APPERSON SEVEN-PASSENGER TOURING CAR

Courtesy of Apperson Brothers Automobile Company, Kokomo, Indiana

Automobile Engineering

A General Reference Work

FOR REPAIR MEN, CHAUFFEURS, AND OWNERS; COVERING THE CONSTRUCTION, CARE, AND REPAIR OF PLEASURE CARS, COMMERCIAL CARS, AND MOTORCYCLES, WITH ESPECIAL ATTENTION TO IGNITION, STARTING, AND LIGHTING SYSTEMS, GARAGE DESIGN AND EQUIPMENT, WELDING, AND OTHER REPAIR METHODS

Prepared by a Staff of

AUTOMOBILE EXPERTS, CONSULTING ENGINEERS, AND DESIGNERS OF THE HIGHEST PROFESSIONAL STANDING

Illustrated with over Fifteen Hundred Engravings

SIX VOLUMES

AMERICAN TECHNICAL SOCIETY
CHICAGO
1920

Authors and Collaborators

CHARLES B. HAYWARD

President and General Manager, The Stirling Press, New York City
Member, Society of Automobile Engineers
Member, The Aeronautical Society
Formerly Secretary, Society of Automobile Engineers
Formerly Engineering Editor, *The Automobile*

C. T. ZIEGLER

Automobile Engineer
With Inter-State Motor Company, Muncie, Indiana
Formerly Manager, The Ziegler Company, Chicago

MORRIS A. HALL

Editor, *Automotive Engineering*
Formerly Managing Editor *Motor Life*, Editor *The Commercial Vehicle*, etc.
Author of "What Every Automobile Owner Should Know"
Member, Society of Automobile Engineers
Member, American Society of Mechanical Engineers

DARWIN S. HATCH, B.S.

Editor, *Motor Age*, Chicago
Formerly Managing Editor, *The Light Car*
Member, Society of Automobile Engineers
American Automobile Association

GLENN M. HOBBS, Ph.D.

Secretary and Educational Director, American School of Correspondence
Formerly Instructor in Physics, The University of Chicago
American Physical Society

HERBERT L. CONNELL, B.S.E.

Late Lecturer, Automobile Division, Milwaukee Central Continuation School
Editorial Representative, *Commercial Car Journal* and *Automobile Trade Journal*
Member, Society of Automobile Engineers
Member, Standards Committee of S. A. E.
Formerly Technical Editor, *The Light Car*

HUGO DIEMER, M.E.

Professor of Industrial Engineering, Pennsylvania State College
American Society of Mechanical Engineers

HERBERT LADD TOWLE, B.A.

Specialist in Technical Advertising
Member, Society of Automobile Engineers
Formerly Associate Editor, *The Automobile*

ROBERT J. KEHL, M.E.

Consulting Mechanical Engineer, Chicago
American Society of Mechanical Engineers

EDMOND M. SIMON, B.S.

Superintendent Union Malleable Iron Company, East Moline, Illinois

EDWARD B. WAITE

Formerly Dean and Head, Consulting Department, American School of Correspondence
Member, American Society of Mechanical Engineers

C. A. MILLER, JR.

Associate Editor, American Technical Society
Formerly Managing Editor of *National Builder*
Member, American Association of Engineers

W. R. HOWELL

President, W. R. Howell and Company, London, England

WILLIAM K. GIBBS, B.S.

Associate Editor, *Motor Age*, Chicago

JESSIE M. SHEPHERD, A.B.

Head, Publication Department, American Technical Society

Authorities Consulted

THE editors have freely consulted the standard technical literature of America and Europe in the preparation of these volumes. They desire to express their indebtedness, particularly, to the following eminent authorities, whose well-known treatises should be in the library of everyone interested in the Automobile and allied subjects.

Grateful acknowledgment is here made also for the invaluable co-operation of the foremost Automobile Firms and Manufacturers in making these volumes thoroughly representative of the very latest and best practice in the design, construction, and operation of Automobiles, Commercial Vehicles, Motorcycles, Motor Boats, etc.; also for the valuable drawings, data, illustrations, suggestions, criticisms, and other courtesies.

CHARLES E. DURYEA

Consulting Engineer
First Vice-President, American Motor League
Author of "Roadside Troubles"

OCTAVE CHANUTE

Late Consulting Engineer
Past President of the American Society of Civil Engineers
Author of "Artificial Flight," etc.

E. W. ROBERTS, M.E.

Member, American Society of Mechanical Engineers
Author of "Gas-Engine Handbook," "Gas Engines and Their Troubles," "The Automobile Pocket-Book," etc.

SANFORD A. MOSS, M.S., Ph.D.

Member, American Society of Mechanical Engineers
Engineer, General Electric Company
Author of "Elements of Gas Engine Design"

GARDNER D. HISCOX, M.E.

Author of "Horseless Vehicles, Automobiles, and Motorcycles," "Gas, Gasoline, and Oil Engines," "Mechanical Movements, Powers, and Devices," etc.

AUGUSTUS TREADWELL, Jr., E.E.

Associate Member, American Institute of Electrical Engineers
Author of "The Storage Battery: A Practical Treatise on the Construction, Theory, and Use of Secondary Batteries"

BENJAMIN R. TILLSON

Director, H. J. Willard Company Automobile School
Author of "The Complete Automobile Instructor"

THOMAS H. RUSSELL, M.E., LL.B.

Editor, *The American Cyclopedia of the Automobile*
Author of "Motor Boats," "History of the Automobile," "Automobile Driving, Self-Taught," "Automobile Motors and Mechanism," "Ignition Timing and Valve Setting," etc.

CHARLES EDWARD LUCKE, Ph.D.

Mechanical Engineering Department, Columbia University
Author of "Gas Engine Design"

P. M. HELDT

Editor, *Horseless Age*
Author of "The Gasoline Automobile"

H. DIEDERICHS, M.E.

Professor of Experimental Engineering, Sibley College, Cornell University
Author of "Internal Combustion Engines"

JOHN HENRY KNIGHT

Author of "Light Motor Cars and Voiturettes," "Motor Repairing for Amateurs," etc.

WM. ROBINSON, M.E.

Professor of Mechanical and Electrical Engineering in University College, Nottingham
Author of "Gas and Petroleum Engines"

W. POYNTER ADAMS

Member, Institution of Automobile Engineers
Author of "Motor-Car Mechanisms and Management"

ROLLA C. CARPENTER, M.M.E., LL.D.

Professor of Experimental Engineering, Sibley College, Cornell University
Author of "Internal Combustion Engines"

ROGER B. WHITMAN

Technical Director, The New York School of Automobile Engineers
Author of "Motor-Car Principles"

CHARLES P. ROOT

Formerly Editor, *Motor Age*
Author of "Automobile Troubles, and How to Remedy Them"

W. HILBERT

Associate Member, Institute of Electrical Engineers
Author of "Electric Ignition for Motor Vehicles"

SIR HIRAM MAXIM

Member, American Society of Civil Engineers
British Association for the Advancement of Science
Chevalier Légion d'Honneur
Author of "Artificial and Natural Flight," etc.

SIGMUND KRAUSZ

Author of "Complete Automobile Record," "A B C of Motoring"

JOHN GEDDES McINTOSH

Lecturer on Manufacture and Application of Industrial Alcohol, at the Polytechnic Institute, London
Author of "Industrial Alcohol," etc.

FREDERICK GROVER, A.M., Inst.C.E., M.I.Mech.E.

Consulting Engineer
Author of "Modern Gas and Oil Engines"

FRANCIS B. CROCKER, M.E., Ph.D.

Head of Department of Electrical Engineering, Columbia University
Past President, American Institute of Electrical Engineers
Author of "Electric Lighting," Joint Author of "Management of Electrical Machinery"

A. HILDEBRANDT

Captain and Instructor in the Prussian Aeronautic Corps
Author of "Airships Past and Present"

T. HYLER WHITE

Associate Member, Institute of Mechanical Engineers
Author of "Petrol Motors and Motor Cars"

ROBERT H. THURSTON, C.E., Ph.B., A.M., LL.D.

Director of Sibley College, Cornell University
Author of "Manual of the Steam Engine," "Manual of Steam Boilers," etc.

MAX PEMBERTON

Motoring Editor, *The London Sphere*
Author of "The Amateur Motorist"

HERMAN W. L. MOEDEBECK

Major and Battalions Kommandeur in Badischen Fussartillerie
Author of "Pocket-Book of Aeronautics"

EDWARD F. MILLER

Professor of Steam Engineering, Massachusetts Institute of Technology
Author of "Steam Boilers"

ALBERT L. CLOUGH

Author of "Operation, Care, and Repair of Automobiles"

W. F. DURAND

Author of "Motor Boats," etc.

PAUL N. HASLUCK

Editor, *Work* and *Building World*
Author of "Motorcycle Building"

JAMES E. HOMANS, A.M.

Author of "Self-Propelled Vehicles"

R. R. MECREDY

Editor, *The Encyclopedia of Motoring*, *Motor News*, etc.

S. R. BOTTONE

Author of "Ignition Devices," "Magnetos for Automobiles," etc.

LAMAR LYNDON, B.E., M.E.

Consulting Electrical Engineer
Associate Member, American Institute of Electrical Engineers
Author of "Storage Battery Engineering"

STANLEY FOUR-PASSENGER STEAM AUTOMOBILE
Courtesy of Stanley Motor Carriage Company, Newton, Massachusetts

TYPICAL MODERN GARAGE

Foreword

THE period of evolution of the automobile does not span many years, but the evolution has been none the less spectacular and complete. From a creature of sudden caprices and uncertain behavior, it has become today a well-behaved thoroughbred of known habits and perfect reliability. The driver no longer needs to carry war clothes in momentary expectation of a call to the front. He sits in his seat, starts his motor by pressing a button with his hand or foot, and probably for weeks on end will not need to do anything more serious than feed his animal gasoline or oil, screw up a few grease cups, and pump up a tire or two.

¶ And yet, the traveling along this road of reliability and mechanical perfection has not been easy, and the grades have not been negotiated or the heights reached without many trials and failures. The application of the internal-combustion motor, the electric motor, the storage battery, and the steam engine to the development of the modern types of mechanically propelled road carriages, has been a far-reaching engineering problem of great difficulty. Nevertheless, through the aid of the best scientific and mechanical minds in this and other countries, every detail has received the amount of attention necessary to make it as perfect as possible. Road troubles, except in connection with tires, have become almost negligible and even the inexperienced driver, who knows barely enough to keep to the road and shift gears properly, can venture on long touring trips without fear of getting stranded. The refinements in the ignition, starting, and lighting systems have added greatly to the pleasure in running the car. Altogether, the automobile as a whole has become standardized, and unless some unforeseen developments are brought about, future changes in either the gasoline or the electric automobile will be merely along the line of greater refinement of the mechanical and electrical devices used.

¶ Notwithstanding the high degree of reliability already spoken of, the cars, as they get older, will need the attention of the repair man. This is particularly true of the cars two and three seasons old. A special effort, therefore, has been made to furnish information which will be of value to the men whose duty it is to revive the faltering action of the motor and to take care of the other internal troubles in the machine.

¶ Special effort has been made to emphasize the treatment of the Electrical Equipment of Gasoline Cars, not only because it is in this direction that most of the improvements have lately taken place, but also because this department of automobile construction is least familiar to the repair men and others interested in the details of the automobile. A multitude of diagrams have been supplied showing the constructive features and wiring circuits of the principal systems. In addition to this instructive section, particular attention is called to the articles on Welding, Shop Information, and Garage Design and Equipment.

Table of Contents

VOLUME V

---

*For page numbers, see foot of pages.
†For professional standing of authors, see list of Authors and Collaborators at front of volume.

WELDING MANIFOLD TUBES IN AN AUTOMOBILE PLANT

Courtesy of Oswald Acetylene Company, Chicago, Illinois

OXY-ACETYLENE WELDING PRACTICE

INTRODUCTION

Welding Field. The welding process is undoubtedly one of the greatest contributors to the efficient and economical manufacture of the modern automobile. It has made possible higher standards of body design and may be given almost exclusive credit for the light weight and great strength of the present-day motor car, producing stronger and better working parts through the use of pressed steel instead of the heavy castings or riveted parts, such as axle housings, Fig. 1, and manifolds, tanks, bodies, etc., Fig. 2.

In the field of automobile repair it is rapidly assuming an equally important place, affording a quick and inexpensive means of permanent repair to parts no longer obtainable from the supply house or manufacturer and permitting the building up of weak parts or the altering of the chassis, as may be required. This great adaptability of the welding unit has made it an essential part of the equipment of every efficiently managed repair shop.

WELDING PROCESSES

Old and New Methods. The old systems—blacksmith, or forge, welding, and brazing—are now seldom used in automobile work. In fact, most blacksmiths have equipped themselves to do welding in the modern way, using it almost exclusively for their repair work because it is cheaper, simpler, more efficient, and can be used on materials which could not be welded by means of the old-style methods. The modern systems of welding include the flame and electric processes. Because it is almost universally used in repair shops, the flame process and the apparatus required in its use will be discussed first. Several flame-welding processes have, from time to time, been introduced, all utilizing oxygen in combination with some fuel gas, such as acetylene, hydrogen, city gas, natural gas, liquid gas, Blau gas, carbo-hydrogen, thermaline, etc. Many enthu-

Fig. 1. Oxy-Acetylene Welding in Manufacture of Rear Axle Housings

Fig. 2. Oxy-Acetylene Welding in Manufacture of Automobile Bodies

siastic claims of superiority have been made for each of these combinations by their advocates.

OXY-ACETYLENE PROCESS

Advantages. The easy control and intensity of the heat developed by the oxy-acetylene flame (approximately 6300° F.) and the adequate supplies of carbide and dissolved acetylene which are maintained in every industrial center in the United States have proved the greater desirability, economy, and efficiency of the oxy-acetylene process.

Another factor which has contributed largely to the popularity of the oxy-acetylene process is the comparatively inexpensive apparatus required and the low cost of its operation. Its speed, portability, and the ease with which its method of operation may be learned by any intelligent workman make it especially well fitted to the need of the automobile repair shop. Very seldom is any extensive dismantling of parts necessary in making an oxy-acetylene repair and, for this reason, it simplifies greatly the work of the repair man.

Gases. As is generally known, two gases are used in the oxy-acetylene process—oxygen and acetylene.

Oxygen. Oxygen is manufactured from air by liquefaction or from water by electrolysis. The former method is by far the greatest source of supply, furnishing practically all the oxygen used in this country and abroad. Oxygen made by the liquid-air process can contain only an impurity such as nitrogen, which cannot possibly do any harm. On the other hand, oxygen made by the electrolytic method contains some hydrogen, which will render it dangerous to handle if more than two per cent is present.

Because of the very high cost of an oxygen plant and the ease with which an adequate supply of compressed gas may be obtained from manufacturers' supply stations, it has been found impractical for even the largest consumers to attempt the manufacture of their own oxygen.

Almost everybody is familiar with the appearance of the oxygen cylinder, shown at the right in Fig. 3, which plays so important a part in present-day manufacturing. These steel cylinders contain 100 or 200 cubic feet of gas compressed to a pressure of 1800 pounds per square inch. They are furnished to the consumer without charge, the customer paying only for the oxygen and returning the cylinder to the manufacturer when the gas has been exhausted.

Acetylene. The acetylene may be obtained in cylinders, shown at the left in Fig. 3, containing 100 or 300 cubic feet, or, where large quantities are required, it is generated on the premises. Though frequently referred to as compressed, the acetylene in cylinders is really not compressed, but is dissolved in a solvent which has the property of absorbing many times its own volume of acetylene as pressure is applied. This liquid in which the gas is dissolved in no way affects the flow of gas except when the acetylene is drawn off from the cylinder at too rapid a rate. Experience has proved that when the gas is used at a rate greater than one-seventh the capacity of the cylinder per hour, the solvent is very likely to travel with the acetylene, lowering the temperature of the flame and thus hindering the work. To overcome this difficulty, where it is necessary to supply gas at a greater rate, several cylinders may be coupled to a manifold, or header, so that the total capacity is at least seven times their hourly discharge.

Fig. 3. Welding Unit for Use with Acetylene in Cylinders, Mounted on Emergency Truck
Courtesy of Oxweld Acetylene Company, Chicago, Illinois

Generators. By means of the acetylene generator it is possible to produce pure acetylene at less than half the cost of dissolved acetylene, so that if any considerable work is to be done a generator will pay for itself within a few months or a year. In these generators small quantities of calcium carbide are automatically fed into a large

Fig. 4. Low-Pressure Acetylene Generator
Courtesy of Oxweld Acetylene Company, Chicago, Illinois

quantity of water, producing the gas at just the rate required by the work in hand.

There are two recognized systems of generating acetylene—the low-pressure system and the pressure system.

Low-Pressure Generator. This type of generator, Fig. 4, delivers acetylene to the blowpipe under a pressure of less than one pound. This system has the advantage of maintaining at all times an absolutely constant pressure, which is an essential requirement. The carbide feed is controlled by the rise and fall of the gas bell, in which the pressure is always the same, without the use of any pressure-regulating device.

Pressure Generator. The pressure generator, Fig. 5, delivers acetylene at a pressure of more than one pound. The carbide feed is controlled by the pressure in the generator. As the acetylene is drawn off and the pressure decreases, carbide is fed into the water;

Fig. 5. Portable Pressure Acetylene Generator
Courtesy of Oxweld Acetylene Company, Chicago, Illinois

the generation of gas increases the pressure and the feeding stops. In order to compensate for this pressure variation, a pressure-diaphragm regulator, or reducer, is necessary so that the acetylene may be supplied to the blowpipe at a constant pressure.

The low-pressure generator furnishes the most satisfactory service under average conditions, though where portability is essential, pressure generators of compact construction may be obtained to meet this need.

Welding Blowpipes. There are two types of oxy-acetylene welding blowpipes, namely, the low-pressure, or injector type and the equal-pressure type.

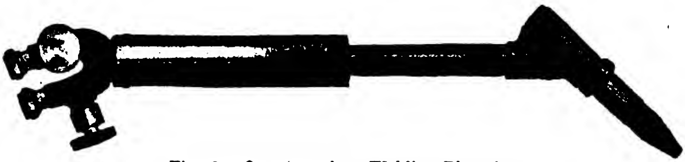


Fig. 6. Oxy-Acetylene Welding Blowpipe
Courtesy of Oxweld Acetylene Company, Chicago, Illinois

Injector Blowpipe. In the injector type, Fig. 6, the acetylene is delivered to the blowpipe at a pressure of only a few ounces. The oxygen at a higher pressure passes through the injector, Fig. 7, and expands rapidly into the mixing chamber. This rapid expansion and high velocity of the oxygen form a suction and draw in the acetylene at a constant ratio. A slight variation in pressure of either

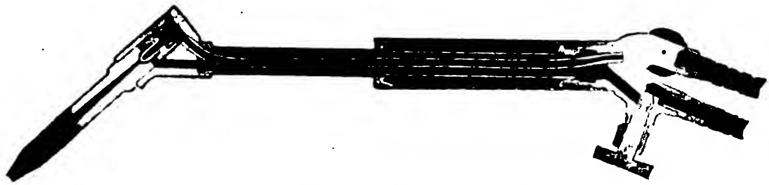


Fig. 7. Section of Injector-Type Blowpipe

the oxygen or acetylene is automatically taken care of by the injector, so that a neutral flame is maintained at all times.

Pressure Blowpipe. In this blowpipe the acetylene is used at almost the same pressure as the oxygen. The oxygen enters the mixing chamber at the rear and the acetylene through a couple of holes at the side.

Fig. 8. Section of Pressure-Type Blowpipe

In the injector blowpipe the rapid expansion into the tapered mixing chamber sets up a whirling action and produces an intimate mixture of the oxygen and acetylene so that a ratio of 1.05 parts oxygen to 1.00 part acetylene is obtained, which is almost the theoretical or perfect ratio of 1.00 to 1.00. In the pressure blowpipe there is no means of obtaining such an intimate mixture of the gases in the mixing chamber, Fig. 8, which in most cases is not tapered, and consequently about the best ratio obtainable is 1.14 to 1.00. This larger amount of oxygen is, of course, wasted and, besides, tends to produce an oxidized weld. It is the surface oxidation, or burning, of the molten metal that leads some operators to believe that they are welding fast, while in reality they are only burning the surface and are not fusing the metal underneath.

Oxy-Acetylene Flame. The oxy-acetylene flame is the hottest flame obtainable. Its temperature of 6300° F. is 2000 degrees above that of any of the other flames. This high temperature allows the work to be done quickly and with only a very slight loss of heat due to conduction and radiation.

There are three phases of the oxy-acetylene flame, Fig. 18, namely, the neutral, or welding, flame; the carbonizing, or reducing, flame; and the oxidizing flame. Each of these has its characteristic appearance and it takes only a little practice to instantly recognize them. The appearance of these will be taken up later under "Flame Regulation", page 25.

Expansion and Contraction. These natural changes of the work, due to the heat of the welding, are taken care of in the case of rolled or forged materials by proper spacing of the edges or by holding the work in suitable jigs and, in the case of castings, by proper pre-heating and cooling. The most satisfactory methods of handling this feature will be taken up under the instructions for welding various materials.

Preparation of the Work. This is a very important feature and should receive the operator's best thought and effort. A fair amount of reasoning and planning on the part of the operator before he attempts a job will save considerable time and keep the cost of the welding low. The operator should figure out several ways and means of handling the particular task at hand, and should then select the best. This applies especially to castings, such as crankcases and cylinders, which may be welded perfectly if the operator uses good judgment but which will be ruined if he does not.

Welding Rod. Thin plates may be welded by bringing the edges into contact and fusing them together. For heavier work, the edges are beveled to form a groove, and a filling material, or "welding-rod", is fused into the groove. In most cases a material similar to the work being welded is used. The operator may build up the weld by means of the welding rod so that the section at the weld is greater than the section before welding, thus insuring a strength even greater than the rest of the piece.

Flux. A suitable flux is used in cast iron, aluminum, brass, copper, etc., welding to dissolve any impurities and to give a film, or protecting coating, to the fused material to prevent oxidation.

Both the welding rod and the flux used are extremely important factors in the welding and should be obtained from a reliable manufacturer who supplies only materials that are tested and analyzed to determine their purity and suitability for the work.

Strength of Weld. With proper equipment and suitable rods and fluxes, the strength of the weld will depend mainly upon the skill

Fig. 9. Oxy-Acetylene Cutting Blowpipe
Courtesy of Oxweld Acetylene Company, Chicago, Illinois

and care of the operator. An operator who has had considerable experience and who is careful with his work should be able to obtain as high as 95 per cent the strength of the original material, although 85 per cent may be taken as a safe lower limit for the average good welder.

Working and Hammering. If the weld is hammered when at the proper temperature, its strength will be increased, in the case of welds in steel, by making the grain of the material finer.

Experience of Operator. Poor work due to carelessness or inexperience of the operator, poorly designed and cheaply constructed apparatus that is not capable of handling the work, may be held responsible for such failures as may occur in the oxy-acetylene process.

The handling of the process is not difficult and, therefore, some operators undertake difficult jobs before they are sufficiently capable or experienced. When such a job fails, it is but natural that both the customer and the operator should blame the process rather than the way in which the work was handled. Time may be very profitably spent in practice on scrap material before undertaking work on materials with which the operator is unfamiliar. By thus laying the foundation for a satisfactory result, the operator may quickly develop

Fig. 10. Electric Spot-Welding Machine
Courtesy of Thomson Spot Welder Company, Cincinnati, Ohio

his skill to the point which will bring him the confidence and patronage of a constantly increasing number of customers.

Oxy-Acetylene Cutting. Cutting by the oxy-acetylene process is done by means of a separate blowpipe, Fig. 9, quite different in construction from that used for welding. A more detailed description of the cutting process is given on page 77.

ELECTRIC PROCESSES

Methods. For a number of years electric welding was used as a laboratory experiment, but recently the process has been more fully developed. Two distinct methods are utilized: one, the electric-resistance welder, or spot-welder, Fig. 10; and the other, the electric-arc welding machine, Fig. 11.

Spot-Welder. The electric-resistance welding process provides for the passage of a heavy current through the joint between the pieces to be welded, allowing the resistance of the bad contact to heat them locally until they are soft enough to stick together; squeezing

Fig. 11. Portable Arc-Welding Outfit
Courtesy of C & C Electric and Manufacturing Company, Garwood, New Jersey

the pieces while soft will then cause them to adhere. This process is used mostly in making light automobile parts, such as mud guards, bonnets, etc., rather than for repair. It is also used to some extent instead of small rivets in light sheet-metal work and for spotting, or tacking, small parts together preparatory to welding them with the oxy-acetylene flame.

Arc Welder. In order to do welding with the electric arc, after suitable equipment has been provided, it is necessary to first connect the work to the positive side of the power-supply circuit and the welding electrode to the negative side of the circuit by means of wires or cables, with the regulating devices in circuit to control the amouut of current flowing. The negative electrode is then placed lightly in contact with the work and quickly withdrawn to make the circuit

Fig. 12. Operator Using Metallic Electrode
Courtesy of C & C Electric and Manufacturing Company, Garwood, New Jersey

and draw the arc, thus providing the high temperature required for welding.

Electric-arc welding usually consists in using the heat of the arc to fuse, or melt, the filling material into the place to be filled, although the article worked upon may be melted down sufficiently to fill the space if it is large enough at the point to be welded.

Two methods, or processes, using the arc for welding, are in commercial use, these being the metallic and the graphite, or carbon, processes.

Metallic Electrode. The metallic welding process consists in using a piece of wire of the proper kind as the negative electrode of the arc and fusing it into place, drop by drop, Fig. 12.

Graphite Electrode. The graphite process consists in using a piece of graphite, or carbon, as the negative electrode and fusing a piece of metal into place by the heat of the arc.

Apparatus. It is possible, though not practical, to do electric-arc welding, having nothing but a source of primary current, and some

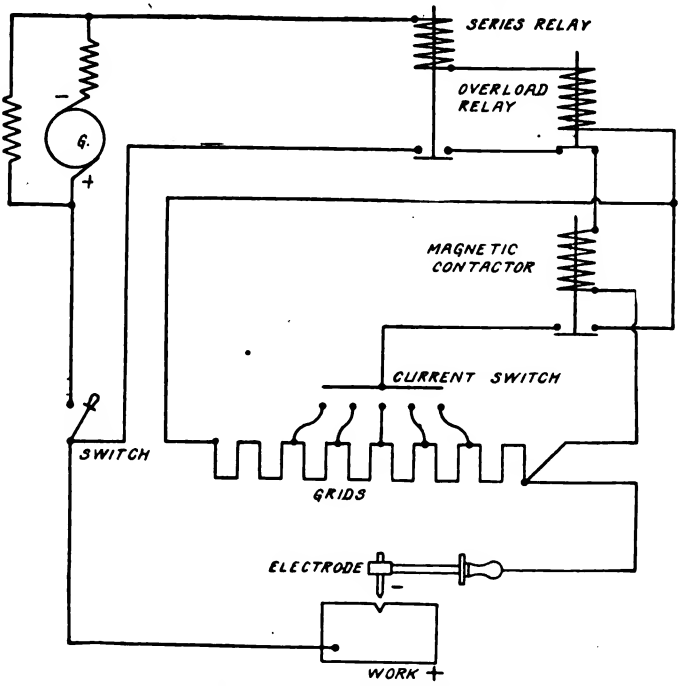


Fig. 13. Wiring Diagram for C & C Welding System

means for regulating the amount of current flowing, but the use of resistance only as a means of regulating the amount of current flow is so wasteful that other apparatus must be used for the sake of economy. It is well known among electrical men that a motor-generator set gives the best regulation of voltage, therefore, the leading arc-welding outfits in use today consist of a motor-generator set with suitable rheostats, resistances, circuit-breakers, fuses, indicating instruments, and switches for controlling the motor-generator and welding circuits, Fig. 13.

From the foregoing description, it will be surmised that an electric-arc welding equipment will be too expensive in initial cost for the average auto repair shop. However, it finds a useful field in the welding of very heavy work where there is sufficient volume of it to justify the investment.

TECHNIQUE OF OXY-ACETYLENE WELDING

SIMPLE WELDING JOB

Apparatus Required. The material in the following paragraphs must not be considered as instructions for welding but merely as a brief discussion of the various steps in making a simple weld. Complete instructions for connecting and operating the equipment are given in detail later. In general, the following equipment is needed for every welding job, no matter how small:

(a) A welding blowpipe
(b) A supply of oxygen
(c) An oxygen regulator
(d) A supply of acetylene
(e) An acetylene regulator
(f) Hose to connect blowpipe to oxygen and acetylene supplies

Preparing the Metal. First, the edges of the two pieces of metal to be welded are chamfered or beveled, so that when they are placed together the two beveled edges form a V, the width of the V being about equal to the thickness of the metal.

Next, the two pieces are placed together on a flat surface of fire brick, or other nonconductor of heat, so that the edges just touch at the bottom of the groove. This gives the line of the weld. The two pieces are then ready to be welded as soon as the apparatus is connected.

Connecting the Apparatus. To connect the apparatus, the following steps should be taken:

(1) The oxygen regulator is connected to the oxygen cylinder.
(2) The acetylene regulator is connected to the acetylene cylinder.
(3) The one hose is connected to the oxygen regulator and to the blowpipe.
(4) The other hose is connected to the acetylene regulator and to the blowpipe.

(5) A welding head is selected and attached to the blowpipe.

(6) The oxygen and acetylene are turned on and the blowpipe is lighted.

Welding. The operator is now ready to weld. He takes the lighted blowpipe in his right hand, Fig. 14, and plays the flame upon the beveled edges of the two pieces of metal to be welded. The intense heat of the flame melts the edges and they flow together. As

Fig. 14. Simple Job of Welding

the edges flow together, the operator melts in new metal from a rod which he holds in his left hand, so that the entire goove is filled up, producing a perfect union or weld.

When the entire groove has been filled in this manner, the operator turns out the blowpipe, and allows the metal to cool.

The foregoing is a brief outline of the steps taken by an operator in performing a simple operation of welding two small pieces of steel.

We will now take up these different steps and will give more specific and detailed descriptions of the welding apparatus and complete instructions in its operation and use.

OPERATION AND CARE OF WELDING APPARATUS

Necessity for Care. It is proper that in the operation of the welding apparatus we should lay stress upon the importance of careful and orderly methods in the handling of such apparatus. It should be borne in mind that the regulators and gages are sensitive measuring devices, that in the blowpipe the orifices are carefully designed and accurately machined to permit the passage of a definite quantity of gas and, therefore, that rough usage and abuse will certainly decrease their efficiency. It is not necessary in this place to give detailed instructions for the operation and care of the various makes of apparatus, because these are invariably furnished by the manufacturers with their equipment.

Because of the fact that dissolved acetylene is most generally used in garages and small job shops, we will confine our explanations to the use of apparatus with cylinder equipment. Owing to the greater simplicity of handling, however, the operator will have no difficulty in making use of generated acetylene when the opportunity arises.

Necessary Welding Apparatus. A complete welding station, Fig. 15, for use with acetylene dissolved in cylinders, consists of the following apparatus:

Welding blowpipe *G* with set of welding heads
Oxygen welding regulator *C* with two gages
Acetylene regulator *D* with one or two gages
Adapter *L* for acetylene cylinder
Two lengths high-pressure hose *E* and *F*
Darkened spectacles, wrenches, hose clamps, etc.

Welding Blowpipe. The two types of welding blowpipes were described on pages 7 and 8, and need no further explanation as to the principles of operation. They are furnished by the manufacturers in various lengths to take care of various classes of work, from short light-weight blowpipes less than a foot long for light sheet-metal work up to blowpipes several feet long, which allow the operator to stay away from the intense heat as far as possible when working on heavy jobs.

Welding Heads and Tips. About ten sizes of welding heads, or tips, are supplied for use on different thicknesses of metal and various classes of work, each giving its own special size flame. The oxygen consumption of the various size heads ranges from about 4 to 70 cubic feet per hour. In some makes the heads are made of one

Fig. 15. Complete Welding Station

piece, while in others they consist of a brass or bronze body and a copper tip, which can be easily and cheaply replaced when necessary.

Working Pressures. The necessary pressures of the gas that are required by the different size welding heads are given by the manufacturers, and it is very important that the operator use only the pressures recommended if he wishes to get the best economy and the strongest weld possible. Some operators believe that by increasing the pressure above that specified by the maker of the apparatus that they are able to do the work more quickly and easily. This idea is wrong, because when the pressure is increased, the larger volumes of oxygen and acetylene cannot mix as well, so that oxide forms in the weld and has to be removed. This takes more time and is very likely to leave a slightly oxidized and weak weld.

If the welding head being used is not large enough, use a larger size; never try to increase the ability of the smaller head by increasing the pressure.

It is equally bad to use a pressure that is too low. If this is done, continual back-firing will result.

Care of Blowpipe. If the blowpipe is handled properly there will be very little deterioration. It should only be necessary to clean the replaceable and working parts and occasionally ream out the tips.

Fig. 16. Cleaning Blowpipe by Means of Oxygen under Pressure

The tips should never be reamed out with any instrument other than a copper or brass wire having a long taper. Care should be taken that the orifices of the tips are not enlarged by reaming. If they become enlarged, they may be closed slightly by placing a conical swag over the end and tapping lightly with a hammer. The end of the tip should then be dressed off square by means of an extra fine file, and the orifice trued round by reaming with a twist drill of the proper size.

The blowpipe may be cleaned by removing both the acetylene and the oxygen hose and connecting the tip to the oxygen hose. Fig. 16, and turning on the oxygen to a pressure of about 20 pounds per square inch, having the *acetylene* needle valve *open* and the oxygen needle valve closed, so as to drive any obstructions through the larger acetylene passages of the blowpipe. Then close the acetylene valve and open the oxygen valve to clean out the oxygen passages.

Regulators. There are various types of regulators on the market today, but the most successful ones are very similar in design and construction. The principal parts of a constant-pressure regulator, Fig. 17, consist of the body proper, regulator valve, diaphragm, pressure-adjusting spring, safety-relief valve, and gages.

The diaphragm may be either special reinforced rubber sheeting or phosphor bronze. The former is preferred, because it is less likely to crack, or split, is more readily replaced, and gives more sensitive regulation because of its finer elastic properties.

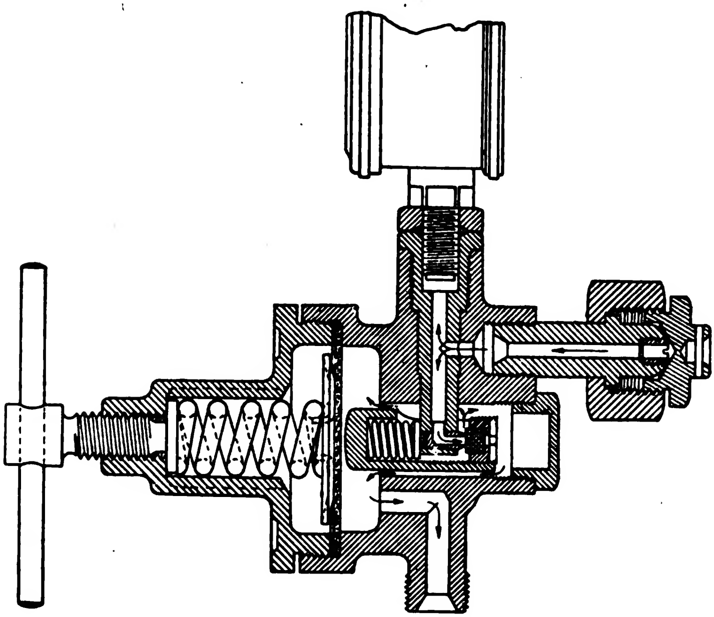


Fig. 17. Section of Pressure Regulator
Courtesy of Oxweld Acetylene Company, Chicago, Illinois

Operation of the Regulator. Gas passes from the cylinder valve through the passageway to the regulator valve. The pressure overcomes the tension of the inner spring and moves the sleeve-piece toward the back of the regulator, opening the valve. This allows gas to pass into the diaphragm chamber and out of the regulator by way of the hose connection. As the pressure in the diaphragm chamber increases, the tension of the pressure-adjusting spring is overcome, the diaphragm deflects, the sleeve-piece moves forward, and the valve closes partly or all the way. Then, as gas passes out of the regulator and the pressure in the diaphragm chamber decreases, the tension of the pressure-adjusting spring and the pressure of the gas entering the regulator move the sleeve-piece backward, admitting more oxygen to the regulator. The pressure in the diaphragm chamber builds up as before, the diaphragm deflects, the sleeve-piece moves outward, and the valve closes.

Oxygen Welding Regulator. This is an automatic regulator which is especially designed for welding operations. It is connected to the oxygen cylinder and is designed to deliver oxygen to the blowpipe at any uniform pressure at which the regulator is set. To do successful welding, the oxygen regulator must be as nearly perfect as it is possible to construct it. This device is required to reduce a pressure which may be as high as 1800 pounds per square inch in the cylinder and which is constantly varying, down to a pressure from 10 to 30 pounds per square inch; at the same time the regulator must keep the lower pressure constant.

Oxygen regulators are usually equipped with two gages. The high-pressure gage shows the pressure of the gas in the cylinder and may be used to determine the amount of oxygen in the cylinder (see under Measuring Oxygen, page 99). The low-pressure gage shows the operating pressure at which the oxygen is being supplied to the blowpipe.

Acetylene Regulator. The acetylene regulator is used with acetylene supplied in cylinders. It is connected to the acetylene cylinder adapter, and this to the acetylene cylinder. The acetylene regulator is designed to deliver acetylene at a uniform pressure, as needed by the blowpipe.

Acetylene regulators are usually equipped with a large gage that shows the pressure in the cylinder, but which cannot be used to accurately determine the contents of the cylinder (see Measuring Acetylene, page 102). A small gage is not necessary with the low-pressure, or injector, blowpipe, because the acetylene pressure required by this type of blowpipe is very low—only a few ounces. With the pressure blowpipe, however, a small gage is necessary, because it is important to know that the acetylene pressure, which ranges from 2 to 13 pounds per square inch, is supplied to the blowpipe at the required pressure for the tip used.

Care of Regulators. Never drop or jar a regulator. Do not use oil, grease, or any organic material for lubrication in connection with regulator. If it becomes necessary to lubricate the pressure-adjusting screw, or to repack a needle valve, make use of a little glycerine—nothing else.

Do not allow dust to enter the regulator. Always insert the dust plug when the regulator is not in use. These are supplied with most regulators and are intended to keep dust out of the regulator when it is not in use and to protect the union nipple at the back.

Do not change the regulator from one cylinder to another without releasing the pressure-adjusting screw. The diaphragm is liable to be ruptured if there is tension on it when the sudden rush of gas takes place as the cylinder valve is opened.

Do not attempt to repair, adjust, or change the internal mechanism of the regulator, other than replacing the diaphragm and resurfacing or replacing the valve seat. Send it to the manufacturer for repairs.

Do not replace diaphragms or valve seats with any material other than that supplied by the manufacturer for this purpose.

Hose. The best hose that it is possible to obtain should be used, because it is really the most economical in the end, although it might cost more at the beginning. A good grade of two-ply hose will be found to be flexible, light weight, easy to handle, and, at the same time, will not kink easily nor be permanently flattened if heavy objects happen to accidentally fall on it. In selecting a hose, the welder should see that he gets a hose that has a finished inside surface, so that small particles of rubber and dust will not flake off and be blown into and clog the blowpipe or welding head.

It is best to use different colored hose for the oxygen than for the acetylene to prevent errors in connecting and to avoid any possible danger from interchanging.

Care of Hose. Both the acetylene and the oxygen hose should be blown out occasionally so that dirt and dust will not be carried into the blowpipe. This can be done by removing the hose from the blowpipe, connecting each in turn to the oxygen regulator, and allowing oxygen of about 20 pounds per square inch to blow through it. Examine the hose, from time to time, for leaks by immersing in water when under pressure.

INSTRUCTIONS FOR CONNECTING APPARATUS

Preliminary Operations. The following directions are given as a starting point for beginners in the operation of welding equipment. The letters given refer to the labeled parts in Fig. 15, page 17.

1. First open the oxygen cylinder valve *B* for a moment to blow out any dirt or dust which may have collected in the valve, so that it cannot enter the oxygen regulator when it is attached to the cylinder.

2. Remove the regulator dust plug and attach the oxygen regulator *C* to the oxygen cylinder *A*.

3. Connect the oxygen hose *E* to the oxygen regulator and to the oxygen hose connection on the blowpipe *G*. The hose connections are usually readily distinguished by markings on the needle valves.

4. Release the pressure-adjusting screw on the oxygen regulator by turning to the *left* until it is perfectly free.

Do not open the valve on the oxygen cylinder until positive that the adjusting screw on the regulator is fully released. The diaphragm may be ruptured and the regulator put out of commission.

5. Slowly open the oxygen cylinder valve *B as far as it will go. Not part way.*

Do not leave the valve on the oxygen cylinder only part way open. This valve seats when fully opened or closed, but is likely to leak when open only part way.

Do not handle the regulator with greasy hands nor allow any oil, soap, or organic matter to come in contact with any part of the regulator or cylinder valve. Oxygen under high pressure coming in contact with these substances is dangerous.

6. Wipe out the acetylene cylinder valve to remove any dirt or dust which may have collected in the valve, so that it cannot enter the acetylene regulator when it is attached to the cylinder.

7. Attach the adapter *L* to the acetylene cylinder *K*.

8. Remove the regulator dust plug and attach the acetylene regulator *D* to the adapter.

9. Connect the acetylene hose *F* to the acetylene regulator and to the acetylene hose connection on the blowpipe *G*.

10. Release the pressure-adjusting screw on the acetylene regulator by turning to the left until it is perfectly free.

11. Open the acetylene cylinder valve about three full turns by means of the wrench *J*.

12. Select the welding head of the size suitable for the work in hand. Screw the welding head down firmly, but not too tightly, into the head of the blowpipe with the wrench provided for that purpose.

Starting the Work

How to Light the Blowpipe. 1. Take the blowpipe in hand and open the oxygen needle valve fully.

2. Turn the oxygen pressure-adjusting screw to the right until the required pressure for the welding head being used shows on the low-pressure gage. See the maker's chart for the correct pressure.

3. Close the oxygen needle valve.

4. Open the acetylene needle valve fully.

5. Turn the acetylene pressure-adjusting screw to the right until a good jet of acetylene issues from the welding-head orifice. In the case of pressure blowpipes, turn the screw until the required pressure for the welding head being used shows on the low-pressure gage. (See the maker's chart for the correct pressures).

6. Open the oxygen needle valve slightly and light the blowpipe by means of the pyro-lighter that is usually furnished.

7. Open the oxygen needle valve fully.

NOTE: A back-fire might occur when turning on the oxygen if there is not enough acetylene being supplied. If this occurs, increase the acetylene supply by turning the acetylene pressure-adjusting screw farther to the right.

8. Adjust the acetylene pressure-adjusting screw to give a slight excess of acetylene to the flame.

9. Adjust the acetylene needle valve to give a neutral flame (see under Flame Regulation, page 25).

How to Shut Off the Blowpipe. In the case of the *injector type blowpipe,* first close the *acetylene* needle valve, and then the oxygen needle valve.

In the case of pressure blowpipes, first close the oxygen needle valve, and then the acetylene needle valve.

When laying aside the blowpipe for a short time, the pressure-adjusting screws on both regulators should be released by turning to the left until free.

When work is suspended for any considerable time, the valves on both cylinders should be closed.

Never light the blowpipe unless some oxygen is passing through it. If the blowpipe is lighted, or burned, with only acetylene passing through it, there will be a deposit of carbon made in the tip, which will in time clog the orifice and interfere with the perfect operation of the blowpipe.

Back-Firing. If the flame is not properly adjusted, or the tip becomes clogged, the blowpipe may back-fire. When this occurs, first close the acetylene needle valve quickly, then open it again fully and relight the blowpipe. If the back-fire continues, close both the acetylene and oxygen needle valves. Then relight the blowpipe and proceed in the usual manner.

If the blowpipe becomes overheated, it may back-fire. When this occurs, it may be cooled by plunging it into a bucket of water. Be sure that the acetylene has been shut off and a small quantity of oxygen is flowing through the blowpipe to prevent water backing into the tip and causing further back-firing when the blowpipe is relighted.

Oxy-Acetylene Blowpipe Flame

Character of Flame. The oxy-acetylene flame consists of two parts—an inner cone, which is incandescent; and an outer envelope, or nonluminous flame, which is sometimes called the secondary flame.

The temperature of the oxy-acetylene flame, taken at the extremity of the inner cone, is very much higher than that of all other flames. It is calculated to be approximately 6300° F. One of the main reasons for the superiority of the oxy-acetylene flame over all other welding lies in the fact that this high temperature is concentrated at the point of inner cone.

The character of the oxy-acetylene flame depends upon the proportion of oxygen and acetylene contained in the mixture and the thoroughness of the mixture as it issues from the tip of the blowpipe. Varying proportions of the gases produce three characteristic types of flame, Fig. 18, called, respectively, reducing, or carbonizing, flame; neutral, or welding, flame; and oxidizing flame. Each type has its characteristic appearance, and it takes only a little practice to instantly recognize each. The welder should at all times observe carefully the type of flame produced and promptly correct any divergence.

Neutral, or Welding, Flame. A neutral flame is produced when acetylene and oxygen burn in the proper proportion, theoretically 1.00 volume of oxygen to 1.00 volume of acetylene. The appearance of this flame is characteristic, Fig. 18 b. It is made up of a distinct and clearly defined incandescent cone, or jet, of bluish hue, surrounded by a faint secondary flame, or envelope, purplish yellow in color and of a bushy appearance.

The incandescent cone may be from $\frac{1}{16}$ to $\frac{3}{4}$ inch in length and is usually rounded or tapered at the end. The maximum temperature of the oxy-acetylene flame is $\frac{1}{16}$ to $\frac{3}{16}$ inch beyond the extremity of this cone.

Fig. 18. Oxy-Acetylene Flame. Top, Reducing Flame; Middle, Neutral Flame; Bottom, Oxidizing Flame

The middle illustration in Fig. 18 shows roughly the characteristic appearance and formation of the neutral, or welding, flame. This flame is the one most extensively used, and no welder is proficient until he is thoroughly familiar with its appearance and distinguishing characteristics and is able to maintain this flame under working conditions.

Flame Regulation. The neutral flame is obtained by starting with a flame having a slight excess of acetylene and gradually cutting down the acetylene supply by means of the blowpipe needle valve. As this is done, the streaky appearance of the inner cone will gradually diminish. The flame is neutral when the streakiness just disappears.

Carbonizing, or Reducing, Flame. The reducing, or carbonizing, flame is produced when there is an excess of acetylene in the flame. This flame is of an abnormal volume, dirty yellow in color, of uniform consistency, and has a streaky appearance. By gradually decreasing the acetylene supply at the needle valve, the size of the flame is decreased, and gradually a white cone of great luminosity appears at the blowpipe tip. The extent of the reducing, or carbonizing, action of the flame is judged practically by the size and definition of the luminous cone. When this cone becomes more clearly defined and takes the form and color of a bluish white incandescent cone, or pencil, the streakiness is further diminished, and the flame approaches the neutral stage. The upper illustration in Fig. 18 shows a reducing, or carbonizing, flame that has a fair but not large excess of acetylene. The temperature of the reducing flame is considerably lower than that of the neutral flame.

Use of Reducing Flame. A slight excess of acetylene is used in the welding of brasses, bronzes, aluminum, and certain alloy steels to guard against the burning out of easily oxidized elements. It has also been used in the case of certain mild steels to increase the carbon content to secure greater hardness. In this connection it must be remembered that increase in hardness is usually accompanied by decrease in strength, so that in general welding an excess of acetylene should not be used.

Oxidizing Flame. An oxidizing flame is produced when there is an excess of oxygen in the flame. The effect of too much oxygen is to diminish the size of the flame, blunt or blurr the inner cone, and produce a weak, streaky, or scattering flame. In some blowpipes, the inner cone is not only diminished in size but is slightly bulged at its extremity as compared with the neutral flame, which is shown in the middle of Fig. 18. The lower illustration in Fig. 18 shows the oxidizing flame.

Caution Against Oxidizing Flame. An oxidizing flame should be carefully guarded against or it will become a source of trouble. An excess of oxygen will burn the metal, causing weak welds, and in the case of cast iron it will produce a hard weld that will be difficult to machine.

Manipulation of Blowpipe and Welding Rod

Position of Hose. Occasionally the hose is thrown over the operator's shoulder. In this case the weight of the blowpipe is suspended and held by the hose so that it is only necessary to impart the peculiar welding motion to the blowpipe, which can usually be done by the fingers. However, this method is not generally recommended, as it seriously hinders the free movement of the welding flame. It should be used only as a relief when the work is of long duration and the operator's wrist and forearm become tired.

Position of Blowpipe. The operator, having lighted the blowpipe and properly adjusted the flame, is now ready to begin welding. Grasp the blowpipe firmly in the hand, as shown in Fig. 19. The blowpipe is so designed that it balances properly when grasped at this point. It is not good practice to hold the blowpipe in the fingers, because it is not possible to manipulate the flame with as great regularity and control, nor will it be possible to do as heavy work without tiring.

Fig. 19. Correct Method of Holding Welding Blowpipe

Fig. 20. Blowpipe Should Not Be Inclined Too Much

Fig. 21. Blowpipe Should Not Be Held Too Vertical

Fig. 22. Blowpipe Should Not Travel Backwards

Inclination of Blowpipe. The head of the blowpipe should be inclined at an angle of about 60 degrees to the plane of the weld.

The inclination of the head should not be too great, Fig. 20, because the molten metal will be blown ahead of the welding zone and will adhere to the comparatively cold sides of the weld. On the other hand, the welding head should not be inclined too near the vertical, Fig. 21, or the secondary flame will not be utilized to its full value for pre-heating the metal ahead of the actual welding.

In ordinary welding practice it is best that the top of the blowpipe be so inclined and so directed that the maximum amount of preheating is obtained without blowing the molten metal ahead.

Travel of Blowpipe. The travel of the blowpipe should be away from the welder and not toward him, Fig. 22, as the work can be observed more closely and done more easily and quickly.

Movement of Blowpipe. In making a weld a simultaneous fusion of the edges of the parts to be joined and the welding rod is necessary. If this does not occur, a true weld is not produced.

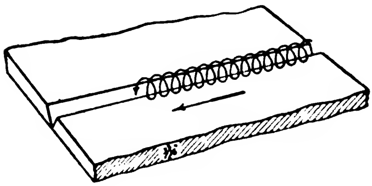


Fig. 23. Circular Motion of Blowpipe for Welding Light Sections

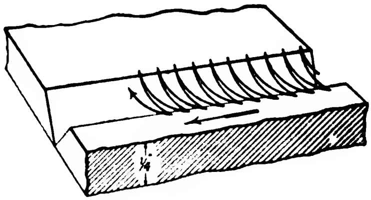


Fig. 24. Oscillating Motion of Blowpipe for Welding Heavy Sections

In the case of parts which have been chamfered out and which require the use of filling material, a peculiar motion must be imparted to the blowpipe, which will take in both edges of the weld and the welding rod at practically the same time.

In comparatively light work a motion is imparted to the blowpipe which will cause the incandescent cone to describe a series of overlapping circles, as shown in Fig. 23. This overlapping extends in the direction of the welding. This motion must be constant and regular in its advance so that the finished weld will have a good appearance. The speed of progress should be such that complete fusion of the three members referred to is secured. The width of this motion is dependent upon the size of the material being welded and varies accordingly with the nature of the work. It does not take much experience to establish the proper size motion and the proper rate of advance for the various sizes and kinds of metals.

In very heavy work, if the above system were used, a great deal of the motion would be superfluous. Consequently, a movement in which the cone of the flame will describe semi-circles should be used, as shown in Fig. 24. This confines the welding zone and concentrates the heat. While the progress is not so fast, it is more thorough than the other system for this class of work.

Importance of Movement. To the average beginner the regular control from these motions is difficult. It requires considerable practice and experience to become skilled in this, but it is the regularity of these motions that produces the characteristic rippled surface of good welding. The progress of a welder and the quality of his work can be determined to some extent by the skill with which he produces this effect.

Position of Welding Rod. After the beginner has mastered the peculiar motions of the blowpipe, his next step will be to properly introduce the welding rod into the weld in such a manner that the regular advance of the blowpipe will not be hindered or retarded.

Fig. 25. Correct Method of Holding Welding Rod

The welding rod, or wire, should be held and inclined, as shown in Fig. 25. In this position a sufficient quantity of material may be added at the right time. If the welding rod were held in a vertical or horizontal position, the welder would be liable to add an excess of metal, part of which would not be properly fused.

When to Add Welding Rod. Great care must be taken in adding this metal that the edges of the weld are in their proper state of fusion to receive it. If the metal is not hot enough, the added material will simply adhere to the sides, resulting in adhesion only, not a true weld. It is, therefore, necessary to produce equal fusion at the edges of the weld with that of the welding rod by the correct motion of the blowpipe.

How to Add Welding Rod. When the proper time arrives to add the filling material, the welding rod is lowered into the weld until it is in contact with the molten metal of the edges. When in this position the flame of the blowpipe is directed upon it, and thus fusion is produced.

In welds of unusual depth the end of the rod is immersed in the molten metal and the blowpipe flame is played around it. The material is thus protected from the air and the gases of the blowpipe. The heat of fusion in this case is supplied mostly from the molten metal which surrounds the rod.

Faults to Be Avoided. The usual faults of the average beginner are: first, failure to introduce the welding rod into the welding zone at the proper time; second, to hold the rod at the wrong angle; and third, to fuse either too little or too much of the rod. The filling material when melted should never be allowed to fall into the weld in drops, or globules, Fig. 26.

Fig. 26. Welding Rod Should Not Be Allowed to Fall into the Weld in Drops

Building Up the Weld. In welding it is customary to build up the welded portion in excess of the thickness of the original section. There are several reasons for doing this. First, the weld is reinforced and the strength is accordingly increased. Second, in case it is desired to finish the surface there is sufficient stock to allow machining. Third, in some cases small pin-holes or blowholes may be found just under the surface of a weld, which do not extend to any depth in the weld and may be removed by filing or machining.

GENERAL NOTES ON WELDING

The above are basic principles involved in producing all good oxy-acetylene welds. There are many detailed operations which must be learned by practice for the successful handling of the different metals, but by keeping in mind these basic principles and by applying them properly, the more difficult operations can be readily mastered.

Haste Fatal to Good Welding. It is a fundamental rule for successful welding that the operator must give his undivided attention to the work in hand. *Do not try to hurry over or slight any step of the work.* You cannot weld faster than the metal will melt and fuse together.

Burning a Hole in the Metal. Occasionally an operator becomes so interested in some minor detail of his work that he allows the flame to burn through the metal and form a hole.

How to Weld Up a Hole. It is a difficult operation for a beginner to fill these holes. His first attempts usually result in enlarging the holes instead of closing them. The proper way to take care of this is to incline the blowpipe so that the flame is almost parallel to the surface of the work, Fig. 27. With the blowpipe in this position, play the flame upon the upper edge of the hole until the sides become plastic, taking care that the edges do not become entirely fused. When the edge is in the proper condition, the welding rod is interposed and a small amount of metal is added to the top edge of the hole. This operation is repeated until the hole is filled in. As the work progresses, the blowpipe is gradually raised until it resumes its normal position.

Fig. 27. Method of Filling in a Deep Hole—Start at the Upper Edge

Overhead and Vertical Welding. In welding overhead, Fig. 28, or vertically, Fig. 29, the same procedure is followed as in filling a hole. The metal should not be allowed to reach the state of fusion that is secured in ordinary welding. It should be hot enough to assimilate the welding rod, but not so fluid that it will flow out of the weld. In overhead welding care should be taken that oxidation does not occur, because the molten oxide will flow from the weld and seriously inconvenience the operator.

Fig. 28. Overhead Welding

Beginning a Long Weld. In beginning a long weld pains should be taken to see that it is started properly, and at this point of the work time should not be spared. When the weld is properly started the speed may be increased. As the weld advances the speed becomes

Fig. 29. Vertical Welding

greater, because the material becomes heated up and the blowpipe action is faster.

Defects in Welds. There are a number of sources of defects in welds, and the average beginner usually encounters all of them before he becomes a skilled welder.

Improper Flame Adjustment. If the flame is not properly adjusted the weld will be inferior. The commonest fault is the presence of too much oxygen in the welding flame. Unless the operator takes a great deal of care in removing the oxidized particles, they will be incorporated in the weld, Fig. 30. The oxide, of course,

Fig. 30. Oxidized Weld

Fig. 31. Failure to Completely Penetrate to the Bottom of the Weld

greatly decreases the strength and greatly affects the other mechanical properties of the weld.

Failure to Penetrate. A fault, not only of the beginner but also of the skilled operator, is failure to penetrate to the bottom of the weld, Fig. 31, and is the cause of a great many defective welds. In his desire to complete a weld as soon as possible, the operator very often hastens over the most important part of the work, which is to secure the absolute fusion of the edges at the bottom of the weld. Failure to do this not only reduces the section of the metal at the weld, but also gives a line of weakness in case the welded pieces are submitted to bending or transverse strains.

the Weld

Adhesion of Added Metal. When molten metal from the welding rod is added to the edges of the weld which are not in fusion, a weld is not secured. The added metal merely adheres to the cooler metal, Fig. 32, and perfect fusion is not secured. Adhesion may be caused by improperly chamfering the pieces to be welded, by improper inclination of the blowpipe, by improper use of the welding rod, or by faulty regulation and manipulation of the welding flame.

The tendency of beginners is to not prepare the pieces properly for welding. Usually the chamfering, or grooving, is either not deep enough, that is, does not extend entirely through the section to be welded, or it is not wide enough. In welding pieces improperly prepared the tendency of adhesion is great.

The most common fault is the addition of the welding rod to the edges of the weld before they are in fusion. The adhesion in this case is applied to both edges. Sometimes one edge of the weld is in fusion. but the other is not. In this case adhesion is applied to only one side,

Fig. 33. Weld *Not* Properly Reinforced

Fig. 34. Weld Properly Reinforced

but with the effect that the strength of the weld is lessened the same as when adhesion occurs on both sides.

In some cases the edges of the metal are brought to a state of fusion too soon, so that oxide has an opportunity to form on the edges of the weld. Then, when the welding rod is added, adhesion occurs with a film of oxide separating the edges and the added material.

Often an operator will concentrate the flame upon the welding rod and the edges of the weld. Then, as the blowpipe is played around the welding rod, some of the molten metal is forced ahead. The metal ahead is not in the proper state of fusion and consequently adhesion results.

Insufficient Reinforcing. It is not uncommon to see welds produced that do not contain enough metal, Fig. 33. All welds should be reinforced with additional metal as in Fig. 34. In case a smooth finish is desired this excess metal can be removed by grinding or machining. Too great an excess of metal must not be added because this takes extra time and the gases are wasted.

WELDING FOR DIFFERENT METALS

PROPERTIES OF METALS

Before the beginner takes up the actual welding of metals, it is necessary that he study their properties, peculiarities, and behavior under the action of the welding flame. Some of the physical properties of the more common metals are given in Table I.

Melting Point. The first property that the welder should consider is the melting point or temperature at which the metal will fuse or become fluid. The average welder is usually fairly familiar with the difference in melting points of lead or zinc, and iron or steel; but he is usually not familiar with the difference between the melting points of brass, bronze, copper, white cast iron, gray cast iron, etc. This knowledge is especially important if it becomes necessary to weld members of dissimilar materials.

Thermal Conductivity. The conductivity of a metal is its ability to transmit heat throughout its mass. This property, which is not the same for all metals and varies within wide limits, is of great importance to the welder. It can be seen that if one metal conducts or transmits the heat from the welding blowpipe more rapidly throughout its mass than another, it is necessary that allowance be made both as to the pre-heating equipment and the size of the blowpipe used.

In welding metals of high thermal conductivity, it is necessary to use oversize blowpipes—as in the case of copper. Although the

TABLE I
Properties of Metals

METAL	Weight Lb. per Cu. In.	Tensile Strength Lb. per Sq. In.	Melting Point Deg. F.	Relative Thermal Conductivity Copper = 1.00	Specific Heat	Coefficient of Linear Expansion	Approximate Expansion from 60° to Melting Point In. per Ft.
ALUMINUM							
Cast	0.093	15,000	1210	0.524	0.22	0.0000123	$\frac{11}{64}$
Drawn	0.098	24,000 to 40,000				0.0000136	$\frac{12}{64}$
BRASS							
Cast, Red	0.3103	20,000		0.251		0.00000957	$\frac{12}{64}$
Cast, Yellow	0.2959	18,000	1740	0.208	0.09		
Drawn		40,000 to 78,000				0.00001052	$\frac{14}{64}$
BRONZE							
Manganese		75,000 to 90,000		0.735			
Phosphor	0.32	50,000	1692			0.0000086	$\frac{12}{64}$
Tobin		60,000 to 100,000					
COPPER							
Cast		22,000	1980	1.00	0.095		
Drawn	0.3195	31,000				0.0000094	$\frac{14}{64}$
IRON							
Grey cast	0.2604	20,000	2190	0.124		0.00000556	$\frac{9}{64}$
White cast		18,000	2000				
Wrought	0.2779	55,000	2730	0.157	0.11	0.00000648	$\frac{13}{64}$
LEAD	0.411	1,780	620	0.091	0.03	0.0000155	$\frac{7}{64}$
NICKEL	0.312	76,000	2650	0.155	0.11	0.000007	$\frac{14}{64}$
STEEL							
Mild	0.283	50,000 to 75,000	2690	0.118	0.117	0.0000063	$\frac{13}{64}$
Hard		65,000 to 80,000	2570		0.1175		
ZINC	0.2526	5,500	785	0.29	0.09	0.0000144	$\frac{8}{64}$

melting point of copper is low, yet the conductivity is high, and, consequently, a blowpipe of the same size as would be used on a similar section of steel must be used.

The conductivity of a metal will have a great bearing on the consideration of expansion and contraction. If one metal absorbs or leads the heat away from the welding blowpipe more rapidly than another, the heated area will become very much larger, and, consequently, the expansion and contraction more severe.

Specific Heat. The specific heat of a metal is the amount of heat that is absorbed when it is raised through a certain range of temperature. A metal having a low melting point but relatively high specific heat may require as much heat to bring it to its point of fusion as a metal of high melting point and low specific heat— as in the case of aluminum compared to steel.

Coefficient of Expansion. The linear increase per unit length when the temperature of a body is raised through one degree is its coefficient of expansion.

The coefficient of expansion varies materially with the different metals. Of the metals most commonly welded, as seen from Table I, aluminum has the greatest expansion, bronze and brass next, then copper, steel, and iron. Aluminum expands almost twice as much as iron or steel, consequently, in dealing with aluminum work it is necessary that this feature be considered very seriously.

Expansion and Contraction. When a body of any material is subjected to an increase in temperature, it expands and its volume and linear dimensions are increased. When the temperature is lowered a reverse action takes place, the body contracts, and its volume and linear dimensions decrease. Metals or metallic bodies are very susceptible to this change in volume due to variations in temperature.

The effect of this expansion and contraction is of great importance to the welder. It is impossible for the welder to produce satisfactory work until he has a knowledge of the nature and the amount of expansion usually encountered and of how to compensate for it.

The expansion and contraction of the welded piece cannot be controlled or arrested mechanically, because the force of expansion is irresistible. In malleable, or ductile, metals the expansion is liable to produce warping or deformation of the piece, while in materials that are not of this nature—brittle materials—such as cast-iron, the result of the expansion and contraction, unless properly taken care of, is fracture.

If the expansion can take place in all directions, it will give the welder no trouble, as the piece will expand equally all over, and upon cooling will contract to its original volume. If, however, the welding takes place at a point that is confined by various parts or by the particular construction of the piece, it is then necessary to give it due consideration.

The resultant effect of contraction, produced by the cooling of the welded object, must be considered equally with that of expansion Contraction produces as much cracking, or checking, and warping as does expansion. Therefore, it is essential that the welder study not only the effect of expansion, but also the subsequent result produced by contraction.

Methods of Handling Expansion and Contraction. There are many ways of taking care of expansion and contraction, such as heating the entire piece to a dull red heat, simultaneously heating opposing similar parts, and breaking the piece at certain points to allow free expansion and then re-welding at the break. If the material is ductile or malleable, it may be warped or bent out of shape to such an extent that the spring will take up completely the opposing force of expansion and contraction. This, however, entails an accurate calculation and should not be used except where no other means are feasible.

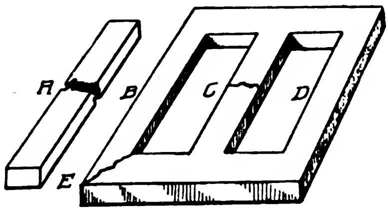


Fig. 35. Simple Case of Expansion and Contraction

Handling Simple Case of Expansion and Contraction. We will first consider the simplest condition of welding. Assume that a long bar which is free at each end has broken at point *A*, Fig. 35. In this case the welding may be carried out without any fear of encountering difficulties due to expansion and contraction. The bar is free to expand and contract at each end. While there might be some warping or deformation due to the heat of welding if the blowpipe is not handled properly, yet, there is very little danger of weakening the weld because of internal strains.

Now let us assume that this bar is part of a casting, as shown at *C*, which is surrounded and joined to a rigid frame *B* and *D*. In this case the expansion and contraction due to welding must be taken care of. It is readily seen that the expansion is not the force that will cause trouble, because when the two pieces expand during welding, the metal, which is in a fused condition, is so soft that the expansion can take place in the weld and the edges will approach each other. This will not affect the confined frame. However, consider the action on the metal when it starts to cool. Contraction sets in and, as it is irresistible, there must be some compensation for the shortening of the bar *C*. If the material is ductile and one that will stand bending, deformation or warping will occur. But, if it is of low ductility, such as cast iron, a break will occur either at the weld or at a line of less resistance.

Methods of Handling. In welding an article of the general nature, shown in Fig. 35, when the break is in an internal member, such as at *C*, there are several ways of handling it.

Heating Entire Casting. The entire piece can be raised to a high temperature as referred to above and in this way produce an expansion in the entire mass, and, consequently, equal contraction. However, this is not necessary, and in some cases is not possible; the operation also takes more time and costs more. It is only necessary at the time of welding to heat simultaneously similar parts to a good red heat, in order that the stiffness of the frame may be lessened, and thus take care of the contraction.

Heating Confining Members. In the example referred to, the application of a pre-heating burner at the points *B* and *D* will cause the frame to expand in the linear direction of the expansion and contraction produced by the weld. Therefore, when the weld is finished and the frame starts to cool and contract, the parts *B* and *C*, in as much as they were raised to practically the same temperature as the metal surrounding the weld, will contract equally and, therefore, a successful weld will be produced.

Use of Wedges. If it is impossible to apply pre-heating at the points referred to, another method may be used. By the use of jacks, wedges, or similar devices, a casting such as shown in Fig. 35 may be sprung or bent out of shape, and the edges of the part to be welded may be separated. After the weld is executed and contraction sets in, the jacks, wedges, etc., may be withdrawn. The return of the sprung parts to their original positions will compensate the contracting strains.

Breaking Another Member. Another method of taking care of expansion and contraction is that of breaking the piece at some extraneous point, such as at *E*. In this case the expansion and contraction will be free to act at the point *C* without any fear of serious after-effect, as the casting is free to spring in any direction, because of the loose joint at *E*. As the point *E* is not confined, it is an easy matter

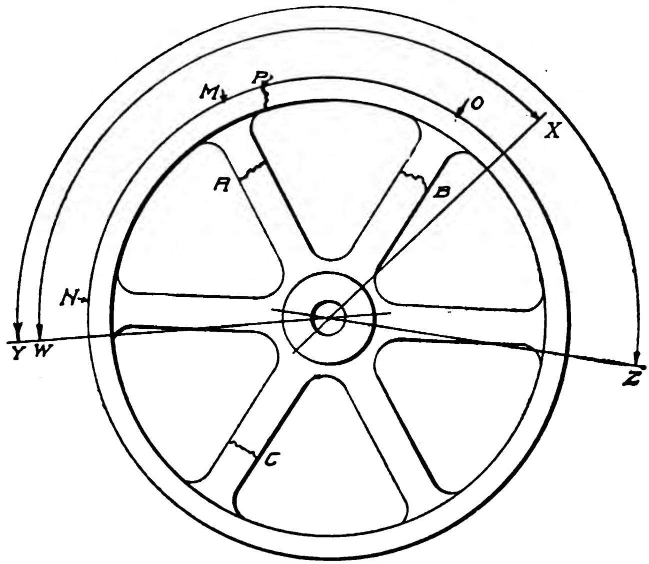


Fig. 36. Complex Case of Expansion and Contraction

to reweld this break without fear of any bad results. This method, however, is dependent upon the thickness of the metal and is one that should not be attempted unless no other means are feasible.

While this diagram is extremely simple, nevertheless the principles to be considered and the methods of handling them are indentical with those experienced in all practical work. A clear conception of the forces acting, the nature of their action, and how to counteract them, is essential in work with the oxy-acetylene blowpipe.

Handling Complex Case of Expansion and Contraction. A good example of a complex case of expansion and contraction is the flywheel or pulley with broken spokes, as shown in Fig. 36.

Assume that the spoke is broken at *A*. If this were welded without considering and allowing for expansion and contraction, the shrinkage strain would be so great that failure would occur.

Pre-heating the rim from *W* to *X* to a dull red heat will cause the rim to expand outwardly, separating the edges of the broken spoke. While in this state the weld should be made rapidly and then the entire wheel allowed to cool slowly. Thus a good weld without the presence of internal strains will be produced. The expansion of the rim, due to the pre-heating, will offset the contraction of the weld in the spoke.

If the crack in the spoke is near the rim, it is only necessary to apply a gas or oil burner to the rim at *M* until it is at a red heat. This will expand the spoke and rim, and separate the edges of the break sufficiently to offset the contraction of the weld.

The spoke may be welded at *A* without pre-heating if the confining member—in this case the rim—is broken to lessen the rigidity. In order to do this the rim must be broken at a point *P*, always close to the spoke. First one side of the spoke is strongly tacked at the weld. Then the other side is welded two-thirds the way through. The tack is then melted out and the weld completed. The rim is then welded at point *P*. If the edges do not meet accurately, they may be brought to do so by heating either at *M* or *O*, according to which edge is low.

If two spokes are broken as at *A* and *B*, the same general procedure as given above may be followed. In case it is necessary to pre-heat a large portion of the casting it is important that the pre-heated area always extend beyond the spokes adjacent to those fractured, from *Y* to *Z*.

If two diametrically opposite spokes are broken such as *B* and *C*, each may be treated as independent of the other and welded by any of the methods given above.

PRE-HEATING

Reasons for Pre-Heating. Pre-heating is employed for three fundamental reasons:

To Compensate for Expansion and Contraction. When pre-heating is used to counteract the effects of expansion and contraction, it is necessary that the casting be heated either in certain confined localities or entirely to a dull red, or in some cases to a bright red heat. With this treatment the internal strains existing in all welds are reduced to a minimum.

To Decrease Cost of Welding. When a weld is being executed on a large casting, it is too expensive to supply the total amount of heat required from the blowpipe alone. To offset this, pre-heating by some cheaper method is used, and the result is usually a saving of from 25 to 60 per cent of the cost of welding by means of the blowpipe alone. Then, too, it is possible to accomplish the welding with greater speed, due to the casting being at a higher temperature.

To Make Metal More Receptive to Action of Welding Flame. When the temperature of a metallic body is raised, the state of the metal

Fig. 37. Pre-Heating with Welding Blowpipe

Fig. 38. Gas Burner for Pre-Heating

surrounding the weld is more nearly that of the molten metal in the weld, and the result is a more homogeneous and smoother-grained union, dependent upon the temperature reached in pre-heating.

Methods of Pre-Heating. There are various means of carrying out this preliminary heating. The method used should be governed by the particular work in hand.

Pre-Heating with Welding Blowpipe. The simplest method and the one most used on light objects is that of utilizing the flame of the welding blowpipe, Fig. 37. In welding thin castings, it is only necessary that the flame of the blowpipe be played upon the parts at the line of the weld for a few moments, in order that the pieces may obtain a red heat. This is, however, expensive, and should only be employed on small objects.

Gas and Oil Burners. If the article to be welded is of fairly large size, the use of gas, Fig. 38, or oil burners, Fig. 39, is economical.

Fig. 39. Oil Burner for Pre-Heating
Courtesy of Oxweld Acetylene Company, Chicago, Illinois

Fig. 40. Charcoal Fire for Pre-Heating Castings

These pre-heating torches, however, limit the area of the surface covered, so consequently are used more successfully on that work which requires localized pre-heating. The flames produced are of sufficient temperature, but not the necessary volume to evenly heat the entire casting.

Charcoal Fire. The most satisfactory method of pre-heating is by means of a charcoal fire built around the article to be welded. The usual procedure is to build a small temporary fire-brick furnace around the piece and fill in with charcoal, Fig. 40. This is ignited by means of kerosene. As the progress of the ignition of the charcoal is rather slow, the pre-heating is carried out gradually. The nature of this pre-heating flame is of such evenness and volume that the temperature imparted to the casting is the same throughout its mass.

In welding large castings of a complicated nature, such as engine cylinders, it is necessary that they be pre-heated evenly throughout and that the welding be carried on while the casting is at a dull red heat. Therefore, the most satisfactory means of accomplishing this is by embedding the casting in charcoal and carrying on the work while it is embedded in the hot coals.

STEEL WELDING

General Considerations. The welding of steel is apparently simple, but in reality it is a fairly difficult material to weld and should receive the welder's best thought and care. It is simple to produce a nice looking weld that has a smooth even surface, but it is not easy to produce a weld that is strong and will stand up under service. Welds of high strength are absolutely necessary in cases like automobile frame and crankshaft repairs, because a poor weak weld might prove fatal.

Oxidation. It is practically impossible to prevent a certain amount of oxidation; but it is very important that it be kept to a minimum. The oxide that forms on the top of the weld may be removed quite easily, because it melts at a lower temperature than the metal. It may be floated off the weld while hot, or removed as a thin skin after the weld becomes cold. Care must be taken, when adding the welding rod, Fig. 30, page 32, that this film of oxide is penetrated, because if this is not done the oxide will be incorporated in the weld, which will therefore be very weak.

Expansion and Contraction. The effect of expansion and contraction is not as severe in steel welding as in cast iron or aluminum;

but, nevertheless, it must receive due consideration. In steel castings it is taken care of in a manner similar to that used for cast iron, that is, by pre-heating. In sheet-steel work the creeping, or drawing, of the edges is taken care of by arranging the edges of the sheets at an angle, or by tacking, or by the use of jigs to hold the work.

Welding Rod. Each welding head is designed for use with a certain thickness of metal. As the volume of the flame varies with the size of the welding head, care must be used to select a welding rod of the correct size in making welds in sheets of various thickness. There is great danger of burning a welding rod that is too small, or, if the rod is too large, it may not melt through and will enter into the weld in a semifused condition and not be thoroughly incorporated in the weld. The following table shows the proper size of welding rod to be used for the different thicknesses of sheets:

Thickness of Sheet	Size of Welding Rod
Up to $\frac{1}{8}$ inch	$\frac{1}{16}$ inch
$\frac{1}{8}$ to $\frac{3}{16}$ inch	$\frac{1}{8}$ inch
$\frac{1}{4}$ to $\frac{3}{8}$ inch	$\frac{3}{16}$ inch
$\frac{1}{2}$ inch and over	$\frac{1}{4}$ inch

Never use twisted wire made up of two or more strands, because this offers a very large surface for oxidation, which is a condition operators must try to avoid.

Neutral Flame. The importance of maintaining a neutral flame at all times cannot be emphasized too strongly. An excess of acetylene in the flame tends to carbonize the work, resulting in a hard brittle weld; while an excess of oxygen will oxidize or burn the metal. It is seldom necessary to adjust the flow of gases through the blowpipe after correct adjustment has once been made, except in the case of very heavy welding where the intense heat of the molten metal tends to expand the orifice in the tip of the welding head. This has some effect on the size and shape of the flame and necessitates more or less frequent adjustment to keep the gases in correct proportion to maintain the neutral flame.

Movement of Blowpipe and Addition of Welding Rod. In welding sheet steel, it is necessary that the oscillating movement previously referred to be imparted to the blowpipe and used continuously—both because of its high-melting point and the behavior of the molten metal under the action of the blowpipe flame. Steel cannot be puddled and it is therefore necessary to add the filling material in thin overlapping layers. The importance of securing a perfect bond between every two layers can be readily seen. To make a true weld, a simultaneous fusion of the edges of the sheets and the welding rod must be produced.

To do this with light- and medium-weight sheets, a motion is imparted to the blowpipe which will cause the flame to describe a series of overlapping circles as previously described, page 28. This overlapping extends in the direction of the welding and, in order to make a weld of good appearance, must be constant and regular in its advance.

In heavier plates, while the same rule governing simultaneous fusing of the edges of the sheets and welding rod apply, the filling of the groove is accomplished in a slightly different manner. On account of the depth of the weld the flame is not large enough to fuse a body of metal of so great an area, and it is impossible to fill the groove entirely from bottom to top with one layer of metal. The bottom edges of the groove must first be thoroughly fused for an inch or two before adding metal. When this is done, bring the flame back to the starting point and when the metal is in the proper molten condition add the filling material, oscillating the blowpipe in a series of semicircles, as previously recommended for welding heavy sections, page 29. Follow this method of filling the groove in sectional layers until the proper height is reached, making sure that thorough fusion is accomplished between the layers themselves and the edges of the sheet and the layers of filling material.

After-Treatment. Correct after-treatment is as essential for successful welding of steel as the actual welding operation. Proper after-treatment will improve the grain of the metal and will materially increase the strength and toughness of the weld. There are three principal treatments that will benefit the material and are easily employed in the repair shop. These are called annealing, hammering, and quenching.

Annealing. Annealing consists of reheating the work to the proper temperature and then allowing it to cool slowly. The work should be heated to a bright cherry red by means of a blowpipe or suitable burner, or in a furnace that can be carefully regulated. Care must be taken that the work reaches the bright cherry red, because heating to a lower temperature will be detrimental and may leave the weld weaker than if not annealed at all. After the work has been heated, it should be allowed to cool very slowly and evenly. It should be covered over with asbestos or dry sand, packed in lime, or left to cool in the furnace. Care must be taken that cold air currents do not strike the work before it has become cold.

Hammering. Hammering consists of reheating the weld to the proper temperature and then hammering while at this temperature with a hand hammer. The weld should be heated to a bright yellow heat and then hammered with quick light blows. Heavy hammers or heavy blows should never be used. The hammering should cease as soon as the weld falls to a dull red, for otherwise the fine grain of the metal will be spoiled and the weld will be weak.

Quenching. Quenching consists of reheating the work to the proper temperature and then plunging it into water, brine, or oil. This method is used mainly for small articles. It is used quite often for hardening and tempering. Quenching should be employed only in special cases, because, although it will make the work strong, it will also make it hard and brittle.

Light Sheet-Steel Welding

Preparation. In welding two short pieces of flat steel, up to $\frac{3}{16}$ inch in thickness, no special preparation of the plates is necessary, except to have them flat as possible and to be sure that the edges are reasonably true. The two pieces of metal should be placed on a level surface, preferably fire brick or some other nonconductor of heat.

Expansion and Contraction. With light sheet, expansion and contraction are cared for by tacking the seam at certain intervals or by arranging the sheets so that the edges to be welded are set at a slight angle rather than parallel, Fig. 41. The correct amount of divergence is determined by the thickness of the metal and should be from $2\frac{1}{2}$ to 6 per cent of the

Fig. 41. Light Sheets in Position for Welding

length of the weld. The amount of divergence between these limits varies also with the speed of welding, fast welding requiring less spread. After the plates are in this position, place two pieces of flat bar steel on each side, about ½ inch from, and parallel to, the line of the weld. Clamp or weight these pieces down so that they cannot be readily moved. The work is now in position for welding.

Jigs. In making this type of weld in flat sheet steel in longer lengths, up to several feet and up to $\frac{3}{16}$ inch in thickness, a welding jig made up with two slotted jaws hinged at one end and provided with hold-down clamps at the other end will be found more convenient than the individual hold-down bars.

