SHOPS AND SHOP PRACTICE

VOLUME I.

THIS BOOK (In Two Volumes) EXPLAINS AND ILLUSTRATES BY DRAWINGS, ETC. THE LOCATION AND ARRANGEMENT OF SHOPS AND STOREHOUSES; THE CARE AND REPAIRS OF LOCOMOTIVES AND CARS; THE PRACTICAL WORK ACCOMPLISHED IN THE SHOPS. SUCH AS LATHE WORK; PLANER AND SHAPER WORK; SLOTTING MACHINE WORK; MILLING MACHINE WORK; GEAR CUTTING; INTERNAL COMBUSTION ENGINES; ERECTING ENGINE TRUCKS, FITTING UP CYLINDERS, VALVE GEAR RODS AND DRIVING BOXES; HANGING GUIDES; LAYING OUT SHOES AND WEDGES; SPRING RIGGING; PIPE FITTING; SETTING VALVES; INJECTORS; BRAKE VALVE; AIR PUMP AND TRIPLE VALVE REPAIRS; LAYING OUT BOILER WORK, ETC.

FORMING ONE OF THE SERIES OF VOLUMES COMPRISED IN THE REVISED AND ENLARGED EDITION OF

THE SCIENCE OF RAILWAYS

BY

MARSHALL M. KIRKMAN

EDITION 1912

CHICAGO:
CROPLEY PHILLIPS COMPANY
1912

TABLE OF CONTENTS.

VOLUME I.

VOLUME II.

INTRODUCTION.

This book (in two volumes) forming one of "THE SCIENCE OF RAILWAYS" series, has reference to one of the most important departments of the railway service—a department which is attracting to itself, more and more, talent of the highest order because the varied duties and great responsibilities inseparably attaching to those immediately in charge of the machinery department of railroads grow each day in the estimation of railway owners and managers who see clearly that with the growth of business the highest class of talent is required to manage the great and diversified interests involved.

In the preparation of this volume the author has sought primarily simplicity and practicability and with these points in view has called to his aid the assistance of practical experts. For the description of shops and roundhouses and the care and repairs of locomotives and cars he is largely indebted to one who not only understands the forces and principles which underlie the organization of the machinery department, but has for many years been actually in direction thereof on one of the largest and best managed railways of the country—Mr. Robert Quayle.

Much of this volume relates to the practical work of the railway machinist to whom, and to apprentices, it is hoped the book will be of particular value because it has to do with the daily problems they encounter and the tools which are their constant companions and responsive to their hands. For so much of the work as relates to practical machine work the author acknowledges the aid and assistance of Mr. A. H. Barnhart, an expert of long and varied experience in such matters.

CHAPTER I.

SHOPS AND ROUNDHOUSES—CARE AND REPAIRS OF LOCOMOTIVES AND CARS.

The varied duties and great responsibilities attaching to those immediately in charge of the machinery department of railways become more and more important with the lapse of time. With the evolution of railways it becomes more and more apparent that the machinery department, embracing equipment and shops, must be in charge of those who by experience, education and mental faculties are fitted to understand and direct the vast interests involved. The force engaged about the shops and roundhouses constitutes a vast and intelligent army and its technical skill is of the highest order.

The value of a railroad is dependent, it may be said, not only upon the stability of its track and the efficiency of its station and train service, but upon the fitness of its locomotives and cars and the efficiency displayed in their construction and care. Their care and maintenance require, in order to carry on the work effectively and economically, needed facilities and appliances of the highest order, embracing adequate grounds, suitable buildings and machinery, convenient storehouses, faithful and skilled workmen and a well organized and competent supervisory force. These things are fundamental.

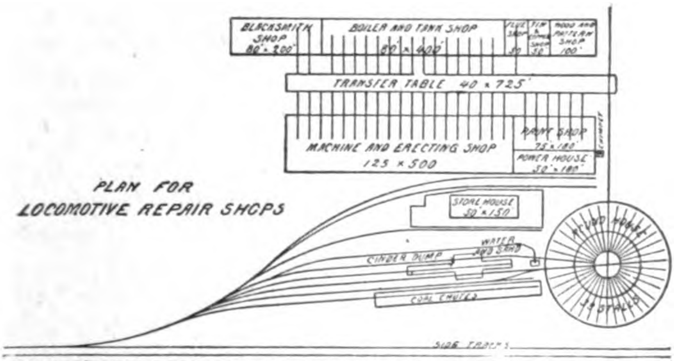
The salient features involved in the care and maintenance of the equipment of a railroad are:

Care of Locomotives,
Repairs of Locomotives,
Repairs of Cars,

with all the buildings, tools and appliances requisite, together with the needed organization.

Care of Locomotives.—In operating the locomotives of a company, suitable buildings arranged for their shelter must be provided at needed places along the line of road. These must, moreover, be fitted with such appliances as may be necessary to enable those in charge to perform such work on the locomotives housed therein as the necessities of daily service require.

In the United States the buildings I refer to are usually of a circular or partially circular form, and so located as to be readily reached from the main line. They are provided with a turn-table connecting with all the tracks in the house. These buildings because of their usual shape are known as "roundhouses." Such a house is needed at places where the requirements of the service render it necessary to station engines or to keep them temporarily, say at the junctions of divisions, at the termini of particular trains and other places where engines must be housed. While the locomotives are thus protected they receive the simple repairs which the exigencies of the service require. So that while these buildings may be called roundhouses and are, in the main, designed simply to house locomotives overnight or temporarily, they are also, in a measure, repair shops, where such appliances are kept in the way of machinery and skilled workmen as the needs of the service require. In view of this, it is proper to call them machine shops.



The dimensions will, of course, be increased or decreased according to the amount of work to be done.

At important centers there are one or more buildings, apart from the roundhouse, especially provided with the machinery needed for making repairs. In any event, however, many repairs are made in every roundhouse. There it is intended the engine shall be cleaned, inspected and fitted for the road. It is, therefore, it will be seen, a place of the greatest importance in the machinery department.*

* "In order that the work may be done effectively, it is important that the roundhouse shall be well lighted. This can be done in the daytime by plenty of windows and at night by electric lighting when practicable. The light will be much improved by reflection from whitewashed interiors. As roundhouses contain much valuable property, it will be well to make provision against fires by building fire walls every ten or twenty stalls." —*Mr. G. W. Rhodes.*

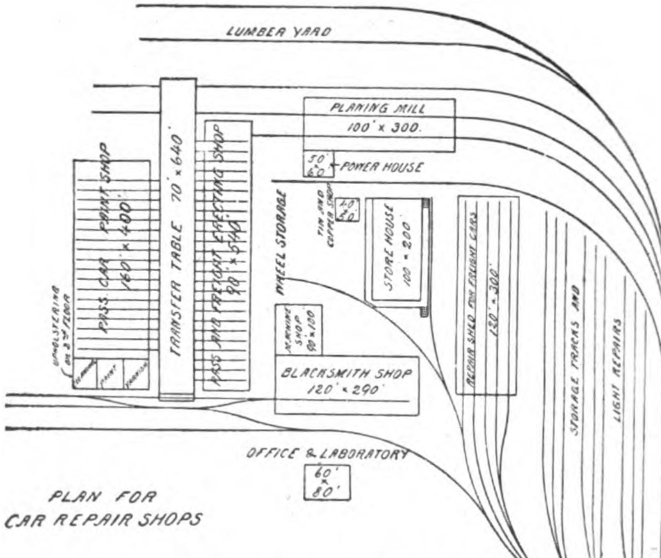
When in the suburban service of a railroad locomotives run to several adjacent stations on schedules which necessitate their being held over at two or more points, it may be economical to locate the roundhouse at an intermediate station rather than the terminal, running the engine back and forth between the roundhouse and the points from which it starts. By so doing, labor may be concentrated and, therefore, more profitably employed and at the same time necessary furnishings and accessories minimized. Generally speaking, however, it may be said that the location of roundhouses must be governed by conditions which can only be determined by special investigation in each case.

The ground for the roundhouse should be selected with a view to drainage and should be amply protected in this respect. If there are repair shops apart from it, convenient tracks connecting the two should be arranged.

The design of the roundhouse and its arrangement give little scope for artistic display. The important things to be considered are first, cost, afterward, expense of maintenance and, finally, convenient and economical arrangement for use. Roundhouses should be protected as far as possible from frost, and in cold climates should be built with that view, either of brick, stone or other suitable substance. They must be deep enough to admit the longest locomotive with tender and allow ample margin at either end. Each stall or track should be provided with a pit as long as the engine and tender and deep enough to enable workmen standing therein to clean or repair such parts of the machine as are not otherwise accessible. The pit should be provided with steam piping around its sides for heating purposes. This piping should be securely fastened or protected so as to prevent employes, when getting into or climbing from the pit, from loosening the joints and thereby rendering the appliance unserviceable or in need of repairs. The method described of heating the roundhouse is superior to all others, as it is important that the heat should be concentrated directly under the principal machinery of the engine, so that when frozen or covered with snow and ice these parts may be quickly thawed out, cleaned and inspected and, if necessary, repaired.* The pits should be provided with adequate draining facilities and sewer connections. Especial attention should be given to sewerage, also the provision for carrying off the sediment and incrustation from the boilers without blocking the drains. Hydrants should be placed between the pits, conveniently located for attaching hose for washing the boilers and filling the tanks. The piping in the roundhouse should, so far as possible, be placed near the roof and in the center of the building. The steam pipes, while carefully protected, should be exposed throughout, so as to facilitate inspection and repair.

---

* "In cold climates low, flat roofs are very generally used. Such construction largely reduces the square feet of area which it is necessary to heat."—*Mr. G. W. Rhodes.*



The dimensions will, of course, be increased or decreased according to the amount of work to be done.

The floor of the roundhouse is an important matter. It should be built of material that will stand the wear and tear of heavy trucks and the blows received from falling pieces of machinery. It should be sufficiently substantial to resist the pressure of the jacks used in raising the locomotives.

Light may be provided by windows in the rear of the building and, if necessary, by inserting panes of glass in the doors. Skylights, if necessary, may be used. The doors of the roundhouse should open outward. They should also be strong and securely hung. They require to be provided with catches for fastening them when open and holding them when closed. The building should have a substantial roof, so constructed as to evade, as much as possible, the corroding action of the smoke and gases from the locomotives. Funnels for carrying the smoke and gas above the roof will be found valuable devices in this connection.

The roundhouse should be equipped with such assortment of wrenches, bars, ratchets, jacks, air motors, tools and work benches as the service requires. Except at very small roundhouses, necessary tools for drilling, turning and planing should be provided. At large roundhouses these should be supplemented by tools for facing valve seats, boring cylinders, drilling out and replacing stay-bolts, and other work of like character incident to daily service. When there is not a central power plant, the roundhouse should be provided with a boiler for generating steam for heating purposes and providing needed power. If very high water pressure is not available, a steam pump of sufficient capacity to afford ample water at high pressure should be provided for boiler washing. The advantages afforded by use of compressed air in connection with roundhouse work make an air compressor a valuable part of the equipment wherever considerable work is done. A sufficient reservoir for air storage should be provided.

Drop pits with power lifts for removing trucks and driving wheels are necessary where much work of this nature is to be performed.* These may be operated to advantage by compressed air.

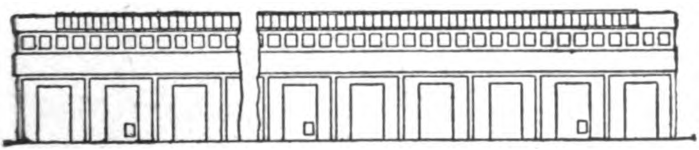
Provision should be made at every roundhouse for the stores it is necessary to keep on hand. In small houses space which would otherwise not be used may be utilized for this purpose, but at large and important places a storehouse is needed. This may sometimes be advantageously attached to the buildings. In other cases it will be more convenient to have it apart.

The foreman's office should, generally, connect with or be immediately adjacent to the storeroom. All material requiring protection from weather or thieves, excepting oils, should

---

* "Driving box brasses and journals, it is to be remarked, can only be thoroughly inspected and examined by dropping out the wheels. When round-houses are not equipped with these facilities a thorough inspection of the parts named is neglected, resulting in a continuation of the difficulties with the engine in place of removing them. An engine was recently cut off of an important train on the line under my charge with a hot box. The cellar was removed and the journal examined as well as it could be without going to the expense of jacking the engine up, the roundhouse not being fitted with a drop pit. Nothing was discovered seriously wrong, the cellar was repacked and oiled, and the engine again put into service. The engine continued running hot and it was found its condition was not bettered. The next roundhouse the engine stopped at was fitted with a drop pit, operated by air. It took but a short time to drop the wheels out and make a thorough inspection of both journal and brass. It was then found that the brass had been so badly cut it would be impossible for the engine to run cool until it was equipped with a new brass. The result of this experience was that a drop pit was at once ordered for the roundhouse that was without one. I think pneumatic drop pits for engine drivers and truck wheels should be in every roundhouse on the main line of important roads."—*Mr. G. W. Rhodes.*

be kept securely locked in the storehouse. At large roundhouses a separate building, as nearly fire-proof as possible and arranged with reservoirs or tanks, should be provided for oils. If located below the level of the ground, the oil may be drawn by pumping it directly from the tanks, or compressed air may be used. The latter is, however, considered preferable. The oil house should be built at a sufficient distance from the other buildings to prevent the fire spreading in the event of a conflagration.*



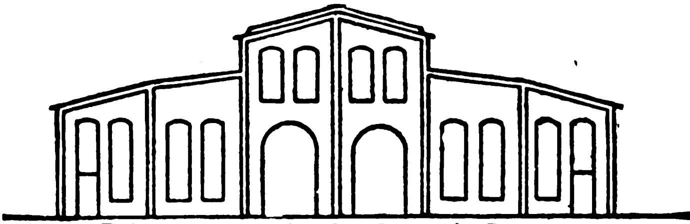
Side Elevation, Erecting Shop, Locomotive Department.

A pit in which to dispose of ashes and other refuse of the ash pan should be located near the turn-table; the closer it is the better, so as to prevent, as far as possible, the injury which accrues to the flues by cold air passing over the grates after the fire has been drawn. The clinker pit should be large enough to accommodate all the locomotives using the roundhouse. As the cinders which thus accumulate must be removed, a depressed track, whereon the cars intended for their removal may stand, will be found an economical appliance. It should be so located that

* The matter of storing material, etc., is fully exploited in another volume.

by opening the door of the clinker pit the cars may be loaded by gravity.*

The coal house, with its contrivances for supplying locomotives by gravity, the supply of sand and the water tank, while not necessarily



End Elevation, Erecting Shop, Locomotive Department.

appendages of the roundhouse, may be so conveniently situated in its vicinity as to be highly desirable. Local conditions will necessarily govern their location. Care should be taken, however, to so group these supplies that the labor each requires may be concentrated so as to be utilized to its fullest extent. For instance, the sand and water cranes should be in such relation to each other that the man in charge of the engine may take on a supply of both water and sand without moving the engine.

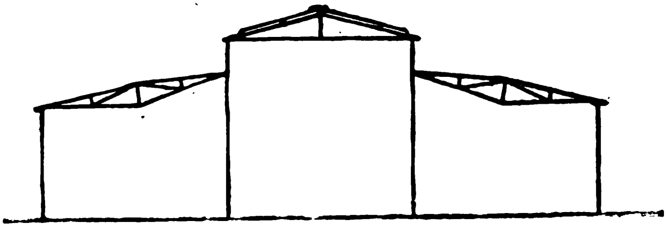
Methods of organization covering the care of

* "At some shops the ashes are handled very economically by the use of air hoists, which avoids the necessity of a depressed track. Portable pans are placed in the clinker pit into which the clinkers and ashes are dumped. These are lifted by air hoists suspended to an overhead traveler and their contents dumped into a car. At some locations, on account of poor drainage, especially in low countries, depressed pits are not practicable. Where air hoists are used the expense of the depressed track may be avoided."—*Mr. G. W. Rhodes.*

locomotives merge with those connected with petty repairs. The force engaged consists of bodies of skilled and unskilled workmen in and about the roundhouse. The skilled workmen comprise machinists and boilermakers and their helpers, respectively. The unskilled workmen embrace wipers and laborers. At large roundhouses the boilerwashers and helpers may constitute a distinct body. All receive instructions from, and are responsible to, the foreman in charge. The latter is subordinate to the master mechanic, and usually reports to him.

If the number of roundhouses on a division is large, they may be grouped. In such case the foreman of each roundhouse will, perhaps, report to and receive instructions from a general foreman for the section, who, in turn, will report to the master mechanic.

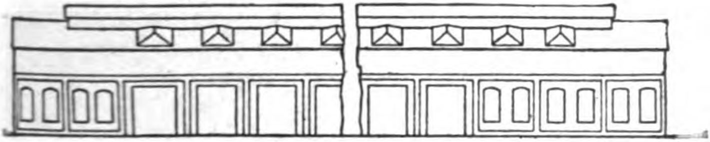
Repairs of Locomotives.—When locomotives become much worn with service, or, in



Cross Section, Erecting Shop. Locomotive Department.

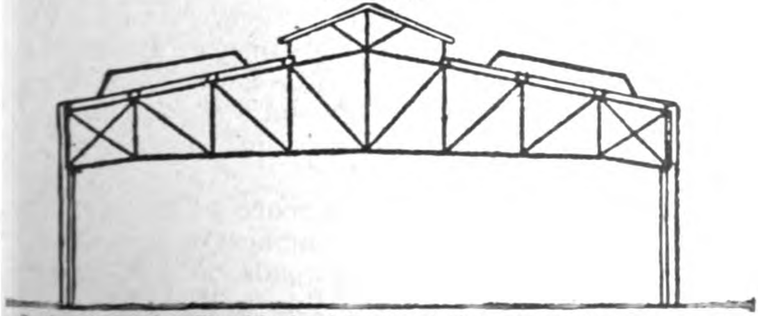
other words, need many repairs, the limited facilities of the roundhouse will not suffice. The engine must then be withdrawn from service and taken to the general repair shops where facilities are provided for such work. It is oftentimes difficult to determine just when this transfer should be made. Much depends upon the character of the service in which the locomotive is engaged; something upon the character of the repairs. If life or property is not jeopardized by continued use of the locomotive, it becomes simply a question of dollars and cents: if saving may be effected by making the repairs, they should be made forthwith; otherwise not. The nature of the water supply determines, very largely, the length of time an engine can be kept in service. If the water is unsuitable, its impurities, precipitated by heat, accumulate in the flues and upon the sheets of the boiler; thus it may be necessary to remove the flues as often as two or three times a year, whereas, if the water is free from impurities, the flues may last for ten years. Therefore, in order to prolong the usefulness of the flues and boiler sheets, and thus minimize cost, pure water should be obtained whenever possible. First cost is unimportant compared with expense of maintenance afterward; yet unfit water is often obtained by sinking wells, or other device, in order to save present outlay, when by a little larger expenditure a permanent supply of good water could be obtained from a running stream, or in some other way.

Much is to be said in reference to the character of the service in which engines are engaged. In the early experience of railroads in the United States small engines were able to haul heavy trains, because the speed was slow and stops infrequent. Now, however, the speed of trains has been increased, while the growth of the country and with it the towns along the line of railroads necessitate more frequent stops. This



Side Elevation. Boiler. Tin. Flue. Wood and Blacksmith Shops. Locomotive Department.

End Elevation. Boiler, Tin, Flue, Wood and Blacksmith Shops, Locomotive Department.



Section. Boiler, Tin, Flue, Wood and Blacksmith Shops, Locomotive Department.

is true of all new countries and of many old ones. Heavier locomotives have thus become necessary with the result that the durability of the machinery is lessened, as it wears out more quickly in heavy service where a large amount of coal is necessarily consumed than where the contrary is the case.

Judicious location of the repair shops for locomotives requires consideration of many varied interests. Among those to be mentioned are accessibility to locomotives to be repaired; proximity to skilled and unskilled labor; facilities for obtaining material and supplies; and, finally, the securing of adequate grounds for buildings, yards and tracks. In this connection the growth of the service, i. e., future needs, must be taken into account.

There are two kinds of repair shops: those arranged for heavy work, such as the thorough overhauling of a locomotive requires, and those for lighter repairs. As the arrangement of both is generally similiar, i. e. differs only in degree, only those designed for extensive repairs are considered here.

The location of these repair shops must be easily accessible from the main track. The shops must also have ample yard room with switching tracks suitable for convenient and economical working, including the handling of material and supplies. The grounds should be well sewered and drained, and provided with fences, gates, etc., so they may be completely enclosed. The terminus of a division or the common terminus of several divisions of a road is the natural place for general repair shops such as those described.

As it sometimes becomes necessary to transfer to the roundhouse the skilled labor of the repair shop, it is desirable that the roundhouse should be located as near to the repair shop as practicable.

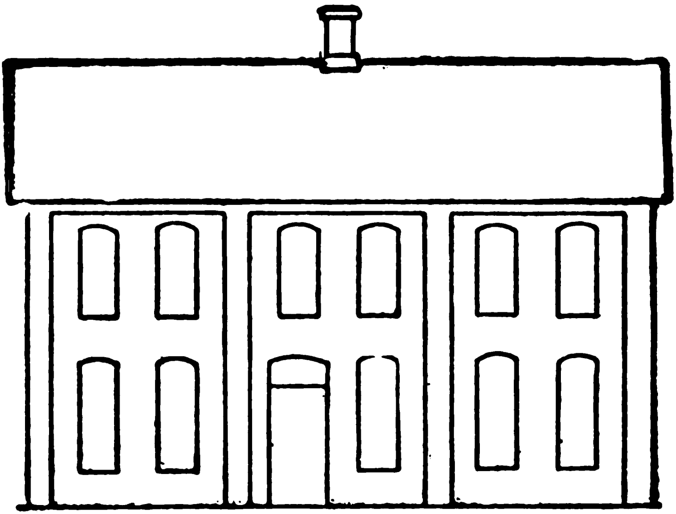
Repair shops, such as those referred to, necessarily consist of a number of buildings in which different parts of the work are done. The arrangement and location of the buildings require careful study. The following observations thereon are offered as tending to reduce cost of repairs by minimizing labor and loss of time in handling material and in making repairs.

The largest and most important building of the group is the machine and erecting shop. In the case of very large plants the erecting building is separate from the machine shop. In other cases the two are placed under one roof. The building, or buildings, must be located so as to be conveniently reached from other shops.

The boiler shop should be located in the immediate vicinity of the erecting shop, so that the boilers may be moved conveniently from one building to the other.

The tank shop, i. e., the shop for the repair of the water tanks of locomotives, should be a part of, or immediately adjacent to, the boiler shop, so that work of a similar nature may be concentrated as much as possible.

The forge and blacksmith shops are usually consolidated under one roof. The location should be convenient to the machine and erecting shop and the boiler and tank shops.



Side Elevation, Tin and Copper Shop.

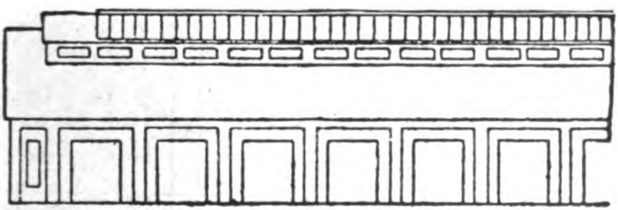
The paint shop should be conveniently located for moving locomotives and tenders from the erecting shop. It should be provided with tracks leading to the roundhouse or main line.*

It is, as a rule, advantageous to locate the foundry some distance from the other buildings so as to have room for supplies stored in its

* "Much less time and care are spent on locomotive painting than formerly, so much so that many important lines do not consider a locomotive paint shop essential. The cabs are built and painted in the coach shop, and the tanks and engines in the machine shops, as they are being completed about in the same way as is generally followed in contract shops."—*Mr. G. W. Rhodes.*

vicinity. The heavier castings should be stored conveniently beween the foundry and the machine shop, where the castings are to be used. In some cases it may be better to store them near the general storehouse. This latter should be conveniently located for the distribution of material to the shops with as little expenditure of time and labor as possible. Spacious platforms and other conveniences should be provided to facilitate the transfer of castings from one part of the house to another.

