted to angular shafts, the lower rotary cutter remaining in a fixed position, while the upper cutter may be raised out of contact with the lower by means of a cutter raising hand wheel, which permits cutting inside of a sheet of metal without cutting the outer edge. In these shears the depth of throat is 36 inches and it is claimed for this machine that it will cut No. 14 gauge iron and lighter (U. S. Standard). It meets the requirements for an efficient, practical, easily operated machine for the slitting of the sheet metal members so extensively used in ventilation, furnace, auto body and fender work, etc.; the angular position of the cutters permitting a clean

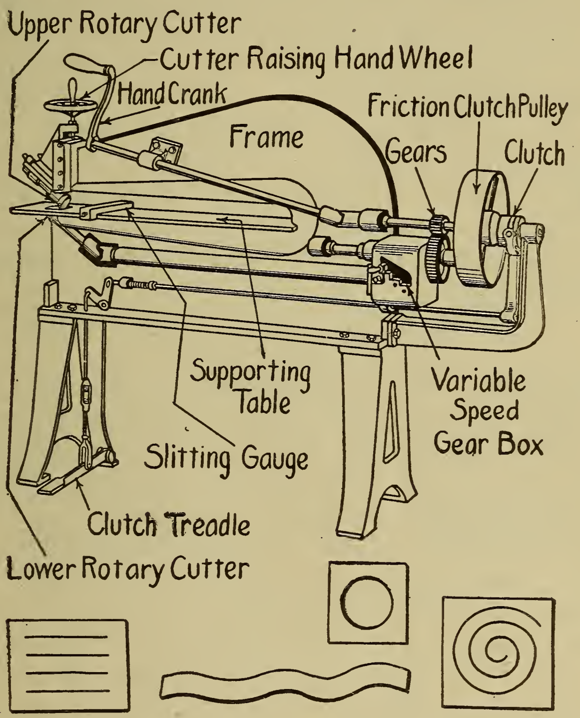


Figure 11.—Rotary Slitting Shears with Angular Cutters.

cut to be made on the inside as on the outside of the work.

Squares, ovals, S-shaped curves, or any serpentine irregular curve with radius as small as 2 inches and larger, can be cut in the center of sheets without cutting in from the side, leaving the material flat and with clean and true edges. Where work is laid out and cut to line, circles may be cut from square blanks 4 inches and larger. It is also claimed for these shears that circles as small as 3 inches in diameter may be cut when sheet iron not heavier than 18 gauge (U. S. Standard) is used. It is fitted with a hand crank and friction clutch pulley, having a positive clutch controlled through a foot treadle, which arrangement provides for both power and hand drive, interchangeable at will instantly, affording the operator full control of the machine as well as the work while the same is passing through the cutters. Three changes of cutter speeds are instantly secured through proper adjustment of a hand lever, fitted in a variable speed gear box,—an arrangement allowing for driving the cutters fast on light work and slow when heavy material is in use.

ROTARY CIRCULAR SHEARS

The circular shears are a necessity in practically every shop where circular blanks cut from sheet metal are used, such as the bottoms for vessels, cans, tanks, sheet metal barrels, etc. The cutting head of a circular shears resembling very much the rotary slitting shears, it is often utilized for straight slitting, and for this purpose an adjustable slitting gauge is provided in the frame of the cutting head; but the circular shears was designed chiefly for the cutting of outside circles or discs from tin plate, soft steel or iron, brass, copper, aluminum, etc.

Construction.—The construction and operating principles are the same in nearly all circular shears. Their main construction consists of a base and cutting head, with parallel cutter shafts driven with gears by means of a hand crank, or with a belt when the machine is arranged with pulleys for power drive. A sliding circle arm is fitted to the base and is adjustable for different diameter circles by sliding on the base to and from the cutters. The blank from which the circle is to be cut must be squared previous to cutting the circle. After being squared true and of a correct size nearest to the size circle to be cut, providing for as little waste as possible, the square blank is inserted between two clamping discs in the circle arm. Through an eccentric clamping lever, or with a crank screw or a hand wheel, according to the design of the machine, the blank is securely clamped and

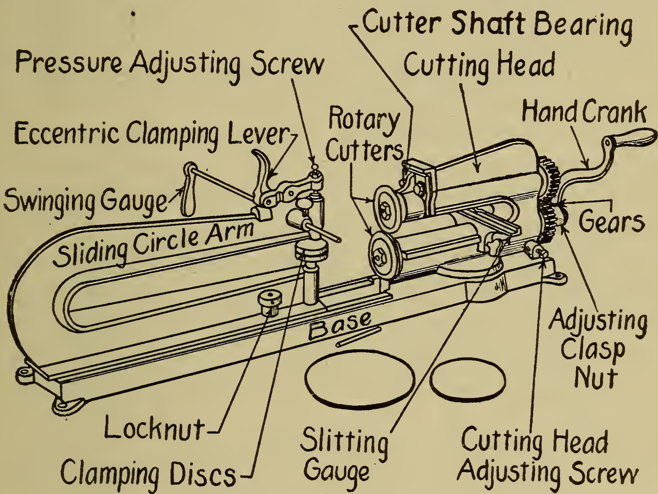


Figure 12.—Rotary Circular Shears.

the rotating of the cutters draws the material through the machine, cutting a true circle.

Operation.—To the base of the rotary circular shears, on which the circle arm slides, a scale graduated in fractions of inches is fitted. Then, if a circle 5 inches in diameter is to be cut, proceed to loosen the lock nut on the circle arm and set the sliding circle arm, drawing it to or from the cutters until the correct position of the circle arm is secured. Indicator on circle arm (not shown in the illustration, Figure 12) pointing to 5 inches on the scale, lock the circle arm securely through the lock nut. Place the square blank between the clamping discs in a central position of equal distance on all sides of the blank from the outside diameter of the clamping discs. If many of the same size of circles are to be cut, after the correct first setting, adjust the swinging gauge so it will strike the edge of the square blank while remaining in the clamping discs. The machine properly set, any number of the same size circles can be cut accurately.

Care should be exercised not to allow the cutters to have too much clearance or to rub against each other too hard; and when adjustment of the cutters for more or less cutter clearance is necessary, the lower shaft to which the lower rotary cutter is attached can be drawn away or to the upper cutter by means of the adjusting clasp nut on the lower shaft next to the gear. After the correct adjustment is secured, be sure to fasten the adjusting clasp nut securely. The upper cutter shaft bearing is adjustable and will raise or lower, allowing for the taking up of the wear of the cutters; and this adjustment should never be tampered with while the cutters are in good condition.

Rotary circular shears are made in a wide variety of sizes and capacities. The one illustrated in Figure 12 is constructed for cutting a circle from 2¾ to 22 inches in diameter, from No. 22 gauge iron and lighter (U. S. Standard).

Ring and Circular Shears.—To better understand the real significance between the ordinary circular shears having parallel cutter shafts and the ring and circular shears arranged with cutters in an angular position, a comparison of Figures 12 and 13 will prove helpful. I have already described the circular shears (Figure 12) as having parallel cutter shafts, intended for outside disc or circle cutting, and unlike these the ring and circular shears (Figure 13) have a lower angular shaft fitted with a cutter, while the upper cutter is fitted to an almost parallel shaft; and instead of remaining fixed, it raises and lowers by means of a cutter raising crank screw, which permits of the cutting inside of a square blank or circle, as shown in the illustration.

For ordinary outside circle cutting, the ring and circular shears does the same work as already described un-

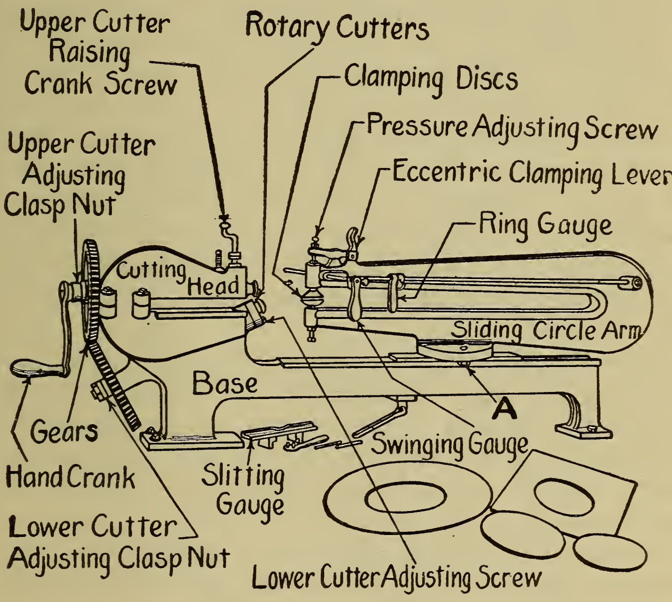


Figure 13.—Ring and Circular Shears.

der circular shears (Figure 12), and owing to the cutter-raising feature in the ring and circular shears, it is not so limited in the work performed. In addition to doing the work already described, the ring and circular shears offers a suitable means for cutting irregular curves when following a scribed line, and for such work the sliding circle arm is not used. The rotary cutters being of small diameter, measuring approximately 1⅝ inches in diameter, and set angular in position, they will cut as true and clean on the inside as on the outside of a sheet of metal.

Operation.—To proceed in cutting an outside circle on the ring and circular shears, the reader will kindly refer to directions given under rotary circular shears (Figure 12). To cut a circle out of a circle, for making a ring, or to cut a circle from the inside of a square sheet of metal, the prepared blank is clamped between the clamping discs in the usual way, and the sliding circle arm with the sheet metal blank inserted is brought toward the cutters, permitting as much of the edge of the sheet metal blank as necessary, according to the size of the inside circle that is to be cut, to slide between the cutters. With the proper alignment of the blank in the machine secured, bring the upper cutter down on the material by turning the crank screw hard enough, so that the cutters will cut the material without burring or buckling the edge.

The ring and circular shears has in addition to the regular swinging gauge a ring gauge which slides on a rod along the circle arm for facilitating the cutting of rings, and through the proper setting of both gauges many quantities of the same kind and size of circles and rings can be cut alike with accuracy.

In using this machine never allow the cutters to have too much clearance or to rub against each other too hard; and when adjustment of the cutters for more or less cutter clearance is necessary, a satisfactory adjustment of the cutters is secured through the adjusting clasp nuts next to the gears on both the upper and lower shafts.

In cutting outside circles of a very small diameter, and sometimes when cutting a small circle inside of a circle for making a ring, if on the edge of the material there should appear a burr or a buckle, this indicates that the circle arm is in too straight a line with the center of the cutters; and in such case the circle arm must be set a trifle out of line with the center of the cutters,—just enough for cutting a true and clean edge. This adjust-

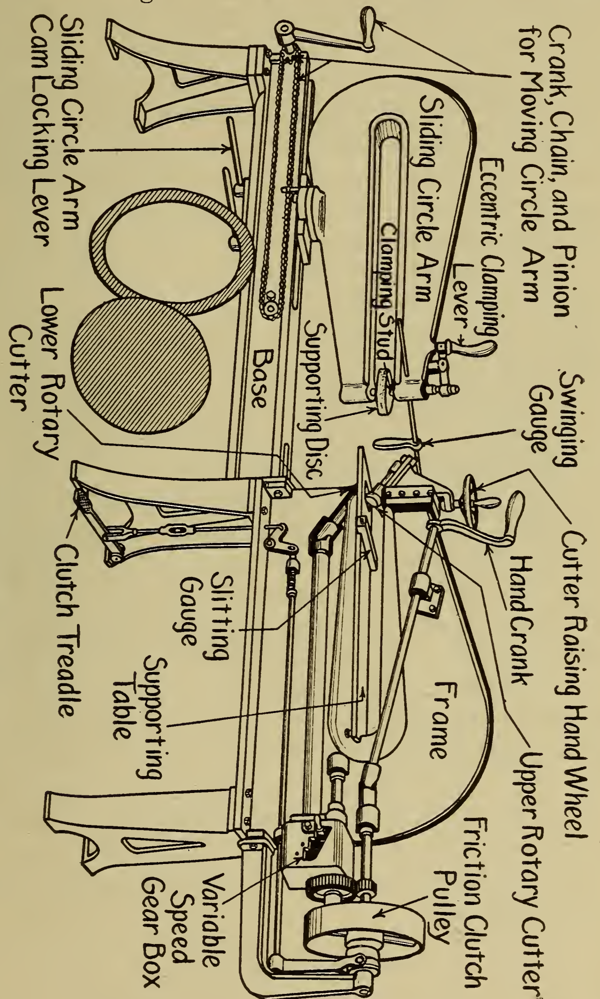


Figure 14.—Ring and Circular Shears for Power.

ment is secured through loosening the bolts marked *A* in the sliding circle arm plate and moving the circle arm as necessary until a proper adjustment is secured for assuring a clean cut.

Ring and circular shears are manufactured in a wide variety of sizes and various capacities. The machine shown in Figure 13 is intended for bench use and is made in two sizes, for cutting circles from square blanks 3¼ to 22 inches, and rings as small as 3¼ inches inside diameter and as large as 22 inches outside diameter,—from No. 20 gauge iron and lighter (U. S. Standard); the larger size machine cutting circles from square blanks 3¼ to 42½ inches and rings as small as 3¼ inches inside diameter and as large as 42½ inches outside diameter from No. 20 gauge iron and lighter (U. S. Standard).

Ring and Circular Shears for Power.—In Figure 14 the rotary slitting shears with angular cutters, as described under Figure 11, is again presented to show a base and sliding circle arm attached to the frame of the cutting head, making an efficient ring and circular shears. So arranged, this machine has a wide range of general usefulness for cutting circles from square blanks from 12¾ to 64 inches diameter, and will cut rings with an inside diameter of 12¾ inches and outside diameter of 64 inches, from No. 14 gauge iron and lighter (U. S. Standard); in addition to doing such work as described under Rotary Slitting Shears by utilizing the cutting head. The circle arm in this machine slides to and from the cutters on the base of the machine, but owing to its great weight a crank-and-chain arrangement provides for instantaneous adjustment of the circle arm, cam locking levers being used to fasten the circle arm after the desired position has been secured.

FOLDING MACHINES

Folding machines are used very extensively to facilitate the forming of locks or edges, as in preparing straight sheets of metal for receiving a wire; also for turning flanges at various angles, and to prepare locks before grooving, in vessels, tanks, pipe, cans, and such work.

The most popular patterns of these machines and those used more extensively may be summed up in three distinct types; namely, the *bar folder, sheet iron folder,* and *pipe folder.* The advantages of each will be described here, the first and most important of the three being the bar folding machine.

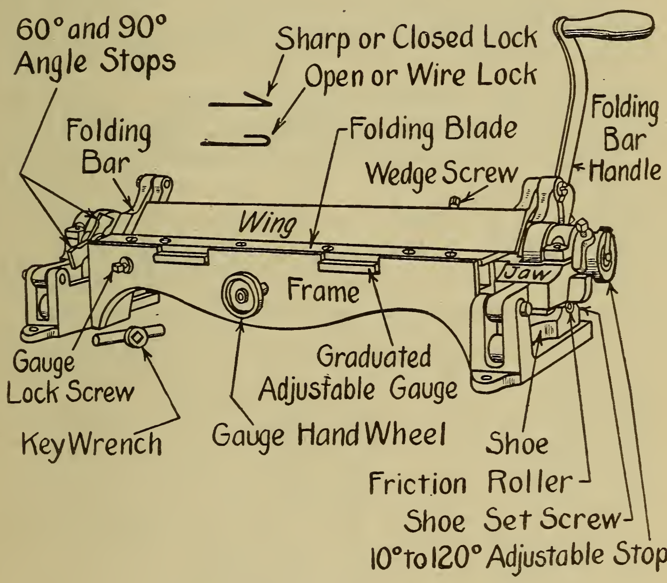


Figure 15.—Bar Folding Machine.

Bar Folding Machine.—Experiments have proven the hand operated bar folding machine as more desirable for rapid execution than a power operated folding machine. The tinware and tin can manufacturers invariably use the hand operated bar folding machine, as more edges on a number of blanks can be formed with greater rapidity on a hand operated machine than on a similar folder operated by power. Absolutely correct proportionment of the folding bar is of great importance for rapid execution, and while the market offers bar folding machines of numerous makes, the machine illustrated (Figure 15)

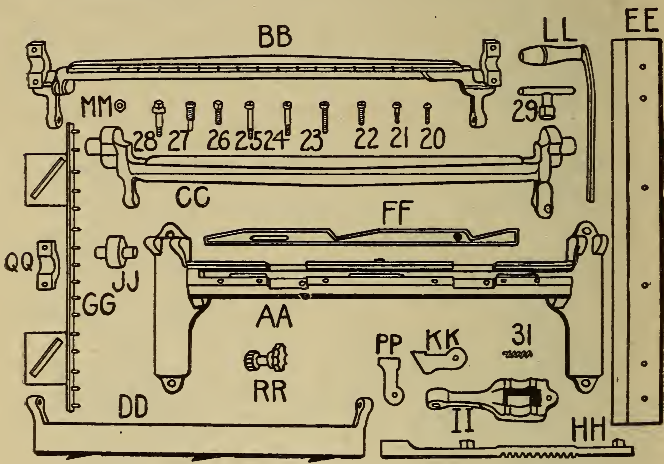


Figure 16.—Working Parts of Bar Folding Machine.

AA—Frame
BB—Jaw
CC—Bar
DD—Wing for Bar
EE—Blade
FF—Wedge
GG—Gauge
HH—Slide
II—Shoe
JJ—Friction Roller
KK—Stop
LL—Handle
MM—Set Nut for Screw No. 23
PP—Stop
QQ—Cap
RR—Gauge Hand Wheel and Pinion

20—Wedge Screw
21—Stop Screw
22—Cap Screw
23—Shoe Set Screw
24—Blade Screw
25—Frame Screw
26—Gauge Lock Screw
27—Wing Screw
28—Wedge Screw
29—Key Wrench
31—Gauge Springs

is recognized by large and small users as most efficient for the shop where time is a big factor and many thousands of blanks must be edged daily.

In using the word "lock" in connection with a folding machine, it means the same thing as a folded edge. Thus the fold of a closed lock is smaller in its radius than that of an open or round lock. This will be seen by referring to the preparation of a flat sheet of metal for lock seaming, where two corresponding edges are to lock together; such as would be prepared in the ordinary stove pipe, or the body of a vessel, where a closed or sharp lock is preferable for facilitating the closing of the seam in another operation. Where an edge must be produced with a radius sufficient to receive a wire, the open or round lock, or as it is often termed, the wire lock, is used. A bar folding machine is adjustable, unlike other folding machines, for forming a sharp or closed and an open or round lock. The construction of the bar folding machine, therefore, covers this wide range of folding usefulness; whereas the ordinary type of folding machine is limited to forming a closed lock only. By the nicety of the work performed and its great accuracy, the bar folding machine has gained deserved popularity and no well-regulated shop should be without one of these useful machines.

Operation.—A feature of great interest is an adjustable gauge, graduated in fractions of inches, which moves by turning a hand wheel. When once set for the size of lock to be formed, the gauge is locked through tightening the gauge lock screw with a key wrench, after which any quantity of blanks may be edged of uniform size with accuracy and rapidity. The wedge screw in the folding bar is adjusted with a key wrench and when moved to the left, facing the front of machine, a wedge raises the wing for a closed lock; while by moving the wedge screw to the right, an adjustment of the wing is secured for forming any convenient open lock, for receiving a wire, etc.

In the manipulation of the wedge screw and while the lock adjustments are made, the folding bar must be held in a position a little more than a right angle with the edge of the folding blade. After the correct adjustment is secured, be sure to fasten the wedge screw again with the key wrench. Two angular stops, fitted to these machines, when properly set will stop the progress of the folding bar for a 60 or 90 degree angle. A graduated adjustable stop is also provided for allowing the formation of angles from 10 to 120 degrees.

For edging heavy stock and to form double locks more clearance between the jaw and the folding blade is necessary. For more or less clearance between the jaw and

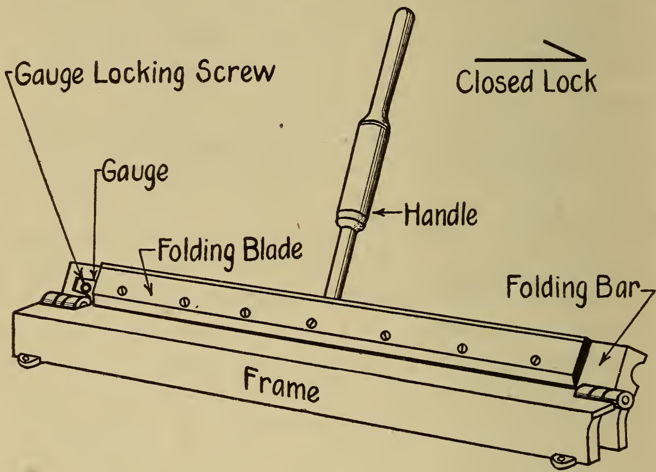


Figure 17.—Sheet Iron Folder.

the folding blade, adjusting the set screws in the shoes on each end of the machine will raise and lower the jaw. After making this adjustment, be sure to fasten again shoe set screws securely.

The bar folding machine (Figure 15) is made in two sizes, with a folding length of 20 and 30 inches respectively, adjustable for forming closed and open locks ⅛ to 1 inch wide, and in connection with the open locks, as formed by this machine, wire as large as ¼ inch in diameter can be used. For locks 3/16 inch and wider No. 22 gauge iron and lighter may be used, and where the material is No. 24 gauge iron and lighter this machine will form a lock as small as 1/8 inch wide and on *XX* tin 3/32 inch wide.

Similar machines are manufactured in 37 and 42-inch lengths respectively, with a lock-forming capacity of 1/8

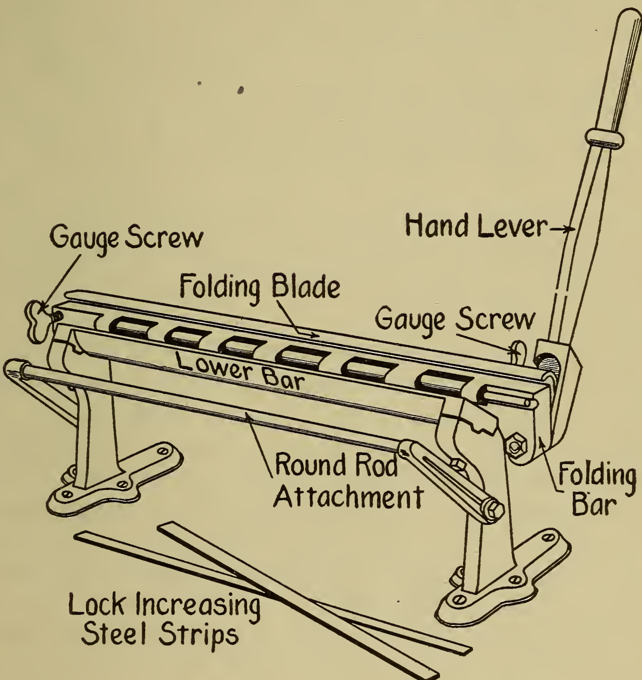


Figure 18.—Pipe Folding Machine.

to 1½ inches wide, and will operate on No. 20 gauge iron and lighter when the lock to be formed is 5/16 inch and larger; forming a lock as small as 3/16 inch when the material is No. 22 gauge iron and lighter (U. S. Standard).

Sheet Iron Folding Machine.—This machine is constructed for general use. In common practice good results can be expected from it, but for work demanding accuracy, uniformity, and a well finished lock these patterns do not compare with the bar folding machine described under Figure 15. Their construction consists of a milled cast-iron frame hinged to a machined cast-iron folding bar, with a steel folding blade. For a gauge a slotted steel strip is used, which moves parallel with the folding blade and is limited in its gauging capacity for producing a closed lock only of ¼ to ½ inch. These folders are manufactured in several sizes and up to a maximum capacity of No. 20 gauge iron and lighter (U. S. Standard). The machine illustrated (Figure 17), in the size of 30 inches with a capacity for working No. 22 gauge iron and lighter (U. S. Standard), represents a size more commonly in use than any other of this type of folding machine.

Pipe Folding Machine.—This folder will do the same work as claimed for the sheet iron folding machine described under Figure 17, but its construction allows for finishing a lock closed over more than a similar lock formed with the sheet iron folder. It produces a lock ready for grooving or seam closing without the assistance of a mallet. Owing to its pipe edging feature, it differs widely from the bar folding machine (Figure 15) and the sheet iron folder (Figure 17).

In edging or forming a lock on a sheet of iron that is intended to make up a common stove pipe, or any other sheet metal piece cylindrical in shape, with the two folding machines already described, the blank must be edged or the lock formed while the sheet remains in the flat, as a first operation, and rolled into a cylinder as a second operation; whereas, the pipe folding machine, the only folder of its kind, will permit the sheet of metal to be rolled into a cylinder as a first operation, and edged, or the lock formed, in a second operation.

In edging, or the forming of a lock on cylinders after the cylinder is formed, in operating the pipe folder one edge of the cylinder is inserted between the folding bar and the lip of the folding blade. With a movement of the hand lever to the left, the work is clamped. The folding bar is then pulled over toward the operator until the lock is completed, when the folding bar is pushed back to its original position, and the work is released by throwing the lever to the right.

For forming the corresponding edge the cylinder is inserted as before, but over instead of under the folding bar, finishing the corresponding edge the same as described before.

The pipe folder will turn a lock 1/4 and 3/8 inch, and with the use of lock increasing steel strips, placed under the sheet of metal and between the folding blade, locks of additional sizes, 1/2 and 5/8 inch, are secured.

These machines are just as practical for edging sheet metal in the flat as for edging formed cylinders. They are made in lengths of 30, 42, and 62 inches, but in edging flat sheets, unlike other folders, their respective lengths do not decide the width of the sheet that may be edged; as a practical round rod attachment, when fitted into a trough provided in the lower bar of the machine, will permit the edging of flat sheets in any length, by sliding the sheet along. This secures a lock on the full length of the sheet in consecutive operations, enough to close the lock down with a mallet. The practice of edging sheets longer than the machine, however, is adopted only in emergency cases, or where only a little of that work is to be done.

The capacity of the machine is No. 22 gauge iron and lighter (U. S. Standard).

Operation.—In using the pipe folder just described special judgment should be exercised in changing the gauge to secure 1/4 and 3/8 inch lock. Care should be taken not to turn in the gauge screw on the lever end so far that it strikes against the folding bar, thus drawing the folding blade out of line; and the gauge screw on the opposite end should not be turned in so far that it pushes the gauge and folding blade out of line. The gauge screws described hold or release a hidden gauge under the folding blade, and have an important part in adjusting the machine for forming the two sizes of locks referred to.

When the gauge screw next to the hand lever is screwed in and the gauge screw on the other end is unscrewed,

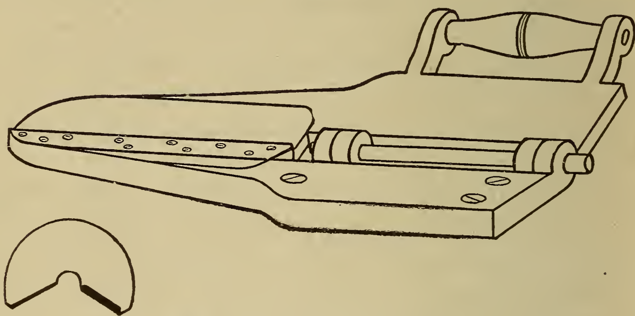


Figure 19.—Can Top Folder.

the gauge is held up next to the folding blade and turns a ¼ inch lock. When the gauge screw next to the hand lever is unscrewed and the gauge screw on the other end of the machine is screwed in, the gauge is held down so as to turn a ⅜ inch lock. Before changing the gauge the hand lever should be pushed toward the left as far as it will go, in order to bring the screw holes to their proper places. As the screws that hold on the cap, folding blade, and gauge sometimes become loosened, see that these screws are tightened enough to hold the folding blade from springing, but not so tight that the folding blade slides hard.

Can Top Folder.—Tapered sheet metal patterns for oil-can breasts, funnel bodies, etc., are usually cut from pattern, as shown in the illustration (Figure 19), and for edging sheet metal blanks with a taper, preparatory to forming, the can top folding machine is used. Tapered

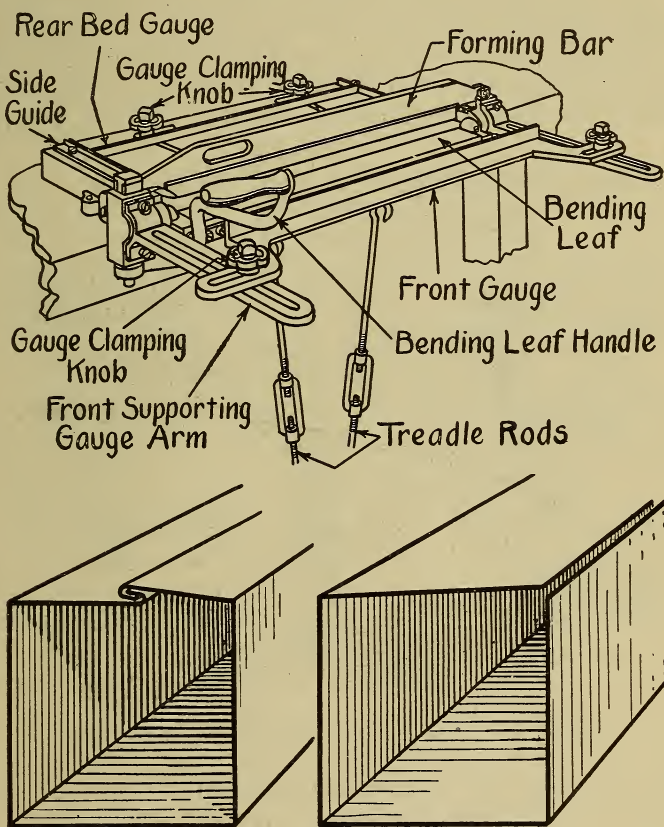


Figure 20.—Square Box and Square Pipe Forming Machine.

sheet metal blanks can not be folded with the ordinary folding machine designed for straight edging or folding. The can top folder is manufactured in three sizes, length of blades 10, 13 and 16 inches respectively, and as made regularly will form a lock of a width of 1/8 inch, but locks of larger width can be formed when the machine is specially made.

The capacity of the can top folding machine is No. 26 gauge iron and lighter (U. S. Standard).

Square Box and Square Pipe Forming Machine.—The bodies of square and oblong cans, heater pipe, boxes, etc., with either lap or lock seams, are formed from the flat

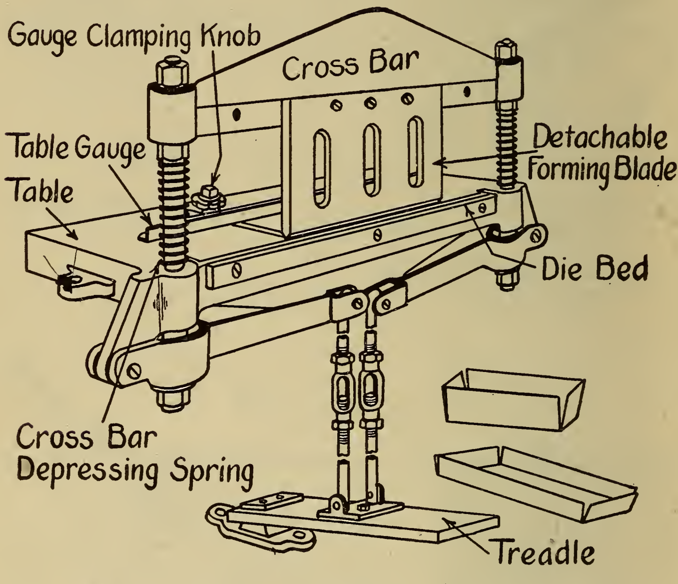


Figure 21.—Square Pan and Box Forming Machine.

sheet in separate operations with the square box and square pipe forming machine shown in Figure 20.

This machine is constructed with a cast-iron table fitted with a gauge. The sheet to be formed is inserted between a forming bar and the table. The depression of a foot treadle forces the forming bar down on the material, clamping the same securely, and while the forming bar is kept depressed the bending leaf is raised with a handle and the first bend made. The succeeding bends are made in like manner, and when all bends are finished, the forming bar is raised and the formed work is slipped, without injury, from one end of the forming bar.

The square box and square pipe forming machine is made in lengths of 15½ and 21½ inches, with No. 24 gauge iron and lighter capacity; and in lengths of 30½ and 36 inches, capacity No. 26 gauge iron and lighter (U. S. Standard).

The size of the box or pipe that can be formed is determined by the size of the forming bar in the machine. The forming bar in the 15½-inch machine measures 1½x1⅝ inches; the 21½-inch machine has a forming bar 2½x1¾″; the 30½-inch machine forming bar measures 2½x2¼″, and the 36-inch machine is equipped with a forming bar 2¾x3½″.

Square Pan and Box Forming Machine.—For forming the four sides of blanks to make a square or irregular shaped box or pan, the square pan and box forming machine shown in Figure 21 was designed.

The blank is first properly prepared, the corners being notched with the notching machine (see Figure 77), or with the ordinary hand shears. The notched blank is placed in the forming machine between a V-shaped forming blade and die bed and all ends are formed, one end at a time, by depressing a foot treadle.

This machine is adapted for forming flaring and straight work, but where there are variations in the flare desired extra forming blades and die beds are used. For each size of pan or box an extra forming blade is necessary.

The length of the die bed is 25 inches and the forming blades are made 8 inches or less in width and from 8 to 25 inches long. With this machine it is possible to form pans as shallow as ½ inch and as deep as 5½ inches; and the lengths of pans that can be formed depends entirely upon the depth of pan required. With special blades and die beds a variety of bending operations can be performed with this useful machine.

Brace and Wire Bender.—Figure 22 shows a brace and wire bender, a machine that is not only handy, but indispensable to have on the sheet metal shop bench for

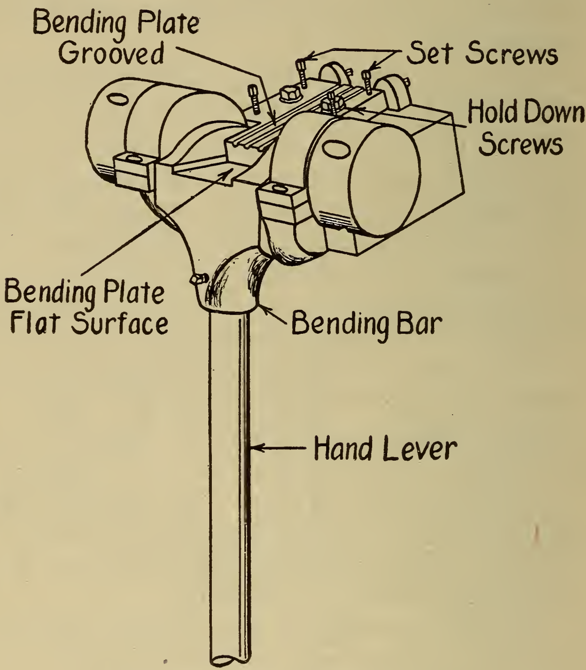


Figure 22.—Brace and Wire Bender.

making braces for gutters, leaders, cornices, etc. A great deal of flat iron up to 1/4 inch thick and 2 inches in width is used by the sheet metal worker, and the purpose of this machine is to bend such stock in angles, as may be required, of from 0 to 90 degrees. Many a good folding machine, cornice brake, and vise has been easily "sprung" in an attempt to do such bending with them, instead of using this bending machine.

Flat steel to be shaped is inserted under the flat surface of the bending plate, and in bending wire the bending plate is reversed and the wire inserted under one of the grooves. Raising the bending bar by means of a hand lever, the bends are made.

The bending plate is adjustable for turning sharp or round corners, and in using different thicknesses of metal the bending plate is regulated by means of the hold-down and set screws located in the top and at the back of the bending plate. The grooved surface of the bending plate permits of the bending of wires, such as are used for wiring the tops of pans, boxes, etc., and several wires can be bent at the same angle in one operation.

The hand lever is interchangeable and may be used in center or at either end of the machine. The bending plate in this machine being made of cast iron, it is suggested that a steel hardened plate be used where the machine is intended for wire bending more exclusively.

BRAKES

Brakes differ very widely in their construction, mechanism, and the work performed from the folding machines already described, and are not as limited in their folding and forming usefulness; having a capacity for forming locks and angles in a wide range of sizes and of unusually large lengths. The folding machine can only form a lock or edge as wide as the depth of the jaw in the machine will permit; whereas, the brake allows the sheet of metal that is to be edged or formed to pass through the jaws from front to back without obstruction.

A comparison may be made at this time of the folding machines illustrated in Figures 15 and 17. In operating the folding machine the sheet of metal to be worked is inserted under the folding blade and by raising the folding bar and pulling the bar towards the operator the lock is formed. The folding machine throwing the sheet toward the operator in the forming of the lock, edge, or angle, is not at a disadvantage when working small pieces, but where the sheets are large the brake invariably proves a more convenient means for edging. In operating the brake the sheet to be edged rests on a bed and when it

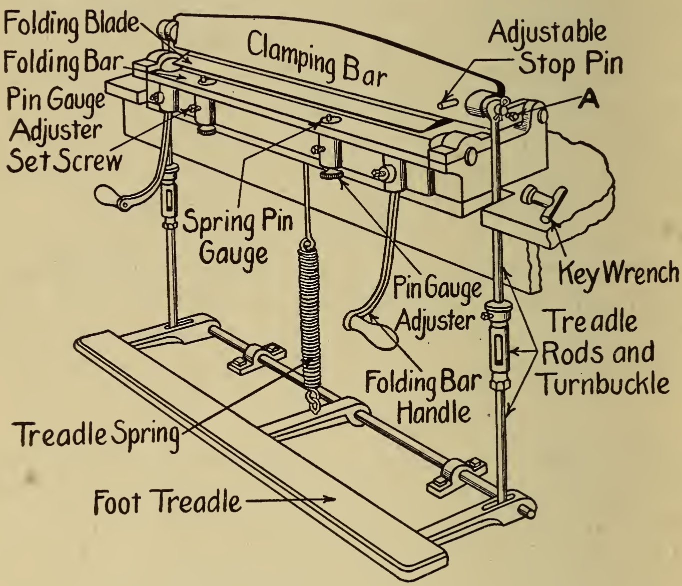


Figure 23.—Open Throat Folding Machine.

is in a proper position, ready for edging, the material is securely clamped and remains in a fixed and stationary position while the bend is made.

Open Throat Folder.—The construction of the brake and of the open throat folder provides for edging sheet metal as described.

Figure 23 illustrates a modern type of open throat folder which operates similarly to the floor brake, or what is better known as the cornice brake (Figure 24).

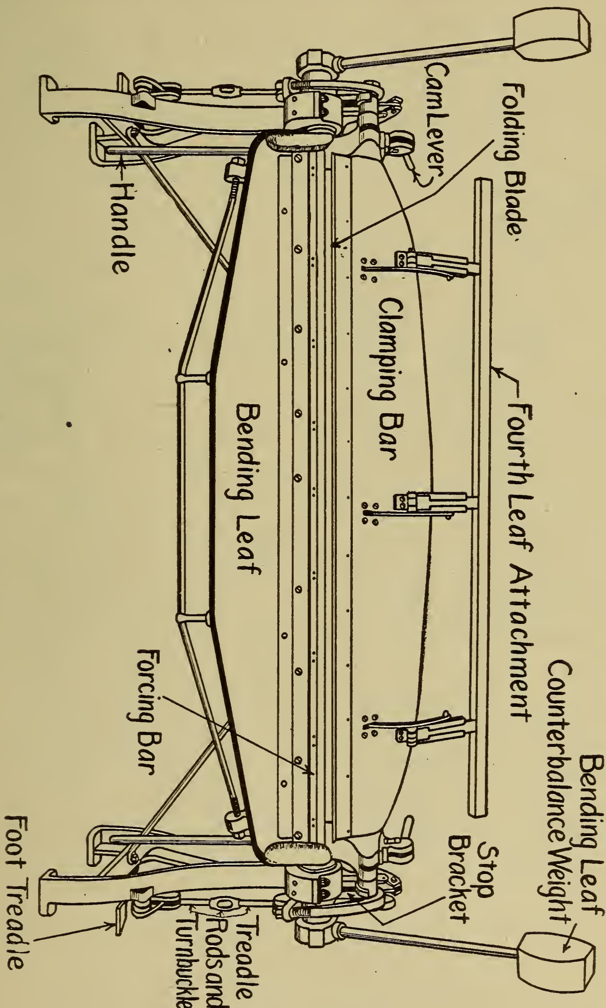


Figure 24.—Cornice Brake.

In operating the open throat folding machine, the sheet of metal being properly inserted in the machine between the clamping bar and bed, the clamping bar is brought down on the material through the depression of a foot treadle and spring, and the foot treadle is not released until the folding bar is raised and the forming of the edge, lock, or angle is completed. The adjustable stop pin on the right end of the machine is adjusted through screw *A* by a key wrench for stopping the progress of the folding bar at any angle. Spring pin gauges are fitted in the folding bar, which permit the forming of locks from $\frac{3}{16}$ to $1\frac{3}{16}$ inches in width on the 30-inch machine, and from $\frac{3}{16}$ to $1\frac{5}{16}$ inches on the 42-inch machine. The open throat folding machines in the lengths mentioned have a capacity for operating on iron of No. 22 gauge and lighter (U. S. Standard). As the sheet of metal that can be edged or formed passes through the jaws from front to back without obstruction, the machine is practical for forming a wide range of angles. Where the angle to be formed is of a width greater than the gauging capacity of the machine, the sheet at the point of edging is laid out with the prick punch or scribed with the scratch awl and the angle formed to line. Through separate operations, or one bend at a time, the open throat folding machine, in addition to performing a variety of folding operations, is adapted for forming square pipe ½ to 1½ inches square and ½ to 2 inches square respectively. This machine also claims an additional feature over the ordinary folding machine as a useful means for forming both single and double locks straight or tapering.

Cornice Brake.—The cornice brake shown in Figure 24, like the open throat folding machine (Figure 23) has open jaws, and the sheet metal to be formed remains stationary and in a fixed position, depending upon a bending leaf or folding bar for effecting the folding operation.

The sheet of metal being properly inserted in the cornice brake, between the bed and the clamping bar, the clamping bar is brought down on the sheet by means of foot treadles at either end of the machine. The proper position of the material for a correct bend to be made being found, it is held securely clamped by means of cam levers, provided on both ends of the machine. The bend made, the hand levers are thrown back and the work released. A stop bracket is provided, and when set prop-

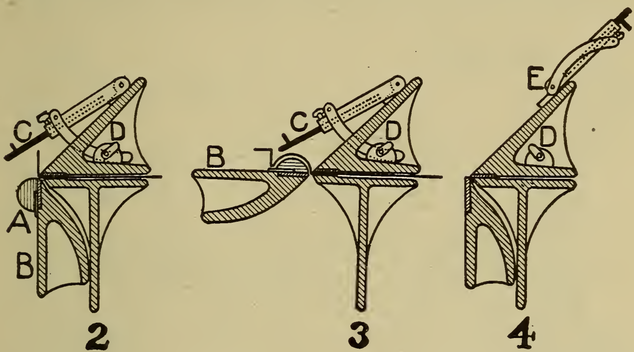


Figure 25.—Fourth Leaf Attachment as Fitted to Cornice Brake, Figure 24.

No. 2.—Showing the machine set ready to make bends, with sheet in clamps.

No. 3.—Position of front leaf after the square and quarter round bends have been made; also the position when setting the upper or fourth leaf.

No. 4.—Shows fourth leaf thrown back, and wood former removed, ready for making square bends and fillets.

To use cornice brake for making circular or semi-circular forms: Put the formers or half round molds in place on apron B of machine. See that the former is down solid and even with the top of apron B. Turn the apron B still higher, until the fourth leaf C rests on the iron plate at the bottom of former A. Then set the clamp D to hold the fourth leaf in place, and the brake is ready to form circular work. Every time the former is changed to a different size, change the fourth leaf to match the former, setting it the same way.

To use the brake for common work, turn the fourth leaf back as shown at E in Cut No. 4, then work it the same as any ordinary brake.

erly will stop the progress of the bending leaf, to form any desired angle.

The universal rule of mechanics that additional leverage gives greater strength is taken advantage of through providing a forcing bar on the bending leaf, reinforcing the leaf for the bending of heavy sheets, and this attachment is easily removed when not required. In cornice work where circular and semicircular forming make for the greatest bending, this cornice brake will take care of such work efficiently.

For the forming of circular and semicircular bends with cornice brakes, wooden forms are always provided, these being fitted as required, on the bending leaf. In

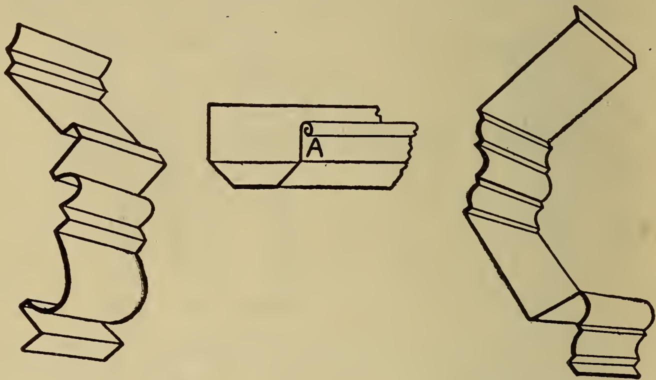


Figure 26.—A Few of the Many Forms that Can be Made on the Cornice Brake.
The bead on gutter, as shown in illustration at A, is made with the Gutter Beader.—See Figures 79-80.

making irregular bends, the material is inserted in the machine in the usual way. The bending leaf being raised to a proper angle, the same as when proceeding to form an ordinary lock or angle, and being held in that position, the material left protruding from the edge of the bending blades is shaped—usually with the hands—over the wooden form on the bending leaf, producing a circular shape in the sheet of metal conforming with the shape of the wooden form used.

The hand method for circular forming with the cornice brake is an operation common with the ordinary type of cornice brake, but with a brake such as shown in Figure 24 the hands are left free for operating the machine, owing to an attachment which allows the circular forming to be effected automatically, as will be seen in Figure 25.

As the cornice brake does not have a gauge, the sheet is laid out previous to forming with the prick punch or scratch awl, breaking the material to line or punch marks made in the sheet.

Cornice brakes are manufactured in a wide variety of

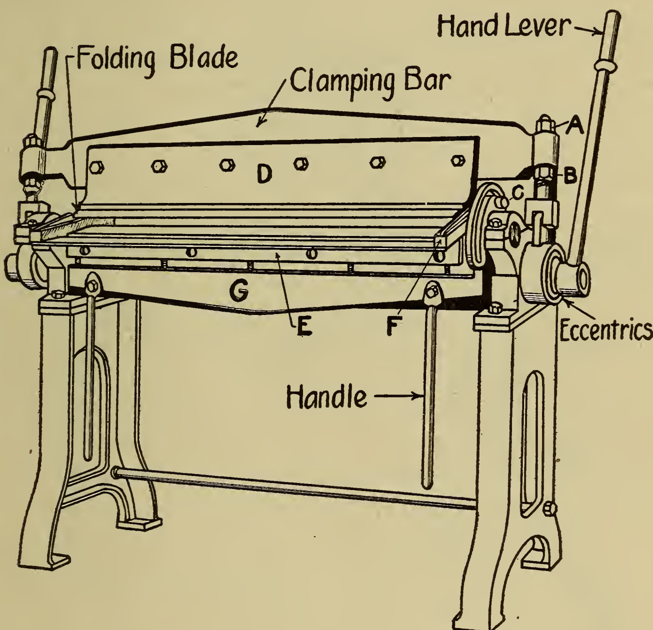


Figure 27.—Combination Brake and Folder.

sizes and capacities, 96 inches being the size most commonly used in cornice work practice.

Combination Brake and Folder.—In principle the combination brake and folder (Figure 27) resembles the cornice brake, but is constructed for forming locks with a radius sufficient for receiving a wire. Its further practicability extends as far as that of the regular cornice brake in forming sharp locks, angles, circular and semi-circular bends, etc.

In operation the combination brake and folder differs

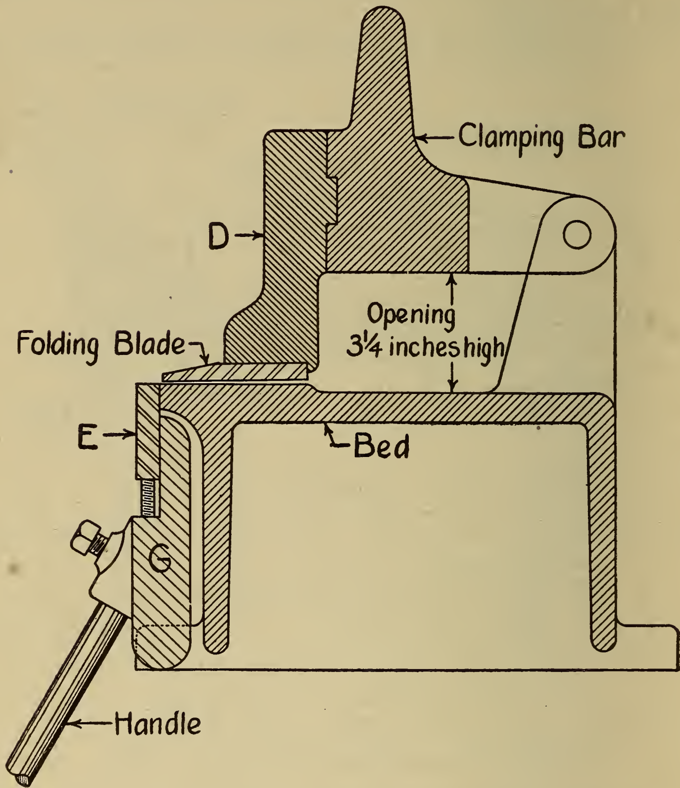


Figure 28.—End View of Combination Brake and Folder.

from the cornice brake (Figure 24) in that the clamping bar is brought down on the material and securely clamped through eccentrics actuated by hand levers from either end of the machine. In this more modern brake this arrangement represents a one-man feature, making the changing of positions for the clamping of the work unnecessary, a feature of individuality not to be found in any other brake.

Adjustments are provided for in the eccentric connection, permitting a maximum pressure to bear on the material in the machine while in the process of forming, thus preventing the work slipping from a true line. This adjustment is secured through loosening the top nut *A* and tightening the lower nut *B* for heavy stock, and the reverse when lighter materials are used. The bending plate marked *E* is adjusted by means of a suitable wrench provided with the machine, and may be raised or lowered for the purpose of forming a closed lock or an open lock for receiving wire in various sizes up to as large as 3/8 inch in diameter. The adjustable stop gauge *C*, when properly set, provides for the forming of angles of any desired degree.

The form *D* is detachable, and to this form the folding blade is attached. Where special work requires it, this form may be quickly replaced for sectional short forms; and when such special forms are used the machine is highly adaptable for a wide range of special work, such as pan work up to 4 inches in depth and of a width in accordance with the depth of the pan to be formed.

The combination brake and folder has another independent feature, consisting of an adjustable gauge for gauging angles from 1/8 to 4 inches. This gauge, *F*, is fitted in such a manner that in the process of forming and in the operation of raising the bending leaf *G*, the gauge *F* throws back out of the way, permitting the bending leaf *G* to rise to its highest point without any obstruction.

This machine has a working capacity for forming open or closed locks from 1/8 to 1¾ inches in width, in addition to forming angles of any size on sheet iron No. 24

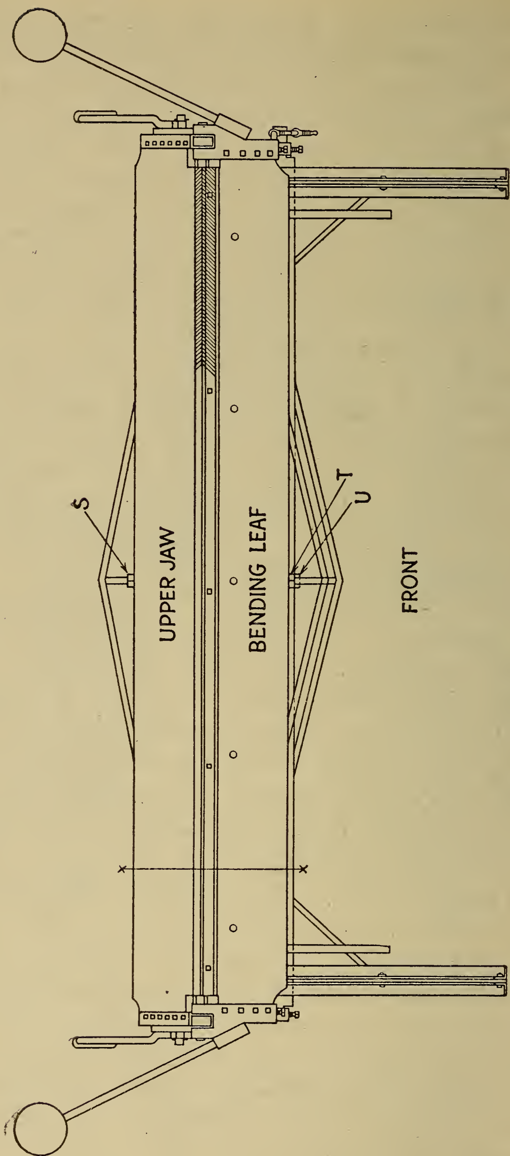


Figure 29.—Chicago Steel Cornice Brake (Front View).

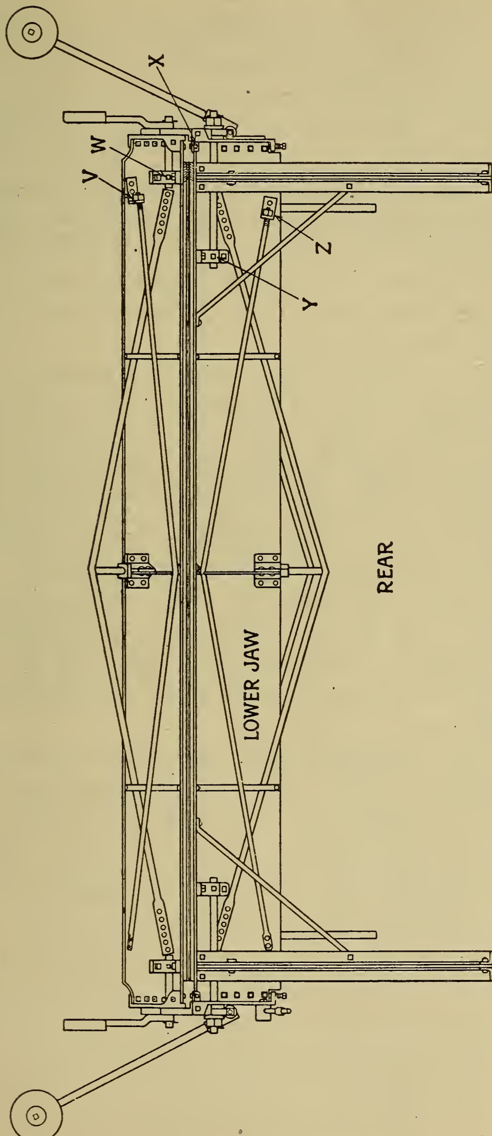


Figure 30.—Chicago Steel Cornice Brake (Rear View).

gauge and lighter (U. S. Standard), and has a wide angle maximum forming capacity on No. 16 gauge iron and lighter (U. S. Standard).

For cornice work, where the making of circular and semicircular bends is necessary, the proper forms are furnished with the combination brake and folder; and when circular forms are used in connection with this machine they are attached to the bending leaf, *G*. All irregular bends are made in a manner similar to that described under Cornice Brake (Figure 24), through a hand operation.

Steel Cornice Brake.—For outdoor construction work the steel cornice brake is preferred over brakes of all-iron construction, owing to the convenience it offers in shifting from one place to another, due to its light weight. A cornice brake is a necessity in every well-regulated shop, but the small shop could not well afford a brake until the machine of steel construction was perfected. There are many of these machines now in use, and as important points relative to their adjustment and operation have never been fully covered elsewhere, some of the characteristic features of the Chicago steel cornice brake will be described here.

Setting Up.—The first important point in setting up a cornice brake, or any other machine for that matter, is to observe carefully that the machine sits level on the floor and to keep all working parts well oiled. When setting up the Chicago steel cornice brake, inspect the large truss rods, seeing that they are reasonably tight. This is done by tightening the nuts marked *S*, *T* and *U* in Figure 29. Particular attention should be paid to the small truss rod in the rear of the upper and lower jaws, which should also be reasonably tight. On the lower jaw this rod should be tightened to the extent of raising the jaw about 1/32 inch above the upper edge of the apron in the center. The rod is tightened by means of the nut marked

Z, Figure 30. This adjustment will allow for the clamping of the sheet securely in the center.

The purpose of the truss rods, aside from giving additional strength to the machine, is to make adjustments so that the brake will bend the same in the center as on the ends.

Operation.—In bending heavy material it is advisable to set the upper jaw back. This is done by loosening cap

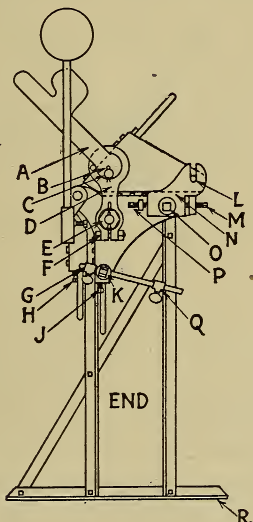


Figure 31.—Chicago Steel Cornice Brake (End View).

screw *O* and set screw *M*, and tightening set screw *P*, Figure 31. It is important that cap screw *O* be tightened after the upper jaw is set to the desired point. There should be enough space for the material between the upper jaw and the bending leaf when the latter is raised to a horizontal position. Adjustment for clamping the material is made by loosening bolt *F*, Figure 31, and turning the eccentric nut *E* shown in the same figure to the desired point, and then tightening bolt *F*.

Should the material creep forward when clamping, see that the pin marked *L* in Figure 31 is down tight before the bending edge of the upper jaw clamps the sheet. If this pin is not down at the proper time, place a block under the rear of the legs at the point marked *R*, Figure 31. This will bring the pin to the proper position. Should the sheet throw over farther on one end than the other,

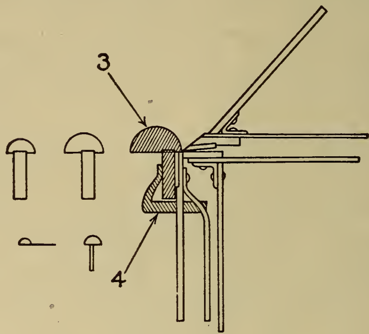


Figure 32.—Showing Method of Fastening Forms.

set the edge of the upper jaw back on which the sheet is thrown over the farthest.

Short heavy pieces should be bent in the center of the brake. This equalizes the strain.

A steel angle bar, marked *1* in Figure 33, is provided with the Chicago steel cornice brake, and is intended to bolt on the edge of the bending leaf, for bending heavy sheets. This gives additional leverage. The ¼-inch bar marked *2*, Figure 33, is made of special carbon steel and is so attached to the bending leaf that it can be removed to allow clearance for making a narrow reverse bend. This bar should not be removed for any other purpose.

The balance weights attached to the bending leaf, shown at each end of the machine in Figure 29, can be raised or lowered to suit the convenience of the user.

Figure 31 at *G* and *Q* shows an adjustable stop gauge which can be used either to regulate the angle of the bend, where duplicate work is done, or the apron can be raised and set for crimping work and for making curves or molds.

Use of Formers.—The Chicago steel cornice brake is furnished with formers, of which there are five sizes; namely, 3, 2¼, 1⅝, 1, and ⅝ inch. For circular or irregular bends these formers are clamped to the edge of

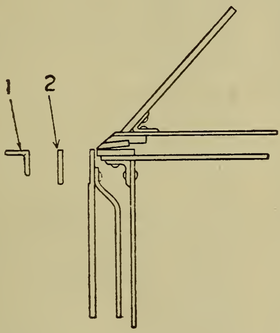


Figure 33.—Showing How Steel Bars Are Used for Increased Leverage.

the apron, as shown in Figure 32, marked *3;* and are held securely by means of friction clamps, marked *4.* After a square bend is made on the sheet, the former is placed in position as described and another former is placed on the exposed part of the sheet, which is then pressed down by hand. The square bend can be made on a number of sheets and the curves bent afterward, as the wide opening of the jaws permits the sheets to pass over the former.

In forming cornices or other sections of girth, it is advisable to start a bend near the center or make a kink on the opposite edge from the bend made first, so as to equalize the buckles in the sheet. The reason for this is that sheets are not always perfectly flat, and if one edge is left buckled while the other edge is straightened by clamping in the brake and a bend is subsequently made in the buckled part, it will straighten out the buckle and will throw the first made bend out of line.

The observing mechanic will learn many other valuable details through the practical use of this machine.

The steel cornice brake for hand use is manufactured in a variety of sizes up to 12 ft. in length and in a wide range of capacities.

Steel Motor Driven Brake.—Figure 34 illustrates a steel motor driven brake, which is made in a variety of sizes and capacities. It is claimed for this brake that it will bend steel plate 3/8 inch thick and of a length of 12 ft. Similar machines are manufactured of very heavy capacity, arranged to operate either by hand gearing, belt drive, or direct motor drive.

FORMING MACHINES

Forming machines, or as they are sometimes called, *rolls,* are a necessity in every sheet metal shop, and probably no other machine is used more extensively. The construction of the forming machine is very simple, consisting of a left and right end frame having three solid steel rolls connected with gears, operated by means of a hand crank or with a belt when fitted with pulleys for power drive, and very often driven with a direct motor connected with the gearing in the machine. The forming machine is very useful for forming sheet iron into cylinders of various diameters, similar to the ordinary stove pipe, elbows, can bodies, vessels, tanks, etc.

The general type of all forming machines is similar, though there are many variations in their mechanism. In principle the forming is done by three rolls. The two front rolls grip the sheet of metal and force it against the rear roll, which bends it around the front upper roll, forming the cylinder. The size of circle that can be formed on a forming machine depends on the nearness of the rear or forming roll to the front upper roll in the

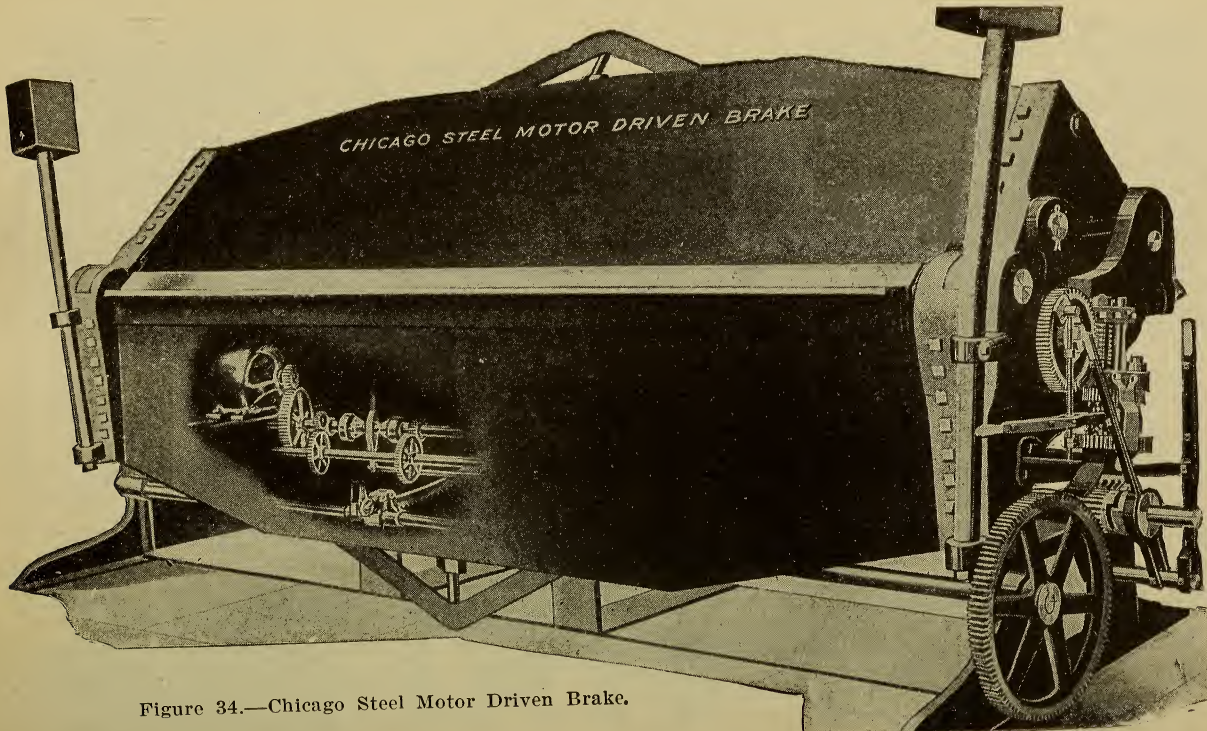


Figure 34.—Chicago Steel Motor Driven Brake.

machine. The pressure of the gripping rolls, which are the two rolls looking from the front of the machine, is regulated by thumb screws, and the rear or forming roll is regulated in the same manner.

Operation.—There is no set rule that may be applied for the setting of a forming machine to secure any desired circle. The adjustments are best secured through experiments. The sheet of metal to be formed is inserted from the front of the machine and passed through the two

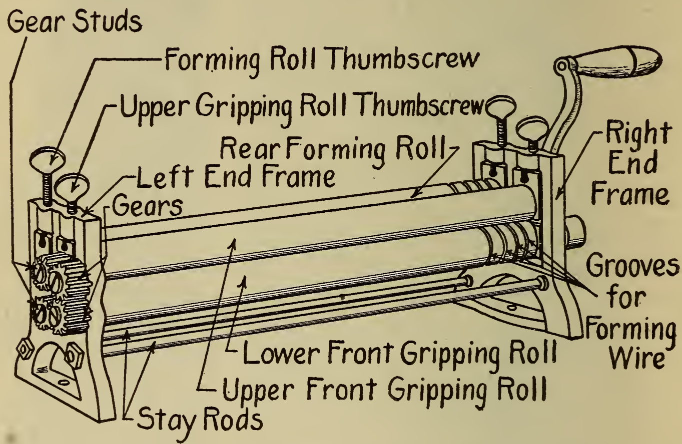


Figure 35.—Forming Machine with Solid Housings.

front gripping rolls, securing uniform pressure of the rolls on the material through thumb screws, so that the sheets will ride through the rolls freely. The sheet, on passing through the gripping rolls, will strike the rear or forming roll, if adjusted high enough, thereby forming a circle. If the circle secured in the first experiment should not prove of correct diameter, the lowering of the rear or forming roll will increase the diameter of the cylinder, or by raising the forming roll the diameter of the cylinder will be decreased. In forming cylinders of very small diameters the blank as soon as entered between the gripping rolls must be given enough curvature with the hands by means of bending the material upward, otherwise it will not strike the rear forming roll for the proper shaping of the cylinder to be formed. When the operator becomes accustomed to the forming machine and its mechanism, accurate settings are easily made after the first few trials, according to the judgment used.

Figure 35 shows a standard type of forming machine, having solid housings, generally used for ordinary work.

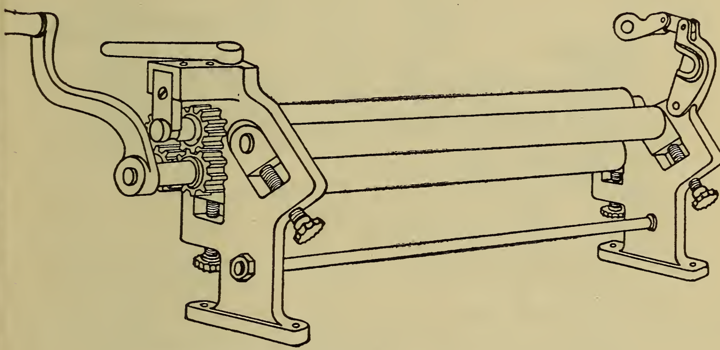


Figure 36.—Forming Machine, Slip Roll Pattern.

It would be well here carefully to compare Figures 35 and 36, noting the difference in construction of the frames between the forming machine with solid housings and the forming machine, slip roll pattern. This being done, I will describe the difference between the two forming machines illustrated in relation to their practicability.

Forming Machine, Slip Roll Pattern.—The slip roll forming machine has an advantage over the forming machine with solid housings, in that it permits the formed work to be readily slipped off from the end of the front upper roll; whereas, with the forming machine having solid housings, the work after being formed must necessarily be slipped over the front upper roll, and unless the operator is an experienced hand and skilled in his art the work will be thrown out of shape or malformed, which is impossible where the slip roll forming machine is used. The slip roll machine also aids in forming a cylinder after the lock or edge is turned on the flat sheet with the folding machine. The skillful operator is able to slip the sheet of metal with the lock turned through the gripping rolls without mashing the lock, to as good ad-

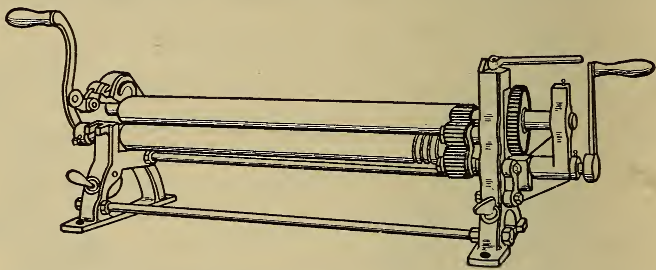


Figure 37.—Forming Machine, Slip Roll Pattern—Back Geared.

vantage on the forming machine with solid housings as on the forming machine, slip roll pattern; but the inexperienced operator will have better success with a forming machine, slip roll pattern, when handling such material.

In all forming machines several convenient grooves of various widths are cut in the rolls on one end and it is between these grooves that sheets previously wired should be rolled. These grooves are cut purposely to facilitate the forming of cylinders which have been previously wired in the flat sheet, and to form straight wire into circles.

Forming machines are manufactured in a variety of lengths, with rolls measuring 1 inch in diameter and larger. For the ordinary sheet metal shop, forming machines with solid housings and slip roll pattern are used quite extensively in lengths of 30 and 36 inches, with rolls measuring 2 inches in diameter. For very heavy and large work rolls are selected measuring from 2½ to 4 inches in diameter, and for extraordinary requirements forming machines with rolls very much larger in diameter than 4 inches are offered.

Figure 37 shows a forming machine, slip roll pattern, back geared and intended for very heavy work. When

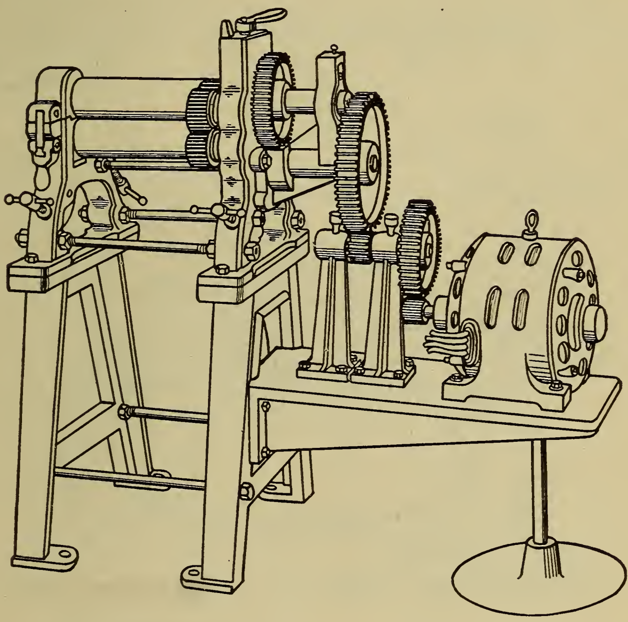


Figure 38.—Forming Machine, Slip Roll Pattern—Back Geared, Direct Motor Drive.

required to stand on the floor the heavy forming machine is fitted to suitable cast-iron floor legs, and when arranged for power the shaft is extended and a tight pulley or tight and loose pulleys are fitted.

The machine shown in Figure 38 is the same machine as shown in Figure 37, but mounted on cast-iron floor legs, with a direct connected motor.

Funnel Forming Machine.—For forming conical and tapering work of various angles, such as can tops, funnels, lamp shades, etc., the funnel forming machine shown in Figure 39 was designed. Two tapered steel rolls 10 inches in length grip the material and a third tapered rear roll does the forming. The two gripping rolls are

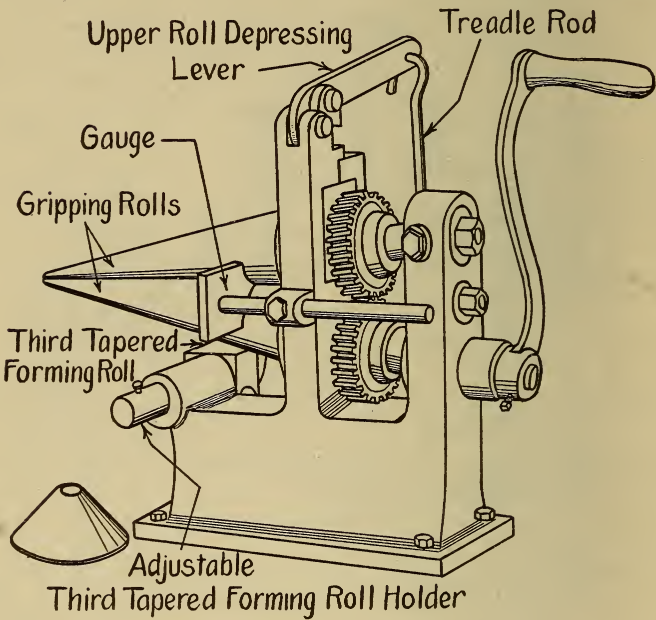


Figure 39.—Funnel Forming Machine.

brought together and the material is clamped through the depression of a foot treadle, and the work formed by means of a hand crank. Through the proper adjustment of the third tapered rear roll various tapers can be formed, measuring as small as 5/8 inch at the small end of the taper and a diameter of 3 inches at the large end. The third tapered rear roll, not shown in the illustration, is supported by a holder, which is adjustable for setting the rear roll close to or away from the two tapered gripping rolls, and is also adjustable to various angles to suit the work to be formed. Where good judgment is used in the setting of this machine, it is not difficult to adjust and operate it so as to secure any number of tapers of uniform size and angle.

The funnel forming machine is very practical for use on sheet iron not heavier than No. 24 gauge (U. S. Standard).

GROOVING MACHINES

Grooving machines follow the folding machines (Figures 15, 17, 18) and are intended for closing or grooving

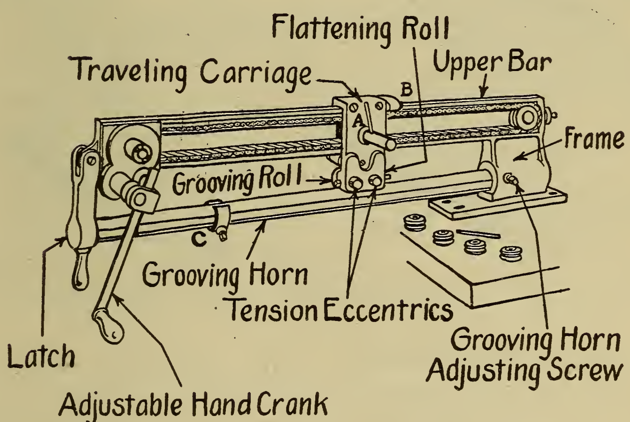


Figure 40.—Grooving Machine.

the seams previously prepared with the folding machine in pipes, cans, tanks, etc. (See Figure 41.) A closed lock is first turned on the sheet of metal by the use of the folding machine. The sheet is then rolled into a cylinder by the forming machine (Figures 35 and 36), when the corresponding edges, as prepared in the cylinder, are snapped together and laid on the grooving horn in the grooving machine. The grooving rolls in the grooving machine run over the seam lengthwise, effecting an operation called "grooving" or "seam closing," and completing the lock, as shown in Figure 41.

The best machine of its kind for ordinary work and where the material to be used is not too heavy, is shown in Figure 40. It differs from the ordinary grooving machine in that it is more rapid and convenient. The operator stands in front of the machine and does not have to change his position when inserting and removing work

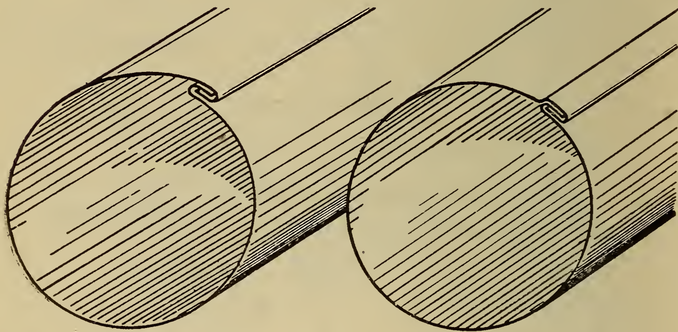


Figure 41.—Showing Section of Pipe Before Grooving, and the Same Section After Grooving, with Seam Located on the Outside.

or operating the machine. The traveling carriage, arranged with one grooving and one flattening roll, on completion of its run over the seam in the work is quickly and easily returned to the starting point, by releasing the lever *A* and pushing the traveling carriage back by hand.

The adjustable stop *B* on the upper bar stops the traveling carriage at any desired point to suit the length of the work to be grooved. The adjustable stop *C* on the lower bar prevents the work from slipping during the process of grooving. A latch connects and holds secure the upper bar and the grooving horn. This latch is thrown back before the work can be inserted in the machine.

When the work is properly placed over the grooving horn the latch is closed, preventing any spring of the grooving horn while the traveling carriage passes over the seam.

The grooving horn is reversible and is made with a series of planed grooves and a flat surface. When it is desired that the seam or groove appear on the outside of the work (see Figure 41), the flat surface of the grooving

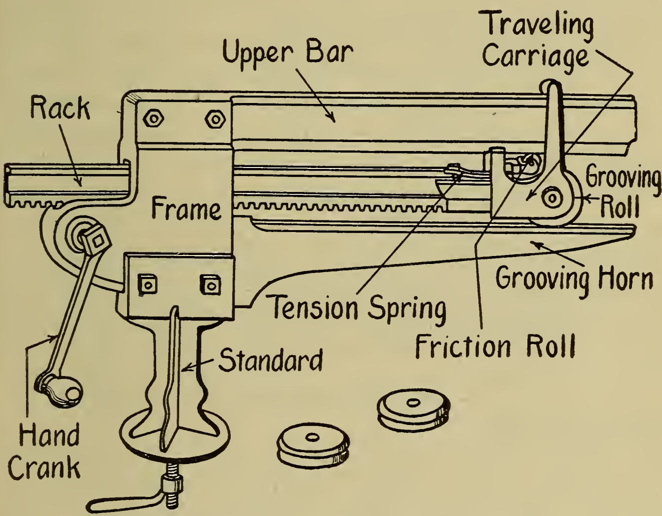


Figure 42.—Grooving Machine, Short Horn.

horn is set upward, using one of the grooved rolls to suit the size of the seam as prepared in the work, and one flattening roll. If the seam is to be located on the inside of the work, one of the grooves planed in the grooving horn, nearest the size of the seam in the work, is selected, and the grooving horn is adjusted so that the selected groove is on top. Using one flattening roll in the traveling carriage provided with the machine, the flat roll passing over the seam will press it in the groove planed in the grooving horn, thus locating the seam on the inside of the work.

The grooving machine, Figure 40, is manufactured in length of 30 inches and will groove work 2½ inches diameter and larger, on material as heavy as No. 24 gauge iron and lighter (U. S. Standard).

For small work, especially where many pieces of the same kind are to be grooved, a short-horn grooving machine is preferable. Figure 42 illustrates a grooving machine for such work. This machine has a tapered grooving horn measuring 3 inches at the large end and 1⅜ inches at the small end, with a length of 20 inches. The grooving horn on this machine is not reversible and the groove or seam locates itself on the outside of the work, as illustrated in Figure 41. Being intended for very light work, a flattening roll is not fitted to the traveling carriage.

The market offers a variety of grooving machines in various designs and capacities, hand operated and for power drive, but in general principle they are all the same.

BENCH MACHINES

The bench machine is a valuable asset in every shop, whether sheet metal work is carried on moderately or extensively. Its construction comprises a frame with shafts and gears, and rolls, or as they are sometimes called, *faces,* of various shapes. These have a very important part in the preparation of sheet metal cylinders, such as cans, tanks, vessels, etc. According to the design of the rolls in the machine, they prepare a groove or seat in sheet metal work for receiving a wire, complete the operation of wiring, turn a burr or flange preparatory to double seaming, and set down seams preparatory to double seaming, in addition to performing a variety of other operations making impressions in flat or irregular shaped sheet metal. The bench machines about to be described are classified as turning machines, wiring machines, burring machines, and setting-down machines, and will be described in that order.

Turning Machines.—Figure 43 shows the turning machine as regularly manufactured and a machine very commonly in use for preparing a seat in the bodies of vessels and such work, for receiving a wire, as shown in Figure 44 at *A*. In operating the turning machine the

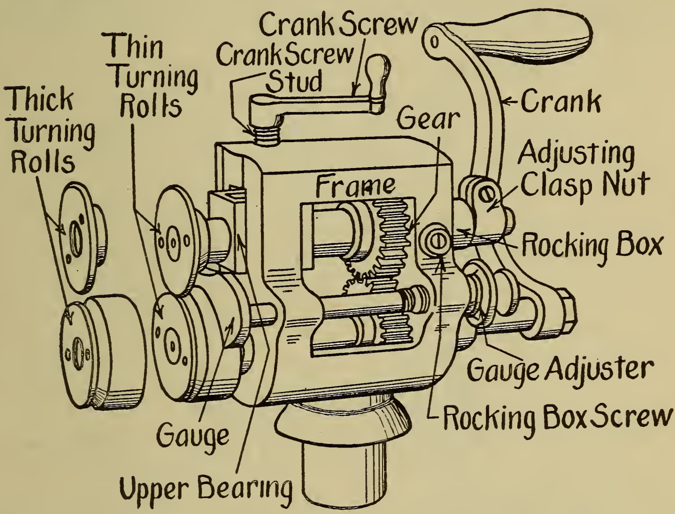


Figure 43.—Turning Machine.

cylinder to be prepared to receive a wire is allowed to rest on the lower roll, one edge of the cylinder striking against the gauge. According to the size of wire to be used, the gauge is adjusted to allow ample material to cover the wire for the wiring operation, which will be described later. The gauge being properly set and the edge of the cylinder to be creased resting on the lower roll while pressing it hard against the gauge, the upper roll is depressed by turning the crank screw, allowing the roll to strike the material slightly. Turning the rolls one revolution with the hand crank, the rolls make a slight crease around the edge of the cylinder. After this crease is secured the crank screw is given another slight turn. In a second and third revolution of the rolls, starting to tilt the work upward, and one or two additional revolutions, bringing extra pressure of the rolls to bear on the work through the crank screw, a deep groove is formed; and in the operation of tilting the work upward, in the process of turning the groove, ample material is left to

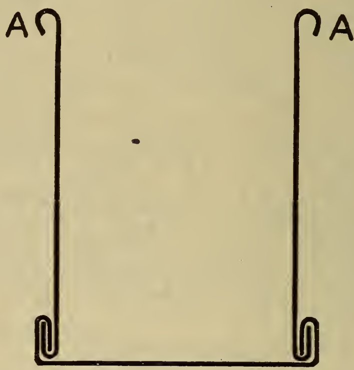


Figure 44.—A, A, Seats for Wire, Made on Turning Machine.

work around the wire after it is laid in the groove made for it. Practice is necessary to make an efficient turning machine operator, but the machine and the work performed are simple and good results are easily attained after a few trials.

The turning machines described are made in two sizes. The small turning machine has rolls measuring $2\frac{1}{16}$ inches diameter and will prepare work for wire as large as $\frac{3}{16}$ inch diameter and as small as 9/64 inch diameter. The large size turning machine, having rolls measuring 3 inches diameter, will prepare work for receiving a wire as large as 15/64 inch diameter, and as small as 11/64 inch diameter on No. 22 gauge iron and lighter (U. S.

Standard). Larger and heavier turning machines of No. 18 gauge iron and lighter capacity, and for preparing work for wire as large as $\frac{5}{16}$ inch, are also manufactured and in these machines the rolls measure 3¼ inches in diameter.

Wiring Machines.—The wiring machine, Figure 45, is used in close connection with the turning machine, Figure 43. The turning operation having been well performed

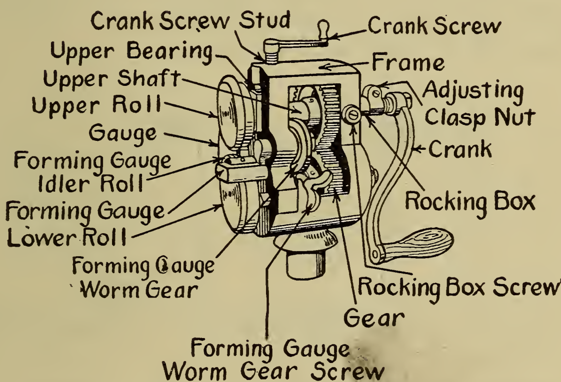


Figure 45.—Wiring Machine.

(see Figure 44), the wire that is to fit into the seat of the vessel as prepared with the turning machine, must be rolled into a circle of a diameter near the diameter of the vessel or cylinder. The forming machines (Figures 35, 36), have grooves cut in their rolls for the purpose of receiving straight wire and forming it into circles. The wire ring secured thus is slipped into the seat prepared by the turning machine, held in its place with the aid of a mallet, closing the metal in the cylinder around the wire one or two inches over the horn in the wiring machine standard (see Figure 55) or over a bench stake.

Proceed to adjust the forming gauge and place the cylinder with the wire inserted between the rolls in the machine, adjusting the gauge in the rear of the machine so that the edge of the upper roll will clear the outer edge of the wire. Then depress the upper roll by means of turning the crank screw, but not too hard for the first revolution of the rolls. In the second and third revolution of the rolls, permit the upper roll to press harder, continuing to close the material left by the turning machine around the wire; and as a finishing operation allow the work to tilt upward, working the material completely and compactly in under the wire (see Figure 46), completing the operation of wiring.

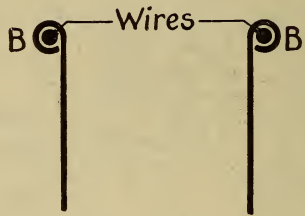


Figure 46.—B, B, Metal Closed Around Wire by Wiring Machine.

The wiring operation with the wiring machine is not difficult with a little practice. The forming gauge in the machine has an idler roll which facilitates the wiring of cylinders, but perfect wiring with the wiring machine is possible with or without the use of the forming gauge, and when not required it is easily detached.

The wiring machine described has rolls measuring 3 inches diameter and is practical for wire up to $\frac{1}{4}$-inch diameter, with a capacity of No. 22 gauge iron and lighter (U. S. Standard). The manufacturer offers larger and heavier wiring machines intended for heavy work and unusually large size wire, hand or power operated; and in such machines the rolls are interchangeable for performing the operations of wiring or turning on the same machine.

Burring Machines.—While a little practice will produce very satisfactory results and make good wiring possible with the use of the wiring and turning machines, as already described, the burring machine (Figure 47) is more difficult to operate, and any attempt to use the burring machine without a teacher would result in a waste of time and not a little spoiled work. A knack is

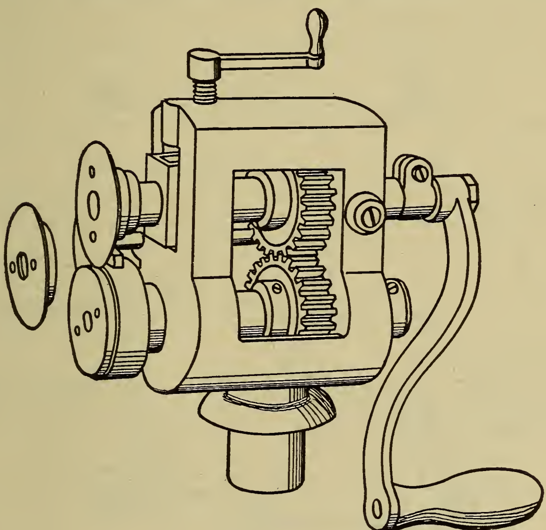


Figure 47.—Burring Machine.

required for holding the work in proper position, and after this is learned a proper and uniform speed is necessary to produce an edge or flange without buckling. See Figures 172-177.

The burring machine is used for creasing, edging rims of covers for pails, boilers, etc., and preparing circular edges of bottoms and bodies of vessels for double seaming. In preparing vessels for double seaming, a burr is first turned at a right angle on the body of the vessel (see Figure 48) ; then one of nearly the same width is turned beyond a right angle around the edge of the bottom. The body is sprung into the last named burr. The vessel is

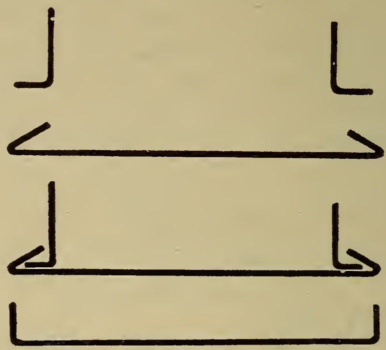


Figure 48.—Three Successive Operations for Double Seaming; also a Bottom Flange, Turned on the Burring Machine.

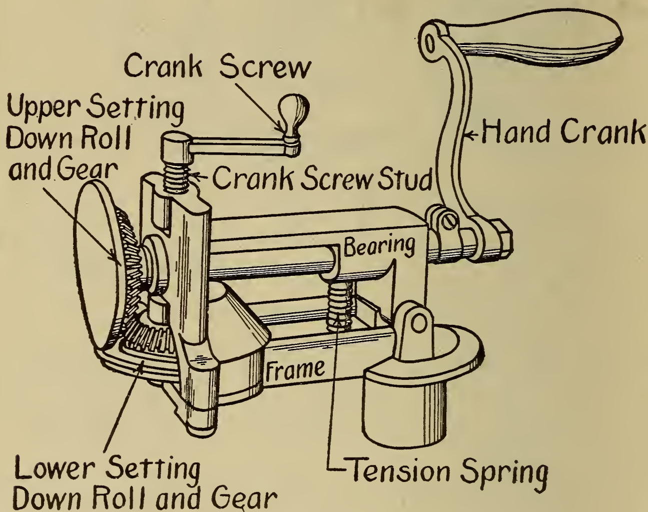


Figure 49.—Setting Down Machine.

then ready for setting down (see Figure 48), using the setting down machines, Figures 49, 52. To turn the burr on the body of the work is not very difficult, but to turn an even burr on the bottom without crimping the burr or warping the bottom requires both teaching and practice.

The burring machine will also turn flanges on bottoms or discs, as shown in Figure 48.

The machine described has a working capacity of No. 22 gauge iron and lighter (U. S. Standard), and is manufactured in a small size with rolls 1½ inches diameter. With the small machine the widest flange or burr that can be turned is $\frac{3}{16}$-inch. The larger machine has rolls measuring 2⅛ inches diameter and the widest flange or burr

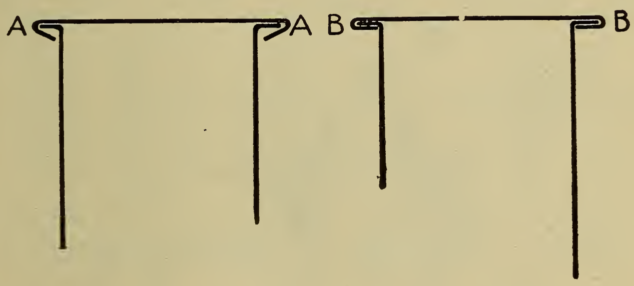


Figure 50.—Edge Turned by Burring Machine.

Figure 51.—Edges Closed on Setting Down Machine.

that can be turned is ¼-inch. According to special requirements, heavier machines of different construction are manufactured for burring or flanging very heavy material, with small or wide flanges as may be preferred.

Setting Down Machines.—The setting down machine, Figure 49, is used to close the seams left by the burring machine (see Figure 48), preparatory to double seaming; and if the work on the burring machine has been well done that of setting down is not hard to learn.

The vessel is held bottom upward and the edge *A*, Figure 50, of the bottom run between two rolls, when the corresponding edges are pressed or closed tight ready for double seaming as shown at *B*, Figure 51. The setting down machine, Figure 49, is more generally used on tinware having seams ⅛ and $\frac{3}{16}$-inch, and where a quantity of the same kind of work is to be set down.

Figure 52 shows a setting down machine intended for the same work as the machine shown in Figure 49, but in this machine the inclined position of both the upper and lower rolls or faces allows the work to be held bottom up or down and the seam to be started inward during the setting down operation, thus facilitating the operation of double seaming (see Figure 67 at *B*). Where seams are

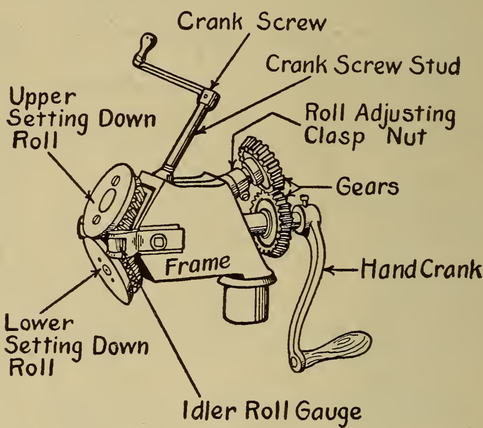


Figure 52.—Setting Down Machine with Inclinable Rolls.

to be closed in other work besides cans, tanks, etc., the construction of the setting down machine, Figure 52, offers a very practical means for general seam closing. It is fitted with adjustable idler roller gauges that guide the work through the rolls, making for more accurate seam closing.

The setting down machine described is made in two sizes, No. 24 gauge iron and lighter capacity (U. S. Standard) for seams up to ⅜-inch, and No. 18 gauge iron and lighter for seams up to ½-inch.

Combination Machines.—A heavy-duty combination turning and wiring machine is shown in Figure 53. This machine has a capacity for working No. 16 gauge iron and lighter (U. S. Standard), and may be used with wire as large as $\frac{5}{16}$-inch diameter and as small as $\frac{1}{8}$-inch diameter. It is back geared and the ratio of gearing is

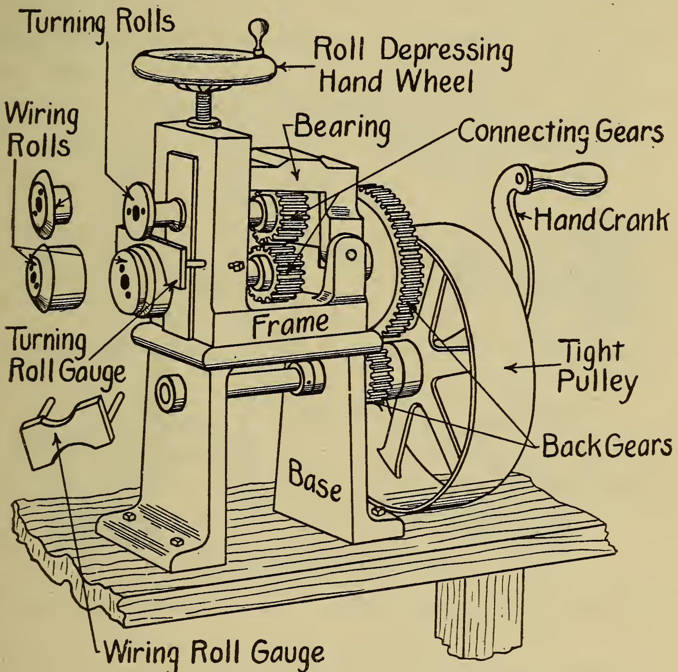


Figure 53.—Heavy Turning and Wiring Machine.

4 to 1. It has a pulley for power drive, and a hand crank fitted to the pulley shaft, which permits the operation of the machine with a belt or by hand.

The wiring and turning rolls fitted to this machine measure only 2½ inches diameter, offering a very practical means for the wiring of flat sheets irregular in shape, such as mudguards, etc. It is suitable for a variety of operations where the work must be perfected with rolls, and when special rolls are fitted it covers a wide field of shaping and forming usefulness.

The machine illustrated in Figure 54 is a combination slitting, crimping and beading machine. When the work

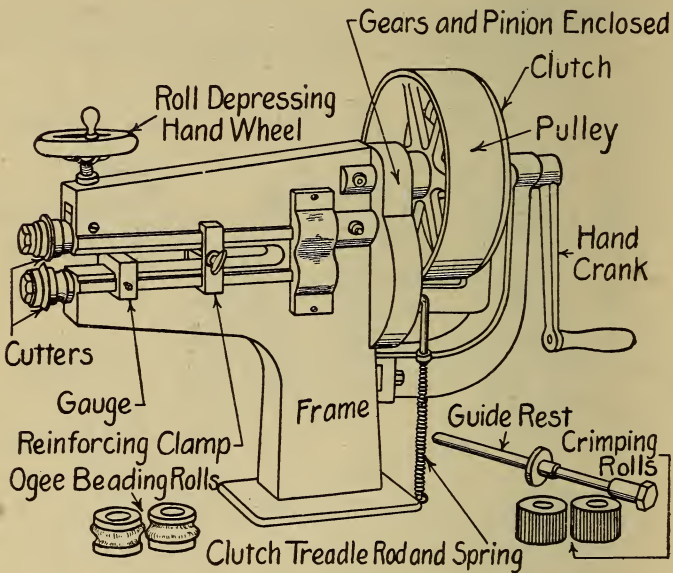


Figure 54.—Combination Slitting, Crimping and Beading Machine.

is not out of proportion to the machine's capacity, wiring rolls and turning rolls are sometimes fitted. The frame is of one piece, compact in construction, and occupies a minimum amount of bench room. Its limited capacity is No. 16 gauge iron and lighter (U. S. Standard). It has a depth of throat of 11 inches, is driven with a belt from a line shaft, and has a friction clutch operated by means of a foot treadle and spring, affording the operator full control of the machine as well as the work in progress. A description of the friction clutch attachment is given under Figure 65.

When so desired, this combination machine can be arranged to run with a direct motor; and where power is not available, it is arranged with a crank for hand drive.

Bench Machine Standards.—The illustrations, Figures 55, 56, show the standards used in connection with the bench machines already described. The machine standard is fastened securely to the workshop bench by means of a screw, button, and hand lever. The horn shown on

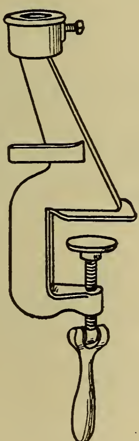


Figure 55.—Wiring Machine Standard.

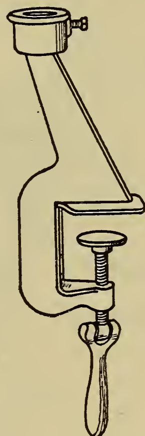


Figure 56.—Regular Machine Standard.

the wiring machine standard in Figure 55, is very handy in preparing work for wiring, as described under Figure 45.

Revolving Standard.—The revolving machine standard shown in Figure 57 will hold eight of any regular bench machines used for perfecting various sheet metal working operations; and with the use of this revolving standard a separate standard for each machine, like those in Figures 55 and 56, is not necessary.

The revolving turret marked *2* holds four machines. Four operations can be completed without changing positions and the four machines set in this turret are always ready for action. The standard is designed with ample room for accommodating from one to four operators. The hand lever *3* holds the revolving turret in a fixed stationary position when so required. The machine holders marked *4* are adjustable; they raise, lower, and

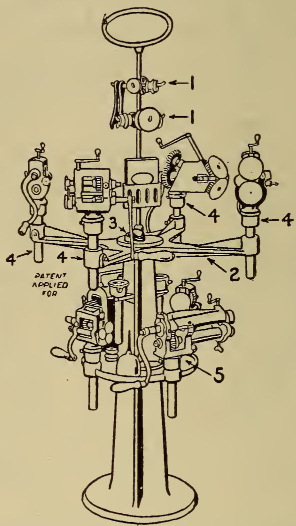


Figure 57.—Revolving Machine Standard.

revolve to suit the operating convenience of the short or tall operator, as well as the work in progress.

The lower stationary turret marked *5* holds four additional machines for quickly interchanging with any machine set in the upper revolving turret. This lower turret also provides for a handy shelf, holding oil can, tools, etc. The brackets marked *1* provide a handy rack for face wrenches, and additional rolls, making "a place for everything and everything in its place."

The practice of taking down and putting up machines many times a day, and throwing them under the bench when it is desired to utilize bench room for some other purpose, only to find some part of the machine broken when its use is most required, is a condition in the average shop which this revolving machine standard entirely eliminates. The standard takes up a floor space of only

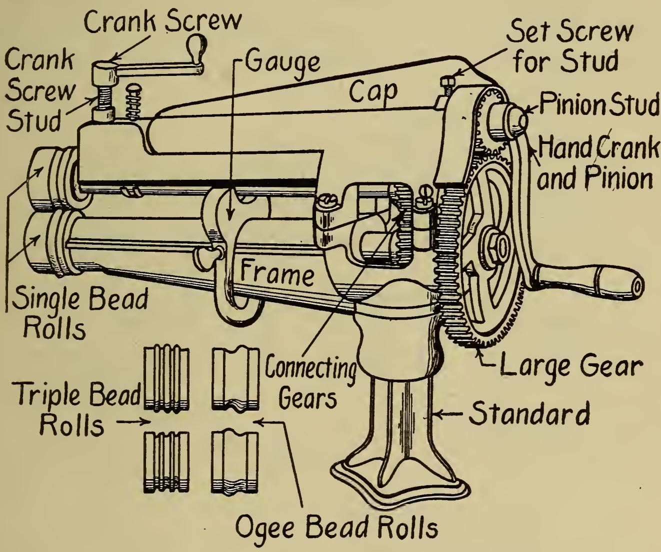


Figure 58.—Beading Machine.