Fig. 42. Jig for Holding Light Sheet Cylinders for Welding

For welding short cylinders, a jig made similar to that shown in Fig. 42 will be found satisfactory.

Tacking. Tacks, or short welds, at intervals of from 2 to 6 inches, according to the thickness of the sheet, can be made the entire length of the seam to hold the edges in position for welding if jigs are not available.

One of the above methods must be used to take care of the creeping action due to expansion when the flame of the blowpipe is applied to the metal. If this action is not provided against and the two sheets are placed with parallel edges, they will first diverge when the welding is started, as in *a*, Fig. 43, and then gradually come together. When about half of the weld has been made, they will again become parallel as in *b*. From this point on as the welding continues the sheets will draw together until they overlap, as shown in *c*.

(*a*) (*b*) (*c*)
Fig. 43. Result of Not Providing for Expansion

Welding Light Sheet. Select the welding head and a piece of iron welding rod of the size suitable for the thickness of the sheet and place the work in position for welding.

As steel is very sensitive to the action of the carbonizing flame and particularly to that of the oxidizing flame, a constant, nonvarying, neutral flame should be maintained. The incandescent jet should be of maximum size and clear outline at all times.

With the correct neutral flame, start welding at the point where the two sheets meet. Impart the circular motion to the blowpipe, described under Movement of Blowpipe, page 28, to produce the correct rippled surface on the finished weld. When the

Fig. 44. Appearance of Good Weld in Light Sheet Steel

Fig. 45. Appearance of Poor Weld in Light Sheet Steel

weld is finished, turn out the blowpipe and allow the work to cool until the metal is black.

Then remove the hold-down bars and examine the weld. If you have followed instructions, your weld will have the appearance shown in Fig. 44 and will not be like that shown in Fig. 45. On closer examination you will find that all the particles of dirt and impurities you noticed floating on the top of the molten metal when you were welding are now lying with the oxide on top and alongside of the weld where they can be readily brushed or scraped off. Now take your job to the shears and cut off one or two pieces. Upon examination, the cross-section should present the same uniform texture and color in both the weld and the sheet.

Fig. 46. Lap Welds Should Never Be Used

Types of Welds in Light Sheet. *Lap Weld.* Lap joints, either single or double, Fig. 46, *should never be used* in welding sheets of any thickness because the weld will be subjected to a shearing strain. Welds should be under tension or compression strains, never under shearing or bending strains.

Fig. 47. Butt Weld in Light Sheet

Butt Weld. The most common and the simplest weld to prepare in light sheet is the butt joint, shown in Fig. 47.

Fig. 48. Flange Weld in Light Sheet

Flange Weld. Another type of weld in light sheet, but one that entails some preparation, is made by flanging up the welding edges about $\frac{1}{32}$ to $\frac{1}{16}$ inch, Fig. 48, laying the two pieces flat and parallel on the welding table and executing a flange, or edge, weld. It is not necessary to use welding wire with this type of weld, because the metal in the flanges when they are fused together acts as a filling agent. By careful manipulation the edges can be fused down to a small bead, practically flush with the surface of the sheet.

Cylinders. In welding light sheets that have been rolled in cylindrical form, the separation of the edges can be accomplished by placing a wedge about two-thirds of the way down the length of the seam after the welding is started, Fig. 49. As the welding progresses the wedge should be moved further along the seam and withdrawn entirely as the work nears completion.

Fig. 49. Method of Welding Light Sheet Cylinders—Using Wedge to Space the Edges

Tacking can also be resorted to in welding cylindrical forms, although this results in the deformation of the cylinder, as shown in Fig. 50, and makes it necessary to hammer or re-roll the cylinder into shape.

Fig. 50. Result of Tacking a Light Sheet Cylinder—The Weld Draws up Pointed

The edges of very light sheet cylinders can be flanged and an edge, or flange weld, executed; but this method cannot be recommended with sheets heavier than $\frac{1}{16}$ inch.

Corner Welds. In making a corner weld in the lighter gage sheets up to $\frac{1}{16}$ inch, the edges of the sheet should be flanged, as shown in Fig. 51. In sheets from $\frac{1}{16}$ to $\frac{3}{16}$ inches in thickness, it is only necessary that the edges of the sheets run as true as possible in position, as shown in Fig. 52. Tacking is necessary in this case, as the sheets, due to expansion, readily move out of position when welding is commenced. On welds of this latter type it is necessary to use welding wire.

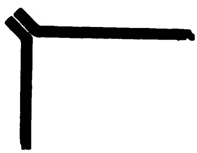


Fig. 51. Corner Weld for Very Light Sheets, up to $\frac{1}{16}$ Inch Thick

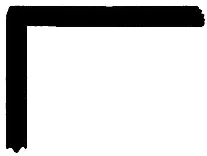


Fig. 52. Corner Weld for Light Sheets, $\frac{1}{16}$ to $\frac{3}{16}$ Inch Thick

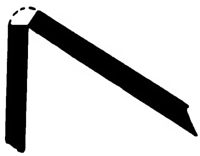


Fig. 53. Sharp Corner Weld for Light Sheets

Two other forms of corner welds are illustrated in Figs. 53 and 54. These sheets should be tacked and, if $\frac{1}{16}$ inch or thicker, welding wire should be used.

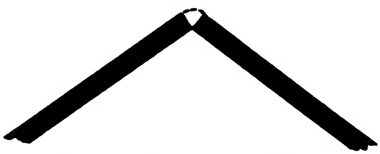


Fig. 54. Broad Corner Weld for Light Sheets

Tank Heads. In making tanks when either a bottom or heads in both ends are required, the method of putting in the heads is governed by the design and purpose for which the tank is intended.

Storage Tanks. If the tank is to be used as a storage receptacle, such as gasoline tanks, the heads can be cut to the outside diameter of the shell, laid flat on the end of the shell and tacked at intervals all the way around, Fig. 55. Then the shell, with the heads securely tacked in place, is laid on its side and the welding is started at any point, the tank being turned, from time to time, as the welding progresses. Or, the heads can be flanged to any depth desired, and backed into the shell until the edge of the flange and the edge of the shell are even, Fig. 56, making sure that the head fits the shell snugly. They are then tacked and welded in an upright position. This latter method is the better of the two from the welding standpoint.

Pressure Tanks. When a tank is built to stand a considerable pressure, such as air-compressor tanks, the heads should always be dished and flanged, the boiler-maker's standard specifications govern

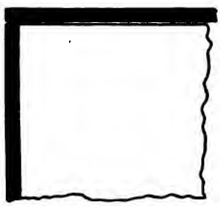


Fig. 55. Head Weld for Storage Tanks

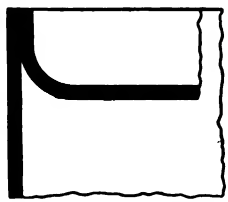


Fig. 56. Head Weld for Storage and Medium-Pressure Tanks

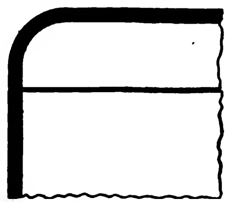


Fig. 57. Head Weld for Pressure Tanks

this. The heads can be either backed in and an edge weld made, Fig. 56, or set up so that the edges of the flange exactly meet the edges of the shell, Fig. 57. In either case the parts should be tacked together before welding. In the second case, care should be used in flanging to have the outside diameter of the flange exactly the same as the outside diameter of the shell. This method is the best because the weld is under direct tension or straight pull.

Tubes. Light-weight tubing should be squared off and fitted nicely before welding is attempted. It should be tacked in several places and then welded.

Heavy Sheet-Steel Welding

Preparation. In welding heavy sheet metal above $\frac{3}{16}$ inch in thickness, a certain amount of preparation is necessary. The success of the weld depends in a great measure upon the proper preparation of the work to be welded. While the preparation is governed largely by the particular location of the weld and form of the sheets to be welded, there are certain general rules that must always be observed.

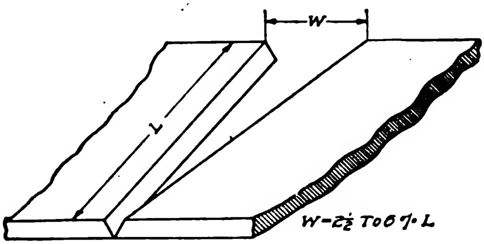


Fig. 58. Heavy Sheets in Position for Welding

In making a perfect weld it is necessary that the metal at the weld be completely fused throughout its entire thickness. In light sheets the projection of the flame is great enough to produce this result, but heavy sheets would require a flame of such magnitude that it could not be readily handled. Therefore, in order to facilitate complete fusion, the edges of the sheets to be welded are

Fig. 59. Welding Heavy Plate Steel Cylinder
Note grooving of edges, spacing clamps and wedge about half way along the seam

chamfered or beveled to form a V-groove, the width of this V being equivalent, or nearly so, to the thickness of the metal.

Expansion and Contraction. With heavy sheet, expansion and contraction are cared for by observing the same rules of spacing, Fig. 58, and clamping, Fig. 59, or, in some cases, tacking, in order to hold the work in position for welding, as described for light sheets on page 47.

Welding Heavy Sheet. Select a welding head and a piece of iron welding rod of the proper size to accomplish the work in hand.

Because steel is sensitive to the carbonizing and oxidizing flames, it is necessary to maintain the correct oxygen pressure and a neutral flame at all times. In ordinary heavy sheet welding there are two general methods of procedure, either of which will produce a good weld when properly executed. These methods may be called welding by sections, and continuous welding.

Welding by Sections. Welding is started by first playing the flame of the blowpipe along the edges of the pieces to be welded. This is done merely as a preliminary heat treatment. The flame is then played on the bottom of the groove at the beginning of the weld until the edges are in a molten condition, at which time the blowpipe is momentarily withdrawn and the molten metal allowed to flow together. This is done without the aid of any filling material. Care must be exercised at this point, because successful welding depends upon complete penetration and perfect union of the bottom edges. When a perfect union of the two members is secured for about one or two inches, the welding rod is brought into use. By playing the flame around the welding rod in contact with the edges of the weld instead of directly on the welding rod, it is possible to bring them both to the point of fusion simultaneously. The rod is then gradually added to the weld, layer by layer, until this particular section of the weld is built up to the required height. The flame is then played on the face of the metal just added and on the bottom of the groove until fusion of these parts is secured. The welder then repeats the operation described above until the next small section of the groove is filled up to the proper level. The welding progresses by means of these small sections, each being built up completely before another is started.

While the metal is in a fused condition, the velocity of the flame will cause the molten metal to become slightly indented. The flame should be withdrawn momentarily, from time to time, thus allowing the fluid metal to flow back to its normal level, in which position it will solidify. Skill in steel welding depends greatly on this manipulation, as the flowing together of the different molten centers produces the weld.

Continuous Welding. In this method the weld advances continuously with each addition of metal. By this method the metal is added in short layers, sloping rather than horizontal. The weld is started by fusing together the bottom edges of the groove as previously described. The filling material is then added so that it will be from ⅛ to ¼ inch high at the starting point and slope to nothing in a length of 1 or 1½ inches along the bottom of the groove. This will give an inclined surface to which the filling material is added in parallel layers. The added metal being on a sloping plane, the fusion of the bottom edges is always carried ahead with the welding, as each layer includes a small section of the bottom of the groove.

Types of Welds in Heavy Sheet. *Lap Weld.* As explained on page 49, the lap weld *should never be used.*

Butt Weld. The beveled or grooved butt joint is the only welded joint that should be employed on heavy sheets, Fig. 60. The most satisfactory method of handling the work is to space the edges, because tacking is very likely to not hold on heavy sheets.

Fig. 60. Butt Weld in Heavy Sheets

Never weld sheets from both sides, because unequal strains are likely to be introduced by localized heating when working on the second side.

Cylinders. Heavy cylinders should also be prepared for the grooved butt weld, for the same reasons as for heavy sheets.

Fig. 61. Corner Welds for Heavy Sheets

Corner Welds. The two most satisfactory corner welds for heavy sheet are shown in Fig. 61. Although the second is a little more costly to prepare, it is more satisfactory than the first because it insures better penetration.

Tank Heads. In welding bottoms or heads in tanks of heavy sheet, the purpose for which the tank is to be used governs the method of constructing the heads as it does in welding tanks of lighter gage. The same general rules apply in both cases, the main difference being

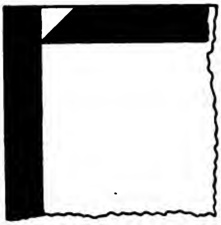


Fig. 62. Head Weld for Storage Tanks

Fig. 63. Head Weld for Medium-Pressure Tanks

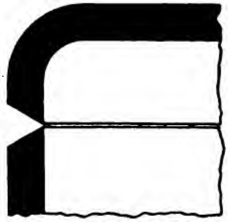


Fig. 64. Head Weld for High-Pressure Tanks

that the edges of the heavy shells and heads are chamfered, dependent on the design of the tank. All require tacking to hold the members in position for welding.

Storage Tanks. In the case of putting on a flat head, the edge of the head only is chamfered, Fig. 62, while in putting in a flanged head where an edge weld is to be executed, as in Fig. 63, both shell and head are chamfered to make the V-groove.

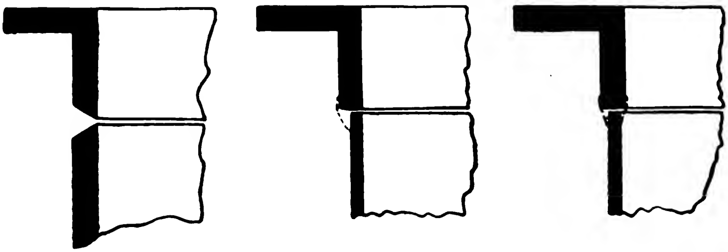


Fig. 65. Welds for Tank Reinforcing Rings

High-Pressure Tanks. When a head is put in, as shown in Fig. 64, both the edge of the flange and the edge of the shell are chamfered. This type of head is the best for high-pressure tanks because the weld is in tension.

This method also applies to the welding of two cylindrical shells end to end in making tanks of such dimensions that one single sheet of steel is not large enough to make a complete shell.

Tank Rings. In welding angle-iron rings to tanks of the same thickness, it is necessary that the edges of both ring and shell be

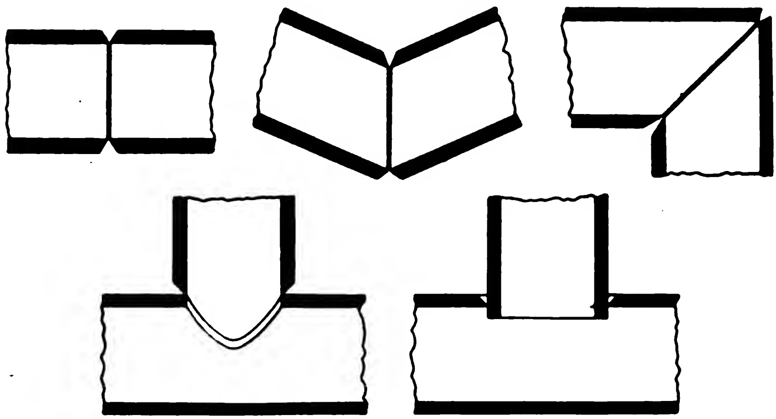


Fig. 66. Various Pipe Joint Welds

beveled as at the left, Fig. 65. Two methods of welding heavy rings to lighter shells are shown at the middle and right. The inside weld at the right should be only enough to smooth off the joint. If too much heat is applied from the inside there is likely to be trouble from warping or buckling. Rings should always be tacked to prevent bowing, twisting of the rings, and buckling of the shell.

Fig. 67. Welds for Pipe Heads

Tubes and Pipes. Various tube and pipe welds are given in Fig. 66.

The methods for closing the end of a pipe with a head are shown in Fig. 67. The first is the easier and stronger of the two.

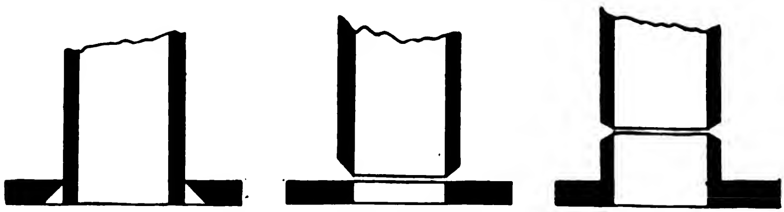


Fig. 68. Welds for Pipe Flanges

Three methods of welding flanges to pipe are shown in Fig. 68. The first method is easier to weld than the second; but the latter is the stronger. The third method is the best method of welding flanges to pipe, but is, of course, a special type of flange.

Welding Heavy Steel Forgings and Steel Castings

Preparation. In welding heavy steel sections, such as crankshafts, axles, and the like, the weld is prepared by grooving or beveling from both sides. This is done because it is easier for the operator to do the work and for the sake of economy, because by beveling from both sides less filling material is necessary and, consequently, less time and gas are needed.

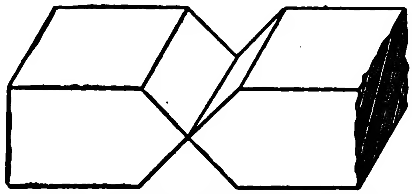


Fig. 69. Preparation of Heavy Forgings for Welding

Square Sections. Square or rectangular sections of forgings are best prepared by beveling half way through from each side, Fig. 69. After the welding has been carried on from one side, the piece turned over and the welding completed from the second side, there will probably be a slight bow, or curve. In the case of forgings, this is not objectionable, because the work can be, and, in fact, should be, reheated and straightened. The reheating in the case of forgings is beneficial to the grain of the material and the strength of the weld. With castings, however, this bending is not possible. Therefore, to keep the work in alignment, it is best to prepare the work as shown in Fig. 70. The welding is carried on two-thirds of the way through from the first side, and then finished by turning over and working from the second side.

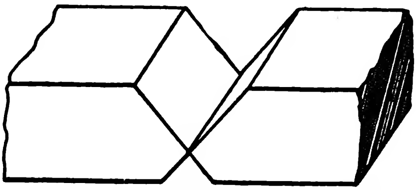


Fig. 70. Preparation of Heavy Castings for Welding

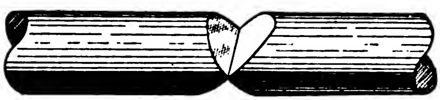


Fig. 71. Preparation of Round Sections for Welding

Round Sections. Round or elliptical sections should be prepared by beveling the ends to a wedge as indicated in Fig. 71. They should never be turned down to a point. By preparing the pieces as shown in the illustration, the welder will have a flat surface to build his weld upon. If the work were prepared to a point, the filling material when added would have no surface to lie upon and would run down in drops, necessitating burning or melting away when the work is turned over, and probably resulting in a weak weld with considerable oxide.

Expansion and Contraction. Expansion and contraction will probably cause very little trouble to the operator in the case of shafts and other heavy pieces that are not connected. The only difficulty the operator will encounter in these cases will be the possible bending, which was noted above, when welding from two sides. However, if the broken part is confined by rigid members, the work should be handled either by pre-heating, or one of the other methods recommended and explained under Expansion and Contraction, pages 36 to 40.

V-Blocks. When welding shafts, it is advisable to line them up in position on V-blocks, so that they may be turned over and still kept in alignment, Fig. 72.

Fig. 72. "V" Blocks for Welding Shafts

Welding Heavy Section. In the case of a heavy section select the proper size welding head and a piece of welding rod of the correct analysis for the particular work at hand, and place the work in alignment.

If the section is over or about one inch, it should be pre-heated by means of a gas or oil burner until it is at a red heat. This will save oxygen and acetylene, and will bring the material to a temperature at which it will be more receptive to the action of the welding flame and thereby insure a more homogeneous weld. If not objectionable to the operator, it is advisable to let the pre-heating burner play on the work while the welding operation is going on, taking care, of course, that the materials of combustion of the pre-heating burner do not strike the molten metal and have a detrimental effect on the weld.

The welding flame is first played on the edges at the bottom of the groove until they are in a molten condition. The flame is then momentarily withdrawn to allow them to flow together and "set", and form the bottom of the weld. When a perfect union of the bottom is secured all the way across, the welding rod is brought into use. By playing the flame around the welding rod and the edges of the weld instead of directly on the welding rod, it is possible to bring them to a fusing temperature at the same time. The rod is then gradually added to the weld, layer by layer, until the entire groove has been filled up. The welding rod is kept plunged into the molten metal all the time to prevent oxidation. Any oxide that forms during the welding is floated to the top and removed by scraping with the welding rod, or by blowing away with the force of the welding flame. The welder must be careful that he does not allow the molten metal to run over the sides of the weld. Each layer is added in such a way that it extends slightly beyond the end of the groove. Then, from time to time, as the groove is filled up, the operator smooths down the two ends.

Hammering. As each section, about ¼ inch thick, is added to the groove, the operator stops the welding operation, heats the work to a bright yellow, and hammers the weld lightly but rapidly to give it as fine a grain as possible. After the weld has been completed, it is either hammered or annealed, as directed on page 45.

CAST-IRON WELDING

General Considerations. Many defects are experienced by the beginner in welding cast iron because of its peculiar properties. The two principal faults noticed are the production of hard, glassy, and brittle metal in the weld, and subsequent cracks, breaks, and checks either in the weld or in the adjacent metal, owing to excessive internal strains set up by unequal contraction. Both are serious defects, and the liability of their occurrence is so great that proper preventive methods should be continually borne in mind and applied while welding this material.

Oxidation. Cast iron melts at about 2000° to 2190° F., and iron oxide melts at about 2450° F. The oxide is formed, however, at low temperatures, a bright red heat being sufficient to cause the combination of oxygen from the air with the iron of the casting.

It is not possible to melt this oxide and flow it from the weld, so it remains in the casting in the form of thin flakes or crust. This not only prevents the alloying of the molten metal, but also combines with the free carbon and is, consequently, conducive to the formation of white iron. Therefore, this oxide must be removed or destroyed.

Expansion and Contraction. Cast iron is absolutely lacking in elasticity, and its tensile strength is very low. In preparing work for welding, it is always necessary to take fullest precautions against the bad effects of expansion and contraction. Expansion and contraction should be treated with more importance in the welding of cast iron than in any other metal.

When the internal strain produced by contraction is greater than the tensile strength of the section to which it is confined, failure will occur. When the strain is not great, but still exists, the resistance of the section to external stresses is reduced in proportion. Thus a casting may appear to be normal after welding but the excessive internal strains caused by the welding may make it fail at the slightest shock.

One of the three general methods of coping with the forces of expansion and contraction, which are given on pages 36 to 40, must be used when welding cast iron. The proper method to pursue is determined by the size and shape of the casting and the nature and location of the break. A very large percentage of the failures due to shrinkage cracks may be prevented by an intelligent anticipation of the forces of expansion and contraction and the proper handling of the work to overcome these.

Pre-Heating. Pre-heating should be used to some extent in all cast-iron welding. If the piece is small and the break is so located that it is not necessary to consider expansion and contraction, the blowpipe should be played upon it until the chill is removed from the casting. If the casting is large, an oil or gas burner, or charcoal fire can be used. In a large casting this preliminary heat treatment not only favors the execution of a good weld but also requires less oxygen and acetylene because of this large volume of heat from a cheap source, thereby reducing the cost of welding.

Welding Rods. The success of cast-iron welding depends greatly upon the selection of a suitable welding rod. It has been proved time and again that hard, brittle, and weak welds have been produced for no other reason than because inferior filling material was used.

The presence of silicon in proper proportion tends to produce a soft gray-iron weld. It increases the fluidity of the metal, retards oxidation, and prevents decarbonization and blowholes. The success of the filling rod is dependent upon the amount of this element it contains. From 3 to 4 per cent is the average silicon content of good welding rods. The welding rod must be of high-grade cast iron, soundly cast and absolutely homogeneous. It must be free from all sand, grit, and rust. For convenience in handling, it is usually cast in 24-inch lengths of three diameters, ¼, ⅜, and ½ inch. In case either a longer or heavier rod is desired, two or more are welded together.

Flux. The principal problem that confronts the welder is to prevent the formation of oxide, and in case it is formed, to reduce it and remove it from the weld. If this is not done, the molten metal will be enclosed in a thin film of nonmetallic material, and any additional metal that may be fused or added will adhere to this film rather than break through it and fuse homogeneously with the other metal. It is not possible to satisfactorily break up this film mechanically, therefore it must be reduced to a molten, or slag, condition. To accomplish this a suitable flux is used that will dissolve the oxide.

A flux is not used solely to dissolve the oxide, but also to float off other impurities, such as sand, scale, and dirt. It forms a protecting glaze on the weld and surrounding surfaces and increases the fluidity of the molten metal.

Borax and salt (sodium chloride) are two compounds often used by welders, but they really contain little merit as a flux. Their low fusibility seems to be the only point in favor of their use. Occasionally, they may be employed to advantage in welding heavy sections or burned iron, such as are found in firebox and grate castings, but their function is only that of a cleanser. Both tend to produce hard iron. There are certain flux powders put on the market that contain large proportions of manganese. These powders cannot help but have a hardening effect on the iron. Others contain potassium perchlorate, a violent oxidizing agent. Still others contain material that chlorinize the weld. Needless to say, powders of this kind must not be used. It is best to guard against the purchase of such defective mixtures by obtaining flux powders from reliable sources.

It is necessary that the welder learn to apply flux properly. An excess will cause as much trouble as an insufficient quantity. Blowholes may be increased in size and number by using too much flux. Also the molten iron will incorporate certain constituents of the flux if it is applied in excess. The amount to be applied depends upon the flux used. A welder must learn to know his flux as well as his blowpipe.

The powder should be applied regularly by dipping the hot welding rod into it. The quantity adhering is sufficient. Do not throw large quantites into the weld as plenty will be added by the welding rod.

Preparation of Welds. All cast iron over $\frac{1}{8}$ inch in thickness should be beveled or chamfered before welding. If this is not done, it is necessary that the metal be burned out by the blowpipe in order that complete penetration be assured. This is bad practice as it is almost impossible to do it without either changing the state of the metal in the groove due to the forced flame, or causing partial adhesion. The chamfering should be a little wider than on other metals for the reason that it is good practice to introduce as much special metal from the welding rod as possible.

The chamfering can be done by various means. If the casting is light and broken in two pieces, it may be taken to an emery wheel and the edges ground off. If the casting is too heavy to move, a portable grinder or cold chisel and air or hand hammer can be used. If the casting is only cracked, the cold chisel and air or hand hammer are the most satisfactory tools to use.

After the weld has been beveled satisfactorily, the adjacent metals should be cleaned about $\frac{1}{4}$ to $\frac{1}{2}$ inch from the edge. This is important, because all dust, sand, scale, etc., should be removed from the welding zone.

To Prevent Crack from Extending. If the defect in a casting is a crack that shows a tendency to extend upon heating, a hole should be drilled in the casting a short distance from the end and in the direction the crack would follow. The crack will not extend beyond this hole, and the hole can be very easily filled in.

Welding Process. Although the melting point of cast iron not high, the total heat required to bring it to fusion is great. refore a blowpipe of large size is used. The speed of welding ncreased considerably, and the selection of the proper size blowe is influenced by the extent of the pre-heating.

Cast iron melts very rapidly after the fusing point is once ched, and when molten is extremely fluid. Because of this perty, the welding should be carried on horizontally, otherwise metal will flow toward the lowest point. This is not desired, because it will tend to produce adhesion. In case it is not possible to arrange the casting so that the weld will be horizontal, the welding must be started at the lower end, and skill must be used to prevent the too rapid advance of the molten metal. It is very difficult to produce vertical and overhead welds because of the fluidity. In welding thin sections of cast iron, the rapidity with which it melts and its fluidity often cause the metal to sink, bulge downward, or drop in. Consequently, it is necessary that close observation and careful manipulation be used on this kind of work.

Flame. The incandescent jet of the oxy-acetylene flame should never impinge on the molten metal. The tip of this jet should be held at a distance of $\frac{1}{8}$ to $\frac{1}{4}$ inch from the metal according to the thickness. The molten iron is seriously influenced by the high temperature of this jet and may become oxidized and decarbonized. This must be rigidly observed except when it is necessary to use the jet to burn out sand holes, blowholes, etc.

Manipulation of Blowpipes and Welding Rods. Because cast iron fuses rapidly when once the melting point is approached and the molten iron is extremely fluid, the circular or oscillating motion imparted to the blowpipe need not be so pronounced. The welding of cast iron is nothing but a succession of overlapping miniature pools, or puddles, of molten metal.

The weld is started by playing the blowpipe on the two lower edges of the weld. The flame should strike the weld almost perpendicularly, because if the blowpipe is inclined, the flame will blow the molten metal ahead of the weld, and adhesion will result. When at the proper temperature, these edges are fused together without any filling material by the aid of a little flux. It is important that this first operation be carefully carried out, as the strength of the weld is dependent upon a good bottom and top. When this first fusion has been successfully obtained, the welding rod is brought into play and the high silicon metal is added. With each addition,

Fig. 73. Warm Welding Rod Is Dipped into the Flux before Each Addition to the Weld

Fig. 74. For Cast-Iron Welding, Blowpipe and Welding Rod Are Held Almost Vertical

the welding rod is previously dipped into the flux can, and the adhering flux introduced in the weld, Fig. 73. As the welding of cast iron is a comparatively rapid procedure, the welding rod can

Fig. 75. Dirt May Be Scraped off by Means of the Welding Rod

Fig. 76. Welding Rod Should Not Be Held Too Far from Welding Zone

be held more vertically and added faster, Fig. 74. In welding "dirty" iron it is sometimes convenient to hold the rod in a horizontal position and scrape out sand, carbon, or any other dirt by means of the rod as soon as it appears, Fig. 75. In this connection, it may be added that the welding rod should be used constantly to work out impurities and blowholes. The welding rod should be melted as much as possible in the molten metal of the weld. It should be plunged into this liquid, and the fusion carried out by playing the flame around it. The welding rod should not be held too far from the welding zone, Fig. 76, nor should it be added to the weld drop by drop as shown in Fig. 77.

As a section of the weld is finished, it should be scraped or rubbed with a file while red hot, Fig. 78, to remove the film of flux, scale, sand, and dust that is present. This film if allowed to cool becomes very hard and is quite resistant to machine tools. Regardless of the

Fig. 77. Welding-Rod Should Not Be Added Drop by Drop

Fig. 78. Scraping Finished Weld with File to Remove Scale

quality of metal beneath it, many welds have been rejected because of the hardness of this superficial surface.

If the weld is carefully executed and the surface is cleaned, it will look like the left of Fig. 79, while if poorly executed and not cleaned, it will look like the right of Fig. 79.

Never go over a weld the second time if it can be avoided. In case it is absolutely necessary, always add fresh metal from the welding rod, as a failure to do this will cause a loss of silicon in the weld and destroy its value to the metal.

Always perform the welding as fast as possible, because extended heating will tend to lower the silicon content of the weld, with the resultant formation of hard iron.

Blowholes. Blowholes occur frequently in the weld and are particularly troublesome if in the bottom of the weld. Their presence can be caused by mechanically enclosed gases or by improper blowpipe handling. When blowholes appear in the weld, they should be instantly worked out. This may be done by forcing with the welding rod and applying flux. In beginning a weld, it is necessary that the presence of blowholes be guarded against, as it is difficult to work out a blowhole at the bottom of the weld after it is finished. Occasionally, in going over a weld, a blowhole is discovered; this must first be

Fig. 79. Appearance of Cast-Iron Welds That Have Been Properly (left) and Poorly (right) Executed

burned out by the white jet of the flame and then worked over with the welding rod.

After-Treatment. The rate of cooling materially influences the structure of the metal in the weld. If rapid cooling is allowed, hard brittle iron is produced. If slow cooling is employed, soft gray iron is formed. Internal strains and stresses may be distributed and adjusted or, in some cases, eliminated by proper cooling and annealing.

Castings which are not large or which it has not been necessary to pre-heat extensively may be satisfactorily annealed by playing the blowpipe on the weld and surrounding metal until it is at a bright red heat. The heated portion is then covered with asbestos paper, cinders, or other nonconducting material that will retain the heat and protect the castings from air currents. For small castings, a barrel or bin of hydrated lime and fiber asbestos is recommended. This makes a convenient arrangement and is very satisfactory as an annealing agent.

Where it is necessary to heat the entire casting in a charcoal or coke fire, the same temporary furnace used for pre-heating may be used in annealing. After the welding has been completed, the casting should be covered over with hot coals and ashes, and the furnace should be bricked up, i. e., all large air ports closed, the top covered with asbestos paper, and the casting allowed to cool with the fire.

The castings should never be removed from the annealing fire until they are entirely cold. This is imperative, as cold air currents on the warm castings may cause checks or cracks. In some cases, 12 to 24 hours are required for satisfactory cooling.

Use of Carbon Blocks. In case it is not possible to line up the weld horizontally, or it is necessary to fill in a wide hole, carbon blocks or steel plates are sometimes used to dam or retard the flow of the metal.

MALLEABLE-IRON WELDING

Malleable Iron. Malleable cast iron, or malleable iron, as it is commonly called, is used extensively in castings where toughness, malleability, and resistance to sudden shock are required. The characteristic that gives malleable iron its greatest value as compared to gray iron is its ability to resist shocks. Malleability in a light casting, $\frac{1}{4}$ inch thick and less, means a soft pliable condition and the ability to withstand considerable distortion without fracture, while in the heavy section, $\frac{1}{2}$ inch and over, it means the ability to resist shock without bending or breaking.

In the manufacture of malleable-iron parts, white iron castings are packed in annealing pots with suitable material, such as mill-scale, borings, etc., and subjected to a cherry red heat for from 48 to 96 hours, after which they are allowed to cool slowly. During this annealing process, the material in which the castings are packed absorbs the carbon from the surface of the casting. In this way the surface becomes really a steel, while the inside, or core, becomes gray cast iron.

Fusion Weld Not Possible. When malleable iron is heated to a fusing heat the malleable properties are destroyed and cannot be regained.

Brazing Malleable Iron. The most successful method of joining malleable iron with the oxy-acetylene blowpipe is by brazing with Tobin bronze. While this gives a joint of different color, yet the strength, malleability, and machining qualities are satisfactory.

The two pieces to be joined are beveled as for cast-iron welding. The edges are brought to a point just below fusion, great care being taken that they *do not* become fused. When the edges are at the right temperature, a rod of Tobin bronze is fused into the groove with the aid of a good brass flux. The work should be carried out by using a flame having a slight excess of acetylene and should be done as rapidly as possible to prevent oxidation of the bronze.

ALUMINUM WELDING

General Considerations. When aluminum approaches its melting point, it does not change color in ordinary light, but retains its silvery appearance even when in the molten condition. When molten, it is very fluid and is, therefore, rather difficult to control under the welding flame.

Oxidation. Aluminum oxidizes very easily when in a molten condition, forming an oxide that melts at about 5400° F. The oxide, therefore, cannot be penetrated by means of the flame, but must be removed either chemically by means of a flux or mechanically by means of a paddle.

Expansion and Contraction. Because of the high heat conductivity of aluminum, expansion and contraction do not give great difficulty owing to localized heating. However, because aluminum expands greatly and is very weak when at high temperatures, contraction strains are very likely to produce cracks or checks unless the work is allowed to cool evenly and slowly. It is advisable to pre-heat aluminum castings to between 300° and 400° F. to aid the distribution of the heat and prevent warping.

Welding Rod. In welding sheet aluminum, such as automobile bodies, the welding rod should be clean material of the same alloy as the sheets that are being welded. If wire cannot be obtained of the same composition as the sheets, narrow strips should be sheared from the sheets themselves and used for a filling material. The strips should be sheared about as wide as the sheets are thick.

For aluminum castings, such as crank cases, a good grade of aluminum wire about $\frac{1}{4}$ inch in diameter should be obtained. Welders should not use the cheap solders or very low fusing cast rods that are sometimes sold, and for which great claims are made. The operator will readily appreciate that when these materials are added to the weld they will merely adhere to the sides, because, while the filling material will be quite fluid, the edges of the weld will not be at a fusing temperature.

Flux. It is impossible to weld sheet aluminum without the use of a good flux to dissolve the oxide and float it to the top as a slag. In cast-aluminum work a paddle may be used to accomplish this result, but such a device is not practical for sheet work. The flux may be applied either by dipping the warm welding rod into the flux powder or by mixing the flux with water to form a paste and applying this to the joints by means of a brush. Care must be taken that too much flux is not used, because an excess will produce a porous weld and one with a poor surface. After the work has been completed the flux should all be washed off with warm water.

Flame. In order to be sure that an oxidizing flame is not being used, it is permissible and advisable to use a flame showing a slight excess of acetylene. This flame will also have the advantages of being slightly larger in volume than the neutral flame and of lower temperature, this last feature being helpful, especially to the new operator.

Sheet-Aluminum Welding

Sheet-aluminum work may be handled very similarly to sheet steel as regards preparation and allowance for expansion and contraction.

Types of Joints. For light sheets under $\frac{1}{16}$ inch the flange weld should be used. The butt joint may be successfully made on light sheets by an experienced operator, but there is a great deal of danger of burning through and having to fill up holes, which will leave a poorly finished weld.

For sheets above $\frac{1}{16}$ inch the butt weld is found to be the best, and for sheets above $\frac{1}{8}$ inch the edges should be beveled the same as for steel plates.

Welding Process. Select the proper size blowpipe and welding rod, a good flux, and arrange the work for welding. Start the welding by playing the secondary flame of the blowpipe over the parts surrounding the weld, to warm them up slightly. If the flux is to be applied with a brush, it should be done at this time, because the heat will evaporate the water and leave the solid flux evenly distributed over the weld. Welding should then be started from ½ to 1 inch from the end—not at the end. The blow pipe should be handled about the same as for steel welding, care being taken that the inner cone of the flame does not come in contact with the metal. For very thin sheet welding it is not necessary to give the circular or oscillating motion to the blowpipe; it is merely necessary to move it forward in a straight line.

On the heavier work, however, the same motions should be used by the welding operator as are used for steel. The welding wire is best held directly in line with the weld and always in contact with the metal just ahead of the blowpipe. If the wire is not in contact with the edges when they become molten, they will be likely to curl up or draw away instead of flowing together. After the main weld has been completed, the operator should go back and weld the short section that was left unwelded at the very beginning. After the work has cooled the flux should be removed by washing off with warm water.

Re-Welding. The operator should be careful that the weld is completed as he goes along, so that he will not have to go back to make repairs or to do re-welding. If it is necessary to go back over a weld, cracks or checks are very likely to result because of the weak condition of the metal when it is at a fusing temperature. If it is necessary to re-weld a certain portion of the joint, the surface should be chipped off so as to present a clean surface for the new filling material to fuse to. Following the suggestions already made, the seam and the surrounding surfaces should be thoroughly preheated before the welding is started to prevent cracking as much as possible.

After-Treatment. If possible, welds in aluminum sheet should be reheated evenly to equalize any internal strains. Then, after the weld has become *cold,* it should be hammered to improve the grain of the metal.

Cast Aluminum Welding

Aluminum Castings. Most aluminum castings are alloys of aluminum, zinc, and copper; the alloy being added to the aluminum to give it a higher tensile strength and increase its resistance to shock. The welding of cast aluminum is different from that of sheet aluminum and resembles in a general way the welding of cast iron. Oxidation is taken care of by using flux or by scraping the oxide out by means of a paddle. The second method is faster and is the one preferred by most operators.

Paddle. The paddle is made by flattening down the end of a $\frac{1}{4}$-inch steel rod to a smooth short flat blade about $\frac{3}{8}$ inch wide. The handle may be left straight or bent to suit the operator. The paddle should be used only when just below a red heat. If it is cold, the molten metal will stick to it, and if it is too hot it will burn and the metal will stick to the roughened surfaces.

Preparation. Sections if over $\frac{1}{4}$ inch in thickness should be chamfered before the welding is started. Sections thinner than this may be worked without beveling. The old metal may be scraped out by means of the paddle in order to give a clean bright surface for the new material to be added to.

Pre-Heating. Because aluminum alloy castings are not very ductile and are weak when at a high temperature, expansion and contraction must be taken care of. This is handled in the same general way as in the case of cast-iron work. The casting should be pre-heated either partially or wholly by some *slow* heating agent, such as a gas burner or mild charcoal fire. The pre-heating should never be carried to too high a temperature, because of the danger of the metal sinking, or caving in. The casting will be sufficiently warm for welding when a file or chisel will mark it easily, or when a piece of dry pine stick is charred upon being drawn across the heated section.

Welding Process. When a flux is used in welding cast aluminum, the work is carried on in the same general manner as in welding cast iron, and the same general precautions regarding the peculiarities of the metal are to be observed as in welding sheet aluminum.

If a paddle is used to break the film of oxide and scrape it out of the weld, the edges are brought to a state of fusion for a length of about 1 or $1\frac{1}{2}$ inches. The paddle is then used to scrape out the weld to make a slight bevel and present clean surfaces for the filling material to be added to. The welding rod is then introduced into this groove. The paddle is used continually to work in the filling material, scrape off any oxide that forms, and then to smooth off the surface of the weld. After a small section of the joint has been completed, the casting is turned over, and the weld for this length is smoothed off on the underside by means of the blowpipe and paddle. The welding is carried on in this manner, section by section, until the entire joint is completed. If the weld were completed on the first side and then turned over and smoothed its entire length on the underside, cracks would develop, and the casting would warp out of shape.

After-Treatment. When the welding has been completed, the casting should be reheated slightly to remove any local strains and should then be covered over with asbestos paper to protect it from drafts and to allow it to cool very slowly. If the cooling is carried on rapidly, or if air currents are allowed to strike the casting, it will very likely crack either in the weld or some weak section.

COPPER WELDING

General Considerations. Because of the high thermal conductivity of copper, the heat from the blowpipe is conducted back into the work rapidly and is lost to the weld. This necessitates the use of a large size welding head or the use of an auxiliary source of heat to assist the welding flame in the case of heavy work. When at high temperatures, copper is weak in tensile strength the same as aluminum. Because of these two factors the effects of expansion and contraction must be carefully considered, so that the work will not cool too rapidly after the welding has been completed, and will not crack at high temperatures.

Oxidation. Copper oxidizes quite readily, forming an oxide which dissolves in the molten metal and changes the structure of the weld. The amount of oxide that can be absorbed is very high, consequently great care must be exercised to keep the absorption at a minimum. Welding rods containing a small percentage of phosphorus and suitable fluxes are used to counteract the oxide and reduce it as much as possible.

Welding Rod. For successful copper welding, it is necessary to use electrolytic copper containing about one per cent phosphorus, supplied in coils and drawn rods. The cast copper alloy rods that are on the market are not satisfactory, because the structure and composition will vary even in a single rod to such an extent that a homogeneous weld cannot be made.

Flux. In welding copper the flux is used not only to cleanse the weld, but also to protect the metal adjacent to the welding zone from the gases of the flame. When welding sheet copper it is advisable to make a paste of the flux by adding water and to coat the metal about one inch adjacent to the edge of the weld. When this flux is melted, it will form a glassy film that will protect the metal from the gases of the flame and the air surrounding the work. Additional flux is added to the weld as the work progresses, by dipping the warm rod into the dry flux, as in welding other materials.

Flame. It is very important that the neutral flame be maintained at all times, and the operator should use great care in adjusting his gases, so the flame will not have an excess of acetylene nor be oxidizing. Because of the peculiar properties of the metal, the gases of the reducing flame are very likely to be absorbed, and because of the ease with which the metal oxidizes, oxidation is liable to occur if the flame contains an excess of oxygen.

Preparation. Sheets that are less than $\frac{1}{8}$ inch in thickness may be butted together without beveling. Sheets heavier than this should always be beveled, and no attempt should be made to depend upon the flame to penetrate the heavier thicknesses. In all cases of copper welding, the edges to be joined and the material adjacent to the edges should be scraped or filed to present a clean surface for the filling material to be added to.

Welding. The edges of the metal surrounding the weld should be raised to a fairly high temperature before the actual welding is started. On small pieces and light-weight work, this may be done by means of the welding blowpipe, but for heavy work and long welds, it is best to do this by means of a gas or oil pre-heating burner. After the work has been brought to a high temperature, the welding should be started at one end and should be performed as rapidly as possible. The welding rod and edges of the weld should reach the state of fusion at the same time, so as to prevent adhesion and to insure a good weld. This feature is harder to accomplish in welding copper than in other metal, because the heat is conducted back into the rod or into the work very rapidly, necessitating very careful and skillful manipulation of the blowpipe and rod. The blowpipe should be held almost vertical, about the same as in the case of cast-iron welding. If held at too great an angle, the molten metal will be blown ahead and will adhere to the cold edges of the weld in advance of the blowpipe. The inner cone of the flame should never come in contact with the metal, but should be held about $\frac{1}{8}$ or $\frac{1}{4}$ inch above the surface of the weld to prevent burning the metal. The oscillating motion should be carried on about the same as in steel welding but a little more rapidly, and should consist of smaller circles. The welding rod should be plunged into the molten metal all the time and should be continuously moved around or stirred, so that it will be thoroughly incorporated and will bring the oxide and slag to the surface. The weld should be built up above the surface of the sheets, so there will be enough material to allow for hammering after the welding has been completed.

Re-Welding. In case it is necessary to re-weld a portion of the joint, it is necessary that the old material be chipped out and new material added.

After-Treatment. After the welding operation has been completed, the work should be heated very carefully and evenly until it is almost at a bright red heat. The weld should then be hammered while hot, so that the strength of the joint will be increased as much as possible. After the hammering has been finished, the work should be again reheated to a red heat and cooled quickly by means of an air blast or chilled by plunging in water. Care must be exercised in this operation if the work be a casting having confined, or rigid members, so that cracking, or checking, does not occur.

BRASS AND BRONZE WELDING

General Considerations. Brass and bronze are both alloys of copper, brass consisting mainly of copper and zinc, and bronze of copper and tin. Both brass and bronze are welded in about the same general manner as copper, but because of the peculiar properties of the alloying metals, zinc and tin, it is necessary that they receive certain variations in welding.

Oxidation. In both brass and bronze, the alloying metal is greatly affected by the high temperature of the flame, and the material will be subject to a loss of zinc or tin, unless proper precautions are taken. These metals will combine with the oxygen and pass off as white vapor, and leave a weld of different composition and color.

Absorption of Gases. The molten metal in both brass and bronze absorbs certain gases very readily, and unless this absorption is counteracted, the weld will be spongy and weak. This may be taken care of by using a suitable welding rod and flux.

Welding Rod. Because of the varying composition of brass and bronze, and because of the loss of the alloying elements when welding, it is practically impossible to produce welds of the same color as the original material. When welding brass, a good grade of drawn brass will be found most satisfactory, and in the case of bronze, a good drawn bronze, such as manganese or Tobin bronze. The cast rods that are on the market are not satisfactory, because it is quite impossible to cast a rod having the same composition throughout.

Flux. The flux used for brass and bronze is practically the same as that used for copper. It should be applied by dipping the warm welding rod into the powder and adding it to the weld in this manner. It is not necessary to use as much flux as in welding pure copper, and care must be taken that an excess is not used, because the weld may become porous.

Flame. A neutral flame must be maintained at all times for the same reasons as explained under copper welding. The blowpipe should be held between $\frac{1}{8}$ to $\frac{1}{4}$ inch from the metal. If the flame is held too close in the case of bronzes, the concentrated heat will cause a segregation or separation of the tin from the copper, and it will be practically impossible to again unite these elements.

Preparation. The edges of the metal for a thickness of less than $\frac{1}{8}$ inch may be merely butted together and welded, while for metals above this thickness the edges should be beveled or chamfered, so as to allow penetration of the flame and insure a good weld.

Welding. Because of the high conductivity of these materials, it is best that they be pre-heated to bring them to a suitable condition for rapid welding. Care must be taken when pre-heating bronze that it does not get too hot, because it is weak at high temperatures and is liable to break or crack under its own weight. The welding is carried on in about the same manner as for copper, and the blowpipe is handled in practically the same way. The welding rod should be in contact with the edges of the metal at all times, and the blowpipe should be played constantly on both the rod and the edges of the metal to keep them at the same temperature in order that adhesion may be prevented.

Re-Welding. Re-welding should be avoided, but if it is absolutely necessary to re-weld the work, the section should be chipped out, and new material added, as in the case of copper.

After-Treatment. Both brass and bronze should be annealed after welding by reheating evenly, and then allowed to cool slowly. Brass may be improved by hammering before the final annealing. Brass of low zinc content, i.e., red brass, should be hammered while hot, while brass of high zinc content, i.e., yellow brass, should be hammered cold.

MISCELLANEOUS PROCESSES

CUTTING

Cutting In Automobile Repairs. The oxy-acetylene cutting blowpipe finds considerable application in the automobile repair shop for beveling the ends of shafts and other pieces of work preparatory

Fig. 80. Beveling Round Shaft for Welding. The other piece is on the table

Fig. 81. Beveling End of Heavy Square Shaft for Welding

to welding, Figs. 80 and 81, cutting reinforcing plates out of large sheets for frame repairs, altering chassis, etc., Fig. 82. The cutting blowpipe is capable of doing this work cheaply and quickly, two necessary factors for the successful first-class repair shop.

Principle of Cutting with Oxygen. At ordinary temperatures, steel oxidizes in the air, forming what is commonly called "rust". At a white heat it will oxidize more rapidly, as is seen in the blacksmith shop when pieces are brought to a very high temperature. When steel is heated to a red heat, and a stream of pure oxygen is directed on it, the oxidation takes place more rapidly and more violently and is restricted to the locality upon which the stream of oxygen is played. This localized oxidation is the basis upon which the oxy-acetylene cutting blowpipe operates.

Metals That Can Be Cut. Steel and wrought iron are the only metals that can be cut successfully by means of the oxygen jet. Although cast iron, copper, brass, bronze, aluminum, etc., oxidize easily, nevertheless they cannot be cut.

Fig. 82. Cutting Reinforcing Plate Out of Large Sheet Steel for Frame Repair

When the oxygen combines with the iron, heat is generated. This heat of formation, with the aid of the heat supplied by the pre-heating flames of the blowpipe, brings the oxide to a molten condition. The molten oxide either flows or is blown out of the cut and leaves a fresh thoroughly heated line through the metal for the further action of the cutting oxygen. In the case of steel and wrought iron, the oxide melts at a much lower temperature than the material being cut and therefore blows out without melting the surface of the material. In the cases of cast iron and certain alloy steels, the melting temperature of the oxide is as high and in some cases higher than that of the metal, and therefore melts the edges or freezes in the kurf and so hinders the cutting. Also, in the case of some of these materials, the heat of formation produced by the combination of the oxygen with the metal is not sufficient to carry the cut through the thickness of the work.

Necessary Cutting Apparatus. A complete cutting station, Fig. 83, consists of the following apparatus:

Cutting blowpipe with set of cutting nozzles
Oxygen cutting regulator with two gages
Acetylene regulator with one or two gages
Adapter for acetylene cylinder
One length high-pressure rubber hose for acetylene
One length copper armoured hose for oxygen
Darkened spectacles, wrenches, hose clamps, etc.

Cutting Blowpipe. In the cutting blowpipe, Fig. 9, page 9, there are usually six small oxy-acetylene flames surrounding a center orifice through which pure oxygen is directed. The six heating jets are used only for the purpose of bringing the edge of the material to a temperature at which the jet of pure oxygen will unite rapidly with the steel, as explained above.

Cutting Nozzle. There are usually four sizes of cutting nozzles furnished for handling work of various thicknesses, from very thin plate up to material 14 and 16 inches thick. Besides these, some manufacturers also furnish what is known as a "rivet cutting nozzle". This is a thin flat nozzle that can be laid against the sheet, allowing, the rivet head to be cut off close to the sheet.

lers,

Courtesy of Oxweld-Acetylene Company, Chicago

Working Pressure. The necessary pressures of the gas that are required by the different sizes of cutting nozzles and for the different thicknesses of material are given by the manufacturers. It is very important that the operator use these pressures instead of higher pressures because of the increased amount of oxygen used and the consequent high cost of operation, also because the cut will not be smooth if too much oxygen is used.

Care of Blowpipe. If the blowpipe is handled properly there will be very little deterioration. It should only be necessary to clean the replaceable and working parts, repack the valves, and occasionally ream out and true up the nozzles. Care should be taken that the orifices of the nozzles do not become enlarged by reaming, because the heating jets will be made thicker and shorter and the cutting jet will spread rather than leave the blowpipe as a long thin stream.

The blowpipe may be cleaned the same as the welding blowpipe by removing both the acetylene and oxygen hose and connecting the nozzle to the oxygen hose, Fig. 16, page 18, and turning on the oxygen to a pressure of about 20 pounds per square inch, having first the cutting oxygen valve open, then the acetylene needle valve, and lastly the oxygen needle valve. This will allow the large particles to be blown out of the larger passages before they have a chance to clog up the smaller passages.

Regulators. The cutting regulator, in principle, is the same as that described on page 20, but in size it is much larger than the welding regulator and is capable of both a higher delivery pressure and a greater volume.

The acetylene regulator is the same as is used in the welding equipment, and described on page 20.

Care of Apparatus. The blowpipe, regulators, and hose should receive the same care and attention as is explained for the welding apparatus on pages 18 to 21.

Instructions for Connecting Apparatus. The regulators and the blowpipe are connected up in the same manner as the welding apparatus, and therefore the operator is referred to pages 22 to 23 for instructions.

How To Light the Blowpipe. (1) Take the blowpipe in hand and open the oxygen cutting valve fully.

(2) Turn the oxygen pressure-adjusting screw to the right until the required pressure for the work to be done shows on the low-pressure gage. (See the maker's chart for the correct pressure.)

(3) Close the oxygen cutting valve.

(4) Open the acetylene needle valve fully.

(5) Turn the acetylene pressure-adjusting screw to the right until a good jet of acetylene issues from the heating orifices. In the case of pressure blowpipes, until the required pressure for the thickness to be cut shows on the low-pressure gage. (See the maker's chart for the correct pressure.)

6. Open the oxygen needle valve one-quarter turn and light the blowpipe by means of the pyro-lighter that is usually furnished.

NOTE—A back-fire might occur if there is not enough acetylene being supplied. If this occurs increase the acetylene supply by turning the acetylene pressure-adjusting screw farther to the right.

7. Adjust the acetylene pressure-adjusting screw to give a slight excess of acetylene to the flame.

8. Adjust the acetylene needle valve to give a neutral flame (see under Flame Regulation, page 25) when the cutting oxygen valve is open.

To Shut off the Blowpipe. In the case of the injector type of blowpipe, first close the acetylene needle valve and then the oxygen needle valve.

In the case of pressure blowpipes, first close the oxygen needle valve and then the acetylene needle valve.

To Cut. With the cutting valve closed apply the heating flames to the edge of the metal, keeping the nozzle at such a distance that the small flames barely touch the metal. As soon as the metal becomes heated to a cherry red, open the cutting valve, raise the blowpipe slightly to increase the distance between the nozzle and metal, and then move it along the surface as fast as a distinct and and clear kurf can be secured. The blowpipe should be held at a constant distance from the work. It should travel away from the operator in order that he may watch the cut advance.

Back-Firing. Occasionally, particles of molten metal will impinge on the nozzle of the blowpipe, or the operator will allow the nozzle to touch the surface of the metal, and the blowpipe will back-fire. When this occurs, first close the acetylene needle valve and allow oxygen to clear the passage, then open the acetylene needle valve fully and relight. If the back-firing continues, close both the acetylene and oxygen needle valves, cool the blowpipe by plunging in water and relight. Other causes of back-firing are loose internal and external nozzles or dirt on the nozzle seat. These can be eliminated by tightening the nozzles and cleaning the seat. These back-fires are usually only a series of pops or sharp reports, and, as a rule, will not extinguish the flame.

Notes on Cutting. *Heating Flames.* The heating flames should be small to produce smooth cutting. If the flames are too small, the blowpipe is liable to back-fire. If they are large, the top edges of the cut will melt and produce a rough cut.

Speed of Cutting. The speed of the blowpipe travel should be slow enough to allow the oxygen jet to penetrate yet not so slow that the oxygen will be wasted.

Restarting Cut. If the blowpipe travels too fast, and the cut is "lost", it is necessary to shut off the cutting oxygen and apply the heating flames to the point of stopping until the metal is hot enough to start the cut again.

To Cut Round Shafts, Etc. The cutting of round pieces will be made easier if the surface of the work is first chipped with a chisel. This will present a good edge for the cutting blowpipe to bite on.

To Pierce Holes. When piercing holes, a high oxygen pressure is necessary, and the metal must be brought to fusion before the cutting oxygen is employed. The blowpipe is held at a slight angle so the sparks will be blown out of the hole and away from the blowpipe.

Cutting Dirty and Poor Material. If there is considerable rust, scale, paint, etc., on the surface, the cutting will be interfered with by small particles flying against the end of the nozzle and perhaps causing back-firing. To overcome this, the heating flames may be made longer, allowing the blowpipe to be held farther away from the surface, or the scale or paint may be removed by first passing the flame over the line of cutting before the cutting is started.

LEAD BURNING

Different Methods. Formerly, lead burning, or lead welding, was confined to garages and service stations that catered to the electric automobile only, but since the introduction of electric lighting and starting batteries for gasoline automobiles, lead burning has become one of the works of the repair man in all garages. It is therefore important that the repair man have a sufficient knowledge of this class of work to enable him to handle any work of this nature that may happen to come into his shop.

Up to the time of the recent development of a very small oxy-acetylene blowpipe for lead-burning work, the hydrogen air burner was used by most lead burners. The oxy-acetylene blowpipe, however, is rapidly supplanting the old method and, as a matter of fact, within two years it has become universally accepted as being far superior to the old method in handiness of operation, speed, and consequent economy, and has been adopted by the large battery makers in both their factories and service stations.

Fig. 84. Oxy-Acetylene Lead Burning Apparatus
Courtesy of Oxweld Acetylene Company, Chicago

When an operator accustomed to the old flame tries the oxy-acetylene blowpipe, he is very likely to discredit it at first and claim that it is not satisfactory. However, every operator who gives the oxy-acetylene lead-burning blowpipe a fair trial and uses it in accordance with the methods recommended by the manufacturers of the apparatus must acknowledge it as being superior to any method he has ever used. Its advantages are emphasized even more emphatically if he returns to the old, slower, and more costly methods.

Lead-Burning Apparatus. A complete lead-burning station for use with oxygen and acetylene, Fig. 84, consists of the following apparatus:

Lead-burning blowpipe with set of tips
Oxygen regulator with low-pressure gage
Acetylene regulator with low-pressure gage
Adapter for acetylene cylinder
Valve-block
Two lengths of high-pressure hose to connect regulators to valve block
Two lengths of small hose to connect blowpipe to valve block

Lead-Burning Blowpipe. To make the blowpipe as light in weight and as handy as possible there are no large valves. Instead, a valve block is furnished for regulating the gases, which may be attached to a bench or a wall. In order to make minor or finer adjustments of the flame, and to allow various size tips to be used on the blowpipe and still maintain a perfect flame, an adjustable injector is provided at the top of the blowpipe within reach of the operator's fingers.

Tips. There are about five sizes of tips supplied for use on different thicknesses and various classes of work, each giving its own special size flame. The oxygen consumption of the various size tips ranges from ½ to 6 cubic feet per hour. For storage-battery work the average consumption is about 2 cubic feet per hour.

Regulators. The regulators supplied with lead-burning apparatus operate on the same principle as the regulator described on page 19, the only difference being that they are of smaller size and especially adapted to small flames.

Operation of Lead-Burning Apparatus. The apparatus is connected in the same general manner as the welding apparatus for which instructions are given on pages 22 to 26. The needle valves on the valve block are used to obtain approximate adjustment of the flame, and then the small thumb-nut on the blowpipe is used to make the finer adjustment. The pressure-adjusting screws should be set to give pressures of about 10 pounds per square inch for the oxygen, and 2 pounds per square inch for the acetylene.

The blowpipe, regulators, hose, etc., should receive the same care and attention as the welding apparatus and for which suggestions are given on pages 18 to 21.

Lead-Burning Process. The oxy-acetylene blowpipe should be handled in such a manner that the flame strikes the work perpendicularly. If the blowpipe is used on a slant, the inner cone will not bring the work to the fusing temperature as rapidly as if held vertically, and the secondary flame, or outer envelope, will be very likely to heat the surrounding metal to such a temperature that it will give way and break under its own weight. When working with the oxy-acetylene flame on storage batteries and the like, the operator should do the burning quickly. He should bring the flame down to the work, fuse the metal, add the necessary burning bar, or filling wire, smooth off the work, and remove the flame, all as rapidly as possible.

Fig. 85. Assembling Terminal Groups

Burning Terminal Groups. When burning plates to terminal bars, a small flame should be used, and the work should be held in a fixture, as shown in Fig. 85. The small ends on the plates should extend up into the terminal bar slots about two-thirds of the way. The burning should be carried on by first fusing the ends of the plates to the bottom of the slots, then filling up the rest of the slot by adding lead from a coil of wire or a burning bar. After the several plates have been burned on in this way, the flame should be moved perpendicularly over the surface to smooth it off and leave a nice finish. The flame should *not be held flat* against the work. It will take longer to smooth off the work, and it will not have nearly as neat an appearance if the flame is used flat.

Burning-On Connecting Links. The terminal poles should extend up into the links about one-third of the way. The flame should be brought down into the hole until the inner cone almost touches the top of the pole, and the pole fused and united with the bottom of the link as quickly as possible. After a good union has been secured in this manner, the burning bar should be introduced and the rest of the cavity filled up, Fig. 86. When working on links and poles it is advisable to do only part of one pole, move to another for a few minutes, and then come back to the first for a few minutes. This will allow the work to cool off slightly and will prevent breaking down or melting away. When burning this class of work, especially if the lead is old and pitted with dirt and cut by acid, it is advisable to increase the supply of oxygen and use an oxidizing flame when working down in the pocket. This will burn out any dirt and will prevent the blowpipe from puffing out when it is burning in the rare atmosphere that exists in the pocket.

Forms or Molds. Small steel frames, or molds, are found very convenient, especially when working on terminal links. These molds are shaped to conform to the work and are placed around it while burning. They are a great help in preventing the corners of the work from breaking down and melting away and, in this manner, relieve some of the tediousness of the work and allow the operator to work under less strain, and permit the work to be done by men who are not skilled lead burners, but who have occasional work of this sort to do.

Fig. 86. Burning-On Connecting Links

CARBON REMOVING BY USE OF OXYGEN

Methods. *Old Process.* Up to within the last few years the methods used for removing the carbon from gas-engine cylinders were very impractical and unsatisfactory. To do this work meant the dismantling of the motor, the removal of all the parts, and the scraping of the cylinder walls by hand. Because this operation necessitated a great deal of work it was not done, in most cases, until the carbon deposit became very heavy.

Oxygen Process. The introduction of the inexpensive process of removing the carbon by burning it out by means of pure oxygen has replaced the old methods and they are no longer used. This new process is so simple, necessitates so little work, can be done so quickly and cheaply, that it can be employed every few months and, in that way, keep the cylinders free from carbon.

Carbon-Removing Apparatus. Complete apparatus for removing carbon by means of oxygen, Fig. 87, consists of the following:

Carbon-removing handle with flexible tube
Oxygen regulator with low-pressure gage
One length of high-pressure rubber hose

It will be seen from this list that all that is necessary for a garage to have in addition to its welding equipment is the carbon-removing handle with a flexible tube.

Burning Out Carbon. Shut off the gasoline at the tank or just in front of the carburetor and allow the engine to run until it has sucked the gasoline out of the lines. Remove the valve caps and spark plugs from all the cylinders.

Turn the engine over by hand until the first piston is at the *upper end of its stroke* and both its *valves are closed.* Introduce a small quantity of kerosene into the cylinder head by means of an oil can or a piece of saturated waste. Light the kerosene in the cylinder, introduce the end of the flexible tube into the cylinder and allow the oxygen to play on the carbon at a pressure of about 5 pounds per square inch. The carbon deposit will catch fire and will continue to burn as long as there is carbon present. Of course, if the carbon is deposited in patches it will be necessary, after one patch has been removed, to start another by means of kerosene.

Fig. 87. Carbon-Removing Apparatus

After the first cylinder has been thoroughly cleaned, turn the engine over by hand until the piston of the second cylinder is at its upper stroke with its valves closed, and then proceed to remove the carbon from this cylinder in the same manner.

After all the cylinders have been thoroughly cleaned, clean the valve caps and spark plugs by scraping or by burning off the carbon and then replace them in the engine.

Notes on Carbon Burning. Before burning out the carbon be sure that there is no chance of gasoline being present which might cause back-firing into the intake manifold.

The oxygen pressure should not be too high. Only enough oxygen should be supplied to keep the carbon kindled. Too much pressure will waste oxygen and increase the cost of burning out the carbon.

Too much kerosene must not be used, because there is a chance of the operator burning his hands with the sudden burst of flame that might result.

EXAMPLES OF AUTOMOBILE REPAIR

Pressed-Steel Parts. All pressed-steel parts of automobiles, such as frames, bodies, fenders, axle housings, tubing, etc., should be welded, using a pure iron welding wire for a filling material.

Frames. Almost all frame repairs necessitate a certain amount of dismantling of other parts. The extent of the dismantling depends upon the location of the proposed weld. If the work is to be done under the body, it is best to remove the car body. This is not absolutely necessary, however, because the work can be done by merely jacking up the body several inches to give enough room to do the work, and protect the body from the heat of the welding flame. If the weld is to be done close to the radiator, this should be removed so that the solder will not be melted out, Fig. 88. If the weld is about 12 inches from the radiator, the solder can be protected by placing sheet asbestos over the radiator. In this connection it is well to remind the operator that it is always advisable to cover the parts of the car near the welding with sheet asbestos to protect them from any possibility of the flame or heat getting too close.

Jacks should be placed under the frame and the frame brought into alignment before the welding is started; the jacks should not be removed until the weld has been completed and has become thoroughly cooled.

It is always advisable to bevel the work by chipping. In the case of frames of light-weight pleasure cars this may be dispensed with if the operator is careful to penetrate through the thickness of the material. All paint, dirt, and grease must be scraped off next to the weld from both the inside and outside of the frame before the welding is commenced, to prevent dirt from being incorporated in the weld.

A reinforcing plate should be prepared about the same thickness as the frame, as wide as the frame is high, and about three times

Fig. 88. Radiator Is Removed if Welding Flame Is Near It

as long as it is wide. This may be cut out of sheet steel by means of the cutting blowpipe, Fig. 82, page 77, or by means of a hack saw. The blowpipe is the quickest and easiest method, especially for cutting plates for curved frames such as are used on pleasure cars. The weld will look better if the reinforcing plate is welded on the inside of the frame, but in some cases that is impossible without a great deal of extra dismantling. It is then allowable to weld it on the outside.

The welding should start at the lower end of the frame and move upward as explained under Vertical Welding, page 31. The two flanges of the channel should then be welded, starting at the corner and moving toward the edge. When welding the lower

Fig. 89. Badly Bent Frame

Fig. 90. Frame after Heating with Welding Flame and Straightening

flange, the work should be carried on as explained under Overhead Welding, page 31. After the frame has been welded, the reinforcing plate should be welded on by welding the horizontal edges first and the ends last.

The weld will be materially strengthened if it is hammered during the process of welding, as explained under Hammering, page 46.

The oxy-acetylene blowpipe is also very valuable in straightening frames that have become bent in accidents. A frame of this sort is shown before and after straightening in Figs. 89 and 90.

Bodies and Fenders. Bodies and fenders that have been torn can be successfully welded if the operator uses his best efforts and is careful.

Fenders, as a rule, do not present very much difficulty because the break usually extends to the edge. It is advisable to pack wet asbestos along both sides of the weld to prevent buckling as much as possible, Fig. 91. The wet asbestos will absorb the heat and will not allow it to be conducted back into the sheet.

Fig. 91. Welding Torn Fender. Wet Asbestos along Weld Will Prevent Buckling of Light Sheets

Bodies should be welded in a similar manner when they are torn. If possible, it is advisable to bend the edges outward slightly before welding. Then, as the weld is cooling, hammer it flat to compensate for the contraction that takes place.

If a patch must be welded in, it should be prepared either round or oval, or should have rounded corners of large radii. The patch should be dished to compensate for the contraction that will take place when the work cools. The hole in the body and the patch should be trimmed so as to fit well. When the patch is ready, it should be tacked in place. The welding should be carried on as quickly as possible. After the weld has been completed, the flame should be played on it to heat it evenly. As the weld starts to cool, the center of the patch should be heated

Fig. 92. Broken Front Axle

Fig. 93. Welded Front Axle

Fig. 94. Crankshaft in Crankshaft Jig Table for Welding

slightly so that it will stretch easily and compensate for the contraction taking place in the weld.

Springs. The welding of springs should not be attempted except for emergency repairs to allow the car to be used until a new spring can be obtained. A steel welding rod of low-carbon content

Fig. 95. Pre-Heating Crankshaft with Gas Burner

Fig. 96. Welding Crankshaft. Note that the Pre-Heating Burner Is Used to Assist the Welding Flame

should be used for filling material. No attempt should be made to re-temper the spring, because the average garage is not equipped to handle work of that nature and, consequently, the spring is very

Fig. 97. Welded Crankshaft

likely to be worse if a poor job of tempering is done than if tempering is not attempted. It is well to pack wet asbestos around the spring next to the weld to prevent the heat being conducted back into the rest of the spring.

Shafts and Axles. Shafts and axles are alloys of nickel, nickel and chromium, or chromium and vanadium. It is desirable to have the filling material of the same composition as the shaft or axle, but this is practically impossible. The most suitable welding rod

Fig. 98. Broken Malleable-Iron Rear-Axle Housing

that can be obtained for this work is one containing about 3.50 per cent nickel, or one containing about 0.20 per cent vanadium and 0.12 per cent chromium. This latter steel is more difficult to handle under the welding flame, so that most welders prefer the 3.50 per cent nickel rod.

Square shafts, Figs. 92 and 93, and round shafts, Fig. 80, page 76, should both be beveled by means of the cutting blowpipe or by grinding, and should then be placed in alignment or in suitable jigs, Fig. 94. A gas or oil pre-heating burner should then be directed

Fig 99. Repaired Malleable-Iron Rear-Axle Housing

on the point of welding, Fig. 95, and the work heated to a red heat before welding is started. The welding should then be carried on, Fig. 96, according to the instructions given under Welding Heavy Sections, page 58. After the welding has been completed the work should be reheated and any straightening done that is necessary.

The weld should then be heated up evenly, covered over with sheet asbestos, and allowed to cool slowly. The finished weld is shown in Fig. 97.

Axle Housings. If the housing is of pressed steel, it will not present any particular difficulty to the welder, except that he will have to take care that it does not get out of alignment. A pure iron welding wire should be used, and the work should be prepared and carried on as explained under Light Sheet-Steel Welding, pages 46 to 50

If the housing is of malleable iron, Figs. 98 and 99, it should be beveled, placed in alignment, and then *brazed,* using Tobin bronze for a filling material as explained under Malleable-Iron Welding, page 67. The work may be pre-heated slightly to relieve the effect of expansion and contraction, but must *not be heated above a dark red.* The operator must be very careful to not bring the malleable iron at the weld to too high a heat or its malleable properties will be destroyed and the housing will be weak.

Fig. 100. Welding Broken Flange on Manifold

Manifolds. Pressed-steel manifolds should be welded according to the directions given under Light Sheet-Steel Welding, pages 46 to 50.

Cast-iron manifolds, as a rule, have only simple breaks to be repaired, such as broken flanges, Fig. 100. These should be beveled, and the parts clamped to a flat surface to keep them straight. They should then be pre-heated in the vicinity of the weld by means of the welding blowpipe before the welding is started. After the weld is completed they should be reheated evenly and then covered over and allowed to cool slowly.

Engine Cylinders. If the water jacket is cracked, the crack should be chipped out and the surface of the casting next to the groove should be cleaned by scraping. If the cylinder is cracked in

Fig. 101. Water Jacket Cut Away to Allow for Welding Cylinder Wall

the head end, it will be necessary to cut away a section of the water jacket by drilling or sawing, Fig. 101. After the cylinder head has been welded, the water-jacket section can be welded back into place, Fig. 102. Sometimes it is quite difficult to detect how far the crack really extends, therefore, care must be taken to be sure that it is chipped out its entire length.

All of the plugs and other fittings must be removed from the cylinders before pre-heating. The cylinders should be placed in

Fig. 102. Cylinder Wall Welded and Section of Water-Jacket Replaced

the pre-heating fire with the open end of the cylinder upward, Fig. 103. They may be placed on a slant if the crack is on the side of the water jacket; but they must be in such a position so there will be no chance for dead air to remain in them. If this precaution is not taken, the cylinder walls are very likely to crack.

The welding should be carried on according to the directions given under Cast-Iron Welding, pages 59 to 67. The cylinders must be left in the charcoal fire all during the welding. It is even advisable to keep the top of the fire covered over and to weld through a hole in the asbestos paper, Fig. 103, to prevent air currents from striking the cylinder while it is hot. After the welding has been

Fig. 103. Welding Cylinders and Preparing Pre-Heating Fire for Cylinders

completed, the fire should be started up enough to heat the entire casting evenly, and should then be covered over and allowed to die out. The cylinder must not be removed until it has become cold enough to be handled with bare hands.

Protection for Machined Surfaces. The finish in the bore of the cylinder will be affected by the heating if some means is not used to protect it. The best protection that can be used is to coat it and other machined surfaces with flaked graphite and oil. This can be made into a paste and painted on, or the surfaces can be oiled and the graphite dusted on. The latter method is really the best if carefully applied. The graphite must be coarse; the fine flake will not do.

Testing Welded Cylinders. There are several ways of testing welded cylinders. The two most generally used are by water pressure and by gasoline. In the first method, the water jacket is tightly plugged, filled with water, and then subjected to pressure by means of a hand pump. The method of using gasoline is simpler and quicker. The water jacket is plugged and filled with gasoline, Fig. 104. If there are any cracks or leaks the gasoline will work its way through and will spread out over the surface surrounding the crack or leak.

Fig. 104. Water Jacket Plugged and Welds Being Tested with Gasoline

Crankcases and Transmission Cases. It is usually necessary to remove the case from the car. But, if the arm is broken some distance from the main case, it may be welded while in position, as shown in Fig. 105. When welding in this manner, it is necessary to cover the parts near the welding with asbestos sheets to protect them from the flame of the blowpipe. The arm should be

Fig. 105. Welding Arm of Crankcase without Dismantling

pre-heated slightly by means of the welding blowpipe before the actual welding is started, and, after the welding has been completed, it should be reheated to relieve any internal strains, and must then be covered over to allow it to cool slowly.

Some operators spend a great deal of time trying to keep the bearing of the case in line, and while doing this they allow the rest of the case to twist, so that it is necessary to take a machine cut off the edges in order that they may fit the other half of the case. It is much better to keep the edges true and dress up the bearings, because it is quite likely that the bearings will have to be trued up anyway. The case should be clamped flat against two straightedges, but not too tight, or the case might crack from the strains produced when heat is applied. The case should be placed on the welding table in such a position that the welder can work on the outside and smooth off the inside without having to disturb its position.

Fig. 106. Badly Broken Transmission Case—Must Be Pre-Heated All Over

Fig. 107. Lower Half of Crankcase with Piece Broken Out—Must Be Entirely Pre-Heated

The most satisfactory method of pre-heating is to place a gas burner under the case and let it burn *without an air blast*. If an air blast is turned on, the case is liable to become overheated and

Fig. 108. Upper Half of Crankcase with Piece Broken Out and Missing

cave in. In fact, unless there are holes to allow some of the heat to escape, the case is liable to become overheated with only the soft gas flame. If the case is broken at one end, as shown in Fig. 108, it is only necessary to heat the one end; but it is very necessary to heat both sides of that end to prevent warping. If like the case shown in Figs. 106 or 107, it is best to heat the entire case. This can best be done by using two gas burners so that the heat will surely spread.

If the case is cracked or a piece is broken off, the welding should start at the inner end of the crack and move toward the edge or corner. The welding should be carried on as directed under Cast Aluminum Welding, page 71.

If a piece has been broken out and lost necessitating building

Fig. 109. Sheet-Iron Form to Back Up Section to Be Welded-In

up a section of the casting, Fig. 108, it is necessary to back-up the work by means of a piece of sheet iron bent to the required shape, Fig. 109. The welding should be started at one edge and should move across the space in a line parallel to the edge. When the added material gets almost to the opposite edge, the welding should stop, the edge of the case and the edge of the new added section should be cleaned, and then the weld completed in the same manner as for welding up a crack, Fig. 110, as outlined above.

COSTS

The cost of welding varies within wide limits for the different metals and the different classes of work. It is, therefore, not possible to give cost tables that will apply to all work. The costs given in Tables II and III are for steel work under fair conditions.

Measuring Oxygen Consumption. Oxygen is supplied compressed to 1800 pounds per square inch, in cylinders containing

TABLE II

Welding Cost Table

Thickness of Metal (in.)	Speed (ft. per hr.)	Oxygen per Linear Foot (cu. ft.)	Acetylene per Linear Foot (cu. ft.)	Cost per Linear Foot Labor.....45c Oxygen.... 2c Acetylene.. 2½c
1/64	26	0.15	0.14	$ .024
1/32	22	0.22	0.21	.030
1/16	17	0.43	0.41	.045
3/32	14	0.68	0.65	.063
1/8	11½	1.03	0.98	.083
3/16	9	1.84	1.74	.13
1/4	7	3.01	2.88	.20
3/8	4½	6.74	6.44	.40
1/2	3	13.2	12.5	.73
3/4	1½	38.7	37.0	2.00
1	1	76.7	72.9	3.81

TABLE III

Cutting Cost Table

Thickness of Metal (in.)	Speed (ft. per hr.)	Oxygen per Linear Foot (cu. ft.)	Acetylene per Linear Foot (cu. ft.)	Cost per Linear Foot Labor.....45c Oxygen.... 2c Acetylene.. 2½c
1/8	90	0.34	0.10	$ .014
1/4	74	0.55	0.17	.021
1/2	55	1.16	0.33	.040
3/4	46	1.91	0.47	.060
1	40	2.75	0.61	.082
1½	33	4.70	0.85	.13
2	29	6.97	1.06	.18
3	24	12.3	1.46	.30
4	20	19.4	1.96	.46
6	15	38.3	3.04	.87
8	11	69.7	4.60	1.55

TABLE IV

Factors for Correcting Oxygen Volumes

Deg. F.	Factor	Deg. F.	Factor	Deg. F.	Factor
100	0.929	75	0.972	50	1.020
95	0.937	70	0.981	45	1.030
90	0.946	65	0.990	40	1.040
85	0.954	60	1.000	35	1.051
80	0.963	55	1.010	30	1.061

100 and 200 cubic feet. The amount of oxygen in a cylinder can be measured quite accurately by means of the high-pressure gage on the regulator. Most of these gages are supplied with two rows

Fig. 110. Upper Half of Crankcase with Section Built-In

of figures on the dial, Fig. 111. The outer circle gives the pressure in the cylinder in pounds per square inch, and the other circle gives the per cent of oxygen remaining in the cylinder. The latter set of numbers makes the calculation very easy: e.g., if a 100-cubic foot cylinder is being used and the gage hand indicates 73, there is 73

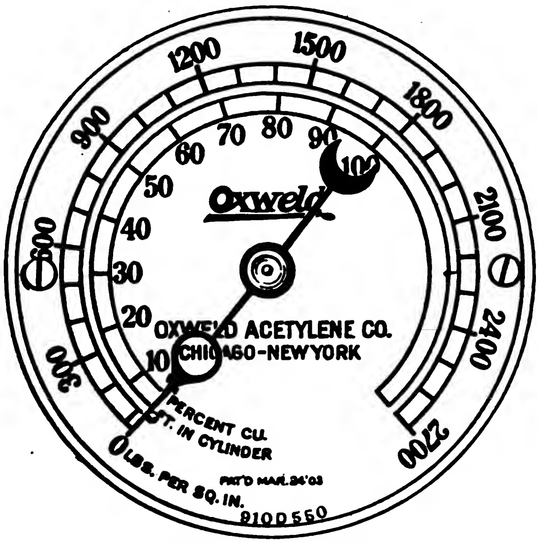


Fig. 111. Dial of High-Pressure Gage of Oxygen Regulator

cubic feet of oxygen in the cylinder. If a 200-cubic foot cylinder is being used, there is $200 \times 0.73 = 146$ cubic feet in the cylinder. The amount of oxygen indicated by the gage reading is more or less approximate and depends upon the temperature of the oxygen in the cylinder. The correction factors given in Table IV should be used to determine the volume of the oxygen at "standard temperature", 60° F., if an accurate measurement is required, e.g., if in the case given above the temperature is 50° F., then the real volume at standard temperature would be $146 \times 1.020 = 148.9$ cubic feet.