If the shops are very extensive they should have a power plant. It should be as centrally



Side Elevation, Passenger and Freight Car Repair Shop.

located as possible. How far this will be practicable, like other problems, can only be determined on the spot. The boilers should, however, be grouped in one building, and steam for heating purposes distributed directly to the entire plant, according to the best modern inventions.

A suitable engine, able to furnish the amount of power needed, should form a part of every power plant for the purpose of driving the dynamos which generate the electrical force used to operate the machinery of each shop. The cost of attendance may thus be reduced.*

The design for shop buildings should, in a general way, follow the lines accepted as best for such plants. The foundations and walls should be strong and of well-laid masonry, with pilasters and strengthening buttresses wherever necessary to carry the load attached to the roof, or needed to support the tracks for traveling cranes. The walls should be sufficiently high to afford headway under the cranes. As abundance of light is needed in every shop the windows and skylights should be ample.

When there are no traveling cranes, the roof trusses should be strong over the entire floor space, as it is often advantageous to attach to the roof appliances which will greatly increase the weight on the trusses. The roof of the building should be substantial, durable and as nearly fire-proof as possible. Slate is preferable.

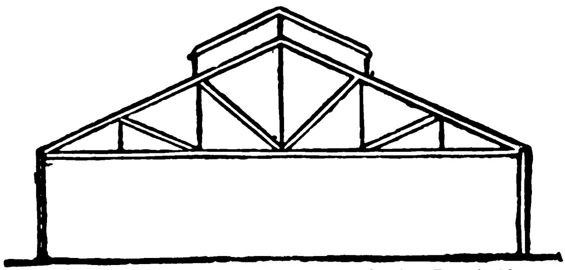
The foregoing applies with more or less force to every building connected with the repair of locomotives. Each building, however, possesses certain features peculiar to itself. These may now be taken up.

In planning the erecting and machine shop, either of two plans may be followed. Each has certain advantages or disadvantages, depending

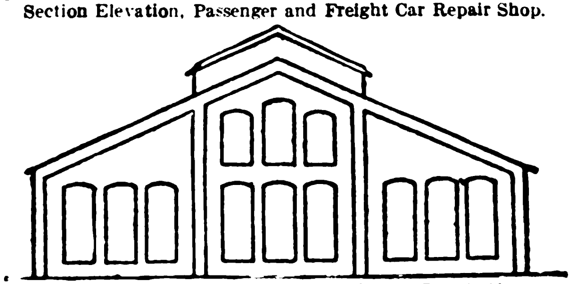
* "Owing to improvements in the working parts of stationary engines, improvements in continuous sight-feed lubricators, etc., it has become the practice in shops of even considerable importance to do away with the stationary engineer and to make the supervision of the stationary engine part of the duties of the leading fireman." —*Mr. G. W. Rhodes.*

largely upon climatic conditions. Both designs, however, contemplate a building varying in width from one hundred to one hundred and twenty-five feet, arranged with a machine shop on one side of a line drawn lengthwise through the center, and an erecting shop on the other side. The length of the building may vary to suit special requirements, but one end should be so located that it may be extended when necessary. In one design tracks run at right angles to the length of the shop. They are spaced from twenty-two to twenty-five feet apart from center to center of track. Each track is provided with a pit deep enough to enable workmen to perform the work required on the machinery and fittings from beneath the engines. Cranes sufficient to lift the heaviest locomotives traverse the entire length of the shop immediately over the pits. This design requires a transfer table close to and extending lengthwise of the shop, accessible to tracks connected with the main line, for moving engines to and from the erecting shop. In the other design the erecting tracks run lengthwise of the shop. One track is usually placed on each side of the allotted floor space, with another track extending lengthwise through the center, upon which locomotives enter and leave the shop. The same provision is made for traveling cranes as in the first instance, so that locomotives may be lifted from the center track to the erecting tracks, and vice versa, as well as on and off their wheels. Pits extending the entire length of the erecting tracks are required as in the other case.

When scrap furnaces are used, the shop boilers may be placed immediately above the same in order to utilize the heat for the purpose of generating the steam required in operating the steam hammers and for other purposes. If



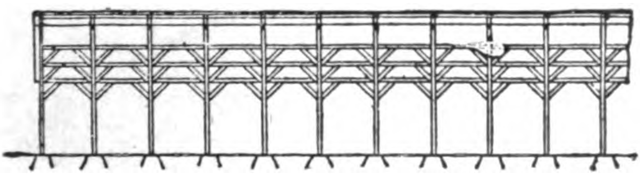
Section Elevation, Passenger and Freight Car Repair Shop.



End Elevation, Passenger and Freight Car Repair Shop.

coal is used for fuel, the furnace may be fed through a chute connecting directly with the cars on which the supply is loaded. If oil is used in the furnace, the supply should be in close proximity to the building, so that the distance the oil will have to flow may be reduced as much as possible.

A boiler shop rarely needs to be more than eighty feet wide. The height of the walls should be the same as for the erecting shop. The arrangement of tracks in the boiler shop should also be the same as in the erecting shop. Adequate crane facilities for moving and turning boilers are required. The boiler shop should be equipped with a hydraulic riveting machine



Longitudinal Section, Repair Shed for Freight Cars.

with accumulator* and tower-lift† for handling locomotive boilers, with a machine and tower, or extension, which will permit a lift under the crane that will support the boiler of the riveting machine at a height of at least thirty-five feet in the clear; and an oil furnace for annealing.‡

* An accumulator is a long cylinder in which a piston is set in vertical position, the cylinder being attached to a large iron drum filled with scrap iron, sand or other heavy material in order to obtain the pressure necessary to operate the machinery. By means of a pump, liquid is forced into the cylinder, which causes the piston and the drum containing the load to rise, thereby obtaining the required pressure.

† A tower-lift is a long cylinder with piston coupled to a crane at the top of a tower, directly over the machine, and is used for holding boilers in suspension while being riveted and in handling other work to be performed at the machine.

‡ The annealing furnace is a large furnace with a door extending across the entire front, in which boiler plates are heated to a red heat and allowed to cool before being placed into the boiler in order to make the metal more pliable.

The blacksmith shop may, if thought desirable, be arranged with a forge shop in an annex, or "L." In this way facilities for storing material without interfering with ready access to the blacksmith shop may be secured. The walls of the building should be substantially constructed, with large openings for ingress and egress. The light should be abundant. Capacious ventilators should be inserted in the roof. The trusses should be strong enough to support such posts, cranes, overhead runways or tracks for transferring material as may be necessary.

Among the prime requisites for a paint shop are light, heat and ventilation. "The last two are best accomplished by what is known as the overhead hot-air system. The large fan which forces the hot air through the pipes in winter is available for inducing a circulation of air in the shops in summer. The best results in drying in a paint shop are obtained when the air circulates freely." * Besides the windows in the walls of the building, the skylights should be fitted into the roof as may be consistent with good construction. The ventilators should be provided with adjustable appliances for preventing waste of heat. The floor should be smooth and made of cement or similar substance so that it may be easily washed and quickly drained.

The foundry building should be substantially built and arranged for traveling cranes when

* Mr. G. W. Rhodes.

necessary. The core rooms and core ovens should be convenient to each other and the latter provided with adequate heating facilities.*

Where there is a brass foundry, it should be adjacent to the main building and should be provided with a good chimney with which the brass melting furnaces should be connected. The cupolas should be located outside of the side wall near the center of the length of the building. Provision should also be made for an ample charging floor and elevator.† "In constructing a brass foundry it should be designed so that the raw product will come in at one end and the finished brass, ready to be loaded into a car and shipped away, come out at the other. This can be accomplished by having the heating furnaces, molders' floor, rattler, grinder, boring machines and lead-lining machines follow each other in close succession so that the completion of each operation places the brasses without additional

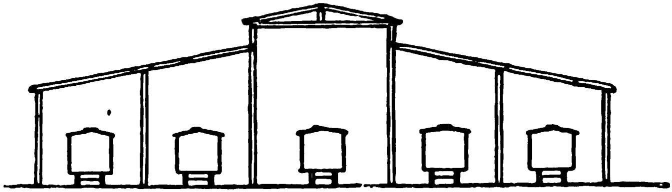
---

* The core room is a room in which cores are made, usually of sand, for the castings made in the foundry. In order that the cores may not break easily or run off easily when molten metal is poured around them, they are baked hard in an iron oven heated by a mild fire. The oven is provided with iron shelves upon which the small cores are placed to be baked.

† The cupola referred to is practically a cylindrical furnace made of sheet-iron and lined with fire brick, which usually extends up through the roof of the building so as to allow the free escape of gases and flame. The charging or filling door is near the top, through which all the iron and fuel are fed. The charging floor is a floor built conveniently to the charging door on which the fuel, iron and such other material as is used in the process of melting and making iron or steel are placed.

handling into a position available for the next operation."*

A good form of storehouse is a building two stories in height. To facilitate loading and unloading material and supplies the lower floor should be elevated to a level with the floor of a freight car. The building should be surrounded by a platform of suitable width on a level with the floor, the platform inclining to the ground at the ends of the structure. Enough doors should be provided for convenient use. The second story floor should be well supported in


End Elevation, Repair Shed for Freight Cars.

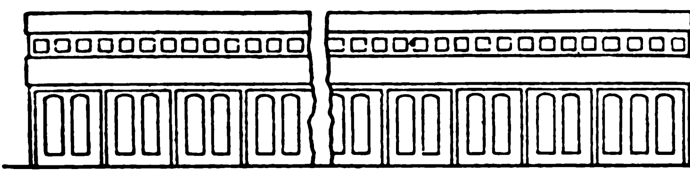
order to bear its burden of stores. The building should be fitted with one or more elevators. Good light is necessary and the building should be provided with bins, racks, and other necessary appliances so arranged as to interfere with the light as little as possible. The first floor and the supports for the second floor should rest on a good foundation of masonry.

The power house, containing the boilers and other accessories, including engines and dynamos, should be designed with reference to the

* Mr. G. W. Rhodes.

economical handling of fuel and ashes.* The building should be ample, but provision should be made for extending it when necessary. It should be located with reference to the easy and economical distribution of steam for heating and (if required) power purposes. The room in which the boilers are located should be well ventilated, and the engine and dynamo rooms provided with a high roof and good light.

The equipment of a shop requires careful study in order that it may meet practical and scientific needs. The tools should be of improved design and construction, though first cost may be considerably enhanced thereby.



Side Elevation, Planing Mill, Car Department.

The arrangement must be such that work passing through the shop will require to be moved as little as possible and the least possible distance. If the tools are not arranged with this view, much unnecessary expense will be incurred thereby for labor and on other accounts.

* "Fuel, when unloaded, should pass into a hopper-formed receptacle, constructed so it will supply itself sufficiently and may be passed with one additional handling into an automatic 'feed,' or, where automatic feeds are not used, shoveled into the fire box without additional handling."—*Mr. G. W. Rhodes.*

Traveling and swinging cranes should be provided in all shops where needed. The efficiency of traveling cranes may be greatly enhanced by equipping them with electric motors. Overhead runways* should also be introduced in shops when they can be utilized. Pneumatic hoists (lifting machines operated by compressed air) suspended from trolleys (trucks), the latter being mounted on overhead runways, are also useful in shops. Careful estimates require to be made, however, of the expense attending the use of power cranes, including cost, before introducing them, lest their practical working value does not justify the outlay.†

The heating appliances of shops should be so designed and arranged as to accomplish in the most satisfactory and economical manner possible the object intended, namely, the free and full circulation of the heated air throughout the space where it is needed. In the case of steam heat especial care is required in order to derive

---

* Tracks for lifting and moving machinery and other articles by pulleys.

† "A useful form to measure the value of such improvements may be mapped out as follows:

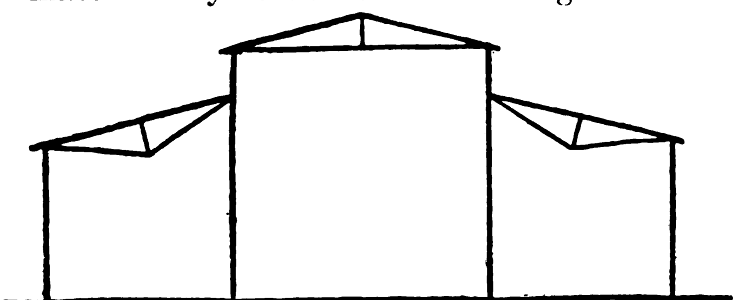
HANDLING CINDERS AT ROUNDHOUSE.

	Value.	Wages Per Month.	Saving Per Month.	Saving Capitalized at 6 per cent.	Number of Men Employed	Saving Per Month.
Ash Pit (Old Method)......		$475.20	....	....	10	....
Ash Hoist (New Method).....	$674.78	288.00	$187.20	$37,440.00	6	40 00%

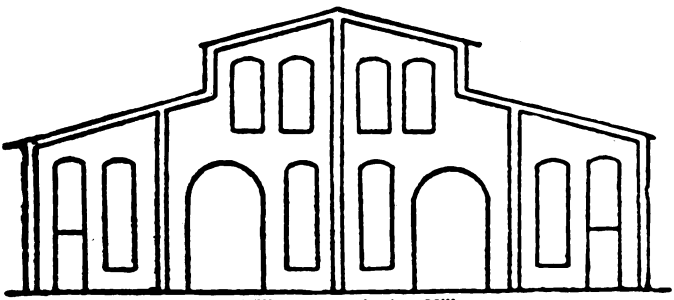
"—*Mr. G. W. Rhodes.*

the full benefit from the steam—in other words, the utility of the steam in the pipes should be exhausted before introducing a new supply.

A drop table—a machine for removing driving and truck wheels from locomotives going into the shop and replacing them on engines going out—should be located somewhere on the track by which the engine enters and leaves the erecting room. It should also be easy of access to the machine shop. At the drop table, a lye tank for cleaning the material stripped from the locomotives should be provided, in order that the material may be cleaned before being taken to



Section, Planing Mill.



End Elevation, Planing Mill.

the machine shop. If the tracks run lengthwise of the erecting shop, the drop table is not necessary, as the engine may be lifted directly from its wheels by the traveling cranes.

The machinery for cleaning the boiler tubes of the locomotive should be located at some place easily accessible by push (small platform) cars from the erecting shop tracks. The arrangement of the cutting off, scarfing, welding and tube testing machinery should be such as to reduce the labor of handling to a minimum.*

Economical operation requires that power facilities shall be provided at every point in a shop where it is required to drive tools, such as drills, taps, reamers, calking and chipping implements, cylinder boring bars, facing and sand-papering machines, and so on. This work may be performed by compressed air or electricity more satisfactorily than in any other way.

Portable riveting machinery should be provided in the boiler shop and, if new boiler work is done to any extent, an hydraulic riveting plant is highly desirable.

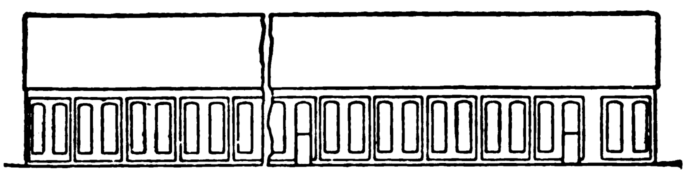
An economical air compressor of sufficient capacity is necessary to the equipment of the locomotive repair shop. If a large amount of compressed air is required, a storage reservoir therefor should be located near the shop, connected with the compressor by piping of ade-

* "This is accomplished by concentrating operations so that the finishing of one operation places the material in a position for commencing the next operation without intermediate handling." —*Mr. G. W. Rhodes.*

quate size. Leaks in the piping and reservoirs occasion waste of energy and are consequently to be avoided.

The blacksmith shop should be equipped with a bulldozer,* forging press† and drop hammer, if needs demand, or with any one of the three that may be profitably used. Attention given to establishing standard details of devices for replacing hand work in forging by machinery fitted with proper dies will also prove profitable.

Heating furnaces (both large and small) should be designed and adjusted so as to give the best possible results in the way of abundant, rapid and uniform heating. Thus, much valuable



Side Elevation, Blacksmith Shop, Car Department.

time may be lost if the furnace in the blacksmith shop is not adequate to keep the hammersmiths going. Especial attention should be given to the construction and arrangement of furnaces. The use of oil for fuel may be more economical than coal, not as regards relative quantity consumed, but in increased work accomplished.

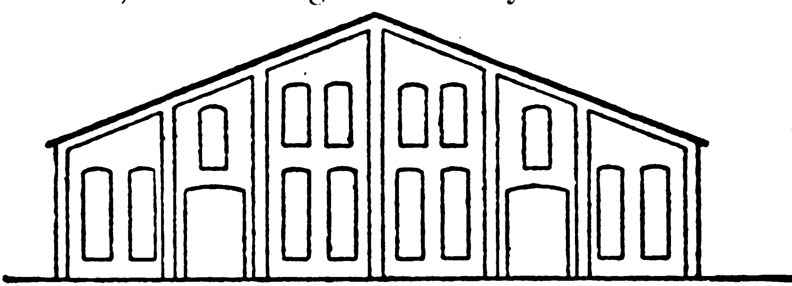
* A bulldozer consists of a heavy bed with a strong cross head to which suitable dies and formers are secured, by which bar iron is pressed into different shapes.

† A forging press is a machine for forging iron, when heated to a white heat, into any shape which dies can be made to squeeze it into. The work is usually done by one operation of the machine.

The equipment of the power plant should be selected and arranged after a careful study of surrounding conditions. It should be of the highest type. When impure water must be used, provision should be made for turning the water, after condensation, into sumps (reservoirs).

The transfer tables necessary in repair shops may, like traveling cranes, be profitably operated by electric motors. They should be strongly built so as to reduce cost of maintenance.

The labor in the repair shops of railroads, like that in roundhouses, comprises skilled workmen as well as a body of unskilled laborers. It, however, includes a greater variety of tradesmen



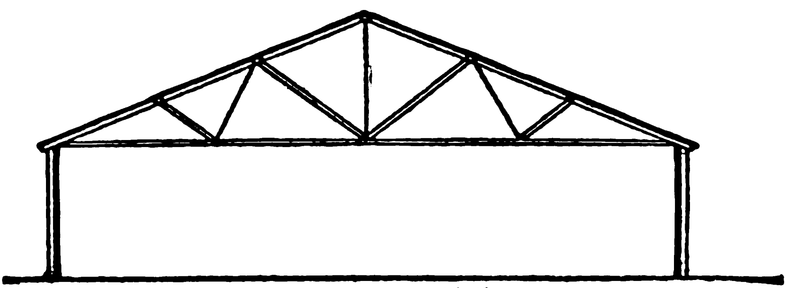
End Elevation, Blacksmith Shop, Car Department.

and, unlike roundhouse work, affords opportunity for employing apprentices in various lines of mechanical work. A practicable plan of organization of labor in this important division of mechanical work may be described as follows:

The workmen in each shop should report to a common foreman from whom they receive instructions. If the works are not too extended, one foreman for each shop will be sufficient. The foremen of the various shops should report to a general foreman, who thus becomes responsible for the practical operation of the entire works. He is immediately subordinate to the master mechanic. Where the works are very extended, the foreman of each shop has assistant foremen, who have charge of particular parts of the work in hand. For example, it may be desirable to have two foremen in the machine and erecting shop—one in charge of machine work, the other in charge of erecting work. In subordination to these will be gang foremen on the erecting floor, each having charge of a body of workmen and personally looking after a certain number of erecting tracks The work in the machine shop may also, in many cases, be divided between two or more foremen, each being responsible for the output, tools and men, of a certain portion of the shop. There should be a foreman in charge of hand tools, standard gauges, and so on. He may be responsible to the foreman of the machine shop, and is held accountable for the safe keeping and maintenance of the tools under his charge. He requires such workmen as may be necessary, also the machine tools, such as lathes, milling machines, grinders, and so on, needed for keeping the tools in repair.

In giving out implements, a simple but effective plan is to require a numbered ticket to be deposited by the workman who receives the tool. When he returns the implement, the ticket he has deposited is given up to him. This avoids book-keeping and yet is an effective safeguard.

Arrangements are also necessary for keeping the time of men. The system must be effective, first, that every man may receive what is due him and, second, that he shall not be credited with time he has not worked. The "check" system may be used in this connection to advantage. Under this plan each man is given a number. He passes through the check room when commencing work in the morning and



Cross Section, Blacksmith Shop.

afternoon, at which times he is given a metal check corresponding to his number. The checks used in the forenoon are marked "A.M.," those in the afternoon "P.M." No checks are given out after the hour for commencing work has passed. If a man is late, he receives what may be termed a "late" slip from his foreman in lieu of a check. It shows the time he commenced work. Each workman is visited twice a day by the time-keeper, who collects the checks and slips, and at the same time he also obtains the data he will require to enable him to distribute the labor, i. e., charge it to the account upon which the work is performed. Another method of keeping time may be called the "clock" system. Each employe has a number, as in the check system. He is given a key corresponding with his number, and when commencing work he registers his number and the time of day by inserting the key in a clock provided for that purpose; upon quitting work he passes through the check room and registers in the same manner: the clock thus tells exactly

Side Elevation, Passenger Car Paint Shop.

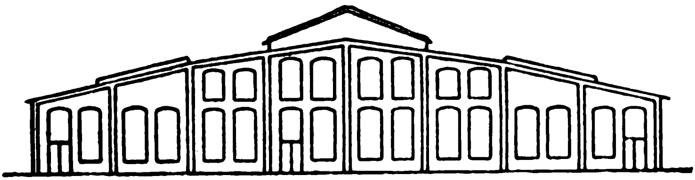
the time he began and the time he quit work. These references in regard to keeping the time of men, it will be understood, are general and wholly superficial. The subject is one of importance because of the vast number of men employed, and the necessity that methods should be adequate thereto. These methods, it is unnecessary to say, while they may be general, yet require modifications to meet particular circumstances and, in any case, the utmost elaboration. The subject does not properly come up here. It is discussed in another volume in which the whole question, including such matters as keeping the time of men, reporting same, pay-rolls, distribution of work, and the accounts, statements and statistics connected therewith, is explained.

The plan outlined for organizing the labor of the locomotive repair shops contemplates careful and constant supervision. If, however, the work is done by the piece instead of by the hour, inspection of it when completed becomes necessary in order to insure satisfactory work and determine the amount due the laborer. If their duties permit, the foremen usually do the inspecting; in other cases inspectors are employed in the different shops. They are responsible to the foreman for the character of the work.

Care of Cars.—Cars, unlike locomotives, are too often not kept under cover, but placed on open tracks spaced and conveniently located for storing and light repairing. They are called repair tracks. These tracks are located at the terminals of the road and near the car repair shops, as convenience and economy dictate. If for freight cars, they should be in the immediate vicinity of the principal switching yard, because there usually the cars which are in bad order are to be found. If the repair track is for passenger cars, it should be near the storage yard for such cars and arranged conveniently for switching cars to and from the latter. Repair tracks thus located will minimize the cost of transferring cars to and from trains and avoid, as well, unnecessary delay in other directions.

Repair tracks are so spaced as to permit ample room for workmen and afford adequate facilities for handling the implements and material needed in making the repairs.

As the fluctuations of traffic will, in a majority of cases, necessitate frequent rearrangement of the repair tracks, they should be located with this thought in view. This is true also of the buildings necessary in connection with these tracks. The buildings are rather storehouses than shops. They are required for storing

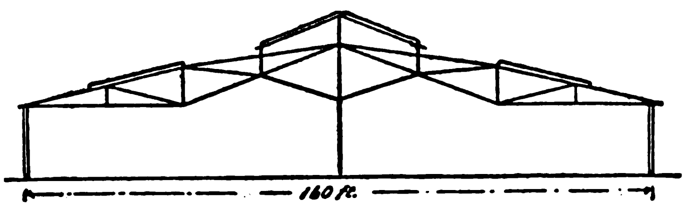


End Elevation, Passenger Car Paint Shop.

tools and such supplies as would be damaged by exposure to the weather or would be likely to be stolen if left unprotected. The buildings should also afford facilities for storing wheels and axles and a supply of oils. They should be provided with convenient benches for working in metals and wood. Compressed air and convenient connections for testing air brakes are also required in connection with these tracks.