30 inches in diameter, and has been approved by veteran sheet metal workers as a modern and improved method of bench machine operation.

BEADING AND CRIMPING MACHINES

The beading or swaging machine is used for making depressions in iron, stiffening and ornamenting automobile mudguards, pipe, the bodies of vessels, and such work, and is very simple to operate. Several pairs of rolls of suitable designs usually accompany the machine. The rolls furnished with the beading machine shown in Figure 58 are of three kinds; namely, single bead, ogee bead, and triple bead. According to the kind of work, the design of bead that will show up on the work most attractively is selected and the work to be beaded is placed in the machine between the rolls, pressing the edge of the work against the gauge. The proper location for the bead in the work being secured, the upper roll is depressed by turning the crank screw. Turning the hand crank

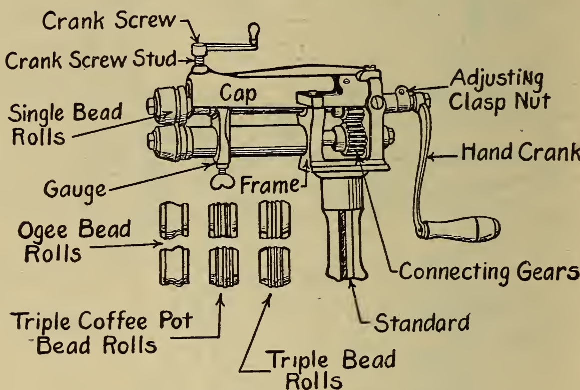


Figure 59.—Light Beading Machine.

with the right hand and guiding the work with the left hand, the work revolves around the rolls, completing an impression in the metal to conform with the design in the beading rolls used, thus ornamenting and reinforcing the body of the work.

The beading machine illustrated in Figure 58 is manufactured in two sizes, having a depth of throat 12 inches and 6¾ inches respectively, and heavy enough to bead or swage iron of No. 20 gauge and lighter (U. S. Standard).

Figure 59 shows a beading machine of light capacity, No. 26 gauge iron and lighter (U. S. Standard), made in two sizes, with a depth of throat of 5½ inches and 4 inches respectively. Four pairs of beading rolls, with an additional pair of rolls with the smaller machine having the 4-inch throat, complete the roll equipment furnished. This type of beading machine is used very extensively by

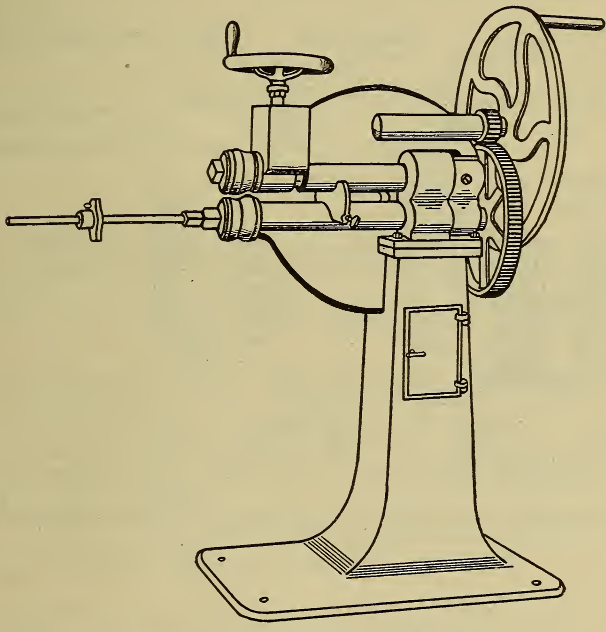


Figure 60.—Heavy Beading Machine.

the tinware manufacturer and in the shop of the sheet metal worker where the work to be beaded or swaged is light and of a uniform kind.

Heavy Duty Beading.—Figure 60 shows a beading machine suitable where a large heavy-duty machine is required. This machine has a depth of throat of 10¼ inches, the rolls measuring $4\frac{7}{16}$ inches in diameter; and is back geared, with a ratio of gearing 4½ to 1. It is claimed that it will make impressions in sheet iron No. 14 gauge and lighter (U. S. Standard). When arranged for power drive, the shafts are extended and tight and loose pulleys are fitted.

A beading machine of this capacity is very much used in shops where furnace casings, large tanks, and such

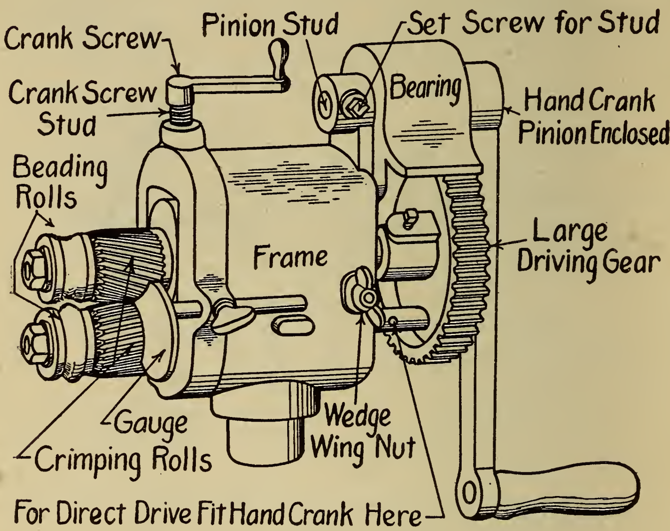


Figure 61.—Crimping and Beading Machine.

parts as go into ventilating systems must be reinforced through making a series of impressions in the iron, for which use the beading machine is intended. Turning and wiring rolls are sometimes used on this machine where the wire and cylinder are large and the material heavy, special alterations making it adaptable for a wide range of work.

Crimping and Beading.—A great deal of descriptive detail is not necessary in connection with the crimping and beading machine, Figure 61, after it is explained that the crimp and bead so much in evidence on the edge of the common stove pipe are made with this machine (see Figure 62). Crimping and beading machines are intended to facilitate the making and putting together of sheet iron pipe of different diameters, by contracting the edge of the pipe so that one joint of pipe will enter another. In putting together the pipe the ogee bead next to the crimp prevents the joints slipping beyond the impression made with the beading rolls.

The crimping and beading machine is easy to operate. The joint of pipe to be crimped is laid over the lower

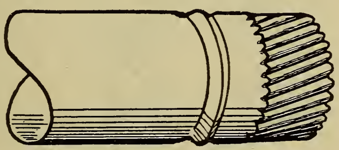


Figure 62.—Showing Crimp and Bead Made with Crimping and Beading Machine.

rolls, pressing one edge of the pipe against the gauge. By means of a crank screw a depression of the upper crimping and beading rolls is made, and turning the hand crank with the right hand, guiding the work with the left hand, the pipe in the machine revolves around the rolls, making an impression around the edge of the pipe called *crimp* and *bead.*

In the machine illustrated a very practical feature is offered in the arrangement of the driving gears. Two speeds are provided for; back geared when using heavy material, and direct drive when the lighter gauges of materials are used. The driving gears at the crank end can be removed and the machine converted instantly into a direct-acting crimper by attaching the crank to the lower shaft. The wedge between the rear bearings in the frame provides an adjustment for regulating the relative depth of crimp and bead. This wedge is adjusted by wing nuts in the front and back of the frame. By turning these wing nuts the upper shaft can be tipped as desired, making a deep crimp and shallow bead, or shallow crimp and deep bead. With the regular equipment, as furnished with the crimping and beading machine, blank collars are included and may be substituted in place of beading rolls where crimping alone is desired.

Cornice Maker's Crimper.—The crimping machine illustrated in Figure 63, commonly known as the cornice maker's crimper, is practically the same as the crimping

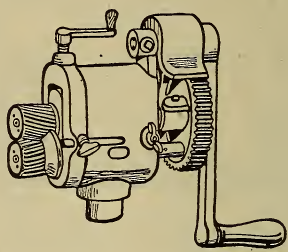


Figure 63.—Crimping Machine.

machine shown in Figure 61, but in this machine the beading rolls are not used and the crimping rolls are attached to their arbors in a manner that leaves the ends or faces of the crimping rolls flat or flush. They are thus adapted for crimping close up to a bend or angle as in cornice work, etc., and are constructed for crimping only.

Heavy Crimping and Beading.—Figure 64 shows a heavy crimping and beading machine. A similar machine is manufactured and constructed for crimping only, with the crimping rolls attached to their arbors flush, as described under Figure 63. The improvement described under Figure 61, consisting of a wedge found between the rear bearings in the frame, providing an adjustment for regulating the relative depth of crimp and bead, are included in the heavy crimping and beading machine, Figure 64.

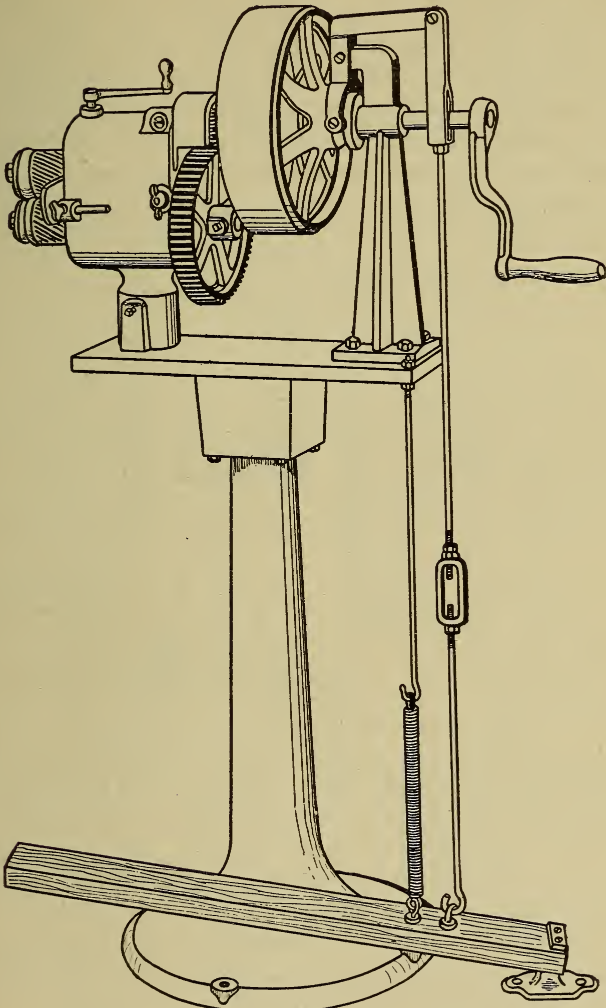


Figure 64.—Heavy Crimping and Beading Machine—Power Drive.

This machine has a ratio of gearing $4\frac{1}{2}$ to 1, and will make an impression of a crimp and ogee bead in sheet metal 18 gauge iron and lighter (U. S. Standard). The rolls are large, measuring $2\frac{15}{16}$ inches in diameter. A friction clutch operated by means of a foot treadle and spring affords the operator full control of the machine, as well as of the work in progress. A depression of the foot treadle starts the machine and when not depressed

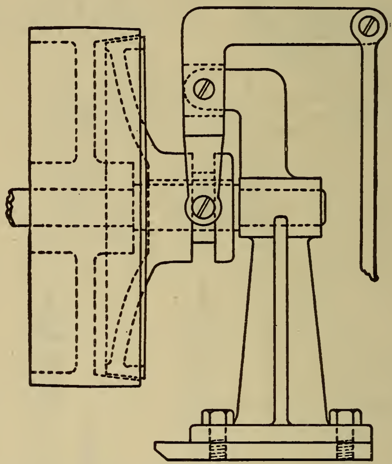


Figure 65.—Friction Clutch Attachment.

the rolls stop instantaneously. The work is placed in the machine over the lower rolls and the upper rolls are depressed by turning a crank screw. As the friction clutch provides for instantaneous starting and stopping of the machine, the operator's hands are left free for guiding the work and manipulating the crank screw. The machines are manufactured for hand use and to fit on the workshop bench where power is not available.

The *Friction Clutch Attachment* is a very practical device when used with the heavy crimping and beading machine, Figure 64, and is often applied to other machines. It is most useful when applied to machines performing operations in sheet metal work with the aid of rolls cut to various shapes and forms for the duty required of them. This clutch, providing for instantaneous starting and stopping of the machine at the will of the operator, prevents much spoiled work.

FLANGING MACHINES

The flanging machine is very useful for turning flanges of various heights for bottoms that go into the bodies of tanks, vessels, etc., and forms a right-angle flange of various heights around the circular edge of sheet metal discs.

The flanging machine shown in Figure 66 has a maximum capacity for operating on No. 14 gauge iron and lighter (U. S. Standard). It will flange bottoms from 12 to 50 inches in diameter, and with the proper flanging rolls a flange can be turned from $\frac{1}{4}$ to $\frac{5}{8}$-inch high on Nos. 18, 20, and 24 gauge iron; from $\frac{1}{4}$ to $\frac{7}{8}$-inch high on No. 16 gauge iron, and from $\frac{7}{16}$ to $1\frac{1}{4}$ inches on No. 14 gauge iron.

Round discs to be flanged are centered and held in the yoke on the counterbalance swiveled arm. The yoke is gradually raised until the flange is turned as far as desired, but not to exceed a right angle. The obtainable height of the flange depends entirely upon the thickness of stock to be used and the expectation as to smoothness of flanges, and it is always advisable to state all flanging requirements in detail to the manufacturer, in order to secure the very best results from a machine.

Cutting discs and turning rolls for preparing a seat in large tank work of heavy material for receiving a wire; wiring rolls for completing the operation of wiring, and beading rolls for stiffening and ornamenting the bodies of tanks, vessels, furnace casings, etc., are often applied to the flanging machine. When these attachments are used, the flanging yoke is removed.

DOUBLE SEAMING MACHINES

A review of the descriptive matter under Burring Machine (Figure 47) and Setting Down Machine (Figure 49) will prove helpful at this time in understanding

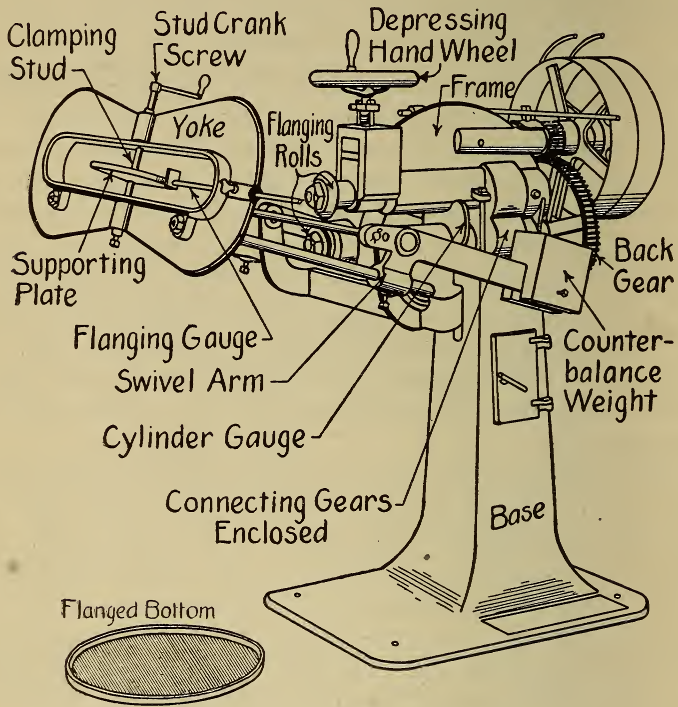


Figure 66.—Power Flanging Machine.

the uses of the double seaming machine. After the setting down machine has done its work, the flange left by it is turned up against the bottom of the vessel, to make both the seam and the bottom tight. In repair shops this is sometimes done with a mallet over the end of the double seaming stake. If much work is to be done, a double seaming machine will prove a time-saver and will turn out better finished work in a fraction of the time that would be required with a hand operation.

The flange, as left and closed down with the setting down machine, is illustrated at *A*, Figure 67. This flange at *A* is turned up against the body of the vessel with the double seaming machine, making the seam and bottom tight, as shown at *C*.

Figure 68 shows the horizontal disc double seaming machine, which is made in several sizes for accommodat-

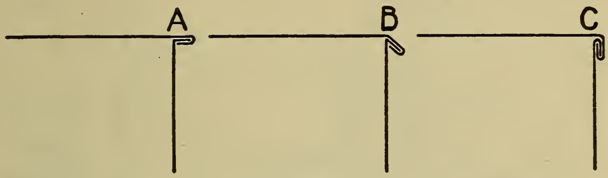


Figure 67.—Work of the Double Seaming Machine.

ing vessels with a depth up to 36 inches and of various diameters.

Where this machine is used it is necessary to start the seam inward while setting down with the setting down machine, as shown at *B*, Figure 67, thus facilitating the operation of double seaming.

In operating the horizontal disc double seaming machine, a disc must be selected of a size nearest to the diameter of the vessel to be double seamed. The vessel is placed over the disc and the upright holding the disc, and the work over it is brought in line and contact with the double seaming roll or face. The flange left as shown in Figure 67, at *B*, is turned up against the body of the vessel as shown in the same figure at *C*, through friction and pressure of the double seaming roll brought to bear on the seam by gradually turning the crank screw while the work is revolving. The seam in the work must not come in contact too close or too far away from the double

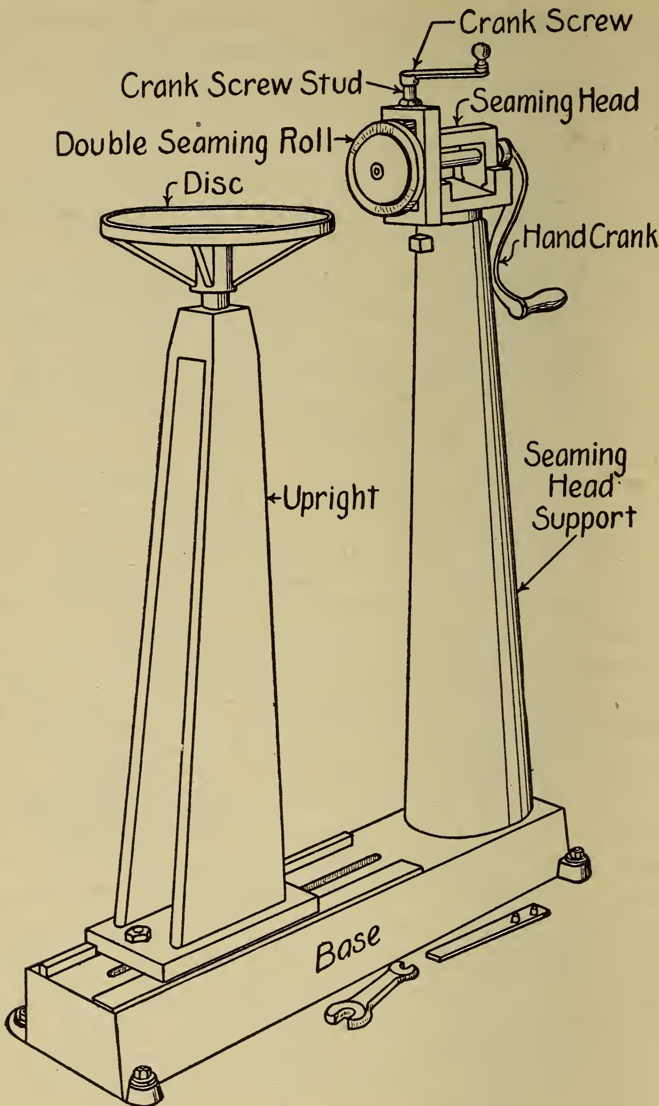


Figure 68.—Horizontal Disc Double Seaming Machine.

seaming roll, the proper setting and adjustment of the upright which supports the work being secured through trials and experiments.

This horizontal disc double seaming machine, Figure 68, will double-seam work of unusually large diameters, of material No. 22 gauge iron and lighter (U. S. Standard), and of any depth up to 36 inches. The machine is made in smaller sizes and lighter capacities, of different construction, but in principle they are nearly all the same.

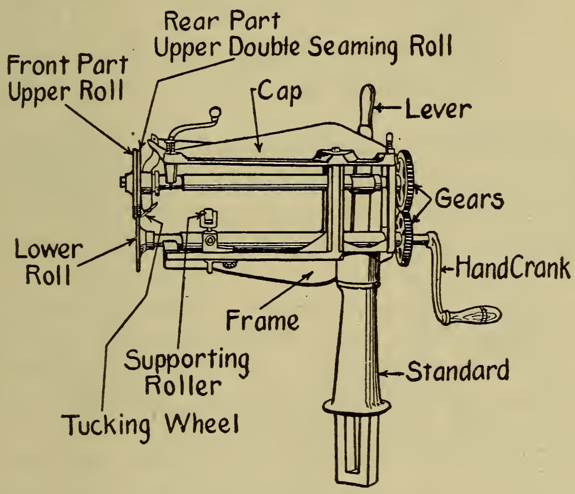


Figure 69.—Double Seaming Machine, Moore's Patent.

Moore's Patent.—The double seaming machine shown in Figure 69, known as "Moore's Patent," is more desirable for general use, as the frequent changing of discs to the nearest size of the vessel to be double seamed is unnecessary.

The operation of double seaming is performed with this machine in two steps, by engaging two parts of the upper roll. The first step throws the seam over part way, as shown in Figure 67 at *B,* and the second step finishes the operation of double seaming as shown in the same figure at *C.*

The work to be double seamed is placed in the machine over the lower roll, and the lever that engages with the upper roll is thrown over to the left, which places the rear part of the upper double seaming roll in position for the first step. A slight depression of the upper roll on the work is then effected by means of turning the crank screw, revolving the vessel around the rolls by turning the hand crank. During this operation the bottom of the vessel must be pressed firmly against the face of the lower roll.

The first step in double seaming completed, the upper roll is raised and the lever thrown to the right, bringing the front part of the upper roll in position for the finishing operation, which is performed in the same manner as just described.

The double seaming machine, Moore's Patent, has a small tucking wheel, which is thrown in position to work with rolls for the first step or operation. This wheel tucks in the edge of the seam in the vessel and aids in bending the seam over.

Care should be exercised not to depress the upper double-seaming roll too hard in the first few revolutions of the rolls, but allow pressure of the double seaming rolls on the seam to bear gradually.

The double seaming machine described will operate on No. 26 gauge iron and lighter (U. S. Standard). The large machine, having a throat of 15½ inches, will double seam work 15½ inches deep, 4½ inches diameter and larger. The small machine, with a throat of 10 inches, will double seam work 10 inches deep, 3 inches diameter and larger.

Machines of the same type are manufactured for power drive and heavy capacity.

ELBOW MACHINERY

In making a pipe elbow the blank is first cut from pattern, and if the elbow is to have a lock seam in the throat, the longitudinal edges of the blank are edged preparatory to grooving or seam closing on the folding machine. The blank with the lock edges is then formed and rolled

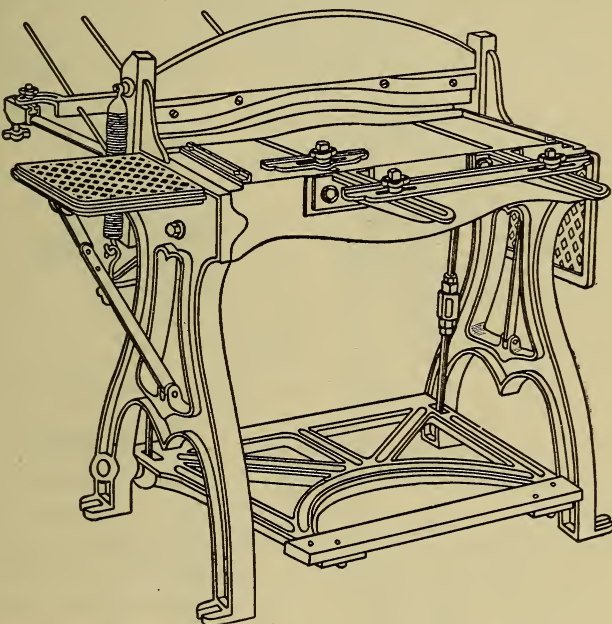


Figure 70.—Curved Elbow Shears.

into a cylinder with the forming machine, and the corresponding edges are locked together and the seam made tight with the grooving machine. In the case of the riveted elbow it is held together with rivets.

In some shops the elbow blank is cut from pattern with the hand snip or the bench shears, but in a shop where many of the same kind of elbows are manufactured a more rapid means of cutting elbow blanks is used, namely, a press and dies, or the curved shears.

Curved Elbow Shears.—This machine (Figure 70) resembles the squaring shears (Figure 1) and is operated in the same manner, but in place of having straight cutting blades, curved blades and blocks are fitted. According to the blades used the curved shears will cut elbow blanks for 2, 3, and 4-piece elbows, with a range of diameters 2, 2½, 3, 3½, 4, 4½, 5, 5½, 6, 7, 8, 9, 10, 12, 14, and 16 inches, of 90 degrees or special angles, with a seam in

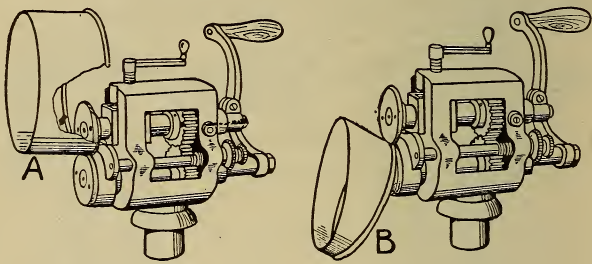


Figure 71.—Bench Elbow Edging Machine.

the throat or on the side of the elbow. The capacity of the curved shears is No. 22 gauge iron and lighter (U. S. Standard).

Elbow Edging.—For making the impression or crease in the circular edge of the elbow, required to lock the corresponding sections together, the elbow edging machine shown in Figure 71 is used.

The different makers of elbows have their preferences as to the kind of seam that makes for the best adjustable or tight joint elbow. The elbow edging rolls shown in Figure 73, and marked 1, are the ones most commonly used. With this elbow edging machine, they are interchangeable.

Figure 71 at *A* shows the position of an elbow section when turning the edge. At *B* the illustration shows how the crease is made to enter the corresponding section. The edge and the crease are made with the same rolls, design

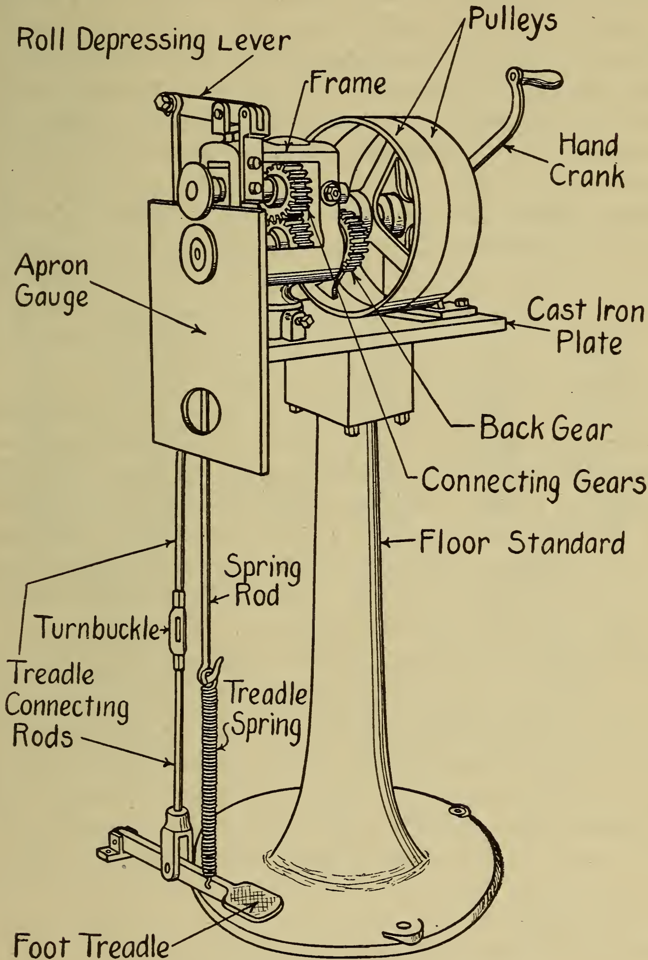


Figure 72.—Power Elbow Edging Machine.

No. 1, Figure 73, making an elbow with a tight or adjustable joint. If any other design of edge is preferred, the elbow edging rolls are used in pairs to conform with the design of seam preferred.

The bench elbow edging machine (Figure 71) is used extensively in the small shop, and proves very useful when it is desired to make an elbow in special size and where only a few elbows are required. The elbow edging rolls in this machine measure 2⅛ inches diameter, and its capacity is No. 24 gauge iron and lighter (U. S. Standard).

Power Elbow Edging Machine.—The elbow manufacturer making elbows in very large quantities must depend upon a power machine for producing with speed and accuracy perfect edges on each and every elbow section. The power elbow edging machine designed for meeting these requirements is illustrated in Figure 72.

Rigidity of the machine while in operation is an essential factor in perfect elbow edging. The machine shown complies with this requirement, as the frame is attached securely to a heavy cast-iron plate and both the machine and its plate are fitted to a heavy iron floor standard. An apron gauge of unusual width, machined with a slight curvature in its face, guides the edge of the elbow through the rolls with extreme accuracy.

The depression of the upper roll is secured by means of a foot treadle and spring, leaving the operator's hands free for guiding the elbow through the rolls. According to the requirements of the elbow manufacturer, elbow edging rolls as shown in Figure 73 are used and interchange with this machine. The rolls used, measuring 3¼ inches in diameter, travel faster and finish an edge in elbows of large sizes in less time than it would take with rolls of smaller diameter.

With the proper rolls and gauges, this machine can be used as a turning, wiring, or burring machine. Where power is not available, it is arranged for hand use, and when so arranged the machine fits into a standard which attaches to the shop bench. The illustration shows this machine fitted with tight and loose pulleys, but when so preferred it can be arranged with the friction clutch attachment shown in Figure 65. When the friction clutch attachment is used, the pressure on the rolls is secured with a crank screw instead of a foot treadle attachment. The capacity of the machine is No. 20 gauge iron and lighter (U. S. Standard).

Elbow Edging Rolls.—The elbow edging rolls shown in Figure 73 are interchangeable for use with the elbow edging machines shown in Figures 71 and 72.

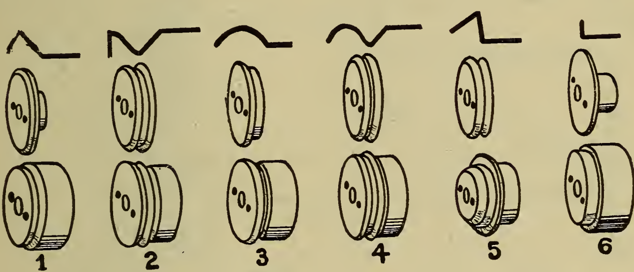


Figure 73.—Elbow Edging Rolls of Various Types.

Rolls of the type marked *1* produce a V-shaped edge and a right-angle edge when the edge in the elbow is formed as described under Figure 71.

Rolls like No. *2* are desirable for edging inside and outside elbow sections of riveted elbows with tight or loose joint.

Rolls like Nos. *3* and *4* are preferable for elbows with riveted or grooved seams and when the joint is to be loose.

Rolls like No. *5* can be used for the outer edge of riveted or grooved elbows; and when using these rolls the inner edge is turned on the regular burring machine or with rolls of design No. *6*.

Elbow Seam Closing.—When sections of elbows are properly edged and put together, the circular seam must be closed, in order to prevent the elbows from breaking apart at their joints through handling. This is done either by means of the elbow seam closing machine or by hand with a mallet over a bench stake.

Figure 74 shows an elbow seam closing machine intended for closing the circular seams of pieced elbows having tight or loose joints. The rolls in the elbow seam

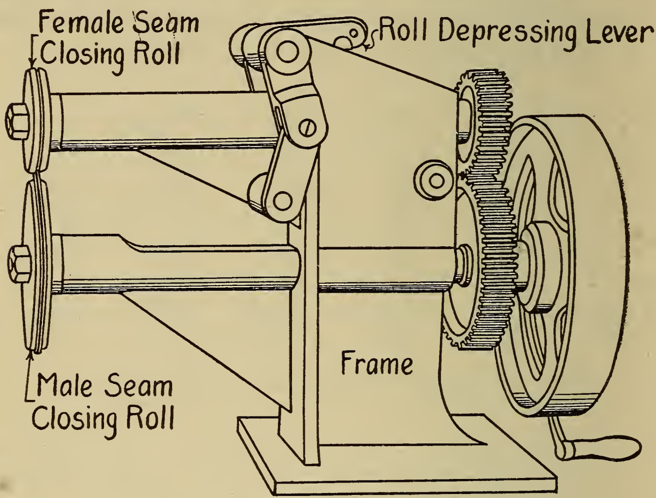


Figure 74.—Elbow Seam Closing Machine.

closing machine are shaped to correspond to the seam in the elbow; and in putting the elbow together in sections the elbow to be closed fits over the lower roll, the seam in the elbow resting over a bead cut in the roll. The upper female roll is depressed by means of a foot treadle and spring, starting the elbow through the rolls by pressure of the upper roll on the seam. The elbow then revolves around the rolls, making the seam tight. Elbow seam closing machines are manufactured with a maximum capacity of Nos. 26 and 24 gauge iron and lighter (U. S.

Standard), suitable for elbows 4 to 7 inches diameter on the lighter machine and 8 to 12 inches diameter on the heavier machine.

PUNCHING MACHINES

Punching machines, as extensively used by the sheet metal worker, are so simple in their operation that a lengthy description is unnecessary. They are made in a

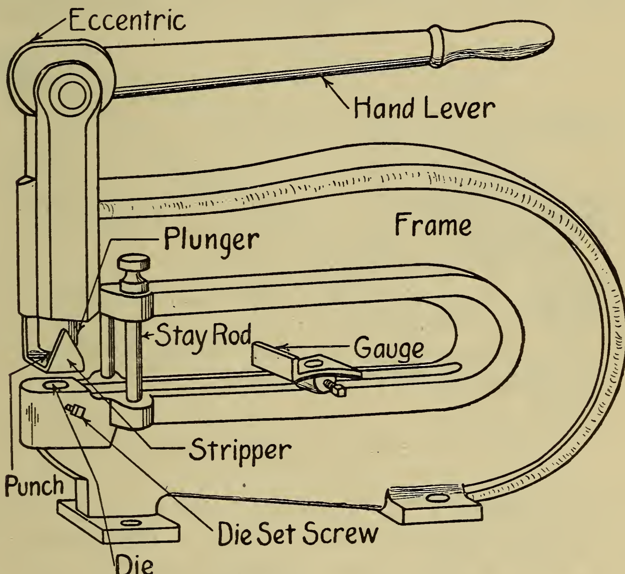


Figure 75.—Punching Machine.

wide variety of sizes and capacities, but for general use the deep throat punching machine is preferable.

Figure 75 shows a lever punch having a depth of throat of 15 inches. It will punch a hole 1/4, $\frac{5}{16}$ or 3/8 inch in diameter, in the center of a 30-inch sheet. It has a capacity for punching as heavy as No. 12 gauge iron (U. S. Standard) and when reinforced by the stay bolts in the frame of the machine it will punch No. 9 gauge iron and lighter.

A heavier and larger punch of similar design is made for punching a 3/8-inch hole in 3/8-inch iron; and by the use of special punches in the heavier machine larger holes can be punched, from 1/2 to 1 1/4 inches in diameter, in sheet iron ranging in thickness from 1/8 to 1/4 inch.

Figure 76 shows a useful combined shears and punch, having a depth of punching gap of 2 3/4 inches. This ma-

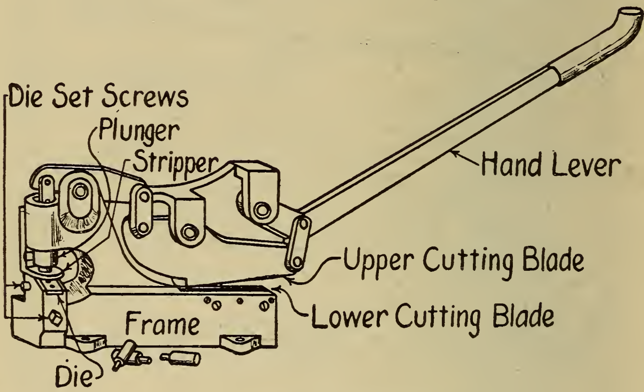


Figure 76.—Combined Shears and Punch.

chine will center sheets 5 1/2 inches wide and will punch a 1/8, 3/16, 1/4, 5/16, or 3/8-inch hole in iron 3/16 inch thick. The cutting blade is 4 3/4 inches in length and will cut sheet iron 1/8 inch thick and narrow bars 3/16 and 1/4 inch.

Combined shears and punches somewhat different in construction are also built for heavy duty, with a punching capacity as great as 3/8-inch hole in 3/8-inch iron, and will cut sheet iron No. 8 gauge (U. S. Standard) and bar iron 1/4x1 1/2, 3/8x3/4, or 1/2 inch square.

The notching machine, Figure 77, is constructed for notching blanks of pieced sheet metal ware, for cutting the corners of square pans, hinged notches of boxes, and similar work. The dies are made in sections, so that they may be easily sharpened and reset. The notching machine has ample gauging capacity for cutting the corners of sheet meal blanks in a wide range of sizes. The sheet

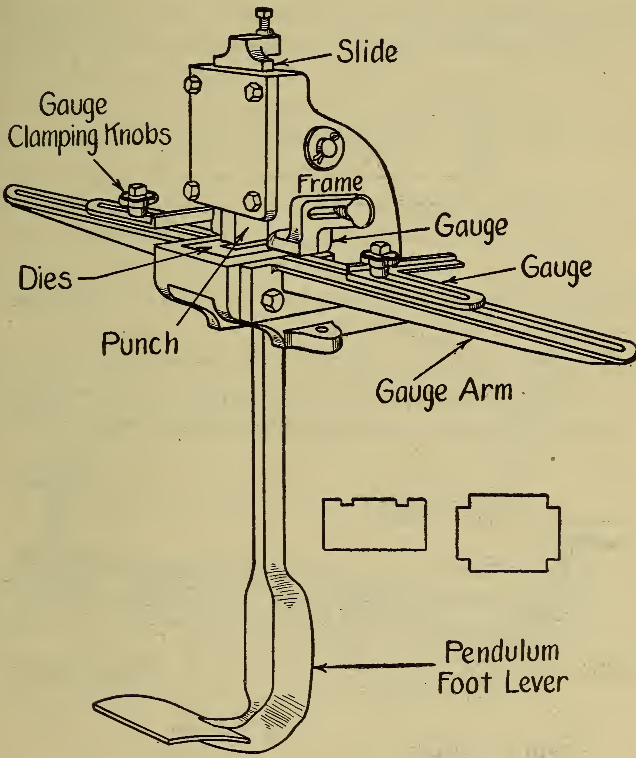


Figure 77.—Notching Machine.

metal to be notched is placed in the machine between the punch and dies, and by operating the pendulum lever with the foot the notch is cut. The regular machine is fitted with one set of dies measuring 1x2 inches, and can be arranged to receive special dies in sizes up to 2x2 inches. The heaviest material that can be used on this machine is No. 20 gauge iron and lighter (U. S. Standard).

GUTTER MACHINES

Gutter beading machines are used for forming a bead on the edge of sheet gutter metal and are easily operated.

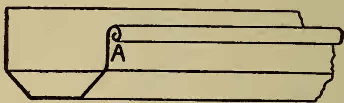


Figure 78.—Gutter with Bead.

A bead as made on a gutter with the gutter beading machine, is shown in Figure 78 at *A*.

Adjustable Beader.—Figure 79 shows an adjustable gutter beader which will form a bead in gutter 30 inches in length, and will receive various sized rods for form-

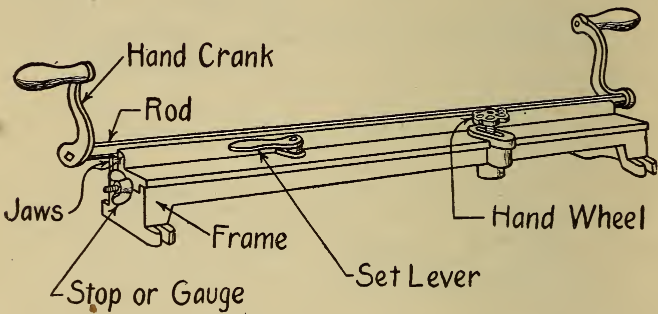


Figure 79.—Adjustable Gutter Beader.

ing a bead 3/8 to 7/8 inch. After the bead is formed, the rod with the sheet of metal and the formed bead can be lifted out of the machine and the work slipped from the rod. The machine has a gauge or stop on the left-hand end, so that after adjusting the jaws and setting the gauge or stop for the size of rod to be used, the jaws can be easily opened to remove the work and rod and again closed to exactly the same position as when the bead was formed. This enables the operator to form any number of beads of exactly the same size. The jaws are adjusted by a hand wheel with rack and pinion, which adjusts both ends of the movable jaw. The sheet of metal to be formed into a gutter bead is inserted in a slot milled in the rod; and by means of a hand crank the material winds around the rod, completing the bead.

Plain Beader.—The plain gutter beading machine, Figure 80, is manufactured in sizes 20, 30, 42, and 60 inches in length. It is intended for the same work as the ad-

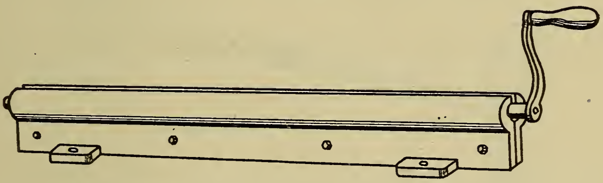


Figure 80.—Plain Gutter Beading Machine.

justable gutter beader (Figure 79), but is not adjustable and each machine will receive only one size of rod, thus making a bead of one size only. Plain beaders are built with a range of rod diameters from ⅜ to 1 inch, according to the length of the machine.

ROOFING AND GUTTER TONGS

Various styles of roofing and gutter tongs are shown in Figure 81.

Stow's improved tongs (*1*) are adjustable for turning five different widths of locks, namely, ½, ¾, 1, 1¼, and 1½ inch.

Reese's patent adjustable gauge tongs (*2*) will turn any size lock from ¾ to 3 inches.

The gutter tongs (*3*) have a depth of jaws of 14 inches. Clamp tongs (*4*) have a depth of jaws of 3 inches.

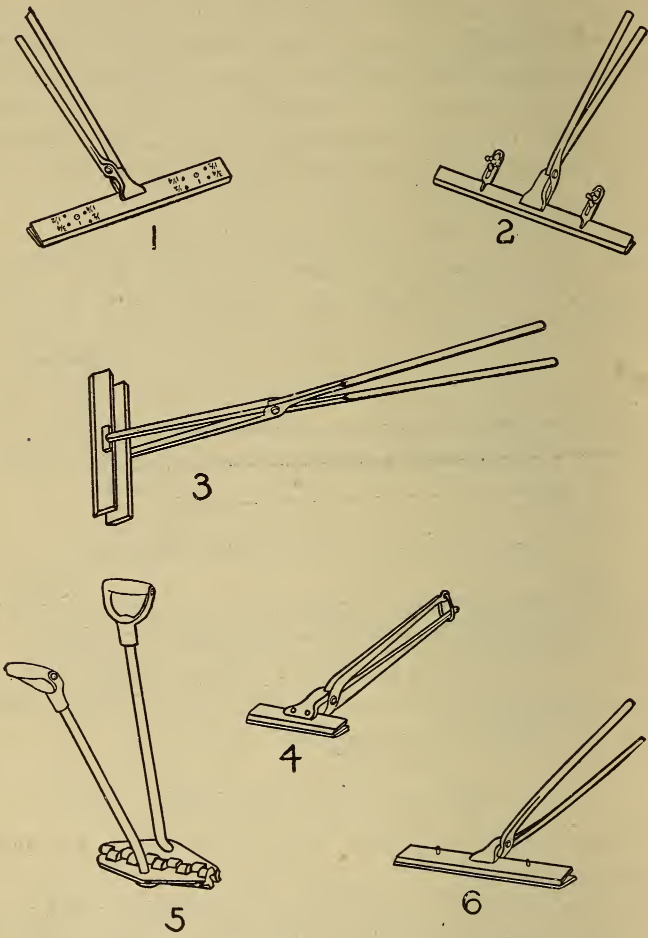


Figure 81.—Roofing, Gutter Tongs and Squeezing Tongs.

The squeezing tongs (*5*) are used in the application of roll and cap roofing with protected cleats.

The regular roofing tongs (*6*) will turn one size lock only and are made in the following range of sizes: ½, ¾, 1, 1¼, 1½, 1¾ and 2 inches.

Figure 82 shows a deep throat roofing tongs, with an

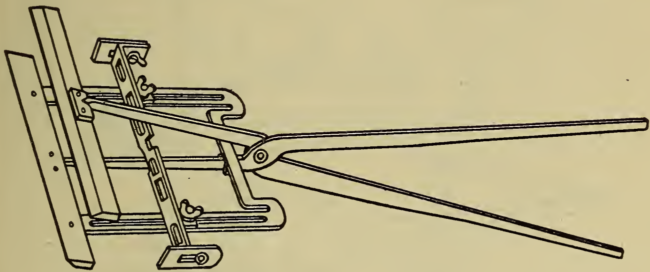


Figure 82.—Deep Throat Roofing Tongs.

adjustable gauge adapted for turning any edge from ½ to 10½ inches.

STANDING SEAM ROOFING

Continuous roll tin roofing is usually prepared from tin plate 20x28 inches for standing seam roofing. After the sheets are edged the cross lock seamer shown in Figure 83 is used for fastening the tin plates together and closing a single or double lock. As the seams are closed a reel winds the sheet into a roll ready to lay on the roof.

The roll of tin being properly placed on the roof, it is edged with the Stow's or regular roofing tongs, as shown in Figure 84.

Roofing Double Seamers.—Having the edges turned with the roofing tongs, as shown in Figure 84, the roofing double seamers, Figure 85, are then used.

The double seamers are used in sets of two pairs and form a double seam in standing seam roofing. They are termed common gauge seamers and wide gauge seamers. The common gauge seamers follow the 1 and 1¼-inch regular roofing tongs. With the roofing tongs the continuous roll roofing, as laid out on the roof flat, is turned up as already stated and illustrated in Figure 84.

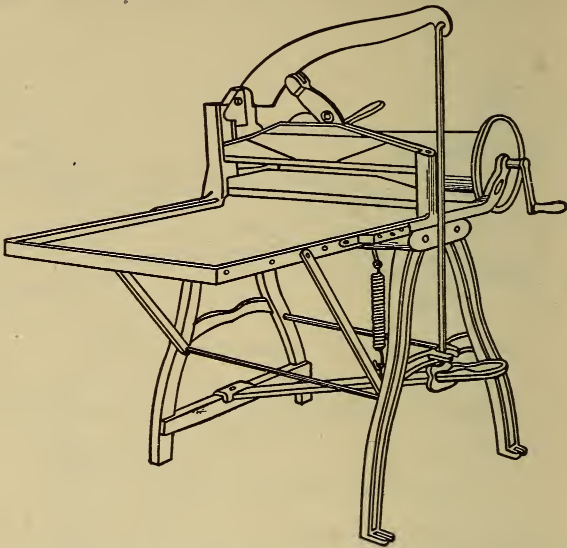


Figure 83.—Burritt's Patent Cross Lock Seamer.

The first pair of common gauge seamers start the seam in operations shown in Figures 86 and 87.

Figure 84.—Roofing Edges Turned, Ready for Double Seam.

For the finishing operation the second pair of roofing double seamers in the set are used, completing the seam in operations shown in Figures 88 and 89, and thus finishing a standing seam ¾ inch high.

The wide gauge roofing double seamers, which follow the $1\frac{1}{4}$ and $1\frac{1}{2}$-inch regular roofing tongs, are used the

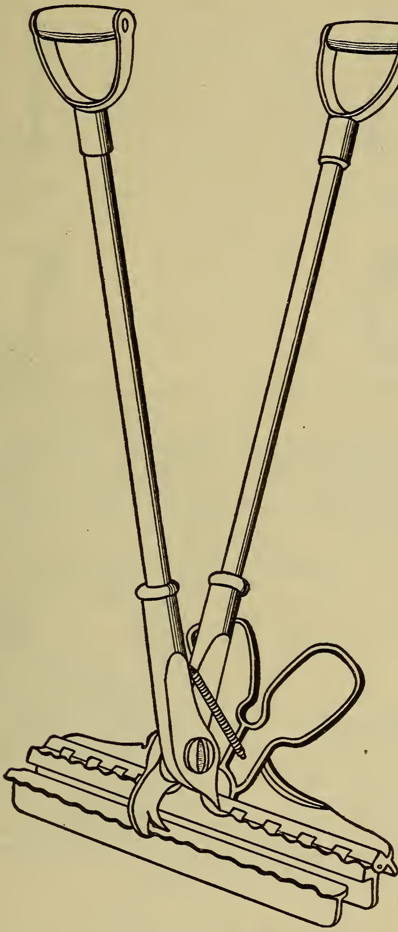


Figure 85.—Burritt's Patent Roofing Double Seamers.

same as the common gauge seamers, but finish a standing seam 1 inch high.

The finished standing seam joint is illustrated in Figure 90, which also shows the method of attaching the tin

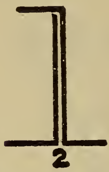


Figure 86.—First Operation in Double Seaming.

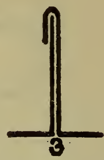


Fig. 87.—Second Operation.

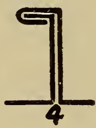


Figure 88.—Third Operation.

Figure 89.—Completing the Seam.

roof to the roofing boards by means of the cleat. This cleat is so arranged that the nail heads do not come in contact with the tin roof itself. Note how the various

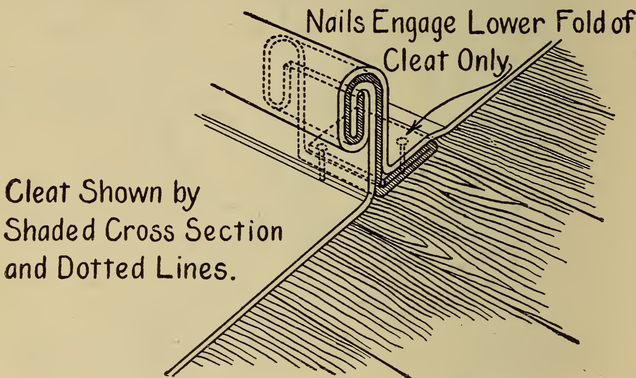


Figure 90.—Standing Seam Roofing Joint and Cleat.

bends and interlocking produce an absolutely watertight joint and make a tin roof with standing seams practically a one-piece roof.

The hand roofing double seamers serve the same purpose as the roofing double seamers, Figure 85, and in

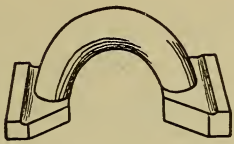


Figure 91.—Hand Roofing Double Seamers.

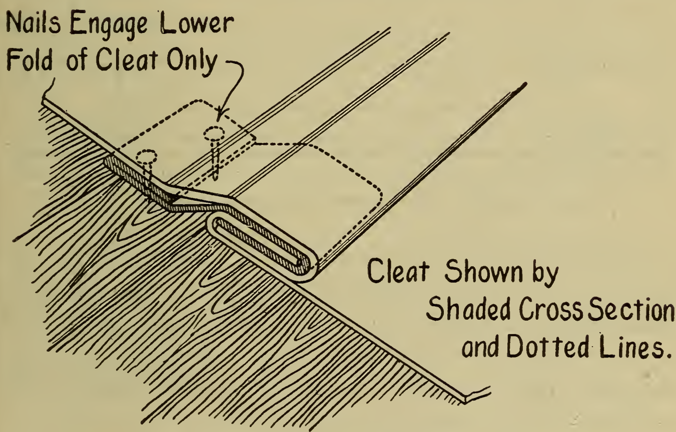


Figure 92.—Flat Seam Roofing Joint and Fastening.

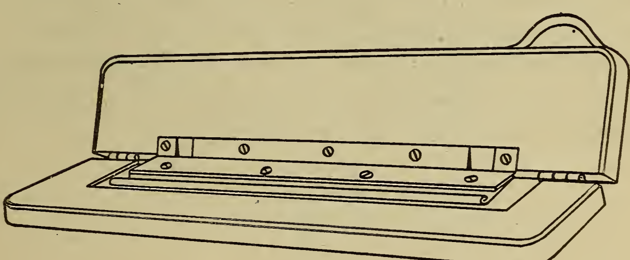


Figure 93.—Adjustable Roofing Folder.

operation follow the regular roofing tongs; but the seams are perfected by hand with a mallet against both sides of their flat surfaces. The hand seamers are also used in sets of two pairs. See Figure 91.

FLAT SEAM ROOFING

Figure 92 shows the method of making the flat seam roofing joint and of fastening the tin to the roofing boards. Note how the cleat interlocks permanently with the seam and how the nail heads holding the cleats to the boards

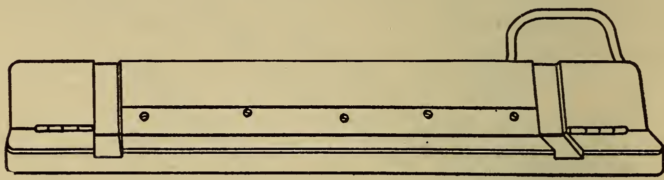


Figure 94.—Common Roofing Folder.

are prevented from coming in contact with the tin itself. The edges are shown trimmed flush, in order to demonstrate that a flat seam tin roof is practically a one-piece roof; that all seams are absolutely watertight.

Roofing Folders.—For flat seam roofing the tin plate is edged with the wood roofing folder.

Figure 93 illustrates the adjustable wood roofing folder, having an adjustable gauge for forming locks $\frac{3}{16}$ to $3/8$ inch, and manufactured in 20 and 30-inch lengths.

Figure 94 illustrates the common roofing folder, manufactured in lengths of 14, 20, 28, and 30 inches, and forming locks of one size only, namely, $\frac{5}{16}$ inch.

III

SHEET METAL WORKING TOOLS

BENCH STAKES

Sheet metal is shaped principally by being bent over anvils of peculiar forms, known as *stakes*. These fit into

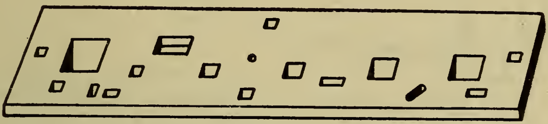


Figure 95.—Bench Plate for Holding Stakes.

holes cut in the work bench; and to save wear of the bench and hold the stakes rigid the bench plate, Figure 95, is used.

A detailed description of each stake will not be given,

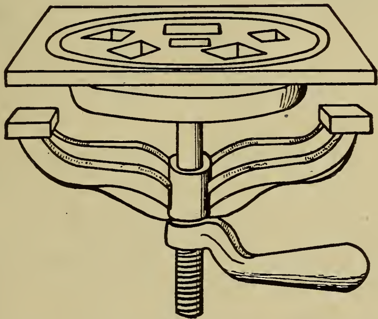


Figure 96.—Revolving Bench Plate for Holding Stakes.

as by reference to the illustrations, the uses of the tools may in most cases be inferred.

The bench plate shown in Figure 96 will prove very handy where only a few small stakes are used and is made in size 8¾x8¾″. This plate is held securely to the bench with a clamp and handle and has a circular swivel plate in which the stakes fit.

Figure 97 shows a stake holder and the different tools capable of being used with it. This holder enables the

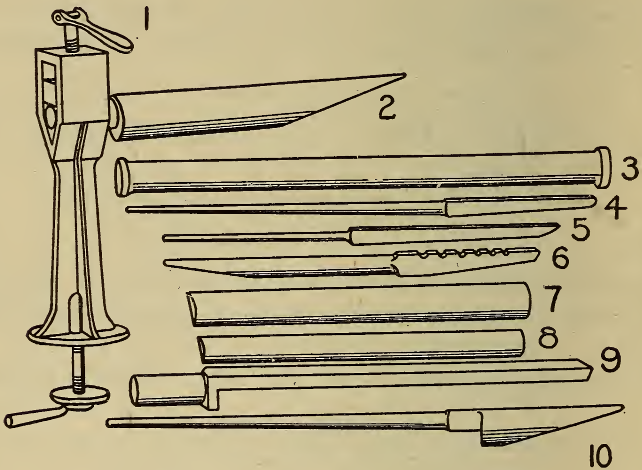


Figure 97.—Stake Holder with Complete Set of Stakes.

workman to use the stakes shown, in any position best suited to the work in hand, without mutilating the bench. One stake may be substituted for another with ease.

No. 1 is the stake holder. Nos. 2 and 9 show a "beak-horn" stake in two pieces; No. 10 is a blowhorn stake; No. 6 a creasing stake with horn; No. 3 a double seaming stake; Nos. 7 and 8 a conductor stake in two pieces; No. 4 a candle-mold stake; No. 5 a needle-case stake.

Further illustrations of bench stakes are given in Figures 98, 99, and 100.

HAND TOOLS

Sheet metal is scribed with the scratch awl, Figure 101, and cut to the size of the pattern as required by means of shears.

Hand shears come in a variety of shapes. A bench shears is shown in Figure 102.

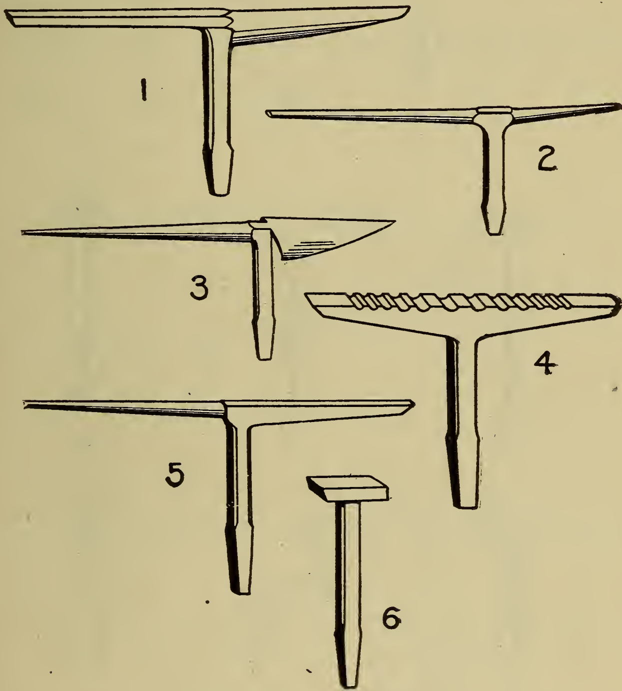


Figure 98.—Bench Stakes.
1, Beakhorn Stake; 2, Candle Mold Stake; 3, Blowhorn Stake; 4, Creasing Stake; 5, Needle Case Stake; 6, Square Stake.

Hand shears, or *snips*, as shown in Figures 103-104, are made with straight and curved blades. The straight blade shears, Figure 103, are used for general straight cutting; the shears shown in Figure 104, known as the circular snip, being made specially for cutting circles.

The Original Hand Snip.—Tapered blades for fine work, laid steel, sharp cutting edges, sloping shoulders to keep metal from curling, joints correctly centered to

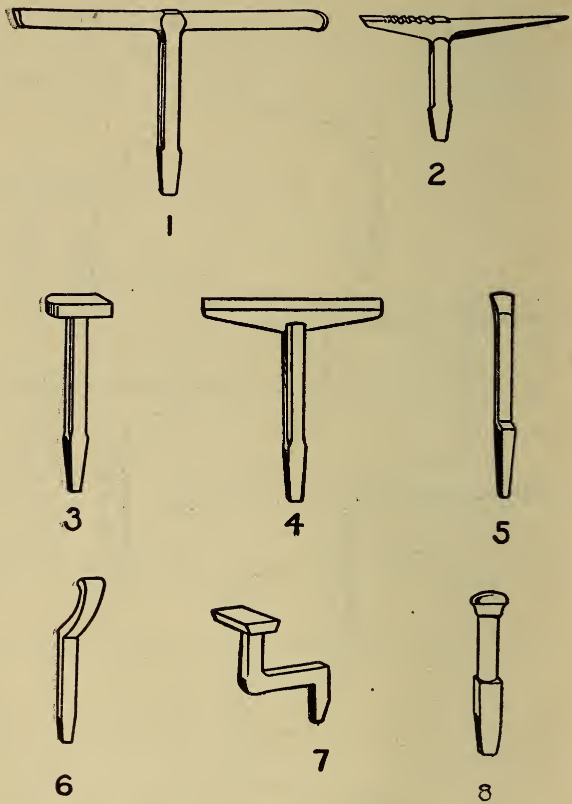


Figure 99.—Bench Stakes (Continued).

1, Double Seaming Stake; 2, Creasing Stake, with Horn; 3, Coppersmith's Square Stake; 4, Hatchet Stake; 5, Bottom Stake; 6, Bath Tub Stake; 7, Bevel Edge Square Stake; 8, Round Head Stake.

avoid lost leverage, accurate balance and hang to prevent tired wrists; and the bows so made as to fit the hand without injury in cutting—all these are important features to have in mind when selecting a pair of hand snips. The Pexto snip embodies these features. The original

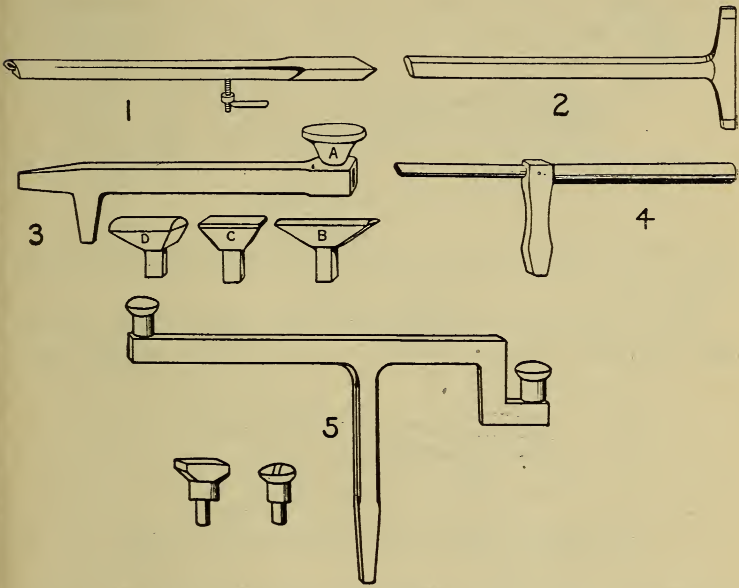


Figure 100.—Bench Stakes (Continued).

1, Hollow Mandrel Stake; 2, Mandrel Stake; 3, Double Seaming Stake, with Four Heads, A, B, C, D; 4, Conductor Stake; 5, Tea Kettle Stake with Four Heads.

pattern was made in 1819 and since that time this snip, known to the sheet metal worker the country over as

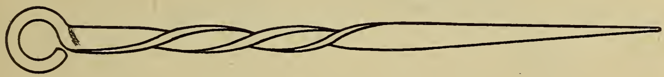


Figure 101.—Scratch Awl.

"P. S. & W. Co.'s 1819 Original," has made the makers the foremost manufacturers of hand shears in the industry.

Figure 105 shows a snip with the blade so shaped as to easily cut circles, scrolls, etc., while adapted to the same class of work as the regular snip. The jaws are beveled, with straight cutting edges which allow the material to

Figure 102.—Bench Shears.

pass freely when cutting curves or changing the direction of the cut.

Figure 106 shows a snip especially adapted for cornice and tin work. They are made to cut circles, scrolls, etc.,

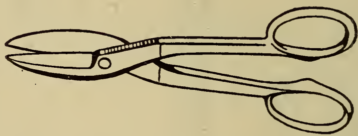


Figure 103.—1819 Original Pexto Straight Snip.

very easily, but they are equally well adapted for regular snip work. The blades are rounding and sharp pointed and can be used for very delicate work.

Scroll and Circular Snip.—A useful combination scroll

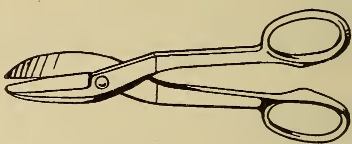


Figure 104.—1819 Original Circular Snip.

and circular snip is shown in Figure 107. With the aid of this snip, work can be cut on a straight line; and it will cut circles or the radii of a circle in very much smaller dimensions than it is possible to cut with any other snip.

The narrow blades, having extremely sharp points, will cut on the inside as well as on the outside of a sheet of

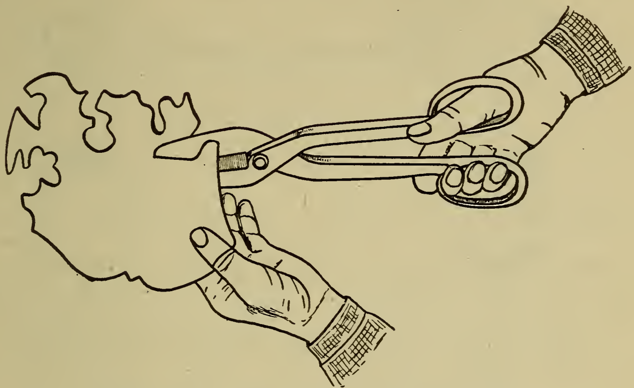


Figure 105.—Hercules Combination Snip.

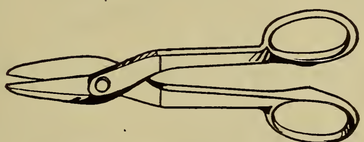


Figure 106.—Lyon Snip.

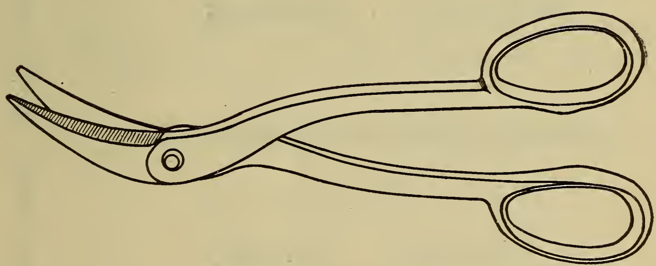


Figure 107.—Hawk's Bill Combination Scroll and Circular Snip.

metal. The blades are hawk-billed in shape and have a peculiar clearance bevel between the cutting edges which

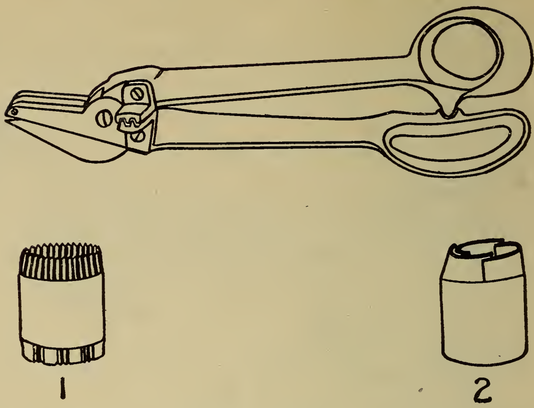


Figure 108—Double Cutting Shears with Pipe Crimper. 1, Crimped with Attachment Fitted to Shears; 2, Old Method.

Figure 109.—Double Cutting Shears, Pocket Size.

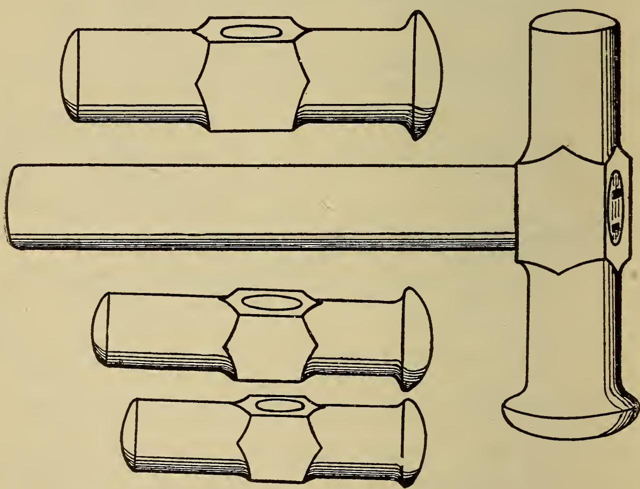


Figure 110.—Raising Hammers.

permits the blades easily to turn a sharp corner or work around a small curve without buckling. The blades being

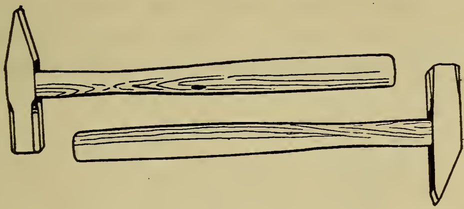


Figure 111.—Setting Hammer. Figure 112.—Riveting Hammer.

unusually narrow and ground to an extreme narrowness at the points, they are highly valuable for cutting open-

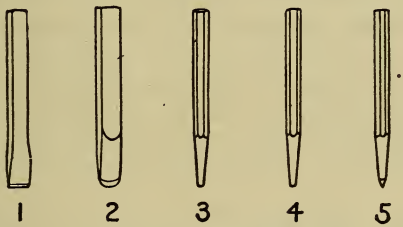


Figure 113.—Chisels and Punches.

1. Wire Chisel; 2, Lantern Chisel; 3, 4, Solid Punches; 5, Prick Punch.

ings in pipe or cylinders of every description, for furnace jackets, thimbles, tee joints, etc. They are especially

Figure 114.—Hollow Punch.

adapted for cornice-work practice in tight places, where the regular hand snip proves cumbersome.

The double cutting shears shown in Figure 108 combined with a pipe crimper are well known. The blade is pointed and readily inserted in the metal at the point desired to begin the cutting. The crimping attachment is designed for crimping any kind of light sheet metal,

Figure 115.—Rivet Set.

round or square. The principal advantages of these shears will be found in their pipe-cutting features, but they are well adapted for cutting off the bottoms of pails, pans, etc., and are suitable for cutting square work.

Figure 109 shows a double cutting shears of a smaller size, intended for light work and without the crimping attachment. The results of the old and new methods of cutting are shown in Figure 109 at *1* and *2* respectively.

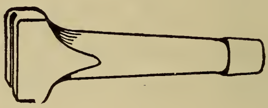


Figure 116.—Hand Groover.

Raising hammers of various sizes are shown in Figure 110.

A setting hammer is shown in Figure 111 and a riveting hammer in Figure 112, made in a variety of sizes, with faces measuring from 5/8 to 1 1/8 inches inclusive.

A wire chisel and a lantern chisel, with a set of solid and prick punches, is shown in Figure 113.

Hollow Punch.—Figure 114 shows a hollow punch, for cutting circular holes out of sheet metal. To avoid the chipping of edges with the hollow punch, the sheet metal to be punched should be placed over a block of lead. Hollow punches are made regularly in a variety of sizes, from ¼ to 3½ inches inclusive, and larger sizes are made specially to order.

The rivet set so much used by the sheet metal worker

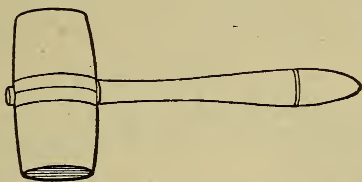


Figure 117.—Tinners' Hickory Mallet.

is shown in Figure 115. It is made in standard sizes and measurements as follows:

Size	00	0	1	2	3	4	5	6	7	8
Size of Hole.....ins.	5/16	9/32	1/64	.2130	.1910	.1660	.1495	.1405	.1285	.1100
" Drill ga. No.	5/16	9/32	15/64	3	11	19	25	28	30	35
For Iron Rivets..lbs.	14	10-12	7-8	6	4-5	2½-3	1¾-2	1½	1-1¼	10-12
" Cop'r " Nos.		5	6	7	8	9	10	12	13	14
" Cop'r " ..Ins.		¼	7/32	3/16	5/32	9/64	⅛	7/64	3/32	3/32

A standard grooving tool is shown in Figure 116, made in numbers and dimensions as follows:

Number	0000	000	00	0	1	2	3	4	5	6	7	8
Weight........lbs.	1/10	1/10	1/6	1/6	1/6	1/6	7/8	7/8	3/4	3/4	3/4	3/4
Size of Groove, Ins.	19/32	17/32	7/16	3/8	11/32	5/16	9/32	7/32	5/32	1/8	7/64	3/32

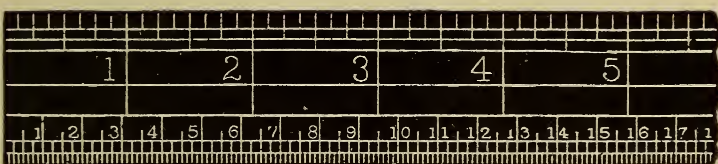


Figure 118.—Steel Circumference Rule.

Figure 117 illustrates the useful tinners' mallets, which are manufactured in various sizes.

Circumference Rule.—A steel circumference rule that will prove invaluable for laying out work in general is shown in Figure 118, which is an exact representation so far as shown. The entire length of the rule is 36 inches. The upper line is the ordinary rule, graduated by eighths of an inch. The lower line shows at a glance the exact circumference of any cylinder by simply ascertaining the diameter; that is, a vessel 5 inches in diameter the rule indicates to be 15¾ inches in circumference. The

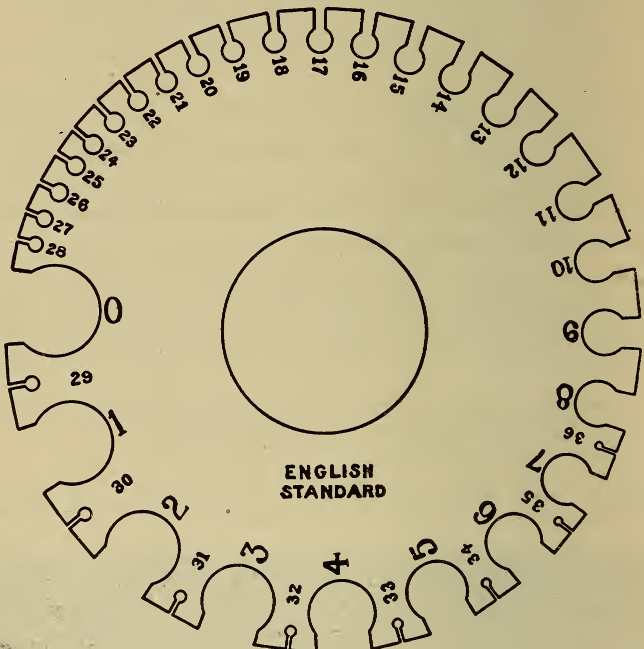


Figure 119.—Wire Gauge, English Standard.

reverse side contains much useful information in large plain figures regarding the sizes of sixty different articles, such as cans, measures, pails, etc., with straight or flaring sides, flat or pitched top, liquid and dry measure in quarts, gallons and bushels. First is given the dimensions for vessels holding 1 to 5 gallons liquid measure; second, one-quarter to 2 bushels dry measure; third, cans with pitched tops 1 to 10 gallons; fourth, cans with flat top 1 to 200 gallons; fifth, vessel holding 1 to 8 quarts and ½ bushel to 3 bushels dry measure.

Wire Gauge.—A wire and sheet metal gauge, a necessity in every shop, is shown in Figure 119. The gauge shown is English standard and manufactured in two sizes; namely, 0 to 36 and 6 to 36.

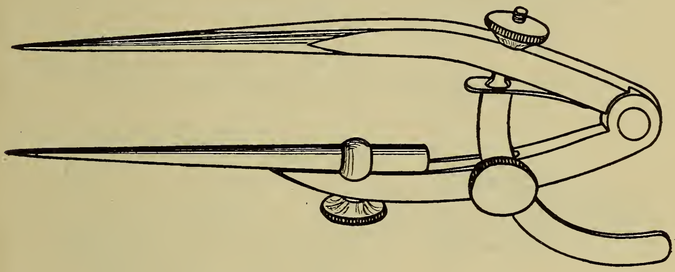


Figure 120.—Single Leg Extension Divider.

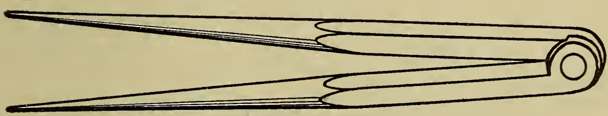


Figure 121.—Compass.

Dividers.—A divider, or pair of dividers, as specially designed for the sheet metal worker, is shown in Figure 120. They are forged from a high-grade steel scientifically tempered. One of the points is movable so that it may be lengthened or shortened as required and will prove a convenient scratch awl. The extension divider is made in sizes from 6 to 10 inches inclusive.

A compass, made in sizes from 3 to 10 inches inclusive, is shown in Figure 121. Figure 122 illustrates a combination pliers with wire cutter, made in three sizes; namely, 6, 8, and 10 inches. Figure 123 shows the tinners' flat nose pliers, and Figure 124 a round nose pliers, made in a variety of sizes from 4 to 8 inches inclusive. A cutting nippers for wire cutting is shown in Figure 125.

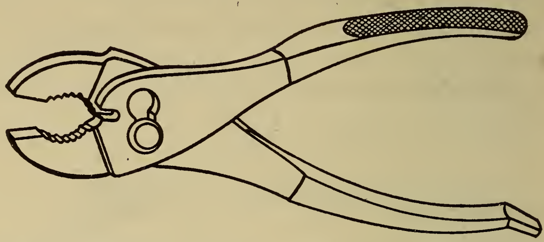


Figure 122.—Combination Pliers with Wire Cutter.

Figure 123.—Flat Nose Pliers.

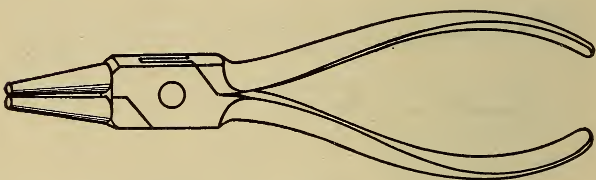


Figure 124.—Round Nose Pliers.

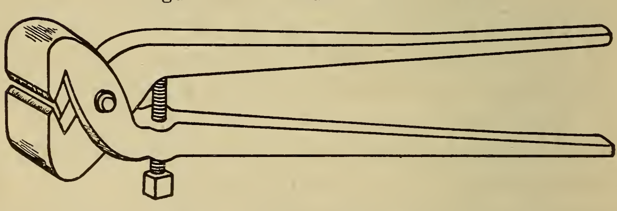


Figure 125.—Cutting Nippers.

TINNERS' FIREPOTS

The firepot shown in Figure 126 is a universal favorite with the tinner and sheet metal worker. It is lined with firebrick and made in a most substantial manner. The draft door is in two sections, which economizes fuel.

Figure 127 shows a firepot so constructed that the ashes fall in a pan beneath the coal and the fire is kept clear and the draft good. It is light and may easily be carried from place to place at the convenience of the workman.

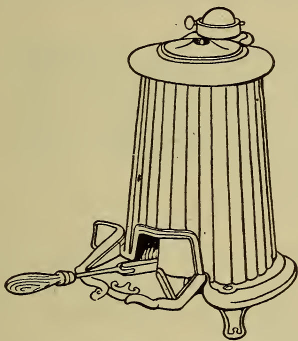


Figure 126.—Cast Iron Firepot.

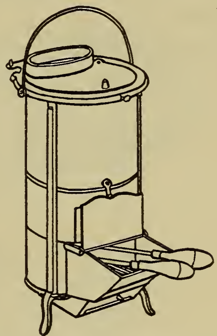


Figure 127.—Sheet Iron Firepot.

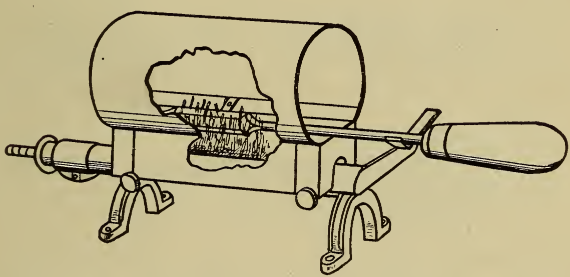


Figure 128.—Single Burner Gas Furnace.

Gas Furnaces.—Figure 128 illustrates a gas furnace for heating soldering coppers. It is light in weight, consumes but little gas, economizes time, and avoids dust and dirt. By regulating the aperture through which the air passes so that the flame has a blue appearance, the very hottest flame produced by gas can be secured. It will burn either natural or artificial gas. It has a single burner with a sheet iron top.

A brick-lined double burner gas furnace is shown in Figure 129. No air blowers being required, this furnace is desirable for heating soldering coppers in the shop. It is always ready for use and with the proper flow of gas will produce a blue hot flame. It will burn either natural or artificial gas.

Soldering Coppers.—Figure 130 shows the ordinary

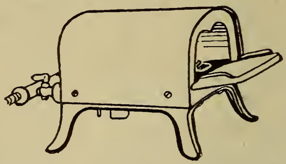


Figure 129.—Double Burner Gas Furnace.

Figure 130.—Square Point Soldering Copper.

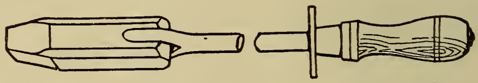


Figure 131.—Roofing Copper.

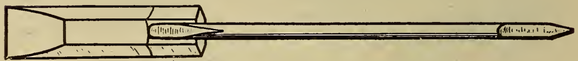


Figure 132.—Bottom Copper.

soldering copper with square point, and a roofing copper with shield and handle is seen in Figure 131. Figure 132 represents a bottom copper, and a hatchet copper with swivel handle is shown in Figure 133.

A soldering copper handle is shown in Figure 134, and two styles of solder scrapers, better known as plumbers' scrapers, in Figures 135, 136. A useful roofing scraper is shown in Figure 137.

The sheet metal working tools described in the fore-

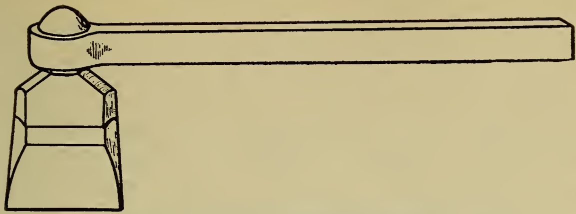


Figure 133.—Hatchet Copper.

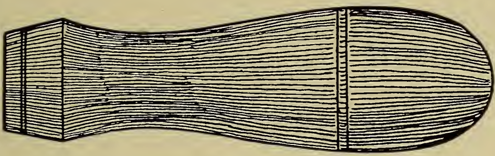


Figure 134.—Soldering Copper Handle.

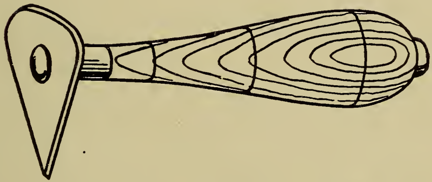


Figure 135.—Plumbers' Scraper.

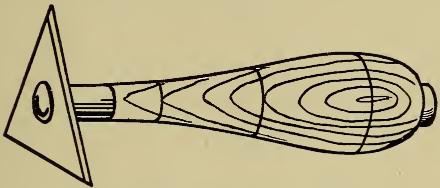


Figure 136.—Plumbers' Scraper.

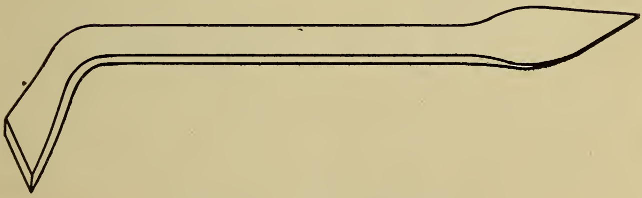


Figure 137.—Roofing Scraper.

going pages are the ones used in sheet metal working practice more than any other kinds, and are manufactured with special attention to their quality, shape, balance and hang by the makers of the Pexto line of tools and machinery. Hand tools for the sheet metal worker are made in a further extensive variety for special purposes, but those in general use have received due mention.

IV

SHEET METAL WORKING SCHOOL SHOP EQUIPMENT

Following is a complete equipment of sheet metal workers' tools and machines suggested for a class of 15 boys:

1 Squaring shears, 30-inch.
1 Ring and circular shears.
1 Bar folding machine, 30-inch.
1 Cornice brake, 48-inch.
1 Forming machine, slip roll, 2 x 30-inch.
1 Groover, 30-inch.
1 Small turning machine.
1 Wiring machine.
1 Large burring machine. } (Without regular standards. To fit in Holdall revolving machine standard.)
1 Setting down machine.
1 Elbow edging machine. } (Without standards. To fit in Holdall revolving machine standard.)
Extra pair No. 3 faces for above.
Extra pair No. 4 faces for above.
1 Beading machine.
1 Crimping and beading machine. } (Without regular standards. To fit in Holdall revolving machine standard.
1 Holdall revolving machine standard.
1 Moore's double seaming machine.
1 Bench punch.
1 30-inch gutter beader with ½-inch rod.
1 Mandrel stake, solid.
1 Mandrel stake, hollow.
1 Beakhorn stake.
1 Blowhorn stake.
1 Double seaming stake.
1 Needlecase stake.
1 Hatchet stake, 13-inch.
1 Hatchet stake, 9-inch.
1 Bevel edge square stake, 2½ x 4½.
1 Double seaming stake with 4 heads.

1 Round head stake.
4 Bench plates, 31 x 8 inches.
15 Mallets, 2½ x 5½ inches.
15 Gas furnaces, double burner.
15 pairs, 2-pound soldering coppers (1 lb. each.)
15 pairs, 3-pound soldering coppers (1½ lb. each.)
1 Hand punch.
15 pairs, snips, straight.
8 pairs, snips, circular.
1 pair, bench shears.
15 Riveting hammers.
15 Setting hammers.
15 Plumbers' scrapers.
1 Raising hammer.
2 Cutting nippers.
1 No. 3 grooving tool.
1 No. 5 grooving tool.
1 No. 0 grooving tool.
8 Size 6, rivet sets.
8 Size 4, rivet sets.
2 Size 2, rivet sets.
15 Prick punches.
3 No. 8 solid punches.
3 No. 6 solid punches.
3 No. 4 solid punches.
1 ½-inch hollow punch.
1 ⅝-inch hollow punch.
1 ¾-inch hollow punch.
1 ⅞-inch hollow punch.
1 1-inch hollow punch.
1 1¼-inch hollow punch.
3 ½-inch wire chisels.
15 Scratch awls.
60 Soldering copper handles.
1 No. 2 wire gauge.
1 Steel rule, circumference.
3 pairs Hawk's bill snips.
1 Conductor stake.
3 10-inch wing dividers with hardened points.
2 Vises.

EQUIPMENT FOR SHEET METAL WORKING CLASS JUNIOR HIGH SCHOOL

1 Squaring shears, 30-inch.
1 Bar folding machine, 30-inch.
1 Cornice brake, 48-inch.
1 Forming machine, slip roll, 2 x 30-inch
1 Grooving machine, 30-inch.

1 Small turning machine.
1 Wiring machine.
1 Large burring machine.
1 Beading machine.
1 Crimping and beading machine. } (Without regular standards. To fit in Holdall revolving machine standard.)
1 Holdall revolving machine standard.
1 Beakhorn stake.
1 Blowhorn stake.
1 Double seaming stake.
1 Needlecase stake.
1 Hatchet stake, 13-inch.
1 Bevel edge square stake, 2½ x 4½.
2 Bench plates, 31 x 8-inch.
15 Mallets, 2½ x 5½.
8 Gas furnaces, double burner.
15 pairs, 2-pound soldering coppers (1 lb. each.)
15 pairs, 3-pound soldering coppers, (1½ lb. each.)
1 Hand punch.
15 pairs, No. 9 snips, straight.
1 pair, No. 8 snips, straight.
2 pairs, No. 9 snips, circular.
1 pair, bench shears.
8 Riveting hammers.
8 Setting hammers.
8 Plumbers' scrapers.
1 Raising hammers.
2 Cutting nippers.
1 No. 3 grooving tool.
1 No. 5 grooving tool.
1 No. 0 grooving tool.
8 Size 6, rivet sets.
8 Size 4, rivet sets.
2 Size 2, rivet sets.
15 Prick punches.
3 No. 8 solid punches.
3 No. 6 solid punches.
3 No. 4 solid punches.
1 ½-inch hollow punch.
1 ⅝-inch hollow punch.
1 ¾-inch hollow punch.
1 ⅞-inch hollow punch.
1 1-inch hollow punch.
1 1¼-inch hollow punch.
1 1½-inch hollow punch.
3 ½-inch wire chisels.
15 Scratch awls.
60 soldering copper handles.
1 No. 2 wire gauge.

1 Steel rule, circumference.
1 Conductor stake.
3 10-inch wing dividers with hardened points.
2 Vises.

EQUIPMENT FOR ELEMENTARY SHEET METAL WORKING CLASS

1 Bar folding machine, 30-inch.
1 Forming machine, slip roll, 2 x 30-inch.
1 Small turning machine.
1 Wiring machine.
1 Large burring machine.
1 Stove pipe crimping and beading machine. (Without regular standards. To fit in Holdall revolving machine standard.)
1 Holdall revolving machine standard.
1 Beakhorn stake.
1 Blowhorn stake.
1 Needlecase stake.
1 Hatchet stake, 13-inch.
1 Bevel edge square stake, 2½ x 4½.
2 Bench plates, 31 x 8 inches.
12 Mallets, 2½ x 5½.
2 Gas furnaces, double burner.
2 pairs, 2-pound soldering coppers (1 lb. each.)
2 pairs, 3-pound soldering coppers (1½ lb. each.)
12 No. 9 snips, straight.
2 pairs, No. 9 snips, circular.
1 pair, bench shears.
8 No. 3 riveting hammers.
8 No. 3 setting hammers.
2 Plumbers' scrapers.
1 Raising hammers.
1 Cutting nippers.
1 No. 3 grooving tool.
1 No. 5 grooving tool.
1 No. 0 grooving tool.
2 Size 6, rivet sets.
2 Size 4, rivet sets.
2 Size 2, rivet sets.
3 Prick punches.
3 No. 8 solid punches.
3 No. 6 solid punches.
3 No. 4 solid punches.
1 ½-inch hollow punch.
1 ⅝-inch hollow punch.
1 ¾-inch hollow punch.
1 ⅞-inch hollow punch.
1 1-inch hollow punch.

1 1¼-inch hollow punch.
1 1½-inch hollow punch.
3 ½-inch wire chisels.
12 Scratch awls.
12 Soldering copper handles.
1 Steel rule, circumference.
1 Conductor stake.
3 10-inch wing dividers with hardened points.
2 Vises.

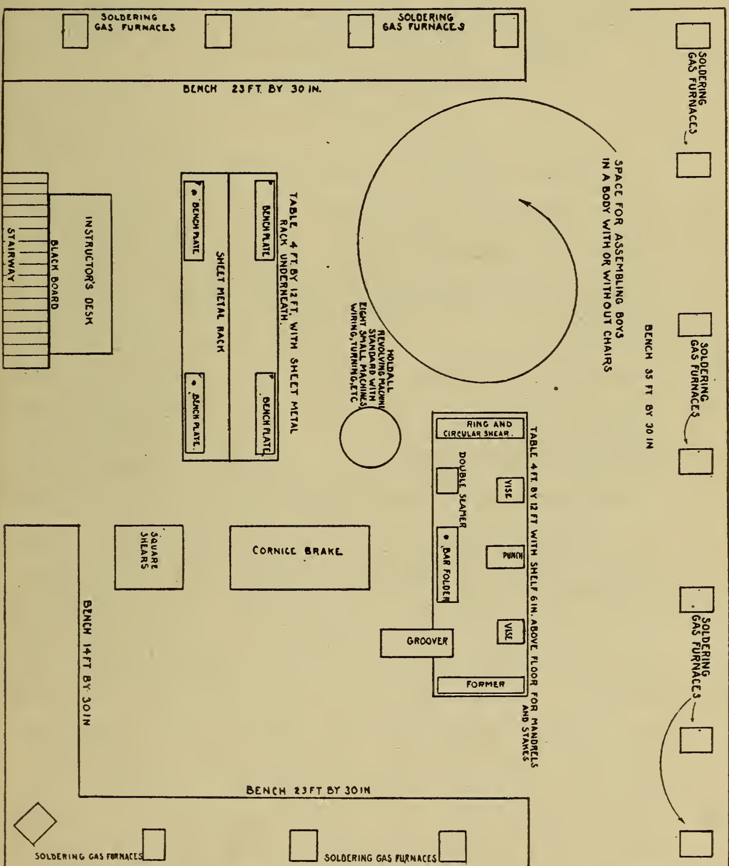


Figure 137A.—Suggested Arrangement of Sheet Metal Working Class Room.

CONTENTS

COURSE IN ELEMENTARY AND ADVANCED SHEET METAL WORK AND PATTERN DRAFTING

V

COURSE IN ELEMENTARY AND ADVANCED SHEET METAL WORK AND PATTERN DRAFTING

CHAPTER I

TRANSFERRING PATTERNS TO METAL

When the student or workman is required to make articles simple in form, from sheet metal, the pattern can be made directly on the metal from given measurements. If he is required to make an article round in form with flaring sides, or an article having an irregular shape, it is highly important to make a full-sized drawing and to develop the patterns. This necessitates operations with the drafting board and drawing instruments, which will be taken up later in this course. After the pattern is developed on detail paper, it may be transferred to the sheet metal and the work of construction begun.

Methods of Transfer.—There are several methods of transfer in use, depending on the nature of the material and the shape of the pattern. For the more expensive materials, such as copper, brass, and German silver, the patterns and designs are transferred to the metal by means of carbon paper in the following manner:

The carbon paper is laid upon the face of the material with the face or glossy surface touching the metal; the pattern is carefully placed over the carbon paper and held in position by small weights; then with a hard pencil, stylus, or pointed tool firmly trace over the lines of the

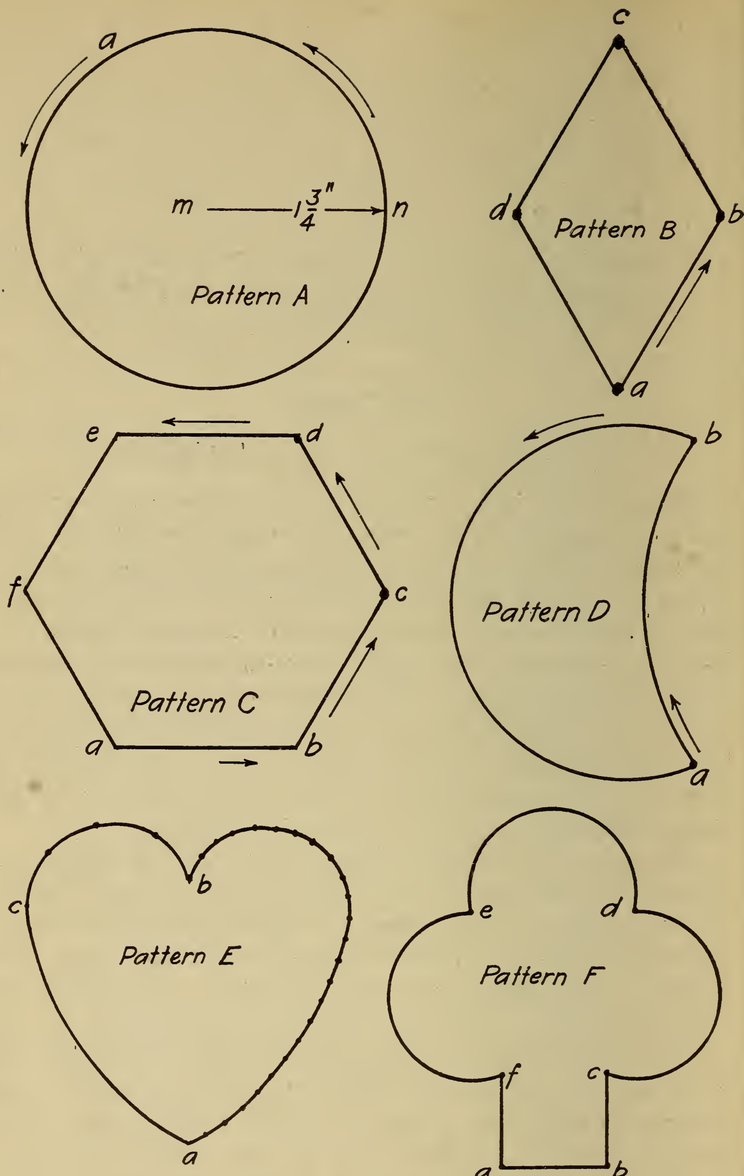


Figure 138.—Simple Patterns, or Templates. Arrows Show Proper Direction to Cut Metals with the Shears.

drawing. This will give a print of the pattern on the bright metal. After obtaining a good impression, the carbon lines may be fixed on the metal by tracing over them with a steel scratch awl.

Another method of transfer is used for the cheaper materials, such as tin plate, zinc, black iron, and galvanized iron. The process is as follows: Place the drawing paper directly on the metal, then go over the outline of the pattern with a sharp tapering prick punch, tapping it lightly with a small hammer, making slight indentations on the metal at the principal points of the drawing. This method will be used throughout this course, and is in general use in the best commercial shops.

The prick punch used in this work should be about four inches long by $\frac{5}{16}$ inch in diameter, the end being forged tapering to a sharp point, as shown in Figure 139 (*J*). A mistake often made by the student is to strike the punch too heavily with the hammer, driving the point through the metal. This is bad practice and should be avoided.

Simple Patterns.—The first work of the student will be to draw to full size on paper, the set of simple patterns shown one-half size in Figures 138 and 139, then to transfer them to metal, using IC bright tin, or light galvanized iron not heavier than No. 28 gauge. These patterns, or templates, are transferred to the metal in the following manner: To transfer pattern *A*, set the dividers 1¾″ equal to the radius *mn*, take a small piece of scrap metal and describe a circle. A mistake is often made by the beginner by pressing too heavily upon the wing divider, causing a deep depression in the center of the circle.

Patterns *B*, *C*, and similar forms, are transferred by pricking through the paper patterns to the metal. Place the pattern on the metal in a position to have as little waste of material as possible, placing a weight on the paper to keep it from moving; light prick marks are

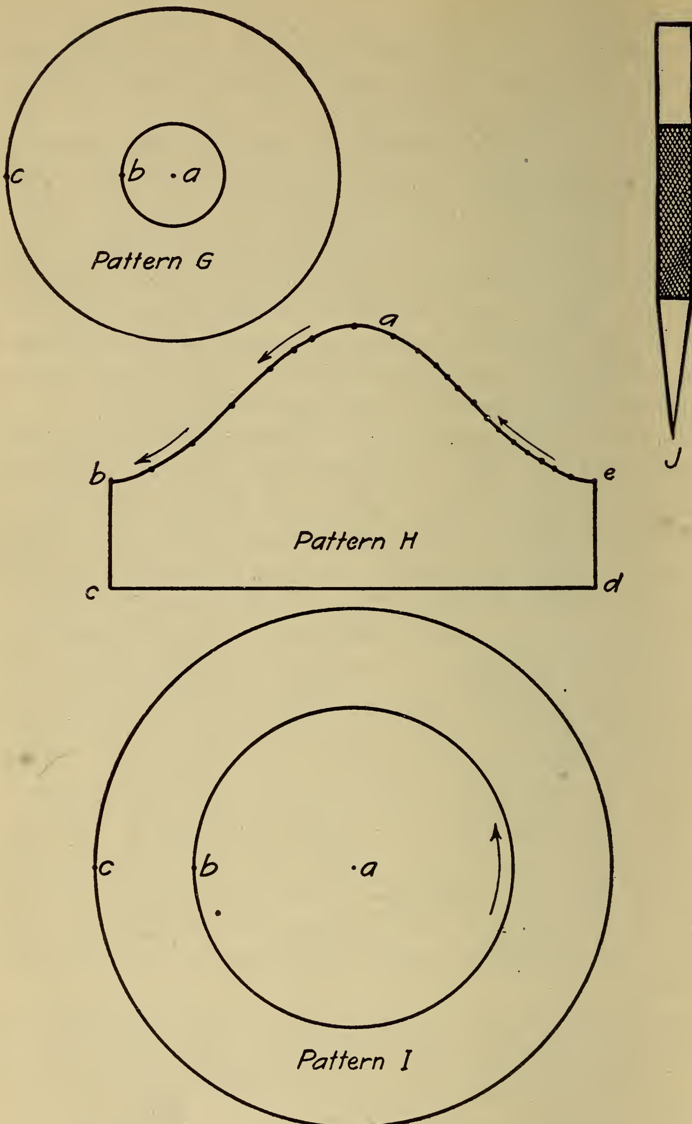


Figure 139.—Simple Patterns, Continued. *J*, a Prick Punch.

made on the metal at corners of the pattern as shown by heavy dots; remove the paper, and with a straightedge and scratch awl, complete the pattern by describing lines connecting the prick marks on the metal.

Patterns *D, E,* and *F,* are transferred to metal by pricking lightly the curved outline of the patterns. In pricking curved lines the prick marks should not be placed too far apart, but should be placed as shown from *a* to *b* in pattern *E.* After pricking the outline of patterns, a scratch awl, or lead pencil, is used to draw the curved line through the points on the metal. If the prick marks were placed too far apart as shown from *c* to *b,* pattern *E,* and *a* to *b,* pattern *H,* it would be impossible to draw the proper curve through the points, and the result would be a worthless pattern.

When transferring patterns *G* and *I,* it is not necessary to prick around the circles. Prick the points *a, b,* and *c,* upon the metal, then set the dividers with the radius *ab,* and *ac,* and describe the circles on the metal.

Use of Patterns.—If two or more pieces from a pattern are desired, do not prick through the paper pattern to obtain each piece. When one pattern is cut from metal, it should be used as a pattern whether two or a dozen pieces are required. Place the metal pattern upon the material, using a scratch awl, and scribe a line around the pattern. If the pattern is large, a weight should be placed upon it to keep it from moving, but if the pattern is small the weight is not necessary, as the pattern can be held in position with the fingers of the left hand while using the scratch awl with the right.