Measuring Acetylene Consumption. The amount of acetylene in a cylinder cannot be determined by means of the high-pressure gage. All the high-pressure gage can be used for, in the case of acetylene, is to indicate very roughly the amount of acetylene in the cylinder. There is only one method that can be used to determine the amount of acetylene used, and that is to weigh the cylinder. Each pound by weight of acetylene is equal to 14.5 cubic feet. Therefore, to determine the amount of acetylene used on a certain job, it is necessary to weigh the cylinder before and after welding and calculate the volume of acetylene used from the difference in weight, e.g., if the cylinder weighs 217 pounds before welding and $207\frac{1}{2}$ pounds after welding, then $(217 - 207\frac{1}{2}) \times 14.5 = 9\frac{1}{2} \times 14.5 = 137.7$ cubic feet.

CUTTING SPROCKETS WITH MULTIPLE-SPINDLE GEAR HOBBER

Courtesy of Gould and Eberhardt, Newark, New Jersey

SHOP INFORMATION

INTRODUCTION

Importance of Shop Equipment. The average garage or repair shop should be equipped to do any repair job which comes into the shop. Of course, the demands in different districts vary somewhat, but a study of the requirements will guide the management in the installation of the equipment necessary. This article is intended to cover the more common bench operations and the operations performed on the various machines which are most necessary. In the article on Building, Equipping, and Running a Public Garage, other suggestions as to equipment of tools and machines are given. In still another article on Oxy-Acetylene Welding Practice, practical instructions for welding various metals and various parts of an automobile are given.

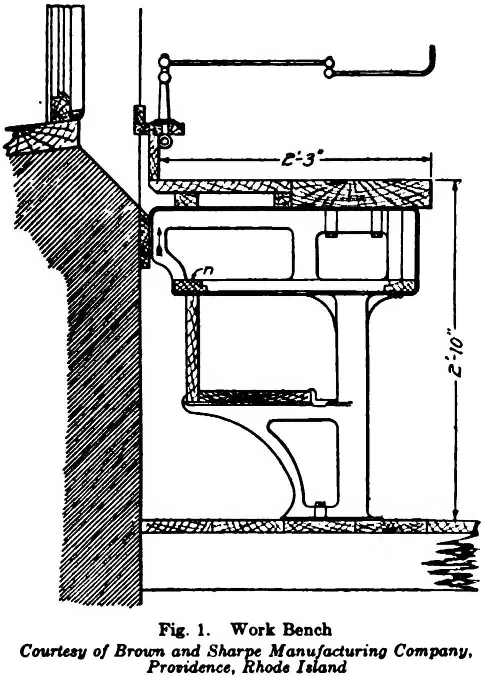


Fig. 1. Work Bench
Courtesy of Brown and Sharpe Manufacturing Company, Providence, Rhode Island

BENCH WORK

Work Bench Design. As a large portion of the repair work in a shop is bench work, the height, width, and equipment of the work bench should be carefully considered. The machinist's bench at which hand work is ordinarily performed should be of substantial character, about 2 feet 10 inches from the floor and 2 feet 3 inches wide, Fig. 1. For the sake of economy it is usual to have a 2½- or 3-inch plank at the front to which the vises are fastened and on which all the heavy work is done, while the rear of the bench is made from 1-inch lumber. Maple and birch are preferred as materials for a bench, although ash makes a very good substitute.

Work Vises. In order that work may be held rigidly for the performance of hand operations, the machinist uses what is termed a vise. They are made in a great variety of forms and sizes, but all consist essentially of a fixed jaw, a movable jaw, a screw, a nut fastened to the fixed jaw, and a handle by which the screw is turned in the nut and the movable jaw brought into position. The sectional view, Fig. 2, shows these parts clearly and also a device,

Fig. 2. Simple Bench Vise

present in some form in all vises, by which the movable jaw is separated from the fixed jaw when the screw is backed out of the nut.

In the machinist's vise both jaws are made of cast iron with removable faces of cast steel. These may be checkered to provide a firm grip for heavy work, or may be smooth to avoid marking the surface of the plate operated upon. When holding soft metal, even the smooth steel jaws would mar the surface; and in such cases it is customary to use false jaws of brass or Babbitt metal, or to fasten leather or paper directly to the steel jaws. The screw and handle are made from steel and the nut from malleable iron.

The common method of fastening a vise to the bench is by means of the fixed base shown in Fig. 2, although a swivel base is really preferable. Vises of this kind often have swivel jaws as well, which enable them to hold tapered work securely. This swivel jaw is provided with a locking pin, which fixes the jaws in a parallel position. The height of the vise from the floor depends somewhat on the class of work to be performed, but a general rule is to have the top of the jaw about 1½ inches below the point of the elbow when standing erect beside the vise.

CHIPPING AND FILING

Chisels. One often hears the term "cold chisel mechanic" used in derision, but the man who can by the use of a hammer and hand

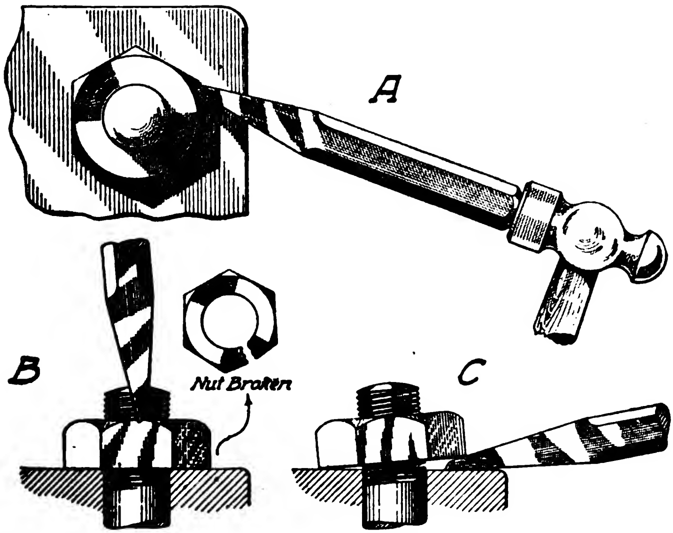


Fig. 3. Methods of Using Chisels on Bolts and Nuts

chisel remove metal neatly and without marring the adjacent parts is a really good mechanic. The term came from the common practice in the early days of the automobile of tightening nuts in place with a cold chisel, which, of course, scarred the nuts very badly. This practice was more the fault of the maker than of the mechanic, as there were places on the automobile where a wrench could not be used. But this difficulty has been corrected on modern cars, and there is now practically no excuse for the use of the cold chisel in this manner.

It is often necessary, however, to remove interfering lugs, etc., when fitting accessories to a car. This is especially true when putting ignition apparatus, lighting and starting equipment, and other attachments on Ford cars. In cutting soft steel with a hand chisel there is little danger of doing damage except by cutting too deep or letting the tool slip, but in cutting cast iron, cast aluminum, and cast brass, which are the metals usually encountered on the motor car, there is great danger of cracking the adjacent part in case deep cuts are attempted with the necessarily heavy hammer blows.

A survival of the old cold-chisel-mechanic days is found in the method of removing nuts. In these days such practice should seldom be necessary around the engine, but it does sometimes happen that nuts on the muffler and other chassis parts become so badly rusted in place that they cannot be removed by a wrench even after the kero-

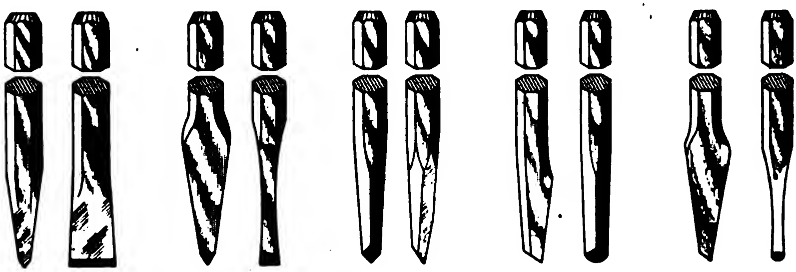


Fig. 4. Common Forms of Hand Chisels

sene-oil treatment. The first thing is to try to start it with a dull chisel at *A*, Fig. 3, but if this does no good and it is desired to save the male member, the nut can be split as shown at *B*. If it is on only an ordinary bolt that can be renewed from stock, it is easier to sheer the bolt, as at *C*, Fig. 1.

Cutting keyways by hand and putting oil grooves in anti-friction metal bearings are the other two uses made of the cold chisel by the automobile mechanic, and these subjects will be taken up in detail later.

Chisel Types. Common forms of hand chisels are shown in Fig. 4 in the following order from left to right: flat, cape, diamond, and two types of round nose.

Flat Chisel. The flat chisel is the most used and works best where the surface to be cut is of less width than the edge of the tool. It is beveled on both sides, an included angle of 70 degrees being best for cast iron, while 60 degrees seems best on wrought iron and steel.

Cape Chisel. The cape chisel is a narrow chisel with the sides ground back so as to give clearance to the cutting edge in a channel. It is used particularly for cutting keyways and for making channels in a large surface preparatory to using a flat chisel.

Diamond Point. The name describes this tool, which is used for cutting sharp-bottomed grooves and for putting holes in sheet metal. It has little application in automobile work.

Round Nose. Round-nose chisels, some very small, are of great importance in cutting the oil grooves in babbitt and die-cast bearings. These are often made with curved shanks.

Chipping. The ball-peen hammer seems best balanced for the chipping process, and the size of the hammer should be consistent with the chisel being used and the class of work in hand. Warning has already been given against unnecessarily heavy blows on any part of iron, aluminum, or brass casting, because these metals are very brittle. Only the cutting edge of the chisel should be in contact with the work, the lower bevel being at a slight angle. For a deeper cut the shank is raised, and for a shallow cut the lower bevel should almost touch the work. The general tendency is to raise the chisel too high and thus drive into the piece instead of making a good cut.

Filing Methods

Types of Files. The greatest time-saver in filing, as a feature of bench working, is in the selection of the correct file for the work at hand. It is therefore imperative, if a shop is to be at all efficient, to have a stock of files which will take care of every kind of work. Although there are a great number of shapes and sizes available with every imaginable type of cutting surface, those most commonly used are the flat file, hand file, warding file, square file, triangular file, half-round file, and the round file.

You can obtain a file which will cut across one angle of the file or one in which the cutting surfaces cross each other. These are known as single or double files. Different materials to be worked on require different coarseness of the cutting surfaces, and there are five general grades most suitable for general work: coarse; bastard; second cut; fine, or smooth; and superfine, or dead cut.

File Shape. In files of fine cutting surface, the length is much shorter than in files with coarse cutting surface. The reason for this is obvious, inasmuch as in heavy cutting one needs a long clean sweep where plenty of muscular effort may be applied to the best advantage; while in fine cutting where the work is more delicate, one needs a file which is light and easy to handle.

Properly constructed files have a very slightly convex surface in the direction of their length. The reason for this is that a perfectly flat file surface, digging-in to the full depth of its cutting ability, presents too much cutting surface to be handled by manual power. With a convex surface, however, the file is first applied at the center of the cutting surface, and this bites into the metal, allowing the rest of the file to be carried in easily. This convexity avoids dulling the cutting teeth, for it prevents frequent skimming strokes over the

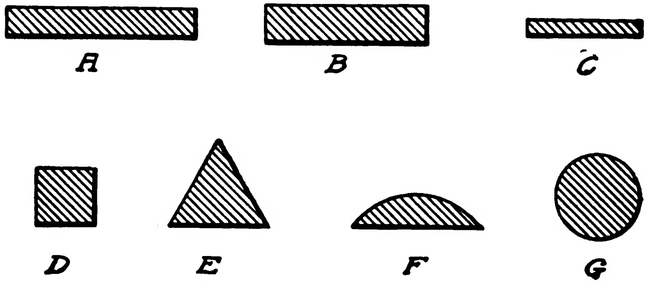


Fig. 5. Sections of Different Types of Files

surface of the metal which, as they apply only the sharp edges of the file, quickly breaks them down. This is naturally not the case when the teeth are deep into the metal. Another purpose which this convex surface serves is to compensate for the bending to which a file is naturally subjected when pressure is applied to it. Although convex in its natural position, the bending action of the file, due to its pressure after the teeth have cut in, very nearly makes up for the convexity. This is, of course, not an accurate compensation.

Proper Files for Certain Work. Before discussing the proper methods of handling files, it will be well to discuss the kind of file to select for a certain work. This is a matter upon which no fixed rules can apply. One mechanic may do a certain job with a long coarse file, where another may do the same job in equally quick time and as well with a finer cutting surface.

Generally, however, the kind of metal being worked determines the character of the file to be used. For cast iron, which presents a clean surface free from scale and an undue amount of rust, a bastard file is generally used. Although this is a softer metal than steel, it presents a surface of porous glassy character which is very hard on the cutting surfaces of a file. Old files—ones whose cutting surfaces have already been dulled by long use—should be used in cast-iron work. On steels of all kinds a second-cut file is generally accepted as presenting the best surface. The superiority of the second cut over the bastard for steel work is due to the fact that the cutting surfaces are shorter, and when sufficient pressure is applied for the file to bite into the surface, there is less tendency for these surfaces to chip off than there is with a coarser file such as the bastard.

Fig. 6. Correct Bench Filing Position

Aluminum, bronze, brass, bearing metals of all kinds, and kindred soft metals permit the use of flat files with coarse cutting edges.

Manipulation of Files. In filing, the work is usually held rigid in a vise, although many jobs are done directly on the automobile itself. In bench work, the surface should be at about the height of the elbow, and in constructing benches and installing vises it is well to bear this in mind.

Handles. Although it might appear to be a trivial matter, one cannot be too particular as to the kind of a handle which is fitted to the file. Before buying your files, hold them in your hand, with the handle against the palm and the other hand holding the steel end of the file. Press the file vigorously against a surface and determine for yourself whether the handle fits the palm in such a way that several hours of work would not become painful. Also make sure that the axis of the handle is on a true parallel with the file.

Position for Filing. If one is to undertake a filing job which will require several hours of concentrated labor, it is well for him to learn that position which will give greatest accuracy and which, at the same time, will be the least tiring. The feet should be placed a foot apart and at right angles to the work bench, or nearly so, Fig. 6, the left foot being in line with the top of the vise and the right slightly ahead of the left. This position allows the body to follow the file accurately and eliminates that swinging sideways movement which is disastrous to accurate work.

Holding the File. Take hold of the handle of the file with the right hand as you would take hold of the steering wheel of the car, with the fingers underneath and the thumb lying across the top. When a big

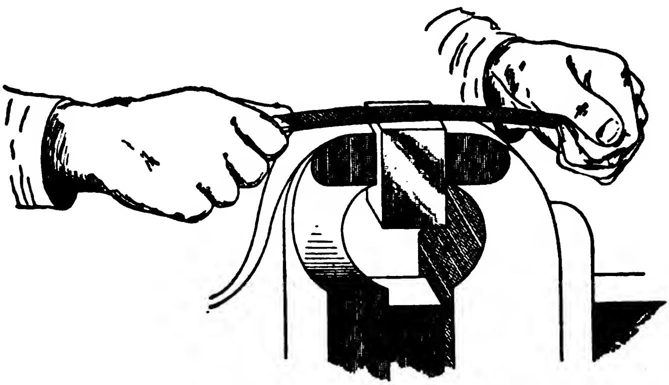


Fig. 7. Position of the Hands for Bench Filing

file is used and the work is heavy, grasp the steel end of the file with the left hand by placing the top of the file into the palm and twining the fingers around the end, Fig. 7. If the work is delicate, it is only necessary to pinch the end of the file with the fingers of the left hand.

Remember that the first dozen strokes of a new file on a tough piece of steel frequently lessens its cutting value as much as an hour of steady cutting on a softer metal. Handle the file firmly and push it into the metal with an even steady stroke to avoid chipping the edges. When much metal is to be filed, the direction of stroke should be changed frequently, thus permitting more accurate work as well as allowing faster removing of metal. The file, when moved endwise, produces small grooves in the direction of the work; when the direction of the file is changed, it cuts into the top edges of the grooves with much the same effect as working against the grain in wood.

Uses of Different Shapes of Files. We have gone into the types of files to be used as to coarseness or fineness of the cutting surfaces. Now let us consider the shapes best suited to various kinds of work.

When one selects a file for a certain job, he must bear in mind the shape and the size of the work, the quality of the metal, the amount of stock to be removed, and the quality of the finished work. The first two mentioned requirements fall under the shape of the file, the others under the nature of the cutting surfaces.

If the surface is a flat one, the flat file, hand file, or warding file will serve. The length will, of course, depend on the length of the surface to be filed. For very light work the length of the file should be about 8 inches, and for heavy work about 18 inches. If the surface is a square interior, such as a keyway, the square file finds its place.

The triangular file finds its use in notching round bars, in cutting through steel tubing, and in filing gear teeth, bolt threads, and kindred applications. The half-round file is used where the curvature of a radial filing job becomes too great for efficient work with a round file. With these large surfaces, it is not possible or even desirable to have the file fit accurately the surface to be cut. In using this file it is imperative, if smooth work is to be done, that the file be given a side sweep with each stroke. The round file, which in its general form is tapered throughout its length, has obvious uses in working with round holes.

Accurate Filing. The matter of accurate filing is a knack which can be acquired only by practice. It is the process of learning a smooth even stroke in which the file is held flat against the work throughout the length of the stroke. However, the file maker has contributed towards accurate work in a safe-edge instrument which has innumerable applications around a motor car.

Use of Safe Edges. Suppose one desired to increase the depth of a keyseat without in any way impairing the surfaces on the sides of that keyseat. If he were to introduce a flat file with cutting edges on all four surfaces, he would have removed considerable metal constituting the sides of the keyseat before he had cut the keyseat much deeper. For this kind of work there is the safe-edge file—one in which there are cutting surfaces on two opposing sides and smooth surfaces on the other two. These are procurable in all sizes and shapes.

Draw Filing. The term draw-filing refers to the process of operating the file over the work at right angles to the length of file. To do this work properly, the file is grasped in the palms of both hands, as one would grasp the handles of a push cart, Fig. 8. The purpose of this method of filing is accuracy in the work. As the belly of the file can be brought to bear on the high spots under better control and with less oscillation than in cross-filing, a less skilled mechanic can obtain more accurate results. Of course, due to the fact that the cutting surfaces operate on a great angle, the amount of cut at each draw is far less than it is in cross-filing.

Filing to a Micrometer Fit. Suppose one has a square block of steel, one side of which is to be cut down to an accurate surface with $\frac{1}{16}$ inch of stock taken off. Calipers or micrometers should be set

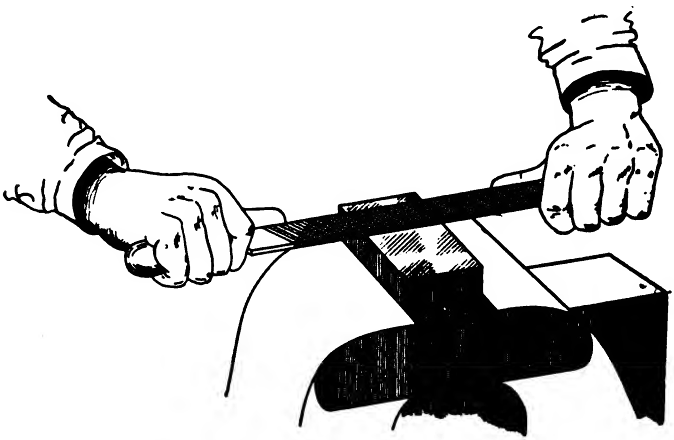


Fig. 8. Position of the Hands for Draw Filing

about $\frac{1}{64}$ inch greater than the finish size of the block. The surface may now be cut down with a flat second-cut file until the piece will just pass within the calipers or micrometers. Now the micrometer or calipers should be set to the exact dimension of the finished piece, and draw filing should be resorted to so as to cut down the surface carefully until the caliper or micrometer is a very tight fit over all the edges and through the center.

Now one should use a small file of a smooth fine grade for the final dressing off and should resort to the cross-filing method, so as to remove the grooves caused by the draw-filing operation. With a little filing, then a measurement from the caliper or micrometer, a little more filing, and still another measurement, etc., a very accurate job is possible.

Revolving Filing. Quite another angle is presented in revolving filing. This means the filing of a piece of work which is revolving in a lathe chuck. The stroke for this kind of work is entirely different than in hand filing. These strokes are fewer and of longer duration inasmuch as the work is revolving rapidly and permits of faster cutting. In filing rotating work very nearly all of the cutting edges should be brought into play, that is, one should stroke slowly from one end of the file to the other.

The file should be held in the hands in the same manner as for cross-filing in a vise, as previously described. If the amount of metal to be removed is considerable, the file should be held at an angle, and, if it has single cutting edges, at the angle which presents these edges, flat against the work. The file should be turned over frequently and held at the opposite angle, thus cutting crosswise of the grooves caused by the cutting edges of the file.

If a smooth finish is required and the amount of surface to be removed is nominal, the file should be held at right angles with the work and turned over frequently. It should be swept in even movement from the right to the left of the surface being filed.

It must be remembered that less pressure is required to make the file bite in revolving work than in stationary work. This permits the use of special files for rotating work with concave surfaces which would not suit at all for stationary work. If one does not desire to purchase special machine files, there is an opportunity for using up the old stock which have become so warped and worn that they are no longer suitable for accurate bench work. This applies to the cutting of the radial surface of rotating work. If one is to file a flat rotating surface, such as the end of a disc, one must use an accurate file with a convex surface, the same as for bench work.

Cleaning Files. It is quite important, if one hopes to minimize the purchase of new files, that the ones in use be carefully cleaned after each operation. If the particles of metal removed in the cutting operation become packed into the teeth, this greatly diminishes the cutting powers of the tool. This cleaning may be done to some extent by striking the edge of the file against a solid surface, but such a cure is not a good one. The work can be done more effectively by using a wire brush made for the purpose or by scraping the edge between the cutting surfaces with a thin piece of brass.

Presence of Grease. In filing any metal on the bench, it is well to assure yourself that all grease is removed both from the file and from the work. Grease tends to hinder the file from cutting into the metal. In steel work, where the job is revolving, the file may be frequently oiled, as this measure tends to keep the file clean.

When one is obliged to file objects in inaccessible places about an automobile, there is no rule which can be laid down other than to do the filing in the easiest possible manner. The work required is seldom so extensive that the file will be harmed, no matter how carelessly the work is done.

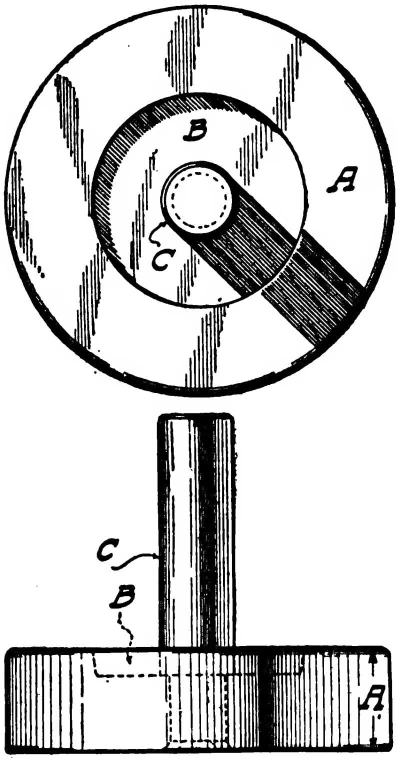


Fig. 9. Jig for Rebabbitting Bearings

REBABBITTING BEARINGS

Types of Jig to Use. There are still a few cars running which embody the old principle of solid bearings in which the bearing metal must be poured into the bearing container. This process is known as rebabbitting bearings. It is not good practice to use the main shaft for the purpose of casting the bearings, because the hot metal is apt to spring the shaft. A better plan is to use a wood jig such as shown in Fig. 9.

It is unfortunate but true that a new jig will probably have to be made for every different size of job, but the jig is easily turned in a lathe in one set-up of the chuck. The solid flange *A* should be about 1 inch thick and should have a diameter 1 inch or so greater than the outer diameter of the bearing. The shaft *C* should be turned to a size $\frac{1}{64}$ inch smaller than the size of the bearing surface, and should be about $\frac{1}{8}$ inch longer than the length of the bearing itself. Then on the shaft side of the flange *A* should be turned a groove *B* having a depth of $\frac{1}{4}$ inch and a diameter equal to the diameter of the hole through the connecting rod when the babbitt metal is removed.

Pouring the Babbitt. The jig is now ready for use. Fill the groove *B* with plastic fire clay even with the surface of the flange and place the bearing container over the shaft of the jig, as shown in Fig. 10. The bearing container should be adjusted over the shaft of the jig so that the space on all sides is exactly the same, determining this with a tapered steel gage, Fig. 11. Drop the gage into one side and note the mark on the taper where it comes to rest when touching the jig shaft and the bearing container. Then move the gage about and determine whether the other side is too close or too far away. Continue this operation until the space to be filled is the same on all sides. It is important that the machined surface of the bearing container rests perfectly flat on the block.

Fig. 10. Jig and Bearing Container Ready for Pouring

With everything properly located, lay a rim of fire clay about $\frac{1}{4}$ inch thick around the top of the bearing container, as shown in Fig. 5, so that the space between can be filled with bearing metal above the edge of the container to take care of contraction.

Everything is now ready for the pouring of the bearing metal, which has been melted in a ladle. Before starting to pour, make sure

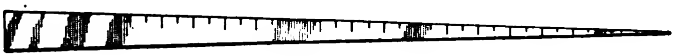


Fig. 11. Tapered Steel Gage

that all impurities which have risen to the top are skimmed off. These impurities, if allowed to pass into the bearing, might cause trouble later. Pour the metal from the ladle into the hole quickly and with a circular movement about the rim of the hole. It is important that it be poured in quickly, because babbitt cools very rapidly. However, this does not imply that the metal should be splashed in recklessly with the probability of throwing out the setting of the jig.

Finishing the Bearing. Allow the metal to cool for a period of 30 minutes and then remove the jig by pulling it out of the hole with a screwing motion. If care has been taken in placing the clay, the babbitt bearing will be held firmly in the bearing container. If the bearing is too tight for the crankshaft, it may be scraped to a proper fit as described in the next section.

When babbitt bronzes are to be relined, it is also necessary that there be a core to fit within the bronze, this core to be the size of the piece upon which the bearing operates.

Of course it is necessary, after the pouring has been done, to chip off the excess babbitt on the upper and lower surfaces of the bearing, smoothing down these edges after the bigger portion has been chiseled off by the use of a coarse file. The final polishing may be done with a fine file.

BEARING SCRAPING

To the amateur repair man, scraping bearings looks like a tremendous task. But if the proper facilities are at hand, it is a comparatively easy matter for a man with some shop experience.

Dismounting the Motor. In order to properly scrape both the connecting rod and the crankshaft bearings, the crankshaft must be removed. There is a method of scraping the crankshaft, or main, bearings without removing the crankshaft, but this operation is too difficult for the average repair man. The first step, of course, is to get the crankshaft out of the motor. This is done by first removing the motor from the frame, after it has been drained of all oil and water, and setting it on a motor stand, or on the bench if a stand is not available. The flywheel is now taken off, and then the cylinders. All that remains on the bench or stand is part of the crankcase with the crankshaft, connecting rods, and pistons. In most cases the removal of the pistons is necessary. By dropping the lower half of the crankcase, the crankshaft and connecting rods may be removed. This assembly should be placed on the bench and the connecting rods removed. Of course if the rods may be removed while in the motor, as is sometimes the case, it is advisable to do so.

Holding Crankshaft. A means of holding the shaft upright on the bench must be devised. Usually on the end of the shaft, there is a flange with a number of holes drilled through. Place the flange end of the shaft on the bench, as shown in Fig. 12, and mark on the bench with chalk the places under the holes. Drill holes through the bench where the chalk marks appear, and bolt the shaft to the bench, using as many bolts as you have holes. The bolts should be long enough to run through the bench and have 1 inch left over.

Cleaning and Fitting Connecting-Rod Bearings. With the crankshaft in the position shown in Fig. 12, clean the shaft thoroughly with gasoline. Emery cloth should be used to rub down any cuts which appear.

Cleaning Parts. Immerse the connecting-rod parts in gasoline, and then rub them dry. The connecting rods, like the cylinders, are numbered from the front to the back of the motor, and in working with them, never put a rod in any but its proper position; that is, rod No. 1 should always be fitted to wrist No. 1. The connecting rods are now ready for an initial fitting.

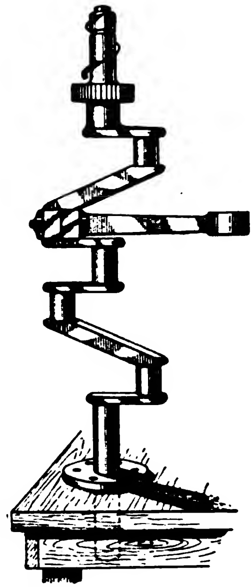


Fig. 12. Connecting Rod in Vertical Position for Adjusting Bearings

Putting Lampblack on the Crankshaft. The connecting-rod wrists on the crankshaft having been cleaned and polished thoroughly with emery, the wrist corresponding to the rod to be fitted is blackened with lampblack. Let us say that rod No. 1 is to be fitted. A little lampblack mixed with oil is rubbed on the wrist with the finger. Connecting rod No. 1 is then placed in position and tightened. In doing this, care should be taken that the nuts are tightened as they should be. Many repair men make the mistake of assuming that the nuts may be drawn up in any order whatever. This is wrong. First tighten one nut a little, then the opposite one a little, then a third and the one opposite about the same amount. Now go back to the first and go over the nuts in the same order. This should be continued until all the nuts are tight and the bolts drawn up as much as possible without springing them. The bolts are very easily stretched and, therefore, care should be taken that they are not tightened excessively.

Cutting-In Bearing. When all the bolts have been drawn up, turn the rod around in one direction for awhile, then run it back and forth for a few minutes, and then all the way around again. The entire operation of cutting-in the bearing, as it is called, should last about 8 minutes. Then take off the connecting rod. The connecting-rod bearing will be covered with little black spots, caused by the lampblack being embedded in the soft metal of the bearing. A piece of clean emery cloth should be used to rub the surfaces of the bearing. The rubbing should be continued until the surfaces are as clean as possible.

Filing Shims. If no black spots appear it is evident that the bearing was not touching the crankshaft at any point. If it is noticed that the rod does not fit snugly when the initial fitting is given, then the shims should first be filed. These are the thin pieces of metal which rest between the two halves of the connecting-rod bearing and regulate the tightness of the bearing. A filing block of wood should be made as shown in Fig. 13. The block should be gouged on its surface in two places so that the resulting shapes resemble those of the shims. They need not fit perfectly, but the indentations must be of the same depth and still too deep to prevent filing the surface of the shim. The shims, when placed in these grooves, are ready for filing. Both shims should be filed at the same time. The block should be placed in the bench vise or in a metal vise. Then a fine mill file should be run over the surface of the shims by holding the file as previously instructed. Do not file much, the object of filing being to bring the two halves of the bearing halves closer together so as to touch the shaft. It will be seen from this that considerable accuracy is necessary in filing shims. The shims should be perfectly level.

Fig. 13. Shims Mounted for Filing

Scraping Process. With the shims filed, place them in position and give the bearing another fitting. Remember the filing was done to bring the bearing together. When it is properly closed, the rod should fit tight enough to require some effort to push it around. Taking for granted that the bearing has been given a fitting and that it has been found to contain a number of black spots, as shown in Fig. 14, the scraping will be begun. For this operation a bearing scraper, Fig. 15, is used. This may be procured at any supply store. The scraper is held as shown in Fig. 14. However, one who is accustomed to scraping may be able to handle the instrument better in another position. One very important point must be borne in mind and that is that the word scraping does not mean — as it usually does—scratching; scratching is detrimental to the bearing. By scraping is meant cutting from the surface of the bearing a very thin shaving of metal and at the same time leaving the surface of the bearing smooth.

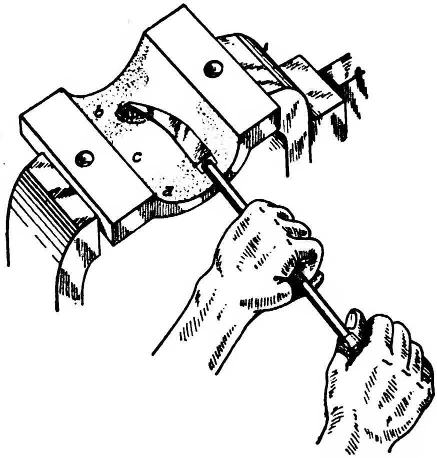


Fig. 14. Inside of Bearing Showing Spots Which Need Scraping

The real object of scraping is to get the bearing to touch the crankshaft at every point. A bearing may be said to be a good one if every $\frac{1}{32}$ inch of the surface touches the crankshaft. It will be supposed that the bearing needs scraping. It does not show little black spots every $\frac{1}{32}$ inch. Instead there are groups of spots, at each end as at *a* and *b*, Fig. 14, while in the center portion *c* there are no spots, which means that at this point the bearing is not touching the shaft at all. The object of the scraping is to make the center portion as well as the two ends touch.

The little black spots are scraped off one at a time or nearly so, using short clean strokes with the scraper and taking care not to roughen the surface of the bearing. The scraper should be moved

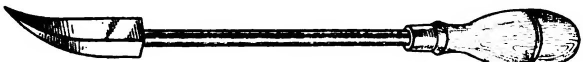


Fig. 15. Type of Bearing Scraper

sideways and at the same time a little forward. One hand is necessary to manipulate the scraper and the other to guide the tool.

After all the black spots have been removed, the bearing is thoroughly cleaned with a cloth. The wrist of the crankshaft is again blackened with lampblack and the rod given another fitting. If at this fitting the rod is loose, due to the bearing having been scraped too much, the shims should be filed a little. After the rod has been turned on the crankshaft for about 5 minutes, it should be removed and the bearing again examined.

Little black spots will again be seen, but this time they will be more evenly distributed if the bearing was properly scraped before. If the entire surface of the bearing contains black spots about $\frac{1}{32}$ inch apart, then the bearing is in good condition. But this holds true only if the rod holds snugly on the shaft. If the black spots are again grouped as shown at *a*, *b*, and *c*, then the individual spot scraping is repeated until the rod gives a snug fit and at the same time has the bearing touching uniformly.

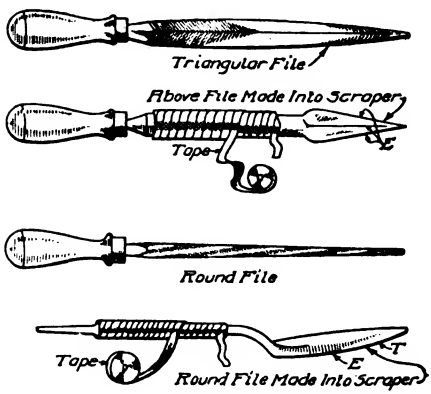


Fig. 16. Scrapers Made from Old Files

Bearing Scrapers from Old Files. Old files, when properly worked into shape and tempered, make excellent bearing scrapers. There are several advantages in favor of the use of a homemade scraper; first of all it is possible to make a scraper that will be more adaptable to the hands of the workman than the standard type.

In Fig. 16 is shown some of the types of scrapers best made from old files. The way to go about making a scraper is to select an old file resembling the type of scraper desired. Heat the file to a light-red heat and forge with a hammer, or bend in a vise as required.

When this is done, allow the file to cool slowly in the ashes at the side of the forge. When cool, it will be much softer than in its original state and most probably will be soft enough to be filed readily into the exact shape desired. If too hard to file conveniently, an emery wheel may be brought into service to shape the tool.

When the proper shape has been obtained, the next operation is to temper the tool. This is done by heating it again to a light red, then immersing the scraper portion in cold water and moving it about for a few seconds until it has entirely lost its red color. It should now be withdrawn and its bright surfaces quickly sandpapered so that the changes of color can be noticed; then when a light yellow or straw color appears, the whole tool should be immersed in water, moved about therein for a few minutes, and then left there until cold.

The last step in the manufacture of the homemade scraper is to grind the surfaces of the tool so as to get smooth sharp-cutting edges. The sharp-edge scraper will of course have its three cutting edges formed by hollow-grinding the surfaces so that about $\frac{1}{16}$ inch of the original flat surface remains on either side of the edge. These surfaces remain flat and afterward are smoothed up on an oil stone.

SOLDERING

General Instructions. It is quite necessary to make use of solder on various parts of the automobile, such as the radiator, the tanks, and the lamps, in spite of the fact that when subjected to stress or vibration such procedure is not considered best. Certain principles must be kept in mind if permanent work is to be accomplished. Cleanliness is a watchword; the surfaces to be joined must be clean, and this cannot be carried too far. Chemically, the metal must be clean as well as free from any oxide. The use of sandpaper or a file to clean and brighten the surfaces is recommended, and this work should be done immediately before the soldering process is begun. It is well to bear in mind that the surfaces of the metal as well as the solder must be hot if a permanent job is to be done. The solder must flow freely, otherwise it will not enter the pores of the metals. Always keep the soldering iron well tinned. Never let it get red hot.

Soldering Flux. The ordinary flux is made by placing zinc clippings in strong hydrochloric acid until no more will dissolve. Some special preparations which are noncorrosive give very good results in soldering. Work soldered with the zinc-hydrochloride as a flux should be thoroughly washed afterwards. A list of the more usual fluxes for the different metals is as follows:

FLUXES FOR SOLDERING

Iron or steel	Borax or sal ammoniac
Tinner iron	Resin or chloride of zinc
Copper to iron	Resin
Iron to zinc	Chloride of zinc
Galvanized iron	Mutton tallow or resin
Copper or brass	Sal ammoniac or chloride of zinc
Lead	Mutton tallow

Light Work. Light work in wire, sheet, and tubes of copper, brass, or iron can be soldered with an ordinary soldering iron, or in a Bunsen flame. The essentials are thorough cleanliness from grease and oxide of the parts and the iron itself, a suitable flux, a good quality of solder, and the iron brought to the right temperature.

Heavy Work. To solder a large tank or radiator, the water should be run out, the place to be soldered should be well prepared, and a large copper soldering iron—sometimes called a "bit"—should be used, preferably one which is automatically heated by a blow lamp. Such a repair is not easy to make, owing to the large cooling surface of the metal. The tank or radiator may have to be taken off the car in order to make the repair conveniently. A soldered joint, of course, will not resist much strain or vibration, and in some cases it is advisable to reinforce the repair by riveting. A brazed joint is much stronger, but brazing is a much more difficult process and should be done only by a skilled operator.

Fig. 17. Soldering Iron Heating Stove
Courtesy of Central Electric Company, Chicago, Illinois

Position of Work. Soldering requires time and judgment. Sufficient time must be given for the heat to flow from the copper to the work. Seams should be held horizontally to prevent the solder

Fig. 18. Electric Soldering Iron
Courtesy of Central Electric Company, Chicago, Illinois

from running away from the seam. The area of the joint being soldered must be large, as the elastic limit of solder is much below its tensile strength. Be sure that the soldered joint is not subjected to bending or other stresses that will localize the strain on the solder.

Use of Blow Torch. If two pieces of considerable thickness are to be soldered, the work cannot be done successfully with a soldering iron, as the metal absorbs the heat faster than the iron can supply it;

consequently, repairs of this kind are usually accomplished by the use of a blow torch. First the ends of the two pieces to be soldered are tinned—covered with solder separately. Then the two surfaces are put together and the blow torch applied, melting the solder and forming a perfect union. Another method sometimes used is known as sweating, in which the two pieces of metal to be joined are first heated by a blow torch in order that the heat from the actual process of soldering will not be so largely consumed by the metal itself. The more tin there is in solder the stronger it is, but it is harder to melt than that in which lead is the predominating element.

Special Stoves and Irons. Special stoves for heating soldering irons are made and vary in construction. Fig. 17 shows one of the most common forms of soldering-iron heating stoves. Some shops make use of an electric iron for soldering, wherein the temperature of the iron is uniform. Such a tool is shown in Fig. 18.

FITTING PISTON RINGS

Importance of Piston Rings. Notwithstanding the fact that the fitting of piston rings requires much accuracy, the average repair man is satisfied if the rings merely fit into the guides in the piston. If every repair man would only stop and think, he would realize that a great deal depends upon the condition of the piston rings and that considerable care should be exercised in fitting them to the piston.

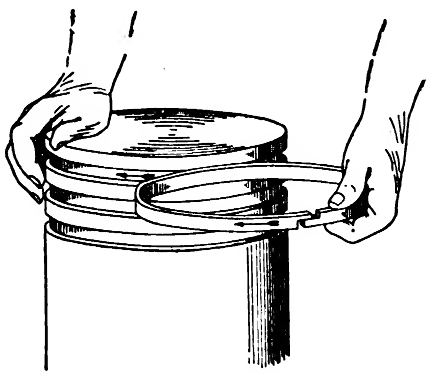


Fig. 19. Starting Piston Ring in Groove to Test the Fit

Fitting Ring in Groove. The first move in fitting rings is to get the grooves or guides of the piston thoroughly clean. This should be done by immersing the piston in gasoline and spraying it thoroughly to remove the least particle of dirt. Much time may be saved by trying the rings in the various grooves to see which ring most nearly fits a given groove.

In Fig. 19 is shown how the ring should be started in the groove, and the arrows show the direction in which the ring should be moved.

The entire circumference of the ring should be rolled around the groove. Of course, if the ring will not fit into the groove, try another groove. The reason the back end of the ring is fitted first instead of the inner is because the latter fitting would require that the ring be put in its usual position around the piston. Slipping the rings over the piston head is not easy in itself and would be difficult were the rings not of the proper size.

Testing and Correcting Length of Ring. The ring should next be inserted into the cylinder to determine whether the ends are the proper distance apart. The distance between the ring ends, when the ring is in the cylinder, varies with the different designs. An electric lamp dropped into the cylinder, while the ring is in, will show immediately whether the ends of the ring are touching. If they do touch, they should be filed slightly, as shown in Fig. 20. The ring should be placed in a vise with one end protruding about an inch. A little of the ring is left sticking out so that it will not sway when filing is being done. The file—a very fine mill file—is placed between the ends as the sketch shows, with the left hand pressing the long end of the ring lightly against the file. The operation should continue for a short time only, about twelve strokes of the file being sufficient. The ring should be put back in the cylinder and the distance between the ends measured with a thickness gage, or as it is called by factory men, a feeler. Fifteen-thousandths is a good distance to allow if the factory measurements cannot be obtained.

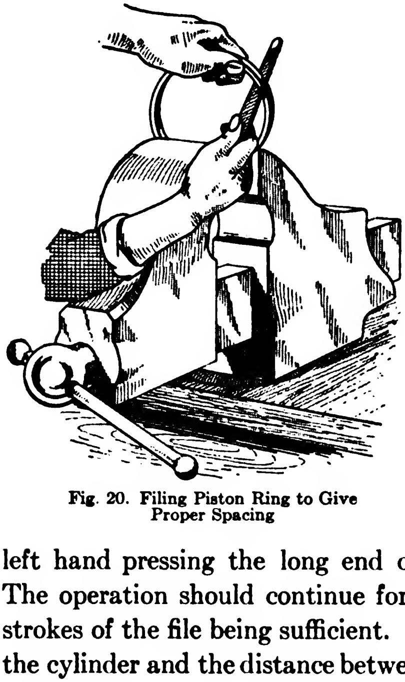


Fig. 20. Filing Piston Ring to Give Proper Spacing

Lapping In the Ring. The next step is to make the ring fit its groove properly. Lapping is the term applied to the operation of grinding the ring down so that it fits. A level steel surface is used, upon which is sprinkled enough very fine emery dust to cover it. Enough water is added to make a pasty mass. The ring is then placed on the steel plate and a block of wood about 6 by 6 inches placed on top of the ring; by exerting a slight pressure on the block and applying a rotary motion, the ring is moved about over the emery.

If the ring will not stay under the wood block, cut a little notch in the block to hold the ring still. After grinding for a few strokes on one side, the ring should be turned over and an equal amount of grinding done on the other side. The entire operation should not last longer than one or two minutes. After lapping, the ring should be immersed in clean gasoline and fitted to the groove which it most nearly fitted before. If every part of the circumference of the ring fits every part of the groove, then the lapping is complete and the ring may be tagged to designate its location. The figures 1-1 on a tag usually represents the first cylinder ring No. 1, this ring being the one nearest the top of the piston. If one part of the ring fits and another does not, the place that is too tight will show up when the ring is dipped in gasoline and then rubbed with a cloth. The high spot will be more shiny than the rest. Lay the ring perfectly flat and with a fine file take a little off from both sides of the ring. Only a little should be taken off at a time, and the ring should be tried after each filing.

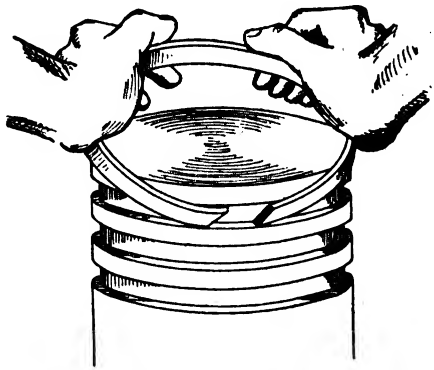


Fig. 21. Putting Piston Ring on Piston End

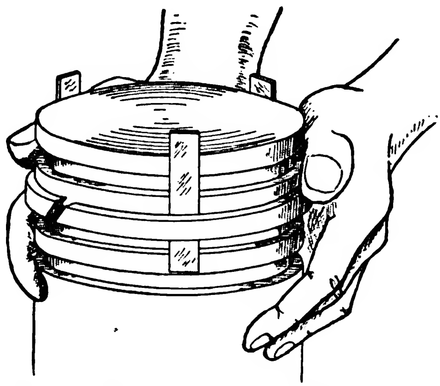


Fig. 22. Using Metal Strips in Properly Placing Piston Rings

Replacing the Rings. When all the rings have been filed in this way, the next step is to place them in their respective grooves, making them occupy their proper position when in use. In Fig. 21 is shown a method for doing this. Ring No. 4 should first be placed in position.

For this operation, three pieces of saw blade with the teeth ground off are used. Hold one blade against the piston with the left hand and with the right hand bring one end of the ring in contact with the blade. Get the blade about $\frac{1}{2}$ inch from the end of the ring, so that the blade can be held in place by pressure against the ring. Then slip the ring over the piston top. There is a space on either side of the blade through which the other blades may be inserted. Push the blades around until they appear as shown in Fig. 22. By sliding the ring on the three blades, it may be placed easily in its groove. With the lapped ring in its groove, the ring must fit so that it may be turned around easily. No up and down play must exist.

Miscellaneous Adjustments of Rings. There are several things to be looked for to determine whether the piston rings are functioning as they should. If gas has been working its way past the rings or if the rings have not been fitting the cylinder walls properly, points where the gas passed will be evidenced by burned, browned, or roughened portions of the polished surface of the piston and rings. Points where this discoloration is noted will more often be at the thin end of an eccentric ring, the discoloration being apparent about $\frac{1}{2}$ to $\frac{3}{4}$ inch each side of the slot. Possibly the rings were not true when put in.

It is well to bear in mind that before replacing pistons in the cylinders one should make sure that the slots in the piston rings are spaced equidistant on the piston. If pins are used to keep the rings from turning, one should be careful to make sure that these pins fit into their holes in the rings and that they are not under the rings at any point. Putting pistons in cylinders really requires the use of two pairs of hands. The manipulation of pistons is discussed in Gasoline Automobiles, Part I.

Fitting New Rings. Fitting new rings will not prove of advantage unless the cylinders are in good condition. Before making a new ring installation, make sure that the cylinders are not out of round, warped, or scored. If found to be so, they should be reground and oversize pistons and piston rings installed. Piston rings must have a uniform wall pressure of sufficient strength to maintain a bearing against the cylinder walls during every revolution of the engine. Piston rings that will assume the shape of the worn or warped cylinder do not have the necessary wall pressure and will collapse under the force of expansion.

USE OF MICROMETERS

Principle of Operation. In case measurements are required to be more accurate than can be obtained with the ordinary calipering devices, the micrometer caliper, as shown in Fig. 23. is used. The accuracy of its measurements is determined, not by direct setting to two lines, but by finely dividing the pitch of the measuring screw and furnishing means for reading these subdivisions. It is a registering as well as an indicating caliper, and thus serves the purpose of a common caliper in combination with a rule, but with a much greater degree of accuracy.

Essentially, the micrometer caliper consists of a crescent-shaped frame carrying a hardened steel anvil *B* at one end and a nut of fine pitch at the other, the axis of the nut being at right angles to the face

Fig. 23. Transparent View of Micrometer Caliper with Friction Stop
Courtesy of L. S. Starrett Company, Athol, Massachusetts

of the anvil. The outside of the nut *A* forms a projection beyond the crescent that is called the barrel. The measuring screw consists of a finely pitched screw to fit the nut, combined with a measuring point *C*, having a face parallel with that of the anvil. To the outer end of this screw is firmly attached a thimble *D*, which fits closely over the barrel. The edge of this thimble is beveled at *A* so that graduations placed on the edge come very close to the barrel. A reference line is drawn on the barrel, parallel to its axis and graduated to represent the pitch of the screw. The chamfered edge of the thimble is so divided that the movement of one division past the reference line on the barrel of the instrument indicates a movement of the measuring point of .001 inch. To illustrate: if the pitch of the measuring screw is .01 inch, there should be ten divisions on the thimble; if .02

inch, twenty divisions; if .04 inch, forty divisions. Most measuring screws have a pitch of .025 inch and these are the type usually used, every fourth dimension on the barrel being lengthened and numbered to indicate tenths of an inch.

How to Use Micrometer. When using the micrometer caliper, it should not be set to the size desired and pushed over the work, but should first be opened, then screwed down until the measuring point *C* and the anvil *B* are in contact with the work. The size may then be read by taking the number of scale divisions on the barrel and adding the value of the parts on the thimble corresponding to the reference

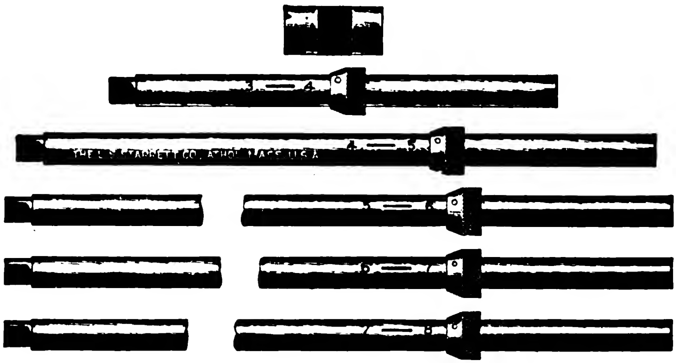


Fig. 24. Inside Micrometers
Courtesy of L. S. Starrett Company, Athol, Massachusetts

line on the barrel. The proper degree of pressure to be applied to the screw is acquired only after extended practice, and some manufacturers place a friction device on the thimble, as shown at the extreme right of Fig. 23, so that undue pressure cannot be exerted.

Value of Micrometer. The value of the micrometer caliper cannot be impressed too strongly upon the user. Not only does it show when work is too large or too small, but it gives the exact amount of variance in desired measurements. It is a distinct improvement over the caliper and enables the user to work with accuracy. The 1-inch size is the most common, but micrometers may be obtained in all sizes up to 20 inches. Using the micrometer for inside measurements is not the usual application, but it is easy to arrange and makes a very simple instrument, as shown in Fig. 24. The ordinary micrometer head is used, except that the outer end of the thimble carries a contact point, attached to a measuring rod which may be of any length. The shortest distance that can be measured with this device is about 2 inches, but there is hardly any limit to length, since the rigidity of the rod is easily accounted for. It is evident that such rigidity is harder to obtain in the curved shape necessary for outside measurement, which fixes the outside limit of this form to about 20 inches.

Reading the Micrometer. All readings are in thousandths. The usual micrometer has forty threads to the inch and the thimble has twenty-five divisions on its circumference. The barrel is divided to correspond to the pitch of the screw with each fourth division numbered. In reading, first note the highest numeral visible on the barrel and express it as so many hundred thousandths; then read the short divisions on the barrel, calling the first division twenty-five thousandths, or .025; the second, fifty thousandths, or .050; and the third, seventy-five thousandths, or .075. Now read the number indicated on the thimble, that is, the number that has passed the line running lengthwise. Add this reading to the readings of the short divisions. The result of adding the highest numeral visible on the barrel, which is expressed in hundred thousandths, the short divisions on the barrel and the number indicated on the thimble, give the distance from the anvil to the measuring point. If the micrometer caliper is a good one, we may be sure the distance does not exceed or fall short of the figures given by .001 inch.

LAPPING CYLINDERS

Worn Cylinders. Where a cylinder of an automobile engine has become worn slightly out of shape or where the rings do not bear equally on the surface of the cylinder wall, the defect may be remedied entirely or to a great extent, depending on the magnitude of the defect, by lapping the cylinder wall. This measure will not cure the cylinder which has become scored but applies only to one which has been worn a very few thousandths of an inch out of round.

Lapping by Hand. The job can be done satisfactorily only by using an old piston of the same bore as the cylinder which is being worked upon. If one does not have a drill press, the hand operation, which will give a very satisfactory job, should be done as follows: Support the cylinder in its inverted position on the work bench. Inasmuch as practically all motors of present-day construction are of the block cast type, this heavy casting should be well supported in an upright position in order that the lapping may be done conveniently.

Cleating Down the Casting. Probably the best and easiest way to support the casting is by cleating it to the bench, as shown in Fig. 25. If the motor is a four- or six-cylinder block-cast type, use three sets of cleats on each side. These consist of a block of wood laid against the side of the cylinder block and clamped in place by wood pieces mitered off at a 45-degree angle, the mitered edge of one end nailed to the block and the mitered edge of the other end nailed to the work bench. This cleating will support the block substantially.

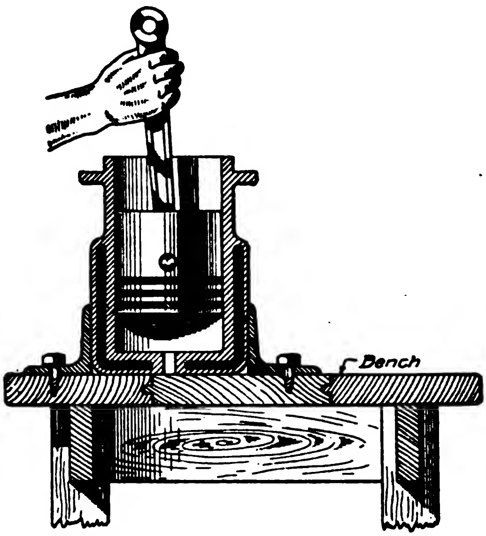


Fig. 25. Cleating Casting to Bench

Proper Fit for Piston. Before proceeding with the work, one must determine that the old piston which is to be used is a proper fit in the cylinder to be lapped. It must be such a tight fit as to require considerable pressure to move it up and down. On the other hand, a loose fit will mean uneven grinding and a great deal more work to obtain the proper lapped surface.

The piston should have a connecting rod fitted into it, or better still, a rod of such a length that it will protrude about 18 inches above the top of the piston. If one contemplates an extensive business in cylinder lapping by the hand method, it would be well to fit up a number of standard size pistons with rods such as just described. The connecting rod itself, however, will serve the purpose if the jobs are so few that they do not merit the special tools.

Emery Paste. With the cylinders blocked up on the work bencn and a suitable piston at hand, one is ready for the lapping operation. There are several pastes on the market made up of fine emery and an oil body which are excellent for lapping work. However, one can make the necessary material himself with very fine emery dust, ordinary motor oil, and a bit of graphite worked into the paste. This compound should be made up to the consistency of library paste and applied thoroughly to the walls of the cylinder to be lapped and to the surface of the piston to be used for the lapping.

When applying the paste, watch the surface upon which it is being applied with great care, especially if the paste has been made up previously and allowed to stand around the shop for some time. It is very easy for metal chips and filings to be dropped into the paste, and if these get into the cylinders when the lapping operation is under way, they are liable to scratch, or score, the surface.

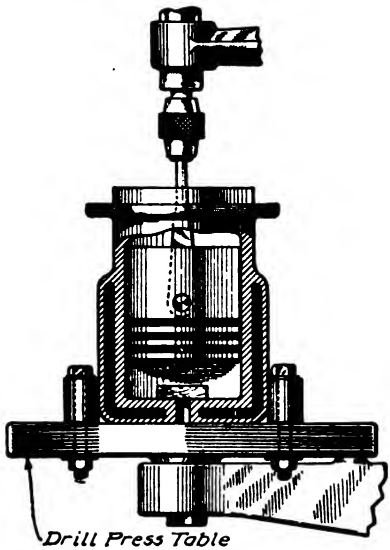


Fig. 26. Cylinder Mounted on Drill Press Bed for Lapping Job

Grinding Process. Lower the piston into the cylinder and proceed with the lapping. In performing this, lower and raise the piston, at the same time maintaining a circular motion, thus turning the piston around so that all surfaces of the piston will be brought to bear upon all parts of the cylinder.

This operation should be continued for a period of from 15 to 30 minutes, depending upon the condition of the cylinder interior. It will not remove scratches and scores and will not iron out a warped or egg-shaped cylinder, but it will dress down the small humps and impart a very smooth glass-like finish to the cylinder walls.

Lapping by Drill Press. If the repair shop is equipped with a fair size drill press, lapping can be performed quickly on this machine. It is especially easy when one has to deal with separate cast cylinders inasmuch as these can be clamped into the drill-press bed without need of special supports, Fig. 26. However, if the job is a block-cylinder casting, one must provide some means of support outside of the drill-press bed and inasmuch as it is a matter of blocking from the floor, it is for the ingenuity of the repair man to devise the best method.

Piston Rod. In drill-press lapping of cylinders it is, of course, necessary that a rod be used to take the place of the connecting rod, this rod to fasten to the wrist pin at one end and be so shaped as to lock into the chuck of the drill press at the other end.

It is well to cut a block of wood which when dropped into the inverted cylinder will come up to the line which marks the top of the piston stroke. To lap the cylinder, the old piston is coated with the lapping paste as previously described and let down into the cylinder. The drill press must be turned at its lowest possible speed. When the lapping is going on, the drill-press arm should be let up and down so that the position of the piston is constantly changing within the cylinder. Of course lapping by this method can be accomplished in about half the time required by the hand method.

Cleaning after Grinding. At the completion of hand or machine lapping, the cylinder interior should be thoroughly washed out with gasoline and the surface polished with a soft cloth. It is imperative that all emery be removed from the cylinder as it would undoubtedly injure the bearings or some other part of the motor, after the motor has been assembled and run.

DRILLING

Types of Drills. There are two kinds of drills which are found in modern repair shops, the *twist* drill and the *flat* drill. The former is the one which is used in practically every kind of work, although the flat drill has as its function the performance of certain operations which the twist drill will not handle at all.

Flat Drills. The flat drill, Fig. 27, is the simplest and, incidentally, the oldest type; until the invention of the twist drill, the flat drill was used for all drilling work. It is made from a piece of round stock, on the end of which are forged thin lips which are ground with three cutting edges, the edges being on the V-shaped end of the tool. For the performance of accurate work the flat drill is a poor tool, its field being in rough drilling of extremely hard metals. As a deep hole drill it is useless because it does not free itself of chips. For drilling out a cored hole in an iron or steel casting preparatory to boring, the flat drill is superior to the twist drill, inasmuch as this work is very injurious to the twist drill because of scale and sand which is bound to be within the core.

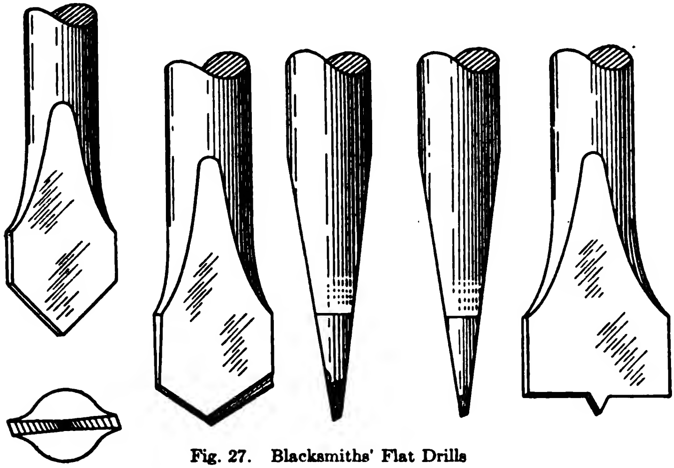


Fig. 27. Blacksmiths' Flat Drills

Twist Drills. In small drill sizes, the twist drills come in straight shanks, Fig. 28, while in the larger sizes, taper shanks, Fig. 29, are most generally used. The shank is the part of the drill which fits into the holding device whether it be the chuck of a drill press or a bit.

Fig. 28. Typical Twist Drill
Courtesy of Union Twist Drill Company, Athol, Massachusetts

As will be seen from the illustrations, a twist drill is fluted or grooved in spirals which follow the direction of rotation of the drill. These flutes serve to carry the chips from the cutting edges which, as is the case with the flat drill, are on the V-shaped end of the tool; the

Fig. 29. Taper Shank Twist Drill
Courtesy of Morse Twist Drill Company, New Bedford, Massachusetts

flutes also act as a channel through which lubricant may be directed to the cutting edges. For small drills the blanks are usually made from steel wire and for large drills from round steel stock. The flutes are milled into the tool.

TABLE I

Morse Tapers

No. of Taper	Taper per Foot	Smallest Drill Using Each Taper (in.)	Largest Drill Using Each Taper (in.)
1	.605	$\frac{1}{8}$	$\frac{19}{32}$
2	.600	$\frac{39}{64}$	$\frac{29}{32}$
3	.605	$\frac{59}{64}$	$1\frac{1}{4}$
4	.615	$1\frac{17}{64}$	2
5	.625	$2\frac{1}{64}$	3
6	.634	Special	Special

Grinding Drills. Great care must be exercised in grinding the twist drill. The angle of lip clearance—the lips being the cutting edges—should be greater at the center than at the outside of the lips. This is to permit the part of the drill which first touches the metal to be drilled to bite in. The usually accepted angle is about 12 degrees, as shown in Fig. 30. If the difference in the angle on the lips is too great, the drill bites too quickly, which may result in tearing off or chipping the cutting edges. If, on the other hand, the angle is too small, the cut is slow, and the drill will consequently heat excessively. Although there are a number of drill grinders on the market which do satisfactory work, the use of drills in a motor-car repair shop is seldom sufficient to warrant the purchase of one. After a little experience with drilling, one can determine the angles which give the best results by the "feel" of the drill and the dull drills can be ground accordingly.

Sizes of Drills. The taper-shank drill is made in six sizes and the shank has the Morse taper. The exact taper and the limiting sizes for which each drill is generally used are given in Table I.

These taper-shank drills are carried as regular stock in all sizes by 64ths from $\frac{1}{8}$ to $2\frac{1}{2}$ inches and by 16ths from that size up to 3 inches. If one needs a drill larger than 3 inches, which would surely be a rare occasion in garage work, that drill would have to be made to order.

The wire gage sizes run by number rather than by dimensions, ranging from No. 80, the smallest twist drill made, up to No. 1.

TABLE II

S.A.E. Standard Taps and Drills

Sizes of Taps	Sizes of Drills
1/4 inch × 28 threads.........	7/32 inch
5/16 inch × 24 threads.........	17/64 inch
3/8 inch × 24 threads.........	21/64 inch
7/16 inch × 20 threads.........	3/8 inch
1/2 inch × 20 threads.........	7/16 inch
9/16 inch × 18 threads.........	1/2 inch
5/8 inch × 18 threads.........	9/16 inch
11/16 inch × 16 threads.........	39/64 inch
3/4 inch × 16 threads.........	43/64 inch
7/8 inch × 14 threads.........	51/64 inch
1 inch × 14 threads.........	59/64 inch
1 1/8 inch × 12 threads.........	1 1/64 inch
1 1/4 inch × 12 threads.........	1 9/64 inch
1 3/8 inch × 12 threads.........	1 17/64 inch
1 1/2 inch × 12 threads.........	1 25/64 inch

The above tap drills allow a thread within 1/64 inch of full thread.

Speed of Drills. The speed at which drills are driven has an important bearing on their wearing quality. Of course small drills can revolve faster than large drills. The proper feeds for drills—which means the speed of cutting as regards depth—varies with the kind of metals which are being cut. A very small drill can cut .02 inch per revolution in cast iron; a large one can cut no more than .005 inch.

Lubrication. For cutting malleable iron or steel the drill must be continually flooded with oil, while in cast-iron, aluminum, and brass drilling, the cutting is performed dry.

TAPPING

Standard Threads. Tapping is that process of cutting on the walls of a drilled hole a series of threads into which a screw is to be

Fig. 31. Section of V-Thread

Fig. 32. Section of United States Standard Thread

fitted. In practically every instance in motor-car practice, the standard taps and drills specified by the Society of Automobile

TABLE III
Drill Sizes for Standard Threads

Size Screw	No. of Threads	Size of Drill			Size Screw	No. of Threads	Size of Drill		
		U.S.S.	V	W			U.S.S.	V	W
1/4	24	.201	.196	.202	15/16	9	.808	.790	.810
1/4	20	.191	.184	.192	1	8	.854	.832	.856
5/16	18	.248	.239	.249	1 1/16	8	.917	.894	.919
3/8	16	.302	.293	.303	1 1/8	7	.957	.932	.960
7/16	14	.354	.345	.355	1 1/4	7	1.082	1.057	1.085
1/2	13	.409	.399	.410	1 3/8	6	1.179	1.144	1.182
1/2	12	.402	.391	.403	1 1/2	6	1.304	1.269	1.307
9/16	12	.465	.453	.466	1 5/8	5 1/2	1.412	1.372	1.416
5/8	11	.518	.506	.520	1 5/8	5	1.390	1.347	1.394
11/16	11	.581	.568	.583	1 3/4	5	1.515	1.472	1.519
3/4	10	.632	.618	.634	1 7/8	5	1.640	1.597	1.644
13/16	10	.695	.680	.697	1 7/8	4 1/2	1.614	1.566	1.619
7/8	9	.745	.728	.747	2	4 1/2	1.739	1.691	1.744

The above sizes give an allowance above the bottom of the thread on sizes 1/4 to 2, respectively, varying as follows: for V-threads, .010 inch to .055 inch; for U.S.S. and Whitworth threads, .005 to .027 inch.

These are found by adding to the size at the bottom of the thread one-quarter of the pitch for V-threads and one-eighth of the pitch for U.S.S. and Whitworth, the pitch being equal to 1 inch divided by the number of threads per inch.

In practice it is better to use a larger drill if the exact size called for cannot be had.

Engineers, Table II, will be used. Drill sizes of U.S.S., V-Standard, and Whitworth threads are given in Table III.

The V-thread is shown in Fig. 31. The U.S.S. thread, Fig. 32, is the same as the V-type except that the tops are cut off and the roots, or bottoms, of the threads are filled in. It is more cheaply produced than the V-thread and does not cut so deeply into the stock, leaving a stronger root. In the Whitworth, or English Standard threads, the tops of the threads are rounded off and the roots are concave. In the S.A.E. Standard thread the U.S.S. principle of construction is used.

Taps. The tools used to cut internal threads is known as a tap, external threads being cut with a die. There are hand taps and machine taps. The difference is principally in the shank. Hand taps have round shanks which are milled square on the end to receive the tap wrench. Three types of taps, called the taper, plug, and bottoming taps, Fig. 33, generally constitute a set.

Taper Tap. The taper tap has straight sides on the point end for a distance of one-fourth the diameter of the tap. The teeth at the shank end are parallel for a length equal to the diameter of the tap.

Fig. 33. Types of Hand Taps: Left—Taper Tap; Center—Plug Tap; Right—Bottoming Tap
Courtesy of Wiley & Russell Manufacturing Company, Greenfield, Massachusetts

The teeth between these parallel teeth and the straight sides are tapered. This gives a graduated cutting depth for the teeth, the front teeth cutting less stock than the back. This tap is best suited for starting a thread, but unless the hole goes entirely through the piece that is being tapped there will, of course, be a space in the bottom of the hole equal to one-fourth the diameter of the hole which will not be threaded.

Fig. 34. Wiley & Russell Pipe Tap

Plug Tap. The plug tap is most commonly used. It has three teeth on the end, tapered off so that while useful to start the thread, they will bottom a hole sufficiently to take a bolt with a tapered or round end.

Bottoming Tap. The bottoming tap is useful to finish out the thread started by a taper tap when the hole does not go entirely through the piece.

There is frequent use in garages for pipe-plug taps, Fig. 34. As will be seen, they are more stocky than bottoming taps, and, of course,

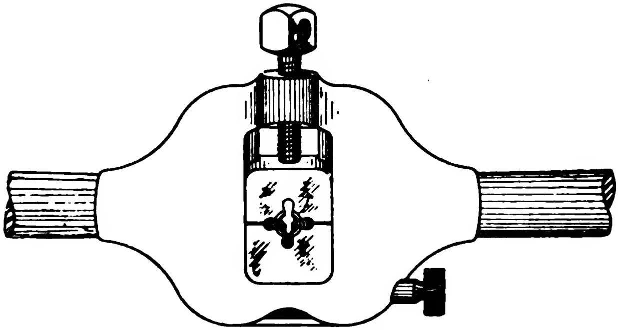


Fig. 35. Threading Die Holder

have a taper throughout the surface of the cutting area to take care of the taper threads required by a pipe plug.

Tapping Process. It must be remembered in using taps that, because of the nature of the work they are called upon to do, they are tempered hard and the cutting edges are very brittle; they must, therefore, be handled with great care. In hand tapping the process

Fig. 36. Two Forms of Adjustable Dies; Left—Card Die with End Taper Screw; Right—Wiley and Russell Die with Side Taper Screw

simply cannot be rushed; the tap must be turned slowly forward about half a turn and then back, advancing the wrench a little each time with an even stroke. As previously mentioned, a wrench must be used which fits over the square end. The pressure of both hands operating the opposite handles of the wrench must be even.

Dies. There are two kinds of dies. One is the split type which requires several settings before the thread is completed and the other which completes the work in one operation. The first kind is shown in Fig. 35, the assembly consisting of a stock or wrench in which the cutting die is held. These dies, for a specified size, may be opened up until the cutting edges will slide over the work and then, when fully closed, will give the completed thread of the correct dimension.

Dies which complete the thread in one operation are made adjustable for wear. They are made up in a solid round piece with one side cut away with a slot, as shown in Fig. 36, so that wear may be taken up by means of a taper-set screw.

Oil should always be used in abundance on taps or dies. When one is threading steel or malleable iron, it is well to turn the die back after every three or four turns forward.

In cutting threads with taps and dies in the lathe, the speed with which the tools may be operated is a very important consideration. Cast iron, brass, and aluminum can be threaded at a much higher speed than steel, but a tap or die must not be run as fast as a drill. A speed of 10 feet per minute in hard stock is a fair average.

REAMING

Function of Reamer. Reamers find their place in the production of round, straight, and smooth holes, uniform in diameter, as required

Fig. 37. Solid Hand Reamer

in the construction of accurate machinery, requirements which a drill cannot always be relied upon to meet. The reamer is a sizing tool

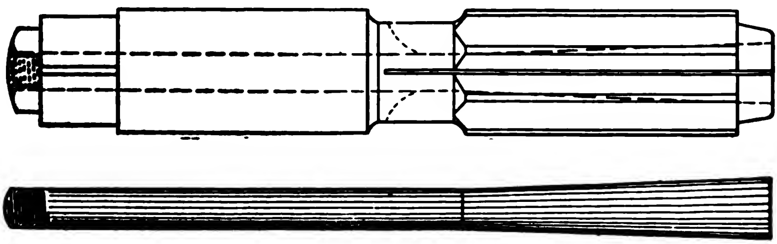


Fig. 38. Expanding Reamer and Arbor

having two or more teeth either parallel or at an angle with each other, the latter forming what is known as a taper reamer. These teeth may be either straight or spiral, a spiral tooth producing a shearing cut and a straight tooth a square cut.

The construction of reamers divides them into two general classes—solid, and adjustable, or expansion, types. A solid reamer, Fig. 37, has a shank and teeth made from a single piece of tool steel. All taper reamers come under the solid class. The expansion reamer is a built-up tool, the usual form consisting of a shank and head, with an expanding arbor passing down through the center, Fig. 38. As adjustment to compensate for wear only is attempted, the amount of expansion is small.

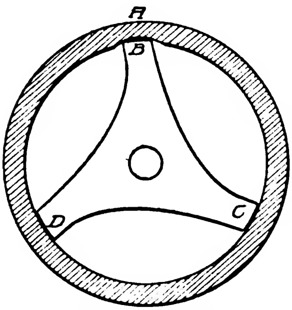


Fig. 39. Diagram Showing Action of Three-Lipped Reamer in Irregular Hole

Number of Teeth. Number, form, and spacing of teeth are important considerations. Reamers having fewer than five teeth are not to be used where an accurate cylindrical shape is desired. A reamer having three teeth cannot be depended upon to produce round holes, inasmuch as any irregularity in the hole being reamed affects the cutting of the tool. For example, suppose a depression *A*, Fig. 39, exists in the drilled hole; if tooth *B* comes to this point and drops in, the cutting of *C* and *D* is decreased, thus producing a hole that is not round. The same effect to a lesser degree is shown in Fig. 40. When the cut is relieved at *A*, the pressure of the cut *C* will crowd the tool toward *E*. Since the pressure of the cut at *B* and *D* balance each other, any decrease of the cut at *C* causes an increase at *D*, and *B* and *C* will overbalance *D*, the body of the reamer moving an appreciable distance toward *E*. With five or more teeth this effect practically disappears. The more cutting edges, the more smoothly will the reamer work. The construction of adjustable reamers does not admit of as many teeth as can be formed on a solid reamer, yet the advantage of adjustability to a certain extent offsets this.

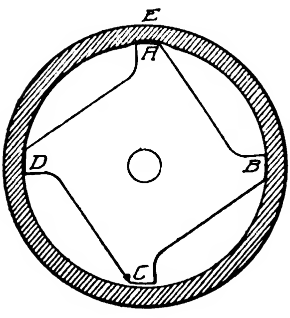


Fig. 40. Diagram Showing Action of Four-Lipped Reamer in Irregular Hole

Where reamers have a number of teeth equally spaced, they do not produce so good results as those having an odd number of teeth. In the former, the teeth fall opposite each other, causing greater tendencies to vibration, and in the case of reaming irregular holes, the greatest cut will be carried on two opposite teeth. With an odd number of teeth the greatest cut must be carried on at least three teeth. Extensive use of reamers having an even number of teeth irregularly spaced is common. This gives practically the same effect as having an odd number of teeth.

Clearances. Grinding of the clearance on top of the tooth is an important point in the construction of a reamer. The clearance should be sufficient properly to relieve the cutting edge, as shown in Fig. 41. If too great a clearance is given, the tooth will be weak and chatter in the work. As is frequently produced, the cleared surface is slightly concave, the amount depending upon the diameter of the emery wheel used in grinding it. As a plane surface is desirable, a wheel of large diameter which gives approximately such a surface should be employed, or better still, the face of a cup emery wheel which gives a straight clearance.

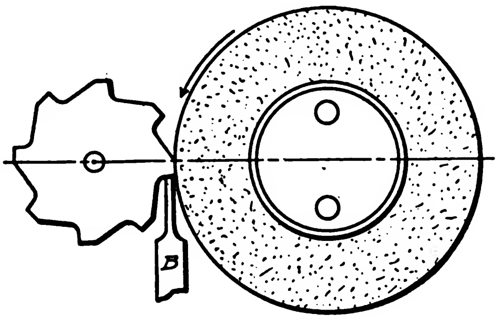


Fig. 41. Diagram Showing Method of Grinding Reamer for Clearance

Clearance Angle. Clearance angle will depend largely on the distance the axis of the emery wheel is set back of the axis of the reamer. In no case must the wheel come in contact with the front face of the tooth being ground on the one next behind, and the guiding finger which steadies the reamer must always bear against the front face of the tooth being ground. When the diameter of the reamer is large and the pitch of the teeth so small that the necessary clearance cannot be given except by using too small an emery wheel, the wheel can be mounted on an axis at a considerable angle to the axis of the reamer. This produces a plane surface, but because of the wear of the emery wheel, it is not so satisfactory as the use of the cup wheel.

The wheel must be so placed as to cut its entire width, otherwise it will be grooved and the cutting edges of the tooth rounded off.

Characteristics of Hand Reamings. Reamers for hand use are made in two lengths, what is known as the *short* reamer being considerably shorter both in the flute and in the shank than the regular, or *jobber's*, reamer. The diameter of the point is about $\frac{1}{64}$ inch under size, the tool tapering to exact diameter at about one-fourth of the length of the tooth from the point. The remainder of the teeth are ground nearly parallel, the diameter of the shank end being from .0005 to .00075 inch small. This slight taper counteracts the tendency that all reamers have to ream a hole slightly over size at the top, which is due to the tool remaining longer in contact with the wall of the hole at the top than at the bottom. The limit of error allowed in their manufacture does not exceed .00025 inch.

Kinds of Reamers. The *spiral-fluted reamer* always is cut with a left-hand spiral. It gives a smooth shearing cut and is especially

Fig. 42. Reamer with Inserted Blades
Courtesy of Brown and Sharpe Manufacturing Company, Providence, Rhode Island

valuable for machine reaming on centers as it does not tend to draw into the work and off from the center. They are also made in shell and taper form.

A *fluted chucking reamer* with a taper shank is not unlike a hand reamer. The teeth are short and slightly tapered at the point, which facilitates starting when used against the dead center of a lathe.

The *three-flute chucking reamer* has a long shank, and the fluted portion is ground cylindrically true and is especially adapted to the reaming of deep-cored holes.

Those classes of adjustable-blade reamers in which each blade is set out independently, Fig. 42, should be reground after each adjustment, as it is almost impossible to set the blades out equally. In using a reamer it should be turned continually forward. Never turn it backward for withdrawal, as this is likely to injure the tool. Oil should be used freely in reaming steel or wrought iron. Cast iron and brass are usually reamed dry. A small amount of oil, however, frequently improves the quality of work in these metals.

FITTING TAPER PINS

Determining Amount of Taper. In order to set the slide rest of the lathe at the proper angle for boring or reaming any degree of taper, measure the diameter of the circular rest-seat, Fig. 43, and

Fig. 43. Compound Tool Slide Rest

describe a circle of that diameter on a flat surface, marking the center of the circle and drawing a radial line *AH*, Fig. 44; mark off on *AH* a distance *AB* equal to the diameter of the small end of the taper hole to be bored and draw the line *AG* at right angles to *AB* and of a length equal to the length of the taper to be bored. Draw *GB* parallel to *AB* and of a length equal to the diameter of the large end of the taper. Connecting *D* and *B*, the distance *EF* measured on the circumference of the circle between the lines will equal the amount that the rest must be swiveled to cut the desired taper.

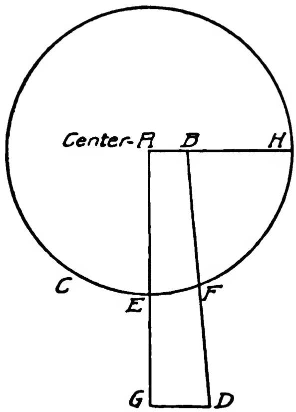


Fig. 44. Diagram for Determining Slide Rest Setting to Give Certain Taper

Reamers and Taper Pins Available. The Pratt & Whitney Company makes standard taper reamers with a taper of $\frac{1}{16}$ inch per foot and diameters from $\frac{1}{4}$ inch up; also 4-inch length of flute up to 2 inches in diameter; finally they make 18-inch length of flute, diameters advancing by 16ths and 32nds. The Pratt & Whitney standard taper-pin reamers taper $\frac{1}{4}$ inch per foot and are made in fifteen sizes.