In caring for passenger cars, ample facilities for cleaning the cars inside and out are needed.

This necessitates hot and cold water. Compressed air affords a convenient and economical method of cleaning upholstery, carpets and involved wood work. This and the uses to which compressed air is put in connection with the air brakes require that repair tracks should be supplied with it. If possible, the repair yards should be located near the roundhouse or machine shops so that steam, compressed air and oil supplies may be obtained therefrom. Air jacks are another convenience which may be advantageously used. When steam is used



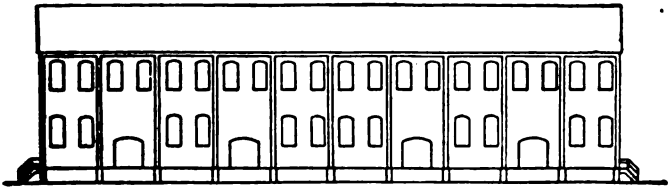
Cross Section, Passenger Car Paint Shop.

for heating cars, a supply is required in the yard so that the cars may be warmed before being put into the train. If conveniently located, this supply may be most economically obtained from the roundhouse or machine shop.

The articles required in making petty repairs to cars are obtained from the nearest storehouse, and in order that work may be done effectively and the cost of labor reduced to the minimum, standard details of car construction are required to be established and maintained.

Stations are established at junctions with other roads and at convenient intervals along a line for the purpose of making such light repairs as the needs of the service demand. Inspectors at these points examine every car in transit with a view to discovering and correcting defects, those requiring repairs not provided for at the inspecting station being sent to the general shops or repair tracks.

The organization that looks after the care of cars may be separated from that provided for repairs and renewals. The service is divided into skilled and unskilled labor, like that for locomotives. It is employed in and about the repair yards and is made up of car repairers, inspectors and laborers, including cleaners.



Side Elevation, Storehouse, Car Department.

These report to and receive instructions from the foreman. The latter is directly subordinate to the superintendent of cars or the master mechanic; in some cases to a general foreman who reports to the general officer in charge.

The supervisory force for the care of cars is generally similar to that for locomotives; in one case it is over car repairers, in the other over roundhouse employes.

REPAIRS OF CARS.—The principles governing the repairs of locomotives as distinguished from their care also apply, generally, to cars. In the case of the latter, however, where climatic conditions permit, repair sheds with only a roof covering are often made to answer the purpose of more enclosed buildings.

It is desirable, when practicable, that the repair shops for cars and locomotives should be contiguous. The advantages of combining the two plants are too valuable to be overlooked and far outweigh any disadvantages that such union engenders. In what follows it is assumed the buildings comprising the two kinds of work are located in convenient, neighborly relation.

The car repair shops may be said, briefly, to comprise a planing mill, erecting shop for passenger cars, erecting shop for freight cars, passenger car paint shop, freight car paint shop, blacksmith and forge shop.* The storehouse is general.

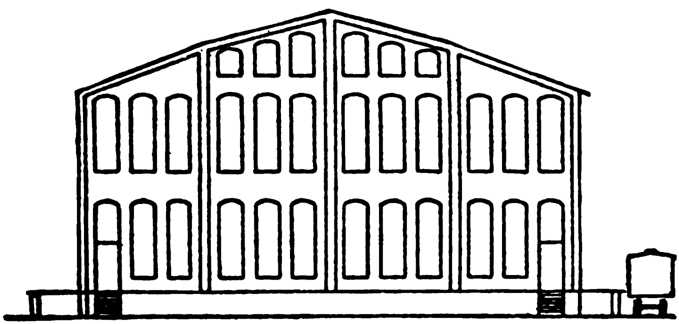
The planing mill must be easily accessible to the lumber yard and dry kiln. At the other extremity of the building the finished material is distributed to the erecting shops. It should also be convenient to the power house, as the planing mill makes large demands in this respect.

It is thought the passenger car erecting shop, the freight car erecting shop, and the paint

* If the road is a small one, these buildings will be consolidated to conform to actual needs. Indeed, this adaptability of the plant to what is required by local conditions will occur in every branch of the service.

shops may be advantageously located parallel to each other, yet separated sufficiently for a transfer table to be placed between them. The dimensions of the transfer tables must be sufficient to hold cars of the maximum length.

The machine shop, blacksmith shop and forge shop may be consolidated under one roof, but should be separated by permanent partitions of masonry running parallel with the end walls.



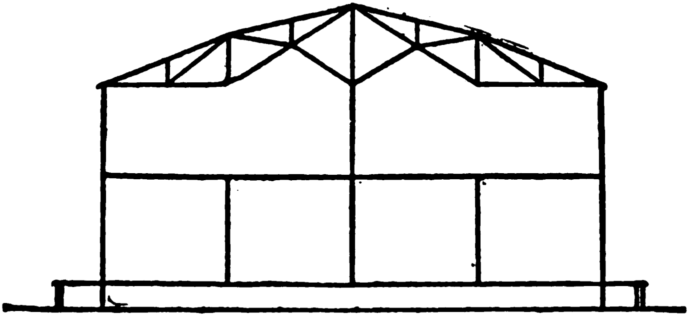
End Elevation, Storehouse, Car Department.

This building should be located so that it may be easily reached with cars loaded with material. Provision for storing car wheels, mounted on axles, and unmounted, should be made near the machine shop.

In that part of the machine shop contiguous to the blacksmith shop, bins and racks should be provided for storing damaged articles, such as bolts and rods, so that they may be repaired and made serviceable in the blacksmith shop with the least expense for handling.

Fuel supplies should be of suitable nature and conveniently located for use.

It is thought that the storehouse serving in common the locomotive and car departments should be located with reference to the convenient handling of material for the latter rather than the former. This is true also of the location of the power plant. Owing to the large amount of power required in the planing mill,



Cross Section, Storehouse, Car Department.

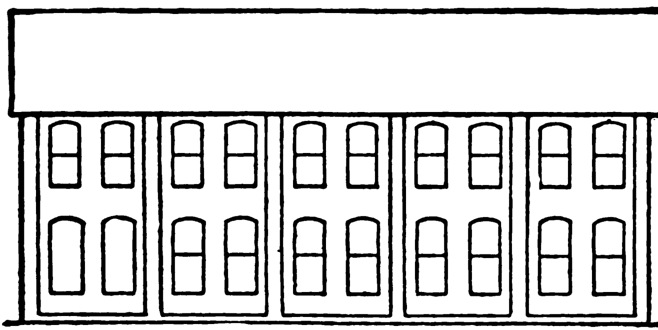
the necessities of this building require that the power should be located as near to it as possible.

The buildings of the car department should be well lighted and ventilated. This is easier of accomplishment than in the case of locomotives, as the machinery is lighter and the dirt and soot less.

The walls of the car repair shops need not be of heavy construction, as it is not necessary to provide for traveling cranes. They should, however, be substantial and covered with a well-braced, durable roof.

The floors of the machine shop, erecting shop and planing mill should be substantial and adapted to resist the wear and tear inseparable from the handling of heavy material. The floor of the paint shop should be of cement, or like substance, finished with a smooth surface and provided with good drainage and sewerage facilities.

The planing mill may be built two stories in height, the upper floor being fitted with machin-



Office and Laboratory.

ery for use by cabinet and patternmakers. Both floors should be well lighted and ventilated. The removal of the sawdust and shavings by what is known as the exhaust process of conveyance makes ventilation and cleanliness easier of accomplishment. The second story floor should be well braced and sufficiently strong to carry the shafting for the machinery on the lower floor without serious vibration.

The erecting and paint shops should be provided with movable platforms and racks for use as scaffolding in working on the upper parts of the cars.

A paint and oil stock room for daily current supplies should be located conveniently to the paint shop. It should be fireproof and kept scrupulously clean.

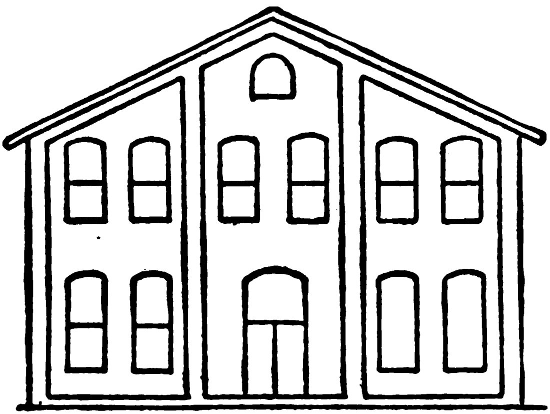
An upholstery room is necessary in or near the passenger car shop. It must contain facilities for upholstering, dyeing, repairing curtains, hangings, linen, bedding, and so on. Compressed air will be found useful and economical in renovating curtains, cushions and carpets. It may also be found desirable to do electroplating work in this branch of the department.

The equipment of the planing mill and car shops requires to be handled with a view to securing the greatest results with the least outlay. This refers both to the nature of the tools used and their arrangement and care. The subject is one of supreme importance and, because of the improvements occurring each day, requires constant attention.

Pneumatic hoists suspended on trolleys operated on overhead runways should be provided when circumstances warrant it. These hoists may also be used to advantage in handling trucks, wheels, axles, and so on.

Portable air-jacks with sufficient capacity to raise one-half the weight of a car—or more if need be—will also be found to be convenient and labor-saving devices.

The repair tracks should be provided with ample yard room, arranged for making repairs on such cars as may be handled to advantage out of doors. A good arrangement of tracks is thought to be in pairs, with wider spacing between each group of two so as to facilitate the



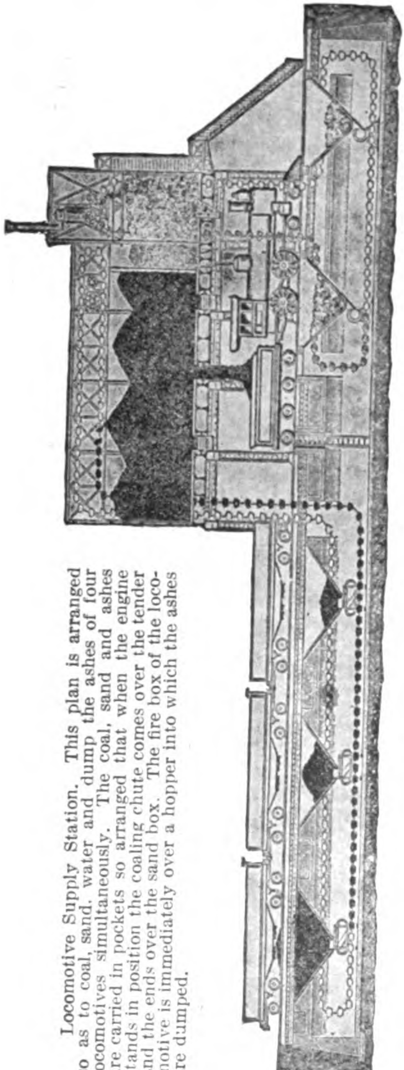
Office and Laboratory.

handling of material, supplies and tools by workmen. The ground between the repair tracks should be suitably paved. A narrow gauge track should be laid between each pair of repair tracks for handling heavy material, wheels, truck timbers and drawbars on push cars. "With suitable turntables this narrow gauge track may be connected through the car machine shop, blacksmith shop and storehouse, so as to allow the raw product from the store to be transferred direct to the blacksmith fire or to the machine shop without additional handling. By using an empty vehicle in connection with the loaded vehicle the raw material may be passed from the loaded vehicle to the machine and from the machine to the empty vehicle, thus avoiding the extra handling which takes place when the material is thrown on the floor from the machine."*

The labor organization of the car repair shops is the same as that noted for repairs of locomotives. All workmen report to gang foremen; these latter usually to departmental foremen. These in turn report to a general foreman who is responsible to the superintendent of cars or the master mechanic, as the case may be.

In general, local master mechanics have charge of the repair of locomotives and cars on the various divisions of a road; all these divisional officers report to the heads of the car and mechanical departments as their work suggests, to the superintendent of motive power (general master mechanic) on matters relating to locomotives, and to the superintendent of cars on matters relating to his department. The machinery department should also include a mechanical engineer in charge of designs for locomotives, cars, machinery, etc. He has charge of the draughtsmen engaged in work connected therewith, drawings, etc. He reports to the general master mechanic or superintendent of cars, according to the work he is engaged upon, or to either solely, as may be prescribed.

* Mr. G. W. Rhodes.



Locomotive Supply Station. This plan is arranged so as to coal, sand, water and dump the ashes of four locomotives simultaneously. The coal, sand and ashes are carried in pockets so arranged that when the engine stands in position the coaling chute comes over the tender and the ends over the sand box. The fire box of the locomotive is immediately over a hopper into which the ashes are dumped.

A well-appointed physical and chemical laboratory, equipped with suitable machinery and fittings for making physical and chemical tests of iron, steel, springs and so on, and chemical tests of other materials, such as oils, paints, water, etc., is a necessary accessory of the machinery department of a railroad.

The laboratory should be in charge of an engineer of tests. He will require such assistants as may be necessary to make tests and analyses promptly, and also to inspect such material as car wheels, tires, axles, round and bar iron, steel, boiler plate, etc., all of which kinds of supplies should be bought under specifications.

If a special building is prepared for the laboratory, it may be built two stories high, with the draughting, blue printing and mechanical engineer's office on the second floor.

The building used for a laboratory will afford, in many cases, desirable headquarters. Here may be grouped the offices of superintendent of motive power (general master mechanic) and superintendent of cars, with their assistants and clerical forces. These varied and important uses require that the building should be centrally located, ample, well lighted and heated, and carefully ventilated. This association of different offices in one building near to valuable sources of information will tend much to simplify business and expedite work. It renders co-operation easier and, therefore, more likely to occur.*

* "The concentration of offices, in my judgment, is just as important as the grouping of various parts of the work so as to avoid the labor which will occur if they are separated. The in-

Important features which relate to shop and attendant work are those questions connected with the handling of material and keeping of the time of workmen and others. In regard to the first, it is referred to very fully in another volume. I have there discussed the disciplinary and other questions which enter into the careful, prudent and economical purchase of material, its inspection when bought, its care afterward, its disbursement in connection with the operations of a road, and, finally, the accounting involved, embracing, among other things, the charging of the material to the thing upon which it is expended.

In regard to the principles which govern those connected generally with the machinery department, so far as relates to questions of labor as between employer and employe, they are discussed in the volume "Organization of Railways." Other and more practical features, such as those connected with the keeping of the time of employees, payment of wages, distribution of the pay-roll to the various accounts upon which the labor has been expended, are discussed in the volume "Safeguarding Railway Expenditures."

Many things of the greatest possible impor-

---

troduction of telephones has made this grouping of offices perfectly practicable. With a good shop telephone system each head of a department can be in close communication with his various shop foremen, and it is a great advantage in having the head men in the same building. A central building of this kind should always have a convenient meeting room. We believe that the most economical management of railroads is where there is the closest co-operation of departments. This co-operation is best accomplished by periodical meetings. The same benefit that the head officials obtain by such meetings, subordinates obtain."—*Mr. G. W. Rhodes.*

tance, as everyone recognizes, enter into questions of labor. In the first place, the principles which govern it, as between employer and employe, must be rightly understood by both, in order that justice may be done and neither party suffer through ignorance or inadvertence. I have taken up this phase of the subject at considerable length in the book referred to above and, while I feel that I have not been able to do it justice, I have endeavored to throw such light on it as my experience and research enable me to do.

In regard to the hum-drum of daily life on a railroad, the appliances must be such that those who work in the machinery department or elsewhere shall surely be allowed the full time they work. This requires that the accounts shall be kept accurately and that returns thereof shall be rendered to headquarters and payment made accordingly. This in the interests of the employe. On the part of the employer it is required that he should know exactly what the labor has been expended upon and the cost thereof, so that he may, at his leisure, classify it month by month, or in detail, as his interests suggest. All these things are matters of routine, and provision is made therefor, both as regards wages and the accounting connected therewith, in the volume referred to.

Questions of accounts relating to material and labor do not affect directly the care and repair of locomotives and cars, but, incidentally, they do, so that in studying the theme as a whole they must be considered. This proves, if proof were necessary, which it is not, what I have so often called attention to elsewhere throughout this work, namely, that in order to understand a particular department of railroad work, one must be generally familiar with all departments. It is not enough to know how a shop should be located, what machinery it should contain and how such machinery shall be used. We must have knowledge concerning questions collateral thereto, which questions, one by one, will be bound to reach out and overlap others until, finally, they cover the whole railway world.

CHAPTER II.

ERECTING SHOP WORK—SETTING FRAMES.

When for any reason the frames of a locomotive have been taken down, the following points should be observed in re-setting them:

(1) They must be parallel to the cylinder center lines.

(2) They must be square vertically.

Locomotive frames are generally made in two sections, the main frame, containing the driving box pedestals, being in one forging and the front frame, to which the cylinders are attached, being in one or two pieces depending on the style of cylinders used.

For the purpose of illustration, the setting of the frames on a modern eight-wheeled passenger locomotive will be taken.

The front frames *a*, *a*, Fig. 1, will be placed in position and bolted temporarily to the cylinders. Then fit and drive the cylinder keys *b*. This for the reason that if the frame bolts are fitted first it will be impossible to properly key the cylinders to the frame, and the working stress will be taken by the bolts instead of by the frame and keys and loose cylinders will result. Ream all holes through the frames and cylinders and have bolts fitted. They should be a good driving fit; do not

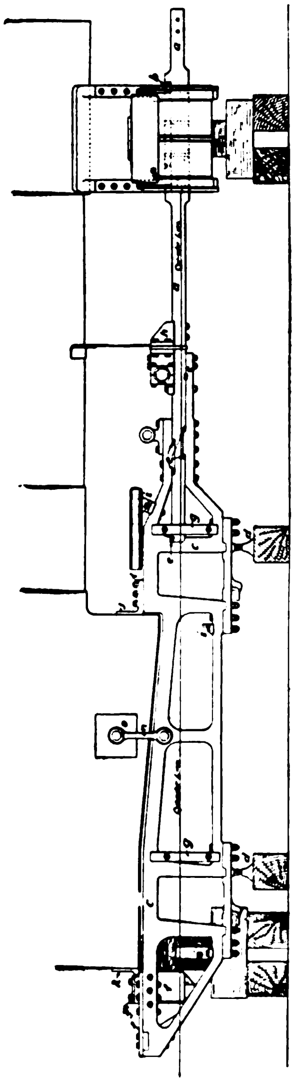


Fig. 1

allow any loose bolts here, as they will cause trouble later.

The main frames *c*, *c* are now placed in position and supported on jacks placed under the pedestals as shown at *d*, *d*. Put temporary bolts through the frame splices and drive the keys *e*, *e* so as to bring the splices into position. The deck casting *f* should now be placed in position, holes reamed and bolts fitted a good driving fit. This will space the frames the correct distance apart at the rear end. Just forward of each jaw place the clamps as shown

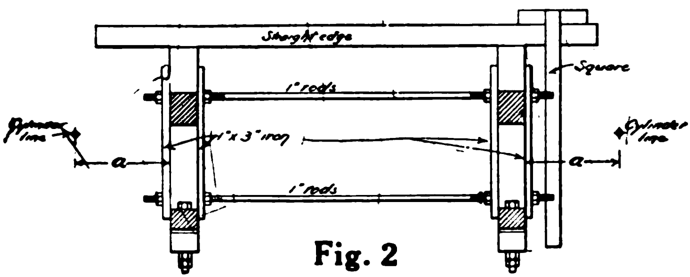


Fig. 2

at *g*, *g* (these are also shown in Fig. 2, and consist of two wrought iron plates for each jaw held together by two 1-inch rods and nuts), by means of which the frames are to be brought parallel with each other and square vertically, using a square and long straight edge across the tops of the frames with the square blade against the pedestal jaws. See Fig. 2. Now run center lines through the cylinders, securing them to some point to the rear of the frames. These lines may or may not be parallel, but the distance *a, a,* Fig. 2, from the lines to the frames at opposite pedestal jaws should be equal. The correct distance may be found by taking one half the sum of the two measurements *a, a.* Suppose the distance *a* from the right line to the frame measures $13\frac{3}{4}$ inches and from the left line to frame $13\frac{1}{4}$ inches. $13\frac{3}{4}'' + 13\frac{1}{4}'' \div 2 = 13\frac{1}{2}''$, the correct distance. Move the frames until they show correct and at the same time bring them the right height. Generally speaking the tops of the frames should be parallel with the cylinder center lines and may be brought so by measuring from the straight edge held across the tops of the frames.

Now fit and drive the keys, *e, e* permanently and ream the holes for the splice bolts and have them fitted a good driving fit. Put up the guide yoke braces *h* and front half of rocker boxes and put guide yoke in place, ream holes and have bolts fitted. Place the cross braces *i, i, i* in position, and also the furnace anchors *j* and *k*. These anchors are bolted to the throat sheet and back head and the holes in the sheets for the studs, in new work, should be laid out from the anchors when in position, after which they should be taken down and the stud holes drilled, tapped and studs fitted. The anchors can then be put up and permanently fastened to the boiler and frames. The front anchor *j* rests on top of the frame and is slotted for the three studs, which should have thimbles over them slightly longer than the anchor is thick, so that the plates *l*, which are rigidly bolted to the top of the thimbles, will not touch the anchors, and allow them to move laterally on the frame as the boiler expands. The rear anchor has two feet which rest on the deck casting between lugs and are held down by plates *m*, bolted to the deck. These plates must not bind the anchor and care must be taken to see that all side motion between the anchor feet and deck lugs is taken up by shims.

The suspension links *n* should now be placed in position and the holes in the side sheet for the studs holding the plate *o* laid out, drilled and studs fitted, after which the plates can be bolted up and links put on. The expansion links should fit the pins without any lost motion, but care should be taken that they are not too tight.

Clamps *g*, *g* are now removed and the job is finished.

In the foregoing it has been assumed that frames were being placed under a new boiler. When the boiler is old the procedure will be the same except that the studs for the furnace anchors and link plates will be in place. In such cases, these studs should be carefully examined and any that show signs of leaking should be removed and new ones fitted. Run a solid die over the remaining ones to straighten up the thread. If the frames were put up correctly in the first place the furnace anchors should come right, but if they do not they will have to be drawn or upset, as the case may be, using care to see that the holes for the studs are not disturbed.

See that all bolts and keys through the frames are tight and a good fit, otherwise all kinds of trouble will be experienced after the engine goes into service.

With engines having the fire box between the frames a slightly different method of procedure will be necessary. See Fig. 3.

Before placing the rear frames in position examine the studs *a*, *a*, *b*, *b*, and remove any that have poor threads or show signs of leaking. Run a solid die over the remaining ones to straighten up the threads.