CHAPTER II

CUTTING PATTERNS AND TEMPLATES

Hand Shears.—Sheet metal patterns are cut from metal by means of shears or snips of various shapes and sizes. The shears in general use for light work is known as the straight hand shears, or snip, having a left-hand cut, the length of the cut commonly being 3½ inches, known as No. 8, an illustration of which is shown in Figure 103 ("Sheet Metal Working Tools"). This shears, when taken in the right hand, has the lower blade on the left side of the shears, and cuts at the left side of the upper jaw. The position of the jaws enables the sheet metal worker to follow the cutting line accurately, as it is always in full view.

Another straight shears, known as Lyon pattern snip, shown in Figure 106, is well adapted for regular work. The jaws are pointed and rounded, permitting the metal to pass freely when cutting curves, scrolls, and circles.

Circular snips, shown in Figure 104, are well adapted for cutting small circles and openings of various shapes in sheet metal. The popular size is No. 9, with a length of cut of 3 inches.

A bench shears, shown in Figure 102, is used for cutting heavy material. This tool is much larger than the ordinary hand shears. When in use it is fastened in the bench by inserting the prong in the bench plate, Figure 95, or a hole of the proper size cut in the bench for this purpose. This shears has a right-hand cut, with the lower blade on the right side of the shears. Note the difference in the position of the upper blades in the right hand shears in Figure 103, and the right hand bench shears in Figure 102.

The double cutting shears, shown in Figure 108, is adapted to cutting off round and square pipes, bottoms of pails, cans, etc. A hole is punched in the article to be cut, and the point of the lower blade inserted, after which the cutting is done in the regular manner, leaving the edges clean and smooth.

Squaring Shears.—Figure 1 ("Sheet Metal Working Machinery") shows a modern squaring shears which is recommended for this course in cutting strips, squaring tin, and making long straight cuts across sheets of metal when shearing material for the construction of pipes and articles cylindrical in form.

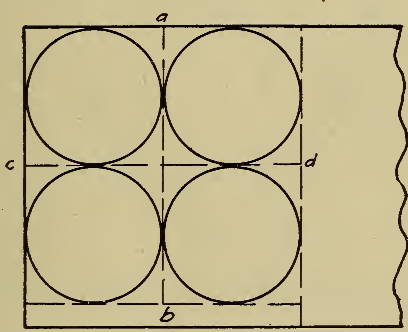


Figure 140.—How to Cut Circles to Avoid Waste of Metal.

If the shears do not respond in cutting material of heavier gauges within the rated capacities claimed by the manufacturer, the blades should be set farther apart. The lower blade must be set back from the upper, though not far enough to burr the edge of the material. This adjustment can be made by releasing slightly the bed bolts that hold the bed of the shears to the legs, and by loosening the two front bed screws. The bed can then be shifted on its seat towards or away from the upper cutting blade until the proper position is secured.

The blades can be easily removed for grinding, and when dull they should be returned to the factory for grinding. After being ground they are fastened securely to their frames and adjusted so that they will cut paper the entire length.

Cutting Circles and Curves.—When cutting circles from metal, as shown in Figure 138, pattern *A*, take the straight shears, Figure 103, in the right hand, start the cut at *n* on the scribed line, and make a continuous cut around the circle in the direction of the arrow shown in

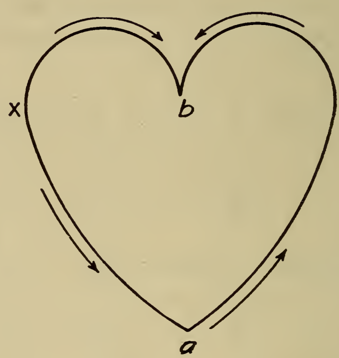


Figure 141.—Direction of Cut Shown by Arrows.

na. When several circles are to be cut from a large piece of metal, care should be taken to avoid waste of material by scribing the circles tangent to each other upon the metal, as shown in Figure 140.

After the circles have been marked on the metal in this manner, cut the metal into squares by following the dotted lines *a* and *b*, after which the circles are cut in the usual manner; care being exercised in having each circle accurate and true.

When cutting curves, the cut should be continuous. Short cuts should never be made; stopping, and starting again at different points on the line, will result in an uneven pattern with rough edges containing slivers and projections that will cut the hands while working with the metal. When cutting patterns *B* and *C*, Figure 138, and similar forms, start to cut at the corner of the pattern, cutting in the direction of arrows *ab*, *bc*.

When cutting concave and convex curves, as shown in the outline of pattern *D*, Figure 138, use the straight shears, starting at *a*, and cut in the direction of arrows as shown in the drawing.

Pattern *E* is shown in Figure 141. Starting at *a*, make a continuous cut from *a* to *b*, then placing the shears at

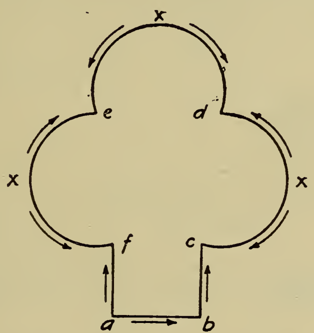


Figure 142.—Best Method of Cutting Indicated by Arrows.

point *x* on the pattern, cut from *x* to *a*. Complete the pattern by cutting in the opposite direction from *x* to *b*.

When cutting pattern *F*, as shown in Figure 142, the cutting should begin at *a*, then to *b*, then to *c*, then starting at *x* the leaves should be cut in the direction of the arrows. A continuous cut could be made from *x* to *x*, but in turning the shears at points *d* and *e*, the metal is likely to be torn and the pattern ruined. The circular shears, as shown in Figure 104, can be used to advantage in cutting the small curves in patterns *E* and *F*.

The small circle in the center of pattern *G*, Figure 139, is cut out by using a hollow punch, as shown in Figure 114. The metal is placed upon a lead or wooden block. A punch of the required size is placed upon the circle and struck with a heavy mallet or hammer. If the piece of metal remains in the punch, it can be removed by striking the punch lightly with the hammer. Hollow punches are made in various sizes.

When an opening is to be cut in a piece of light metal as at *a* in pattern *I,* Figure 139, place the metal upon a block of lead; then by using a hollow punch or small thin chisel, cut a hole in the metal large enough to insert the point of the lower blade of the circular shears in the opening; then cut along the line in the direction of the

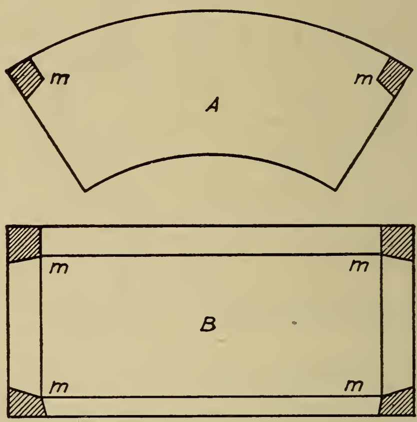


Figure 143.—Notched Patterns, the Shaded Portions Being the Notches.

arrow. The outer circle is cut in the usual manner, which completes the pattern.

Cutting Elbow Patterns.—When cutting elbow patterns or similar forms, as shown in *H,* Figure 139, the straight cuts *b* to *c, c* to *d, d* to *e,* are made with the straight snips, or upon the square shears. The upper curve of the pattern is cut by using the straight shears, starting at *e* and making one continuous cut ending at *b.*

In using the hand shears, a mistake is often made by the student in cutting beyond the stopping point shown on the pattern. This can be avoided by always completing the cut with the *point* of the shears. When cutting from *a* to *b*, Figure 141, the end of the shears should be directly upon point *b* when making the final cut. The point of the shears is also used in notching patterns, as shown in *A* and *B*, Figure 143. When cutting out the shaded portion of patterns, the end of the shears blade should never extend beyond the point *m* in the pattern.

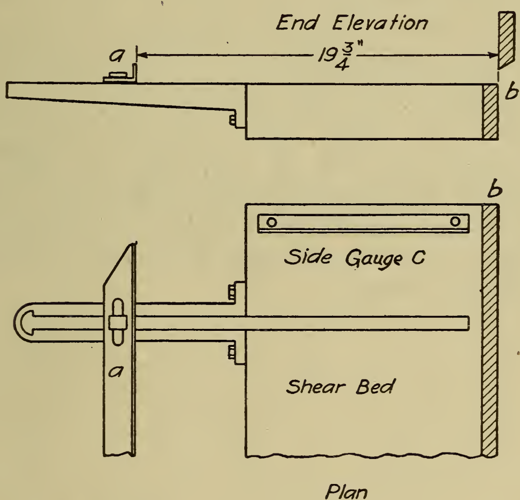


Figure 144.—Plan and End Elevation of Squaring Shears.

Hints on the Care and Use of Hand Shears.—The following suggestions are offered on the use and care of the hand shears and should be followed carefully by the student or workman:

When using the shears the blade should be held in a vertical position, making straight up and down cuts.

Never twist the shears sidewise when cutting, as this causes the bending of the edge of the metal, leaving a burred edge, which requires additional work in flattening it out with a mallet on a stake or level plate.

Keep the shears sharp, but do not grind too fine an edge.

The bolt and nut joint should be oiled frequently, and the nut adjusted so the shears will work easily at all times.

Never use the cutting edges of shears for cutting wire, but always use instead the cutting nippers which are made for this purpose.

Squaring Sheets of Metal.—In preparing sheets of tin for roofing purposes and constructing various sheet metal articles which require the sheets to be perfectly square and exactly the same size, with the edges true and straight, the sheets can be squared very rapidly and accurately on the squaring shears, Figure 1. A plan and end elevation of the squaring shears are shown in Figure 144, where *a* is the front gauge, *b* the lower cutting knife, and *c* the side gauge.

CHAPTER III

FOLDING EDGES AND SEAMING

One of the most important processes in sheet metal working is that of seaming. Seams of various kinds are used, depending on the strain to be resisted and the equipment on hand for constructing them. The machine in general use for bending the edges of sheet metal for seaming is known as the adjustable bar folder, as shown in Figure 15. The following edges and seams are extensively used in light sheet metal work:

Single Edge.—This edge, as shown in Figure 145, is used in constructing seams and hemming the edges of

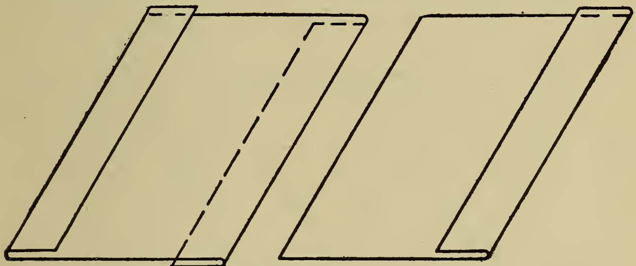


Figure 145.—Single Edges formed on Sheet Metal.

sheet metal. In forming this edge in the folder, set the gauge to the required width, then insert the metal in the machine, holding it firmly against the gauge with the left hand. Grasp the handle with the right hand and bring the folding bar over until it rests on top of the machine. The handle of the machine is now brought to its former position and the metal removed from the machine, completing the operation.

Double Edge.—The double lock, shown in Figure 146, while used in certain work, is most commonly utilized to strengthen sheet metal forms. When used for this purpose it is known as a double hemmed edge. This edge is

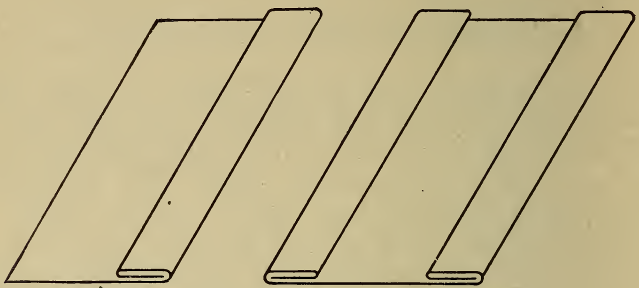


Figure 146.—Double Hemmed Edges.

formed in the folder in the same manner as the single edge. After the latter is formed, the sheet is turned over,

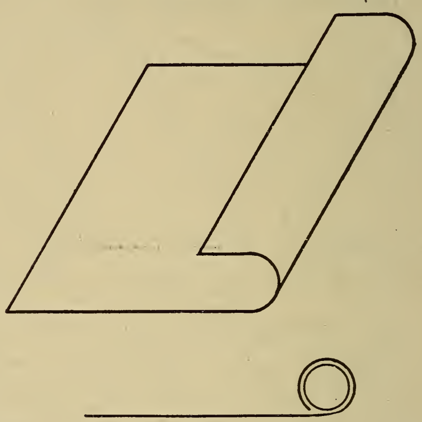


Figure 147.—Wire Edge, Open and Closed.

then the single edge is placed in the machine against the gauge and the operation is repeated.

Wire Edge.—It is often necessary to increase the strength of articles made from sheet metal by inclosing a wire in certain of their edges. The edges for this purpose must be rounded as shown in Figure 147. To form an open or round lock for wiring, set the gauge on the

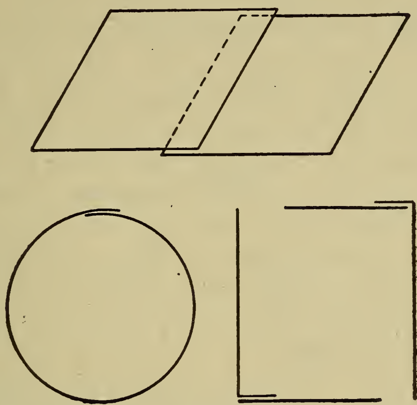


Figure 148.—Ordinary Lap Seams.

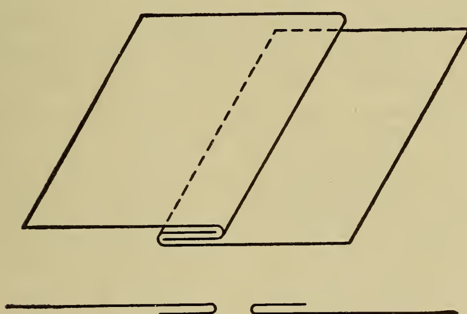


Figure 149.—Folded Seam, Consisting of Two Single Edges Hooked Together.

folder equal in width to two and one-half times the diameter of the wire to be used. Using the wrench, loosen the lock screw to the right on the back of the machine, and by moving this screw to the right or left in the slot the wing is raised or lowered. In adjusting the machine, lower the wing equal in width to the diameter of wire to be used, fasten the lock screws firmly, then turn the edge in the usual manner.

Lap Seam.—In Figure 148 is shown the ordinary lap seam, as used in the construction of small cylinders, square pipes, cornice miters, etc. This seam is usually soldered or riveted. When thin metal is used and the seam is to be soldered, allow from 1/8″ to 1/4″ for lapping.

Folded Seam.—In making this seam, a single edge is turned on the metal, and the edges are hooked together as shown in Figure 149, after which they are hammered down with a wooden mallet. Seams that are malleted down smooth are stronger and easier to solder than when uneven. Seams of this kind are used in laying flat seam tin and copper roofing.

Grooved Seam.—With light material, the grooved seam is the universally used method of joining the edges of sheet metal. This seam is frequently used in joining two flat sheets of metal, making longitudinal seams in round and square pipes, and vertical side seams in sheet metal articles having a flaring or cylindrical surface. An illustration of this seam, showing the construction, is seen in Figure 150. When joining two flat pieces of metal by this method, set the gauge on the folding machine to the width of the edge required, and turn a single edge on the sheets as shown at *A*. Hooking the edges together as shown at *B*, the seam is laid on the horn of the grooving machine (Figure 42). The rolls run over the seam lengthwise, completing the seam as shown at *C*. When the grooving wheel is run over the seam, an offset is made in the upper sheet *e* at *m*, which prevents the seam from coming apart. The seam is finished by placing it on a mandrel stake, pounding it with a wooden mallet, closing it down, and leaving the seam tight and smooth.

Allowance for Grooved Seam.—The amount of material to be added to the pattern for making a grooved seam from light sheet metal depends upon the width of the single edge turned on the folder, as shown in Figure 145. Three times the width of the single edge must be added to the pattern. The finished seam as shown at *C*, Figure 150, has four thicknesses of metal at *a*, the sheets *d* and *e*

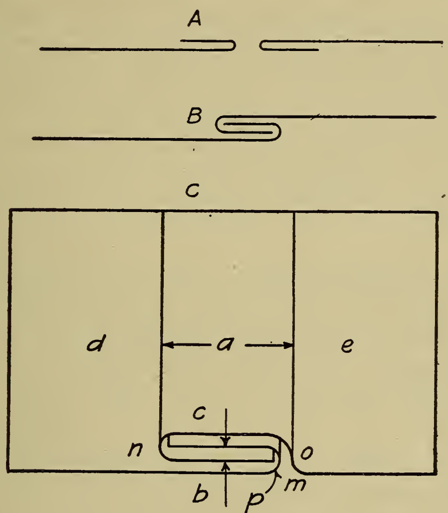


Figure 150.—Grooved Seam, Showing Construction.

joining at *m*. The sheet *d* has a single edge *c*, while sheet *e* has a double edge, as shown at *a* and *b*. This shows the necessity of making an allowance equal to three times the dimension *a*, or width of the edge, for a grooved seam. When seaming tin plate and metal lighter than No. 24 gauge, no allowance is made for the stock taken up by the bends *n*, *o*, and *p*, in *C*, Figure 150.

Where heavier material is used and accuracy is required, the actual amount of material taken up by these bends must be added. The student can determine the amount by making a test seam in the following manner:

Take a strip of metal six inches long. After cutting it into two parts, turn an edge on each piece. Groove the seam and close it down with a wooden mallet. Then measure the length of the strip accurately, and the difference between this dimension and the length of the piece before seaming will be the amount of material to be added for the seam.

CHAPTER IV

FORMING, GROOVING, BEADING, AND CRIMPING

This chapter will treat of the various processes used in the construction of conductor pipes, stove pipe, furnace pipe, and air ducts. Although work of this kind is chiefly used in building construction and heating and ventilating systems, the following will apply as well to forming and seaming sheet metal articles cylindrical in form, where the longitudinal seam is made with the usual grooved seam.

When constructing pipes and cylinders the student must first find the circumference by multiplying the diameter by 3.1416, and to this dimension add the amount of material necessary for making the grooved seam, as shown in Figure 150. This will give the exact length to cut the material.

Constructing Sheet Metal Pipe.—When constructing pipes an allowance should be made for the thickness of metal used. This is necessary to permit the small end of the joint to fit snugly into the large end of the adjoining joint of pipe. The usual method is to cut the small end of the joint 1/8″ less in circumference than the large end when using tin plate and light iron up to No. 26 gauge, and 1/4″ for No. 24 to No. 20 gauge. The best practice is to make a difference of seven times the thickness of the metal between the large and small end of pipe.

When making pipe it is customary to place the sheets of metal on a bench behind the squaring shears (Figure 1). Then set the front gauge back from the cutting blade of the shears, having the left end of the gauge equal to the length of the large end of the pipe and the right end equal to the length of the small end. The sheet of metal is then passed between the shears blades. The student should extend his fingers and press down upon the middle of the sheet while holding it firmly against the gauge, and then cut the joint. Notch one corner of the small end. This notch will show which is the small end after the pipe is formed up.

After all the sheets have been cut, the joints are placed behind the folding machine (Figure 15) with the notched

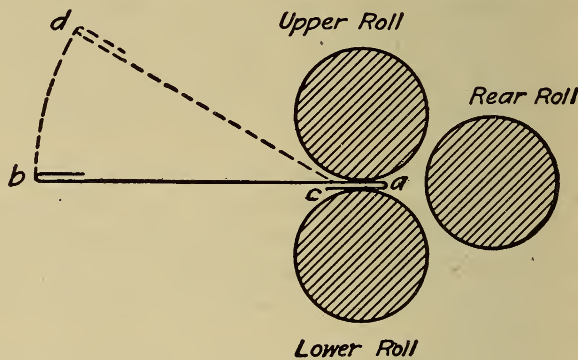


Figure 151.—Inserting the Sheet Between the Rolls of a Forming Machine, to Form a Cylinder.

end to the right of the machine, and the single edges are turned as shown in Figure 145.

Forming Cylinders.—The next step in the construction of the pipe is to form it into shape on the forming machine (Figures 35, 36). This machine is easily adjusted by means of the adjusting screws on each end of the machine, and the rolls can be set for forming any desired size of cylinder. The upper front roll is slightly raised, to allow the folded edge of the sheet to pass between the rolls without closing the lock. The sheet with the folded edge on the under side is inserted in the machine just far enough to allow the front rolls to grip the edge, as shown in *a,* Figure 151. Then holding the handle of the machine firmly to keep the sheet in this position, raise the sheet to the dotted position *d,* making a slight bend at *c.* This bend enables the sheet to pass easily over the rear roll, giving it the required curve, as shown in Figure 152.

The adjustment is made by raising or lowering the rear roll until the required diameter is obtained. A cylinder having a grooved seam should be formed a trifle less than

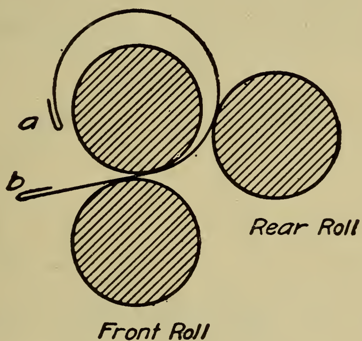


Figure 152.—Position of Sheet When Cylinder Is Nearly Formed.

its full diameter. This will allow the edges to hook tightly together while being grooved.

GROOVING SEAMS

Having formed the pipe properly, it is now ready for the grooving operation, which can be performed either by hand with the hand groover (Figure 116) and mallet over a mandrel stake (Figure 100) or upon the grooving machine (Figure 40).

Operating the Grooving Machine.—After the edges of the pipe have been hooked together as shown in *a,* Figure 153, the front latch of the machine is raised and the cylinder inserted over the grooving horn, the end of the cylinder resting against the lower adjustable stop, which prevents the work from slipping. The traveling carriage is then brought forward, allowing the grooving roll to run over the seam lengthwise, completing the seam as shown in *b*, Figure 153. The carriage is returned to the starting point by means of a handle. It has two rolls, one for grooving, and one for flattening the seam at the same operation.

Countersunk Grooved Seam.—This seam is used extensively in the construction of stove pipe, furnace pipe, and other sheet metal articles. This method of grooving places the seam on the inside, leaving an unbroken surface on the outside of the article, as shown in *a*, Figure 154.

Figure 153.—Pipe Seam Hooked Together and Grooved.

When making this seam on the improved grooving machine, Figure 40, remove the grooving wheel from the traveling carriage, loosen the set screw, then turn the reversible grooving horn, bringing upward one of the grooves which is planed into the horn, as shown in *b*, Figure 154. The cylinder is placed on the grooving horn with the locked edges directly over the planed groove. The traveling carriage containing the flat roll is brought forward, which presses the seam into the groove and thus completes the operation.

Grooving Seams by Hand.—The ordinary small grooving machine shown in Figure 42, is used for seaming tinware, furnace pipes and articles made from light sheet metal, where a small seam can be employed to advantage. In sheet metal shops not equipped with a grooving machine, when it is required to seam articles made from black and galvanized iron by hand the article to be grooved is placed on the hollow mandrel (Figure 100), or the solid mandrel stake. The edges are hooked tightly together for their entire length. The hand grooving tool (Figure 116) is placed against the edge of the seam and struck with a wooden mallet (Figure 117). In this way the seam is grooved at one end for several inches. The other end is then grooved in the same manner, after which

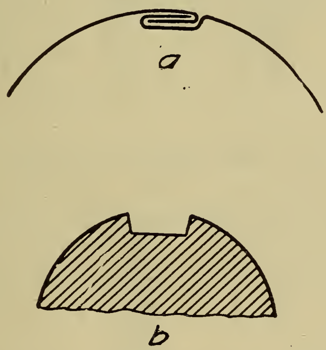


Figure 154.—*a*, Seam Grooved Inside Pipe; *b*, Groove in Horn of Grooving Machine.

the entire seam is grooved by striking the hand groover with the mallet while moving it along the seam. Care must be taken that the groover does not cut or mark the metal on either side of the seam. The seam is completed by flattening it down closely with the wooden mallet.

BEADING AND CRIMPING

In constructing articles cylindrical in form from light sheet metal, they are usually reinforced by being beaded or swaged upon the beading machine shown in Figures 58, 59. When making cylinders or pipe of large diameter, several beads are usually placed close together near the ends of the cylinder. This tends to strengthen the body, keeping it round in form.

The beading machine is furnished with several sets of rolls, consisting of the single bead, ogee bead, triple bead, and the triple coffee pot bead rolls. The single and ogee bead rolls are generally used in beading the ends of pipe and large cylinders made from sheet iron. The triple

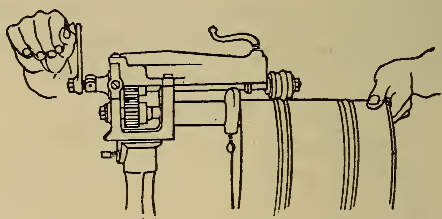


Figure 155.—Beading a Cylinder.

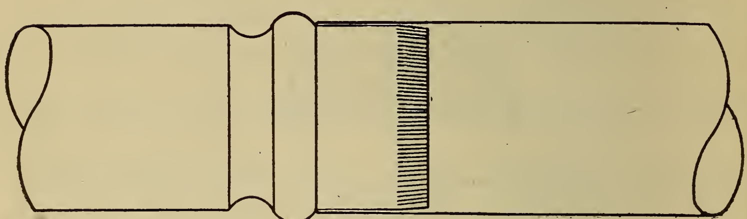


Figure 156.—Plain Lap Pipe Joint, Showing Crimped Edge.

bead and coffee pot bead rolls are used in swaging articles of tinware, both round and flaring in form. When making pipe of various sizes, a single or ogee bead is usually made on the small end of the pipe. This bead serves to stiffen the pipe and aids in keeping the pipe straight when riveting the joints together.

Operating the Beading Machine.—When beading pipe the gauge is moved back about 1½ inch or 2 inches from the beading roll and fastened by means of the set screws. The small end of the pipe is then inserted between the rolls, with the end resting against the gauge. The rolls are now pressed together by means of the hand screw on top of the machine. The pipe is held in a horizontal position with the left hand while the machine is being turned with the right. The large end of the pipe should be allowed to pass easily through the fingers while being revolved in the machine, and care should be taken that the small end of the pipe is against the gauge at all times during the operation. A mistake often made by the student is to depress the upper roll too much. If this is done, there is great danger of cutting through the material. The beading process is clearly shown in Figure 155.

Crimping Pipe.—After the pipe has been beaded, the next step is to draw in the small end with the mallet on the mandrel stake, or crimp the edge about ½ inch in width on the crimping machine shown in Figure 63. This operation contracts the edge of the pipe so that it will enter the next joint easily, as shown in Figure 156. The illustration shows a plain lap joint, having a lap of about 2 inches, and can be either riveted or soldered, or both as required.

CHAPTER V

SOLDERING

The process of soldering consists of welding together pieces of metal by means of another metal of lower melting point. Soft soldering may be taken to mean the uniting of pieces of metal with fusible alloys of tin and lead.

In the operation of soldering, which is done by using soldering coppers for applying the heat, the solder must be fused to the pieces which are being joined. This is done by raising the temperature of the solder and the parts to be soldered to the fusing point. The solder is applied and sweated in by holding a hot soldering copper in contact with the seam until a correct fusing temperature has been attained, with the result that the metals fuse together into one homogeneous mass, making a perfect joint at every point.

The absolute necessity of heating the parts to be soldered and raising them to the correct fusing temperature can not be too strongly emphasized.

Fluxes.—When soldering two pieces of metal together, a perfect bond cannot be made unless oxide is kept out of the joint, and a flux must be used to prevent oxidation while the soldering operation is going on. The basis of all good fluxes is zinc chloride.

Many sheet metal workers prepare their own flux by "cutting" zinc in muriatic acid. This is done by putting pieces of zinc into a bottle of muriatic acid until the acid stops boiling and bubbles cease to rise. The acid eats away the zinc, liberating hydrogen during the process. This action continues until the acid is "cut" or "killed;"

in other words, until all the hydrogen in the acid has been given all the zinc it will eat. What is left in the bottle is no longer muriatic acid, but is known as chloride of zinc.

Muriatic acid is the commercial name for hydrochloric acid, and is often used in its raw state as a flux for soldering galvanized iron and zinc.

Chloride of zinc, or "killed acid," is used as a flux when soldering clean galvanized iron, zinc, copper, and brass. When the material to be soldered is tin plate, bright copper, or lead, rosin is used as a flux, and when melting has a tendency to penetrate into the lock or seam. There are several kinds of soldering salts and noncorrosive fluxes on the market, that are being used with good results by the sheet metal trade. A too strong flux will do harm to the work and to the soldering tools. Whatever flux is employed should be diluted with water to the weakest condition for the work on hand.

Solder.—Practically all solders used by the sheet metal worker are combinations of tin and lead. The quality of the solder must not be overlooked. Solder should be purchased from a reliable dealer who will furnish a good article, having the correct proportions of lead and tin. The solder generally used is composed of half tin and half lead, commonly called half-and-half. It melts at about 370 degrees Fahrenheit. A better flowing solder, one having more resistance to stress, is composed of 60 per cent tin and 40 per cent lead. It melts at about 340 degrees F. The latter is the best possible combination, with the objection, however, that it is very costly.

Soldering Furnaces.—Furnaces for heating soldering coppers are made to burn gasoline, gas, oil, and charcoal. The fire pot shown in Figure 126 is well adapted for burning charcoal. Gas furnaces, as shown in Figures 128, 129, are most generally used; their greatest point of superiority being in the continuous supply of fuel.

SOLDERING COPPERS

Soldering coppers of different sizes, suitable for different kinds of work (Figures 130-133) should be included in every shop equipment, and can be obtained in various weights.

A small copper should not be used on heavy work, as

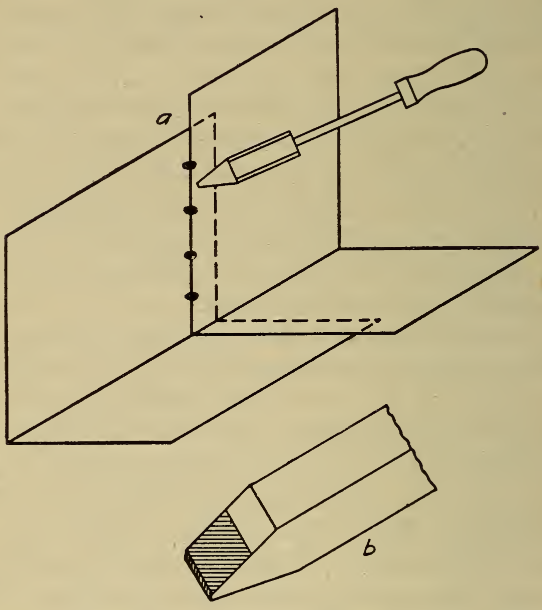


Figure 157.—*a*, Soldering Copper for Tinware, Applied to Vertical Seam; *b*, Bottom Copper.

it cannot contain enough heat to allow the solder to flow and sweat into the joint as it should. When the small copper is applied to the metal, it becomes cool quickly, with the result that the workman wastes much time in trying to keep the coppers hot, or in soldering with relatively cold coppers, which means poor work. After selecting coppers of suitable weight for the work at hand, the next point to consider is the required shape.

Forging and Tinning Coppers.—Soldering coppers are forged to any desired shape by placing the copper in the furnace and heating it to a dark cherry color. The dross and scale is removed by means of a coarse file; the copper is then forged to the required shape on an anvil or block of iron by means of a heavy hammer. Copper can be forged very easily if the metal is annealed or softened. The annealing operation for copper consists of heating the metal to a dull red heat. It can be allowed to cool out slowly in the air or by immersing in water.

The soldering copper shown in Figure 157 (*a*) is forged to a pointed shape. It is well adapted for soldering seams in tinware or any other bench work and generally weighs three or four pounds a pair. The bottom copper shown in Figure 157 (*b*) is wedge-shape in form and is used for soldering the bottom seams of sheet metal articles on the inside.

For soldering flat seams, coppers shaped as shown in Figure 131 are best adapted, being especially suitable for soldering flat-seam roofing, and should weigh from 6 to 10 pounds a pair.

Tinning Points of Coppers.—When tinning pointed coppers, they should be heated, then filed bright on four sides, not higher than about ¾ inch from the point. This gives a bright smooth surface, ready for tinning. The coppers are again placed in the furnace and heated sufficiently to melt solder. The point of the copper is then rubbed lightly on a small block of sal ammoniac, which cleans the surface. A small portion of solder is now melted upon the sal ammoniac and by lightly rubbing the copper back and forth upon the solder and sal ammoniac, it will become tinned and ready for use.

Soldering coppers can be tinned with rosin, instead of sal ammoniac. This is usually done by placing a piece of solder and some rosin upon a board or soft brick. The copper is filed in the usual manner, then heated just hot enough to melt solder. It is next taken and rubbed on the solder and rosin until the solder adheres to the copper. This method of tinning is generally used when soldering tin, and if rosin is being used as a flux.

Keeping the point of the copper bright and clean at all times is of vital importance. Never allow an oxide or scale to form on the points, for copper oxide is almost a non-conductor of heat and an oxidized soldering copper gives up its heat so poorly as to be practically useless. If a scale be allowed to form on the point, it flakes off and causes serious trouble in the soldering. A copper can never remain in good condition if it is overheated. When a copper is allowed to become red hot its usefulness is gone until it has been retinned.

Dipping Solution.—When using charcoal, gasoline, or gas for heating, the point of the copper becomes discolored. Using an earthen fruit jar, mix a solution composed of ½ ounce of powdered sal ammoniac and one quart of water. After the sal ammoniac has been dissolved the solution is ready for use. The point of the heated copper, when taken from the furnace, is dipped quickly into this solution. This facilitates the soldering operation by making the tinned surface bright and clean.

METHODS OF SOLDERING

Soldering Flat Seams.—In Figure 158 is shown the method of soldering a flat seam having ½-inch to ¾-inch lap. In this case two pieces of galvanized iron, about 2½ by 8 inches, are used as shown by *a* and *b*. Muriatic acid is employed as the flux and care must be taken that the flux is allowed to enter the seam the width of the lap, and not merely brushed over the edge of the seam without allowing the acid to penetrate. The seam is now tacked with solder as shown at *x*. The seam is then soldered its entire length by placing the copper directly upon the seam and soldering from tack to tack, being careful always to allow the solder to cool before soldering from one tack to another. In placing the copper directly upon the seam as shown at *c,* Figure 158, the solder is drawn into the seam its full width, soaking it thoroughly as shown at *d.*

Flat-locked seams are soldered in the same manner, by placing the copper directly upon the seam, as shown at

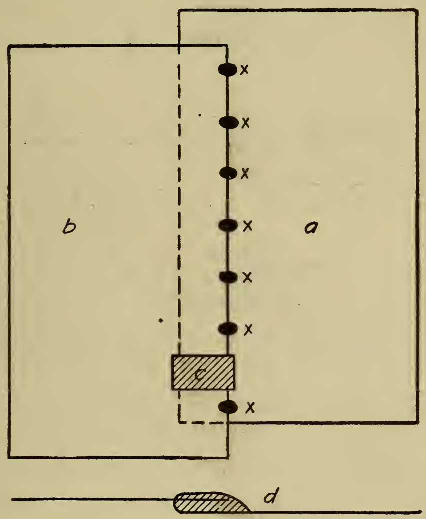


Figure 158.—Method of Soldering a Flat Seam.

a, Figure 159. Having applied the flux properly, the heated copper draws the solder into the seam, fusing the various metals and making a compact mass, as shown at *b.*

An improper way of placing the copper on the seam is shown at *c;* the soldering copper *c,* resting on the edge of the seam, allows but little solder to sweat into the joint as shown at *d,* resulting in a poorly soldered seam.

When soldering a grooved seam on the inside of sheet metal articles, a mistake is often made by workmen and students in placing the copper on the seam in the position shown at *e*, Figure 159. When placed in this position, the copper is held on the wrong side of the seam, drawing the solder away from, instead of into the seam. The copper should be held directly upon the seam, heating it thoroughly and drawing the solder into the joint.

Soldering Vertical Seams.—Upright seams in roof flashing, cornice gutters, and other work, whether lapped

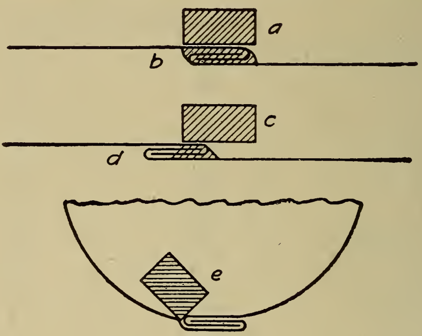


Figure 159.—Soldering Flat-Locked Seams; an Improper Method of Placing the Copper Is Shown at *e*.

or locked, are more diffiicult to solder than flat seams. The ordinary lapped vertical seam is shown at *a*, Figure 157. When upright seams are to be soldered, no matter what metal is used, the soldering copper should be forged wedge-shape, being about ¾-inch wide and ¼-inch thick at the point when completed. The end and top side only are tinned as shown by the shaded portion in *b*, Figure 157.

When the end and upper face only are tinned, the solder can be easily controlled when applied to the seam. If the four sides of the copper were tinned, much of the solder would run to the under side and away from the seam, and result in a waste of time and material.

When soldering vertical seams, the handle must be held higher than the copper to allow the solder to flow forward until the required amount has been transferred to the seam and sweated into the joint. This is done by moving the copper to the right and left on the seam, heating it thoroughly and drawing the solder into the seam, as shown at *d,* Figure 158.

Repair Work.—When soldering old work and repairing sheet metal articles, the surface must be free from dirt or any substance which will prevent the solder from adhering to the metal. The parts to be soldered must be made perfectly bright by scraping or filing. Scraping is the best method and is usually done by means of a knife blade or tinner's scraper, shown in Figure 135. Regardless of what method is used, the surface must be cleaned and made perfectly bright or good soldering cannot be done. When soldering old tinware, after the metal has been scraped, use chloride of zinc or "killed acid" as a flux, instead of rosin.

Soldering Bench Work.—When soldering flat seams, ornaments on cornice work, bottom seams of tinware, and other small work at the bench, the work is often discolored by the hot copper burning the bench underneath and leaving a dark spot on the surface of the metal. This can be overcome by using a piece of black sheet iron, thick glass, or marble slab, upon which the work to be soldered can be placed. The glass or marble slab should be ½ to ¾-inch thick. It can be easily cleaned and also serves as a level plate while soldering.

EQUIPMENT

A good equipment for soldering is shown in Figure 160. This includes a gas furnace, acid cup, jar for dipping solution, small block of sal ammoniac, pointed soldering coppers, and a marble slab 14 inches square by ¾-inch thick. When soldering small articles, the solder should be applied to the copper, instead of directly to

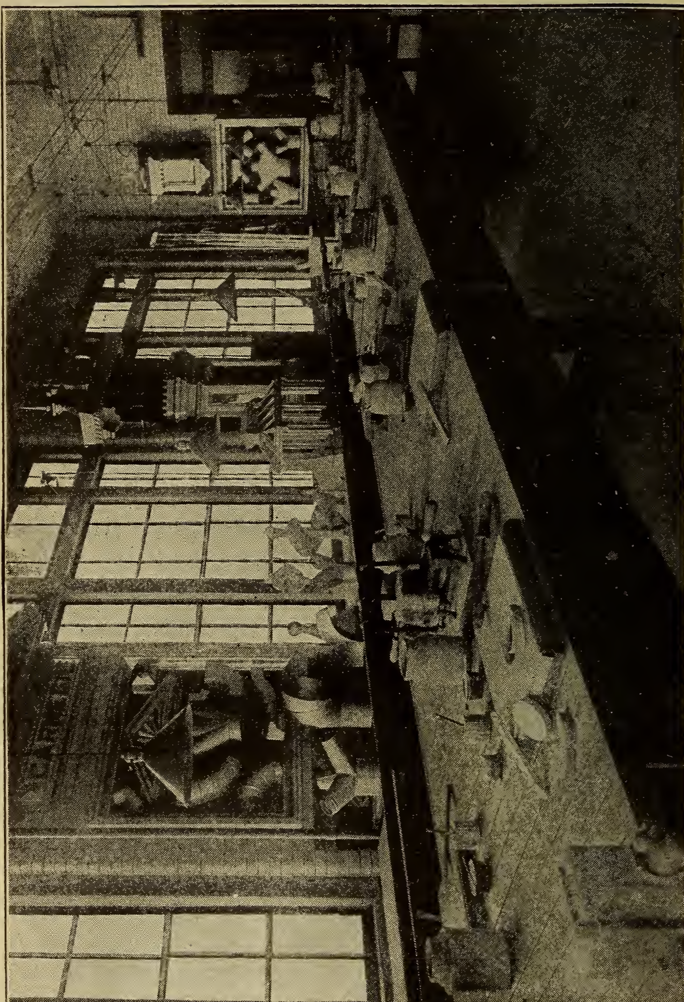


Figure 160.—Soldering Bench and Equipment.

the work. A bar of solder is placed on the bench, one end being raised by resting it on the edge of the marble slab, or by placing some small tool under it. The end of the bar of solder is touched with the point of the copper, and if it has been properly tinned, a small portion of the solder will melt and adhere to the copper, which is then applied to the parts to be soldered.

STRIPPING ORNAMENTS AND PATTERNS

When constructing dentils, brackets, letters, figures, and ornaments made from sheet metal, the parts are usually joined by the method of stripping. The next exercise in soldering will be to strip the pieces cut from patterns *A* and *I*, Figs. 138-139, in which the student obtains practice in soldering work of this kind. Using light galvanized iron as the material, set the gauge on the squaring shears (Figure 1) and cut strips ¾-inch in width and equal in length to the circumference of the circles, having them perfectly square on the end. The strips are now formed into a circle on the forming machine (Figures 35, 36) in the same manner as any pipe or cylinder. The pattern or face of the ornament is then placed on the marble slab. The circular strips are placed directly on top of the patterns, flush with the outer edge, and are soldered on the inside. A mistake often made by the student is to wrap the strip around the outer edge of the pattern. When this is done, the ornament when viewed from the front will show the edge of the strip.

When soldering work of this kind, hold the strip in position with the left hand; flux the joint with a little muriatic acid, then transfer a small drop of solder from the end of the bar to the seam with a pointed copper, tacking it about an inch apart its entire length; after which solder the seam between tacks, as described in the instructions for soldering flat seams.

CHAPTER VI

DOUBLE HEMMED EDGE

In Figure 161 are shown several cake cutters of various forms, made of bright tin (see Figure 138). The upper edge of the body and edges of the handle are reinforced by a double hem. These simple articles can be made of scrap material. The strips for the body are cut 1½-inch wide and equal in length to the circumference

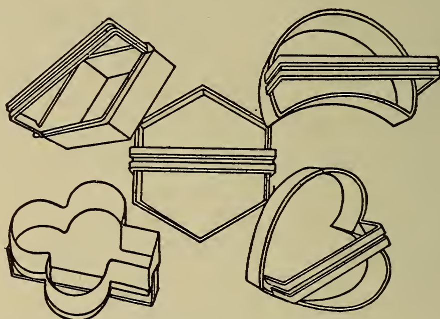


Figure 161.—Cake Cutters of Patterns Seen in Figure 138.

of the patterns *B, C, D, E, F,* Figure 138. To this length ⅛-inch is added for a lap seam where the ends are joined.

Hexagon-Shaped Cake Cutter.—In Figure 162 are shown a plan view, side view, and pattern of the hexagon-shaped cutter *C,* Figure 138. To find the length of material required, set the dividers equal to the length of one side as *1-2* in the plan. Starting at one end of the metal strip, mark the length of each side by spacing with the dividers, making a light impression on the metal at each point. Lines drawn through these points across the strip, as shown in *A, 1234561,* will mark the corners where

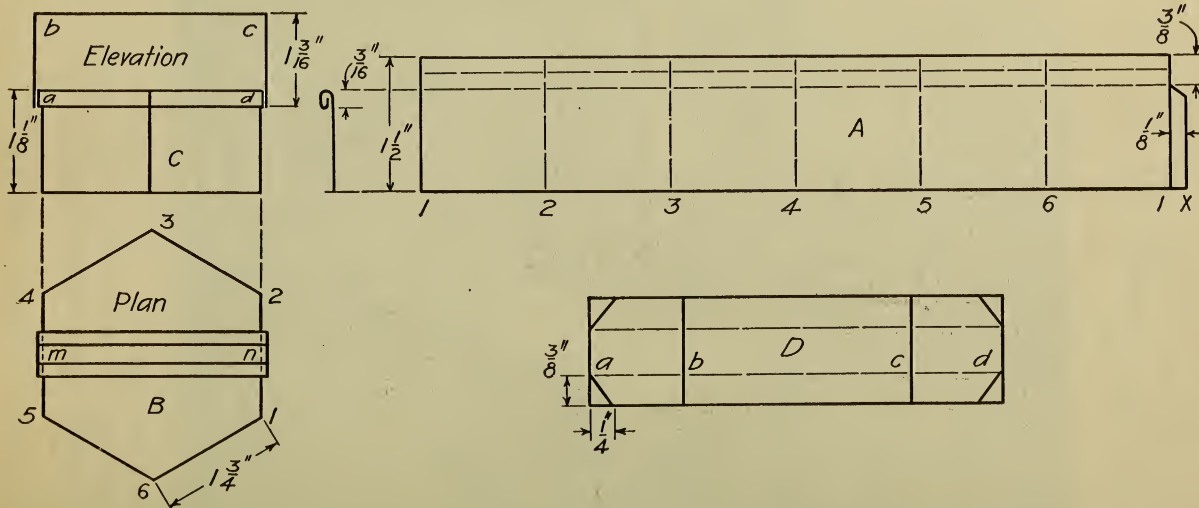


Figure 162.—Plan, Side View, and Pattern of Hexagon-Shaped Cake Cutter.

the metal is bent when formed into shape; 1/8-inch is added for a lap seam, as shown at x. The lap is notched 3/8-inch on the upper corner. This is done to allow for a

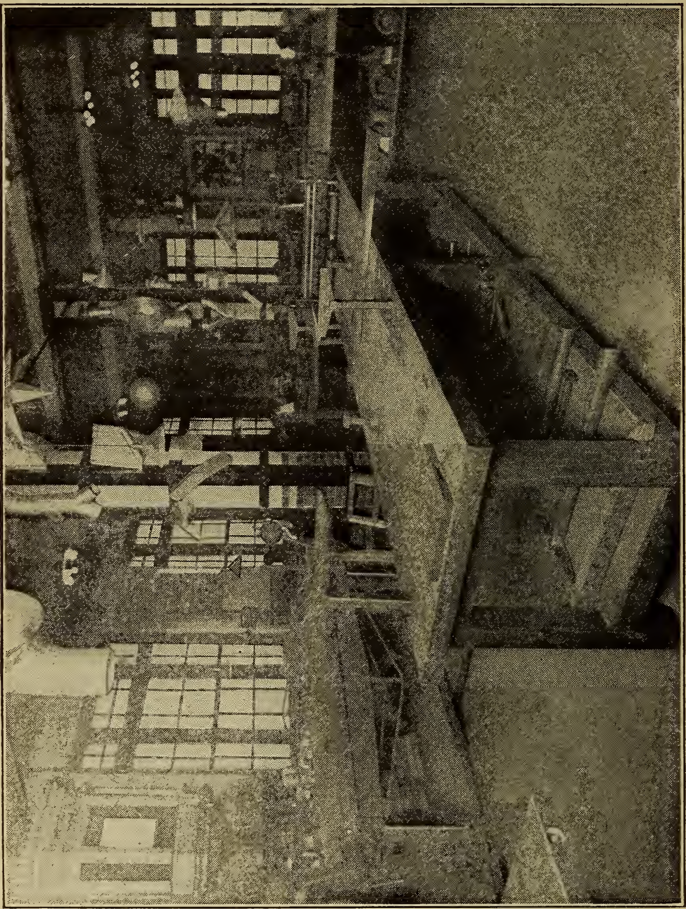


Figure 163.—Work Bench, with Stakes and Bench Plates.

3/16-inch double hem, which will be turned on the upper edge of the strip. The pattern for the handle is cut 1 3/8 inch wide and equal in length to *abcd* in the elevation. Notch the corners of the handle, as shown at *D*. Then set the gauge on the folding machine (Figure 15) $\frac{3}{16}$-inch and turn a double edge on each side of the handle and the upper edge of the body.

The next step will be to form the handle and body by hand on the needle case stake, shown in Figure 98. Place the metal strip with the bending line on the edge of the flat end of the stake, then bend the metal to the required angle, as shown by the template *B*. Each corner is bent in the same manner and should fit the template accurately when completed. The handle is formed by making a square bend on lines *b* and *c* in pattern *D*. The cutter is completed by soldering the seam at the corner and soldering the handle to the upper edge of the body in the position shown at *mn* in plan *B*.

The cutters *B, D, E, F,* Figure 138, are formed in a similar manner over the various stakes at hand. The following stakes are suitable for this purpose: Hatchet stake, conductor stake, blowhorn stake, candle mold stake, beakhorn stake. See Figures 98, 99, 100.

These stakes are used for various purposes and are fastened to the bench by inserting the square tapered shank into the proper size holes, cut in the bench for this purpose, or by having a cast-iron bench plate fastened to the bench, as shown in Figure 95. These bench plates can be obtained in different sizes and contain the proper size holes for holding stakes, bench shears, etc.

In Figure 163 is shown an illustration of a work bench with bench plates inserted in the top. The bench is 3x16 feet in size with a shelf underneath for holding stakes when not in use. This is a good arrangement for a school shop, as students can work on both sides of the bench at the same time.

CHAPTER VII

WIRING PROCESS

In constructing work made of tin-plate and light gauge metal several methods are used to reinforce the top of the article, to keep its shape and to withstand rough usage. For very small articles this is done by turning a single or double hem on the edge of the metal, as previously described. Large sheet metal articles are often stiffened by having band iron riveted to the top edge as shown in Figure 164.

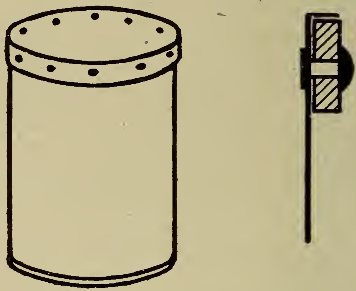


Figure 164.—Sheet Metal Can and Method of Riveting Band Iron to the Top Edge.

The method most commonly used to increase the strength of flaring and straight articles is to inclose a wire or iron rod of suitable size in certain of their edges. The wire can be laid in by hand or by means of the wiring machine shown in Figure 45.

Allowance for Wiring.—It is important to know the exact amount to be added to the height of the pattern for the take-up of the wire. The amount usually added for this operation is equal in width to two and one-half times the diameter of the wire. Another method is to allow three-fourths of the circumference of the wire.

When using tin plate and light sheet metal, it is customary to make no allowance for the thickness of the metal, but in wiring heavy plate an allowance must be made for the thickness of the material used. The amount of material for covering the wire will vary according to the thickness of the metal and the size of the wire to be inclosed and is found by the following rule:

Add twice the diameter of wire to four times the thickness of metal.

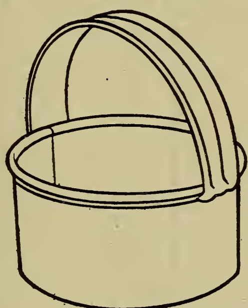


Figure 165.—Biscuit Cutter, Wired in Top Edge.

As an example, suppose in constructing a tank from sheet iron $\frac{1}{16}$-inch thick, the top is to be reinforced by inclosing a $\frac{1}{2}$-inch rod; then the amount to be added to the net height for wiring will be $\frac{1}{2} \times 2$ plus $\frac{1}{16} \times 4$, equals $1\frac{1}{4}$ inch.

The most accurate and practical method to determine the allowance for wiring is to take a narrow strip of metal and bend it closely around the wire with the pliers. This will give the exact amount of material required.

In wiring articles made from tin plate, Nos. 8, 10, 12, 13, and 14, coppered or tinned iron wire is commonly used. The amount of material to allow for inclosing the above sizes of wire when using IC tin plate, and the width

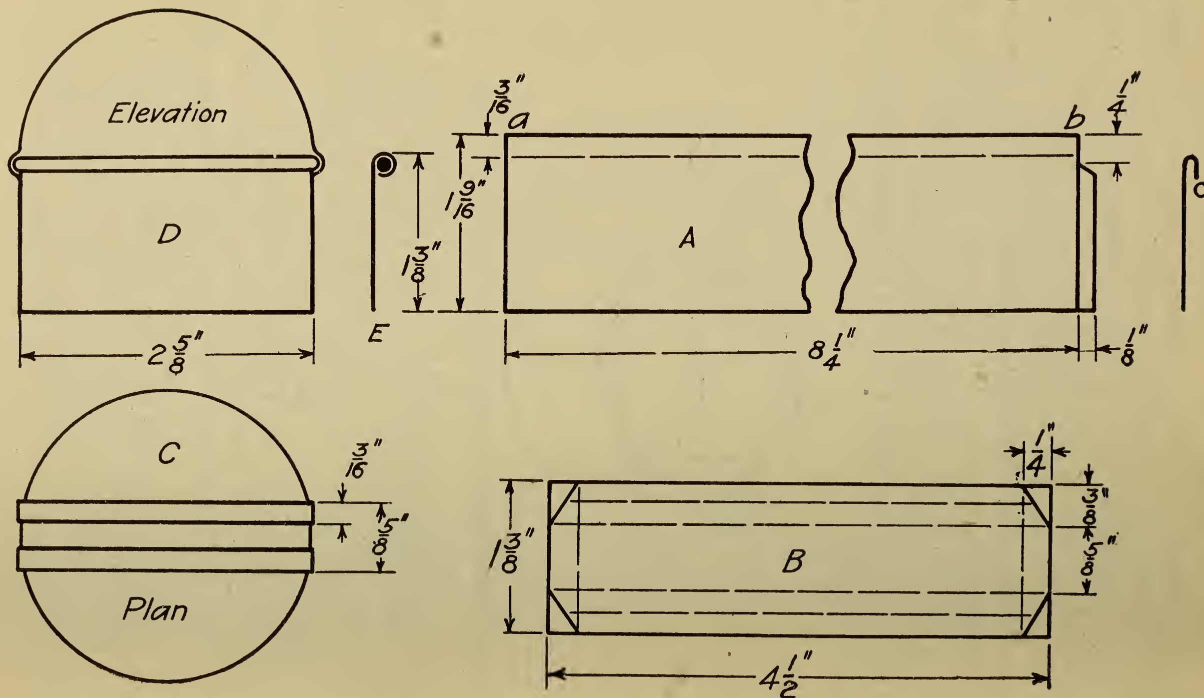


Figure 166.—Plan and Patterns for Biscuit Cutter.

of edge to be turned on the folding machine, are given in the following table:

No. 14,	Wire	Allowance	$\frac{3}{16}''$	Set	Gauge	on	Folder	$\frac{5}{32}''$
No. 13,	"	"	$\frac{7}{32}''$	"	"	"	"	$\frac{3}{16}''$
No. 12,	"	"	$\frac{1}{4}''$	"	"	"	"	$\frac{7}{32}''$
No. 10,	"	"	$\frac{5}{16}''$	"	"	"	"	$\frac{1}{4}''$
No. 8,	"	"	$\frac{3}{8}''$	"	"	"	"	$\frac{5}{16}''$

Wiring Operation.—When wiring articles cylindrical in form having straight sides, such as cans, tanks, and articles of tin-ware, the wire is inclosed in the edge of the metal while in the flat sheet before being formed into shape. The following problem is given to demonstrate the wiring operation and the method used in laying out patterns for work of this kind:

In Figure 165 is shown a biscuit cutter. This is a useful article made from IC bright tin, having a No. 14 iron wire inserted in the top edge. The seam in the body is lapped and soldered. The handle is double hemmed on the edges. The dimensions of the cutter and the patterns for the body and handle are shown in Figure 166. The pattern *A* for the body is cut $8\frac{3}{8}$ inches long by $1\frac{3}{4}$ inches wide. To find the length of the pattern, multiply the diameter $2\frac{5}{8}$ inches by $3.1416 = 8\frac{1}{4}$ inches; to this amount add $\frac{1}{8}$-inch for the lap seam. The height of cutter is $1\frac{3}{8}$ inches when completed; to this dimension add $\frac{3}{16}$-inch, the allowance required for inclosing a No. 14 wire; then $1\frac{3}{8}+\frac{3}{16}=1\frac{9}{16}$ inches, is the width of pattern; the $\frac{1}{8}$-inch lap is notched $\frac{1}{4}$-inch at the upper corner to allow for turning the wire edge.

The open or round edge for the wire is now turned on the folder as shown at *c*, a piece of wire equal in length to *a b* in pattern *A* is laid under the edge, and the metal closed over the wire for about one inch from the end. This is done with the hammer over the horn on the standard of the wiring machine.

Wiring Machine.—In Figure 167 is shown a sectional view of the wiring machine, used to complete the operation. Holding the work *D* in a horizontal position, place it on the lower roll *B* with the wire edge held firmly

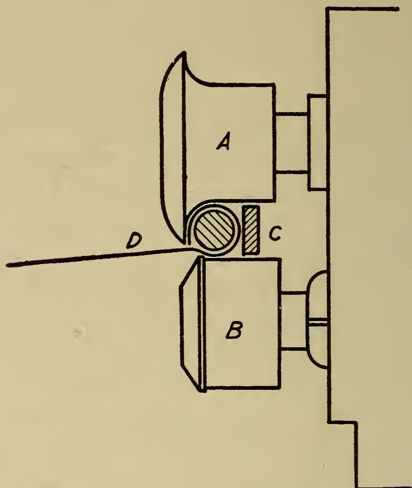


Figure 167.—Sectional View of Wiring Machine.

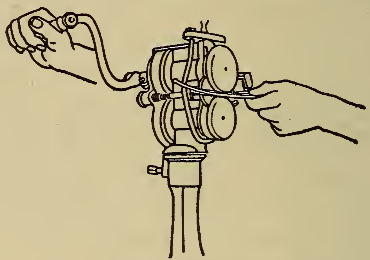


Figure 168.—Wiring Machine in Operation.

against the gauge *C*, bring down the upper roll *A*, and adjust the gauge, having the curved flange on the upper roll fit snugly over the wire. The work is then run through the rolls until the metal is fitted closely over the wire.

In Figure 168 the wiring operation is illustrated, giving a full view of the machine and the proper position of the hands. If the rolls should slip when wiring heavy metal, this is overcome by pulling the work lightly as it passes through the rolls.

The next step in the construction of the cutter is to form the body on the forming rolls (Figures 35, 36). The wired edge is placed in one of the grooves cut in the end of the rolls for this purpose, and the body is then formed

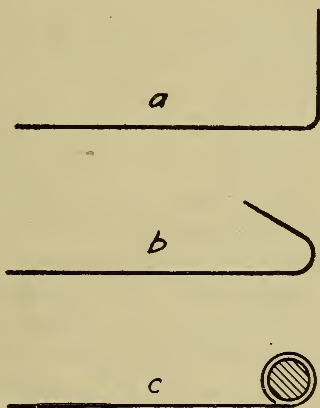


Figure 169.—Operations in Wiring an Edge by Hand.

the same as a cylinder. The wire should never be formed elsewhere than in these grooves.

Before inserting the work in the forming machine, place the work on the conductor stake (Figure 100) and slightly curve both ends of the wire by striking it lightly with a mallet. This enables the work to pass easily over the back roll of the forming machine.

Pattern *B* (Figure 166) for the handle is formed in the usual manner, after which the ends of the wire on the body are joined together, and the seam is soldered having the lap on the inside. The handle is soldered to the top in the position shown in *C* and *D*, Figure 166.

When forming cylinders in very small diameters, made from stiff or heavy metal, do not attempt to secure the correct diameter by passing the work once through the rolls, but form it gradually by passing through several times.

Wiring by Hand.—In wiring very heavy material, or when the sheet of metal is greater in length than the folding machine, making it impossible to turn the edge for wire on the folder, the wiring operation is performed by hand as follows:

After marking the wire allowance on the metal by means of the dividers or scratch awl, lay the sheet with the scribed line directly over the edge of the bench or some other straight edge. Take the mallet and bend the metal to an angle of 90° as shown at *a*, Figure 169. Turn the sheet over on the bench and by means of the mallet bring the edge to the position shown at *b*. The wire is then laid under the edge and the metal is bent closely over the wire as shown at *c*. The operation is completed by running the work through the wiring machine (Figure 45) in the usual manner. The right angle bend *a*, Figure 169, can also be made on the cornice brake (Figures 24, 27, 29) and the wiring operation completed as described above.

CHAPTER VIII

NOTCHING AND BURRING

Every experienced sheet metal worker understands the importance of notching patterns properly for wiring and seaming. Special attention should be given by the student to this part of the work, and great care should be taken that the corners are notched in such a manner that

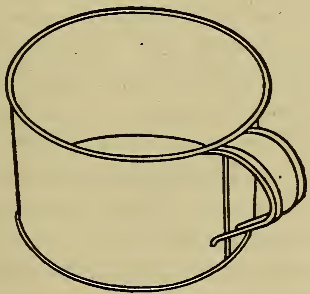


Figure 170.—Sheet Metal Cup, Notched and Burred.

when the work is formed up and seamed, the notched corners will fit snugly together without overlapping or leaving an opening exposing the wire at the end of the seam.

In constructing sheet metal articles in the form of a cylinder, having a wire inserted in the top edge, and the lower end inclosed with a bottom of the same material, if the side seam is grooved the corners of the pattern must be notched for wiring and seaming in such a manner that when finished the article will present a neat appearance.

We will take for a description of the notching and burring processes the making of a sheet metal cup, shown in Figure 170. This is the next problem given in the graded series that we are following. These cups are made up in different sizes and for various purposes.

The method of construction and patterns for the cup are shown in Figure 171, in which the sectional view at *E* shows the construction. A No. 12 wire is inclosed in the top edge at *kk,* the bottom with a single edge at *mm* is slipped over the body and soldered on the inside. The pattern *C* for the body is a rectangular piece of IC bright tin, equal in length to the circumference of the body shown at *A*. To this dimension is added an allowance for a 1/8-inch grooved seam. The width of pattern is equal to the height plus the 1/4-inch allowance for a No. 12 wire.

Notching Patterns.—Having cut the material the required size, the next step is to notch the pattern for wiring and seaming, as shown by the shaded corners in pattern *C*. The upper corners are notched for wiring as shown by *abcd.* The width of the notches *da* and *ef* is equal to one and one-half times the width of the 1/8-inch edge turned for the seam. When a 1/8-inch edge is turned, 3/8 inch is allowed for the seam, and one-half of this amount or $\frac{3}{16}$ inch is notched from each corner. This will allow the notched corners *a* and *e* to fit snugly together. The grooved seam extends up to the wire as shown at *o*. The distance *ab* should be slightly greater than the allowance for covering the wire. A continuous cut is made from *a* to *b* to *c,* cutting *bc* on an angle of 45°. The lower corners are notched on an angle of about 45°, the width being one and one-half times the width of the edge to be turned. The corners *g* and *h* will then fit together, leaving only one thickness of metal on the lower edge after the grooved seam is completed.

After the pattern has been properly notched, set the gauge on the folder (Figure 15) 1/8 inch, then place one end of the pattern against the gauge, with the upper corners that have been notched for wire facing toward the right end of the machine. By placing the work in the folder in this manner, the edges for the seam are turned in their proper position for wiring and seaming. The body is then wired, formed up on the rolls, and the seam grooved. These operations have been fully described in previous chapters.

The pattern *D* for the handle is laid out by drawing a center line, making *ad* equal in length to *abcd* in elevation *A*. Through points *a* and *d* at right angles to the center line draw *st* and *uv*, equal to the width of the top and bottom of the handle. Next draw lines *su* and *tv*. Then *sutv* will be the pattern for the handle, with the allowance added for a single hemmed edge. The corners are notched as shown in the drawing, and a ⅛-inch single edge turned on the sides. The handle is then formed by hand over the tapering end of the blowhorn stake (Figure 98).

The method of drawing the profile of the handle is shown in the elevation. At pleasure locate the point *c* where the lower end of the handle joins the cup. The upper end of the handle fits closely under the wire at point *a*. Using the 45° triangle, draw lines from points *c* and *a* intersecting at *b*. Bisect line *ab* at *e*; with *eb* as radius, and *e* as center, describe a half circle connecting *a* and *b*. The amount *cd* is added for a lap at the lower end. Then *abcd* will be the profile and stretch-out of the handle.

After the edges have been turned on the handle, as shown in *F*, Figure 171, set the gauge on the small burring machine (Figure 47) equal to the width of the edge *nw*. Then run the work through the machine, having the upper roll turn the inner edge *n* against the handle, as shown at *y* in *G*. This operation will make the handle rigid, giving it a finished appearance after being formed into shape.

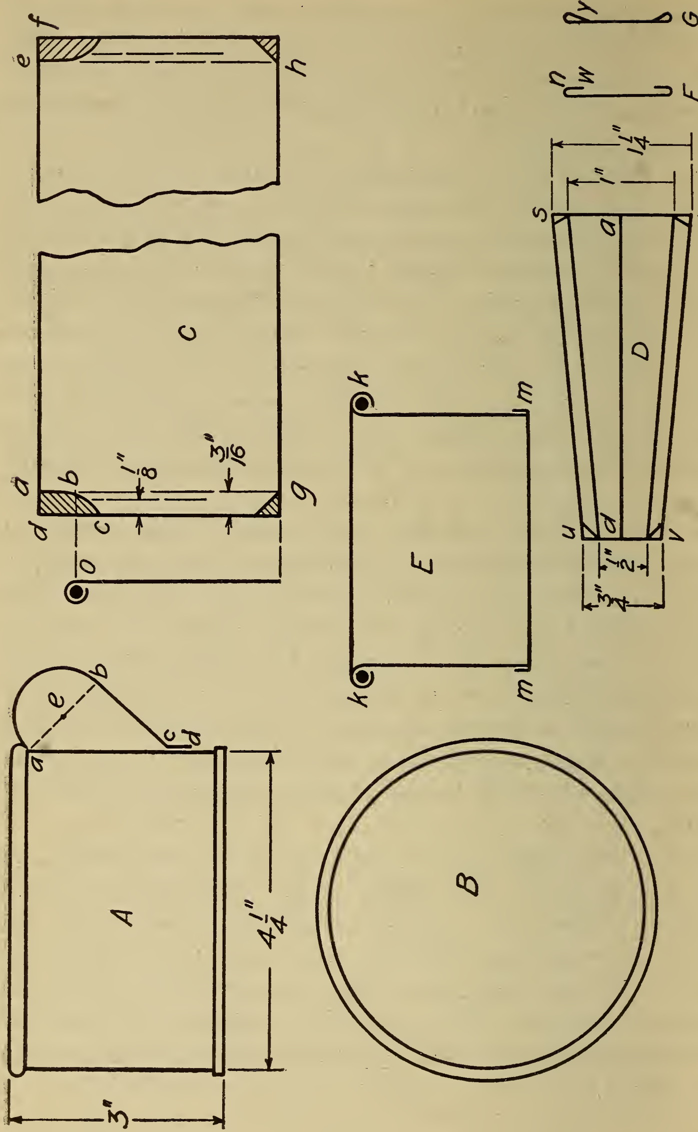


Figure 171.—Construction and Patterns for Sheet Metal Cup.

BURRING MACHINE

The burring machine shown in Figure 47 is used for various purposes and is well adapted for turning small edges on circular pieces of metal, edging hoops and rims of covers, and bodies of sheet metal articles for seaming. These machines are made in two sizes for general work. The small machine is used for turning edges on small curves, and will burr edges up to $\frac{3}{16}$ inch in width. For large curves the large machine is preferable; an edge or flange up to $\frac{1}{4}$ inch wide can be turned on this machine.

When burring edges for seaming light sheet metal, the experienced workman will turn the edge as small as possible, as he fully understands that it is almost impossible to turn a wide edge evenly on thin metal without crimping the burr. A narrow edge for seaming is practically as strong as a wide edge. It can be turned easily, and the seam will have a more finished appearance when completed.

Burring Edges.—Turning edges on the burring machine is a difficult operation for the beginner. It requires careful work and practice to become proficient in burring an even edge on a circular piece of flat plate, without crimping the burr or warping the metal.

The pattern for the cup bottom with an allowance for a single edge is shown in *B*, Figure 171. The bottom is simply a circular piece of metal having an edge $\frac{1}{8}$ inch wide turned at a right angle. To find the size of the bottom, measure the diameter of the body, and to this dimension add twice the width of the burr to be turned by means of the small burring machine.

After the bottom is cut from metal, then proceed to burr the edge in the following manner: Having made an allowance for a $\frac{1}{8}$-inch burr on the bottom, set the gauge on the machine a scant $\frac{1}{8}$ inch from the edge of the upper roll. This will allow for the take-up of the material after the edge is turned. Then holding the bottom in a horizontal position, place the edge of the metal on the lower roll, touching the gauge. Next bring down the upper roll until the metal is held firmly between the rolls. Then with the palm of the left hand resting against the frame of the machine, grasp the bottom between the thumb and fingers, the ball of the thumb resting on the upper side near the center, with the fingers extended on the lower side. With the hand in this position, holding the edge of the bottom firmly against the gauge, allow the metal to pass between the thumb and fingers while revolving in the machine. After the first revolution and while the machine

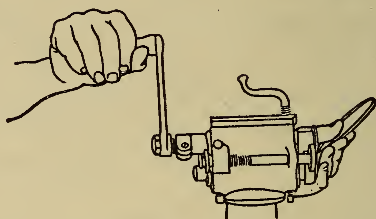


Figure 172.—Burring an Edge on Cup Bottom.

is turning, the bottom is gradually raised until the edge is turned to the required angle.

The correct position of the hand while burring edges on flat circular pieces of metal is shown in Figure 172. This method of holding the disc will keep the metal from warping out of shape while turning the edge. The bottom is then slipped over the body and the cup soldered on the inside, after which the handle is soldered in position, completing the problem.

BRAKING TIN

When constructing articles made from tin plate, sharp parallel kinks or wrinkles will often appear on the metal after being formed on the rolls. This can be avoided if the sheets are taken before wiring and passed through the forming rolls three or four times. With each pass they are reversed, then straightened out by being pulled over the rear roll while making the last pass through the machine. When formed up again the metal will not wrinkle. This process is known to the sheet metal worker as "braking tin" and is used constantly by the careful workman, for the parallel kinks are always evident if the metal is only rolled once.

SUPPLEMENTARY PROBLEMS

Before continuing with the next of the graded problems in this series, several supplementary problems are given, the construction being similar to the cup problem described in this chapter. These problems consist of small drinking cups and measuring cups for household use, and are usually made from IC or IX bright tin, having a No. 14 wire inclosed in the top. As these utensils hold a given quantity, unusual care must be observed by the workman when making the allowances for wiring and seaming.

Cup Dimensions.—The following table gives the diameter and height for different cups from ½ pint to one quart in size:

Size	Diameter (Inches)	Height (Inches)
½ pint	2 9/16	2 15/16
½ pint	2¾	2⅜
1 pint	3	3⅞
1 quart	3 9/16	5⅝
Drinking cup	3	2½
Drinking cup	3⅝	2¾

PATTERNS FOR A MEASURE LIP

Another adaption of the cup problem is the one quart lipped measure shown in Figure 173. The construction is the same, except that a circular flaring lip is attached to the top. The handle is double hemmed, and the body is graduated into four parts and marked on the metal by means of the beading machine. (Figure 59.)

The dimensions of the measure and method of obtaining the pattern for the lip are shown in Figure 174. First draw the elevation *A* to the required size. Then draw the side view of the lip *B* as shown by *abcd,* extending the lines until they intersect at *e.* With *f* as center describe the half section of the top of the measure as shown by *b5d;* divide this semicircle into equal parts as shown. The

Figure 173.—One-Quart Measure with Flaring Lip.

lip is an intersected frustum of a right cone, which can be developed by the radial method.

If the time is limited and only a few pieces are required, there are several short methods which can be applied to the same purpose. An approximate pattern developed by one of the short methods in common use is shown in *C,* Figure 174, and may be produced as follows: Draw a center line as *AB* and on it fix a convenient point *e.* With the compasses set to a radius equal to *ed* in the elevation *A,* scribe the arc *dbd;* starting from the point *b* space off a distance *dd* on each side equal to one-half the circumference of the top of the measure, as shown by the figures 1 to 9 in the half-section in the elevation. Draw a line from *e* extended through *d,* and place the width of the back of the lip as shown from *d* to *c.* Now take the distance of the front of the lip *ab* and place it as shown from *b* to *a*. Draw a line from *c* to *a* and bisect it to obtain the center point *m*. From *m* at right angles to *ca*,

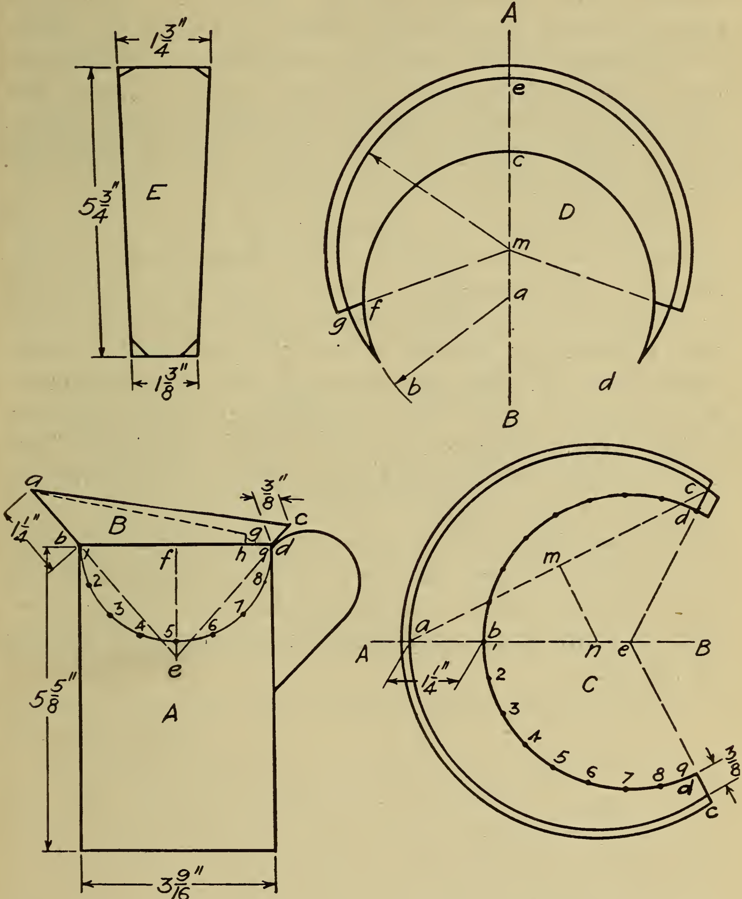


Figure 174.—Plan of Measure with Flaring Lip, and Patterns for Lip.

draw a line intersecting the center line *AB* at *n*. Then with *n* as center and *nc* as radius, describe the arc *cac*, which will complete the net pattern for the lip. Add an allowance for a lap seam on the end, and a ⅛-inch edge for a single hem on the top. After this edge has been turned in the burring machine (Figure 47) the lip is placed on a flat stake and the edge closed down by means of the mallet. Then the lip is formed on the blowhorn stake, placed in position on the top of the measure, and soldered on the inside. Lips for measures of large diameter are usually wired at the top edge, and the allowance for wire is made in the usual manner.

Another style of lip is shown by *abgh* in elevation, and incloses about three-fourths of the circumference of the measure. The top is cut off as shown by the dotted line *ag*. The method of laying out the pattern for a lip of this form is shown in *D*, and is obtained as follows: Draw center line *AB*. Set the compasses to a radius equal to three-quarters of the diameter of the top of measure. With *a* as center, describe the arc *bcd*. Next set off the width *ce*, and make the distance *cm* equal to one-half the diameter of the measure. With *m* as center and *me* as radius, describe an arc intersecting the arc *bd*. Cut off the end of the pattern as shown, making *fg* equal in width to *gh* in the elevation. Add allowances for wiring or hemming the top, thus completing the approximate pattern for the lip.

CHAPTER IX

DOUBLE SEAMING, PEENING, AND RAISING

The next problem of this series is the covered pail shown in Figure 175, the construction of which involves the processes of cutting, notching, wiring, seaming, and

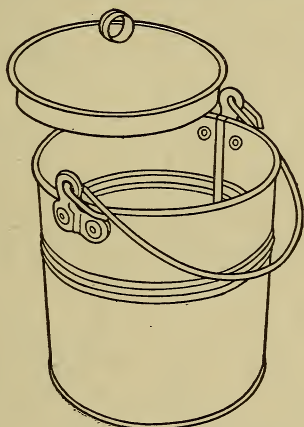


Figure 175.—One-Quart Covered Pail with Bottom Double Seamed.

burring, the same as the sheet metal cup described in the last chapter.

The construction of the body is practically the same, the only difference being that the bottom of the pail is double seamed to the body, instead of being slipped over the side as was done in constructing the cup. When the bottom of any sheet metal article is to be joined to the body, the diameter of which is 4 inches or larger, it is generally double seamed, either by hand or machine. The operations are fully described and shown in constructing the problem as follows:

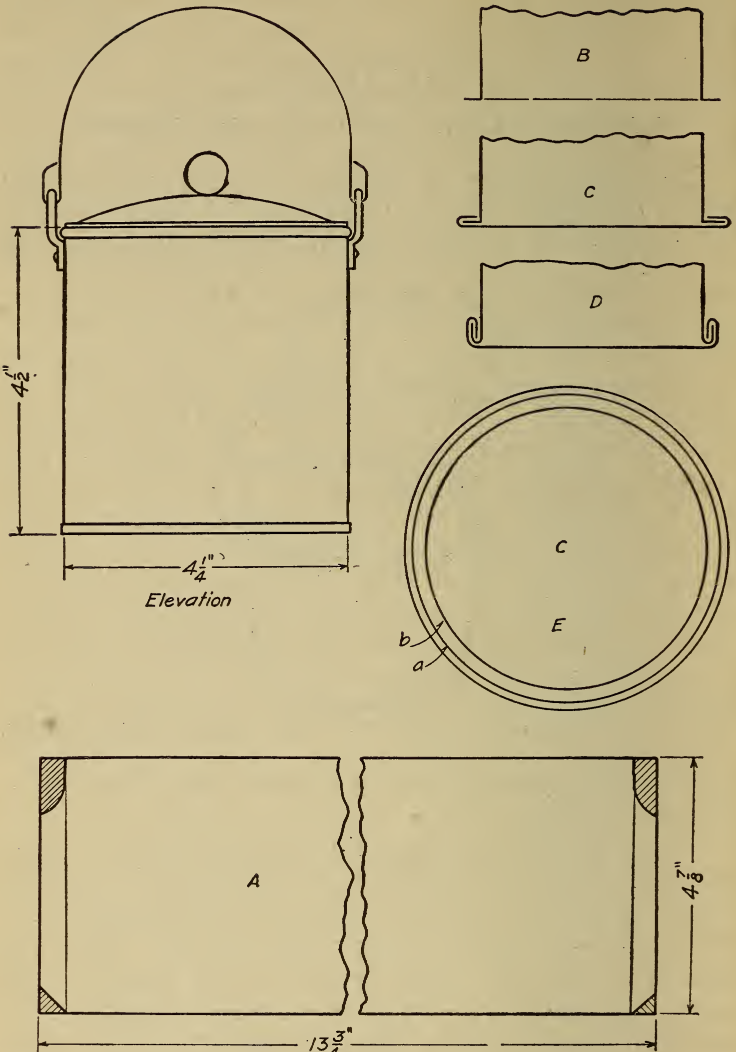


Figure 176.—Elevation and Patterns of One-Quart Covered Pail.

In Figure 176 are shown the elevation, patterns, and dimensions of a one-quart covered pail. This is a regular stock size and will allow two bodies to be cut from a 10x14 sheet of tin without waste. The body has a No. 12 wire inclosed in the top, with a ⅛-inch grooved seam on the side. The cover is raised into shape from the flat metal, having a flaring hoop attached that fits on the inside of the pail. The wire bail or handle is fastened to the ears, which are made of malleable iron riveted to the body. The pattern *A* for the body is cut on the squaring shears (Figure 1) to the required size. The corners are notched and the edges turned for wiring and seaming. The body is then wired, formed, and the side seam grooved on the machine.

THE DOUBLE SEAMING PROCESS

After the body has been completed, we are ready for the bottom, which is joined to the body by the process of

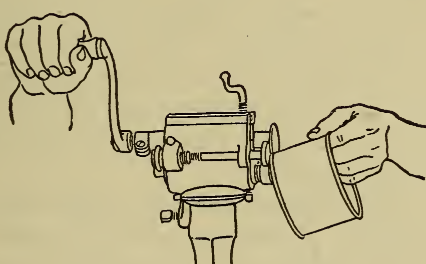


Figure 177.—Burring Edge on Bottom of Pail, Showing Correct Position of the Hands.

double seaming. The operations are clearly shown at *B*, *C*, *D*, Figure 176. The sectional detail at *B* shows an edge turned at a right angle to the body. The bottom is hooked over the edge on the body, as shown at *C*. The last operation and finished seam is shown at *D*.

Burring Edge on Body.—The first operation, burring the edge on the body, is shown in Figure 177. This edge is turned by means of the small burring machine (Figure 47) as follows: Set the gauge on the machine the required width for turning a ⅛-inch edge. Then hold the work in the left hand and place the edge against the gauge. Now, bring down the upper roll until the metal is held firmly between the rolls. The edge is then burred by allowing the work to revolve between the thumb and fingers while holding it against the gauge as it passes through the machine. The edge is brought to a right angle to the body by slightly raising the left hand while it is being burred. The correct position of the hands during this operation is shown in Figure 177.

Edge Allowance for Bottom.—The pattern for the bottom and the allowance for edges are shown at *E*, Figure 176. The diameter of the body is shown at *C*, and the allowance for a ⅛-inch edge on the body at *b*; a smaller edge turned on the bottom is shown at *a*.

When making a double seam, an experienced workman will always turn the edge on the bottom smaller than the edge turned out on the body. This will allow the edge to be doubled over without binding against the side during the operation. Never turn wide edges for double seaming. A small edge is more easily seamed and will have a neater appearance when finished.

After the edge has been turned on the body of the article, the diameter of the bottom is usually found by measuring from edge to edge through the center; to this dimension add twice the width of the edge to be turned on the bottom. The bottom is now cut from metal and the edge burred on the small burring machine (Figure 47) while holding the bottom in the position shown in Figure 172. The bottom is then hooked over the edge on the body as shown at *C*, Figure 176. The edge is next closed down tightly by means of the setting hammer (Figure 111) or the setting down machine (Figure 49).

THE PEENING PROCESS

The term *peening* means to the sheet metal worker the process of closing or "setting down" edges by means of the setting hammer shown in Figure 111. These hammers are made in different sizes, having a narrow beveled edge on one end, the face of the hammer being square in form. Figure 112 shows a riveting hammer used by sheet metal workers. This tool has a rounded edge on the tapered end, and is not suitable for peening purposes.

The bottom of the pail in our problem being ready for peening, the operation is simple and is clearly demonstrated in Figure 178. The illustration shows the bottom resting on the flat top of the square stake, also the posi-

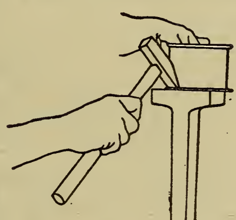


Figure 178.—Peening Edge of Bottom, Showing Position of Hands and Setting Hammer.

tion of the hands and hammer while closing down the edge. When peening the edge, care must be taken not to strike the sharp edge of the hammer against the body of the article, as that will make a disfiguring mark on the metal, showing careless work. This method of setting down the edge is universally used when seaming heavy material or large articles made from light metal.

Setting Down Machine.—When double seaming articles made from tin plate or light metal, if the edges have been turned true and even, the peening operation can be performed on the setting down machine (Figure 49). This operation is shown in Figure 179. The article is held bottom upward and the edge run between the two rolls, which will turn down and compress the edges, making a tight smooth joint ready for double seaming.

An improved setting down machine is shown in Figure 52. This machine is well adapted for setting down the edges on both straight and flaring articles. The inclined position of both rolls allows the work to be held with

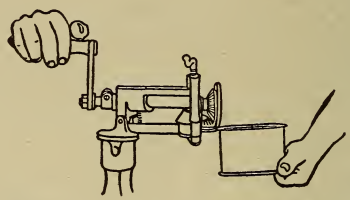


Figure 179.—Operating the Setting Down Machine.

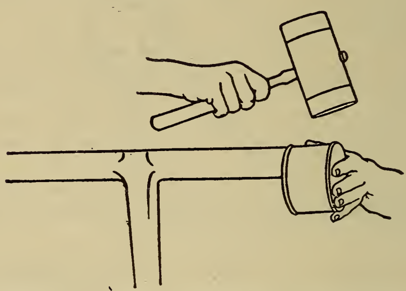


Figure 180.—Double Seaming on Stake.

the bottom up or down, and the operator can start the seam inward while setting it down to facilitate double seaming.

Double Seaming by Hand.—The final operation of the double seaming process is shown in Figure 180. The body of the article is slipped over the end of the double seaming stake and the edge bent over by means of the wooden mallet in the following manner: Hold the body firmly on top of the stake with the left hand in the position shown in the illustration; then turning the article slowly, strike an inward blow with the mallet, bending the edge at an angle of 45° while making one revolution of the bottom; complete the operation by hammering the seam down tight and smooth while holding the mallet in a vertical position.

When double seaming small articles, the double seaming stake shown in Figure 99 is well adapted for the work. For seaming large work or articles made from heavy material, the double seaming stake with four heads shown in Figure 100 will prove very suitable for a variety of work.

Double Seaming by Machine.—Double seaming machines are made in various styles, and if work is to be constructed in large quantities a machine for this purpose is indispensable. The machine shown in Figure 69 is adapted to many kinds of work, and many sheet metal workers prefer this type of seamer for general use.

Constructing Covers.—When constructing a cover made from light metal, it must be remembered that the first requirement is that it shall be rigid and strong enough to hold its shape without warping after the hoop has been attached to the rim. The hoop is made flaring in shape, so that it can be fitted snugly on the inside of the article. Covers of large diameter are generally constructed in the form of a flat cone, while the smaller sizes are either machine stamped or raised into shape from the flat metal by means of the raising hammer shown in Figure 110. Raising hammers can be obtained in different sizes and weights suitable for the work in hand.

Template for Hoop.—The method of laying out the patterns and the construction of the one-quart pail cover is shown in Figure 181. A detailed section showing the construction is given at *A*. The template, or pattern, for scribing the arc of the flaring hoop is shown at *B*, and is made in the following manner:

Using a piece of heavy tin 20 inches long, turn a double hem on one side; locate points *d* and *e* 1½ inches from hemmed edge as shown by *ef;* then with the trammel points, using a 36-inch radius, scribe an arc from *d* to *e*. The metal is now cut on this line and a ½-inch hole punched near one end for hanging the template on the wall for future use. This template can be used for mark-

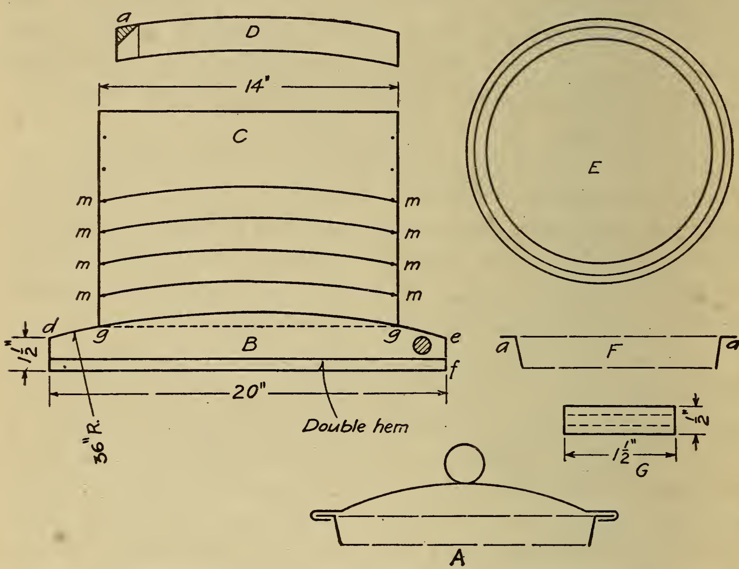


Figure 181.—Patterns and Construction of One-Quart Pail Cover.

ing out hoops of any diameter. For large covers the hoop can be made in two or more pieces.

The hoop for the one-quart pail cover is made from one piece of metal, equal in length to the circumference of the body, and is laid out directly on the metal as shown at *C*. Whether one or a dozen pieces are required, set the points of the wing dividers equal to the width of the hoop. Then start at the lower edge of the sheet and mark the width of each hoop by making a light impression on the metal with the point of the dividers, as shown at *mm* on both ends of the sheet. The template *B* is now placed on the lower edge of the sheet with the rounded side touching the corners. Then using the scratch awl, scribe a line on the metal as shown from *g* to *g*. The template is moved upward on the sheet to the prick marks *mm,* and the arc is scribed across the sheet, completing the pattern for one

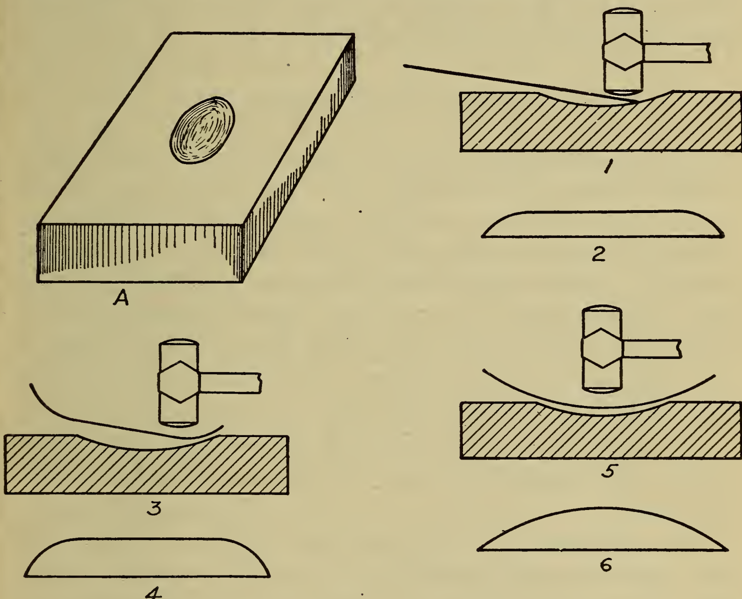


Figure 182.—The Raising Block (*a*) and Method of Raising a Circular Disc or Cover.

hoop. This process can be repeated for any number required.

After the hoop has been cut from metal and formed upon the rolls, it is fitted to the pail by inserting it in the top, having it project about ⅛ inch above the wired edge. While in this position mark the end; then cut off the surplus length, allowing about ⅜ inch for lap, and notch the corner as shown at *a* in pattern *D*. After the lap is soldered, a ⅛-inch edge is burred on the upper edge, as shown in the drawing at *aa* in *F*. A pattern for the cover, shown at *E,* is simply a circular piece of metal, the diameter of which is found in the same manner as the pattern for the pail bottom shown at *E,* Figure 176. After the dimension has been ascertained by this method, cut the metal ⅛ inch larger in diameter, to allow for the take-up during the raising process.

THE RAISING PROCESS

The Raising Block.—In constructing sheet metal balls, ornaments for cornice work, curved moldings, and covers for various articles, the sheet metal worker is often required to raise, or bump, the work into form from the flat metal, by means of the raising hammer and raising block. The raising block is made from some substance giving resistance to the blows, and a hardwood or lead block is generally used for this purpose. The trunk of a hardwood tree, about 36 inches high and 12 inches in diameter, having several shallow circular depressions of varying depth and diameter, cut in one end, is well adapted for this work.

When raising small forms, lead blocks are generally used, cast in a shape similar to that shown at *A,* Figure 182. These lead blocks are about 9x12 inches in size and about 4 inches high. The depression in the top is made by hammering with the round end of the raising hammer.

When raising a circular disc or cover, always start at the outer edge, working inward in courses toward the center, gradually turning the disc as each blow is struck. A mistake often made by the student and workman is to strike too hard while raising the center, which results in the curve being of greater depth than required.

In bumping curved moldings and raising the sections of a sheet metal ball, the raised flare often shows marks and dents made by the hammer. To obtain a smooth, round surface, the work is placed on the round head stake shown in Figure 99, and dressed evenly by means of the wooden mallet.

Raising Pail Cover.—Having the pail cover *E*, Figure 181, cut from metal, we are now ready for the raising process. First, hammer a circular depression 3½ inches in diameter and ⅜ inch deep in the top of a lead block. Next, place the flat disc of metal over the depression in the block, in the position shown at *1*, Figure 182, and with the raising hammer strike blows all around the edge of the circle, hammering out any wrinkles that may form during the operation. This will raise the metal to the shape shown at *2*. Then, with the cover in the position shown in *3*, strike another course of blows around inside of the first course. Continue this process until the cover is brought to the shape shown at *4*. The center is then raised by striking light blows with the hammer while holding the cover in the position shown at *5*. This completes the operation, as shown at *6*. When raising covers made from light material, two or more of them can be placed together and raised at the same time.

Turning Machine.—Figure 43 shows a turning machine, better known to the sheet metal worker as the "thick edge." These machines are furnished with rolls of different thickness, suitable for a large variety of work, and are well adapted for turning edges on heavy material, preparing the edges of flaring articles for wiring, edging pieced elbows, and making a depression or bead on the metal when marking the width of a flange to be turned on a cylinder or cover.

Flanging the Cover.—After the cover has been hammered or raised into shape, it will be necessary to turn a wide edge or flange on the rim, to allow for joining the hoop and cover by means of a single seam shown at *A*, Figure 181. The first step in flanging is to set the gauge on the turning machine (Figure 43) about ⅜ inch from the edge of the upper roll. Next, place the edge of the cover against the gauge, bring down the upper roll, and revolve the work in the machine, making a depression or bead as shown at number *1,* Figure 183. Then invert the cover and place the flange on top of the square stake, in the position shown at *2;* after which the edge is hammered down evenly by means of the wooden mallet. This

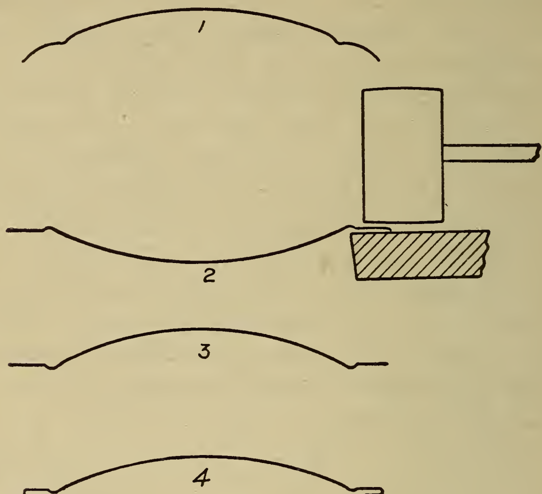


Figure 183.—Method of Flanging a Pail Cover.

completes the operation, leaving a flat surface ⅜ inch wide around the edge of the cover as shown at number *3.* By means of the small burring machine (Figure 47), a ⅛-inch edge is turned on the cover, as shown at number *4.* The cover is now hooked over the edge burred on the hoop, and the seam closed down by means of the setting hammer.

The ring for the cover is made from a piece of metal 1½ inches long and ½ inch in width, as shown at *G,* Figure 181. A single edge is turned on both sides, and the metal strip is formed into shape over the round end of the needle case stake (Figure 98). The ring is then soldered in position, which completes the construction of the cover.

Forming Wire Bails.—The small malleable ears that are riveted to the pail, and the progressive steps in forming the wire bail are shown in Figure 184. When making bails for articles having straight sides, cut the wire in length equal to two and one-half times the diameter of

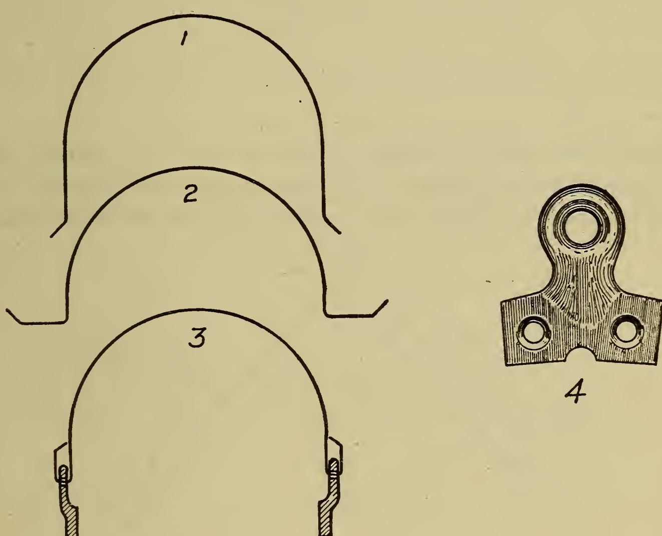


Figure 184.—*1, 2, 3,* Steps in Forming a Wire Bail; *4,* Malleable Ear to Receive Bail.

the top, and form into shape on the forming rolls (Figures 35, 36). Then place the wire in one of the grooves on the creasing stake (Figure 98), with the end extending about ¼ inch over the edge of stake; bend the wire by means of the hammer to an angle of 45°, as shown at number *1*, Figure 184. Next, move the wire forward on the stake about ⅝ inch and bend to an angle of 90°, as shown at number *2*. Both ends of the bail are now inserted into the opening in the ears and bent into shape on the creasing stake, as shown at number *3*.

Figure 185.—Bending Hook on Wire Bail, Showing Use of Creasing Stake.

An illustration showing this method of forming the hook on the end of a wire bail is seen in Figure 185. In Figure 99 is illustrated another type of creasing stake,

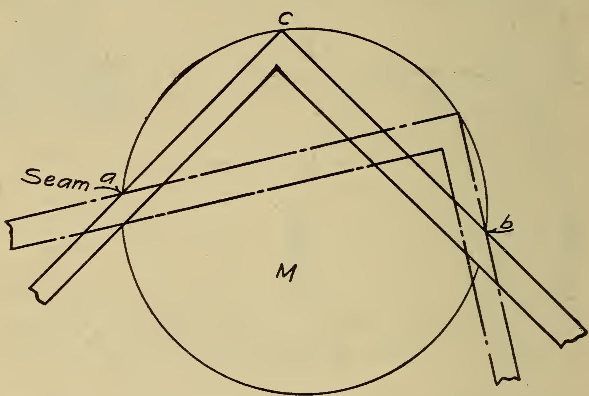


Figure 186.—Method of Finding Position for Ears with the Steel Square.

having a tapering horn on one end, which is very useful in forming small flaring articles.

Placing the Ears.—When riveting kettle ears on a sheet metal article, circular in form, one of the ears is placed directly over the seam where the two ends of the wire are joined together. The other is placed on the opposite side and the position located by measuring from the seam a distance equal to one-half the circumference of the body. This point is usually marked on the metal before it is formed in the rolls.

If the position of the ear is not marked on the metal before being formed into shape, it can be found by the method shown in Figure 186. Let the circle *M* represent the top of the article. Place the steel square on the circle in the position shown by the solid lines. With the outer edge of the blade on the seam at *a*, and the heel touching the circle at *c*, mark the metal where the outer edge of the blade intersects the circle at *b*. This gives the required point for riveting the ear. No measurements are necessary by this method. The square could be placed in the position shown by the dotted lines, obtaining the same result.

CHAPTER X

RADIAL LINE DEVELOPMENTS

The problems in this chapter will teach in a simple, progressive manner the construction and method of developing the patterns for tapering forms that have for a base the circle, or any of the regular polygons in which lines drawn from the corners terminate in an apex over the center of the base.

Patterns for tapering forms are developed by the radial method, by means of radial lines converging to a common center. When developing such patterns, first draw an elevation showing the true length of the axis, and the true length of the radius with which to describe the stretch-out arc of the pattern. The stretch-out must be described with a radius equal to the length of the true edge of the solid, as shown by *AC,* Figure 187. Then a plan view must be drawn from which the length of the stretch-out can be obtained, as shown by *DEFG* in Figure 187.

The simplest forms of tapering article are the cone and pyramid, and these are applied in the construction of chimney caps, ventilator heads, pitched covers, etc.

The sheet metal worker is frequently required to construct an article in the form of a frustum, or plane section of a cone, and the method used in developing the pattern is simply to develop a pattern for the entire cone and then cut off the upper portion, leaving the desired frustum.