Brown & Sharpe make eighteen sizes of tapers ranging from 0.20 inch to 3 inches in diameter at the small end; taper 0.5 inch to 1 foot, except the number 10, which is 0.5161 inch per foot.

The Jarno taper is 0.05 per inch, or 0.6 inch per foot. The number of the taper is its diameter in tenths of an inch at the small end, in eighths of an inch at the large end, and the length in halves of an inch. Thus, No. 3, Jarno taper is $1\frac{1}{2}$ inches long, 0.3 inch in diameter at the small end and $\frac{3}{8}$ inch in diameter at the large end.

HAND KEYSEATING

Hand keyseating is that process of cutting a groove into a piece of metal into which a key will fit accurately. The need of accuracy in keyseating is the great drawback to the hand method inasmuch as it is a tedious job to cut a true seat with a chisel.

Keyseating Process. The roughing out of the keyseat is done by chipping, a process already described. The first thing to determine is the size of the keyseat, and this is obtained from the S.A.E. table of standard sizes of keyseats, Table IV. It is well to have a chisel with a cutting surface about $\frac{1}{8}$ inch smaller than the width of the keyseat to be cut, although with a large keyseat a smaller chisel will do the work but with somewhat more cutting. A cape chisel, Fig. 4, is the tool used for keyway cutting.

Laying Out the Keyway. The next operation is to very carefully mark off the keyway with scratched lines or chalk, the distance between the lines to be from $\frac{1}{16}$ to $\frac{1}{18}$ inch less than the width of the key. Use these lines to guide the chisel and cut the keyway to a depth approximately within $\frac{1}{16}$ inch of the depth of the finished keyway. One must always leave sufficient stock on the sides and bottom of the keyway for an accurate finish filing.

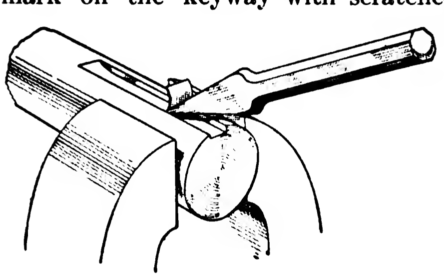


Fig. 45. Chipping Keyseat in Round Shafting

Chipping. The work is held in a vise, and the chipping is done by grasping the chisel firmly with the left hand, holding the cutting edge to the work and striking the head of the chisel with the hammer, Fig. 45. The eyes must be kept on the cutting edge of the chisel to

TABLE IV

Standard Sizes of Keyseats

For straight keys, height of keyseat $= D$
For feather keys $D = \frac{1}{2}A$
Keyseat in shaft same depth as D in small end
Standard Taper $= \frac{1}{8}$ inch per foot.

watch the progress of the work. The beveled side of the chisel is the guiding surface and this should be held at a very slight angle with the surface of the work that is being cut. Of course, to increase or decrease the amount of the cut, it is only necessary to raise or lower the chisel. If the hand is carried too low, the tool will run out before the end of the cut; while if the hand is carried too high, the chisel will gouge into the stock and make the progress of the work slow. In steel, malleable iron, and cast iron, the depth of the cut should vary from $\frac{1}{16}$ to $\frac{1}{8}$ inch, but should never be greater than the latter figure.

Chipping Malleable Iron and Steel. When chipping malleable iron or steel, one should keep on the work bench a piece of waste or cloth saturated with oil. After each complete cut is made through the work, the chisel should be rubbed in this waste or cloth. This lubricates the cutting edges and prolongs the life of the chisel.

Finish Filings. It is in the finish filing that the greatest accuracy must be observed. It is not advisable to attempt cutting keyways to an accurate size by the use of inside calipers or other measuring instruments; it is best to have at hand the key which is to be fitted into the keyway. As the work of filing progresses, test the key in the keyway at frequent intervals. The sides and bottom should be filed at the same time, and it is quite important that the proper width of file be obtained. One should so file the keyway that the bottom and sides will be cut down to the proper size at about an equal rate. The key must not be a loose fit but a press fit within the slot.

Woodruff Keys. Although it is a very difficult and time-consuming task, it is possible to cut Woodruff keys with a chisel. These are "half moon" keys, the radial surface serving to lock the key into the seat after the matching keyways are fitted over it. The cut and try process is the only method to use in fitting Woodruff keys. Have the key at hand and chip the concave keyway, using the key as a pattern.

RIVETING

Brake Linings. *Types of Rivets.* Rivets used for brake linings are of three kinds, the flat head, countersink, and split rivets, Fig. 46. The former is headed like an ordinary nail and may be procured in a number of head-diameter sizes. The countersink rivet has a head which is flat on top and tapered underneath to fit a countersunk hole. The split rivet has a countersunk head with a split shank to permit the bending over of the ends like a cotter pin.

The split rivet with countersunk head is the easiest rivet to handle in relining brake bands. It is not well to use the old brake lining as a pattern for a new one, but a new one should be cut. Wrap new lining around the band, being sure that it is tight all around the surface and cut it off the right length, allowing no overhang.

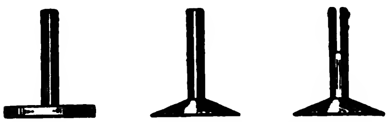


Fig. 46. Types of Rivets for Brake Linings

Riveting the Lining. Fasten the band in the vise with the convex surface up and one end within the jaws of the vise. Procure a drill the size of the rivet holes in the brake band. With a sharp instrument prick the brake lining through the two end rivet holes and drill the lining through. Then countersink these holes so that the top surface of the rivet is very slightly below the top of the lining. Do not countersink so deep that the rivets will pull through. Now insert the copper rivets through the lining and brake band. If split rivets are used, proceed as follows: Select a bolt of such a size that it will give a firm seat for the head of the screw and fasten it in the vise with the threaded end up. Place the rivet head against the end of the bolt, spread the two ends of the split rivet with a screwdriver, and then pound them firmly against the band with a hammer. If solid head rivets are used, the head should be riveted solidly with the round end of a machinist's hammer.

Proceed around the band with consecutive rivets, keeping the lining stretched firmly at all times.

Clutch Facings. The most common cause of faulty cam-clutch action is some defect of the leather facing. When one has determined that the facing needs replacement, he is confronted with the proposition of installing a new leather, and here is where one must have a working knowledge of the proper methods of riveting.

Proper Clutch Leathers. Just a word about clutch leathers. If one decides that a leather must be replaced, then it is the best plan to replace it with a new one from the factory of the maker of the automobile. Of course, it is not a difficult matter to cut a clutch leather (see instructions in Gasoline Automobiles, Part IV), and if the garage has a stock of good clutch leathers, then cutting your own is the simpler plan. One difficulty, however, is that the quality and thickness of the leather you purchase may not be suited at all to the clutch upon which it is to be put. The factory leathers are of a material and size specified by the engineers of that factory and are the right ones to use.

Preparing the Leather. Before riveting the new leather in place it should be made as pliable as possible by soaking it in neat's-foot or castor oil. This soaking should be carried on until the oil has penetrated the leather from surface to surface. Do not soak the leather in water with the idea that it will fit more tightly over the cone; there is a big chance of its shrinking too much and pulling away from the rivets.

Putting Leather on Clutch. It is best to purchase the leather in endless form, that is, sealed at the ends so that it will fit perfectly over the cone. First, place the leather on the cone with one side flush with the large diameter of the cone. Then pry the leather on until it is evenly fitted to the metal surface. If the leather hangs over the small-diameter edge of the cone, it is not on far enough and should be pried farther over the edge of the taper. No trouble should be experienced in fitting the leather by the use of the hands only.

Riveting Process. The holes in the leather should be countersunk deep enough so that the rivet heads will be below the surface and yet not so deep that there will be danger of the leather pulling away from the rivets. Incidentally, after the leather facing has been applied, it is well to rub off the high spots of the leather with

TABLE V

Proportions for Riveted Steel Plates with Iron Rivets

	Inch	Inch	Inch	Inch	Inch
Thickness of plate	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$
Diameter of rivet	$\frac{11}{16}$	$\frac{3}{4}$	$\frac{13}{16}$	$\frac{7}{8}$	$\frac{15}{16}$
Diameter of rivet hole	$\frac{3}{4}$	$\frac{13}{16}$	$\frac{7}{8}$	$\frac{15}{16}$	1
Pitch—single riveting	2	$2\frac{1}{16}$	$2\frac{1}{8}$	$2\frac{3}{16}$	$2\frac{1}{4}$
Pitch—double riveting	3	$3\frac{1}{8}$	$3\frac{1}{4}$	$3\frac{3}{8}$	$3\frac{1}{2}$

the edge of a piece of glass. Insert a rivet through one of the countersunk holes in the leather, which, of course, matches up with a hole drilled through the clutch cone. Flat-headed countersink rivets of copper should be used, the rivets being long enough to project $\frac{3}{16}$ inch through the clutch cone. Place a bolt with the head ground slightly flat in a vise, the head end being up. Hold the rivet in the clutch leather against the bolt head and hammer a head on the rivet with the round end of a ball-peen hammer. Duplicate this operation for each of the rivets.

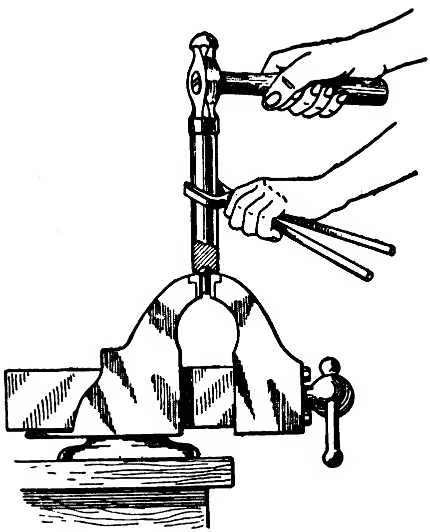


Fig. 47. Easily-Made Type of Rivet Set

Cold-Riveting Metals. Rivets are used to hold together two or more pieces of sheet metal and are employed in the assembly of frames, the supporting of spring hangers, etc. Table V gives the proportions for riveted joints in steel plates with iron rivets. Cold riveting can be applied to work where accuracy is not a requisite and the rivets are of small size, as in sheet metal work.

Hot-Riveting Metals. For hot-riveting work there are two general classes of rivets used: countersunk rivets and flush rivets, Fig. 47. Flush rivets are used to support the spring hangers to the frame and in riveting cross-members to the frame, etc. Countersunk rivets are used cold in brake lining facing and clutch facing, as previously described, and in joining pieces where clearance is a factor, as in riveting the ring gear to the differential case flange.

Rivet Set. In heading large rivets, it is always advisable to use a rivet set, and in the case of riveting the ring gear to the differential case flange this tool is essential. The rivet set is a tool with a spherical depression in the end. When this spherical depression is applied to the shank end of a rivet and the rivet set is hammered, the end of the rivet will be headed over in a nicely rounded head. It is the only way that accurate riveting can be accomplished.

Installing New Ring Gear. Usual rivet sizes for use in fastening the ring gear to the differential housing flange are $\frac{1}{4}$, $\frac{5}{16}$, and $\frac{3}{8}$ inch. The rivets used are round-headed or countersunk and are made of iron. To do a good job of installing a new ring gear proceed as follows:

Removing Old Gear. The first thing to be done is to remove the old gear. This is done by cutting off the rivet heads with a sharp chisel in the manner shown in Fig. 3. If the rivet is countersunk, the head may have to be drilled out to remove it. After the gear is off, go over the surface of the differential housing flange with a file—especially over the rivet holes—to remove any burrs or irregularities in the metal which would cause an untrue seat and thus throw the ring gear out of line. Do the same thing on the face of the ring gear which is to fit against the differential housing flange.

Heating Rivet. Although this job may be done by cold riveting, the hot method is a stronger and truer assembly because it permits more accurate seating and firmer fastening of the rivets. The rivets should be of such a length that they will extend beyond the flange a distance equal to one and one-half times the diameter of the rivet. The rivets should be placed through the flange and gear in consecutive order but alternating in direction; that is, the head of one rivet should go through in one direction and the head of the rivet next to it in the other direction.

One of the best methods of heating the rivets is by means of an oxy-acetyline flame, although they may be heated in a forge as well. The rivets must be put into the holes red hot, as they are more easily headed over, and, in addition, the shrink in the rivets as they cool draws the pieces closer together. The constant hammering in forming the head thoroughly fills the hole.

Making Rivet Set. If one does not desire to purchase a rivet header, it is not hard to make one. One of the simplest ways is as follows: Procure a bar of round steel about twice the diameter of the head of the rivet. Fasten one of the rivets in a vise with the shank within the vise and the under side of the head flat against the top of the vise jaws. Now heat one end of the bar to a white heat and drive the heated end against the round rivet head, thus making a depression in the end of the bar, Fig. 47. It will probably be necessary to reheat the bar two or three times, using a new rivet each time, to get the depression deep enough. This depression should be of such depth as to take in the entire head of the rivet. Another method is to drill the depression into the end of the bar, thus giving a V-shaped depression. Such a depression will serve nearly as well as the round one for the work at hand.

Heating the Rivet. It is now assumed that one has rivets, red hot, in the forge, a rivet set of the proper size, and that an anvil or a block of steel or iron, upon which the riveting may be done, is available. Extract one of the rivets from the forge with the tongs and insert it quickly into the rivet hole. It is imperative that the work be done quickly, so that the final heading is completed before the rivet has had a chance to cool. The head of the rivet is dropped down against the anvil or block of iron or steel. With the assembly held firm against the anvil or block, place the rivet set over the shank of the rivet and hammer with quick light strokes against the other end of the rivet set with a fairly heavy machinist's hammer. Convenience and quick work demand that this be made a two-man job, one to hold the work and the other to do the riveting. In shaping the head, oscillate the rivet set in the hand so that the head will be evenly rounded on all sides. A properly shaped rivet head should be very nearly the same shape as the head, which was a part of the rivet in its original form, as shown in Fig. 48 A. A well-rounded head is stronger than one which is more or less flat and which spreads over a larger area. In Fig. 48 B is shown the section of a countersunk head joint.

Fig. 48. Section of Rivets in Place

Fig. 49. Modern Motor-Driven Forge
Courtesy of Canedy-Otto Company, Chicago, Illinois

FORGING

Forging Equipment. *Forges.* Many of the jobs in a repair shop require the use of a forge, two kinds being necessary for all well-equipped shops. Forging and welding are easily cared for by the power-driven blower forge, Fig. 49. This type of forge is made of steel and the medium size is best for automobile repair shop work. For brazing, melting babbitt metal, hardening, tempering, annealing, and heating soldering irons, it is best to use a gas forge that takes its air from the tank of the air-compressor outfit and its gas from the regular city or town mains. Portable gasoline forges Fig. 50, are obtainable and work equally well It is well to have also a small hand torch, Fig 51, for use in smaller brazing or soldering jobs

It is well to set up these two necessary forges with a bench between them. The bench

Fig. 50. Double-Jet Brazer
Courtesy of Turner Brass Works, Chicago, Illinois

should have a large drawer and a good vise attached to it, and will be found useful both in brazing and soldering processes; the drawer can be divided into compartments, one to hold the blacksmith tools and the other the soldering irons and sheet-metal tools. The vise will come into use innumerable times at either forge.

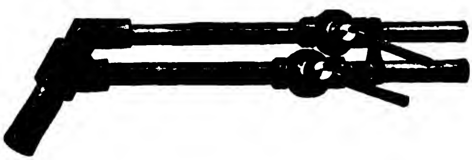


Fig. 51. Hand Gas Torch for Brazing

Tools. The remaining equipment is simple. A medium size anvil, Fig. 52; two sledge hammers, medium and heavy; three, or perhaps four, forge hammers; tongs for holding round, flat, and irregular work; tools for cutting off material, both hot and cold; and finally flatting and swaging tools. Melting ladles can be placed over either coal or gas flame, and either forge can be used in melting the antifriction metals used in lining bearing boxes.

Blacksmithing Repair Outfit. A complete blacksmithing outfit that is adequate for ordinary repair shop work can be purchased for approximately $50. This will give a forge that uses coal as a fuel, a vise, a set of taps and dies, anvil, drill press, hammers, drills, tongs, wrenches, and a few small tools. Some of the tools that apply strictly to horseshoeing can be applied to the repair of automobiles. These consist of a farrier's hammer, knife, and pincers. All of the other tools mentioned apply to general metal work. A post drill will be found very practical for shops not provided with power. As complete sets of drills usually accompany the post-drill outfit, it is not necessary to stock up on a variety of tongs, for these can be made best to suit the purpose for which they are to be used.

Fig. 52. Anvil Fastened to Block

Electric or Gas Furnaces. If the shop is a large one, there probably will be considerable tool dressing that will require heat-treating of various parts, and an electric furnace may be procured to handle this class of work. With a furnace of this kind, the amount of heat may be regulated within close limits, and temperatures may be reached that are sufficiently high for hardening, carbonizing, or annealing any pieces within the range of the furnace. It is questionable whether a furnace of this kind would be practical, except for large shops where there is much of this class of work to be done. Furnaces of the gas- or oil-burning types, Fig. 53, are probably more serviceable and less expensive than the electrically heated form. Welding is a very useful repair process in automobile work and it will be found fully treated in another article.

Heat Treatment. Since there is an almost universal use of high-grade alloy steel in automobile construction, it is quite necessary that the repair man have some knowledge of heat treatment of the various metals. It must be known that metals of this character cannot be machined unless they are annealed and are of but little greater value than the ordinary machinery steel parts if they are not properly heat-treated to bring out the physical characteristics desired after fabrication.

Fig. 53. Simple Gas Furnace
Courtesy of American Gas Furnace Company, New York City

Tempering Steel. The simplest method of tempering steel is the old-fashioned method of only partly cooling the tool when quenching it, then quickly withdrawing it, polishing off its working surface, and letting the heat which remains in the tool produce the required temper as judged by the color. When first quenched, the point of the tool is the coolest and, on withdrawing it, the heat in the balance of the tool heats up the point, changing its color from light straw to deep straw, then light brown, darker brown, light purple, dark purple, dark blue, light blue, and finally blue tinged with green and black. When black appears, the temper is gone. When the color desired is reached, the tool should be completely quenched.

The following tabulation shows the temperature in degrees Fahrenheit at which steel assumes certain colors.

Degrees	Color
430	Very light straw
450	Light straw
470	Dark straw
490	Very dark straw
500	Brownish yellow
520	Yellow tinged with purple
530	Light purple
550	Dark purple
570	Dark blue

The modern method of tempering is by means of a furnace, as shown in Fig. 54, an oil bath being heated by an oil or gas flame to the proper temperature, as indicated by the thermometer, and the tools immersed in the bath. When they have reached the same temperature, they are lifted out and quenched in a hardening bath. The use of such a furnace makes the tempering of the shop tools more uniform.

Hardening Steel. As it is necessary to maintain the steel in the state it was at the moment quenching began, the quenching bath is a very important part of the process of hardening. The better the bath, the more nearly perfection is attained.

Various baths are used for cooling steel when hardening, on account of the different rates at which they cool the

Fig. 54. Typical Tempering Furnace
Courtesy of Strong, Carlisle and Hammond Company, Cleveland, Ohio

heated metal. An oil bath is used when the steel is wanted tougher and not excessively hard, as the oil cools the steel more slowly than water. Brine or an acid bath is used when the steel is wanted very hard, as they absorb heat more rapidly than water. For excessively hard work, mercury or quicksilver is sometimes used, as it absorbs the heat very rapidly.

Self-Hardening Steel. Self-hardening steel is used to a large extent in modern practice for lathe tools, much being used in the shape of small square steel blades held in special holders, as Fig. 55. Self-hardening steel, as its name indicates, is almost self-hardening by nature; generally, the only treatment that is required to harden the steel being to heat it red hot and allow it to cool. Sometimes the steel is cooled in an air blast or is dipped in oil. It is not necessary to draw the temper. The self-hardening quality of steel is given to it by the addition of chromium, molybdenum, tungsten, or one of that group of elements, in addition to the carbon which ordinary tool steel contains. High-speed steel is lower in carbon.

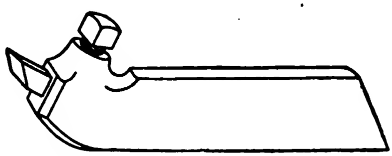


Fig. 55. Tool Using Self-Hardening Steel Blade

Self-hardening steel is comparatively expensive, costing from 40 cents and upward per pound, some of the more expensive grades costing $1 or so. However, when in use, self-hardening steel will stand a much higher cutting speed than the ordinary so-called carbon steel, and for this reason it is much more economical to use, although its first cost is higher.

Self-hardening steel cannot be cut with a cold chisel and must be either cut hot or nicked with an emery wheel and snapped off. Great care must be used in forging it, as the range of temperature through which it may be forged is comparatively slight, running from a good red heat to a yellow heat. Some grades of self-hardening steel may be annealed by heating the steel to a high heat in the center of a good fire and allowing the fire and the steel to cool off together. Steel which has been annealed in this way may be hardened by heating to the hardening heat and cooling in oil.

Hardening High-Speed Steel. High-speed steel has a much higher critical temperature than carbon steels. A temperature of about 1350° to 1600° F. is sufficient for carbon steels in general.

High-speed steels require heating from 1800° to 2300° F. and to be cooled in oil such as machine, fish, or linseed.

Bending Rods. If a piece of hard tubing is to be bent, it must first be annealed, otherwise it is likely to break. If the piece to be bent is thin-walled tubing, it will collapse. Occasionally, the bending of a moderately thick-walled piece of tubing can be accomplished without heating or filling, although it always is best to fill the tubing before attempting to bend it. If the interior is made solid, or nearly so, with some substance and if the tubing is properly heated and of the right temper, it can be bent to a curve of small radius without damaging the walls of the tubing. It is poor policy to avoid filling the tube by the use of a vise or wrench, or hammer and anvil for bending, as the walls of the tube will suffer and the appearance of the finished work will be unsatisfactory. There are several methods of filling tubing that give good results. Some molten substances can be poured into the tubing, such as resin for thin copper, and brass or lead alloy in steel tubing. The fillers can be removed by heating the tubing after the bend has been made. Some make use of a steel rod when the bending describes a part of a circle, as the filler rod takes the same curve as the tube and thus comes out easily. When many pieces of about the same size of tubing are to be bent, it can be very satisfactorily accomplished with a grooved jig, as shown in Fig. 56.

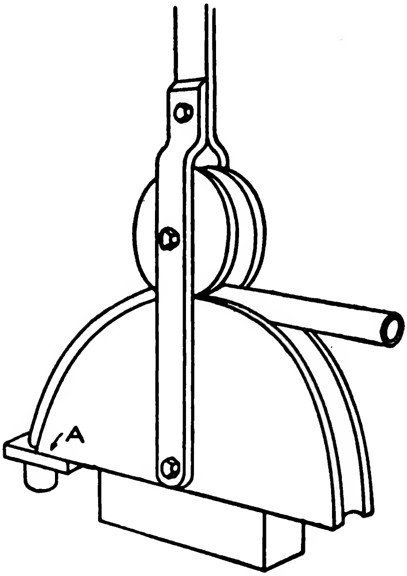


Fig. 56. Grooved Jig for Bending Pipe

CUTTING GEARS

Definition of Terms. In designing or cutting gears, it is quite essential that the terms as applied to this practice be clear to the operator. The nomenclature of gears and their measurements are such that only by diagram, shown in Fig. 57, together with the following explanation, can one obtain a clear conception of the various measurements:

Pitch Diameter. The pitch diameter is the diameter of the *pitch circle.*

Addendum Circle. The addendum circle has the same diameter as the outside diameter taken over the points of the teeth.

Dedendum Circle. The dedendum circle is known also as the *root circle* and is the circle at the bottom of the teeth.

Pitch. Pitch is the distance from the center to the center of the teeth when measured on the pitch circle. Measured in this way, it is called the *circular pitch.*

Fig. 57. Names of Tooth Parts

Face. The face of the tooth is that part of the curve outside of the pitch circle.

Flank. The flank of the tooth is the portion of the curve within the pitch circle.

Thickness. The thickness is the width of the tooth, taken as the chord of an arc of the pitch circle.

Space. The space is the distance between adjacent teeth, measured as the chord of an arc of the pitch circle.

Method of Design. In designing gears two methods are employed, one known as the fixed-pitch method and the other as the diametral-pitch method. The latter perhaps is the more popular since the first involves some tedious calculation, but in the event that one may wish to apply it, it is well to explain the process and what it means.

Fixed-Pitch Method. It once was the practice to design gears on the basis of a fixed distance representing the teeth and this was usually based on the common fractions of an inch. Thus the desired number of teeth multiplied by the given pitch gave the circumference, and the distance, found in this way, divided by 3.1416 gave the diameter of the pitch circle.

Let us suppose that the pitch is divided into fifteen parts, seven of which represent the thickness of the teeth and eight the width of the space. To find the length of the teeth, the pitch is divided into ten parts, of which seven represent the length of the teeth—three parts covering that portion outside of the pitch circle and four parts the length of it, one part being allowed for bottom clearance. Because of the tedious calculation involved in this method, mechanical engineers devised the diametral pitch method.

Diametral-Pitch Method. The diametral-pitch method designates the pitch by a number instead of giving the length of the pitch in inches. This number indicates the number of teeth for each inch of diameter of the pitch circle. Thus, if the diametral pitch is 6 and the diameter of the pitch circle is 10 inches, the gear will have 6 times 10, or 60 teeth. Also, if we know that the pitch is 6—or as usually expressed "6-pitch"—and the gear has 60 teeth, the pitch diameter is 60÷6, or 10. If the gear has 60 teeth and the diameter of the pitch circle is 10 inches, the pitch is 60÷10, or 6-pitch. Three simple rules cover the diametral-pitch method:

(1) *Multiply the diameter of the pitch circle by the diametral pitch to get the number of teeth.*

(2) *Divide the number of teeth by the diameter of the pitch circle to get the diametral pitch.*

(3) *Divide the number of teeth by the diametral pitch to get the diameter of the pitch circle.*

Proportions of tooth parts are determined by rules quite as simple as those of the pitch. These are as follows:

(1) *The addendum is equal to one inch divided by the diametral pitch.* For example, the addendum on a 6-pitch gear will be $\frac{1}{6}$ inch.

(2) *The dedendum is equal to the addendum increased by the clearance, which is equal to $\frac{1}{10}$ the thickness of the tooth on the pitch circle.*

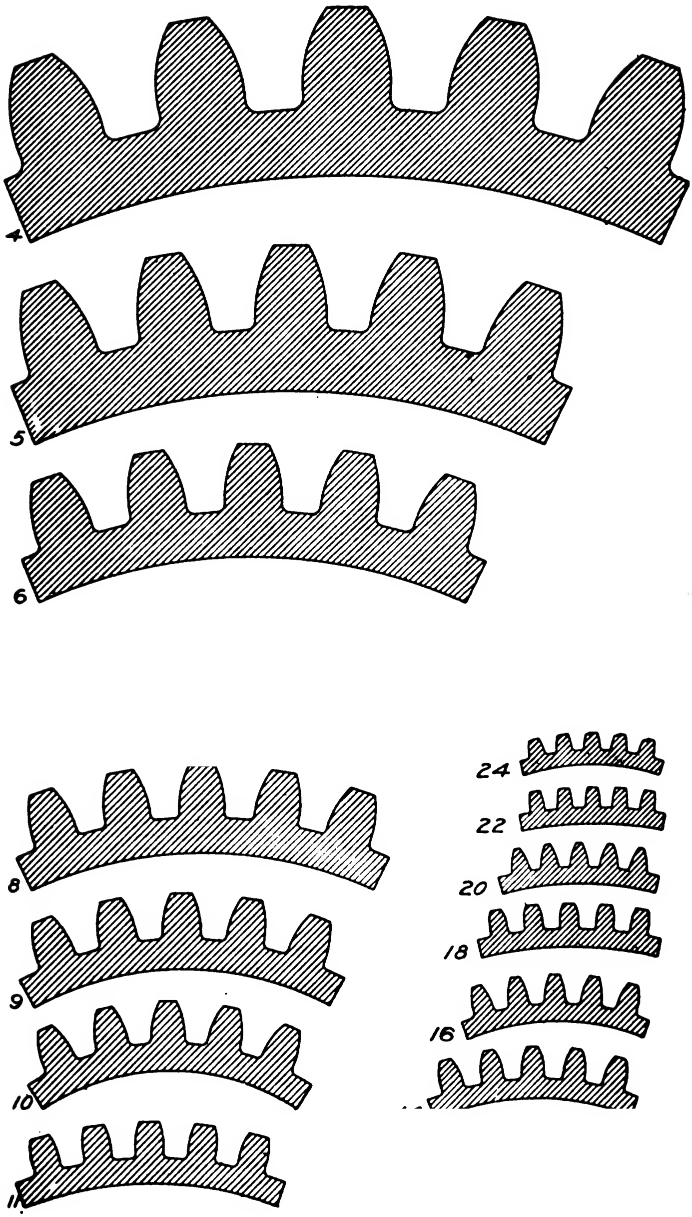


Fig. 58. Proportions of Teeth of Different Diametral Pitches

Determination of the thickness of the tooth and the width of the space at the pitch line is not by the same rule as that given in the former method. In all accurately cut gears, the width of the space exceeds the thickness of the tooth only as much as may be necessary to permit the gear teeth to roll freely together and need not be over .03 of the circular pitch. In cut gears for ordinary purposes, this amount may be doubled, while in gears having cast teeth, it may be necessary to make it as great as 0.10 of the circular pitch, depending largely on the accuracy of the casting. That a clear conception may be obtained of the relative dimensions of spur-gear teeth of different diametral pitches, the gear teeth are shown in full size in Fig. 58. These are the more common pitches. The larger ones are usually 1-, 1½-, 2-, 2½-, and 3-pitch.

MISCELLANEOUS BENCH METHODS

Best methods for doing work are constantly coming up in all shop work, and the success with which the desired end is attained depends largely upon the skill and judgment of the man in charge. A few examples of the questions likely to arise and suggestions for handling them to give the best solution follow.

Peening. Stretching metal on one side of a piece of work is called peening. There is considerable difference between peening and bending. Let us suppose that you have a warped piece of metal to be straightened. If it were to be bent until it were straight, it could be placed on a block with the concave side down and struck with a hammer and driven down past the line of support. This strain would reduce it into an approximately straight line. However, this method could not be applied to a piece of metal with complicated outline for it would remain wavy. In peening to trueness such a piece as that previously mentioned, the piece is placed on an anvil with the convex side down and struck sharp blows with the peen of the hammer on the concave side, with the result that the metal is stretched at the point where the blow is struck. Working successively over the whole surface results in the concave side being stretched so that it is equal in dimension to the convex side, and the piece becomes straight and remains so. Skillful use of the hammer will straighten almost any piece of thin metal. The same process of stretching the metal is sometimes applied to a hole in a ductile metal which is too large. Possibly a screw has worked the threaded hole too large, but by peening the metal around the hole with a hammer and prick punch, the fit is made tight again. Such a method is not good shop practice but accomplishes a quick repair.

Drilling Hard Metals. When a hole is to be drilled in a very hard metal, the drill must also be very hard and must be run at a relatively low speed. The drill must be forced against the metal with as much pressure as possible without breaking the point and an abundant supply of oil is necessary. A drill may be excessively hardened by heating it to a dull red in a charcoal fire and quenching it in mercury instead of in water to make the cooling more rapid. Nicking the surface of the metal with a cold chisel also will give the drill a start, and beneficial results are obtained by using turpentine in place of oil in some cases. Very thin chilled cast iron may be softened somewhat by placing a small amount of sulphur on the place where the hole is desired and then heating to a dull red. This should be done slowly, however.

Avoiding Scale. When cast iron is being worked in a lathe or a planer, the point of the tool always should work beneath the scale, which is the outer shell that covers all cast iron as it comes from the foundry. This scale is very hard and brittle and if the edge of the tool is made to work in, or against it, the edge is soon dulled. When the tool works beneath the scale, raising the chip removes the scale.

Pickling. All castings that are to be machined to dimensions that are only slightly less than those of the rough castings should be pickled or washed in a solution of sulphuric acid and water, which causes the scale to drop off in flakes and leave the metal bare, unprotected, and rusty. Either submersion or swabbing is effective. After being pickled the casting should be washed in a sal soda solution. A good pickling solution for this work is one part of commercial sulphuric acid to ten parts of water.

MACHINES AND MACHINE PROCESSES

ARBOR PRESSES AND GEAR PULLERS

Types of Machines. An arbor press is one of the most useful tools for an automobile repair shop. Arbor presses are available in a number of forms. In the simplest type, the pressing medium is a rod which is forced down by pulling down on the handle which is counter-weighted on the opposite end. By a ratchet principle, the rod is held against the work while another stroke of the handle forces the rod farther down. When the handle is let up to the top of its stroke, the locking mechanism is released and the rod may be pushed up by hand.

Fig. 59. Arbor Press for Automobile Work

There is now on the market a universal press especially adapted for automobile work, Fig. 59. This machine has a capacity of 22 tons and allows a 42-inch clearance for the work. It has two levers, one for high-speed work, geared 1000 to 1, and one for low-speed work, geared 2200 to 1. In the illustration, the mechanic is shown pressing off transmission gears with channel blocking, using the 2200 to 1 leverage. The other attachments furnished with the machine are shown on the floor.

Uses of Arbor Press. *V-Block.* For automobile work, a useful part of the arbor press equipment is a V-block, shown on the floor beside the machine in Fig. 59. This block is a receptacle for a great many different kinds of stock.

Handling Press Fits. In automobile construction, there are a great many parts which are a press fit into another part. A press fit differs from a sliding fit in that one piece must be forced into another for permanent location while those parts are performing their function; with a sliding fit, one part is located within another so that it may be readily moved, as in a bearing. The arbor press easily handles press fits in replacement and repair.

Where a shaft is a press fit within a gear, that shaft may be pressed into the gear by means of the arbor press. The gear should be located on the bed of the press. If it has a hub, the gear should be supported underneath as close to this hub as possible so there will be no danger of springing the gear. The shaft is then started into the hole; the screw or rod of the arbor press tightens down against it and presses the shaft into the gear. It is well to remember that the available pressure in an arbor press is enough to bend a sizable piece of steel, and with this in view, work should always be very carefully centered and, in the case of shafting, the shaft should be perfectly parallel with the sides of the hole it is about to enter.

Removing Bearing Bushings. One of the biggest fields for the arbor press in a garage is in the removal of bearing bushings. There are a great many places about the car where bearings are pressed into their containers, a notable instance being in the springs. Bearing bushings may be very readily pushed out of springs with an arbor press. In most universal joints the steel bushings are pressed in with an arbor press and about the only satisfactory way they can be removed is to press them out with the same kind of a machine.

Straightening Parts. Another use for the arbor press is in straightening parts. In the modern automobile, practically all parts which take a considerable amount of strain are constructed from alloy steel. In order to properly prepare alloy steel for severe strains, it must be heat-treated in an accurately calibrated oven to a temperature averaging about 1500° F. Too many repair men make the mistake of trying to straighten these heat-treated parts in a forge. Once they are heated in a forge, the value of the previous heat-treating is lost and it can only be put back into the metal again in a heat-treating oven.

Furthermore, parts made of alloy steel which have been subjected to the heat-treating process, although capable of tremendous bending strains, may nevertheless be bent without harm to them providing enough pressure is applied. An arbor press capable of exerting a 15-ton pressure can be used for straightening front axles, steering knuckles, and like parts.

The arbor press may also be used for straightening tubing and cylindrical parts, such as torsion tubes and rear-axle housings. In doing this work, a screw press is superior to the kind where leverage alone is the pressure factor, because it permits more careful pressing. With an available pressure of 15 or 20 tons, it is a very easy matter to crack a piece of tubing or a cylindrical part, such as a torsion tube or a rear-axle housing, and great care should be exerted in the bending operation.

Gear Pullers. Although the arbor press may be used for gear pulling, there is a simpler device, known as a gear puller. Where gears are fitted to small shafts, they are in a great number of cases made a press fit on the shafting. If one were to attempt to hammer the gear off, he would very likely either damage the teeth of the gear or bend the shaft. A gear puller will remove the gear without damaging any part of the assembly. It is a simple device consisting of a beam at the ends of which two arms are fastened with pins. These arms are constructed with hooks on the ends. Through the center of the beam is a thread cut for the purpose, and in this is a screw with one end shaped to a V and the other end squared to permit the application of a wrench.

In operating, the hooked ends of the two arms are fastened to the back of the gear or pulley. Then the screw is turned down until the V-end fits against the center of the shaft on the opposite side of the gear or pulley to which the hooks of the arms are fastened. Screwing down the screw by means of a wrench will exert sufficient pressure to force the shaft out of the gear.

Combination Gear and Wheel Puller. There is now an instrument on the market which is a combination gear and wheel puller, Fig.

60. As will be seen, in this instrument the arms cross like a pair of pliers, and the upper ends of the arms have a number of holes drilled in them. A center block between the arms carries the thread for the screw, as well as a tapped hole on each side. Screws are passed through the drilled holes in the arms at various points and into the tapped holes of the center block, thus giving considerable variation in adjustment for the different sizes of work.

GRINDERS

Advantages of Grinding. Machine-shop grinding operations depend upon the abrasive or cutting qualities of stone, emery, carborundum and corundum, when suitably held and presented to the work. The use of solid grinding wheels has made it possible to attain many refinements in machine construction that would have been impossible without them. It has made it practical economically to finish hardened steel parts that could not possibly be machined with cutting tools in the lathe or the planer, and with the softer materials it has made possible smoother and truer surfaces than can be obtained by any other method.

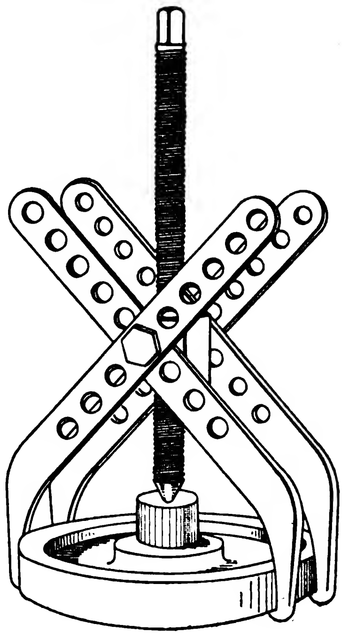


Fig. 60. Combination Gear and Wheel Puller
Premier Electric Company, Chicago

Types of Grinding. There are four principal divisions to grinding: hand grinding, tool and cutter grinding, cylindrical grinding, and surface grinding. The two latter classes are never required in repair work.

Hand Grinding. Under hand grinding is included all the operations in which the work is held to the wheel by hand or with a rest, as in rough grinding, ordinary lathe-tool grinding, buffing, and polishing. The class of machine used for this work is of the simplest form, consisting of the wheel-carrying spindle mounted on suitable bearings on a substantial head or pedestal. Some machines of this character carry one wheel, others two. Adjustable rests are provided upon which the work being ground can be steadied. This class of grinders is designed for dry grinding of rough and heavy material, where the danger of overheating the work is negligible.

If the work to be ground is tempered, or is likely to become over-heated, a grinder in which a supply of water is constantly on the rim of the wheel to keep the work cool is used. Buffing heads or spindles usually consist of a standard with a shaft carried on two bearings, the pulley for operating being mounted between the two bearings in a Y-yoke. This shaft usually extends well out from the bearings so that work may be conveniently handled. The ends of the shaft are fitted with wheels having rims of wood, leather, or cloth, which are charged with emery or other grinding material. With the buffer no rest is used.

Fig. 61. Small Milling Machine Tool and Reamer Grinder
Courtesy of Cincinnati Milling Machine Company, Cincinnati, Ohio

Tool and Cutter Grinding. For tools and cutter grinding, a better class of grinding machinery is required than for the hand-grinding operations. In this case the term tool refers to drills, reamers, milling cutters, and the finest class of tools, and does not include ordinary hand or lathe tools, which usually are ground on a grinder where the wheel is in constant touch with water.

The Cincinnati Milling Machine Company makes a universal cutter and reamer grinder, shown in Fig. 61. As the name implies, these tools are provided with all necessary attachments for grinding the cutting edges of all classes of reamers and milling cutters, and in many cases may be used for doing a limited amount of cylindrical grinding, both internal and external.

Cutter grinders have become very necessary to the modern repair shop through the extensive use of the rotating cutter in machining operations and the necessity of keeping these cutters true and sharp. In the grinding of cutters, care and judgment must be exercised, and not until the operator has become thoroughly familiar with all the setting combinations of the machine can he expect to get the best results. Since water is not used on the wheels of cutter grinders, the wheels are usually quite hard and fine, and light cuts

Fig. 62. Grinding Milling Cutter with Cup Wheel
Courtesy of Cincinnati Milling Machine Company, Cincinnati, Ohio

must be made in order not to draw the temper of the tool at its cutting edge. The cutter support should be adjusted to bear against the tooth being sharpened, and its position relative to the wheel should be such as to give the necessary amount of clearance to the cutting edge. A setup of the above grinder for sharpening a milling cutter with a cup wheel is shown in Fig. 62.

Care of Tools. *Twist Drills.* Much care should be taken in the grinding of twist drills to see that the angle and clearance is correct and equal on both sides. Correctly ground drills cut faster, stand up longer between grindings, and produce the proper size of hole. It will be found that a correctly ground drill seldom breaks, since it cuts its way cleanly and does not scrape nor jam as it does when the angle and the clearance are not right.

Proper Wheels. Wheels for any class of grinding should be properly adapted to the work as to shape, grade, and hardness. Shape and character of the work determine in any case the shape of the wheel to be used, while the material of which the work is composed, the amount of metal to be removed, and the condition of the finished surface must determine the quality of the wheel. A free cutting wheel which is run at the proper speed and with a light cut is best for accurate grinding, since it removes the metal without pressure and consequently cuts the high spots without heating up the work.

However, if the work is to be very accurate, it is best to use water on the wheel, as a slight temperature tends to have a noticeable effect upon the work. When long cuts are to be taken, it sometimes is difficult to get the wheel to stand up so as to give a parallel cut. Since the harder wheels hold the emery longer, they can be run somewhat slower and they are best adapted for giving cuts of this kind. The wheel should have a wide face and be of large diameter so as to present as many grains of abrasive as possible to perform the required work. It also is necessary to use the coarser feed and lighter cuts in order that the wheel may cover the entire surface before it drops materially in diameter.

Manufacturers of grinding wheels give a table of speeds for wheels of different diameter, but these speeds are not always best suited to the work. All wheels should fit easily, yet closely, on their spindle, to prevent any possibility of cracking, and a soft washer of uniform thickness should be placed between the sides of the wheel and the clamping washer. In grinding long work, it is quite necessary to support the work at one or more points between its end bearings, for otherwise true work is impossible.

DRILL PRESSES

Function of Drill Press. The standard drilling machine, in its various forms, consists primarily of a revolving spindle which carries the cutting tool; a work-holding plate, or table; and a substantial frame connecting the two. Details of spindle adjustment and also of spindle drives and feeds, while they differ in points of detail in the several designs and classes, all bear close mechanical relations to each other. Boring holes of comparatively small diameter is the specific field for this class of tools, but reaming and tapping these holes are in many cases added to the work of the drill by means of special tools and fixtures, thus taking over the work that at one time was done on the lathe.

Method of Action. In the class of drill presses termed standard upright, the feed is automatic, and usually a variety of feed speeds is given as well as an automatic knock-off that stops the work at any desired point. In addition to the automatic feed, both wheel and lever feeds are usually provided. The rack and pinion method of moving the spindle is common to practically all makes and types of drill presses. The spindle usually has its lower bearing in a quill which is given a close sliding fit in the head. The feed rack is secured to the quill. This has particular reference to that type of drill press having a sliding head, the head having a vertical adjustment on the front face of the column to adapt the machine to work of different heights and to drills and tools of varying lengths. The head is counter-weighted so as to make operation convenient. The head can be firmly clamped in any position.

An arm supports the work table and this arm is manipulated by means of a screw and a crank. It can be swung to a considerable angle either side of the spindle and firmly clamped in almost any position. In case the work is too high to be supported on the adjustable table, a lower-base table may be used.

A stationary head usually is found on the smaller machines of this class, all the vertical adjustment being accomplished by moving the table up or down, as required. Such machines are regularly made up to 52-inch capacity, the size indicating the maximum diameter of the work whose center can be reached by the spindle.

In work where small drills can be used, a light machine called a sensitive drill should be used in order to obtain the high speed required and the lightness of parts necessary. Here, the term sensitive commonly means lightness of parts, smooth running, and perfect balance, which enables the operator to judge as to the pressure he is applying to the drill and, consequently, lessens the danger of breaking the drill. Some manufacturers go a little farther and employ at some point in the drive an adjustable friction clutch with which the speed of the drill can be regulated.

Securing Work. Securing work on the table of drilling machines requires clamps, bolts, jacks, and blocking, as in other types of heavy machines. The same care should also be exercised in the setting, for true work requires careful setting. The use of a square and surface gage as well as good parallel bars is essential in setting up work for drilling. For through drilling, the work must be located so that the drill in passing through will enter a slot or the central hole on the table. If the work is too large or if for any other reason this cannot be done, then the parallel bars on the table should be used before putting on the work. These should be sufficiently thick to allow the drill to pass through without striking the table.

Lubrication in Drilling. Drilling of steel and wrought iron requires lubrication for the cutting tool, while cast iron and brass are drilled dry. Lard oil makes the most satisfactory lubricant, however, its cost usually makes its use prohibitive. The lubricant tends to conduct away the heat generated by the cutting tool and it should be applied directly on the part of the work that is being cut. Some drills have a special reservoir in the head for carrying oil and the lubricant is forced on to the cutting edge.

POWER HACK SAWS

Method of Action. Very general use is made of power-driven hack saws in the automobile repair shop. These machines use the regular pattern of hack-saw blades, which with proper care do a remarkable amount of cutting; the machines require but little attention and when properly adjusted will saw off work reasonably square. There is usually an arrangement by which the machine comes to a stop when the work has been cut and the saw drops through.

Pressure on the Blades. When the saw blade is new, the weight on the top of the saw frame should be a little less than after the teeth have become worn, for, when new, the saw bites into the metal considerably faster than after they have become dulled from use. Furthermore, there is danger of stripping the teeth or breaking the blade, especially if the work is of small diameter. A comparatively light pressure permits contact with but a few of the teeth at each point in the stroke. Tubing is very hard on blades and should be cut with a very light pressure and with saws which are somewhat worn. Never use oil on the hack-saw blade.

Pressure for Different Metals. It also should be borne in mind that different metals require different amounts of pressure on the saw. Unless one desires to break saws and strip teeth, a close adherence to the following must be observed: Aluminum or any other soft metal of this character cuts twice as easily as cast iron and approximately four times as easily and as fast as steel, consequently the weight on the frame of the saw must be moved forward or backward to give the proper pressure. Perhaps the best point for locating the weight in cutting aluminum is at the extreme outer end of the frame, about the middle for cast iron, and well toward the inner end for steel. Of course, there is no regulation of the backward and forward speed of the hack saw, hence it is necessary to bring judicious use of the weight into play if the life of the saw blade is to be preserved.

Power hack-saw blades should last as long in comparison to the amount of sawing done as the hand hack saw, perhaps longer, if the saw is not called upon to do duty at a faster pace than that for which it was designed.

Allowance for Cut. The novice in using the hack saw frequently does not make allowance for the cut but measures off the length of his piece, marking the exact length, and then starts sawing with the blade exactly on the mark. When the piece has been cut off, he finds that it falls short of his measurement, perhaps $\frac{1}{64}$ inch. This shows that allowance must be made for the width of the saw cut instead of sawing directly on the mark, for the $\frac{1}{64}$ inch which the blade removes sometimes makes the piece useless.

LATHES

Characteristics. Of course the most important power machine in a motor-car repair shop is the lathe. In this discussion, the engine lathe only will be considered in its simple form, or modifications of it, as shown in Fig. 63. The lathe is capable of handling a great variety of work. There are four main parts in the ordinary engine lathe: bed A, headstock B, tailstock S, and carriage X. The bed is the bench, or foundation, upon which the rest of the machine is supported. Placed on top of the bed are what are known as shears, which are really tracks upon which the moving parts ride. There are two pairs of these shears, and the headstock and tailstock rest upon the inside pair and the carriage on the outer pair. The headstock contains the pulleys and other devices which receive and transmit the power to the work. The tailstock is the holding device for centering

Fig. 63. Typical Engine Lathe
Courtesy of Reed-Prentice Company, Worcester, Massachusetts

material to be worked upon between itself and the headstock. The carriage carries the tools which perform work upon the material at hand.

Before attempting to operate a lathe, it is advisable for one to acquaint himself with the mechanism. An examination without instructions will show one what levers move the tail stock, adjust the tools, regulate the speeds, etc.

Lathe Tools. It is with the tools for the lathe that the amateur repair man finds his greatest difficulties. Only the most important points in tool use can be touched upon because of the limited scope of this article. Many shapes and sizes in cutting tools may be fitted for various jobs which one encounters but the standard tools will be found satisfactory for most jobs. Tool-holders for holding tungsten steel cutters are very useful and are probably more convenient than the usual lathe tools because the cutters do not have to be sharpened so often. In Fig. 64 are shown three typical forms of cutting tools. The first is a holder with straight body; the second, a cutting-off tool; and the third, a right-hand holder (left-hand holders are also available). There are a number of other necessary tools, of which thread-cutting tools and knurling tools might be mentioned.

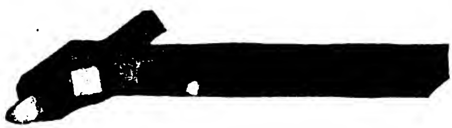


Fig. 64. Typical Lathe Tools
Courtesy of Armstrong Brothers Tool Company, Chicago

Lathe Equipment. *Headstock and Spindle.* The headstock is fastened on the left hand of the bed and carries the main running gear of the lathe. At each end of the headstock there is a bearing for the spindle. The right end of the spindle is threaded to carry the face plate *F*, Fig. 63, and is recessed to receive the live center *G*. The dead center *H* is mounted in the tailstock. The work is mounted between these centers, the left end of the work being held by a dog which is fastened to the face plate to keep the work from slipping.

Holding Devices. For lathe work in which only one end can be supported, there are four classes of holding devices: the center rest, the carriage, faceplate, and chuck. In center-rest work, the center rest of the lathe carries one end of the work and the live spindle the other. In carriage work, the work is secured stationary to the carriage and a rotary cutter mounted on the spindle performs the machining. With chucks or faceplates, the work is supported in jaws within a live spindle. A live spindle is one which rotates and is direct driven from the power medium.

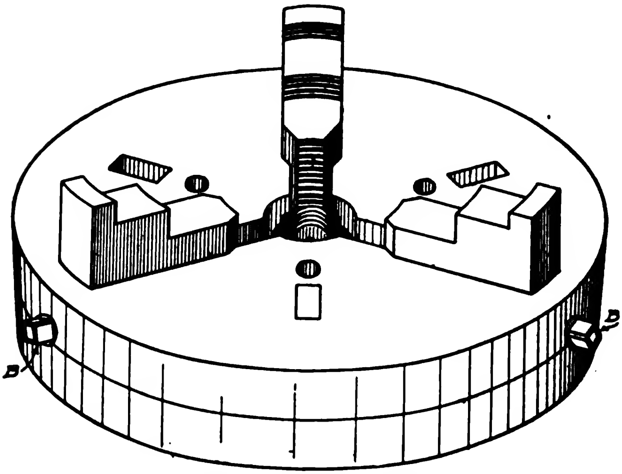


Fig. 65. Combination Chuck

Every lathe should have one or two chucks as a part of its equipment. These are made in two-, three-, and four-jaw types, but the three-jaw type, Fig. 65, is adaptable for most work.

Simple Lathe Work. The beginner's job on a lathe is to turn a plain spindle between centers. For example, assume that a bar of 1-inch round steel is to be reduced to a diameter of $\frac{7}{8}$ inch.

Centering Stock. The piece to be turned down is first cut to the proper length allowing enough for squaring and is then centered.

Centering means placing V-shaped depressions in the exact center of each end of the piece.

There are some very handy centering tools on the market which are adjustable for different lengths and diameters of stock and afford a quick means of placing an accurate center in each end of a bar. Fairly accurate centering can be done with a center punch and hammer. Each end of the piece must be bisected with two horizontal lines to obtain the center, this being done with a surface gage. Then depressions can be hammered into the ends of the stock by placing the point of the center punch at the point where the bisecting lines cross, which should be the center point of the stock. Another method is to mark the centers, as described, and drill centers into the end in the drill press.

These centers do not have to be deep or wide, but should have just enough of V to afford a firm support for the points of the centers. Where the work is going to consume considerable time and the piece which is being worked is heavy, it is advisable to make deeper centers and cut oil grooves into the sides of them with a cape chisel so that the center may be frequently oiled. In centering the piece, it must be neither a tight nor a loose fit.

Squaring Off Work. With the work centered, the ends of the piece are squared off with a cutting tool. This is an operation requiring care. The expert lathe man will square the end to within a very small fraction of an inch of the tailstock center, but will not ruin the center by cutting into it.

Roughing Cut. The next operation is the cutting down of the surface of the stock to within about $\frac{1}{32}$ inch of the finished diameter. The depth of each cut, of course, depends on the material which is being worked on. In soft metals, such as brass and aluminum, a fairly deep cut is possible, while in steel it should be around $\frac{1}{32}$ inch. This is a matter which can be determined by watching the action of the tool and examining the point frequently to see what effect the cuts are having on it. This roughing operation tends to work the center into a smooth easy-running bearing.

Reversing Work. The work is then removed from the centers and changed end for end. Another roughing cut is made and then the work is ready for the finish cut. It must be remembered that no part of the work shall receive its finish cut until the parts have been roughed over and the centers have been well worn in. These provisions are necessary for accuracy.

Finish Cut. The finish cuts must necessarily be light ones. On the second roughing, that is, the cut which is made after the piece has been reversed, the stock should be cut down enough, so that only one cut is necessary for the finish job.

Mild steel can be cut with cutting-speed settings of 25 to 100 feet per minute, depending on the hardness and quality of the stock. Although too much speed is to be avoided, it is a fact that the beginner generally cuts far too light, not realizing the possibilities in the cutting tool.

If the surface is to be a polished one, the mechanic must make some allowance for filing and finishing with emery. Here is found another beginner's fault in that he generally leaves far too much stock to be filed off. It must be remembered that it is a difficult proposition to file a rotating piece and still keep it cylindrically true. The finishing cut, when filing is to be done, should leave about .003 inch to be filed and smoothed off. This work of cutting down a bar between centers is the elemental training for all between-center work, in fact to a greater or less degree, for all kinds of lathe cutting.

Boring. The majority of work done in chucks and with carriage support comes under the head of boring. As work of this kind is usually performed on solid stock, it is necessary to drill a hole sufficiently large to allow the boring tool to enter. This hole can be easily drilled in the lathe by using an ordinary twist drill supported in the tail center. If the work is to be of large size, the taper shank drill is best suited for this work, inasmuch as it readily cleans itself of the cuttings. If the drilling is to be very deep, the drill must be frequently drawn out, cleaned, and oiled, or the generated heat will damage the flutes of the drill.

Drill and Boring Tool. The size of drill which one must use for making holes preparatory to boring depends, of course, on the nature of the work. If the work is to be small in diameter and of considerable depth, a drill within one-sixteenth of an inch of the diameter of the finished hole should be used if possible. If the hole is to be of large diameter and shallow, the drill should open a hole large enough to permit the entry of a short stiff boring tool, and this naturally does not have to be very large. There may be obtained boring bars of universal type which will take a variety of tool shapes. In these the tool is secured in a mortise through the bar by suitable wedges or, more usually, the tool is of round steel fitted into a hole through the bar and secured in position by a set screw. In cylinder boring, or reboring, more than one cutter is generally used inasmuch as a single cutter would be liable to spring the cylinder and gouge the metal. The use of a cutting bore equipped with three cutters gives a tool which will operate steadily and make a very satisfactory bore. As in all cases in lathe work, the finish cuts should always be light ones to insure true work.

Mounting the Work. It is more or less of an art to fit a piece, especially an irregular one, into a lathe chuck. No rules can be laid down for this inasmuch as each piece must be centered to take care of its regularity or irregularity in shape. In a good many jobs, the work is of such shape that it cannot be held in a chuck. In such cases, the work may be clamped to the face plate or to an angle plate fastened on to the face plate. This is a setup which requires a great deal of care and patience. In such parts as gear blanks and other pieces having hubs, the work should be chucked on these hubs whenever possible. Work held in this manner will run true if properly bored and turned. It must be remembered that a chuck centers the job. For instance, if one has a piece with a flange and a hub as a part of it, he can have the bore run true with the hub by chucking the work on the hub; but if he desires to have the bore run true with the flange, he should chuck the work on the flange.

Degrees of Fit between Shaft and Hole. When a piece of shafting or tubing is to be turned down to fit a certain drilled or bored hole, there are three kinds of fits which apply, viz, working fits; driving, or forced, fits; and shrink fits. A *working fit* is one such as is found in a bearing, that is, the work will be so machined that it will slide easily in the piece. A *driving, forced, or press, fit* is one in which the work is so machined as to require pressure, either by hammering or in an arbor press, in order to get the cylindrical stock into the hole. In automobile construction, a working fit is generally machined so accurately that the difference in diameter between the cylindrical piece and the hole is extremely small, and still a perfect sliding fit is maintained. The importance in fitting bearings is to have the surfaces of both pieces true to one another within .001 or .002 inch.

In accurate work, this agreement runs into ten-thousandths inch. A *shrink fit* differs very little from a driving fit. It must be so machined in both pieces that, when the bored or drilled piece is heated enough to expand it a few thousandths of an inch, it will allow the cylindrical piece to be easily pushed into it. Then when the heated piece shrinks or contracts, a very tight fit is naturally the result. There is one thing to be avoided in making a forced fit and that is the tendency to swage the metal. This is not the case in a shrink fit inasmuch as the piece goes in easily and then the hole closes squarely down upon the center. It is very important in making a press fit that the cylindrical piece be introduced squarely into the hole. In the shrink fit, it is quite necessary that the relative positions of the two parts, one within another, be quickly made because the shrinking takes place rapidly and causes the two parts to lock together. With a forced fit, in which it is contemplated that the parts will have to be separated, the surfaces of the hole and the cylindrical piece are lubricated, thus preventing oxidization of the metals and making it easier to drive out the shaft. The easiest way to do this is to heat the ring, thus expanding it, in the meantime keeping the shaft as cool as possible by pouring cold water over it.

SHAPERS

Characteristics. In many respects the shaper and the planer are alike. The same cutting tools may be used in either and the general principles involved in the operation of these machines are quite similar. However, they differ materially in design; with the planer the work moves to the tool, while with the shaper the tool moves over the work. On the planer the vertical and lateral feeds are given to the tool, while on the shaper the lateral feeds are usually given to the work and the vertical feed to the tool. In what is known as the traverse-head shaper, both feeds are given to the tool and the work is held perfectly stationary. A shaper of standard design is shown in Fig. 66.

Clamping Work in Shaper. Proper securing of the work in the vise on the shaper table for planing operations is a most important step in the production of satisfactory work. The variety of work assigned to the shaper is great and the operator will continually find himself with new problems to solve, problems that require the exercising of good judgment and care. In the majority of cases more skill is required in setting up the work than in the actual machining.

In work that is compact and heavy and where the amount of metal to be removed is comparatively small, there is but little danger of springing the work; but if the work is large, of irregular shape, or light, the danger of springing is materially increased. In the first

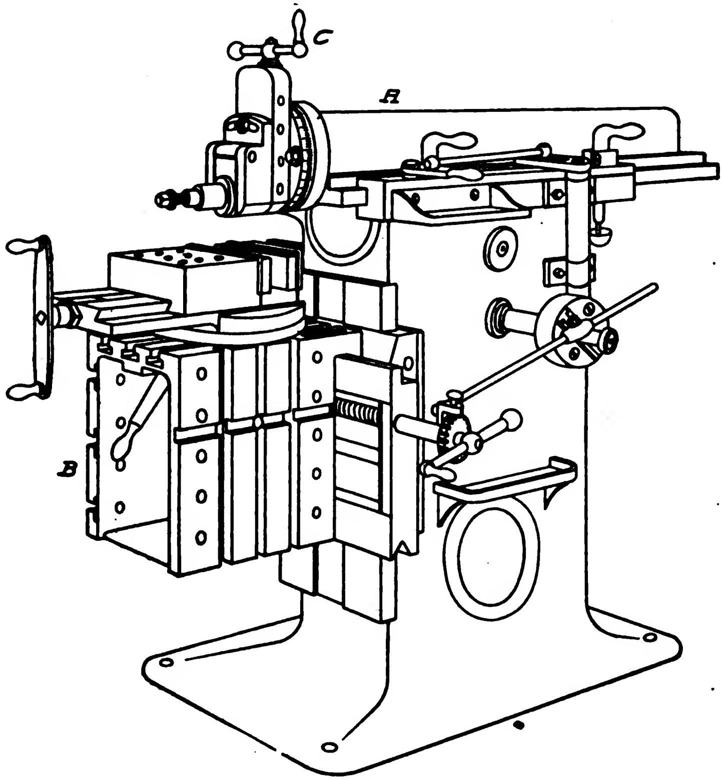


Fig. 66. Typical Pillar Shaper

place, lack of uniformity in clamping distorts the work and throws the machined surfaces out when it is unclamped. Again, the removal of the outer surfaces of a casting or forging, which frequently relieves shrinkage and forging strains, throws the work out of true. The first of these difficulties can be overcome only by using the utmost care in setting up the work, and the second, by first roughing off all surfaces as far as possible before taking any finishing cuts, thus allowing the work, after the roughing, to assume its normal condition.

It is very important that the clamping of the work to the table be done with due consideration for locating the points of clamp pressure directly over the points of support. The supports should be firm and bear about equally on the work and the table. If only a thin shim is required to level up the work, this should be of metal in preference to card board, leather, or any compressible material which will allow the clamp to spring the work. Good blocks and parallel bars are indispensable in the shaper and planer outfits. For work where the points cf support vary in height, leveling wedges and small jack screws are excellent, as they can be adjusted quickly to any desired height. These wedges, especially if any single wedge is used, should have only a very slight taper.

Operation Suggestions. When it comes to operating the shaper, the beginner should keep a few points closely in mind. Not all geared shapers have a fixed length of stroke, the depth of the cut and the speed of the countershaft affecting in a certain degree the points at which reversal takes place. Some allowance must, therefore, be made for the overtravel of the tool. An excessive amount of overtravel, however, means a large loss of time. Roughing cuts should be as heavy and with as coarse feeds as the machine will conveniently handle and as the strength and character of the work will permit. First, before planing side surfaces, see that the top of the tool box is inclined from the work. This allows the tool to swing out and clear the work surface on the return stroke. If it is not inclined, the point of the tool drags hard on the work surface and, should it be inclined to the wrong side, the tool will swing into the work and do damage. Raising the tool clear of the work on the return stroke preserves the cutting edge. Means are often arranged for accomplishing this automatically.

Keep the cross-rail clamped firmly to the housing, when in use, and parallel with the table. Before putting in the feed, see that the feed gear is on the right spindle, as otherwise the tool may start up or down when it is intended to move across the work. As there is usually more than one way to do a certain piece of work, you should study which is the best way to do it. Those factors that have a great deal to do with turning out quality and quantity work are the manner in which the work is set up, the kind of tools and the way they are ground, as well as the efficient handling of the machine.

MISCELLANEOUS EQUIPMENT

Milling Machines. Although the milling machine is not an essential part of the well equipped repair shop, it is really a necessity in a large shop which does building and rebuilding and all kinds of machine work. In its elemental form the milling machine is made up of a rotating cutter which is held in one plane and a moving bed which carries the work under the cutting edges of this cutter. If one is to thoroughly familiarize himself with one of these machines, there is so much to learn in the setting and manipulation that it is hardly practical to try to give a detailed list of instruction herein. Therefore, only a brief description of the machine will be given. If a man has no idea of the operating principles of a milling machine, the quickest and best way to familiarize himself is to appeal for instruction from a man who knows how to operate this machine. The milling machine is a much more accurate tool than a shaper inasmuch as it cuts stock off with one sweep where a planer requires several sweeps with new adjustments for each sweep if accurate work is to be done.

Types. The plain and universal milling machine of the column pattern are the ones generally used for repair-shop work. In this machine, the upper portion of the column carries the spindle and cone, this spindle being back-geared in the same manner as is a lathe. The outer end of the spindle is supported by a suitable overhanging arm. The work table is adjustable vertically and horizontally, these adjustments being made by means of screws which operate with wheels and handles. There is a wide range of cutting speeds provided in the feed mechanism.

Cutters. Milling machine cutters are produced in a variety of forms designed to take care of different kinds of work. One of the most commonly used cutters is the axial type which has teeth on the cylindrical surface only. In the small cutters, these teeth are straight across the surface, and in cutters above $1\frac{1}{2}$ inch they are cut spirally. Another and similar type of cutter is the plain milling cutter with nicked teeth. This has merit in being able to take a deeper cut inasmuch as the chips are broken up by the nicked cutting teeth.

The narrow cutters come in what are known as straddle-mill, radial-face, and side cutters. Another type is the end, or shank, milling cutter which is similar to the radial-mill except that it has its independent shank. These are generally used for small milling work, and frequently the teeth are cut spirally. When one desires to do slot milling at the end of a shank cutter, there is a special type provided, having radial teeth on the inner ends provided with cutting edges, which enables them to cut their way out when moved along the work. For cutting standard T-slots, there are special tools provided having a shank end and inasmuch as they work with the shank vertical to the slot, it is necessary that the center portion be cut away first to allow the narrow end of the shank to pass between. For annular cutting, there is a variety of tools built up to take care of every kind of this work. Probably the most economical for milling tools are those having removal cutters which may be replaced when worn out.

Planers. It is only in the very large repair shops that the planer will find use. As the name indicates, the planer is used for finishing flat surfaces. As has already been said, the planer resembles the shaper, and no further description will be given.

SEVEN-PASSENGER KING TOURING CAR WITH EIGHT-CYLINDER ENGINE
Courtesy of King Motor Car Company, Detroit, Michigan

BUILDING, EQUIPPING, AND RUNNING A PUBLIC GARAGE

PRELIMINARY PROBLEMS

RANGE OF BUSINESS

Service of Public Garage. During the years of development of the automobile, the problems of its care have been solved with equal precision. The automobile mechanic has become skilled in his line, so that the repair shops, which are almost invariably a part of a public garage, render valuable service in curing the aches and pains which every car develops at some time or another. The system of garage service, too, has become standardized; but a point that is appreciated all too little in the business is that a garage is essentially a service proposition. A man takes his car to the garage to be cared for and pays the charges for this to relieve himself of this work. Many men patronize a public garage because they do not want the work of washing, cleaning, and oiling their cars; many others go there because they lack mechanical knowledge and prefer to pay for this knowledge and the service which goes with it, in the way of adjustments, replacements, and general care, rather than to try to learn these things themselves.

Viewed from this standpoint, the garage is nothing but a service proposition, rendering service which the public would rather pay for than to carry out itself. No man should go into the garage business with any other thought than to render the utmost of service and to charge a fair price for it. Many garages have been unsuccessful in the past because their owners lacked an understanding of this principle, the businesses having been run with the idea of rendering as little service as possible and getting as much money as possible for it; in short, the garage business has been reduced to a housing proposition, that is, payment for floor space and a roof to protect the cars from the weather. Another phase of this question is that many garages have been unsuccessful in the past simply because they rendered services of value without making an adequate charge for it. The garage can no more afford to give away its product—services and work—than can the butcher or baker afford to give away his produce. Similarly, when the garage takes on the sale of the most needed accessories as a side line, it cannot afford to give these away even in the smallest quantities. Therefore, no one should go into the garage business unless thoroughly imbued with the idea of selling service and getting as well paid for the service rendered as is legitimate. Moreover, this thought should be prominent from the start, so that the building can be planned and built with facilities for rendering this service the most quickly and easily, and with the least cost to the management.

Selling Cars as a Side Line. The question of whether it is advisable and profitable to sell cars as a side line and whether it works in well with the garage business is one that depends upon the place where the garage is located and also upon the man. There undoubtedly are situations in the country or in the small town where this combination is a nautral and desirable one, because the business will be small enough to make it almost necessary to concentrate everything—sale of cars and of accessories, and the care and repair of both after the sale—in a single building and under one management. As a rule, however, it has been found that the two lines are separate businesses and require separate and distinct methods of handling. The men fitted for one business are seldom, if ever, suited to the other, and the nature of the buildings—its fittings or surroundings, equipment, care, heating, lighting, and many other things—is so different as to warrant separating the two; in short, it is very seldom that the garage and the salesroom can be operated together to advantage.

Selling Accessories. The secondary question of whether it is advisable to go into the sale of accessories must also be considered. It might almost be taken for granted that the garage would sell oil, grease, and other lubricants; gasoline, kerosene, and other oil products; but in the matter of the smaller but frequently used accessories, such as spark plugs, tire-repair kits, jacks, and other small tools, tires, and similar supplies which are in constant demand, local conditions outside of the garage usually govern.

In the country or in the small town, where automobile accessories and supplies are not handled by any other stores, it is advisable for the garage builder to consider this point and to provide space and a suitable arrangement for handling them.

In the city, on the other hand, there are many stores that handle accessories on a scale far beyond the ability of the garage man. This enables the big stores to give a choice in the way of quality and price that puts the garage man at a disadvantage. To sum up the matter, where the number of people, and, as a result, the number of cars and trucks, within a reasonable radius of the garage is great, there will be stores specializing in supplies and equipment; and it is inadvisable for the garage man to go into their sale on as large a scale as capital and business in sight will permit.

Special Side Lines. Practically the same conclusions apply to the matter of including the auxiliary business. By side lines, reference is had to vulcanizing and tire repairs; to painting, upholstering, and top work; to general machine shop work and alterations on a large scale, such as the remodeling of old cars, the conversion of cars into trucks, etc.; complete overhauling which necessitates facilities and equipment beyond the average garage; and other things. In the country and the small town, it is advisable to go into these various auxiliaries as far as the business in sight will warrant, but in the cities where there are specialists in these lines who can give more and better service, give it quickly and advantageously, and perhaps at a lower price with profit, it is inadvisable, and the garage man should not attempt anything outside of strictly garage service.

In the medium size town, it is frequently advisable to consider the general proposition of having a number of such auxiliary businesses in the same building, apparently component parts of the garage, but, in reality, separate and distinct firms, each run by a different man. This makes a convenient working unit for the people owning cars, yet the various businesses being separate, and each run to facilitate a special line of work or endeavor, they do not conflict; on the contrary, each one derives business from its close association with the others.

Financial Problems. One point which should be considered with more care than any other is the matter of financing. It is a big mistake to start a garage on the assumption that it will pay a profit from the start. This is seldom the case, and the prospective garage man should plan his finances so that he will have sufficient money to care for running expenses for a considerable length of time. This should be done even if the initial building is not built as large as the garage man plans to have it ultimately, and even if the equipment is not as complete as might seem desirable. In a very short time, if the garage has been planned wisely, the location chosen carefully, and if the business is run on a basis which holds all boarders who come in and attracts more, the profits will come, and the extensions of building and equipment can follow.

CHOOSING THE LOCATION

Probably no single item will have a greater influence on the success or failure of the garage business than the wise choice of location. Three things must be considered: existing car owners, the location and proximity to main highways, and the allowable size and shape of the building. The value of the land will have an influence on the overhead expense, for what might seem an ideal location in every other way may be beyond the financial means of the garage man.

Land Values and Size of Building. Size is closely inter-related to value of land and to the cost of the building, as will be shown by a simple example. If a plot 80 x 100 can be arranged to such advantage as to hold the same number of cars as another plot 100 x 100, and the former cost but $8000, while the latter is held at $10,000, other things being equal, the first is the best business proposition. Suppose both plots will hold 56 cars; then the land cost alone is $143 per car for the first lot and $178 per car for the second. Obviously, a greater price would have to be charged for storage in the second case than in the first, to make an equal margin of profit. And what is true of the land is equally true of the building, for a building 100 x 100 would cost at least 15 per cent more than a similar one which measured only 80 x 100.

Central Location in Territory Desirable. In choosing a site there are two points to consider. Generally speaking, that site in the proposed territory would be best which is in the geographical center of the cars that would use it. This could be arrived at mathematically, of course, but this is unnecessary, because a rough inventory of the cars upon which the garage would depend for patronage will locate a general center of action that is satisfactory.

If the surrounding residents protested against a garage at the location decided upon, or if there were any other reasons why it could not be located in the place desired, a second item would have its influence upon the second best choice. This is the proximity to a through highway. The importance of this point may be judged from the plain statement that many garages, during the touring season, derive more than 25 per cent of their receipts from passing cars. The transient trade grows more important each year as touring increases. The influence of this growth would be such that when the second choice has to be made outside of the center of action of the territory to be served, this location should be such as to bring the garage nearer, as much nearer as practicable to the point where it can retain the permanent trade and still get that of the through highway.

DETERMINING SIZE OF GARAGE

Methods of Calculating Size. The inventory of the proposed territory is valuable, since it gives a good basis for the size of the garage. Obviously, in a territory with but 25 cars all told, of which perhaps 15 were well housed in private garages, it would be foolish to build for more than 30 to 40 cars, that is, the 10 to start with, perhaps as many added in the first year because of the presence of the garage, and an average of 4 or 5 transients would be about all that could be counted on throughout the first year. This totals less than 25 cars on the average, and a building large enough to house 30 to 35 cars is all that this much business would warrant. Of course, a small quantity of oils, gas, and minor supplies would be sold to the owners of the other cars, but the profit from these would be very small because the sum total of the sales would be small. Transient trade bulks up large, by comparison with steady boarders, principally because it is almost universally charged about twice as much, that is, a garage having a flat monthly rate of $15 a month, will charge all transients $1 a day, or $30 a month, making one transient, while it stays, the equal of two steady boarders. The boarders, however, form the backbone of the business, since without them the garage could not exist to take the transient trade.

Knowing the number of cars available and estimating the additions and the average number of transients during the first year, a rough total can be arrived at which can be used to determine the size of the building. An average car must have a floor space of approximately 15 x 7, and at least 20 feet should be allowed for a comfortable aisle, or driveway, between standing cars. Few cars, if any, actually total 15 feet in length, or 7 feet in width, but, on the other hand, cars cannot be placed in the space assigned within a few inches; so the space given is about as small as can be used.

Methods of Arranging Cars. The size of car and of the aisle space brings out our first rule of garage proportioning, in which there are three ways of arranging cars: one row on each side of a central aisle; two rows deep on one side, and one row on the other side of a central aisle; two rows deep on each side of the aisle; also duplications of these arrangements when the garage is unusually wide. Taking the figures given above, we get the following preferred widths, namely, two 15-foot spaces and a 20-foot aisle for the first case, or a 50-foot total; three 15-foot spaces and a 20-foot aisle in the second, or a 65-foot total; and four 15-foot spaces and a 20-foot aisle in the third, or an 80-foot total. Doubling up on these gives 100 feet for the first, 130 feet for the second, and 160 feet for the third. This last is probably too wide for all normal conditions, but the other five are possibilities.

To make these more clear, Fig. 1, in which these five cases are shown, respectively, at *A*, *B*, *C*, *D*, and *E*, is presented. The depth needed per car is 7 feet; so the width having been determined, and one of the above five methods having been fixed upon as the best for the purpose, the total depth is found by dividing the number of cars to be housed by the number accommodated in one 7-foot width, and then multiplying this result by 7. Thus, suppose a narrow garage has been fixed upon, under scheme *B*, Fig. 1, which accommodates three cars in one width, or 7 feet. And suppose the total number of cars to be provided for is 90; then 3 goes into 90 30 times, and 30 times 7 gives 210 feet for the total depth. As this is deeper than lots usually run, it would be best to change to scheme *C*, which accommodates 4 cars per strip of width, thus 4 goes into 90 22 plus, and 22 times 7 equals 154 feet for the depth. Under certain conditions, a strip might be available straight through the block, so that instead of changing to scheme *C* we could go the other way, changing to *A* and making the garage narrower and longer.

On this basis, 90 cars would need a strip 50 x 315 feet. The advantage of the last method would be to provide two entrances, one on each street.

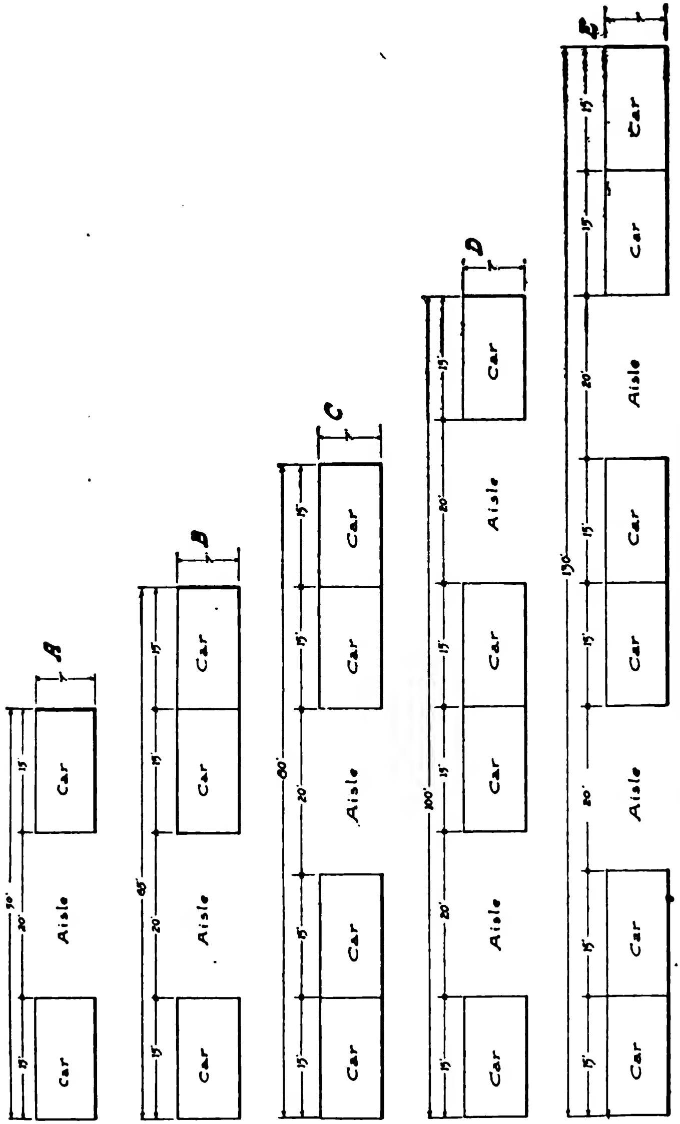


Fig. 1. Various Possible Arrangements for Garage Interiors

The writer has seen cars placed in a garage parallel to the aisle, as sketched in Fig. 2. This placing has the disadvantage of making much extra work in putting in or taking out a car behind those in the front row. Usually, where the cars all face in one general north and south or east and west direction, there is little trouble in getting a car in or out, except at the times when all owners come in or go out at once. But as soon as a different placing is introduced, there is difficulty, for not only must more cars be moved, but they must be moved in different directions, and some of those moved will obstruct the passage of the car coming in or going out, thus making double work. This method, however, is usable; in fact, it is in fairly wide use. It increases the width in scheme *A* to about 57 or, in round figures, 60 feet, and adds one car in each two strips for every 14 feet. In *B* it makes the width 72 or, in round figures, 75

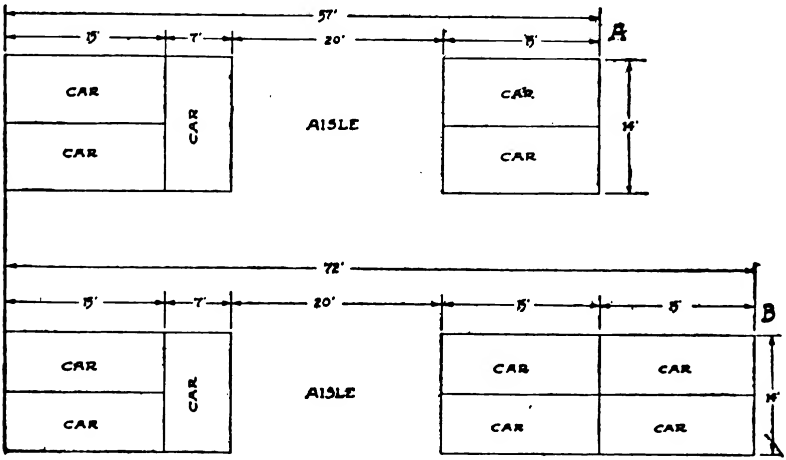


Fig. 2. Modifications of the Garage Arrangements of Fig. 1, Made Possible by Turning Part of the Cars

feet, and adds one car for every 14 feet of depth. In *C* it makes the width 87 or, in round figures, 90 feet, and adds one car for each 14 feet, or adds two—one on each side—when it is 95 feet in width. Schemes *D* and *E* may be handled in a like manner.