Place the frames in position, supporting them on jacks as shown, and bring them to proper height, which will be when the buckles will slip over the studs. Place the deck in position and bolt down as previously described. This spaces the frames at the rear end and by means of the clamps *g*, *g* bring the frames parallel and square vertically. Put in the splice keys *e*, *e*, and temporary splice bolts. Now run center lines through the cylinders and bring the frames central between them by making the distance *a*, *a*, Fig. 2, from the lines to opposite pedestal jaws equal. Suppose at the front jaws the right one measures $13\frac{1}{2}$-inch and the left one $13\frac{3}{4}$-inch. The correct distance will be $13\frac{1}{2}'' + 13\frac{3}{4}'' \div 2 = 13\frac{5}{8}''$, hence the frames must be moved $\frac{1}{8}$-inch to the left. This can be done by driving wedges between the fire box and frame at *c* and *d* on the left side until the distance is correct. Place wedges between the fire box and frame at the same points on the right side, but do not drive

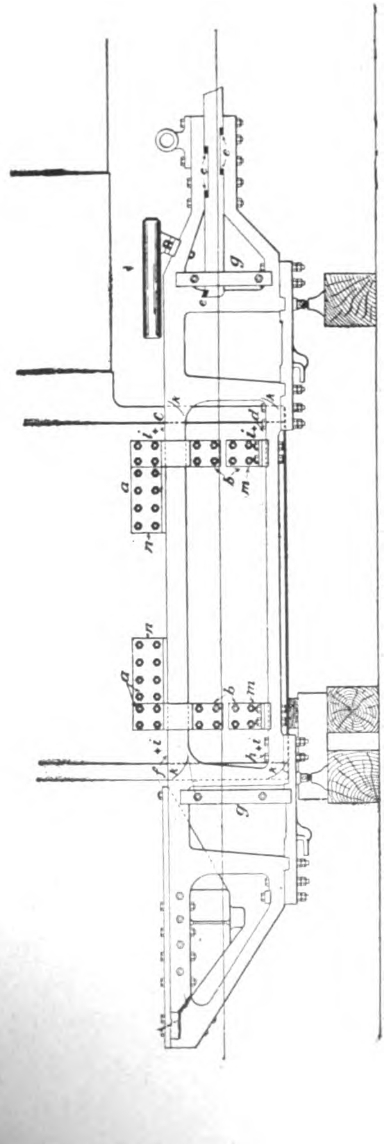


Fig. 3

them down, as they are simply to keep the frame in position. Suppose the back jaws measure $13\frac{7}{8}$-inches from the left line and $13\frac{1}{8}$-inches from the right one. The correct distance will be $13\frac{1}{2}$-inches and the frames will have to be moved to the left $\frac{3}{8}$-inch. Do this by driving wedges between the fire box and frame on the left side at points *f* and *h*. Put wedges at the same points on the right side. Now try the frames for square vertically as shown in Fig. 2, as they may have been thrown out in wedging the frames over. Suppose we find the bottom of the right pedestal shows 1-16-inch away from the square

Fig. 4

blade. We could bring the bottom out 1-16-inch by loosening the left front bottom wedge and driving down the right front bottom one the required amount, but this would throw the frame out of line. To square the frames up and at the same time keep them in line loosen up the left front bottom wedge enough to allow the frame to go to the right 1-32-inch and drive down the right bottom wedge until the frame is drawn 1-32-inch to the right. Now loosen the right top wedge enough to allow the frame to go 1-32-inch to the left and drive down the left top wedge until the frame is drawn 1-32-inch to the left. A little thought will show that the frame is now square and also in line. Proceed the same for the back pedestals.

The frames are now in position, and as a check on this, and to know that the liners, when fitted, are of the correct thickness, make a small tram of any convenient length, as shown in Fig. 4. Make a center punch mark on side of fire box at *i*, and from these points with the tram scribe short arcs on the frames as shown at *k*, *k*, *k*, *k*. Do the same on the opposite side. If the liners are the correct thickness, the tram point will fall in the same arcs when the liners are in place and frame buckles bolted up.

The liners should now be fitted up. Generally the old ones can be used, but in case new ones must be made they must be planed the exact thickness to fill in between the frame and fire box and also have holes for studs drilled as well as clearance holes for the heads of the stay bolts. After the liners are in place the studs through them should be screwed in and the buckles bolted up. Care should be taken to see that the buckles do not bind on the frame, as they should be loose enough to allow them to slide on the frame as the bolier expands.

The bottom pads *m*, *m* are lipped over the outside of the lower frame brace and fastened to it by two bolts through each pad. These bolts are a driving fit in the frame brace, but work in slots cut in the pads and have thimbles over them. These thimbles rest on the frame and project a little above the pads so the plates, which are bolted rigidly to the top of the thimbles, do not touch the pads and allow the latter to move laterally as the boiler expands. The upper pads *n*, *n* are bolted to the sides of the fire box and simply rest on top of the frames,

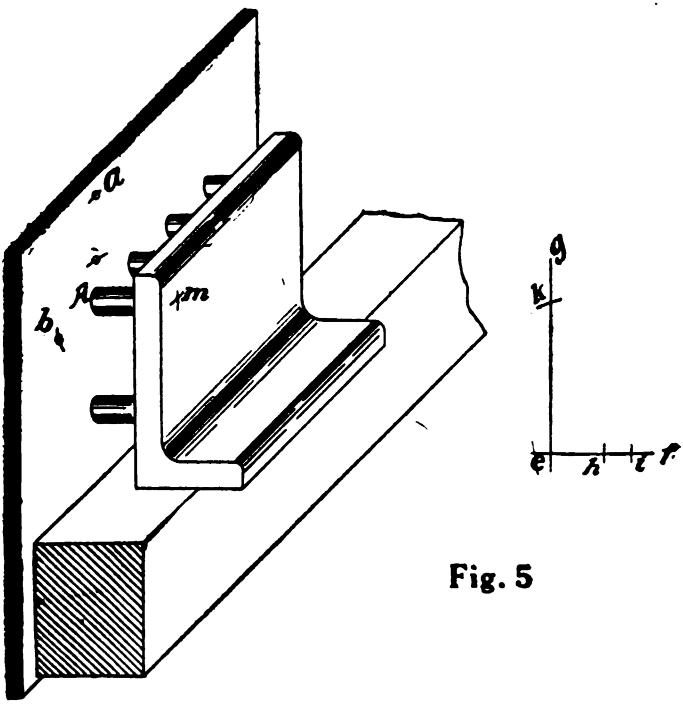


Fig. 5

not being fastened to them in any way. Their function is to carry the weight of the boiler.

When necessary to apply new buckles or expansion plates where the studs are in the boiler, it will be found rather difficult to lay out the holes in the plate accurately. Sometimes it can be done with a surface gauge, but as good a way as any is as follows, (see Fig. 5). From the center of one stud with any convenient radius scribe arcs on the fire box sheet as shown at *a* and *b*, and make small center punch marks on the arcs as near 90 degrees apart as convenient. Now, on a board or sheet of tin draw the lines *e, f* and *e, g*, at right angles. From *e*, on line *e, f*, lay off the point *h*, distant from *e* the length of the stud, and also the point *i*, distant from *h* the thickness of the plate. From the point *h*, with the same radius used in drawing the arcs *a* and *b*, scribe the short arc cutting line *e, g* at *k*. Then set the dividers to the distance *k, i*. Place the expansion plate or buckle on the frame in proper place lengthwise and against the studs as shown, and from the center punch marks *a, b*, with the radius *k, i*, scribe short arcs on the outside of the plate intersecting at *m*. This will be the center of the hole for this stud. Locate a center for another stud in the same manner and from these two centers the rest of the holes in the plate may be laid out accurately. This method of locating centers will be found of general application.

When an engine comes to the shops for general repairs it will generally be found that the pedestal binders will need re-fitting. If, on account of heavy boiler work, it is necessary to take the main frames down, it will be found most convenient to do this work while the frames are on the floor, and with this end in view they

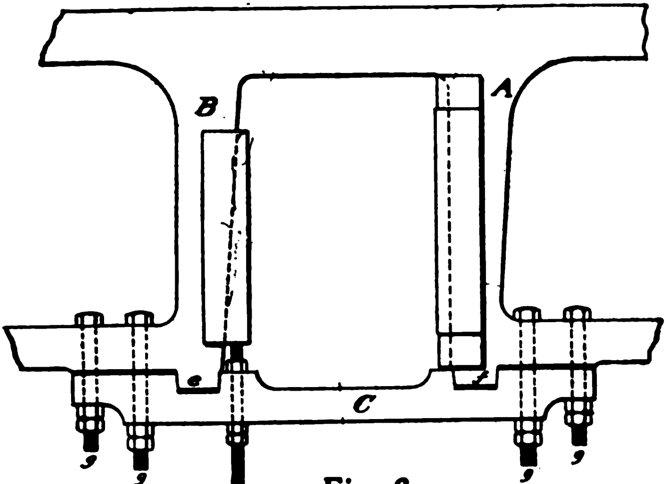


Fig. 6

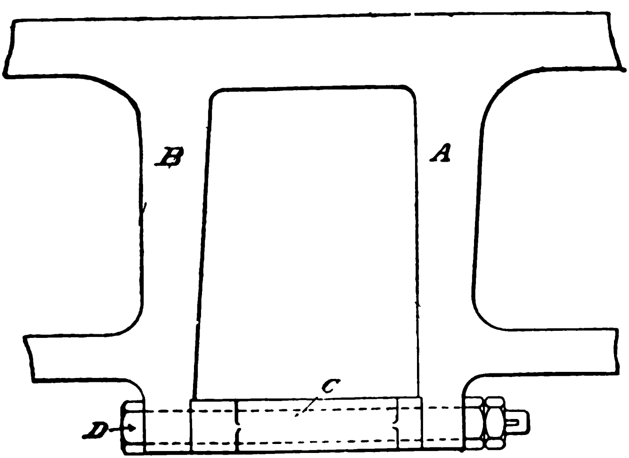


Fig. 7

should be placed bottom up on blocks about one foot high, which will bring them into a convenient position for this work, and also the facing up of the pedestal jaws.

Pedestal binders are of two general types as shown in Figs. 6 and 7. In Fig. 6, the pedestal jaws *A* and *B* are joined by the binder *C*, recesses in which fit the tapered projections *e* and *f*, on the bottom of the jaws. This cap or binder is held in place by the through bolts, or in some cases studs, *g*, *g*, *g*, *g*. In Fig. 7, the space between the jaws is filled by the cast iron thimble *C*, and they are tied together by the binder bolt *D*. There are several other styles of binders in use, but they can all be brought under the two types as shown.

In fitting up binders of the type shown in Fig. 6, the projections *e* and *f* should first be filed at right angles to the frame's length, and all to the same bevel, which should be, in the absence of drawings, from 6 degrees to 8 degrees from perpendicular to the top of the frame. The inside faces of these fits should be about ⅛-inch below the face of the pedestal jaws *A* and *B*, in order that the jaws may be re-faced without destroying the fit of the binder.

In case the old binders are to be re-fitted the method will be as follows: Try all the binders in position and observe the fit. In Fig. 8, it is found that the binder just touches the two outside faces of the jaw at *d* and *c*, and is 1-32-inch loose at *a*, and 1-64-inch loose at *b*. Have the blacksmith draw it 5-64-inch between the points *a* and *b*. This will take up the lost motion at *a* and *b*, and allow something for a re-fitting, but will destroy the fit at points *d* and *c*. It will therefore be necessary to close it 1-32-inch plus enough for re-fitting at *f*, and 1-64-inch plus enough for re-fitting at *g*. The slots in the binder should now be filed out to fit the projections on the jaws so as to allow the binder to bed solid on the frame. Put a center punch mark in the side of one jaw as at *i*, Fig. 8, and with a solid tram scribe a line *k*, *k* on the opposite jaw and fit the binder so that when in place the tram

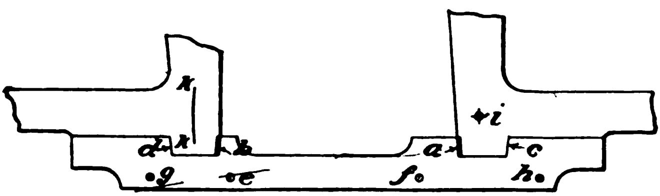


Fig. 8

will fall in the line. By drawing the binder in the manner described the holes for the bolts, or studs, will be thrown out the minimum amount and save, in many cases, reaming or filing the holes. In some shops it is the practice to fit the binder to the projections on the frame so as to allow it to stand off from the frame from 1-16-inch to ⅛-inch. It is questionable, however, whether this is good practice, as a binder fitted in this manner will be found working in a short time and unless looked after will soon destroy the fit to the frame.

If a new binder is to be fitted it should first be planed on one side. If the frames are on the floor, two straps of flat iron *e* and *f*, Fig. 9, about 8″x1½″x⅛″ should be clamped to the frame as

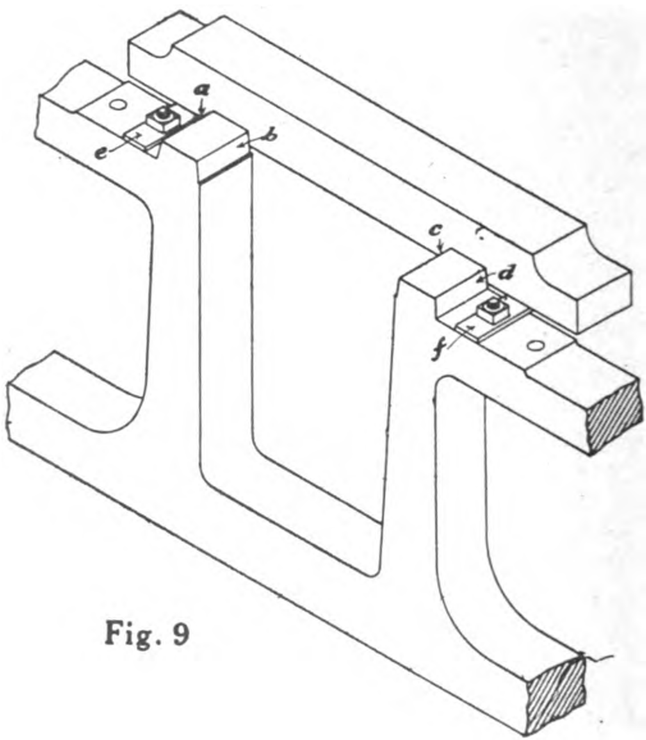


Fig. 9

shown, allowing them to project out from the frame far enough to support the binder which is to be placed on them planed side down and against the side of the frame. Bring the planed side of the binder at right angles to the side of the frame by bending the strips up or down and fasten it in this position, being particular that it is in proper position lengthwise. With a straight edge held against the jaw fit at *a*, *b*, *c* and *d*, scribe a line across the binder on the planed side, and on the side next to the frame scribe around the end of the fits to show the bevel the recesses are to be planed to. Have the slots in the binders planed about $\frac{1}{32}$ inch deeper than the height of the frame fits. After planing, the binder should drop down to within about $\frac{1}{8}$ inch of the bottom of the frame and should be fitted by filing until it will bear solid on the frame and at the same time fit tight on all four faces of the jaw fits. The holes for the frame and wedge bolts should now be laid out and drilled.

If frames are in place under the engine and engine on blocks see that it is so blocked that there will be no unnatural stress upon the frames. Then clamp the binder up in the same relative position as shown in Fig. 8, and proceed the same.

With the form of binder shown in Fig. 7, if they are found to be more than $\frac{1}{64}$ inch loose, enough should be planed off from the end furthest from the wedge bolt holes to enable a piece of $\frac{1}{16}$-inch sheet iron or steel to be tacked on to the end by four $\frac{3}{16}$-inch or $\frac{1}{8}$-inch rivets. This end should then be planed or filed so as to just fit between the jaws. The binder bolt should be a loose fit in the frame and binder so that it can be shoved into place by hand, for if it is a tight fit trouble will be experienced whenever it becomes necessary to take it out while the wheels are under the engine. With this style of binder the nuts must be drawn up very solid and should be inspected every trip the engine makes. The same is also true of the binder bolts in the style shown in Fig. 6.

The faces of the frame jaws which form the seatings for the shoes and wedges should be

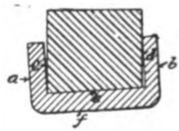


Fig. 10

filed up to a surface plate and at right angles to the length of the frame. If the variation in this respect is slight it may be neglected, but if considerable it should be corrected, otherwise the side flanges of the shoes and wedges not bearing on the sides of the frame are liable to be broken. Fig. 10 shows this condition in an exaggerated manner. The faces *a*, *b*, *c* and *d* of the shoes and wedges are planed at right angles to the face *e*, hence the shoe or wedge will take the position shown.

CHAPTER III.

ERECTING SHOP WORK—FITTING UP CYLINDERS.

In fitting new cylinders to an old boiler or old cylinders to a new boiler the following points should be observed:

(1) The longitudinal center line of the boiler must be in the same vertical plane as a line drawn midway between and parallel to the center lines of the cylinders.

(2) The longitudinal center lines of the cylinders must be in the correct position relative to the longitudinal center line of the boiler as shown by the erecting card, or in case no drawings are at hand, in the position occupied by the old cylinders.

(3) The cylinders must be located the proper distance from the throat sheet.

For the purpose of illustration, the problem of fitting a pair of new cylinders to an old boiler will be taken, the method given being one that is in general use and has proven satisfactory.

The cylinders will be received from the machine shop properly bolted together and should be placed on a truck and leveled up cross ways. The boiler should be blocked up as shown in Fig. 1, high enough to allow the cylinders to be run into position under the arch, making the distance from the throat sheet at *g* to the center line of the cylinders at

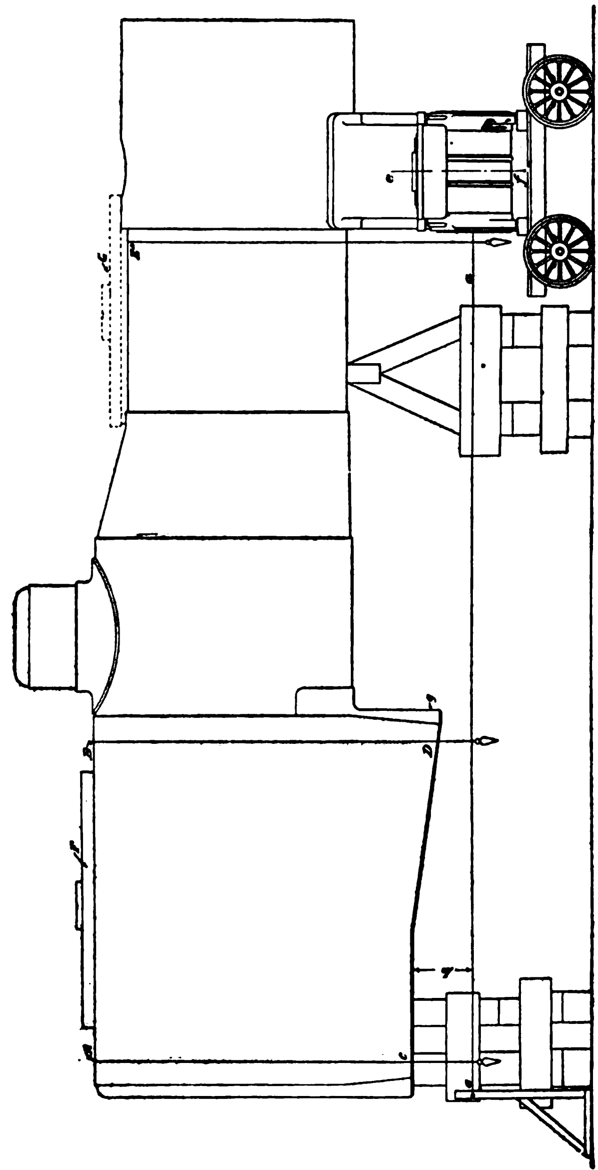


Fig. 1

e, f equal to the dimension called for by the erecting card. In case no drawings are at hand, this measurement should be taken before the old cylinders are removed from the boiler. Center lines should be run through the cylinders and fastened to some point to the rear of the fire box as shown.

The following operations, while being described separately, will, in practice, be carried on at the same time.

(1) The boiler should be leveled up transversely by placing plumb lines over the roof sheet at the points *A* and *B*, allowing them to extend below the mud ring and making the distance from these lines to the sides of the fire box at the points *c* and *D* (and the two similar points on the opposite side of the box) equal. If from faulty construction of the boiler they cannot be made equal, they should be averaged.

(2) The front end of the boiler should be brought central between the cylinders by placing a plumb line over the barrel at the point *E* just back of the cylinders and moving the boiler until the distance from the plumb lines to the cylinder center lines is equal on both sides, (see Fig. 2). At the same time the rear end of the boiler should be made central by measuring from the plumb lines *A* and *B* to the cylinder center lines.

(3) The center line of the boiler and the lines through the cylinders should be made parallel lengthwise by the use of a long straight edge placed at *F*, or *G*, with proper packing under it

to make up for the lap of the sheets in case it extends over more than one sheet, and with an adjustable level placed on the straight edge

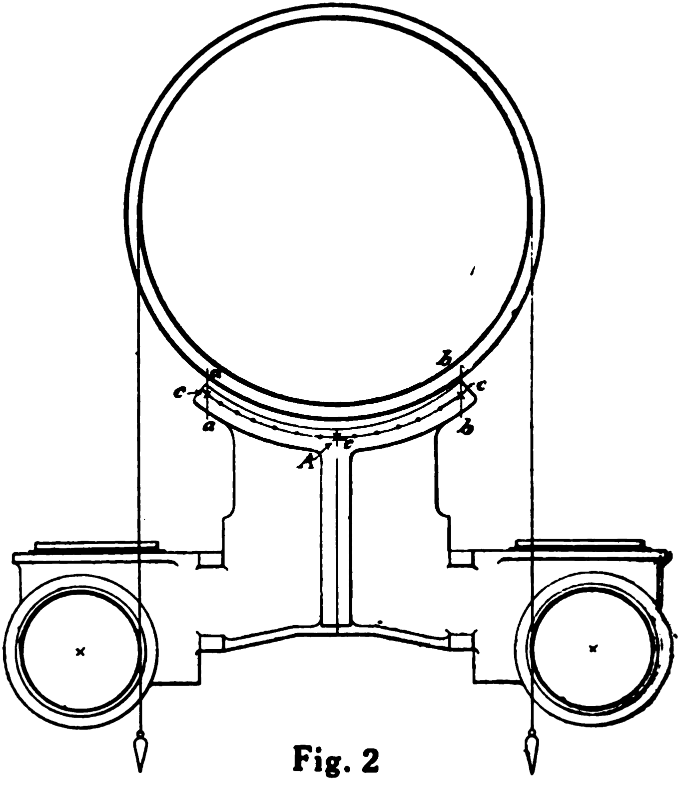


Fig. 2

and in the cylinder bore, move the boiler or cylinders into such position that the level will show the same.

In the foregoing operations the height of the boiler is immaterial, except that the bottom of the arch should be kept as close to the top of the saddle as possible.

The cylinders and boiler are now in correct position, except that the vertical distance between their center lines is too great by the amount the arch is above the saddle and the amount to be chipped off in making the fit. Measure the distance *b* between the bottom of the mud ring and the cylinder lines, and the difference between this measurement and the one given on the erecting card, or as was determined before the old cylinders were removed, will be the amount the boiler must be lowered or the cylinders raised. Measure this distance down from the bottom of the arch at the center of the saddle, front and back, as shown at *A*, Fig. 2, and near the four corners of the saddle scribe short vertical lines *a*, *a*, *b*, *b*, and lay off this same distance down from the arch vertically. This gives three points on the saddle, front and back, through which the chipping line must pass.

Have a wooden template as *A*, Fig. 3, made to fit the bottom of the arch. This template should be somewhat longer than the saddle is wide, and if the arch is not the same curvature at both ends, two of them should be made and marked so as to be easily identified. Place this template on the saddle so that the curve will pass through the three points previously found and scribe the line *c*, *c* on each side of the saddle. With a straight edge scribe lines on each side of the saddle joining the ends of the lines *c*, *c*, and locate all the lines permanently with prick punch.

Fig. 3

The cylinders should now be run from under the boiler and chipped to the lines, using a template as shown at *B*, Fig. 3, for a guide transversely, by coating the edge with marking and chipping until the template shows a full bearing. Use a straight edge to get the surface level lengthwise.

After the chipping is finished the cylinders should be run back under the boiler and jacked up against the arch and the lines again run through them and tested with the plumb lines over the boiler to see that they come square, which they should do if the work has been properly done. If everything is correct the holes in the saddle for the arch bolts should be laid out, drilled, reamed and bolts fitted. The surface of the saddle between the chipping strips should be filled with cement to make a solid bearing between the saddle and arch.