The bodies of well-known tapering articles, such as the furnace hood, funnel, dipper, coffee pot, strainer, bucket, pan, etc., are of this character, and when developing their

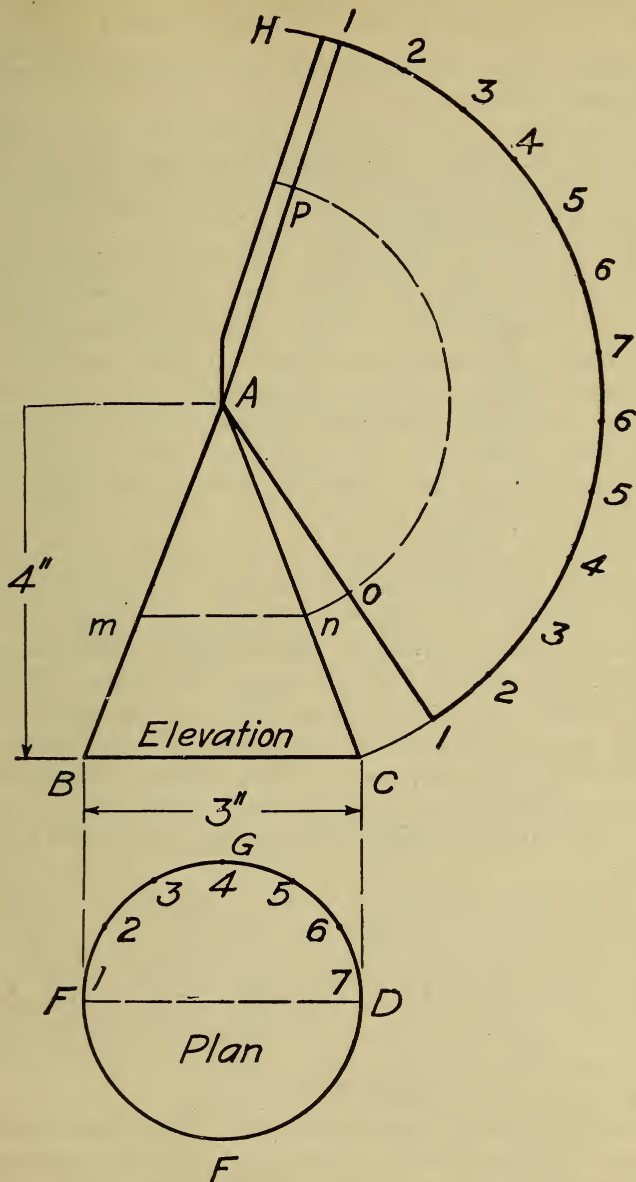


Figure 187.—Radial Method of Developing Pattern for a Right Cone.

patterns they are treated as the frustums of cones, as referred to above.

Pattern for Cone and Frustum.—In Figure 187 is shown the method of developing the pattern for a right cone, which contains the principles applicable to all frustums of pyramids and cones.

Draw the elevation *ABC.* Then describe a circle to represent a plan view of the base as shown by *DEFG.* Divide one-half of the outline of the base in the plan into a number of equal parts as shown by the figures 1 to 7; from the apex *A* of the cone as center, with a radius equal to the true length of the slant height of the cone as shown by *AC,* describe the stretch-out arc *CH.* On any convenient point on the stretch-out locate point *1* and draw a line from *1* to *A.*

Then set dividers equal to the length of one of the spaces in the plan, and starting at point *1,* mark off spaces equal to twice the number of those on the plan as shown by *1-7-1,* which will make the stretch-out equal in length to the circumference of the base of the cone. From the end point thus located draw a line to the apex *A,* and then add an allowance for seaming. This completes the pattern for the right cone. When adding allowances for seaming flaring work, care should be taken that the added lines are drawn parallel to the edge lines of the net pattern.

When the frustum of a cone is desired as shown by *mnBC,* Figure 187, then the diameter of the small end of the frustum will be equal to *mn,* and the radius to describe the upper edge of the pattern will be equal to *An.* With *A* as center and *an* as radius, describe the arc *op* as shown by the dotted line. Then *op 1-7-1* will be the pattern for the frustum of the cone.

Pattern for a Square Pyramid.—This development is shown in Figure 188 and the same principles used in developing the pattern for a conical-shaped object are ap-

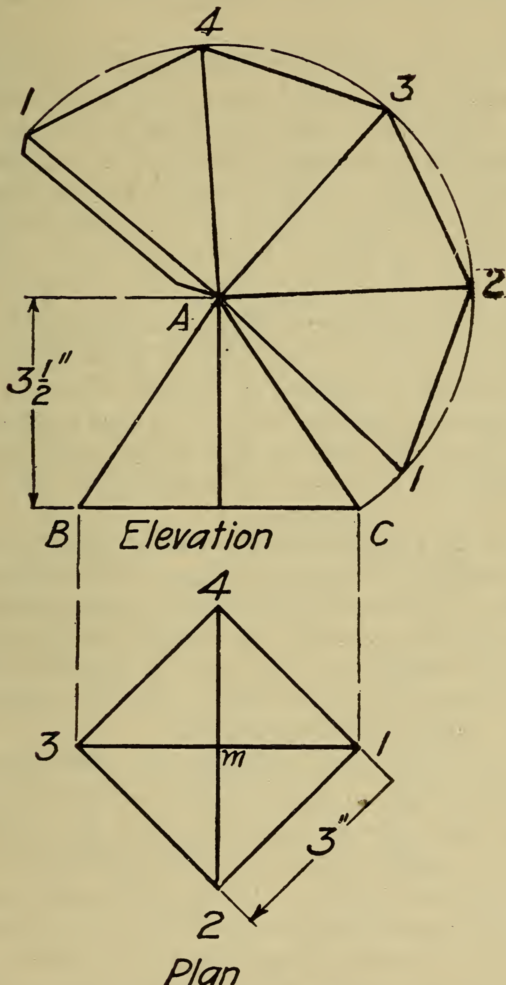


Figure 188.—Pattern for a Square Pyramid.

plicable to the developments of pyramids having a base with any number of sides. In this case we have a square pyramid.

Draw the elevation as shown by *ABC* and the plan view as shown by *1-2-3-4*, according to the dimensions given in the figure. Next draw the two diagonal lines *1-3* and *2-4*, intersecting in the center at *m*. When the plan view is placed in the position as shown, the line *AC* in the elevation represents the true length of one of the corners of the pyramid. With *A* as center and *AC* as radius the stretch-out arc is described in the same manner as in the case of the cone in the preceding problem. After setting the dividers to the width of one side of the base, as *1-2* in the plan, starting at *1*, mark off on the stretch-out line spaces equal to *1-2-3-4-1* in plan; connect these points by straight lines as shown, and draw lines from each point to the apex *A*, completing the development.

Pattern for a Hexagonal Pyramid.—The development of this problem, as shown in Figure 189, does not differ from that of the preceding problem, except that the line *AD* in the elevation is not the correct radius with which to strike the stretch-out arc, and it is therefore necessary to draw a line that will represent the true length in the elevation. This is found as follows:

First draw the plan and elevation according to the dimensions given in the drawing. From the center *m* draw the line *m-n* at right angles to *6-1* in the plan. From *m* as center with the radius *m-6* describe an arc intersecting line *m-n* at *a*. From *a* erect the perpendicular line intersecting the base line *BD* of the elevation extended at *g*. From *g* draw a line to the apex *A*, which will be the true length of *m-6* in the plan, and is also the radius with which to describe the stretch-out arc. With this radius and the apex *A* as center, describe the stretch-out line.

After setting the dividers to the width of one of the sides of the base which is shown in the plan, mark off six

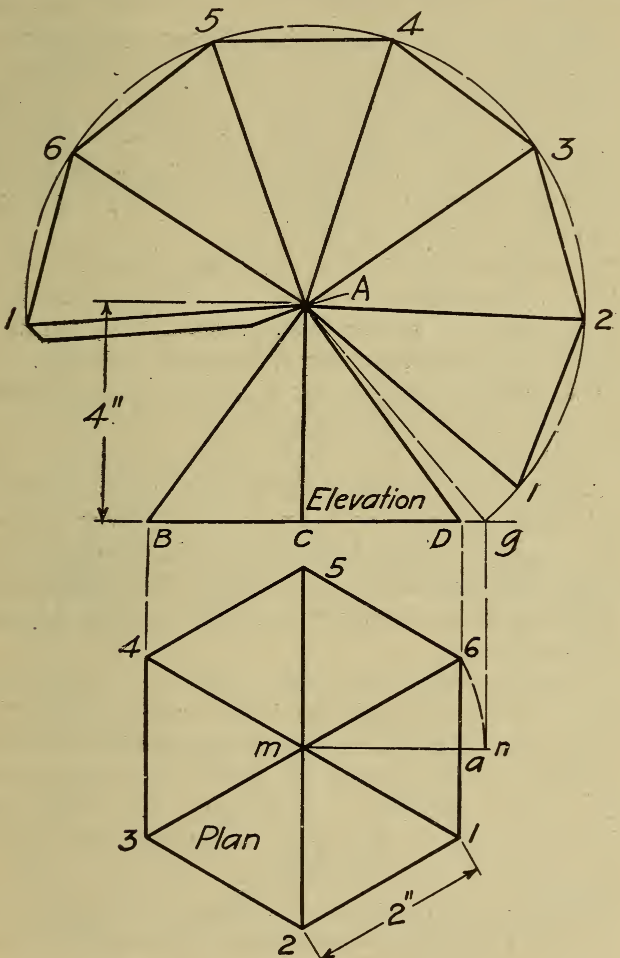


Figure 189.—Pattern for a Hexagonal Pyramid.

spaces on the stretch-out arc, and complete the pattern in the same manner as shown in the preceding problem.

Patterns for these problems should be developed, and models made from sheet metal, thus giving practice in construction. These models will at once show any error in the pattern which might otherwise be overlooked.

Rectangular Pitched Cover.—Sheet metal workers are frequently required to construct ornaments in cornice work, a hood, canopy, or a cover for an article square or rectangular in form. These articles are usually made in the form of a square or rectangular pyramid having a short height or rise to the apex.

Patterns for work of this kind are usually laid out directly on the metal by a short method in which no elevation is required, as the true length of the radius for describing the stretch-out arc is found in the plan. Figure 190 shows the development of a pattern for a rectangular pitched cover by this method.

The half elevation and section can be omitted. They were drawn in this case to show the construction and method of connecting the hoop *B* to the cover shown at *A*. The hoop is a strip of metal of the required width, having a single hem on the lower edge and an edge turned to a right angle on the upper side for seaming, as shown in the section.

The length, width and height of cover being known, first draw a plan to the required size, as shown by *1-2-3-4*. Next draw the diagonal lines intersecting in the center at *m*, which lines represent the hips of the pitched cover in plan. Bisect the line *1-2* and locate the point *x*, then draw a line from *x* to the center *m*, showing the position of the seam. Before describing the stretch-out arc for the pattern, find the true length of one of the hip lines in the plan and use that dimension as the radius for describing the stretch-out.

To find the radius, draw the line *m-o* at right angles to the hip line *m-3* in the plan. The height of the cover as shown by *ad* in the elevation is marked on the line *m-o* at

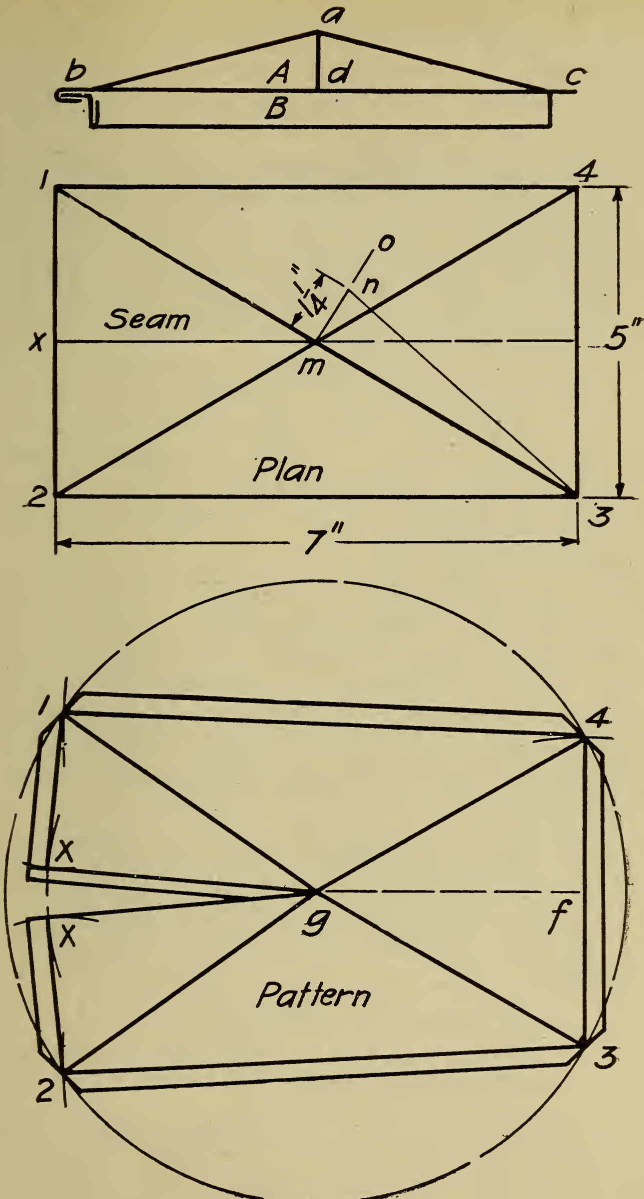


Figure 190.—Pattern for a Rectangular Pitched Cover.

n. Now draw a line from *n* to *3;* then *n-3* is the true length of the line *m-3* in the plan and is the radius for describing the stretch-out.

After setting the dividers equal to *n-3* in plan, with *g* as center describe a circle on the metal. Starting at any convenient point on the circle, as point *3*, space off the length of the end and sides of the cover as shown by *1-2-3-4* in the pattern. From *1-2* as centers, with a radius equal to one-half the width of the cover as shown by *1-x* in the plan, describe short arcs on the pattern as shown. The true length of the seam line is shown by the dotted line *g-f* in the pattern. Then with *g-f* as radius and *g* as center describe arcs at *x*. Connect all points by straight lines and draw lines from them to the center *g*. This completes the net pattern, to which allowances for seaming are added as shown.

After the pattern has been cut from metal, notch the corners and turn edges on the folder. The pattern is formed by placing the metal on the hatchet stake and bending on the hip lines to the required angle. The lap seam is riveted or soldered, and the hoop is attached to the cover as shown at *b* in the elevation. The edge is then closed down by means of the setting hammer, completing the construction.

Construction of a Flaring Pan.—In Figure 191 is shown a perspective view of a flaring pan, the form of which is seen to be the part or frustum of a cone. It is to be made of IC bright tin, according to the following dimensions:

Diameter of top, 6¼ inches.
Diameter of bottom, 4¾ inches.
Height, 2⅝ inches.

A No. 12 wire is inclosed in the top edge and the bottom is double seamed to the body. The body is made in two pieces cut from a 10x14 sheet of tin. The number of pieces in which the body of an article in this form is made will depend upon its size and the material from which it is to be constructed.

In Figure 192 is shown a half elevation, also a half sectional view and the method of obtaining the pattern for a flaring pan made in two pieces. In developing the pattern, first draw the center line *GH*, upon which place the height of the pan, as shown by *AD*. Through these points draw lines at right angles to the center line. On

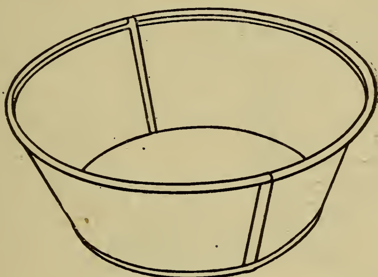


Figure 191.—Flaring Pan, Perspective View.

either side of the center line *GH*, from the points *AD*, place the half diameters *AB* of the top and *CD* of the bottom. Then *ABCD* shows the half elevation, while *AFDE* shows the half sectional view. Draw lines connecting *BC* and *EF* and extend them until they meet the center line at *K*, which is the center point with which to describe the pattern. With *CD* as radius and *D* as center, describe the quarter circle *CM*, and divide it into a number of equal spaces, as shown by the figures *1* to *7*. This quarter circle represents a one-quarter plan of the bottom of the pan.

The pattern is developed as follows: With *K* as center and the radii equal to *KB* and *KC*, draw the arcs *NO* and *RS* as shown.. From *N* draw a line to the apex *K*, and starting from the point *R*, space off on the arc *RS* the stretch-out of twice the number of spaces contained in the quarter plan, as shown by the figures *1-7-1* on the arc *RS*. From *K* draw a line through *S*, extending it until it intersects the arc *NO* at *O*. Add laps for seaming and wiring, as shown by the dotted lines. This completes the half pattern for the pan.

A one-half elevation and a quarter plan of the top or bottom is all that is required to find the stretch-out and

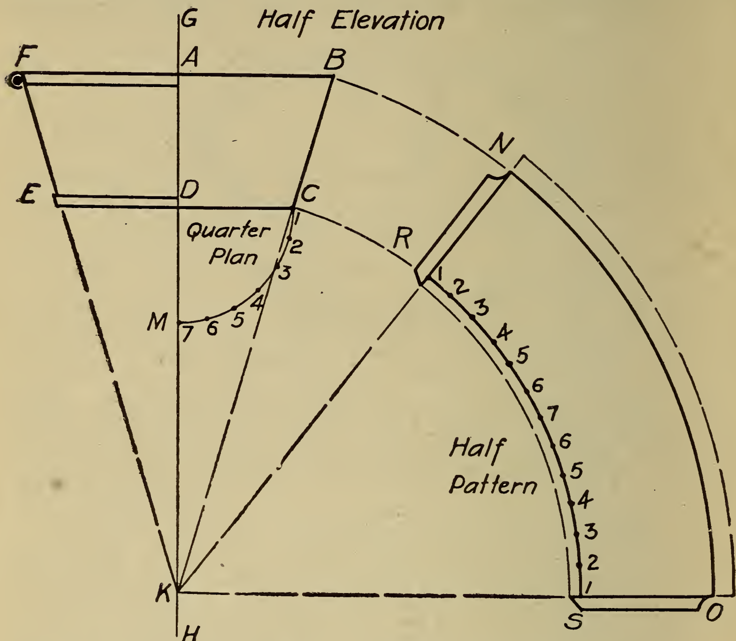


Figure 192.—Development of Pattern for a Flaring Pan.

radius for describing the pattern for the frustum of a cone. The allowances for seaming and wiring are made in the same manner as for the straight work described in previous chapters.

Wiring Flaring Articles.—Articles in the form of a frustum of a cone, such as a coffee pot or liquid measure, which have a wire inserted in the edge of the small end or top of the body, are wired while in the flat before being formed into shape; while flaring articles such as pails, pans, etc., having a wire inclosed in the large end, are wired after the body has been formed up and seamed together. A flaring article is to be wired always before seaming the bottom to the body.

Turning a Wire Edge.—Having completed the pattern for the one quart pan, Figure 192, transfer it to metal and cut two pieces from a sheet of 10x14″ bright tin. Notch the upper corners for wiring and the lower corners for seaming, as described in Chapter VIII. Place the two pieces together and form them into a semicircle on

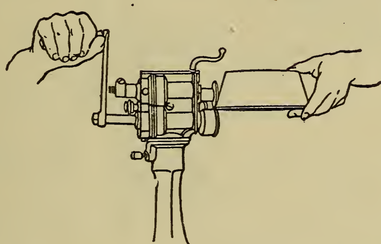


Figure 193.—Turning a Wire Edge on the Folding Machine.

the forming rolls (Figs. 35, 36). Next, turn the edge for the side seams on the folding machine (Figure 15), and then groove the seams and close them down by means of the mallet on the mandrel stake.

The next step will be to turn the edge for the wire. This is done on the small turning machine (Figure 43), in the following manner:

Having made an allowance of ¼ inch to the edge of the pattern for a No. 12 wire, set the gauge on the machine ¼ inch from the center of the depression in the lower roll. Then placing the upper edge of the pan against the gauge, bring down the upper roll and revolve the work in the machine, making a deep depression or bead on the metal.

Run the work through the machine several times, gradually raising the work until the edge is turned to the required angle, which will bring the side of the pan to a vertical position, almost touching the upper roll.

When turning a wire edge on the turning machine, it is often a difficult matter to keep the work circular in form; this difficulty can be overcome by pulling the work and rounding it into shape as it passes through the machine.

The edging operation and the position of the workman while operating the machine is shown in Figure 193.

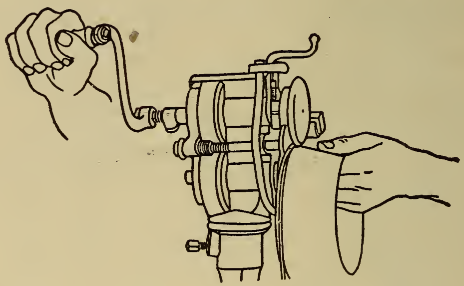


Figure 194.—Wiring a Flaring Article, Showing Correct Position of the Hands.

Use of Wiring Machine.—After turning the edge for wire, we are ready for the wiring process, which is the same as that described in Chapter VII, except that the wire is formed in the rolls before being inclosed in the edge of the article. First cut a piece of wire about ½ inch longer than the circumference of the top of the pan and form it circular in shape on the forming rolls (Figures 35, 36). Then placing one end of the wire at the side of a vertical seam and under the wire edge, close the metal over the wire for a short distance from the end by means of the hammer and the horn on the standard of the machine, or some suitable stake.

After setting the gauge on the wiring machine (Figure 45) to the required width, run the work through the rolls, wiring the top about three-fourths of its circumference. By stopping the operation at this point, the end of the wire can be held away from the edge of the metal and easily cut off to the required length by means of the wire cutters. The ends of the wire should fit close together. The work is then run through the rolls, completing the operation. In Figure 194 is shown a wiring machine and the correct position of the hands when wiring a flaring article.

The bottom is now double seamed to the body in the same manner as the bottom for the covered pail, and the process is fully described in Chapter IX. Using rosin as a flux, solder the bottom and the side seams on the inside of the pan, which completes the construction of the problem.

DIMENSIONS OF FLARING PANS

It is important that the student should know something of the standard sizes and dimensions of flaring pans that can be constructed with the least possible waste of material. For this purpose the following schedule of sizes and dimensions is presented:

Size	Diameter of Top	Diameter of Bottom	Height (Inches)
1 Pint	5¾	4	2⅜
1 Quart	6¼	4¾	2⅝
3 Pint	8⅛	6⅜	2½
2 Quart	8⅝	6⅛	3½
6 Quart	12¾	9	4
10 Quart	14¾	9⅜	4⅛

Making a Funnel.—A useful article in the form of a frustum of a cone is the common funnel shown in Figure 195. It is to be made from bright tin or No. 28 galvanized iron, having a No. 12 wire inclosed in the upper edge.

The vertical height is 3½ inches. The diameter of the top is 5 inches, and the lower opening in the body measures one inch in diameter. The spout is 2 inches long, having a ½-inch outlet, the seam being lapped and soldered. The body is made in one piece, having a ⅛-inch grooved seam on the side.

The body and spout are merely two frustums of cones and the patterns are developed in a similar manner by the radial method as shown in Figure 196. In this figure, the full elevation is drawn, but in actual practice

Figure 195.—Common Funnel, in Which Both Body and Spout Are Frustums of Cones.

much extra work can be avoided by drawing only one-half of the elevation, as shown, on one side of the center line *AB*. This is done to simplify the work and to avoid the drawing of unnecessary lines. To develop the patterns, extend the side lines of the body and spout until they intersect the center line at *M* and *G*. For the pattern for the body proceed as follows:

With *g* as center and radii equal to *GF* and *GE*, describe the arcs *ee* and *ff* of the pattern. On the arc *ee* step off four times the number of spaces contained in the quarter plan *C;* then draw lines to the center *g*. Add laps for seaming and wiring.

The pattern for the spout is developed in a similar manner, with a lap added to the upper edge and side for soldering.

After the pattern has been cut from metal, notch the corners, and turn the edge for the side seam on the folding machine. When the outline of the pattern is a semi-

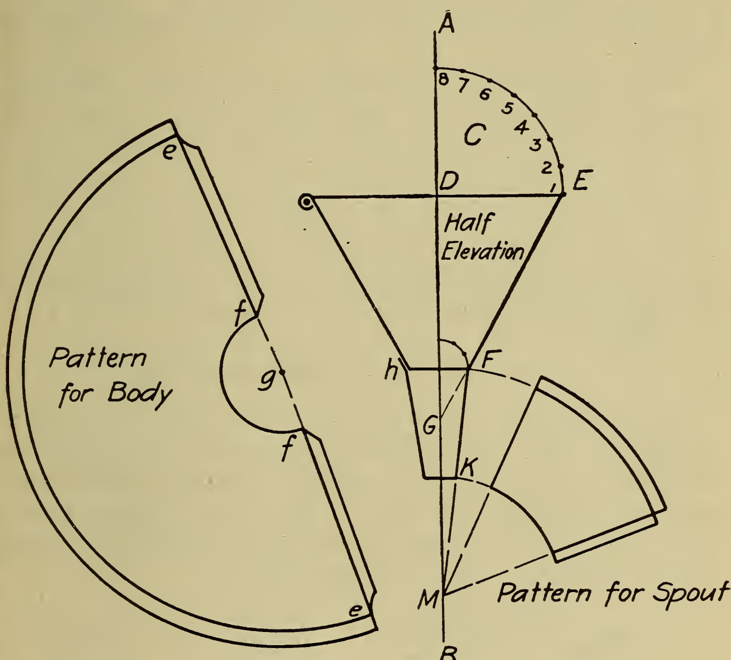


Figure 196.—Patterns for Funnel Body and Spout, Developed by the Radial Method.

circle or larger, place the work in the folder and bend the edge to a right angle, then finish the operation by means of the mallet on the hatchet stake. The patterns are now formed on the blowhorn stake, after which the side seam of the body is grooved and the upper edge is wired in the same manner as described in the preceding problem. The spout is slipped over the lower end of the funnel and soldered in position, as shown at *h*.

Flaring Liquid Measure.—Another application of the processes of wiring and seaming of flaring articles is the construction of flaring measures. These measures are usually made from bright tin, having a wire inclosed in the upper edge, and the bottom double seamed to the body.

When constructing measures of small size, the upper edge of the lip and side edges of the handle are usually hemmed, in the same manner as the one-quart lipped measure described in Chapter VIII. For the larger measures, greater strength is obtained by wiring these edges. As they must hold a given quantity when completed, the greatest accuracy is required in developing the patterns and in making the allowances for wiring and seaming.

DIMENSIONS OF FLARING MEASURES

While there are various proportions used by different workmen and for different purposes, the following schedule is one that is commonly used by sheet metal workers in commercial shops. The table presented gives the height, bottom and top diameters for flaring liquid measures from ¼ pint to 5 gallons.

Size	Top Diameter	Bottom Diameter	Height
¼ Pint	$2\frac{1}{16}$ in.	2¼ in.	2¼ in.
½ Pint	2¼ "	2½ "	2⅜ "
1 Pint	$2\frac{11}{16}$ "	3 "	$4\frac{9}{16}$ "
1 Quart	3¼ "	4 "	$5\frac{7}{16}$ "
½ Gallon	3½ "	$5\frac{3}{16}$ "	7¾ "
1 "	5 "	6½ "	8⅞ "
2 "	6¾ "	8¾ "	9¾ "
3 "	8 "	10½ "	10¼ "
4 "	8½ "	11 "	$12\frac{5}{16}$ "
5 "	9½ "	12½ "	$12\frac{1}{16}$ "

One-Half Gallon Measure.—Assuming that a one-half gallon measure is to be made from IX bright tin, the pattern for the body is developed by the radial method, as

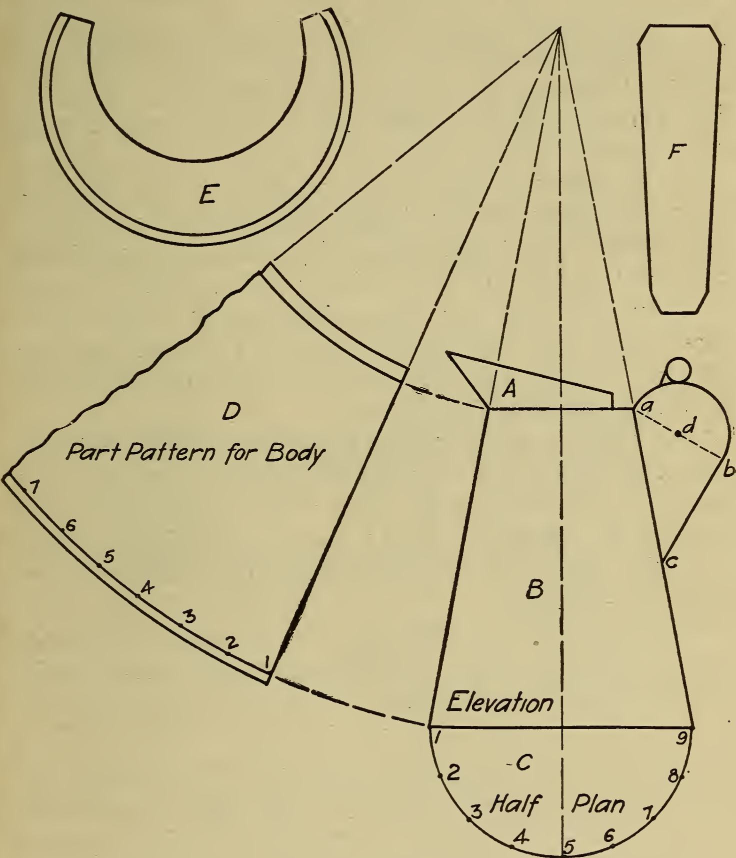


Figure 197.—Patterns for One-Half Gallon Measure, with Lip.

described in preceding problems. Using the dimensions given in the foregoing table, first draw the elevation and half plan as shown by *ABC* in Figure 197. Next lay out the pattern for the body in the usual manner and add allowances for wiring and seaming, as shown by the part pattern *D*. The pattern *E* for the lip is laid out by the short method shown in Figure 174, an allowance for a No. 14 wire being added to the upper edge. The pattern for the handle is shown at *F*. The length of this pattern is found by spacing the outline of the handle, as shown by *abc* in the elevation; to this dimension add laps at each end for soldering.

The handle is strengthened by inclosing a No. 13 wire in the side edges. After the patterns have been cut from metal, notch the corners, and turn edges on the folding machine (Figure 15) for wiring the handle and seaming the body. The edge for wire is now turned on the upper edge of the body and lip by means of the small turning machine (Figure 43), and wired in the usual manner on the wiring machine (Figure 45).

Next form the body, lip and handle in the forming rolls (Figures 35, 36), but do not place the wired edges in the grooves on one end of the rolls when passing the work through the machine. The bottom is double-seamed to the body, the lip and handle soldered in position, completing the problem.

Flaring articles in the form of a frustum of a cone, such as measures, pans, tapering pipes, etc., can be easily shaped on the forming rolls.

CHAPTER XI

PITCHED COVERS AND FLARING ARTICLES

The problems in this chapter are some of the many articles made by the sheet metal worker in which the patterns are developed by the radial method described in Chapter X.

In Figure 198 is shown a sheet metal can, cylindrical in form, with a pitched cover inclosing the top. These cans

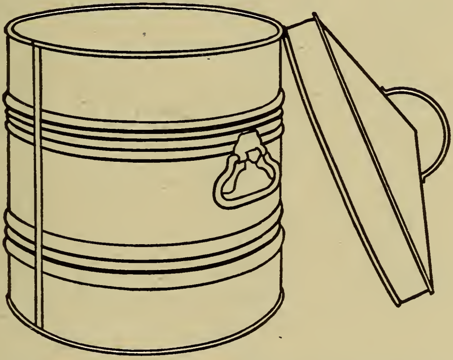


Figure 198.—Sheet Metal Waste Can with Pitched Cover.

are made from tin and galvanized iron, in a variety of sizes and for different purposes. The pitch of the cover can be varied at the pleasure of the workman.

The rim of the cover can also be made flaring in shape and fitted to the inside of the article in the same manner as the one-quart pail cover shown in Figure 181. As the sheet metal worker is often required to construct cans and tanks that will hold a given quantity, the following table is presented, giving the size, diameter, and height for cans from 1 to 200 gallons in capacity.

DIMENSIONS OF CANS AND TANKS

Gallon	Diameter	Height
1	6¾	6¾
2	8½	8¾
3	9	11½
5	10½	13¾
6	11½	13½
8	13½	13½
10	13½	16½
15	15½	19
20	17½	19½
20	16	23
25	18	23
30	18½	26½
35	18½	30½
40	18¾	34
45	19½	35
50	20½	35
55	21¼	36
60	22	37
65	22½	38
70	23	40
75	23½	40
80	24½	40
85	25	40
90	24½	45
95	25	45
100	26	45
125	27½	50
150	29	52½
175	30	57½
200	30¾	64

The waste can, Figure 198, shows the pitched cover having a straight rim 1½ inches wide fitted over the outside of the body. This style of cover is generally used when constructing flour cans and receptacles for waste material of various kinds. The body of the can is 12 inches in diameter. The height is 14 inches. The ma-

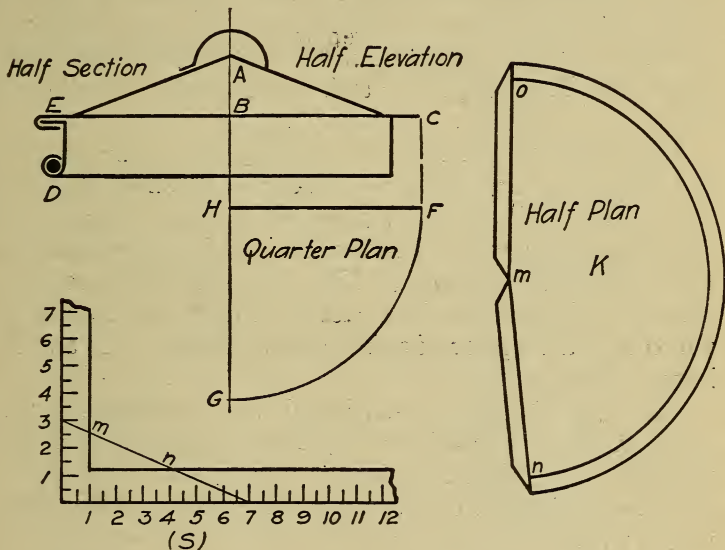


Figure 199.—Development of Pattern for Pitched Cover: s, Section of Steel Square and Method of Use in Laying Out Pattern.

terial used is No. 26 galvanized iron and a No. 8 wire is inclosed in its upper edge. An edge ¼ inch in width is used for the grooved side seam, and the bottom is attached to the body by a double seam in the usual way. The body is strengthened by several ogee beads. Tinned malleable iron handles are placed in position on the side as shown in the illustration.

Pattern for a Pitched Cover.—Figure 199 shows the method of obtaining the pattern for the pitched cover, which is in the form of a complete cone and is made in two pieces. First, draw the half elevation as shown by *ABC*. Make *AB* equal to the altitude and *BC* equal to one-half the diameter of the cover. With *BC* as radius and *H* as center, describe the arc *FG;* then *HFG* will represent a one-quarter plan view of the cover. With *m* as center and radius equal to *AC,* describe the arc *no* of the half pattern *K*. On this arc, step off twice the number of spaces contained in the one-quarter plan, then draw lines from *no* to *m,* and add laps for seaming, as shown.

After the edges have been turned on the bar folder, the two pieces are formed by hand and joined together with a grooved seam. The cover is now flanged and seamed to the rim, as shown at *E*. These operations are fully described in Chapter IX. The rim of the cover is simply a circular band of metal, having the lower edge wired and the upper edge burred, as shown at *D* and *E,* Figure 199.

Use of Steel Square.—Although the drawings for this problem are to be made on the drawing board, in actual practice many workmen lay out the pattern by means of the steel square and dividers directly upon the sheet metal, without the use of any drawing. This short method can be used for developing the patterns for cones and pitched covers of any diameter or height.

Assuming that a pitched cover 14 inches in diameter and 3 inches high is to be made in two pieces, to obtain the pattern by this method proceed as follows: At *S* in Figure 199 is shown the section of a steel square. Place one point of the dividers on the vertical arm of the square at *3*, which is the height of the cover, and the other point at *7*, which is one-half the diameter; the distance shown by the line *mn* will be the true radius with which to describe the stretch-out arc of the pattern. With a radius equal to *3-7*, and with any point, as *m* in the half pattern, as center, describe the arc *no*. To find the length of the stretch-out of the full pattern, multiply the diameter 14 by 3.1416, which will equal 44 inches. Set the points of the dividers 1 inch apart, and step off 22 spaces on the arc *no*. Draw lines from *n* to *m* and *o* to

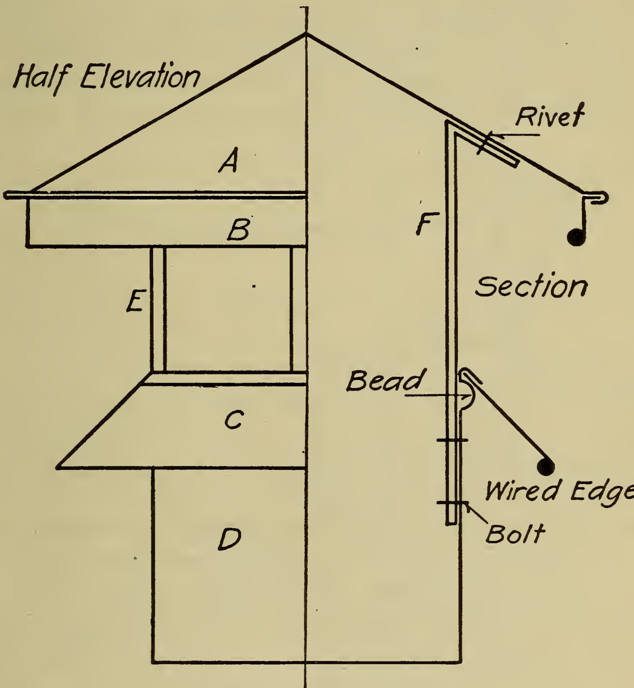


Figure 200.—Half Elevation and Details of Round Ventilator Head.

m, and add laps for seaming, which will complete the one-half pattern for the cover.

Round Ventilator Head.—A ventilator head which is used for a variety of purposes, and with equal efficiency as the top for a smoke jack or a ventilator cap, is shown in Figure 200. The proportions are varied somewhat by different workmen. The rule usually employed is to make the upper hood *A* and the lower flange *C* twice the diameter of the pipe *D*. The supports *E* and *F* are generally made from band iron, riveted to the hood and pipe as shown in the drawing. The straight flange *B* is merely a band of metal, having the lower edge wired and the upper edge attached to the top in a similar manner as the rim of the pitched cover described in this chapter.

The drawing, Figure 200, is made to a scale of 3 inches to the foot, and represents a ventilator having a 6-inch

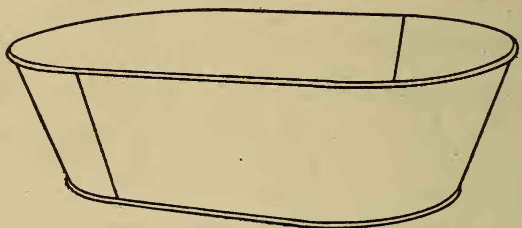


Figure 201.—Oblong Flaring Pan with Semicircular Ends.

opening. The half-section shows the construction and method of assembling the different parts.

To construct the ventilator, first draw the elevation full size, making it four times larger than the scaled drawing. The lower flange *B* has an inclination of 45° and the pitch of the upper hood *A* is at an angle of 30°. Since the upper hood is simply a flat cone, and the lower flange the frustum of a cone, the development of their patterns needs no explanation, as the method has been fully described in Chapter X.

Flaring Oblong Articles with Semicircular Ends.—Figure 201 shows a finished view of a flaring oblong pan with semicircular ends. The body is made in two pieces, having a wire inclosed in the top edge and the bottom double seamed in the usual manner. Articles of this form are made in various sizes and for different purposes.

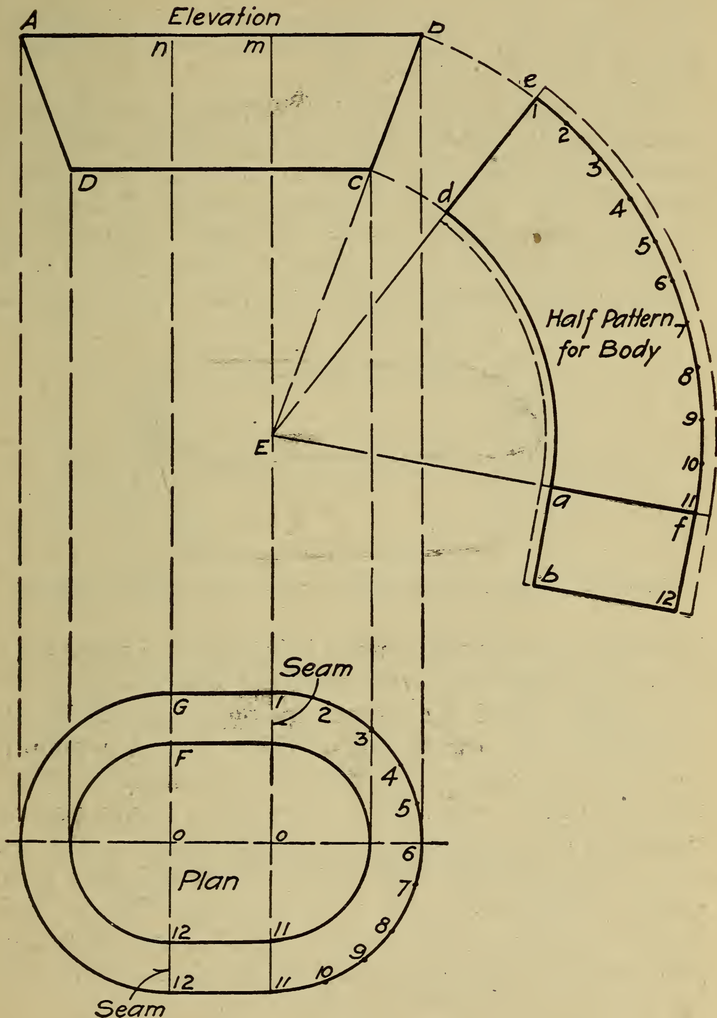


Figure 202.—Pattern for Oblong Flaring Pan with Semicircular Ends.

The dimensions of the pan shown in the illustration are as follows: Top 11x15 inches, bottom 8x12 inches, vertical height $4\frac{1}{4}$ inches. The method of developing the pattern is shown in Figure 202.

Draw the elevation *ABCD* according to the given dimensions; next, draw the plan of the top and bottom, the semicircular ends being struck from the centers *o* and *o*, with the radii *oF* and *oG* equal to one-half the width of the top and bottom. Divide the outer arc into a convenient number of equal spaces, as shown from *1* to *11*. From *o* erect the perpendicular line *om*, then extend the

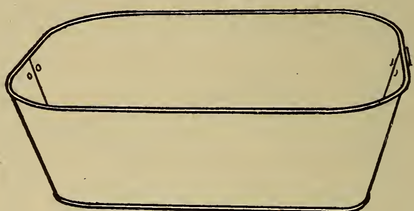


Figure 203.—Oblong Flaring Pan with Quarter-Circle Corners.

line *BC* in the elevation until it intersects the line *om* at *E*, which is the center with which to describe the arcs of the pattern. With *E* as center and radii equal to *EB* and *EC*, describe the arcs *da* and *ef*. Now, from any point on the outer arc, draw a line from *e* to the center *E*. Starting at point *1*, step off the stretch-out of the pattern, making it equal in length to the semicircle, as shown from *1* to *11* in the plan. From point *11*, draw a line to the center *E*, intersecting the lower arc at *a*. Then at right angles to the line *11a* draw the lines *11-12* and *ab*, making them equal to the straight side of the plan, as shown by the figures *11* and *12* in the plan.

This completes the pattern, with the exception of the allowances for seaming and wiring. Since these allowances differ in no way from those of preceding prob-

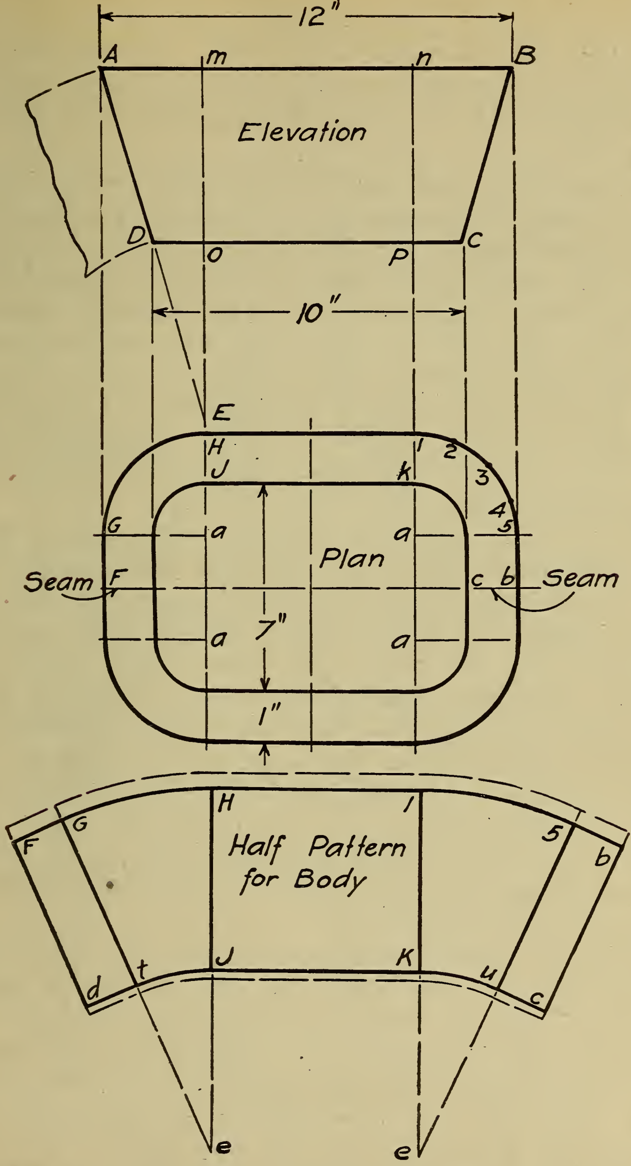


Figure 204.—Pattern for Oblong Flaring Pan with Quarter-Circle Corners.

lems, they need no further explanation. The pattern for the bottom is laid out by merely adding an allowance for double seaming to the outline of the bottom shown in the plan view.

Oblong Article with Quarter-Circle Corners.—Another application of the processes of double seaming and wiring is the construction of a flaring article having straight sides and quarter-circle corners. Since problems of this form frequently occur in the sheet metal trades, the construction and method of developing the patterns should be thoroughly mastered by the student and workman. The common form of this article is shown in Figure 203. The body is made in two pieces; the top edge is wired and the bottom attached by a double seam. The method of obtaining the pattern is shown in Figure 204.

First draw the plan and elevation in accordance with the dimensions shown on the drawing. The quarter-circle corners of the top and bottom are struck from the four centers shown by *a* in the plan, the radius of the arcs for the corners of the bottom, as shown by *aj,* being 1½ inches. Draw the perpendicular lines *am* and *an,* then extend the side *AD* of the elevation until it intersects the line *am* in the point *E,* which gives the height of the cones, portions of whose frustums are to form the corners of the finished article. Next, by the line *Fb,* divide the plan into two equal parts, then divide one of the outer quarter-circles into a convenient number of equal parts, as shown by the figures *1* to *5*.

To lay out the half-pattern for the body, first draw the line *H1* equal in length to *H1* in the plan, and at right angles to this line draw the lines *He* and *1e,* equal in length to *AE* in the elevation. Make *HJ* and *1K* equal to the slant height of the side shown by *AD* in elevation. Then with *e* and *e* as centers and radii equal to *eK* and *e1,* describe the arcs *1-5* and *Ku,* also the arcs *HG* and *Jt.* Starting at points *H* and *1,* step off the stretch-out

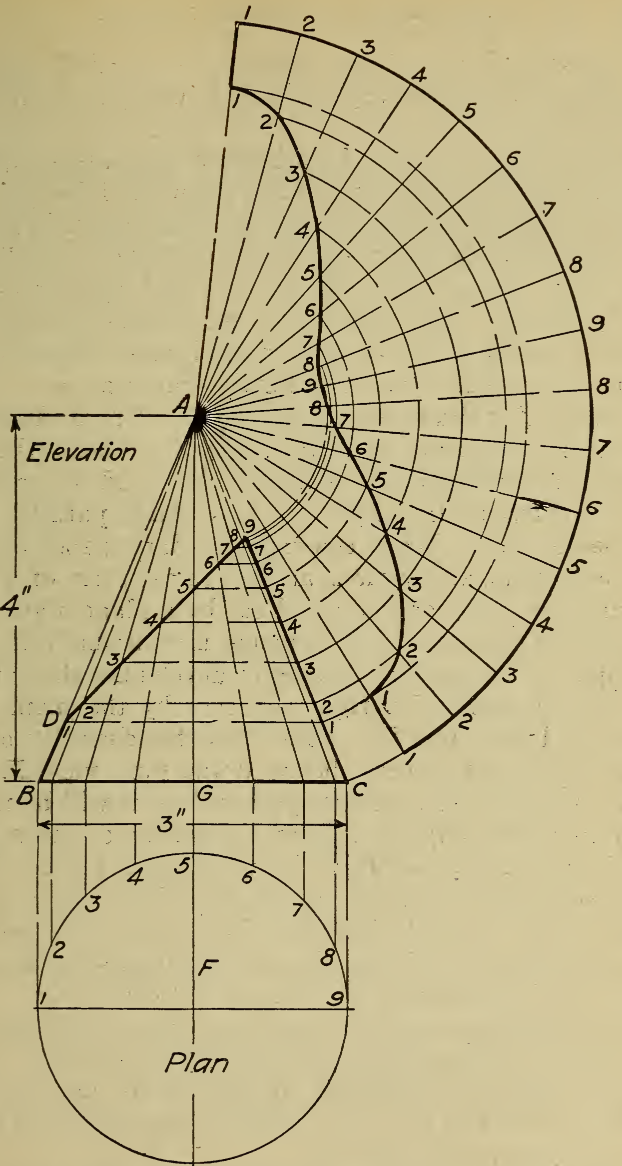


Figure 205.—Method of Obtaining Pattern for Frustum of Right Cone.

of the arcs of the pattern, making *1-5* and *HG* equal in length to the quarter-circle shown in the plan by the figures *1* to *5*.

From points *5* and *G,* draw lines to the centers *e* and *a,* and at right angles to these lines, draw the lines *GF* and *td* on the left, and *5b* and *uc* on the right, equal in length to one-half the straight end of the pan, shown by *FG* in the plan. Connect these points and add laps for wiring and seaming. The pattern for the bottom is found by merely adding to the outline of the bottom shown in the plan, the allowance required for the double seam.

Pattern for Frustum of Right Cone.— The problems in radial developments up to this point have been what we might call articles in the form of a cone and the frustum of a cone having the upper and lower bases parallel or in the same plane. When constructing flaring roof collars, gutter outlets, and various articles in the form of a cone having the upper or lower end cut by a plane other than parallel to its base, the development is somewhat different.

Figure 205 shows the method of developing the pattern for the frustum of a right cone cut by the plane represented by the line *D9*. First draw the elevation of the cone *ABC,* and directly below it the plan view *F*. As both halves of the cone are symmetrical, it will be necessary to divide only one-half of the outline of the plan *F* into equal spaces, as shown by the figures *1* to *9*. Next represent the cutting plane *D9* by a line drawn at an angle of 45° with the base line *BC,* making the point *D* one inch from *B*. From the various points in the plan erect lines intersecting the base of the cone from *1* to *9*. From these points on the base line, draw radial lines to the apex *A,* intersecting the line *D9* as shown. From these points of intersection on the line *D9,* and at right angles to the axis line *AG,* draw lines as shown intersecting the side of the cone *AC*.

Then using *A* as center with *AC* as radius, describe the stretch-out arc. From *1*, draw a line to the apex *A*, and starting from point *1*, step off on the arc twice the number of spaces shown in the plan *F*, by the figures *1-9-1*. From these points draw radial lines to the apex *A*. Then, using *A* as center, with radii equal to the various points which are shown in their true length on the

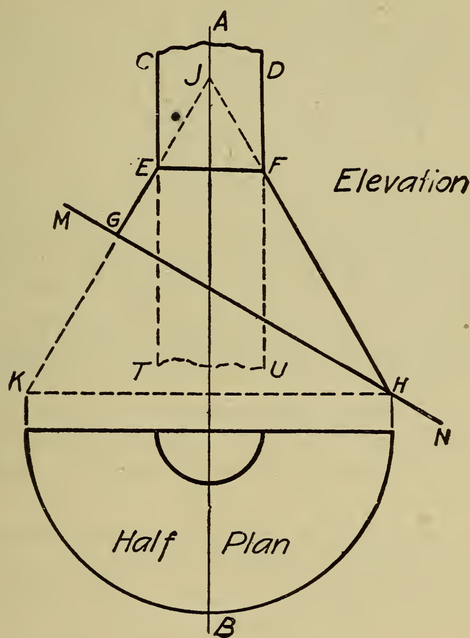


Figure 206.—Half Plan and Elevation of a Flaring Roof Collar.

line *AC*, draw arcs intersecting similar numbered radial lines in the pattern. The irregular curve is now traced through points thus obtained, which completes the desired development.

Flaring Roof Collar.—The principles used in developing the pattern for the intersected cone shown in Figure 205 are applicable, no matter at what angle or point the bases of the cone are intersected. The workman will apply these principles in developing the pattern for a flaring roof collar shown by *EFGH* in Figure 206. A roof collar of this kind is commonly used by plumbers and sheet metal workers to secure a watertight joint when flashing around stacks and vent pipes that extend through the pitched roof of a building.

First, draw the center line *AB* and then draw the roof line *MN* at an angle of 30°. Next draw the outline of the vertical pipe shown by *CDTU,* and make the upper base of the collar *EF* at any convenient distance from the roof line. At a proper angle, draw the side lines of the collar through the points *EF* extended until they meet at the apex *J.* Next draw the horizontal line *HK,* and extend the side line *JG,* intersecting the line *HK* at *K,* as shown by the dotted lines. Then *JKH* will represent a right cone which is cut off on the lines *EF* and *GH.* The pattern is now developed in the same manner as the previous problem.

CHAPTER XII

PARALLEL LINE DEVELOPMENT

Practical workshop problems, such as arise in every day practice, in which the patterns are developed by means of parallel lines, will now be presented. This method is used in laying out patterns for elbows, tee joints, roof gutters, skylights, cornices, etc. All of the problems should be carefully studied and the patterns drawn accurately. Unless the drawings are exact, they are of no value. There are certain fixed principles that apply to developments by this method, and the following rules should be carefully observed by the student and workman:

1. A plan and elevation must first be drawn, showing the article in a right position, in which the parallel lines of the solid are shown in their true length.
2. The pattern is always obtained from a right view of the article in which the line of joint or intersection is shown.
3. A stretch-out, or girth line, is always drawn at right angles to the parallel lines of the articles, upon which is placed each space contained in the section or plan view.
4. Measuring lines are always drawn at right angles to the stretch-out line of the pattern.
5. Lines drawn from the points of intersection on the miter line in the right view, intersecting similarly numbered lines on the stretch-out, will give the desired pattern.

Two-Pieced Elbow.—Figure 207 demonstrates the method of developing the patterns for a two-pieced 90° elbow.

First draw the elevation *ABCDE7.* Then below the elevation describe a circle representing the profile or plan, shown at *F.* As each half of the pattern is symmetrical, draw a line through the plan *F,* and divide the upper half of the circle into a number of equal parts, as shown from *1* to *7.*

From these points perpendicular lines are drawn intersecting the miter line *C-7* as indicated. Then at right

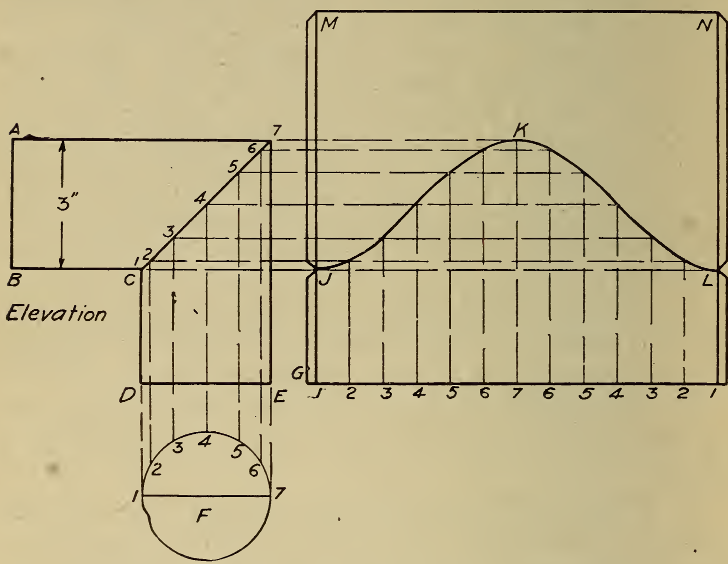


Figure 207.—Patterns for Two-Pieced 90° Elbow.

angles to the lower arm of the elbow *E-7,* draw the stretch-out line *GH,* and upon this line step off twice the number of spaces indicated in the plan, which will give the circumference of the elbow, as shown by the points *1-7-1* on the line *GH.* From these points and at a right angle to *GH,* measuring lines are erected and intersected by like numbered lines drawn at a right angle to the cylinder from similar numbered points of intersection on the miter line *C-7* in the elevation. A line traced through points thus obtained will be the pattern for the lower arm of the elbow, as shown by *GHLKJ*.

The manner of laying out the pattern for the upper arm of the elbow may need some explanation. The irregular curve traced through the points of the pattern is the only one required for both pieces of the elbow. The stretch-out of both pieces being of equal length, extend the outer lines of the pattern to *M* and *N* as pointed

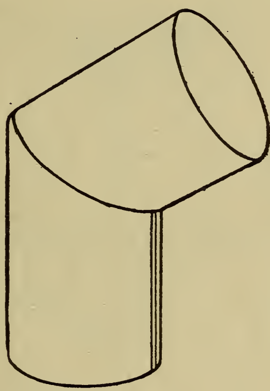


Figure 208.—Round Conductor Elbow.

out, and make *JM* and *LN* equal in length to the long side of the upper arm as shown by *A-7* in the elevation. Draw a line from *M* to *N;* then *JKLNM* will be the pattern for the upper arm of a two-pieced elbow. Allowances for seaming or riveting must be added as indicated. This method of development is applicable to any pieced elbow, no matter what angle is required.

Conductor Elbow.—An article often required to be made up from tin plate, sheet copper, and galvanized iron, is a round conductor elbow, shown in Figure 208. It is usually made at other than a right angle, to allow for drainage purposes.

Figure 209 shows the elevation and plan view of a two-pieced conductor elbow, the circle representing the plan or profile being 3 inches in diameter. Draw the elevation and let *DEF* be the required angle. The miter line of a

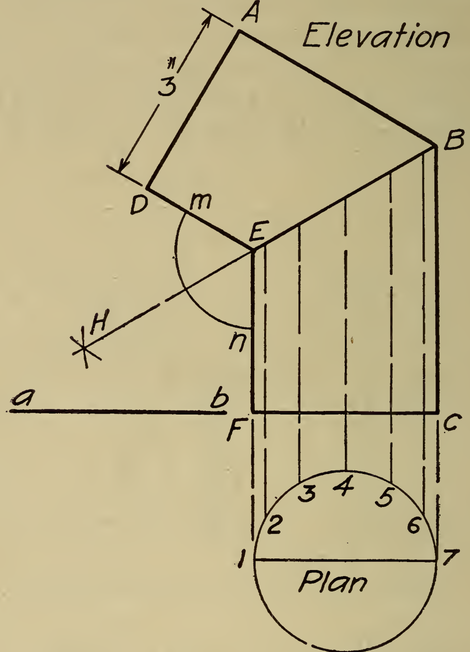


Figure 209.—Elevation and Plan of Two-Pieced Conductor Elbow.

two-pieced elbow is always found by bisecting the angle and is obtained as follows:

With *E* as center and any convenient radius describe the arc *mn*. With a slightly larger radius and *m* and *n* as centers, describe two arcs, intersecting at *H*. Then draw the line *HB*, which is the bisector of the angle *DEF*, and *EB* is the required miter line of the elbow.

The upper half of the plan is spaced into a number of equal parts, and from these points vertical lines are drawn, intersecting the miter line *EB* in the elevation. The stretch-out line as shown by the line *ab*, is now drawn at right angles to the lower arm of the elbow, and the patterns for both arms are laid out in the same manner as the 90° elbow. This development is shown fully in Figure 207 and the workman should have no trouble in completing the problem.

Pipe and Roof Flange.—A roof flange used by plumbers and sheet metal workers when flashing around vent

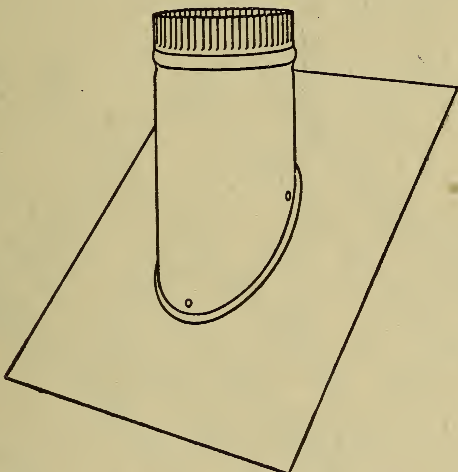


Figure 210.—Pipe and Roof Flange.

pipes and stacks that come through the slanting sides of a roof, is shown in Figure 210. As may be seen by the illustration, the roof flange is merely a flat plate of metal which is seamed to a cylinder or pipe having one end cut at an angle equal to the pitch of the roof.

Figure 211 shows the method of developing the pattern for the pipe and the opening in the roof plate. First draw the roof line *BC* at an angle of 45°, which will show the pitch of the roof. Then draw a side view of the

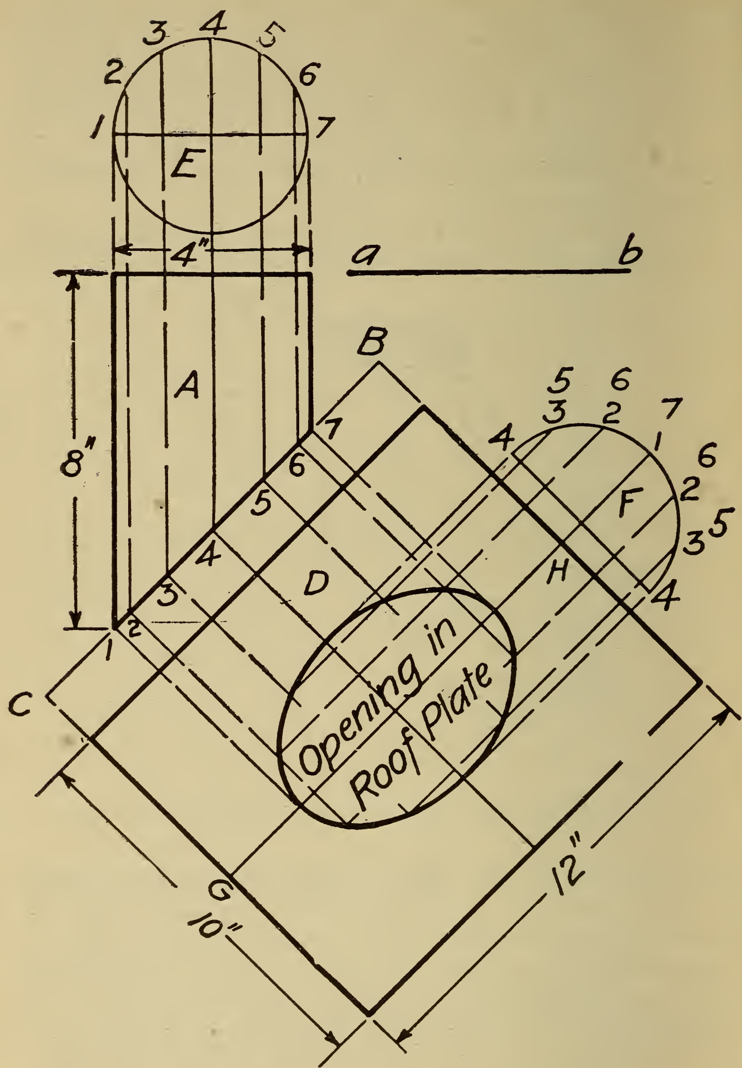


Figure 211.—Method of Obtaining Pattern for Pipe and Opening in Roof Plate.

pipe *A* and its section, indicated by the circle at *E*. One half of the circle is divided into a convenient number of equal parts, and from these points parallel lines are drawn, intersecting the roof line *BC* as shown.

We are now ready to develop the pattern for the pipe *A*, which is a cylinder having one end cut at an angle of 45°. Draw the stretch-out line *ab* at right angles to the vertical side of the pipe, and obtain the pattern in a manner similar to the development of the lower arm of the two-pieced elbow shown in Figure 207.

The pattern for the opening in the roof plate is developed in the following manner:

First draw lines at right angles to the roof *BC* from the points *1* to *7*. Then at right angles to these lines

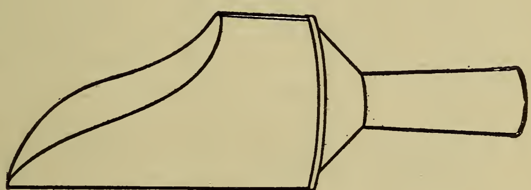


Figure 212.—Common Hand Scoop.

draw the line *GH* through the center of the roof plate *D*. On the line *GH* place half of section *E* as shown by *F*, and divide the half circle into the same number of equal spaces to correspond to the half-section *E*. From these points in *F* draw lines parallel to *GH*, intersecting similar numbered lines that have been drawn from the points on the line *BC*. A line traced through the points thus obtained will be the pattern for the opening in the roof plate.

Hand Scoop.—A typical hand scoop, commonly used, is represented in Figure 212. The illustration shows that the body is in the form of an intersected cylinder, and the handle and the brace are the frustums of two right cones. This problem, as presented, will require the development of patterns by both the parallel line and radial methods. In the construction of the patterns no prin-

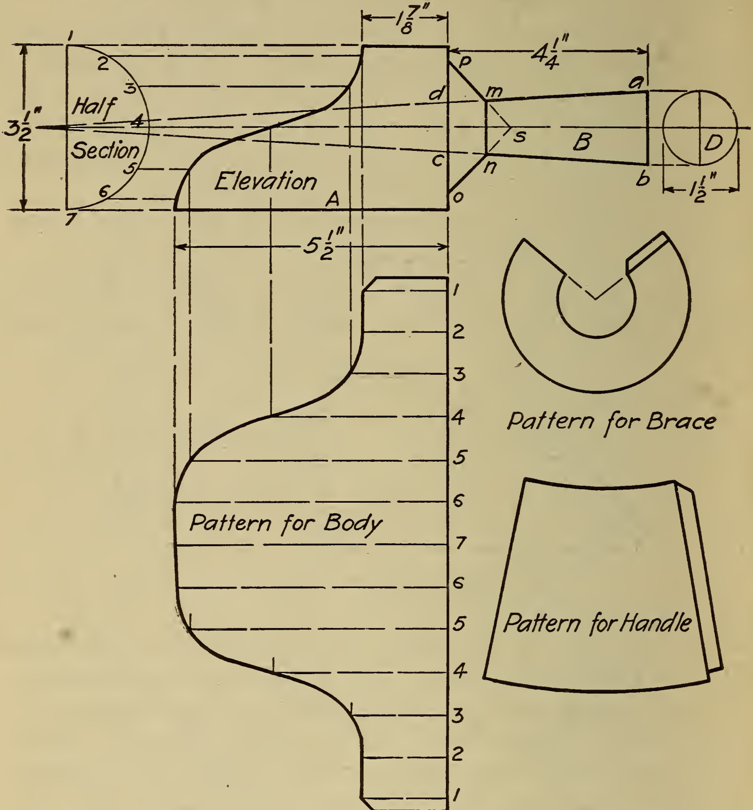


Figure 213.—Patterns for Body, Brace, and Handle of Hand Scoop.

ciples are employed other than those used in previous problems already given in this course.

To obtain the patterns, first draw the side elevation and half section to the dimensions shown in Figure 213. Divide the half section into a number of equal spaces, as shown from *1* to *7*, and from these points draw parallel lines intersecting the curved edge of the scoop as indicated. This curved edge can be drawn to any angle or shape at the pleasure of the workman.

To obtain the pattern for the body of the scoop, draw the stretch-out line *1-7-1*, upon which step off twice the number of spaces contained in the half section. From these points on the stretch-out line draw horizontal lines, which are intersected by vertical lines drawn from similar numbered points on the curved edge of the scoop, shown in the elevation. A line traced through these points will give the pattern for the body, to which laps are added for a 1/8-inch grooved seam. The scoop handle *B* is the frustum of a cone, shown by *abcd*, which is soldered to the center of the flat back of the scoop.

The conical brace is shown by *mnop*. The patterns for the brace and handle are shown in the drawing, and the method of development has been fully described in previous problems. The pattern for the back is simply a flat circular piece of metal, equal in diameter to the body of the scoop, to which allowances are added for seaming. The pattern for the end of the handle is a circular piece of metal, equal in diameter to the large end of the handle, shown at *D*. This disc is cut from the flat metal by means of a hollow punch of the required size. It is then placed in the opening and soldered in position.

CHAPTER XIII

PIPE INTERSECTIONS AND TEE JOINTS

Pipes of the Same Diameter.—Figure 214 shows the method of developing the patterns for a T, or tee joint, or the intersection of two cylinders of the same diameter at right angles. Draw the half plan and elevation, making both pipes 3 inches in diameter. Make the height of the vertical pipe *A* 6 inches, and the short side of the horizontal pipe 1½ inches. Draw the half section of the horizontal pipe *B* and divide it into a number of equal parts, as shown in *1* to *7* in *D*. Then divide the half plan into the same number of spaces, placing the numbers in their proper positions, as shown.

In the half section *D* of the horizontal pipe the points *1* and *7* are on the top and bottom, while the point *4* is on the long side of the pipe, and when looking down upon the end of the vertical pipe, point *4* will intersect the vertical pipe on the side, as shown by point *4* in the half plan. Now draw horizontal lines from the points in section *D*, which are intersected by vertical lines drawn from similar numbered points in the half plan *C*. Lines traced through these points of intersection will give the miter line. The two pipes being of the same diameter, the miter is represented on the drawing by straight lines at an angle of 45°, shown by *abc*.

To obtain the pattern *E* for the horizontal pipe *B*, draw the stretch-out line *mn*, upon which step off twice the number of spaces contained in the half section *D*. From the various points on the stretch-out line of the pattern, draw horizontal measuring lines which intersect by vertical lines drawn from similar numbered points on the miter line *abc*. Trace a line through these intersections, shown by *defg*, and the desired pattern is secured.

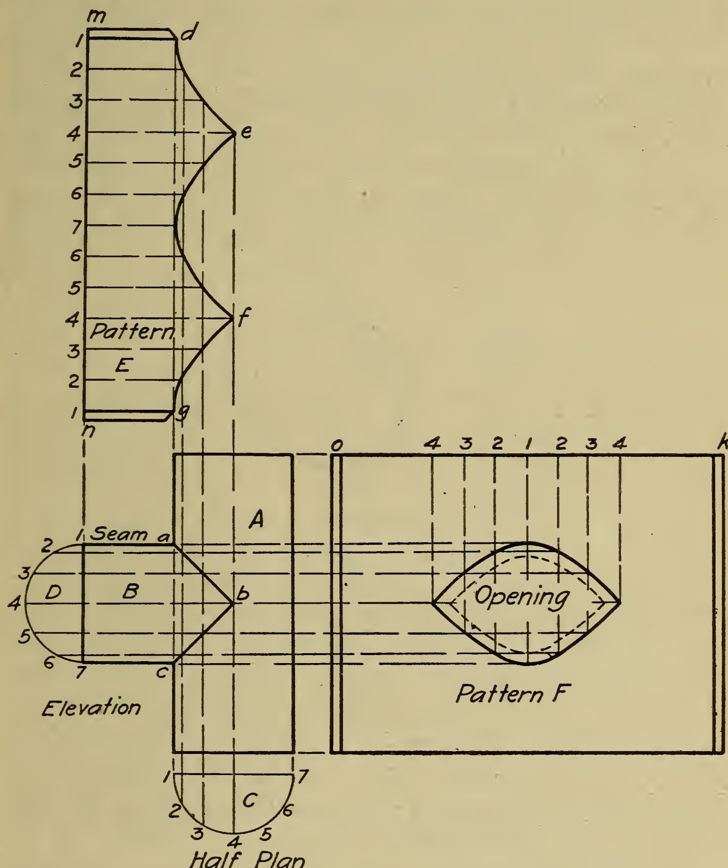


Figure 214.—Development of Patterns for a T or Tee Joint.

The pattern *F* for the vertical pipe *A* is simply a rectangular piece of metal, the width being equal to the height of the pipe and the length equal to its circumference. The pattern for the opening to be cut in pattern *F*, to receive the pipe *B*, is laid out in the following manner:

Upon the upper edge of the pattern, shown by the line *ok*, locate point *1*, which will be the center of the opening. On each side of point *1* step off the spaces shown from *1* to *4* in the half plan *C*, which will give the length of the opening. From these points on line *ok* draw vertical lines, which intersect by horizontal lines drawn from similar numbered points on the miter line *abc* in the elevation. A line traced through these

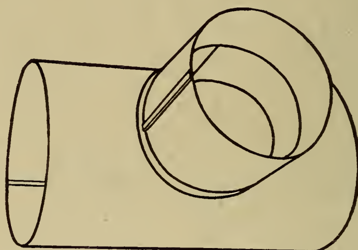


Figure 215.—T-Joint in Pipes of Different Diameters, Angle of 90°.

points of intersection will give the pattern for the opening. An allowance added for seaming is shown by the dotted line drawn parallel to the outline of the opening.

After the pattern for the vertical pipe has been transferred to metal, the opening is cut on the dotted line by means of the circular snips. Using the points of the straight snips, the lap is then notched, making the cuts about ½ inch apart around the entire opening.

The pipe is now formed up and seamed in the usual manner. Then using the flat pliers, bend the notched lap outward to fit inside the horizontal pipe, which is slipped over the flange thus made and can be soldered or riveted in position.

When constructed from black iron, the short stub is slipped over the flange and one or two rivets placed on each side at point *b* in the elevation. The flange is then closed tightly against the pipe on the inside by means of the hammer, making a tight, rigid joint between the two pipes.

Pipes of Different Diameters.—Figure 215 shows the finished view of a T-joint, the pipes being of different

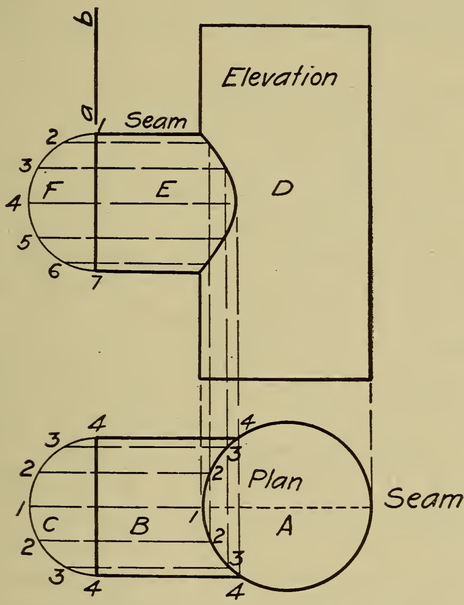


Figure 216.—Plan and Elevation for Right Angled Pipe Joint.

diameters, the horizontal pipe being placed in the center of the vertical pipe at an angle of 90°. Applying the method given in Figure 214, develop the patterns for the inclined pipe, also the opening in the vertical pipe.

First draw the plan and elevation shown in Figure 216; make the diameter of the large pipe *A* 4 inches and of the small pipe *B* 3 inches. The height of the vertical pipe *D* is 7 inches and the length of the shortest side of the horizontal pipe is 3 inches. After the outline of the small pipe *B* has been drawn in the plan-view, draw the half section *C* and divide it into a number of equal spaces. Then draw horizontal lines from these points, intersecting the large circle *A* as shown in the drawing. Next draw the half section *F* on the end of the small pipe in the elevation, which must be a duplicate of the half circle *C* in the plan, and is divided into the same number of spaces, the points being numbered in their proper position.

From these points in section *F* draw horizontal lines which are intersected by vertical lines drawn from similar numbered points on the large circle *A* in the plan. A curved line traced through these points of intersection will give the miter line between the two pipes.

To develop the pattern for the small pipe, draw the stretch-out line *ab* and proceed in the same manner as explained in the previous problem.

The pattern for the opening in the large pipe is obtained in the same manner as the opening in the vertical pipe shown in Figure 214. The stretch-out of the opening is shown by the figures *4-1-4* in the plan. The spaces being unequal in width, they must be transferred separately to the stretch-out line of the pattern.

Joining the Pipes.—The two pipes can be joined together by the method described in the previous problem, but if it is desired to make a more substantial connection, the method commonly used by the sheet metal worker when joining two pipes of unequal diameters is shown in Figure 215, and the joint is made in the following manner:

After the small pipe has been formed up and seamed, turn a flange about ¼ inch wide on the curved end, by means of the rounded end of the riveting hammer and square stake. A collar is now inserted in the end and riveted in several places about ½ inch above the flange.

The collar is cut slightly smaller in length than the circumference of the stub, and should be wide enough to allow for riveting, and extend about 3/8 inch beyond the flanged end after it has been trimmed parallel to the outline of the end.

The projecting edge of the collar is notched and inserted into the opening of the large pipe; the notched edge of the collar is now bent over and fitted closely against the inside of the pipe by means of the hammer. By this

Figure 217.—T-Joint of 45° Angle.

method the large pipe is held firmly between the two flanges of the smaller pipe.

The principles used in the development of the patterns in this problem (Figure 216) are applicable, no matter what diameters the pipes are, or whether the small pipe is placed in the center or at one side of the vertical pipe. The pipes can also be placed at any angle, and differ in profile.

T-Joint at an Angle of 45°.—Figure 217 shows the finished view of a T-joint, both pipes having the same diameters, joined at an angle of 45°. The full development is shown in Figure 218. The principles in this problem do not differ from those given in Figure 214. The prob-

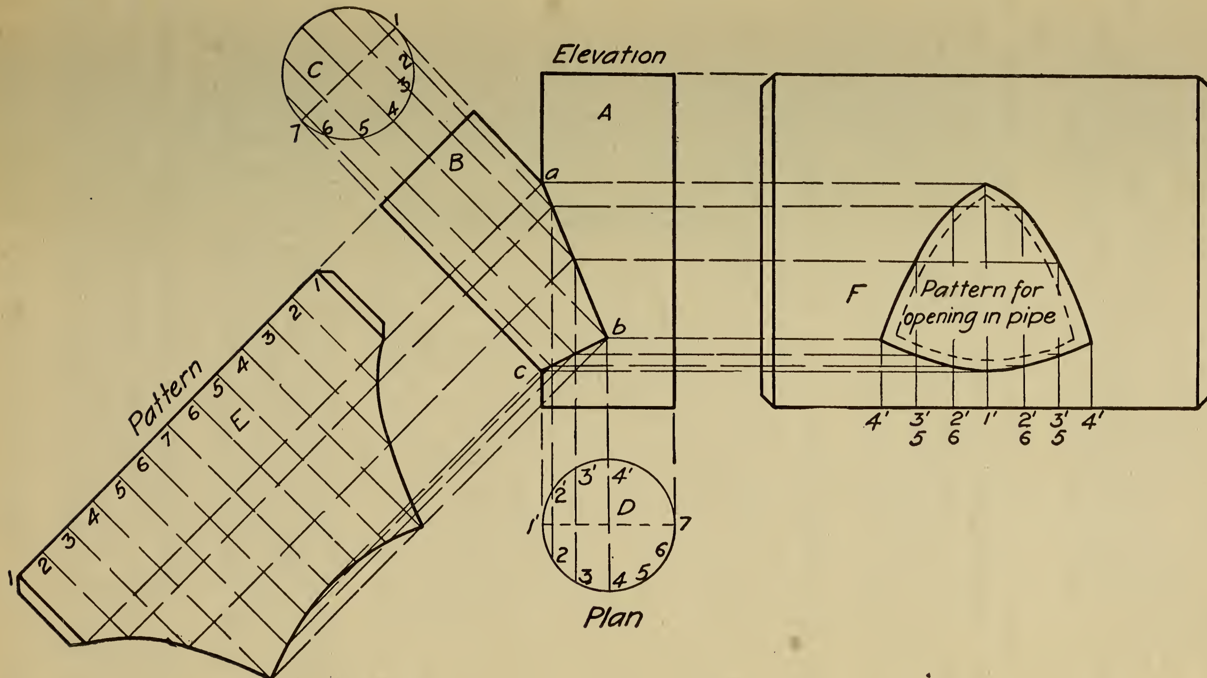


Figure 218.—Development of Patterns for 45° T-Joint.

lems are the same, except in the position of the horizontal pipe *B*.

Draw the elevation and plan, making both pipes 3 inches in diameter, pipe *B* having an inclination of 45°. Space the plan *D*, and section *C* in the usual manner. Draw lines from these points intersecting in the elevation. A line traced through the intersections thus obtained will

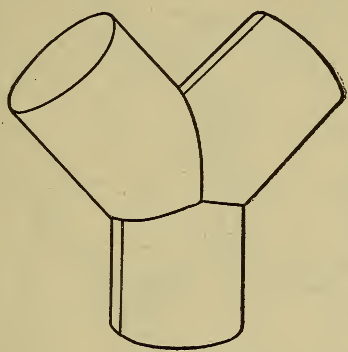


Figure 219.—Y-Joint in Pipes of Equal Diameters.

give the miter line between the two pipes, shown by *abc* in the elevation. Pattern *E* for the inclined pipe and pattern *F* for the vertical pipe are shown fully developed, and will require no further explanation, as the method has been described in the previous problems in this chapter.

Y-Joint.—Figure 219 is the illustration of a Y-joint, the diameter of each branch being the same. The sheet metal worker needs no introduction to this familiar form, as it is used for many different purposes in the trade. This problem is presented to give practice in developing patterns for intersected cylinders having the same diameter.

The elevation, partial development, and dimensions are shown in Figure 220. First draw the elevation according to the dimensions shown on the drawing, making the arms *A* and *B* at an angle of 90°. The miter line *ab* is obtained by bisecting the angle *cad,* as shown.

The pipes being of the same diameter, a half section of the arm *A*, shown at *D,* is all that is required. Divide

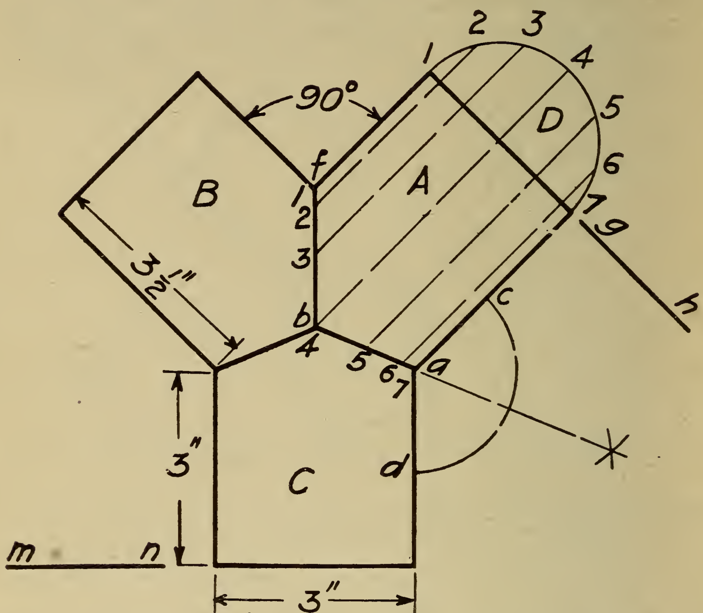


Figure 220.—Elevation and Partial Development of Pattern for Y-Joint.

the half section *D* into a number of equal parts, being careful to place a point on the quarter-circle, as shown by point *4*. Draw parallel lines from these points intersecting the miter lines *fb* and *ba* as shown. At right angles to the arms *A* and *C,* draw the stretch-out lines *gh* and *mn,* and complete the patterns as directed in the preceding problems.

Chimney Cap.—Figure 221 shows the elevation of a ventilator head, or chimney cap, the pipes being of the same diameter. This is presented as a test problem, as it involves the development of two problems described in this chapter. The arms *A* and *B* form a T-joint at a right angle, similar to Figure 214, while the arms *B* and *C* are joined at other than a right angle, similar to the problem shown in Figure 218.

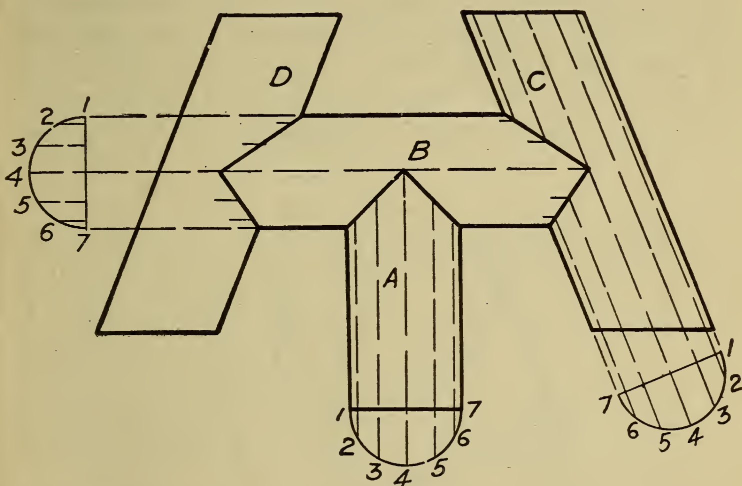


Figure 221.—Elevation of a Chimney Cap, or Ventilator Head.

Draw the elevation and half sections as shown in the drawing. Then develop the patterns for the arms *ABC*. The method of development has been fully explained in preceding cases, so that no further demonstration need be given.

CHAPTER XIV

ELBOWS

An illustration of a four-piece 90° elbow, which is used universally in heating and ventilating work, is shown in Figure 222. Elbows of this form, having a small radius in the inner curve or throat, are commonly made use of in stovepipe work, furnace work, and in duct work where

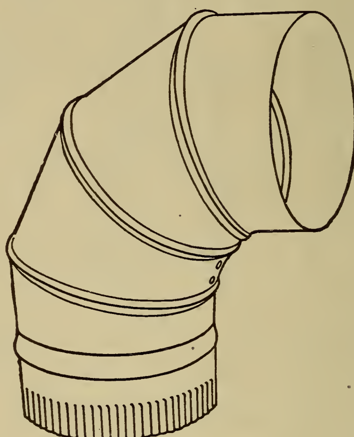


Figure 222.—Four-piece 90° Elbow.

a blast is not used. Elbows having a large radius in the throat are generally used for making turns in grain conveyers, exhaust and blow-piping work. In projects of this kind an elbow having a short radius should never be used if it can be avoided.

The drawings shown in Figure 223 contain all the necessary details for development of the patterns for elbows at any angle, having any number of pieces. The work-

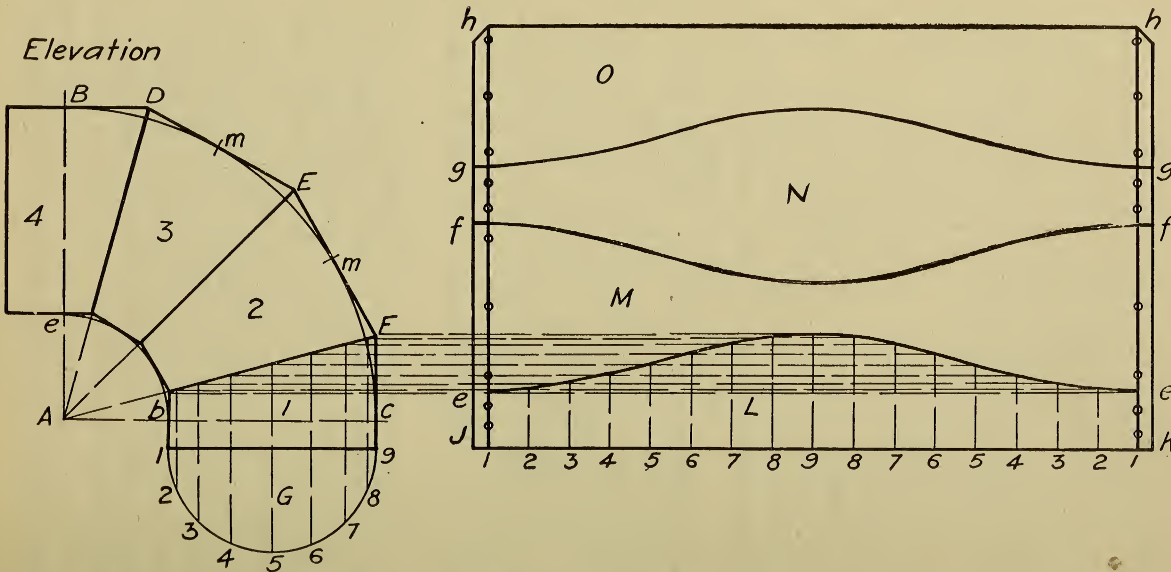


Figure 223.—Patterns for Four-piece 90° Elbow of 5 Inches Diameter.

man should follow the instructions carefully, and memorize the construction of the problem.

Four-Piece 90° *Elbow.*—Figure 223 shows the method of obtaining the patterns for a four-piece 90° elbow having a diameter of 5 inches; the length of the radius for the inner curve of the elbow being 3 inches. First draw the right angle shown by the dotted line *BAC*. Next, on the line *AC* lay off a distance of 3 inches from *A* to *B*. With *A* as center and *Ab* as radius, describe the quarter circle *be,* which gives the required curve for the throat. Make *bC* equal 5 inches, the diameter of the elbow, and with *AC* as the radius and *A* as center describe the outer arc *BC*.

The joint lines of the elbow, shown by *DEF*, are found by dividing the outer arc *BC* into equal parts one less in number than the pieces required in the elbow; in this case into three spaces, shown by *Bm, mm,* and *mC*. Each of these spaces is bisected, and lines drawn from these points to the apex *A* will represent the joint or miter lines of the elbow. The outline of the different pieces of the elbow is now completed by drawing lines tangent to the arcs *eb* and *BC,* as shown in the drawing.

The above method can be used in obtaining the miter line for an elbow of any angle or of any desired number of pieces. After the elevation has been completed, draw the half section G, and divide it into a number of equal spaces, as shown by the figures *1* to *9*. From these points draw vertical lines intersecting the miter line *AF* in the elevation.

The pattern for the first section of the elbow is developed by drawing the horizontal line *JK,* upon which place the stretch-out of twice the number of spaces contained in the half section *G*. From these points on the stretch-out line draw vertical lines, which intersect lines drawn from similar numbered points on the miter line *AF* in the elevation. Through the points thus obtained, the irregular curve of the pattern may be traced, as shown by *eLe*, which completes the pattern for piece No. 1 of the elbow. This irregular curve is the only one needed, and is used in laying out the patterns for the entire elbow.

The patterns for the sections numbered 2, 3 and 4 are usually laid out directly on the metal, in the following manner: A piece of metal equal in length to the stretch-out of the pattern is provided, and pattern *L* is transferred to the metal by the usual method of pricking, as described in Chapter I. Next, take the length of the wide side of section 2, as shown by *EF* in the elevation,

Figure 224.—Five-piece 60° Elbow.

and mark this dimension on each end of the metal, as shown by *ef*. Then take the throat width or short side of piece No. 3, and place it as shown by *fg*. The length of the long side or top of piece No. 4 is placed on the metal, as shown by *gh*.

Pattern *L* is now cut from the metal, after which the metal pattern is turned over and the curved edge placed on the points *ff*. The irregular curve of the pattern is scribed on the metal by means of the scratch awl, which completes the pattern for piece No. 2, shown at *M*.

The patterns for pieces Nos. 3 and 4 are completed by placing the curved edge of pattern *L* on the points *gg;*

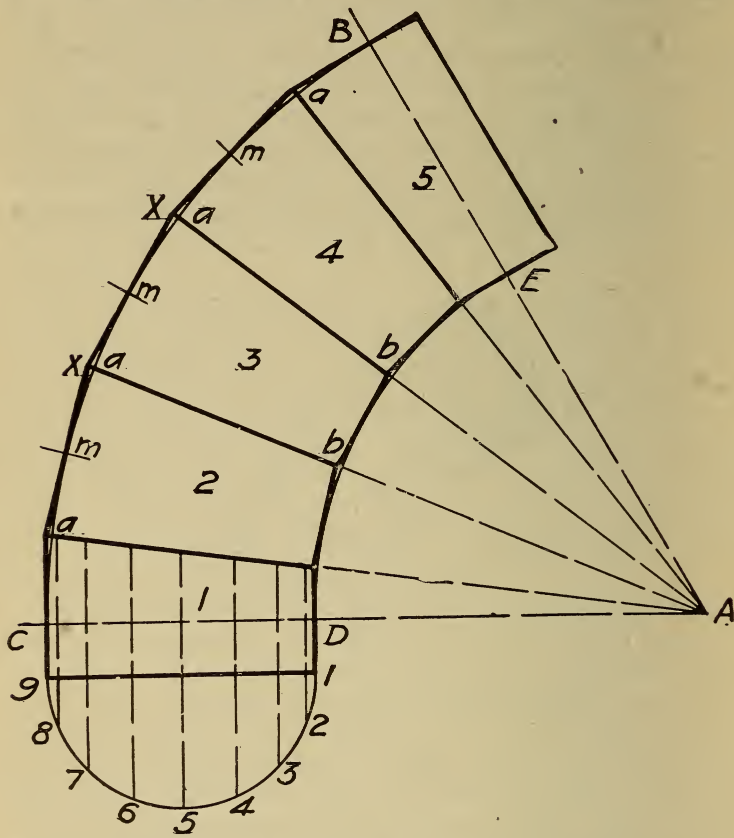


Figure 225.—Elevation of Five-piece 60° Elbow.

then scribe the irregular curve on the metal, and connect the points *hh* with a straight line, completing the patterns *N* and *O*.

This method of grouping the patterns places the seams opposite each other, and allows the patterns to be cut from a rectangular piece of metal without waste of material.

The patterns are now cut from the sheet, corners notched, rivet holes punched, formed in the forming machine (Figures 35, 36) and riveted on the mandrel stake; after which the edges for seaming the pieces together are turned on the elbow edging machine (Figure 71).

Five-Piece 60° *Elbow.*—Figure 224 shows a finished five-piece elbow with an angle of 60°, such as would be used in ventilating and blow-pipe work, where it is desired to reduce the friction to the lowest possible amount by constructing an elbow having a long length of throat.

In Figure 225 is shown the elevation of a 5-piece 60° elbow, the inner curve or throat being described with an 8-inch radius. This problem is introduced in order to give practice in developing the patterns for elbows at other than a right angle.

First, draw the required angle *BAC*. Next, on the line *AC*, measure off a distance of 8 inches from *A* to *D*, which is the required radius for the throat curve of the elbow. With *A* as center, describe the arc *DE*. Make *DC* equal 5 inches, and with *AC* as radius describe the outer arc *CB*, which is divided into four equal spaces, one less in number than the pieces in the elbow. These spaces are shown by *Bm, mm,* and *mc* in the drawing. Each of these spaces is bisected as shown at *a, a, a, a,* and lines drawn from these points to the apex *A* will give the required miter line for each section of the elbow.

Complete the elevation, and develop the pattern for piece No. 1. The development is not shown on the drawing, as the work would be simply a repetition of the operations described in laying out the patterns for the four-piece 90° elbow shown in Figure 223.

The end pieces, Nos. 1 and 5, may be made any length at the pleasure of the workman, but the length of the heel and throat of the middle sections 2, 3, and 4, should be taken from the elevation. These dimensions are shown by *xx* and *bb* in section No. 3, and cannot be changed when once the arc *DE*, representing the inner curve of the elbow, has been described on the drawing.

DUCT ELBOWS

Square or rectangular piping, or duct work, has become a very important part of the sheet metal trade, and is largely used in the installation of heating and ventilating

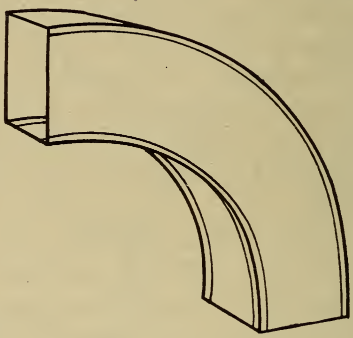


Figure 226.—Rectangular Duct 90° Elbow.

systems. A curved elbow, of the style generally used in this class of work, is shown in Figure 226. These elbows are made in four pieces, consisting of the two sides, the heel, and the throat. The heel is the outer and the throat the inner curve.

When laying out the patterns for duct elbows of this kind, the radius for describing the inner curve or throat should be equal to the width of the duct. The pieces are usually joined together by riveting or double seaming the corners by means of the double-seaming stakes or "hand dollies."

This problem is presented to give practice in the con-

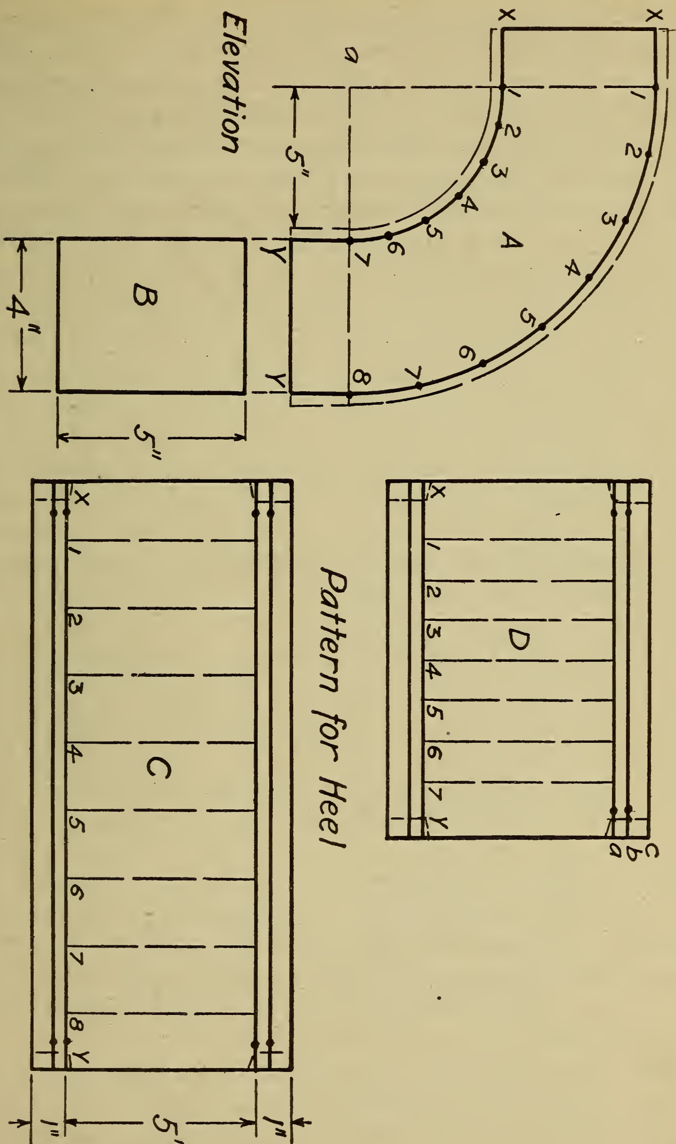


Figure 227.—Layout of Patterns for a 90° Rectangular Elbow.

struction of a duct elbow, and to describe an easy and quick method for seaming the corners of elbows and square or rectangular pipes by the method commonly known in the trade as "the Pittsburgh seam."

Rectangular Duct 90° Elbow.—In Figure 227 is shown the method of laying out the patterns for a 90° rectangular elbow, in which the turn is made on the short side of the pipe. Draw the elevation *A* and profile *B* according to the dimensions given on the drawing. First draw the right angle shown by *1-a-8.* With *a* as center and *a7* as radius, describe the quarter circle *1-7,* which represents the inner curve or throat of the elbow. Next make *7-8* equal the narrow side of the elbow, and with *a* as center and *a8* as radius describe the arc *1-8.* This is the outer curve, or the heel; the straight parts shown by *x1* and *y8* are added to the quadrant to make an easy connection with a straight duct. An allowance of ¼ inch, as shown by the dotted lines, is now added to the heel and throat for seaming; then the elevation *A* will also be a pattern for the two sides of the elbow.

The patterns for the heel and throat shown at *C* and *D,* are simply rectangular pieces of metal equal in length to the stretch-outs shown by *xY* in the elevation. The width is equal to the wide side of the elbow, to which 1 inch has been added on each side for seaming, as shown by *abc* in pattern D, making *ab* equal ⅜ inch and *bc* ⅝ inch. Prick marks are made at these points for bending purposes, as shown by dots on each end of the patterns.

"The Pittsburgh Seam."—In Figure 228 is shown the method of bending the edges of the patterns for seaming. The operations are performed on the cornice brake and the various bends are shown by the letters *abc,* in the diagram at *A.*

The first operation is shown at *B.* Insert the sheet in the brake and bring down the upper clamp on the prick mark shown at *a,* then raise the lower bending leaf, bringing the metal up to a right angle, as shown at *B*. The sheet is now turned over, the edge placed in the brake, and the upper clamp closed down on the prick mark *b;* raise the bending leaf as far as it will go, which will bend the metal in the position shown at *C*. Now place the sheet in the brake once more on the point *a,* and bend it up as far as it will go, as shown at *D*. Place a strip of

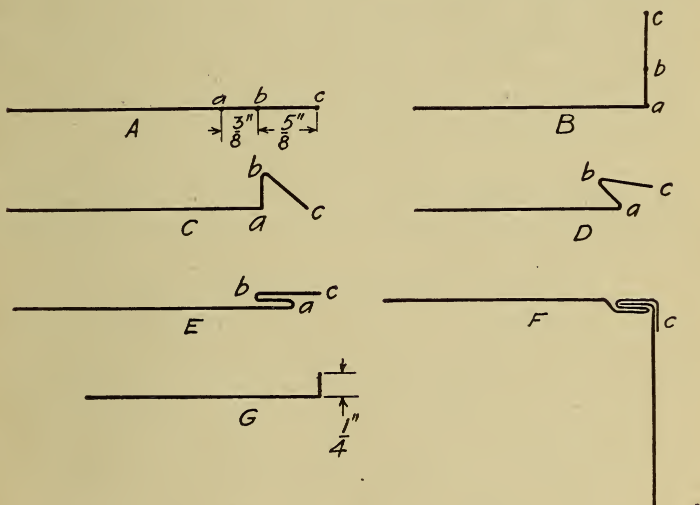


Figure 228.—Progressive Operations of Bending Edges to Form "the Pittsburgh Seam" on the Cornice Brake.

metal between *a* and *c,* and bring down the upper clamp, pressing the bends together closely. The strip of metal is removed and the edge of the sheet will appear as shown at *E*. The ¼-inch edges are now turned at a right angle on the sides of the elbow, as indicated at *G*.