Modifications of Size Due to Situation. If the garage is situated in a small town or in the country, it is possible to slightly trim the dimensions given. Thus, a Ford car needs but 12 feet; being uniformly narrower and turning shorter than other cars, it can be handled in a narrower aisle. This would mean that a garage entirely for Fords could have, under scheme *A*, Fig. 1, a width as little as 12 + 15 + 12, or 39 or, in round figures, 40 feet. This is an unusual supposition, but is given to show how valuable the inventory of the territory is and how complete it should be, for this inventory would show the relative number of small machines.

Other Modifications and Deductions. *Space for Office Fuels, Etc.* In what has been said previously, the entire inside of the building has been figured as storage space and aisles for cars. This is not ordinarily possible, for there are many other things to consider, all of which deduct from the interior space. First, there is the office which must be well and wisely located, for it must govern the incoming and outgoing in such a way as to keep a perfect check on all cars. Then there is the room, preferably separate from the office, for the oils, fuels, and greases. Usually, the building regulations require a fire wall all around this room, and, even if they did not, it is good policy to build it that way. Then, the wash rack is a very important place and takes up the space of at least two cars, possibly more. Toilet rooms for both sexes, lockers, air compressor, and other things require floor space. Also, if there is a sales department connected with the garage, either for small things or for the larger units, as tires, a show room and storage space are both needed. Then, too, there is the matter of auxiliaries. If the shop has a tire-repair department, space must be allowed for this. Similarly, if any of the other auxiliaries are included, they deduct from the floor space for car storage.

Space for Stairways and Elevators. If the building is more than one story high, the space taken up by the elevator and immediately surrounding it on all floors, or that taken up by ramps, or inclines, if they are used, must be considered. This space might be thought to be small at first, but, in figuring it over, it will be found that the elevator must be at least 16 x 8 in size, which means at least an 18 x 10 total. To this space must be added at least 10 x 10 for the machinery to operate it, and approximately as much more, 10 x 10, which must be kept clear at the elevator in order to give access to it readily. This space totals 38 x 10, a space almost equal to four cars, which should be deducted on each floor, while ramps would take out still more space.

Space for Posts. In order to support the roof or upper floors, as the case may be, posts or expensive structural steel trusses are necessary. The location of these posts influences the arrangement of the cars, both as to width and as to depth, so that unless they are very cleverly placed much space can be lost around them. In a comparatively large garage of considerable width where more than one row of posts is needed, the space taken up by posts mounts up considerably, and can easily total that of two or three cars.

Summary of Deductions. By the time the space of two cars is allowed for the office, that of two more for toilets, one for lockers, one for the fuel and oil room, that of two or three more for the wash rack or twice this amount if there are two wash racks, that of one or two for the posts, etc., and the total added up, it is found that a fairly large percentage of the storage space is gone. If the building be one with upper floors, it is found that elevators or ramps have taken out fully as much more, and that all this deduction is repeated on each floor, with the exception of the office space and of the fuel and the oil spaces.

All the modifications and deductions stated in the preceding paragraph must be taken into account in laying out the original plans and in buying the site and erecting the building. If the net floor space which can store cars, and the number of cars which can be stored in this space be multiplied by the average price which can be obtained for each space, the answer will, to a great extent, determine the revenue. Consequently, if the deductions reduce the space below the point previously considered necessary, the size should be increased to compensate for this loss, that is, if deductions cut out 10 cars that were figured in, the size should be increased sufficiently to house 10 more cars than were provided for originally.

The plans for four different sizes of garage will be considered in detail. These plans are not offered as ideal, for such a thing as an ideal garage does not exist, but they will present, in a more easily grasped form, some of the difficulties of garage planning and construction. The sizes have been selected upon the basis of being: small; medium size; large; very large.

Except for the very large size, which is too large for any but city use, these garages might be located anywhere. After the garages have been considered in detail, the matter of equipment will be taken up, and the equipment that is generally considered necessary will be indicated; also the equipment that is desirable and perhaps profitable but not necessary, as well as that which the handy garage man can make for himself; most of the latter equipment is also desirable and profitable, but it is not absolutely necessary. Finally, such other details as heating, ventilating, safety, lighting, cleanliness, and other similar subjects will be considered according to their value.

DESIGNS OF PUBLIC GARAGES

SMALL SIZE GARAGE

While it might be considered small in the country, or in a very small city or town, a garage approximately 50 x 100 is generally spoken of and considered as a small garage. Such a garage can seldom be arranged to regularly care for more than 25 cars and take care

Fig. 3. Average Arrangement of Small Garage (50 x 100) to House 27 Cars

of them well. If any accessories are sold, the space they occupy cuts down the number of cars. If an agency for a car or a truck is maintained, space must be provided for a show room and salesroom, and a building of this size can seldom be used to store as many as 20 cars. Although it may seem large, it is, in reality, small.

Typical Arrangements. *Layout 1.* Let us see how this space can be arranged to the best advantage. In Fig. 3 is shown a layout in which the cars are arranged along the two walls at the front part of a 50 x 100 building, but the last 32 feet of this space have been partitioned off into a form of repair shop, with a bench along the rear wall and a few tools in one corner. This layout provides no office and no locker space, but just the bare storage room, with a little space for repair work, and few facilities for doing it. It accommodates 26 cars, as the sketch shows.

Layout 2. If the intention was to have storage space only, with simply a bench provided for repair work, this space could be managed more advantageously by rearranging it, as shown in Fig. 4. Here the partition has been taken out, and for a short distance along one wall all cars have been moved out into the central aisle a few feet. This allows room for the work bench and space beside it in which to do work. Space is provided for 28 cars, 2 more than in layout 1, and, if it were necessary, two cars could be put against the rear wall in the aisle, as shown by the dotted lines, to make a total of 30. Of course, the corner for tools and the tools themselves

Fig. 4. Rearrangement of Small Garage to Hold 28 (and possibly 30) Cars

have been taken out, but, aside from that, the rearrangement has added almost 16 per cent to the revenue.

Layout 3. This is perhaps the maximum space for this size of garage, as nothing but storage space has been provided. If a wash rack is to be added, that will cut the storage space down. So, too, will an office for accessories and a show room. Another arrangement is shown in Fig. 5, in which the entire front of the building is given up to display, the cars entering at the rear. Note how the show room takes the larger part of the front, and the accessory salesroom the other part; also how the offices, toilet rooms, and stock room take up space back of the salesroom, so that the garage itself houses but 19 cars. The wash rack is really in the aisle, although at one end.

Layout 4. By eliminating the private office, or rather combining it with the other office, with a door opening into both the show room and the accessory salesroom, and by leaving out the toilets, as indicated in Fig. 6, which is this same plan revised, 5 cars may be added to

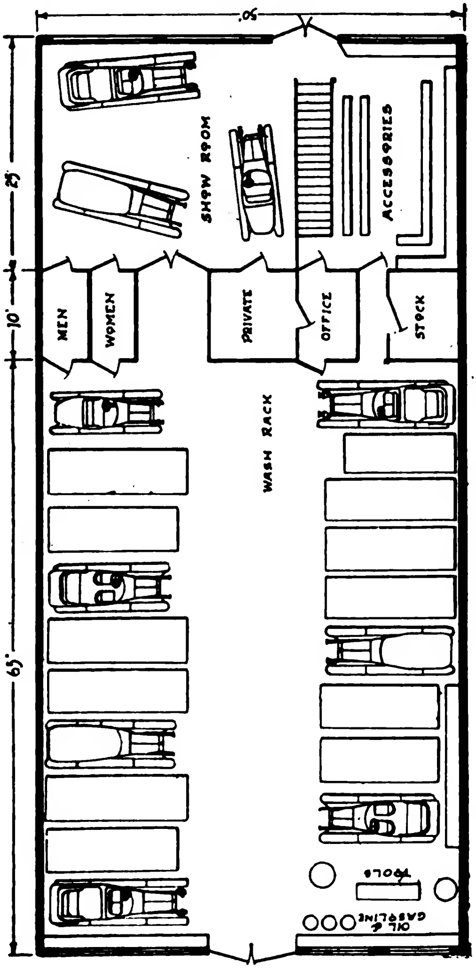


Fig. 5. Another 50 x 100 Garage Arrangement Which Provides Show-Room Space

the storage total, making 24 in all. This arrangement would be particularly good if the shop walls of the central office were of glass, for then it would be possible for a person in the office to keep track of the entire establishment—show room, accessory salesroom, and garage. This layout provides for oil and gasoline storage, tools, work bench, wash rack, salesroom, accessory room, stock room, and office, yet it houses 24 cars.

Layout 5. Another 50 x 100 floor plan is shown in Fig. 7. This plan provides for the grouping in one unit, on the right side

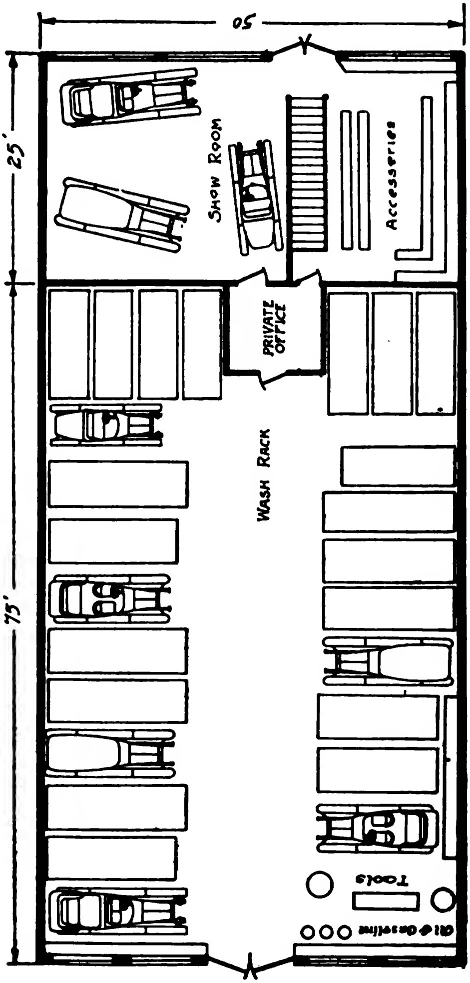


Fig. 6. Rearrangement of Fig. 5 to Give More Car Storage Space

of the entrance, of the two salesrooms, office, stock room, and men's toilet. It is intended for the man or firm wishing to have considerable window display space at the front, and, for that reason, both the salesroom window at the right and the other window at the left are arranged for displays. The window at the right is for cars, while the one at the left is for small parts. A good idea of this plan is obtained from the front view of the establishment, Fig. 8. This

Fig. 7. Different Arrangement of Small Garage with Show Rooms and Offices
Courtesy of "Motor World"

plan is mentioned because it has a bearing on the floor space available for car storage, the display window for accessories and the oil-barrel arrangement just back of it taking up the space of one car.

Fig. 8. General Appearance of Front of Garage Shown in Fig. 7 Plan
Courtesy of "Motor World"

A modest repair outfit at the rear is composed of a work bench, lathe, drill, emery wheel, and press. The capacity, as shown, is for 17 cars, but by arranging the cars directly back of the accessory and parts stock room and parallel to the aisle, as shown in the dotted lines, one car can be added, making the total 18.

Modification of Layout 5. Considering the diversity of other things provided for, this layout seems excellent. For the man who might like this arrangement, yet who does not wish to give any space to car sales, the layout shown in Fig. 7 can be modified. The oil barrels can be removed and the accessory department moved to the extreme front, while the accessories and parts stock room can be eliminated. If the garage man sold only small accessories—the little things which could be handled at a simple counter or from ordinary shelves on the wall back of the counter—he would need little or no stock room, as such storage room as was needed for excess stock could be found under the counter, on the top shelves, or elsewhere. By this rearrangement, as can easily be figured, 8 or 9 cars may be added, making the total 25 to 26 cars, without changing the front or general good arrangement; in short, the layout shown in Fig. 7 provides for a car-agency arrangement, and also storage for 17 or 18 cars. The same layout without the agency space can be arranged for the storage of 25 or 26 cars.

In making his initial plans and the building layout, the garage man must balance his income from storage plus that from car sales against the increased income from storage alone, that is, in the two layouts just shown in Fig. 7 and its suggested change, he must figure out whether he will make more money from a 17- or 18-car garage and a sales agency, or from a 25- or 26-car garage and no sales agency. The accessory sales are about the same in the two cases, although possibly in the case of having a car agency, he might sell more accessories to the people who bought cars from him. This question, however, is problematical.

MEDIUM SIZE GARAGE

Typical Arrangements. *Layout 6.* In the following, a garage is considered of medium size, which has a floor space of approximately 10,000 to 12,000 square feet. In a square form, this gives from 100 x 100 to 100 x 120 feet, and in a long narrow form, 60 x 200 feet, with various other forms in between these two. As a matter of fact, neither the exactly square form nor the unusually long and very narrow shape is an advantageous one. A floor plan of a Brooklyn, New York, public garage is shown in Fig. 9. This garage measures exactly 100 feet each way. It is on a corner, with an entrance on each street. Moreover, the single central post appears to give a maximum of floor space. The supply room and the office are small, and apparently little space is wasted or taken up for things other than car storage. Yet, when we come to figure out the number of cars which this building will store—only 30, as can be figured from the plan, Fig. 9, and with little or no aisle room, so that cars would have to be moved every time one not in the first row was taken out—the truth of the statement that the square shape is not economical is proved. By inspecting this layout for an opportunity to improve upon it, we see that only two things can be rearranged to advantage. One is to reduce the number and size of the lockers. This size and arrangement may have been forced by local conditions, competition, or by some other reason, but even that arrangement of lockers is not as good nor as economical of space as if they were grouped in one corner.

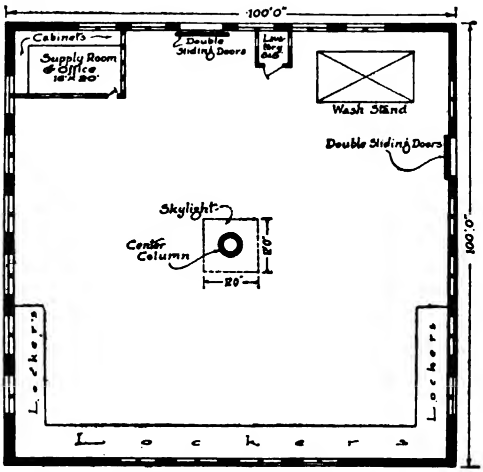


Fig. 9. Brooklyn Medium Size (100 x 100) Garage, Located on Corner

The washstand, however, seems to occupy the best corner of the building, yet there is a space on the Sea Gate Avenue front, between the office and the door, which is large enough for the washstand but which will hold only one car. By moving the washstand to this spot, the other corner would be available for cars. These spaces are shown by the dotted lines, which indicate that four cars could be put in the space now occupied by the washstand and this number, less the one lost in the other corner, would make a net gain of 3, bringing the total to 33 cars. If, now, it were possible to place the lavatory in a corner of the office space by slightly reducing its size, say from 8 x 8 to 6 x 7, two cars could be put in the space which it now occupies. So this square shape could store as many as 35 cars.

It compares unfavorably with the preceding layout, the rearranged Fig. 7, which was only 50 x 100 and was rearranged to

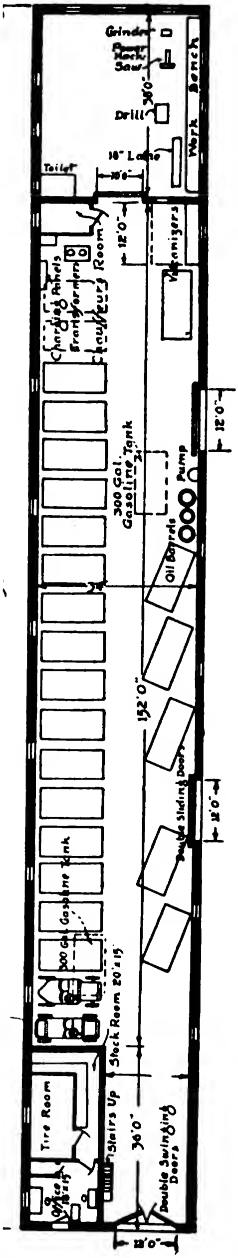


Fig. 10. Long and Narrow New Jersey Garage, Which Is Wasteful of Space

house 24 cars, while this 100 x 100 can hold but 35. If this shape were as efficient as the other, the doubled size should hold at least twice as many cars, or 48.

Layout 7. A New Jersey establishment, very long and narrow in shape, is shown in Fig. 10. This garage is built on a corner and extends through to a rear street, so that it has three street fronts. The third street front is utilized only for light, as the location of the repair shop at the end precludes having an entrance there. The dimensions show that this garage is not quite as large as the other, since it has but 8100 square feet of floor space. Moreover, it is so narrow that a row of cars cannot be put along each of the two walls to take advantage of the length. The best that can be done is 20 cars along the one all, with a maximum of 6 along the street wall, and even this number can be obtained only by placing them at an angle. The repair shop is sufficiently large so that it might easily hold 5 cars on which work was being done. This gives a maximum of 31, or if the repair shop be considered as separate from the storage, 25 only.

Two ways of improving layout 7 suggest themselves. One of these is to move the chauffeur's room, charging panels, and transformer inside the repair shop; by doing this, storage space for 2 more cars along the wall could be gained. The other method would be to move the repair shop up alongside of the office and the tire room. This can be done in two ways: It can be placed along the back wall, where a depth of 49 feet would give it about 60 per cent of its present space, replacing 7 cars. Then at the rear, in its former space, providing the vulcanizers were moved with it, space for a total of 9 cars could be made. This would be a gain of 2 cars, which, with the previous gain of 2 by moving the chauffeur's room, gives a total of 30 storage cars. On the other hand, the repair shop would be so small that it could accommodate but three cars for repairs.

The way to improve this layout would be to place the office and tire room back alongside the repair room, allowing the repair room to occupy the full width of the building. In this rearrangement, the chauffeur's room, charging panels, and transformers would be taken care of also, so that while 16 feet would be taken off the length, the entire balance of the floor space would be available for storage of cars. This rearrangement would not take off anything at the rear, and the space added at the front corner would store 6 cars, while one more could be set at an angle against the outside wall. This plan, then, would bring the total capacity of this long narrow garage up to 33 cars. The only way in which the layout could be further improved would be by the removal of one of the doors on Railroad Avenue; by doing this, 2 more cars could be set at an angle along that wall, making a total of 35. When cars are set at an angle like this, however, the projecting corner of each car makes a bad point to pass, as this corner is a fender, which is a rather weak unsupported part. This arrangement, too, cuts down the available aisle to a space scarcely sufficient for cars to pass through, certainly not enough for them to pass through at speed.

Layout 8. Both the above arrangements provide for car storage and small accessories only, one having a repair shop, with battery-charging and tire-repair facilities, but neither having car sales space. A layout with slightly more floor space is shown in Fig. 11. This layout is an irregular space having a tapering corner which renders it doubly interesting, and space is provided for painting and trimming, also for a small car salesroom, and for an additional store that could be rented. The car space will store an even 40 cars, while the repair shop provides space for 6 more, and the paint shop and the trim room can accommodate 2 cars each, thus making room for a total of 50 cars in the establishment.

The building is on a corner and has entrances on three sides. If the prospective garage man has a layout like this, and if it were desirable to make it yield more revenue by adding storage space, the elimination of the store and the small office corner would allow storage for about 8 more cars in that space. In figuring this space, however, the net additional revenue from 8 cars would have to be balanced against the net revenue from the rental of the store. In this layout, where the offices are at the front and the paint and trim shops are at the rear, the cars enter from the street at the right, while the other cars can enter either at the front or at the rear through the repair shop. Consequently, the space at the rear end of the

Fig. 11. Combined Garage, Salesroom, Paint, Trim, and Repair Shop on Irregular Corner
Courtesy of "Motor World"

right portion of the building could be used for two more cars, as the dotted lines show. These two changes would bring the capacity up to 50 storage cars, with 10 more cars in the three shops, so there would be a source of revenue from a total of 60 cars.

As the tapering corner is the part that gives the trouble, layout 8 might be improved by using this irregular portion for the three shops. If a partition were run from the back to the front, between the door and the window in the far corner and parallel with the right side until it met the present office lines, it would leave a car storage space 85 x 60 feet, with square corners and three entrances. It would also give all the office space of this layout and allow the shops more floor space than they have, that is, over 3400 feet as compared with over 3000 feet. This layout, shown in Fig. 12, by narrowing down the present aisle from the street at the right and putting in another double row toward the back would permit storing 47 cars. In addition, two more cars could be put in the corner where the two aisles meet, thus giving storage for 49 cars as compared

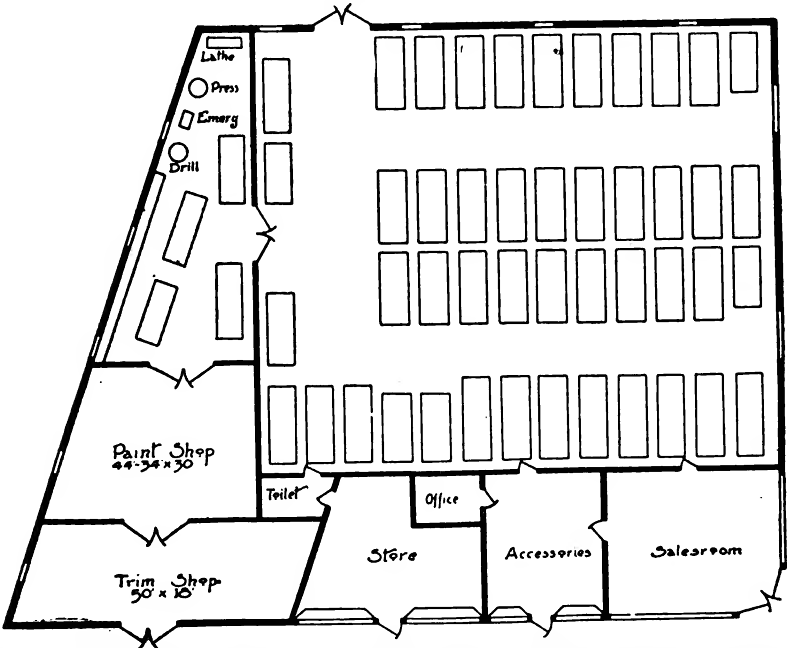


Fig. 12. Rearrangement of Medium Garage Shown in Fig. 11, to Give More Regular Car Space

with the present 40, and yet retaining all the present advantages. This might seem a small amount for so much trouble, but it can be figured as follows; If one car pays a minimum of $20 a month, which is $240 a year, 9 cars would add $2160 a year or, in round figures, $2000. At the same time, all three repair shops have more space than previously, and the garage space is cut down to a rectangular shape, with four square corners, making it easy to arrange, use, and keep clean. This rearrangement also makes the garage portion more accessible for cars, despite the fact that the front street entrance is eliminated in so far as the garage portion is concerned.

LARGE SIZE GARAGE

General Characteristics. A garage is considered large which has in excess of 20,000 feet floor space, that is, while the small garage would have about 5000 feet, and the medium size garage somewhere near 10,000 feet, the larger form would be about twice the size of the medium, or four times the size of the small garage. As a general thing, there are few garages of this size, which would work out at somewhere between 60 x 340 for the longest and narrowest shape, and 150 x 150 for the square, that is, when a garage has sufficient business to warrant this much floor space, it is in a section where the land is too valuable to be used in the form of a one-story building, for which reason most of the large garages occupy two stories, two stories and basement, three stories, or even more. This immediately brings in a point not previously touched upon, namely, the method of handling the cars on other floors than the ground floor.

Elevators vs. Ramps. In garages of more than one story, the cars are handled in one of two ways, by means of elevators or by inclines called ramps. Ramps have come into use in the last few years, and present the following advantages: They are usable at will, at any time of the day or night; the attendant and the machinery to run the elevator are eliminated, as is also the danger from the open pit. The ramp minimizes the fire hazard, which the elevator shaft always increases by providing a natural chimney, while ramps are never continuous from basement to top floor, and are made of concrete. On the other hand, they take up more space on all floors than elevators. Where the layout of the building allows it, however, they are considered a better investment. Certainly, from a service viewpoint, ramps can and do render much quicker and more efficient service than any number of elevators. They are said to cost less, for the increase in the building cost is more than offset by the saving in the cost of the elevator and its machinery.

In the large garages to be shown and described, some have elevators and others have ramps, and although no direct means of comparison is afforded, an analysis can be made in every case, and the question of which method would have been better can be settled.

Typical Arrangements. *Layout 9.* Fig. 13 shows a one-story garage of the amount of floor space which entitles it to be called large. It is an old remodeled building with a width sufficient to

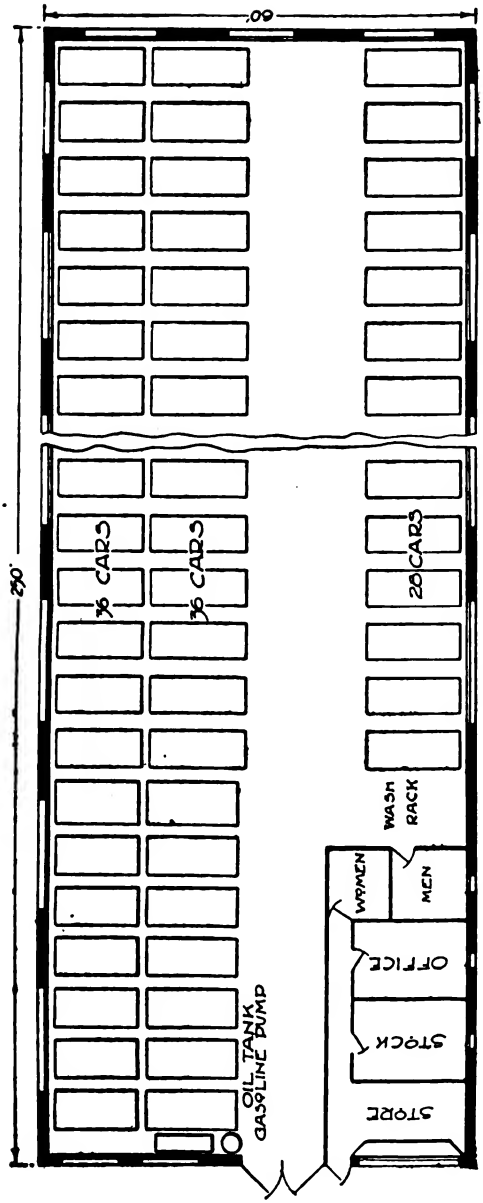


Fig. 13. Very Long and Narrow Building Made into 100-Car Garage with Very Regular Layout
Courtesy of "Motor World"

allow the arrangement *B*, shown in Fig. 1. With this arrangement the building has room for 100 cars. There is provision for a small store, a stock room, office, toilets for men and women, wash rack, also fuel and oil pumps. The latter are placed at the street front, just inside the door. The building, although as long as the average block is deep, does not run through to another street, so there is no back entrance. This plan makes it possible for some cars to be placed at the back end of the aisle against the rear wall and as far forward as seems advisable, as indicated by the dotted lines. Despite the number of windows on all four sides, it is advisable to have several skylights in a building of this size and shape. In an old building altered for garage use, the better way is to cut the skylights through the roof.

Use of Basement. This layout, beyond its unusual length, shows few, if any, features. It has, however, everything on one floor. When it comes to building several stories, the question arises as to whether it is cheaper to excavate a full basement and use that, or to merely go down far enough for foundations and build one story higher to offset the lack of a basement. In a specific case where three floors are needed, they can be obtained by the use of a basement and two stories, or three stories above ground and no basement.

The question of which construction is better must be settled by local conditions. If the general increase appears to promise a need for more space in a few years, the basement and two-story building would provide the three floors for the present need, and the walls could be made heavy enough for the addition of one or more floors above, later. On the other hand, the three floors might represent the limit of future expansion, that is, as far as the garage man could see ahead, while excavation was high priced, or the site contained rock or something of that sort. At any rate, it is a question to be settled in advance, for the basement cannot be put in after the building is erected.

Steady boarders do not like the basement unless it is unusually well lighted and kept very clean. But this is not a great disadvantage, as there are many things about a garage that patrons do not like. If a choice is offered between a basement with a ramp and a third story, the patron will take the basement every time. From the viewpoint of some garage men, the basement has the advantage of lacking in natural light, and there is a disinclination on the part of patrons whose cars are located there to work on them, consequently the garage gets more work than it would if all cars were on or above the ground level where the floors are well lighted and the owner is given to doing much of his own work.

Layout 10. A three-floor garage with two elevators is shown in Fig. 14. This might be either a basement and two-story building or a three-story building. The layout includes a repair shop and a paint shop, located at the rear of the top floor for the best light and occupying the full width of the building. On the ground floor is a salesroom, accessory sales space, stock room, office, a private room, and toilets for men and women. In the car-storage space are two wash racks, located directly in front of the two side entrances. The lack of wash racks above the ground floor would appear to be a big disadvantage here, for the 54 cars on the second and the 33 cars on the top floor would have to be brought down one at a time, washed, and then taken up again, or else not washed at all.

Since a paint shop needs a form of wash bench, it would seem as though one should have been laid out on the top floor in connection with the paint shop and another on the second floor, to obviate this drawback. On the other hand, a garage of this type will often rent most of its entire top floor, totaling, in this case, space for 33 cars, for dead storage, the balance being occupied by cars to be repaired, for which there is not room in the repair shop. In this case, no washing

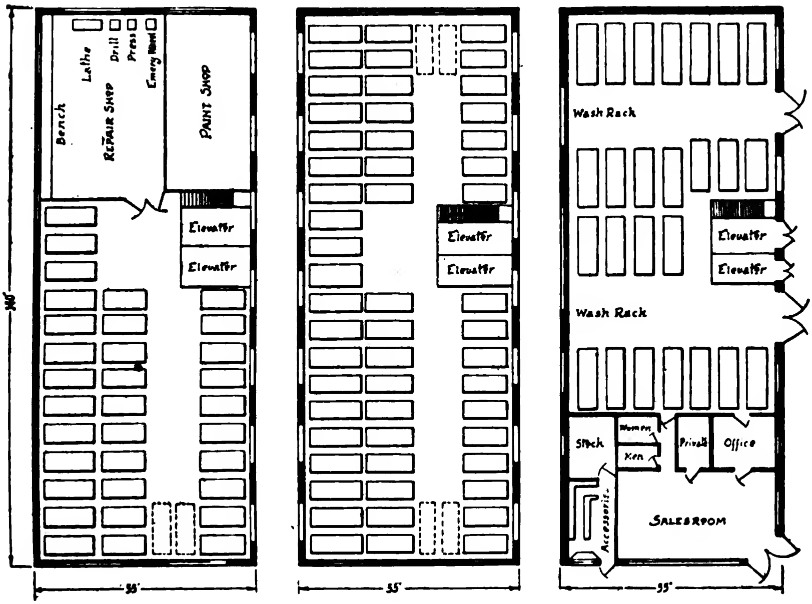


Fig. 14. Arrangement of Three-Story Garage, in Which Two Elevators, Side by Side, Are Used

or other attention need be given the cars; so, in the usual garage, the need of light and heat would be eliminated. It is an excellent layout, and could not be improved upon for quantity or economy of space, unless the ends of the aisles at the front and back of the building were used. As the dotted lines show, this would add room for four cars on the second floor and two on the top.

Improvements of Layout 10. The elevator arrangement in this building might be criticised on the ground that the two elevators are so close together and so located in the middle of the building as to be no better than one, except for frequency of service. As they are

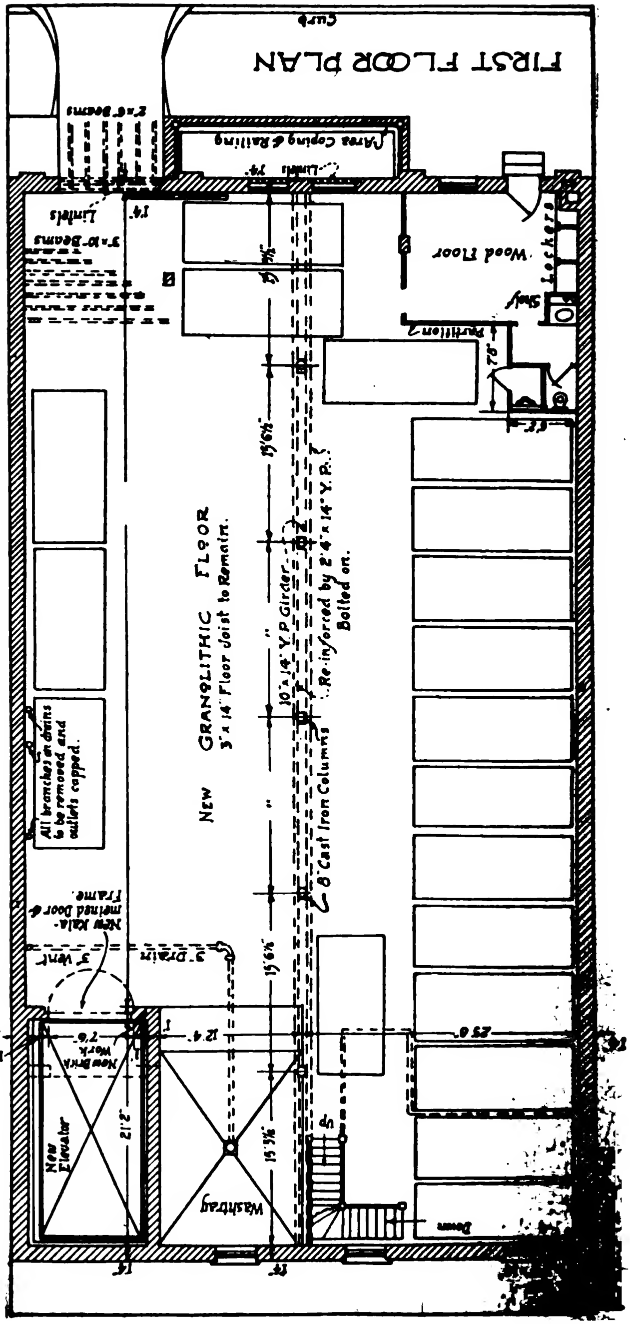


Fig. 15. Ground Floor Layout of Narrow City Garage with Entrance at One Side

placed, they take out the space of three cars on every floor. If they had been placed back in the corner at the rear, only two cars each would have been displaced on the ground and second floors, but the paint shop arrangement would have been upset, and there would still have been the objection of two elevators side by side being little better than one. If the elevator nearest the front were left where it is, and the other one moved back to the rear corner, the two cars displaced on the ground floor would have been offset by the three which could be added at the present position, thus gaining one. On the second floor, the two cars displaced would just equal the two which could be added, while on the top floor two cars would be added, so that the net result would be 3 car spaces gained. In addition, the paint, repair shops, and the second floor would get better elevator service.

Layout 11. A typical city garage, built on a very narrow lot, so narrow that the garage floor space is not economical, is shown in Fig. 15. This is the first-floor plan, as the basement is not used for cars, although the three upper floors are. The arrangement shown, with the office, clothes closets, and toilet in one corner at the front, the entrance on one side, with the elevator at the rear on the same side, the wash rack alongside the elevator, and the stairs close to the wash rack, all cut into the space so that but 19 cars can be housed. If the building were a few feet wider and had the entrance in the middle, the cars could be lined up along the two walls, in which case the single floor capacity would be in excess of 32 cars. On the upper floors this is actually done, as a large percentage of the vehicles are taxicabs, the owner of this garage being interested in a taxicab company. These taxicabs are small, being shorter than regular touring cars, and therefore need less space for standing room and for maneuvering. As a result, the second floor houses 30 cars, the third floor 30, and the top floor about 10, the balance of this floor being given up to the repair, paint, and trim shops, and to cars waiting to be put in shape. There is a wash rack on both the second and the third floors, immediately above the one shown on the ground floor. The whole makes a convenient arrangement, considering what the building is and the impossibility of lengthening or widening it, or of making any other material change. Fig. 16 shows a photograph taken on the ground floor, and Fig. 17 shows one of the upper floors. These pictures show no crowding, as they were taken during the day when nearly all cars were in use, so that by comparison with its total number of machines, the garage was almost empty.

Fig. 16. Photograph Showing Ground Floor Arrangement of Garage, Shown in Fig. 15

Layout 12. Another garage of about this same total capacity is shown in Fig. 18, but this is both wide and deep, and has a basement

Fig. 17. Second Floor View of the Same Garage, Showing Lighting and Washing Provisions

which is used. The connection from ground floor to basement is by a ramp along one wall, but so placed as to have direct access to the street. There is provision in one corner for a small car salesroom, an accessory salesroom, stock room, private office, and a general room, also an aisle to the shop, off of which are the toilets, as well as a fair size store for renting. On this floor are also two wash racks

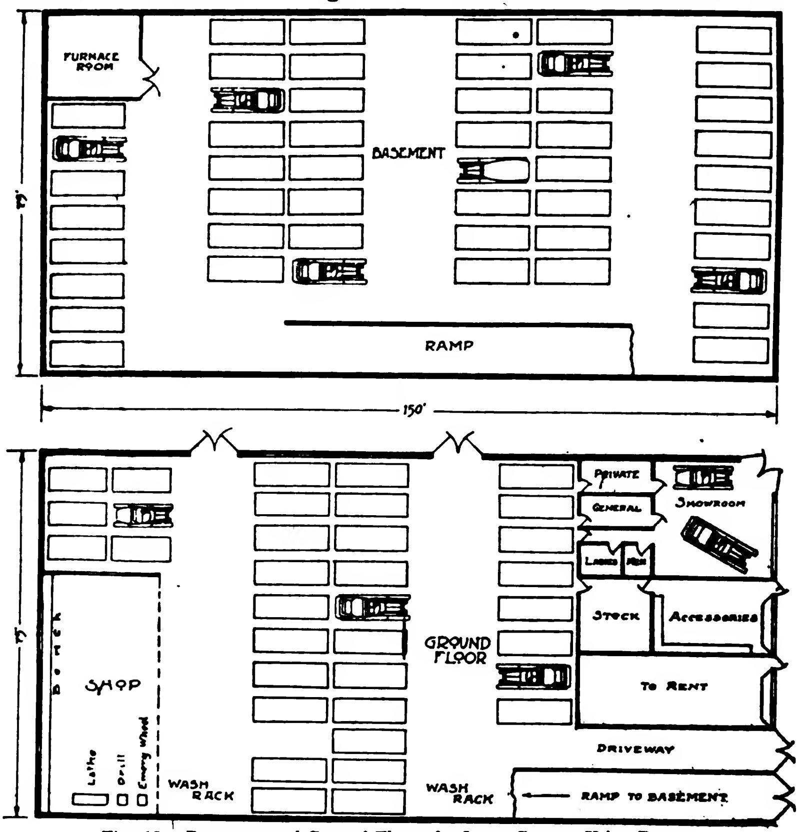


Fig. 18. **Basement and Ground Floor of a Large Garage, Using Ramps**
Courtesy of "Motor World"

and a fair size repair shop. The basement has no provision except for cars, and a furnace room in one corner, which houses the heater and the coal. It accommodates 50 cars, despite the ramp and many aisles. The capacity could be increased to 60 cars, by putting them in the ends of the aisles against the walls and under the ramp.

On the ground floor are three entrances, which give easy and quick access to the cars. The arrangement is good, compact, and efficient, the ends of all aisles forming the wash racks. The capacity might be increased by taking out the store for renting and utilizing the space for cars. By making this change, 6 more cars could be accommodated. The present total is 35, and this would bring it up to 41. In considering this change, the revenue from 6 cars the year round would have to be balanced against the annual rent of a store of this size. The whole building now houses 85 cars, but with the suggestions made, it could handle 100, as it has 22,500 square feet of floor space. This gives an average of 265 square feet per car for the original layout and 225 for the modification. As a car occupies but 15 x 7 feet or 105 square feet, it can be seen that this garage, which has a good average layout, is about 40 per cent efficient, and could be made 47 per cent. It is an unusually good layout which works out at 50 per cent, everything considered.

VERY LARGE GARAGE

When a garage can or does house in excess of 100 cars, or when its floor space is 30,000 square feet or more, it is not an exaggeration to call it a very large one. The very large garage is interesting beyond the other forms just described because its equipment is usually more complete, it possesses more facilities for doing work, its arrangement is generally studied out more carefully because of the enormous investment, and because of the number of cars which must be overhandled.

Typical Arrangements. *Layout 13.* An unusually large garage is shown in plan view in Fig. 19. This is unusual for the reason that it houses only 100 cars and a few odd dead-storage vehicles when its width and length would allow the handling of almost twice that number with ease. It is one story high, without a basement, and has a chauffeur's room, a toilet, an office, a storeroom, and a wash rack, all housed in an L near the center of one side. Aside from vacuum-cleaning machinery, the balance of the entire floor, which runs clear through a city block, is available for cars. This space is 88 feet wide and 275 feet long, sufficiently wide for an arrangement like *C*, Fig. 1, with an additional width of 8 feet in the center aisle. This arrangement provides for 4 cars per 7 feet of length. The garage shown is 275 feet long, so there could be 39 such strips. Even if 2 cars were omitted to make room for the vacuum machinery, and 4 more in front of the office and wash rack, there would still be space for 150 cars with a central aisle of unusual width. The garage actually has 100 and will take no more.

Use of Vacuum Arrangement. The vacuum machinery is an unusual feature. It removes all dirt and dust from all cars. The machinery is connected to each car space by means of a 2½-inch pipe, while a removable hose with a nozzle is carried around by the workman. Another unusual feature is that the machine shop, which is large and unusually well equipped, is located two blocks away. In addition to its broad central aisle, approximating 58 feet with but two rows of cars along the walls, two very large central skylights

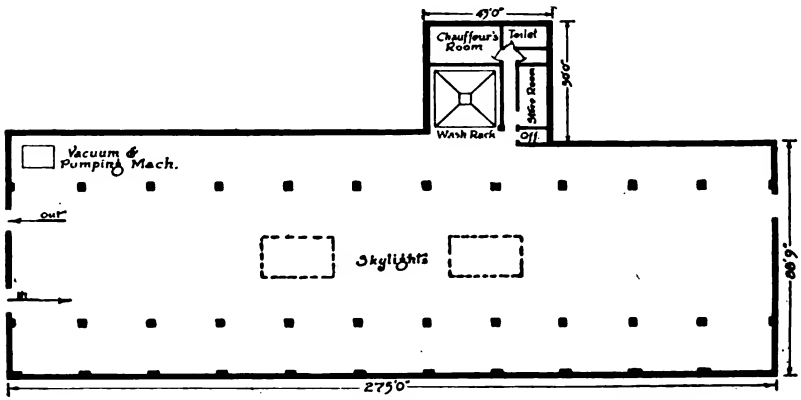


Fig. 19. Very Large Western Garage Which Runs through the Block

make it very light and airy. Another feature is that each car space has a steel locker 40 inches one way, so that the largest tires in use can be stored there with perfect safety. The arrangement of the entrances is well worked out. On the street at the right there is but one entrance, this being used for both entrance and exit, but on the other street, where there are two, one is used for entrance only, and other for exit only.

Layout 14. Another very large garage is shown in Fig. 20. This garage has a shape not unlike the one shown in Figs. 11 and 12, and the size is not radically different, being 100 feet wide by from 100 to 154 feet long, an average length of 127 feet. It differs from the other in that perhaps 50 per cent of the ground floor space is given over to salesrooms, offices, elevators, and apparatus, and also in having four floors and a roof; the roof is a special feature to be spoken of later. This garage was built for and is run in connection with the sales agency for one of the largest cars, hence the amount of space given over to the salesrooms at the front of the building. While the single elevator might be thought inadequate for a building of this size and height, in combination with the turntables provided—

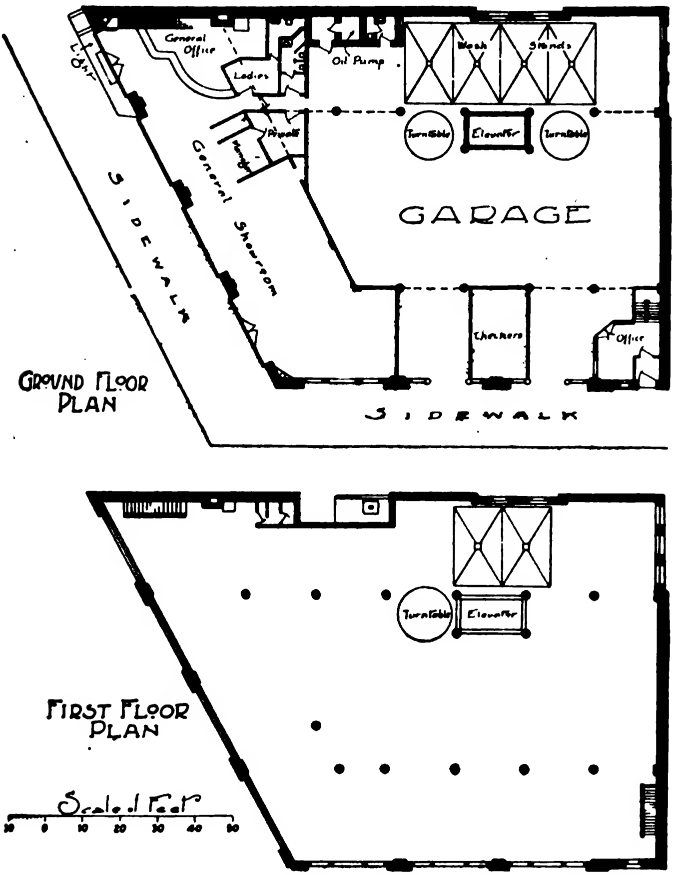


Fig. 20. Very Large New York City Garage with Many Unusual Features

two on the ground floor and one on every other floor except the roof—it is quite sufficient, and there is seldom, if ever, any waiting.

The car capacity is 20 on the ground floor; 60 on the second floor; 75 to 80 on the third, which is utilized for dead storage; and from 40 cars upwards on the fourth, which has a large and very well equipped repair shop; and 25 cars on the roof. The latter is a distinct feature never seen elsewhere. The building has a high ornamental coping rising more than 10 feet above the roof, which is covered with tile. Inside of this coping, around the two sides of the obtuse angle, that is, the south and west sides, a light roof has been carried in for 25 or 30 feet, making a protected space of that width along those two sides. As the elevator runs up high enough to serve the roof as well as the lower floors, cars can be placed in this space and be as well protected as on any lower floor, except against a driving rain or snow from the north or east, accompained by a very high wind. Even then it is doubtful if the car would get wet. This space, in summer months, is as good as space anywhere else in the building. The length of the roof along these two sides is such that the cars can be placed end to end along it and still leave over 10 feet of working space under the light roof. This gives a capacity, in round figures, of 150 cars on live and 75 to 80 on dead storage, or 225 to 230 cars total which the garage handles. About 50 men, exclusive of sales and office employees, are needed to handle this number properly.

Prices for Service. The prices, which are those of the trade association, are about as follows:

STANDARD GARAGE CHARGES IN NEW YORK CITY

Runabouts below 20 h.p.	$20.00
Touring cars from 20 to 40 h.p.	30.00 to $35.00
Touring cars over 40 h.p.	40.00
Roadsters over 40 h.p.	30.00 to 35.00
Landaulets, any power	30.00 to 35.00
Limousines, any power	35.00 to 45.00
Transient storage, per night, no cleaning	1.00
Repair work, per hour	.75
Dead storage	10.00 and up

Striking a rough average of the 150 cars on live storage at $30 would give a monthly revenue of $4500, and the dead storage on the 80 cars at $12 would bring in $960 a month, a total of $5460 a month, or $65,520 a year. This estimate is exclusive of repair work, spare parts, accessories, oil, gasoline, grease, waste, etc., all of which would probably bring the yearly income up to $75,000.

Layout 15. Another very large garage, interesting by reason of having ramps up to the third floor, is shown in Fig. 21. Not that

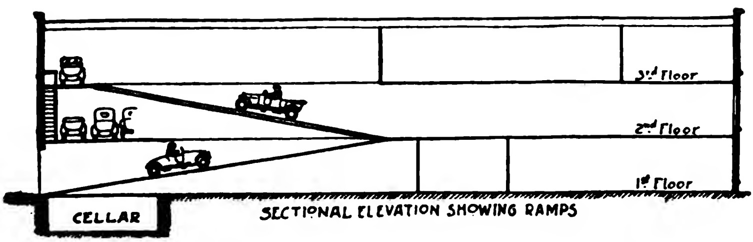


Fig. 21. Floor Plans and Sectional Elevation of Very Large Three-Story Garage Using Ramps
Courtesy of "Motor World"

ramps cannot be used as high up as desired (6, 8, or even 10 stories), but it is unusual. When a high building is considered, the elevator is usually thought best, while ramps have the preference in a low one. This garage, with its three floors, has almost exactly 30,000 feet of floor space, housing 127 cars and giving an average of slightly over 236 square feet per car, as against the 105 considered necessary. This garage has an efficiency of 44.5 per cent.

The ground floor has two unusually large show rooms at the front, on either side of an entrance, with an accessory salesroom and stock of parts back of one of them. At the rear are two more entrances, one central, the other to the ramp. The wash rack is in the center of the aisle, midway of its length, and thus handy from both ends. The second floor is very simple, with the ramp coming up close to one side wall, crossing the building and going on up alongside of the other wall. This influences the layout of the cars, which is square and very simple, with a wash rack at the end of the large longitudinal aisle. The third floor has the ramp coming up at one side near the end, while the repair shop is across the rear end. This combination calls for a broad center-aisle space and considerable other waste room. Even with this waste, the ground floor has spaces for 40 cars, the second for 50, and the third for 37 cars, outside of those in the repair shop. One car could be added on the second floor, and two or three on the third, without disturbing anything, as shown by the dotted lines. The sketch at the bottom shows how the ramps proceed from floor to floor. The big problem in laying these out is to balance the desire to save as much space as possible against the keeping of the slope within a reasonable figure. Of course, cars coming in under their own power can negotiate slopes up which it would be very difficult to push a car by hand.

FINANCES AND BUILDING COSTS

Income and Expense Estimates. As something has been said about costs and also about revenue, it will be well to take up the subject of financing. In this connection, the sets of figures in Tables I and II are of pertinent interest. A group of men planning a large garage in New York City brought the estimate of costs, as given in Table I, to the writer for comment. In this estimate it seemed that everything was figured and figured properly, yet there was no profit. The amount left for net income, \$6900, was but $2\frac{3}{4}$ per cent on the total investment, and was not considered an adequate return.

Analysis of Actual Estimate. The writer was asked to go over the figures and see what was the matter with them. The biggest item was that of the building itself, and it was discovered that this had been figured at 18 cents per cubic foot, while good standard practice showed but 13 cents necessary in garage construction, and very serviceable garages had been built and were in satisfactory operation which cost but 12 cents per foot. As the idea here was to show an opportunity for large profit, the lower cost per foot was used as a basis for a revised estimate. This changed the building cost, the interest on the building while being built, the cost of obtaining a building loan on it, and, in the operating expense, lowered the annual interest charges.

On the other hand, no allowance had been made for equipment, elevators being included in the building cost, and other equipment was considered as "not costing much". In the matter of the number of machines, the spaces had not been well planned, and a rearrangement showed how 290 machines could be housed instead of 165. The district selected being an excellent one, where there were many cars and not many garages, also where the opportunity for motor trucks was beginning to show up very large, the vacant space was cut down from 20 per cent to 15 per cent. The revenue per car was refigured on the basis of actual gasoline, oil, and other supplies which an average city car would have to have, and the profit figured from this. It substituted a more exact method for a lump sum process.

Analysis of Revised Estimate. Table II shows the revised figures and indicates how the final profit of over 30 per cent was arrived at, this being over and above the 6 per cent interest on the money invested. In looking these figures over in the light of present conditions, it would seem as though fewer elevator men would be needed, but this would be offset by the fact that the office force seems inadequate for a building of this size and for the handling of such a large number of cars—almost 250—with the attendant number of book accounts.

TABLE I

Five-Story and Basement Garage

FIRST ESTIMATE OF COST

Ground	$60,000	
Building (1,000,000 cu. ft. at 18 cts.)	180,000	
Architect	2,000	
Interest on ground during construction	1,600	
Interest on building during construction	2,400	
Taxes and insurance during construction	1,000	
Cost of obtaining loan	5,000	
Incidental expenses	3,000	
Total cost		$255,000

FIRST ESTIMATE OF INCOME

5 Stories, 30 machines each at $30 average	$54,000		
Basement, 15 machines at $30 average	5,400		
Gasoline, oils, etc., profit per month on each machine, $5	9,900		
		$69,300	
Running 80% full (deduct ⅕)		13,860	
Total income			$55,440

FIRST ESTIMATE OF EXPENSES

Interest at 6% on $255,000	$15,300		
Annual taxes and insurance	4,500		
Electric current for elevators, etc	3,600		
Monthly supplies and sundry expenses	1,800		
1 Day superintendent at $150 per month	1,800		
1 Night superintendent at $100 per month	1,200		
1 Bookkeeper and stenographer at $75 per month	900		
8 Elevator men at $40 per month	3,840		
10 Floor men at $70 per month	8,400		
10 Washers at $60 per month	7,200		
Total expenses		$48,540	
Estimated Net Income			$6,900

In submitting this second estimate, the writer made the point that the territory in which it was proposed to build this garage was a rich field for an electric garage, so that by investing an additional $6000 for switchboard, wiring, and plugs, and adding an electrician at $100 a month to the payroll, at least one-third of the capacity

TABLE II

Five-Story and Basement Garage

REVISED ESTIMATE OF COST

Ground	$60,000	
Building (1,000,000 cu. ft. at 12 cts.)	120,000	
Equipment	12,000	
Architect	2,000	
Interest on ground during construction	1,600	
Interest on building during construction	2,000	
Taxes and insurance	1,000	
Cost of loan	4,000	
Incidental expenses	3,000	
Total cost		$205,600

REVISED ESTIMATE OF INCOME

55 Cars a floor, 5 floors, at $30 a month per car	$99,000		
15 cars in basement at $30 per car	5,400		
Sale of gasoline on basis of 8 gallons a car per day, 3 cents profit on a gallon	17,000		
Sale of oil, grease, and supplies at an average profit of 5 cents a car per day	3,500		
Other revenue from rental of lockers, repair parts, charging, ignition, vehicle batteries, etc.	2,000		
Total income		$126,900	
Deduct 15 per cent for space not filled		19,035	
Total yearly revenue			$107,865

REVISED ESTIMATE OF EXPENSES

Interest at 6 per cent on $205,600	$12,336	
Annual taxes and insurance	4,500	
Electric current for elevators and for charging	3,000	
Monthly supplies and expenses	1,800	
1 Day superintendent at $110 per month	1,320	
1 Night superintendent at $110 per month	1,320	
1 Bookkeeper and stenograper at $75 per month	900	
6 Elevator men at $40 per month	2,880	
10 Floor men at $70 per month	8,400	
10 Washers at $60 per month	7,200	
Total expenses		$43,656

SUMMARY

Yearly income, as above	$107,865	
Yearly expenses, as above	43,656	
Yearly Profit		$64,209

would be taken up by electrics which would yield $50.00 a piece a month for pleasure cars, and the following rates for trucks:

1000-lb. capacity	$40 per month
2000-lb. capacity	45 per month
3000-lb. capacity	50 per month
2-ton capacity	55 per month
3-ton capacity	60 per month
4-ton capacity	65 per month
5- and 6-ton capacity	70 per month

On this basis, an average figure would be around $54 a car for the electrics, at which rate 82 (one-third the net capacity kept filled constantly), even after deducting one-third from the table allowance for rental and for gasoline and oil sales, would add a little over $10,000 to the annual receipts, and only $1200 plus the extra interest of $360 on $6000 to the running expense. The net result, all things considered, would be to increase the rate of profit on the increased investment and over the interest charge to 34.3 per cent. This showed that it would be a profitable proposition to consider the electrics, which had not been given a thought previously.

This is about 32 per cent profit on an investment of $205,600, over and above the 6 per cent interest figured in above Tables I and II.

While these figures represent a big car layout and city conditions, the average which can be worked out from them is not very far off for any kind of an installation. Thus, the original investment of $830 per car housed cannot be lowered very much. Using this estimate as a basis, a garage large enough, say 50 x 110 feet, to house 30 cars would necessitate a total investment of $24,900 or, in round figures, $25,000. Experience has shown that this is not a bit too much. The average income per car is put down at $440 a year, and the average cost of operation per car housed at approximately $100. The income for a typical 30-car layout would give a total of $13,200, and the cost of operation is $3000. It is doubtful whether a 30-car garage could be run on this low basis of cost, which shows the economy of having the larger institution. On this basis, the small garage could have but one bookkeeper and stenographer at $40 a month, and one floor man at the same figure, with the owner acting as both day and night superintendent, washer, etc. On a small layout of this kind, it is a question whether the cost of operation per car would not run closer to $200, while the revenue per car, owing to the considerable number of small cars, would probably come down as low as $300.

The amount of money to be invested, in addition to the cost of the building and its equipment, should be such as to carry on the business for a reasonable length of time, even without any income. Too many garages have been started without this capital, going on the assumption that motorists had plenty of money and would pay promptly upon receipt of bills. This is not true enough to be laid down as a rule or to be counted upon. So the garage man who is just starting should have enough cash to carry his establishment for several months without any income. It is not urged that the building and lot be kept entirely free and clear, or even that it be owned, but some capital, considerable, in fact, is a necessity.

TYPICAL EXTERIOR DESIGN

Building Materials. It would be unwise to specify any one material as the best, regardless of location, conditions, or amount of money involved, for practically all the materials used for other buildings are used also for garages. Among the materials which are widely used are: wood; steel; wood and steel; concrete in solid or in reinforced forms; hollow tile or other tile, usually stucco covered; concrete, in combination with any or all those given previously; brick; stone; brick or stone combined with any or all the others; and glass combined with any of the others.

The kind of material to use should be selected according to (a) its first cost, balanced against its probable life and depreciation costs; (b) its availability, which is generally governed by local conditions and which has a very large influence upon the cost; (c) its fireproof qualities and their effect upon maintenance charges, through the insurance rates; (d) ease of erection; (e) architectural appearance when completed; and (f) general suitability to the garage business.

First Cost. The cheapest material might be the shortest in life so that depreciation charges would be the greatest; on the other hand, the material which was most expensive in the first place might last the longest and thus have the smallest annual charges for depreciation and repairs. These things have to be considered and balanced one against the other. That form might be said to be the best in any case, which showed the greatest number of advantages in all respects. For instance, wood was formerly a very cheap material, but now it is fast getting out of that class; in certain locations, it is even a very expensive material. On account of its short life, high depreciation, and other drawbacks to be brought out later, it would be a poor material to use. Under some circumstances, however, wood is so cheap that nothing else can compare with it, its first cost being so low as to overbalance its shorter life and greater depreciation. In a case of this sort, wood would be the very best material to use. These same general remarks may be true of many other materials.

Availability. Availability has been partly discussed above. When a material is freely available, it is sure to be cheap, whereas a material which is difficult to get is equally sure to be expensive. Beyond being plentiful, availability means also easy to order, easy to have delivered, easy to handle in loading and unloading, easy for workmen to handle and use, and of such a nature that no difficulty will be encountered in getting it to the garage site, regardless of where that may be. All these items count, each one has a value, and in determining the choice of material they should be taken into account.

Fireproofness. There is so much gasoline, oil, and other inflammable material around a garage that fire is always a possibility. Garage insurance rates are high and always cut a big figure in the annual running charges of the garage, so that a wise man will consider these in detail before building. Not alone is fire a source of danger to the garage building, but it is also dangerous to the business, and indirectly to the garage man through his customers' cars, as the owners of the cars might sue if a fire occurred. From this point of view, the all fireproof building is the best, but the materials differ. All concrete construction, with metal window sash and door frames, probably comes the nearest to being fireproof; but all brick, with, concrete floors and metal sash and door frames, is almost as good, as is also the hollow-tile stucco-covered form and the stone or structural-iron framework, covered with tile or brick, as well as various other combinations.

Here again, the relative advantages of each material must be balanced, and that one selected which has the greatest number of good points, also the preceding qualities must be considered, as well as those which follow. Thus, in a location where concrete might be admittedly the best on all counts, cement for making it might not be available or, if so, in such limited quantities as to make it difficult to erect such a building. A wooden structure, possessing the merits of being the cheapest, is often made semifireproof by being covered with galvanized iron inside and out, the combination possessing many real advantages despite its crudeness.

Ease of Erection a Factor. Ease of erection is somewhat a matter of local conditions. For a contractor who knows his business, no one building is more difficult to erect than another. But there are conditions in which there would be difficulties in the way of erecting buildings, say of concrete, that would put this material entirely out of consideration. It will be admitted that bricks are easier to lay up than stone, so that the former would have an advantage almost anywhere over the latter. In a town lacking a structural iron works, steel or iron as a framework would undoubtedly be out of the question.

Architectural Appearance. Architectural appearance has been considered all too little in the past, both as regards the appearance of the material and in the matter of design of the building. With reference to the appearance, it will be admitted that wood does not have a good appearance for garage use, especially when it is covered with galvanized iron, as in the example just given. Sheet steel does not appear well either. Solid concrete does or does not appear well, according to the method of handling. Brick presents a good appearance if handled well, but it can be so handled as to have ugly outlines. Stone usually presents a good appearance; and also the combinations of brick and stone; brick or stone with glass; concrete with brick or stone, or with wood in the form of half timbering; and other forms. In short, almost any form can be made to present a splendid appearance, regardless of the appearance of the material itself in the raw state.

With reference to the general appearance of the garage itself, it cannot be urged too strongly that the garage builder employ an architect and let him design an exterior that will be both simple and pleasing. Too many garages, like Topsy, have "just growed", and they look it. In going along the road looking for a place to buy some gasoline, or other supplies, 99 motorists out of 100 will stop at the best looking of two garages set opposite each other. Viewed from this standpoint, a pleasing exterior appearance is a commercial asset; it brings in business, therefore it has a value, and should be studied out as carefully as any other point in the garage design or construction that will have an influence on the right side of the ledger.

Typical Exteriors of Good Design. In this connection, some sketches of exteriors made from actual photographs of successful

Fig. 22. Pleasing Garage Exterior Lines Produced through Symmetry and Disposition of Windows and Doors

garages will be presented, and the garage man considering the building of a new structure can study them out and see which appeals most strongly and why. Having determined this point, his existing or projected building can be modified to have these lines, in order to bring the same success.

Fig. 22 shows an ornamental and pleasant front obtained by the arrangement of the windows in large and small units. Despite the straight lines, it is regular and symmetrical. The building is of brick, with a front of white-faced brick, on which the name appears in gold letters. The ground floor is of cement, the second floor double $\frac{7}{8}$-inch Georgia pine laid at right angles. All ceilings and partitions are covered with pressed-sheet steel, enameled white. The roof is flat and has two skylights. It measures 60 x 100 feet and holds 75 cars.

Another brick building is shown in Fig. 23. This is one story higher, and the roof overhangs the third story, giving a pleasing touch.

Fig. 23. Good Garage Front Which Was Brought about by the Use of Tapestry Brick, Concrete, and Tile on Simple Lines

The front is of tapestry brick, with tooled cement trimmings and columns. The roof tiles are semicircular in form and green in color. The building is fireproof throughout, with metal sash and door frames. Such a large part of the building is used for show room and salesrooms that the garage capacity is small.

Fig. 24 shows another brick building in which a considerable amount of glass gives the structure an open pleasing appearance,

Fig. 24. Large High Garage with Big Capacity, Yet of Pleasing Appearance Owing to Neat Lines and the Free Use of Glass

Fig. 25. Ornamental Overhanging Roof Lines and the Rising Central Portion Break Monotony of Straight Lines and Give this Garage a Good Appearance Which Draws Trade

at the same time increasing the interior light in a marked manner. Floors are made of cement. The front shows what can be done with perfectly plain materials and plain straight lines. The garage shown in Fig. 25 is built of brick on a steel framework, while the roof, having many skylights with wire glass, is on steel trusses. The ornamentation by means of the raised center, curved lines, overhanging tile roofs, and small overhanging ledges of red tile above the two symmetrically disposed entrances, all combine to make a pleasing building to look at, and one which the people of the neighborhood would not object to. The floor is made of concrete. The size is 88 x 275 feet, and it houses slightly over 100 cars.

Fig. 26. Tapestry Brick, Symmetry, and Long Low Lines Make This Garage Most Pleasing to Look at and an Ornament to Any Neighborhood

The garage in Fig. 26 is attractive because of its long low lines, its Spanish Renaissance style of architecture, the very large windows on the ground floor, and the symmetrical disposition of all windows, the whole building being symmetrical about a center line. It is faced with tapestry brick, has an overhanging red-tile roof, and is set back 50 feet from the street. The walk is of tapestry brick, the car entrance being on the side street occupying a prominent corner. The floors are of concrete, the entire building being of brick and reinforced concrete. It measures 162 x 260 and houses over 120 cars, besides giving up the whole front to the offices and showrooms. The rear, or garage, portion is but one story high.

A western garage is seen in Fig. 27, having a bold front of stucco and red tile in the Mission style. Its long low lines, the red tiles standing out from the dead-white stucco, the straight lines broken up by the ornamentation, with just enough curves added, and the symmetrical placing of all doors and windows make it very attractive to look at. The owners did this intentionally, and some one from that city has said of it: "Outside of its service, the bold

Fig. 27. Stucco, Red Tile, and the Ornamental Touches Make This a Distinctive Garage

pleasing front which is in harmony with adjoining buildings and with the evergreen park on the opposite side of the street, is the most valuable asset of the garage." The garage measures 80 x 80, all of which is for live storage except a 12 x 28 office. Forty-five cars are handled normally, but places have been made for 58.

A southern reinforced concrete structure is seen in Fig. 28. It is of a Spanish type of architecture with an overhanging flat-tiled roof. It is on a prominent corner and has three stories and a basement, each measuring 103 feet square, all with cement floors. All the shops are located on the top floor, while a small part of the ground floor is used as salesroom and show room.

General Suitability of Design to Garage Business. This means neither more nor less than proper planning. If the building has been planned for easy entrance or easy exit and has an arragement that gives the washers the least amount of car moving to do, that provides for a large enough office so placed as to have supervision over all cars coming in or going out, with the oil room located where it is easy and convenient to all customers as well as to the workmen, with a location of the fuel tank at a point where it may be easily filled and customers easily supplied inside the garage as well as transients at the curb, and if it has all the other features which will make the garage easy to operate and which also will make for efficiency

Fig. 28. An Example of What Can Be Done with Reinforced Concrete, When Well Designed and Suitably Ornamented

and for a minimum of lost time and wasted steps, then it will be suitable for the garage business. If space allowed, it would be an easy matter to show how any one of these items, if overlooked, can bring about the failure of the business. It will suffice to say, however, that if entrance and exit are difficult, customers will not come in, or having come in once will not come again; if the arrangement makes the washers a maximum amount of extra and unnecessary work, it will be difficult to get them to do their work thoroughly, and customers will be displeased and will go elsewhere; if the office is too small, or so located that the incoming and outgoing cars cannot be observed, there will be large losses; if oil and gasoline are not quickly accessible, people will go elsewhere to buy their supplies of these materials; so too, with many other features which might be mentioned, and, if these things are not well studied out in advance and provided for, it will not be possible to run the business on an efficient profitable basis.

NECESSARY EQUIPMENT FOR GARAGE

Major Equipment. Ordinarily, a person thinks of equipment as tools, supplies, and other means of doing work, but these might almost be called minor equipment in comparison with the major equipment. Major equipment might be listed as *lighting*, both natural and artificial; *heating*, which almost always means the individual heating plant for the garage, as there are few cities where heat, like electricity or gas, can be bought; *ventilation*, which may be incorporated in the building in part, or it may mean fans, blowers, and the like, in addition to those means which the building provides; *water supply and provision for washing*, in which the water supply may mean the installation of a pump, the provision of a special tank, power for driving the pump, etc.; *drainage*, which is closely allied with ventilation, for means must be provided for taking care of the fumes from gasoline, oil, kerosene, etc., which are dangerous and must not be allowed to reach city sewers; *provision for power* to drive machine tools, tire pumps, vacuum cleaners, buffers, etc.; *an elevator or a ramp* and a turntable—provision for moving the cars up and down, if there is more than one floor, or around the garage; *fuels and oils, greases*—in liquid form and in cans or packages—*and waste;* benches, lockers, cabinets, racks, stands, and other similar things which might be called garage furniture; and, finally, *tools*, both large and small.

Lighting. *Natural Light.* The interior width of the garage has a large influence on the number of windows needed for natural, and the number of lights needed for artificial, lighting. The narrower the garage, the easier it is to light it adequately by means of windows set close together on the sides of the building. But, as it widens out, the dark zone in the middle of the building becomes greater and greater until the point is reached at which artificial lighting is needed all the time, day as well as night. One of the axioms of building should be to keep the width down below the point where artificial lighting must be used day and night.

The location of the lot on which the garage is to be built, that is, whether it is between other buildings, on a corner, facing on three streets, running to an alley, etc., is important as regards the lighting, for plenty of natural light will be available in all these locations except in the first. The location in a downtown part of a large city has an unfavorable influence on the lighting situation, for it is almost a certainty that the light will be obstructed in one or more directions. The necessity for going higher up in the air, that is, building several stories high, brought about through the value of the land, makes a garage darker than would be the case otherwise. With a one-story building, many large skylights can be used, and these supply excellent light. An irregular shape is difficult to light if it is large; on the other hand, if it is small, it is very likely to have a greater area of outside walls relative to its interior or car space than would a regular shape and thus an opportunity for more windows than would ordinarily be the case, which would reduce the necessity for excessive interior lighting.

Artificial Lighting. The garage man should study out all these things so as to get the maximum amount of natural light, for that costs nothing, and to use the minimum amount of artificial light, for that is expensive. Electricity is the only satisfactory form of artificial lighting, all other forms having an exposed flame which will ignite gasoline and oil fumes. If a supply of electricity is not available, a small self-contained plant, with a gas engine and a generator set proportioned to the number of lights needed, and a set of storage batteries to equalize the supply and demand should be installed.

There is a wide difference of opinion as to the number of lights needed. The writer would say that the equivalent of one 16-candle-power lamp is needed for each four cars. These lights need not be installed in just this way, but they can be grouped in threes, fours, fives, or sixes in such a way as to give a better total effect than the single bulbs strung out would give. In a large garage with sufficiently high ceilings to admit doing it to advantage, arc lights can be substituted, on some such basis as one arc light to a very small floor, two to a small medium size, three for a medium or large size, and others according to the size of the garage and its needs. It is generally advisable to have very good light around the wash rack, as most of the washing in city garages is done at night.

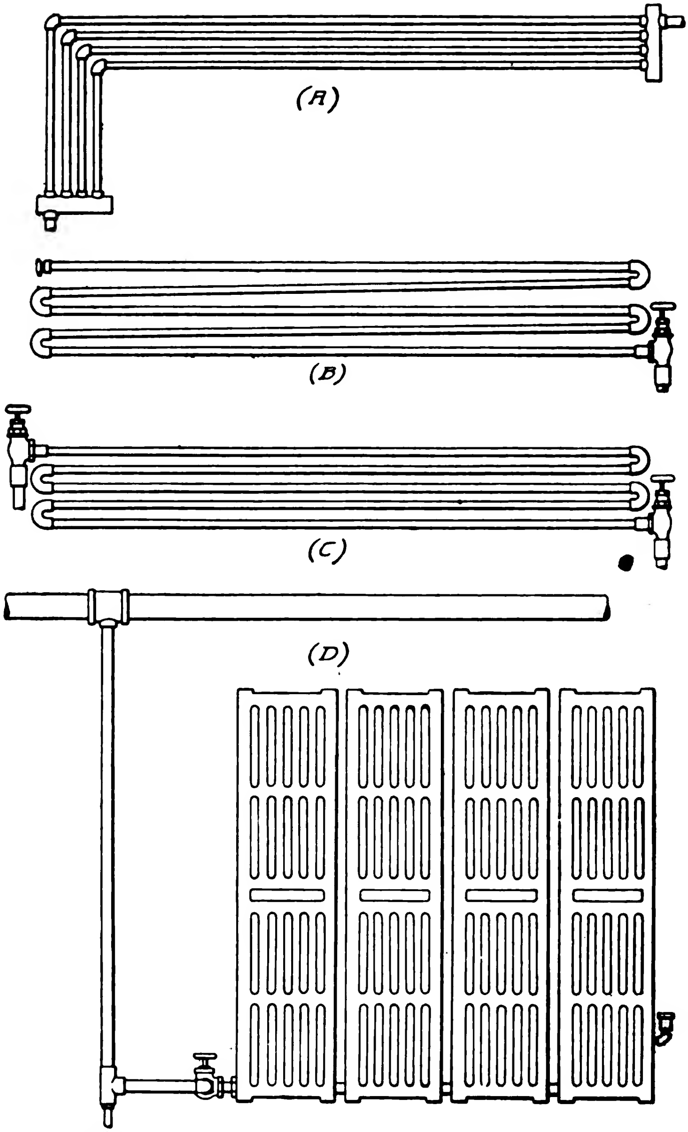


Fig. 29. Four Methods of Piping a Garage for Heating Purposes

Heating. The idea of heating the garage is not alone to keep the water in car radiators from freezing, as many garage men seem to think, but also to make it a comfortable place for workmen and car owners to come into or to work in, and to keep the cars at such a temperature as will allow quick and easy starting. Many kinds of heating plants are available, but steam or hot water are the best, for with either of these the heat can be used to warm the water for washing the cars, thus making washing easier and quicker. If a lighting plant is necessary, the exhaust from the engine can be utilized, whether it be steam or gas. The exhaust may not be sufficient of itself, but it can be used as far as it goes, effecting a considerable saving. When either steam or hot water is used for heating, the radiators are generally made up of pipes, or else a wall radiator is used. A specially thin form for this purpose may be had. The radiators can be put in one of three forms, viz, pipes to and from a header, as at *A* in Fig. 29; return bends, which may be either single, as seen at *B*, or double, as shown at *C;* and the wall radiator, shown at *D*.

Ventilation. In a small garage, a ventilator on the roof, or two windows opened so as to create a draft through the building will suffice generally, but in a large garage it is advisable to provide a form of fan or blower, the fan to draw out the air, and the blower to force in fresh air. Either one can be placed in the upper sash of a window; so no special place need be provided. The open doors with their large area, the elevator shaft or the ramp, and the big open space of the interior generally make ventilation easy, but it is desirable to provide some mechanical means of changing the air and thus of being on the safe side. This is doubly necessary, for the vapors from gasoline, kerosene, and oils are explosive, while the exhaust gases are poisonous.

Water Supply. For the city garage, water supply is simply a question of proper pipe connections and prompt payment of bills, but in the country it may mean much more. It may mean, for instance, the boring of a well before starting to build the garage and the installation of a pump to draw the water up from this well and force it to a large overhead tank. All this costs extra money. In planning the water system for a garage, it should be borne in mind that the water is used not alone for washing, for use in toilets, and for other personal uses, but it is also used for filling radiators, so

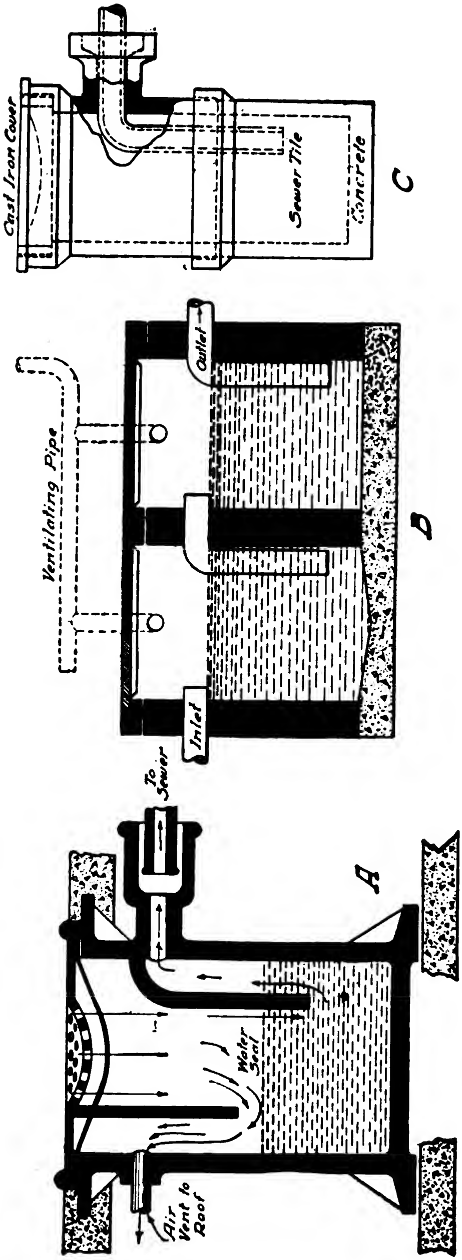


Fig. 30. Three Different Kinds of Efficient Garage Drains

that a pure water without too much free lime is needed. The water system also forms a large part of the fire protection of the garage and should receive adequate consideration.

Drainage. Garages need good drainage to carry off the water used in washing the cars and to carry away the gasoline and oil drippings from the engine, transmission, axles, and other parts. The best way is to give the cement floors sufficient pitch to carry off the heavy stuff, and the drainage for the water will be very good. The arrangement should be such that all drainage will flow into a trap, or into several traps. Gasoline will float upon water and will vaporize while laying upon it, while oils, greases, etc., will sink. A water seal on the trap, with a ventilating pipe connecting the surface chamber to the roof, carries off the vapors, while the heavier materials will sink to the bottom and will accumulate. Several forms of traps are shown in Fig. 30. At *A* is shown a cast form, which is very rugged and is provided with both a ventilating pipe to the roof and a safety air space around the sewer pipe. At *B* is shown a homemade trap of concrete and of iron pipe. At *C* is shown another homemade form constructed from two sewer tiles, one with an L-outlet, with cement to close the bottom, and a cast-iron cover for the upper one.

Provision for Power. If there is to be a machine shop, power must be provided, but even if there is no machine shop, there is generally a need for some power, as for the driving of the water pump, of the ventilating fans, of the air compressor, or of other units. If a lighting outfit is a necessity, it can be so arranged as to supply small amounts of power, either directly through belting, shafting, and pulleys, or indirectly in the form of electricity to electric motors. The indirect method is the preferred way, for it is simpler, cleaner, neater, more economical, and more up to date. If the garage is supplied with electricity, the question of power takes care of itself; in fact, it may work to reduce the lighting cost, as current rates are generally based upon the quantity of electricity used, the lower rate being given for the greater quantity.