Various materials may be used for this purpose, such as stove putty or the various iron cements. If the work does not come square further chipping will be necessary. Shims are sometimes used, but it is poor practice and should not be tolerated.

On account of damage by wrecks or other accidents it is sometimes necessary to fit up one new cylinder only. In this case the work must be done entirely by templates. The broken cylinder should be taken down, together with the front frames if necessary. Make a template as shown it *A*, Fig. 4, the straight side being fitted to the half saddle at *b*, *b*, while

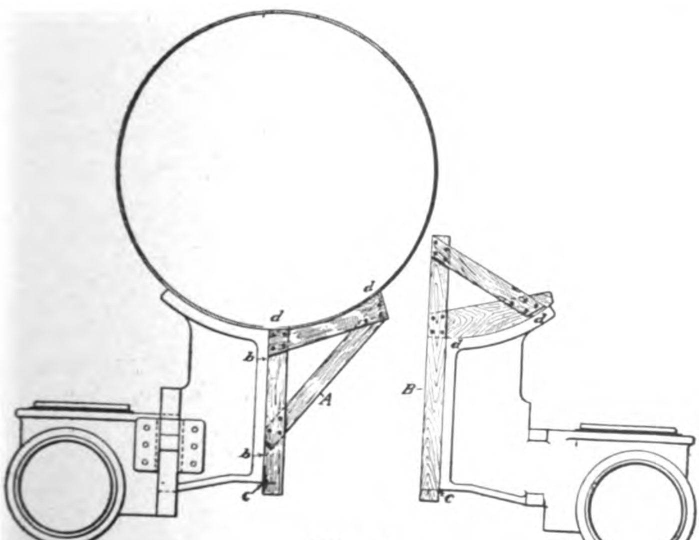


Fig. 4

the curved portion is fitted to the arch at *d*, *d*. With the template in the position shown, the line *c* should be marked on it in line with the planed surface at the bottom of the saddle. Now make another template as shown at *B*, Fig. 4, to fit the first one and on this mark the line corresponding to *c*. With template *B* placed on the new cylinder as shown, with line *c* fair with the bottom of the saddle, a line can be scribed on the ends of the half saddle corresponding to line *c*, *c*, Fig. 2.

The remainder of the work will be similar to that described previously. After chipping to the lines the cylinder should be placed in position, the joints for the heads being brought into line by means of a long straight edge and the cylinder firmly clamped in position. The holes may now be laid out, drilled, reamed, and bolts fitted.

CHAPTER IV.

Erecting Shop Work—Laying Out Shoes and Wedges.

The function of the shoes and wedges is to hold the driving boxes, and therefore the axles, parallel to each other and the correct distance apart; also at right angles to the transverse center line of the cylinders and at the same time allowing movement in a vertical direction. They also afford protection to the pedestal jaws and provide a means for taking up lost motion between the driving boxes and wedges caused by the wear due to the vertical movement of the boxes. They must be accurately fitted to the pedestal jaws so that their wearing surfaces will be exactly parallel and square with the top of the frame, the distance apart of these surfaces to be equal to the width of the driving box. The long wedge, or shoe as it is commonly called, should be the same length as the distance from the top of the pedestal binder to the under side of the frame over the jaw so that it cannot move in a vertical direction. It is generally held tight against the pedestal jaw by a bolt through the leg. To prevent ridges being formed at the ends, due to the driving box not covering the full length, the thickness at the ends should be reduced. As the short wedge is less than the driving box in length no reduction of metal at the ends is necessary. The wedge is generally held to the face of the pedestal jaw by a bolt similar to the shoe with the exception that the hole for the bolt through the frame is slotted to allow for the vertical adjustment of the wedge.

The operation of laying out shoes and wedges consists in locating certain lines or points on them for the guidance of the planer hand so that when planed the above conditions will be attained, and is chiefly a matter of intelligent

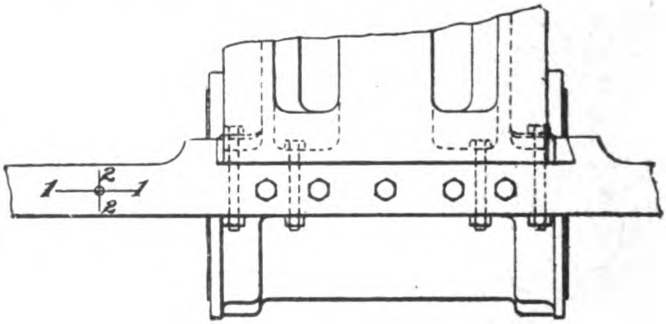


Fig. 1

and careful measurement. There are several methods of performing this work, differing in detail only, the principles underlying being the same in all cases.

Assuming that the frames have been properly set up as described in a preceding chapter with the pedestal braces bolted up, the first thing we must have is a starting point. On the inside of each front frame, see Fig. 1, scribe a short line 1, 1 near the cylinder saddle parallel to and at equal distance from the top or bottom of the frames. With a straight edge held across the frames and square with the cylinders, which may be determined by measuring from the back cylinder head joints, and a square from the straight edge, scribe the lines 2, 2 on each frame. At the point of intersection make a small center punch mark. With a tram, from these centers, scribe short arcs 3, 3 and 4, 4 on the cylinder saddle, see Fig. 2. The point *c*, where these arcs intersect, will be midway between the frames

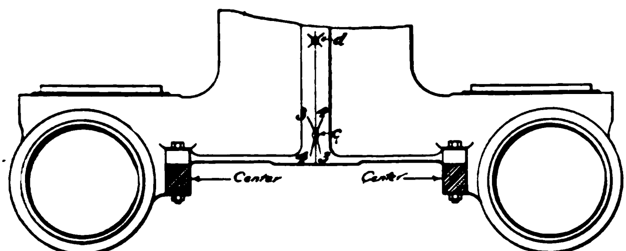


Fig. 2

and will be the starting point for laying out the shoes and wedges. Some judgment must be used in locating point *c* on the saddle so that it will be in a convenient position for traming to the main jaws as described later. In some cases it may be necessary to locate it near the top of the saddle, as at *d*.

Now over all of the jaws draw the lines 1, 1, Fig. 3, parallel to and the same distance from the top of the frame. The main jaws should next be centered as follows. If only one leg of the jaw is tapered, with a straight edge held against the face of the straight jaw draw the line 2, 2, and where it intersects line 1, 1 make a small prick punch mark. As a general proposition the pedestal jaws are so designed that with the wedge in its lowest position (about ½ inch above the pedestal binder) its thickness at the upper end will be equal to the thickness of the shoe. Hence on the side of the tapered jaw mark a point even with the top of the wedge when in its lowest position and from this point with a square from the top of the frame draw the line 3, 3, marking the point of intersection with line 1, 1 with a prick punch mark. With the dividers bisect the line 1, 1 between lines 2, 2 and 3, 3. This will give point 9 the center of the jaw. Do the same on the opposite side of the engine. If both jaws are tapered, draw the lines 2, 2 and 3, 3 in line with the faces of the jaws and find the central point 9.

The "square centers" should now be located, and good judgment must be used, taking into consideration the construction of the engine. The point being to so locate these centers as to make the minimum number of measurements to get the lines on the shoes and wedges. The tram used for this work is made of a long piece of pipe having one end drawn down to a point, the other end carrying a common adjustable tram point. Suppose with this tram we find that we can tram from point *c*, Fig. 2, on the cylinder saddle to the lower front leg of the main pedestal. With the tram held in center *c*, scribe the arc

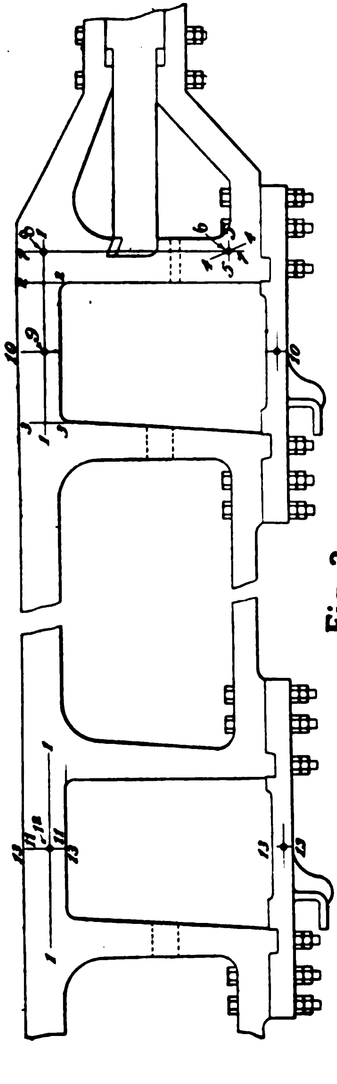


Fig. 3

4, 4 on the outside leg of each main pedestal and from the top of the frame, parallel to it and the same distance down on each side of the engine, scribe the lines 5, 5, intersecting the arcs 4, 4 at 6. These points of intersection 6 are the square centers. A little consideration will show that a line drawn through points 6, 6 on opposite sides of the engine will be at right angles to the cylinder center lines. With a square, from the top of the frame, through points 6, draw the lines 7, 7, intersecting lines 1, 1 at 8. Now with the dividers try the distance from points 8 and 9 on opposite sides of the engine. If they measure the same the jaw centers 9 are correct. If not the same, points 9 must be changed to make them measure the same by moving the point on one side ahead and the other one back one-half the difference. Having located points 9, 9 correctly, with a square from the top of the frame draw the lines 10, 10 across the frame and pedestal binders, intersecting point 9. If our work has been correctly done lines 10, 10 will be parallel to lines 7, 7, and as the center of the axle will lie in the plane of lines 10, 10, it will be square with the cylinders.

From centers 9, 9, with trams set to the length of the side rods, scribe arcs 11, 11, intersecting lines 1, 1 over the back jaws at 12, which will be the center of the back jaws. If the engine has the fire box between the frames, set the trams $\frac{1}{32}$-inch short of the length of the side rods. Scribe line 13, 13 through point 12, square with line 1, 1 across the frame and

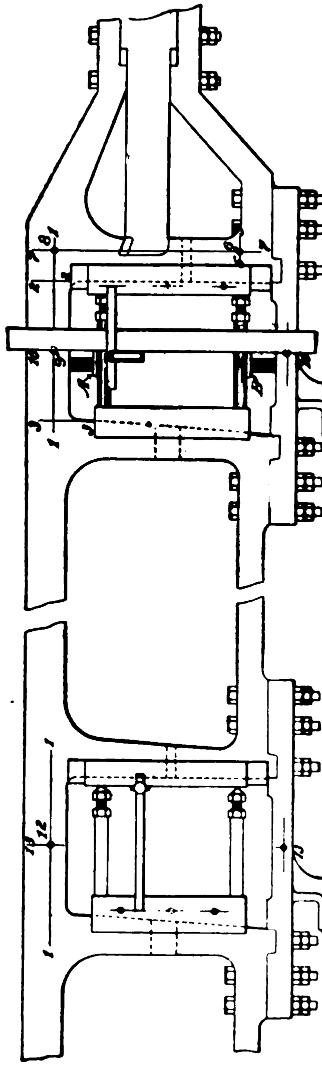


Fig. 4

pedestal binders. If the engine has more than two pair of drivers locate the jaw centers for all of them in the same manner.

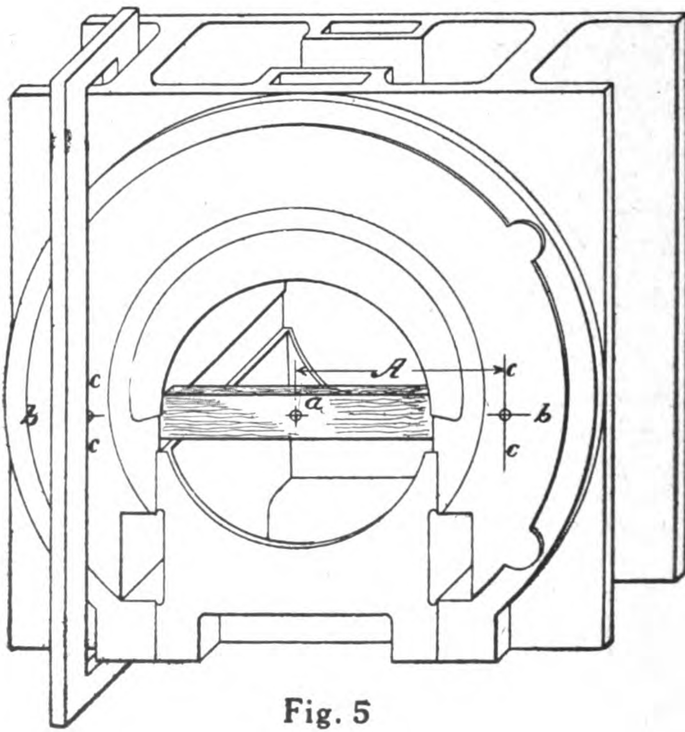


Fig. 5

We are now ready to lay off the shoes. Secure them in position by means of spreaders as shown in Fig. 4. Get two straight edges long enough to reach across the frames and secure one between the top spreader and frame as shown at *A*, and the other one between the pedestal binder and bottom spreader as at *B*. Now with a straight edge held true with lines 10, 10 bring the front edges of the long straight edges in line on both sides of the frame. The front edges of the long straight edges now lie in the plane of the center of the axle.

Place the driving boxes on the floor opposite their respective jaws, with the tops toward the rail and outer sides up. See Fig. 5. Locate the centers *a*, and through them scribe the line *b*, *b*, at right angles to the flange of the box. With the transfer plate or box marker scribe the lines *c*, *c*, intersecting lines *b*, *b*, as shown. The distance between the lines *c*, *c* is the width of the box between the shoe and wedge bearing surfaces, and the distance *A* is the distance between the center of the axle and the finished face of the shoe.

Take the distance *A*, Fig. 5, plus ½ inch with an adjustable square, and with a short straight edge held against the two long straight edges and square against the short straight edge as shown in Fig. 4, scribe two short lines on the outside of the shoe near the ends. In the same manner scribe one line on the inside of the shoe as shown by the dotted line near the center. Do the same for all the shoes and send them to the planer with instructions to plane them down to within ½ inch of the scribed lines. When properly planed the surface of the shoe should show just ½ inch from the lines when tested as shown in Fig. 6.*

Having the shoes all planed, place them in position again and file them until they show perfectly square across their faces when tested with a long straight edge held across the opposite shoes. They should show very nearly square if the work of laying out and planing has been properly done.

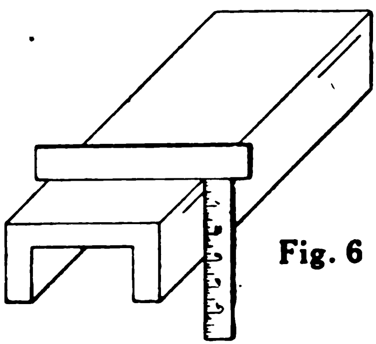


Fig. 6

Go to the driving boxes again and with the gauge shown at the bottom of Fig. 7 get the size of the box with the aid of a straight edge held as shown. Then place the gauge against the finished shoe as shown at the rear pedestal in Fig. 4, and scribe two lines on the outside of the wedge and one on the inside. As the

* The distance ½ inch is an arbitrary measurement and may be anything convenient. It is taken for the reason that it is easier to plane to a certain distance from a line than to plane exactly to a line. When going onto a shoe and wedge job in a strange shop it is well to inquire what the practice is in this respect in order to avoid mistakes.

body of the gauge is just ½ inch thick, these scribed lines will be ½ inch from the finished face of the wedge. Lay off all the wedges in a similar manner and send them to the planer with instructions to plane them to within ½-inch of the lines. On receiving them from the planer put them in place and file perfectly

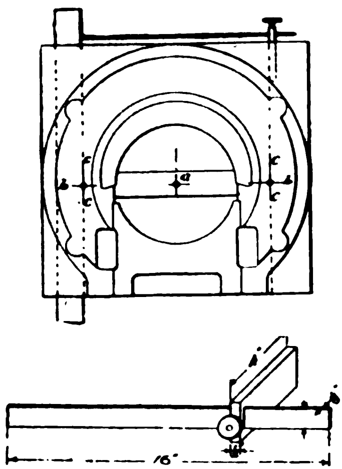


Fig. 7

square across their faces as was done with the shoes. Then set a pair of inside calipers to the size of each box and test all the shoes and wedges for parallel, setting the wedges to proper height, and mark a line on the outside of each pedestal jaw even with the top of the wedge so that they can be set to proper height after the wheels are placed under the engine.

In the foregoing it has been assumed that the frames have been correctly set up. In case the frames have not been down, and therefore their location with reference to the cylinder center lines not known, better results will be had by locating the square centers directly from the center lines through the cylinders. To do this proceed as follows: See Fig. 8.

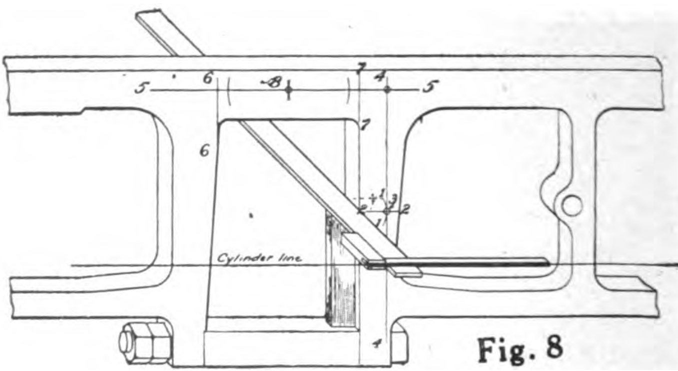


Fig. 8

Run fine lines through each cylinder, letting them extend at least to the rear of the main jaws. Place a straight edge across the frames through the main jaws and support it as shown so that it will be the same height as the cylinder lines. By means of a square set the straight edge at right angles with the lines. From the straight edge with a pair of hermaphrodite calipers set to any convenient distance, scribe the arc 1, 1 on the side of the front pedestal far enough ahead to clear the flange of the shoe. Scribe these arcs on the inside of the pedestals also. From the top of the frame, with hermaphrodites set to the center of the straight edge, scribe on both outside and inside of the pedestals the lines 2, 2, intersecting the arcs 1, 1 at 3. The point of intersection 3 will be the "square centers." On the outside of the frames draw the lines 4, 4, perpendicular to the top of the frames and through the point 3. Draw lines 5, 5 parallel to and at equal distance from the top of the frame over all the pedestal jaws. Center the jaws as previously described by drawing lines 6, 6 and 7, 7 and bisecting the line 5, 5 between them at 8. Compare the distance of point 8 from the square line 4, 4 on opposite sides of the engine, and if not equal make it so by moving the centers 8 forward and back one half the difference.

With the long trams set to the length of the side rods locate square centers 3 on the outside and inside of all the other jaws, if the construction of the engine will admit. If not, locate the outside ones with the trams and by means of a straight edge set across the frames parallel to the outside centers locate the ones on the inside. Draw the lines 2, 2 and square lines 4, 4 on all the jaws.

On the square lines 4, 4 lay off two points, 9 and 10, at any convenient distance from the square centers 3, and through these points scribe lines 11–13 and 12–14 on both shoes and wedges. See Fig. 9. These lines should be parallel to the top of the frame. Now on a sheet of tin or board draw the line *a, b,* as shown in the lower figure of Fig. 9. From *a* lay off the point *d,* with the dividers set to the distance *A* in Fig. 5, plus ½-inch. In this case it is 7⅛-inch. Also from *a* lay off point *c,* with the dividers set to the distance from the jaw center 8, to the square line 4, 4, in this case 10¾ inches. At

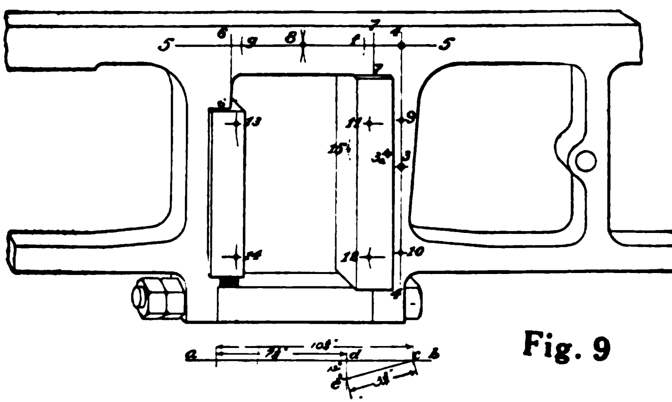


Fig. 9

d draw the line *d, e,* perpendicular to *a, b,* and locate the point *e* distant from *d* the thickness of the shoe flange, in this case 1-inch. Set the dividers to the length of the line *c, e,* in this case 3.76 inches, and from the points 9 and 10 scribe arcs on the shoe locating points on lines 11 and 12 as shown, and with the same setting from the inside square center 3_a locate point 15 on the inside of the shoe. Do this for all the shoes and send them to the planer. When received from the planer place them in position and file them square across their faces, after which the wedges may be laid out from the shoes by means of the box gauge as previously described.

If it is desired to lay off the wedges from the shoes and have them all planed at once it may be done by setting the dividers or short trams to the width of the driving box plus 1 inch and from points 11, 12 and 15 on the shoes scribe arcs on the wedges locating points 13, 14 and 16 as shown in Fig. 9.*

In case it is desired to line up the old shoes and wedges, and in such cases where the driving boxes are of different sizes and the brasses not bored out central, proceed as follows:

Set the straight edge in the main jaws and square it up to the cylinder lines as previously described and shown in Fig. 8. From the straight edge locate the "square centers" 3 in the same manner as described with reference to Fig. 8, with the exception that they are located on the rear jaw as shown in Fig. 10. Through the square centers scribe the square lines 4, 4, perpendicular to the top of the frame. Draw the lines 5, 5, 6, 6 and 7, 7 and center the jaws at 8 as has been described.

Place a wood stick between the frame and pedestal binder as shown in Fig. 10, having the face flush with the outside of the frame, and locate a piece of tin on same in line with points

*Point 16 does not show in the figure, but it is located on the inside of the wedge, and corresponds with point 15, on the inside of the shoe.

8 and 3. Through 8 scribe a line perpendicular to the top of the frame, and through point 3 scribe a line parallel with the top of the frame. The point of intersection *C* will be the jaw center.

From points 3, with trams set to the length of the side rods, locate similar square centers on the front and back pedestals as before described and draw square lines 4, 4, also the lines 11, 11 and 12, 12.

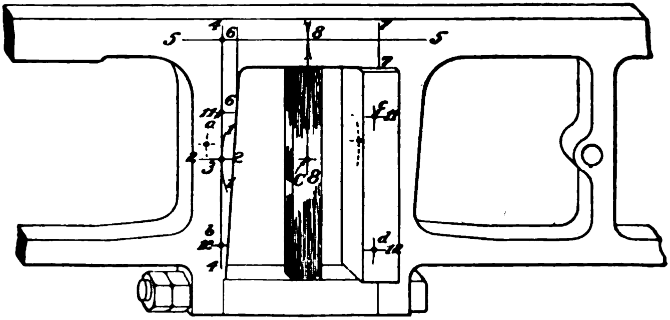


Fig. 10

Place the driving boxes on the floor opposite their respective jaws with the tops toward the rail and the hub side up; see Fig. 11. Find the center *c* of the brass and through it draw the line *a*, *a*, square with the flange of the box. Locate the point *e*, on line *a*, *a*, the same distance back from the center of the box that the square center 3 is from the jaw center *C*; see Fig. 10. With the transfer plate or box marker draw lines *d*, *d*, and *g*, *g* (see Fig. 11), and set the hermaphrodite calipers to the distance from point *e* to line *d*, *d*. Remove the center from the jaw and clamp the shoe in position. With the point of the hermaphrodites in center 3, Fig. 10, determine the thickness of the liner to be riveted to the shoe. Allow $\frac{1}{32}$-inch to come off the

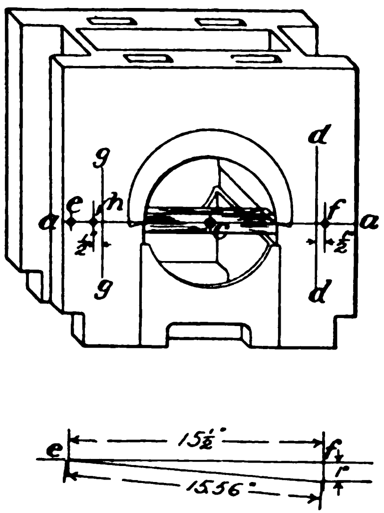


Fig. 11

shoe, and if the liner is to be planed allow $\frac{1}{16}$-inch. Determine the liners necessary for all the shoes in the same manner. After the liners have been riveted on and planed, place the shoes in position and set the dividers or small trams to the distance *e*, *f*, Fig. 11, plus the required amount as determined by similar construction as shown in the lower figure of Fig. 11. With one point of the dividers in the centers *a* and *b*, Fig. 10, scribe arcs cutting lines 11 and 12 on the shoe at *c* and *d*, and from the square center on inside of frame scribe an arc on the shoe on the inside face. Lay out three similar points on all the other shoes and send them to the planer.