The patterns for the heel and throat are given the required curve in the forming rolls, and during the operation a strip of metal is again placed between bends *a* and *c,* so that the pressure of the rolls will not close the opening between the bends. The parts are assembled by inserting the ¼-inch edge of the side pattern into the pocket edge of the throat and heel. The projecting edge *c* shown at *E*, is then hammered over, which completes the seam as shown at *F*. This seam, known as "the Pittsburgh seam," is used in the sheet metal trade to good advantage for various purposes. It is easily constructed and makes a tight, rigid joint.

CHAPTER XV

RETURN AND FACE MITERS

This chapter treats of the method of obtaining patterns for miters between sheet metal moldings. The patterns are developed by the parallel method described in previous chapters. Any profile or shape may be used, and in order to illustrate the application of the principles underlying the development as applied to moldings, a number of practical problems are presented.

Square Return Miter.—In Figure 229 is shown the illustration of a square return miter, such as would be

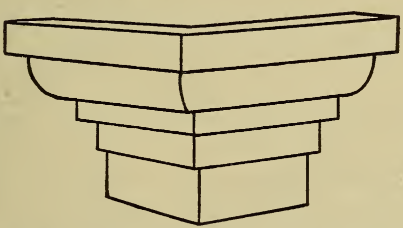


Figure 229.—Square Return Miter.

employed when a molding was made to return around the corner of a building. Figure 230 shows two methods of obtaining the pattern, known respectively as the long and the short method. The short method is the rule generally employed by the sheet metal worker, but can only be used when the miter is one of 90°; that is, a square miter. The long method can be used for obtaining the patterns for a miter between moldings, no matter what angle is required.

To develop the pattern by the long method, proceed as follows: First draw a full-size detail of the profile or section, the dimensions being taken from the section

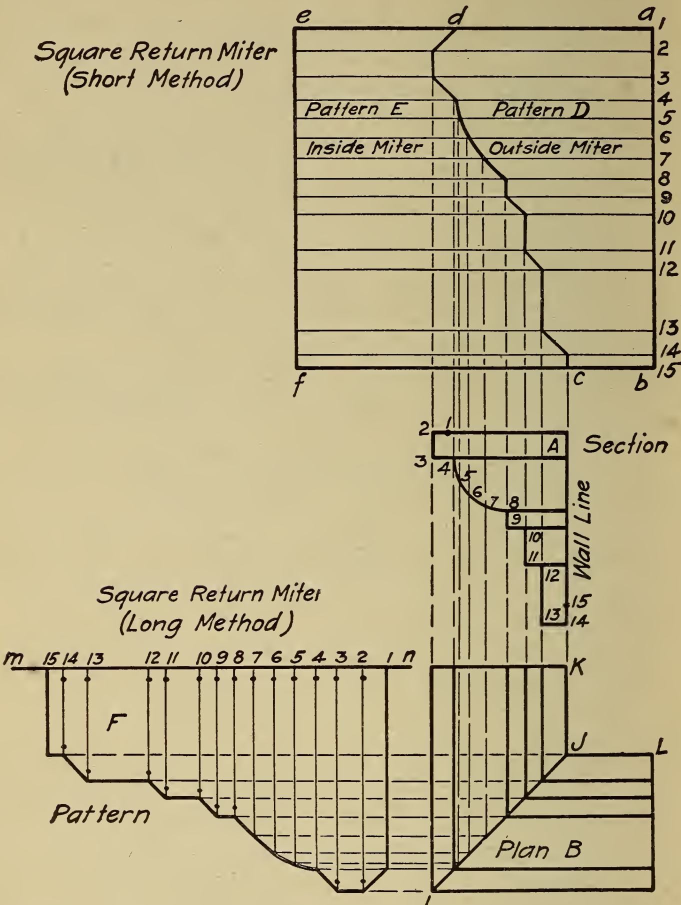


Figure 230.—Long and Short Methods of Obtaining Pattern for Square Return Miter.

shown at *A* in Figure 230, which is drawn to a 2-inch scale; but any other profile may be used if desired. Divide the curve into a number of equal spaces, placing a sufficient number of points on the curve, so that the outline of the pattern may be traced with accuracy. Number these points, also the corners of the molding, as shown by the figures *1* to *15*. Next, draw the plan *B* as shown, and bisect the angle *KJL* by the line *J1*, which will give the required miter line.

From the various points in section *A*, draw vertical lines intersecting the miter line in plan *B*. At right angles to *JK* draw the stretch-out line *mn;* upon this line place the stretch-out of the section, as shown by the

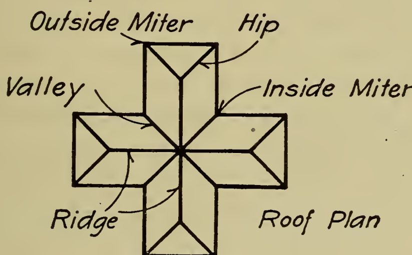


Figure 231.—Plan of Hipped Roof, Showing Outside and Inside Miters.

figures *1* to *15*. From these points on the stretch-out line draw vertical lines, which are intersected by horizontal lines drawn from similar numbered points of the miter line *J1* in the plan *B*. The outline of the pattern is then traced through the points thus obtained, and the lines upon which bends are to be made are marked by small circles or dots, as shown on the completed pattern at *F*.

The development of the pattern by the short method, in which no plan is required, is shown by pattern *D*. After the profile has been drawn in its proper position, as shown at *A*, the stretch-out line may conveniently be drawn either above or below the drawing of the profile. In this case it was drawn above, as shown by the vertical line *ab*. Upon this line place the stretch-out of the profile, and number the points in the usual manner, shown by the figures *1* to *15*. From these points at right angles to the stretch-out line, draw measuring lines, which intersect by vertical lines drawn from similar numbered points on the profile *A*. A line traced through the points thus located will complete the pattern, which is similar to pattern *F*, that was obtained from the plan and developed by the long method.

Outside and Inside Miters.—For the purpose of illustrating the difference between an outside miter and an inside miter, a sketch of a roof plan, representing a hipped roof, is shown in Figure 231. When constructing moldings and gutters, the workman is often required to develop patterns for miters returning around the outer and inner angles of a roof. Miters for the outer and inner angles are called outside and inside miters, and are placed as shown in the sketch. Pattern *D*, shown by *abcd* in Figure 230, is the pattern for an outside miter, while the opposite cut, shown by *defc*, is the pattern for an inside miter. It will be seen that both patterns are produced by a single miter cut, and it is important to know that this is also true when developing patterns for miters at any angle.

Octagon Return Miter.—Figure 232 shows the method of obtaining the pattern for an octagon return miter, and is also applicable for miters at any angle. The octagon miter is often employed in the construction of roof finials and cornices, and also frequently occurs in moldings and gutters passing around parts of a building octagonal in form.

The pattern for an octagonal return miter is developed from a plan view of the molding by the long method shown in Figure 232, which is drawn to a 2-inch scale. First draw a full size section of the molding shown at *A*, taking the dimensions from the scaled drawing. Next extend the wall line of the profile and draw the octagonal angle of 135°, shown by *mno*, which will represent the wall line in the plan *C*. Bisect the angle *mno* and draw the miter line *RN*. The curve in the profile is divided into a number of equal spaces and the points numbered as shown by the figures *1* to *15* in section *A*. From all

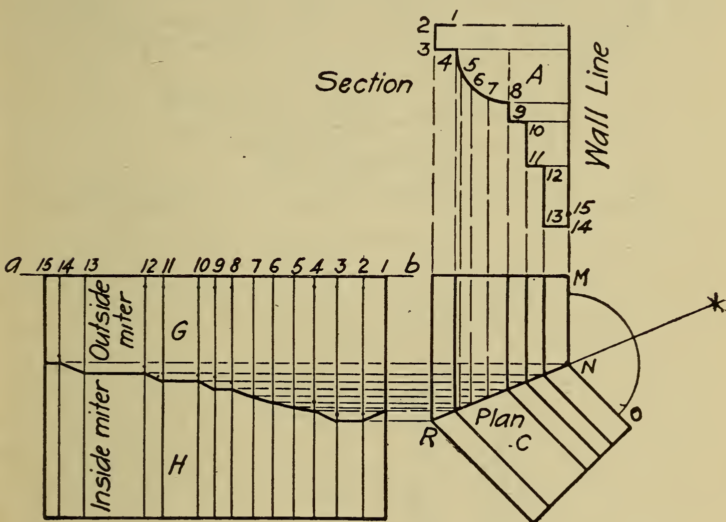


Figure 232.—Pattern for Octagon Return Miter.

points on the profile draw vertical lines intersecting the miter line *RN* in the plan.

The stretch-out of the molding is now placed upon the line *ab*, which is drawn at right angles to the wall line *MN* in the plan. Measuring lines are drawn from these points, which are intersected by horizontal lines drawn from similar numbered points on the miter line. A line traced through these intersections will complete the pattern, as shown at *G*. Should an inside miter be required, the opposite cut of pattern *G* is used, as shown by pattern *H*.

Molded Gutter.—In Figure 233 is shown a finished view of a molded face gutter, or eave trough miter. This is simply a square return miter, and it is immaterial what

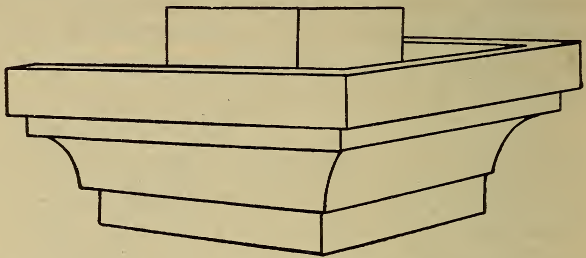


Figure 233.—Molded Face Gutter, or Eave Trough Miter.

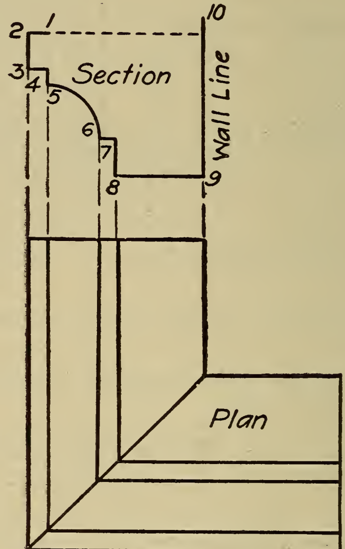


Figure 234.—Section and Plan of Molded Face Gutter.

profile or shape the gutter has,—the method of developing the pattern is the same.

In Figure 234 is shown a 2-inch scale drawing giving the section and plan view of a molded face gutter, for which a square outside miter pattern is to be developed by the short method shown in Figure 230. Place the stretch-out line either above or below the section, and omit the plan when making the full-size drawing.

Octagon Gutter Miter.—The next exercise for practice is the octagon gutter miter shown in Figure 235, which

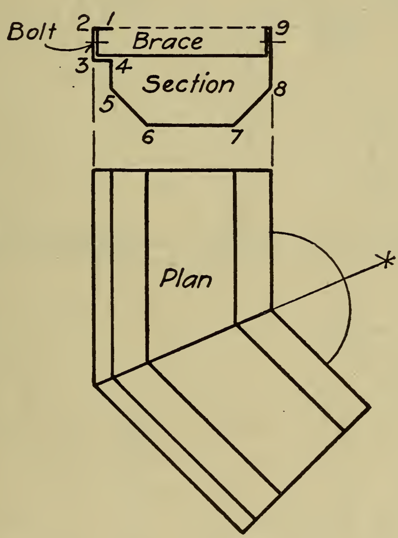


Figure 235.—Section and Plan of Octagon Gutter Miter.

is also drawn to a scale of 2 inches to the foot. In this drawing the section and plan are given of an octagon gutter forming a miter at an angle of 135° in the plan. Draw the section and plan as shown. Number the corners on the section and draw vertical lines intersecting the miter line in the plan. At right angles to the wall line draw the stretch-out line, and develop the pattern in the usual manner.

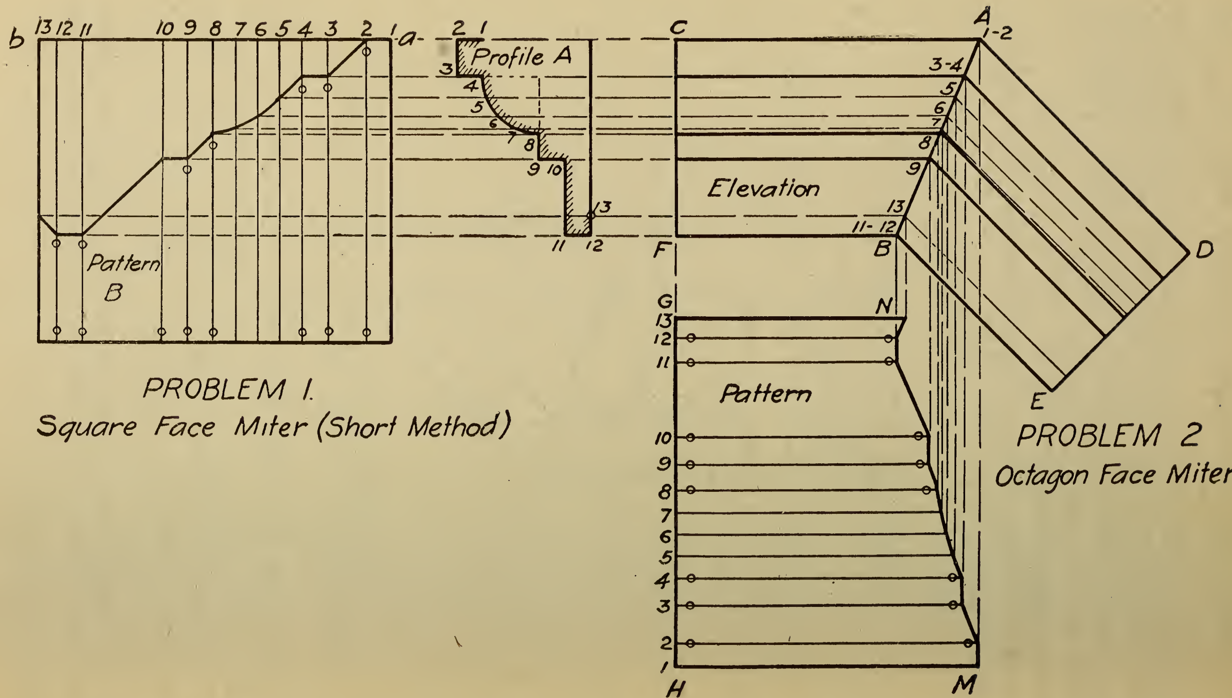


Figure 236.—Face Miter Problems: 1, Pattern for Square Face Miter; 2, Pattern for Octagon Face Miter.

Face Miters.—The method of developing the pattern for a face miter is shown in Figure 236. This process is employed when developing the patterns for miters in panel moldings, picture frames, and gable moldings, also to obtain the miter cut when the return molding of a dormer window butts against a mansard roof or other inclined surface. As may be seen from the drawing, the method of development is similar to that described for the return miter, Figure 230. The only difference is in the position of the stretch-out line *ab* in the pattern for the square face miter shown at *B*. In this case the stretch-out line is placed in a horizontal position at the left of the profile, while the stretch-out for the square return miter, Figure 230, is placed in a vertical position above the profile.

When developing the patterns for moldings, the sheet metal worker must always be careful to place the stretch-out line in its proper position, or, instead of having a face miter as indicated in Figure 236, he will have a return miter, as shown in Figure 230.

In Figure 236 two problems in face miters are presented and the drawings are made to a scale of 3 inches to the foot. Problem 1 shows the method of obtaining the pattern for a *square face miter* by the short method. Draw the profile *A*, and place the stretch-out line *ab* to the left of the profile. The operations in the development of the pattern are the same as described in Figure 230, and need not be described further.

Problem 2, Figure 236, shows the development of an *octagonal face miter*. The patterns for face miters at other than a right angle are developed by the long method, and the miter line is found in the elevation. In problem 2 the elevation is shown at the right of the profile.

First draw the required angle *CAD*, which is bisected in the usual manner to obtain the miter line *AB*.

Next, from the various points on the profile, draw horizontal lines intersecting the miter line as shown. At right angles to the line *BF* in the elevation, draw the stretch-out line *GH*. Upon this line place the stretch-out of the profile shown by the figures *1* to *13*. Measuring lines are now drawn from these points, which are intersected by lines drawn from similar numbered points on the miter line. Through the points thus obtained trace the pattern *GHMN*.

Molded Panel.—The development of the face miter described in previous problems leads naturally to the problem of the molded panel, shown in Figure 237.

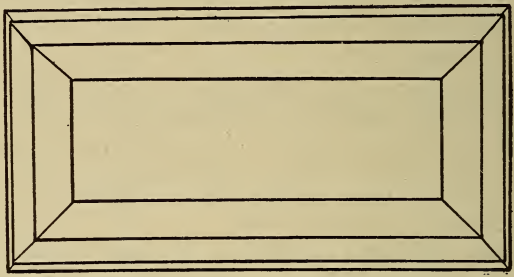


Figure 237.—Oblong Molded Panel.

The method of obtaining the pattern for an oblong panel is shown in Figure 238. First draw a section of the panel mold *A*, as indicated by the shaded portion of the drawing. Then divide the curve into a number of equal spaces and number each point on the section, as shown by the figures *1* to *8*. Through these points draw lines parallel to *EB*, intersecting the miter line *mB* as shown. From the points thus obtained on the miter line, draw lines parallel to *BC*, intersecting the miter line *nC*. At right angles to *BC* in the elevation, draw the stretch-out line *ab*, upon which place all of the divisions contained in the profile *A*. Through the points on the stretch-out line, draw horizontal measuring lines, which intersect by vertical lines drawn from similar numbered points on the miter lines *mB* and *nC* in the elevation. A line traced through the points of intersection will complete the pattern for the ends of the panel. This is the

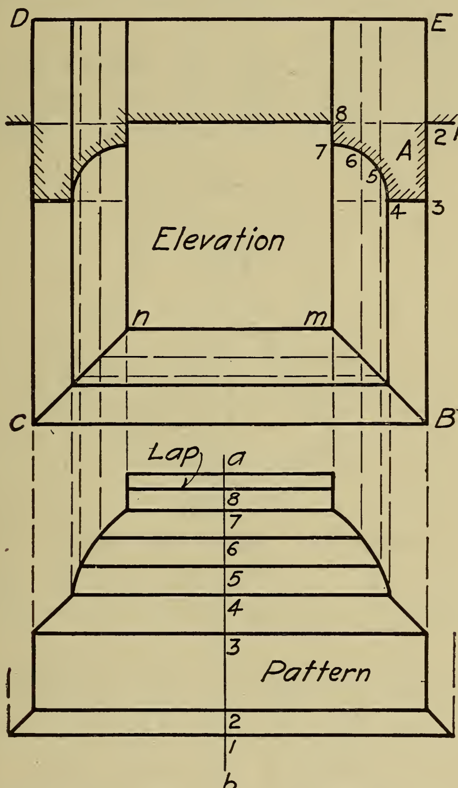


Figure 238.—Pattern for an Oblong Panel.

only pattern necessary for the construction of the problem, for the same miter cut is also used for the long side of the panel.

Roof Finial.—The sheet metal worker is often called upon to provide the apex of a hipped roof or tower with an ornamental finish made from galvanized iron or sheet copper. A plain fitting so used is shown in Figure 239 and is called a roof finial. The body, square in form, is made in four pieces, and is commonly used to provide a finish at the apex of a square tower, or as an ornament in cornice construction.

The method of laying out the pattern for a square finial is shown in Figure 240, which is drawn to a scale of 2 inches to the foot. The profile can be changed to

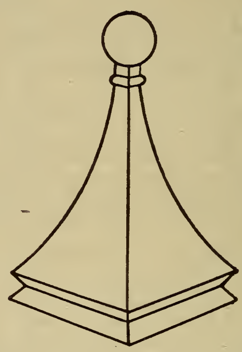


Figure 239.—Square Roof Finial.

any shape, but the development would be the same in every case.

First draw the center line *AB* and construct the elevation shown at *D*, the ball *C* being 3 inches in diameter. Divide the profile into a number of equal spaces and number the points, as shown by the figures *1* to *10*. The finial being square in form, the sides are joined together at an angle of 90°, and the miter on the corner is simply a square return miter, for which the pattern can be developed by the short method in the following manner:

Place the stretch-out of the profile *D* upon the center line *AB*, which is extended below the elevation. At right angles to *AB* draw the measuring lines, which are inter-

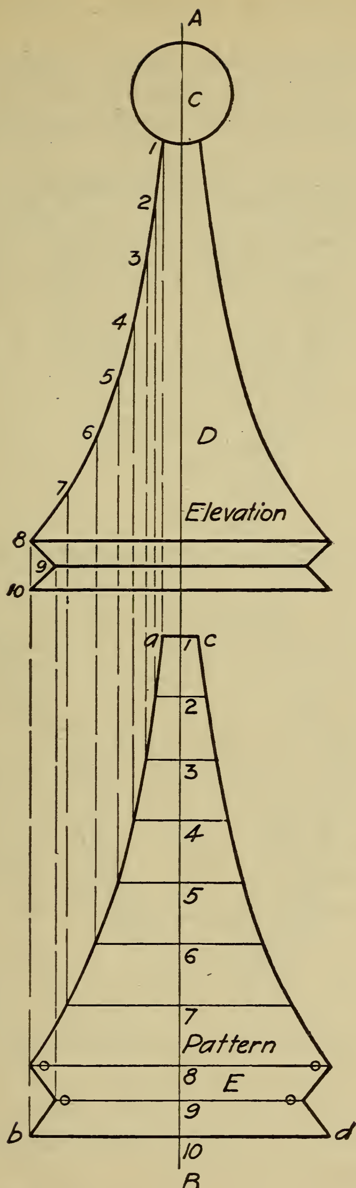


Figure 240.—Layout of Pattern for a Square Finial.

sected by lines drawn from similar numbered points in the elevation. Now, measuring from the center line, transfer these points to the opposite side of the pattern

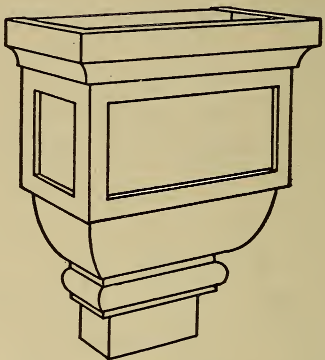


Figure 241.—Ornamental Conductor Head.

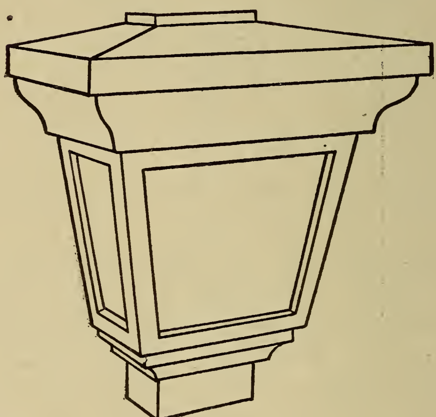


Figure 242.—Conductor Head with Inclosed Top.

by means of the dividers. Trace a line through the points thus obtained, completing the pattern for one side of the finial, shown by *abdc* at *E*.

Conductor Heads.—When a conductor pipe is used to drain a roof where the outlet extends through a parapet wall, the connection should be made by means of a conductor head. The object in using a conductor head is that if the down spout should become obstructed in any manner, the water will overflow from the conductor head, leaving the roof outlet clear, which will prevent the water from backing up and flooding the roof.

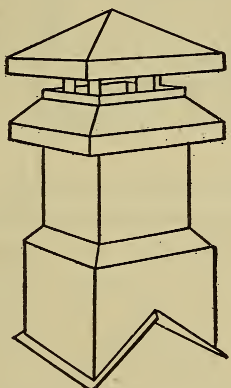


Figure 243.—Square Ventilator.

Figure 241 shows an ornamental conductor head having a flat back, the outer corners being mitered in the usual manner. Another form of head, having an inclosed top, is shown in Figure 242. There is no limit to the various designs that can be made at the pleasure of the workman.

The miters on the outer corners of the conductor heads shown in the illustrations are simply square return miters, and the patterns are developed by the short method described in the previous problem.

Square Ventilator.—The method of development used in obtaining the pattern for the roof finial, Figure 240, can also be applied in developing the patterns for the

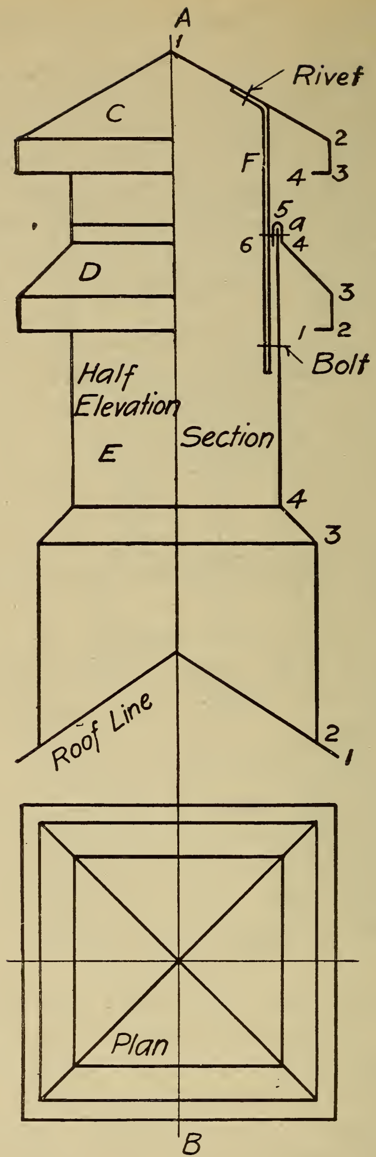


Figure 244.—Half Elevation, Section, and Plan of a Square Ventilator.

square ventilator shown in Figure 243. These ventilators are usually made from sheet copper or galvanized iron, and are largely used in skylight construction and ventilating work.

In Figure 244 is shown the half elevation, also the half sectional and plan view of a square ventilator, which is drawn to a scale of 3 inches to the foot. As in the preceding problem (Figure 240), the first step is to construct the proper elevation, but in actual shop practice the half sectional view is all that is required for the development of the different patterns. Let *C* represent the hood of the ventilator and *D* the flange, which is joined to the square base shown at *E*.

The half sectional view shows the profile of the different sections, also the method used in joining the flange and base, which is shown at *a*. The position of the band-iron brace used in connecting the hood and base of the ventilator is shown at *F*. After the full-size elevation has been drawn, omit the plan view, and develop the patterns for the hood, flange, and base of the ventilator by the short method shown in Figure 240.

VI

OUTLINE COURSE IN SHEET METAL WORK

EMERGENCY WAR TRAINING

The following course in sheet metal work, as recommended by the Federal Board for Vocational Education, Washington, D. C., is intended to give training in general sheet metal work, soldering, brazing, and general repair. Sheet metal pattern drafting is not included. Much of the work in the army is in the nature of repairs to equipment. Skill in the use of the soldering iron is a prime requisite.

UNIT S-1.—SOLDERING

Oral Instructions.—Explain the use of fluxes, cleaning of parts to be soldered; care of soldering iron, and the tinning of the same.

Cautions: Avoid breathing fumes from the acids. Keep acids and fumes away from steel tools.

Fluxes:

Muriatic acid.—Used raw.

Cut or boiled acid.—Muriatic acid with all the zinc that will dissolve. Dilute with 25 per cent water for ordinary work.

Nitric acid.—Used to clean quickly. As soon as part is clean, dip in cold water to stop action. Avoid the acid fumes.

Sal ammoniac.—Solid and solution. Used to clean the soldering iron.

Rosin, pulverized.—Used to solder lead and sometimes tin.

Tallow.—To solder lead.

Lesson 1.—Dress and tin a pair of soldering irons. A special shape is sometimes required and may be made by heating the copper to a good red heat and forging to shape with a hammer. Clean with a coarse file; dip in sal ammoniac solution while the iron is hot and apply solder, or rub on a cake of sal ammoniac with solder. Continue this until the surface is well coated with solder. A good, clean, well tinned iron is the first requisite to good soldering.

Lesson 2.—Practice soldering tin, using a plain lap joint. The solder must flow through the joint and the seam be left smooth without a surplus of solder.

Lesson 3.—Solder holes of various sizes. If the hole is too large it is often possible to peen the metal around the hole and partly close it before applying the solder. Be sure the metal is clean before trying to solder. If necessary scrape the surface well and then clean with raw acid, wash with water and then flux with cut acid. Always leave the repair smooth.

Lesson 4.—Join two pieces of copper pipe about ¼ inch diameter. Taper one end with a file and expand the other, using a conical point. Clean and tin the ends. Place them together with a twisting motion. In soldering use cut acid as flux; hold the copper on the joint until it is hot enough to melt the solder and sweat the joint thoroughly. A sleeve can be made very easily from the next larger size of tubing with a rat-tail file.

Lesson 5.—Join two pieces of sheet iron. Clean the metal thoroughly with a file and apply raw acid till a slight copper color is seen. Wash with water and solder as with tin, using cut acid.

Lesson 6.—Cast iron can be soldered quite readily by first cleaning the parts thoroughly with a file, apply raw acid and rub well with the swab or brush; then wash with clean water and tin with solder, using cut acid as a flux. In using the soldering copper apply the flat surface to the cast iron so as to heat the part as much as possible. This method is often used to solder light pieces, particularly brass, to face plates of machines instead of holding them in chucks. This is done to avoid springing the piece.

Solder brass to cast iron as above. It may be removed with the hot iron or a torch.

Lesson 7.—Solder cracks in cast iron; for example, a cracked water jacket of a gas engine. File out a V where the crack is, using the edge of a half-round file; clean with raw acid; wash with water and use cut acid as a flux. A special solder made from 70 per cent tin and 30 per cent lead will hold better than the ordinary half-and-half solder.

(*Note.*—Soldering automobile tanks and radiators is frequently required. Soldering tanks is not difficult for one who is skilled in the use of the soldering iron. Have the work clean before attempting to solder. Use raw acid for a flux on galvanized iron.)

Caution: It is very important that tanks or cans that have contained gasoline should be thoroughly cleaned. Wash out with hot water and allow to dry before attempting to do *any* soldering. Get tanks and cans from a junk dealer for practice.

Lesson 8.—Mend several tanks. Large holes may require a patch.

Lesson 9.—Test radiators and solder the leaks. For this purpose a tank large enough to take in a radiator must be provided. It should contain water enough to cover the radiator being tested. Plug the inlet and outlet pipes and close up the cap tightly. By forcing air in at the overflow pipe the leaks are indicated by bubbles.

Caution: If compressed air is used, the operator must be careful not to use pressure that will burst the thin radiator sections. Radiator repair calls for great skill and ingenuity as each job requires special treatment. Often the soldering iron must be given a special shape.

The following procedure may be followed on tubular radiators: Heat the tubes where they are split, with a blow torch. Apply cut acid several times with a squirt can. Rinse off. Heat again and apply cut acid. Pour a ladleful of melted solder over the tubes and catch in a pan.

UNIT S-2.—AVIATION WORK

A thorough mastery of the lessons on soldering is necessary. Put special emphasis on Lessons 8 and 9.

Lesson 1.—Wrap wooden pieces, such as found in the airplane, with copper wire and coat this wire with solder to form ferrules. Be sure that the ends of the wire are securely fastened.

Lesson 2.—Tip wooden parts with sheet metal. The metal must be cut out in proper shape, sometimes shaped by peening, to fit neatly, must be tacked on and the joints and tack heads thoroughly soldered.

Patterns for sheet metal tips may often be quickly made by folding paper around the part, taking up the slack in the paper by folds, cutting the paper and fitting by the "cut-and-try" process.

Lesson 3.—Make several wire splices as described in Government Specifications and Signal Corps Manuals for Airplane Crews. Be sure that the solder runs entirely through every part of the splice. Remove all trace of acid, so as to avoid corrosion. Avoid heating the wire to a point where the colors start, as this softens and weakens the wire. Do not use a blow torch.

Lesson 4.—Make up wire loops as directed on pages 18 and 19, "Notes on Rigging for Air Mechanics." (See second annual report of the National Advisory Committee for Aeronautics, 1916, published by Government Printing Office, Washington, D. C.) These loops are often required to be on each end of a wire and of an exact distance apart. The lashing must be soldered thoroughly. (*Note.*—Much practice is required in this work. It will require previous experience as a tinsmith or exceptional mechanical ability. Airplane sheet-metal workers are expected to be able to weld small parts by the oxy-acetylene welding process.)

UNIT S-3.—BRAZING

Brazing is uniting parts by hard solder or spelter. It is used where more strength is required. What is known as silver solder is sometimes used. This comes in thin sheet form. Spelter is available in granular and wire form.

Lesson 1.—Braze two strips of sheet iron or steel. Bevel the ends of the pieces so as to make a uniformly thick lap joint with a lap of about ½ or ⅝ inch. Clean with raw acid; wash with water. The pieces should be held together with a clamp, fixture, or rivet. Put a piece of silver solder between the lapped pieces. Have a pair of heavy pliers ready to pinch the joint together when heated. Heat the joint with a blow torch or a pair of brazing tongs. When the solder melts remove the tongs or torch and quickly close the joint with the pliers. Finish the joint to a uniform thickness with a file.

Lesson 2.—Braze a steel tube into a fitting. Have the joint fit closely so the molten spelter will be drawn into the joint by capillary attraction. Drill and rivet the pieces together after cleaning, as in Lesson 1. Heat with a blow torch. The work should be surrounded by fire brick to retain the heat. It is an advantage to have a bed of clean coke or charcoal to work on. The gas flame will ignite this coke and help secure an even heat around the joint. When a red heat is secured, apply borax as a flux. When the borax runs over the joint, apply the spelter in granular or wire form; wire is better, as it can be placed where wanted. If the joint is not fitted well, the spelter will not fill the cavity and the joint may look perfect but be poor. The heating can be done in an ordinary forge if care is used, but it is difficult to get an even heat throughout the joint and there is much more danger of overheating.

Calcined borax is better for flux. Prepare by heating the borax until the water is driven off. Then cool to a glass form and pulverize.

UNIT S-4.—SHEET METAL PATTERNS

This branch of sheet metal work requires some knowledge of drawing and development of surfaces. The following lessons involve considerable drawing:

Lesson 1.—Make a cylinder 4 inches in diameter with a butt joint. Roll to shape and tack with solder at several points.

Lesson 2.—Make a reducing pipe 4 to 3 inches, 6 inches long. Roll to shape and tack with solder as in *1.* The ends must be in a plane perpendicular to the axis.

Lesson 3.—Make a 90° two-piece elbow 4 inches in diameter. Develop the pattern, cut out of tin, shape, and solder.

Lesson 4.—Make a 90° four-piece elbow 4 inches in diameter, as in *3.*

Lesson 5.—Make a funnel of predetermined dimensions. This involves two truncated cones. Wire the edge.

Lesson 6.—Make a tin cup 4 inches in diameter and 4 inches deep. Wire the edge and solder the seams.

Lesson 7.—Make a 2-quart pail 6 inches in diameter and 5 inches deep. Roll a stiffening ring with beading or swaging rolls. Wire the edge, solder the seams, and attach the ears and bail complete.

Lesson 8.—Make a T fitting 4 by 4 by 4 inches. Allow for seams. Develop the pattern and complete the fitting.

Lesson 9.—Make a T fitting 4 by 4 by 3 inches; that is, a 4-inch pipe entered by a 3-inch pipe. Complete as in *8*.

Lesson 10.—Make a fitting as in *9*, 4 by 4 by 3 inches, with the 3-inch pipe entering at a 30° angle.

Lesson 11.—Make a conical collar that will fit around a 4-inch pipe at the small end, the included angle of the cone to be 60° and the base 8 inches.

Lesson 12.—Make a conical collar to fit over a 4-inch pipe that passes through a one-third-pitch roof.

(*Note.*—The making of various shapes, fittings, and sheet-metal parts can be extended indefinitely, but it is felt that schools had better confine themselves to the elementary work.)

EMERGENCY WAR TRAINING SHEET-METAL WORKING EQUIPMENT

Individual:

1 pair No. 8 snips, straight
1 pair No. 8 circular snips
1 riveting hammer, 1⅛-inch face
1 set solid punches
1 roof scraper
1 No. 6 rivet set
1 chisel, ¾ by 6 inches
1 chisel, ¾ by 10 inches
1 pair flat pliers, 7-inch
1 flat bastard file, 10-inch

For each 2 *men*:

1 table 3 by 7 feet, 32 inches high
1 fire pot (gas, gasoline, or charcoal)
1 pair soldering irons

For each 4 *men*:

1 gasoline blowtorch

For each 6 *men*:

1 bench vise

For Unit S-4 add the following (sheet-metal patterns).

For each 10 *men*:

1 turning machine, small
1 burring machine, large
1 hollow mandrel stake

For each 20 *to* 25 *men*:

1 36-inch square shear
1 37-inch by 2½-inch adjustable slip roll former
1 4-foot cornice brake
1 30-inch bar folder
1 beading machine
1 crimper and beader
1 wiring machine
1 creasing stake
1 blow-horn stake

VII

OXY-ACETYLENE WELDING AND CUTTING

The oxy-acetylene process of welding and cutting is an adaptation of a very ancient art, which was first practiced by the Egyptians. The early process consisted of heating metals of a low melting point by means of a torch, using a crude fuel gas and drawing the necessary oxygen from the air.

The modern process of blowpipe welding is somewhat similar, but it is applied successfully to the welding of high-melting-point metals as well. It involves the use of dissolved acetylene and compressed oxygen. These gases, burned in a suitable blowpipe, produce a flame temperature of approximately 6,300 degrees Fahrenheit, which is capable of bringing metals to a molten state very rapidly.

Blowpipe welding is generally known as "autogenous" welding, but this term may also be applied to electric welding. Autogenous welding, however, has gradually come to be understood as meaning the oxy-acetylene blowpipe welding process, which, in commercial fields, has practically supplanted the older methods of blowpipe welding, such as oxy-hydrogen and oxy-coal-gas processes.

The oxy-acetylene process of welding consists of heating the pieces of metal to be joined, at the point of weld, to a molten state by means of the oxy-acetylene flame, causing them to run together or "fuse" into one homogeneous piece. A rod or stick of special metal (commonly called filling or "filler" rod) is used to fill in between pieces of new metal being welded together.

This process must not be confused with soldering or brazing, as the welded joint is one in which the parts joined together are *fused* into a solid piece of the same structure and character throughout. A soldered or a brazed joint is one in which a new metal, having certain adhesive qualities, is used as a binder. This new metal adheres to the parts to be joined, but does not fuse with them, as its melting point is much lower than that of the parts being operated upon. In the fusing process, or the melting together of the pieces welded, lies the strength, neatness, and economy of the oxy-acetylene welding process, which is rapidly supplanting the older riveting and soldering methods.

Necessary Gases Universally Obtainable.—Oxygen is manufactured for commercial purposes by the liquid-air and electrolytic processes and is obtainable universally in portable steel cylinders, into which the oxygen is compressed to 1,800 pounds to the square inch. Being compressed under this high pressure, a single cylinder contains enough oxygen for considerable work, and yet it is perfectly safe, being manufactured under strict regulations, enforced by the Interstate Commerce Commission.

Dissolved acetylene for commercial purposes is prepared in equally convenient form by such concerns as The Prest-O-Lite Company, Inc. The gas is generated at central charging plants, washed, dried, and purified to remove elements which are injurious to the weld, and furnished to the user in specially constructed steel cylinders of various capacities.

Contrary to a popular supposition, these gas tanks are not empty steel shells, but are completely filled with a porous substance. This porous matter is saturated with a liquid solvent which has the peculiar property of absorbing or dissolving many times its own volume of acetylene at atmospheric pressure. Thus, gas tanks that would hold only 2 cubic feet of water when empty will hold 300 cubic feet of dissolved acetylene at 225 pounds pressure, 60 degrees Fahrenheit. It is in this way that large quantities of acetylene are stored in small containers at comparatively low pressure.

Prest-O-Lite dissolved acetylene in large welding cylinders is obtainable in any industrial center. In light welding work, where the demands for acetylene are not heavy, Prest-O-Lite gas tanks such as are commonly used on automobiles, and which are obtainable and exchangeable in almost any town or village, can be used.

The advantages of having both oxygen and acetylene in portable cylinders are quite evident, as a complete independent welding plant is provided, which may be moved from place to place where its services are required.

Qualifications of the Operator.—It does not take very long for an intelligent student or workman to become a fair welder on simple work. A few weeks' practice will develop all the skill necessary to enable a workman to handle ordinary welding work likely to be met with in the average shop. Very thin plate work, however, requires more skill. It takes more time to attain the steadiness of hand necessary to make neat welds, and to learn how best to overcome the buckling difficulties that invariably are met. It is impossible to make any hard and fast rule on the best methods of accomplishing this. Experience is the best teacher, but to this must be added perseverance on the part of the operator.

The welding together of plates over ¼ inch thick should not be attempted on serious work until the operator has demonstrated, by first welding some sample pieces and then breaking them at the weld, that he is capable of making a sound, unburned joint of uniform strength and quality throughout.

A positive desire on the part of the workman to do good work is absolutely essential, because it is difficult to judge the quality of a weld by merely looking at it after completion.

Anyone watching a blowpipe welding operation for the first time is apt to come to the conclusion that the process is so simple that any workman can operate a torch with little or no practice. In a sense this is true, but it is essential that the operator have a fair knowledge of the nature and properties of the metals being welded, the effects of expansion and contraction, the reason for the use of fluxes and filling rods, the proper kind of filling material, how to apply heat without burning the metal, etc. All this is necessary to attain the most satisfactory results, and this certainly cannot be gained in a single day.

Oxy-acetylene welding must be considered a trade, for a skilled welding operator is just as much an artisan as a blacksmith or a machinist.

WELDING APPARATUS

There are a great many oxy-acetylene welding outfits manufactured in various types. A typical portable welding outfit is shown in Figure 245. The type of blowpipe shown with this apparatus is of sufficient capacity to handle the widest field of oxy-acetylene welding operations practicable.

The welding apparatus proper consists of the welding blowpipe (Figure 246) and two lengths of rubber hose, one for acetylene and one for oxygen, which are connected to acetylene and oxygen regulators.

The Blowpipe.—Designed for use in connection with compressed gases, this style of blowpipe works on the equal pressure system; that is to say, both gases are delivered to the blowpipe inlet at equal pressures and no injector device is necessary. The gases are mixed near the handle and flow together along the full length of the stem, insuring a perfect mixture by the time the tip is reached. The stem is fitted to the mixing chamber by means of a union nut, which permits the operator to

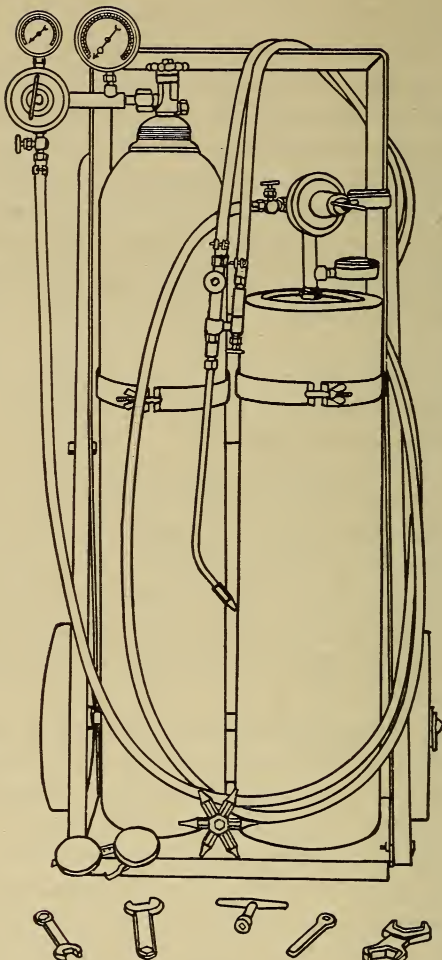


Figure 245.—A Typical Portable Welding Outfit, Employing Both Welding Gases (Oxygen and Acetylene) in Safety Storage Cylinders, Mounted on a Two-Wheeled Truck. This Outfit Weighs Less Than 300 Lbs., and May Be Handled Easily by One Man.

point the welding tip in any direction without changing his method of holding the blowpipe. Line adjustments of the oxygen and acetylene supplies are made by control valves in the blowpipe.

For continuous light welding work the smaller blowpipe, shown in Figure 247, is more suitable, permitting

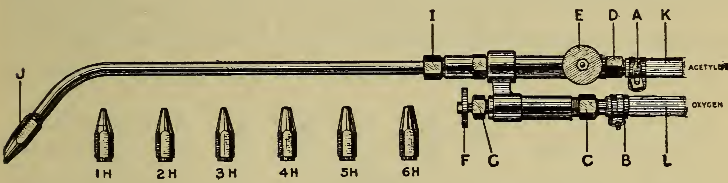


Figure 246.—Equal Pressure Welding Blowpipe. *A,* Clamp for Holding Acetylene Hose on Nipple; *B,* Clamp for Holding Oxygen Hose on Nipple; *C,* Union Nut on Oxygen Hose Nipple; *D,* Union Nut on Acetylene Hose Nipple; *E,* Needle Valve for Controlling Acetylene Supply; *F,* Needle Valve for Controlling Oxygen Supply; *G,* Stuffing Nut on Oxygen Needle Valve; *I,* Union Nut for Disengaging or Changing Angle of Barrel of Blowpipe; *J,* Interchangeable Welding Tip, Size *7H, 1H, 2H, 3H, 4H, 5H,* and *6H* are Extra Interchangeable Welding Tips.

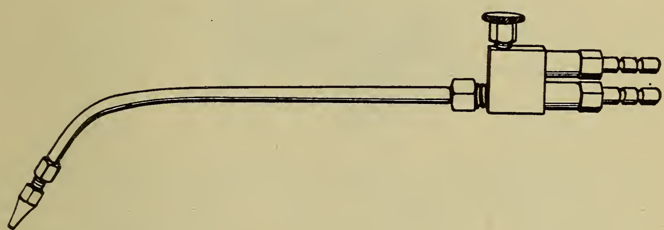


Figure 247.—Oxy-Acetylene Welding Blowpipe for Continuous Light Work, also for Lead Burning.

of more skillful manipulation. This size blowpipe is also to be used for lead burning.

A number of blowpipe tips of different sizes are usually furnished with welding blowpipes, for use on different classes of work. These tips are constructed of brass or copper and are interchangeable. Full instructions for the selection of tips for different operations are furnished by the manufacturers.

Acetylene Regulators, as illustrated in Figure 248, regulate the pressure of the acetylene from the source of supply. Regulators used in connection with gas cylinders are fitted with two pressure gauges. The inlet, or high-pressure, gauge indicates the approximate contents of the cylinder, and the outlet, or working pressure, gauge indicates the acetylene pressure in the hose line. The working pressure is regulated by an adjusting screw in the acetylene reducing valve. The pressure can be further regulated by an outlet needle valve at the hose connection.

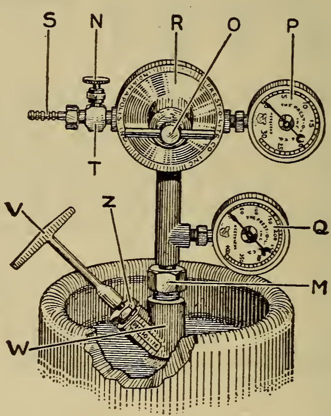


Figure 248.—Automatic Constant Pressure Acetylene Regulator. *M,* Union Nut Securing Regulator on Acetylene Cylinder Valve; *N,* Acetylene Regulator Outlet Needle Valve; *O,* Acetylene Pressure Regulator Screw; *P,* Low or Working Pressure Gauge; *Q,* High or Cylinder Pressure Gauge; *R,* Acetylene Reducing Valve; *S,* Acetylene Hose Nipple; *V,* Wrench on Acetylene Cylinder Valve; *W,* Acetylene Cylinder Valve; *Z,* Gland Nut on Acetylene Cylinder Valve.

The oxygen regulator, connected to the valve of the oxygen cylinder, is essentially the same as the acetylene regulator, excepting the pressure gauges, which are designed for the higher pressure at which oxygen is used.

Welder's goggles, which are usually furnished with all welding outfits, are very essential and should be worn in all welding work. While the oxy-acetylene flame gives off only slight ultra-violet rays, they are so intense that it is very dazzling and tiresome to the naked eye. Goggles also guard the eyes against sparks and particles of molten metal.

Welder trucks, on which the gas cylinders are mounted and which facilitate moving the welding outfit where it is desired, can be had from manufacturers.

THE OXY-ACETYLENE WELDING FLAME

Chemistry of the Flame.—Acetylene (C_2H_2) is composed of carbon (C) and hydrogen (H). On combustion, the carbon combines with oxygen to form carbon dioxide (CO_2), and the hydrogen combines with oxygen to form water vapor (H_2O). This takes place in the following manner:

When the gases issue from the blowpipe into the welding flame, the acetylene immediately dissociates; in other words, it splits up into carbon dioxide and water vapor. In consequence of the high flame temperature (6,300° Fahr.), the water vapor formed by this primary combustion is immediately dissociated into hydrogen and oxygen. The oxygen assists in the burning of the carbon, while the hydrogen (which can only combine with oxygen at a temperature below 4,000° Fahr.) passes away from the high temperature zone and combines with the oxygen of the atmosphere at the outer blue part of the flame, where the temperature is sufficiently low to permit it. The result of this is that the inner or welding cone of the flame is protected by a shield of free hydrogen, which prevents loss of heat and also tends to protect the weld from oxidation.

The temperature of the oxy-acetylene flame is approximately 6,300° Fahr., at the hottest part of the flame, which is the tip of the inner white cone. The effect of this tremendous heat at the point of treatment is to bring the metal very rapidly to a molten state, so that it flows together and mixes thoroughly with the proper quantity of metal added by the operator.

The molten mass thus formed does not merely cement two pieces of metal together—it fuses them into one uniform mass.

Flame Adjustment.—It is absolutely necessary at all times that the welding flame be neutral; that is, that there

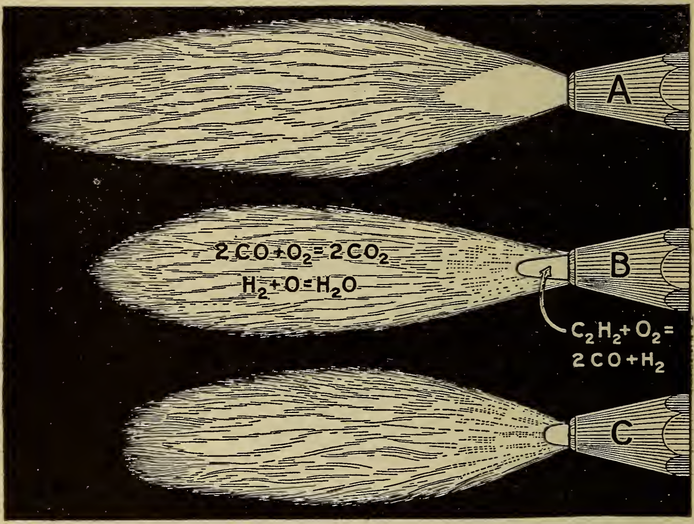


Figure 249.—The Oxy-Acetylene Flame. *A* shows a Welding Flame with an Excess of Acetylene; *B* Shows a Correct Natural Welding Flame; *C* a Welding Flame with an Excess of Oxygen.

be no excess of oxygen or acetylene. A correctly adjusted (neutral) flame is shown at *B* of Figure 249. It will be noted that the inner cone is clear, and well defined. *A* of Figure 249 shows a flame having an excess of acetylene. The inner cone is ragged in appearance. To make such a flame "neutral," the acetylene should be cut down by reducing the pressure, either at the regulator or at the blowpipe, or by increasing the oxygen supply. *C* of Figure 249 shows an excess of oxygen. The inner cone has a very pale violet color and is shorter than the cone in the neutral flame at *B*. Proper adjustment, in this case, is accomplished by reducing the oxygen pressure or increasing the acetylene pressure, at the regulators or at the blowpipe.

The correct oxygen and acetylene working pressures for the various size blowpipe tips are given in welding tables furnished by the manufacturer. After a few days' practice, the operator will learn to know when he has a correct welding flame, and will pay less attention to the working pressure gauges on the regulators.

Methods of Adjustment.—The beginner will be able to get a correct adjustment of the flame more easily, and with absolute certainty, by first opening the blowpipe valves wide and then adjusting the oxygen and acetylene pressures at the regulators, according to the manufacturer's recommendations for the tip used. Start the adjustment with a slight excess of acetylene, as indicated by the ragged appearance of the flame, and then slowly throttle the acetylene until a clear, well-defined inner cone is obtained.

The following is another method of adjusting the welding flame which has proved quick, effective, and quite reliable to many experienced operators. Adjust the acetylene and oxygen pressures at the regulators to the values given in the table, or to values slightly higher than these. Turn on the acetylene at the blowpipe and light the blowpipe. Continue to turn on the acetylene until a point is reached where the smoky yellow flame jumps away from the end of the welding blowpipe tip, so that the tip and the flame are separated by a gap of a small fraction of an inch. As soon as this point is reached, turn on sufficient oxygen pressure to neutralize the flame. In almost all cases the result will be a neutral flame which will work satisfactorily under all conditions.

Note.—All adjustments at the regulators must be made while the blowpipe is alight.

The regulation of the welding flame really means the regulation of the white inner cone. This cone should always be as large as possible, provided its outline is sharp and distinct. A long, clear inner cone should always be sought. The gases should be readjusted several times, if necessary, until the desired result is obtained.

When the blowpipe is first lighted, it is cold. Radiated heat from the molten metal will gradually warm it. This is apt to affect the welding flame slightly. It usually will be found necessary to make readjustment of the gas pressures, by means of the oxygen and acetylene needle valves on the blowpipe, after the blowpipe has been at work for a few minutes.

Effects of Improper Regulation.—It should be remembered that steels and cast iron are combinations of iron and carbon. It will be appreciated, therefore, that if the welding flame has an excess of oxygen, the metal will be decarbonized or oxidized, and the nature of the metal changed.

On the other hand, molten iron or steel will absorb carbon. Thus, excess of acetylene in a welding flame will carbonize the metal. This should be avoided, except in special cases where it is desired to carbonize mild steel.

PREPARATION FOR WELDING

The operator should remember that any job to be welded must be properly prepared, cleaned, lined up, etc., before the blowpipe is lighted.

Butt Welding.—Metals of 1/8 inch in thickness or less are usually butt welded without beveling (see Figure 250).

In welding metal parts more than 1/8 inch in thickness, the entire thickness of each side should be beveled at an angle of about 45° (Figure 251). Beveling insures penetration of the weld entirely through the metal. This is especially necessary in heavy sections. When the metal is more than ¾ inch thick, and it is possible to weld

Figure 250.—Example of Butt Joint Before Welding on Thin Sheet Metal up to ⅛ Inch in Thickness, Where Beveling Is Unnecessary.

Figure 251.—Bevel Employed on Metal Less than ⅝ or ¾ Inch and Over ⅛ Inch in Thickness.

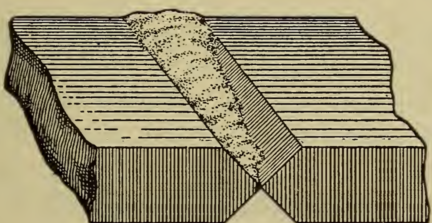


Figure 252.—Example of Beveling and Welding Sections Over ¾ Inch in Thickness. Parts Are Beveled and Welded on Both Sides, as Shown.

Figure 253.—Beveling of Sections Over ¾ Inch in Thickness Where Parts Must Be Welded from One Side Only.

from both sides, it is advisable to bevel as illustrated by Figure 252. If it is impossible to weld from both sides, considerable time and material will be saved by beveling roughly, as shown in Figure 253.

For work exceeding ¾ inch in thickness, the beveling operation, in the case of steel, can be performed by means of the oxy-acetylene cutting blowpipe.

On thinner sections, the beveling can be performed by grinding, or with a hammer and chisel. On the thinnest sections where beveling is necessary, use a file.

Flange Welds.—In construction work on extremely thin sheet metal sections the edges of the parts to be

Figure 254.—Flange Made on Thin Sheets Before Welding.

welded should be flanged (Figure 254). When this is done, no filling material need be used, the metal in the flange serving this purpose. Figure 255 shows the appearance of a weld made on thin sheets, flanged before

Figure 255.—Appearance of a Weld Made on Thin Sheets, Flanged Before Welding.

welding. Figure 257 shows a type of clamp that can be used to advantage on thin metal sheets flanged for welding. It can be operated by a helper, who grips the metal a few inches ahead of the weld and moves the clamp

Figure 256.—A Lap Joint, Before Welding.

when the welder comes up to him. On long seams a number of these clamps can be used, being held in position by the locking ring which is shown around the handles in Figure 258.

The lap weld (Figure 256) has some disadvantages and should only be attempted when butt welding or flange welding is impossible. The weld does not penetrate the total overlap of the parts and is therefore of uncertain strength.

In all welding operations, the parts to be welded should be set in proper alignment before the flame is ap-

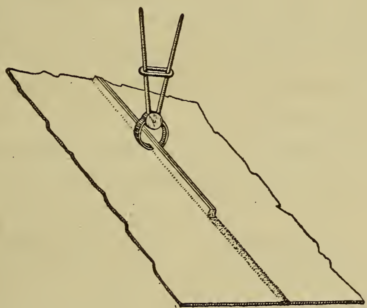


Figure 257.—Method of Holding Flanged Thin Sheets in Position for Welding.

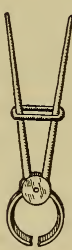


Figure 258.—Clamp with Locking Ring.

plied. Too often, operators fail to take enough time at the start to properly line up the parts to be welded. The result is that the work is sometimes found to be out of alignment and the part rendered useless, no matter how good a weld has been made.

FILLING RODS

The gap, or crack, that exists between two pieces prepared for welding requires that some additional metal be supplied to fill it up. For this purpose rods or wires known as filling or welding rods of various styles are employed.

It will be appreciated that the strength and nature of the welded joint will depend to a great extent on the nature of the filling rod. In order to obtain a joint that will be the same as the metal of the parts being welded, it is of course necessary that the added metal, after the welding is completed, be of the same percentage composition. In order to obtain this ideal result, it is often necessary that the filler, before it is melted into the gap or crack, contain some excess of the substances (foreign to the pure metal) which gave to the sections of the metal part to be joined their particular characteristics of hardness, ductility, or high tensile strength.

The necessity at times for adding an additional quantity of this particular quality-giving substance is due to the fact that a portion of this substance may be burned out (or volatilized) during the welding. As an example, take the case of 0.20 percent (20-point) carbon steel. If it was desired to have a welded joint with the carbon content the same, it would probably be best to use a filler that had 0.35 percent (35-point) carbon content; and then a good deal would depend on the speed at which the work was performed and the skill of the operator.

Fortunately such ideal results are not often necessary in practice, and the employment of good filler, as supplied by firms of repute, will give joints that are of such a nature that they will stand the stress and wear of use.

Steel and iron filling rods should always be kept in a dry place to prevent rusting. If they do become rusted they must be thoroughly cleaned before using.

FLUXES

Some metals do not flow together readily under the action of the blowpipe flame. By using a suitable flux this difficulty is overcome. A welding flux is a combination of chemicals in the form of a powder, which assists fusion and either prevents the formation of oxides or breaks down oxides when formed.

Flux should not be sprinkled on the weld, but should be applied by dipping the heated filling rod, from time to time, into the flux, enough of which will adhere to the rod. Flux at all times should be used sparingly.

Fluxes always should be kept in airtight tins, as some absorb moisture and others deteriorate if exposed to the air for any length of time.

For successful welding, it is absolutely necessary that the proper flux be used. Fluxes should be purchased from a reliable company, preferably from one making a specialty of this particular line and recognizing fully the conditions to be met. Cheapness should never be a guide in the purchase of this material.

EXECUTION OF WELDS

General Instructions.—The following general instructions apply to the welding of all metals and should be borne in mind at all times:

The size of the blowpipe tip to be used for the particular job must first be decided on, according to the recommendations of the manufacturer.

Butt Welds.—In the case of a butt weld on metals under 1/8-inch thickness, where no beveling is necessary, the edges of the two parts to be welded are heated at the same time and brought to the fusion point. While this is going on, also heat up the filler or welding rod in the welding flame, and bring it up to the fusion point at the same time with the parts being joined. Now touch the parts with the melted end of the filler rod and apply the hottest part of the flame to the rod. A portion of the rod will immediately adhere to the molten part. Withdraw the filler rod and play the blowpipe flame with a "figure 8" motion (see *A* of Figure 259) on the parts and added metal. Get them to flow together. Continue this process along the entire line to be welded, making sure that the weld penetrates the entire thickness of the metal.

Whenever possible, the welding flame should be directed toward the metal which has been added. After starting the weld at a certain point, the blowpipe should be held so

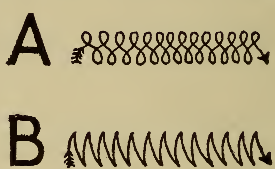


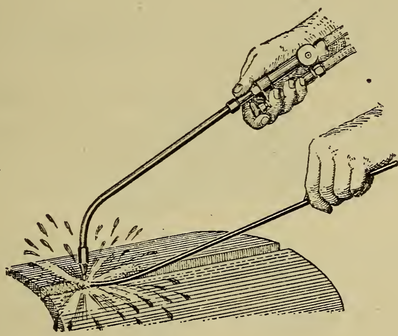
Figure 259.—Two Correct Movements to Give the Welding Flame. *A,* Figure 8 Movement, Best Suited to Ordinary Work; *B,* Zigzag Movement, Which Some Operators Prefer.

that the added metal will be piled toward that point, instead of being scattered away from it along the line to be welded..

While playing the flame over the weld, it is advisable to give the blowpipe a short, sharp twist, so as to make the force of the flame push the molten metal quickly to any desired spot. This is also helpful in piling up the metal a little over the joint.

Do not confine the heat too much to the line of the weld. Let the movement of the blowpipe be such that it will heat a small area adjacent to the weld. This applies particularly to iron and steel.

Beveled Plate.—Now take the case of plates that have been beveled. Hold the blowpipe so that it points, as nearly as possible, at the angle illustrated in Figure 260. Apply the flame to both sides of the bevel, gradually bringing the bottom of the "V" to a molten state. Now add metal as described in butt-welding, gradually making a bath of the molten metal, until the same is level with, or slightly higher than, the surface of the parts to be



Correct Method of Holding the Blowpipe with Relation to the Line of Weld.

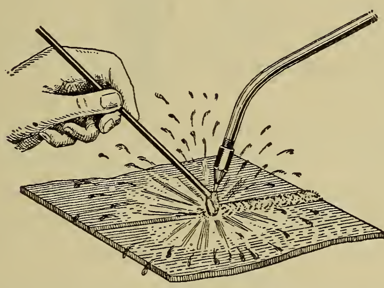


Figure 261.—Incorrect Method of Applying Filling Material. The Blowpipe Is Also Held at the Wrong Angle with Relation to the Line of Weld.

joined. (See Figure 262.) When the metal operated on exceeds ½-inch in thickness, the end of the filling rod may be plunged into this molten bath, which will gradually absorb it and thus increase its own volume.

Never melt the filling rod when it is not touching or plunged into the molten metal. You will never produce a satisfactory weld by allowing melted drops from the filling rod to fall on the heated parts. This bad practice is illustrated by Figure 261.

Some operators prefer a zigzag motion as shown in *B* of Figure 259, instead of the "figure 8" motion.

While spreading the heat is beneficial, yet at the same time the weld should be made as quickly as possible, keep-

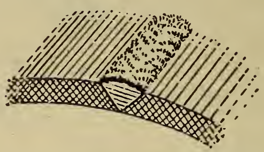


Figure 262.—Metal Is Slightly Built Up Over the Beveled Joint.

ing the metal in a molten state as long as is absolutely necessary.

No general rule can be given on how to hold the blowpipe. This will be largely a matter of choice with each operator. Use the position which seems most natural. The position illustrated in Figure 260 is almost universally employed.

The welding of different kinds of metals very often requires different methods, all of which cannot possibly be covered under any general rule.

IRON AND STEEL

Under this heading are included commercial iron and mild or "low carbon" steel.

The operator will be able to work more intelligently if he knows something of the composition and nature of these metals. Iron, as a material of construction, is no longer used. Practically all of the so-called "wrought iron" on the market today is in reality a mild steel. For this reason wrought iron and mild steel metals are discussed as one.

"Low Carbon" or Mild Steel is quite ductile and malleable, but has a lower tensile strength and lower elastic limit than the "high carbon" or hard steels. No close distinction can be made between high and low carbon steels, but in general anything below 25-point carbon (0.25 per cent) may be designated as mild steel, while those containing more than this amount are either half hard or hard. Most of the steels that the operator will be called upon to weld are mild.

Preparation of Parts.—Several methods of preparing various kinds of parts to be welded are shown in the accompanying illustrations.

Figure 263.—Location of Joint When Welding Convex End to Steel Cylinder.

Figure 263 shows a section of one side of a steel cylinder and a convex head which is to be welded on. The weld should be made in the straight portion of the cylinder as shown, and not directly at the bend.

Figure 264 shows the method of accomplishing the same result in the case of a concave end. If the parts are beveled as shown, the joint will be a strong one.

When butt-welding two lengths of plate, or when welding the longitudinal seam of a cylinder, it is advisable to "tack" along the line of weld before commencing on the finished weld. This will prevent the overlapping of the sheets at the end farthest away from the point of welding. When starting to weld two lengths of sheet at one end, which have previously been placed in proper align-

Figure 264.—Welding Concave Head in Steel Cylinder. Note that Both Head and Shell Are Beveled.

ment, it will be found that they tend to spread apart, as shown in Figure 265. As the welding progresses, this spreading movement of the sheets ceases, and later they come together again, with a tendency to overlap.

Figure 265.—Sheets Spreading Apart During Welding, Away from Point of Weld.

"Tacking" (Figure 266) holds the sheets in true alignment and prevents this overlapping. Another method of preventing overlapping of the plates, in the case of cylinders, is to insert a wedge a short distance ahead of the weld, moving the wedge as the weld progresses. This is shown in Figure 267.

In some cases when welding a longitudinal seam, it will be found advantageous to start to weld in the middle of the seam and work first toward one end and then toward the other.

When welding angle iron rings to cylinders, where the thicknesses are the same, both edges should be set up as shown in Figure 268. When the angle to be welded to the plate is thicker than the plate (Figure 269) apply the

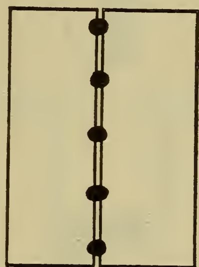


Figure 266.—Sheets "Tacked" Before Welding, to Prevent Spreading or Buckling.

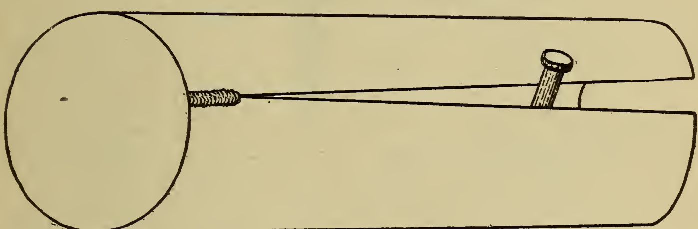


Figure 267.—Wedge Inserted in Split Tube Ahead of Weld, to Prevent Overlapping.

flame more on the angle than on the plate. This will tend to bring the parts to the fusion point at the same time. Metal must be added as shown by the dotted line.

When welding a flat end into a tube, prepare the end as shown in Figure 270, making a driving fit.

The welding of flat flanges to tubes is an operation that requires care, as the flange is usually considerably thicker than the tube and has to stand a good deal of strain.

Figure 268.—Preparation of Angle Iron and Steel Cylinder of Same Thickness Before Welding.

Figure 269.—Dotted Line Shows How Filling Material Must Be Built Up When Welding Angle to Thinner Section Plate.

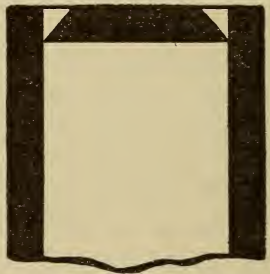


Figure 270.—Preparation of Flat End to Be Welded into Steel Tube.

The flange and the tube are best prepared as shown in Figure 271. The welding flame should play more on the flange than on the tube.

When repairing cracks in plates, always see that the crack is beveled through its entire thickness. The plate being welded should be free to move. If it is impossible to provide for this, instead of attempting to repair the crack, use a patch. A patch piece should always be

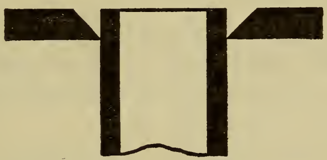


Figure 271.—Preparation of Flange to Be Welded to Thinner Section Plate.

Figure 272.—Patch Plate Bellied and With Edges Beveled Before Welding.

slightly bellied and have edges beveled as indicated in Figure 272.

Selection of Blowpipe Tip.—The size of tip to use for welding iron and steel depends upon the thickness of the metal and the recommendations of the manufacturer. Do not forget that the flame should be neutral at all times.

Filling Material.—For filling in the case of work that is not under tension, use Norway or Swedish iron of the first quality to get the best results. This is free from slag, sulphur, phosphorus, and other impurities. It should be remembered that Swedish or Norway iron has a comparatively low tensile strength. However, it is very ductile (elastic) and hence is very suitable for welding. In the case of mild steel work that is in tension, it is advisable to use filling material that will produce a joint of the same quality and nature as the material operated on; or even use a filler of vanadium or nickel steel, so that the resulting weld will be as strong or stronger than the rest of the part. Filling material used on iron or steel should never exceed 3/8 inch in thickness. For thin work never use a filler thicker than the metal to be welded.

Flux.—The use of a flux is not necessary in welding wrought iron or steel.

Execution of Welds.—The general instructions already given under this head apply in the welding of wrought iron and steel. The end of the small white cone should be allowed to just touch the metal.

Treatment After Welding.—Annealing or hammering, or both, will improve the quality of steel welds. Welds preferably should be treated in this manner wherever great strength is desired. The hammering should be done with the metal at a yellow white heat. Hammering at a dull red heat is likely to produce cracks or fissures in the welded portion. Before hammering, it is necessary to reheat the work thoroughly to the proper color. The welded part may then be annealed by heating to a cherry red heat and allowing to cool naturally.

SHEET ALUMINUM

Sheet aluminum is as a rule pure metal, and has to be handled somewhat differently from an alloy. Where welding has to be done, the sheets are very rarely over 1/8 inch in thickness. If they are, they can be welded in the same way as castings, except that the pure drawn aluminum rod must be used as a filler and sheet aluminum flux used. Preheating is seldom necessary and any reheating or annealing that may be deemed advisable along the line of weld can be done with the blowpipe flame, using a slight excess of acetylene. Beveling of the plates before welding has hardly ever to be done, and practice will show that the plates tend to bevel themselves as they come up to the melting point along the line of weld.

The welding of aluminum sheets below ⅛ inch in thickness will be found to be a somewhat delicate operation, and a good deal of practice is required before sound, neat joints can be made. The process is somewhat similar to lead burning, and a lead burner rapidly becomes efficient in welding thin aluminum sheets.

Blowpipe.—To facilitate the operation it is desirable to use a light blowpipe of the type shown in Figure 273. This style of blowpipe, together with some light-weight hose and a regulating block, is supplied by many manufactur-

Figure 273.—Type of Light Blowpipe Suitable for Welding Sheet Aluminum, Lead Burning, Etc., Showing Bench Block at the Left.

ers of equipment as an accessory to the standard equipment employed on general work. When using this light blowpipe, the rubber hose from the regulators is connected up to the bench block instead of direct to the blowpipe, and the adjustments that would be made at the blowpipe with the standard equipment are made at the bench regulating block instead. The needle valve control at the oxygen inlet on the small blowpipe provides additional facility for maintaining a non-oxidizing flame.

Preparation of Work.—Sheets between $\frac{1}{16}$ inch and ⅛ inch in thickness need not be beveled or flanged. Sheets $\frac{1}{16}$ inch thick and under should be flanged to a height of 1 to 1½ times the thickness of the metal. Clean the work thoroughly and have it bright along the line of weld.

For quantity work, the manufacture of sets of good heavy clamps will well repay the outlay, and will help secure sound, neat work. Figure 258 shows the type of clamp or tongs that should be used when aluminum sheets are flanged.

Preheating.—Preheating of sheet aluminum prior to welding is only necessary occasionally, and then only to counteract movements of the plates due to expansion.

Filling Material.—Pure aluminum rod or wire must be used. When work is flanged, no filler is necessary.

Flux.—A proved brand of sheet aluminum flux must be employed. The flux is best if it contains no acid or alkali, which might have a corroding effect if traces were left in the body of the weld or on the surface of the sheets.

Most fluxes for sheet aluminum can only be used in a dry form. When used dry, it is applied by dipping the heated filling rod into the powder, when sufficient will adhere for application at one time. Some fluxes can be used wet or dry, but before application by the wet method is tried, assurance should be obtained from the source of supply that the flux is suitable to be used wet.

To use the flux in a wet form, it is mixed with clean water in sufficient quantity to produce a mixture of cream consistency. To apply, use a piece of clean rag or cloth, dip in the flux, and apply along both edges of the metal to be joined; let the flux be applied at least 3/8 inch away from the line of weld. This effectually removes surface oxide. Then apply a second coating with a small, stiff brush. Any further flux required to obtain uniform flow of metal can be added by dipping the filling rod in the mixture.

Execution of Welds.—Careful regulation of the blowpipe flame is necessary. A slight excess of acetylene is recommended. Avoid contact between the metal and the white cone of the flame. It will be found that the first fusion of the metal takes some time, due to loss of heat by conductivity, and on this account the rate of welding will increase as the work progresses and as the edges ahead are gradually heated by conductivity.

For sheets $\frac{1}{16}$ inch thick a blowpipe tip consuming about 2 cubic feet of acetylene per hour will be found suitable. With this size, quick diffusion is obtained before conductivity has had time to diffuse the heat. With thicker sheets, conductivity absorbs a great deal of the heat, and a larger blowpipe tip must be used, in order to procure rapid fusion and prevent oxidization, which will take place if the weld is made slowly. With sheet aluminum, expansion troubles are not so difficult to deal with as is the case with iron or steel, due to the fact that the high conductivity of the metal tends to even up the distribution of the heat in the whole.

Treatment After Welding.—Owing to the high conductivity of the metal and consequent even distribution of the heat, contraction does not as a rule cause cracking. Remember, the metal is fragile at temperatures near the melting point, and should therefore be carefully handled while cooling, which should take place slowly and away from draughts. Do not be in too great a hurry to remove clamps.

After the work is cold, wash away with water any traces of flux on the surface. Inferior flux might, if left on the surface, have a corroding effect on the metal, and any flux left on the surface would be injurious to paint work and cause it to scale.

Cold hammering along the line of weld, after the flux is removed, is good practice; it gives texture and grain to the weld. A spring power hammer is good for this work if available. Subsequent annealing will remove hammer marks.

COPPER

Heat radiates from copper very rapidly, and as copper is also an exceptionally good conductor of heat, it is found that the heat of the blowpipe flame alone, when dealing with large masses of copper, is not sufficient to keep up the fusion. Therefore, in order to keep up fusion, it is necessary to preheat and to use a continued application of heat at or near the point of weld by another source, in addition to the blowpipe.

Preparation of Work.—Copper parts are prepared for welding in a manner similar to that for steel and iron. Use a larger blowpipe tip than for the same thickness of steel.

The work, as much as possible, should be covered with asbestos, to prevent radiation. Copper when heated has very little strength, so that work to be welded must be left free to move; otherwise the contraction of the cooling metal may cause a fracture. For instance, when welding together two long lengths of copper pipe, the pipe should be supported on rollers, so that it may move freely and prevent undue strain on the weld while cooling. In welding long lengths of copper together, it is well to wrap wet asbestos around the part a little bit away from the weld, and keep it wet during the welding operation. This prevents the welding heat being conducted throughout the total length of the pieces, insuring the least possible expansion and contraction while cooling is going on.

Filling Material.—For all classes of work, a phosphor copper filling rod should be employed. Phosphorus is one of the best deoxidizing agents for copper.

Copper when molten oxidizes very rapidly, and the process is so intense that the metal may actually be transformed into an alloy of copper and copper oxide. Phosphorus, when added to the molten metal in the form of "phosphor copper," rapidly diffuses and destroys the oxide, forming phosphoric acid, which will dissolve more oxide. A slag forms, which rises to the surface and forms a protective film. The phosphorus also prevents the absorption of gases in the molten mass, thus insuring a weld free from blowholes.

The percentage of phosphorus in the filler is very small, just sufficient to obtain metal free from oxide. A metal containing too much phosphorus lacks fluidity, and melts at a lower temperature than pure copper; and if used will probably produce the defect of adhesion in the weld and be the source of structural defects, in addition to reducing the electrical conductivity.

Flux.—A flux must be used when welding copper. Employ the same flux as for welding brass. This should be used sparingly.

Execution of Welds.—The filling material must never be added until the edges of the parts to be welded are in a molten condition. The operation must proceed rapidly, to prevent the heat from spreading.

BRASS

The welding of brass is quite simple. Preheating is not necessary, except from an economical point of view. Use special flux for brass and bronze. As a filling material, use the best grade of brass spelter. Where great strength is desired, Tobin bronze may be used with the brass flux. The weld should be made rapidly, but the white cone of the flame should not be allowed to touch the metal.

LEAD

Lead can be readily welded. The process, however, is usually known as "lead burning." The oxy-acetylene process provided a means of doing this work faster and at lower cost than is possible by other means. Skill in the manipulation of the blowpipe is necessary on vertical seams. A "lead burner," if not prejudiced, will quickly attain such skill when using these gases as to prove the superiority of the process. A light blowpipe, as illustrated in Figure 273, should be used.

When welding sheet or plates, proceed as in lead burning by other processes.

The burned joint on a lead or block tin pipe-line is not only a neat and permanent joint, but with a little practice can be made in much less time, with a considerable saving in labor, material and fuel.

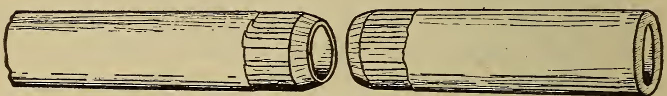


Figure 274.—Method of Preparing Lead Pipe Ends for Burning.

Another large advantage in many cases is that a lead line thus joined is all lead, and a block tin line is all block tin. The joints are fused together with the addition of enough metal of the same kind. If, for instance, a lead pipe-line is to carry acid, the burned joints contain no solder which could be attacked by the acid.

Figure 275.—The Finished Lead Pipe Joint.

Figure 274 shows the method of preparing lead pipe for welding. Note that the two pipe ends are scraped clean in the vicinity of the burn, and are tapered slightly at the edges. It is not necessary to drive one pipe into the other. The two ends are merely placed in contact and burned with the addition of more lead to fill up the joint. No flux, no grease, and no "wiping" of any kind is needed. Notice the neatness of the finished joint, Figure 275.

TABLE OF APPROXIMATE WELDING RESULTS

The following is an approximate welding table, as used by The Prest-O-Lite Co., Inc., for its Type H blowpipe:

Tip No.	Tip Drill Size	Gas consumption Cu. ft. per hour		Thickness of Metal	Blow-pipe pressures Lbs. per sq. in.		Lineal feet welded per hour
		Oxygen	Acetylene		Oxygen	Acetylene	
1H	69	3 to 4	3 to 4	$\frac{1}{32}$ to $\frac{3}{64}$ in.	2 to 3	2 to 3	30 to 35
2H	60	6 to $8\frac{1}{2}$	6 to 8	$\frac{1}{16}$ to $\frac{3}{32}$ in.	2 to 3	2 to 3	24 to 32
3H	55	10 to $12\frac{1}{2}$	10 to 12	$\frac{1}{8}$ to $\frac{5}{32}$ in.	3 to 4	3 to 4	12 to 16
4H	52	12 to 21	12 to 20	$\frac{3}{16}$ to $\frac{7}{32}$ in.	4 to 6	4 to 5	9 to 12
5H	49	18 to 28	18 to 26	$\frac{1}{4}$ to $\frac{5}{16}$ in.	5 to 7	5 to 6	6 to 8
6H	44	24 to 40	24 to 38	$\frac{3}{8}$ to $\frac{7}{16}$ in.	8 to 11	8 to 9	$4\frac{1}{2}$ to 6
7H	35	35 to 54	35 to 50	$\frac{1}{2}$ in. and up	10 to 15	10 to 14	2 to 3
7J	35	35 to 54	35 to 50	$\frac{1}{2}$ in. and up	9 to 13	9 to 12	Not used on plates
8J	31	40 to 60	40 to 55	$\frac{1}{2}$ in. and up	9 to 14	9 to 13	Not used on plates

The figures quoted in the above table are based on straight work on steel plate, beveled when over $\frac{1}{8}$ inch in thickness and welded without preheating.

The gas pressures given are only approximate, and are quoted merely as a guide to the beginner who has had no practice experience. After a few days the operator will learn to regulate his flame without paying any particular attention to the pressure gauges on the regulators. In general, use the high pressures for cast iron and lower pressures on steel plates.

The reader should not get the impression from the above table that $\frac{1}{2}$-inch thickness is the limit of welding.

HINTS ON OXY-ACETYLENE WELDING

It may be taken as a standard in the case of sheet or plate welding in iron or steel, that for each $\frac{1}{16}$ of an inch in thickness an approximate hourly consumption of 5 cubic feet of acetylene and $5\frac{1}{2}$ cubic feet of oxygen will be necessary. These figures are useful to bear in mind when estimating for welding work.

Welds on sections up to $3/8$ inch in thickness should always be made as rapidly as possible. The size of blowpipe given in the foregoing table for different thicknesses of metal apply to the average welder. A really skilled welder, who is on "repeat" work, would probably be able to use a size larger blowpipe tip than is quoted in the table, due to his continuous experience on the particular job and his ability to control the molten metal better than a less skilled or less practical operator.

Any correctly adjusted, neutral oxy-acetylene flame gives a temperature of approximately 6,300° Fahr., no matter what size tip is used. The larger tips are used, of course, on the heavier sections of metal, since they produce a larger flame and a greater *volume* of heat, though not a greater *degree* of heat.

Some metals require a larger flame for the same thickness of material than others. This may be due to: First, a high melting point; second, a high specific heat, that is, a greater ability to absorb heat; third, a higher heat conductivity, that is, a greater ability to spread the applied heat rapidly throughout the whole of the piece being welded.

OXY-ACETYLENE CUTTING

The cutting blowpipe is commonly used for cutting through various thicknesses of wrought iron and steel up to 14 inches. (Wrought iron and steel are the only metals that can be cut by this process.) As an adjunct to a welding equipment, it is used for beveling and for cutting out patches and holes. It also has many uses in destructive and constructive work.

The process is based on the fact that a jet of oxygen directed upon a previously heated spot of iron or steel, causes it to ignite, with the result that the metal, acting as its own fuel, burns away rapidly in the form of iron oxide. A special blowpipe is provided for this work.

The oxygen cutting blowpipe cannot be used for welding, any more than can the welding blowpipe be used for cutting.

The same source of gas supply is used as for welding. The same acetylene regulator is used.

The oxygen regulator for welding can be used for cutting on work up to 1½ inch in thickness.

The cutting blowpipe is connected to the gas supply through the regulator in exactly the same way as the welding blowpipe.

Types of Blowpipe Used.—There are two kinds of oxy-acetylene cutting blowpipes, known as the *central jet* and

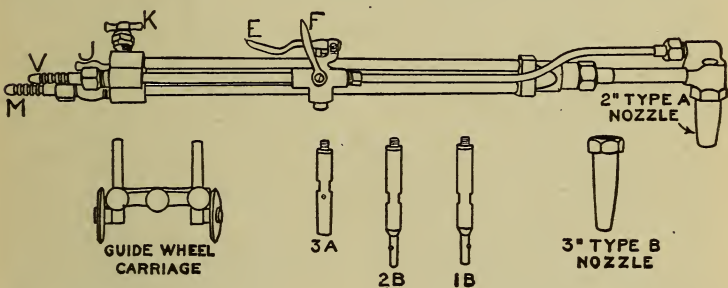


Figure 276.—Oxy-Acetylene Cutting Blowpipe (Central Jet Type); *3A, 2B, 1B,* Internal Tips.

following jet types. The central jet type has a number of oxy-acetylene heating flames surrounding a central hole, through which oxygen only passes. The following jet type consists of one oxy-acetylene heating and one oxygen jet. The holes for these jets are usually drilled in the same tip, but sometimes have separate tips, which are set close together.

Adjustment and Operation.—Figure 276 illustrates the principles of operation of an oxy-acetylene cutting blowpipe of central jet type.

The oxygen and acetylene supplies are connected up through the regulators and rubber hose to the hose nipples on the blowpipe at *V* and *M*.

To start work with the cutting blowpipe after connecting up, open the valves of both oxygen and acetylene cylinders slowly. Close the outlet valve on both regulators. Turn the oxygen pressure regulating screw to the right, to the pressure recommended for the thickness of metal to be cut. Adjust the acetylene regulator until the working

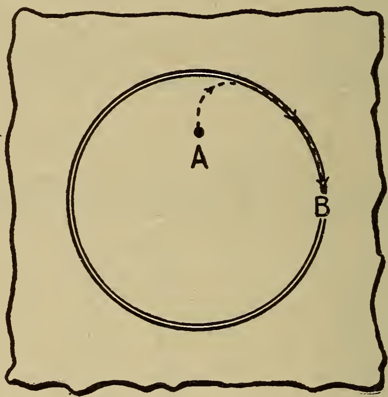


Figure 277.—Point of Start (*A*) When Cutting Circular Hole in Plate.

gauge shows proper pressure. Open fully the outlet valves on both regulators. Turn on slightly the acetylene at the blowpipe by means of needle valve *J* of Figure 276. Light the blowpipe. Slightly open oxygen needle valve K and adjust until a neutral heating flame is obtained. Next press down lever *E*. This permits the cutting oxygen to pass to the tip. Observe if the heating flame remains neutral. If not, adjust at *J* and *K*. If when *E* is pressed down, there is a fall in the working pressure on the oxygen supply, as indicated on the pressure gauge, adjust at the regulator until the pressure is right. This should be done while *E* is pressed down. The blowpipe is then ready for work. While work is progressing, *E* may be locked in position by means of lock *F*.

When the cutting operation is once under way, the heating and cutting proceed together. The cutting operation is very simple and can be mastered in a few hours.

One inner tip may cover quite a range of thicknesses

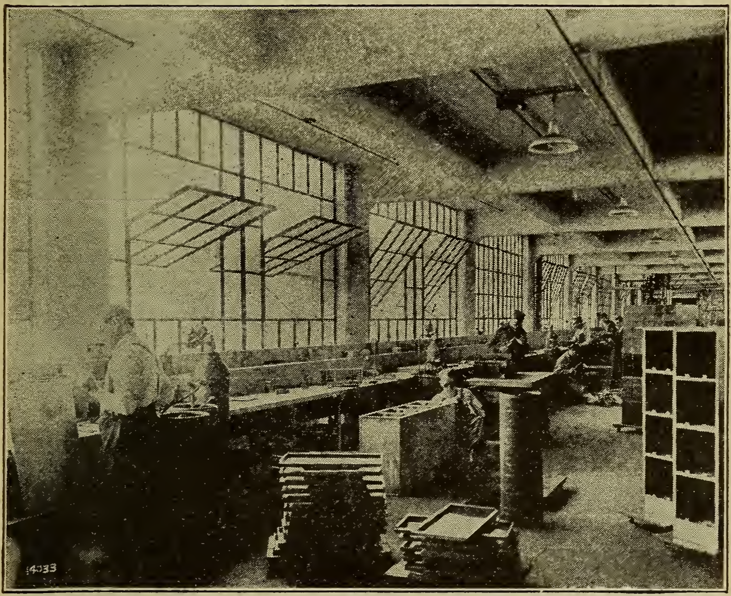


Figure 278.—Oxy-Acetylene Welding in the Manufacture of Metal Furniture. A Typical Scene in a Large Shop.

of metal, but the pressure of the oxygen supply will have to be varied in each case. The figures quoted in the instructions issued by the manufacturer should be followed closely. It should be appreciated that the oxygen pressure has to be made sufficiently strong, so that it will blow away the iron oxide, insuring a clean, narrow cut being made through the metal.

The Heating Flame.—The size of the heating flame must be adjusted for each thickness of work to be cut. It is impossible to give any hard and fast rule as to the size

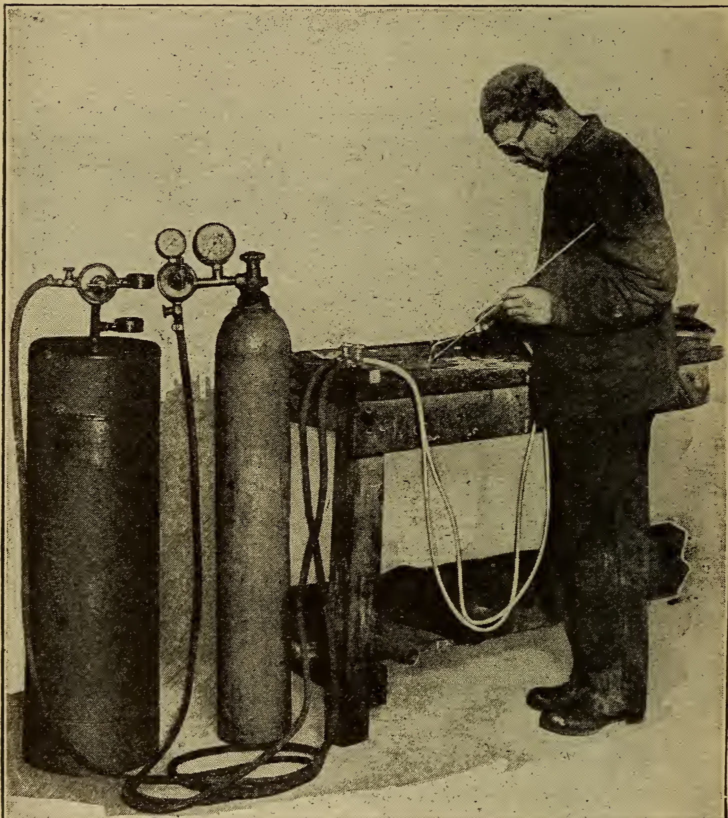


Figure 279.—Welding Outfit with Light Blowpipe in Operation. This Outfit Is Especially Used for Small Repeat Work at the Bench and for Lead Burning. Note the Bench Block, Where the First Regulation or Adjustment of the Welding Flame Is Made.

of the flame. The operator must, if necessary, gradually increase the size of the heating flame, by opening the acetylene needle valve and heating oxygen needle valve on the blowpipe, until the rate of cutting agrees with the figures given in the Cutting Table furnished by the manufacturer of the blowpipe. Bear in mind, however, that these figures are intended for work on clean plates, and that when the work to be cut is rusty or covered with scale the rate of cutting will be considerably slower.

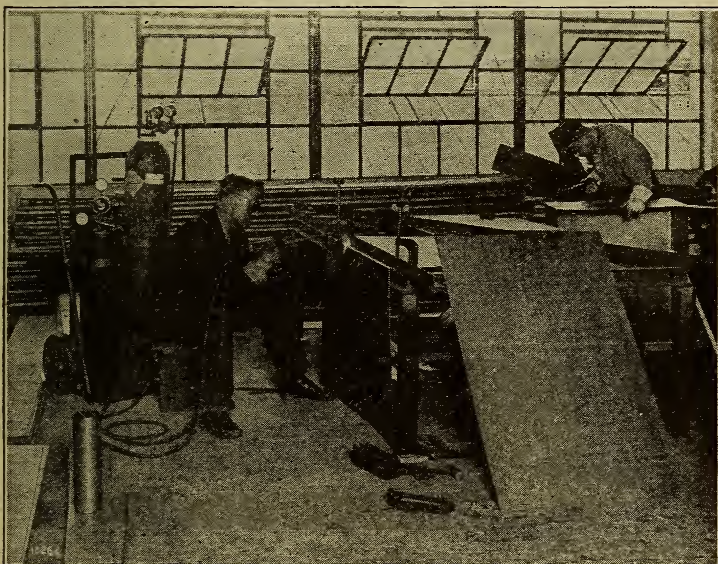


Figure 280.—The Oxy-Acetylene Welding Process Employed on Sheet Steel Work. Note the Goggles and Gauntlets of the Workmen.

How to Cut.—Cutting may be made to follow any desired line. When special forms and shapes have to be cut, it is advisable to use a special mechanical contrivance with which to steady and guide the blowpipe, and thus insure a clean cut. Hold the blowpipe tip about ¼ inch away from the surface of the metal to be cut.

This blowpipe is provided with a set of guide wheels which may be attached to the outer nozzle by means of set screws. The distance between the blowpipe nozzle and the surface of the work can be adjusted by means of the outer set screws.

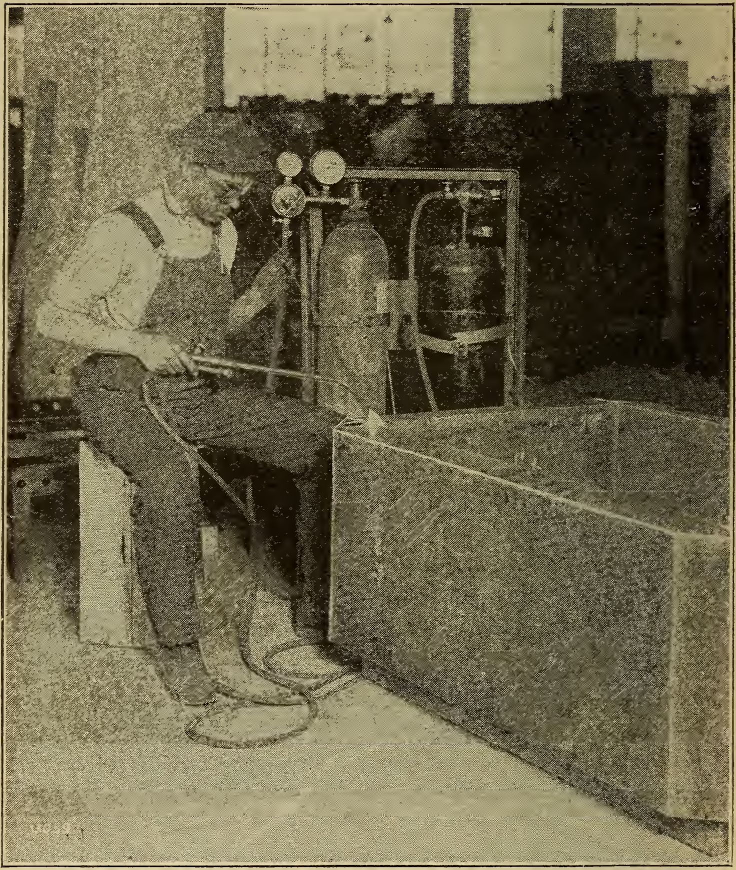


Figure 281.—Welding by the Oxy-Acetylene Process of a Double-Jacketed Steel Tank Used for Heating Purposes.

A cut should start from the edge of the metal whenever possible. When it is desired to cut a piece out of the center of a plate, start inside the circumference of the piece to be cut (Figure 277). On thick plate, where the cut cannot be started from the edge, it may be necessary to drill a hole to get a quick start.

Precautions.—Certain precautions are necessary before the operator starts to work on a piece of metal. A bucket

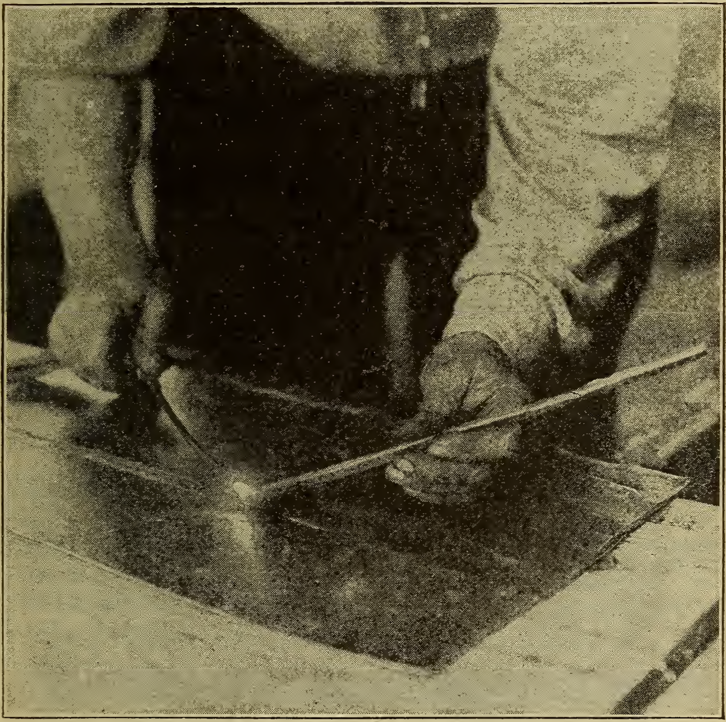


Figure 282.—The Oxy-Acetylene Process of Lead Burning, as Used on Flat Sheet Work.

of water should be near at hand, for cooling the cutting tip when necessary. Both oxygen and acetylene should be shut off at the blowpipe, to extinguish the flame, before dipping the tip of the blowpipe into the water. To expel any steam formed inside the tip, turn on the oxygen valves at the blowpipe, and allow oxygen to flow for a moment before turning on the acetylene and lighting.

When an operator is working in a confined place, such as inside a boiler, he should have an attendant to turn off the gas supplies at the cylinders if necessary. It is also advisable under these conditions to employ armored fireproof hose.

If the blowpipe tip becomes obstructed in any way, due to beads of iron being splashed over it, or from any other cause, a copper wire or copper wire brush should be used to clean it. *No sharp or hard instrument should be employed.*

Colored-lens glasses or goggles should be used to protect the eyes of the operator from the glare and from particles of burned metal. Gauntlets of asbestos or other protective material are also advisable.

TABLE OF APPROXIMATE CUTTING RESULTS

The following table shows approximate results obtained with cutting blowpipes furnished by The Prest-O-Lite Co., Inc.:

Thickness of steel	Size of Internal Nozzle Type B Cutter	Size of Internal Nozzle Type K Cutter	Oxygen pressure lbs. per sq. in.	Lineal feet cut per hour*	Oxygen consump'n cu.ft.per hr. (approx.)	Acetylene consump'n cu.ft.per hr. (approx.)
1/8	1	1A or 1	7	90	35	13
1/4	1	1A or 1	10	71	40	14
1/2	1	1A or 1	25	60	58	16
3/4	1	1A or 1	30	49	76	18
1	1	1A or 1	35	40	94	21
1½	2	2A or 1	40	33	116	29
2	2	2A or 1	50	29	225	36
3	2	2A or 2	60	24	289	37
4	3	3A or 2	65	20	357	38
5	3	3A or 3	75	17	422	39
6	3	3A or 3	85	14	488	40
7	4	4A or 4	100	12	622	41
10	4	4A or 4	150	6	1020	46

* These results are based on plate with clean surface and in position where the operator can work on straight cuts without any difficulties.

VIII

ELECTRIC WELDING

Two distinct forms of electric welding apparatus are in use, one producing heat by the resistance of the metal being treated to the passage of the electric current, the other using the heat of the electric arc.

The resistance process is of the greatest use in manufacturing lines where there is a large quantity of one kind of work to do—many thousand pieces of one kind, for instance. The arc method may be applied in practically any case where any other form of weld may be made. The resistance process will be described first.

Resistance Method.—It is a well known fact that a poor conductor of electricity will offer so much resistance to the flow of electricity that it will heat. Copper is a good conductor, and a bar of iron, a comparatively poor conductor, when placed between heavy copper conductors of a welder, becomes heated in attempting to carry the large volume of current. The degree of heat depends on the amount of current and the resistance of the conductor.

In an electric circuit the ends of two pieces of metal brought together form the point of greatest resistance in the electric circuit, and the abutting ends instantly begin to heat. The hotter this metal becomes, the greater the resistance to the flow of current; consequently, as the edges of the abutting ends heat, the current is forced into the adjacent cooler parts, until there is a uniform heat throughout the entire mass. The heat is first developed in the interior of the metal, so that it is welded there as perfectly as at the surface.

The electric welder (Figure 283) is built to hold the parts to be joined between two heavy copper dies or contacts. A current of three to five volts, but of very great volume (amperage), is allowed to pass across these dies,

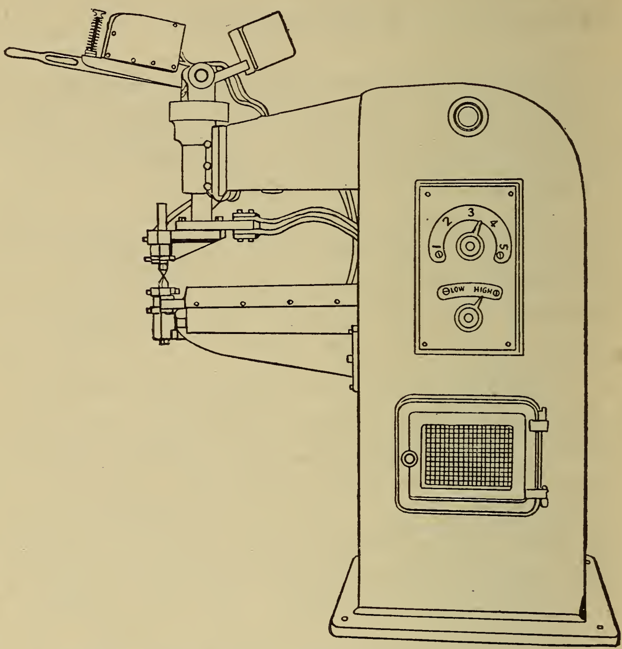


Figure 283.—Electric Spot Welding Machine.

and in going through the metal to be welded, heats the edges to a welding temperature.