Provision for Moving Cars. The subject of elevator versus ramp has been discussed previously and will not be repeated here. The garage of more than one story must have one or the other means of moving cars up and down. In addition, all large garages should have turntables, as these save a great deal of time and space in arranging the cars in their places, and in getting them out when needed. By referring back to the illustrations previously shown, it will be noted that a number of the larger garages had a turntable provided on each upper floor, and two on the ground floor, all being in front of the elevator. This enables turning the car as it comes off the elevator or before putting it on so that it points in the desired direction. The elevator at the back of a building must have a turntable to work with it, for every car would come in frontwards, and if it went on to the elevator that way, it would have to be backed off and, unless there was a turntable right there, backed to its place. Similarly, when being taken out, it would come to the elevator front end on, and when it reached the ground floor, the owner would not want to back it out. In such a case, a turntable saves double trouble with each car every time it comes in or goes out.

Fuels and Oils. Nearly all fuel systems nowadays are of the buried-tank type, with surface pumps. These systems have developed through the need of having the gasoline tank out of the way and protected from harm, also where it could be very large and consequently have a big supply. When it is considered that a car can easily use from 5 to 10 gallons of fuel a day, with the average around 7, it is easy to figure what supply a 100-car garage needs to have, namely, 700 to 1000 gallons per day. When transient trade is added to this, such a garage should have provision for close to 1800 gallons

Fig. 31. Bowser Remote-Control Fuel-Supply System
Courtesy of S. F. Bowser Company, Ft. Wayne, Indiana

a day. The mere handling of this amount is sufficient to keep one man busy, but, as it is profitable, the garage man should provide for it. Many systems are now in use, the most popular for large installations being like that shown diagrammatically in Fig. 31. Here, the tank is underground, outside of the building, while there is a pump in the basement, which is operated by an electric motor. This motor is set in motion by a lever at the curb stand, or draw-off station. This same general layout, but without pump and motor, is used in those systems in which the liquid is actually pumped by hand, through the rotation of a handle.

For use in and around the garage, it is desirable to have a smaller portable tank and pump, like that shown in Fig. 32. This tank has a capacity of about 50 gallons and makes it possible to fill cars wherever they are located instead of forcing the driver to come to the pumping station. This often saves time, as the attendant can fill the tank while the owner or driver is doing something else. It has been found to be both handy and economical in large garages.

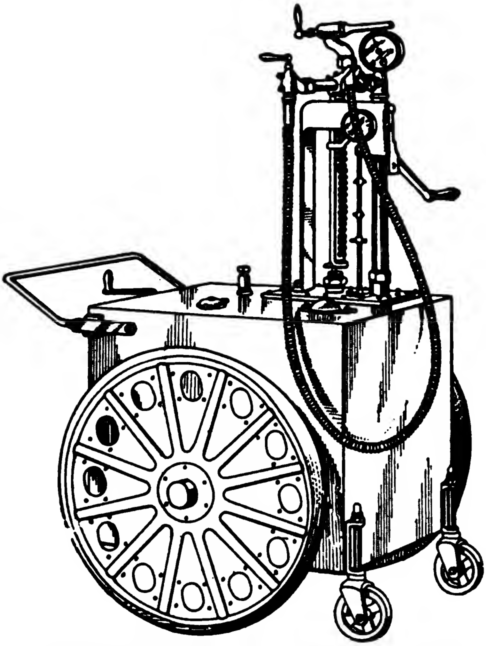


Fig. 32. Portable Supply Tank for Use in and around the Garage

The garage man who desires such a form of underground gasoline tank, but cannot afford to buy one, should buy the components and make one. Such an outfit is shown in Fig. 33, although this one has a limited capacity. The tank must have three openings—filler, suction pipe, and pressure pipe. These are marked *F*, *D*, and *B*, respectively, in the cut. A large pump supplies the air pressure which forces the gasoline upward through pipe *D* when the cock *E* is opened.

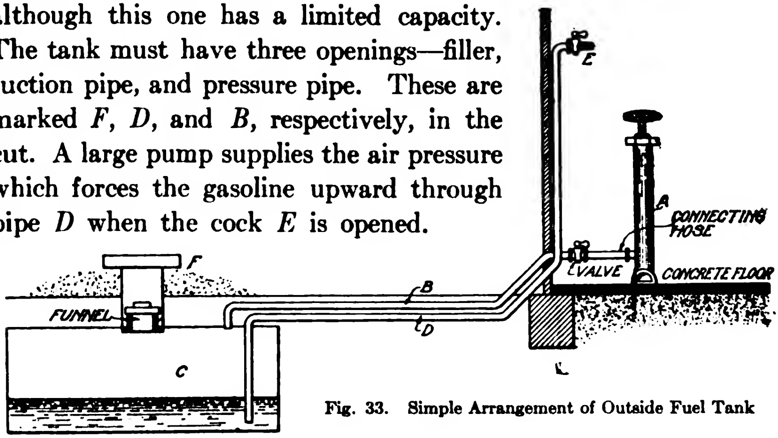


Fig. 33. Simple Arrangement of Outside Fuel Tank

For handling oils, a different form of pump is needed. Oils are generally kept in a special oil room, and the different qualities are kept separated. Moreover, in comparison with gasoline, small quantities of oil are sold at a time. Aside from the fact that the receptacles are small and do not have wheels, the oil-supply system usually resembles a battery of units, like that illustrated in Fig. 32.

Air-Supply System. Thus far, no mention has been made of a source of air supply, which is very necessary. Air is constantly in demand for inflating tires, and no up-to-date garage should be without it. In addition, it is handy for cleaning upholstery, for cleaning off repair parts, and in many other ways. The general

Fig. 34. Four Different Air Supply Systems in General Use

sources of supply are hand (or foot) power, which is inadequate for a large garage; electric power; and a belt-driven or engine-driven air compressor. Fig. 34 shows these three forms at *A*, *B*, and *C*, respectively, while at *D* is shown the steam-driven form, which is similar to railway locomotive compressors, and is a very efficient and compact form for use in large garages. Air compressors are now made in small sizes and mounted upon wheels, with electric-motor drives and lamp-socket connections, so that they can be wheeled around the garage to the desired position, then started and air supplied as desired.

Garage Furniture. The garage has need for many articles of wood and steel, such as engine stands, work benches, lockers, etc., which cannot be described by any other name. These are really necessary, and the garage without them is not adequately equipped. In addition to the necessities in this line, there are of course many more which are desirable, which save time and space, and which are supposed to save money too. Also there is much of this kind of stuff that the handy man can make himself, that is, given enough equipment and furniture to start the garage, the handy man can make additional furniture and equipment as the demand arises, thus gradually improving his place without much expense. The necessary furniture will be described first.

There are so many different bolts, screws, and nuts around an automobile that a supply cabinet for these articles is a prime necessity. One of the best of these cabinets is shown in Fig. 35. It consists of an eight-sided cabinet, each side of which has twelve drawers, so that a total of 96 drawers of small size are provided in a very small space.

Fig. 35. Useful Revolving Cabinet

Practically the same thing, but in a different form, is the type of cabinet shown in Fig. 36. This has a large number of small drawers arranged in a horizontal plane. The form shown at the left is made with 54 drawers, the one at the right with 60. The case has a steel back, the drawers are made of galvanized steel and are dustproof. The larger drawers at the bottom are made with removable partitions. A pair of these cabinets set back to back make an excellent combination for a good size garage. The general run of drawer size in this form is so much larger than that shown in Fig. 35 that it would be possible to utilize both in the same garage, the one shown in Fig. 35 for small bolts, nuts, cotter pins, and similar very small parts, and the one shown in Fig. 36 for much larger parts.

Other ways of producing the same results are by the use of made boxes, the idea being to purchase a supply of these boxes to suit present needs and to erect shelving to fit the boxes bought; then, as more boxes were bought, more shelves could be erected. These boxes are really well-made drawers, with locked corners, and are made in interchangeable sizes so that one large, two medium, or three small, or still other combinations may be used on the same shelf. Unit steel

Fig. 36. Excellent Type of Plain Cabinet for Small Parts, Bolts, Nuts, Etc.

shelving is also used, the steel shelves, with drawers, if desired, being made up in a variety of sizes and shapes to fit the various needs. They are built on the unit system, so it is possible to buy a few for a start and add others as the business grows.

Besides the cabinets for automobile parts are the lockers in which customers may hang their clothes, etc., and the various racks and shelf brackets or salesroom fittings to display and hold the various accessories which the garage sells. They may be made in any shape, homemade fittings being very serviceable, but the lockers are generally made of steel. They are made in two forms, both of the same height outside. One form has the full height per locker, while the other is divided in the center, thus giving two lockers each of the half height. Both forms are made in several widths.

Work Benches. The work bench is an important adjunct of the garage, and in every garage, unless it be a city place with a repair shop in connection, a work bench will be found at least along one wall. They almost always have a wood surface, usually of about two-inch lumber, but the framework is of wood and steel. The wood form is easy to make or to have the carpenter make, as it consists simply of a

Fig. 37. Garage Interior Showing Model Work Bench Layout and General Arrangement

framework of four-by-four timbers, with a top of two-inch lumber and a facing, or corner board, of one-inch stock, and a tie, or brace, of about one by six stock below and close to the ground. If the bench is carefully designed, there will be a shelf underneath it for small boxes, and a series of these boxes will be made for small parts, replacing, in part, the cabinets spoken of previously. There should be one or more large drawers, also shelves or racks on the wall behind and above the bench. The bench height varies from 2 feet 8 inches to 3 feet, but 2 feet 10 inches is about the average. An excellent example of this, although made with cast-iron supports for the ends, is that shown in

Fig. 37. This shows not only the size, shape, and arrangement of the bench, but also the size and disposition of the drawers, location, and arrangement of the fixed and swivel vises, and the arrangement of the other tools and parts. Maple and birch are considered the best woods for benches.

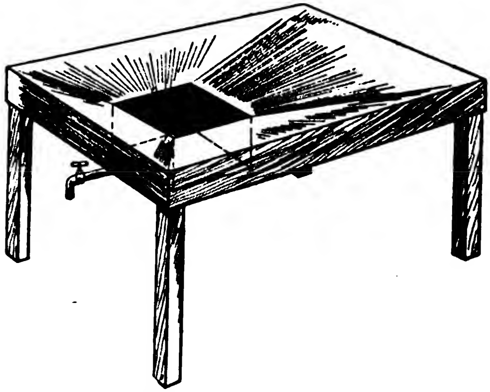


Fig. 38. Zinc-Lined Washing Bench, Which is Very Useful When Disassembling Cars
Courtesy of "Motor World"

For cleaning parts, a special bench is desirable, and this should be lined with zinc, by preference, and have a tapering or sloping surface. It should be low, and should be provided with a drain so that oily parts can be deposited on the drain and the oil cleaned off and saved. The oil can then be filtered, and the better parts used again. Such a bench is illustrated in Fig. 38, which shows all of its construction, unless it is the braces needed underneath to stiffen it. These braces are desirable, for the bench often holds a very heavy load of parts. By making the squared section of the drain large, frequent draining is avoided. A further necessity in a garage is a small bench on wheels or on casters, stout enough to work upon, but not too heavy to be easily moved around. It should be a few inches lower than a regular work bench, which will also facilitate moving it about. Such a bench is very handy when disassembling or assembling a car or some of its units, since it gives a place to lay the parts as they are taken out, or to lay them out in the order in which they are to go together again, as well as a place on which to lay the tools which are being used. Sometimes

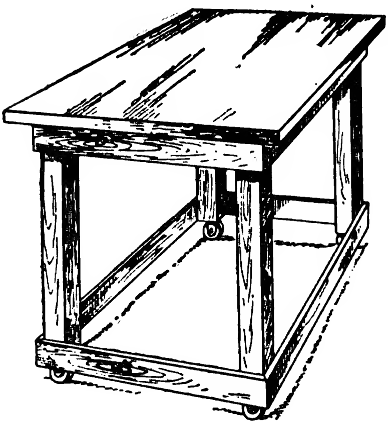


Fig. 39. Small Work Bench on Casters, a Very Handy Device

these tables are made with a drawer and are oftentimes stout enough to carry a vise attached to the working surface. The simplicity of the construction of one of these benches is shown in Fig. 39.

Special Stands for Units. Where the nature of the work is such that a good many units of one kind and size from some one machine

Fig. 40. Handy Form of Engine Stand Constructed from Piping
Courtesy of Shewalter Manufacturing Company, Springfield, Ohio

are handled, it is advisable to have special stands made for them, as, in so doing, much work and trouble can be saved. Several such stands [illegible]

A portable unit-motor stand made of tubing is shown in Fig. 40. The oil drip pan and shelf arrangement at the open end are features. The disadvantage of this form, however, is that the unit motor sets only in an upright position. This makes work on the crankshaft bearings and other parts on the under side of the motor difficult.

A stand which will hold the engine unit in various positions is shown in Fig. 41. It is made by the International Motor Company, of Plainfield, New Jersey, for its own use, and is an excellent but expensive stand.

A pair of stands are shown in Fig. 42. *A* is made of pipe fittings and angle irons and can be adjusted to the transmission or to the engine. *B* is a specialized stand for transmissions. The stands in

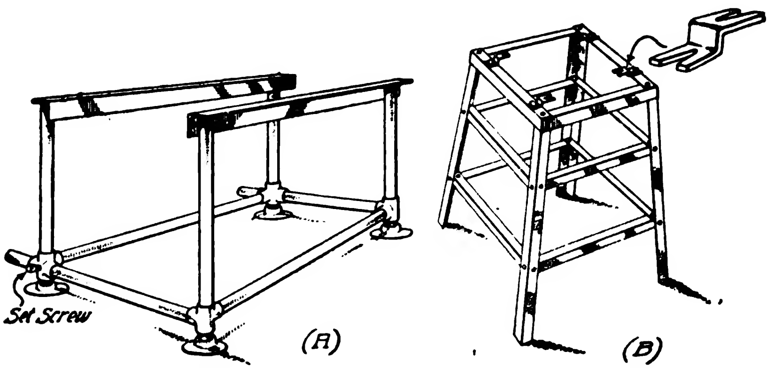


Fig. 42. Two Types of Handy Transmission Stands

this figure have the disadvantage of holding the units in an upright position only.

GARAGE TOOLS

The tools for use in the garage may be divided into two general and widely different classes, hand tools and machine tools. In the former class come all those tools which are used, but which require nothing but hand power to drive them. In the second class come all those tools which garages have or should have, but which require power to drive them.

Hand Tools. In the way of hand tools, which are too widely known and used to need any description, are: hammers, chisels, files, scrapers, punches and drills, clamps, reamers, taps and dies, measuring instruments, screwdrivers, saws (for wood), brace and bit, hack saw, jacks, wrenches, vulcanizers, breast drill, blow torch, oil stones, snips for cutting sheet metal, oil can and oilers, kit tire tools, spring leaf spreader, pliers, etc.

Vises. Vises as a means of holding work are very important and come under the heading of hand tools. While there are a number of different types, only two are used regularly, the plain bench vise and the swivel type. With the former, the jaws can only be opened or closed, but with the latter, the whole vise, including the work, can be revolved to a more convenient position. In addition, the latter type has a swivel jaw, a big advantage in gripping tapered work. By means of the locking pin at the right end, the jaws are fixed in a parallel position.

Machine Tools. The garage which does any work upon cars will soon require a few machine tools. This statement applies to the small shop that would not undertake regular machine work under any conditions. Such a shop should have, as a minimum, a lathe, a drill press, an emery wheel or other grinding means, with perhaps an electric motor having buffing and grinding attachments and of a portable type so as to be capable of use anywhere in the shop.

Lathe. Of these tools, the lathe is the most important, and the small garage man with limited capital should pick this out with great care. It should be as small as will handle his work, although some of this work, notably flywheels and clutches, will require an 18-inch size. This fact immediately brings up a point which the garage man should decide in advance, and that is whether he will handle this big work or send it out. If he decides upon the latter method, his lathe size can be limited to a 10- or 12-inch machine. From a garage man's point of view, it is to be regretted that no manufacturer has ever seen fit to bring out a special model for this class of work, as there should be a market for hundreds of them. What a garage man needs is a two-purpose, or two-spindle, or gap-bed type of lathe, which would give a maximum capacity of 12 inches for all normal work, perhaps 360 days in the year, and a greater capacity, say up to 18 inches, for use one or two days a year, as for flywheels, clutches, brake drums, etc. A lathe of this kind is not made, however, so the next best thing is a high-quality plain engine lathe.

Lathe Accessories. With a lathe, a considerable volume of accessories are necessary for handling a variety of work. It is advisable for the garage man to go slow in the purchase of these, until the nature of his work has shown the necessity for them. By this, reference is had to the various compound gears for screw cutting, different forms of face plates, center and steady rests, chucks, mandrels, tool holders, tool posts, taper cutting attachments, tool grinders, boring heads, and other things.

Drill Press. Drill presses are of three kinds, generally speaking, the sensitive drill which is too small and delicate for the range of average garage work, the usual drill press, and the radial type. The garage has little or no use for the latter type, nor for the modification of the standard form known as the multiple-spindle drill. A plain stout drill spindle which is made to a size that will handle drills up to and including ¾ inch is all that is needed.

Emery Wheel, or Grinder. The nature and quantity of the work would determine the size and quality of the grinding wheel to be used. A plain rotating emery wheel can be used for so little, while a properly selected grinding wheel can do so much work that is almost machining and, in this way, replace, perhaps, a planer, a shaper, or a milling machine, that the garage man should make his choice very carefully. It is a very handy tool, with many advantages over the ordinary emery wheel using the edge only for grinding.

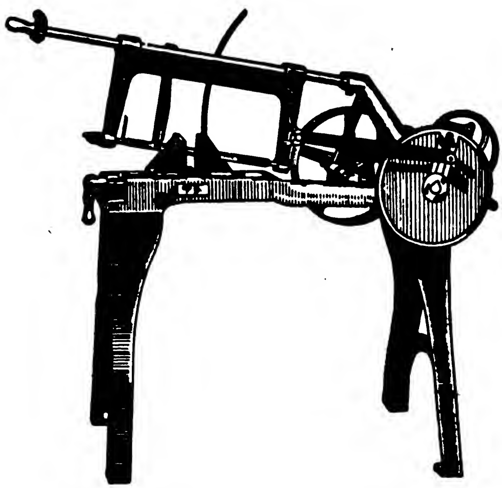


Fig. 43. Typical Power-Operated Hack Saw with Changeable Stroke Feature

Hack Saw. The power-driven hack saw is an inexpensive tool, and even the smallest garage finds sufficient work to warrant its cost. It is useful for cutting all kinds of material into lengths, as, for instance, bar stock in square, round, or other form. It works almost without attention and will do more than three times as much work as a man with a hand hack saw can, do it much quicker, more neatly, and better in every way. In Fig. 43 is shown a power hack saw, which may be taken as typical, although there are many different sizes and styles. A feature of this saw, which is not common to all saws, is the adjustable stroke. The disc which drives the saw is slotted, and the driving bolt in this can be set in various positions. When set as far out as possible, it gives the longest stroke, and when set close in to the center, it gives a very short stroke.

One thing needed for, or rather with, a power hack saw is an outboard support for long work. Such a stand is shown in Fig. 44. It is simple and is easily made.

Fig. 44. Outboard Stand for Hack Saw Facilitates Handling Long Stock

Of almost greater necessity than the stand is a stop for the saw, or a power shut-off which will work when the cut is finished. Normally, a power hack saw is started on its work and left. In the press of other work, this work is often forgotten, and the saw completes it and then continues sawing idly at the air. To give a signal the device shown in Fig. 45 may be used; this consists simply of an electric bell connected to a dry cell in such a way that the dropping of the end of the work pulls the switch, thus closing the circuit so that the bell rings. When the work is put in and the saw started, all that is necessary is for the workman to attach the string to the end which is to be cut off, with the switch open, taking care to have the string tight encugh so the dropping of the piece will open the switch.

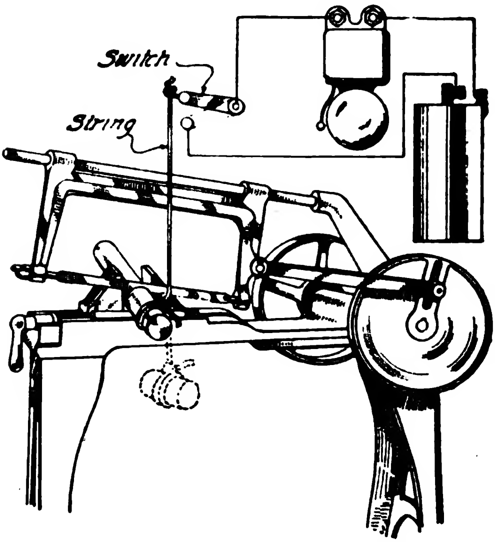


Fig. 45. Simple Electric Signal Applied to Hack Saw

Grinding in the Lathe. Many a shop owner does not feel that the cost of a separate grinder is warranted by his work, even though he does have quite a little grinding to do. When this is the case, a grinder can be rigged up on the lathe. This is done as shown in Fig. 46. The large pulley on the line shaft and the small pulley at the grinder give a sufficiently high speed. The lathe ways form a support for the work if it is large, while the carriage feed and cross-feed give a movement of the grinding wheel along or across the ways as needed.

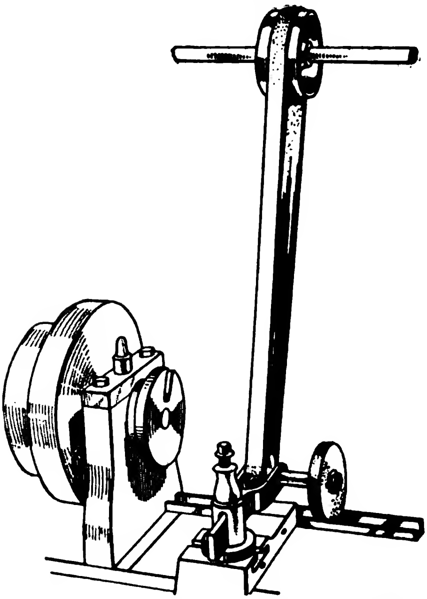


Fig. 46. Method of Rigging up Grinder on Lathe
Courtesy of "Motor World"

Milling in the Lathe. In using the lathe for milling purposes, the cutter is mounted on the spindle, and the work is placed in a special fixture which will allow an up and down movement. The carriage travel carries the work up to the cutter, the cross-feed allows feeding it across the face of the cutter, while the fixture gives an up and down feed. By this means, a considerable range of flat surface work can be done.

Utility of Portable Electric Motor. Mention of the utility of the portable electric motor in the small shop has already been made, but

Fig. 47. Arrangement of Portable Electric Motor on Truck
Courtesy of "Motor World"

this subject should be emphasized. When a small portable electric motor is properly rigged up and used to its full extent, it is surprising how much good work and what a diversity of work it will do. For grinding, buffing, and similar work, the motor, with a flexible shaft, should be rigged up on a movable truck about as shown in Fig. 47. When the drilling must be exact, the motor can be mounted in a special vertical stand as shown in Fig. 48.

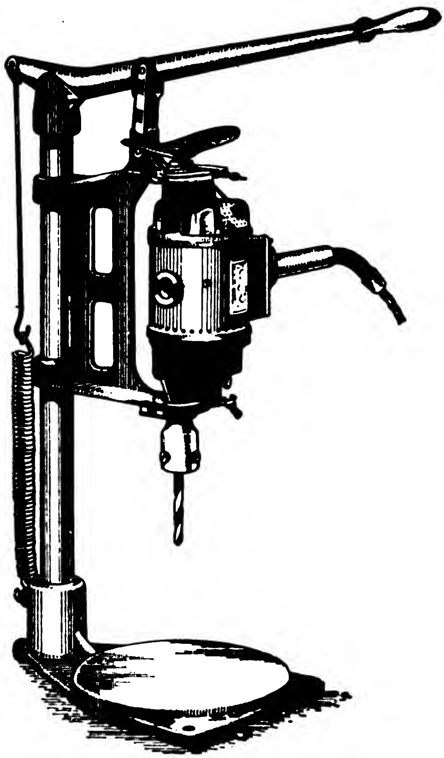


Fig. 48. Framework Which Allows Using Portable Electric Motor as Drill Press

Tool Equipment for Larger Shops

Additional Tools. Usually the larger and more pretentious shop will have a fully equipped repair shop. Such a shop would have all of the tools that have been described, with their various attachments and accessories, and also a number of larger machine tools, which are necessary and are economical, or time saving, on larger or more complicated work. Some such tools are the planer shaper milling machine; milling cutter grinder and other special grinders, as crankshaft and cylinder grinders; and arbor and other presses, etc. As these are in all respects identical with those found in any machine shop, no further explanation of their uses is given here.

Other Tools. There are many other machine tools, but they are mainly modifications of the basic types which have been mentioned. Moreover, the garage man is not interested in them because they are high priced, and are not particularly adapted to his work. The main things the garage man should have in mind when buying machine tools is adaptability to his work and the necessary volume of work to warrant the expenditure. If all garage men would purchase their tools on this basis, and this alone, they would avoid much useless expenditure and equally needless extra overhead charges on account of idle machines.

HARLEY-DAVIDSON THREE-SPEED ELECTRICAL-EQUIPPED TWIN-CYLINDER MOTORCYCLE

Courtesy of Harley-Davidson Motor Company, Milwaukee, Wisconsin

MOTORCYCLES

INTRODUCTION

Evolution of the Motorcycle. The same period which has brought the automobile to its present state of perfection has also witnessed the birth and development of the motorcycle. This two-wheeled motor vehicle was developed from the bicycle; in fact, the first motorcycles were bicycles with motors attached. However, owing to the comparatively high speed attained, the strains put upon the bicycle frame were too great, and extensive modifications were carried out, which resulted in a distinctive design and construction to stand the requirements of the service. It is significant of the general improvement in the construction that several motor bicycles have recently been designed and are giving good service.

The motorcycle started entirely as a pleasure, or sporting, vehicle, used by a few bicycle enthusiasts who desired greater speed or by racing men for pacemaking. Gradually, however, the utility of the machine in many directions became established, and now its place in its own field is as surely fixed as that of the automobile itself. For single or tandem road work, for package delivery, for messenger service, for military duty, and for a hundred other important offices, it is unexcelled, and the thousands upon thousands of machines that are sold every year in this country alone bear testimony to its popularity. There are other indications in some recently developed types that the field of usefulness of this flexible machine will be broadened still further.

Standard Specifications. The conventionalized American motorcycle is of two-cylinder construction. The frame is tubular and diamond shaped, with a double crossbar at the top, between which bars are located a gasoline tank and an oil tank. At its lowest point the frame is in the form of a loop, in which is clamped the aluminum crankcase of a twin-cylinder air-cooled motor, with the cylinders set V-shaped and a carburetor fitted between. Separate exhaust pipes lead from each cylinder to a muffler. The motor is of the L-head type, with the cylinders, as a rule, cast in one piece. The exhaust valves are at one side of the motor and are operated by cams on the lower side of the crankcase. The same cam often operates both exhaust valves.

In a removable cage on the roof of the valve pocket just over the exhaust valve, is located the intake valve, which is operated by a rocker arm above it, controlled by a push rod running up the side of the motor from the cam case. The crankcase contains two flywheels, which form also the crank arms of a built-up crank. Both connecting rods are fastened to the same crankpin, and these rods run down between the flywheels.

In the cam case is a small plunger oil pump which pumps oil in small quantities to the forward cylinder, this oil being delivered through the wall of the cylinder directly onto the piston at the lower end of its stroke. From this point the oil drops into the crankcase and is thrown up through the rest of the motor by the splash system. The crankshaft on one side runs into the cam case, from which a train of gears drives a magneto for ignition. The advance and the retard of this magneto are controlled by twisting one of the handlebars of the motorcycle, this motion being ordinarily transmitted to the magneto through a series of bell cranks and rods. The throttle is controlled by twisting the opposite handlebar; so the control of the entire machine is always within the driver's grasp.

The right end of the motor shaft projects beyond the right side of the case and ends in a small roller-chain sprocket, from which a chain runs to a larger sprocket on a countershaft set at the base of (or just back of) the vertical frame-tube member. Since change-speed gearsets are becoming common, this shaft is generally located back of the seat-post tube. The large countershaft sprocket connects with a small countershaft sprocket or with a gearset by means of a multiple-disc friction clutch, either of the dry fabric-faced type or of the metal type. This clutch may be operated by a lever in front of the driver's seat or by a foot pedal or by both. From the countershaft, a chain runs from a smaller sprocket to a larger sprocket on the rear wheel hub of the motorcycle. In this hub is located a brake (or brakes) of the expanding or contracting type or of both, operating on a brake drum. The rear end of the frame is often mounted on springs from the seat-post back, the lower frame forks being pivoted and the upper connection sprung. Within this triangle and generally back of the seat post is fitted a tool box, while over the wheel a luggage carrier forms the stock equipment. A stand is always fitted on the rear wheel to enable one to leave the motorcycle without its falling over.

The saddle is very large, as compared with a bicycle seat, and has sensitive springs, as well as being mounted usually in a spring-seat post located in the vertical-tube member. This saddle is always placed as low as possible on the frame. The front forks are mounted on some sort of springs—generally of the flat-leaf type—in order to absorb the shocks and thus avoid metal fatigue in the machine as well as bodily fatigue in the rider. This, in outline, is the American motorcycle of today.

Present Trend of Models. This outline is that of what might be called the American heavy-duty motorcycle. About 1914 or 1915, it looked as if this twin-cylinder type, with a change-speed mechanism, would soon displace all other designs. Later developments, however, have brought out several decidedly light-weight machines and at least two motor wheels, so that for 1917 there are more types than ever before. One set of riders has been demanding greater power and greater comfort in each season's models, until we have the expensive high-powered three-speed electric-lighted machines, suitable for all kinds of cross-country work; another class has been clamoring for a light machine of minimum cost both for initial price and for up-keep. These light machines are, of course, limited to city work and other more or less ideal conditions, but they are meeting the want of a large class of buyers. Many of the designs are very similar to the experimental machines developed abroad in the last few years preceding the war.

HISTORY

Early Machines. The first motorcycle built was the work of Gottlieb Daimler, who in 1885 built a two-wheeled vehicle to try out a gasoline motor with which he was experimenting. This machine was the forerunner not only of the motorcycle but of the automobile as well. De Dion of France, with Karl Benz of Germany, developed along with the automobile the gasoline motor, and the De Dion type was soon applied to a motor tricycle, followed by a motor bicycle using the same motor.

This motor was the predecessor of the motorcycle motor of today. The cylinder arrangement and the location of the compression chamber were almost identical. Two flywheels were used, with a connecting rod between, and the flywheels were entirely enclosed in the crankcase. Viewed in the light of modern design, the motor was very crude but developed horsepower enough to drive this early machine at what was then considered an astonishing speed—30 miles per hour.

The foreign machines were developed between 1894 and 1898, when an American inventor, who had been building racing bicycles, took up the motor-driven tandem as a pace-making mount for bicycle racing. As the motorcycle is all wheel base and no tread, it has no difficulty in holding the road at any speed; a fact which made it very adaptable to this kind of service. The transmission of this machine, designed by Oscar Hedstrom, was the basis of the formation of a company for the manufacture of motor bicycles, with George M. Hendee as the business manager of the concern. At about the same time, the Thomas, the Holly, the Orient, and the Mitchell motorcycles were being developed.

Two-Cylinder Motors. Glenn Curtiss was one of the first to develop a two-cylinder motor. It was in connection with his experiments with motors that he built a motorcycle equipped with an eight-cylinder V-type motor, which, covering a mile in 26.4 seconds—the fastest mile ever covered by man—held the record until recent date.

The first motors built were small-power engines of about the same stroke as bore; they attained surprising speed and cooled very successfully with flanges of small area.

Starting with 2.5-horsepower motors, power and weight were continually added until motors of 12- and even 14-horsepower have become common practice. The latter are, for the most part, of large bore and of comparatively slow speed, but, through the activity of European developments, light-weight machines with high-speed motors are coming into prominence.

Influence of High-Speed Motors. In the early days, when materials and workmanship were questionable except at a great expense, high speed in a motor was a disadvantage and tended toward short life. Belt drive from the motor to the rear wheels was common, and hence motors could not be geared below a certain ratio without having the belt pulley too small to transmit the power. Flat belts became very popular in America and were used on such machines as the Excelsior, the Harley-Davidson, the Yale, etc., while the Reading-Standard and the Indian factories consistently held to chain drive. Within the past few years, with the introduction of change-speed gears and high-speed motors, a positive drive has become a necessity, and chain drive with reduction to a countershaft located between the motor and the rear wheel has become almost standard practice. Foreign designers still favor the belt to transmit the power from the countershaft to the rear wheel, claiming that this gives greater flexibility of drive. American makers obtain smoothness of action by incorporating a slipping clutch in the transmission.

Light-Weight Machine. First to bring into prominence the light-weight motorcycle and high-speed motor was the Douglas Company, of England, which built a small horizontal-opposed two-cylinder air-cooled motor—a success above 4000 r.p.m. by virtue of its almost perfect balance of moving parts. This motor was set fore-and-aft in a light frame, with a chain taking the power from the motor to a countershaft at the frame junction below. A V-type pulley was the front member of the belt-driven system, and the gear reduction of the first chain drive threw a minimum strain on the belt and hence proved very reliable. This machine weighed, complete, about 183 pounds, and yet it was capable of the same road performance as the high-power American machines of greater weight.

In developing the new series of light-weight machines, already mentioned, the American designers have undoubtedly been influenced by the English successes along these lines. The single cylinder has been retained, and the two-cylinder opposed engine is coming rapidly to the front.

Modern Improvements. While the light machines have been developing, the refinement of the standard twin V-type has gone steadily on. The greatest improvements of recent date have been toward making the motorcycle more comfortable, cleaner, easier to operate, more reliable, and more foolproof. This, in nearly every case, has meant an increase in cost rather than a decrease, but buyers prefer a completely equipped machine at higher prices to partially developed mounts at lower figures. Four-cylinder machines are becoming popular with each succeeding year, and the manufacturers are also incorporating three-speed gearsets, self-starting systems, and other automobile features to as great an extent as possible.

With the many improvements in construction, convenience, and reliability in the motorcycle has come a broadening of its field of usefulness. Fitted with a sidecar and with an extra wheel, it has become the family carryall or has been utilized for city runs and delivery purposes. In the recent wars, motorcycles have played a very important part in the transmission of messages and in the quick dispatch of repair men and scouts for emergency service. A number of the sidecar vehicles have even been fitted with machine guns and very successfully used for rapid reconnoissance work.

TYPES OF MOTORCYCLES

Smith Motor Wheel. Although not a motorcycle in itself, the Smith Motor Wheel for attachment to bicycles has added hundreds of

Fig. 1. Smith Motor Wheel Attached to Rear of Bicycle
Courtesy of A. O. Smith Corporation, Milwaukee, Wisconsin

enthusiasts to the motorcyclist family. This wheel is a self-contained power plant consisting of a single-cylinder four-cycle air-cooled engine, having a bore of $2\frac{3}{8}$ inches and a stroke of $2\frac{1}{4}$ inches.

The engine is carried upon a bed which is flexibly attached to the bicycle frame, the motor wheel following slightly behind the rear

Fig. 2. Four-Wheel Buckboard with Smith Motor Wheel Attached
Courtesy of A. O. Smith Corporation, Milwaukee, Wisconsin

wheel of the bicycle, as shown in Fig. 1. One end of the engine crankshaft carries the flywheel, while the other end is geared internally to the driving wheel. The effect of this attachment is very much the same as that of the person running along the side of a bicycle rider and pushing him by means of the seat post, the connection between the motor wheel and the bicycle being quite flexible. This motor wheel has been adapted to all kinds of service, such as light delivery

Fig. 3. Rear of A. O. Smith Buckboard

vans and children's automobiles. The Smith Company has recently brought out a very light four-wheeled buckboard, Fig. 2, carrying two passengers and driven by the motor wheel. The rear connection of this model is shown in Fig. 3.

Dayton. Using the same construction of power plant, the Davis Sewing Machine Company has developed the Dayton Motor Bicycle, which has a motor wheel suspended between the front forks in place

Fig. 4. Dayton Motor Bicycle Showing Power Plant in Front Wheel
Courtesy of Davis Sewing Machine Company, Dayton, Ohio

Fig. 5. Engine Side of Merkel Motor Bicycle
Courtesy of Merkel Motor Wheel Company, New York City

of the ordinary front bicycle wheel, Fig. 4. The illustration also indicates the location of the gasoline tank on the handlebars.

Merkel. Newest in the motor-wheel development is the design of Joseph F. Merkel, who is well known in the motorcycle world through the success of the Merkel Flyer. This Merkel motor wheel is a combination of single-cylinder engine and rear bicycle wheel.

Fig. 6. Flywheel Side of Merkel Motor Bicycle
Courtesy of Merkel Motor Wheel Company, New York City

The engine is on one side of the wheel, Fig. 5, and the flywheel and magneto is carried on the other side, Fig. 6. The whole assembly is intended to replace the rear wheel of an ordinary bicycle, Fig. 7.

Cyclemotor. Besides this crop of motor wheels and of motor-wheel applications, there has appeared again a group of engines to be attached to the frame of the bicycle, driving through a belt to a pulley added to the rear wheel. Some years ago the same idea was attempted, but, owing to mechanical imperfections, did not seem to be successful. The big advance, however, which has been made in the design

Fig. 7. Complete View of Merkel Motor Bicycle

Fig. 8. Side View of Cyclemotor with Belt Drive
Courtesy of Cyclemotor Corporation, Rochester, New York

and construction of small gasoline engines and in the accessories employed with them, bids fair to make a success of these newer developments; in fact, some of them have been on the market long enough to have made a favorable impression already. A good example of this type of machine is the cyclemotor, illustrated in Fig. 8.

Auto-Ped. It would be hardly fair to leave this crop of near motorcycles without mention of the Auto-Ped, which is a device on two wheels, with a small board between, and with an engine attached to the front wheel. The operator stands upon the board between the two wheels, as on a child's coaster, and controls the device through a handle which takes care of the steering.

Light-Weight Motorcycles. No attempt will be made to describe or to even list all the light-weight machines that are now on the market. Short descriptions, however, will be given of the machines which are representative of a certain type of construction. In relation to the light-weight movement, the two-cycle engine has come back into striking prominence.

Fig. 9. Excelsior Light-Weight Motorcycle
Courtesy of Excelsior Motor Manufacturing and Supply Company, Chicago, Illinois

Excelsior. One of the best examples of the two-cycle engine is the Excelsior Light-Weight model, Fig. 9, which employs a single-cylinder two-cycle engine of $2\frac{17}{64}$-inch bore and $2\frac{3}{4}$-inch stroke, giving a piston displacement of 22.87 cubic inches. The ignition is provided for by a high-tension magneto driven by a silent chain, and the drive is through a two-speed gear and V-belt. The ratio on high speed is $5\frac{7}{16}$ to 1 and on low speed $8\frac{11}{16}$ to 1. This design shows well-developed springing and a kick starter.

Indian. Of the two-cylinder opposed chains the Indian Light Twin, Fig. 10, is among the most interesting. The cylinders lie fore-and-aft at the bottom of a very large loop in the frame and are air cooled. The bore is 2 inches and the stroke is 2½ inches, giving a total

Fig. 10. Indian Two-Cylinder Opposed Light-Weight Motorcycle
Courtesy of Hendee Manufacturing Company, Springfield, Massachusetts

piston displacement of 15.7 cubic inches. The Dixie magneto is mounted directly over the crankshaft. A three-speed sliding-gear transmission, and a dry-plate clutch deliver the power to the final roller-chain drive.

Thor. While cost of purchase and of upkeep have undoubtedly been the leading factors in developing these light-weight machines, lightness, for its own sake, has a strong appeal to a large class of riders, and the Thor line includes a light twin of the V-cylinder construction, Fig. 11, in which low purchase cost does not enter into consideration. This machine has cylinders with a $2\frac{3}{4}$-inch bore and a $3\frac{1}{4}$-inch stroke, or a total displacement of 38.6 cubic inches, and is provided with a high-tension magneto and with all the other refinements of its brother Thor machines of double the horsepower.

Fig. 11. Thor Light-Weight Motorcycle
Courtesy of Aurora Automatic Machinery Company, Chicago, Illinois

Developments in Standard Types. *Two-Cylinder*. So much for the general types representative of the new light-weight high-speed engine movement. Turning to the more standard American machines, we find no radical changes in the twin-cylinder V-models or in the four-cylinder machines. There are, however, the usual improvements and refinements, with a seeming tendency to decrease the number of models by discarding the two-speed gear and standardizing the three-speed type. This is probably owing to the fact that every machine sold is more than liable to have a sidecar, a rear car, or some other kind of a car or freight-carrying attachment placed upon it, and the three-speed machine has now been developed to a point where it can adequately take care of this kind of service—a demand which, a few seasons ago, the makers were inclined to feel was an abuse. Fig. 12 shows the latest of the Harley-Davidson Twins, the engine having a bore of $3\frac{5}{16}$ inches and a stroke of $3\frac{1}{2}$ inches, which gives it a piston displacement of 60.34 cubic inches. The dry-plate clutch,

Fig. 12. Harley-Davidson Standard Twin-Cylinder Three-Speed Motorcycle
Courtesy of Harley-Davidson Motor Company, Milwaukee, Wisconsin

the three-speed transmission, the kick starter, and other features are not new, the only changes being slight refinements, which each season brings about.

In passing, it should not be forgotten that the large single-cylinder type, which was the predecessor of the V-type, is still on the market, although its demise was predicted several seasons ago. This is because a number of large public-service corporations have found this type so successful in their trouble departments that they insist upon purchasing more of them each season. The wide-awake companies, however, are beginning to look more favorably upon the twin-

Fig. 13. Henderson Four-Cylinder Motorcycle
Courtesy of Henderson Motorcycle Company, Detroit, Michigan

cylinder three-speed machines for their heavy service, and there is no question but that the large slow-speed single-cylinder type will in time drop out of sight.

Four-Cylinder. The Henderson Motorcycle Company, of Detroit, has been the successful champion of the four-cylinder design, Fig. 13. These engines are air cooled and have a bore of $2\frac{1}{2}$ inches and a stroke of 3 inches, giving a piston displacement of 58.9 cubic inches. The Henderson has been on the market for several years, and the construction in the past has included a bevel gear at the rear of the crankshaft, which drove through a chain to a planetary two-speed transmission incorporated in the rear hub. For the coming season,

Fig. 14. Side View of Militaire Four-Cylinder Motorcycle
Courtesy of Militaire Motor Vehicle Company, Buffalo, New York

this construction has been replaced by a three-speed sliding gear at the rear of the crankshaft, with a chain drive back to the standard types of hub and band brakes. One of the features of the four-cylinder machine is its very rapid acceleration, which makes it very easy to handle in traffic—excellent for police-department work.

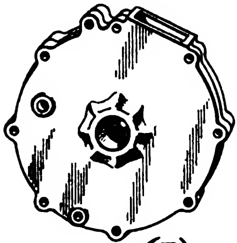
Another four-cylinder machine, the Militaire, has recently been announced, which is illustrated in Fig. 14. This carries an engine of $2\frac{11}{16}$-inch bore and 3-inch stroke, with a piston displacement of 68 cubic inches. The specifications list such unusual features as a selective sliding-gear shaft having three speeds forward and a reverse, which forms a unit with the engine. The drive is by propeller shaft,

Fig. 15. Rear View of Militaire Motorcycle, Showing Auxiliary Wheels in Position for Supporting Motorcycle
Courtesy of Militaire Motor Vehicle Company, Buffalo, New York

and the wheels are of artillery rather than wire type. In Fig. 15 it will be noted that there are two auxiliary wheels which swing up off the ground; in their normal position, they lie at each side of the rear wheel. These auxiliary wheels are lowered, as shown in the figure, when the machine is left standing or when it is driven in very slow heavy traffic where the motorcyclist so often has to drag his feet upon the ground.

ANALYSIS OF MOTORCYCLE MECHANISMS

Nomenclature. Before going on with a discussion of engines and how to take care of them, it is best to make sure that the reader under-



(B)

(H)

Fig. 16. Diagrams of Various Parts of Motorcycle

stands the names and purposes of the various parts that go to make up the complete machine. When dealing with the principles of the internal-combustion engine, we always deal with the single-cylinder type for the sake of simplicity, pointing out that in the two-cylinder and four-cylinder engines there has been but a combination of several single-cylinder engines.

Referring to Fig. 16, we have at *A* the cylinder casting, which is made of gray cast iron, although in some cases it does not look it, owing to methods of sand blasting, enameling, etc. The cooling ribs are cast integral and are not of a different material shrunk on as was tried on some air-cooled automobile engines. At *B* is the crankcase, which is an aluminum casting, usually highly polished. Most automobile crankcases are split along a horizontal plane, but the motorcycle crankcase is divided in the verticle plane and bolted together as shown. Piston, connecting rod, and flywheel assembly is shown at *C*. The piston moves up and down in the bore of the cylinder. It is usually made of cast iron and often drilled with a number of comparatively large holes to decrease its weight and also to assist in the lubrication of the cylinder wall. Aluminum is gaining in favor as a piston material because of its light weight. The purpose of the connecting rod is to change the back and forth, or reciprocating, motion of the piston into rotary motion at the crankshaft. This means that there are bearings at both ends. At the upper end, the bearing is called the wrist-pin bearing, because the small shaft across the piston is called the wrist pin. At the lower end, the bearing is known as the connecting rod bearing and the big end bearing.

One of the main differences between the general design of the motorcycle engine and that of a small marine or an automobile engine is in construction. In the ordinary design, a one-piece crankshaft, as at *D*, is used, and this extends through the crankcase with the single flywheel *E* fastened on the outside, as in the Motor Wheel and in the Indian Light Twin. In all other motorcycle designs in this country, however, enclosed flywheels are used. In this case there is a flywheel on each side, as shown at *F*, these being housed inside the crankcase. The counter weights to balance the inertia forces of the piston are cast as part of these flywheels instead of being fastened on as is sometimes done with automobile crankshafts.

A valve assembly is shown at *G*, giving the valve, the valve seat, the valve spring, the tappet, and the cam. The valve usually has a bevel seat, as shown, but in some cases it is flat. As the cam is revolved by the gearing from the crankshaft, the high portion comes under the bottom of the tappet and raises it upward. The tappet, in turn, raises the valve from its seat, allowing gases to enter or to be exhausted from the cylinder, as the case may be. There is often an arm, or cam follower *H*, interposed between the cam and the lower end of the tappet, but the general action is the same.

It is quite common to use an overhead valve for the inlet, and in that case the valve often works in a removable cage *H* instead of seating directly on the cylinder casting. In order to get the action of the cam carried to the valve, the tappet raises a long push rod and this, in turn, raises one end of a rocker arm, the combination of motions opening the valve.

PRINCIPLES OF ENGINE OPERATION

Classification. Motorcycle engines of all designs are of the internal-combustion engine type, which means that fuel is burned, or exploded, inside the cylinder of the engine, where the heat energy liberated is transformed into mechanical energy. An example of an external-combustion engine is the ordinary steam engine, where the burning of the fuel takes place outside of the engine itself.

There are two general types of the internal-combustion engine, known as the four-cycle and the two-cycle engines. Since these terms refer to the number of strokes of the piston for each power impulse for one particular cylinder, it would be more proper to speak of them as the four-stroke-cycle and the two-stroke-cycle, but custom has dropped the word *stroke*.

Four-Stroke-Cycle, or Four-Cycle. Taking up the four-cycle operation first, as it is the more important so far as the number of machines is concerned, we will assume that the piston has passed the upper dead center, as at *A*, Fig. 17, and that at this point the inlet valve is well open. As the piston travels downward, the explosive mixture is drawn into the cylinder, and at the lower dead center the inlet valve closes. As the piston travels back, both valves are closed *B*, and the mixture is compressed to from sixty to ninety pounds per square inch. At the time the piston reaches the top of the stroke again *C*, the spark occurs at the plug, igniting the charge. The rapid expansion, or explosion, of the gases, drives the piston down, this being known as the power stroke. The other two strokes are called the intake, or suction, and the compression strokes. At the end of the power stroke the exhaust valve opens *D*, and as the piston

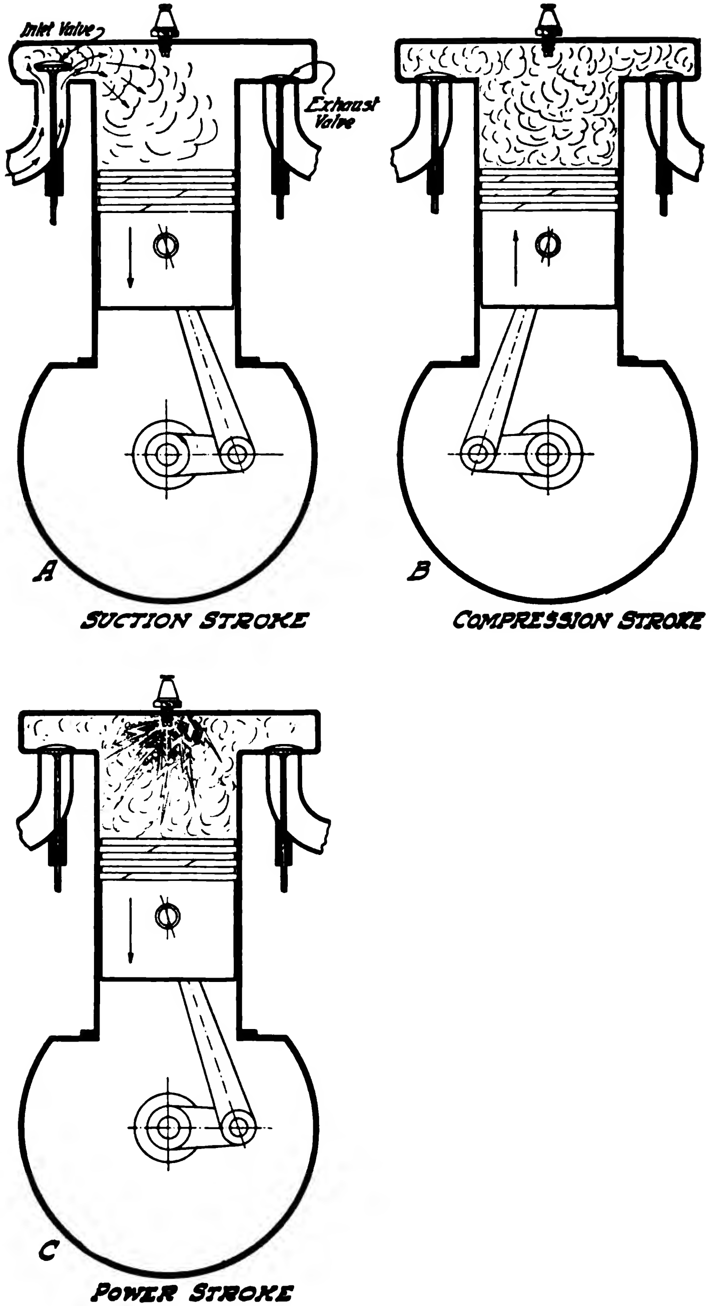


Fig. 17. Diagrams of Various Operations of Four-Cycle Engine
Courtesy of "Motor Age", Chicago

returns to the top position, the burned gases are pushed out through the exhaust valve. The cycle of events is then repeated. Thus, we have four strokes of the piston for each power impulse, and this requires two complete revolutions of the crankshaft.

Two-Stroke-Cycle, or Two-Cycle. In the two-cycle engine, the same series of operations is performed in two strokes of the piston, or one revolution of the crankshaft; and this is accomplished by the use of crankcase compression and the difference in density of hot and cold gases. Referring to Fig. 18, it will be noticed that instead of the usual poppet valves of the four-cycle engine, the two-cycle engine has

Fig. 18. Diagrams of Operation of Three-Port Two-Cycle Engine
Courtesy of "Motor Age", Chicago

openings in the side of the cylinder, which are known as ports. There are two classes of these engines, based upon the number of ports employed. The more common is the three-port engine, in which the carburetor is connected by a passage to the crankcase, the port of this passage being opened and closed by the skirt of the piston.

Starting with the piston at the lower dead center and traveling upward, there will be a partial vacuum produced in the crankcase which is air tight. When the skirt of the piston uncovers the inlet port, the vacuum will cause a rush of explosive gas into the crankcase *A*, Fig. 18. When the piston has reached the top dead center and started down again, it will shut off this gas passage, and its further travel will compress the mixture in the crankcase to a few pounds pressure. Near the lower dead center *B*, the top of the piston will uncover the port of the by-pass from the crankcase to the chamber above. The gas in the crankcase, being under slight pressure, will rush up into the combustion chamber with considerable velocity, and, being colder than the spent gases of the preceding explosion, will drive these hot gases out through the third port, which was uncovered by the top of the piston a moment before it uncovered the by-pass.

Fig. 19. Diagrams of Operation of Two-Port Two-Cycle Engine
Courtesy of "Motor Age", Chicago

In order that the fresh gases shall not pass directly across the piston and out through the exhaust port, leaving burned gases in the top of the cylinder, the piston is provided with a deflector so as to send the cold gases up to the top of the cylinder, driving out the exhaust with as little waste of the fresh gases as possible. As the piston continues to pass upward, both the by-pass and the exhaust ports are closed again and the remainder of the stroke compresses the fresh gases. At the end of the compression stroke, that is, just after the piston passes upper dead center *C*, the spark occurs, igniting the charge and giving the power impulse to the piston. Thus we have inlet, compression, firing, and exhaust taking place in two strokes of the piston, or, in other words, there is a power impulse for every revolution of the crankshaft.

Upon the face of things, one might think that the two-cycle engine of equal dimensions and running at the same speed as a four-cycle engine would have exactly double the power of the latter. This, however, is not so, as the method of getting the gas into and out of the cylinder is less efficient in the two-cycle than in the four-cycle design.

The two-port two-cycle engine varies from the three-port in but one particular, and that is that the passage between the crankcase and the carburetor is closed by an automatic spring-controlled valve instead of by the opening and closing of a port by the skirt of the piston. This is clearly shown in Fig. 19.

CONSTRUCTION DETAILS

Spring and Frame Construction. *Seat-Post Springs.* The springs used on a motorcycle to absorb the road shocks or to add to the comfort of the rider are usually located on the front forks, in the rear frame, or in the seat post. One of the first firms to adopt a spring-seat post was the Harley-Davidson, but the Merkel had used a spring-frame construction some time previous. The more prominent of the modern spring constructions will be illustrated and discussed.

Fig. 20. Flying Merkel Spring Seat Post

The Merkel spring-frame construction is shown in Fig. 20, a coil spring being fitted under the saddle and forming a continuation of the upper forks. In action, the lower forks are pivoted about the crankshaft of the motor below, this acting as a radius for the rear axle. The upper forks support the entire weight of the motorcycle on the coil spring.

The Harley-Davidson and the Dayton systems, which are very similar, are illustrated in Figs. 21 and 22. In these constructions, the vertical tube of the frame contains a plunger operated from a fixed center with a coil spring on either side. The saddle fastens to a radius rod at the top of this plunger, the front end of this radius rod being bolted to a clutch on the frame. The entire weight of the rider is supported through the saddle on the coil spring below, allowing a very easy-riding action.

Rear and Front Frame Springs. The Pope uses a leaf-spring front fork and a spring type of rear suspension, Fig. 23. The suspension consists of a drop-forged bracket on each side, brazed to the rear end of the frame, with a tension spring fastened to the top surface of the bracket. Double guide rods, as shown in the figure, are used, these rods carrying an axle yoke which is free to move between the jaws of the bracket, thus allowing the spring to absorb the rear vibration. Fig. 24 illustrates the Indian cradle-spring frame at the rear. This construction has the lower forks pivoted as on the Merkel,

Fig. 21. Harley-Davidson Spring Seat Post

Fig. 22. Dayton Spring Seat Post

but the weight of machine and rider is supported on the two leaf springs, as shown. The details of the front-fork leaf springs of the Indian are shown in Fig. 25.

Types of Frames. There are two types of frames ordinarily used in motorcycle construction. One is formed with a loop, as shown in Fig. 26, the motor fastening to lugs on either side of the loop. This construction makes the machine very easy to assemble, and the frame is equally strong whether the motor is in or out of the frame. The other construction is similar to this, except that the loop below is eliminated, as shown very noticeably in Fig. 9. The lugs fasten directly to the crankcase of the motor, which thus becomes the lower member of the frame.

Motors. Motors for motorcycle use are usually of the four-cycle air-cooled variety. These motors, as previously described, are now built with one, two, and four cylinders. Water-cooling has been tried abroad on motorcycles with considerable success, but so far has not been applied in America.

Single-Cylinder Type. We have already predicted the disappearance of the large size single-cylinder engine which is still favored by some of the public-service corporations, and, at the same time, have pointed out the crop of new machines of the light-weight type which employ the one-cylinder engine, to say nothing of the popular motor-wheel type. Some of these light singles work upon the four-cycle principle, while there is also a large crop of the two-stroke variety. Fig. 27 shows a section of the Excelsior light-weight two-cycle engine, in which one of the points worth noting is the de-

Fig. 23. Pope Rear Frame Spring Arrangement

Fig. 24. Indian Rear Cradle-Spring Rim

flector built into the piston head for the purpose of causing the fresh gases to sweep clear around the dome of the cylinder before reaching the exhaust port. It may also be noted that the top piston ring is pinned,

Fig. 25. Indian Front-Leaf Spring

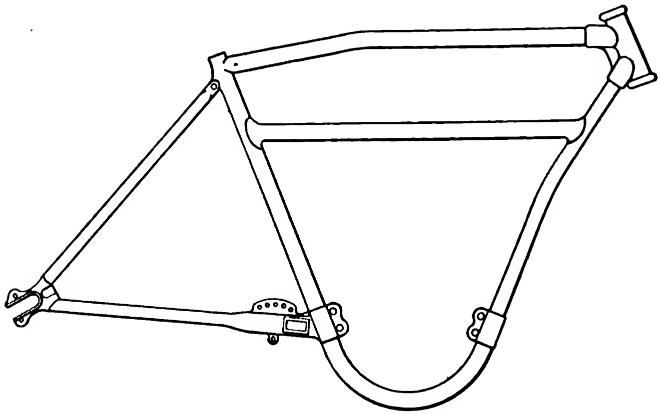


Fig. 26. Loop Frame Showing Lugs for Motor Attachment

as should be the case in all two-cycle engines in order to prevent the ends of the rings from working around and becoming snapped off at the cylinder ports. The piston is drilled full of large holes in order to assist the lubrication and, at the same time, reduce the weight. This is another one of the engines with the outside type of fly-wheel and with the split-bushing-capped connecting-rod end, both similar to automobile practice. The valve at the upper left-hand portion of the combustion chamber has nothing to do with the two-cycle operation, but is merely a relief valve which releases the compression at the time of cranking.

Another single-cylinder type, Fig. 28, is the Smith Motor Wheel power plant. This type works on a four-cycle principle. The inlet valve above is of the automatic type, that is, instead of being opened mechanically, it is opened by the difference in pressure during the suction stroke. The exhaust valve is mechanically opened by the usual valve mechanism. Again, we have the outside flywheel and the split lower end to the connecting rod. In this case, the lubrication is by splash, and a large dipper will be noted upon the lower half of the connecting-rod cap. The construction of the Dayton Motor Bicycle engine is the same.

Fig. 27. Single-Cylinder Motorcycle Motor
Courtesy of Excelsior Motor Manufacturing and Supply Company, Chicago, Illinois

Two-Cylinder Type. In the two-cylinder field the V-type engines seemed to be supreme in 1915; but again the light-weight brothers have disturbed the trend of practice, and the two-cylinder four-cycle opposed engine is making as hard a fight for popular favor in the light-weight field as the single-cylinder two-cycle. In the Indian model, a cross-section of which is shown in Fig. 29, we have an example of this construction. It is the same general design which English makers have been able to run at 4000 r.p.m. in their light-weight machines. The crank throws are set at 180 degrees. In the V-machines the cylinders stand at from 42 to 50 degrees between the center lines, depending upon the ideas of the designer. An interesting feature of the design is to be noted in the placing of the valves at an angle in the combustion chamber, making the engine very compact. The split connecting-rod bushing and the external flywheel are used.

Fig. 28. Diagram of Smith Motor-Wheel Power Plant
Courtesy of A. O. Smith Corporation, Milwaukee, Wisconsin

In Fig. 30, we come back to what we have come to think of as the highest development of American motorcycle practice, namely, the two-cylinder V-type engine. This particular figure shows the Harley-Davidson power plant, which is of the L-head cylinder construction with the inlet valve above the exhaust and operated mechanically by a push rod and rocker arm. Other engines of the

V-type have the inlet and the exhaust valves side by side in the bottom of the combustion chamber, while the third school of design places both the inlet and the exhaust valves in the top of the cylinder head, operating them through rocker arms as just described.

Instead of an external single flywheel, as we have just described in several cases, the V-cylinder engines have enclosed flywheels with the crankpin and two crankshafts fitted into them by stout tapers.

Fig. 29. Section of Indian Twin-Cylinder Opposed Engine
Courtesy of Hendee Manufacturing Company, Springfield, Massachusetts

The counterbalances for the inertia forces of the piston are cast as part of the flywheels. With the single crankpin and the two rods, there are two possible constructions for the lower-end bearings. One would be with the rods placed side by side, while the other would be the forked rod as shown in Fig. 31. This is the design that has become standard practice. Although at first the amateur might think that these rods would interfere with each other, the relative motion between them is really very slight.

In the highest development of these machines, roller bearings are used at the big end of the connecting rods instead of the split bushing, which has been referred to in the light-weight engine described. Great skill is required in fitting these bearings, for if one roller is larger than the other rollers by a very small fraction of an inch, there will be a binding of the bearing upon the shaft. When they are correctly fitted, however, and properly lubricated, their life is very long, and the friction loss is held at a minimum.

Fig. 30. Side View of Harley-Davidson Twin-Cylinder Engine

Instead of the cams working directly upon the ends of tappets to raise the valves, it is usual to interpose arms, or followers, as shown in Fig. 30. Just above the cam wheel or the large gear is a small rack or portion of a gear. This is connected to the compression relief and when it is desired to relieve the compression to the motor, this part gear is rotated and, through a lever connected to it, raises both inlet valves slightly off their seats so that the compression is materially decreased.

Four-Cylinder Type. Figs. 32 and 33 illustrate the Henderson four-cylinder motor-

Fig. 31. Typical Forked Piston Rods for V-Type Twin-Cylinder Engine

cycle. This is also air-cooled and of the L-head type, with overhead inlet valves. It is designed for medium-high speed, has a three-bearing four-throw crankshaft, three-ring pistons, an enclosed flywheel, and a bevel-gear reduction. The motor is lubricated by splash from the oil in the base of the crankcase, as will be noted in Fig. 33. This motor is particularly neat, noiseless, and flexible.

European High-Speed Type. Foreigners, with their generous experimenting, have gone farther in motorcycle design than have our

Fig. 32. Rear View of Henderson Four-Cylinder Engine and Transmission
Courtesy of Henderson Motorcycle Company, Detroit, Michigan

designers in America. The progress, however, has been in the line of experimental work and individual building rather than in workmanship or in accuracy of production, the latter being the American's strong specialization. America, in spite of its heavy road conditions, is not experimenting with water-cooled motors for motorcycles, though England uses them to a limited extent. One of the most prominent motorcycle builders in England departs from standard practice in adopting both water-cooled and two-cycle principles.

Consistent performance as a result of these innovations, coupled with good workmanship, has given this machine great prominence.

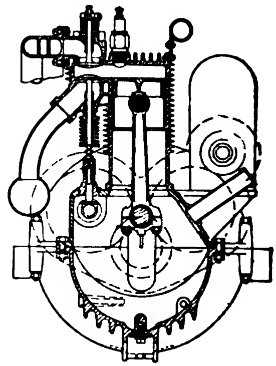


Fig. 33. Side and End Sections of Henderson Four-Cylinder Motor

Europe's greatest advantage, however, in motorcycle construction has been exemplified by the development of the high-speed motorcycle motor. This is ordinarily of the horizontal-opposed type, the most prominent high-speed low-weight construction being the Douglas, a British machine. This motor is able to maintain this high speed through a crankshaft balance which is practically perfect, allowing it to run at the abnormally high speed of 4000 r.p.m. for long periods without fatigue of material, and hence with great efficiency. The motor is of the L-head type, with air-cooled cylinders and an outside flywheel. The cylinders being placed opposite each other, the counterbalanced cranks are set 180 degrees apart. The entire motorcycle is said to weigh under 200 pounds and attains speeds well above a mile a minute.

Fig. 34. Excelsior Lubricating System

Water cooling is another English experiment, which has proven successful. It has not been generally adopted in Europe, however, and air cooling has been perfectly satisfactory in this country.

Lubrication. *Path of Oil.* A lubricating system, as used on the Excelsior motorcycle motor, is shown in Fig. 34, and gives the particularly neat method by which motors of this type are oiled. In this case, the oil is first fed to the main bearing on the cam-case side, as shown by the arrow. This oil is fed by pressure from a pump and, after covering this bearing, is forced out at the end and flows through the drill hole shown, which brings it out above by centrifugal force to the connecting-rod bearing. This bearing throws the excess oil out, splashing it in all directions and up through the slot through which the connecting rod runs. From here it runs out on either side and gathers in a groove at the bottom edge of the cylinder. The bottom of the piston drops into this trough of oil every time it comes down, thus carrying the even film with it up the walls of the cylinder. The excess oil flows down the side of the crankcase and feeds the right-hand bearing. Excess from here is caught on the outer end of the shaft and returned to the crankcase, where it is splashed up again into the motor for further use.

Fig. 35. Excelsior Oil Pump

In a V-type twin-cylinder motor where the oil trough at the bottom of the cylinder cannot catch an even amount on account of the cylinder angularity, the oil is generally allowed to drain back at once on the rear cylinder, and, instead of going to a main bearing first, it is fed to the forward cylinder.

Fig. 36. Harley-Davidson Roller-Cam Oil Pump

Oil Pumps. Fig. 35 shows a type of oil pump which is used to feed the oil to the motor. In this construction a small worm drive from the cam case or the magneto gear case turns a small crank which operates a vertical plunger. This plunger cylinder is so arranged that on the top of the stroke oil may flow into the cylinder space, a ball check valve holding the oil from being sucked into the cylinder. On the down stroke, the oil inlet is covered by the piston, and the ball check valve opens to allow the plunger to force the oil in the cylinder out of the motor.

Fig. 37. Excelsior Starter with Automatic Compression Relief

Fig. 36 illustrates a special type of pump, in which the plunger *P* is operated by a peculiar-shaped roller cam *H*.

Fig. 38. Indian Kick Starter
Courtesy of Hendee Manufacturing Company, Springfield, Massachusetts

The shaft of this roller cam contains the elements of a rotary valve, with openings at *A* and *D*, so that the oil is fed positively through a sight feed *G* on its way to the motor. There are no ball check valves in this construction, and a screw *J* enables one to adjust the amount of oil delivered to the motor within very narrow limits. The intake oil pipe is shown at *S*. The oil is fed to the motor through the opening *G*. Since oiling is so important a part of the high-speed motor operation, the development of this device has made a change in the reliability of the modern motorcycle.

The quality of the oil used is of great importance in the life of a motorcycle. Each maker recommends oils suited to his machine, and it is well to follow these suggestions.

Starting. It is hardly probable that the complication of electric starting will be adopted widely for motorcycle use, as it is generally more trouble to operate a power starter and keep it in repair than to use the simple form of kick starter which has become so popular and which now is fitted to almost all American machines.

Fig. 39. Typical Expanding-Band Brake
Courtesy of Harley-Davidson Motor Company, Milwaukee, Wisconsin

Figs. 37 and 38 show forms of starters in use on the Excelsior and Indian motorcycles, respectively. The main shaft on one side or the other is fitted with a small gear pinion which is fastened to the shaft on a ratchet or over-running clutch. Off to one side is pivoted a gear quadrant fastened to a pedal, which is often of the folding type. Pushing down on this pedal with the foot meshes the pinion with the quadrant, and a quick thrust or kick of a quarter-turn will then turn the motor over several times at fair speed. When the motor starts, the small pinion is released, and a strong pull brings the quadrant back to its former position, out of mesh with its pinion. The pedal is generally fastened in this upward position by means of a clip so that it cannot rattle.

Brakes. A number of types of brake construction are used on motorcycles, but they are mostly of the expanding- or contracting-band variety. Fig. 39 shows the construction of an expanding-band brake. The band is of springy material and covered with a brake-lining material. The shoe, or ring, fits inside the brake drum which is keyed to the rear-wheel hub. Operation of the lever pushes the ends of the band apart so that it expands forcibly against the interior of the drum.

A similar band may be fitted outside the drum, but in this case the fabric will be on the inside of the band, and the lever will pull the band tight on the outside of the drum. This is known as the contracting-band brake. Fig. 40 shows the brake used on the Excelsior motorcycle combining both types, the expanding and contracting

Fig. 40. Typical Double-Acting Band Brake
Courtesy of Excelsior Motor Manufacturing and Supply Company, Chicago, Illinois

bands being shown in section with their linings in place. The operation is by two levers, shown in the lower part of the illustration.

Fig. 41 illustrates the pedals fitted to the Henderson motorcycle, which operate the brakes of this complete little machine.

Drive. *Belt Drive.* The early motorcycles employed belt drives of either the V- or the flat-faced types. As the power output increased, the belt slippage became excessive and the chain drive began to predominate. In the new light-weight machines, however, the belt drive has reappeared, especially in the V-type of construction, which consists of a continuous two- or three-ply belt of leather with blocks of leather riveted to it, Fig. 42. The blocks are about 1 inch thick, and the sides are beveled off at the same angle as the V-pulleys.

Fig. 41. Henderson Foot Rest and Brake Pedals

Fig. 42. Peerless V-Belt for Motorcycle Drive
Courtesy of Peerless V-Belt Company, Cedar Rapids, Iowa

Shaft Drive. The Pierce Company of Buffalo at one time built a shaft-driven four-cylinder motorcycle, but discontinued it after a few seasons. The shaft drive is again announced on the Militaire, a four-cylinder machine, already shown in Fig. 14.

Fig. 43. Indian Multiple-Disc Clutch and Three-Speed Gear Set

Chains. For heavy powers the roller chain seems to have proved itself the most efficient. This construction is the outgrowth of bicycle practice, and we now usually find two chains, one from the engine to the gearset and the other from the gearset back to the rear hub. The chain is made up of a series of rollers turning on hardened pins which stand between the side bars. If kept in proper condition, the friction loss is very small.

Clutches. Several kinds of clutches are used on motorcycles, the one most used being of the multiple dry-disc type, as shown at the left end of Fig. 43. This consists of a number of thin metallic discs faced with fabric brake-lining material and keyed alternately to the center shaft and the containing drum. When springs are allowed to thrust these plates tightly together, the amount of friction generated makes a reliable drive between the drum and the central shaft. Suitable mechanism is arranged so that, when it is desired to disengage the clutch, a lever or pedal can release this spring pressure and allow the discs to run free without friction between them.

Fig. 44. Sectional View of Reading-Standard Cone Clutch

Fig. 45. Indian Neutral Countershaft
Courtesy of Hendee Manufacturing Company, Springfield, Massachusetts

Metal-to-metal clutches consist of a set of metal discs brought into or out of contact by means of a lever. These are generally run in oil to prevent their heating. When the spring pressure is applied, it takes a number of revolutions to drive out the oil from between the plates and thus prevent a grabbing clutch.

The Reading-Standard motorcycle, instead of employing a countershaft back of the motor, fits an internal-gear countershaft to the side of the crankcase and drives from this to the main drive sprocket by means of an ordinary automobile-type cone clutch. This clutch is shown in Fig. 44. A cone on this clutch is faced with leather and operates exactly like an automobile clutch.

Gearsets, or Change-Speed Mechanisms. Modern motorcycles are almost invariably fitted with change-speed gears, which might be classed as one-, two-, and three-speed types.

One-Speed. The one-speed gear—if it can be so called—is merely a dog-clutch arrangement, Fig. 45, used to disconnect the motor from the rear wheels when the clutch is in engagement. The central part is a ring which can be moved from right to left in order to fit the notches in its face into those on an adjacent ring connected to the driving sprocket. The sliding of this member is accomplished by means of the small lever.

Fig. 46. Dayton Multiple-Disc Clutch and Sliding-Gear, Two-Speed Transmission

Two-Speed Planetary. Where but two speeds forward are desired, the planetary, or epicyclic, gearset has proven popular. This type, which is sometimes called the sun and planet gear, is made up of a nest of small gears which usually mesh with an internal gear at the same time that they are revolving about a common center gear. The small gears not only revolve in space, but also revolve upon their own axes. By holding the internal gear in place, a desired reduction can be obtained. Such gears were employed upon the Harley-Davidson and the Henderson; but, as mentioned before, the trend is toward the three-speed sliding-gear transmission, and none of the late catalogues of the well-known makers list the planetary gear.

Two-Speed Gear. Fig. 46 shows a Dayton sliding ring two-speed transmission fitted with a multiple-disc clutch, shown in section. This clutch is operated by a lever or pedal and, when in engagement, enables the sprocket at the left to drive through the gear mechanism to the middle, or main drive sprocket. If the small cam ring, shown in the center of the gearset, is moved to the left by a lever, the dogs engage a shaft from the left sprocket direct to the main sprocket, so that one is driving on high gear. On releasing the clutch, the cam

Fig. 47. Harley-Davidson Three-Speed Transmission

ring in the center of the gearset can be shifted to the right to mesh with the smaller gear on that side, which is driven by the sprocket at the left. This gear now drives through the two lower back gears, back through the upper left-hand gear to the main sprocket, which now, instead of traveling with the left one, travels at about half its speed. This is low-gear position. This type of gearset is used on a number of prominent motorcycles, the differences being mainly in details.

Three-Speed Gear. Fig. 47 shows a three-speed gear fitted to the Harley-Davidson, operating on the same principle as the two-speed gears just mentioned. At the extreme left is shown the clutch and the large and small sprockets. The lower shaft to the gearset is the main shaft, and the two gears at the right on this lower shaft slide on keys on the shaft. The shaft is driven by a big sprocket, while the smaller sprocket is fastened to the left-hand gear. If the two sliding gears are shifted to the left, a dog engages them with the left-hand gear, these dogs being clearly seen in the cut. If the gears move to the position shown in the cut, the machine is on second speed, driving through the four gears which are in mesh. If the two gears are shifted farther to the right, the right-hand one of the two lower gears comes in mesh with the right-hand big gear, and the machine is on its lowest gear ratio. The method of mounting this gearset on the Harley-Davidson is shown in Fig. 48.

Fig. 48. Method of Mounting Transmission in Harley-Davidson Frame

A smaller three-speed gearset used on the Indian motorcycle is shown in Fig. 43 in connection with the disc clutch attached. In this case a single sliding gear on the princpial shaft makes all the connections and gives a progressive gearset of extreme simplicity. A gearset is a necessity on motorcycles intended for passenger use.

Electrical Equipment. *Development from Battery Current.* In the earlier days of the motorcycle, the electrical current for ignition was furnished by dry cells and stepped-up to the required voltage by an induction coil. The next development was the almost universal equipment with high-tension magnetos, which generated the spark

Fig. 49. Remy Motorcycle Generator

mechanically and directly furnished high-tension current. With the coming of electric lighting and starting equipment on all automobiles, the motorcycle enthusiast saw the advantage of the electric head and tail lights, to say nothing of a warning signal, and was not slow to demand this upon his own type of machine. The very nature of dry cells works against their continual use for supplying headlight current, and the storage battery has therefore been the only solution of the problem. A storage battery, however, to be carried upon the motorcycle must be rather small in size and thereby limited in capacity.

Fig. 50. Splitdorf Magneto Generator as Used on the Indian Motorcycle

In the history of automobile lighting, the owner soon demanded that a generator be driven by the engine for the purpose of keeping the storage battery in a charged condition, instead of having to take it some place for charging from an external source. The same thing followed in the motorcycle field; and we have seen developed a series of generators, Fig. 49, driven mechanically by the engine, which are capable of keeping the battery floating on the line or of sometimes taking care of the lights.

Fig. 51. Parts of Splitdorf Mag-Generator
Courtesy of Splitdorf Electric Company, Newark, New Jersey

Magneto Generators. These generating machines — the Splitdorf type shown in Fig. 50 is used on the Indian—are a unique conception and apparently have not been influenced by automobile practice, for the instruments usually combine a high-tension magneto and a low-tension generator. This combination makes a single-unit machine mechanically, but a double-unit machine electrically, there being two separate armatures, as shown in Fig. 51, the same field winding exciting both fields. In a way, it is wrong to speak of this as partly a magneto, because the term magneto implies the use of permanent magnets for the production of the magnetic field. The armature, however, is of the regular magneto type and delivers a high-tension current to the spark plug. The generator armature is wound so as to deliver about three amperes of current at thirty miles per hour, charging a 6-volt battery. The above description covers, in general, the Splitdorf system.

In automobile practice it is very common, at present, to use the battery or generator current for the ignition; and, in order to do this, a transformer coil is used to step-up the 6-volt current to the extremely high voltage required to jump the spark gaps. This coil is very often mounted right on the generator. The same practice is followed on some of the motorcycle systems, one being the Midco system used upon the Excelsior, Fig. 52. The ignition current is stepped-up by two small coils which are mounted in a protecting case directly above the generator, as shown in Fig. 53. In a system of this kind there must be both a circuit-breaker and a distributor; these two devices are mounted upon the end of the main drive shaft of the machine as shown.

Fig. 52. Midco Magneto-Generator as Used on Excelsior Motorcycle
Courtesy of The Teagle Company, Cleveland, Ohio

Automatic Switches. In all electrical systems charging the storage battery, it is necessary to have an automatic switch between the generator and the battery and also some kind of device for regulating the output of the generator so that it will not rise to too high a value

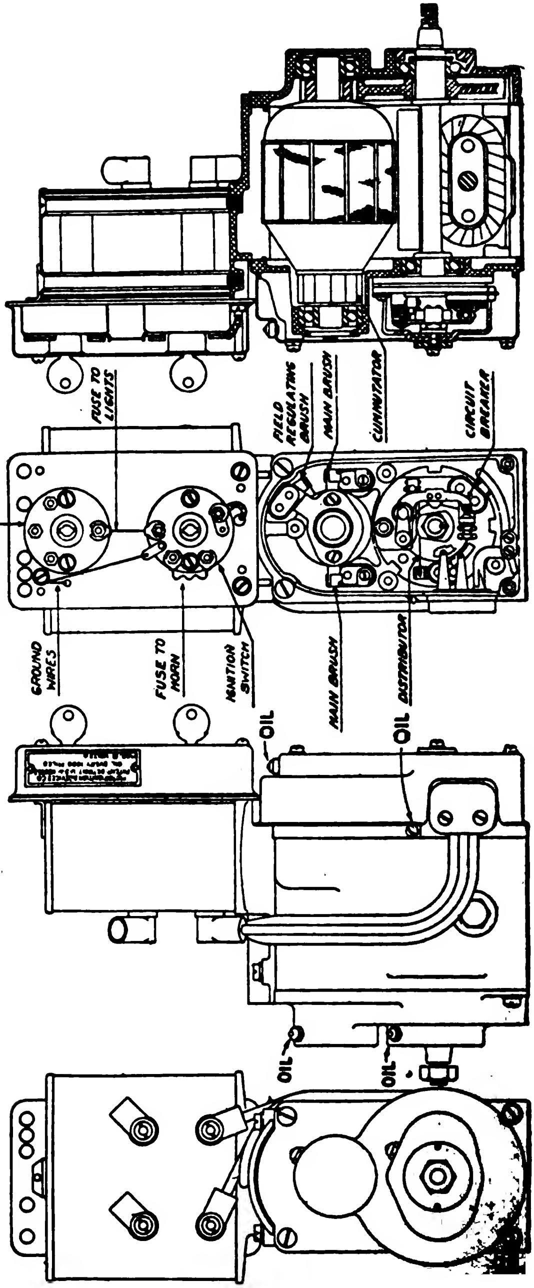


Fig. 53. Side, End, and Sectional Views of Midco Magneto-Generator
Courtesy of The Teagle Company, Cleveland, Ohio

at very high speeds of the engine. The first instrument is variously known as a cut-in, cut-out, relay, etc., and is merely a device to keep the circuit open as long as the battery voltage is higher than the voltage being delivered by the generator. Of course, when the engine is at rest, the generator voltage is zero, and it is not until a road speed of some 8 to 12 miles per hour is attained that the voltage rises above the 6 or 6½ volts of the storage battery. If the circuit was not kept open during this period of still engine or of slow running, the battery would discharge itself through the generator. These relay cut-in switches are usually of the electromagnetic type; and the pull of the magnet when the generator is giving out seven volts closes the circuit, and the generator begins to charge the storage battery. If the lights are on, the generator may take care of the light load and, at high speed, charge the battery besides. As the engine slows down, our conditions for wasting the storage-battery current through the generator appear again, and the automatic switch opens the circuit.