After planing place the shoes in position again and determine the thickness of the liner necessary for the wedges by using inside calipers set to the size of the box. After riveting the liners on the wedges they should be placed in position and laid out from the shoes by either method previously described.

CHAPTER V.

Erecting Shop Work—Spring Rigging.

Anyone at all familiar with round house work will be impressed with the large amount of work necessary to keep the spring rigging of locomotives in repair, hence it should be borne in mind that when an engine is in the shop for general repairs these parts should receive particular attention so that when the engine is placed in service they will be in the best possible condition to withstand the severe stresses thrown on them by rough track, derailments, etc.

Spring riggings are divided into two classes according as the springs are placed above or below the frames. Fig. 1 shows the over-hung style, while Figs. 2 and 3 show two styles of underhung springs.

With the overhung type of rigging the springs are supported by saddles *a, a,* Fig. 1, the legs of which should be long enough to allow the underside of the saddle to clear the frame about ¼-inch when the driving box rests on the pedestal binder. It will generally be found that with old driving boxes the saddle pockets in the tops of the boxes will be worn more or less and the legs of the saddles must be carefully fitted to these pockets so there will be no rock or shaking, and also so that the spring seat *b* will stand square with the outside face of the driving box

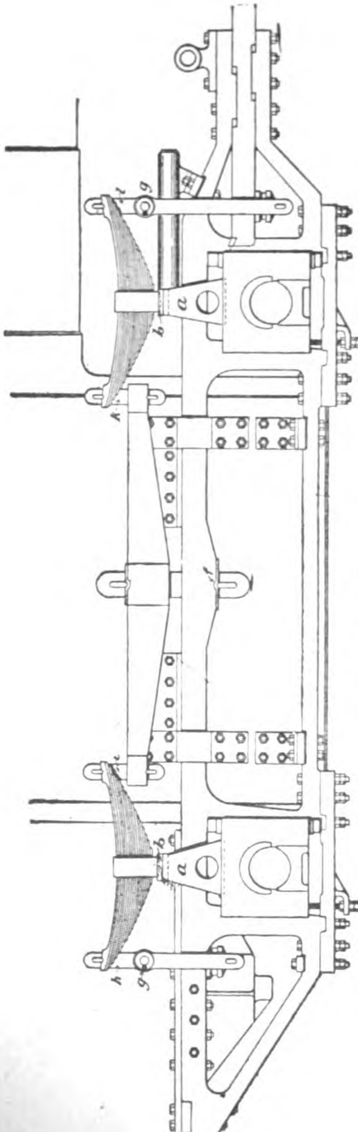


Fig. 1

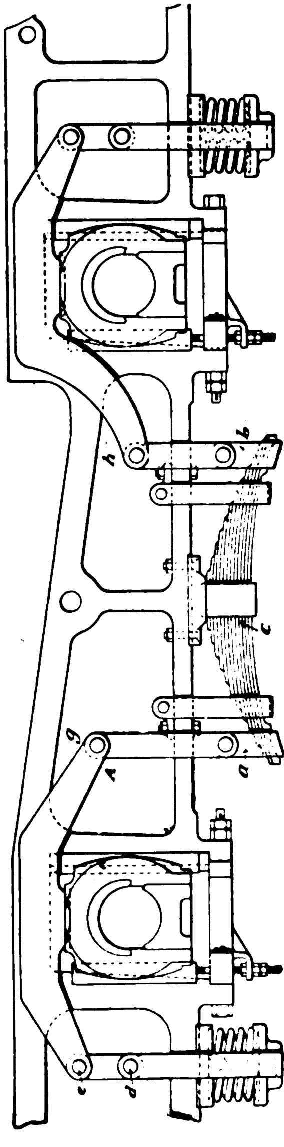


Fig. 2

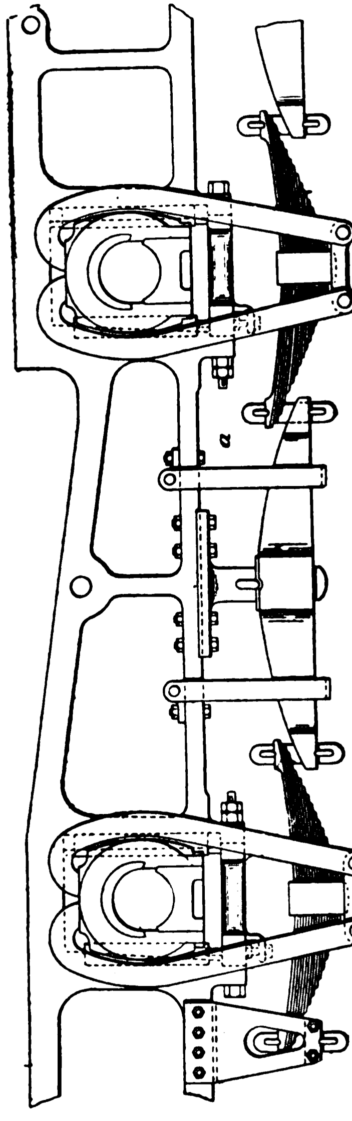


Fig. 3

and square with the shoe and wedge bearing surfaces. First bed the saddle legs to the boxes so the above conditions will be attained and then have them cut in the shaper to such length that, when placed in their respective boxes, they will all stand at equal distances above the frame. Fig. 7 shows a very handy tool for use in squaring up the spring saddle seats in the driving boxes. The tool is made of ½-inch machine steel with the long leg of the square 1⅜ inches wide and the other ⅝ inch wide.

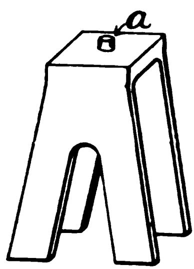


Fig. 4

The two feet are also made of machine steel, turned to proper size and shape. The drawing indicates its use so fully that further description is unnecessary. The bearing surface for the spring band at *b*, Fig. 1, must be square with the legs of the saddle and if worn must be trued up. With the style of saddle shown in Fig. 1 the spring seat *b* is separate from the saddle proper and if worn may be replaced by a new one. With the style shown in Fig. 4 the top surface where the spring band rests must be trued up if worn. If this leaves the saddle too thin a new one must be used. In this style of saddle the spring is held in position by the pin *a*, entering a hole drilled in the spring band, and these pins should be examined and renewed where necessary.

The equalizers should be carefully examined for cracks, and the bearings for the gibs trued up and made parallel with each other. The surface at *c*, Fig. 10, should be filed square with the body of the equalizer and the surfaces at *d* at each end filed parallel with surface *c*, as determined by straight edges applied as shown. The bearing for the gib at *f*, Fig. 1, should be filed square with the side of the frame. Overhaul all gibs and replace the badly worn ones with new. If there are any pin connections as shown at *g*, renew all worn pins, and if holes are worn have them plugged and new holes drilled or bushed as the practice of the shop may be.

To determine the proper length of the hangers *h*, *i*, *k* and *l*, in case no drawings are at hand, place the saddles in position and block them up to the height they would be if the boxes were at the top of the pedestals. Place the springs on them perfectly level. Place the equalizers in position and block them up solid as high as they will go with the gibs in place, keeping the ends the same distance from the frames. Now, as a general proposition, the springs are given such set that when the load is on them and the boxes are as high in the jaws as they will go, the top leaves of the springs will be straight as shown in dotted lines in Fig. 5. The proper length of the hangers between the gibs will be the distance between the gib seats in the springs and equalizers as at *a* and *b*, less the set of the springs. In the particular case shown the distance between the gib seats is 12¼ inches and the set of the spring is 4 inches, hence the correct length of hanger between the gibs will be 8¼ inches. The length of the front and back hangers will be found in the same manner. In this case the front hanger is 8¼ inches from the top gib to the center of the pin hole.

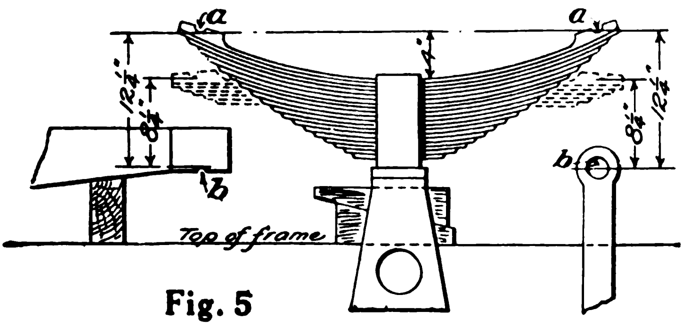


Fig. 5

In placing the spring rigging up the principal thing is to see that everything comes in line and sets square, also that the engine is level transversely.

With the overhung type of springs, when necessary to remove the rear spring, it will generally be necessary to let the equalizer up, as there is no way of pulling the rear spring. To do this requires an equalizer puller similar to that shown in Fig. 6. This is hung over the equalizer, and by means of a long bar caught under the frame the equalizer is pulled down sufficiently to release the gib and then let up entirely. This releases the springs and a new one may be put in. After the hangers have been connected the equalizer is pulled down and gib replaced. See to it that your bar does not slip, for if it does someone is liable to be badly hurt.

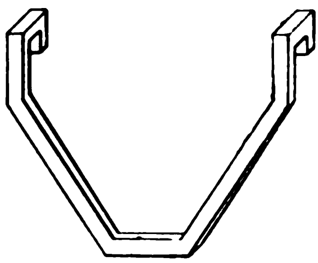


Fig. 6

In putting in the front springs the equalizer may be let up or the spring pulled by some form of a spring puller, one style of which is shown in Fig. 11 and another in Fig. 12. The latter style is known as a "chain puller" and will be found to be the best under all conditions. The chain is made of ⅜-inch links of suitable length and can be passed through the small spaces between the frames and driving wheels with much more facility than the other arrangement. In case the spring puller is used, block up the end of the equalizer next the spring to be removed before jacking up the engine. Then put the spring puller on the front half of the spring, blocking between the band and puller to keep it from slipping down on the spring. The screw is then turned up, pulling down the spring until the gib is released. In replacing the spring, connect the back hanger first, then

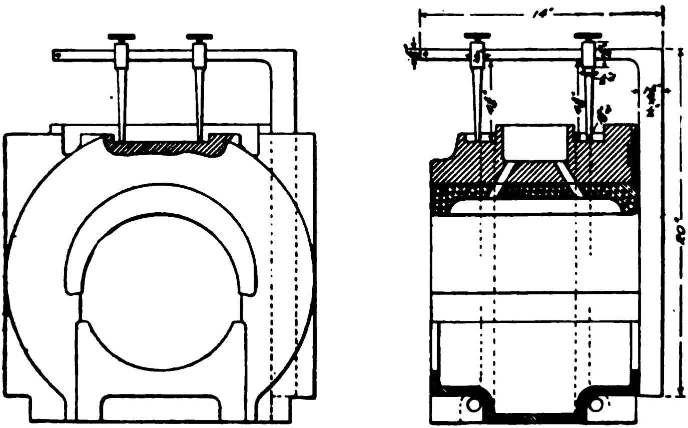


Fig. 7

pull down the spring and connect the front hanger. Be sure that *all* gibs and hangers are in proper position as well as all blocks and filling pieces.

If the engine has equalizer stands of the type shown in Fig. 8, and it is necessary to put on new ones, they should first be planed on the bottom at *a* square with the upright portion of the stand, also along the outside edge *b*, parallel with the upright part. Then scribe a line *c*, *c* across the outside edge at the center of the gib hole as shown and set this line true with a line scribed on the frame midway between the jaw centers. The holes in the stand may then be laid out by scribing through the holes in the frame. The bolts holding the stand to the frame should not be a tight fit either in the stand or frame, but should simply fill the holes, and you should be able to put them in place

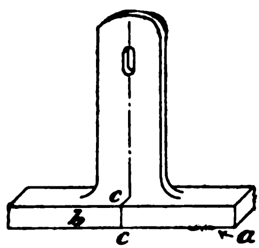


Fig. 8

without driving, otherwise it will be hard to get them out in case the bolts should break, and they have a habit of doing this quite frequently. When only one or two of these bolts break and you find that some misguided machinist has made them a driving fit, you can make a temporary repair quickly by putting on a clamp as shown in Fig. 9. This is made of say $1'' \times 2\frac{1}{2}''$-iron bent to a "U" shape with 1-inch or $1\frac{1}{4}$-inch bolt placed close to the frame.

In fitting up spring rigging of the type shown in Fig. 2, the equalizers resting on the tops of the boxes should be fitted so that the pins at each end will enter freely and at the same time the equalizers must stand parallel to the face of the box. To get the length of the spring hangers *a* and *b*, proceed the same as for the overhung type. The equalizers should stand level as well as the main spring *c*. For the coil springs assume that when the box is as high as it will

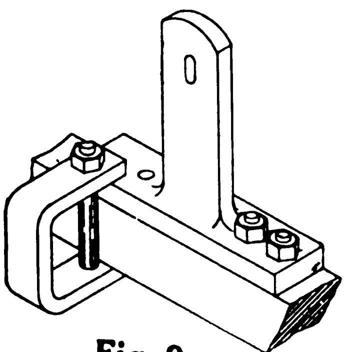


Fig. 9

go these springs will be closed down solid. With this type of rigging be careful to put all pins in in such a manner that they can be taken out while the wheels are under the engine. A failure to do this sometimes causes no end of trouble in the roundhouse.

To put in a back coil spring, block under the front end of back equalizers at A. Then set a jack under the coil spring and jack up until pin *d* or *e* can be taken out. Place the new spring in position and jack up until pin can be replaced. If the spring has broken so as to allow the front end of the equalizers to go down it will be necessary to put a jack under the main spring at *f*, and jack up at both points until the pins can be replaced.

To put in a new main spring it will be necessary to block between the frame and tops of

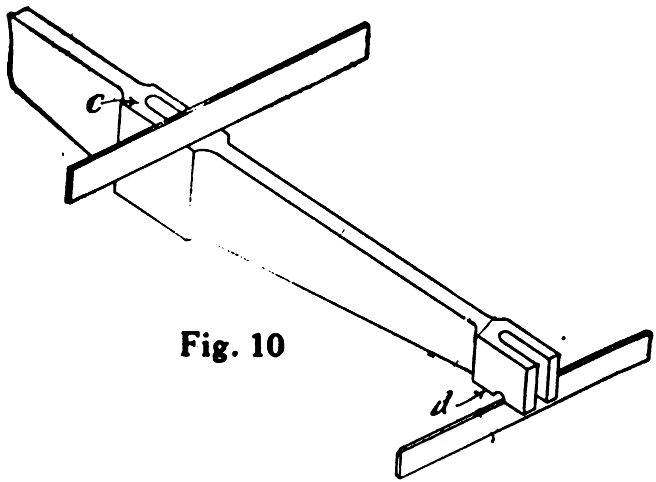


Fig. 10

equalizers at *g* and *h*. Then set jack under one end of spring and jack up until one hanger can be disconnected. The old spring can then be taken out and new one put in and jacked up until the hanger can be connected. Then remove the blocking at *g* and *h*.

With the rigging shown in Fig. 3 the springs are supported by a seat which is suspended from the top of the driving box by four hangers. These hangers must be fitted up so that when the pins are in place the spring seat will be level both ways, with its center exactly in line with

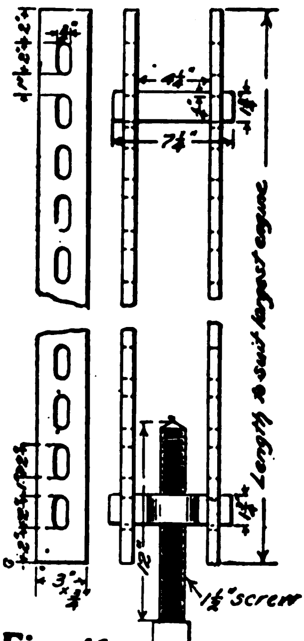
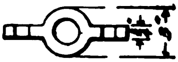


Fig. 11



the center between the tops of the hangers. The spring seats should also be at practically the same distance from the frame. The length of the short hangers may be found in the same manner as for the overhung springs. To put in one of these springs, say the back one, block between the frame and equalizer at *a*. Then set a jack under the spring seat at *b*, and jack up until the pins are released. Drop the old spring out and put new one in place; connect the gibs

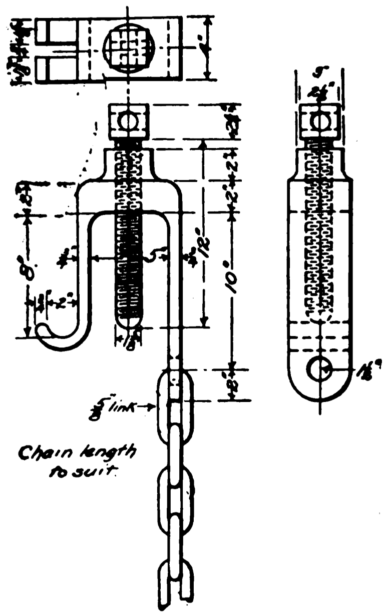


Fig. 12

and jack up the spring until the pins can be put through the hangers. Remove the blocking from over the equalizer. To take out one of the long hangers set a jack under the spring seat and jack up until the pins are loose.

CHAPTER VI.

ERECTING SHOP WORK—FITTING UP DRIVING BOXES.

The driving box in universal use under American locomotives is shown in Figs. 1, 5 and 6, and consists of the box proper, shown in Fig. 1, made of cast iron or cast steel; a bearing shell, an end view of which is shown in Fig. 3, made of brass or bronze which is pressed into a suitable recess machined in the box, and a cellar to hold the oil and waste for lubrication. The cellar is generally made of cast iron.

The boxes are first machined on the two faces and are sent to the slotter. A square line *A*, *A*, Fig. 1, is scribed across the face of the box and the template, Fig. 2, laid on the box with the line *a*, *a* set to the square line on the box. A line is scribed around the template and the box slotted to the line until the template will fit in the recess. The surfaces *d*, *d*, Fig. 1, for the cellar fit, are finished to size at this setting.

The brass shell, Fig. 3, is placed on a mandrel similar to that shown in Fig. 4, and is turned on the outside to the size of the recess, or a trifle smaller, after which the template is laid on it and the lines *a*, *a* and *b*, *b* scribed on the end. The brass is then sent to the planer and planed to these lines. The brass is now filed along the entire surface on each side for a distance of about 1½ inches or 2 inches near the bevels as shown and the edges *c*, *c* fitted to the box so that the brass will press into the box with a final pressure of from 10 to 12 tons, depending on the size of the brass and weight of the box. This will spring the box open from $\frac{1}{16}$ inch to $\frac{3}{32}$ inch at *e* and *f*, Fig. 1.

After pressing in the brass, holes about ¾ inch in diameter are drilled through the box and brass at *c* and *d*, Fig. 5, and brass plugs driven in. These plugs hold the brass in position in case it should become loose in the box and also tend to prevent it from closing in on the journal. The oil holes shown at *e* are drilled and the box is ready for the planer.

The shoe and wedge bearing surfaces will be planed at equal distances from the brass fit in the box. After planing, with the box marker as shown in a preceding chapter the lines *B*, *B* and *C*, *C*, Fig. 5, are scribed on the box in line with the shoe and wedge bearing surfaces. The square line *A*, *A* is located across the box one-half the diameter of the journal plus enough to allow for cleaning up the brass in boring, down from the crown of the brass at *f*, and the line *D*, *D* drawn parallel to line *A*, *A*, and distant from it one-half the distance between the shoe and wedge bearing surfaces. Midway between the lines *B*, *B* and *C*, *C*, on line *D*, *D*, locate point *b* and scribe a small circle around it; also scribe small circles around the intersection of lines *B*, *B* and *C*, *C* with line *A*, *A* at *a* and *a*. Points *a*, *a* and *b* are at equal

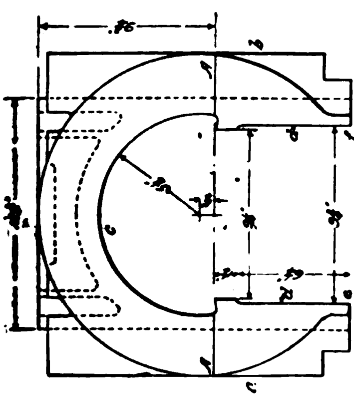


Fig. 1.

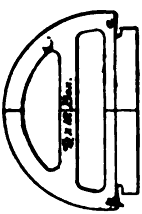


Fig. 2.

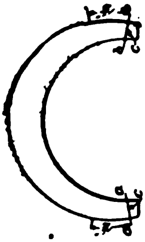


Fig. 3.

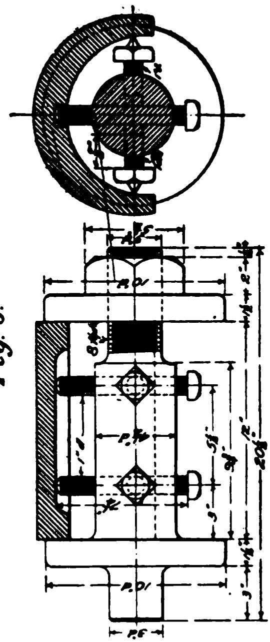


Fig. 4.

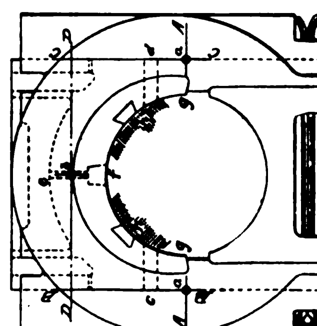


Fig. 5.

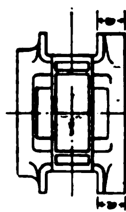


Fig. 6.

distances from the center of the brass and are for the lathe or boring mill hand to set the box by. If these points are correctly located and the box set to them accurately, the bore for the journal will be in the center between the shoe and wedge bearing surfaces.

At the time of boring the brass the outside face is turned off to the correct thickness to give the desired lateral motion between the driving wheel hubs, and the thickness *a* of the outside flange of the box as shown in Fig. 6 should be given for each box. To determine this thickness see Fig. 7.

Measure the distance *a*, Fig. 7, from outside to outside of the driving wheel hubs; caliper the thickness of the hubs as *b* and *c;* measure the distance *d*, over the outside flanges of the shoes. The thickness of the flange for the left hand box will be denoted by equation 1, while that for the right hand box will be given by equation 2. Another way to get these dimensions would be to take a stick of suitable length and from one end of it lay off the distance between the outside of the hubs as *g* and *h*, Fig. 7. Bisect this distance as at *m*, and from *m* lay off each way a distance equal to one-half the distance over the outside flanges of the shoes as at *k* and *l*. From the hub lines lay off the thickness of the respective hubs as *i* and *j*. The distance between lines *i* and *k*, and *j* and *l*, will be the required thickness of the box flanges if there is no lateral motion allowed. From these measurements deduct the required lateral and the remainder will be the figure for the flange thickness to be given the machine hand. Make a table similar to the following:

Boxes for Engine 162

R. F.	Journal	8–$\frac{29}{32}$″.	Flange	2–$\frac{31}{32}$″.
R. M.	"	9″	"	3–$\frac{3}{32}$″.
R. B.	"	8–$\frac{15}{16}$″.	"	3–$\frac{1}{16}$″.