Voltage and Amperage.—It may be explained that the voltage of an electric current measures the pressure or force with which it is being sent through the circuit and has nothing to do with the quantity or volume passing. Amperes measure the rate at which the current is passing through the circuit, and consequently give a measure of the quantity which passes in any given time. Volts correspond to water pressure measured by pounds to the square inch; amperes represent the flow in gallons per minute. The low voltage used in this electric welder avoids all danger to the operator, this pressure not being sufficient to be felt even with the hands resting on the copper contacts.

Current is supplied to the welding machine at a higher voltage and lower amperage than is actually used between the dies, the low voltage and high amperage being produced by a transformer incorporated in the machine itself. By means of windings of suitable size wire, the outside current may be received at voltages ranging from 110 to 550 and converted to the low pressure needed.

Alternating Current Used.—The source of current for the resistance welder must be alternating, that is, the current must first be negative in value and then positive, passing from one extreme to the other at rates varying from 25 to 133 times a second. This form is known as alternating current, as opposed to direct current, in which there is no changing of positive and negative.

The current must also be what is known as single phase, that is, a current which rises from zero in value to the highest point as a positive current and then recedes to zero before rising to the highest point of negative value. Two-phase or three-phase currents would give two or three positive impulses during this time.

As long as the current is single phase alternating, the voltage and cycles (number of alternations per second) may be anything convenient. Various voltages and cycles are taken care of by specifying all these points when designing the transformer which is to handle the current.

Direct current is not used, because there is no way of reducing the voltage conveniently without placing resistance wires in the circuit, and this uses power without producing useful work. Direct current may be changed to alternating by having a direct current motor running an alternating current dynamo, or the change may be made by a rotary converter, although this last method is not so satisfactory as the first.

Voltage Must Be Constant.—The voltage used in welding being so low to start with, it is absolutely necessary that it be maintained at the correct point. If the source of current supply is not of ample capacity for the welder being used, it will be very hard to avoid a fall of voltage when the current is forced to pass through the high resistance of the weld. The current voltage for various work is calculated accurately, and the efficiency of the outfit depends to a great extent on the voltage being constant.

A simple test for fall of voltage is made by connecting an incandescent electric lamp across the supply lines at some point near the welder. The lamp should burn with the same brilliancy when the weld is being made as at any other time. If the lamp burns dim at any time, it indicates a drop in voltage, and this condition should be corrected.

Dynamo.—The dynamo furnishing the alternating current may be in the same building with the welder and operated from a direct current motor, as mentioned above, or operated from any convenient shafting or source of power. When the dynamo is a part of the welding plant, it should be placed as close to the welding machine as possible, because the length of the wire used affects the voltage appreciably.

Rheostat.—In order to hold the voltage constant the Toledo Electric Welder Company has devised connections which include a rheostat to insert a variable resistance in the field windings of the dynamo, so that the voltage may be increased by cutting this resistance out at the proper time. An auxiliary switch is connected to the welder switch, so that both switches act together. When the welder switch is closed in making a weld, that portion of the

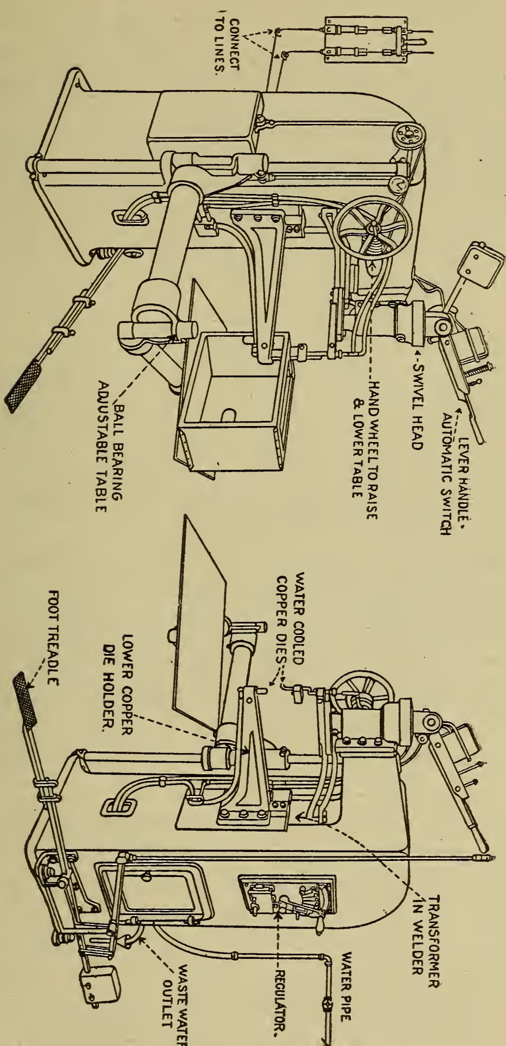


Figure 284.—Operating Parts of a Toledo Electric Spot Welder.

rheostat resistance between two arms determining the voltage is short circuited. This lowers the resistance and the field magnets of the dynamo are made stronger so that additional voltage is provided to care for the resistance in the metal being heated.

Operating Parts.—A typical machine is shown in the accompanying cut (Figure 284). On top of the welder are two jaws for holding the ends of the pieces to be welded. The lower part of the jaw is rigid, while the top is brought down on top of the work, acting as a clamp.

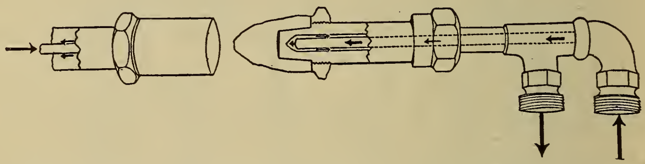


Figure 285.—Detail of Water-Cooled Spot Welding Head.

These jaws carry the copper dies through which the current enters the work being handled. After the work is clamped between the jaws, the upper set is forced closer to the lower set by a long compression lever. The current being turned on with the surfaces of the work in contact, they immediately heat to the welding point, when added pressure on the lever forces them together and completes the weld.

The transformer is carried in the base of the machine, and on the left-hand side is a regulator for controlling the voltage for various kinds of work. The clamps are applied by treadles, convenient to the foot of the operator. A treadle is provided which instantly releases both jaws upon the completion of the weld.

One or both of the copper dies may be cooled by a stream of water circulating through it from the city water mains (Figure 285). The regulator and switch give the operator control of the heat, anything from a dull red to the melting point being easily obtained by movement of the lever (Figure 286).

Welding.—It is not necessary to give the metal to be welded any special preparation, although when very rusty or covered with scale, the rust and scale should be removed sufficiently to allow good contact of clean metal

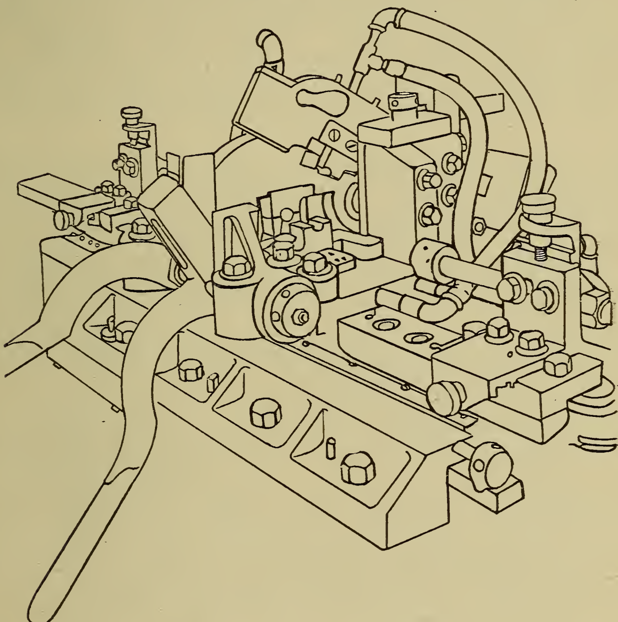


Figure 286.—Welding Head of a Water-Cooled Electric Welder.

on the copper dies. The cleaner and better the stock, the less current it takes, and there is less wear on the dies. The dies should be kept firm and tight in their holders to make a good contact. All bolts and nuts fastening the electrical contacts should be clean and tight at all times.

Removal of Scale.—The scale may be removed from forgings by immersing them in a pickling solution in a wood, stone, or lead-lined tank.

The solution is made with five gallons of commercial sulphuric acid in 150 gallons of water. To get the quickest and best results from this method, the solution should be kept as near the boiling point as possible, by having a coil of extra heavy lead pipe running inside the tank and carrying live steam. A very few minutes in this bath will remove the scale, and the parts should then be washed in running water. After this washing they should be dipped into a bath of 50 pounds of unslaked lime in 150 gallons of water to neutralize any trace of acid.

Iron and Steel.—Cast iron cannot be commercially welded, as it is high in carbon and silicon, and passes suddenly from a crystalline to a fluid state when brought to the welding temperature. With steel or wrought iron the temperature must be kept below the melting point to avoid injury to the metal. The metal must be heated quickly and pressed together with sufficient force to push all burnt metal out of the joint.

High carbon steel can be welded, but must be annealed after welding to overcome the strains set up by the heat being applied at one place. Good results are hard to obtain when the carbon runs as high as 75-point (0.75), and steel of this class can only be handled by an experienced operator. If the steel is below 25-point (0.25) in carbon content, good welds will always be the result. To weld high carbon to low carbon steel, the stock should be clamped in the dies with the low carbon stock sticking considerably farther out from the die than the high carbon stock. Nickel steel welds readily, the nickel increasing the strength of the weld.

Copper and Brass.—Iron and copper may be welded together by reducing the size of the copper end where it comes in contact with the iron. When welding copper and brass the pressure must be less than when welding iron. The metal is allowed to actually fuse or melt at the juncture, and the pressure must be sufficient to force the burned metal out. The current is cut off at the instant the metal ends begin to soften, this being done by means of an automatic switch which opens when the softening of the metal allows the ends to come together. The pressure is applied to the weld by having the sliding jaw moved by a weight on the end of an arm.

Copper and brass require a larger volume of current at a lower voltage than for steel and iron. The die faces are set apart three times the diameter of the stock for brass and four times the diameter for copper.

Light gauges of sheet steel can be welded to heavy gauges or to solid bars of steel by "spot" welding, which will be described later. Galvanized iron can be welded, but the zinc coating will be burned off. Sheet steel can be welded to cast iron, but will pull apart, tearing out particles of the iron.

Sheet copper and sheet brass may be welded, although this work requires more experience than with iron and steel. Some grades of sheet aluminum can be spot-welded if the slight roughness left on the surface under the die is not objectionable.

Butt Welding.—This is the process which joins the ends of two pieces of metal as described in the foregoing part of this section. The ends are in plain sight of the operator at all times and it can easily be seen when the metal reaches the welding heat and begins to soften (Figure 287). It is at this point that the pressure must be applied with the lever and the ends forced together in the weld.

The parts are placed in the clamping jaws (Figure 288) with ⅛ to ½ inch of metal extending beyond the jaw. The ends of the metal touch each other and the current is turned on by means of a switch. To raise the ends to the proper heat requires from 3 seconds for ¼-inch rods to 35 seconds for a 1½-inch bar.

This method is applicable to metals having practically the same area of metal to be brought into contact on each end. When such parts are forced together a slight projection will be left in the form of a fin, or an enlarged portion called an upset.

The degree of heat required for any work is found by moving the handle of the regulator one way or the other

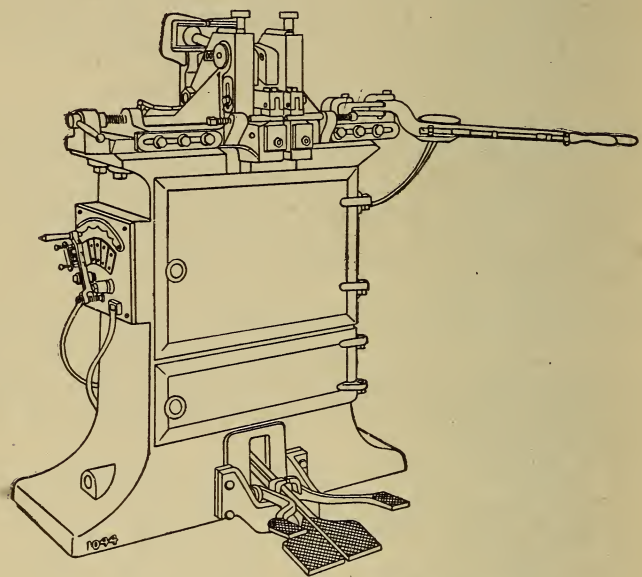


Figure 287.—Electric Butt Welder.

while testing several parts. When this setting is right the work can continue as long as the same sizes are being handled.

Copper, brass, tool steel and all other metals that are harmed by high temperatures must be heated quickly and pressed together with sufficient force to force all burned metal from the weld.

In case it is desired to make a weld in the form of a capital letter T, it is necessary to heat the part corresponding to the top bar of the T to a bright red, then bring the lower bar to the preheated one and again turn on the current, when a weld can be quickly made.

Spot Welding.—This is a method of joining metal sheets together at any desired point by a welded spot about the size of a rivet. It is done on a spot welder

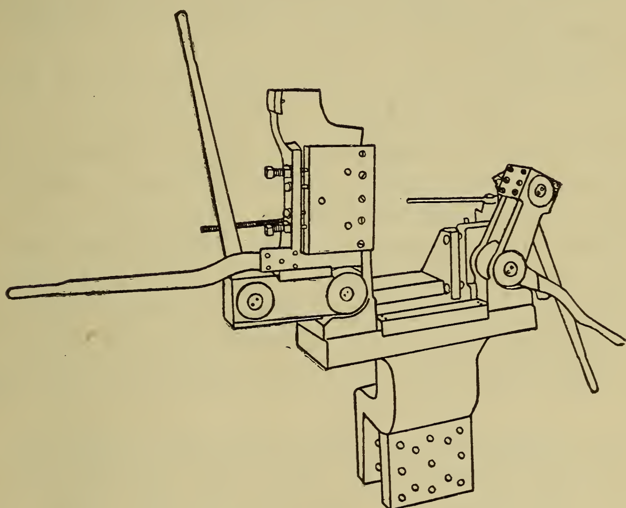


Figure 288.—Clamping Dies of an Electric Butt Welder.

(Figures 283, 284), by fusing the metal at the point desired and at the same instant applying sufficient pressure to force the particles of molten metal together. The dies are usually placed one above the other, so that the work may rest on the lower one while the upper one is brought down on top of the upper sheet to be welded.

One of the dies is usually pointed slightly, the opposing one being left flat. The pointed die leaves a slight indention on one side of the metal, while the other side is left smooth. The dies may be reversed, so that the outside surface of any work may be left smooth. The current is allowed to flow through the dies by a switch, which is closed after pressure is applied to the work.

There is a limit to the thickness of sheet metal that can be welded by this process, because of the fact that the copper rods can only carry a certain quantity of current without becoming unduly heated themselves. Another reason is that it is difficult to make heavy sections of metal touch at the welding point without excessive pressure.

Lap Welding is the process used when two pieces of metal are caused to overlap and when brought to a welding heat are forced together by passing through rollers, or under a press, thus leaving the welded joint practically the same thickness as the balance of the work.

Where it is desirable to make a continuous seam, a special machine is required, or an attachment for one of the other types. In this form of work the stock must be thoroughly cleaned and is then passed between copper rollers which act in the same capacity as the copper dies.

Other Applications.—Hardening and tempering can be done by clamping the work in the welding dies and setting the control and time to bring the metal to the proper color, when it is cooled in the usual manner.

Brazing is done by clamping the work in the jaws and heating until the flux, then the spelter, has melted and run into the joint. Riveting and heating of rivets can be done by bringing the dies down on opposite ends of the rivet after it has been inserted in the hole, the dies being shaped to form the heads properly.

Hardened steel may be softened and annealed so that it can be machined by connecting the dies of the welder to each side of the point to be softened. The current is then applied until the work has reached a point at which it will soften when cooled.

TROUBLES AND REMEDIES

The following methods have been furnished by the Toledo Electric Welder Company and are recommended for this class of work whenever necessary.

To Locate Grounds in the Primary or High Voltage Side of the Circuit.—Connect incandescent lamps in series by means of a long piece of lamp cord, as shown in Figure 289. For 110 volts use one lamp, for 220 volts use two lamps, and for 440 volts use four lamps. Attach one end of the lamp cord to one side of the switch, and close

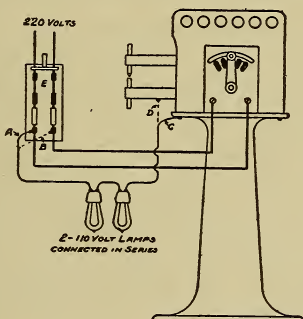


Figure 289.—Method of Testing Electric Welder.

the switch. Take the other end of the cord in the hand and press it against some part of the welder frame where the metal is clean and bright. Paint, grease and dirt act as insulators and prevent electrical contact. If the lamp lights, the circuit is in electrical contact with the frame; in other words, grounded. If the lamps do not light, connect the wire to a terminal block, die or slide. If the lamps then light, the circuit, coils or leads are in electrical contact with the large coil in the transformer or its connections.

If, however, the lamps do not light in either case, the lamp cord should be disconnected from the switch and connected to the other side, and the operations of connecting to welder frame, dies, terminal blocks, etc., as explained above, should be repeated. If the lamps light at any of these connections, a "ground" is indicated. "Grounds" can usually be found by carefully tracing the primary circuit until a place is found where the insulation is defective. Reinsulate and make the above tests again to make sure everything is clear. If the ground can not be located by observation, the various parts of the primary circuit should be disconnected, and the transformer, switch, regulator, etc., tested separately.

To Locate a Ground in the Regulator or Other Part.—Disconnect the lines running to the welder from the switch. The test lamps used in the previous tests are connected, one end of lamp cord to the switch, the other end to a binding post of the regulator. Connect the other side of the switch to some part of the regulator housing. (This must be a clean connection to a bolt head or the paint should be scraped off.) Close the switch. If the lamps light, the regulator winding or some part of the switch is "grounded" to the iron base or core of the regulator. If the lamps do not light, this part of the apparatus is clear.

This test can be easily applied to any part of the welder outfit by connecting to the current carrying part of the apparatus, and to the iron base or frame that should not carry current. If the lamps light, it indicates that the insulation is broken down or is defective.

An A. C. voltmeter can, of course, be substituted for the lamps, or a D. C. voltmeter with D. C. current can be used in making the tests.

A Short Circuit in the Primary.—This is caused by the insulation of the coils becoming defective and allowing the bare copper wires to touch each other. This may result in a "burn out" of one or more of the transformer coils, if the trouble is in the transformer, or in the continued blowing of fuses in the line. Feel of each coil separately. If a short circuit exists in a coil, it will heat excessively. Examine all the wires; the insulation may have worn through and two of them may cross, or be in contact with the frame or other part of the welder. A short circuit in the regulator winding is indicated by failure of the apparatus to regulate properly, and sometimes, though not always, by the heating of the regulator coils.

The remedy for a short circuit is to reinsulate the defective parts. It is a good plan to prevent trouble by examining the wiring occasionally and see that the insulation is perfect.

To Locate Grounds and Short Circuits in the Secondary, or Low Voltage Side.—Trouble of this kind is indicated by the machine acting sluggish or, perhaps, refusing to operate. To make a test, it will be necessary to first ascertain the exciting current of your particular transformer. This is the current the transformer draws on "open circuit," or when supplied with current from the line with no stock in the welder dies. The following table will give this information close enough for all practical purposes:

K.W.	Amperes at			
Rating	110 Volts	220 Volts	440 Volts	550 Volts
3	1.5	.75	.38	.3
5	2.5	1.25	.63	.5
8	3.6	1.8	.9	.72
10	4.25	2.13	1.07	.85
15	6.	3.	1.5	1.2
20	7.	3.5	1.75	1.4
30	9.	4.5	2.25	1.8
35	9.6	4.8	2.4	1.92
50	10.	5.	2.5	2.

Remove the fuses from the wall switch and substitute fuses just large enough to carry the "exciting" current.

If no suitable fuses are at hand, fine strands of copper from an ordinary lamp cord may be used. These strands are usually No. 30 gauge wire and will fuse at about 10 amperes. One or more strands should be used, depending on the amount of exciting current, and are connected across the fuse clips in place of fuse wire. Place a piece of wood or fiber between the welding dies in the welder, as though you were going to weld them. See that the regulator is on the highest point and close the welder switch. If the secondary circuit is badly grounded, current will flow through the ground, and the small fuses or small strands of wire will burn out. This is an indication that both sides of the secondary circuit are grounded or that a short circuit exists in a primary coil. In either case the welder should not be operated until the trouble is found and removed. If, however, the small fuses do not "blow," remove same and replace the large fuses, then disconnect wires running from the wall switch to the welder and substitute two pieces of No. 8 or No. 6 insulated copper wire, after scraping off the insulation for an inch or two at each end. Connect one wire from the switch to the frame of the welder; this will leave one loose end. Hold this a foot or so away from the place where the insulation is cut off; then turn on the current and strike the free end of this wire lightly against one of the copper dies, drawing it away quickly. If no sparking is produced, the secondary circuit is free from ground, and you will then look for a broken connection in the circuit. Some caution must be used in making the above test, as in case one terminal is heavily grounded the testing wire may be fused if allowed to stay in contact with the die.

The Remedy.—Clean the slides, dies and terminal blocks thoroughly and dry out the fiber insulation if it is damp. See that no scale or metal has worked under the sliding parts, and that the secondary leads do not touch the frame. If the ground is very heavy, it may be necessary to remove the slides in order to facilitate the examination and removal of the ground. Insulation, where torn or worn through, must be carefully replaced or taped. If the transformer coils are grounded to the iron core of the transformer or to the secondary, it may be necessary to remove the coils and reinsulate them at the points of contact. A short circuited coil will heat excessively and eventually burn out. This may mean a new coil if you are unable to repair the old one. In all cases the transformer windings should be protected from mechanical injury or dampness. Unless excessively overloaded, transformers will last for years without giving a moment's trouble, if they are not exposed to moisture or are not injured mechanically.

The most common trouble arises from poor electrical contacts, and they are the cause of endless trouble and annoyance. See that all connections are clean and bright. Take out the dies every day or two and see that there is no scale, grease or dirt between them and the holders. Clean them thoroughly before replacing. Tighten the bolts running from the transformer leads to the work jaws.

ELECTRIC ARC WELDING

This method bears no relation to the one just considered, except that the source of heat is the same in both cases. Arc welding makes use of the flame produced by the voltaic arc, in practically the same way that oxy-acetylene welding uses the flame from the gases.

If the ends of two pieces of carbon, through which a current of electricity is flowing while they are in contact, are separated from each other quite slowly, a brilliant arc of flame is formed between them, which consists mainly of carbon vapor. The carbons are consumed by combination with the oxygen in the air and through being turned to a gas under the intense heat.

The most intense action takes place at the center of the carbon which carries the positive current, and this is the point of greatest heat. The temperature at this point in the arc is greater than can be produced by any other means under human control.

The Flaming Arc.—An arc may be formed between pieces of metal, called electrodes, in the same way as between carbons. The metallic arc is called a flaming arc, and as the metal of the electrode burns with the heat, it gives the flame a color characteristic of the material being used. The metallic arc may be drawn out to a much greater length than one formed between carbon electrodes.

Operation.—Arc welding is carried out by drawing a piece of carbon which is of negative polarity away from the pieces of metal to be welded while the metal is made positive in polarity. The negative wire is fastened to the carbon electrode, and the work is laid on a table made of cast or wrought iron to which the positive wire is made fast. The direction of the flame is then from the metal being welded to the carbon, and the work is thus prevented from being saturated with carbon, which would prove very detrimental to its strength. A secondary advantage is found in the fact that the greatest heat is at the metal being welded, because of its being the positive electrode.

The carbon electrode is usually made from one quarter to one and a half inches in diameter and from six to twelve inches in length. The length of the arc may be anywhere from one inch to four inches, depending on the size of the work being handled.

Precautions.—While the parts are carefully insulated to avoid danger of shock, it is necessary for the operator to wear rubber gloves as a further protection, and to wear some form of hood over the head to shield him against the extreme heat liberated. This hood may be made from metal, although some material that does not conduct electricity is to be preferred. The work is watched through a piece of glass formed with one sheet, which is either blue or green, placed over another which is red. Screens of glass are sometimes used without the head protector. Some protection for the eyes is absolutely necessary because of the intense white light.

It is seldom necessary to preheat the work, as with the gas processes, because the heat is localized at the point of welding and the action is so rapid that the expansion is not so great. The necessity of preheating, however, depends entirely on the material, form and size of the work being handled. The same advice applies to arc welding as to the gas flame method, but in a lesser degree. Filling rods are used in the same way as with any other flame process.

PRINCIPLES OF ARC WELDING

It is the purpose of this explanation to state the fundamental principles of the application of the electric arc to welding metals, and by applying the principles the following questions will be answered:

What metals can be welded by the electric arc?

What difficulties are to be encountered in applying the electric arc to welding?

What is the strength of the weld in comparison with the original piece?

What is the comparative application of the electric arc and the oxy-acetylene method and others of a similar nature?

What is the function of the arc welding machine itself?

The answers to these questions will make it possible to understand the application of this process to any work. In a great many places the use of the arc is cutting the cost of welding to a very small fraction of what it would be by any other method, so that the importance of this method may be well understood.

Metals That Can Be Welded.—Any two metals which are brought to the melting temperatures and applied to each other will adhere so that they are no more apt to break at the weld than at any other point outside of the weld. It is the property of all metals to stick together under these conditions. The electric arc is used in this connection merely as a heating agent. This is its only function in the process.

It has advantages in its ease of application and the cheapness with which heat can be liberated at any given point by its use. There is nothing in connection with arc welding that the above principles will not answer; that is, that metals at the melting point will weld and that the electric arc will furnish the heat to bring them to this point. As to the first question, then, what metals can be welded? The answer is, all metals can be welded.

Difficulties.—The difficulties which are encountered are as follows:

1. In case of brass or zinc, the metals will be covered with a coat of zinc oxide before they reach a welding heat. This zinc oxide makes it impossible for two clean surfaces to come together, and some method has to be used for eliminating this possibility and allowing the two surfaces to join without the possibility of the oxide intervening. The same is true of aluminum, in which the oxide, alumina, will be formed, and several other alloys comprising elements of different melting points.

In order to eliminate these oxides, it is necessary in practical work to puddle the weld; that is, to have a sufficient quantity of molten metal at the weld, so that the oxide is floated away. When this is done, the two surfaces which are to be joined are covered with a coat of melted metal on which float the oxide and other impurities. The two pieces are thus allowed to join while their surfaces are protected. This precaution is not necessary in working with steel, except in extreme cases.

2. Another difficulty which is met with in the welding of a great many metals is their expansion under heat, which results in so great a contraction when the weld cools that the metal is left with a considerable strain on it. In extreme cases this will result in cracking at the weld or near it. To eliminate this danger it is necessary to apply heat, either all over the piece to be welded or at certain points. In the case of cast iron, and sometimes with copper, it is necessary to anneal after welding, since otherwise the welded pieces will be very brittle on account of the chilling. This is also true of malleable iron.

3. Very thin metals which are welded together and are not backed up by something to carry away the excess heat, are very apt to burn through, leaving a hole where the weld should be. This difficulty can be eliminated by backing up the weld with a metal face, or by decreasing the intensity of the arc, so that this melting through will not occur. However, the practical limit for arc welding without backing up the work with a metal face or decreasing the intensity of the arc, is approximately No. 22 gauge, although thinner metal can be welded by a very skillful and careful operator.

4. A common difficulty with arc welding is the lack of skillful operators. This method is often looked upon as being something out of the ordinary and governed by laws entirely different from other welding. As a matter of fact, it does not take as much skill to make a good arc weld as it does to make a good weld in a forge fire, as the blacksmith does it. There are few jobs which cannot be handled successfully by an operator of average intelligence with one week's instruction, although his work will

become better and better in quality as he continues to use the arc.

Strength of the Weld.—Now comes the question of the strength of the weld after it has been made. This strength is equally as great as that of the metal that is used to make the weld. It should be remembered, however, that the metal which goes into the weld is put there as a casting and has not been rolled. This would make the strength of the weld as great as the same metal that is used for filling if in the cast form.

Two pieces of steel could be welded together, having a tensile strength at the weld of 50,000 pounds. Higher strengths than this can be obtained by the use of special alloys for the filling material, or by rolling. Welds with a tensile strength as great as mentioned will give a result which is perfectly satisfactory in almost all cases.

There are a great many jobs where it is possible to fill up the weld, that is, make the section at the point of the weld a little larger than the section through the rest of the piece. By doing this, the disadvantages of the weld being in the form of a casting in comparison with the rest of the piece being in the form of rolled steel can be overcome, and make the weld itself even stronger than the original piece.

Comparative Application.—Another question is the adaptability of the electric arc in comparison with forge fire, oxy-acetylene, or any other method. The answer is somewhat difficult if made general. There are no doubt some cases where the use of a drop hammer and forge fire, or the use of the oxy-acetylene torch, will make, all things being considered, a better job than the use of the electric arc, although a case where this is absolutely proved is rare.

The electric arc will melt metal in a weld for less than the same metal can be melted by the use of the oxy-acetylene torch; and, on account of the fact that the heat can be applied exactly where it is required and in the amount required, the arc can in almost all cases supply welding heat for less cost than a forge fire or heating furnace.

The one great advantage of the oxy-acetylene method in comparison with other methods of welding is the fact that in some cases of very thin sheet, the weld can be made somewhat sooner than is possible otherwise. With metal of No. 18 gauge or thicker, this advantage is eliminated. In cutting steel, the oxy-acetylene torch is superior to almost any other possible method.

Arc Welding Machines.—A consideration of the function and purpose of the various types of arc welding machines shows that the only reason for the use of any machine is either for conversion of the current from alternating to direct, or, if the current is already direct, then the saving in the application of this current in the arc.

It is practically out of the question to apply an alternating current arc to welding, for the reason that in any arc practically all the heat is liberated at the positive electrode, which means that, in alternating current, half the heat is liberated at each electrode as the current changes its direction of flow or alternates. Another disadvantage of the alternating arc is that it is difficult of control and application.

In all arc welding by the use of the carbon arc, the positive electrode is made the piece to be welded, while in welding with metallic electrodes this may be either the piece to be welded or the rod that is used as a filler. The voltage across the arc is a variable quantity, depending on the length of the flame, its temperature, and the gases liberated in the arc. With a carbon electrode the voltage will vary from zero to forty-five volts. With the metallic electrode the voltage will vary from zero to thirty volts. It is, therefore, necessary for the welding machine to be able to furnish to the arc the requisite amount of current, this amount being varied, and furnish it at all times at the voltage required.

The simplest welding apparatus is a resistance in series with the arc. This is entirely satisfactory in every way except in cost of current. By the use of resistance in series with the arc and using 220 volts as the supply, from eighty to ninety per cent of the current is lost in heat at the resistance. Another disadvantage is the fact that most materials change their resistance as their temperature changes, thus making the amount of current for the arc a variable quantity, depending on the temperature of the resistance.

There have been various methods originated for saving the power mentioned and a good many machines have been put on the market for this purpose. All of them save some power over what a plain resistance would use. Practically all arc welding machines at the present time are motor generator sets, the motor of which is arranged for the supply voltage and current, this motor being direct connected to a compound wound generator delivering approximately seventy-five volts direct current. Then by the use of a resistance, this seventy-five volt supply is applied to the arc. Since the voltage across the arc will vary from zero to fifty volts, this machine will save from zero up to seventy per cent of the power that the machine delivers. The rest of the power, of course, has to be dissipated in the resistance used in series with the arc.

A motor generator set, which can be purchased from any electrical company, with a long piece of fence wire wound around a piece of asbestos, gives results equally good and at a very small part of the first cost.

It is possible to construct a machine which will eliminate all losses in the resistance; in other words, eliminate all resistance in series with the arc. A machine of this kind will save its cost within a very short time, providing the welder is used to any extent.

Putting it in figures, the results are as follows for average conditions: Current at 2c per kilowatt hour, metallic electrode arc of 150 amperes, carbon arc 500 amperes; voltage across the metallic electrode arc, 20; voltage across the carbon arc, 35. Supply current 220 volts, direct. In the case of the metallic electrode, if resistance is used, the cost of running this arc is sixty-six cents per hour. With the carbon electrode, $2.20 per hour.

If a motor generator set with a seventy-volt constant potential machine is used for a welder, the cost will be as follows: Metallic electrode, 25.2c; carbon electrode, 84c per hour.

With a machine which will deliver the required voltage at the arc and eliminate all the resistance in series with the arc, the cost will be as follows: Metallic electrode, 7.2c per hour; carbon electrode, 42c per hour.

This is with the understanding that the arc is held constant and continuously at its full value. This, however, is practically impossible and the actual load factor is approximately fifty per cent, which would mean that operating a welder as it is usually operated, the result will be reduced to one-half of that stated in all cases.

IX

HAND FORGING AND WELDING

The course given here on Hand Forging and Welding is not presented with the idea of making a toolsmith or blacksmith of the sheet metal worker, but is intended to show another method of joining steel and iron.

It has been shown elsewhere in this book how metal can be joined by soldering, brazing, and electric and oxy-acetylene welding processes. Another method, hand welding, is introduced in this chapter. Structural steel is greatly utilized for reinforcing sheet iron, and the sheet metal contractor who is called upon to read plans and make estimates in building construction and other work must have some knowledge of these different processes, as they enter into specifications laid before the contractor and his workers to solve.

A good soldering job would not recommend the oxy-acetylene welding process; a good hand-welding job would not suggest electric spot welding, and while our reader might not be afforded an opportunity to practice these different methods, he can learn about them from the information in these pages.

The exercises given show how steel, when heated over the forge and placed on the anvil, can be transformed into many shapes of usefulness. They bring into use the tools and other equipment used in hand forging and welding practice. As the student progresses in his studies and later finds a place in the industrial shop, he will better understand how intimately hand forging and welding are connected with sheet metal working, making a knowledge of these methods necessary in the modern shop.

FORGE-SHOP TOOLS

Anvils and Blocks.—Anvils suitable for light work are manufactured of semi-steel in sizes varying from 50 to 150 lbs., also cast-iron anvil blocks suitable for the various sizes of anvils. These semi-steel anvils are considerably

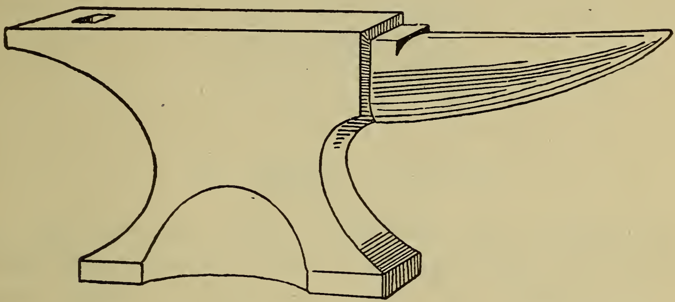


Figure 290.—Regular Steel Anvil.

cheaper than regular steel anvils, but usually answer the purpose of the training school and small shop.

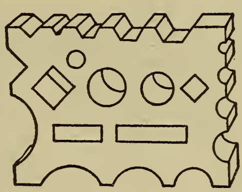


Figure 291.—Swage Block.

Swage Blocks.—These are made in various sizes of cast iron and in almost any shape desired, round, square, or hexagonal. Where a variety of work is done, a swage block (Figure 291) is almost indispensable as an adjunct to the anvil, often saving the purchase of special tools.

Combination Vise.—A very handy tool in the school or shop is the combination vise, which includes in one machine an anvil, anvil-vise, pipe-vise, and drill press. The face of the anvil is 3x8″, while the pipe jaws are removable and will grip pipe from ⅛″ to 3″ in diameter.

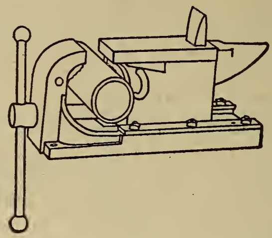


Figure 292.—Combination Vise.

Grindstone.—The grindstone in the modern shop is motor-driven and fitted with a tool rest and water tank.

Induced-Draft Forge.—A good type of forge, with hand instead of power blast, has a convenient geared

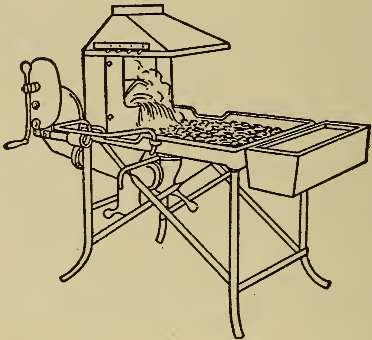


Figure 292A.—Induced-Draft Forge, Equipped with Silent Blower.

hand blower, with overhead down-draft exhaust hood which recirculates a portion of the gases that arise, thereby increasing the temperature of the blast and the natural draft on the forge. This is called an induced-draft forge. (Figure 292A.)

Lever Drill.—A convenient machine for the forge shop has a compound lever feed with which a one-inch hole

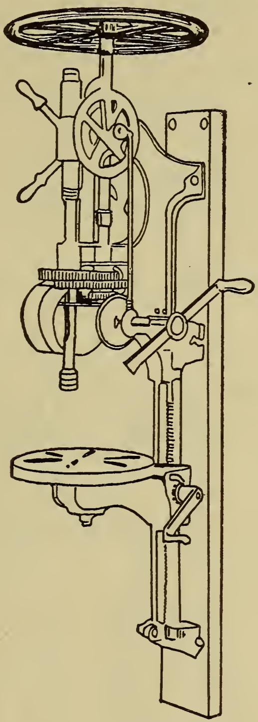


Figure 293.—Lever Drill.

can be readily drilled. It may be driven by a ½ H. P. motor.

Punch and Shear.—This is a machine tool, now made of armor plate steel and stronger than the old cast iron type which weighed four times as much. It is usually furnished with three punches, of varying sizes up to ½-inch, and is used for punching holes in plate metal, also for cutting metal rods and bars.

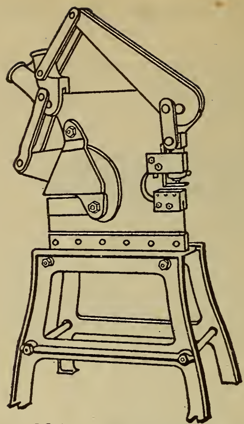


Figure 294.—Punch and Shear.

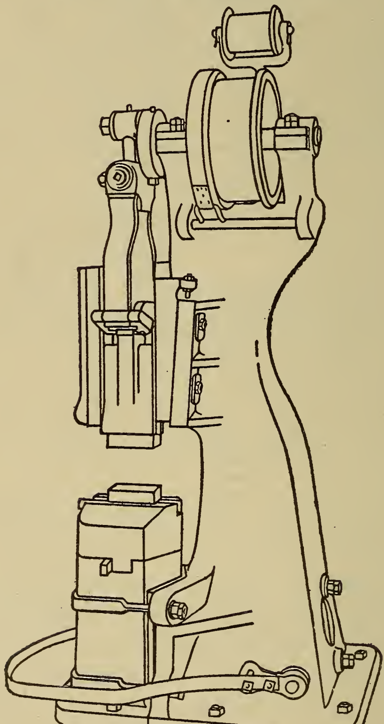


Figure 295.—Power Hammer.

Power Hammer.—This useful machine is designed for continuous service and can be operated at a very high rate of speed. Every working part is of steel. The ram of a typical machine is connected with spring arms,

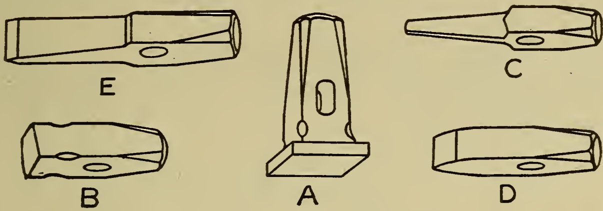


Figure 296.—Anvil Tools: *A*, Square Flatter; *B*, Set Hammer; *C*, Round Punch; *D*, Cold Chisel; *E*, Hot Chisel.

through which it gives a very elastic, cushioned, and powerful blow. It is started, stopped, and regulated by a foot treadle, through varying pressure on which any desired speed or force of blow is obtained.

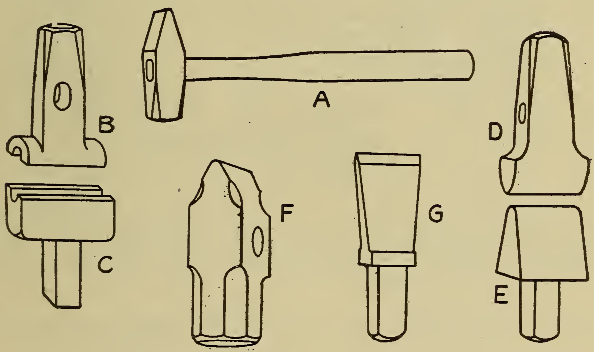


Figure 297.—Anvil Tools: *A*, Hand Hammer; *B*, *C*., Top and Bottom Swages; *D*, *E*, Top and Bottom Fullers; *F*, Sledge; *G*, Hardie.

Square Flatter.—This is a blacksmith's anvil tool used for smoothing and finishing flat forgings. Round flatters are also used on work where the corner of a square flatter would be in the way.

Set Hammers.—These are used for setting down the metal in a forging to form a square corner at a point where the section changes.

Swages.—Swages are used for shaping, sizing, and smoothing round forgings. Top and bottom swages are used.

Fullers.—These are used for necking and grooving forgings, and also for drawing down a forging to a smaller section.

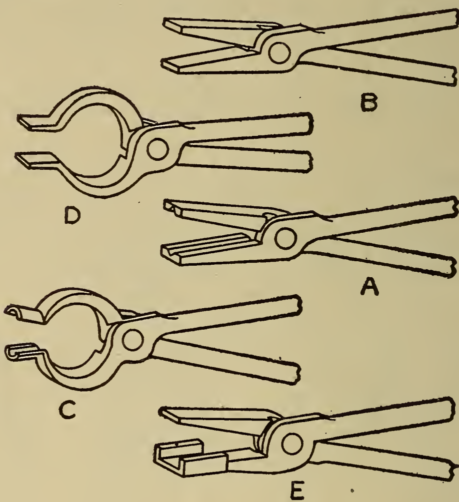


Figure 298.—Blacksmith's Tongs: *A,* Straight Lip, to Hold Squares; *B,* Straight Lip, for Holding Thin Flat Work; *C,* Bolt Tongs, for Round Work; *D,* Tongs for General Forging Purposes; *E,* for Holding Bar Stock When Forging Lathe Tools.

Sledge.—The sledge is the familiar blacksmith's large heavy hammer. A weight commonly used is 8 lbs.

Hardies.—These are tools which are set in the anvil and used for cutting off forgings.

Tongs.—Many forms of tongs are used in forging, including shapes for holding thin flat work, squares, bolts or other round work, bar stock, etc. The tongs used for general forging purposes are usually 18 inches long, with a flat jaw, but the smith often shapes his tongs himself to suit his individual needs.

Other tools used at the forge include the hand hammer, cold chisel, hot chisel, and round punch, with the uses of which every student is familiar.

NOTES ON IRON

Iron is the most important of the metallic elements, silvery white in color when pure, very tenacious, malleable and ductile. It was first produced in America in 1622 near the James River, Virginia. It is used in the industrial arts in four forms—cast iron, malleable iron, wrought iron, and steel, each form having its own marked physical properties, fitting it for a special purpose.

Cast Iron.—Cast iron is an alloy. It is often called pig iron because of the fact that it is molded in little bars or pigs as it runs from the furnace. The process of making this iron is that of smelting, or melting the ore in a blast furnace in connection with various fluxes, particularly limestone. These furnaces are from 50 to 60 feet high and are called "blast" furnaces because the blast is forced into them. This species of iron is extremely brittle and melts at a relatively low temperature; is crystalline in construction, and can only be used for such articles as may be made or cast in molds. It contains a large percentage of carbon and usually silicon, phosphorus and sulphur. The amount of carbon varies from 1.5 per cent to 4.5 per cent.

Malleable Iron.—Malleable iron is cast iron which has been toughened during the process of baking in an oven for six or eight days. This decarbonizes the cast iron.

Wrought Iron.—Wrought iron is the extreme of the series. It is an alloy of iron and comes the nearest to being pure, having an extremely small percentage of carbon, practically none. It is very malleable, fusing at a very high temperature; becomes pasty during a considerable range of heat; will keep in a malleable condition above a red heat, which is much below the fusing point, and thus can be bent and formed into different shapes with the hammer. Iron work produced in this way is called wrought iron. Wrought iron manipulated when hot is said to be forged. Two pieces brought to a fusing point may be united into one piece by hammering. Pieces so united are said to be welded. It will not become hard and brittle like cast iron, as it is of a fibrous construction; it shows a high tensile strength at a fracture. This iron is divided into two classes—common or refined iron and Norway iron. Wrought iron has been largely displaced for most purposes by the increased production of steel. The iron used in making the exercises in this course should be Norway iron, as better results are attained than by using common iron.

Puddling.—The general process of making wrought iron at the present day is known as "puddling." This process was invented about the year 1780 by Henry Cort, and improved about fifty years later by Joseph Hall. The method employed is one of melting cast iron in a chamber or on the hearth of a reverberatory furnace, the flame passing over the molten metal. The requisite time for this operation is about thirty minutes. When the metal becomes melted, an oxidizing metal is added. All phosphorus, sulphur, carbon, and other impurities may be eliminated by stirring. During the melting a slag forms and adjusts itself to the iron around each fiber, showing a fibrous rather than a crystalline structure. There are many varieties of furnaces of various capacities; the capacity of the most common size ordinarily being from 500 lbs. to 1,500 lbs.

THE ART OF HAND WELDING

Some metals, when heated, become gradually softer as the temperature increases, until a heat is attained at which the metal is in such a condition that if two separate pieces are brought into contact by slight pressure, they will adhere and form a single piece. Every metal is not

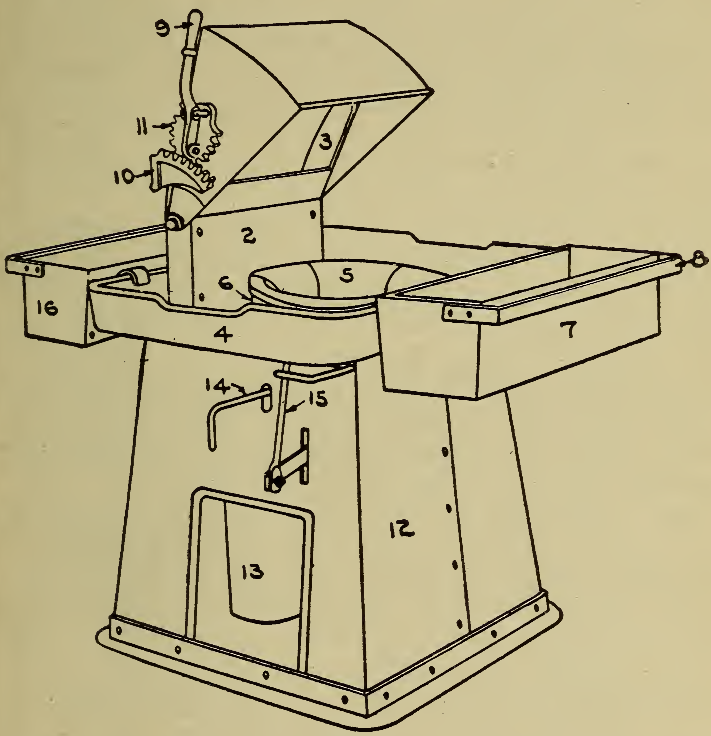


Figure 299.—Stationary Down-Draft Single Forge: *1,* Adjustable Hood; *2,* Stationary Hood; *3,* Front Plate; *4,* Hearth; *5,* Fire Brick; *6,* Fire Pot; *7,* Water Tank; *8,* Tool Rack; *9,* Adjusting Lever; *10,* Segment; *11,* Pinion; *12,* Base; *13,* Exhaust Pipe; *14,* Tuyère Lever; *15,* Blast Gate Lever; *16,* Coal Box.

affected in this manner. Cast iron, for instance, does not become gradually softer as the heat is increased, but remains firm until a certain temperature is reached and then softens suddenly and goes to pieces. Any metal which softens gradually when heated, may be welded, while metals which act as cast iron does, can not be welded.

Welding Heat.—The condition at which pieces of metal are ready to adhere, is known as the welding heat. The two pieces of metal properly shaped are brought to this welding heat, placed together and thoroughly hammered, or forged together by pressure in such a way as to bring the two pieces into contact at all parts of the weld. The weight of the blow must be governed by the size of the bar, as the blow must be sufficient to affect the metal from the surface to the center. With this precaution a good weld may be produced. It is necessary to make some of the most difficult welds at one heat, as it is often impossible to reheat. In all welding, the greatest care must be observed to heat the piece properly. A piece of wrought iron, when brought to a welding heat, is almost white, and little explosive sparks appear upon the surface. These little sparks are small particles of iron which become separated from the bar and burn.

Fire for Welding.—It is very essential to have and maintain a good fire on the forge during the process of welding. Good coal and material are among the essentials. The good fire is indispensable in order to attain the best results in welding. The tuyère iron, or blast pipe, must be well covered with coke and the fire must be absolutely free from all clinkers and well banked with green coal, burning up quickly to allow all gas to escape. Keep plenty of coke on top of the iron. Do not continually poke the fire.

Oxidation of Iron.—If a piece of iron is heated in contact with air, it will absorb oxygen from the air and form a scale upon the surface, which is known as oxide of iron. The hotter the iron, the more rapidly this scale will form. The scale does not adhere firmly to the iron and cannot be welded. Two methods are used to guard against oxidation. In the first, it is accomplished by having a thick bed of fire for the air to pass through before coming in contact with the iron and by maintaining a moderate blast. The second method is by coating the surface of the iron with a substance called flux, which lowers the melting point of the scale and makes welding easier. This flux is formed by a fusible mixture which offers protection to the iron. The most common flux for iron is clean, sharp sand and borax; the latter is used for fine work and steel.

To weld steel is quite a different proposition, for the welding temperature of steel is, on account of its greater fusibility, considerably less than that of iron. There are so many different kinds of steel that the same rule will not apply to all of them. Cast tool steel is the most difficult to weld.

The Scarf or Lap Weld.—This weld is the one usually adopted by smiths, and is the best when it is practicable. For most welding, the ends of the pieces must be so shaped that when welded together, they will form a smooth joint. This shaping of the ends is called "scarfing" and the shaped end is called a "scarf."

The scarfs should be so shaped that when placed together they will touch in the center, leaving the sides open. In this way the scale is forced out between the pieces. If the pieces should join on the sides and leave the center hollow the scale would be imprisoned, making a bad weld. Prior to making a scarf weld, the metal should be reinforced or upset, as far back as it is to be exposed to the intense heat. This upset allows for wasting away.

In case of failure to make a perfect weld at the first heat, then a second heat should be taken. No sign of the scarf should be seen on a perfect weld.

For ordinary lap weld the length of the scarf may be made one and one-half times the thickness of the bar. If the scarfs are long, the laps must be long. In welding a round bar, the scarf is made the same as the lap weld, except that the scarf should be drawn to a sharp point instead of to a chisel edge. This is done in order that the corners may not project beyond the edge of the bar when welding, thus causing considerable trouble.

Place the pieces in the fire with the scarf down, as the under side of the iron is always the hottest. Do not heat the iron too quickly, as it will come to a welding heat on the outside and yet not be thoroughly heated, so that when exposed to the air it will cool too rapidly.

When each piece has attained a clean, white heat, remove them, giving each a jar upon the anvil while the scarf is down, thus dislodging any dirt which may have adhered. Turn the one in the right hand over and place the other on top of it, bringing them together as quickly as possible. In putting the two pieces together, the point of one scarf should just meet the heel of the other. Hammer rapidly, in order that they may become united before the heat gets below the welding point. The cold anvil very quickly reduces the heat.

STEEL AND ITS MANUFACTURE

Steel is the name applied to carbonized iron, having a high tensile strength combined with elasticity. It was first made by the ancient Egyptians and other early races, by reducing very pure iron ore mixed with chopped wood, in clay crucibles, which were heated in charcoal fires blown by goatskin bellows. From this steel, the celebrated Indian sword blades were fashioned. No finer tool steel has ever been made.

The term "steel" as used in early times, designated a form of carbonized iron which would harden or "temper" when dipped in cold water, after having been heated to a red heat. This definition no longer holds good, as the carbonized iron produced by modern methods and used extensively in structural work, goes by the name of steel.

Up to the time of the invention of the open hearth process, the only commercial process of making steel was by decarbonizing cast iron, and then recarbonizing the resulting wrought iron in the cementation furnace.

Steel may now be defined as a metal produced by a complete fusion of iron or iron alloys, in a bath, the

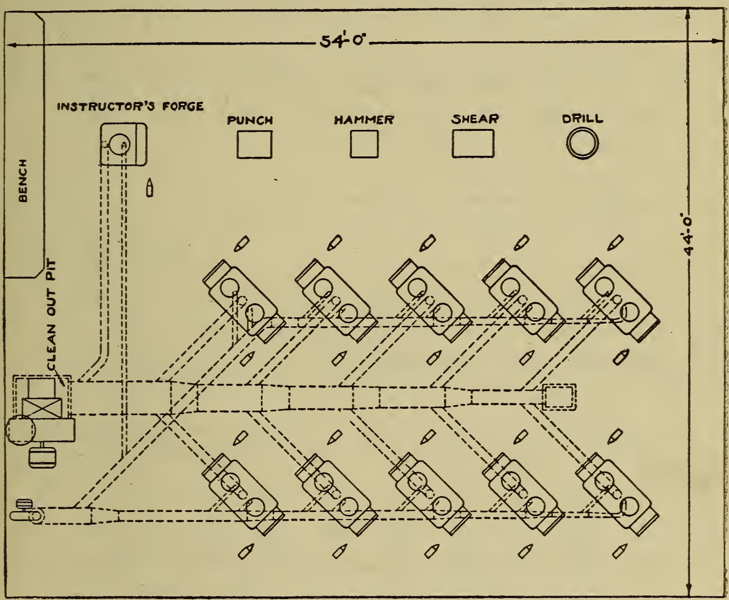


Figure 300.—Layout of Shop with Double Down-Draft Forges.

necessary properties being given after conversion by the addition of carbon or carbon alloys. Many theories have been advanced as to what steel really is. One held by many metallurgists is that "steel is an alloy of pure iron and carbon only," all other elements being regarded as impurities. Good steel is of a bluish, gray color, uniform in grain and having little luster.

There are three distinct methods used in making steel, the open hearth, the Bessemer, and the crucible. The latter is the oldest of the present methods of manufacture, having been in use for centuries. The first two methods are probably the ones most commonly used at the present time. In these, the carbon in the cast iron is burned out, while in the last method, the carbon is burned into the wrought iron. Other methods formerly

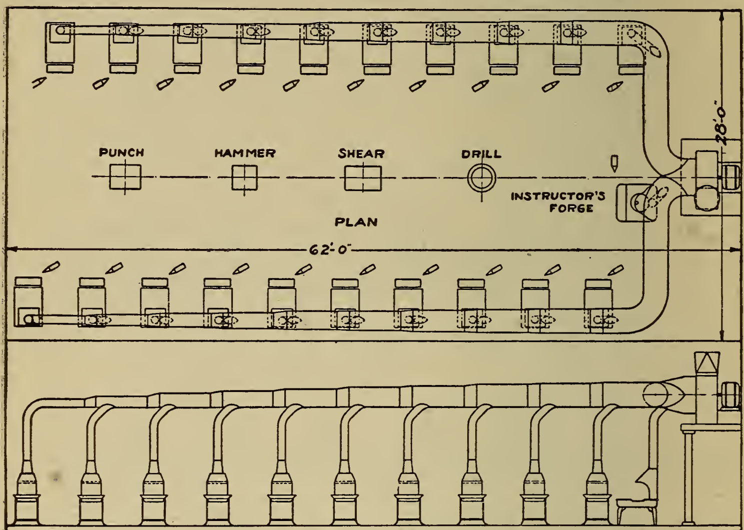


Figure 300A.—Layout of Shop with Induced-Draft Forges.

produced cement or blister steel and shear steel. In commercial importance, the processes rank, open hearth, Bessemer, and crucible. It was not until the open hearth and Bessemer processes came into use that steel began to supplant wrought iron to any extent.

Open Hearth Steel.—This method of making steel was discovered about the year 1845. It is under better control than the Bessemer process, since at any time it affords opportunity for testing and for making such additions as may be necessary to yield the desired product. The open hearth furnace also permits of the highest temperature without requiring a strong draft. These furnaces are built to hold from ten to fifty tons of metal. The time for an operation or "heat" is from eight to eleven hours. Steel rails, structural materials, plates, etc., are produced by this process.

Bessemer Steel.—The Bessemer process is named after its inventor, Sir Henry Bessemer, an Englishman, and was introduced in 1856. For many years after its introduction it ranked first among all the processes. Bessemer steel is made by decarbonizing cast iron by forcing a current of air through the molten metal in a pear-shaped crucible or vessel, called a "converter." There has been little change in the design of the converter from that originally used. A common size of this converter has the following dimensions: Diameter 8 ft., height 15 ft. It is made of boiler plate, lined with refractory material. It is suspended upon an axis to admit of its being turned from an upright to a horizontal position. In the bottom there are twelve tuyères, or blast pipes, which have to be replaced after about twelve to fifteen blows or heats.

The usual capacity of the converter is from six to fifteen tons of cast iron. The blast of air forced through the molten cast iron produces great heat. The resulting gas and flame escapes from the mouth of the converter, the combustion of carbon and silicon producing a temperature sufficient to keep the mass thoroughly melted, thus quickly burning out the carbon and silicon, this last result being indicated by the color of the flame. The molten metal is poured into a ladle and then there is added to it manganiferous pig iron, which reintroduces the necessary amount of carbon and manganese. This entire process takes about twenty minutes. It is then cast into ingots, and, after being treated in the reheating furnace or "soaking-pit," is rolled to the required thickness. Bessemer steel is used for nails, screws, wire, and in fact for all products where cheapness rather than quality is the requirement.

Crucible Steel.—Crucible or tool steel, the oldest and simplest process, takes its name from the methods employed in its manufacture. In this process, carbon is added to a low phosphorus and sulphur wrought iron. Swedish or Norway iron is used in preference to other kinds, as it has proved superior in making high-grade tool steel. This iron is cut into small pieces one inch long from flat iron bars, 2″x½″. These pieces are then placed in a clay crucible (sometimes a graphite crucible is used, although it is not as good) which is about 20″ high and 1 foot in diameter. A certain amount of powdered charcoal is mixed with these pieces, and the crucible is then tightly sealed and subjected to great heat, which melts the iron. After having remained in a molten state for some time, it is poured into molds and forms ingots, which are afterward rolled or hammered under a steam hammer into bars. This process has undergone but little change in all the years it has been employed, the only important change being a more direct method for introducing the carbon into the steel. In the main, however, the method now used is the same as that used centuries ago. Owing to the high cost of production, this method is now used principally for making high-grade tool steel. The elasticity of this steel makes it of use in many places where no other steel could be safely used.

Tempering.—The term "temper," as used by steel makers, refers to the percentage of carbon in the steel. It has a different meaning when used by the steel maker than when used by the hardener. In the steel mill, it means the amount of carbon the steel contains. The meanings have been tabulated by an authority as follows:

Very high temper	150-point carbon
High temper	100 to 120-point carbon

Medium temper	70 to	80-point carbon
Mild temper	40 to	60-point carbon
Low temper	20 to	30-point carbon
Soft or dead soft temper..........		20-point carbon

A "point" is 1/100 of 1 per cent of any element that enters into the composition of steel, so a 150-point carbon steel contains 1½ per cent carbon. In the steel mill such a steel is spoken of as 150 steel.

"Tempering," on the other hand, also denotes the process by which steel is brought to a previously determined degree of hardness. A steel chisel can be made so hard that it will cut another piece of steel; or so soft that driving it into a piece of hard wood will dull its point. This property of steel enables the mechanic to make it into tools suitable for any kind of work.

Steel is tempered by various means, all of which depend upon a heating and subsequent cooling of the metal. For instance, a piece of tool steel which is heated to a cherry red heat and then plunged into cold water, becomes very hard. If allowed to cool slowly, it becomes soft. Between these extremes all degrees of hardness can be obtained. Every tool is tempered to the hardness that makes it most useful.

When a polished piece of steel, hardened or unhardened, is exposed to heat in the presence of air, it assumes different colors as the heat increases. First will be noted a faint straw color, which changes to a deeper straw, then to a dark brown with purple spots, then to a dark blue, and finally to a light blue. These colors are due to a thin film of oxide that forms as the heat progresses. These colors are valueless, however, to the toolmaker unless the metal has first been cooled in a bath of water, oil, or some other liquid, when at a red heat. Drawing hardened steel to any of these colors is called "tempering." The following list of colors applies to all of the tools commonly made:

Color.	Tool.
Pale or light straw	Lathe tools
Dark straw	Taps, dies, milling cutters, etc.
	Woodworking tools (cooled in oil)
Purple	Center punch, stone drills
Dark blue	Cold or cape chisels
Light blue	Screwdrivers

Tool Tempering.—Let us now consider the tempering of a tool, taking for example the cold chisel, a tool widely known and generally abused. To obtain a good chisel, it must be properly forged at a comparatively low heat, and then hammered with light blows at the last until it has cooled considerably below the heat ordinarily used when metal is displaced. The object of the light blow on the cooling metal, is to close the grain or refine the steel, making it tough. Tools of this character stand up better if they are heated to a cherry red heat and allowed to cool before hardening. This is not always possible, but when it is, make the hardening heat a separate operation.

To harden, heat two-thirds of the part forged to a cherry red heat, using great care not to overheat the point, and then cool one-half of the blade in cold water; always move the tool about or set the water in motion, avoiding any danger of making a water crack at the water edge.

The next operation is to brighten one broad surface with an emery stick. A piece of emery cloth tacked over a stick of wood makes a very good polisher. The heat remaining in the body of the chisel will reheat the end already cooled, and the various colors will appear in order on the polished surface. The proper color for a cold chisel when correctly tempered, is dark blue. When this color is attained at the point the entire tool is then immersed in water and is not removed until cold. If the tool is not cooled off enough in the first operation, the colors will run down very rapidly and become compact, and if not watched closely, they will be gone before the tool can be cooled.

When a tool is to be hardened all over, it is first heated to a cherry red heat and then cooled. After brightening with the emery stick, place on a square or flat piece of hot iron. The tool will absorb the heat and the colors will soon commence to run. When the desired color is attained, cool again in water or oil. In a commercial plant where a great many tools of the same kind are made, and where the composition of the steel is known, a hardening bath is used.

Spring Tempering.—The method employed in hardening a spring in oil is as follows: First, heat to a cherry red heat, as in hardening in water; cool all over in oil; hold over the fire until the oil upon the surface blazes. This is called "flashing." Cool again in oil. This "flashing" is done three times before the process is complete. Another method of hardening a spring employs a water bath instead of the oil. Pass the spring over the fire or through a flame until it is hot enough to make a pine stick show sparks; then cool in water and a spring "temper" results.

Annealing.—The process of softening a piece of steel is called "annealing." A piece of steel is softened or "annealed" prior to being worked upon in the lathe or otherwise machined, as this process brings about a uniform softening, relieving any strain that might have occurred in forging. To anneal a piece of steel it should first be heated to a cherry red heat, and then allowed to cool slowly. When long pieces of steel, or a number of pieces, are to be annealed, and a furnace is employed, the pieces are placed in a long tube or pipe, and both ends sealed. They are then brought to a cherry red heat and allowed to cool. When a piece is heated in the forge, it is covered over in the annealing box. Dry slack lime or ashes can be used for this purpose, to keep out air.

COURSE IN FORGE PRACTICE

Care of Forge.—Operation of forge as to use of firepot, tuyères, draft and blast.

Building and maintaining fires for different classes of work. Production of coke for the fire. Removal of ashes and clinkers.

Elements.	*Suggested Problems.*
	Forge and Anvil.
Drawing.	Gaggers, staples, S hook, square angle irons.
Bending.	Form ring for subsequent welding.
Shouldering.	Tapering round irons for drafting holes in patterns.
Twisting.	Burning irons for fitting chisel handles. Pointing pokers, tapping irons.
Upsetting.	Eyelet drawing pins for lifting patterns.
Forming.	Pipe hooks, bolts of stock sizes.
Punching.	Hook for whippletree.
Chamfering.	Upsetting stock for subsequent tool holder.
Use of finishing tools such as swages, fullers, hardies.	Open square jawed wrench.
	Draw plates for bolts.
	Brackets for tool racks.
	Flat alligator wrench.
	Welding.
Scarfing.	Rings and links for whippletree.
Proper heat.	

Elements.	*Suggested Problems.*
Fluxes.	Stock scrap used to form bar iron.
Lap weld.	
Faggot weld.	Flat angle irons, gaggers.
Tee weld.	
Angle weld.	

Tool Steel.

Annealing heat.	Flat cold chisel.
Forging heat.	Cape chisel.
Hardening heat.	Center punches.
Case hardening.	Diamond point chisel.
Temper for cutting wood.	Wood turning chisel.
Temper for cutting iron.	Side cutting chisel.
High speed steel work.	Round nose chisel.

Vise Work.

Numbering and lettering work with steel stamps.	Angle irons.
Laying out and center punching for drilling on press.	Bolts.
Reaming.	Draw pins.
Cutting threads on bolts and draw-pins with die.	Draw plates.
Tapping draw plate.	Anchor plates.
Riveting.	Tool holder.

Drill Press, Shear and Grinder.

Getting out stock for standard jobs.	Iron plates of various kinds.
Drilling and countersinking.	Machine tool holder.
Grinding and finishing.	Lathe tools.

Elements.	*Suggested Problems.*
	Steam Hammer.
Drawing.	C-clamp. Crucible handles. Tongs, lever arm.
Upsetting.	Mast ring. Large open wrenches.
Forming.	Connecting rod. Single throw crankshaft.
Welding.	Hammer heads for machine shop stock.

Lectures and Recitations.—History of blacksmithing, sources of supply, machine forging, Bessemer processes, open hearth processes, high speed steel.

Visits of Inspection.—General jobbing shop, steam forge shop, drop forge shop, rolling mill.

EXERCISE NO. 1

Stock—Norway Iron—½″ x ½″—Convenient length.

Explanation.—One end of the stock is to be drawn until a length of 5″ or more is ⅜″x⅜″; 5″ of the drawn portion is then to be cut off on the hardie end, the cut end squared.

The finished piece, *A* (Figure 301), must be smooth, true to size, square in section and straight.

Operation.—Beginning near the end of the stock, strike every other blow on a given face, and the alternate blows on one of the adjoining faces. Occasionally turn the work so that the two faces previously on the anvil may be brought under the hammer.

To mark the work where it is to be cut hold the square to the edge of the hardie across which slide the stock as indicated by the arrow, *B*, until its end is opposite the 5″ mark on the square. Put down square, take up hammer, and strike a light blow. After this cut on all four

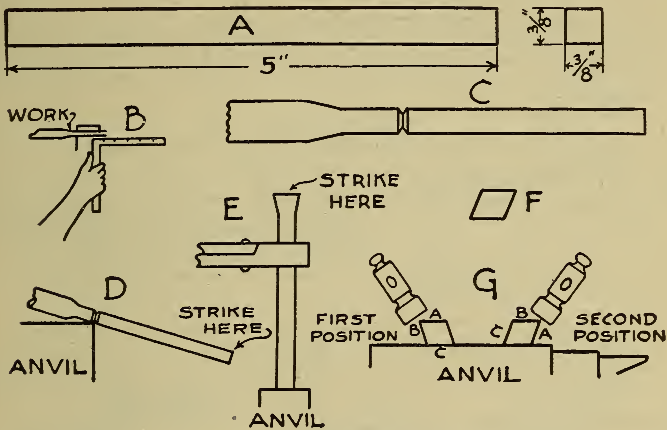


Figure 301.—Exercise No. 1.

sides, *C*. Break the piece off by bringing the cut over the edge of the anvil, *D*, and deliver a blow on the end of the piece.

To square the cut end, first upset, *E*, and then draw down to size.

Caution.—If it is discovered that the stock is becoming diamond shaped, *F*, instead of square in section, hammer on the high sides, *G*.

EXERCISE NO. 2

Stock—Norway Iron—½″ x ½″—5″ long.

Explanation.—Stock to be upset to 3″ in length. The finished piece, *A* (Figure 302), must be sound, must be square and uniform in section. True to size, straight, and smooth.

Operation.—The stock having been brought to a white heat, blows are to be delivered as shown by *B*. One result

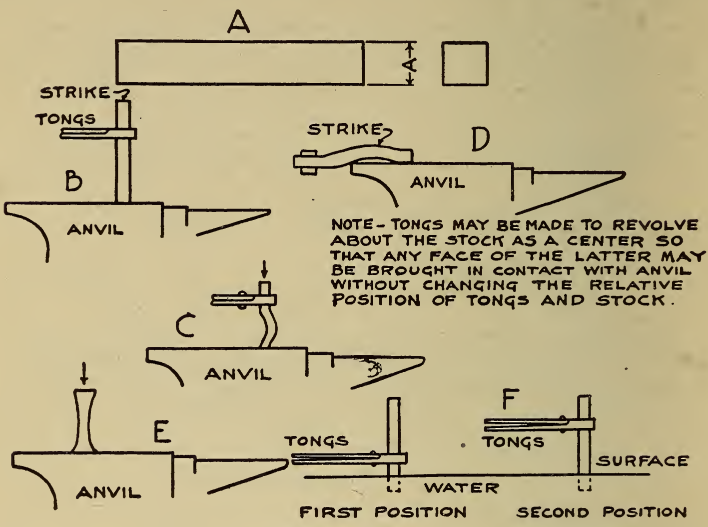


Figure 302.—Exercise No. 2.

of such blows is illustrated by *C*. The stock may be straightened without changing the tongs, *D*, or the tongs may be changed to one end. A second result of blows, *B*, is shown by *E*. This may be overcome and the piece upset evenly, by slightly cooling the ends, *F*.

Caution.—Do not work the stock after it has cooled to a bright red heat. Strike true or the stock is likely to fly from the tongs, endangering your own safety and the safety of others. Do not attempt to straighten unless the stock is hot. In straightening be sure that the work beds well on the anvil before striking it, otherwise it is likely to fly. Do not take so much time in cooling that, *F*, the body of the stock will become cool.

EXERCISE NO. 3

Stock—Norway Iron—½″ diameter—6″ long.

Explanation.—A round section is to be drawn to a square; a square to an octagon; and an octagon to a round point.

The finished piece must agree with the drawing, *A* (Figure 303), in form and dimensions.

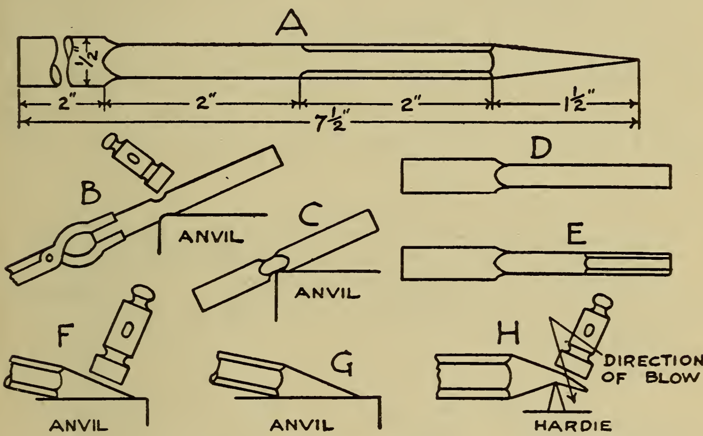


Figure 303.—Exercise No. 3.

Operation.—Square one end of stock (see *D*), make center punch mark 2″ from squared end. After heating with squared end of stock in tongs, bring center punch mark over edge of anvil and strike one blow, *B*. Turn the stock through an angle of 90° and strike a second blow, *C*. Draw the stock to a square section as shown by *D*.

Lay off center punch mark 4″ from squared end, and proceeding as before, produce the form *E*.

Lay off center punch mark 6″ from squared end and draw the point first to a square, *F*, and then to a round, *G*. If there is excess of stock cut it off on the hardie, *H*.

Caution.—Do not let the shoulders, *E*, cover the punch marks. Better form them a little in front of the mark and draw them back to it.

When rounding the point turn the stock; turn the stock first in one direction, then in the opposite, otherwise the point will be twisted off. The point will split if drawn at too low a heat.

EXERCISE NO. 4

Stock—Norway Iron—½″ diameter—5″ long.

Explanation.—A piece of ½″ round stock is to be upset until a portion of its length is large enough to form a ½″

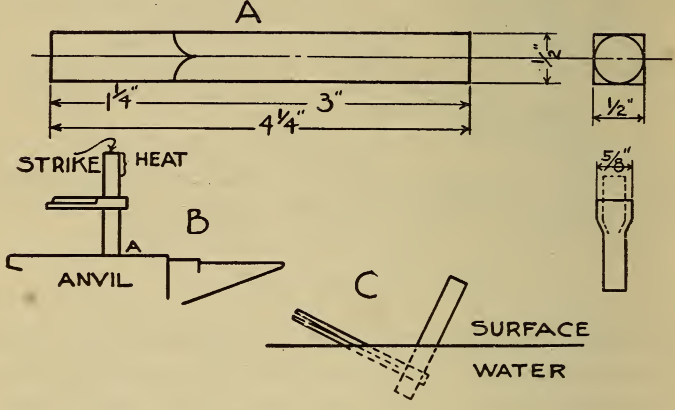


Figure 304.—Exercise No. 4.

square. The finished piece must agree with the drawing, *A* (Figure 304).

Operation.—Make a center punch mark 2″ from one end and heat from end to punch mark. Apply the tongs to the side of the stock before taking the latter from the fire. If the portion heated is too long, cool to punch mark, *C*. In any case cool the extremity of the heated end slightly, to avoid the effect illustrated by *F* (Figure 302). Strike as shown by *B* (Figure 304). Continue to upset until the enlarged portion is about ⅝″ in diameter, then draw to a square. If when down to size, the corners are not sharp, upset again. By drawing they will become sharp. The square portion completed, finish the opposite, *A*, in the illustration, *B*.

Caution.—If it is necessary to cool the stock to the punch mark, *C*, give it a very slight up end motion, so that the change from hot to cold may not be too abrupt. Otherwise the stock is likely to crack on the line of the surface of the water.

EXERCISE NO. 5

Stock—Common Iron—¼″ diameter—8¼″ long.

Explanation.—A piece of ¼″ stock is to be bent to a circle. The finished piece, *A* (Figure 305), must be free

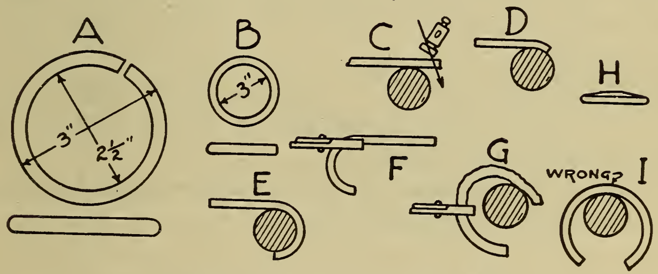


Figure 305.—Exercise No. 5.

from hammer marks, as nearly a true circle as possible, and "out of wind."

The blacksmith's rule for finding the length of stock for an unwelded ring is "3 x inside diameter + 3 x width of stock": In this case, (3 x 2½″) + (3 x ¼″) = 8¼″. If the ring is to be welded, one half the thickness is added.

This rule applies to rectangular sections as well as to round sections. For example, suppose the ring, *B*, is to be made. The necessary stock will be 3 x 3″ (inside diameter) + 3 x ¼″ (width) + 1½″ (half the thickness) = 10¼″.

Operation.—Heat to a cherry red about half the length of the stock. Allow the end of the heated portion to project about ⅜″ over the horn, and strike as shown by *C*, with the effect shown by *D*. Advance the stock over the horn after each blow until half the stock is bent, as at *E*. Change the stock in the tongs, *F*, and repeat the operation. The result will be a ring more or less round.

An examination will show that some portions of the stock are bent too short, while others are not short enough. To unbend the stock when the curve is too short, strike as shown by *G*.

Having completed the ring as seen in plan, examine it in elevation. If it is "in wind" it will appear as shown in *H*. To get the ring out of wind hold it flat on the face of the anvil and strike with light blows the *low parts*, which will then seem to rise to the level of the adjoining portions.

Caution.—As there is no opportunity to smooth the work by hammering, the stock must not at any time be heated hot enough to scale.

Never strike the stock directly over the horn, *I*, as such blows can have no bending effect.

EXERCISE NO. 6

Stock—Norway Iron—⅜″ x ⅜″—5⅝″ long.

Explanation.—The finished piece must be smooth and must agree with the form and dimensions shown by *A* (Figure 306).

Operation.—Lay off punch marks as shown by *B*.

Guided by marks, draw the stock to the form shown by *C*. To bend the large eye, *A*, first set the stock back as shown by *D*, then begin at the end and bend, as in *E*.

The small eye, *A*, is to be formed in the same way. To twist the body, heat between the punch marks *C* and *D*, in *B*, to an even dull red, drop one end of the stock in

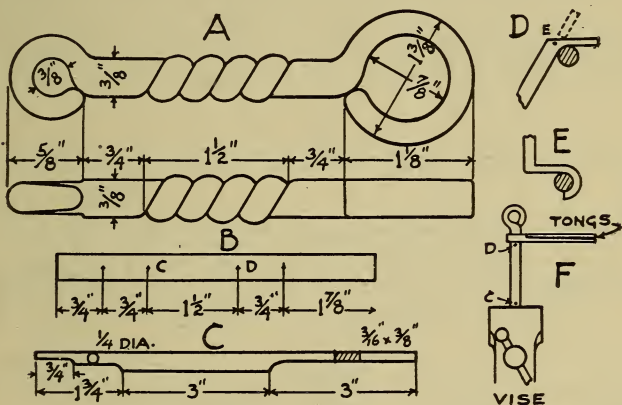


Figure 306.—Exercise No. 6.

the vise to the punch mark *C* and apply the tongs at the punch mark *D*, all as shown by *F*; then carry the tongs once around and the twist will be made.

Caution.—In setting back the stock, *D*, be careful that the blows do not fall directly over the horn; unless care is exercised the stock will be reduced at *E*, in *D*.

After the stock has been fastened in the vise for twisting, the operation must go on rapidly; if too much time is taken the vise will absorb heat from the stock and the twist will be uneven.

EXERCISE NO. 7.

Stock—Norway Iron—3/8″ x 1″—Convenient length.

Explanation.—The stock is folded to form three thicknesses, *H* (Figure 307), which are to be welded together. The welding finished, the welded portion is to be cut off and brought to the form and dimensions shown by *A*.

Operation.—Lay off center punch marks *A* and *B*, in illustration *B*, and repeat *B* on opposite face. With the

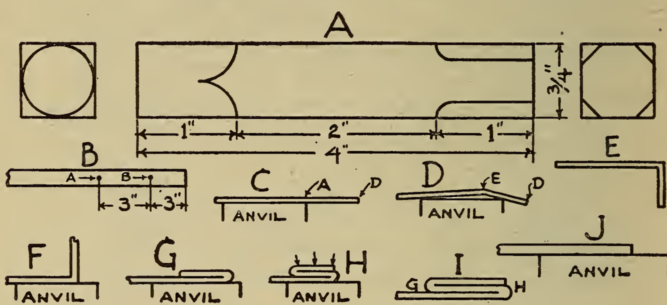


Figure 307.—Exercise No. 7.

stock at the point *A*, at a white heat carry it over the rounded edge of the anvil, as in *C*, and bend first by striking at *D*, in *C*, and then at *E*, in *D*, and so on until the form, *E*, is produced. Next strike *F*, producing the form, *G*.

Guided by the punch mark *B* and operating as before, produce the form, *H*.

Secure a welding heat over the whole piece and strike with heavy blows as shown by arrows, in *H*. Stop striking the instant the stock has cooled below a welding heat. Before taking a second welding heat, peen the joints between the layers as shown along *GH*, in *I*. The joints on both faces having been peened, take a second welding heat and after delivering two or three blows as shown by the arrows, *H,* turn the work and deliver the blows on the edges, as in *J.*

When the welding is completed, draw the piece to ¾″ square; cut off the ragged ends, making the stock 3⅞″ long.

Locate a punch mark 1″ from each end and draw to the form shown by the finished piece, *A.*

If, after welding, the stock is less than ¾″ square, allowance must be made for upsetting, before cutting it off.

Caution.—Be sure that the welding heat is where it is wanted and that the different pieces to be welded are equally heated.

Remember that every blow delivered after the welding heat is gone unnecessarily reduces the stock, which is thus likely to come "undersize" before it is finished.

EXERCISE NO. 8

Stock—Norway Iron—1 Piece ⅜″ x 1″—3″ long.
1 Piece ⅜″ x 1″—Conv. length.

Explanation.—A three-inch piece is to be welded to the end of a longer piece, forming a "scarfed weld." The welded portion is to be cut to length and finished as shown by *A* (Figure 308).

Operation.—The finished piece is to be of the same cross section as the stock. The latter must therefore be upset enough to make up for waste in welding, *B.* The proper form of scarf is known by *C.* To produce it carry the stock to the edge of the anvil and draw as indicated by *D,* striking on the edges as much as may be necessary to keep them from spreading beyond the width of the stock. The scarfed ends of both pieces having been brought to a welding heat, they are to be "struck" as follows: First, with the tongs holding the shorter piece in the right hand, and longer piece of stock in the left hand (the scarfs of both being down in the fire) draw both out and give them a sharp rap on the anvil, *E*, to remove coal, etc., from the surface of the scarfs. Next bring the short piece to the position shown by *A* in *F*, and follow with the longer piece to the position of the dotted outline *B*. Without losing contact between the longer piece and the anvil, bring *B* down upon *A* as shown. The contact with the anvil assists in controlling the movements of *B*. When *B* is once placed on *A*, a little pres-

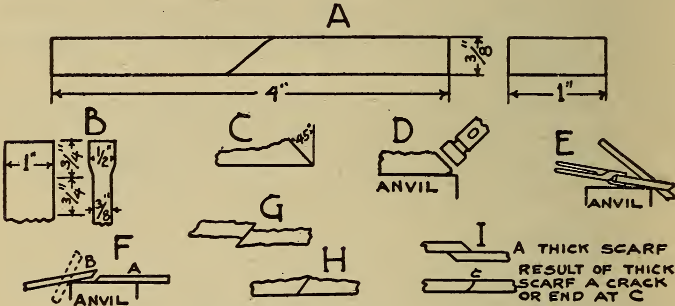


Figure 308.—Exercise No. 8.

sure on the former will hold both in their relative position, while the tongs are dropped, as in *F* (thus relieving the right hand) the hammer taken and a blow delivered in the direction of the scarf. The amount the pieces should lap is shown by *G*. As soon as the pieces are stuck the ends of the scarf must be brought down, *H*, and if thick must be peened out to the edge, shown by *H*.

Draw to size (3/8″x1″); square the end beyond the weld, measuring from the squared end, cut the stock to length, and square the cut end.

Caution.—Do not make the scarfs too long; increasing their length increases the length of the portion to be welded. They are sufficiently long when they may be hammered down without cutting.

EXERCISE NO. 9

Stock—Common Iron—½″ diameter—9″ long.

Explanation.—A piece of common iron is to be bent to a ring and welded. The finished work must agree with the form and dimensions shown by *A*, Figure 309.

Operation.—Upset the stock at both ends as shown by *B*. If a scarf for round stock be made the same as for square or flat stock, *C*, that of one piece will fold itself

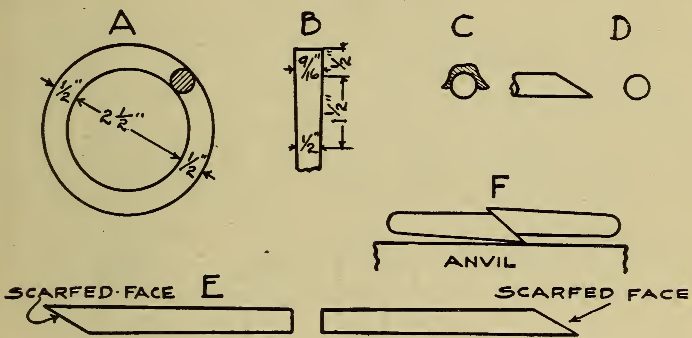


Figure 309.—Exercise No. 9.

about the other piece so that in welding the hammer must follow around the stock before all parts are reached: moreover, the effect of a blow on any portion of the scarf, *C*, tends to spread other portions, as at *B*, away from the center of the work. These difficulties are avoided by making the scarf end in a point which may be easily covered by the hammer. *D* may be considered a typical form for round stock. It is best drawn by using the hammer on three faces only. The ends must be scarfed in opposite directions as shown by *E*.

Bend the stock so as to bring the scarfs in the relative positions shown by *F*. Thus bent the piece may be welded entirely on the face of the anvil, after which it may be drawn to a uniform section on the horn.

To make the ring round, heat it to a dull red, press it as far up on the horn as it will go and turn it slowly while it is being lightly hammered.

Caution.—Common iron cannot be worked at a low heat and it will not stand a very high heat. For upsetting it must be nearly to a welding heat. For welding it must be taken from the fire as soon as it is hot enough to stick.

EXERCISE NO. 10

Stock—Norway Iron—½″ x ½″—8½″ long.

Explanation.—It is easy to bend a piece of stock so that one part will stand at right angles with the other, but it is not easy to draw the stock to a sharp corner as in *A,* Figure 310. This is the essential feature of the

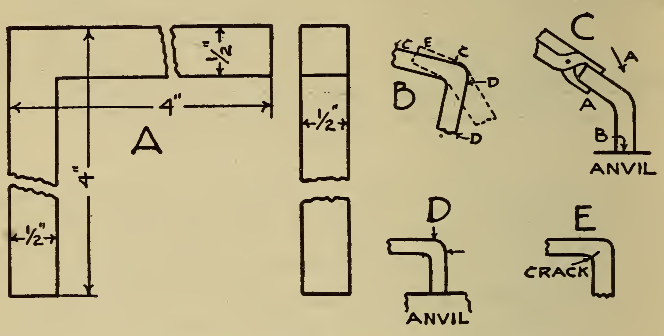


Figure 310.—Exercise No. 10.

exercise. The finished piece must be sound and square and must agree with the drawing in form and dimensions.

Operation.—Heat the piece in the center; cool the ends and bend the sides to angle of about 110°, as in *C.* Hold an end of the piece, *A,* in the tongs, and resting the other end, *B,* on the anvil, deliver a series of blows in the direction of the arrow *A.* Then hold the piece by the other end, *B,* and with the end *A* on the anvil, deliver blows as before. Such blows will tend to produce a surface as *CD,* in *B,* which may be worked down to meet each other. As the surfaces come to a corner, bend the sides in so that they will be at an angle of 90° at the same time the corner is formed. Cool the ends back about two inches every time after heating, to keep them in shape as much as possible. When the corner is square make the parts straight and square with each other. Square the ends, cutting them to length if necessary.

Caution.—In drawing the corners do not, at first, have the angle any more accurate than is shown in *C* and do not at any time deliver blows directly down as indicated by *D.* A mistake in either of these respects will result in a crack as indicated by *E.* Moreover do not attempt to forge the inside corner sharp; a corner thus forged not only offers a starting place for a break when the finished forging is under strain, but in most cases the process of making starts the crack.

EXERCISE NO. 11

Stock—Norway Iron—1 Piece ¼″ x 1″—3¾″.
1 Piece ¼″ x 1″—4¾″.

Explanation.—The exercise gives practice in welding two pieces at right angles with each other as shown by *A,* Figure 311. The finished piece must be sound, must have a good weld and must agree with the drawing in form and dimensions.

Operation.—Upset both pieces as shown by *B.* In scarfing the important thing is to have such parts of each piece that are to lap on the other piece drawn to an edge so that there will be nothing on one piece to cut into the other. This will be better understood by reference to *C* which shows the pieces scarfed. See also *D.*

Before taking a welding heat, practice taking the pieces from the fire and placing them together (See Figure 308, *E* and *F*.) When the weld is made, smooth and form to dimensions.

Caution.—Be very sure that you stick the pieces in their proper relative position. Be sure to get the pieces

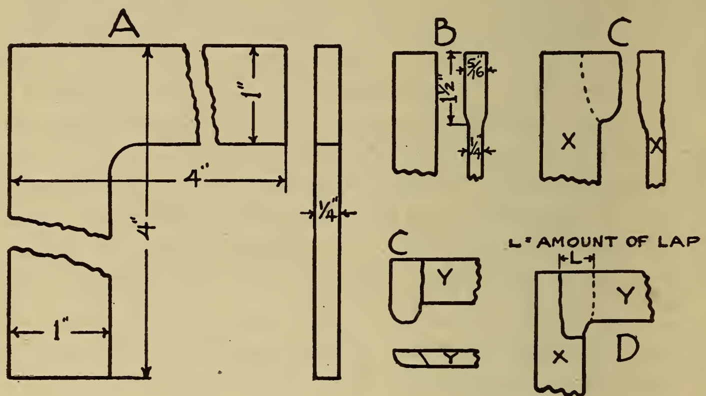


Figure 311.—Exercise No. 11.

scarfed as shown in *C,* unless for a left-handed person. In this case the scarfs must be opposite to these shown in *C,* so that the piece *Y* may be held in the right hand and placed upon the piece *X*.

EXERCISE NO. 12

Stock—Norway Iron—1 piece ¼″ x 1″—5″—called X.
1 piece ¼″ x 1″—4″—called Y.

Explanation.—This exercise, while similar to the preceding, is more difficult in heating and welding. The finished T should agree with the drawing, *A*, Figure 312, in form and dimensions.

Operation.—Upset X as shown by B, and Y as shown by Figure 312, C. Scarf as shown by D. The pieces should be lapped for welding so that the points A will agree with points A', D.

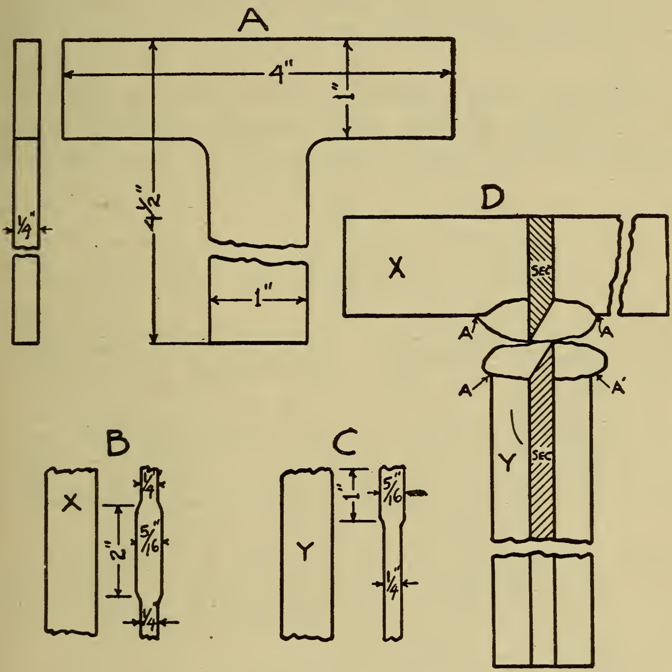


Figure 312.—Exercise No. 12.

Caution.—Difficulty is experienced in heating X at the scarf, it being easier to heat the end. The fire should be small so that the end may be passed through it. If in spite of precautions taken the end does heat faster than the scarf, cool it before it reaches a welding heat.

EXERCISE NO. 13

Stock—Norway Iron—3/8″ x 1″—any length.
Steel 3/8″ x 1″—4″.

Welding steel to iron and steel to steel.

Operation.—Draw the stock 3/4″ x 1/2″ and scarf one end of each as for a scarf weld. Draw the iron 2″ from the end.

Welding.—When welding steel, borax is used as a flux, to prevent the steel from burning. Heat the iron to a red heat before putting the steel in the fire. When the

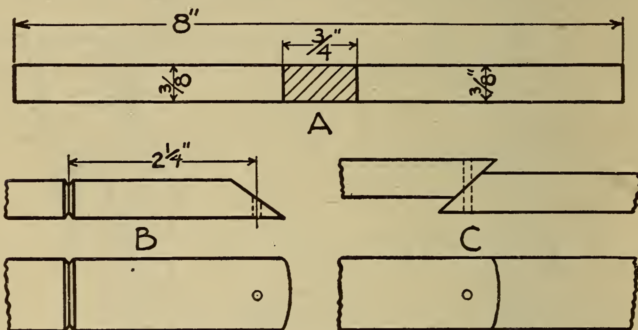


Figure 313.—Exercise No. 13.

steel becomes bright red put on the flux and replace it in the fire. Watch it carefully and when small white blisters are seen coming on its surface it is at the proper heat to weld; be sure that the iron is brought to the proper heat at the same time. After this weld is made scarf and punch the end of the steel as shown by Figure 313, *B*, and cut off 2 1/4″ from the end; scarf and punch the end from which the piece was cut off, rivet the pieces as shown in *C* and it will be ready to weld. Weld and draw the whole piece to the form and sizes given in *A*.

STEEL FORGING

The Fire.—The fire should be kept clean and well banked; the coal should be well coked before the steel is put into the fire. Do not let the fire get hollow, but keep a good bed of coals for the work.

Heating.—Keep the steel well covered with coals: heat slowly by using light draft. Turn the steel occasionally so that it may be heated evenly. Never heat hotter than a cherry red, as overheating destroys the good qualities of the steel.

Forging.—Steel forging is similar to iron forging. Heavy blows should be delivered so that the piece may be formed with as little heating as possible. Never hammer the steel after it loses its redness.

EXERCISE NO. 14

Stock—Norway Iron—1½″ diameter. Finished Piece, from Exercise No. 4.

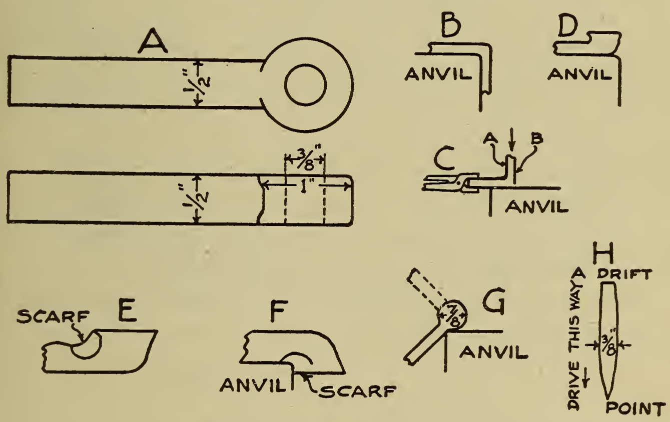


Figure 314.—Exercise No. 14.

Explanation.—The finished piece must agree with Figure 314, *A*, in form and dimensions.

Operation.—Make center punch mark 1½″ from round end, heat to a white heat, place the mark over the edge of the anvil, and bend as shown by *B*. Deliver blows as indicated by *C*, taking care that they fall in line with the stock, and that latter does not bend in any direction, as for example, in the direction *A* and *B*. When the stock is reduced to the proportions shown by *D*, draw the scarf, as in *E*.

Deliver one blow as indicated in *D*, and then turn the stock and strike as shown by *F*. Draw the eye to the proper thickness and make it round in plan, as in *G*. By punching, the diameter of the eye will be increased by nearly ⅛″ so that at this stage its diameter should be ⅞″.

In punching the hole work from one side until a dark spot appears on the other side under the punch, then turn the work over, and guided by the dark spot, start the punch in the opposite direction. When the punch is well started, bring the stock over a hole in the anvil so as to allow the little button that is formed to drop out. The punched hole will agree with the taper of the punch; to make its diameter uniform drive a drift-pin, as in *H*, entirely through. The drifted hole will correspond to the largest diameter of the drift-pin.

Caution.—If the scarfing is not properly done, the stock will be cut where the eye joins the body. Do not keep the punch too long in the work; strike two or three sharp blows, then dip the punch in water.

If the punch becomes hot it will upset in the stock so that it cannot be easily withdrawn.

EXERCISE NO. 15.

Stock—Norway Iron—⅜″ x ⅜″—Convenient length.

Explanation.—This exercise in nail making affords excellent practice in the use of the heading tool. Five nails are to be made, each as nearly as possible of the form shown by *A*, Figure 315.

Operation.—Draw the stock to the form shown by *B* and try it in the heading tool to make sure that it will enter to the shoulder, leaving sufficient material above the shoulder to form the head. Cut all around as shown by *C*. Heat between the shoulder and cut, thrust the stock into the heading tool, and by a forward and back-

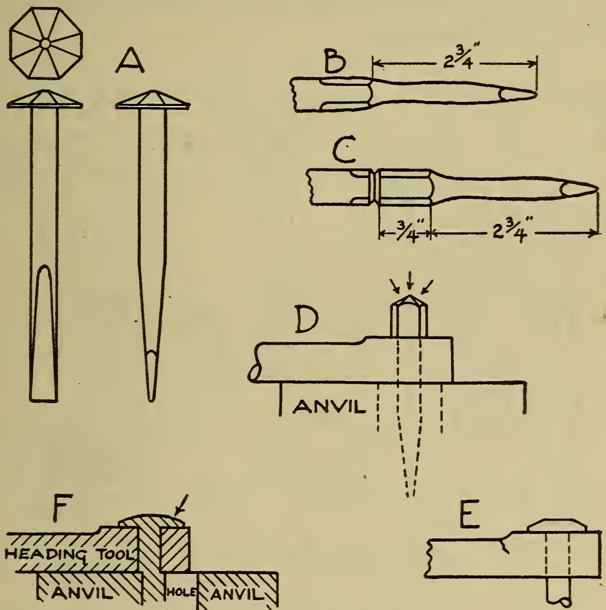


Figure 315.—Exercise No. 15.

ward movement, break it off at the cut. Deliver blows as shown by *D* to make the head.

If it is found that the head is formed on one side of the body, *F*, draw in the proper direction by blows as indicated by arrow.

By a little practice one can make a nail at a single heat.

Caution.—Do not allow the nail to become injured by the conditions illustrated by *F*.

EXERCISE NO. 16

Stock—Norway Iron—½″ diameter, 6¼″ long.

Explanation.—The finished piece is shown by Figure 316, *A*. The body must be straight and concentric with the head. If the proper amount of stock is not secured in the head, its diameter should be maintained at the expense of its thickness.

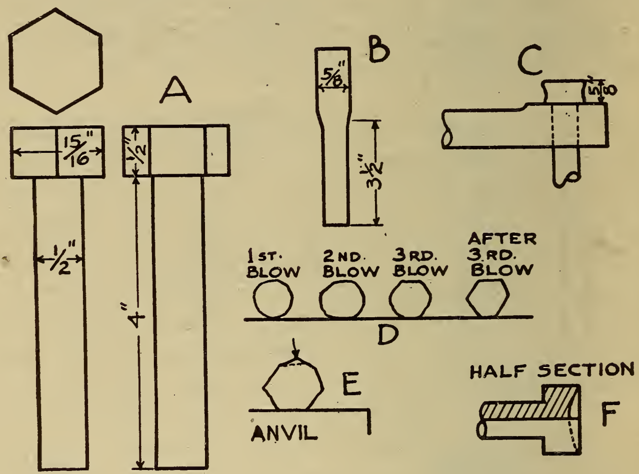


Figure 316.—Exercise No. 16.

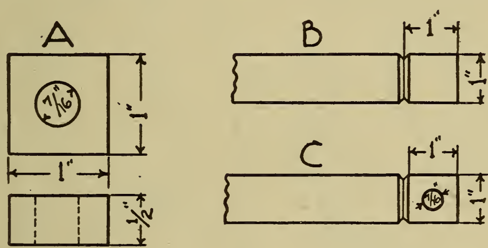
Operation.—Upset as shown by *B*. If the end in *B* becomes battered or upset, it must be drawn to its original diameter. Forge to the form shown by *C*, taking care that the upset portion is in the center of the stock. See *E*. Take the stock from the heading tool and strike three blows as indicated by *D*. If the surfaces thus produced are an equal distance apart continue to draw them without regard to the diameter of the head, until the proportion of the head in plan is satisfactory. If it is found that some of the faces are becoming wider than others, draw as shown by *E*. After getting the form in plan, use heading tool again to bring the head to thickness. So continue until the head is finished.

Caution.—Be careful that in using the heading tool the first time, *C*, the stock is not made too thin. The center of the head cannot be thickened: the most that can be done if it is once made too thin is represented by *F*.

EXERCISE NO. 17

Stock—Norway Iron—1″ x ½″—Convenient length.

Square Nut.—Finished to dimensions and form of *A*, Figure 317, process shown by illustration.



Stock—Norway Iron—1″x⅜″—Convenient length.

Hexagon Nut.—Finished at form and dimensions of *D*, Figure 317; process shown by illustration.

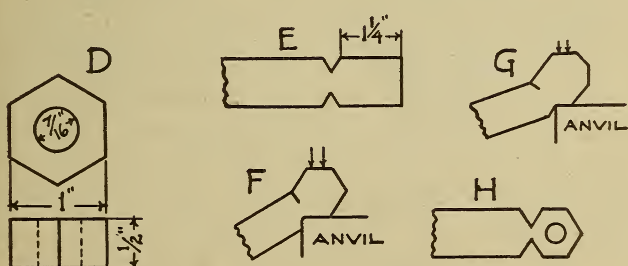


Figure 317.—Exercise No. 17.