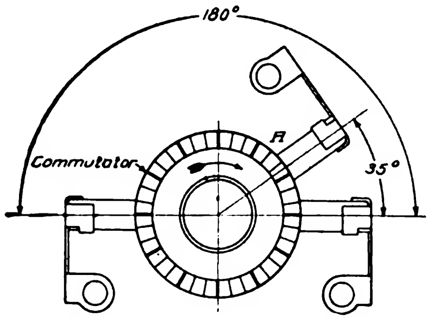


Fig. 54. Midco Third-Brush Regulation

Regulation. Roughly speaking, the voltage and therefore the current, other things remaining equal, of a generator increases with the speed of the machine. If the generating device is designed to keep the battery in a charged condition at reasonable driving speeds, one can imagine the high charging rate that would result if there were no regulation of the output, and the driver "let her out" for several miles over a fine stretch of country concrete. Such a charging rate would probably burn out the winding of the generator itself and also cause serious damage to the battery, owing to overheating and a resulting buckling and falling to pieces of the plates of the battery. One method of regulation is to take advantage of the distortion of the field and attach one end of the field windings to a third brush, as at *A*, Fig. 54. This is known as the third-brush regulation and as the speed increases, the strength of the field automatically decreases, thus counteracting the effect that speed ordinarily has upon the current output. In other cases the regulation is accomplished through the throwing in of resistance into the field circuit, which is done automatically by means of an

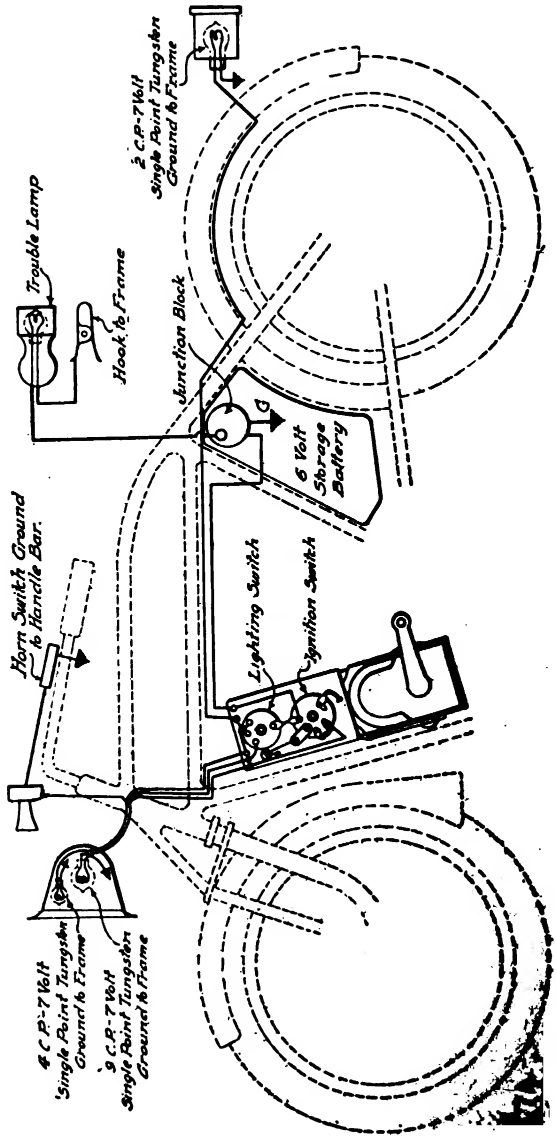


Fig. 55. Wiring Diagram of Mideo System on Excelsior Motorcycle
Courtesy of Excelsior Motor Manufacturing and Supply Company, Chicago, Illinois

electromagnetic device very similar to and often combined with the relay switch.

One- and Two-Wire Systems. There is the same variation in practice in the motorcycle field as on the automobile in regard to the one- and two-wire systems. The one-wire system is also known as the single- or grounded-return system, and the two-wire as the ungrounded-circuit system. In the grounded-return system but one wire is led to each lamp, and the current passes back through the fixture and through the metal parts of the motorcycle to the grounded side of the storage battery. In the two-wire system a wire runs both to and from each bulb, and there are two contact points in the base of the lamp bulb. Thus, in purchasing lamp bulbs, one must examine the old light to see whether it is of the single- or the double-contact type.

Fig. 56. Splitdorf Ammeter

It is not advisable to add much more electrical equipment than comes with the machine, such as cigar lighters, hand warmers, and what not, for these put a load upon the storage battery not calculated in the design, which will cause not only unsatisfactory holding of the charge but also a possible heating and buckling of the plates, owing to excessive discharge. Fig. 55 shows the wiring diagram of the Midco system on the Excelsior amd indicates a double headlight of nine candle power and four candle power and a tail light of two candle power. It will be noted that the bulbs are marked 7-volt, while the Midco is a 6-volt system. Seven-volt lamps are used because they give satisfactory light and still have a very long life. Six or six and one-half volt lamps will work perfectly well, but will burn somewhat more brightly and will not last as long.

Fig. 57. Combination Headlight and Horn

Ammeter. In case one has an electric generator and a storage battery upon his machine but no ammeter, it is well to provide such an instrument, shown in Fig. 56, as it gives a close check on the condition of the system at all times. The most valuable type is that with a zero in the center and a charge scale reading one way and a discharge scale reading the other. These instruments are usually wired into the system, so that they do not show the actual generator output, but rather the output and input of the storage battery. The rider, however, soon learns to know whether or not the generator is more than able to take care of the lamp load at any certain speed, that is, whether it also can charge the battery. One of the valuable features of the instrument is that it will show a short-circuit of any account.

Fuses. Another device in the electrical system is the fuse. This is a piece of wire which will melt when a current of greater value than is normal for the system is passed through it. The wire is carried in a small cartridge which slips between the clips on the fuse block.

There is hardly another place where space is at a greater premium than upon the modern motorcycle; and to assist in its conservation a combined headlight and horn, shown in Fig. 57, has been brought out.

Storage Batteries. The storage battery, Fig. 58, which is such an essential part of the new complete electric-lighting and ignition equipment, is made up of a series of composition lead plates and a solution of sulphuric acid known as the electrolyte. The plates of two kinds, positive and negative, are assembled alternately positive and negative to form a cell. Each cell has a potential of a little over 2 volts, and there are therefore 3 cells connected in series to form a 6-volt storage battery. The capacity of the battery, that is, its ampere-discharge rate, is dependent upon the number and the size of the plates. Because of the very limited space on the motorcycle, it can be understood that only a battery of small capacity can be used. It is, therefore, even more necessary than in automobile work to make sure that the generator is charging at its proper rate.

Fig. 58. Typical Motorcycle Storage Battery
Courtesy of Willard Storage Battery Company, Cleveland, Ohio

When the battery is fully charged, and everything is in good condition, the density of the electrolyte should be from 1250 to 1300, as read by the hydrometer syringe. As the battery discharges, the density decreases and should not be allowed to drop below 1150. The charging and discharging of the battery results in the generation of a certain amount of heat, which causes the water in the electrolyte to evaporate through the vent plugs. This must be replaced at least once a week with distilled water which has not come in contact with a metal vessel. Ordinary drinking water or distilled water which has been kept in a metal vessel contains enough minerals to cause local action within the battery, which greatly shortens its life. The Society of Automobile Engineers has formulated a set of rules for the proper care of a storage battery. These rules will be found in the article on Electric Automobiles, or can be provided by the battery manufacturers. They should be carefully read by every storage-battery owner.

Spark Plugs. While on the subject of electrical equipment, it may not be out of place to mention the variety of spark-plug standards. The majority of motorcycles use what is commonly known as the metric plug, which means that the fine threads on this plug are cut according to the metric system. The ½-inch pipe-thread plug, which is cut upon the same taper as the usual pipe standards, also is used in motorcycle engines. There is still another very common plug standard, which does not seem to have been taken up by the motorcycle makers, but which might be purchased easily by mistake. This is the S.A.E. ⅞-inch plug with eighteen threads per inch. In the early days of the automobile industry, this same plug, which is distinguished by a shoulder and a copper gasket, was known as the ALAM plug. Every motorcycle owner should know with what type of plug his machine is equipped, so that he will not be buying and carrying about with him, for an emergency, plugs which would be of no service.

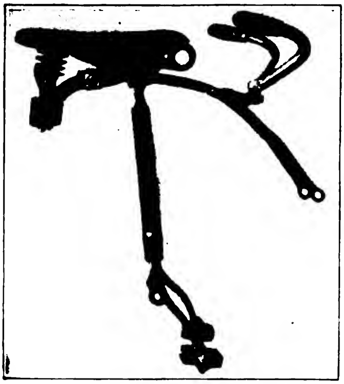


Fig. 59. Simple Passenger Attachment for Motorcycles

SPECIAL BODIES AND ATTACHMENTS

Passenger Attachments. The motorcycle has become so popular a vehicle that owners wish to take their friends with them, hence has come about the popularity of passenger attachments. Fig. 59

Fig. 60. Harley-Davidson Side Car
Courtesy of Harley-Davidson Motor Company, Milwaukee, Wisconsin

shows the simplest type of passenger attachment for motorcycles. This attachment consists of an extra seat that fastens at the back of

Fig. 61. Harley-Davidson Commercial Van
Courtesy of Harley-Davidson Motor Company, Milwaukee, Wisconsin

the driver's seat, which makes a tandem vehicle of the machine. Many thousands of these are in use in America. While at first they were viewed with a certain degree of contempt by the automobilist, they have become accepted as a proper means of conveyance. Many motorcycle owners who are not possessors of this attachment fit a heavy cushion to the luggage carrier over the rear wheel and mount a passenger on this.

Seeking for more dignity in a passenger attachment, motorcycle riders have adopted sidecars, shown in Fig. 60, as a solution. Separate upholstered body constructions are fitted with an extra wheel, all of

Fig. 62. Rear View of Flxible Side Car Showing Truss Frame and Spring Arrangement
Courtesy of Flxible Side Car Company, Loudonville, Ohio

which attaches to the side of an ordinary motorcycle so that the passenger may be carried in a comfortable conveyance alongside the driver.

The Harley-Davidson Company also manufactures what is called a commercial van, Fig. 61. This, it will be noticed, is built on the same chassis as the regulation sidecar, Fig. 60, a box taking the place of the passenger body. Sidecars are becoming more popular every year, as the length of good roads is increasing. Their chief disadvantage is the side strain caused by the pull of the third wheel. Improvements have been made in sidecar construction, as well as in all other motorcycle developments, and the design known as the Flxible Sidecar, shown in Fig. 62, is intended to relieve much of the side strain on the machine when rounding corners. Not only do we have sidecars and rear seats for carrying passengers, but there is manufactured a series of rear cars, which goes so far as to include a limousine, Fig. 63.

The framework for these sidecars, rear cars, etc., furnishes an opportunity for all kinds of commercial applications, and besides the

Fig. 63. Unique Motorcycle Limousine
Courtesy of Cygnet Rear Car Company, Buffalo, New York

light delivery in all forms, including the motor wheel, the motorcycle chassis has been fitted out to carry machine guns, fire-fighting equipment, life-saving **apparatus**, etc.

Cripples have also taken advantage of the sidecar and have had levers and rods rearranged, until it is possible for them to ride in the car and operate the whole machine therefrom.

Novelties in Motorcycle Equipment. The motorcycle manufacturers have lately made other substantial additions to their equipment. One of these is the three-wheeled motorcycle in which seats for two or three passengers are built around the rear axle; but, in

Fig. 64. Dayton Tri-Car Chemical—An Efficient Chemical Fire Engine for Small Fires
Courtesy of Davis Sewing Machine Company, Dayton, Ohio

the face of the failure of the cyclecar and the light-car types and the consequent reduction of the price of the smaller standard-tread cars to considerably less than $500, this new form of tricycle seems hardly justified. Improvements in the styles of package vans also have been made. Still another novelty has been put out by the Davis Sewing Machine Company, which consists of a three-wheel chassis carrying a fully equipped chemical engine, Fig. 64. Such a device has so much

Fig. 65. Thor Front Stand, Showing Usefulness When Removing Front Wheel
Courtesy of Aurora Automatic Machinery Company, Chicago, Illinois

more speed than the horse-drawn chemical engine and is so much lighter than the combination chemical and steam fire engine that its adoption should be a matter of time only. So many fires are put out by the aid of a few hand grenades or by the "chemical" that a light engine of this type, capable of 30 to 45 miles per hour, would be a distinct advantage. These are useful in suburban districts where neither the water supply nor the fire-fighting equipment are always adequate.

This tri-car is well built, the chemical equipment being carried on a steel frame running from the front axle to the crankcase. The load is carefully balanced, and seats are provided for two men.

Front Stand. Each year brings out some small device which adds to the comfort of the motorcycle rider. Among the latest of these small improvements is the front stand, by which the motorcycle can be made to stand alone with the front wheel removed, as shown in Fig. 65. This will be particularly appreciated when the rider is in the country and has to work upon either the front tire or the front wheel itself, as that is the time when the soap box support is never available.

OPERATION AND REPAIR OF MOTORCYCLES

OPERATION SUGGESTIONS

The Motor. When the motor is in good working order, it requires practically no attention other than to supply it with fuel and keep it properly lubricated. When any serious trouble occurs, a safe plan is to take the machine to an expert and have it properly repaired. This will usually prove the cheapest way in the end. Some of the more common sources of trouble may, however, be located by the use of a little common sense and judgment. It is of fundamental importance that the motor should be securely attached to its base, as otherwise it may be twisted around by the belt or chain, and thus thrown out of alignment. It is, therefore, a good plan to go over the motor and its connections from time to time, tightening up all loose nuts.

A very common form of trouble is indicated by a knock, or pound, which will ordinarily be found to be due either to lost motion or to premature ignition. The pounding due to lost motion indicates too much play between parts which have relative motion and would most commonly be caused by looseness of connecting-rod or crankshaft bearings. Premature ignition, on the other hand, causes pounding of a sharper and more metallic sound and may be due either to overheating or to the fact that the spark is advanced too far. In some cases it also may be caused by carbon deposits in the cylinder, which become incandescent and in this manner cause premature ignition of the gas, A good way to locate a knock is by the sense of sound, which may be assisted by putting one end of a piece of metal, such as a heavy wire, against different parts of the motor and holding the other end between the teeth. The source of the trouble will then be indicated by excessive vibration as the wire approaches it.

The forming of carbon in the cylinder is objectionable, since it causes overheating and loss of power as well as premature ignition. This can be avoided by occasionally injecting into the cylinders a small quantity of kerosene while the motor is warm, turning the engine over a few times, and leaving it thus over night. In the morning the kerosene should be forced out by turning the motor over; the foul oil should be drained from the crankcase and replaced with fresh oil.

The leakage of gases from the cylinder, escaping past the pistons, because of wear either in the cylinder or in the piston rings, is likely to cause overheating of the upper part of the crankcase. When it is found difficult to turn the engine over, the cause is probably the overheating and consequent binding of the piston.

Valves. In order to obtain the best results from the motor, it is important that the valves should be properly seated, and that the springs should be neither too stiff nor too weak. It is somewhat commonly supposed that grinding the valves will prove a cure for almost any of the ills to which the gasoline motor is heir. This is a mistake, and valve grinding should not be resorted to unless it is necessary. The grinding of valves is a comparatively simple process, but one that should not be carried to excess as it lowers the valve on its seat; this produces the same effect as does the lengthening of the valve stem, namely, prevents the valve from seating properly, thereby causing a difficulty greater than that which the grinding was expected to relieve. In order to grind a valve, a paste should be made from emery and oil. This should be put both on the seat and on the edge of the valve itself. Then the valve should be placed in position and turned slowly in its seat by means of a screwdriver, a steady pressure being maintained meanwhile; the turning should, for the most part, be in one direction but an occasional part-turn backward should be taken. During the process, care should be exercised to see that the pressure is in a perfectly vertical direction, as otherwise an uneven grinding will result. In order to tell when this process has been continued long enough and the valve is properly ground, the surface of the valve seat and also of the valve may be coated with smoke from a candle; the valve should then be placed carefully in its seat, turned completely around once, and examined. If the grinding has been properly done, a complete bright ring will be seen all the way around. Breaks in this ring indicate that the grinding should be continued.

Carburetor. The proper action of the carburetor is of vital importance to the smooth operation of the motor, and, on this account, when anything goes wrong, it is very common for a beginner to decide at once that the trouble is in the carburetor and begin to tinker with it. As a matter of fact, however, it would be wise for the novice not to attempt any adjustment of the carburetor until he has made a careful study of the type he is using.

Ordinarily, the motor should start without priming the carburetor, unless it has been standing a long time, or unless the weather is cold. In case it does not start readily, priming may be resorted to, although it should be remembered that over-priming does more harm than good, since the motor then becomes supplied with too rich a mixture, which is as hard to fire as one which is not rich enough. If the gasoline refuses to flow altogether even after priming, the trouble can sometimes be relieved by blowing into the opening of the gasoline tank. Ordinarily, about the only attention the carburetor requires is an occasional cleaning, the frequency of which depends very largely upon the quality of the fuel used and the care with which it is strained. In case the spray nozzle becomes so seriously choked that blowing into the tank will not relieve it, the difficulty can usually be overcome by holding the finger on the priming pin until the carburetor floods, simultaneously racing the motor.

The adjustment of the carburetor can be determined by observing the exhaust. If the mixture is too rich, black smoke and red flame will appear. If it is not rich enough, it will be indicated by a yellow flame, while normal conditions are indicated by a blue flame. An important point to bear in mind is that the proper mixture varies with atmospheric conditions and that a richer mixture is required in cold or damp weather than when it is hot or dry.

Ignition. In connection with the ignition system, it is necessary to be sure that all connections are clean and firmly made and that the insulation is sound throughout. In case of battery ignition it is, of course, necessary to see that the batteries are in good condition. In order to get the best results from the batteries, it is well to have an ammeter with which to test them. New batteries should test from 15 to 18 amperes and about 1.5 volts. When a battery has run down to 4 or 5 amperes, it can no longer be depended upon and should be thrown out. Each cell should be tested separately, and it is never well to connect an old cell with new ones, as the old cell tends to reduce the life of the new ones. The terminals of a battery should never be short-circuited by testing directly across them with a wire or screwdriver, as a battery can be completely exhausted in this way in a short time. It is well to go over all joints and connections periodically, making a careful examination to see that all binding posts and set screws are tight and that all points of electrical contact are bright and clean. The insulation also should be examined from time to time, looking not only for spots where the insulation has been worn away by chafing, but also for any places where it has become saturated with oil. Inspection of this sort is particularly important in the secondary winding, because the insulation in this winding must be much more perfect, on account of the high voltage employed, than in the low-tension primary wiring. In regard to the contact-breaker, it is important to see that it is properly adjusted and that the platinum tip is clean and bright.

A common cause of trouble in the ignition system is due to soot on the points of the spark plug. The spark plug should accordingly be removed occasionally and the points cleaned.

The magneto is very seldom the cause of trouble and, under ordinary conditions, should not be tampered with by an inexperienced person. One common source of trouble with the magneto, which can be easily relieved, is the binding of the carbon brush in its holder, thereby preventing proper contact between the brush and the commutator. The same thing will, of course, result if the spring which holds the brush against the commutator becomes weak or is broken.

Lubrication. The matter of lubrication has already been mentioned, but it is so vital to the satisfactory operation and to the life of a motorcycle that it will bear repetition. The oiling should not be a perfunctory operation to be taken care of at random, but should be done methodically at intervals depending upon the grade of oil used. Of course, it is possible to go to extremes and oil too frequently, but too much oil is more preferable than too little.

Only the best grade of oils should be used, as the difference in cost is only slight, and a poor oil is sure to cause trouble. The manufacturers are always glad to give advice as to the kind and grade of oil best suited to their make of motor, and one would do well to be guided by such advice, since no one knows a machine so well as the maker, and it is also to his interest that the machine give a good account of itself.

Tires. The principal point to be borne in mind in connection with the tires is that they should be kept pumped up hard, as riding on soft tires is likely to injure both the casing and the inner tube, as well as requiring more power to drive the machine. A tire pump should always be carried when on the road, and the condition of the tires should be examined frequently for any indication of softness.

A spare inner tube, sprinkled with tire powder, carefully folded, and enclosed in a separate package, should be carried along for replacement in case of a puncture or a blow-out. In addition, a tire-repair outfit for making quick repairs on the road should always form part of the rider's equipment.

In replacing tires with metal tire tools, care should be taken not to chip the enamel off the rim, as this will cause it to rust, and the rust will, in turn, injure the tires. On this account, it is well to paint the rims occasionally as a guard against rust. Grease and oil are very injurious to rubber and should never be allowed to remain on the tires, but should be washed off at once with gasoline.

Control. The speed and the amount of power developed by a motorcycle depend upon two factors: the quantity of gas supplied to the motor; and the time at which the spark occurs with relation to the position of the piston in its travel back and forth in the cylinder.

The devices for controlling these two factors or for regulating the throttle and the spark should be conveniently located so that they can be manipulated instantly, while at the same time keeping the hands in position upon the handlebars.

Nearly all the earlier machines were equipped with the twist-grip type of control in which twisting one grip varied the position of the throttle and the other the position of the spark. This type of control has the disadvantage that in heavy going where a firm hold on the handlebars is necessary the rider is in danger of twisting one or both of the grips unintentionally, thereby varying the position of the throttle or spark at the wrong time. This objection is overcome to a large extent by having the twist grip located in front of secondary grips which are rigidly attached to the handlebars.

Handlebar, or lever, control is rapidly coming into favor. This form of control consists of levers placed in front of the grips with rod and knuckle joints or with wire cable leading therefrom to the carburetor and to the spark mechanism. Cable seems to be the more satisfactory, for with its use there is no lost motion as is the case with the rod and knuckle-joint system. An advantage of the lever type of control is that the exact position of the levers can be seen at a glance.

Whatever the type of control, the rider should so accustom himself to its manipulation that he can, in case of emergency, throw off the power and apply the brakes instantly. In fact, these operations should be so familiar as to become automatic.

General Instructions. Before starting out, the rider should be sure that he has an ample supply of gasoline and oil in the tanks, never using anything but strained gasoline. The machine should be well oiled and the tires examined to see if they have sufficient air. All bolts, nuts, and screws should be gone over, and tightened if necessary. The wiring should be examined for loose connections or breaks in the insulation, and the batteries should be tested with an ammeter. Any excessive slack in belt or chain should be taken up. If these matters are attended to systematically before starting out, many an awkward and embarrassing delay on the road will be avoided.

The matter of physical comfort while on the road is of importance, and in order that the greatest degree of comfort be obtained the saddle should be placed fairly low and not too far back. The handlebars should be high enough to avoid the necessity of stretching or bending forward, and the bars should be so shaped that the hands rest upon them in a position which is easy upon the wrists.

The rider should become so familiar with his machine that he can tell by the sound when it is running properly. Any unusual noise is a sure indication of something wrong, and the machine should be stopped instantly and examined for the cause. It is probable that the trouble can be located and repaired in a moment if attended to at once; but, if allowed to go on, it might easily develop into something which would cause serious injury to the machine. The motor should not run for long periods of time on the stand and should never be allowed to race unnecessarily.

No definite rules other than those which would be dictated by common sense can be given for governing the rider's conduct when on the road. A proper consideration for the rights of other vehicles, and particularly for pedestrians, should be observed, and one must, of course, take into consideration the rules in regard to speed limit which obtain in the particular locality through which he is driving. The machine should be kept under control at all times, so that it can be brought to a stop almost instantly in case of any sudden obstruction in the traffic. Also it is well not to drive too close to the vehicle ahead, as this may stop suddenly, while the one behind you may not stop, thus causing an awkward, if not serious, situation. In turning corners or in passing other vehicles, a wide curve should always be taken in order to avoid the tendency to skid, which arises from taking sharp turns at high speed. Always slow up when turning a corner.

One of the principal causes which has brought the motorcycle into disrepute is the excessive noise caused by riders opening the muffler cut-out unnecessarily. There are times when it is necessary to do this, but the use of the cut-out should never be carried to excess.

When starting on a trip which will keep the rider out after dark, the lighting system should be examined to see that it is in good condition, as it is required that the motorcyclist show a headlight and a tail light at all times after dusk sets in.

Upon returning from a ride, the motorcycle should always be cleaned before putting it away or at least as soon as possible thereafter. The longer the cleaning process is delayed, the more difficult an operation does it become. Mud which is allowed to cake upon the cooling flanges of the motor cuts off the circulation of the air and causes overheating. Oil running down from the bearings collects dirt, which is sure to work back into the bearings sooner or later and cause trouble, while the presence of mud and moisture on the machine causes rust, which soon injures the appearance of the machine, if it does not do more serious harm. In fact, cleanliness at all times and in connection with all parts of the machine is a golden rule of motorcycling, and is an investment of time which will give large returns in the satisfactory operation and life of the machine.

OVERHAULING AND REPAIR OF MOTORCYCLES

Carburetors. Probably the greatest number of calls made upon the motorcycle repair man are for the readjustment of the carburetor. This is often simply a matter of ordinary adjustment, but where the owner finds himself unable to get a satisfactory adjustment, although he has been able to do so in the past, it is usually because of some fault in the carburetor or in its control mechanism. A common source of trouble is the sticking of the auxiliary air valve, which the repair man may often cure by a drop of oil on the shaft.

In the types of carburetors where the amount of opening of the throttle valve controls some other function, as the lift of the needle valve, a great deal of trouble will be experienced by wear and subsequent play of the shaft and connections carrying the throttle valve. The action will be very erratic, depending upon which way the play happens to be when the throttle is being closed or opened; in fact, the engine may even speed up during the closing operation. The repair for this is usually a small bushing to bring the shaft back to firm alignment.

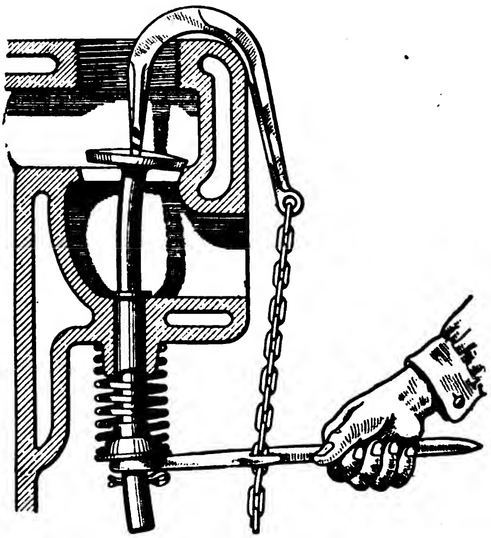


Fig. 66. Diagram Showing Bad Results from Using Valve Lifter with Too Great Pressure

When flooding of the carburetor is not caused by dirt under the float valve, it is usually a matter of a fuel-soaked float. These floats are generally made of cork, and the cure is to dry them out and recoat with yellow shellac. When the floats are made of metal, tiny pin holes, or porous places, in the soldering sometimes develop, which allow gasoline to enter and causes flooding. To discover the place of the leak, the float should be submerged in very hot water, which will cause the gasoline to vaporize and bubble through the leaking portion. After this has been marked, a fair size hole should be punched in the top of the float, through which the entrapped gasoline may be drained out. The portion showing the leaks should then be soldered, and, after the float has cooled down, the hole in the top should be closed with solder. If this top hole is closed before the leaks are soldered, the heat of soldering will cause a partial vacuum inside the float, resulting in a seepage of gasoline through a seemingly tight float.

Valve Troubles. A great many times the carburetor and carburetor adjustment will be blamed by the owner when the trouble is from some other source. For instance, the back-firing, which is the usual indication of a lean mixture, may be caused by poorly seating inlet valves. On the other hand, the galloping of the engine, which is usually the symptom of too rich a mixture, may be due to leaking or sticking exhaust valves. On the modern machines one of the causes for faulty valve spring and valve action is very often the accumulation of dirt inside the sleeves which cover the valve mechanism. The cure, of course, in this case, is a thorough cleaning. The cure for leaking valves is a matter of grinding in.

Removing Valves. In the removal of valves the use of valve lifters has become very common, and their operation is so simple that little need be said concerning them. However, there is one warning which is worth while, particularly when using a type of lifter with which the operator is not familiar, and that is, that he does not catch the spring retaining-pin in the lower part of the lifter at the same time that pressure is being exerted upon the top of the valve, Fig. 66. The result in such a case would be a bent valve stem, which is very hard to remove.

Air Leaks in Inlet Manifold. Irregular running may be caused by air leaks at the joints of the inlet manifold. The repair man's test for this is to take the priming gun in the gasoline tank and squirt a good quantity of fuel around all the joints. If these joints leak, the engine will die from an over-rich mixture. The same galloping effect that was noted from the poorly seating exhaust valve also may be caused by weak exhaust-valve springs.

When an engine is cold, a certain amount of clearance must be left between the top of the tappet and the valve stem. This is in order that the valve may expand upon heating up and still not ride upon the tappet, which would cause a poor seating of the valve. So far as wear upon the cam and upon the valve mechanism is concerned, it is fortunate that the motorcycle rider is not the fiend for silence that his cousin, the automobilist, has become. For this reason, the valves are set with plenty of clearance, .008 of an inch being good practice. In some cases the design is such that the cylinder actually lengthens more than the valve, owing to the heat of running. In such a case the tappet clearance would be increased instead of decreased upon warming up, and the noise would probably be excessive. Such engines, of course, may be adjusted much closer than the figure above

Fig. 67. Handling Tappet Nuts with Two Wrenches
Courtesy of Hendee Manufacturing Company, Springfield, Massachusetts

given. Both the owner and the repair man should have a set of feelers and also two wrenches of the size of the tappet nuts, Fig. 67, so they need not be forced to use a bicycle wrench for making these adjustments. With air-cooled motors, it is surprising how often the tappet clearances have to be checked up for good results.

Overhauling. Where an overhauling job is on hand, the first thing, of course, is the stripping of all connections between the engine and the frame of the machine. In the repair shop, it is usually handiest to do all the overhauling work on the bench; therefore the whole engine is at once removed from the frame.

Valves. The scraping of carbon and the grinding of valves go, as a matter of course, with every overhauling job; and, where the majority of the work is with one make of machine, considerable time may be saved in grinding in the valves by having a dummy valve seat. It has been found, particularly in the case of badly-pitted exhaust valves, that it takes a much longer time to obtain a satisfactory surface on the valve itself than it takes on the cylinder seat, and, therefore, this dummy will save the unnecessary cutting down of the motor casting. The dummy may be made of cast iron, from a special pattern, or it may be a portion of an old damaged cylinder. Another thing used by one of the large motor-car companies, and justifiable only where a great many machines of the same make are worked upon, is to have made up a special seating reamer that will give a convex surface rather than a flat conical one to the seat in the cylinder. The advantage claimed for this is, that it takes less grinding to obtain a gas-tight joint, and that the pounding action of the valve tends constantly to widen the seat. Some valves are designed with a flat instead of conical seat, but the grinding process is the same.

Piston Pins. Whenever the engine is down, the repair man should not fail to look at the fastening of the piston pin to see whether there is any trouble in that direction. A piston pin which comes loose and works sideways will act exactly like the tool in a shaper, cutting a broad groove down the side of the cylinder. As a general rule, the piston-pin bearings are bronzed bushings, and, although wear at this point is not commonly excessive, poor lubrication or very great mileage will produce play. This causes a knock which is very often mistaken for a piston slap. The remedy, of course, is a new bushing or, very possibly, both a bushing and a pin.

Big-End Piston Bearings. At the lower end of the rod, the big-end bearings in the large twin machines are usually of the roller type, and when these give trouble, new sets of rollers have to be fitted. In case it is simply a matter of wear from long service, slightly oversized rollers are used. This particular job is one requiring unusual care and skill, and the repair man should be absolutely certain that the rod can be spun on the shaft for any length of time without the rollers climbing or jamming owing to the presence of some of slightly different size. In some of the older machines, bronze bushings were used for the big-end bearings and these, of course, are much more easily renewed.

Gaskets and Washers. It has been found that it does not pay to try to use any of the old gaskets in putting the job back together, as

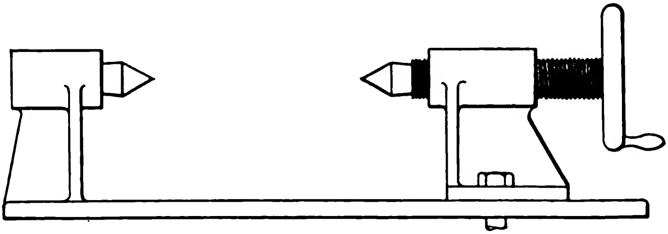


Fig. 68. Set of Centers Made up for Handling Crankshafts

they are almost sure to leak. New felt washers at the crankcase should also be used, even though the old ones seem in pretty fair

Fig. 69. Method of Marking Timing Gears
Courtesy of Hendee Manufacturing Company, Springfield, Massachusetts

shape, for, before another overhauling, it is more than likely that the old ones will begin to leak oil.

Truing up Crankshafts. When the built-up type of crankshaft and the double flywheel have been torn down, for the fitting of new bearings or for some other purpose, it is practically sure to be out of true when reassembled. In some cases, a line is marked upon the surface of both flywheels, and the truing is done by placing the crankshaft ends on blocks and striking with a soft hammer until a steel straightedge may be laid across the flywheels so as to exactly coincide with the two lines and show no light underneath on the flywheel surfaces. An even better way of truing the assembly is to have made up a set of centers, similar to Fig. 68, and, by the use of a machinist's gauge discover where the crankshaft is out of true. It is then straightened by the hammer method. In the first case, it is really the flywheels that are being trued, while in the second case, it is the more important shaft itself. Before the truing operation, the nuts may be drawn up good and snug; but, after the truing is done, it is found that they can be drawn still tighter.

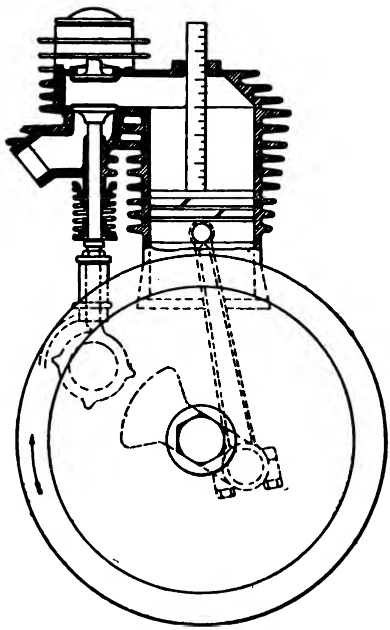


Fig. 70. Method of Following Out Valve Timing by Means of Scale

Valve Timing. *Marking Gears.* In a complete overhauling job, it is more than likely that the timing gears have been removed for cleaning and inspection, in which case the engine has to be re-timed upon assembling. It is usual for the manufacturer to place marks, in the form of little cuts or prick-punch centers, on the gears, Fig. 69, so that they may be replaced in the proper manner. One method is to prick-punch each set of teeth while under some certain conditions, such as at the point of closing of the exhaust valve. Another method is to line up certain marked teeth with marks made in the back wall of the gear case. It sometimes happens that the manufacturer's marks are not found, and a new set of marks is put on by the repair man before disassembling the job. At a later date, both sets of marks may show up, with a resulting confusion. It is well, then, to know something of the valve timing, instead of having to depend blindly upon the marking of the gears.

Opening of Valves Not on Dead Center. In the discussion of the principle of operation of a four-cycle engine, one would be led to believe that the inlet valve opened exactly on upper dead center and closed on lower dead center, while the exhaust valve had an opposite performance. This is theoretically true; but practice has shown that, owing to the inertia of the flow of gases and other little-known conditions within the engine, the valve timing can be changed considerably from the dead center points, giving marked improvement in the power output of the engine.

Marking Flywheels—Automobile Practice. In automobile practice, it is customary to speak of valve timing in degrees on the crankshaft circle, and the openings and closing of the valves are usually laid off and marked upon the rim of the flywheel. Since in most of the motorcycles the flywheels are enclosed, this method is not employed, and where the maker furnishes information as to the valve timing, it is in terms of the travel of the piston from the upper or from the lower dead center, as measured in inches.

Getting Valve Timing with Scale. Where the cams are all made integral, only one point of the timing can be controlled, the other points being in a fixed relation, the accuracy of which depends upon the workmanship in the cam-grinding department. Since the closing of the exhaust and the opening of the inlet is important for smooth running, this is the point that is taken for setting the valves. Fig. 70 shows a very easy method of following out the valve timing. A scale is dropped through one of the openings in the top of the cylinder, possibly the spark-plug hole, and, after the dead-center points have been noted, the crankshaft is revolved until the scale shows that the piston has moved down or up the desired distance from dead center. With the crank at this point, the gears are slipped into mesh so that the valve will be just opening or closing, as the case may be.

In some cases, the inlet and exhaust valves can be timed separately. Owing to the inaccuracies in grinding, one seldom can obtain both the opening and the closing points stated by the manufacturer. It is best, therefore, to set the timing on the closing of the exhaust and the opening of the inlet, letting the opening and closing, respectively, take care of themselves.

The following timing instructions are taken from the instruction book of a well-known maker and are illustrative of the form:

Twin-Cylinder Motor

The exhaust valve should open when the piston is $\frac{5}{8}$ inch to $\frac{3}{4}$ inch before bottom center and should close $\frac{1}{32}$ inch to $\frac{1}{16}$ inch after top center. The inlet valve should open $\frac{1}{16}$ inch to $\frac{3}{32}$ inch before top center and close $\frac{1}{8}$ inch to $\frac{1}{4}$ inch after bottom center. With advanced spark, the motor should fire $\frac{1}{4}$ inch to $\frac{5}{16}$ inch before dead center. Time each cylinder separately as the interrupter housing steel segments are often out of line

Single-Cylinder Motor

The exhaust valve should open $\frac{5}{8}$ inch to $\frac{3}{4}$ inch before bottom center and close $\frac{1}{32}$ inch to $\frac{3}{32}$ inch after top center. The inlet valve should open on dead center and close $\frac{1}{4}$ inch to $\frac{3}{8}$ inch after bottom center. The spark timing is the same as that of the twin.

Oily Clutches. The dry clutches with alternate discs covered with a woven fabric of asbestos and brass or with copper wire give considerable trouble from slipping, owing to the presence of grease or to the glazing of the surfaces. When grease is the cause, the clutch is disassembled and washed in gasoline. One shop takes the plates and piles them in pairs and then sets fire to pieces of oil-soaked waste, shown in Fig. 71, in order to completely burn out all the grease. The surface is then roughened up with coarse emery cloth and chalked, after which the clutch is again assembled. The chalk is for the purpose of soaking up the grease and of giving a fairly harsh engagement. In case the trick has been overdone, a little engine lubricating oil squirted into the clutch will make the engagement easy again.

Fig. 71. Burning Oil Off Clutch Discs

The most clutch trouble has come when a side car has been added; and in one case the makers provided for this by so designing the clutch that the usual equipment of eight springs could be increased by eight when a sidecar or a delivery van was attached to the machine. This makes the clutch action suitable under all kinds of service. Most motorcycle clutches, whether of the cone or of the disc type, have more than one clutch spring—usually three or five. It is of very great importance, therefore, in adjusting one of these clutches, to give the nuts on each spring exactly the same number of turns, otherwise the action will be very unsatisfactory and the clutch liable to serious damage. On some of the older cars with belt drive, the clutch has been accused of slipping, when, in truth, the trouble was with the belt. This resulted in continued adjustment of the clutch, until the load upon the thrust bearing was so great that it went to pieces.

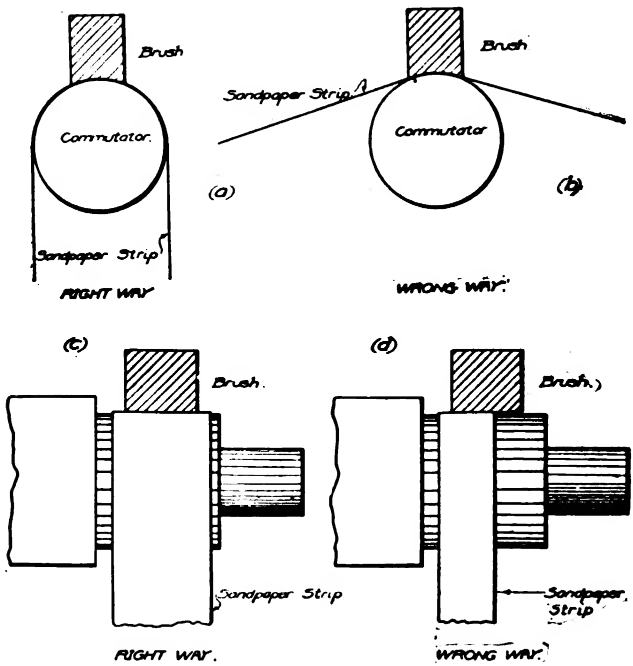


Fig. 72. Method of Sanding-In Brushes
Courtesy of Auto Electric Systems Publishing Company, Dayton, Ohio

Cleaning Chains. A roller chain and set of sprockets is a highly efficient transmission unit when kept in good condition, but not otherwise. One or more times during a season, depending upon the mileage, the chains should be removed, cleaned well in gasoline or kerosene, and then let soak over night in oil. The next day, they should be hung up to drip until they are dry. There is no use trying to hurry the oiling process, as the object is to let the lubricant work into the small bearings between each pin and roller.

Although chains and sprockets are laid out by the designers, with such a number of teeth that the one particular link of the chain will be a long time reaching a particular tooth for a second time, it does sometimes happen that the wear is not evenly distributed. In such a case, a chain which was satisfactorily quiet and apparently having considerable service left in it will be found noisy, or will bind when replaced after the overhauling. Before their removal, therefore, it is not unwise to mark, in some way, the position of the chains and to return them to the same location after the cleaning process.

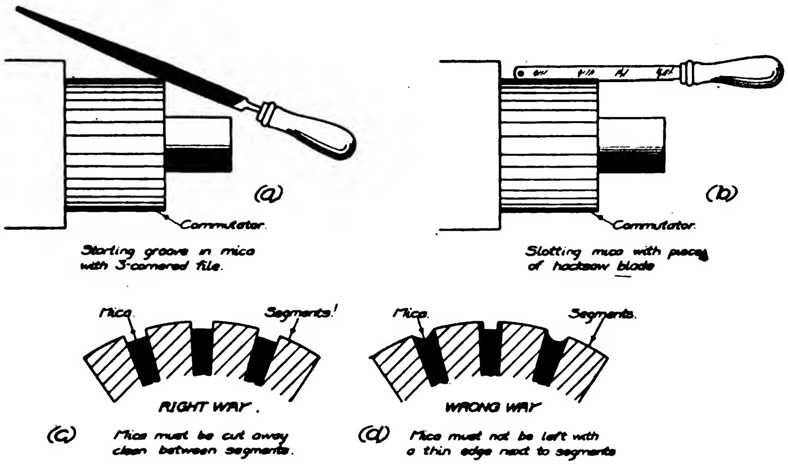


Fig. 73. Method of Undercutting Mica Insulation on Commutator
Courtesy of Auto Electric Systems Publishing Company, Dayton, Ohio

Dirty Muffler. There is one unit of the machine which the careless repair man or the amateur may neglect to go over in the overhauling job, and that is the muffler. This is a grave mistake, for an air-cooled motor naturally burns a good deal of cylinder oil; and it will be found that after a season's running the muffler will be pretty well choked up with carbon. With an engine which has been burning an excessive amount of oil, there may even be an accumulation of carbon and oil in the muffler, which will be of the consistency of wet cement. These conditions produce a back pressure upon the engine, which cuts down the power no matter in what mechanical condition the engine may be. It is the allowing of dirty mufflers that probably causes so many riders to annoy the public with the use of the muffler cut-out. If the muffler is clean and clear, there is really no excuse for the cut-out except in testing for engine operation, for, under these conditions, the difference in power attained is almost negligible.

Electrical Troubles. Electrical troubles may be classified under two heads: short-circuits and open circuits. In the first case, there is a path back to the generator or storage battery before the current has reached the desired point. This is usually due to chafed installation or to a loose strand of wire. The open circuit means a break in the path of the current and often occurs at the point where the wire enters the connection to a lamp, a horn, etc.

Short-Circuits and Open Circuits. A serious short-circuit will blow the fuse, and there is no object in replacing it with a new fuse until the point of trouble has been found, as the new fuse will, in turn, be blown out. A trouble lamp may be inserted in the fuse block, as shown in the Excelsior diagram, Fig. 55, and as soon as the difficulty is found, the lamp will go out. The open circuit is usually easier to trace, as the lamp or the horn in that circuit will fail to work, while the rest of the system will be in good order.

Lubrication of Electrical Equipment Requires Care. Over-lubrication of a generator is a serious matter, for if oil works its way into the windings, it is liable to soften the installation and also to cause other damage. On the other hand, all bearings must be lubricated, particularly those running at the high speed that armature bearings do.

Care of Brushes. In time, the brushes may need dressing and the armature brightening up. Fine sandpaper can be used for this purpose, as shown in Fig. 72. Emery cloth should never be used on the brushes or the armature of a generator, as emery is a conductor of electricity, and if it becomes embedded between the commutator segments, it will cause a short-circuit in the armature. After long service, the mica installation between the commutator bars may need dressing down, and the method of doing this is shown in Fig. 73.

Storage Batteries. So far, the demand for storage-battery work on motorcycles has not become extensive enough for many motorcycle repair shops to put in a battery charging and overhauling department. Many shops will probably do so soon, as the number of electrically equipped machines keeps increasing and small-capacity charging sets are being developed. At present, the regular battery service stations are best equipped to handle all major battery work.

DOBLE FOUR-PASSENGER STEAM CAR—SPORT TYPE
Mr. Doble in Rear Seat
Courtesy of Doble-Detroit Steam Motors Company, Detroit, Michigan

STEAM AUTOMOBILES

INTRODUCTION

Development of Steam Engines. That steam could be employed to produce mechanical motion was first noted in history about 130 B. C., but it was not until the seventeenth century that it found practical application in the industries. The developments were comparatively slow, however, until James Watt (1769) developed his engines to a point where they employed practically all the principles of the modern double-acting, condensing steam engine.

With these rapid inprovements came the idea of using the steam engine as a means of road locomotion, and in the opening years of the nineteenth century such machines were actually built and known as "road locomotives", Fig. 1. These machines might be called the forerunners of the steam automobile, although structurally they more nearly resembled the later traction engines. Bad roads, great weight, public opinion, and the development of railroads caused road locomotives to drop out of sight until the real coming of the automobile almost a hundred years later.

Fig. 1. Early Steam Carriage Built by Cugnot (France) in 1770

In the meantime the steam engine—both stationary and locomotive types—had reached a high state of development and hence many of the early automobiles carried this type of power plant.

Later improvements were made and are still being made along lines peculiar to steam automobile construction. Although during the last few years the steam car has not kept pace in numbers with other types of automobiles, it has certain characteristics, such as strong pulling powers at low speeds, capacity for big overloads, and ease in driving on the road, which make it especially useful under some conditions, the success of the London steam omnibuses being a good example.

CHARACTERISTIC FEATURES OF STEAM CARS

In the modern steam automobile the power plant is made up of the same general units as make up the stationary power plant, the only difference being the extreme compactness necessary and the development of the great flexibility required to meet the sudden changes in load conditions. With both plants there must be a supply of fuel, a means of burning it, a boiler or steam generator, a supply of water, an engine, and various means of controlling the amounts of fuel, water, and steam.

Location of Engine. With steam automobiles there is no uniformity of practice as to the placing of the different units in the

Fig. 2. Plan View of Stanley Steam-Car Chassis
Courtesy of Stanley Motor Carriage Company, Newton, Massachusetts

running gear or chassis. For instance in the Stanley, Fig. 2, the boiler is under a hood in front of the driver and the engine is geared directly to the rear axle. In the case of the White cars, which were built in comparatively large quantities from 1904 to 1910, the engine was placed under the hood in front with a shaft running back to the rear axle. In the White car, a set of gears was also used in the drive, by which the relation of engine to wheel speed could be reduced to one-half the usual amount, thus doubling the driving effort, or "torque". The White boiler was under the front seat. The new Doble, Figs. 3 and 4, uses the general arrangement of the Stanley. In

Fig. 3. Side View of Doble Chassis
Courtesy of General Engineering Company, Detroit, Michigan

the Leyland steam truck, Fig. 5, and the National busses, both of England, the boilers are in front, the engines are under the floor boards, with a countershaft and final chain drive, as in Fig. 5, or a shaft drive direct to the rear axle.

Boiler and Engine Types. Almost equal variation is found in the types of boilers and engines. The difference between fire-tube,

Fig. 4. Side View of Doble Steam-Car Chassis
Courtesy of General Engineering Company, Detroit, Michigan

water-tube, and flash generators is taken up in the section devoted to boilers, while the engine types are taken up in their respective section.

Fig. 5. Leyland Steam Truck with Chain Drive to Rear Wheels
Courtesy of Leyland Motors Company, Ltd., England

Some of the cars use the water over several times by condensing the steam in coolers, or "condensers", placed at the front of the car. The

White and Lane did this, and it is now done by the Stanley, Doble, and most of the English steam cars and trucks. The Stanley, up to 1915, had no condensers, allowing the steam to escape into the air after it had passed through the feed-water heater.

Simplicity of Control. As a general rule, the steam cars do not employ a transmission for giving various forward-gear ratios and a reverse. The extra heavy loads, as in starting, are taken care of by lengthening the cut-off and by "simpling", terms which will be more fully explained later. Instead of running the engine always in one direction and using a gearset for reversing the car, as is done on gasoline automobiles, the engine is itself reversed by means of changing the timing of the valves through the aid of the valve gear, or linkage.

This change of the valve-timing is used only at starting, reversing, or under very heavy load conditions, all ordinary running being accomplished with the cut-off in one position. The control of the speed of the car, therefore, is accomplished under normal conditions by changing the amount of steam going to the engine. The steam is turned on or shut off by a hand-operated valve, known as the "throttle valve", and this valve is turned by a lever, or second small wheel, just above or below the steering wheel. Thus the actual driving of a steam car consists of steering and operating the throttle. There are, however, numerous gages, valves, etc., which have to be worked upon when firing up, and which have to be given occasional attention on the road; these will be considered in detail in the following pages.

Having treated in a general way the different types of steam cars and their parts, the theory underlying the behavior of steam will be touched upon before taking up the details of construction and the operation of the various units.

HEAT AND WORK

HEAT TRANSMISSION

All forms of energy, such as light, sound, electricity, and heat, are believed to be different forms of vibration either of the molecules of material substances or of the ether which is believed to pervade all space.

Energy is indestructible, but any form of energy may be converted into any other form. Steam engines are classed as heat engines since they are employed to transform heat energy into mechanical work. Heat may be transmitted from one body to another in three ways, namely, by radiation and absorption, by conduction, and by convection.

Radiation and Absorption. Radiation is the transfer of heat from one body to another body not in contact with it. It takes place equally well in air or *in vacuo*. The rate of heat transferred depends partly on the distance separating the two bodies, and partly on the nature of their surfaces. In general, light-colored and polished metal surfaces radiate heat more slowly than rough and dark-colored surfaces. The laws governing absorption are the same as those governing radiation.

Conduction. Conduction is the transfer of heat through the substance of a body—solid or liquid—to other portions of the same body, or to another body in physical contact therewith. Metals are the best conductors of heat, but some metals, such as copper, are better conductors than others. Other solids, such as stone, wood, etc., rank after the metals. Liquids are very poor, and gases still poorer, conductors of heat. A vacuum is perfectly non-conducting, though radiation may still take place through it.

Convection. Convection is the term applied to the absorption of heat by moving liquids or gases in contact with heated surfaces. If a blast of air be directed on a piece of hot iron, the iron cools far more rapidly than it would in still air. The reason is that, as the air is a poor conductor, its molecules do not transmit heat readily from one to the next, but if each molecule on becoming heated is immediately replaced, heat is rapidly transferred. This property of air of taking up heat rapidly when blown over a hot surface is employed in gasoline automobiles to cool the so-called "radiators". In reality, the heat radiated cuts a small figure compared with that dispersed by convection.

What has just been said regarding air is equally true of other gases. It is also true of most liquids.

Relative Conductivity. Heat conducting qualities vary for different substances. Silver, copper, and aluminum conduct heat very rapidly, while asbestos is a poor heat conductor and is therefore used around the outside of automobile boilers.

Expansion. Another heat property which has to be considered in the selection of material for steam cars is that of expansion. Some metals expand much more than others for each degree of rise in temperature. Since brass and copper both expand under heat much more than iron they are used in preference to iron in the construction of expansion tubes, which are fully described later.

Temperature Measurement Scales. Temperature, which is the measure of the intensity of heat, is expressed by means of divisions called *degrees* on some thermometer scales. The two thermometers in most general use are the Fahrenheit and Centigrade; the former being the more common in America and England for both engineering and household use, while the latter is used exclusively on the Continent.

Freezing of water occurs at 32° F. (Fahrenheit) and boiling of water at 212° F. The scale between these two points is divided into 180 equal parts. On the Centigrade scale, the points of freezing and boiling occur, respectively, at 0° C. and 100° C., and there are, therefore, 100 equal divisions between the two points, Fig. 6. Thus it is seen that every 5 degrees Centigrade equal 9 degrees Fahrenheit.

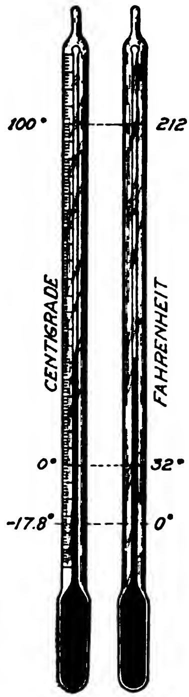


Fig. 6. Centigrade and Fahrenheit Thermometers, Showing Comparison

Conversion of Scales. To convert readings in one scale to readings in the other, the reading given is substituted in the following equation:

$$\frac{°F-32}{180}=\frac{°C.}{100}$$

Thus, if a temperature is given as $-5°$ C. it is equal to 23° F.; 23° C. equals 73.4° F. Conversion tables over large ranges are given in engineering handbooks, such as Kent.

Absolute Zero. In engineering calculations the absolute zero and the absolute scale are sometimes spoken of. This absolute zero, which will be mentioned again, is taken as $-270°$ on the Centigrade scale and $-460.6°$ on the Fahrenheit scale. Thus $-5°$ C. equals $+265°$ on the C.-absolute scale and $+483.6°$ on the F.-aboslute scale.

LAWS OF GASES

Almost all substances expand with rise of temperature. Solids expand least, and in some the expansion is imperceptible. Liquids expand about as much as solids, sometimes slightly more. Gases and vapors expand a great deal if free to do so.

Boyle's Law. Before considering the expansion of gases under changes in temperature, let us see how they act when the temperature is unchanged. A gas is perfectly elastic, that is, if not confined in any way it would expand indefinitely. The attraction of gravity is all that prevents the atmosphere surrounding the globe from dispersing into infinite space. When air is partly exhausted from a closed vessel, the remainder, no matter how small, expands so as to distribute itself equally throughout the vessel.

If a cubic foot of air at atmospheric pressure be compressed into one-half cubic foot without change in temperature, its pressure will be precisely twice what it was before. In speaking of gas pressures in this manner, it is customary to deal with absolute pressures, that is, pressures above a perfect vacuum. Thus atmospheric pressure at sea level is approximately 14.7 pounds per square inch, and a cubic foot of air reduced one-half in volume will have an absolute pressure of 29.4 pounds.

This relation of pressure and volume is expressed in "Boyle's Law", which states that, so long as the temperature is unchanged, the product of the pressure and volume of a given weight of gas is constant. That is

$$P\,V = C$$

This is the most important of all the laws of gases.

Curve Expressing Boyle's Law Relation. Fig. 7 expresses the relation between volume and pressure of a given weight of air starting at atmospheric pressure and compressed to a pressure of 500 pounds without change in temperature; also expanded to a pressure of one pound absolute. Horizontal distances represent volumes, the volume at atmospheric pressure being unity; and vertical distances represent absolute pressures. To find the pressure of the air for any volume greater or less than one, locate the given volume on the base line, then, from this point, read up to the curve and find the desired pressure by moving horizontally from the curve to the scale at the left.

Behavior of Gases with Changes of Temperature. As heat is a mode of motion, it follows that when all heat is withdrawn motion ceases, and the molecules, even of a gas, become fixed. From experiments and theoretical considerations the absolute zero, representing the absence of all heat, is believed to be $-273°$ C., or approximately $-460°$ F. In most theoretical studies of the behavior of gases, temperatures are reckoned from absolute zero instead of from the arbitrary zeroes of the conventional thermometer.

When a gas of given weight at an absolute temperature of 273 degrees—that is, 0° C. on the customary scale—is raised in temperature one degree without change in pressure, its volume is increased $\frac{1}{273}$. A second degree of added temperature increases its volume the same amount, and so on. In other words, for each degree Centigrade of added temperature its volume is increased $\frac{1}{273}$ of its volume at 273° A.

Fig. 7. Curve Showing Relation between Volume and Pressure of Air

If degrees Fahrenheit are taken instead of Centigrade, the expansion is $\frac{1}{492}$ of the volume at 32° F. for each degree of rise in temperature. Five degrees C. equal nine degrees F.

If the gas thus heated is so confined that it cannot expand, it will suffer an increase in pressure in the same proportion, that is, $\frac{1}{273}$ of its pressure at 0° C. for each degree Centigrade. If the gas, instead of being heated, is cooled, its shrinkage in the one case or its loss of pressure in the other will follow the same rule as above. Theoretically it follows that at $-237°$ C.—absolute zero—the gas would have no volume at all. Of course that is impossible, but at ordinary temperatures the gases behave as if the assumption were true.

HEAT TRANSFORMATION

Specific Heat. The temperature of a body and the heat it contains are two different things. A gallon of water at 100° F. contains twice as much heat as half a gallon at the same temperature. That is to say, twice as much heat was imparted to it in raising it to that temperature.

Like quantities of different substances at the same temperature do not always contain the same quantity of heat. A pound of water contains more heat than a pound of oil or alcohol at the same temperature. It requires 7.7 times as much heat to raise a pound of water one degree in temperature as a pound of cast iron.

The quantity of heat required to change the temperature of a given weight of a substance one degree, compared with that required to change the temperature of the same weight of water a like amount, is called the "specific heat" of that substance.

Specific heat varies considerably for different substances, and for different temperatures and states of the same substance. Thus the specific heat of steam is much less than for water and varies slightly as the temperature and pressure of the steam is varied.

British Thermal Unit. The quantity of heat required to raise the temperature of one pound of water one degree F. is known as the "British thermal unit" (B.t.u.). Another unit is the "calorie", which is the quantity of heat required to raise the temperature of one kilogram (2.2046 lb.) of water one degree Centigrade. One calorie equals 3.968 B.t.u. The B.t.u. is the unit generally used in this country for engineering calculations. The latest investigations lead to slightly different and more complicated definitions of the B.t.u. from the one given above, but this is near enough for practical calculations.

Heat Value of Fuels. The number of heat units liberated by burning a pound of fuel varies for different fuels. The *heat value* for fuels is determined by experiment, and by calculation when the chemical composition is known. Due to the variation in the composition of commercial gasoline, different samples will give different results, but for most calculations the figure of 19,000 B.t.u. Kerosene has a slightly higher value.

Force. Force is defined as that which produces, or tends to produce, motion, and in practical work is usually expressed in units of weight, for example, pounds, kilograms, or tons. A force may exist without any resulting motion, and therefore without work being done. For example, the weight of any object represents the force of gravity attraction between the earth and that body. The atmosphere exerts a pressure or force of approximately 14.7 pounds per square inch at sea level.

Work. Work is done when force is exerted by or on a moving body, and is measured by the product of the force into the distance through which it is exerted. A convenient unit of work is the "foot-pound", which is the work done in lifting a weight of one pound against the force of gravitation a vertical distance of one foot, or exerting a force of one pound in any direction through a distance of one foot.

Power. Power expresses the rate at which work is done. If a foot-pound of work is performed in a minute, the power is small. If it is done in a second, the power is 60 times as great. The customary unit of power is the horsepower, which is 33,000 foot-pounds per minute. Whether a force of 33,000 pounds be exerted through one foot of distance, or one pound be exerted through 33,000 feet in the same time, the power is the same.

Mechanical Equivalent of Heat. Heat may be converted into work or work into heat. Experiments have been made in which water was agitated in a closed vessel by means of paddles run by falling weights and the resulting rise in temperature of the water carefully determined. From these and other experiments, it has been ascertained that one British thermal unit is the equivalent of 778 foot-pounds of work. That is, a weight of one pound falling 778 feet, or 778 pounds falling one foot, develops sufficient energy to raise one pound of water one degree F. in temperature. A horsepower, therefore, equals 42.416 B.t.u. per minute. The combustion of one pound of either gasoline or kerosene liberates approximately 19,900 B.t.u., but the kerosene is heavier for equal bulk. One U. S. gallon of gasoline weighs about 5.6 pounds; of kerosene, about 6.25 pounds. The combustion of a gallon of kerosene per hour develops theoretically about 49 horsepower but the actual amount of energy obtained falls far short of this. Owing to heat losses in the boiler and exhaust, and to radiation, etc., only a small fraction of this energy can be converted into useful work.

THERMODYNAMICS OF STEAM

Latent Heat. If water be heated in an open vessel it will reach a temperature of approximately 212° F. (100° C.) and will then boil away without further rise in temperature. The added heat is absorbed in converting the water into steam.

It takes far more heat to convert water into steam than to raise its temperature. A pound of water heated to boiling from 32° F. absorbs only 180 B.t.u., but in boiling away at 212° F. it absorbs 966 B.t.u. additional. At atmospheric pressure the volume of the steam is 1645 times the volume of the water whence it came. This bulk of steam must displace an equal bulk of air, and part of the heat energy represented by the steam has been spent in pushing back the air to give it room. This will be made clearer from the sketch, Fig. 8, showing a long tube open at the top and containing a little water at the bottom. On top of the water is a piston, supposed to be air-tight and without weight or friction. If the water be boiled into steam, the piston will be pushed upward against the atmospheric pressure a distance equal to 1645 times the original depth of the water. The work in foot-pounds thus done will be 14.7 times the area of the piston in square inches times the distance in feet through which it has moved. Approximately 7.45 per cent of the heat imparted to the steam represents work done against the atmosphere; the remainder is spent in overcoming the mutual attraction of the molecules of water. The heat which has been absorbed by the change in state from water to steam without change in temperature is called the "latent heat of vaporization".

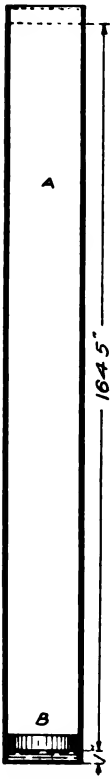


Fig. 8. Expansion of Water into Steam

If a vessel containing water at 212° F., which is the atmospheric boiling point, be put under the receiver of an air pump and the air partly exhausted, boiling will take place spontaneously without further addition of heat. At the same time the temperature of the water will decrease, because part of the heat contained in it has been absorbed by the conversion of water into vapor. If the air pump keeps on working, the water will boil continuously while its temperature steadily descends. If the experiment be carried far enough, with the vessel so supported that it can absorb little or no heat from adjacent objects, and if the vapor given off be rapidly absorbed, for example, by placing a tray of quick-lime or sulphuric acid adjacent, the water may actually be frozen by its own evaporation.

This experiment shows that the boiling point of water—and this includes other liquids also—is not a fixed temperature but depends on the pressure. All volatile liquids when exposed to partial or complete vacuum give off vapor; on the contrary, this vapor when subjected to pressure partly re-condenses and a higher temperature is needed to produce boiling. Under an absolute pressure of 147 pounds or 10 "atmospheres", the boiling point is 356.6° F. At 500 pounds absolute pressure the boiling point is 467.4° F. (242° C.).

The "total" heat of steam at the boiling point corresponding to a given pressure is the sum of its latent heat of vaporization and the heat contained at the same temperature in the water from which the steam was formed. The total heat of steam increases slowly, but the latent heat diminishes nearly in proportion as the boiling point rises. The space occupied by a given weight of steam diminishes approximately in proportion to the increase in pressure. In this respect the steam resembles a perfect gas without change of temperature in accordance with Boyle's Law. Tables showing the pressures, temperatures, latent heat, etc., of steam are given in Kent and other handbooks.

The experiment just cited of producing spontaneous boiling in water by exhausting the air above it, may be duplicated with hot water at any temperature and pressure. For example, the boiling point of water under 100 pounds absolute pressure is 327.6° F. If, in a boiler containing water at that temperature and pressure, the pressure be reduced to 50 pounds by the withdrawal of steam, the water will boil spontaneously, absorbing its own heat in doing so, until it reaches a temperature of 280.9° F., which is the boiling point for 50 pounds absolute pressure.

Cause of Boiler Explosions. Owing to the property of giving off steam under reduction of pressure, every steam boiler constitutes a reservoir of energy which may be drawn upon to carry the engine through a temporary period of overload. In other words, the boiler will give out steam faster than the fire generates steam, the difference being supplied from the heat stored in the water itself. This is an exceedingly useful feature of the ordinary steam boiler. At the same time, and for the same reason, it is a source of danger in case of rupture of the boiler shell. If a boiler explosion involved simply the release of the steam already formed it would not be so serious a matter; but when a seam starts to "go" the adjacent portions are unable to carry the abnormal strain put upon them, and the result is a rent of such proportions as to release almost instantly the entire contents of the boiler. The hot water thus suddenly liberated at high temperature bursts into steam until the whole mass drops to a temperature of 212 degrees, and this steam is many hundred times the volume of the water from which it came. It is to this fact that the violence of boiler explosions is due.

To take an extreme case, if a boiler bursts under 500 pounds pressure, approximately thirty-seven per cent of the water it contains will pass instantly into steam, and at atmospheric pressure the volume of the steam will be over 600 times the volume of the entire original liquid contents of the boiler.

Automobile boilers and steam generators are so designed as to minimize the danger of explosion, and only ordinary care is needed to insure entire safety.

Superheating. The foregoing paragraphs have dealt exclusively with steam at the boiling temperature due to its pressure. Such steam is called "saturated" steam. Steam will not suffer a reduction of temperature below this point; if heat be absorbed from it a portion will condense. On the other hand, steam isolated from the water whence it came may be raised in temperature indefinitely. It is then called "superheated" steam. The more it is superheated the more nearly does it act like a perfect gas.

Superheated steam is preferred for power purposes to saturated steam, for the reason that the latter condenses more or less, both in the pipes on its way to the engine and in the engine itself. Steam which condenses thus is a total loss, and it is more economical to add sufficient heat to it before it reaches the engine to replaces radiation losses, etc., without cooling the steam to the saturation point. To accomplish this in automobiles, the steam from the boiler is led through one or more pipes exposed to the maximum temperature of the fire. These pipes are called superheaters, or superheating pipes.

MECHANICAL ELEMENTS OF THE STEAM ENGINE

General Details of Steam Engine Parts. In Fig. 9 a plan view of a stationary steam engine is given, with the cylinder and valve chest shown in cross section, and with the various parts marked by letters. A view of a stationary engine is used because it is not so condensed as an automobile engine, and the parts are therefore easier to mark and pick out. The relations and names of parts are the same in an automobile engine.

Fig. 9. Plan View of Typical Stationary Engine

A, Cylinder. *B*, Outer cylinder head. *C*, Piston rod. *D*, Crosshead. *E*, Connecting rod. *F*, Crankpin. *G*, Crank. *H*, Crankshaft. *I*, Eccentric. *J*, Eccentric rod. *K*, Eccentric crosshead. *L*, Valve stem. *M*, Steam chest. *N*, Steam pipe connection. *PP*, Flywheels. *Q*, Crosshead guides. *R*, Valve stem guide. *S*, Engine frame. *T*, Stuffing box. *U*, Piston. *V*, Wristpin. *WW*, Steam ports. *X*, Slide valve. *Y*, Eccentric strap. *Z*, Clearance space between piston and cylinder head at end of stroke.

A is the cylinder to which steam is admitted through the passages, or ports, *W W*, which connect it with the steam chest *M*. The opening and closing of these ports is accomplished by the movement of the valve *X*. Because of its shape, the valve here shown is called a D-slide valve. Other types of valves are piston valves and poppet valves, names which explain themselves. The valve is attached to the valve stem *L* and is guided by the valve-stem guide *R*. Motion back and forth is given the valve by the eccentric *I*, which is a circular disk on the crankshaft, with its center offset from the center of crankshaft *H*.

Returning to the cylinder, *U* is the piston, which is driven back and forth by the steam. Connected to the piston is the piston rod *C*, which passes through the gland, or stuffing box *T*. This gland is for the purpose of holding the packing which prevents the escape of steam around the piston rod. The end of the rod, or crosshead *D* slides back and forth in the crosshead guides *Q Q*. To the crosshead is attached the connecting rod *E*, by means of the wristpin *V*. In the lower end of the connecting rod is the crankpin *F*.

In steam automobile engines the flywheels *P P* are usually not needed and are consequently omitted. The rim of the gear wheel, when the engine is geared directly to the rear axle, has a slight flywheel action.

SLIDE VALVE

The leading mechanical elements of the steam engine have been briefly described. It remains now to show the precise manner in which the steam is used.

Elementary Slide Valve. Fig. 10 represents an elementary slide valve. In order to indicate the movements of the crankpin and the valve eccentric on one drawing, the crankshaft center is located at *A*. *B* represents the crankpin center with the piston *C* at the inner end of its stroke. The larger dotted circle is the crankpin circle, and the small circle is that in which the center *D* of the eccentric moves. With the crankpin traveling as the arrow shows, the valve is in mid-position when the piston starts to move, and the first effect of its movement is to uncover the steam port *E*, at the same time establishing com-

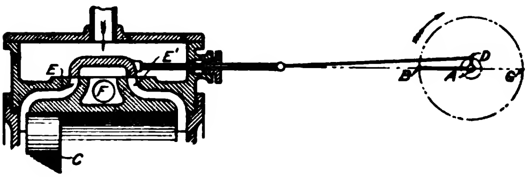


Fig. 10. Elementary Slide Valve—Valve in Mid-Position

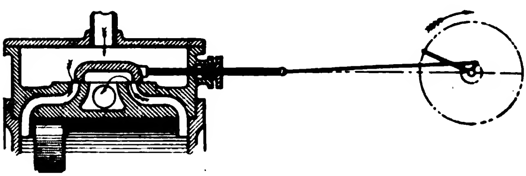


Fig. 11. Elementary Slide Valve—Inlet and Exhaust Ports Partly Uncovered

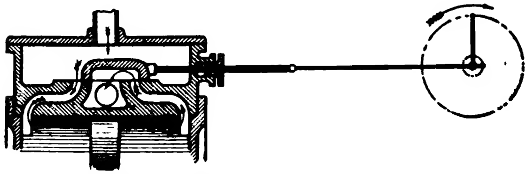


Fig. 12. Elementary Slide Valve—Inlet and Exhaust Ports Fully Opened—Piston in Mid-Position

munication between port E' and exhaust port F, Fig. 11. At half-piston stroke the ports are wide open and the valve starts to return, Fig. 12. When the crankpin reaches the outer dead center G the ports are again closed.

Use of Steam Cut-Off. A steam engine with valve arranged as above would take steam through the entire stroke, and would exhaust at boiler pressure. It would develop the maximum power of which it was capable at that pressure, but no use would have been made of

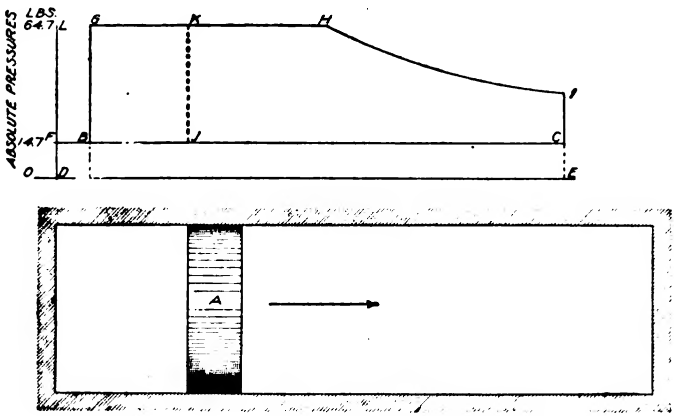


Fig. 13. Theoretical Indicator Diagram for One-Half Cut-Off

the expansion force of the steam. For this reason, all practical steam engines are made to admit steam only for the first portion of the stroke, that is, about one-half stroke or less, the remainder of the stroke being devoted to expansion. In Fig. 13, suppose A represents the position of a piston moving from left to right. The horizontal distance $B\ C$ represents the stroke, and vertical distances represent steam pressures. $D\ E$ is the line of zero pressure, and $F\ C$ that of atmospheric pressure. Suppose steam is admitted at 50 pounds gage pressure during the first half of the stroke from G to H; the steam port then closes and the steam expands with diminishing pressure along the curve $H\ I$. Since work is the product of force into distance traveled, it follows that for each fraction, such as $B\ J$ of the piston travel, the included area $B\ G\ K\ J$ will represent the work done during that portion of the stroke, and the area of the entire card $B G\ H I C$ will represent the work done during the whole stroke.

In the case under consideration, the area of the whole diagram is 84.4 per cent of that which would have been produced if the steam had entered during the entire stroke, yet only half as much steam is used.

Indicator Diagrams. A diagram such as Fig. 13 is called the "indicator diagram" or "indicator card", and is employed to study the internal action of the engine. The expansion curve of steam follows Boyle's Law with sufficient closeness for practical purposes. Fig. 14 is similar to Fig. 13 except that the steam is cut off at one-quarter stroke, point *H*.

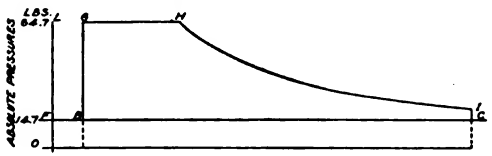


Fig. 14. Theoretical Indicator Diagram for One-Quarter Cut-Off

In the foregoing, no mention has been made of the contents of the steam passages between the slide valve and the cylinder, or of the clearance volume between the piston and the cylinder head when the crank is on dead center. These clearance spaces cannot wholly be avoided, but it is desirable to reduce them as much as possible. It is customary in indicator cards to represent the clearance space by an area to the left of the actual indicator card. This area is *F L G B* in Fig. 13 and Fig. 14. Its volume averages about 5 per cent of the volume swept by the piston. Owing to the necessity of taking the steam in the clearance space into account, the actual steam consumption in Fig. 14 is a trifle more than half that in Fig. 13.

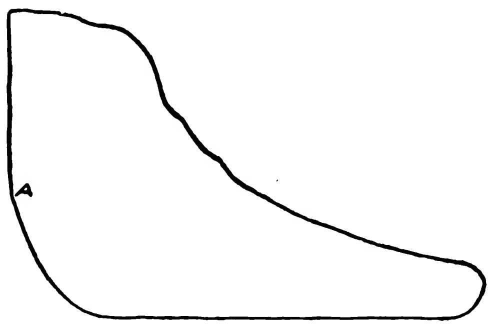


Fig. 15. Actual Indicator Card, Showing Compression

Effect of Compression on Indicator Card. The objectionable influence of the clearance may be neutralized by closing the exhaust port before the piston has finished its return stroke, thereby trapping the remaining steam at atmospheric pressure and compressing it to boiler pressure. If this is done, none of the entering steam is wasted merely in filling the clearance space. Fig. 15 shows the effect of compression on an actual indicator card. It is not carried to boiler pressure, but only to point *A*.

Another reason for using compression is to cushion the reciprocating parts at the end of their stroke and prevent the shock which may otherwise occur on suddenly admitting live steam.

Effect of High Pressure and Early Cut-Off. As Fig. 14 shows, no great advantage is gained when working with steam at 50 pounds by cutting off earlier than one-third stroke. If higher pressure is used, however, the cut-off can be considerably shortened. Fig 16 is a theoretical indicator diagram for 200 pounds gage pressure (214.7 absolute). The clearance is 5 per cent of the piston displacement, and cut-off occurs at one-tenth stroke. The weight of steam per stroke is about the same as in Fig. 14, but the work done by the higher pressure is nearly two-thirds greater. This shows strikingly the economic advantage of using high pressure, provided the cut-off is shortened to correspond.

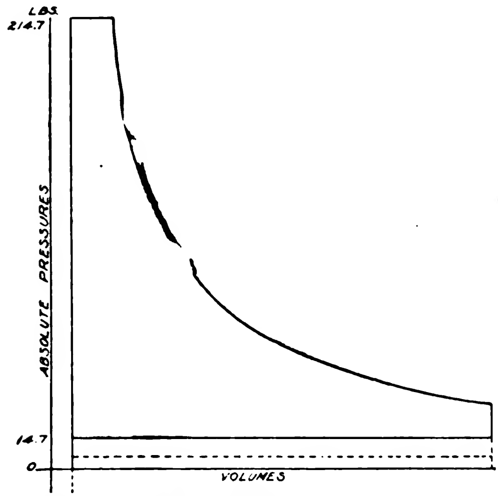


Fig. 16. Theoretical Indicator Card for One-Tenth Cut-Off

Effect of Adding Steam Lap. To produce a short cut-off, what is known as outside lap or steam lap is added to the edges of the slide valve *A A*, Fig. 17. To produce compression inside exhaust lap *B B* is also added. Figs. 18 and 19 show how the valve mechanism is affected by these changes. In Fig. 18 the piston is about to begin its stroke, but the valve is no longer in mid-position. Instead, the eccentric has had to be advanced through an angle, known as the "angle of advance", in order

Fig. 17. Section of Slide Valve, Showing Steam and Exhaust Laps

to open the port as the piston starts to move. The necessary travel is also increased in order to accomplish the idle movement when all ports are closed. As the diagrams show, the valve reaches the end of its movement, returns, and closes the steam port while the piston is in the first quarter of its movement. It then continues to move, but with only the exhaust open.

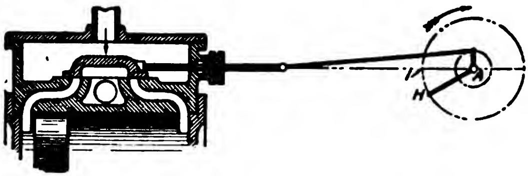


Fig. 18. Elementary Slide Valve, Showing Effect of Adding Laps

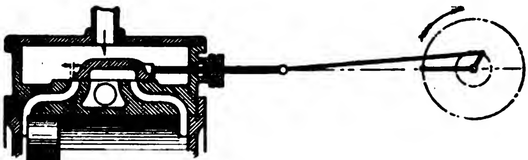


Fig. 19. Elementary Slide Valve, Showing Adjustment of Lead

It is customary, as Fig. 19 shows, to open the steam port a trifle before the piston begins its stroke in order to avoid wire drawing of the steam before the port goes fairly open. If this were not done, there would be an appreciable drop in pressure at the beginning of the stroke. The amount of this premature opening of the valve is called its "lead".

SUPERHEATED STEAM AND COMPOUND EXPANSION

Superheating to Avoid Cylinder Condensation. When steam expands its temperature drops by reason of expansion, causing the cylinder walls to assume an average temperature which slightly increases from contact with the hot steam and slightly diminishes at the end of every stroke. The hot entering steam condenses on the walls, and re-evaporates near the end of the stroke. This is very undesirable, and is avoided by superheating the steam sufficiently to compensate for the initial loss of heat to the walls. In addition, heat loss by radiation is minimized by lagging the cylinder walls and heads with asbestos, magnesia, or other non-conducting coverings.