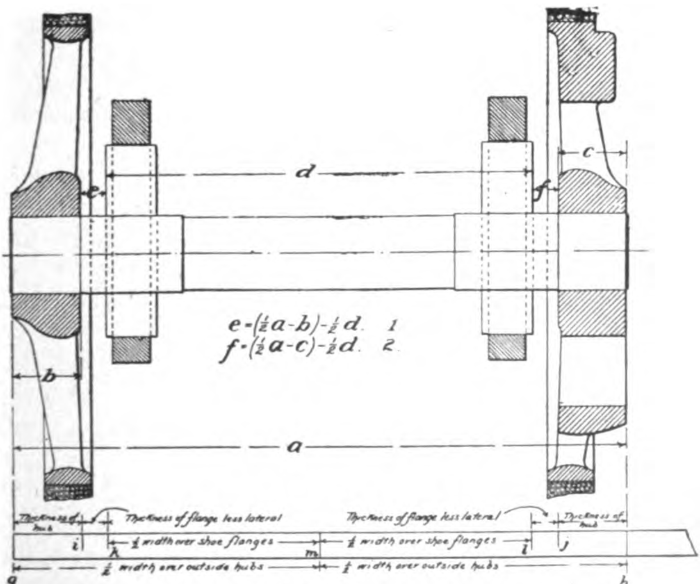


Fig. 7

and so on for all the boxes under the engine.

The proper amount of lateral motion to be given varies with the physical characteristics of the track. On a smooth, straight road bed

$\frac{1}{16}$-inch lateral between the hubs would be sufficient, while under some circumstances this may be increased to over $\frac{1}{4}$ inch. However, these matters are determined by each road and instructions issued.

The box is now ready for fitting to the journals. The box should be bored the exact size of the journal, never larger, as it is better to have it too small than too large, for if bored too large it can never be properly fitted to the journal. If bored out a trifle small the sides at *g*, *g*, Fig. 5, are eased off with the file and the brass is ready, bearing at *h*, *h* and clearing at *f*. A properly fitted bearing should clear the journal about $\frac{1}{16}$ inch at *g*, *g*, and have a good bearing at *h*, *h*, as shown by the shading, clearing the journal in the crown at *f* about $\frac{1}{32}$ inch. In a few days the bearing will come on the crown, and it should, if possible, be left in the same condition as it comes from the machine. The least possible fitting done consistent with getting a good general bearing at *h*, *h*, the better the bearing will run in service. Some men will spot a bearing all over like a steam tight joint; this is a waste of time. The edges of the oil recess at *f* should be rounded off and oil grooves chipped in the bearing in the form of a letter "X" on both sides. When there is babbit in the brass it is well to scrape around it so that it will "stand up" slightly, say the thickness of a sheet of paper.

For handling driving boxes while fitting to the journals as good a way as any is to fit up a plank as shown in Fig. 8, and use a piece of pipe under the box for a roller. This illustration explains itself, and in this way the box can be easily handled on and off the journal.

Before starting to fit up the brass, all oil holes and grooves should be filled with putty to prevent the filings, etc., from getting into them.

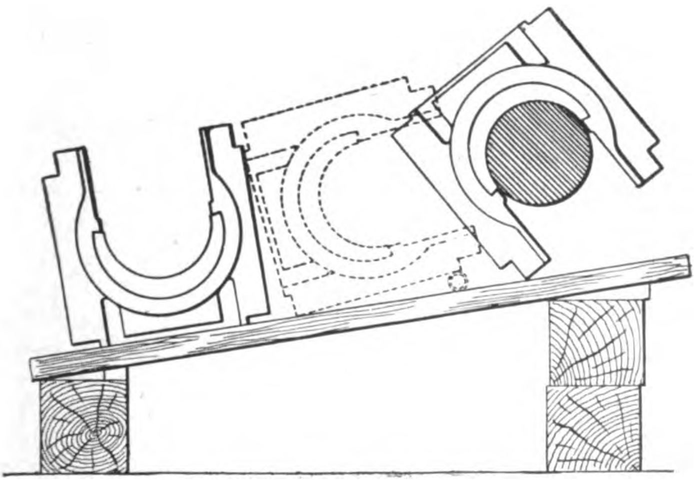


Fig. 8

The cellars should be fitted to the box tight so they will prevent the box closing in. As before stated the cellar fits are slotted parallel before the brass is pressed into the box. In pressing in the brass the box is opened up so that the cellar fits will be slightly out of parallel, being say $\frac{1}{32}$ inch wider from *e* to *f*, Fig. 1, than at the top. The cellars should be planed with this much taper and fitted perfectly tight when clear up in place.

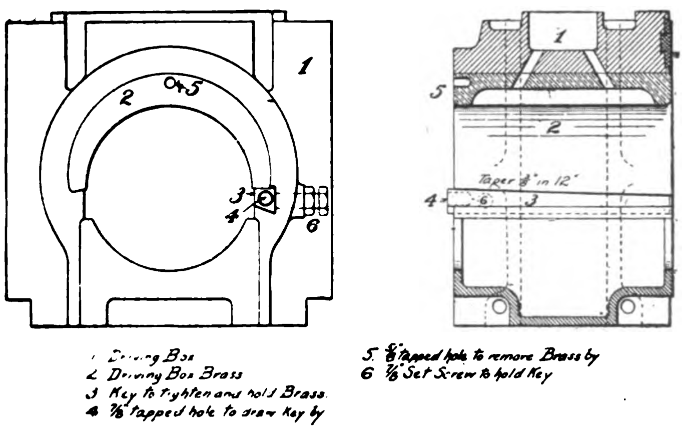
If the brasses are pressed into the boxes too tight they are more apt to work loose than il a moderate pressure had been used, for the reason that when heated the brass expand: more than the box, and as it is pressed tigh' in the recess in the box it must be compresse(more or less while hot. If this compressioı exceeds the elastic limit of the material of whicl the brass is made, it takes a permanent set an(when brass and box have cooled off the bras will be loose.

To overcome this disadvantage, among othe things, some roads are casting the bearing shel in the driving boxes, and report very satisfactor results. There is a saving in machine wor and labor necessary in fitting up the commc form of box and it has also resulted in a lesseı ing of the number of loose brasses. See tl American Engineer and Railroad Journal f(July, 1907.

An improvement in the method of fittiı removable bearing shells has been patent(by Mr. Charles Markel, machine shop forem: of the C. & N. W. Ry. at Clinton, Iowa, and as follows. See Fig. 9.

As shown by the illustrations, the bra: instead of being pressed into the box as befc described, is held in position by a taper key that it is possible to tighten or remove the brε without removing the box from the engiı

Referring to Fig. 9, it will be noticed that one side of the recess for the brass is the same as in the ordinary type, while on the other side the recess is extended down a sufficient distance to receive a wedge or key which is driven in to tighten the brass in the box. In practice the brass is turned $\frac{1}{32}$ inch smaller than the box



MARKEL REMOVABLE DRIVING BOX BRASS.

Fig. 9

fit, and by driving in the wedge 1⅜ inch it so tightens the brass in the box as to require 40 tons pressure to start it out. If through heating, as previously mentioned, the brass should become loose, all that is necessary is to drive the wedge in a little, and thus tighten the brass. All brasses and keys for each different sized box are made interchangeable. Reports from engines with this box in service on the C. & N. W. Ry. indicate that it is perfectly satisfactory in service.

CHAPTER VII.

ERECTING SHOP WORK — FITTING UP VALVE GEAR.

In actual shop practice the work of overhauling the valve gear of a locomotive in the shop for general repairs will be divided among several machinists. One man will face the valves, fit up valve yokes, chests, rocker boxes, etc.; another will do all necessary work on the links, reversing shaft, and reverse lever; another will fit up the eccentrics and straps. Most shops have one or more men who attend to the link work for all engines in the shop, leaving the steam chests, valves, eccentrics, etc., to be fitted up by the different pit gangs. In what follows it will be assumed that all this work is to be done by one man.

If the valve seat is badly worn the valve facing machine, shown in Fig. 1, should be used. To set up this machine, screw the four corner studs *a, a, a, a* in position and adjust the machine so that the tool will finish the four corners of the seat at the same time. Also set the machine so that the under surface, where the tool slide travels, is parallel with the steam chest seat. Use as broad a tool and coarse a feed as the condition of the machine and the thickness of the cut will allow, and leave a small spot untouched as a witness mark. After finishing with the machine, test it with a surface plate and file or scrape it until it shows a good general bearing. If there is no machine at hand, it will be necessary to chip down the high places, using a pneumatic hammer or hand hammer and chisel, using a straight edge to keep the surface true and being particular to keep it level with the seat for the steam chest. After chipping, the seat is filed to a good bearing as

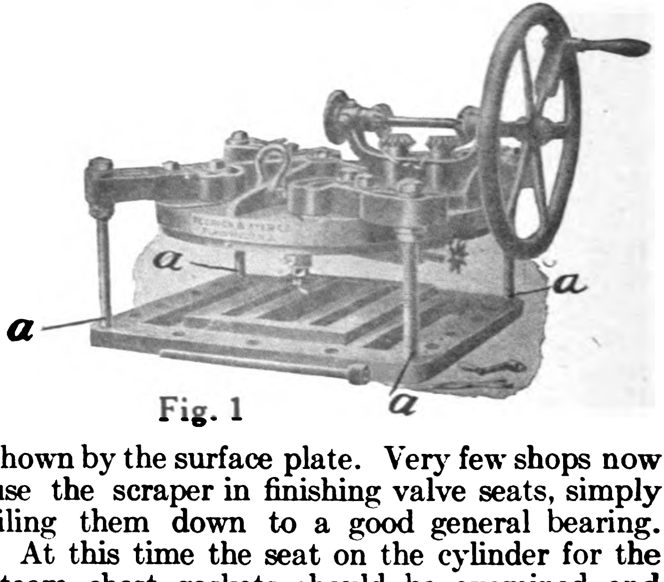


Fig. 1

shown by the surface plate. Very few shops now use the scraper in finishing valve seats, simply filing them down to a good general bearing.

At this time the seat on the cylinder for the steam chest gaskets should be examined and any places where the steam has cut through should have copper patches put in. This is done by chipping out the cut place and dovetailing in a piece of copper which is finished off flush with the seat.

If the cylinders are fitted with false valve seats of the loose type, they are taken off and sent to the planer whenever facing is necessary. If a good job of planing is done on the valve and seat very little work will be required to bring them to proper bearing.

In fitting up a new false valve seat, the face of the old seat on the cylinders should be trued up with the facing machine and scraped to a good bearing as shown by the surface plate. The false seat should then be bedded to this surface as near perfect as possible. If the seat is removable or held in position by wings, it should be set true with the steam ports and the chest placed in position. The wings are now scribed along the inside of the chest and cut and fitted to the chest. Seats of this kind are held down by these wings fitting under lugs cast on the inside of the chest, and care should be used to see that the chest when tightened down does not cramp the lugs, as that will spring the seat and destroy the fit to the cylinder. If the seat is to be permanently fastened to the cylinder, it will be drilled in a jig, after which it is placed in position and the holes in the cylinder laid out. These holes are then drilled and tapped and bolts fitted. The seat is now placed in position and fastened down solid. If the bolts are of brass they are finished flush with the top of the seat, but if iron they should be cut off at least $\frac{1}{8}$-inch below the face of the seat. The top surface is now finished as before described.

Judgment should be used in determining

when it will prove profitable to set up the facing machine, as in many cases the work can be done more rapidly by hand.

In overhauling valves with the Richardson form of balance, examine the grooves for the strips *c, c, d, d,* Fig. 4. If they are worn wider at the top than bottom, they should be trued up and have new strips fitted. If the grooves are all right, but strips worn too thin, new strips should be applied. Sometimes all that is necessary to be done is to have the top edge of the strips, which bear on the balance plate, trued up. Too much care can not be taken in fitting the strips in these valves. They should fit the grooves an easy sliding fit, but must not be loose enough to shake. The short strips *a* are fitted up first, and as the long strips fit between them, the ends *e, e* of the long strips must be carefully filed up square all around and the exact length between the short strips, so that the joints will be steam tight. The long strips have two 3-16-inch pins *f, f,* placed in the underside near each end, to retain the springs in place. The short springs are held in place by the 3-16-inch pins *g, g, g, g,* placed in the valve as shown. The springs should be tested by straightening them out flat before placing them in position.

The American balanced valves are known under the following heads:

Single Disc Balance—One ring and one disc, shown in Fig. 5.

Double Disc Balance—Two rings and two discs.

Single Cone Balance—One ring, with cone cast on valve.

Double Cone Balance—Two rings, with two cones cast on valve, shown in Fig. 5½.

Referring to Fig. 5, the top of the valve body *a* is recessed for a bearing surface for the balancing disc *b*, and is scraped for tight fitting. The disc and valve are held together by four ⅞-inch bolts which are relieved from the duty of driving the disc; this being done by the valve itself by means of the lugs *c*, *c*. The bolts have a ¼-inch hole drilled through them for the purpose of relieving the pressure from the back of

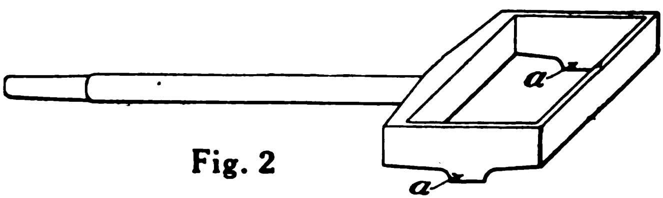


Fig. 2

the valve. They should be fitted steam tight on the threads and also have copper washers under the heads. As this form of balance has no springs or other delicate parts liable to be broken, about the only repair necessary is to put on a new ring when the old one has worn out from the top downward. As the new rings are 1 inch deep they can easily wear ⅜-inch and still adjust themselves to the cone. When the old ring is taken off the cone and a new one from stock is placed on the old cone, it fits, as there is no lateral wear on ring or disc. The rings are made to gauges and therefore interchangeable, and it will not require more than thirty minutes work to fasten on the L shaped piece for covering the cut in the ring. The detail of this joint and ring is shown at the left of Fig. 5.

After the valves have been planed they should be filed or scraped until they show a good general bearing over the entire seat.

The valve yoke should fit the valve without lost motion, but loose enough so that when in

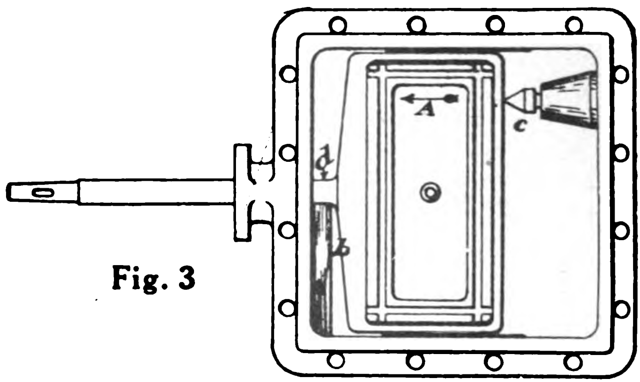


Fig. 3

position the end of the stem can be moved up and down through a distance of $\frac{1}{8}$-inch to $\frac{1}{4}$-inch, depending on the distance from the center of the yoke to the rocker arm connection. If the yoke is too loose it is closed under a press. In doing this, be careful to close both ends alike in order to keep the valve stem square with the valve fit. If a new yoke, the face resting on the valve (some roads carry the yoke on bearing strips cast on the inside of the chest) should be

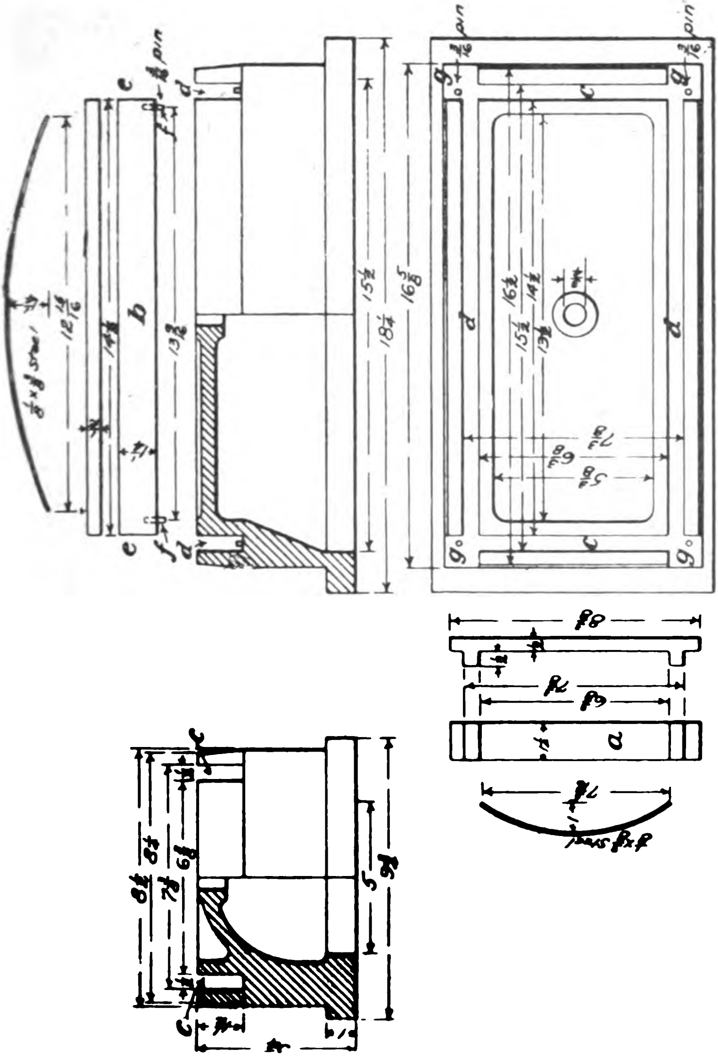


Fig. 4

so planed as to bring the stem central, or a little high, in the stuffing box. It is a general practice, when the valves and seats have been planed, to weld lugs on each side of the yoke, as shown at *a*, *a*, Fig. 2, planing these to the height necessary to bring the stem central in the stuffing box. If the valve stem is keyed to the valve rod, see that the key-way in the stem is in such position as to bring the rocker pin hole parallel with the hole for the pin in the rocker arm, and at the same time have the bottom of the yoke parallel with the valve seat. Also see that the valve rod is of such length as will allow the valve to stand central on the valve seat when the rocker arm is plumb. The distance from the center of the valve yoke to the shoulder of the valve rod fit should be standard, and all yokes for a given class of engines made the same. Any changes in length, if necessary, should be made in the valve rod. If the connection of the valve stem and valve rod is made by means of a right and left hand nut, the length of the valve rod and stem should be adjusted to conform to the above noted conditions.

The valve fit in the yoke is slotted square with the valve stem. After fitting the yoke to the valve, the stem and valve rod should be coupled together, and the rocker pin put in place in the rocker arm. Test the valve to see that the outside edges are square with the steam ports. If they do not so show, the valve stem must be bent as close to the yoke as possible,

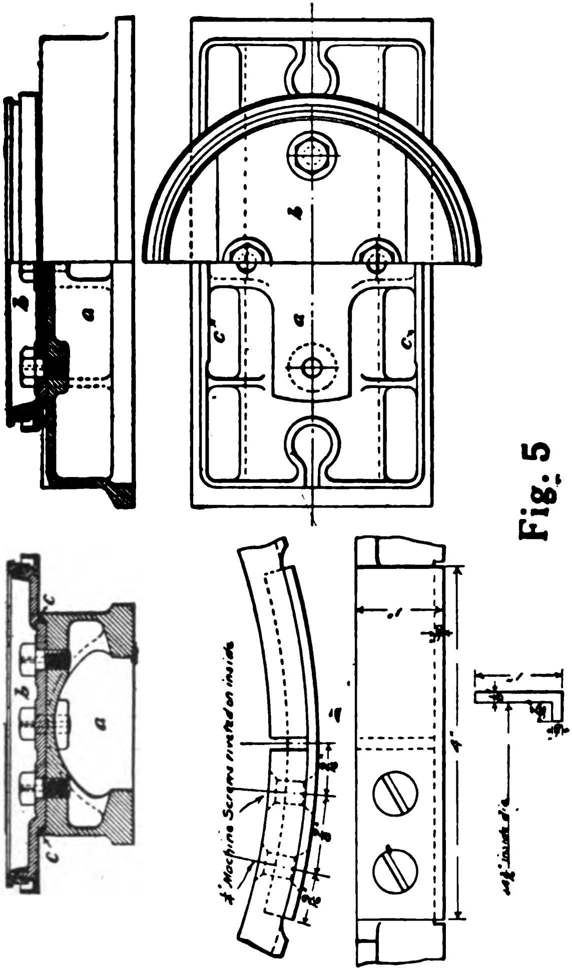


Fig. 5

until the edges of the valve come in line with the ports. A method of doing this is shown in Fig. 3. Suppose the end of the yoke, marked *A*, needs to be moved in the direction of the arrow, in order to bring the valve in line with the port edges. Move the yoke and valve as far back in the chest as possible, blocking against the stem at *b*. Place a small jack at *c*, and tighten up, which will bend the stem slightly at *d*. The valve stem may be pened at *b*, which will throw the end of the yoke in the required direction, but only a slight change may be made in this manner.

Piston valves have no yoke, the stem being turned to fit the bore of the valve and is held in position by means of nuts or keys. The points to be observed in fitting up these valves are as follows: Have the key-way for the connection to the valve rod so placed, in case the stem must fit into the valve in one position, that the cuts in the valve packing rings will come on the bottom of the valve bushing. See that the valve rod, when keyed to the valve stem, can be coupled to the rocker arm without binding in any degree. The same considerations as to length of stem and rod as were described under valve yokes should be observed.

If the valves or seats have been faced, it will be necessary to examine the chest covers and balance plates to see that the clearance between the valves and balance plates is correct. When the chest is in place, with the cover tightened down, there should be about $\frac{1}{32}$ inch clearance between the balance plate and the top of the valve, if it is of the Richardson type, and $\frac{1}{8}$ inch if it is the American type of balance. The American Balanced Valve Co. is very positive with regard to this amount of clearance, as the rings are bored to fit the cones when in this position. With the American type of valve the balance plate should be $\frac{1}{8}$ inch

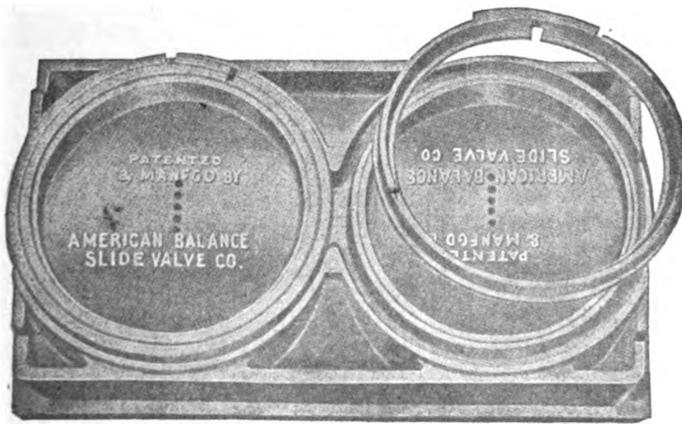


Fig. 5½

above the top of the cone. To determine the thickness of the washers to be placed between the cover and the plate, proceed as follows: Measure the height of the chest with the joint gaskets in place. From this, substract from $\frac{3}{32}$ inch to $\frac{1}{8}$ inch, to allow for the flattening of the gaskets when the cover is tightened down, if they are made of round copper, or $\frac{1}{32}$ inch if the gaskets are made of flat copper. Call this quantity "A." Add the height of the valve, the distance the valve seat is above the joint seat on the cylinder, and the amount of clearance desired between the plate and the valve. Call this sum quantity "B." The difference between "A" and "B" will be the amount the face of the balance plate must be from the joint surface of the cover. If "A" is greater than "B" it indicates that the face of the plate will be above the joint on the cover, while if "B" is greater than "A," it will be below. The difference between this quantity and the actual distance the face of the balance plate is from the joint of the cover will be the required thickness of the washers. The washers should be machined to this thickness and placed between the cover and the plate, and the bolts tightened up as much as possible, using copper gaskets under the bolt heads. If the balance plate has not been planed, allowance should be made for the stock to be taken off to true it up.