EXERCISE NO. 18

Stock—Norway Iron—3 Pieces—$\frac{5}{16}''$ diameter—6″ long.

Three links of a chain, shown in *A*, Figure 318, form the finished piece.

Operation.—Upset each end of the piece, taking one heat for each end. Heat the piece in the center, cool

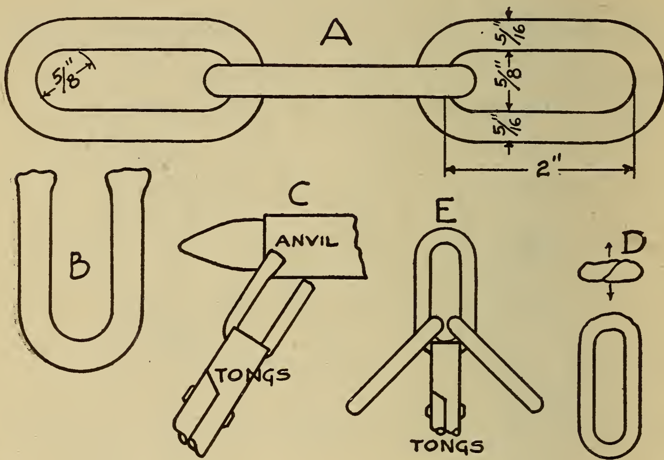


Figure 318.—Exercise No. 18.

about 1½″ of each end and bend to the shape of the letter U, as in *B*.

In scarfing the ends, place one end upon the sharp edge of the anvil, as in *C*, and striking light blows, swing the piece around, bringing the toe of the scarf to a thin edge. After one end is scarfed turn the piece over and scarf the other in the same manner. Bend the scarfed ends over the horn of the anvil so they will lap as shown by *D*.

Weld and finish two links each independent of the other and complete in itself. Bring third link to the form of *D*. Spread the ends in the direction shown by arrows and slip on the finished links. Apply the tongs as shown in *E*, close the ends of the link, and weld. In finishing see that the links are of the same size and form.

EXERCISE NO. 19

Stock—Norway Iron—⅜″ x 1″—4½″ long.

The hook as shown by *A*, Figure 319, is the finished piece.

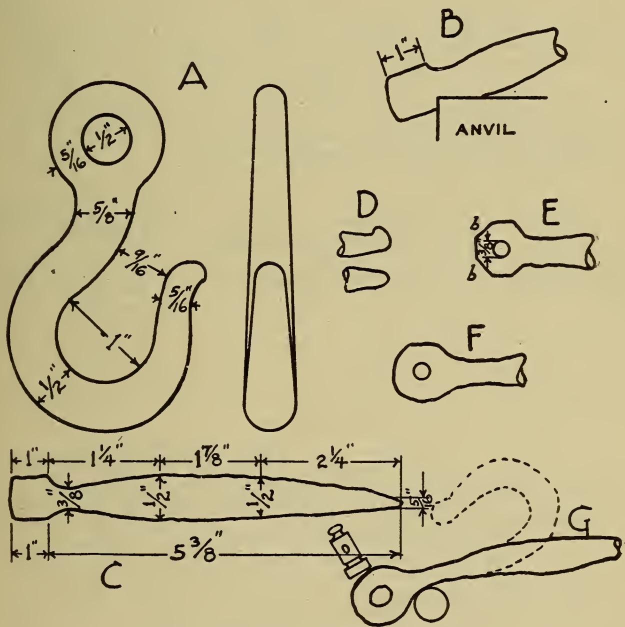


Figure 319.—Exercise No. 19.

Operation.—Lay off center punch mark 1″ from one end. Heat and draw first to the form shown by *B*, then to that shown by *C*. Set over the end, *C*, and finish as shown by *D*.

Cut the corners, punch the hole, as in *E* and draw the eye on the horn to the form shown by *E*.

Heat at *O*, in illustration *F*, cool the eye and bend as shown by *G*. Complete the bending as indicated by the dotted lines in *G*.

EXERCISE NO. 20

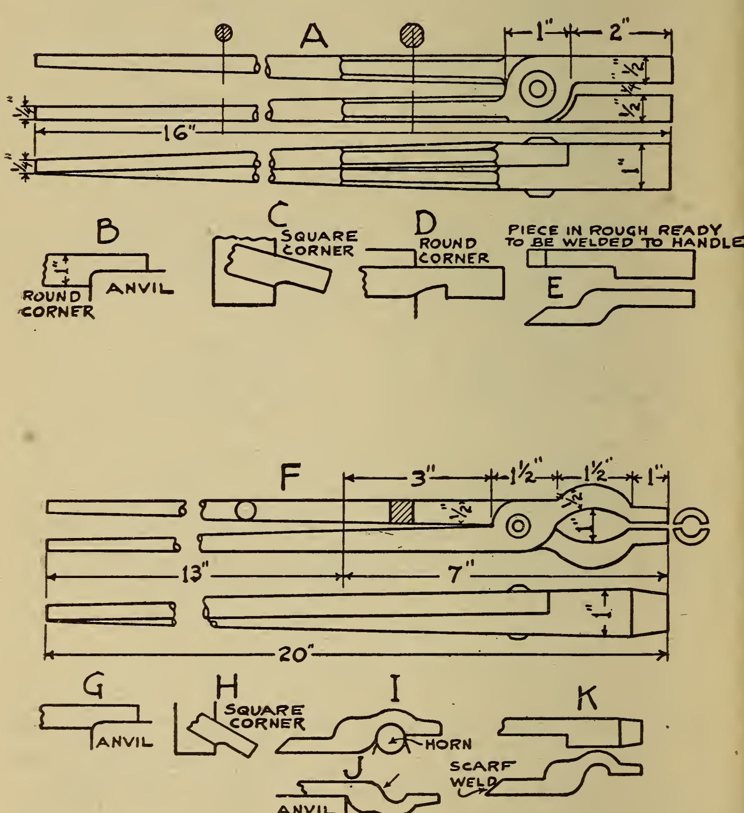


Figure 320.—Exercise No. 20.

Stock—Norway Iron— 1″ x 1″—8″,
½″ x ½″ x 8″—2 pieces.

Tongs.—Finished to size and form of *A*, Figure 320. Process shown by illustrations: the two pieces are made alike and joined by a ⅜″ rivet. Illustration *A* shows position of weld in finished piece.

Stock—Norway Iron—1″ x 1″—8″—½″ diameter, 13″—2 pieces.

Tongs.—Finished to size and form of F. Process shown by illustration: the two pieces are made alike and joined by a ⅜″ rivet.

X

OUTLINE COURSE IN HAND FORGING AND WELDING

EMERGENCY WAR TRAINING

This course of training, as recommended by the Federal Board for Vocational Education, Washington, D. C., is intended to prepare men for the field and base units of the Army. Reliable work quickly done is the requirement. How much of this course a man can cover in a given time depends on his previous experience. A green man probably could not cover all that is given here in the time specified. In any case, sufficient practice should be given to develop confidence and to get work right the first time.

Army work consists chiefly of repairs of all kinds of equipment and is similar to that of the jobbing blacksmith. Motorcycle, automobile, truck, gas engine, and wagon repairs are probably the most common.

Methods of Conducting Class.—The work must consist largely of actual practice. What oral instruction is given should be largely demonstration. The following is suggested as a daily schedule:

8 to 8:30. Instruction and demonstration.
8:30 to 12. Forge practice.
1 to 1:30. Instruction and demonstration.
1:30 to 5. Forge practice.

(*Note.*—The first part of the course will require more time for instruction before the class. Later the important thing is practice.)

Emphasis should be laid upon working direct from the broken piece or sample and from rough sketches rather than from finished drawings. Practice on a portable forge should be given.

In case of congestion, it would be possible to assign one or more men as helpers. It is not desirable to work more than one man at a forge at one time, but the men may act as helpers in rotation. One instructor should be available for every 24 men.

Equipment.—The equipment necessary is that of a good trade school or commercial shop, approximately as follows:

One forge, anvil, and tools for each man.

One hand shear, one cone, and one swage block for every 15 men.

One portable forge for every 15 men.

FUNDAMENTALS

Give careful instruction about building a fire. Insist on clean, deep fire of thoroughly coked coal. Keep the fire no larger than necessary for the work being done.

Lesson 1.—Heat and draw out stock to increase its length by at least ¾ inch, using stock ⅝ or ¾ inch diameter.

Lesson 2.—Point iron or soft steel ⅝-inch diameter with cone point and square pyramid point, making taper 1½ inches in length. Points must not be split or twisted.

Lesson 3.—Shape stock ⅜-inch round into S hook, and staples with square points.

Shape stock ¼ inch square into twisted gate hook.

Insist on good proportions and symmetry.

Lesson 4.—Upset stock ⅝ by ⅝ by 5 inches till it is 4 inches long and uniform section.

Upset stock ⅝-inch diameter by 5 inches till it is 4 inches long and uniform section.

Lesson 5.—Upset and form standard bolt heads (both square and hexagonal) on stock ½ or ⅝ inch diameter. Use heading tool.

Lesson 6.—Make standard nuts (square and hexagonal) for ½, ⅝, and ¾ inch bolts. Have hole central and tap drill size.

Lesson 7.—Make bolts with standard square and hexagonal heads by welding on stock for heads. Size ¾ inch or over.

Lesson 8.—Weld square and round stock, size ½ to ⅝ inch, with and without helper. Have finished welds full size and thoroughly welded. Test by bending.

Lesson 9.—Chain ring, stock ½ inch. Ring to be round and uniform in section. Make several ⅜ inch single chain links. Keep the links uniform in size, shape and section.

Lesson 10.—Chain 4 feet of ⅜ inch. Keep links small, uniform, welds sound. Attach ring from No. 9.

Lesson 11.—Grab hook, stock ⅝ inch square. Punch the eye and bend to shape. Attach to chain No. 10. C hook, weld, eye.

Lesson 12.—Make band ring 5 inches inside diameter and flat ring 5 inches outside diameter. Stock ¼ by 1 inch. Shrink band ring on flat ring. Make band ring smaller, if necessary, by heating and cooling first one edge and then the other.

Lesson 13.—Flat lap weld. Stock ¼ by 1 inch. Test by bending.

Lesson 14.—T and angle welds. Stock ¼ by 1 inch. Emphasize the advantage of fillet, where one can be permitted.

Lesson 15.—Butt or jump weld. Stock 1 inch diameter or over.

PRACTICE JOBS

Lesson 1.—Open-end wrenches to fit standard nuts for ½ to 1-inch bolts. Closed wrenches to fit standard nuts, bolts, or fittings of 2 inches or more in size. Spanner wrenches of miscellaneous size and type.

Lesson 2.—One pair plain tongs. One pair chain-link tongs.

Lesson 3.—One pair bolt tongs or box-jaw tongs. Redress two or more tongs.

Lesson 4.—Make collar from 3/8 by 1½ inch stock. Shrink this collar on pipe or bar having a diameter between 4 and 6 inches.

Lesson 5.—Weld broken rods and other pieces that require to be of fixed length when finished.

Lesson 6.—Stop leaks in water jackets by shrinking bands on the part. Also by use of split collars drawn together with bolts.

STEELWORK

(*Note.*—The following points are to be emphasized by lecture and demonstration.)

Use clean, deep fire. Do not allow blast to strike steel without passing through a bed of coke Heat thoroughly. Forge at a good heat. Use heavy blows that will penetrate deeply and thus avoid stretching the surface and starting internal flaws.

Anneal before hardening. Harden at the lowest possible heat and always on the rising heat. Temper by running or drawing the color or in tempering bath as is best for the work on hand.

Lesson 1.—Make 3 cold chisels. One each from ½, 5/8, and ¾ inch octagon steel. Make one diamond-point chisel from 5/8 inch octagon steel. Make one ½-inch cape chisel from ¾-inch octagon steel.

(*Tempering Note.*—Explain and demonstrate the different methods of tempering. Run the temper, draw the temper, flashing off oil, and tempering in bath.)

Lesson 2.—Temper chisels and punches by running the temper.

(*Caution.*—Avoid overheating the edge or corners. If any part is overheated, lay the tool one side till it cools to black heat; then reheat and harden on rising heat.)

Lesson 3.—Make hardie to fit anvil. Draw to an edge by sledge and fuller.

(*Caution.*—Heat thoroughly. Work with heavy blows.)

Lesson 4.—Redress and temper several hardies or handled chisels.

Lesson 5.—Make or redress and temper rock drills. Redress and temper hand picks. Sharpen and temper mattocks.

STEEL WELDING

Emphasize the following: Use of flux, clean fire, deep fire, heavy blows with heavy hammer to thoroughly weld the pieces.

Lesson 1.—Weld steel to iron. Lap weld and split weld.

Lesson 2.—Lay steel on mattocks and steel bits in picks.

Lesson 3.—Weld leaf springs. Hammer-temper these springs. Set the spring leaves and assemble the full spring.

Lesson 4.—Temper flat, leaf, and other springs. Harden in oil and flash, also harden and draw the temper as is best suited to the spring in hand. Practice each method.

Lesson 5.—Case-harden bolts, nuts, and pins. Caution in the use of cyanide.

ADVANCED JOB WORK

Lesson 1.—Straighten structural iron or steel shapes as angle iron, channel iron, and I beams. Straighten auto frames.

Lesson 2.—Straighten connecting rods and axles.

Lesson 3.—Babbitt connecting rods. Set up rods on babbitting fixtures with liners properly in place. Preheat the head and mandrel. Have metal proper heat.

Lesson 4.—Replace broken lugs by forged pieces fastened on by studs or cap screws. Use care in screwing into thin cast-iron walls.

Lesson 5.—Stop leaks by shrinking bands on the part, also by split collars drawn together by bolts.

Lesson 6.—Set tires on cart and wagon wheels. Explain "dish."

Lesson 7.—Repair broken straps, braces, and other iron parts on wagons. Other repair jobs that may be encountered.

Lesson 8.—Make riveting hammer. Temper the same. Dress hand hammers.

Lesson 9.—Make handled cold and hot chisels. Fit handles to hammers and mount the same to give the proper "hang."

Lesson 10.—Draw temper on tools that require tempering for considerable length of cutting edge, as reamers.

XI

BRAZING

Brazing is a process for joining metal parts, very similar to soldering, except that brass is used to make the joint, in place of the lead and zinc alloys which form solder. Brazing must not be attempted on metals whose melting point is less than that of sheet brass

Two pieces of brass, to be brazed together, are heated to a temperature at which the brass used in the process will melt and flow between the surfaces. The brass amalgamates with the surfaces and makes a very strong and perfect joint, which is far superior to any form of soldering where the work allows this process to be used, and in many cases is the equal of welding for the particular field in which it applies.

Brazing Heat and Tools.—The metal commonly used for brazing will melt at heats between 1350° and 1650° Fahrenheit. To bring the parts to this temperature, various methods are employed, using solid, liquid, or gaseous fuels. While brazing may be accomplished with the fire of the blacksmith forge, this method is seldom satisfactory, because of the difficulty of making a sufficiently clean fire with smithing coal, and it should not be used when anything else is available. Large jobs of brazing may be handled with a charcoal fire built in the forge, as this fuel produces a very satisfactory and clean fire. The only objection is in the difficulty of confining the heat to the desired parts of the work.

The most satisfactory fire is that from a fuel gas torch built for this work. These torches are simply forms of Bunsen burners, mixing the proper quantity of air with the gas to bring about a perfect combustion. Hose lines lead to the mixing tube of the gas torch, one line carrying the gas and the other air under a moderate pressure. The air line is often dispensed with, allowing the gas to draw air into the burner on the injector principle, much the same as with illuminating gas burners for use with incandescent mantles. Valves are provided with which the operator may regulate the amount of both gas and air, and ordinarily the quality and intensity of the flame.

When gas is not available, recourse may be had to the gasoline torch made for brazing. This torch is built in the same way as the small portable gasoline torches for soldering operations, with the exception that two regulating needle valves are incorporated in place of only one.

The torches are carried on a framework, which also supports the work being handled. Fuel is forced to the torch from a large tank of gasoline, into which air pressure is pumped by hand. The torches are regulated to give the desired flame by means of the needle valves, in much the same way as with any other form of pressure torch using liquid fuel.

Another very satisfactory form of torch for brazing is the acetylene-air combination, a form of torch which burns the acetylene after mixing it with atmospheric air at normal pressure. This torch gives the correct degree of heat and may be regulated to give a clean and easily controlled flame.

Regardless of the source of heat, the fire or flame must be adjusted so that no soot is deposited on the metal surfaces of the work. This can only be accomplished by supplying the exact amounts of gas and air that will produce a complete burning of the fuel. With the brazing torches in common use, two heads are furnished, being supplied from the same source of fuel, but with separate regulating devices. The torches are adjustably mounted, in such a way that the flames may be directed toward each other, heating two sides of the work at the same time and allowing the pieces to be completely surrounded with the flame.

Except for the source of heat, but one tool is required for ordinary brazing operations, this being a spatula, formed by flattening one end of a quarter-inch steel rod. The spatula is used for placing the brazing metal on the work and for handling the flux that is required in this work, as in all other similar operations.

Spelter.—The metal that is melted into the joint is called spelter. While this name originally applied to but one particular grade or composition of metal, common use has extended the meaning until it is generally applied to all grades.

Spelter is variously composed of alloys containing copper, zinc, tin and antimony, the mixture employed depending on the work to be done. The different grades are of varying hardness, the harder kinds melting at higher temperatures than the soft ones and producing a stronger joint when used. The reasons for not using hard spelter in all cases are, first, the increased difficulty of working it, and, second, the fact that its melting point is so near to that of some of the metals brazed that there is great danger of melting the work as well as the spelter.

The hardest grade of spelter is made from three-fourths copper with one-fourth zinc and is used for working on malleable and cast iron and for steel. This hard spelter melts at about 1650° and is correspondingly difficult to handle.

A spelter suitable for working with copper is made from equal parts of copper and zinc, melting at about 1400° Fahrenheit, 500° below the melting point of the copper itself. A still softer brazing metal is composed of half copper, three-eighths zinc and one-eighth tin. This grade is used for fastening brass to iron and copper and for working with large pieces of brass to brass.

For brazing thin sheet brass and light brass castings, a metal is used which contains two-thirds tin and one-third antimony. The low melting point of this composition makes it very easy to work with, and the danger of melting the work is very slight. However, as might be expected, a comparatively weak joint is secured, which will not stand any great strain.

All of the above brazing metals are used in powder form, so that they may be applied with the spatula where the joint is exposed on the outside of the work. In case it is necessary to braze on the inside of a tube or in any deep recess, the spelter may be placed on a flat rod long enough to reach to the farthest point. By distributing the spelter at the proper points along the rod it may be placed at the right points by turning the rod over after inserting it into the recess.

Flux.—In order to remove the oxides produced under brazing heat and to allow the brazing metal to flow freely into place, a flux of some kind must be used. The commonest flux is simply a pure calcined borax powder; that is, a borax powder that has been heated until practically all the water has been driven off.

Calcined borax may also be mixed with about 15 per cent of sal ammoniac to make a satisfactory fluxing powder. It is absolutely necessary to use flux of some kind and a part of whatever is used should be made into a paste with water, so that it can be applied to the joint to be brazed before heating. The remainder of the powder should be kept dry for use during the operation and after the heat has been applied.

Preparing the Work.—The surfaces to be brazed are first thoroughly cleaned with files, emery cloth, or sand paper. If the work is greasy, it should be dipped into a bath of lye or hot soda water, so that all trace of oil is removed. The parts are then placed in the relation to each other that they are to occupy when the work has been completed. The edges to be joined should make a secure and tight fit, and should match each other at all points so that the smallest possible space is left between them. This fit should not be so tight that it is necessary to force the work into place, neither should it be loose enough to allow any considerable space between the surfaces. The molten spelter will penetrate between surfaces that water will flow between, when the work and spelter have both been brought to the proper heat. It is, of course, necessary that the two parts have a sufficient number of points of contact so that they will remain in the proper relative position.

The work is placed on the surface of the brazing table in such a position that the flame from the torches will strike the parts to be heated, and with the joint in such a position that the melted spelter will flow through it and fill every possible part of the space between the surfaces, under the action of gravity. That means that the edge of the joint must be uppermost and the crack to be filled must not lie horizontal, but at the greatest slant possible. Better than any degree of slant would be to have the line of the joint vertical.

The work is braced up or clamped in the proper position before commencing to braze, and it is best to place fire brick in such positions that it will be impossible for cooling draughts of air to reach the heated metal, should the flame be removed temporarily during the process. In case there is a large body of iron, steel, or copper to be handled, it is often advisable to place charcoal around the work, igniting this with the flame of the torch before starting to braze, so that the metal will be maintained at the correct heat without depending entirely on the torch.

When handling brass pieces having thin sections, there is danger of melting the brass and causing it to flow away from under the flame, with the result that the work is ruined. If, in the judgment of the workman, this may happen with the particular job in hand, it is well to build up a mold of fire clay back of the thin parts, or preferably back of the whole piece, so that the metal will have the necessary support. This mold may be made by mixing the fire clay into a stiff paste with water, and then packing it against the piece to be supported, tightly enough so that the form will be retained even if the metal softens.

Brazing.—With the work in place, it should be well covered with the paste of flux and water, then heated until this flux boils up and runs over the surfaces. Spelter is then placed in such a position that it will run into the joint, and the heat is continued or increased until the spelter melts and flows in between the two surfaces. The flame should surround the work during the heating, so that outside air is excluded as far as is possible to prevent excessive oxidization.

When handling brass or copper the flame should not be directed so that its center strikes the metal squarely, but so that it glances from one side or the other. Directing the flame straight against the work is often the cause of melting the pieces before the operation is completed. When brazing two different metals, the flame should play only on the one that melts at the higher temperature, the lower melting part receiving its heat from the other. This avoids the danger of melting one before the other reaches the brazing point.

The heat should be continued only long enough to cause the spelter to flow into place and no longer. Prolonged heating of any metal can do nothing but oxidize and weaken it, and this practice should be avoided as much as possible. If the spelter melts into small globules in place of flowing, it may be caused to spread and run into the joint by lightly tapping the work. More dry flux may be added with the spatula if the tapping does not produce the desired result.

Excessive use of flux, especially toward the end of the work, will result in a very hard surface on all the work, a surface which will be extremely difficult to finish properly. This trouble will be present to a certain extent anyway, but it may be lessened by a vigorous scraping with a wire brush just as soon as the work is removed from the fire. If allowed to cool before cleaning, the final appearance will not be as good as with the surplus metal and scale removed immediately upon completing the job.

After the work has been cleaned with the brush, it may be allowed to cool, and is then finished to the desired shape, size, and surface by filing and polishing. When filed, a very thin line of brass should appear where the crack was at the beginning of the work. If it is desired to avoid a square shoulder and fill in an angle joint to make it rounding, the filling is best accomplished by winding a coil of very thin brass wire around the part of the work that projects, and then causing this to flow itself, or else allow the spelter to fill the spaces between the layers of wire. Copper wire may also be used for this purpose, the spaces being filled with melted spelter.

XII

PIPE BENDING

Before taking up the construction of bends from flat sheet-metal, it will not be out of place to devote some little space to a consideration of the methods to employ, and the tools to use, in bending ordinary metal tubing. This is knowledge often wanted in the sheet-metal workshop, and is by no means common there. The workman who is unacquainted with these methods and tools finds great difficulty in giving to a straight piece of tubing a desired curvature; that is, so shaping it that the completed bend shall be free from ridges, dents, or kinks, and not flattened in the throat; the perfection of a bend, of course, being when the internal diameter or bore of the tube is the same throughout.

What has to be done in the way of pipe bending in the ordinary workshop must be done with the appliances that are usually found there, or can easily be made there. The tools necessary for the production of bends, especially when smooth and circular in section, such as those of wind musical instruments, cannot be made in the ordinary sheet metal workshop. It will be well, however, to give also a brief description of the working of these bends.

Iron or Gas Pipe Bends.—The method of bending a pipe or tube varies with the metal, its diameter, and the curvature required. Ordinary gas pipe, of the smaller sizes, may readily be bent without any special preparation to curves, even of small radius. A piece of iron, preferably round iron, being gripped in a vise, horizontally or vertically as most convenient, and used as a fulcrum or bending post, the barrel may be shaped round it to the curve required. A slight curvature should first be given, then, changing the place of contact of pipe and fulcrum, a further curvature, and so on. A piece of wood, if of sufficiently large diameter to bear the strain it will be put to, may be similarly used.

If the pipe is of so large a diameter that its bending against a piece of iron in the manner described is beyond the workman's strength, it should be made red hot where the bend is to come. Thus softened, the workman will find the bending comparatively easy.

In bending iron pipe in this way there is always a slight flattening in the throat of the bend. In such work, however, as iron pipe is generally used for, this flattening is not of consequence; the thickness of the pipe and the toughness of the metal prevent any great amount of flattening.

Bends of Copper, Brass, and Softer Metal Tubes.—The procedure necessary to bend tubes made of metals softer than iron, of copper, brass, zinc, tin, or lead, is less simple, and to prevent buckling, puckering or flattening, in the throat of a bend, such pipe must be "loaded." The materials used for loading are various, and the choice between them depends upon the metal of which the pipe to be bent is made, and greatly upon the finish and symmetry required in the particular work to be done. Lead, rosin, pitch, and rosin and pitch in equal parts, are the substances most in favor. When set after being melted and run into the tube, they are found to bend without breaking as the bending of a tube progresses, and to offer the needful resistance to change of section of the tube.

A spiral spring not closely coiled, or a piece of cane or solid rubber, may often be advantageously used to load soft metal pipe with. Either of these loadings can be pulled through the made bend, and will serve again and again as loading. A tightly rolled piece of paper will often serve, even for brass tubing. If used for brass tubing, it can be burned out if need be.

In an emergency, and if the ends of the piece of tube to be bent are tightly corked or otherwise sealed up, and the look of the finished work is not of particular importance, a pipe may be loaded with sand, or even water. The reason why sand and water, as loading, are suitable only for an emergency, is that the plugging at one of the pipe ends often gives way in the course of the bending.

The melting point of lead is 323° Centigrade, and as a loading substance for brazed brass tube, lead has this disadvantage, that when melting it out of a bent tube, there is danger lest any weak spot in the brazed seam should crack or open up. Special care needs to be taken to warm up the tube slowly and equally in melting out the lead, because of this.

When the lead has been run out of a bent tube, little particles of lead often remain in the tube, adhering to the surface. To dislodge these, the tube should be again warmed up to a temperature a little higher than that of the melting point of lead, and the open end struck smartly on the bench, or with a piece of wood, the tube being held with a pair of pliers, or otherwise as may be convenient.

Rosin or pitch, as loading substances, leave behind a thin adherent film after being melted out of a pipe. This must not be forgotten when choice of a loading substance has to be made. If it is imperative that the inner surface of a bent pipe should be clean, then neither of these substances can be used with a tube of soft metal, as the film has to be burnt off, which would mean spoiling the tube. They may be used with copper or brass tubing, when, for the reason that the throat of the bend need not be perfectly circular in section, it is desired that the loading substance shall not offer any great resistance to bending.

Brass or copper drawn tubing should be annealed before being bent.

Loading.—In loading a piece of pipe with either lead, pitch, or rosin, two or three layers of brown paper should be wrapped round one end of it and securely tied. If lead is the loading material, the tube should be rigidly fixed vertically, with its closed end embedded in sand, so that molten lead may not run out to do mischief. The lead may be poured from an ordinary plumbers' ladle. And in loading with pitch and rosin the tube should rest and be secured with its closed end on some solid substance, to prevent leaking out of the hot pitch or rosin.

Bending Small Pipes.—Small copper pipes, tubes, and spouts are readily bent into curves without wrinkling, if they are first filled with lead. One end of the pipe is closed with thick brown paper, and the pipe laid in a box of damp sand, while the lead is being poured in. The lead must be soft.

An iron rod is cast in with the lead, its end standing out at a distance of a few inches to afford the necessary leverage for bending the pipe. This, of course, is melted out after the bending is done. The bending is variously effected, with a mallet or with leverage, or with both in combination. Before running the lead out, the outside of the work should be covered with a solution of whiting in water.

Copper pipe may also be filled with rosin before bending. Lead is better for quick bends, rosin for long ones. Only the part to be bent and that immediately beyond need be filled, a wad of paper, or cotton waste, being inserted at the locality beyond which the filling material is not required. The part which has to be bent must be annealed first to a cherry red, in daylight. Portions which have to be left straight must be left unannealed, or hard.

Bending by Power.—There are many methods and rigs adopted for bending copper pipes. Much depends on the size of the pipe. Up to about five inches diameter manual labor is sufficient, but above that hydraulic power is generally employed. The bending is always done by leverage or pressure, never by hammering.

In all coppersmiths' shops there is a strong bending block sunk in the floor for the purpose of pipe-bending. It is of cast iron, about twelve inches square, and standing up to about the ordinary height of a workbench. It is made to receive the various attachments required for pipe-bending. The top of the block is shouldered down to receive a strap, which confines a bending-block. The latter is a stout plate of lead, with a hole or holes in it for the insertion of pipes. The lead being soft does not bruise the pipe which is being bent. It is secured with the strap. On one side of the block a back plate is inserted, with pins fitting into the holes cast in the block, which affords an essential point of leverage in the bending of pipes. Holes are cast in the top of the block to receive pins, which also form suitable points of leverage.

Planishing.—Most work in sheet copper is planished at some stage or other. The object of planishing is to close and harden the grain of the metal, taking the limpness out of it, and to make it more elastic and rigid so that it will retain its shape. Often this operation is performed before any work is done upon the sheets, in order to make them stiff enough to work upon. Often it is done at a later stage. Planishing consists in hammering over the whole surface in detail until every portion has been subjected to the hardening effect of the hammer blows. The hammering is done in straight lines or in concentric curves, depending on the nature of the work. The planishing is done on a bottom stake, fixed in the floor-block, or on a level block of metal. Various hammers are used for different work.

Copper goods are polished with a file first, followed by emery cloth applied on a stick, then by fine emery, rubbed on with hempen rope, wrapped round with a single hitch, and drawn to and fro, and finally with a metal burnisher and sweet oil.

XIII

PROPERTIES OF METALS AND THEIR ALLOYS

The properties of the common metals and their alloys are well marked, and the different degrees in which these qualities are possessed by the different metals and alloys render each better adapted for certain purposes than the others. These properties are:

Metallic luster, tenacity, ductility, malleability, conductivity, fusibility, specific gravity.

Each of these qualities is of special value in its place. Thus, metallic luster is the capacity of the metal for taking a polish in brightening, planishing, and finishing copper and tinned goods. Tenacity is the strength of a metal or alloy to resist stress, pressure, pulling, bending, in vessels, bars, rods, wires. Ductility is the capacity for drawing out, upon which property the art of wire-drawing is based. Without malleability it would be impossible to roll thin sheets, or to flatten or raise them into curved forms. The good conductivity, or conducting power, of metals for heat renders them suitable for warming and domestic purposes, while their power of conducting electricity is a property of equal value, as bearing on wires and plates. Fusibility lies at the basis of all casting, but though the sheet metal worker is but slightly interested in this branch, a knowledge of the fusibility of alloys is essential to the practice of brazing and soldering. The specific gravity, or relative weight, of metals is an important property, from the point of view of the worker in sheet metals, since all sheets of tin, lead, copper, and zinc are sold by pounds weight to the foot. A few remarks by way of explanation of these several qualities, possessed in common by metals and alloys, therefore, preface the descriptions of the metals and alloys to follow.

Metallic Luster.—This is, in fact, nothing more than the power of reflecting light rays. If a surface absorbs light rays largely, the reflection is broken, and the appearance of the surface will not be bright, but dull. A broken or rough surface absorbs and scatters the light rays; a smooth surface, in the sense of being polished, reflects them. A porous substance cannot be polished. For a surface to be capable of taking a polish and becoming lustrous, it must be dense, close, or hard. Thus no amount of polishing would make the natural surface of wood lustrous like that of iron, and no amount of polishing would make the surface of iron as lustrous as that of the harder steel. Metals not hard enough in themselves to take a high polish can be rendered harder and more lustrous by the admixture of another metal. Tin and copper in various proportions form speculum metal and bell metal, each extremely hard and lustrous, and so of alloys of other metals.

Tenacity is equivalent to strength, or the resistance offered by a body to forces tending to pull its particles asunder. It is measured in pounds or tons per square inch. That is, if the ultimate tensile strength of a bar of iron is 40,000 pounds per square inch, that means that a load of 40,000 pounds suspended at the end of a bar 1 inch square, in cross section, would just suffice to tear the bar asunder. Tenacity, in this sense of breaking strength, is not of so much relative interest to the sheet-metal worker as it is to the engineer. Still, there are some matters cognate thereto which it is well to be aware of, such as the effect of the presence of impurities, the effect of temperature, and the effect of drawing out. In brief, the presence of foreign matters varies, in some cases and in certain proportions tending to increase, in others to diminution of strength. The effect of increase of temperature is to lessen the tenacity of metals, and replacing the fibrous condition by the crystalline; on the other hand, the tenacity is raised by moderate drawing out. Steel and iron possess the highest tenacity, while zinc, tin and lead possess the least.

Ductility.—In proportion to the ductility of metals and alloys they are adapted for the purpose of wire-drawing; hence, steel, wrought iron, and copper, being highly ductile, are used for this purpose. Gold, silver, and platinum stand highest in the range of ductility, but their cost precludes their use for any but some special purposes. Tenacity is closely related to ductility, inasmuch as a weak metal will break before it can be reduced to a fine wire. Zinc, tin, and lead, though soft, will not stand drawing down, because their tenacity is so low. Ductile metals become hardened and crystallized during the process of wire-drawing, until they reach the limit of the coherence of their particles. Then annealing becomes necessary. This is effected by heating the metal, and allowing it to cool slowly, the effect of heat being to produce a natural rearrangement of the molecular particles.

Malleability is not identical with ductility, though in some respects akin to it. The effect of hammering or rolling is to destroy the cohesion of the particles of metal, to restore which annealing is necessary. The softest metals are not the most malleable, neither are the most tenacious metals the most readily rolled and hammered. Lead and tin are soft, iron and steel are strong, or tenacious, but neither are malleable, as are gold, silver, and copper. Copper is the only really malleable substance used by sheet-metal workers, and that can be hammered into almost any form. Sheet iron and steel can be bent and rolled, but cannot be raised under the hammer or in dies to anything like the same extent as copper. The malleability of thick metals is generally increased by heat, that of thin metals is not practically affected by it.

The malleability of metal lies at the basis of the formation of work in sheet metal. There is an essential difference between the operations of the boilermaker and those of the sheet-metal worker. The materials are largely the same—steel, wrought iron, and copper—but the difference in thickness renders the methods of working different. The first-named class of artisans do much of their work by the aid of heat; the second, in the cold. The difference is due to the relative thicknesses of the plates used by the first, and of the sheets used by the second. A thick plate cannot be bent to a quick curvature unless it is heated; a thin sheet can be bent, or hammered, or stamped in the cold to almost any outline. The reason of this is readily apparent on a little consideration.

Take a plate of thick metal, a sheet of thin metal, and a sheet of rubber, and note the effect of bending in each case. The thick plate can only be bent by the application of much force, assisted, if the curvature be quick, by heat; the thin steel can be bent most readily to the same curvature, the rubber also with extreme ease. In each case the effect of bending is to extend the outer layers, and compress the inner layers. The layers in the center of the plate, or sheet, are neither extended nor compressed, and this central plane of bending is called the neutral axis. The difference in bending thick and thin metal plates is due to the fact that in the first the layers which are in compression and extension are at a considerable distance from the neutral axis, while in thin plates these layers are practically coincident therewith; so that in a thin plate there is no appreciable amount of compression or extension, hence the ease with which they can be bent.

But if the metal in the plates were highly elastic and mobile, like rubber, then, even though thick, extension and compression would take place in thick plates as in thin. The effect of heating thick plates is to cause the molecules to move over one another, and to become rearranged permanently, and this not necessarily in a state of high extension or compression, such as would result if the plates had been bent cold, but in a safe and natural way, provided the amount of bending does not exceed the limit which the nature of the material will permit it to sustain.

The same kind of thing occurs in thin sheet metals which are subjected to severe rolling, hammering, or stamping. Some movement and rearrangement of the particles of metal takes place, and the greater the amount of curvature or distortion of form produced, the more severe will be the stresses produced in the substance of the material. If a flat plate is raised by hammering, or if it is deeply beaded or dished, or set out, it will be brought into so high a state of tension that it will probably crack, unless heating is resorted to for the purpose of rearranging the particles of metal. It is therefore obvious that the result of hammering, rolling, and stamping is to cause the particles of metal to glide over one another, extending some parts and compressing others, with the frequent coincidence also of thinning down some of the portions which have been subjected to the most severe treatment. If, therefore, the metals did not possess this property of malleability and that of ductility, but were such that their particles could not be made to glide one over the other, no irregular metallic forms could be produced by hammering or stamping, but casting would be the only method available for obtaining these forms.

Conductivity of heat is the property which renders the metals so valuable for heating purposes. The conducting power of metals varies, but it so happens that copper, which is the best conductor among the metals in common use, is also the most malleable. Wrought iron is also an excellent conductor. The thinner the sheets, the more rapidly is heat transmitted through them. And, moreover, heat is transmitted so quickly through thin malleable sheets that there is no risk of fracture occurring, due to unequal contraction, as there is in many metallic substances.

Fusibility.—The melting of steel, copper, and brass does not concern the worker in sheet metal, but the relative fusibilities of the numerous brass, lead, and tin solders are matters of much practical importance to him. These all melt at comparatively low temperatures, and it is essential to know at what temperatures certain solders melt, in order to employ on any given job a solder, the melting point of which is well below that of the material which has to be united. Coke or charcoal fires, jets of gas, and copper bits are used to fuse the various solders employed.

Specific Gravity.—The specific gravity of a metal is estimated relatively to that of a given bulk of pure water at a temperature of 62 degrees Fahrenheit. Beyond the commercial classification of sheets by weight, the relative weights of metals do not concern the sheet-metal worker much.

PROPERTIES OF ALLOYS

The manner in which the physical properties of the alloys is affected by small variations in the proportions of their constituents is often remarkable. Malleability, ductility, fusing points, even appearances, are often radically modified. Some metals are more readily influenced in this way than others. Among familiar examples may be noted the effect which very minute percentages of carbon, phosphorus, and silicon exercise on steel.

Taking very common examples, it is remarkable that the union of two soft and malleable metals, as copper and tin, results in alloys ranging from the tough yellow gun metal to the brittle bell and speculum metals of silvery whiteness. So, too, copper alloyed with the very brittle and crystalline zinc forms the soft yellow brass, which is bent and cut with so much ease. Or, copper with lead forms an alloy so soft as to be hardly workable. Again, tin and lead alloyed together fuse at a temperature lower than that of either of the constituents—a fact which renders them valuable as solders. And by adopting different proportions, various fusing points higher and lower are obtained, suitable for soldering different qualities of metal or alloy.

Copper Alloys.—Copper is not only highly valuable in the pure state, but its value is perhaps even greater when alloyed in various proportions with tin, lead, zinc, or other metals. It is only necessary to instance gun metal, brass, bell metal, and the solders. The subject of alloys is one of such great interest and value that volumes might be devoted to them. But, strictly speaking, the subject is of greater interest to the founder than to the sheet-metal worker. Still, there is very much of interest in it to the latter, since all brass sheets and wires are alloys. All tinning of copper vessels is effected by a union of the surfaces of dissimilar metals. The difference in qualities of sheets and wires depends mainly on the proportions in which certain elements occur. All solders, whether hard or soft, are alloys. So that for these and other reasons a knowledge of the principles which underlie the union of dissimilar metals to form alloys is desirable.

Whether alloys are true chemical compounds has been doubted. At least, they are not recognized as such in science. The reason is, that there is no fixed and definite proportion in which, and in which alone, combination of the metallic elements occurs. In a true chemical compound such is the case. They invariably combine in definite proportions known as their combining weights, or in multiples of those combining weights. But true alloys are formed apart from any such definite combinations, so that one or other of the elements in one alloy shall be in excess by comparison with another alloy of the same metals. It seems, however, as though true chemical combination must take place, but that the compound is mechanically associated with an excess of one or more of the elements. The reason for assuming the existence of a true compound is, that an alloy usually possesses physical characteristics very different from those possessed by its separate elements—a feature in which it closely resembles most true chemical compounds. The strength, tenacity, hardness, and fusing points of alloys are generally higher than those of their constituent elements, in some cases very much higher—effects which do not seem possible by a mere mechanical mixture of elements.

Copper is alloyed with tin, lead and zinc in various proportions. Alloyed with tin alone it forms the gun metals, bronzes, bell metals, and speculum metal. When alloyed with zinc only it forms various brasses and spelter solders. Alloyed with lead only, it forms the very common pot metals. Alloyed with tin, zinc, and lead, it forms various gun metals and bronzes.

Alloys of copper with zinc alone are used chiefly to form spelter solder and brass. Copper and zinc mix in all proportions, but exact proportions are difficult to determine, because zinc volatilizes readily. The fusibility of copper-zinc alloys increases with the proportion of zinc. The color ranges, with the successive additions of zinc, from the red of copper to silvery white, and the malleability decreases until a crystalline character prevails.

An alloy of about 1 part of zinc to 16 parts of copper is used for jewelry, one of 3 to 4 parts of zinc to 16 parts of copper for sundry alloys once known as pinchbeck; about 6 to 8 parts of zinc to 16 parts of copper form common brass, the latter being slightly more fusible than the former. Equal parts of zinc and copper form soft spelter solder; or 12 or 14 parts of zinc to 16 parts of copper would probably be the ultimate proportions after volatilization.

Copper and tin also mix in all proportions. Successive additions of tin increase the fusibility of the alloy, the malleablity diminishes, and the color gradually changes from red to white.

Copper-tin or gun metal alloys range from about 1 part of tin to 16 parts of copper in the softest, to 2 or 2½ parts of tin to 16 parts of copper in the hardest. Beyond the last proportion, up to 5 parts of tin to 16 parts of copper, range the bell metal alloys; from 7¼ to 8¼ parts of tin to 16 parts of copper form speculum metal.

The alloys of copper with lead alone are used in the cheap pot metals. The fusibility is increased with successive additions of lead, the malleability is soon lost, and the red color of copper gives place to a leaden hue. About 6 parts of lead to 16 parts of copper is the limit at which a true alloy can be formed. With an increase in the proportion of lead, the latter separates in cooling.

Alloys of copper with zinc, tin, and lead are largely used under the names of brasses, bronzes, gun metals, and pot metal. There is practically no limit to the range of these alloys.

Generally, these alloys are not proportioned separately, but the copper is added to a brass alloy. In many mixtures lead is not used at all, but copper, tin, and zinc only. Antimony is also sometimes used. A little iron added to yellow brass hardens it. Lead, on the contrary, makes it more malleable. Zinc added to a pure mixture of copper and tin makes it mix better, and increases the malleability. Pot metal is improved by the addition of a little tin, and also of antimony.

THE COMMON METALS

Aluminum.—This metal, when of 98.5 per cent purity, is bright white in color, somewhat resembling silver, though its appearance depends much on the temperature at which it has been worked. It is capable of taking a high polish. Its fusing point is about 1,050° Fahrenheit, but this may be increased to 1,832° Fahrenheit if impurities are present or if it is alloyed with another metal. Aluminum is only slightly elastic; it is, however, fairly malleable and ductile, but these latter properties are impaired by the presence of its two chief impurities, silicate and iron. If of more than 99 per cent purity, it can be rolled into leaves 1-40,000th part of an inch in thickness, in this respect being inferior only to gold. Aluminum has a tensile strength of 12,000 pounds to the square inch. When pure, it is non-corrosive and resists the oxidizing action of the atmosphere, but this advantage has to be partly sacrificed to obtain increased hardness and elasticity, by adding small quantities of copper, nickel, or zinc. It dissolves in hydrochloric acid and in most solutions of the alkalines, but is only slightly affected by dilute sulphuric acid, and not at all by nitric acid. The rolled or forged metal breaks with a fine silky fracture.

Aluminum is not found in a metallic state, but when in combination with oxygen, various alkalies, fluorine, silicon, and acids, it is the base of many clays and soils. Frequent compounds of aluminum are felspar, mica, gneiss, and trachyte, while other aluminum compounds, classed as precious stones, are the ruby, sapphire, garnet, turquoise, lazulite, topaz, etc. The ores from which aluminum is commercially reduced are bauxite, cryolite, and corundum.

The chemical method of producing aluminum has been superseded by the cheaper and more satisfactory electrical process. There are three electrical methods, the first depending on the heating effect of the electric current and producing aluminum alloys only, whereas by the two later methods aluminum salts are submitted to electrolytic action at a high temperature, pure metal being produced.

The sheet-metal worker would do well to acquaint himself thoroughly with the many peculiarities of aluminum, which is replacing other metals for ornamental sheet metal work and in the formation of culinary and other utensils, for which purpose its indifference to the action of most acids and to atmospheric conditions renders it especially suitable.

The great disadvantage of aluminum is the difficulty encountered in forming reliable soldered joints. This is caused by the formation of an oxide on the surface of the heated metal, the oxide preventing the soft solder from alloying with the aluminum and producing a good joint. With care the difficulty can be surmounted by employing soldering alloys of an easily fusible nature and by melting them with a special copper bit. Good solders for the purpose are given by authorities as follows: Tin 95 parts, and bismuth 5 parts. Tin 97, bismuth 3. Aluminum 2.5, zinc 25.25, phosphorus .25, tin 72. Aluminum, 10, tin 90. Cadmium 50, zinc 20, tin 30. The copper bit should be wedge-shape and bent roundly to a quarter circle. Its edge is then at right angles to the aluminum, and by lightly moving the bit backward and forward over the metal and the flowing solder the film of oxide can be removed. The coated surface can then be soldered with an ordinary copper bit.

Antimony.—This is a bluish white metal, very crystalline and brittle, and so can easily be powdered. Its chief use is in the formation of serviceable alloys, such as white metal and pewter, to which it imparts brittleness. The melted metal rapidly oxidizes if exposed to the air, and if highly heated burns with a white flame, giving off fumes of antimony trioxide. Antimony is dissolved by hot hydrochloric acid, hot concentrated sulphuric acid, and aqua regia, and if treated with nitric acid forms a straw-colored powder known as antimonic acid. Commercial antimony contains impurities in the form of potassium, copper, iron, and lead.

Antimony occurs native, but generally the metal is found in combination with others. The chief antimony ore is stibnite. The antimony is recovered from this ore by two distinct processes. By the first of these is separated the antimony sulphide, which in its turn is refined by the second process. In Germany, where much commercial antimony is produced, the ore is placed in covered pots having perforated bottoms, below which are receivers. Between the pots is the fire, the heat of which fuses the sulphide, which runs through the holes into the receivers. Crucibles heated in circular wind-furnaces are employed to refine the sulphide. The charge is 40 pounds of sulphide and 20 pounds of scrap iron, and the product is antimony and iron sulphide, which is again melted, this time with sulphate of soda and some slag, a product of the next process. The resultant metal is melted with pearlash and slag, and cast into ingots. Antimony can also be produced by electro-deposition.

Bismuth.—This metal is reddish white in color, and has a bright luster. It is very brittle and crystalline, volatilizes at a high temperature, and, burning, forms a crystalline scale—flowers of bismuth. The most important use of bismuth is in forming alloys, as its addition to any metal has the effect of considerably lowering the melting point of that metal. Bismuth may be alloyed with antimony, lead, or tin. Bismuth solders may be formed of: Tin 4 parts, lead 4 parts, bismuth 1 part. Tin 3, lead 3, bismuth 1. Tin 2, lead 2, bismuth 1. Equal parts of tin, lead, and bismuth. Tin 2, lead 1, bismuth 2. Tin 3, lead 5, bismuth 3.

Bismuth is found in the metallic state in the form of bismuth-glance (bismuth and sulphur), in combination with oxygen as an ochre, and in the ores of silver, lead, tin, copper, and cobalt. Furnaces for reducing bismuth each contain a number of inclined iron tubes, in which the ore is placed. A wood-fire is lighted, and the fused bismuth, together with some impurities, flows through apertures at the lower ends of the tubes into clay or iron pots heated by a fire underneath. The sulphur and arsenic contained in it are removed by again fusing the metal, this time accompanied by one-tenth its weight of nitre.

Gold.—This metal has a very limited application in the art of the sheet metal worker, but merely on account of its comparative scarcity as a metal, and hence its expensiveness. Were it not for this, its high malleability and ductility would cause it to be very extensively used in many of the industrial arts. So malleable is gold that it may be reduced to leaves only the 290,000th part of an inch in thickness. It is but very slightly affected by the atmosphere, and resists the action of all solvents with the exception of selenic, aqua regia, and aqueous chlorine. Gold is found in a metallic state in the form of grains in sand and it is then often in combination with silver, copper, platinum, or iron. Veins of gold quartz occur, and occasionally the metal is found native in lumps, termed nuggets. The ores of galena, copper pyrites, and iron sometimes contain traces of gold.

Tin.—This metal has nearly the lustrous whiteness of silver, is highly malleable, harder than lead, but is not very tenacious. It oxidizes only on being heated, when it forms stannic oxide. Tin can be decomposed by many acids, and, as has already been shown, easily alloys with most metals. Tin plate as used by the sheet-metal worker is not solid tin, but steel plate thinly coated with tin by a special process. Many of the more important alloys have tin as their principal constituent. Some of these alloys are solders.

Tin occurs in the form of sulphuret and oxide, but more generally in the form of ore, known as tin stone. This is smelted either in blast or reverberatory furnaces. In the latter case the treatment is in two stages, one being the actual extraction of the metal and the other the refining. The roasted ore is washed to remove the sulphates, and is then placed in a furnace having an inclined bed and lined with about 8 inches of fireclay. Previous to placing in the furnace, the ore is mixed with anthracite coal and a small quantity of lime and fluor-spar. At the end of five hours more anthracite coal is thrown into the furnace, and in about an hour after that the molten metal can be run off. The remaining slag is an iron silicate which contains some oxides.

To refine the pig tin, it is placed in a reverberatory furnace and gradually heated to about 450° Fahrenheit. At this temperature the tin melts, and is drawn off into iron pots. The mass left in the furnace contains for the most part iron. On again melting the tin and stirring it with a pole of green wood, it is caused to boil by the escape of gases, and by this means the impurities, such as iron and arsenic, are brought to the surface, from which they are skimmed.

Grain tin is made by allowing the molten metal to fall from a height on to a hard cold surface. To produce what is known as common tin, the metal passes at once to the molds. Refined tin is the result of using better ores and lengthening the poling process. The purest metal in the mold is the upper portion, the middle portion is the common, and the bottom portion is too impure for use at all, and requires another fusing and poling. The ingots are known as block tin.

Iron and Steel.—Iron in a state of purity is comparatively little known, but the ores of it are various and abundant. In its commercial forms, as plate or sheet, bar, and cast iron, it is universally known. As sheet, it can be cut into patterns and bent into desired forms; as bar, it can be made hot and wrought, that is, shaped by means of the hammer, and when molten it can be run or cast into all sorts of shapes. But cast iron is brittle, crystalline in fracture, and not workable by the hammer.

In sheet and bar form, wrought iron is malleable, mostly fibrous in fracture, and capable of being welded. The presence of impurities in bar iron, that is, the presence of substances not wanted in it at the time being, seriously affects its malleability. Thus the presence of phosphorus, or tin, renders it brittle when cold, and the presence of sulphur makes it unworkable when hot. Iron quickly rusts if exposed to damp air, as in the case of iron exposed to all weathers, or to air and water, as with vessels in which barely sufficient water is left to cover the bottoms, the rusting being then much more rapid than when the vessels are kept full.

When iron is heated to redness and above, scale rapidly forms and interferes greatly with welding.

The effects of the presence of foreign substances in iron as impurities has been alluded to, but the presence in it of carbon has not been spoken of. This is a substance which in its crystalline form is known as the diamond, and in its uncrystalline form as charcoal. The presence of carbon in iron destroys its malleability, but at the same time gives to it properties so remarkable and useful to mankind that to say, as a defect, of a piece of iron with carbon in it, that it is not malleable, is simply equivalent to saying that a piece of brass is not a piece of copper. Quite the reverse of being matter in the wrong place, carbon in iron furnishes a compound so valuable on its own account that, if there were other substances not metals, the compounding of which with a metal gave products at all resembling those of iron and carbon, all such compounds would form a class of their own. The iron and carbon compound, however, stands alone.

Iron is alloyed with carbon in proportions varying from say ½ to 5 percent. When in the proportion of from 2 percent upward, the compound is cast iron, that is, iron suitable for casting purposes. In other proportions it is known as *steel.* In cast iron the metallic appearance is somewhat modified, in steel it is maintained. Originally steel was made by the addition of carbon to manufactured iron, and the word had then a fairly definite signification, meaning a material of a high tensile strength, that by being heated dull red and suddenly cooled could be made so hard that a file would not touch it, that is, would slide over it without marking it; and that could have that hardness modified or tempered by further application of heat.

But with the introduction of the Bessemer process of steel making, and of the Siemens process of making steel direct from the ores, processes by which any desired percentage of carbon can be given, the signification of the word *steel* has become enlarged, and it now includes all alloys of iron and carbon between malleable iron and cast iron, except that the term *mild steel* is sometimes applied to those alloys that approach in qualities to malleable iron. Steel plates are now produced equaling in toughness, and it is said even excelling, the best charcoal plates, and as they are much cheaper, the old process is very generally giving way to the direct process. In practice, however, these plates are found to be more springy than good charcoal plates, and not so soft and easy to work.

As iron is very liable to rust, surface protection is given to it by a coating of tin, or of an alloy of lead and tin, or of zinc. Plates coated with tin are termed *tin plates;* coated with lead and tin they have the name of *terne plates;* and if coated with zinc they are said to be *galvanized.* Terne plates are used for roofing, for lining packing cases, also for work to be japanned.

Large iron sheets of various gauges, coated with tin and having the same appearance as tin plate, are called tinned iron. But the latter term is more generally applied to sheets of iron which are coated with lead and tin, and are dull like terne plates.

Iron coated with zinc is not so easily worked as when ungalvanized. In galvanizing, the zinc alloys with the surface of the iron, and this has a tendency to make the iron brittle. Galvanized iron is useful for water tanks and for roofing purposes, as the zinc coating prevents rust better than a tin coating. For roofing, however, terne plates are largely used, and, kept well painted, are found to be very durable. Owing to the ease with which zinc is attacked by acids, galvanized iron is not suitable for vessels exposed to acids or acid vapors.

Copper.—This, the only red metal, is malleable, tenacious, soft, ductile, sonorous, and an excellent conductor of heat. For this reason, and because of its durability, it is largely used for cooking utensils. It is found in numerous states of combination with other constituents, as well as native. Its most important ore is copper pyrites. Copper melts at a dull white heat and becomes then covered with black crust. It burns when at a bright white heat with a greenish flame. No attempt at explanation of its manufacture will here be made, as any but a lengthy description would simply lead to bewilderment.

For the production of sheet copper it is first cast in the form of slabs, which are rolled, and then annealed and re-rolled, this annealing and re-rolling being repeated until the copper sheet is brought down to the desired thickness. In working ordinary sheet copper, it is hammered to stiffen it, and close the grain. Hard-rolled copper is, however, nowadays produced that does not require hammering.

In the course of the manufacture of copper it undergoes a process termed *poling*, to get rid of impurities. We mention this because we shall find a similar process gone through in preparing solders. The poling of copper consists of plunging the end of a pole of green wood, preferably birch, beneath the surface of the molten metal, and stirring the mass with it. Violent ebullition takes place, large quantities of gases are liberated, and the copper is thoroughly agitated. It is doubtful if this poling process is fully understood, for, though it is quite obvious that there may be insufficient poling, it is not easy to explain overpoling. But overpoling, as a fact, is fully recognized in the manufacture of copper, and the metal is brittle, both if the poling is too long continued or not long enough. If duly poled, the cast slab when set displays a comparatively level surface. If underpoled, a longitudinal furrow forms on the surface of the slab as it cools. If overpoled, instead of a furrow, the surface exhibits a longitudinal ridge. Copper, duly poled, is known as "best selected."

Zinc.—Of this metal, known also very commonly as spelter, calamine is a very abundant ore. Another abundant ore is blende. Zinc is extracted from its ores by a process of distillation. The metal volatilizes at a bright red heat, and the vapor, passing into tubes, condenses, and is collected from the tubes in powder and in solid condition. If required pure, further process is necessary. Zinc is hardened by rolling, and requires to be annealed at a low temperature to restore its malleability. Until the discovery of the malleability of zinc when a little hotter than boiling water, it was only used to alloy copper, and sheet zinc was unknown. Zinc expands 1/340th by heating from the freezing to the boiling point of water. The zinc of commerce dissolves readily in hydrochloric and in sulphuric acid; pure zinc only slowly. If zinc is exposed to the air, a film of dull gray oxide forms on the surface, and it suffers afterwards little further change. Zinc alloys with copper and tin, but not with lead. It also alloys with iron, for which it is largely used as a coating, iron so coated being known as galvanized iron.

Lead.—Another metal that is prepared in sheet is lead. This metal was known in the earliest ages of the world. It is soft, flexible, and has but little tenacity. One of its principal ores is galena. Being a soft metal, it is worked by the plumber into various shapes by means of special tools, which often saves the making of joints. As it is comparatively indestructible under ordinary conditions, it is largely used for roofing purposes and for water cisterns. It is also used for the lining of cisterns for strong acids, in which case the joints are not soldered in the ordinary way with plumber's solder, but made by a process termed autogenous soldering or lead burning. Lead prepared in sheet by casting is known as cast lead, but when prepared by the more modern method of casting a small slab of the metal and then rolling it to any desired thickness, is called milled lead.

Alloys.—An alloy is a compound of two or more metals. Alloys retain the metallic appearance, and while closely approximating in properties to the metals compounded, often possess in addition valuable properties which do not exist in either of the constituent metals forming the alloy. Thus, an alloy of copper and zinc has a metallic appearance and working properties somewhat similar to those of the individual metals it is made up of, and so with an alloy of gold, or silver, and a small percentage of copper. But the latter alloys have the further property of hardness, making them suitable for coinage, for which gold, or silver, unalloyed, is too soft. Like this addition of copper to gold or silver is the addition of antimony to lead and to tin, by which alloys are obtained harder though more brittle than either lead or tin by itself. The alloy of lead and antimony is used for printer's type, for which lead alone is too soft.

XIV

PRACTICAL GEOMETRY AND MENSURATION

DEFINITIONS OF PLANE FIGURES

A *line* is length without breadth.

The *extremities of a line* are points.

A *straight line* is that which lies evenly between its extreme points.

A *plane surface* is that in which, any two points being taken, the straight line between them lies wholly in that surface.

The *extremities of a surface* are lines.

A *plane rectilineal angle* is the inclination of two straight lines to one another in a plane, which meet to-

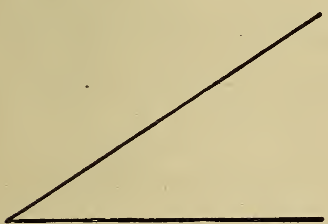


Figure 1.

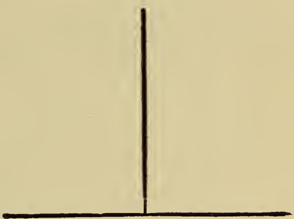


Figure 2.

gether, but are not in the same straight line, as in Figure 1.

When a straight line, standing on another straight line, makes the adjacent angles equal to one another, each of the angles is called a *right angle* and the straight line which stands on the other is called a *perpendicular* to it, as in Figure 2.

Figure 3.

Figure 4.

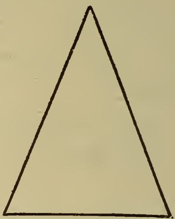


Figure 5.

Figure 6.

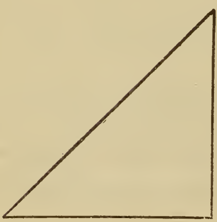


Figure 7.

Figure 8.

An *obtuse angle* is that which is greater than a right angle, as in Figure 3.

An *acute angle* is that which is less than a right angle, as in Figure 1.

A *term or boundary* is the extremity of anything.

An *equilateral triangle* is that which has three equal sides, as in Figure 4.

An *isosceles triangle* is that which has two sides equal, as in Figure 5.

A *scalene triangle* is that which has three unequal sides, as in Figure 6.

A *right-angled triangle* is that which has a right angle, as in Figure 7.

An *obtuse-angled triangle* is that which has an obtuse angle, as in Figure 6.

The *hypothenuse* in a right-angled triangle is the side opposite the right angle, as in Figure 7.

A *square* is that which has all its sides equal and all its angles right-angles, as in Figure 8.

A *rectangle* is that which has all its angles right angles, but only its opposite sides equal, as in Figure 9.

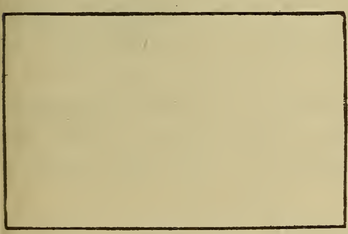


Figure 9.

Figure 10.

A *rhombus* is that which has all its sides equal, but its angles are not right angles, as in Figure 10.

A *quadrilateral* figure which has its opposite sides parallel is called a *parallelogram*, as in Figures 8, 9, and 10.

A line joining two opposite angles of a quadrilateral is called a *diagonal.*

An *ellipse* is a plane figure bounded by one continuous curve described about two points, so that the sum of the

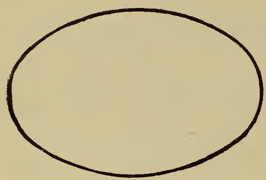


Figure 11.

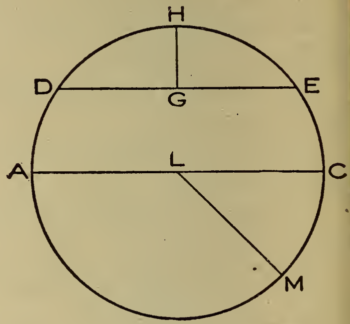


Figure 12.

distances from every point in the curve to the two foci may be always the same, as in Figure 11.

PROPERTIES OF THE CIRCLE

A *circle* contains a greater area than any other plane figure bounded by the same length of circumference or outline.

A *circle* is a plane figure contained by one line and is such that all straight lines drawn from a point within the figure to the circumference are equal, and this point is called the center of the circle.

A *diameter* of a circle is a straight line drawn through the center and terminated both ways by the circumference, as *AC* in Figure 12.

A *radius* is a straight line drawn from the center to the circumference, as *LM* in Figure 12.

A *semicircle* is the figure contained by a diameter and that part of circumference cut off by a diameter, as *AHC* in Figure 12.

A *segment* of a circle is the figure contained by a straight line and the circumference which it cuts off, as *DHE* in Figure 12.

A *sector* of a circle is the figure contained by two straight lines drawn from the center and the circumference between them, as *LMC* in Figure 12.

A *chord* is a straight line, shorter than the diameter, lying within the circle, and terminated at both ends by the circumference, as *DE* in Figure 12.

An *arc* of a circle is any part of the circumference, as *DHE* in Figure 12.

The *versed sine* is a perpendicular joining the middle of the chord and circumference, as *GH* in Figure 12.

Circumference.—Multiply the diameter by 3.1416; the product is the circumference.

Diameter.—Multiply the circumference by .31831; the product is the diameter; or multiply the square root of the area by 1.12837; the product is the diameter.

Area.—Multiply the square of the diameter by .7854; the product is the area.

Side of the square.—Multiply the diameter by .8862; the product is the side of a square of equal area.

Diameter of circle.—Multiply the side of a square by 1.128; the product is the diameter of a circle of equal area.

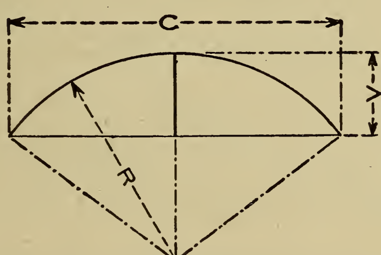


Figure 13.

To find the versed sine, chord of an arc, or radius when any two of the three factors are given.—Figure 13.

$$R = \frac{C^2 + 4V^2}{8V} \qquad C = 2\sqrt{(2R - V)}$$

$$V = R - \sqrt{\frac{4R^2 - C^2}{4}}$$

To find the length of any line perpendicular to the chord of an arc, when the distance of the line from the

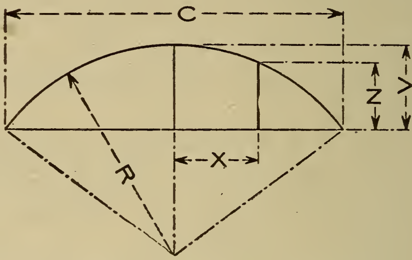


Figure 14.

center of the chord, the radius of the arc, and the length of the versed sine are given.—Figure 14.

$$N = \sqrt{(R^2 - X^2)} - (R - H) \qquad R = \frac{C^2 + 4V^2}{8V}$$

$$C = 2\sqrt{(2R - V)} \qquad V = R - \sqrt{\frac{4R^2 - C^2}{4}}$$

To find the diameter of a circle when the chord and versed sine of the arc are given.

$$AC = \frac{DG^2 + GH^2}{GH}$$

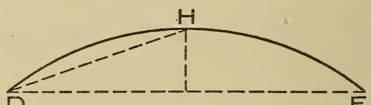


Figure 15.

To find the length of any arc of a circle, when the chord of the whole arc and the chord of half the arc are given. —Figure 15.

$$\text{Arc DHE} = \frac{8\text{DH} - \text{DE}}{3}$$

DEFINITIONS OF POLYGONS

A *polygon*, if its sides are equal, is called a regular polygon; if unequal, an irregular polygon.

A *pentagon* is a five-sided figure.

A *hexagon* is a six-sided figure—Figure 16.

A *heptagon* is a seven-sided figure.

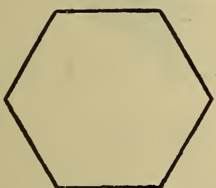


Figure 16.

Figure 17.

An *octagon* is an eight-sided figure—Figure 17.

A *nonagon* is a nine-sided figure.

A *decagon* is a ten-sided figure.

A *undecagon* is an eleven-sided figure.

A *duodecagon* is a twelve-sided figure.

DEFINITIONS OF SOLID FIGURES

A *solid* has length, breadth, and thickness. The boundaries of a solid are surfaces.

A *solid angle* is that which is made by two or more plane angles, which are not in the same plane, meeting at one point.

A *cube* is a solid figure contained by six equal squares—Figure 18.

A *prism* is a solid figure contained by plane figures of which two that are opposite are equal, similar, and parallel to one another; the other sides are parallelograms —Figure 19.

A *pyramid* is a solid figure contained by planes, one of which is the base, and the remainder are triangles,

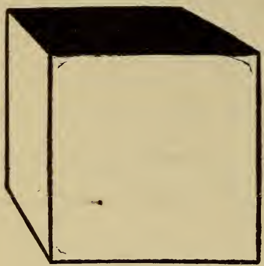


Figure 18.

Figure 19.

Figure 20.

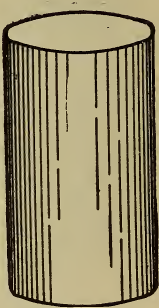


Figure 21.

whose vertices meet in a point above the base, called the vertex or apex of the pyramid—Figure 20.

A *cylinder* is a solid figure described by the revolution of a rectangle or parallelogram about one of its sides —Figure 21.

The *axis* of a cylinder is the fixed straight line about which the parallelogram revolves.

The *ends* of a cylinder are the circles described by the two revolving sides of the parallelogram.

A *sphere* is a solid figure described by the revolution of a semicircle about its diameter, which remains fixed—Figure 22.

The *axis* of a sphere is the fixed straight line about which the semicircle revolves.

The *center* of a sphere is the same as that of the semicircle.

The *diameter* of a sphere is any straight line which passes through the center and is terminated both ways by the surface of the sphere.

A *cone* is a solid figure described by the revolution of a right-angled triangle about one of its sides contain-

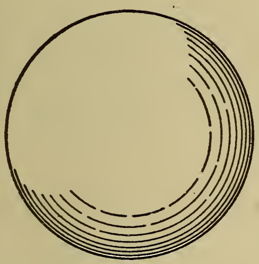


Figure 22.

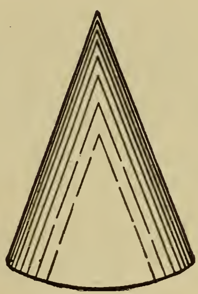


Figure 23.

ing the right angle, which side remains fixed—Figure 23.

The *axis* of a cone is that side of the triangle containing the right angle which remains fixed.

The *base* of the cone is the circle described by that side of the triangle containing the right-angle which revolves.

If a cone be cut obliquely so as to preserve the base entirely, the section is an *ellipse*.

When a cone is cut by a plane parallel to one of the sloping sides, the section is a *parabola;* if cut at right angles to its base, a *hyperbola*.

CONSTRUCTION OF ANGLES

To bisect a given angle.—Let *DAC* be the given angle. With center *A* and any radius *AE* describe an arc cutting *AC* and *AD* at *E* and *G*. With the same radius and centers *E* and *G*, describe arcs intersecting at *H*, and join *AH*. The angle *DAC* is bisected—Figure 24.

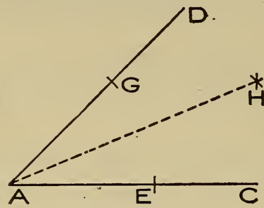


Figure 24.

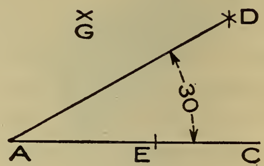


Figure 25.

To construct an angle of 30°.—With radius *AE* and with center *A* and *E*, describe arcs intersecting at *G*. With the same radius and with centers *E* and *G*, describe arcs intersecting at *D*, and join *AD*. The angle *DAC* contains 30°—Figure 25.

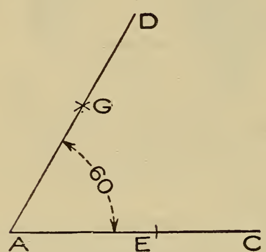


Figure 26.

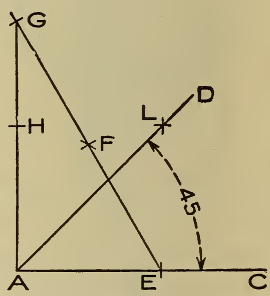


Figure 27.

To construct an angle of 60°.—With radius *AE*, and with centers *A* and *E*, describe arcs intersecting at *G*, draw *AD* through *G*. The angle *DAG* contains 60°—Figure 26.

To construct an angle of 90°.—With radius AE and centers A and E, describe arcs intersecting at F, draw EG through F, and make FG equal to FE. Join GA, and with center A and radius AE make AH equal to AE, with the same radius and with centers E and H describe arcs intersecting at L, draw AD through L. The angle DAC is 45°—Figure 27.

To construct an angle of 90°.—With radius AE and centers A and E, describe arcs intersecting at F, with

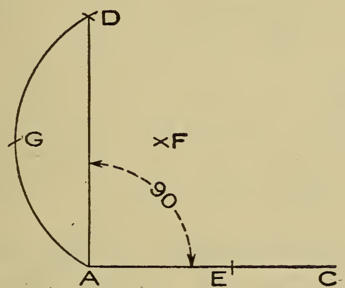


Figure 28.

the same radius and center F describe the arc AGD, with radius AE, lay off AG and GD and join DA. The angle DAG is 90°—Figure 28.

PRACTICAL PROBLEMS IN GEOMETRY

To bisect a straight line.—Figure 29. Let BC be the straight line to be bisected. With any convenient radius greater than AB or AC describe arcs cutting each other at D and E. A line drawn through D and E will bisect or divide the line BC into two equal parts.

To erect a perpendicular line at or near the end of a straight line.—Figure 30. With any convenient radius and at any distance from the line AC, describe an arc of a circle as ACE, cutting the line at A and C. Through the center *R* of the circle draw the line *ARE*, cutting the arc at point *E*. A line drawn from *C* to *E* will be the required perpendicular.

To divide a straight line into any number of equal parts.—Figure 31. Let *AB* be the straight line to be

Figure 29.

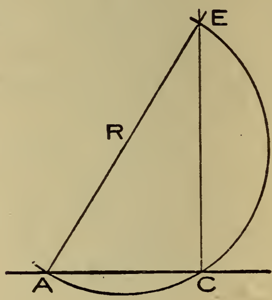


Figure 30.

divided into a certain number of equal parts: From the points *A* and *B*, draw two parallel lines *AD* and *BC*, at any convenient angle with the line *AB*. Upon *AD* and *BC* set off one less than the number of equal parts required, as *A-1, 1-2, 2-D*, etc. Join *C-1, 2-2, 1-D*. The

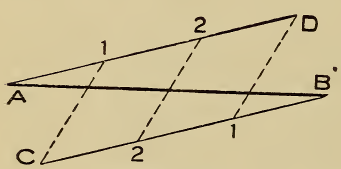


Figure 31.

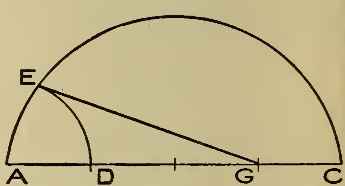


Figure 32.

line *AB* will then be divided into the required number of equal parts.

To find the length of an arc of a circle.—Figure 32. Divide the chord *AC* of the arc into four equal parts as shown. With the radius *AD* equal to one-fourth of the chord of the arc and with A as center describe the arc DE. Draw the line EG and twice its length will be the length of the arc AEC.

To draw radial lines from the circumference of a circle when the center is inaccessible.—Figure 33. Divide

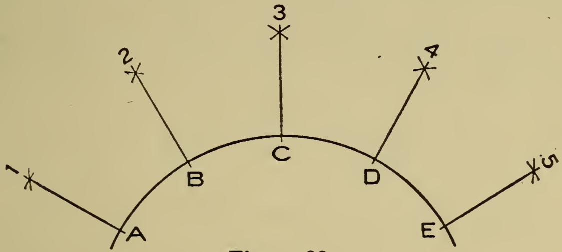


Figure 33.

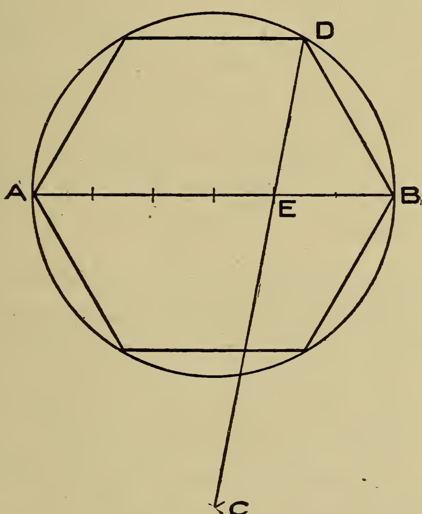


Figure 34.

the circumference into any desired number of parts as AB, BC, CD, DE. Then with a radius greater than the length of one part, describe arcs cutting each other as

A-2, C-2, B-3, D-3, etc., also *B-1, D-5.* Describe the end arcs *A-1, E-5* with a radius equal to *B-2.* Lines joining *A-1, B-2, C-3, D-4* and *E-5* will all be radial.

To inscribe any regular polygon in a circle.—Figure 34. Divide the diameter *AB* of the circle into as many equal parts as the polygon is to have sides. With the points *A* and *B* as centers and radius *AB,* describe arcs cutting each other at *C.* Draw the line *CE* through the

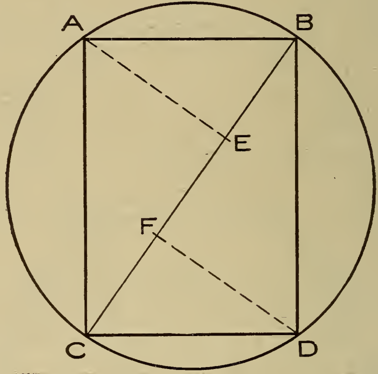


Figure 35.

second point of division of the diameter of *AB,* intersecting the circumference of the circle *D.* A line drawn from *B* to *D* is one of the sides of the polygon.

To cut a beam of the strongest shape from a circular section.—Figure 35. Divide any diameter *CB* of the circle into three equal parts, as *CF, FE,* and *EB.* At *E* and *F* erect perpendiculars *EA* and *FD* on opposite sides of the diameter *CB.* Join *AB, BD, DC* and *CF.* The rectangle *ABCD* will be the required shape of the beam.

To divide any triangle into two parts of equal area.—Figure 36. Let *ABC* be the given triangle: Bisect one of its sides *AB* at *D* and describe the semicircle *AEB.*

At D erect the perpendicular DE and with center B and radius BE describe the arc EF, which intersects the line AB at F. At F draw the line FG parallel to AC. This divides the triangle into two parts of equal area.

To inscribe a circle of the greatest possible diameter in a given triangle.—Figure 37. Bisect the angles A

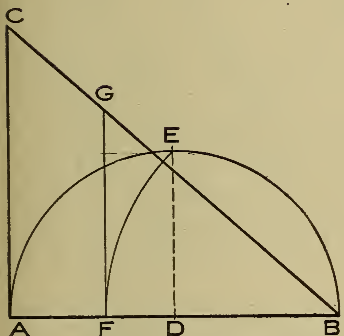


Figure 36.

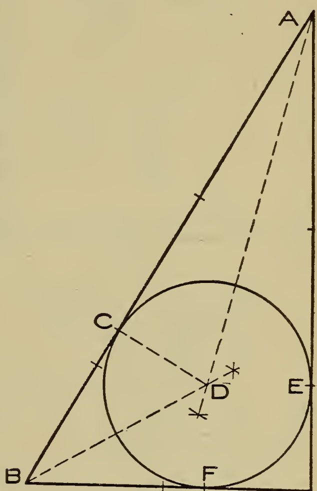


Figure 37.

and B, and draw the lines, AD, BD which intersect each other at D. From D draw the line CD perpendicular to AB. Then CD will be the radius of the required circle CEF.

To construct a square equal in area to a given circle.—Figure 38. Let $ABCD$ be the given circle: Draw the diameters AB and CD at right angles to each other, then bisect the half diameter or radius DB at E and draw the line FL, parallel to BA. At the points C and F erect the perpendiculars CH and FG, equal in length to CF. Join HG. Then $CFGH$ is the required square. The dotted line FL is equal to one-fourth the circle $ACBD$.

To construct a rectangle of the greatest possible area in a given triangle.—Figure 39. Let ABC be the given triangle: Bisect the sides *AB* and *BC* at *G* and *D*. Draw the line *GD* and from the points *G* and *D*, draw the lines

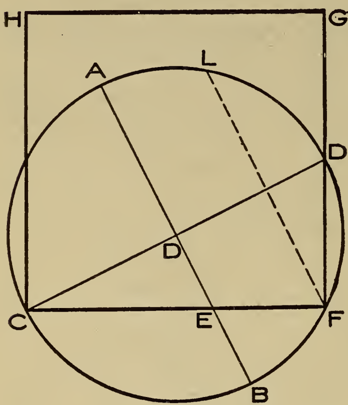


Figure 38.

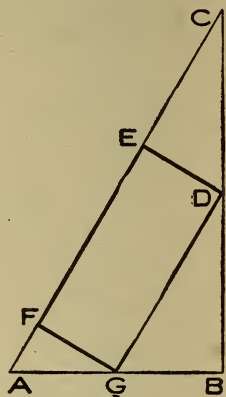


Figure 39.

GF and *DE* perpendicular to *GD*. Then *EFGD* is the required rectangle.

To construct a rectangle equal in area to a given triangle.—Figure 40. Let ABC be the given triangle: Bisect the base *AB* of the triangle at *D* and erect the perpendiculars *DE* and *BF* at *D* and *B*. Through *C* draw the line *ECF* intersecting the perpendiculars *DE* and *BF* at *E* and *F*. Then *BDEF* is the required rectangle.

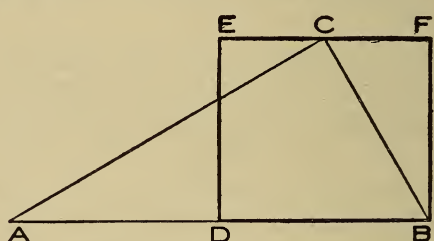


Figure 40.

To construct a triangle equal in area to a given parallelogram.—Figure 41. Let *ABCD* be the given parallelogram: Produce the line *AB* at *B* and make *BE*

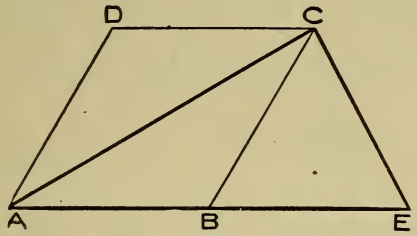


Figure 41.

equal to *AB*. Joint the points *A* and *C* and *ACE* will be the triangle required.

To inscribe a square within a given circle.—Figure 42. Let *ADBC* be the given circle: Draw the diameters *AB* and *CD* at right angles to each other. Join *AD, DB, BC,* and *CA*. Then *ACBD* is the inscribed square.

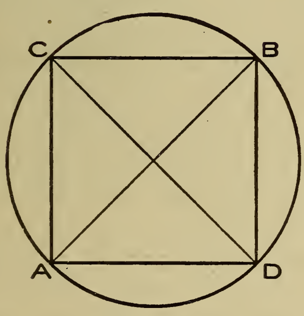


Figure 42.

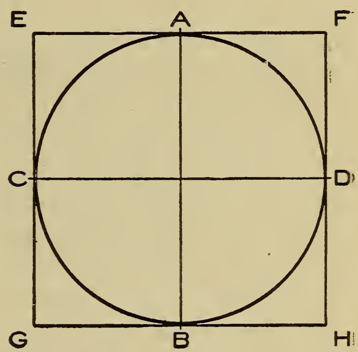


Figure 43.

To describe a square without a given circle.—Figure 43. Draw the diameters *AB* and *CD* at right angles to each other. Through *A* and *B* draw the lines *EF* and *GH*, parallel to *CD*, also draw the lines *EG* and *FH* through the points *C* and *D* and parallel to *AB*. This completes the required square *EFGH.*

To construct an octagon in a given square.—Figure 44. Let *ABCD* be the given square: Draw the diagonal lines *AC* and *BD,* which intersect each other at the point *O.* With a radius equal to *AO* or *OC,* describe the arcs

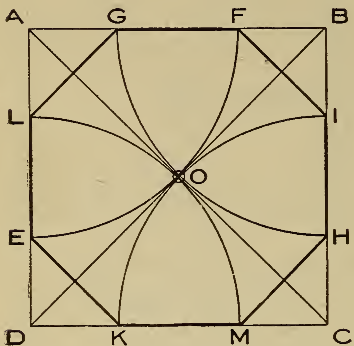


Figure 44.

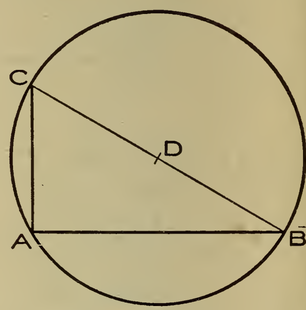


Figure 45.

EF, GH, IK and *LM.* Connect the points *EK, LG, FI* and *HM.* Then *GFIHMKEL* is the required octagon.

To construct a circle equal in area to two given circles.—Figure 45. Let *AB* and *AC* equal the diameters of the given circles: Erect *AC* at *A* and at right angles to *AB.* Connect *B* and *C,* then bisect the line *BC* at *D* and describe the circle *ACB,* which is the circle required and is equal in area to the two given circles.

To describe an octagon about a given circle.—Figure 46. Let *ACBD* be the given circle: Draw the diameters *AB* and *CD* at right angles to each other. With any convenient radius and centers *A, C, B* and *D* describe arcs intersecting each other at *E, H, F* and *G.* Join *EF* and *GH,* which form two additional diameters. At the points *A, B, C, D,* draw the lines *KL, PR, MN* and *ST,* parallel with the diameters *CD* and *AB* respectively. At the points of intersection of the circumference of the circle by the lines *EF* and *GH*, draw the lines *KP, RM, NT* and *SL* parallel with the lines *EF* and *HG* respectively. Then *PRMNTSLK* is the required octagon.

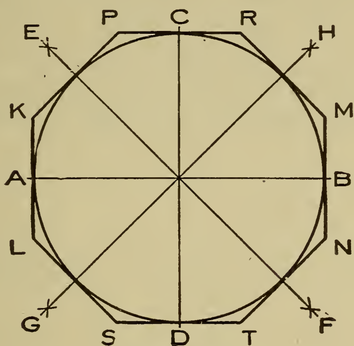


Figure 46.

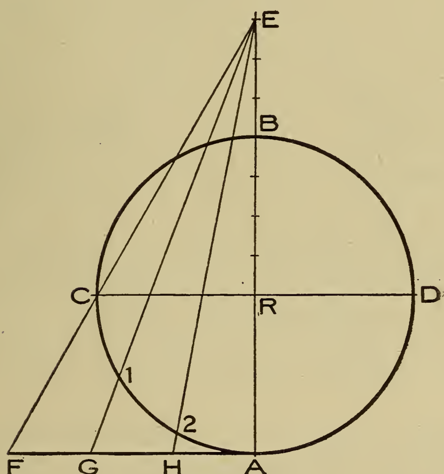


Figure 47.

To draw a straight line equal in length to a given portion of the circumference of a circle.—Figure 47. Let *ACBD* be the given circle: Draw the diameters *AB* and

CD at right angles with each other. Divide the radius *RB* into four equal parts. Produce the diameter *AB* at *B*, and make *BE* equal to three of the four parts of *RB*. At *A* draw the line *AF* parallel to *CD*, and then draw the line *ECF*. The line *AF* is equal to one-fourth of the circumference of the circle *ACBD*. If lines be drawn from *E* through points in the circumference of the circle as *1* and *2*, meeting the line *AF* at *G* and *H*, then *C-1*, *1-2* and *2-A* will equal *FG*, *GH* and *HA* respectively.

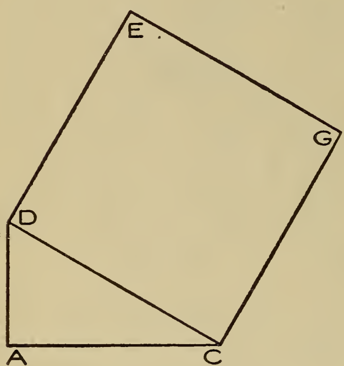


Figure 48.

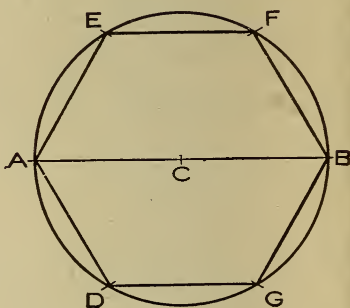


Figure 49.

To construct a square equal in area to two given squares.—Figure 48. Let *AC* and *AD* be the length of the sides of the given squares: Make *AD* perpendicular to *AC* and connect *DC*. Then *DC* is one of the sides of the square *DCEG* which is equal to the two given squares.

To inscribe a hexagon in a given circle.—Figure 49. Draw a diameter of the circle as *AB*: With centers *A* and *B* and radius *AC* or *BC*, describe arcs cutting the circumference of the circle at *D*, *E*, *F* and *G*. Join *EF*, *FB*, *BG*, *GD*, *DA* and *AE*. This gives the required hexagon.

To describe a cycloid, the diameter of the generating *circle being given.*—Figure 50. Let BD be the generating circle: Draw the line *ABC* equal in length to the circumference of the generating circle. Divide the circumference of the generating circle into 12 parts as shown. Draw lines from the points of division *1, 2, 3,* etc., of the

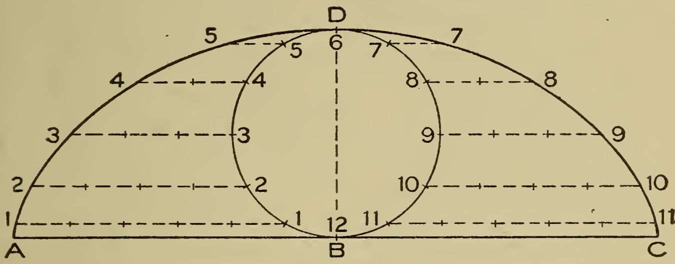


Figure 50.

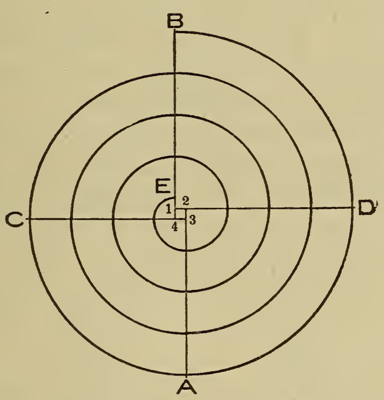


Figure 51.

circumference of the generating circle, parallel to the line *ABC* and on both sides of the circle. Lay off one division of the generating circle on the lines *5* and *7,* two divisions on the lines *4* and *8,* three divisions on the lines *3* and *9,* four divisions on the lines *2* and *10,* and five divisions on the lines *1* and *11.* A line traced through the points thus obtained will be the cycloid curve required.

To develop a spiral with uniform spacing.—Figure 51. Divide the line *BE* into as many equal parts as there are required turns in the spiral. Then subdivide one of these spaces into four equal parts. Produce the line *BE* to *4*, making the extension *E-4* equal to two of the subdivisions. At *1* draw the line *1-D;* lay off *1-2* equal to one of the subdivisions. At *2* draw *2-A* perpendicular to *1-D* and at *3* in *2-A* draw *3-C,* etc. With center *1* and radius *1-B* describe the arc *BD;* with center *2* and radius *2-D* describe the arc *DA;* with center *3* and radius *3-A,* etc. until the spiral is completed. If carefully laid out, the spiral should terminate at *E,* as shown in the drawing.

MENSURATION

Mensuration is that branch of arithmetic which is used in ascertaining the extent and solidity or capacity of bodies capable of being measured.

Definitions of Arithmetical Signs.—

$=$ Sign of Equality, as $4+8=12$.

$+$ Sign of Addition, as $6+6=12$, the Sum.

$-$ Sign of Subtraction, as $6-3=3$, the Remainder.

$\times$ Sign of Multiplication, as $8\times4=32$, the Product.

$\div$ Sign of Division, as $24\div6=4$ $^{24}/_{6}=4$.

$\surd$ Sign of Square Root, signifies evolution or extraction of square root.

^{2} Sign of to be squared, thus $8^2=8\times8=64$.

^{3} Sign of to be cubed, thus $3^3=3\times3\times3=27$.

MENSURATION OF PLANE SURFACES

To find the area of a circle.—Figure 52. Multiply the square of the diameter by .7854.

To find the circumference of a circle.—Multiply the diameter by 3.1416.

Circle: Area $= .7854D^2$.
Circ. $= 3.1416D$.

To find the area of a semicircle.—Figure 52. Multiply the square of the diameter by .3927.

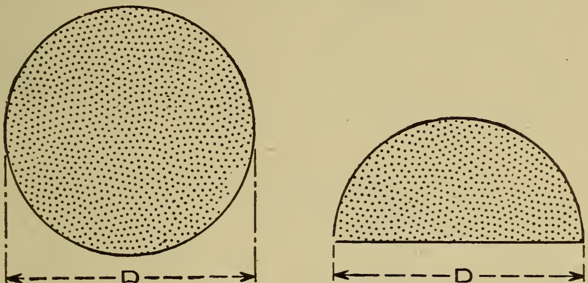


Figure 52.

To find the circumference of a semicircle.—Multiply the diameter by 1.5708.

Semicircle: Area $= .3927D^2$.
Circ. $= 1.5708D$.

To find the area of an annular ring.—Figure 53. From the area of the outer circle subtract the area of the inner circle, the result will be the area of the annular ring.

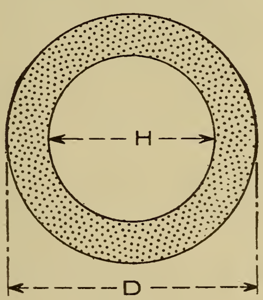


Figure 53.

To find the outer circumference of an annular ring.—Multiply the outer diameter by 3.1416.

To find the inner circumference of an annular ring.—Multiply the inner diameter by 3.1416.

Annular ring: Area = .7854 $(D^2 - H^2)$.
Outer circ. = 3.1416 D.
Inner circ. = 3.1416 H.

To find the area of a flat-oval.—Figure 54. Multiply the length by the width and subtract .214 times the square of the width from the result.

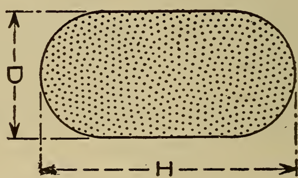


Figure 54.

To find the circumference of a flat-oval.—The circumference of a flat-oval is equal to twice its length plus 1.142 times its width.

Flat-oval: Area = D (H — 0.214D).
Circ. = 2 (H + 0.571D).

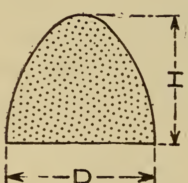


Figure 55.

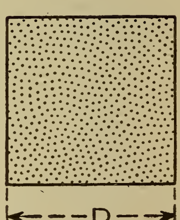


Figure 56.

To find the area of a parabola.—Figure 55. Multiply the base by the height and by .667.

Parabola: Area = .667 (D × H).

To find the area of a square.—Figure 56. Multiply the length by the width, or, in other words, the area is equal to square of the sides.

To find the circumference of a square.—The circumference of a square is equal to the sum of the lengths of the sides.

Square: Area = D^2.
Circ. = 4D.

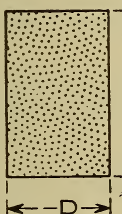


Figure 57.

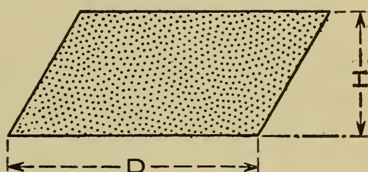


Figure 58.

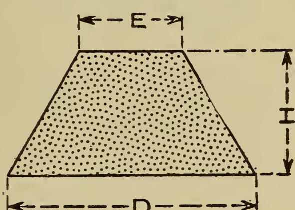


Figure 59.

To find the area of a rectangle.—Figure 57. Multiply the length by the width; the result is the area of the rectangle.

To find the circumference of a rectangle.—The circumference of a rectangle is equal to twice the sum of the length and width.

Rectangle: Area = D × H.
Circ. = 2 (D + H).

To find the area of a parallelogram.—Figure 58. Multiply the base by the perpendicular height.

Parallelogram: Area $= D \times H$.

To find the area of a trapezoid.—Figure 59. Multiply half the sum of the two parallel sides by the perpendicular distance between the sides.

$$\textit{Trapezoid:}\quad \text{Area} = \frac{H(E + D)}{2}$$

To find the area of an equilateral triangle.—Figure 60. The area of an equilateral triangle is equal to the square of one side multiplied by .433.

To find the circumference of an equilateral triangle.—The circumference of an equilateral triangle is equal to the sum of the length of the sides.

Equilaterial triangle: Area$=0.433D^2$.
Circ. $= 3D$.

To find the area of a right-angled or of an isosceles triangle.—Figure 61. Multiply the base by half the perpendicular height.

To find the circumference of any regular polygon.—Figure 62. The circumference of any polygon is equal to the sum of the length of the sides.

$$\textit{Polygon:}\quad \text{Area} = \frac{\text{No. of sides} \times D \times P}{2}$$

Circ. $=$ No. of sides $\times$ D.
D $=$ Length of one side.
P $=$ Perpendicular distance from the center to one side.

MENSURATION OF VOLUME AND SURFACE OF SOLIDS

To find the cubic contents of a sphere.—Figure 63. Multiply the cube of the diameter by .5236.

To find the superficial area of a sphere.—Multiply the square of the diameter by 3.1416.

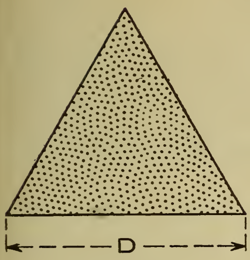


Figure 60.

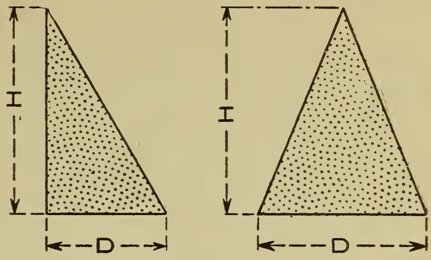


Figure 61.

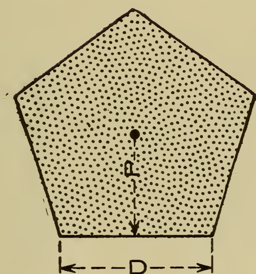


Figure 62.

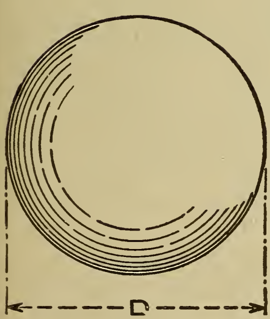


Figure 63.

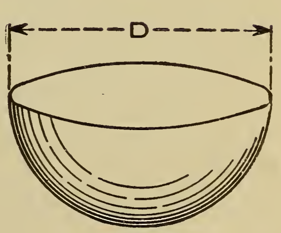


Figure 64.

Sphere: Cubic contents = $.5236D^3$.
Superficial area = $3.1416D^2$.

The area of the surface of a sphere is equal to the area of the surface of a cylinder, the diameter and the height of which are each equal to the diameter of the sphere. Also, the area of the surface of a sphere is equal to four times the area of its diameter.

The latter definition is easily remembered, and is useful in calculating the areas of the hemispheres, because the area of the sheet or disc of metal required for raising a hemisphere must be equal in area to the combined areas of two discs, each equal to the diameter of the hemisphere.

To find the cubic contents of a hemisphere.—Figure 64. Multiply the cube of the diameter by .2618.

To find the superficial area of a hemisphere.

Hemisphere: Cubic contents = $.2618D^3$.
Superficial area = $2.3562D^2$.

To find the cubic contents of a cylindrical ring.—Figure 65. To the cross-sectional diameter of the ring add

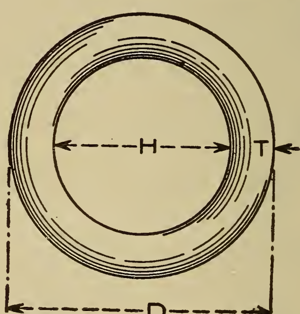


Figure 65.

the inner diameter of the ring, multiply the sum by the square of the cross-sectional diameter of the ring and by 2.4674. The product is the cubic contents.

To find the superficial area of a cylindrical ring.—To the cross-sectional diameter of the ring add the inner diameter of the ring. Multiply the sum by the cross-sectional diameter of the ring and by 9.8696; the product is the superficial area.

Cylindrical ring: Cubic contents $= 2.4674T^2\ (T+H)$
Superficial area $= 9.8696T\ (T+H)$
$D = (H + 2T)$.

To find the cubic contents of a cylinder.—Figure 66. Multiply the area of one end by the length of the cylin-

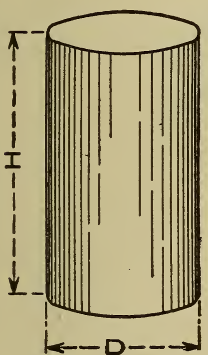


Figure 66.

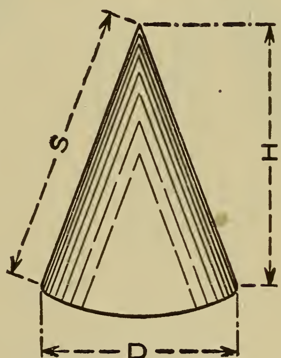


Figure 67.

der. The product will be the cubic contents of the cylinder.

To find the superficial area of a cylinder.—Multiply the circumference of one end by the length of the cylinder and add to the product the area of both ends.

Cylinder: Cubic contents $= .7854\ (D + H)$.
Superficial area $= 1.5708D\ (2H + D)$.

To find the cubic contents of a cone.—Figure 67. Multiply the square of the base by the perpendicular height and by .2618.

To find the superficial area of a cone.—Multiply the circumference of the base by one-half the slant height and add to the product the area of the base.

Cone: Cubic contents $= .2618\ (D^2 \times H)$.

Superficial area $= .7854D\ (2S + D)$.

To find the cubic contents of the frustum of a cone.—Figure 68. To the sum of the areas of the two ends of the frustum, add the square root of the product of the diameters of the two ends; this result multiplied by one-third of the perpendicular height of the frustum will give the cubic contents.

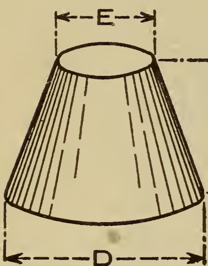


Figure 68.

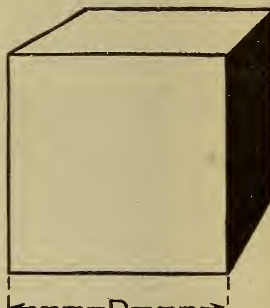


Figure 69.

To find the superficial area of the surface of the frustum of a cone.—Multiply the sum of the diameters of the ends by 3.1416 and by half the slant height. Add to the result the area of both ends and the sum of the two will be superficial area.

Frustum of cone:

$$\text{Cubic contents} = \frac{H\ (.2618\ (E^2 + D^2)\ \sqrt{E \times D})}{3}$$

$$\text{Superficial area} = 3.1416S\left(\frac{D + E}{2}\right) + .7854\ (E^2 + D^2)$$

$$S = \sqrt{\left(\frac{D - E}{2}\right)^2 + H^2}$$

To find the contents of a cube.—Figure 69. The contents are equal to the cube of one of its sides.

To find the superficial area of a cube.—The superficial area of a cube is equal to six times the square of one of its sides.

Cube: Cubic contents $= D^3$.

Superficial area $= 6D^2$.