When steam is used at pressures above 100 pounds, compound engines are preferable, although not always used.

Compound Engines. In a compound engine the work done by expansion is divided as nearly equal as practicable between two cylinders, called respectively the high-pressure and the low-pressure cylinder. The high-pressure cylinder is the smaller in diameter, and it exhausts into the low-pressure cylinder instead of into the atmosphere. In the diagram, Fig. 20, showing the elements of a compound engine, the steam is being transferred from the high-pressure cylinder to the low-pressure cylinder. The steam expands by reason of the difference in the areas of the two pistons.

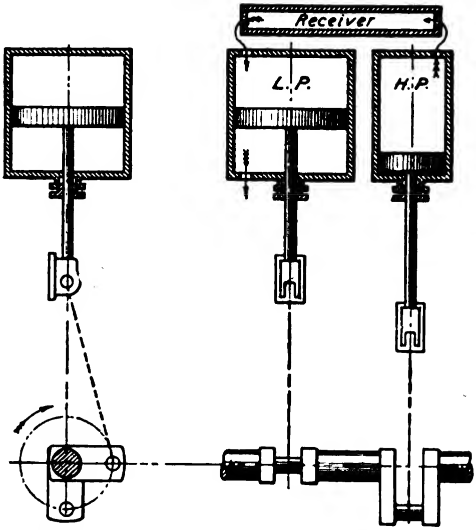


Fig. 20. Elements of a Compound Steam Engine

A compound engine may be considered as though the steam were expanded wholly in the low-pressure cylinder, and the indicator diagrams of the two cylinders may be combined to show the total work done, by shortening the horizontal distances of the high-pressure card in proportion to its smaller piston area.

Comparison of Indicator Diagrams for Stationary and Automobile Engines. Fig. 21 is a combined diagram from the high- and low-pressure cylinders of a stationary compound engine. Both cards are drawn to the same scale as regards stroke, but the low-pressure card reads from right to left. *F* is the point of admission to the high-pressure cylinder. The slight peak at *A* is due to the inertia of the in-rushing steam. At *B* the admission valve closes. At *C* the steam is released and goes into the receiver between the cylinders. *D E* is the

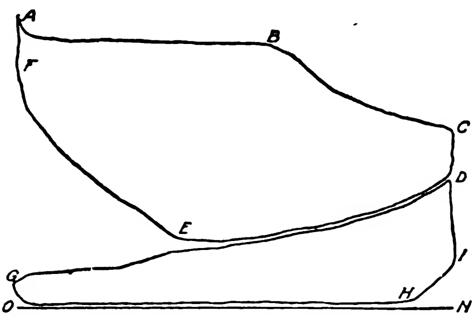


Fig. 21. Indicator Diagram of a Stationary Compound Steam Engine

exhaust line, and *E F* the compression line. From *D* to *E* steam passes from the high- to the low-pressure cylinder, the difference between the two lines being due to frictional resistance of the passages. At *G* the exhaust valve opens. *HI* is the compression line of the low-pressure cylinder.

Use of Condensers. In the foregoing paragraphs steam is supposed to be exhausted at atmospheric pressure. In other words, the steam in the working end of the cylinder must overcome a back pressure of 14.7 pounds per square inch in the exhaust end. If the exhaust steam were discharged into a closed vessel and condensed, a vacuum would be formed containing only water vapor at a pressure

Fig. 22. Stanley Radiator

Fig. 23. Doble Radiator

proportionate to its temperature. This would mean the addition of 5, 10, or even 12 pounds to the height of the indicator card without having to increase the heat units put into the steam. To do this requires considerable apparatus—condenser, vacuum pump, etc., all of which it has been found inadvisable to install on an automobile.

Condensers on steam cars are not for the purpose of increasing the total expansion by dropping below atmospheric pressure, but to condense the water at atmospheric pressure so as to be able to use it again and avoid having to fill the water tank so often.

As shown in Figs. 22 and 23, both the Stanley and the Doble use condensers of the same general construction and appearance as the radiators used on the ordinary gasoline car. The exhaust steam from the engine enters at the top of the radiator and is forced downward by the steam which is following. As it passes down the radiator, the air going through the spaces between the water passages cools it, until, by the time it reaches the bottom, it has been condensed into water.

VALVE GEARS

Throttling and Reversing. Steam engines are regulated partly by the cut-off and partly by throttling. As has been pointed out above, it is impracticable to use a cut-off so short as to expand the steam to, or below, exhaust pressure. Beyond this point reduction of power must be had by throttling the steam on its way to the engine. The shortening of the cut-off, and the complete throwing over of the valve timing to the other side of the dead center to reverse the engine, may be accomplished by shifting the angular position of the eccentric on the crankshaft or by the use of one of several valve gears or linkages.

Types of Gears. Up to the last few years the most common gear was the "Stephenson Link", developed by Robert Stephenson and Company, in 1842. In locomotive work the Stephenson gear has been largely displaced by the Walschaert gear. Practically all the earlier steam automobiles used the Stephenson, but later some changed to the "Joy Gear", which is one of a number of radial gears employing linkages without the use of eccentrics.

Stephenson Link. The Stephenson link is shown in Fig. 24. It consists of two eccentrics *A* on the crankshaft—one for the forward motion and the other for the reverse. The two eccentric rods are pinned to the link *B*, in which there is a curved slot. In the slot is carried the block *C*, which is a sliding fit and is pinned to the valve stem.

By means of the hanger rod *D* and the reverse lever arm *E*, the link is moved up and down, so that the slide is in different positions from the center of the slot. When the block is on one side of the link center it partakes of the motion of one of the eccentrics, and when on the other side of the motion of the other eccentric. Thus the valve timing is changed from the forward running position to the reverse by changing the position of the block in the curved slot.

It is a feature of the Stephenson link motion that by rocking the link toward (but not to) its mid-position the valve travel and cut-off are shortened, and this feature is utilized to improve economy. At the same time the lead is increased, that is, steam is admitted before the piston begins its new stroke. This is not a disadvantage

Fig. 24. Stephenson Link Motion Used on Stanley Steam Cars

at high speeds, as the fresh steam has a cushion effect on the reciprocating parts. At low speeds, however, the engine runs jerkily, and consequently the cut-off is shortened only at medium to high speeds.

Joy Gear. The Joy gear is a well known English development, which is used on a number of steam automobiles. Its operation may

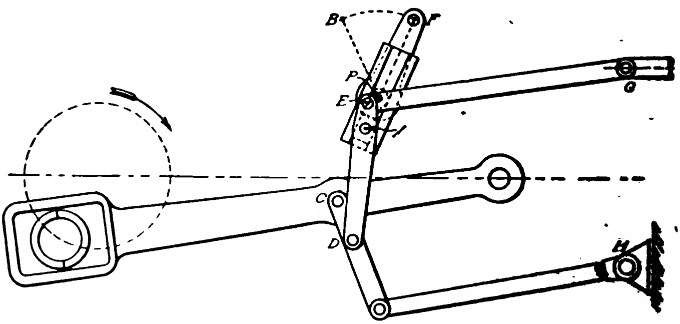


Fig. 25. Diagram of Joy Valve-Gear Mechanism

be understood by referring to Fig. 25. A link is pinned at one end to the engine at *H* and at the other end to a link, which in turn is pinned to the connecting rod at *C*. To this second link is pinned the link

D E, to the upper end of which is attached the rod *E G*, which moves the valve. At *A* on *D E* is pivoted the block *A*, which slides in the slotted guide, the guide being slightly concave on the side toward the valve. This guide is pinned to the engine frame at its center point *P*. In the position of the guide, as shown, the valve is in full gear for forward running, but if the guide is swung about the point *P*, by means of a connection at *F*, until it is in the position *B F*, the engine will then be in full reverse.

As with the Stephenson, the moving of the Joy toward the half-way point shortens the cut-off. This gear has an advantage over the Stephenson in that the lead is not increased and the distribution of steam to the two ends of the cylinder on short cut-off is more nearly equal. The Joy gear also gives a rapid opening and closing to the valve.

ENGINE TYPES AND DETAILS

Although makers have their individual preferences in engine types as regards the placing of the cylinders, compounding, and other features, the practice of using two cylinders has become almost universal.

Stanley. An example of the two-cylinder type is the Stanley engine, which, in the present models, is made in three sizes of the following bore and stroke: 3½ by 4½, 4 by 5, and 4½ by 6½ inches. This engine is geared directly to the rear axle by a spur gear mounted on the crankshaft, as shown in Fig. 26, and the frame rods are attached radially from the axle housing. The cylinder end is attached to the frame of the car. The rear-axle gear ratio in the small light runabout model is 30 to 56, and in the heavy delivery car is 40 to 80. With a gear ratio of 40 to 60 in one of the touring cars the engine turns over at 447 r.p.m. when the car is running 30 miles per hour.

Both cylinders take high-pressure steam at both ends, the engine being of the double-acting, simple type. The steam chest, Fig. 27, lies between the two cylinders, with the D-slide valves driven by the eccentrics lying next to the drive-shaft gear. In Fig. 26 is shown the Stephenson link by which the cut-off is hooked up and the reversing of the engine accomplished. This valve gear has been described in detail on page 23. The cross shaft, working the link, and the hook, for holding it in the normal position, are shown just to the left of *A*.

The hooking up is done by the left pedal, which can be released by a pedal beside it called the clutch pedal.

Roller and ball bearings are used extensively in the Stanley motor. The crosshead bears on a plain crosshead guide, and the connecting-rod and eccentric-strap bearings are of the ball type. The counterweights are also shown in Fig. 26.

Lubrication of the outside parts is effected by enclosing the gears, crankshaft, and other parts in a sheet-metal case, which is kept about half full of moderately thin mineral oil. The lubrication of the cylinder walls is accomplished by feeding the oil into the steam line, and the special superheated steam-cylinder oil recommended is given fully in a later section.

The Stanley power pumps for water, fuel, and oil, shown in Fig. 46, are driven from the rear axle.

Fig. 26. Stanley Two-Cylinder Steam Engine, Showing Link Motion and Balanced Shaft

Doble. The Doble engine, shown in full length section in Fig. 28, is made up of two cylinders of the same size. It is of the simple-expansion double-acting type, and the interesting feature is that the uni-flow principle is employed. The cylinder bore is 5 inches and the stroke is 4 inches.

On top of the cylinders are the valve chests. Each valve is made up in two pieces so that it may lift when the compression pressure exceeds the steam pressure, as sometimes happens in slow running. This construction allows the use of high compression, which is desired at the

Fig. 27. Cylinder Construction of Stanley Steam Engine, Showing Steam Chest in Center

higher speeds. The gear used to control the valve motion is a modification and simplification of the Joy gear, Fig. 25. In the Doble gear the connecting and anchor links are done away with, and a straight rocker guide is employed. In starting, the cut-off is five-eighths stroke, and this same position is used for heavy pulling. For ordinary running, one-fifth stroke cut-off is used, while for economy and high speed it is reduced to one-eighth stroke.

Fig. 28. Section of Doble Engine
Courtesy of General Engineering Company, Detroit, Michigan

By the uni-flow principle is meant that the steam moves in but one direction within the cylinder. It enters through the inlet passage at the extreme end of the cylinder, expands against the piston head, and passes out of the exhaust ports, which are uncovered by the piston a little before it reaches the end of the stroke. It is claimed for this system that the thermal conditions are so good that the use of superheated steam, with its attendant troubles, is unnecessary.

Aluminum is employed for the crankcase, with large cover plates, top and bottom, for easy access to the moving parts. The accessibility of the valve gear is very well shown in Fig. 29. The case, which has its cover removed, contains all the moving parts of the engine with the exception of the valves and pistons; and, since the case and the axle tubes, which are bolted to it, are oil-tight, all these parts are kept in a bath of

Fig. 29. Rear Portion of Doble Chassis, Showing Easy Access to Moving Parts
Courtesy of General Engineering Company, Detroit, Michigan

Fig. 30. Piston and Crosshead Guide of Doble Engine

oil. This oil keeps comparatively cool and as there is no combustion, it does not deteriorate as in the gasoline car.

A special design of long cast-iron gland is used for the piston rod at the cylinder, and there is a stuffing box where the rod passes into the crankcase. The crosshead guide is part of a cylinder, as shown in Fig. 30, giving a large bearing surface. Annular roller bearings are used for the big end of the connecting rod, for the crankshaft, and for the differential. Hardened steel, running in hardened steel bushings, is used for all the other bearings.

Being geared at practically a 1 to 1 ratio to the axle shafts, the engine always runs at comparatively slow speed. A 47-tooth pinion is carried on the engine crankshaft and to this is fastened the counterbalance. This gear meshes with one of 49 teeth on the differential spider. The differential is of the three-pinion bevel-gear type. Meshing with the axle gear is an idler, and then a gear on the electric generator, which furnishes current for the combustion system and the lights.

Fig. 31. Top View of National Power Plant for London Steam Omnibuses
Courtesy of Society of Automobile Engineers, New York City

Fig. 32. Separate Engine and Dynamo for Lighting National Busses
Courtesy of Society of Automobile Engineers, New York City

National. In the National steam omnibuses of London, England, the engines are placed under the floor boards, Fig. 31, and, unlike any of the American engines, the two cylinders lie across the chassis. The drive is taken by a shaft to worm gearing at the rear axle. These engines have a Joy gear, and the pumps for the water and kerosene are driven from a cross shaft, which in turn is driven by a worm gear off the extension of the crankshaft, as is shown in the illustration. An interesting feature of the National chassis is the use of an entirely separate steam engine for driving the electric-lighting generator, which supplies the large number of lights used inside the busses. This auxiliary engine is shown in Fig. 32.

From what has been said it must not be supposed that all automobile steam engines use two-cylinder engines with either D or piston valves. The Pearson-Cox steam truck of England has a three-cylinder vertical engine with poppet valves in chambers at each side of the cylinders, and the whole engine looks very much like a vertical poppet-valve gasoline motor.

A number of very heavy English trucks, or "lorries" as they call them, are driven by steam, and are very popular in England. These carry from 3 to 10 tons, and the boilers and parts of some of them are very large.

FUELS AND BURNERS

Gasoline and Kerosene as Fuels. Energy for driving steam engines is derived, of course, from the fuel burning and forming steam from the water, the steam in turn doing mechanical work by its expansion in the engine. In an automobile it is of prime importance that the fuel be as easily handled, carried, and purchased as possible. Of the commercial fuels, gasoline and kerosene come the nearest to these ideals and are, therefore, the most popular. Kerosene is less expensive than gasoline, but does not vaporize at as low a temperature while, as a rule burners are specially designed for kerosene, many modern burners will handle either of these fuels or a mixture of them.

To burn either of these fuels the vapor must be mixed with air, which supplies the necessary oxygen for combustion. Either of these vapors, if mixed with the right amount of air, is highly inflammable and explosive, and therefore, care must be taken in storing and in filling the fuel tank, not to have open lights about—not even lighted cigars.

Burner Principles. *Bunsen Burner.* The purpose of the burner is first to vaporize the liquid fuel by heating it and then to mix it with enough air to produce the hottest possible flame under the boiler. In principle the burner is the same as the ordinary Bunsen burner, Fig. 33, in which the gas passes under moderate pressure through the small opening *b*. In going up the tube *a* it draws in a certain amount of air through the openings *o*, the fuel gas and air becoming well mixed in the tube before reaching the flame. In case either too much or too little air is mixed with the gas, the flame will run back through the tube *a*, and will burn at *o*. This is called "popping back", and not only takes away the effect of the flame but will ruin the burner if allowed to continue in operation in this way.

Modifications for Automobile Work. In automobile work the burner is somewhat modified in order to act over a large area and to give a flame of more intense heat. For the purpose of feeding more gas, and to mix it more quickly with the air, the fuel is fed under considerable pressure.

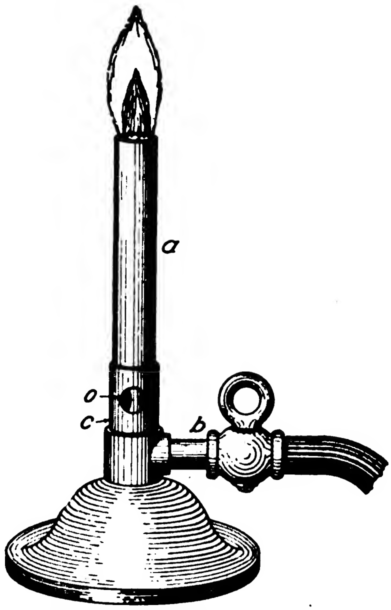


Fig. 33. Typical Bunsen Burner

The correct mixture of air and fuel gas gives a blue flame, just slightly tinged with orange at the top, and burning rather close to the burner. If too much air is given the mixture, the flame will start a considerable distance above the burner and will be very blue. The excess air tends to cool the flame. Too little air is equally bad, for the combustion will then be incomplete and, since gasoline and kerosene are hydrocarbons, soot will be deposited on the surfaces above the flame. Such a flame is indicated by a yellow color. As in the ordinary Bunsen burner, poor mixtures are apt to pop back. When this happens the operator must turn off the burner and relight it. The popping back is indicated by a roaring sound.

Pilot Light. As the demand for steam is not constant in an automobile, it is desirable to have the main burner come on and off automatically. In order to light the main burner whenever it may come on, a small light is kept burning continuously while the car is in use, whether running or standing still. It is even the practice of some owners to keep this pilot light, as it is called, lighted over night. Besides relighting the main burner when the car is running, the pilot is lighted first when firing up a cold boiler. The burning of the pilot serves to heat the vaporizer of the main burner as well as to light the main fire. The handling of the pilot in firing up will be taken up later.

Due to its easier vaporization, gasoline is always used for the pilot-light fuel even when kerosene is used for the main burner. It is also quite general to have the two fuel systems separate, although both may be using gasoline. In starting up a cold system the pilot vaporizer must be heated by some outside means. This is done in several ways: one is to use a separate gasoline torch; another is to use an acetylene torch instead of a gasoline torch; and a third method is to light a little pool of gasoline below the vaporizer, similar to the method used in many gasoline cook stoves and plumbers' torches.

Fig. 34. Stanley Burner, Showing Vaporizer and Mixing Tubes
Courtesy of Stanley Motor Carriage Company, Newton, Massachusetts

Types of Burners. Different makers, of course use somewhat different constructions for their burners, but in all cases the fuel gas is vaporized by heat and mixed in a burner of the Bunsen type. As a fair example of all the burners, that of the Stanley will be described in detail, while short descriptions will also be given of other makes.

Stanley. Either gasoline, kerosene, or a mixture of the two can be burned in the Stanley main burner. The burner, Fig. 34, consists of a corrugated casting with a large number of slots cut across the peaks of each parallel corrugation. Vaporization of the fuel takes place in the two coiled tubes *A A* which lie directly over the fire. From the vaporizing tubes the gas flows at high velocity through the nozzles *B B* into the mixing tubes *C C* drawing with it the air necessary for good combustion. The mixing tubes lead under the burner, and combustible gas issues through the fine slots, where it burns with an intensely hot blue flame tipped with orange. No air currents are present to blow or cool the flame, for the burner casting excludes all air except that drawn in and mixed with the gas through the tubes *C C*. To adjust the amount of air to give the correct color to the flame, bend the nozzles closer to the opening of the mixing tube for less air, and *vice versa.*

Between the two main-burner vaporizer tubes is located the pilot light, which is a small independent casting. The pilot burns gasoline, supplied from a separate tank, irrespective of whether the main burner uses gasoline or kerosene. Due to the position of the pilot, it keeps the main-burner vaporizer warm when the main burner is shut off by either the automatic or hand valve controlling it. When the main burner is turned on, the pilot flame ignites the gas. Since the pilot is independent of the main-burner valves, it remains lighted until turned off by its own hand-operated valve. The heat from the pilot is sufficient to hold steam in the boiler for several hours after the car is stopped and the main burner shut off.

In starting up the pilot of the Stanley when cold, an acetylene torch is played on the pilot vaporizer to vaporize the first gasoline, after which the heat from the pilot light itself keeps the pilot vaporizer warm. The acetylene is carried in a "Prest-O-Lite" tank and turned on by a valve at the tank. The torch lights by simply applying a match, and should be played on the pilot vaporizer until it is sizzling hot, which takes between 15 and 30 seconds. The torch is then moved so that the flame enters the peek-hole, lighting the pilot, after which the torch is played upon the upper part of the vaporizer for 15 to 30 seconds, until the main burner nozzles are sizzling hot.

After closing the acetylene-tank valve the main-burner valve is opened and closed quickly several times until the gas from the main nozzles is dry. It is then left open, being lighted by the pilot flame. The pilot nozzle is provided with a wire which is filed off on one side to allow the passage of the gas. If the pilot light does not seem to burn strongly, it can be cleaned while burning by turning the outside screw back and forth with a screwdriver. If this does not suffice, the wire should be taken out and cleaned; it is good practice to do this every day before firing up. The color of the flame can be adjusted by bending the nozzle tube to bring the nozzle in or out from the mixing tube, the same as is done in adjusting the main burner.

In the older models of Stanley cars, which used only gasoline as the main-burner fuel, the pilot fuel system was a branch of the main system, and the pilot vaporizer was heated by a gasoline torch.

Fig. 35. Section through Combustion Chamber and Boiler of Doble Car
Courtesy of General Engineering Company, Detroit, Michigan

Doble. Very radical departures from the long-established Bunsen type of burner have been made in the combustion system on the new Doble car. The fuel is ignited by electricity and there is no pilot light. Kerosene is used for both starting and running and is fed from the main fuel tank to a float chamber by an air pressure of three pounds per square inch. From the float chamber, which is of the standard gasoline-carbureter type, the fuel passes through a spray nozzle, which is located in the throat of a Venturi tube leading to the combustion chamber.

Air for the support of the combustion of the fuel is drawn through the radiator by means of a multiple-vane fan driven by a small electric motor. It passes the jet with sufficient velocity to draw out the fuel and atomize it. Owing to the enlarging of the passage directly beyond the throat, the velocity is decreased in order to give time for the complete combustion of the gas by the electric spark, which takes place at this point.

The combustion chamber, Fig. 35, is completely closed and lined with a highly refractory material. As soon as the combustion has been started, the electric spark is automatically shut off, and the burning of the gas is continuous until it is stopped by the action of the automatic steam control, as described later. The lining of the chamber not only has the property of resisting high heats, but it holds and gives back the heat so as to assist in completely burning the gases. The combustion chamber is also well illustrated in Fig. 41, page 40.

Fig. 36. Ofeldt Blue Flame Kerosene Burner
Courtesy of F. W. Ofeldt and Sons, Nyack-on-the-Hudson, New York

Ofeldt. The Ofeldt burner, Fig. 36, is designed especially for the use of kerosene as a fuel. Forming the foundation of the burner is a galvanized iron pan, lined around the sides with millboard asbestos. In the bottom of the pan are drilled rows of small holes. Since these holes are in straight lines under the burner pieces, and of equal size, they admit even amounts of air throughout the lengths of the burner pieces.

Fig. 37. Kerosene Burner, Used on National Busses with Starter
Courtesy of Society of Automobile Engineers, New York City

Cast iron is used for the burner pieces, which radiate from a central gas-distributing chamber, into which they are screwed. The gas flows through fine slots cut in the burner pieces. Surrounding the mixing tube is the main vaporizer *A*, which passes through the outside of the pan, ending in the nozzle *B* at the opening of the mixing tube. The mixing tube is a part of the central gas-distributing chamber.

Attached below the burner pan is the pilot *D*, where its flame heats both the main and the pilot vaporizers and the mixing tube. By means of a hand valve the pilot flame can be adjusted to keep up steam when the main burner is out, or it can be turned down so as to keep only the main vaporizer warm.

A comparatively low pressure is used on the Ofeldt system, the fuel being kept under about 60 pounds per square inch.

National. Kerosene is used as the fuel in the National busses. These burners are quite different in appearance from those described above, as is shown in Fig. 37.

Fig. 38. Stanley Fire-Tube Boiler

AUTOMOBILE BOILERS

Classification. In stationary steam-power plants there are two distinct classes of boilers, the fire-tube and the water-tube. These two types are also used in automobile work, together with a third type, the flash boiler, which is a development of the water-tube type.

Fire-Tube Boilers. In principle the fire-tube boiler is like a big tea-kettle filled with vertical tubes, which run from the bottom to the top for the purpose of carrying up the flame and hot gases. This construction gives a very large surface on one side of which are water and steam and on the other flame and hot gases.

Stanley. One of the simplest of the fire-tube boilers is the Stanley, Fig. 38. This is made up of a pressed-steel shell, which includes the lower head, the upper head being a separate piece.

Between these two heads run a large number of tubes of $\frac{33}{64}$ inch outside diameter, which are expanded into the heads by a taper expanding tool. Stanley boilers are made in three sizes, 20, 23, and 26 inches in diameter and 14 and 16 inches in height, respectively. The number of tubes is 550, 751, and 999, giving 77, 104, and 158 square feet of heating surfaces. To keep down the radiation losses, the boiler shell is lagged with asbestos, and the strength of the shell is greatly increased by winding it with steel piano wire.

To keep a reserve of steam, and to have the steam free from particles of water, the boiler is kept only about two-thirds full of water, the upper space being filled with steam. Tò further insure dry steam at the engine the steam is led by a pipe from the top of the boiler down to a superheating coil directly over the burner.

Fusible Plug. As a warning against too low water the side of the boiler is provided with a fusible plug, held in a fusible-plug tube which, in turn, screws into a steel fitting. The elbows on this fitting are made on a taper and are driven into two short tubes in the boiler. As long as the water level is above these tubes the circulation prevents the plug from melting. If the water gets below the plug and about 3 inches from the bottom of the boiler, the plug will melt and the noise of the escaping steam wfll warn the operator of the danger—not danger of an explosion of the boiler, but danger of doing the boiler damage by heating it without water. There are other means by which the operator may know that the water is getting low before it gets low enough to blow out the plug, and these will be taken up in detail later, together with the causes of unexpected low water and other points.

The fusible plug may melt out, not only from low water but also because of dirt or something retarding the circulation of water around the tubes or fittings. The blowing off of the steam will usually remove the obstruction. If the escaping steam is dry, it is a sign that the melting has been caused by low water, but if it is wet the trouble is due to faulty circulation. It is good practice to replace the fusible plug once every two or three weeks, doing this when the boiler is cold.

Since the addition of the condenser to the Stanley in 1915, these boilers have been made without the fusible plugs. Among other improvements in these boilers is the brazing, or welding, of the tubes in the lower heads. This is to prevent any trouble from oil, which might be carried over into the condensing system. Before the boilers are turned out from the factory, they are tested by a water pressure of from 1500 to 1800 pounds per square inch.

Water-Tube Boilers. Water-tube boilers also are made up of tubes, but in this case the tubes carry the water and steam *inside* and the fire and hot gases pass over the tubes. The metal hood over this type of boiler carries no pressure, but merely serves to keep in and direct the hot gases. In stationary practice the tubes are often straight or only slightly bent, but to economize space the automobile boiler has the tubes coiled to give the most surface to the fire in the least possible space.

Ofeldt. The Ofeldt safety water-tube boiler, Fig. 39, is built about a central standpipe of 5 inches or more in diameter, with a bottom of ½-inch metal welded in. Threaded into the upper end of the standpipe is a steel cap with three arms, to the ends of which the sheet-metal hood, or cover, is fastened.

Fig. 39. Ofeldt Safety Water-Tube Boiler

The object of the standpipe is to hold a reserve of water at the bottom and of steam at the top, and to distribute the water to the coils. In the coils and standpipe the reserve of water varies from 3 gallons in the small sizes to 8 gallons in the 24-inch size.

Water is fed to the bottom of the standpipe, from where it flows into the coils. As it passes up the coils it turns into steam. A pipe from the center of the standpipe carries the steam down to the superheater, which lies under the boiler directly over the burner, as shown in Fig. 39. From the superheater the steam is carried by the second straight pipe back to the top of the boiler and then to the engine.

These boilers are supposed to supply steam at 250 pounds pressure but are tested up to 1000 pounds per square inch.

Doble. Almost as great a departure from ordinary practice has been made in the Doble boiler as in the combustion system previously described. The generator is of the water-tube type, with the tubes arranged in rows, which are really separate sections, Fig. 40. There are 28 of these sections in the generator part of the boiler. The tubes are made from seamless drawn-steel tubing of about $\frac{1}{2}$-inch diameter and are swaged down to a diameter of about $\frac{3}{8}$ inch at the ends. These ends are welded into the top and bottom headers, thus making each section a continuous piece of steel.

Besides the 28 sections of tubes in the generator portion, there are 8 more sections in the economizer or feed-water heater. The

Fig. 40. One Section of Doble Boiler
Courtesy of General Engineering Company, Detroit, Michigan

arrangement of all these sections is clearly shown in Fig. 41, the view being cut across each of the 36 sections, similar to Fig. 40. The picture does not show all the details but has been arranged to give an idea of the general layout and the direction of flow of the hot gases and of the water and steam. The boiler sections are completely covered over, except at the bottom, by a $\frac{3}{4}$-inch wall of heat-resisting and insulating Kieselguhr material. Over this is a planished iron jacket.

All of the sections are connected together by headers, which run along the sides of the boiler. One of the features of the construction is that if anything should go wrong with a section of tubes, it can be very easily cut out of operation by means of the side headers, until such time as it is convenient to replace the section.

In Fig. 41, the direction of flow of the hot gases of combustion is shown by the heavy arrows, while the flow of the water and steam is indicated by the small arrows. From the combustion chamber at the bottom of the boiler, the gases pass upward and then over the top of the fire wall between the generator proper and the economizer. Here they turn and pass downward in order to escape through the

Fig. 41. Section through Doble Boiler, Showing Combustion Below and Economizer Section at Right

exhaust at the bottom. It should be noted that the power-driven feed pump forces the water in an upward direction in the economizer tubes, exactly opposite to that of the gas flow outside of the tubes.

From the top headers of the economizer sections, the water overflows through a manifold to the lower headers of the generator sections. An automatic valve controls the feed water, so that the water in the boiler, under normal conditions, stands about half-way to the top. On the road, the usual pressure is around 600 pounds per square inch, which is maintained by an automatic valve controlling the fuel supply. Each section of the boiler is tested to a water pressure of 5000 pounds per square inch. The actual bursting pressure is said to be over 8000 pounds. As a precaution against any danger, however, a safety valve is attached to the boiler.

Flash Boilers. Flash boilers differ from the fire- or water-tube types, both of which have a reserve of steam, in that the steam is generated only in the quantity demanded each moment by the engine. These boilers consist of a continuous metal tube in one or more coils lying over the burner. As the water from the reservoir passes along the tube it gets hotter and hotter until at some point in the tube it bursts into steam. During the rest of its travel the steam is superheated.

As practically no steam is kept in reserve, the capacity of the boiler and burner must be great enough to supply at once the maximum demand for hill climbing. The relations of water and fire must be nicely balanced at all times to prevent too much superheat on one hand and wet steam on the other.

Safety against a dangerous explosion is the leading argument for the flash type of boiler. Since there is no reserve of steam or hot water under pressure, there is no large amount of energy to be liberated in case of a rupture of any part of the boiler.

Serpollet System. In the early days of steam automobiles a Frenchman named Serpollet reduced the amount of water in a boiler to an extremely small amount. To give the maximum of heating-surface area together with a minimum of cross-sectional area, the tubes were made a U-section instead of circular; this type, however, was abandoned later.

With the Serpollet system the fuel and water were fed simultaneously, one lever varying the strokes of both pumps. To avoid trouble from extreme superheat, single-acting pistons and poppet valves were employed. The valve cut-off was variable and worked in conjunction with the fuel and water supplies. Since there was no reserve of energy to the system, it took a great deal of skill to handle it smoothly, especially in hilly country.

White. A great improvement over the Serpollet system was the flash generator of the White Company. Although the White steam cars were discontinued in 1911, they were the leading example of the flash system in this country.

In the White generator there was a sufficient supply of water to serve as a reserve in cases of sudden demand. Referring to Fig. 42, it will be noted that the boiler was made up of several rows of tubes, each coiled in a horizontal plane, and each connected to the row below by a tube which first passes to the top of the boiler. Unlike the ordinary fire-tube or water-tube boilers, the water entered the White boiler at the top, through the pipe *128*. The upper coil was in the coolest portion of the gases from the burner. After passing through the top coil, the water flowed through the tube at the end of the coil, being carried up and over the top of the boiler and then down to the second coil, and so on down from coil to coil. Being nearer the burner, each coil was hotter than the one above, and,

Fig. 42. Generator, Burner, and Fuel Connections Formerly Used on White Steam Cars

since the vertical pipes at the ends of the coils kept the hot water from circulating back to the coil above, there was some point in the lower coils where the water burst into steam. The steam became superheated during the remainder of its travel through the coils and left the boiler by the pipe *129*.

These principles of construction were held to in all the White steam cars from 1904 to 1911 inclusive. Because of the strength of the small-diameter tubes and the small amounts of steam and water in the boiler at any one time, it was possible to carry a working pressure in these generators of 600 pounds per square inch.

Special Types. *Lane.* The Lane boiler, Fig. 43, was a combination of the fire-tube and flash systems. The main part of the boiler was of the fire-tube type, with very large tubes. Above this were several coils of brass tubing, the water entering the top and getting hotter as it passed down the tubes until it was partly converted into steam by the time it passed into the main part. The water was here separated from the steam, falling to the bottom of the boiler, while the steam was superheated by coming in contact with the hot upper portion of the fire tubes.

Fig. 43. Lane Boiler

National. For the National London busses a water-tube boiler is used, and these stand a great deal of abuse, often being run dry by the carelessness of the drivers. As is shown in Fig. 44, these boilers are built around a central steel drum, which is pressed from a single piece of metal.

Fig. 44. Water-Tube Boiler Used on National London Busses
Courtesy of Society of Automobile Engineers, New York City

BOILER ACCESSORIES AND REGULATION

Besides the main units of burner, boiler, and engine on the steam automobile, there have to be many other small units, most of them automatic in their operation, for the control of the fire, water feed, and engine to meet the conditions of the wide variations in road and driving conditions. These are the power pumps, the hand pumps, valves, feed-water heater, condensers, and others.

Check Valves. In the lines where it is desired to have the fuel, water, or steam pass in but one direction there are placed valves which allow only this one-way passage and are known as check valves. There are several types, including poppet, hinged, and ball checks. The latter, Fig. 45, is very largely used and consists of a ball which rests on a seat forming a ground, fluid-tight joint. When the fluid is passing in the desired direction it lifts the ball off the seat. The body of the valve is so made that it keeps the ball from being carried on down the line with the fluid. As soon as the direction of flow or pressure changes to the opposite direction the ball drops onto its seat, closing the valve against this opposite flow.

Fig. 45. Crane Ball Check Valve

Check valves are used in many places in the fuel, water, and steam lines, as is indicated by the diagrams further along. For instance, there are check valves on the inlet and outlet sides of the water pumps. When the piston is on the suction stroke, the inlet check is open while the outlet check is closed, keeping the water already pumped from being drawn back. As soon as the piston starts on the delivery stroke the inlet check closes and the outlet valve opens. This action applies to all the types of check valves.

If dirt lodges on the seats of a check it will leak and, if the dirt cannot be forced off by vigorous action through the valve, the valve must be opened up and the seat cleaned and possibly ground. In most check valves this can be done without removing the whole valve from the line.

Fuel System. Considerable fuel-carrying capacity is always provided in automobiles, and for this reason there should always be enough in the car for more than one run. Before starting out it is always well to see that there is plenty of fuel in the main and pilot supply tanks. Not only is running out of fuel on the road very inconvenient, but the running-dry of the tanks may air-lock the pumps and cause a loss of considerable extra time in getting the

Fig. 46. Power Pumps of Stanley Engine

system back into smooth action. The above applies equally well to the water supply.

As mentioned in the section on burners, the fuel is fed under pressure. In some cases the pressure is carried on the main tank, while in other cases it is carried by air or spring pressure on small auxiliary tanks. The power and hand pumps on steam cars are of the plunger type.

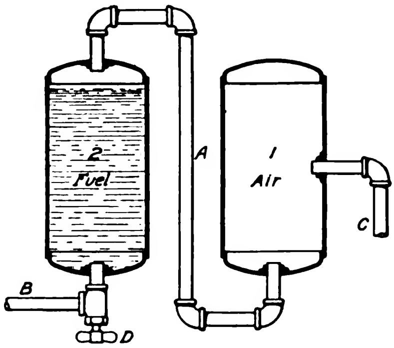


Fig. 47. Fuel Pressure Tanks on Stanley Cars

Due to the interrelations between the demands for steam, water, and fuel and the automatic devices, one controlled by the other, it is difficult to deal separately with the various units. For this reason one complete fuel, water, and steam system will be discussed and then descriptions of other makers' units and methods of operation will be taken up. The Stanley system will be used to show the relation and operation of the various units.

Stanley Fuel, Water, and Steam Systems. *Fuel System.* On the Stanley cars the main fuel tank is carried under atmospheric pressure and the fuel is drawn from the tank by the power-driven pump, Fig. 46. In series with the power fuel pump is a hand pump for use when the engine is not running or if the power pump should be out of order. The *small pressure tanks* on the Stanley are shown in Fig. 47. The fuel does not flow through the left tank, marked *2*, but merely rises and falls in it, the tank acting as a pressure equalizer between the strokes of the power pump, similar to the standpipe in many city waterworks systems. Tank number *1*, on the right, is filled with compressed air, which is supplied by the power-driven air pump or by the hand air pump. A pressure gage on the dashboard shows the operator what the pressure is on the tanks. From the auxiliary tanks the fuel passes to the vaporizer.

Fig. 48. Stanley Gasoline Automatic Valve

Since the fuel power pump has a capacity greater than that usually demanded by the burner an *automatic by-pass valve*, called the fuel automatic relief, Fig. 48, is placed in the line. When the fuel from the pump is at a higher pressure than is being carried on the

Fig. 49. Stanley Fuel System
Courtesy of Stanley Motor Carriage Company, Newton, Massachusetts

pressure tanks, the needle valve of this fuel automatic relief is raised and part of the fuel is returned to the main tank, as shown in the layout of the fuel system, Fig. 49.

Should this needle valve fail to seat properly, it is probably due to dirt between the needle and the seat. This can often be removed by taking the tension off the spring by unscrewing the adjusting nut and then pumping fuel with the hand pump. If this does not cure the trouble the whole valve should be taken apart and cleaned and, if necessary, the needle ground into the seat.

Beyond the pressure tanks there is a *fuel filter* which should be watched for leaks and cleaned every once in a while. Near the tanks is also a pressure-retaining valve, which may be closed by hand when the car is left standing, the purpose being to keep the pressure on the tanks, as it might otherwise be lost, due to slow leaks in the lines, and thereby necessitate the pumping-up of pressure by hand.

Actual fuel supply to the vaporizer, and hence to the burner, is governed by the steam automatic regulator, or "diaphragm regulator", as it is sometimes called, Fig. 50. This regulator governs the relation between the steam pressure and the fuel supply to the burner. It consists of a metal diaphragm, clamped between the cap and the body. When the steam pressure rises above the predetermined amount, the pressure against the diaphragm causes it to bulge and thus move the rod attached to it so as to keep the ball valve from leaving its seat, thereby shutting off the fuel to the boiler.

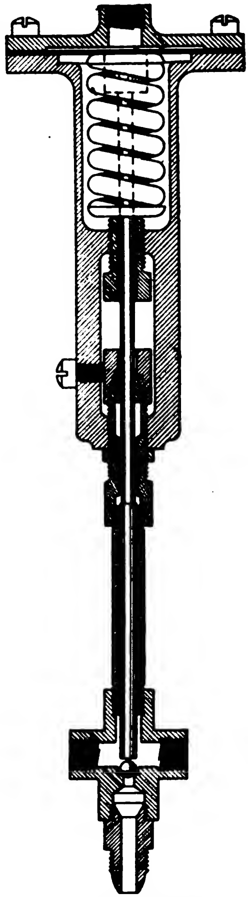


Fig. 50. Stanley Steam Automatic Valve

The strength of the spring determines at what steam pressure the fuel is shut off. To regulate the strength of the spring the adjusting screw is moved in or out. The valve stem is provided with a stuffing box which can be tightened up to stop leaks through the gland. The screw locks the gland in place after the adjustment is made. Care must be taken not to get the gland too tight.

Upon the older Stanley models, in which gasoline was used for the fuel of the main burner as well as for the pilot light, the line for the latter was a branch of the main fuel line. In the newer models, the pilot system is entirely separate, so that kerosene may be used for the main burner. The pressure on the separate gasoline tank is pumped up by a hand pump and should be kept at from 20 to 30 pounds per square inch. In leaving the pilot burning over night the pressure will not fall over 5 to 10 pounds.

Water and Steam System. From the main water tank the water is drawn by two opposite *power-driven pumps,* Fig. 46, and follows the course shown in Fig. 51. A *hand pump* is also provided for use

Fig. 51. Diagram of Stanley Water System
Courtesy of Stanley Motor Carriage Company, Newton, Massachusetts

when the car is standing still or in case of a failure of the power pumps. Beyond the pumps are by-pass valves, the opening of which allows the water to return to the supply tank. The rear by-pass is operated by the usual type of handle, while the one in front is controlled by a lever on the steering post. The handling of these by-pass valves will be taken up in relation to the general operation of the car.

On the way to the boiler, the water passes to the water-level indicator, which is explained in detail in the following paragraph, and then to the *feed-water heater.* Over the water pipes in the feed-water heater the exhaust steam from the engine is passed. In this way much of the otherwise waste heat of the exhaust is given back by heating the water before it reaches the boiler, resulting, of course, in a saving of fuel. The feed-water heater also serves as a muffler for the sound of the engine exhaust.

The *water-level indicator* is for the purpose of showing the operator the amount of water in the boiler. It consists of three tubes, Fig. 52, *M*, *N*, *O*, which are brazed together. The middle one *N* is a part of the water column, that is, its lower end connects with a pipe leading

Fig. 52. Diagram Showing Stanley Low-Water Automatic Valve with Three-Tube Indicator Body

to the bottom of the boiler and its upper end is in communication with the top of the boiler, so that the water stands in this column at the same height that it does in the boiler. At the lower end of tube *N* is the low-water try cock.

Tube *M*, at the left, is part of the water system from the pumps to the boiler and, when the car is running, water is constantly passing through it. The standpipe *O* is closed at its upper end and at its lower end is connected by a copper tube to the glass water glass on the dashboard in front of the driver. The standpipe, tube, and glass form a U-tube which is filled with water, the level of which, when cold, stands about an inch above the bottom of the glass.

If the water level in the boiler, and therefore in the tube *N*, is above the top of the standpipe *O*, the cold water passing through *M* on its way to the boiler will keep the standpipe *O* comparatively cool, and the water in the glass will show about an inch above the bottom; but if the water in the boiler falls below the top of the standpipe, it will no longer keep cool and the resulting heat will turn some of the water in the standpipe into vapor. Since the end of the standpipe is closed, the pressure of the vapor will cause the water in the glass to rise, showing the driver that the water in the boiler is getting low.

It is important to remember that when the water is *high* in the glass it is *low* in the boiler. It should also be noted that the glass gives the correct reading only when the car is running, and that when the boiler is cold the water in the glass will be at the bottom whether the boiler is full or empty. A false reading of the glass may also occur from the heating-up of the indicator body when the car is left standing with steam up. This will make the water rise in the glass, apparently showing the water to be low in the boiler even though it were full. Directly upon starting the car, water will be pumped through tube *M* and the indicator body will cool down, giving a correct reading in the glass.

To fill the standpipe, U-tube and glass with water, the plug is removed from the top of the standpipe and water is poured into the glass faster than it can flow out of the standpipe. When all the air has been forced out in this way, the screw is replaced while the water is still running, but is screwed down only lightly. The water is then shut off and, when the level in the glass has gone down to about an inch above the bottom, the screw in the top of the standpipe is tightened up.

In freezing weather an anti-freeze solution should be used in the U-tube and glass. This can be made of equal parts of glycerine and water or of alcohol and water. A test of the indicator can be made when steam is up by opening the low-water pet cock until the water rises in the glass and then pouring cold water over the body of the indicator, which should cause the water in the glass to fall.

When the boiler is cold the amount of water in it is determined by opening the low-water pet cock. If water flows it shows that there is enough in the boiler to allow firing up. If no water comes and a wire run in the pet cock shows that it is not stopped up, water should be pumped in the boiler by hand. When trying the water level by the pet cock the water should be allowed to run several seconds so as to be sure that it is not merely the condensation which may have gathered.

If dirt or incrustation should stop up the lower end of the water column, it would cause false readings of the indicator and try cock. It is therefore important that this be guarded against by *blowing down* the boiler regularly. The procedure in blowing down will be referred to later.

Another protecting device of the Stanley is the low-water automatic valve, which in its action and location is closely connected to the water-level indicator. The purpose of this valve is to shut off the fuel supply in case the water becomes low in the boiler. As shown in Fig. 50, it consists of a valve *B* in the fuel line, an expansion tube *D* and two rods *C*, the latter forming a framework or support.

When the water in the boiler and water column gets below the try cock, the expansion tube *D* fills with steam and the heat of this steam causes the tube to become longer. This expansion moves the valve stem *E*, connected to the end of the tube, and this closes the valve, shutting off the fuel to the burner.

In case the low-water automatic valve closes, first make sure that there is water in the main tank, and that the pumps are working properly. Then with both by-pass valves closed run the car as far as it will go. By this time the pumps probably will have delivered enough water to cover the bottom of the expansion tube, allowing the fuel valve to open again. If not, the engine can be run with the wheels jacked up or water can be pumped by the hand pump.

There are four other accessories to the Stanley and other power plants, which have not yet been mentioned: the safety valve, steam gage, siphon, and oil pump.

The *safety valve* is connected to the boiler and will blow if the steam pressure exceeds the amount for which the valve is set. The *steam gage* is placed on the dash and indicates the steam pressure in pounds per square inch. The steam itself does not actually enter the gage, but the pressure in the system is communicated to the gage by means of a tube filled with oil, which will not freeze in winter.

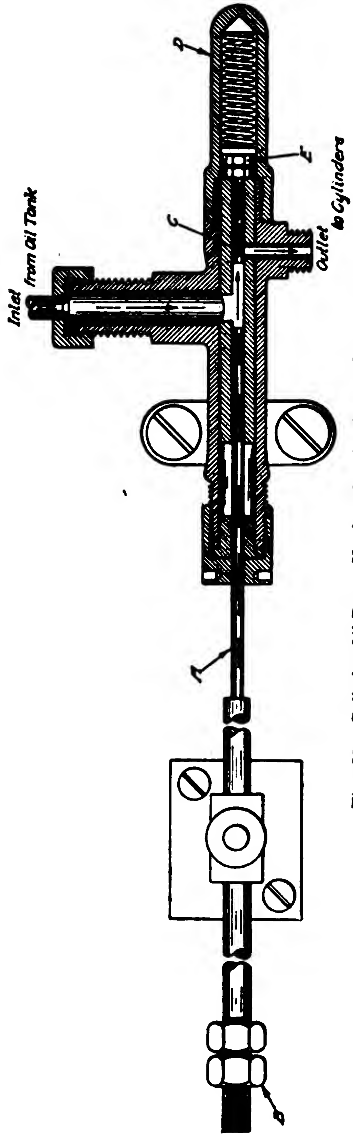


Fig. 53. Cylinder Oil Pump Used on Stanley Steam Cars
Courtesy of Stanley Motor Carriage Company, Newton, Massachusetts

When it is desired to draw water from a water trough or some other place from which it cannot be run into the tank from a faucet, the *siphon* is used. This is a hose, a branch of which is connected to the steam system by a hand valve. One end is placed in the tank-filler opening and the other end, which is provided with a screen, is put in the supply of water. The steam is turned on and, due to an injector action, draws the water up into the tank.

Driven by the same mechanism which drives the Stanley fuel and water pumps, is the *oil pump*, Figs. 46 and 53. From the oil tank the pump forces the oil through the sight feed on the dash, from which it is led into the steam line to the engine.

In the oil pump, Fig. 53, the plunger *A* is set in its extreme foreposition, so that the end will just come to the outlet. This is done by removing the delivery stub cap and delivery check ball and inserting a small wire in the outlet. When the driving crosshead is in the extreme position, the plunger should come to a point where it will strike the wire; the lock nut *B* is then tightened. This adjustment should be looked to if the position of the driving crosshead becomes changed.

To vary the amount of oil pumped, the distance between the end of the adjusting piston *C* and the pump inlet is varied. The shorter this distance the less the amount of oil pumped. The adjustment is made by removing the cap *D* and adjusting the set nut *E*. If the oil tank is allowed to run dry the pump may become air-locked, and it is then necessary to disconnect the copper pipe and work the pump until the air is expelled.

All ordinary steam-cylinder oil is not suitable for use in these engines because of the high degree of superheat. The Stanley Company recommend either the "Harris superheat steam-cylinder oil" or the "Oilzum high-pressure superheated steam-cylinder oil". Other makers recommend different classes of oils best suited to their particular engines and these will be noted later.

Now that a general idea of the make-up and operation of the power-plant accessories has been given in the description of the Stanley layout, attention will be turned to the characteristics of the accessories offered by other makers.

Doble. The details of construction of the Doble combustion chamber and boiler have already been shown in Figs. 35 and 41, and discussed on pages 34 and 40. The water level in the boiler is kept at the half-way point by an automatic by-pass valve, which is operated by the expansion of a regulator tube. As the water rises in the boiler, the tube is filled from an outside pipe with comparatively cold water. The decided change of temperature causes the tube to contract again, and the water is by-passed to the supply tank. The steam pressure is maintained around 600 pounds by another automatic device, which controls the fuel system.

From the upper headers of the generator sections, the live steam passes into a manifold which leads it through the throttle valve and then to the engine. From the engine, it passes back to the condenser, being forced along by the following steam.

A non-rusting alloy is used for the seats of the throttle valve. The valve, shown in Figs. 28 and 29, is a compound design, being a combination of a poppet and piston valve. The piston portion regulates the flow of steam, while the poppet serves to keep the valve in a tight, or non-leaking, condition.

The force of the steam constantly coming from the engine causes the steam to pass from the top to the bottom of the radiator condenser and, under normal conditions, the steam has been completely condensed to water before it reaches the bottom. This water of condensation enters the water tank very near the bottom, so that any steam which still remains will be condensed as it bubbles up through the tank. Rapid acceleration from a slow speed or very hard slow pulling are the two conditions under which some steam may remain uncondensed in passing through the radiator. As a safety measure, in case of a very long stretch of slow heavy pulling, the water tank is provided with a vent at the top. With this condensing system, it is said that a car will run 1500 miles on one filling of water.

Doble Lubrication. Another one of Doble's departures from standard steam-automobile practice is in the matter of lubrication. The throttle, engine valves, cylinder walls, water pumps, and interior of the generator are all lubricated by regular gasoline-engine oil instead of the heavy steam-cylinder oil used in power plants.

This comparatively light mineral oil at once forms an emulsion with the water, due to the shaking up from the roughness of the road and the agitation of the feed water as the condensation enters the tank from the radiator. The oil, therefore, is sent into the generator along with the feed water and gives the interior of the tubes a very thin coating of lubricant. How thin this is may be judged by the statement that the generator temperature is 485° F. at the working pressure of 600 pounds. This coating not only prevents the tubes from rusting, but keeps scale from forming as it cannot stick to a greasy surface. The oil in the water also prevents scale from forming in other places and pipes, for it coats each particle of lime, etc., which may be thrown down and keeps it from sticking to any other particle and building up a deposit. It is this same oil that is carried over with the steam that lubricates the throttle valve and cylinder parts. The condenser saves the oil supply as well as the water, so that the lubricant is used over and over again, and a car is said to run 8000 miles on one gallon of oil.

Steaming Test. One of the main features claimed for the Doble design is the short length of time required to raise steam to a working pressure, that for ordinary running being 600 pounds per square inch. The following test was recently given out by the company.

The generator had approximately 150 square feet of surface and contained, when the water was at its normal level, 8½ gallons. Combustion started with the water in the generator at 66° F. The first trace of steam came in forty seconds.

Pressure lb. per sq. in.	Elapsed Time	Pressure lb. per sq. in.	Elapsed Time
Trace	40 sec.	700	3 min.
100	1 min., 20 sec.	800	3 min., 10 sec.
200	1 min., 45 sec.	900	3 min., 15 sec.
300	2 min., 10 sec.	1000	3 min., 20 sec.
400	2 min., 25 sec.	1100	3 min., 25 sec.
500	2 min., 40 sec.	1200	3 min., 30 sec.
600	2 min., 50 sec.		

Ofeldt. *Fuel, Water, and Steam Connections.* Fig. 54 gives a clear idea of the fuel, water, and steam connections of the Ofeldt

Fig. 54. Diagram of Connections for Ofeldt Boiler Feed and Fuel Systems
Courtesy of F. W. Ofeldt & Sons, Nyack-on-the-Hudson, New York

system, the burner and boiler of which have been described previously. The feed-water pump *A* and the fuel pump *e* are usually on opposite crossheads of the engine, but to make the two systems clearer they have been separated in the diagram.

The Ofeldt Company makes these accessories either for use as a complete system, as shown in the diagram, or for use with other units. The company does not make a complete automobile.

An expansion tube *N* is the basis of the Ofeldt water regulator. This tube stands at right angles to the middle point of the boiler water column *P*, and when the water becomes low enough in the boiler and column for the tube to fill with steam, the expansion causes the closing of the water by-pass valve through the movement of the linkage *O*, *M*, *L*. When used with the Ofeldt water-tube boiler it is claimed that a water-level glass is unnecessary.

Fuel regulation is accomplished by the diaphragm valve, *w*. This is made up of two concave discs with a steel diaphragm fastened between them. Combined with the upper disc is the valve controlling the fuel supply. When the steam pressure on the lower side reaches the point for which the valve has been adjusted, the diaphragm pushes upward, shutting off the fuel. Upon the decrease of the steam pressure, the natural spring of the diaphragm again opens the fuel valve. Where used with a pilot light the closing of the valve completely shuts off the fuel to the main burner, but where no pilot is used just enough fuel is allowed to pass to keep the fire burning.

Automatic Fuel Feed. Possibly the most interesting of the Ofeldt accessories is the automatic fuel feed *i*, in which a spring is used to keep the fuel under pressure. It consists of a brass cylinder, 18 to 36 inches long and 4 inches in diameter, which is plugged at one end and capped at the other. Running the length of the cylinder is a coil spring with a piston at one end. The engine fuel pump *e*, or hand pump *d*, forces the fuel into the tank, pushing back the piston and compressing the spring. This spring keeps the pressure on the fuel the same as is done by the air tanks in the Stanley system. As part of the pressure layout is a safety or by-pass valve *J*, which can be set for the desired pressure on the fuei, the excess fuel from the by-pass valve and from the leakage past the piston in the regulator are returned to the fuel tank.

MANAGEMENT AND CARE OF STEAM CARS

In the preceding description considerable has been said as to the management and care of the units, but in this section some further hints will be added on the operation of steam automobiles.

Management on the Road. As will be understood from the foregoing, the operator's part in managing the power plant—other than attention to the throttle—is ordinarily limited to watching the water-level indicator and managing the by-pass valve—if not automatic—in accordance with the water level. When the level drops, the by-pass valve must be closed, thereby causing all the water pumped to enter the boiler. When the water level exceeds the proper height, the by-pass valve is opened and water ceases to enter the boiler. It is not practicable to open the by-pass valve part way, as this would cause the water to go through the valve at boiler pressure and, in time, the scouring action due to the pressure would make the valve leak.

Blind adherence to the above rule will not always give as good results as may be obtained through manipulation. For example, if one sees a hill ahead, he can fill the boiler somewhat higher than its usual level and give the added water time to get hot before the hill is reached. This affords a reserve supply for surmounting the hill. In the average hilly country, one can make a practice of pumping water on down grades when little or no steam is being used and the heat of the fire is available to heat the incoming water. Near the bottom of the hill the by-pass valve is opened and the ascent taken in good style. If the accumulated pressure has caused the fire to shut off, the throttle may be opened just before the bottom of the hill is reached, and the drop in pressure will bring the fire on while impetus is being gained. It is a general rule for all classes of steam cars that *the fire should, if possible, be "on" before an up grade is begun.* By proper management the fire may be kept burning continuously in a hilly country, while power is used only on the up-grades.

In applying the above principles it should be remembered that only the wetted inside surface of the boiler is available for making steam. If the water is low, steam cannot be raised as rapidly as when the boiler is full, assuming that the water is hot in both cases. On the other hand, if the boiler is worked too full one may get wet steam despite the superheater, with loss of power due to condensation. In an extreme case, enough water might even be carried through to choke the clearance spaces at the cylinder ends. This would probably result in a head being knocked out or a connecting rod or crank bent, as the water could not be ejected quickly enough by the lifting of the slide valve to save the engine from severe shock when the piston reached the end of its stroke. A boiler of the Lane type, in which the water is partly converted into steam in coils above the boiler proper, and in which the fire tubes are large enough to permit combustion to take place inside of them, is an exception to the above, in that superheating takes place chiefly in the "boiler".

The more rapidly fuel is supplied to the burner, the hotter will be the fire. Where ample power is desired, therefore, the burner is worked under more than ordinary pressure. In the Stanley cars, which carry pressure only in the auxiliary tank, 120 to 140 pounds is recommended.

Firing-Up. The following remarks apply particularly to cars with the Stanley type of burner and boiler. In the case of the Doble car, the constructions are so different that many of the instructions will not apply. The Doble system has been described in detail in the preceding pages, and the reader is referred back to these paragraphs for the firing-up of the boiler, etc. As will be explained later, it is customary at the end of a run to *blow down* the boiler for the purpose of ridding it of whatever sediment may be present. The blow-off valve is shut when a few pounds of pressure still remain, and the condensation of this remaining steam should suck the boiler full of water, *provided* the by-pass valve is closed. The presence of this water is desirable to protect the superheating coil when the fire is started. Therefore, if the car has a conventional fire-tube boiler with superheating coil beneath, the first step is to ascertain whether the boiler is actually full. Close the by-pass (if open), open the upper try cock, and if no water comes out, work the hand pump. See that the water tank is full. Open the throttle and the drip valve on the steam chest and continue pumping by hand till water comes out. Leave them open while starting the fire, to allow the water to expand.

If there is no pressure in the fuel tank, pump it up to the minimum working pressure by hand. Heat the pilot, either by burning gasoline in a cup, by an alcohol wick, or by the modern acetylene torch, as the case may be. When thoroughly heated, slowly open the pilot-light supply valve. If a blue flame does not result, close the supply valve and admit more gasoline to the cup.

After starting the pilot light, allow it to burn till the vaporizer is hot, then open the main-burner valve carefully. If it fires back into the burner, shut it off, wait a minute or two and try again. Turn the burner to full height gradually. If the flame is yellow or smoky, it is not getting enough air; if it is noisy and lifts off the burner, it is getting too much air. Once adjusted for a given fuel pressure, the nozzle or air shutter should not need changing.

While the water is getting hot, the oiling up can be attended to. As soon as the pressure begins to rise, water will issue from the drip cock on the steam chest. Close this cock and the throttle valve as soon as clear steam comes out.

When pressure reaches 100 or 200 pounds, get into the car, throw the reverse lever to its full forward or backward position, open the throttle slightly and then close it at once. Repeat till the engine starts. With some yards of clear way, work the reverse lever back and forth with the throttle open only a crack, so that the car "seesaws" slowly. This will work the water out of the engine and warm up the cylinders till the entering steam ceases to condense. This process must not be hurried. An attempt to cut it short is likely to result in damage to the engine. As long as water is present the engine will run jerkily. When it runs smoothly the car is ready to start.

On starting, the first few blocks should be run slowly to complete the warming-up process. If the air pressure is below normal the air pump should be kept going.

At the End of a Run. On finishing a run, the boiler should be blown down with the fire turned off. This should be done by opening the blow-off valve near the bottom of the boiler. The escaping water will carry with it all the mud and precipitate that have accumulated. Close the blow-off valve at about 100 pounds, and the subsequent condensation will fill the boiler by suction from the tank. If the water in the tank is covered with oil, the end of a hose should be inserted and the tank flushed out to get rid of the oil. It is a good plan to put a cupful of kerosene into the tank. It will not only loosen whatever oil may be clinging there, but will help loosen the scale liable to form from hard water.

A thermostat water-level indicator operates only when steam is up. When the boiler is cold it indicates high water whether water is present or not. When the car is running, a faulty reading of the water level is usually soon noticed, and if it is overlooked there is still protection of the fusible plug. If, however, the boiler should be fired up with no water in it, the fusible plug would melt without the fact being heralded by escaping steam. Therefore, the fusible plug, like the water-level indicator, is useful only when steam is up.

Engine Lubrication. For the older cars not using superheated steam, the regular power-plant steam-cylinder oil is usually recommended. This is a mineral oil mixed with tallow to make it hold on the wet cylinder walls. It often contains graphite. This type of oil will not stand the high temperatures of superheated steam, and special oils must be used. As an example, the Stanley Company has recommended either "Harris superheat steam-cylinder oil" or "Oilzum high-pressure superheated steam-cylinder oil". The Doble uses the same kind of gasoline-engine oil as is used by the ordinary motor-car driver. Other engines use different grades of oil to the best advantage, and it is best in each case to find out the maker's recommendations.

The Fusible Plug. If the fusible plug blows out when the car is running, the escape of steam may be shut off by closing a valve usually interposed between the boiler and the plug. The fire should be shut off at once and, if possible, the car should be run to reduce the pressure, thereby allowing the boiler to cool somewhat. When the drop in pressure compels a halt, close the by-pass valve and pump water in by hand till it shows in the lowest try cock. Then, after replacing the fusible plug, the fire may be relighted and the water level restored while the car runs.

If the plug blows simply because the by-pass valve has been open too long, the by-pass can be closed, the main fire shut off, and the engine run by jacking up the rear wheels, till water shows in the lowest try cock.

Causes of Low Pressure. Low pressure is generally due to insufficient fire. If the burner pressure is low, steam will not be made rapidly. If the burner pressure is all right, the burner nozzle may be clogged or the vaporizing tube may be choked with carbon. The nozzle may usually be poked out with a bent wire without turning off the fire. If, however, the vaporizer is clogged it will have to be removed when the car is cold and cleaned, with a drill or otherwise, as the makers direct.

Occasionally the valve controlled by the diaphragm regulator may be choked, and rarely the main-burner valve. Either can be cleaned by disconnecting and running a wire through.

Occasionally the pilot light may clog in the same way, usually at the nozzle. The remedy is the same as for the main burner.

If the air pump fails to raise the pressure on the fuel tank to the required degree, it is probable that the intake or outlet check valves leak. If, as is likely, they have oil on them, the oil may have gathered dust. The valves should be taken out and cleaned, and a drop of oil put on them to make them tight.

The various packings about the engine and auxiliaries require occasional tightening, and once in a while new packing is necessary. If the new packing is soft, like wicking, it may be put on top of the old, otherwise the old must be removed. The packing should not in any case be tighter than necessary to prevent leakage, for unnecessary friction would thereby be caused. A slight leakage about the water and air pumps may be permitted to save friction. As the hand pumps are rarely used their packings can be looser than those of the power pumps.

Scale Prevention and Remedies. In sections where hard water is used, the subject of scale is a serious one, and its treatment will depend on the character of the mineral contained in the water. Frequently it is possible to precipitate the mineral before putting the water into the tank. Sometimes the addition of a small quantity of lime will do this, sometimes carbonate of soda or "soda ash". Still other waters are successfully treated by adding caustic soda. Sometimes the simple addition of kerosene to untreated water will loosen the scale as above indicated. If these remedies are not successful, the user is advised to send a sample gallon of water to a maker of boiler compounds and have it analyzed, after which a suitable compound can be recommended. Scale allowed to accumulate by neglect is not only very detrimental to the boiler by interfering with the free flow of heat, but it also seriously reduces the steaming power. Instances have been known of the steaming capacity of boilers being reduced fifty per cent or more by scale. At the same time the shell and tubes get hotter than they should, resulting in unequal expansion and leakage.

Filling the Boiler. Before firing up, be sure that the boiler and superheaters are full. To be sure of this, open the throttle valve and steam-chest drip, close the by-pass valve and work the hand pump until water comes from the steam-chest drip. If more convenient fill the boiler from the town supply by means of the coupling furnished for this purpose, connecting to the blow-off valve. Never light the fire until you are sure that the boiler is full.

At the end of a run open the blow-off valve at the front of the boiler, and blow down to about 100 pounds. Fill the water tank and close the by-pass valve, and the condensing steam in the boiler will siphon the boiler full. Before blowing down, see that the pilot light is out, as well as the main burner. It can be extinguished by blowing into the pilot mixing tube.

Raising Gasoline Pressure. If the pressure tanks are empty and the pressure zero, proceed as follows:

Open the hand gasoline-pump valve and work the pump till the air gage registers 10 or 15 pounds. Tank 2, Fig. 47, is now full of gasoline, and tank 1 is full of compressed air. Attach the hand air pump to air valve and pump air into tank 1 till the gage indicates 80 or 90 pounds, which is the working pressure for the burner.

If now the fire is lighted and the car stands still, the pressure will gradually drop, but may be raised in a moment by working the hand gasoline pump. When the car runs, the power pump maintains the supply.

The air in tank 1 is gradually absorbed, and additional air is required. This is indicated, first, by the vibration of the air-pressure-gage needle when running; second, by a rapid drop of pressure when the car stands still. In case of doubt whether the drop is due to lack of air or to a leak in the automatic or pump valves, close the pressure-retaining valve. If the pressure still falls the air is insufficient.

Occasionally empty the pressure tank by opening valve *D*, and refill in order to determine definitely the amount of gasoline in it.

If the car is to stand some time with pilot burning, close the pressure-retaining valve to prevent the gasoline from leaking back through the valves and automatic. Be sure to open again on starting.

General Lubrication. On page 60, are mentioned the different grades of oil suitable for cylinder lubrication in the various types of engines. The lubrication of the cylinder walls and valves, however, is not the end of the subject, for, wherever there are two moving surfaces in contact, there must be lubrication in order to keep the friction losses at a minimum. Useless friction in the running parts of the engine and chassis of the car means an increased consumption of fuel. This, however, is often of secondary consideration in comparison with the wear and resulting repair bills, often caused by lack of lubrication. When a bearing becomes dry, it usually heats up and expands, and in case this is continued to the point of "freezing", the car may be completely disabled on the road.

Of course all parts of the car do not have the same amount of motion and, therefore, do not require the same amount of lubrication. All makers of cars issue instruction books for each model and, when possible, the operator should provide himself with a copy and follow the oiling instructions. This, however, is often impossible, and it is then a matter of good judgment based on the known requirements of other cars. Outside of the power plant there is no particular difference between the construction and care of a steam- and a gasoline-engine driven car, and the lubrication chart of any of the later makes can be safely followed.

In the modern Stanley and Doble types, the crankshaft, cross-head, and other moving engine parts, other than piston, together with the rear-axle bearings, are all lubricated by splash, the crankcase being thoroughly oil-tight. The level of this oil should be inspected every two months, although it will probably not need renewing that often. Some of the older cars require that the eccentric be given a squirt of oil daily, by a hand gun. It is a good habit to give all grease cups a turn-down each day.

Water Pump. If the water pump fails to work, first see if the tank is empty. In addition to this there are three other causes to which failure is mainly due, viz, (1) *The pump may be air-bound.* To remedy, open the by-pass valve and run the engine. The air will work out readily, since there is no pressure against it. (2) *The check valves may leak.* There are three check valves, one on the pump intake, another on the outlet, and the third at the boiler. The intake valve is the most likely to leak. Remove the valve cap and clean the valve ball and its seat, being careful not to scratch them. If the boiler check valve is leaking, it will permit steam to escape into the water tank when the by-pass valve is open. This valve can only be examined when there is no pressure. (3) *The pump packing may leak.* Tightening the packing nut generally suffices, but occasionally repacking is necessary. Do not screw the packing nut tighter than is necessary, as it causes needless friction; a slight leakage may be tolerated. In case the power pump fails, use the hand pump, first running with the main fire off till the pressure is reduced to about 100 pounds. After pumping, close the valve with the pump plunger in.

Gasoline Pump. In most respects the gasoline pump resembles the water pump. If it becomes air-bound, it can be primed by using the hand gasoline pump, which is much larger and, drawing through the power pump, will suck out the air.

The gasoline pump packing should not leak at all, as it is both wasteful and dangerous. The pump is so small that adjusting is seldom needed.

If the hand gasoline pump becomes air-bound, unscrew the valve, which is open when the hand pump is used, till it comes out. Press the thumb over the valve-stem hole when the pump plunger is pulled out, and lift it off when the plunger is forced in. Repeating this several times will expel the air.

If the hand gasoline pump and hand water pump work together, the packing nut on the gasoline pump should be just tight enough to hold the gasoline, and the water pump should have its packing so adjusted that the pump will run perfectly free.

To pack the gasoline pump, put in first a thin leather washer, then three of the special packing rings supplied by the makers, then another thin leather washer, and screw the stuffing-box nut only hand tight. Do not use a tool to tighten it, otherwise the plunger will cut out the packing.

Care of Engine Bearings. If the engine is regularly lubricated the bearings will seldom require adjustment. If the bearings show the slightest discoloration from rust they have been insufficiently oiled. Adjustments are made as follows:

The crosshead guides are taken up by screwing down the nut on the bolt holding the frame rods together. The crosshead balls must be under sufficient pressure to keep them from slipping.

The wrist pins are taper and are adjusted with a screw held by a lock nut. First loosen the lock nut, turn up the screw till it stops, then back it one-eighth turn and tighten the lock nut.

The crankpin ball bearings are adjusted by removing the bolt, taking out the plug, and reducing it slightly by filing. When correctly adjusted the bearings should have no perceptible play.

The main bearings and eccentrics can only be adjusted after the engine is taken out of the car. They are adjusted to take up lost motion by filing or grinding down the face of the bearing cap, which must be very carefully done.

Be sure the engine-frame hangers are properly adjusted. Should the nuts work loose, the front end of the engine will sway, to the damage of the engine case and gears. In adjusting the engine-frame hangers do not set them up so tight that they will not swivel around the rear axle. If necessary insert shims of paper or thin brass, removing the rear engine case to gain access.

Operating the Cut-Off and Reverse. In the more recent Stanley cars the cut-off is variable from one-quarter to one-half stroke. On the engine is a quadrant from which the reverse lever works in connection with the reverse pedal. The quadrant has one notch, into which a dog attached to the reverse lever drops when the engine is "hooked up", that is, operating on short cut-off. To hook up the engine, press on the reverse pedal only. To release the dog, press a pedal beside the reverse pedal, called the *clutch pedal*. This releases the reverse pedal and a spring pulls it back, allowing the engine to cut-off at half-stroke. The car should always be started with the reverse pedal released, and the cut-off should not be shortened until the engine attains good speed. If it operates jerkily, release the reverse pedal by pressing the clutch pedal.

Care of the Burner. If the car does not steam well, look at the fire first. See that the gasoline pressure is not below 100 pounds.

If the pressure is right, the gasoline line may be clogged in the automatic valve, vaporizer, burner nozzle, or main-burner valve. If the burner has two mixing tubes, see if both sides are affected; if so, the trouble is probably in the automatic valve. If the two burner flames are unequal, the trouble may be in the vaporizing tubes or the nozzle, more likely the latter. Clean the nozzles by running a small wire through them with the screw out, or by using a bent wire without removing the screw.

If the vaporizing tubes are clogged, uncouple at the back of the burner, take out the bundle of wires from the tubes, and clean the tubes and wires thoroughly, using the bundle as a swab. Extinguish all fire before beginning.

If the pilot-light nozzle becomes clogged, use a screwdriver to turn the horizontal nozzle screw back and forth. A wire projects from this screw through the nozzle orifice and turning the screw causes the wire to clean the nozzle. Do this only with the pilot burning.

To regulate the air received by the pilot, bend the pilot vaporizer tube slightly away from the mixing tube for more air, or inward for less air. The pilot should burn with a blue flame slightly tinged with yellow, and may be adjusted while lighted.

Never use a reamer for cleaning either the pilot or main-burner nozzle, as it is likely to enlarge the hole, which is that of a No. 62 drill.

Sometimes after the automatic valve closes, the gas pressure at the nozzles will reduce gradually, causing the burner to light-back. When next the automatic valve opens, the fire will burn inside the mixing tubes with a roaring sound. This sound should be the instant signal for closing the main-burner valve and allowing the mixing tube to cool.

If the burner should fire back frequently and with a sharp explosion, it would indicate either a leak in the burner or a leak of steam in the combustion space. To test for a steam leak, first get up steam pressure, then take off the burner and examine the boiler, then run the front wheels against something immovable and open the throttle valve to see if steam escapes from the superheaters.

To Adjust the Throttle. If the throttle valve leaks it must be reground or a new valve substituted. It may, however, appear to leak owing to improper adjustment. There should be some tension on the valve stem when the lever is locked in the closed position. There is a distance rod running from the body of the throttle valve through the dashboard close to the throttle-valve stem. To increase the tension on the throttle, adjust the nuts on the distance rod.

To Adjust the Automatics. To carry a higher steam pressure, screw the adjusting screw on the automatic valve further in; for a lower pressure, screw it out. The same regulation of the gasoline relief valve will produce similar variations of the fuel pressure.

To Lay Up for the Winter. Run the car, on the road or with the rear wheels jacked up, till everything is hot, then extinguish the fire and blow off the boiler. While steam is escaping, open the safety and siphon valves and take out the fusible plug to clear them of water. Empty the tank, take off the caps of the check valves, and blow into the suction holes to clear the water from the checks ahead. Take off the water indicator and empty it, unless it is filled with non-freezing mixture.

General Remarks on Operating. The commonest fault of Stanley operators is opening the throttle too abruptly on starting. This is bad enough if the cylinders happen to be clear of water; if they are not clear, the results may be destructive. Always start slowly, and do not come up to road speed till the engine runs smoothly.

Never open any of the valves more than two or three full turns. They are screw valves, and if turned a dozen or more times they will come clear out.

Practice reversing where you have plenty of room. The ability to look and steer backward while operating the reverse pedal and throttle is not a natural gift. After reversing, be sure that the pedal has been released, by pressing the clutch pedal before giving steam.

REVIEW QUESTIONS

REVIEW QUESTIONS

ON THE SUBJECT OF

WELDING IN AUTOMOBILE REPAIR SHOPS

---

1. Name two methods of welding heavy sheet steel and describe one of them.

2. Give the characteristics of the low-pressure acetylene generator.

3. Name and describe the characteristics of the three types of blowpipe flames.

4. What kind of welding rod and what flux are used in welding copper?

5. In what essentials does the cutting blowpipe differ from the welding blowpipe?

6. Give the method of measuring the oxygen used in a welding job.

7. Describe the essentials of an electric welding outfit.

8. Draw a simple diagram showing the essential parts of an acetylene welding outfit and their location.

9. Describe the process of welding up a hole which has been accidentally made in the work.

10. Why is pre-heating important?

11. Give the important distinctions between the treatment of steel, cast iron, aluminum, and copper during the welding process.

12. What is the action of the acetylene regulator?

13. Give the various steps in butt-welding a pair of steel plates, showing how to manipulate the blowpipe.

14. What are the principal factors in the production of defective welds and what can be done to avoid them?

REVIEW QUESTIONS

ON THE SUBJECT OF

SHOP INFORMATION

---

1. Explain the process of scraping a crankshaft bearing.

2. What tap and die equipment should be found in a good automobile repair shop?

3. Give the most important parts of a lathe and the accessories necessary for ordinary shop operations.

4. What other machines besides the lathe are useful or necessary in a repair shop?

5. Give the process of mounting a clutch leather.

6. Describe how a cylinder is lapped by means of a jig in a drill press.

7. Give the principle of action of a micrometer caliper and show the uses to which the instrument may be put.

8. Give the names of the different kinds of files used in repair work.

9. How are piston rings fitted and put in place on the piston?

10. What fluxes are used in soldering the various common metals in the repair shop?

11. How would you cut a keyseat in a piece of round steel shafting?

12. Give the number of flutes advisable on a reamer and state your reasons.

13. Give a diagram showing how to calculate the setting for the graduated circle on the lathe slide rest to produce a given taper. Explain.

REVIEW QUESTIONS

ON THE SUBJECT OF

BUILDING, EQUIPPING, AND RUNNING A PUBLIC GARAGE

1. What power machines are most necessary for an automobile repair shop and what are the uses of these machines?

2. Explain the basis of calculation of a garage proposition as an investment.

3. Analyze the revenue from all sources for a garage holding, say, 100 cars.

4. Give a good layout for a one-story garage, size 75 by 200 feet, giving the location of necessary equipment and the most efficient arrangement of cars.

5. What building equipment is necessary in a 3-story garage?

6. Discuss elevators vs. ramps.

7. Under what circumstances is a garage justified in carrying accessories and selling cars?

8. Explain how a garage owner is going to settle the question of exclusive storage of cars, as compared with part storage space and part sales space. Give figures to justify conclusions.

9. Give the points necessary to consider in determining a good location for a garage.

10. Is the square shape of building economical for a garage? Explain, and give the best arrangement for a square floor plan.

11. What is the best use to which a basement in a garage can be put?

12. Give a sketch showing a safe arrangement for the gasoline supply.

13. What should be the specifications for a garage as to fireproofness?

REVIEW QUESTIONS

ON THE SUBJECT OF

MOTORCYCLES

---

1. How many cylinders has the conventional American motorcycle, and what type motor is usually used?

2. In what way has the installation of high-speed motors influenced the design of motorcycles?

3. Give a complete description of the Smith motor wheel.

4. What is a cyclemotor?

5. Give specifications for the engine used in the Excelsior No. 9.

6. What American companies manufacture 4-cylinder motorcycles?

7. Give complete specifications for the engine used in the Henderson motorcycle.

8. What is the difference between a 4-cycle and a 2-cycle engine?

9. Describe the spring frame construction used in the Merkel.

10. What two main types of frames are used in motorcycle construction?

11. How are the crankshafts fitted on flywheels in 5-cylinder engines?

12. Describe the action of the Indian roller-cam oil pump.

13. What type of transmission is used in the Harley-Davidson?

14. Describe the principle of operation of the Midco magneto-generator as used on the Excelsior.

15. Describe the Harley-Davidson commercial van.

REVIEW QUESTIONS

ON THE SUBJECT OF

STEAM AUTOMOBILES

1. Define radiation, absorption, conduction, and convection.

2. What is absolute zero? What molecular state does it theoretically represent?

3. Discuss the location of the steam engine on automobiles.

4. Convert 65 degrees Fahrenheit into centigrade.

5. State Boyle's Law.

6. Define force, work, power, and horsepower.

7. Describe and sketch the action of an elementary slide valve.

8. Define British thermal unit.

9. Draw a theoretical indicator card for one-fourth cut-off.

10. Define latent heat. How many British thermal units are absorbed in boiling away a pound of water at atmospheric pressure?

11. Discuss the effect of compression on the indicator card of an engine.

12. Why is the explosion of a stationary boiler so destructive?

13. Define superheat. What is its object?

14. What is the purpose of condensers if used on steam cars?

15. Describe and sketch the Stephenson link valve motion.

16. Describe the Bunsen burner.

17. What is the object of the pilot light?

18. Describe the Ofeldt burner.

19. How are automobile boilers classified?

20. Explain the principles of the fire-tube boiler.

21. In what way do flash boilers differ from the other types?

22. For what purpose are check valves used; how are they constructed?

INDEX

INDEX

The page numbers of this volume will be found at the bottom of the pages; the numbers at the top refer only to the section.

Note.—For page numbers see foot of pages.

C

Note.—For page numbers see foot of pages.

Note.—For page numbers see foot of pages.

Note.—For page numbers see foot of pages.

Note.—For page numbers see foot of pages.

Note.—For page numbers see foot of pages.

Note.—For page numbers see foot of pages.

Note.—For page numbers see foot of pages.

Note.—For page numbers see foot of pages.

Note.—For page numbers see foot of pages.

Note.—For page numbers see foot of pages.

Note.—For page numbers see foot of pages.

Note.—For page numbers see foot of pages.