To find the cubic contents of a rectangular solid.—Figure 70. Multiplying together the length, width, and

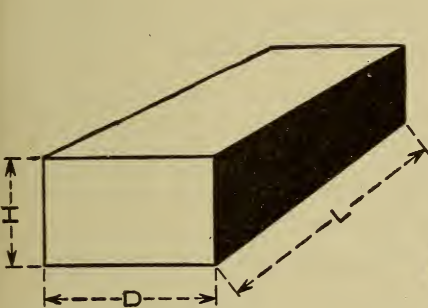


Figure 70.

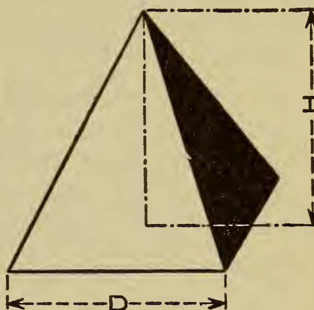


Figure 71.

height will give the cubic contents of the rectangular solid.

To find the superficial area of a rectangular solid.—Multiply the width by the sum of the height and length and add to it the product of the height multiplied by the length. Twice this sum is the superficial area of the rectangular solid.

Rectangular solid:

Cubic contents $= D \times H \times L$

Superficial area $= 2\,(D\,(H + L) + HL)$

To find the cubic contents of a pyramid.—Figure 71. Multiply the area of the base by one-third the perpendicular height and the product will be the cubic contents of the pyramid.

To find the superficial area of a pyramid.—Multiply the circumference of the base by half the slant height and to this add the area of the base. The sum will be the superficial area.

Pyramid: Cubic contents $= \frac{D^2 \times H}{3}$

$$\text{Superficial area} = \left(\frac{4D + S}{2}\right. + 4D$$

$$S = \sqrt{\frac{D^2}{4} + H^2}$$

MENSURATION OF TRIANGLES

To find the base of a right-angled triangle when the perpendicular and the hypotenuse are given.—Figure 72. Subtract the square of the perpendicular from the square of the hypotenuse. The square root of the difference is equal to the length of the base.

$$\text{Base} = \sqrt{\text{Hypotenuse}^2 - \text{Perpendicular}^2} \text{ or } B = \sqrt{C^2 - H^2}$$

To find the perpendicular of a right-angled triangle when the base and hypotenuse are given.—Subtract the

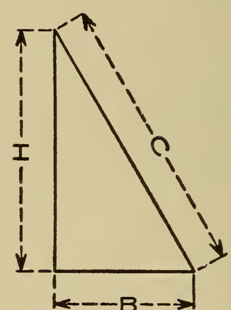


Figure 72.

square of the base from the square of the hypothenuse. The square root of the difference is equal to the length of the perpendicular.

$$\text{Perpendicular} = \sqrt{\text{Hypotenuse}^2 - \text{Base}^2} \text{ or } H = \sqrt{C^2 - B^2}$$

To find the hypotenuse of a right-angled triangle when the base and the perpendicular are given.—The square root of the sum of the squares of the base and the perpendicular is equal to the length of the hypothenuse.

$$\text{Hypotenuse} = \sqrt{\text{Base}^2 + \text{Perpendicular}^2}$$

$$C = \sqrt{B^2 + H^2}$$

To find the perpendicular height of any oblique angled triangle.—Figure 73. From half the sum of the three

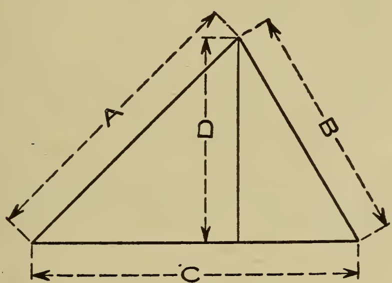


Figure 73.

sides of the triangle, subtract each side severally. Multiply the half sum and the three remainders together and twice the square root of the result, divided by the base of the triangle, will be the height of the perpendicular.

$$D = \frac{2\sqrt{S\,(S - A)\,(S - B)\,(S - C)}}{C}$$

$$S = \frac{\text{Sum of sides}}{2}$$

To find the area of any oblique angled triangle when only the three sides are given.—From half the sum of the three sides, subtract each side severally. Multiply the half sum and the three remainders together and the square root of the product is equal to the area required.

$$\text{Area} = \sqrt{S(S-A)\ (S-B)\ (S-C)}$$

To find the height of the perpendicular and the two sides of any triangle inscribed in a semicircle, when the

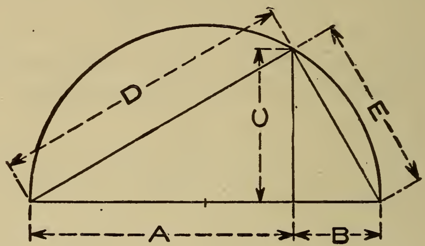


Figure 74.

base of the triangle and the location of the perpendicular are given.—Figure 74.

$$A = \frac{C^2}{B} \qquad B = \frac{C^2}{A} \qquad C = \sqrt{A+B}$$

$$D = \sqrt{A\ (A+B)} \qquad E = \sqrt{B\ (A+B)}$$

XV

USEFUL TABLES

The Metric System.—Although the metric system was legalized by the United States Government in 1866, it has been little used in this country outside of the schoolroom and laboratory.

The recent great expansion of the foreign trade of the United States has, however, brought about conditions which render some knowledge of the metric system and its equivalents in our ordinary standards of weights and measures very useful, if not absolutely necessary, both to the manufacturer and the mechanic.

The metric system is based on the meter, which was designed to be one ten-millionth part of the earth's meridian, passing through Dunkirk and Formentera. Later investigations, however, have shown that the meter exceeds one ten-millionth part by almost one part in 6400. The equivalent of the meter, as authorized by the United States Government, is 39.37 inches.

The three principal units are the *meter,* the unit of length; the *liter,* the unit of capacity; and the *gram,* the unit of weight. Multiples of these are obained by prefixing the Greek words, *Deka* (10), *Hekto* (100), and *Kilo* (1,000). Divisions are obtained by prefixing the Latin words, *deci* (1-10), *centi* (1-100), and *milli* (1-1000). Abbreviations of the multiples begin with a capital letter, and of the divisions with a small letter, as, for example: Dekameter is abbreviated thus, Dm, and decimeter thus, dm.

The liter is equal to the volume occupied by 1 cubic decimeter. The gram is the weight of one cubic centimeter of pure distilled water at a temperature of 39.2 degrees Fahrenheit, the kilogram is the weight of 1 liter of water, the tonne is the weight of 1 cubic meter of water.

The Metric System of Measurement.

Table No. 1.—Measures of Length.

1 Millimeter (mm.) = 0.03937 inches, or about $\frac{1}{25}$ inches
10 Millimeters = 1 Centimeter (cm.) = 0.393 inches
10 Centimeters = 1 Decimeter (dm.) = 3.937 inches
10 Decimeters = 1 Meter (m.) = 39.370 inches, 3.280 feet, or 1.093 yards
10 Meters = 1 Dekameter (Dm.) = 32.808 feet
10 Dekameters = 1 Hektometer (Hm.) = 19.927 rods
10 Hektometers = 1 Kilometer (Km.) = 1093.61 yards, or 0.621 mile
10 Kilometers = 1Myriameter (Mm.) = 6.213 miles
1 inch = 2.54 cm. 1 foot = 0.3048 m. 1 yard = 0.9144 m. 1 rod = 0.502 Dm. 1 mile = 1.609 Km.

Table No. 2.—Measures of Weight.

1 Gramme (g.) = 15.432 grains Troy, or 0.032 ounce Troy, or 0.035 ounce avoirdupois
10 Grammes = 1 Dekagramme (Dg.) = 0.352 oz. avoir.
10 Dekagrammes = 1 Hektogramme (Hg.) = 3.527 oz. avoir.
10 Hektogrammes = 1 Kilogramme (Kg.) = 2.204 pounds
1000 Kilogrammes = 1 Tonne (T.) = 2204.621 pounds, or 1.102 tons of 2000 pounds, or 0.984 tons of 2240 pounds
1 grain = 0.064 g. 1 ounce avoirdupois = 28.35 g. 1 ton 2000 pounds = 0.9072 T.

Table No. 3.—Measures of Capacity.

1 Liter (l.) = 1 cubic decimeter = 61.027 cubic inches, or 0.035 cubic feet, or 1.056 liquid quarts, or 0.908 dry quarts, or 0.264 gallon.
10 Liters = 1 Dekaliter (Dl.) = 2.641 gallons, or 1.135 pecks
10 Dekaliters = 1 Hektoliter (Hl.) = 2.8375 bushels
10 Hektoliters = 1 Kiloliter (Kl.) = 61027.05 cubic inches, or 28.375 bushels.
1 cubic foot = 28.317 l. 1gallon = 3.785 l.

TABLE NO. 4—SQUARES, CUBES, SQUARE ROOTS, CUBE ROOTS AND RECIPROCALS OF NUMBERS FROM 1 TO 500.

No.	Square	Cube	Square Root	Cube Root	Reciprocal
1	1	1	1.00000	1.00000	1.00000
2	4	8	1.41421	1.25992	.50000
3	9	27	1.73205	1.44224	.33333
4	16	64	2.00000	1.58740	.25000
5	25	125	2.23606	1.70997	.20000
6	36	216	2.44948	1.81712	.16666
7	49	343	2.64575	1.91293	.14285
8	64	512	2.82842	2.00000	.12500
9	81	729	3.00000	2.08008	.11111
10	100	1000	3.16227	2.15443	.10000
11	121	1331	3.31662	2.22398	.09090
12	144	1728	3.46410	2.28942	.08333
13	169	2197	3.60555	2.35133	.07602
14	196	2744	3.74165	2.41014	.07142
15	225	3375	3.87298	2.46621	.06666
16	256	4096	4.00000	2.51984	.06250
17	289	4913	4.12310	2.57128	.05882
18	324	5832	4.24264	2.62074	.05555
19	361	6859	4.35889	2.66840	.05263
20	400	8000	4.47213	2.71441	.05000
21	441	9621	4.58257	2.75892	.04761
22	484	10648	4.69041	2.80203	.04545
23	529	12167	4.79583	2.84386	.04347
24	576	13824	4.89897	2.88449	.04166
25	625	15625	5.00000	2.92401	.04000
26	676	17576	5.09901	2.96249	.03846
27	729	19683	5.19615	3.00000	.03703
28	784	21952	5.29150	3.03658	.03571
29	841	24389	5.38516	3.07231	.03448
30	900	27000	5.47722	3.10723	.03333
31	961	29791	5.56776	3.14138	.03225
32	1024	32768	5.65685	3.17480	.03125
33	1089	35937	5.74456	3.20753	.03030
34	1156	39304	5.83095	3.23961	.02941
35	1225	42875	5.91607	3.27106	.02857
36	1296	46656	6.00000	3.30192	.02777
37	1369	50653	6.08276	3.33222	.02702
38	1444	54872	6.16441	3.36197	.02631

No.	Square	Cube	Square Root	Cube Root	Reciprocal
39	1521	59319	6.24499	3.39121	.02564
40	1600	64000	6.32455	3.41995	.02500
41	1681	68921	6.40312	3.44821	.02439
42	1764	74088	6.48074	3.47602	.02380
43	1849	79507	6.55743	3.50339	.02325
44	1936	85184	6.63324	3.53034	.02272
45	2025	91125	6.70820	3.55689	.02222
46	2116	97336	6.78233	3.58304	.02173
47	2209	103823	6.85565	3.60882	.02127
48	2304	110592	6.92820	3.63424	.02083
49	2401	117649	7.00000	3.65930	.02040
50	2500	125000	7.07106	3.68403	.02000
51	2601	132651	7.14142	3.70842	.01960
52	2704	140608	7.21110	3.73251	.01923
53	2809	148877	7.28010	3.75628	.01886
54	2916	157464	7.34846	3.77976	.01851
55	3025	166375	7.41619	3.80295	.01818
56	3136	175616	7.48331	3.82586	.01785
57	3249	185193	7.54983	3.84850	.01754
58	3364	195112	7.61577	3.87087	.01724
59	3481	205379	7.68114	3.89299	.01694
60	3600	216000	7.74596	3.91486	.01666
61	3721	226981	7.81024	3.93649	.01639
62	3844	238328	7.87400	3.95789	.01612
63	3969	250047	7.93725	3.97905	.01587
64	4096	262144	8.00000	4.00000	.01562
65	4225	274625	8.06225	4.02072	.01538
66	4356	287496	8.12403	4.04124	.01515
67	4489	300763	8.18535	4.06154	.01492
68	4624	314432	8.24621	4.08165	.01470
69	4761	328500	8.30662	4.10156	.01449
70	4900	343000	8.36660	4.12128	.01428
71	5041	357911	8.42614	4.14081	.01408
72	5184	373248	8.48528	4.16016	.01388
73	5329	389017	8.54400	4.17933	.01369
74	5476	405224	8.60232	4.19833	.01351
75	5625	421875	8.66025	4.21716	.01333
76	5776	438976	8.71779	4.23582	.01315
77	5929	456533	8.77496	4.25432	.01298
78	6084	474552	8.83176	4.27265	.01282
79	6241	493039	8.88819	4.29084	.01265
80	6400	512000	8.94427	4.30886	.01250

No.	Square	Cube	Square Root	Cube Root	Reciprocal
81	6561	531441	9.00000	4.32674	.01234
82	6724	551368	9.05538	4.34448	.01219
83	6889	571787	9.11043	4.36207	.01204
84	7056	592704	9.16515	4.37951	.01190
85	7225	614125	9.21954	4.39682	.01176
86	7396	636056	9.27361	4.41400	.01162
87	7569	658503	9.32737	4.43104	.01149
88	7744	681472	9.38083	4.44796	.01136
89	7921	704969	9.43398	4.46474	.01123
90	8100	729000	9.48683	4.48140	.01111
91	8281	753571	9.53939	4.49794	.01098
92	8464	778688	9.59166	4.51435	.01086
93	8649	804357	9.64365	4.53065	.01075
94	8836	830584	9.69535	4.54683	.01063
95	9025	857375	9.74679	4.56290	.01052
96	9216	884736	9.79795	4.57885	.01041
97	9409	912673	9.84885	4.59470	.01030
98	9604	941192	9.89949	4.61043	.01020
99	9801	970299	9.94987	4.62606	.01010
100	10000	1000000	10.00000	4.64158	.01000
101	10201	1030301	10.04987	4.65700	.00990
102	10404	1061208	10.09950	4.67232	.00980
103	10609	1092727	10.14889	4.68754	.00970
104	10816	1124864	10.19803	4.70266	.00961
105	11025	1157625	10.24695	4.71769	.00952
106	11236	1191016	10.29563	4.73262	.00943
107	11449	1225043	10.34408	4.74745	.00934
108	11664	1259712	10.39230	4.76220	.00925
109	11881	1295029	10.44030	4.77685	.00917
110	12100	1331000	10.48808	4.79141	.00909
111	12321	1367631	10.53565	4.80589	.00900
112	12544	1404928	10.58300	4.82028	.00892
113	12769	1442897	10.63014	4.83458	.00884
114	12996	1481544	10.67707	4.84880	.00877
115	13225	1520875	10.72380	4.86294	.00869
116	13456	1560896	10.77032	4.87699	.00862
117	13689	1601613	10.81665	4.89097	.00854
118	13924	1643032	10.86278	4.90486	.00847
119	14161	1685159	10.90871	4.91868	.00840
120	14400	1728000	10.95445	4.93242	.00833
121	14641	1771561	11.00000	4.94608	.00826
122	14884	1815848	11.04536	4.95967	.00819

No.	Square	Cube	Square Root	Cube Root	Reciprocal
123	15129	1860867	11.09053	4.97318	.00813
124	15376	1906624	11.13552	4.98663	.00806
125	15625	1953125	11.18033	5.00000	.00800
126	15876	2000376	11.22497	5.01329	.00793
127	16129	2048383	11.26942	5.02652	.00787
128	16384	2097152	11.31370	5.03968	.00781
129	16641	2146689	11.35781	5.05277	.00775
130	16900	2197000	11.40175	5.06579	.00769
131	17161	2248091	11.44552	5.07875	.00763
132	17424	2299968	11.48912	5.09164	.00757
133	17689	2352637	11.53256	5.10446	.00751
134	17956	2406104	11.57583	5.11722	.00746
135	18225	2460375	11.61895	5.12992	.00740
136	18496	2515456	11.66190	5.14256	.00735
137	18769	2571353	11.70469	5.15513	.00729
138	19044	2628072	11.74734	5.16764	.00724
139	19321	2685619	11.78982	5.18010	.00719
140	19600	2744000	11.83215	5.19249	.00714
141	19881	2803221	11.87434	5.20482	.00709
142	20164	2863288	11.91637	5.21710	.00704
143	20449	2924207	11.95826	5.22932	.00699
144	20736	2985984	12.00000	5.24148	.00694
145	21025	3048625	12.04159	5.25358	.00689
146	21316	3112136	12.08304	5.26563	.00684
147	21609	3176523	12.12435	5.27763	.00680
148	21904	3241792	12.16552	5.28957	.00675
149	22201	3307949	12.20655	5.30145	.00671
150	22500	3375000	12.24744	5.31329	.00666
151	22801	3442951	12.28820	5.32507	.00662
152	23104	3511808	12.32882	5.33680	.00657
153	23409	3581577	12.36931	5.34848	.00653
154	23716	3652264	12.40967	5.36010	.00649
155	24025	3723875	12.44989	5.37168	.00645
156	24336	3796416	12.48999	5.38321	.00641
157	24649	3869893	12.52996	5.39469	.00636
158	24964	3944312	12.56980	5.40612	.00632
159	25281	4019679	12.60952	5.41750	.00628
160	25600	4096000	12.64911	5.42883	.00625
161	25921	4173281	12.68857	5.44012	.00621
162	26244	4251528	12.72792	5.45136	.00617
163	26569	4330747	12.76714	5.46255	.00613
164	26896	4410944	12.80624	5.47370	.00609

No.	Square	Cube	Square Root	Cube Root	Reciprocal
165	27225	4492125	12.84523	5.48480	.00606
166	27556	4574296	12.88409	5.49586	.00602
167	27889	4657463	12.92284	5.50687	.00598
168	28224	4741632	12.96148	5.51784	.00595
169	28561	4826809	13.00000	5.52877	.00591
170	28900	4913000	13.03840	5.53965	.00588
171	29241	5000211	13.07669	5.55049	.00584
172	29584	5088448	13.11487	5.56129	.00581
173	29929	5177717	13.15294	5.57205	.00578
174	30276	5268024	13.19090	5.58277	.00574
175	30625	5359375	13.22875	5.59344	.00571
176	30976	5451776	13.26649	5.60407	.00568
177	31329	5545233	13.30413	5.61467	.00564
178	31684	5639752	13.34166	5.62522	.00561
179	32041	5735339	13.37908	5.63574	.00558
180	32400	5832000	13.41640	5.64621	.00555
181	32761	5929741	13.45362	5.65665	.00552
182	33124	6028568	13.49073	5.66705	.00549
183	33489	6128487	13.52774	5.67741	.00546
184	33856	6229504	13.56466	5.68773	.00543
185	34225	6331625	13.60147	5.69801	.00540
186	34596	6434856	13.63818	5.70826	.00537
187	34969	6539203	13.67479	5.71847	.00534
188	35344	6644672	13.71130	5.72865	.00531
189	35721	6751269	13.74772	5.73879	.00529
190	36100	6859000	13.78404	5.74889	.00526
191	36481	6967871	13.82027	5.75896	.00523
192	36864	7077888	13.85640	5.76899	.00520
193	37249	7189057	13.89244	5.77899	.00518
194	37636	7301384	13.92838	5.78896	.00515
195	38025	7414875	13.96424	5.79889	.00512
196	38416	7529536	14.00000	5.80878	.00510
197	38809	7645373	14.03566	5.81864	.00507
198	39204	7762392	14.07124	5.82847	.00505
199	39601	7880599	14.10673	5.83827	.00502
200	40000	8000000	14.14213	5.84803	.00500
201	40401	8120601	14.17744	5.85776	.00497
202	40804	8242408	14.21267	5.86746	.00495
203	41209	8365427	14.24780	5.87713	.00492
204	41616	8489664	14.28285	5.88676	.00490
205	42025	8615125	14.31782	5.89636	.00487
206	42436	8741816	14.35270	5.90594	.00485

No.	Square	Cube	Square Root	Cube Root	Reciprocal
207	42849	8869743	14.38749	5.91548	.00483
208	43264	8998912	14.42220	5.92499	.00480
209	43681	9129329	14.45683	5.93447	.00478
210	44100	9261000	14.49137	5.94392	.00476
211	44521	9393931	14.52583	5.95334	.00473
212	44944	9528128	14.56021	5.96273	.00471
213	45369	9663597	14.59451	5.97209	.00469
214	45796	9800344	14.62873	5.98142	.00467
215	46225	9938375	14.66287	5.99072	.00465
216	46656	10077696	14.69693	6.00000	.00462
217	47089	10218313	14.73091	6.00924	.00460
218	47524	10360232	14.76482	6.01846	.00458
219	47961	10503459	14.79864	6.02765	.00456
220	48400	10648000	14.83239	6.03681	.00454
221	48841	10793861	14.86606	6.04594	.00452
222	49284	10941048	14.89966	6.05504	.00450
223	49729	11089567	14.93318	6.06412	.00448
224	50176	11239424	14.96662	6.07317	.00446
225	50625	11390625	15.00000	6.08220	.00444
226	51076	11543176	15.03329	6.09119	.00442
227	51529	11697083	15.06651	6.10017	.00440
228	51984	11852352	15.09966	6.10911	.00438
229	52441	12008989	15.13274	6.11803	.00436
230	52900	12167000	15.16575	6.12692	.00434
231	53361	12326391	15.19868	6.13579	.00432
232	53824	12487168	15.23154	6.14463	.00431
233	54289	12649337	15.26433	6.15344	.00429
234	54756	12812904	15.29705	6.16224	.00427
235	55225	12977875	15.32970	6.17100	.00425
236	55696	13144256	15.36229	6.17974	.00423
237	56169	13312053	15.39480	6.18846	.00421
238	56644	13481272	15.42724	6.19715	.00420
239	57121	13651919	15.45962	6.20582	.00418
240	57600	13824000	15.49193	6.21446	.00416
241	58081	13997521	15.52417	6.22308	.00414
242	58564	14172488	15.55634	6.23167	.00413
243	59049	14348907	15.58845	6.24025	.00411
244	59536	14526784	15.62049	6.24879	.00409
245	60025	14706125	15.65247	6.25732	.00408
246	60516	14886936	15.68438	6.26582	.00406
247	61009	15069223	15.71623	6.27430	.00404
248	61504	15252992	15.74801	6.28276	.00403

No.	Square	Cube	Square Root	Cube Root	Reciprocal
249	62001	15438249	15.77973	6.29119	.00401
250	62500	15625000	15.81138	6.29960	.00400
251	63001	15813251	15.84297	6.30799	.00398
252	63504	16003008	15.87450	6.31635	.00396
253	64009	16194277	15.90597	6.32470	.00395
254	64516	16387064	15.93737	6.33302	.00393
255	65025	16581375	15.96871	6.34132	.00392
256	65536	16777216	16.00000	6.34960	.00390
257	66049	16974593	16.03121	6.35786	.00389
258	66564	17173512	16.06237	6.36609	.00387
259	67081	17373979	16.09347	6.37431	.00386
260	67600	17576000	16.12451	6.38250	.00384
261	68121	17779581	16.15549	6.39067	.00383
262	68644	17984728	16.18641	6.39882	.00381
263	69169	18191447	16.21727	6.40695	.00380
264	69696	18399744	16.24807	6.41506	.00378
265	70225	18609625	16.27882	6.42315	.00377
266	70756	18821096	16.30950	6.43122	.00375
267	71289	19034163	16.34013	6.43927	.00374
268	71824	19248832	16.37070	6.44730	.00373
269	72361	19465109	16.40121	6.45531	.00371
270	72900	19683000	16.43167	6.46330	.00370
271	73441	19902511	16.46207	6.47127	.00369
272	73984	20123648	16.49242	6.47922	.00367
273	74529	20346417	16.52271	6.48715	.00366
274	75076	20570824	16.55294	6.49506	.00364
275	75625	20796875	16.58312	6.50295	.00363
276	76176	21024576	16.61324	6.51083	.00362
277	76729	21253933	16.64331	6.51868	.00361
278	77284	21484952	16.67333	6.52651	.00359
279	77841	21717639	16.70329	6.53433	.00358
280	78400	21952000	16.73320	6.54213	.00357
281	78961	22188041	16.76305	6.54991	.00355
282	79524	22425768	16.79285	6.55767	.00354
283	80089	22665187	16.82260	6.56541	.00353
284	80656	22906304	16.85229	6.57313	.00352
285	81225	23149125	16.88194	6.58084	.00350
286	81796	23393656	16.91153	6.58853	.00349
287	82369	23639903	16.94107	6.59620	.00348
288	82944	23887872	16.97056	6.60385	.00347
289	83521	24137569	17.00000	6.61148	.00346
290	84100	24389000	17.02938	6.61910	.00344

No.	Square	Cube	Square Root	Cube Root	Reciprocal
291	84681	24642171	17.05872	6.62670	.00343
292	85264	24897088	17.08800	6.63428	.00342
293	85849	25153757	17.11724	6.64185	.00341
294	86436	25412184	17.14642	6.64939	.00340
295	87025	25672375	17.17556	6.65693	.00338
296	87616	25934336	17.20465	6.66444	.00337
297	88209	26198073	17.23368	6.67194	.00336
298	88804	26463592	17.26267	6.67942	.00335
299	89401	26730899	17.29161	6.68688	.00334
300	90000	27000000	17.32050	6.69432	.00333
301	90601	27270901	17.34935	6.70175	.00332
302	91204	27543608	17.37814	6.70917	.00331
303	91809	27818127	17.40689	6.71657	.00330
304	92416	28094464	17.43559	6.72395	.00328
305	93025	28372625	17.46424	6.73131	.00327
306	93636	28652616	17.49285	6.73866	.00326
307	94249	28934443	17.52141	6.74599	.00325
308	94864	29218112	17.54992	6.75331	.00324
309	95481	29503629	17.57839	6.76061	.00323
310	96100	29791000	17.60681	6.76789	.00322
311	96721	30080231	17.63519	6.77516	.00321
312	97344	30371328	17.66352	6.78242	.00320
313	97969	30664297	17.69180	6.78966	.00319
314	98596	30959144	17.72004	6.79688	.00318
315	99225	31255875	17.74823	6.80409	.00317
316	99856	31554496	17.77638	6.81128	.00316
317	100489	31855013	17.80449	6.81846	.00315
318	101124	32157432	17.83255	6.82562	.00314
319	101761	32461759	17.86057	6.83277	.00313
320	102400	32768000	17.88854	6.83990	.00312
321	103041	32076161	17.91647	6.84702	.00311
322	103684	33386248	17.94435	6.85412	.00310
323	104329	33698267	17.97220	6.86121	.00309
324	104976	34012224	18.00000	6.86828	.00308
325	105625	34328125	18.02775	6.87534	,00307
326	106276	34645976	18.05547	6.88238	.00306
327	106929	34965783	18.08314	6.88941	.00305
328	107584	35287552	18.11077	6.89643	.00304
329	108241	35611289	18.13835	6.90343	.00303
330	108900	35937000	18.16590	6.91042	.00303
331	109561	36264691	18.19340	6.91739	.00302
332	110224	36594368	18.22086	6.92435	.00301

No.	Square	Cube	Square Root	Cube Root	Reciprocal
333	110889	36926037	18.24828	6.93130	.00300
334	111556	37259704	18.27566	6.93823	.00299
335	112225	37595375	18.30300	6.94514	.00298
336	112896	37933056	18.33030	6.95205	.00297
337	113569	38272753	18.35755	6.95894	.00296
338	114244	38614472	18.38477	6.96581	.00295
339	114921	38958219	18.41195	6.97268	.00294
340	115600	39304000	18.43908	6.97953	.00294
341	116281	39651821	18.46618	6.98636	.00293
342	116964	40001688	18.49324	6.99319	.00292
343	117649	40353607	18.52025	7.00000	.00291
344	118336	40707584	18.54723	7.00679	.00290
345	119025	41063625	18.57417	7.01357	.00289
346	119716	41421736	18.60107	7.02034	.00289
347	120409	41781923	18.62793	7.02710	.00288
348	121104	42144192	18.65475	7.03384	.00287
349	121801	42508549	18.68151	7.04058	.00286
350	122500	42875000	18.70828	7.04729	.00285
351	123201	43243551	18.73499	7.05400	.00284
352	123904	43614208	18.76166	7.06069	.00284
353	124609	43986977	18.78829	7.06737	.00283
354	125316	44361864	18.81488	7.07404	.00282
355	126025	44738875	18.84144	7.08069	.00281
356	126736	45118016	18.86796	7.08734	.00280
357	127449	45499293	18.89444	7.09397	.00280
358	128164	45882712	18.92088	7.10058	.00279
359	128881	46268279	18.94729	7.10719	.00278
360	129600	46656000	18.97366	7.11378	.00277
361	130321	47045881	19.00000	7.12036	.00277
362	131044	47437928	19.02629	7.12693	.00276
363	131769	47832147	19.05255	7.13349	.00275
364	132496	48228544	19.07878	7.14003	.00274
365	133225	48627125	19.10497	7.14656	.00273
366	133956	49027896	19.13112	7.15309	.00273
367	134689	49430863	19.15724	7.15959	.00272
368	135424	49836032	19.18332	7.16609	.00271
369	136161	50243409	19.20937	7.17258	.00271
370	136900	50653000	19.23538	7.17905	.00270
371	137641	51064811	19.26136	7.18551	.00269
372	138384	51478848	19.28730	7.19196	.00268
373	139129	51895117	19.31320	7.19840	.00268
374	139876	52313624	19.33907	7.20483	.00267

No.	Square	Cube	Square Root	Cube Root	Reciprocal
375	140625	52734375	19.36491	7.21124	.00266
376	141376	53157376	19.39071	7.21765	.00265
377	142129	53582633	19.41648	7.22404	.00265
378	142884	54010152	19.44222	7.23042	.00264
379	143641	54439939	19.46792	7.23679	.00263
380	144400	54872000	19.49358	7.24315	.00263
381	145161	55306341	19.51922	7.24950	.00262
382	145924	55742968	19.54482	7.25584	.00261
383	146689	56181887	19.57038	7.26216	.00261
384	147456	56623104	19.59591	7.26848	.00260
385	148225	57066625	19.62141	7.27478	.00259
386	148996	57512456	19.64688	7.28107	.00259
387	149769	57960603	19.67231	7.28736	.00258
388	150544	58411072	19.69771	7.29363	.00257
389	151321	58863869	19.72308	7.29989	.00257
390	152100	59319000	19.74841	7.30614	.00256
391	152881	59776471	19.77371	7.31238	.00255
392	153664	60236288	19.79898	7.31861	.00255
393	154449	60698457	19.82422	7.32482	.00254
394	155236	61162984	19.84943	7.33103	.00253
395	156025	61629875	19.87460	7.33723	.00253
396	156816	62099136	19.89974	7.34342	.00252
397	157609	62570773	19.92485	7.34959	.00251
398	158404	63044792	19.94993	7.35576	.00251
399	159201	63521199	19.97498	7.36191	.00250
400	160000	64000000	20.00000	7.36806	.00250
401	160801	64481201	20.02498	7.37419	.00249
402	161604	64964808	20.04993	7.38032	.00248
403	162409	65450827	20.07485	7.38643	.00248
404	163216	65939264	20.09975	7.39254	.00247
405	164025	66430125	20.12461	7.39863	.00246
406	164836	66923416	20.14944	7.40472	.00246
407	165649	67419143	20.17424	7.41079	.00245
408	166464	67917312	20.19900	7.41685	.00245
409	167281	68417929	20.22374	7.42291	.00244
410	168100	68921000	20.24845	7.42895	.00243
411	168921	69426531	20.27313	7.43499	.00243
412	169744	69934528	20.29778	7.44101	.00242
413	170569	70444997	20.32240	7.44703	.00242
414	171396	70957944	20.34698	7.45303	.00241
415	172225	71473375	20.37154	7.45903	.00240
416	173056	71991296	20.39607	7.46502	.00240

No.	Square	Cube	Square Root	Cube Root	Reciproca
417	173889	72511713	20.42057	7.47099	.00239
418	174724	73034632	20.44504	7.47696	.00239
419	175561	73560059	20.46948	7.48292	.00238
420	176400	74088000	20.49390	7.48887	.00238
421	177241	74618461	20.51828	7.49481	.00237
422	178084	75151448	20.54263	7.50074	.00236
423	178929	75686967	20.56696	7.50666	.00236
424	179776	76225024	20.59126	7.51257	.00235
425	180625	76765625	20.61552	7.51847	.00235
426	181476	77308776	20.63976	7.52436	.00234
427	182329	77854483	20.66397	7.53024	.00234
428	183184	78402752	20.68816	7.53612	.00233
429	184041	78953589	20.71231	7.54198	.00233
430	184900	79507000	20.73644	7.54784	.00232
431	185761	80062991	20.76053	7.55368	.00232
432	186624	80621568	20.78460	7.55952	.00231
433	187489	81182737	20.80865	7.56535	.00230
434	188356	81746504	20.83266	7.57117	.00230
435	189225	82312875	20.85665	7.57689	.00229
436	190096	82881856	20.88061	7.58278	.00229
437	190969	83453453	20.90454	7.58857	.00228
438	191844	84027672	20.92844	7.59436	.00228
439	192721	84604519	20.95232	7.60013	.00227
440	193600	85184000	20.97617	7.60590	.00227
441	194481	85766121	21.00000	7.61166	.00226
442	195364	86350888	21.02379	7.61741	.00226
443	196249	86938307	21.04756	7.62315	.00225
444	197136	87528384	21.07130	7.62888	.00225
445	198025	88121125	21.09502	7.63460	.00224
446	198916	88716536	21.11871	7.64032	.00224
447	199809	89314623	21.14237	7.64602	.00223
448	200704	89915392	21.16601	7.65172	.00223
449	201601	90518849	21.18962	7.65741	.00222
450	202500	91125000	21.21320	7.66309	.00222
451	203401	91733851	21.23676	7.66876	.00221
452	204304	92345408	21.26029	7.67443	.00221
453	205209	92959677	21.28379	7.68008	.00220
454	206116	93576664	21.30727	7.68573	.00220
455	207025	94196375	21.33072	7.69137	.00219
456	207936	94818816	21.35415	7.69700	.00219
457	208849	95443993	21.37755	7.70262	.00218
458	209764	96071912	21.40093	7.70823	.00218

No.	Square	Cube	Square Root	Cube Root	Reciprocal
459	210681	96702579	21.42428	7.71384	.00217
460	211600	97336000	21.44761	7.71944	.00217
461	212521	97972181	21.47091	7.72503	.00216
462	213444	98611128	21.49418	7.73061	.00216
463	214369	99252847	21.51743	7.73618	.00215
464	215296	99897344	21.54065	7.74175	.00215
465	216225	100544625	21.56385	7.74731	.00215
466	217156	101194696	21.58703	7.75286	.00214
467	218089	101847563	21.61018	7.75840	.00214
468	219024	102503232	21.63330	7.76393	.00213
469	219961	103161709	21.65640	7.76946	.00213
470	220900	103823000	21.67948	7.77498	.00212
471	221841	104487111	21.70253	7.78049	.00212
472	222784	105154048	21.72556	7.78599	.00211
473	223729	105823817	21.74856	7.79148	.00211
474	224676	106496424	21.77154	7.79697	.00210
475	225625	107171875	21.79449	7.80245	.00210
476	226576	107850176	21.81742	7.80792	.00210
477	227529	108531333	21.84032	7.81338	.00209
478	228484	109215352	21.86321	7.81884	.00209
479	229441	109902239	21.88606	7.82429	.00208
480	230400	110592000	21.90890	7.82973	.00208
481	231361	111284641	21.93171	7.83516	.00207
482	232324	111980168	21.95449	7.84059	.00207
483	233289	112678587	21.97726	7.84601	.00207
484	234256	113379904	22.00000	7.85142	.00206
485	235225	114084125	22.02271	7.85682	.00206
486	236196	114791256	22.04540	7.86222	.00205
487	237169	115501303	22.06807	7.86761	.00205
488	238144	116214272	22.09072	7.87299	.00204
489	239121	116930169	22.11334	7.87836	.00204
490	240100	117649000	22.13594	7.88373	.00204
491	241081	118370771	22.15851	7.88909	.00203
492	242064	119095488	22.18107	7.89454	.00203
493	243049	119823157	22.20360	7.89979	.00202
494	244036	120553784	22.22611	7.90512	.00202
495	245025	121287375	22.24859	7.91045	.00202
496	246016	122023936	22.27105	7.91578	.00201
497	247009	122763473	22.29349	7.92109	.00201
498	248004	123505992	22.31591	7.92640	.00200
499	249001	124251499	22.33830	7.93171	.00200
500	250000	125000000	22.36067	7.93700	.00200

Table No. 5.—Decimal Equivalents of Millimeters and Fractions of Millimeters.

1 mm. = .03937 inches.

Mm.	Inches.	Mm.	Inches.	Mm.	Inches.
1-50	= .00079	26-50	= .02047	2	= .07874
2-50	.00157	27-50	.02126	3	.11811
3-50	.00236	28-50	.02205	4	.15748
4-50	.00315	29-50	.02283	5	.19685
5-50	.00394	30-50	.02362	6	.23622
6-50	.00472	31-50	.02441	7	.27559
7-50	.00551	32-50	.02520	8	.31496
8-50	.00630	33-50	.02598	9	.35433
9-50	.00709	34-50	.02677	10	.39370
10-50	.00787	35-50	.02756	11	.43307
11-50	.00866	36-50	.02835	12	.47244
12-50	.00945	37-50	.02913	13	.51181
13-50	.01024	38-50	.02992	14	.55118
14-50	.01102	39-50	.03071	15	.59055
15-50	.01181	40-50	.03150	16	.62992
16-50	.01260	41-50	.03228	17	.66929
17-50	.01339	42-50	.03307	18	.70866
18-50	.01417	43-50	.03386	19	.74803
19-50	.01496	44-50	.03465	20	.78740
20-50	.01575	45-50	.03543	21	.82677
21-50	.01654	46-50	.03622	22	.86614
22-50	.01732	47-50	.03701	23	.90551
23-50	.01811	48-50	.03780	24	.94488
24-50	.01890	49-50	.03858	24	.98425
25-50	.01969	1	.03937	26	1.02362

10 Millimeters = 1 Centimeter = 0.3937 inches.
10 Centimeters = 1 Decimeter = 3.937 inches.
10 Decimeters = 1 Meter = 39.37 inches.
2.54 Centimeters = 1 inch.

TABLE NO. 6.—TAPERS AND ANGLES.

Taper Per Foot	Whole Angle.		Half Angle with Center Line.		Taper Per Inch of Whole Angle.	Taper Per Inch from Center Line or Half Angle.
	Deg.	Min.	Deg.	Min.		
1/8	0	36	0	18	.010416	.005203
3/16	0	54	0	27	.015625	.007812
1/4	1	12	0	36	.020833	.010416
5/16	1	30	0	45	.026042	.013021
3/8	1	47	0	53	.031250	.015625
7/16	2	05	1	02	.036458	.018229
1/2	2	23	1	11	.041667	.020833
9/16	2	42	1	21	.046875	.023438
5/8	3	00	1	30	.052084	.026042
11/16	3	18	1	39	.057292	.028646
3/4	3	25	1	47	.062500	.031250
13/16	3	52	1	56	.067708	.033854
7/8	4	12	2	06	.072917	.036456
15/16	4	28	2	14	.078125	.039063
1	4	45	2	23	.083330	.041667
1 1/4	5	58	2	59	.104666	.052084
1 1/2	7	08	3	34	.125000	.062500
1 3/4	8	20	4	10	.145833	.072917
2	9	32	4	46	.166666	.083332
2 1/2	11	54	5	57	.208333	.104166
3	14	16	7	08	.250000	.125000
3 1/2	16	36	8	18	.291666	.145833
4	18	54	9	27	.333333	.166666
4 1/2	21	40	10	50	.375000	.187500
5	24	04	12	02	.416666	.208333
6	28	06	14	03	.500000	.250000

Table No. 7.—Decimal Parts of an Inch.

1-64	.01563	11-32	.34375	43-64	.67188
1-32	.03125	23-64	.35938	11-16	.6875
3-64	.04688	3-8	.375		
1-16	.0625			45-64	.70313
		25-64	.39063	23-32	.71875
5-64	.07813	13-32	.40625	47-64	.73438
3-32	.09375	27-64	.42188	3-4	.75
7-64	.10938	7-16	.4375		
1-8	.125			49-64	.76563
		29-64	.45313	25-32	.78125
9-64	.14063	15-32	.46875	51-64	.79688
5-32	.15625	31-64	.48438	13-16	.8125
11-64	.17188	1-2	.5		
3-16	.1875			53-64	.82813
		33-64	.51563	27-32	.84375
13-64	.20313	17-32	.53125	55-64	.85938
7-32	.21875	35-64	.54688	7-8	.875
15-64	.23438	9-16	.5625		
1-4	.25			57-64	89063
		37-64	.57813	29-31	.90625
17-64	.26563	19-32	.59375	59-64	.92188
9-32	.28125	39-64	.60938	15-16	.9375
19-64	.29688	5-8	.625		
5-16	.3125			61-64	.95313
		41-64	.64063	31-32	.96875
21-64	.32813	21-32	.65625	63-64	.97438

Table No. 8.—Melting Points of Alloys of Tin, Lead and Bismuth.

Tin.	Lead.	Bismuth.	Melting Point in Degrees Fahrenheit.	Tin.	Lead.	Bismuth.	Melting Point in Degrees Fahrenheit,
2	3	5	199	4	1		372
1	1	4	201	5	1		381
3	2	5	212	2	1		385
4	1	5	246	3		1	392
1		1	286	1	1		466
2		1	334	1	3		552
3	1		367				

TABLE NO. 9.—DIMENSIONS OF WROUGHT-IRON PIPE.

Nominal Inside Diameter.	Actual Outside Diameter in Inches.	Actual Inside Diameter in Inches.	Thickness of Metal in Inches.	Threads per Inch.	Length of Full Thread in Inches.
1/8	.405	.270	.068	27	.19
1/4	.540	.364	.085	18	.29
3/8	.675	.493	.091	18	.30
1/2	.840	.622	.109	14	.39
3/4	1.050	.824	.113	14	.40
1	1.315	1.048	.134	11 1/2	.51
1 1/4	1.660	1.380	.140	11 1/2	.54
1 1/2	1.900	1.610	.145	11 1/2	.55
2	2.375	2.067	.154	11 1/2	.58
2 1/2	2.875	2.468	.204	8	.89
3	3.500	3.067	.217	8	.95
3 1/2	4.000	3.548	.226	8	1.00
4	4.500	4.026	.237	8	1.05
4 1/2	5.000	4.508	.246	8	1.10
5	5.563	5.045	.259	8	1.16
6	6.625	6.065	.280	8	1.26
7	7.625	7.023	.301	8	1.36
8	8.625	7.981	.322	8	1.46
9	9.625	8.937	.344	8	1.57
10	10.750	10.018	.366	8	1.68
11	11.75	11.000	.375	8	1.78
12	12.75	12.000	.375	8	1.88
13	14.	13.25	.375	8	2.09
14	15.	14.25	.375	8	2.10
15	16.	15.25	.375	8	2.20

Taper of the thread is 3/4 inch to one foot.

Pipe from 1/8 inch to 1 inch inclusive is butt welded and tested to 300 pounds per square inch.

Pipe 1 1/4 inch and larger is lap welded and tested to 500 pounds per square inch.

TABLE No. 10.—WEIGHT PER FOOT OF SQUARE AND ROUND IRON BARS, IRON WEIGHING 480 POUNDS PER CUBIC FOOT.

Thickness or Diameter in Inches.	Weight of Square Bar One Font Long.	Weight of Round Bar One Foot Long.	Thickness or Diameter in Inches	Weight of Square Bar One Foot Long	Weight of Round Bar One Foot Long
1-16	.013	.010	2 1-16	14.18	11.14
1-8	.052	.041	1-8	15.05	11.82
3-16	.117	.092	3-16	15.95	12.53
1-4	.208	.164	1-4	16.88	13.25
5-16	.326	.256	5-16	17.83	14.00
3-8	.469	.368	3-8	18.80	14.77
7-16	.638	.501	7-16	19.80	15.55
1-2	.833	.654	1-2	20.83	16.36
9-16	1.055	.828	9-16	21.89	17.19
5-8	1.302	1.023	5-8	22.97	18.04
11-16	1.576	1.237	11-16	24.08	18.91
3-4	1.875	1.473	3-4	25.21	19.80
13-16	2.201	1.728	13-16	26.37	20.71
7-8	2.552	2.004	7-8	27.55	21.64
5-16	2.930	2.301	15-16	28.76	22.59
1	3.333	2.618	3	30.00	23.56
1-16	3.763	2.955	1-16	31.26	24.55
1-8	4.219	3.313	1-8	32.55	25.57
3-16	4.701	3.692	3-16	33.87	26.60
1-4	5.208	4.091	1-4	35.21	27.65
5-16	5.742	4.510	5-16	36.58	28.73
3-8	6.302	4.950	3-8	37.97	29.82
7-16	6.888	5.410	7-16	39.39	30.94
1-2	7.500	5.890	1-2	40.83	32.07
9-16	8.138	6.392	9-16	42.30	33.23
5-8	8.802	6.913	5-8	43.80	34.40
11-16	9.492	7.455	11-16	45.33	35.60
3-4	10.21	8.018	3-4	46.88	36.82
13-16	19.95	8.601	13-16	48.45	38.05
7-8	11.72	9.204	7-8	50.05	39.31
15-16	12.51	9.828	15-16	51.68	40.59
2	13.33	10.47	4	53.33	41.89

TABLE NO. 11.—PROPERTIES OF METALS.

	Melting Point. Degrees Fahrenheit.	Weight in Lbs. per Cubic Foot.	Weight in Lbs. per Cubic Inch.	Tensile Strength in Pounds per Square Inch.
Aluminum	1140	166.5	.0963	15000-30000
Antimony	810-1000	421.6	.2439	1050
Brass (average)	1500-1700	523.2	.3027	30000-45000
Copper	1930	552.	.3195	30000-40000
Gold (pure)	2100	1200.9	.6949	20380
Iron, cast	1900-2200	450.	.2604	20000-35000
Iron, wrought	2700-2830	480.	.2779	35000-60000
Lead	618	709.7	.4106	1000-3000
Mercury	39	846.8	.4900	
Nickel	2800	548.7	.3175	
Silver (pure)	1800	655.1	.3791	40000
Steel	2370-2685	489.6	.2834	50000-120000
Tin	475	458.3	.2652	5000
Zinc	780	436.5	.2526	3500

NOTE.—The wide variations in the tensile strength are due to the different forms and qualities of the metal tested. In the case of lead, the lowest strength is for lead cast in a mould, the highest for wire drawn after numerous workings of the metal. With steel it varies with the percentage of carbon used, which is varied according to the grade of steel required. Mercury becomes solid at 39 degrees below zero.

TABLE NO. 12.—MELTING, BOILING AND FREEZING POINTS IN DEGREES FAHRENHEIT OF VARIOUS SUBSTANCES.

Substance.	Melts at Degrees	Substance.	Melts at Degrees
Platinum	3080	Antimony	810
Wrought-Iron	2830	Zinc	780
Nickel	2800	Lead	618
Steel	2600	Bismuth	476
Cast-Iron	2200	Tin	475
Gold (pure)	2100	Cadmium	442
Copper	1930	Sulphur	226
Gun Metal	1960	Bees-Wax	151
Brass	1900	Spermaceti	142
Silver (pure)	1800	Tallow	72
Aluminum	1140	Mercury	39

Substance.	Boils at Degrees	Substance.	Freezes at Degrees
Mercury	660	Olive Oil	36
Linseed Oil	600	Fresh Water	32
Sulphuric Acid	590	Vinegar	28
Oil of Turpentine	560	Sea Water	27½
Nitric Acid	242	Turpentine	14
Sea Water	213	Sulphuric Acid	1
Fresh Water	212		

Table No. 13.—Weight and Area of Square and Round Steel, and Circumference of Round Bars.

Thickness or Diameter in Inches.	Weight of Square Bar 1 ft. long.	Weight of Round Bar 1 ft. long.	Area of Square Bar in Square Inches.	Area of Round Bar in Square Inches.	Circumference of Round Bar in Inches.
3-16	.120	.094	.0352	.0276	.5890
1-4	.213	.167	.0625	.0491	.7854
5-16	.332	.261	.0977	.0767	.9817
3-8	.478	.375	.1406	.1104	1.1781
7-16	.651	.511	.1914	.1503	1.3744
1-2	.851	.668	.2500	.1963	1.5708
9-16	1.076	.845	.3164	.2485	1.7671
5-8	1.329	1.044	.3906	.3068	1.9635
11-16	1.608	1.263	.4727	.3712	2.1598
3-4	1.914	1.503	.5625	.4418	2.3562
13-16	2.246	1.764	.6602	.5185	2.5525
7-8	2.605	2.046	.7656	.6013	2.7489
15-16	2.990	2.348	.8789	.6903	2.9452
1	3.402	2.672	1.0000	.7854	3.1416
1-16	3.841	3.017	1.1289	.8866	3.3379
1-8	4.306	3.382	1.2656	.9940	3.5343
3-16	4.798	3.768	1.4102	1.1075	3.7306
1-4	5.316	4.175	1.5625	1.2272	3.9270
5-16	5.861	4.603	1.7227	1.3530	4.1233
3-8	6.432	5.052	1.8906	1.4849	4.3197
7-16	7.030	5.521	2.0664	1.6230	4.5160
1-2	7.655	6.012	2.2500	1.7671	4.7124
9-16	8.306	6.524	2.4414	1.9175	4.9087
5-8	8.984	7.056	2.6406	2.0739	5.1051
11-16	9.688	7.609	2.8477	2.2365	5.3014
3-4	10.419	8.183	3.0625	2.4053	5.4978
13-16	11.177	8.778	3.2852	2.5802	5.6941
7-8	11.961	9.394	3.5156	2.7612	5.8905
15-16	12.772	10.031	3.7539	2.9483	6.0868

TABLE NO. 13 CONTINUED.—WEIGHT AND AREA OF SQUARE AND ROUND STEEL, AND CIRCUMFERENCE OF ROUND BARS.

Thickness or Diameter in Inches.	Weight of Square Bar 1 ft. long.	Weight of Round Bar 1 ft. long.	Area of Square Bar in Square Inches.	Area of Round Bar in Square Inches.	Circumference of Round Bar in Inches.
2	13.61	10.69	4.0000	3.1416	6.2832
1-16	14.47	11.36	4.2539	3.3410	6.4795
1-8	15.36	12.06	4.5136	3.5466	6.6759
3-16	16.28	12.79	4.7852	3.7583	6.8722
1-4	17.22	13.52	5.0625	3.9651	7.0686
5-16	18.19	14.02	5.3477	4.2000	7.2649
3-8	19.19	15.07	5.6406	4.4301	7.4613
7-16	20.21	15.87	5.9414	4.6664	7.6576
1-2	21.26	16.70	6.2500	4.9087	7.8540
9-16	22.34	17.55	6.5664	5.1572	8.0503
5-8	23.44	18.41	6.8906	5.4119	8.2467
11-16	24.57	19.30	7.2227	5.6727	8.4430
3-4	25.73	20.21	7.5625	5.9396	8.6394
13-16	26.91	21.14	7.9102	6.2126	8.8357
7-8	28.12	22.09	8.2656	6.4918	9.0321
15-16	29.36	23.06	8.6289	6.7771	9.2284
3	30.62	24.05	9.0000	7.0686	9.4248
1-16	31.91	25.06	9.3789	7.3662	9.6211
1-8	33.23	26.10	9.7656	7.6699	9.8175
3-16	34.57	27.15	10.160	7.9798	10.014
1-4	35.94	28.23	10.563	8.2958	10.210
5-16	37.33	29.32	10.973	8.6179	10.407
3-8	38.75	30.43	11.391	8.9462	10.603
7-16	40.20	31.57	11.816	9.2806	10.799
1-2	41.68	32.74	12.250	9.6211	10.996
9-16	43.17	33.91	12.691	9.9678	11.192
5-8	44.71	35.12	13.141	10.321	11.388
11-16	46.26	36.33	13.598	10.680	11.585
3-4	47.84	37.57	14.063	11.045	11.781
13-16	49.45	38.84	14.535	11.416	11.977
7-8	51.09	40.13	15.016	11.793	12.174
15-16	52.75	41.43	15.504	12.177	12.370
4	54.45	42.77	16.00	12.566	12.566

Table No. 14.—Weight per Foot of Flat Bar Steel.

Thickness in Inches	Width in Inches. 1	1 1-4	1 1-2	1 3-4	2	2 1-4	2 1-2	3	3 1-2	4
3-16	.638	.797	.957	1.11	1.28	1.44	1.59	1.91	2.23	2.55
1-4	.850	1.06	1.28	1.49	1.70	1.91	2.12	2.55	2.98	3.40
5-16	1.06	1.33	1.59	1.86	2.12	2.39	2.65	3.19	3.72	4.25
3-8	1.28	1.59	1.92	2.23	2.55	2.87	3.19	3.83	4.47	5.10
7-16	1.49	1.86	2.23	2.60	2.98	3.35	3.73	4.46	5.20	5.95
1-2	1.70	2.12	2.55	2.98	3.40	3.83	4.25	5.10	5.95	6.80
9-16	1.92	2.39	2.87	3.35	3.83	4.30	4.78	5.74	6.70	7.65
5-8	2.12	2.65	3.19	3.72	4.25	4.78	5.31	6.38	7.44	8.50
11-16	2.34	2.92	3.51	4.09	4.67	5.26	5.84	7.02	8.18	9.35
3-4	2.55	3.19	3.83	4.47	5.10	5.75	6.38	7.65	8.93	10.20
13-16	2.76	3.45	4.14	4.84	5.53	6.21	6.90	8.29	9.67	11.05
7-8	2.98	3.72	4.47	5.20	5.95	6.69	7.44	8.93	10.41	11.90
15-16	3.19	3.99	4.78	5.58	6.38	7.18	7.97	9.57	11.16	12.75
1	3.40	4.25	5.10	5.95	6.80	7.65	8.50	10.20	11.90	13.60
1 1-16	3.61	4.52	5.42	6.32	7.22	8.13	9.03	10.84	12.15	14.45
1 1-8	3.83	4.78	5.74	6.70	7.65	8.61	9.57	11.48	13.39	15.30
1 3-16	4.04	5.05	6.06	7.07	8.08	9.09	10.10	12.12	14.13	16.15
1 1-4	4.25	5.31	6.38	7.44	8.50	9.57	10.63	12.75	14.87	17.00
1 5-16	4.46	5.58	6.69	7.81	8.93	10.04	11.16	13.39	15.62	17.85
1 3-8	4.67	5.84	7.02	8.18	9.35	10.52	11.69	14.03	16.36	18.70
1 7-16	4.89	6.11	7.34	8.56	9.78	11.00	12.22	14.66	17.10	19.55
1 1-2	5.10	6.38	7.65	8.93	10.20	11.48	12.75	15.30	17.85	20.40
1 9-16	5.32	6.64	7.97	9.30	10.63	11.65	13.28	15.94	18.60	21.25
1 5-8	5.52	6.90	8.29	9.67	11.05	12.43	13.81	16.58	19.34	22.10
1 11-16	5.74	7.17	8.61	10.04	11.47	12.91	14.34	17.22	20.08	22.95
1 3-4	5.95	7.44	8.93	10.42	11.90	13.40	14.88	17.85	20.83	23.80
1 13-16	6.16	7.70	9.24	10.79	12.33	13.86	15.40	18.49	21.57	24.65
1 7-8	6.38	7.97	9.57	11.15	12.75	14.34	15.94	19.13	22.31	25.50
1 15-16	6.59	8.24	9.88	11.53	13.18	14.83	16.47	19.77	23.06	26.35
2	6.80	8.50	10.20	11.90	13.60	15.30	17.00	20.40	23.80	27.20

Table No. 15.—Weight per Foot of Flat Bar Iron.

Thickness.	1	1¼	1½	1¾	2	2¼	2½	3	3½	4
	WIDTH IN INCHES.									
⅛	.42	.53	.63	.74	.84	.95	1.05	1.26	1.47	1.68
¼	.84	1.05	1.26	1.47	1.68	1.90	2.11	2.53	2.95	3.37
⅜	1.26	1.58	1.90	2.21	2.53	2.84	3.16	3.79	4.42	5.05
½	1.68	2.11	2.53	2.95	3.37	3.79	4.21	5.05	5.89	6.74
⅝	2.11	2.63	3.16	3.68	4.21	4.74	5.26	6.32	7.37	8.42
¾	2.53	3.16	3.79	4.42	5.05	5.68	6.32	7.58	8.84	10.10
⅞	2.95	3.68	4.42	5.16	5.89	6.83	7.37	8.84	10.32	11.79
1	3.37	4.21	5.05	5.89	6.74	7.58	8.42	10.10	11.79	13.47

Plate iron weighs 40 pounds per square foot, 1 inch thick. Hence, a square foot weighs 10 pounds if ¼ inch thick, 5 pounds if ⅛ inch thick, etc.

To find the weight of round iron, per square foot in length: Square the diameter, expressed in quarter inches and divide by 6.

Thus, a 1¼ inch rod weighs $5 \times 5 = 25$, $25 \div 6 = 4\frac{1}{6}$ pounds per foot.

To find the weight of square or flat iron, per yard in length: Multiply the area of the cross section by 10.

Thus, a bar 2 by ⅜ has an area of ¾ of a square inch, and consequently weighs $\frac{3}{4} \times 10 = 7\frac{1}{2}$ pounds per yard.

To find the tensile strength of round iron: Square the diameter, expressed in quarters of an inch, the result will be its approximate strength in tons.

Thus, a rod 1 quarter inch in diameter will sustain 1 ton; 2 quarters, 4 tons; 3 quarters 9 tons; 4 quarters, or 1 inch, 16 tons.

If the rod is square, and of the same diameter as the round bar, it will carry about 25 per cent more, hence, a bar 1 inch square will sustain about 20 tons.

TABLE NO. 16.—WIRE GAUGES IN USE IN THE UNITED STATES.

Number of Wire Gauge.	American or Brown & Sharpe.	Birmingham or Stubs' Wire.	Washburn & Moen Mfg. Co., Worcester, Mass.	Imperial Wire Gauge.	Stubs' Steel Wire.	U. S. Standard for Plate.	Number of Wire Gauge.
000000				.464		.46875	000000
00000				.432		.4375	00000
0000	.46	.454	.3938	.400		.40625	0000
000	.40964	.425	.3625	.372		.375	000
00	.3648	.38	.3310	.348		.34375	00
0	.32486	.34	.3065	.324		.3125	0
1	.2893	.3	.2830	.300	.227	.28125	1
2	.25763	.284	.2625	.276	.219	.265625	2
3	.22942	.259	.2437	.252	.212	.25	3
4	.20431	.238	.2253	.232	.207	.234375	4
5	.18194	.22	.2070	.212	.204	.21875	5
6	.16202	.203	.1920	.192	.201	.203125	6
7	.14428	.18	.1770	.176	.199	.1875	7
8	.12849	.165	.1620	.160	.197	.171875	8
9	.11443	.148	.1483	.144	.194	.15625	9
10	.10189	.134	.1350	.128	.191	.140625	10
11	.090742	.12	.1205	.116	.188	.125	11
12	.080808	.109	.1055	.104	.185	.109375	12
13	.071961	.095	.0915	.092	.182	.09375	13
14	.064084	.083	.0800	.080	.180	.078125	14
15	.057068	.072	.0720	.072	.178	.0703125	15
16	.05082	.065	.0625	.064	.175	.0625	16
17	.045257	.058	.0540	.056	.172	.05625	17

TABLE NO. 16 CONTINUED.—WIRE GAUGES IN USE IN THE UNITED STATES.

Number of Wire Gauge.	American or Brown & Sharpe.	Birmingham or Stubs' Wire.	Washburn & Moen Mfg. Co., Worcester, Mass.	Imperial Wire Gauge.	Stubs' Steel Wire.	U. S. Standard for Plate.	Number of Wire Gauge.
18	.040303	.049	.0475	.048	.168	.05	18
19	.03589	.042	.0410	.040	.164	.04375	19
20	.031961	.035	.0348	.036	.161	.0375	20
21	.028462	.032	.03175	.032	.157	.034375	21
22	.025347	.028	.0286	.028	.155	.03125	22
23	.022571	.025	.0258	.024	.153	.028125	23
24	.0201	.022	.0230	.022	.151	.025	24
25	.0179	.02	.0204	.020	.148	.021875	25
26	.01594	.018	.0181	.018	.146	.01875	26
27	.014195	.016	.0173	.0164	.143	.0171875	27
28	.012641	.014	.0162	.0149	.139	.015625	28
29	.011257	.013	.0150	.0136	.134	.0140625	29
30	.010025	.012	.0140	.0124	.127	.0125	30
31	.008928	.01	.0132	.0116	.120	.0109375	31
32	.00795	.009	.0128	.0108	.115	.01015625	32
33	.00708	.008	.0118	.0100	.112	.009375	33
34	.006304	.007	.0104	.0092	.110	.00859375	34
35	.005614	.005	.0095	.0084	.108	.0078125	35
36	.005	.004	.0090	.0076	.106	.00703125	36
37	.004453			.0068	.103	.006640625	37
38	.003965			.0060	.101	.00625	38
39	.003531			.0052	.099		39
40	.003144			.0048	.097		40

TABLE No. 17.—WEIGHT OF SHEET IRON AND STEEL PER SQUARE FOOT.

Thickness by Birmingham Gauge.				Thickness by American (Brown & Sharpe's) Gauge.			
No. of Gauge.	Thickness in Inches.	Weight in Pounds.		No. of Gauge.	Thickness in Inches.	Weight in Pounds.	
		Iron.	Steel.			Iron	Steel.
0000	.454	18.16	18.52	0000	.46	18.40	18.77
000	.425	17.00	17.34	000	.4096	16.38	16.71
00	.38	15.20	15.30	00	.3648	14.59	14.88
0	.34	13.60	13.87	0	.3249	13.00	13.26
1	.3	12.00	12.24	1	.2893	11.57	11.80
2	.284	11.36	11.59	2	.2576	10.30	10.51
3	.259	10.36	10.57	3	.2294	9.18	9.36
4	.238	9.52	9.71	4	2043	8.17	8.34
5	.22	8.80	8.98	5	.1819	7.28	7.42
6	.203	8.12	8.28	6	.1620	6.48	6.61
7	.18	7.20	7.34	7	.1443	5.77	5.89
8	.165	6.60	6.73	8	.1285	5.14	5.24
9	.148	5.92	6.04	9	.1144	4.58	4.67
10	.134	5.36	5.47	10	.1019	4.08	4.16
11	.12	4.80	4.90	11	.0907	3.63	3.70
12	.109	4.36	4.45	12	.0808	3.23	3.30
13	.095	3.80	3.88	13	.0720	2.88	2.94
14	.083	3.32	3.39	14	.0641	2.56	2.62
15	.072	2.88	2.94	15	.0571	2.28	2.33
16	.065	2.60	2.65	16	.0508	2.03	2.07
17	.058	2.32	2.37	17	.0453	1.81	1.85
18	.049	1.96	2.00	18	.0403	1.61	1.64
19	.042	1.68	1.71	19	.0359	1.44	1.46
20	.035	1.40	1.43	20	.0320	1.28	1.31

TABLE NO. 17 CONTINUED.—WEIGHT OF SHEET IRON AND STEEL PER SQUARE FOOT.

Thickness by Birmingham Gauge.				Thickness by American (Brown and Sharpe's) Gauge.			
No. of Gauge.	Thickness in Inches.	Weight in Pounds.		No. of Gauge.	Thickness in Inches.	Weight in Pounds.	
		Iron.	Steel.			Iron,	Steel.
21	.032	1.28	1.31	21	.0285	1.14	1.16
22	.028	1.12	1.14	22	.0253	1.01	1.03
23	.025	1.00	1.02	23	.0226	.904	.922
24	.022	.88	.898	24	.0201	.804	.820
25	.02	.80	.816	25	.0179	.716	.730
26	.018	.72	.734	26	.0159	.636	.649
27	.016	.64	.653	27	.0142	.568	.579
28	.014	.56	.571	28	.0126	.504	.514
29	.013	.52	.530	29	.0113	.452	.461
30	.012	.48	.490	30	.0100	.400	.408
31	.01	.40	.408	31	.0089	.356	.363
32	.009	.36	.367	32	.0080	.320	.326
33	.008	.32	.326	33	.0071	.284	.290
34	.007	.28	.286	34	.0063	.252	.257
35	.005	.20	.204	35	.0056	.224	.228

	IRON.	STEEL.
Specific gravity.	7.7	7.854
Weight per cubic foot,	480	489.6
Weight per cubic inch,	.2778	.2833

As there are many gauges in use differing from each other orders for sheets should always state the weight per square foot, or the thickness in thousands of an inch.

Table No. 18.—Showing Zinc Gauge as Compared With Other Gauges.

Zinc Gauge Can Be Maintained Only Approximately.

Matthiessen & Hegeler Zinc Company			American or Brown & Sharpe		Stubbs		United States Standard	
No.	Square Foot in Pounds	Thickness in Inches	No.	Approx. Thickness in Inches	No.	Approx. Thickn's in Inches	Number	Approx. Thickness in Inches
3	.22	.006	34	.0063	35	.005	38	.0062
..	.....	.....	...	.....	...	....	37	.0066
..	.....	.....	33	.0070	34	.007	36	.0070
4	.30	.008	32	.0079	33	.008	35	.0078
..	.....	.....	31	.0089	...	....	34	.0086
..	.....	.....	...	.....	32	.009	33	.0093
5	.37	.010	30	.0100	31	.010	32	.0101
..	.....	.....	29	.0112	30	.012	31	.0109
6	.45	.012	28	.0126	29	.013	30	.0125
7	.52	.014	27	.0141	28	.014	29	.0140
8	.60	.016	26	.0159	27	.016	28	.0156
..	.....	.....	25	.0179	26	.018	27	.0171
9	.67	.018	24	.0201	25	.020	26	.0187
10	.75	.020	23	.0225	24	.022	25	.0218
11	.90	.024	22	.0253	23	.025	24	.0250
12	1.05	.028	21	.0284	22	.028	23	.0281
13	1.20	.032	20	.0319	21	.032	22	.0312
14	1.35	.036	19	.0353	20	.035	21	.0343
15	1.50	.040	18	.0403	...	....	20	.0375
16	1.68	.045	17	.0452	19	.042	19	.0437
17	1.87	.050	16	.0508	18	.049	18	.0500
18	2.06	.055	15	.0570	17	.058	17	.0562
19	2.25	.060	14	.0640	16	.065	16	.0625
20	2.62	.070	13	.0719	15	.072	15	.0703
21	3.00	.080	12	.0808	14	.083	14	.0781
22	3.37	.090	11	.0907	13	.095	13	.0937
23	3.75	.100	10	.1018	12	.109	12	.1093
24	4.70	.125	9	.1144	11	.120	11	.1250
..	.....	.....	8	.1284	10	.134	10	.1406
..	.....	.....	7	.1442	9	.148	9	.1562
..	.....	.....	6	.1620	8	.165	8	.1718
..	.....	.....	5	.1819	7	.180	7	.1875
..	.....	.....	4	.2043	6	.203	6	.2031
..	.....	.....	3	.2294	5	.220	5	.2187
..	.....	.....	...	.....	4	.238	4	.2343
25	9.40	.250	2	.2576	3	.259	3	.2500
..	.....	.....	...	.....	2	.284	2	.2656
..	.....	.....	1	.2893	1	.300	1	.2812
..	.....	.....	0	.3249	0	.340	0	.3125
26	14.00	.375	000	.4096	000	.425	000	.3750
27	18.75	.500	...	.....	...	....	0000000	.5000
28	37.50	1.000	...	.....	...	....	....	.....

TABLE NO. 19.—GAUGE TABLE OF SHEET ZINC.

Zinc Gauge Can Be Maintained Only Approximately.

NUMBERS.......		4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Weight per sq. ft...		.30	.37	.45	.52	.60	.67	.75	.90	1.05	1.20	1.35	1.50	1.68	1.87	2.06	2.25	2.62	3.00	3.37
Approx. thickn's in.		.008	.010	.012	.014	.016	.018	.020	.024	.028	.032	.036	.040	.045	.050	.055	.060	.070	.080	.090
Size of Sheet	Sq.Ft. Per Sheet	APPROXIMATE WEIGHT PER SHEET																		
24x84......	14.0	4.2	5.2	6.3	7.3	8.4	9.4	10.5	12.6	14.7	16.8	18.9	21.0	23.5	26.2	28.9	31.5	36.7	42.0	47.2
26x84......	15.2	4.6	5.6	6.9	7.9	9.1	10.2	11.4	13.7	16.0	18.3	20.5	22.8	25.6	28.4	31.3	34.2	39.9	45.6	51.2
28x84......	16.3	4.9	6.0	7.4	8.5	9.8	10.9	12.2	14.7	17.1	19.6	22.0	24.5	27.4	30.5	33.6	36.7	42.7	48.9	54.9
30x84......	17.5	5.3	6.5	7.9	9.1	10.5	11.8	13.2	15.8	18.4	21.0	23.6	26.2	29.4	32.8	36.1	39.4	45.8	52.5	59.0
32x84......	18.7	5.6	6.9	8.4	9.7	11.2	12.6	14.1	16.9	19.7	22.5	25.3	32.8	31.4	35.0	38.5	42.0	49.0	56.1	63.0
34x84......	19.9	6.0	7.4	9.0	10.4	12.0	13.4	15.0	18.0	20.9	23.9	26.9	29.9	33.4	37.2	41.0	44.8	52.2	59.7	67.0
36x84......	21.0	6.3	7.8	9.5	10.9	12.6	14.1	15.8	18.9	22.0	25.2	28.4	31.5	35.3	39.3	43.3	47.2	55.0	63.0	70.8
36x96......	24.0	7.2	8.9	10.8	12.5	14.4	16.1	18.0	21.6	25.2	28.8	32.4	36.0	40.3	44.9	49.5	54.0	62.8	72.0	80.9
36x108.....	27.0	8.1	10.0	12.2	14.1	16.2	18.1	20.3	24.3	28.4	32.4	36.5	40.5	45.4	50.5	55.6	60.7	70.7	81.0	91.0
40x84......	23.4	7.0	8.7	10.6	12.2	14.1	15.7	17.6	21.0	24.6	28.1	31.6	35.1	39.3	43.8	48.2	52.6	61.3	70.2	78.8
40x96......	26.8	8.0	9.9	12.1	14.0	16.1	18.0	20.1	24.1	28.1	32.2	36.2	40.2	45.0	50.1	55.2	60.3	70.2	80.4	90.3
44x84......	25.7	7.7	9.5	11.6	13.4	15.4	17.2	19.3	23.1	27.0	30.8	34.7	38.6	43.2	48.1	53.0	57.8	67.4	77.1	86.6
46x90......	28.7	8.6	10.6	12.9	14.9	17.2	19.2	21.5	25.8	30.1	34.4	38.7	43.0	48.2	53.7	59.1	64.6	75.2	86.1	96.7
48x84......	28.0	8.4	10.4	12.6	14.6	16.8	18.8	21.0	25.2	29.1	33.6	37.8	42.0	47.0	52.4	57.7	63.0	73.4	84.0	94.1
48x96......	32.0	9.6	11.9	14.4	16.7	19.2	21.5	24.0	28.8	33.6	38.4	43.2	48.0	53.8	59.9	65.9	72.0	83.9	96.0	107.8
50x108.....	37.5	11.3	13.9	16.9	19.5	22.5	25.1	28.2	33.8	39.3	45.0	50.7	56.3	63.0	70.1	77.3	84.4	98.3	112.5	126.4
52x84......	30.4	9.1	11.3	13.7	15.8	18.3	20.4	22.8	27.4	31.9	36.5	41.0	45.6	51.0	56.9	62.6	68.4	79.6	94.2	102.5
54x84......	31.5	9.5	11.7	14.2	16.4	18.9	21.1	23.6	28.4	33.1	37.8	42.5	47.2	52.9	58.9	64.9	70.9	82.5	94.5	106.2
56x84......	32.7	9.8	12.1	14.7	17.0	19.6	21.9	24.5	29.4	34.3	39.2	44.1	49.0	54.9	61.1	67.4	73.6	85.7	98.1	110.2
58x84......	33.8	10.1	12.5	15.2	17.6	20.3	22.6	25.4	30.4	35.5	40.6	45.6	50.7	56.8	63.2	69.6	76.1	88.6	101.4	113.9
60x84......	35.0	10.5	13.0	15.7	18.2	21.0	23.5	26.3	31.5	36.8	42.0	47.3	52.5	58.8	65.4	72.1	78.8	91.7	105.0	118.0

TABLE No. 20.—WEIGHTS AND MEASURES.

TROY.

24 grains (gr.)	1 pennyweight—dwt.
20 dwt	1 ounce—oz.
3.2 grains	1 carat, diamond wt.

By this weight gold, silver and jewels only are weighed. The ounce and pound in this are the same as in apothecaries' weight.

APOTHECARIES'.

20 grains	1 scruple	8 drs	1 ounce
3 scruples	1 drachm	12 oz	1 pound

AVOIRDUPOIS.

16 drachms	1 ounce	4 qrs	100 weight—cwt.
16 ounces	1 pound	20 hundredweight	1 ton
25 lbs	1 quarter—qr.		

5,760 grains apothecaries' or troy weight	1 lb.
7,000 grains avoirdupois weight	1 lb.

Therefore, 144 lbs. avoirdupois equal 175 lbs. apothecaries' or troy.

LIQUIDS.

1 gallon oil weighs	7.32 lbs. avoirdupois
1 gallon distilled water	8.33 lbs.
1 gallon sea water	8.55 lbs.
1 gallon proof spirits	7.68 lbs.

MISCELLANEOUS.

Iron, Lead, Etc.		Beef, Pork, Etc.	
14 pounds	1 stone	200 pounds	1 barrel
21½ stones	1 pig	196 lbs. (flour)	1 barrel
8 pigs	1 fother	100 lbs. (fish)	1 quintal

DRY.

2 pints	1 quart—qt.	4 pecks	1 bushel—bu.
8 quarts	1 peck—pk.	36 bushels	1 chaldron

LIQUID OR WINE.

4 gills	1 pint—pt.	U. S. Standard gallon	231 cubic inches
2 pints	1 quart—qt.	Beer gal	282 cubic inches
4 quarts	1 gallon—gal.	36 beer gallons	1 barrel
31½ gal	1 barrel—bbl.		
2 bbls	1 hogshead—hhd.		

TIME.

60 seconds	1 minute	30 days (in computing interest)	1 month
60 minutes	1 hour	52 weeks and 1 day or 12 cal. months	1 year
24 hours	1 day	365 days, 5 h., 48 m. and 49 seconds	1 solar year
7 days	1 week		
4 weeks	1 lunar month		
28, 29, 30 or 31 days	1 calendar month		

CIRCULAR.

60 seconds	1 minute	90 degrees	1 quadrant
60 minutes	1 degree	4 quadrants or 360 degrees	1 circle
30 degrees	1 sign		

TABLE No. 21.—TIN AND SHEET IRON WORKERS' CIRCUMFERENCE TABLE.

To Increase a Given Diameter.

For ⅛ inch, add to its circumference, ⅜ and 1/64
" ¼ " " " ¾ " 1/32
" ½ " " " 1½ " 1/16
" 1 " " " 3⅛

The following measures do not allow for seams, which are different on sheet iron.

Dia.	Cir.	Dia.	Cir.	Dia.	Cir.	Dia.	Cir.	Dia.	Cir.
½	1 9/16	6	18⅞	12	37¾	18	56⅝	24½	77¼
⅝	1 15/16	¼	19¾	¼	38⅝	¼	57⅜	25	78 13/16
¾	2 11/32	½	20½	½	39½	½	58¼	½	80 7/16
⅞	2¾	¾	21¼	¾	40¼	¾	59	26	82
1	3⅛	7	22 1/16	13	41	19	59⅞	½	83 9/16
¼	3⅞	¼	22 13/16	¼	41¾	¼	60⅝	27	85⅛
½	4 11/16	½	23⅝	½	42 9/16	½	61⅜	½	86 11/16
¾	5 7/16	¾	24⅜	¾	43 5/16	¾	62¼	28	88¼
2	6 5/16	8	25 3/16	14	44⅛	20	63	½	89 13/16
¼	7⅛	¼	26	¼	44⅞	¼	63¾	29	91⅜
½	7 15/16	½	26¾	½	45¾	½	64 9/16	½	92 15/16
¾	8 11/16	¾	27 9/16	¾	46½	¾	65 5/16	30	94½
3	9⅜	9	28 5/16	15	47¼	21	66⅛	½	96 1/16
¼	10¼	¼	29⅛	¼	48	¼	66⅞	31	97⅝
½	11 1/16	½	29⅞	½	48 13/16	½	67¾	½	98 3/16
¾	11 13/16	¾	30 11/16	¾	49 9/16	¾	68½	32	100¾
4	12⅝	10	31 7/16	16	50⅜	22	69¼	½	101 5/16
¼	13⅜	¼	32¼	¼	51⅛	¼	70	33	103⅞
½	14 3/16	½	33 1/16	½	51 15/16	½	70 13/16	½	104 7/16
¾	14 15/16	¾	33 13/16	¾	52 11/16	¾	71 9/16	34	107
5	15¾	11	34⅝	17	53½	23	72⅜	½	108 9/16
¼	16½	¼	35⅜	¼	54¼	¼	73⅛	35	109¼
½	17 5/16	½	36 3/16	½	55 1/16	½	73 15/16	½	110 13/16
¾	18 1/16	¾	36 15/16	¾	55 13/16	¾	74¾	36	113¼
						24	75 7/16		

For Common English Sheet Iron Nos. 25 and 26, the above table will apply as it is; but for every fourth number heavier, add ⅛ inch to the above measure. For Russia Sheet Iron add ⅛ inch to every fourth number heavier than No. 10.

TABLE No. 22.—TABLE OF DIAMETERS, CIRCUMFERENCES, AND AREAS OF CIRCLES.

And the Contents in Gallons at One Foot in Depth.

AREA IN FEET

Dia.	Circ.	Area in ft.	Gallons	Dia.	Circ.	Area in ft.	Gallons
Ft. In.	Ft. In.		1 ft. depth	Ft. In.	Ft. In.		1 ft. depth
1	3 1⅝	.7854	5.8735	4 8	14 7⅞	17.1041	127.9112
1 1	3 4⅜	.9217	6.8928	4 9	14 11	17.7205	132.5209
1 2	3 8	1.0690	7.9944	4 10	15 2⅛	18.3476	137.2105
1 3	3 11	1.2271	9.1766	4 11	15 5¼	18.9858	142.0582
1 4	4 2⅛	1.3962	10.4413	5	15 8½	19.6350	146.8384
1 5	4 5⅜	1.5761	11.7866	5 1	15 11⅝	20.2947	151.7718
1 6	4 8½	1.7617	13.2150	5 2	16 2¾	20.9656	156.7891
1 7	4 11⅝	1.9689	14.7241	5 3	16 5¾	21.6475	161.8886
1 8	5 2¾	2.1816	16.3148	5 4	16 9	22.3400	167.0674
1 9	5 5⅞	2.4052	17.9870	5 5	17 0⅛	23.0437	172.3300
1 10	5 9	2.6398	19.7414	5 6	17 3¼	23.7583	177.6740
1 11	6 2¼	2.8852	21.4830	5 7	17 6⅜	24.4835	183.0973
2	6 3⅜	3.1416	23.4940	5 8	17 9⅝	25.2199	188.6045
2 1	6 6½	3.4087	25.4916	5 9	18 0¾	25.9672	194.1930
2 2	6 9⅝	3.6869	27.5720	5 10	18 3⅞	26.7251	199.8610
2 3	7 0¾	3.9760	29.7340	5 11	18 7⅛	27.4943	205.6133
2 4	7 3⅞	4.2760	32.6976	6	18 10⅛	28.2744	211.4472
2 5	7 7	4.5869	34.3027	6 3	19 7½	30.6796	229.4342
2 6	7 10¼	4.9087	36.7092	6 6	20 4⅞	33.1831	248.1564
2 7	8 1⅜	5.2413	39.1964	6 9	21 2⅜	35.7847	267.6122
2 8	8 4½	5.5850	41.7668	7	21 11⅞	38.4846	287.8230
2 9	8 7⅝	5.9395	44.4179	7 3	22 9¼	41.2825	308.7270
2 10	8 10¾	6.3049	47.1505	7 6	23 6¾	44.1787	330.3859
2 11	9 1⅞	6.6813	49.9654	7 9	24 4⅛	47.1730	352.7665
3	9 5	7.0686	52.8618	8	25 1½	50.2656	375.9062
3 1	9 8¼	7.4666	55.8382	8 3	25 11	53.4562	399.7668
3 2	9 11⅜	7.8757	58.8976	8 6	26 8⅜	56.7451	424.3625
3 3	10 2½	8.2957	62.0386	8 9	27 5¾	60.1321	449.2118
3 4	10 5⅝	8.7265	65.2602	9	28 3¼	63.6174	475.7563
3 5	10 8¾	9.1683	68.5192	9 3	29 0⅝	67.2007	502.5536
3 6	10 11⅞	9.6211	73.1504	9 6	29 10⅛	70.8823	530.0861
3 7	11 3	10.0846	75.4166	9 9	30 7½	74.6620	558.3522
3 8	11 6⅛	10.5591	78.9652	10	31 5	78.5400	587.3534
3 9	11 9⅜	11.0446	82.5959	10 3	32 2⅜	82.5160	617.0876
3 10	12 0½	11.5409	86.3074	10 6	32 11¾	86.5903	647.5568
3 11	12 3⅝	12.0481	90.1004	10 9	33 9¼	90.7627	678.2797
4	12 6¾	12.5664	93.9754	11	34 6⅝	95.0334	710.6977
4 1	12 9⅞	13.0952	97.9310	11 3	35 4⅛	99.4021	743.3686
4 2	13 1	13.6353	101.9701	11 6	36 1½	103.8691	776.7746
4 3	13 4⅛	14.1862	103.0300	11 9	36 10⅞	108.4342	810.9143
4 4	13 7¼	14.7479	110.2907	12	37 8⅜	113.0976	848.1890
4 5	13 10½	15.3206	114.5735	12 3	38 5¾	117.8590	881.3966
4 6	14 1⅜	15.9043	118.9386	12 6	39 3¼	122.7187	917.7395
4 7	14 4⅝	16.4986	123.3830	12 9	40 0⅝	127.6765	954.8159

These tables are theoretically correct, but variations must be expected in practice.

Table No. 23.—Standard United States Gauge of Sheet Iron.

Adopted by the Association of Iron and Steel Sheet Manufacturers, July 1st, 1893.

No. of Gauge.	Weight per Square Foot in Pounds Avoirdupois.	Weight per Square Foot in Ounces Avoirdupois	Approximate Thickness in Fractions of an Inch.	Approximate Thickness in Decimal Parts of an Inch
0000000	20.00	320	1-2	.5
000000	18.75	300	15-32	.46875
00000	17.50	280	7-16	.4375
0000	16.25	260	13-32	.40625
000	15.	240	3-8	.375
00	13.75	220	11-32	.34375
0	12.50	200	5-16	.3125
1	11.25	180	9-32	.28125
2	10.625	170	17-64	.265625
3	10.	160	1-4	.25
4	9.375	150	15-64	.234375
5	8.75	140	7-32	.21875
6	8.125	130	13-64	.203125
7	7.5	120	3-16	.1875
8	6.875	110	11-64	.171875
9	6.25	100	5-32	.15625
10	5.625	90	9-64	.140625
11	5.	80	1-8	.125
12	4.375	70	7-64	.109375
13	3.75	60	3-32	.09375
14	3.125	50	5-64	.078125
15	2.8125	45	9-128	.0703125
16	2.5	40	1-16	.0625
17	2.25	36	9-160	.05625
18	2.	32	1-20	.05
19	1.75	28	7-160	.04375
20	1.50	24	3-80	.0375
21	1.375	22	11-320	.034375
22	1.25	20	1-32	.03125
23	1.125	18	9-320	.028125
24	1.	16	1-40	.025
25	.875	14	7-320	.021875
26	.75	12	3-160	.01875
27	.6875	11	11-640	.0171875
28	.625	10	1-64	.015625
29	.5625	9	9-640	.0140625
30	.5	8	1-80	.0125
31	.4375	7	7-640	.0109375
32	.40625	6½	13-1280	.01015625
33	.375	6	3-320	.009375
34	.34375	5½	11-1280	.00859375
35	.3125	5	5-640	.0078125
36	.28125	4½	9-1280	.00703125
37	.265625	4¼	17-2560	.006640625
38	.25	4	1-160	.00625

NOTE.—This table gives gauge numbers and approximate thickness in inches and weights per square foot of uncoated sheets. Galvanized sheets weigh 2½ ounces more per square foot than uncoated sheets of the same gauge.

For the purpose of securing uniformity of gauge throughout the United States, Congress, under date of March 3rd, 1893, adopted the above as the legal standard for determining the thickness of uncoated iron and steel sheets, allowing a variation of 2½ per cent either above or below for practical use and application.

Table No. 24

Net Weight Per Box Tin Plates

Basis, 10x14, 225 Sheets; or, 14x20, 112 Sheets

Trade Term		80 lb.	85 lb.	90 lb.	95 lb.	100 lb.	IC	IXL	IX	IXX	IXXX	IXXXX
Approximate Wire Gauge . . .		No. 33	No. 32	No. 31	No. 31	No. 30	No. 30	No. 28	No. 28	No. 27	No. 26	No. 25
Weight, per Box, lbs.		80	85	90	95	100	107	128	135	155	175	195
Size of Sheets	Sheets per box											
10 x14	225	80	85	90	95	100	107	128	135	155	175	195
14 x20	112	80	85	90	95	100	107	128	135	155	175	195
20 x28	112	160	170	180	190	200	214	256	270	310	350	390
10 x20	225	114	121	129	136	143	153	183	193	221	250	279
11 x22	225	138	147	156	164	172	184	222	234	268	302	337
11½x23	225	151	161	170	179	189	202	242	255	293	331	368
12 x24	112	82	87	93	98	103	110	132	139	159	180	201
13 x13	225	97	103	109	115	121	129	154	163	187	211	235
13 x26	112	97	103	109	115	121	129	154	163	187	211	235
14 x28	112	112	119	126	133	140	150	179	189	217	245	273
15 x15	225	129	137	145	153	161	172	206	217	249	281	313
16 x16	225	146	155	165	174	183	196	234	247	283	320	357
17 x17	225	165	175	186	196	206	221	264	279	320	361	403
18 x18	112	93	98	104	110	116	124	148	156	179	202	226
19 x19	112	103	110	116	122	129	138	165	174	200	226	251
20 x20	112	114	121	129	136	143	153	183	193	221	250	279
21 x21	112	126	134	142	150	158	169	202	213	244	276	307
22 x22	112	138	147	156	164	172	184	221	234	268	202	337
23 x23	112	151	161	170	179	189	202	242	255	295	333	370
24 x24	112	164	175	185	195	204	220	263	278	320	360	401
26 x26	112	193	205	217	229	241	258	309	326	374	422	471
13½x19½	112	75	80	85	89	94	100	...	...	...	...	...
14 x21	112	84	89	95	100	105	112	...	...	...	...	...
14 x22	112	88	94	99	105	110	118	...	...	...	...	...
16 x20	112	91	97	103	109	114	122	...	...	...	...	...
14 x31	112	124	132	140	147	155	166	...	...	...	...	...
15½x23	112	102	108	115	121	127	136	...	...	...	...	...

Approximate Wire Gauge D Plates		DC No. 28	DX No. 26	DXX No. 24	DXXX No. 23	DXXXX No. 22
12½ x 17	100 Sheets per box, weight	94	122	142	162	182
17 x 25	50 " " " "	94	122	142	162	184
15 x 21	100 " " " "	140	181	211	241	271

TAGGERS

Gauge	Size	Sheets	Approx. Wt. Box
34	14 x 20	150	112 lbs.
36	"	180	112 "
37	"	200	112 "
38	"	225	112 "
34	20 x 28	150	224 "
36	"	180	224 "
37	"	200	224 "
38	"	225	224 "

TRUNK IRON

Gauge	Size	Sheets	Approx. Wt. Box
30	20 x 40	79	224 lbs.
32	"	79	180 "
34	"	79	160 "
36	"	90	160 "
30	20 x 36	88	224 "
32	"	88	180 "
34	"	88	160 "

TABLE No. 25.—WEIGHTS OF SHEET COPPER PER SQUARE FOOT, AND THICKNESS PER STUBBS' GAUGE.

Rolled Copper has specific gravity of 8.93. One cubic foot weighs 558 125/1000 lbs.

Stubbs' Wire Gauge	Thickness in Decimal Parts of 1 inch	Weight per Square Foot	Weight of Sheet 14x48 inches	Weight of Sheet 24x48 inches	Weight of Sheet 30x60 inches	Weight of Sheet 36x72 inches	Weight of Sheet 48x72 inches
		Oz.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
0	.340	253	....	126½	198.	285.	380
1	.300	223	....	111½	174.	251.	335
2	.284	211	....	105½	165.	238.	317
3	.259	193	....	96	151.	217.	289
4	.238	177	....	88½	138.	199.	266
5	.220	164	....	82	128.	184.	246
6	.203	151	....	75½	118.	170.	227
7	.180	134	....	67	105.	151.	201
8	.165	123	....	61	96.	138.	184
9	.148	110	....	55	86.	124.	165
10	.134	100	....	50	78.	112.	150
11	.120	89	....	44½	70.	100.	124
12	.109	81	....	40½	63.	91.	122
13	.095	70	....	35	55.	79.	105
14	.083	64	18.66	32	50.	72.	96
15	.072	56	16.33	28	43.75	63.	84
16	.065	48	14.	24	37.50	54.	72
18	.049	40	11.66	20	31.25	45.	60
19	.042	32	9.33	16	25.	36.	48
21	.032	24	7.	12	18.75	27.	36
22	.028	20	5.83	10	15.62	22.50	30
23	.025	18	5.25	9	14.06	20.25	27
24	.022	16	4.66	8	12.50	18.	24
26	.018	14	4.08	7	10.93	15.75	21
27	.016	12	3.50	6	9.37	13.50	18
29	.013	10	2.91	5	7.81	11.25	15
31	.010	8	2.33	4	6.25	9.	12
33	.008	6	1.75	3	4.68	6.75	9
35	.005	4	1.16	2	3.12	4.50	6

WEIGHT OF SHEET COPPER PER SQUARE FOOT.

1/16	inch	thick	weighs	3	pounds	to the	square foot.
⅛	"	"	"	6	"	"	"
¼	"	"	"	12	"	"	"
½	"	"	"	24	"	"	"
1	"	"	"	46½	"	"	"

TO ASCERTAIN THE WEIGHT OF COPPER—Find the number of cubic inches in the piece, multiply by 0.3214, and the product will be the weight in pounds. Or, multiply the length and breadth (in feet), and that by the pounds per square foot.

These weights are theoretically correct, but variations must be expected in practice.

Table No. 26.—Showing Quantity of 20×28 Tin Required to Cover a Given Number of Square Feet with Flat Seam Tin Roofing.

In the following estimates all fractional parts of a sheet are treated as a full sheet.

Full size of sheet, 20x28, locked at ends.

Covering surface 490⅞ sq. in. or 3.41 sq. feet.

No. of Sq. Feet.	Sheets required.	No. of Sq. Feet.	Sheets required.	No. of Sq. Feet.	Sheets required.	No. of Sq. Feet.	Sheets required.	No. of Sq. Feet.	Sheets required.	No. of Sq. Feet.	Sheets required.
1	1	27	8	53	16	79	24	125	37	310	91
2	1	28	9	54	16	80	24	130	39	320	94
3	1	29	9	55	17	81	24	135	40	330	97
4	2	30	9	56	17	82	25	140	42	340	100
5	2	31	10	57	17	83	25	145	43	350	103
6	2	32	10	58	18	84	25	150	44	360	106
7	3	33	10	59	18	85	25	155	46	370	109
8	3	34	10	60	18	86	26	160	47	380	112
9	3	35	11	61	18	87	26	165	49		
10	3	36	11	62	19	88	26	170	50		
11	4	37	11	63	19	89	27	175	52		
12	4	38	12	64	19	90	27	180	53		
13	4	39	12	65	20	91	27	185	55		
14	5	40	12	66	20	92	27	190	56		
15	5	41	13	67	20	93	28	195	58		
16	5	42	13	68	20	94	28	200	59		
17	5	43	13	69	21	95	28	210	62		
18	6	44	13	70	21	96	29	220	65		
19	6	45	14	71	21	97	29	230	68		
20	6	46	14	72	22	98	29	240	71		
21	7	47	14	73	22	99	30	250	74		
22	7	48	15	74	22	100	30	260	77		
23	7	49	15	75	22	105	31	270	80		
24	8	50	15	76	23	110	33	280	83		
25	8	51	15	77	23	115	34	290	86		
26	8	52	16	78	23	120	36	300	88		

A full box, 20x28, 112 sheets, will cover approximately 380 square feet.

TABLE NO. 27.—COST OF TIN FOR FLAT SEAM ROOFING.

Size, 20x28. Price per box, per square foot and per hundred square feet.

When Tin Costs	Flat Seam Roofing Costs	Flat Seam Roofing Costs
$6.00 per box 20x28	.0157 per sq. ft.	or $1.57 per sq.
6.50 " "	.0170 "	1.70 "
7.00 " "	.0183 "	1.83 "
7.50 " "	.0196 "	1.96 "
8.00 " "	.0209 "	2.09 "
8.50 " "	.0222 "	2.22 "
9.00 " "	.0234 "	2.34 "
9.50 " "	.0248 "	2.48 "
10.00 " "	.0261 "	2.61 "
10.50 " "	.0274 "	2.74 "
11.00 " "	.0287 "	2.87 "
11.50 " "	.0300 "	3.00 "
12.00 " "	.0314 "	3.14 "
12.50 " "	.0327 "	3.27 "
13.00 " "	.0340 "	3.40 "
13.50 " "	.0353 "	3.53 "
14.00 " "	.0366 "	3.66 "
14.50 " "	.0379 "	3.79 "
15.00 " "	.0392 "	3.92 "
15.50 " "	.0405 "	4.05 "
16.00 " "	.0418 "	4.18 "
16.50 " "	.0431 "	4.31 "
17.00 " "	.0444 "	4.44 "
17.50 " "	.0457 "	4.57 "
18.00 " "	.0470 "	4.70 "
18.50 " "	.0483 "	4.83 "
19.00 " "	.0496 "	4.96 "
19.50 " "	.0509 "	5.09 "
20.00 " "	.0522 "	5.22 "
20.50 " "	.0535 "	5.35 "
21.00 " "	.0548 "	5.48 "
21.50 " "	.0561 "	5.61 "
22.00 " "	.0574 "	5.74 "
22.50 " "	.0587 "	5.87 "
23.00 " "	.0600 "	6.00 "
23.50 " "	.0614 "	6.14 "
24.00 " "	.0628 "	6.28 "

The above estimates do not include cost of laying the material.

TABLE No. 28.—SHOWING QUANTITY OF 20×28 TIN REQUIRED TO COVER A GIVEN NUMBER OF SQUARE FEET WITH STANDING SEAM TIN ROOFING.

In the following estimates all fractional parts of a sheet are treated as a full sheet.

Full size of sheet, 20x28, locked at ends.

Covering surface, 474.9 sq. inches or 3.3 sq. feet.

No. of Sq. Feet.	Sheets required.	No. of Sq. Feet.	Sheets required.	No. of Sq. Feet.	Sheets required.	No. of Sq. Feet.	Sheets required.	No. of Sq. Feet.	Sheets required.	No. of Sq. Feet.	Sheets required.
1	1	27	9	53	17	79	24	125	38	310	94
2	1	28	9	54	17	80	25	130	40	320	97
3	1	29	9	55	17	81	25	135	41	330	100
4	2	30	10	56	17	82	25	140	43	340	103
5	2	31	10	57	18	83	26	145	44	350	106
6	2	32	10	58	18	84	26	150	46	360	109
7	3	33	10	59	18	85	26	155	47	370	112
8	3	34	11	60	19	86	27	160	49		
9	3	35	11	61	19	87	27	165	50		
10	4	36	11	62	19	88	27	170	52		
11	4	37	12	63	20	89	27	175	54		
12	4	38	12	64	20	90	28	180	55		
13	4	39	12	65	20	91	28	185	57		
14	5	40	13	66	20	92	28	190	58		
15	5	41	13	67	21	93	29	195	60		
16	5	42	13	68	21	94	29	200	61		
17	6	43	14	69	21	95	29	210	64		
18	6	44	14	70	22	96	30	220	67		
19	6	45	14	71	22	97	30	230	70		
20	7	46	14	72	22	98	30	240	73		
21	7	47	15	73	23	99	30	250	76		
22	7	48	15	74	23	100	31	260	79		
23	7	49	15	75	23	105	32	270	82		
24	8	50	16	76	24	110	34	280	85		
25	8	51	16	77	24	115	35	290	88		
26	8	52	16	78	24	120	37	300	91		

A full box 20x28, 112 sheets, will cover approximately 370 sq. feet.

TABLE No. 29.—COST OF TIN FOR STANDING SEAM ROOFING.

Size, 20x28. Price per box, per square foot and per one hundred square feet.

When Tin Costs	Standing Seam Roofing Coats	Standing Seam Roofing Coats
$6.00 per box 20x28	.0162 per sq. ft.	or $1.62 per sq.
6.50 " "	.0175 "	1.75 "
7.00 " "	.0189 "	1.89 "
7.50 " "	.0202 "	2.02 "
8.00 " "	.0216 "	2.16 "
8.50 " "	.0230 "	2.30 "
9.00 " "	.0243 "	2.43 "
9.50 " "	.0256 "	2.56 "
10.00 " "	.0270 "	2.70 "
10.50 " "	.0283 "	2.83 "
11.00 " "	.0297 "	2.97 "
11.50 " "	.0310 "	3.10 "
12.00 " "	.0324 "	3.24 "
12.50 " "	.0337 "	3.37 "
13.00 " "	.0351 "	3.51 "
13.50 " "	.0364 "	3.64 "
14.00 " "	.0378 "	3.78 "
14.50 " "	.0391 "	3.91 "
15.00 " "	.0404 "	4.04 "
15.50 " "	.0418 "	4.18 "
16.00 " "	.0432 "	4.32 "
16.50 " "	.0446 "	4.46 "
17.00 " "	.045[illegible] "	4.59 "
17.50 " "	.0473 "	4.73 "
18.00 " "	.0486 "	4.86 "
18.50 " "	.0500 "	5.00 "
19.00 " "	.0513 "	5.13 "
19.50 " "	.0526 "	5.26 "
20.00 " "	.0540 "	5.40 "
20.50 " "	.0553 "	5.53 "
21.00 " "	.0567 "	5.67 "
21.50 " "	.0580 "	5.80 "
22.00 " "	.0594 "	5.94 "
22.50 " "	.0607 "	6.07 "
23.00 " "	.0621 "	6.21 "
23.50 " "	.0634 "	6.34 "
24.00 " "	.0648 "	6.48 "

The above estimates do not include cost of laying the material.

Table No. 30.—Tinners' Rivets (Flat Heads).

Size Weight per 1,000 Ozs. and Lbs.	Dimensions (Inches)	
	Diameter	Length
4	.070	⅛
6	.080	9/64
8	.090	5/32
10	.094	11/64
12	.101	3/16
14	.109	3/16
Lbs.		
1	.115	13/64
1¼	.120	7/32
1½	.125	15/64
1¾	.133	¼
2	.140	17/64
2½	.147	9/32
3	.160	5/16
3½	.163	21/64
4	.173	11/32
5	.185	⅜
6	.200	25/64
7	.215	13/32
8	.225	7/16
9	.230	29/64
10	.233	15/32
12	.253	½
14	.275	33/64
16	.293	17/32

TABLE No. 31.—SIZES OF WIRE EXPRESSED IN FRACTIONS OF AN INCH.

No.	Inch	No.	Inch
000.000 is equal to	15/32	1 is equal to	9/32
00.000 " "	7/16	3 " "	¼
0.000 " "	13/32	4½ " "	7/32
000 " "	⅜	6 " "	3/16
00 " "	11/32	8 " "	5/32
0 " "	5/16	11 " "	⅛

TABLE No. 32.—SIZE, WEIGHT, AND LENGTH OF IRON WIRE.

Wire Gauge, Nos.	Diameter, Inches	Weight of 100 Feet, Lbs.	Feet in 63 Lbs., Feet	Wire Gauge, Nos.	Diameter, Inches	Weight of 100 Feet, Lbs.	Feet in 63 Lbs., Feet
0000.000	.49	63.63	99	9	.148	5.8	1.086
000.000	.46	56.10	112	10	.135	4.83	1.304
00.000	.43	49.01	129	11	.120	3.82	1.649
0.000	.393	40.94	154	12	.105	2.92	2.158
000	.362	34.73	181	13	.092	2.24	2.813
00	.331	29.04	217	14	.080	1.69	3.728
0	.223	27.66	228	15	.072	1.37	4.598
1	.283	21.23	296	16	.063	1.05	6.000
2	.263	18.34	343	17	.054	.77	8.182
3	.244	15.78	399	18	.047	.58	10.862
4	.225	13.89	470	19	.041	.45	14.000
5	.207	11.35	555	20	.035	.32	19.687
6	.192	9.73	647	21	.032	.27	23.333
7	.177	8.30	759	22	.028	.21	30.000
8	.162	6.96	905	23	.025	.17	35.000

INDEX

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