Rockers, if badly worn, should have the bearing surface at *a* and *b*, Fig. 7, trued up in the lathe, and also the hubs at *c* and *d* faced off square. The pins *e* and *f* should be examined, and if a good fit in the rocker arms, should be trued up if worn. If these pins are case hardened, as they should be, they will have to be annealed. The rocker should be tested to see that the arms are not sprung. To do this proceed as follows: The rocker should be carefully centered at both ends. It is generally

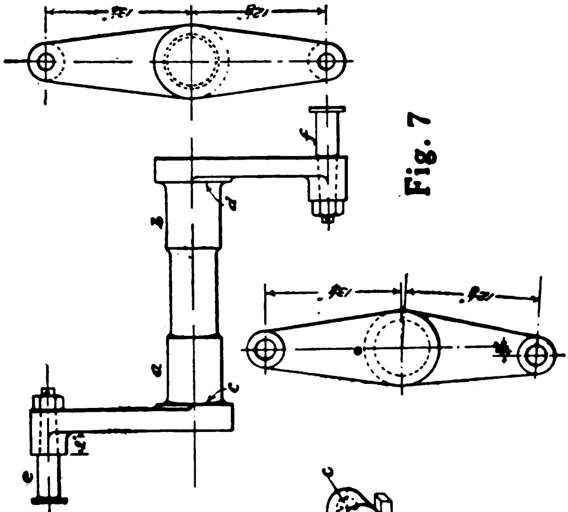


Fig. 7

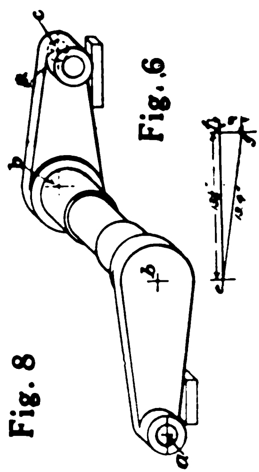


Fig. 6

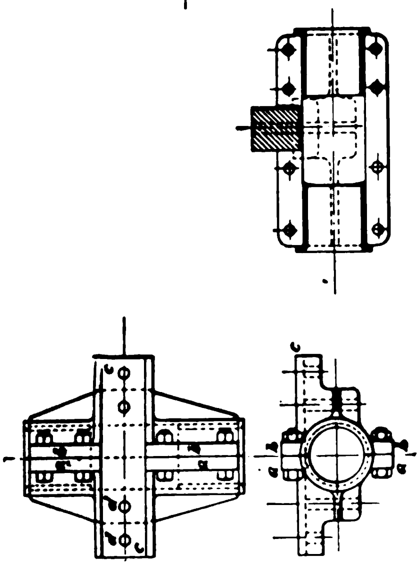


Fig. 8

the custom to cut a circle on each end with a fine-pointed tool while the rocker is in the lathe, so that by plugging up the center holes with lead and scribing arcs with the dividers from this circle, the centers may be located. If these circles have not been scribed on the ends, the centers of the shaft will have to be found in the same manner as described under the paragraph describing the laying out of a new rocker arm. Having found these centers, the rocker is laid on a face plate in the position shown in Fig. 6, and blocked up until the centers at each end of the shaft are the same height when tested with the surface gauge. Centers should be located in the pin holes at the ends of the arms. With a wedge or small parallel piece under one arm, adjust the arm so that the center of the pin hole *a* is the same height as the center *b* of the shaft. With the rocker in this position, if there is no "back set" to the arms, the center in the other pin hole *c* should be the same distance from the face plate as *a*. In other words, if the rocker is correct, all four centers will be the same distance from the face plate. If the rocker arms have "back set," as shown in the end view to the left of Fig. 7, when the centers of the shaft and one pin hole are in line, the other pin hole center should show off the amount of the "back set," which is $\frac{3}{4}$ inch in the rocker shown. The pins should be placed in the holes and tested with the surface gauge. They should show parallel to the face plate when turned to four different positions in the arms. If they do not so show, and are not themselves sprung, it is evident that the arms must be twisted, and will have to be heated and straightened.

To lay out a new rocker arm, proceed as follows: Place the rocker on two V blocks lined up parallel with the face plate and high enough to allow the rocker arms to clear the plate; see Fig. 9. With the surface gauge set to any convenient height, scribe the lines *a*, *a* on each end of the shaft; then turn the shaft one-fourth of a turn and scribe the lines *b*, *b* on each end, and so on, scribing lines *c*, *c* and *d*, *d* in turn. From these four lines the center of the shaft *g* on each end may be located. On the end of one arm scribe the arcs *e*, *e* and *f*, *f*, as near the center of the boss as possible. Set the surface gauge to the height of the centers *g* and turn the rocker until line *h*, *h*, scribed through the center *g*, will pass midway between the arcs *e*, *e* and *f*, *f*. Blocking the rocker in this position, go to the other end and scribe a line across the other arm as *i*, *i*. If the rocker arms have no "back set," line *i*, *i* will pass through the center of the pin hole in that arm. If it has "back set," set the surface gauge the amount of the "back set" higher or lower than line *i*, *i*, as the case may be, and scribe line *m*, *m*, which will pass through the center of the pin hole. Referring to Fig. 7, the arm to the left has a boss extending from the face 2 inches, and the throw of the arm is 13¼ inches. To locate the center of the pin hole, allowance must be made for the projection of the boss. This may be done by drawing, on a sheet of tin or a board, the line *e, f*, Fig. 6, and on this line lay off from *e* the point *f*, distant from *e* the amount of the throw, in this case 13¼ inches. Through *f* draw the line *f, g*, at right angles to *e, f*, and lay off point *g*, distant from *f* the amount the hub extends out from the face of the arm, in this case 2 inches. If the dividers are set to points *e* and *g*, and one point held in the center *g* of the shaft, Fig. 9, and the line *k, k* scribed across the boss, the point of intersection with line *h, h* will be the center of the pin hole. From this center scribe a circle on the boss, and locate it permanently with prick punch marks. The other arm is laid off in a similar manner.

After the rocker shafts are finished, the rocker boxes will have to be fitted to them. The box shown in Fig. 8 has removable cast-iron bushings, and it will probably be necessary to fit new ones. As shown in the drawing, these bushings are bored out to fit the rocker shaft and turned on the outside to fit the bore in the box. The thickness of the flanges on the bushings is such as to fill between the hubs of the rocker. After being finished in the lathe, they are sawed in two, and the halves thus made are secured in the box by rivets, and fitted to the rocker shaft. If the box has not been bushed, it will be necessary to fit it to the rocker shaft by closing the bore. This is done by filing or planing off the faces *a, a* and *b, b*, care being used to keep these faces square both ways with the machined recess for the frame *c, c*. It is the practice of some shops to plane enough off these faces, when the box is new, so that a liner about ¼ inch thick can be placed between them. In such cases, when necessary to close the box, the required amount is planed off the

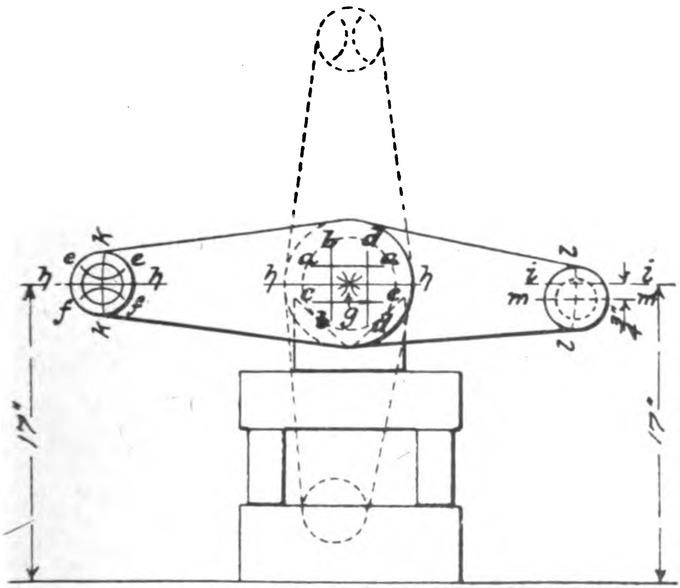


Fig. 9

liner. This is a better way than filing off these faces each time it is necessary to close the box. When the box has been closed, it will be necessary to file out the rear of the holes *d, d* for the frame bolts, as the process of closing will move the rear half of the box forward. Sometimes boxes of the style shown are divided in a horizontal plane, in which case the frame bolt holes are not disturbed by the closing.

If it is desired to bush an old box, liners are placed between the halves of sufficient thickness to bring them into their original position, and the box is bored out to a diameter which will allow the bushings to be not less than $\frac{3}{16}$ inch thick. The ends of the box are faced off so the flanges on the bushings will be from $\frac{3}{16}$ inch to $\frac{1}{4}$ inch thick.

In securing the rocker boxes to the frames, the bolts should be a good driving fit in both the frame and the box, and should be reamed if not in good condition.

When a set of links is received at the bench for fitting up, they should be taken apart, giving all parts a careful inspection to determine which will need renewal. If the blade pins are a good fit in the blade ends, and not worn to the limit of size, they should be annealed and sent to the lathe to be trued up and have new bushings fitted. Similarly the link block pins, saddle pins, etc., should be trued up, or new ones made as the case may be. If the link block is in good condition and large enough to stand refitting, it should be done, bushing the hole for the block pin. The link will probably be found worn near the center, if a road engine, and the wearing faces will need truing up. If only slightly worn, they may be ground true to a template. In this connection it should be said that all shops where this class of work is done should be provided with a set of templates for the different classes of engines, similar to that shown in Fig. 10. These should be made of steel, somewhat shorter than the link, and about $\frac{1}{8}$ inch think. Edges *a* and *b* should be carefully fitted to a new link, the width *c* being the thickness of the block.

If the links are badly worn, they should be sprung under a press at the worn spot, in order to save stock in truing them up. If the shop is not equipped with a grinding machine, it

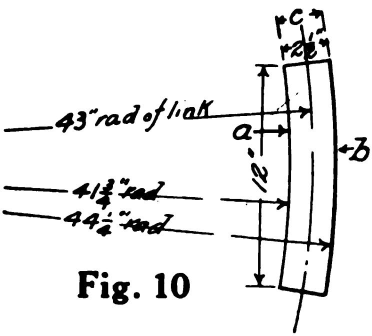


Fig. 10

will be necessary to have them annealed and true them up by filing. Care should be used in either case to have the bearing surface square with the sides. If the sides of the link are badly worn by the block flanges, they should be ground, planed or filed true, keeping them parallel and both pieces the same thickness. The flanges of the link block should be taken off, planed up, and the block planed off the right thickness.

If the link is case hardened after being trued up, it will generally spring more or less, and will have to be straightened up under the press.

If the link block is to be refitted, it should be filed or ground up to the same template as the link, making the two bearing faces equal distances from, and parallel with the hole for the block pin.

Bushings for all pins should be pressed into place after hardening, with a pressure of 3 to 5 tons. Be sure that all oil holes are drilled in these bushings, and that they come fair with the holes in the link, or other parts into which they go. In fitting pins and bushings that are to be case hardened, bear in mind the fact that in case hardening the work usually swells in all dimensions. Thus bores become smaller, while outside dimensions become larger, and sometimes the length will increase slightly.

If the block has been refitted, it will be thinner than before, thus necessitating the closing of the link. The end blocks should be faced off somewhat thinner than the block, using proper shims to bring the slot the correct width. If the link is one having the end bolts radial, the holes through the links and end blocks will have to be reamed to bring them in line. Place the block in position and bolt the link together. The block should move free the entire length of the link slot, but without any lost motion. It will probably be found that owing to the end blocks not bearing perfectly, the block will be free at some points and tight at others. If tight in the center, the slot may be sprung open by placing a thin paper shim inside the end bolts. If loose in the center, the shims should be placed outside the bolts. If the link has been closed it will be necessary to file off one side of the saddle bolts, or file out one side of the holes in the saddle, and care should be used to see that the offset of the saddle pin is not changed.

The tumbling shaft, or lifting shaft, should be examined and the bearings for the boxes trued

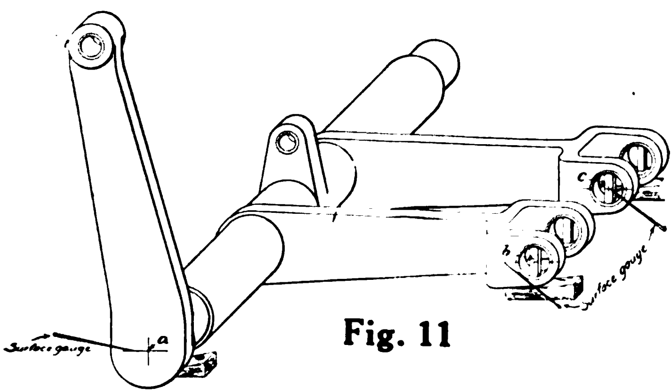


Fig. 11

up if necessary, and the shaft tested to see that the centers for the holes for the hanger pins are in the same plane, as the arms are liable to be sprung more or less. To test these, the shaft should be carefully centered at both ends, as at *a*, Fig. 11, and centers *b* and *c* placed in the hanger pin holes. Place the shaft on a surface plate, or planer bed, supporting the bearings in V blocks, and shiming them up until the centers *a* in the ends of the shaft are the same height. Block one of the arms up until the center *b*, in the pin hole, is the same height as the center *a* of the shaft. If the arms are correct, the center *c*, in the other pin hole, will show the same height as centers *a* and *b*. If it does not show the same, one or the other of the arms should be sprung until the centers show the same. These holes should also be tested at this time, to see if the hanger pins will stand parallel with the center line of the shaft. If not, the arms will require twisting to bring the pins parallel.

The tumbling shaft boxes should be bushed if necessary, and examined to see if the centers of the holes are equal distances above or below the frames, as the case may be. They should also be examined to see that they stand square cross ways of the frame.

The link hangers should be tested to see that the center to center distance of the holes is correct, and especially that this distance is the same for both hangers. If not, the hangers should be drawn or upset, as the case may require. They should also be tested to see that the holes are parallel in both a horizontal and vertical plane. If found "out," they will have to be bent or twisted, depending on which way they are out of parallel. These holes should be bushed to fit the pins.

All pins in the reverse lever should be examined, holes reamed and new pins fitted where necessary. Where the latch bears against the lever, it will generally be found worn, and will need to be faced up. If the latch teeth are badly worn, and the latch body is long enough, they should be re-cut, and the connection rods to the latch handle lengthened out to suit. If the latch can not be re-cut, a new one should be made. If the quadrant teeth are in poor condition and the quadrant has sufficient stock, the teeth may be re-cut. If this cannot be done, put on a new quadrant.

The reach rod should be looked over and new pins and bushings put in where necessary. It should also be tested for length and if very much out, should be made correct. Generally it should be of such length that the reverse lever will stand vertical when the arm on the tumbling shaft is vertical.

The eccentric rods, or blades as they are commonly called, should be examined as to the fit in the eccentric straps. They should fit the recess in the straps without any lost motion in a vertical direction, and would better be a little snug, rather than loose. The fit of the pins connecting the blades to the links should be examined. These should be very good and if the fits in the blades are worn, due to loose pins, new ends should be made and welded on, in case the holes can not be reamed.

The eccentrics should be examined to see that all keys, set screws, bolts or studs holding the two pieces together are in good condition. The key ways in the axle should be examined and if found worn wider at the top than at the bottom, they should be squared up. The eccentrics should be calipered, and if found very much out of round, or under size, they should be taken off and new ones substituted. This for the reason that all eccentrics and straps should be maintained "standard" so far as possible. Broken eccentric straps are of frequent occurrence, and if the eccentrics are kept at practically standard size, a new strap can be fitted very quickly. If the eccentrics are worn

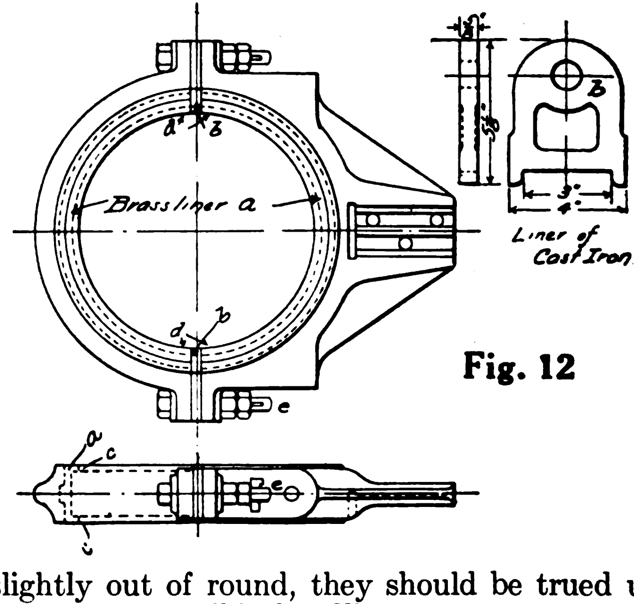


Fig. 12

slightly out of round, they should be trued up as near as possible by filing.

In putting on new eccentrics, they should fit the axle snugly when bolted together. The fit should be such that they can be moved on the axle by means of a large wrench or other tool. They should be placed in position on the axle with a well fitting "straight key." If this is done, it will be an easy matter for the valve setter to figure on the proper off-set to be given the key when it comes to the final adjustment.

If the eccentric straps need closing, they should be bolted together with the liners in place. Caliper each strap and eccentric, marking the difference in the sizes on the respective straps. If the straps are to be planed off to close them, one-half this difference in size should be marked on each half of the strap before sending them to the planer. If the liners are to be reduced, mark the whole amount to be taken off on the liner. In case the straps are to be re-bored, they should be closed enough to allow for cleaning up the bore to fit the eccentric.

A number of roads are now using quite extensively an eccentric strap as shown in Fig. 12. The strap proper is made of cast steel, provision being made for the brass or cast iron wearing liner *a*. When the liner is worn out it is replaced with a new one. With this form of eccentric strap, always reduce the thickness of the liners *b*, *b*, when closing the strap, for when the brass liner *a* is renewed the liners *b*, *b* will be replaced by new ones of standard thickness.

The straps should be fitted to the eccentrics so as to be perfectly free at all points, and should not bear on the fillets or edges of the flanges at *c*, *c*, Fig. 12. The fit at *d*, *d*, near the joints, should be eased off, as it will be found that the straps have a tendency to close across these points in boring out. The strap bolts *e*, *e* should just fill the holes in the straps, and should be secured by two nuts and a split key. See that the slot in the bolt is cut so that the key will bear against the nut and not stand away from it as is commonly the case.

Assuming the rockers, tumbling shaft, eccentrics, etc., in position, and the wheels under the engine, the links should be put up by securing the block pins to the rocker arms. Put the link hangers on the saddle pins, and see if the upper end of the hanger can be connected to the lifting arm without binding in any manner. If it can not be done the hangers will have to be bent or twisted until it can be accomplished.

The eccentric blades should be bolted to their respective eccentric straps and tried with the link. The end of the blades which connect to the link should move laterally through a distance of about $\frac{1}{4}$ inch, and this movement should be divided equally on both sides of the link. It may be necessary to move the eccentrics on the axle, and if this does not answer, the blades will have to be bent. The blade pins should enter the link and blade without binding in any manner, and it may be necessary to twist the blades as well as bend them.

Fig. 13 shows a tool for bending the blades. The body is made of machine steel, with two lugs forged on to take a flat key $\frac{3}{4}$ inch thick. To bend the blade, the tool is placed on it at the point it is desired to have the bend, and the key slipped into place. As the screw is tightened, the blade is forced to bear on the rounded end of the tool body, and the point of the screw on one side, and against the key on the other side. By screwing in the screw, any amount of bend may be placed in the blade. In bending blades, always use a double bend, thus bringing the jaws in line with the link and square with same.

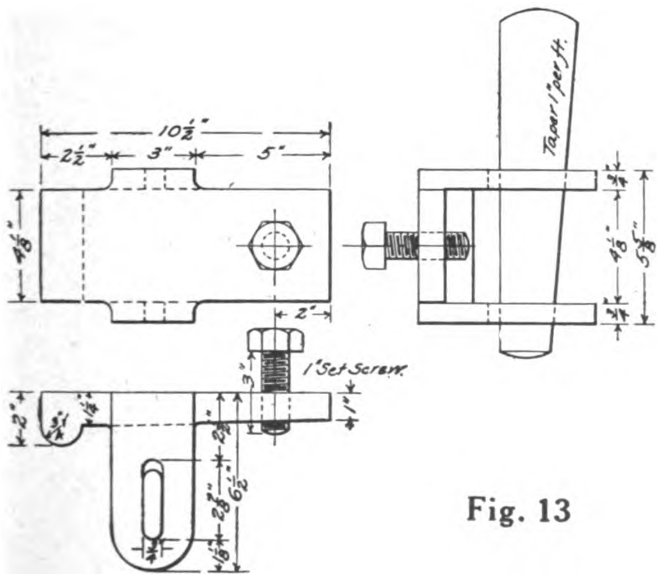


Fig. 13

Fig. 14 shows a tool for twisting the blades. It consists of two hook shaped pieces connected at the end opposite the hooks, by a 1-inch bolt. The bolt has the under side of the head finished spherical, as is also the nut, and the holes are counterbored to fit these heads. The bolt is prevented from turning while being tightened, by a small dowell under the head, and is kept from dropping out while the tool is being put in place by the ¼ inch x ¾-inch strap fastened

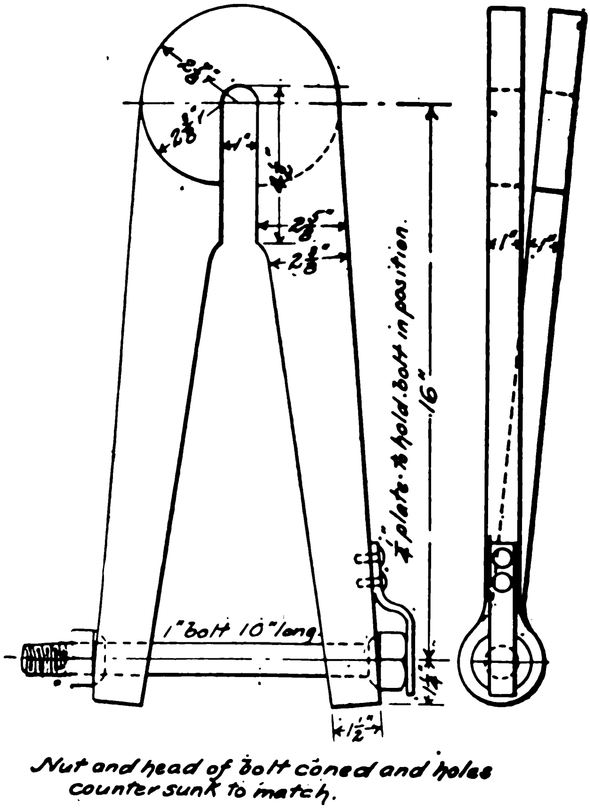


Fig. 14

to the body of one of the hooks. To twist a blade, the hook ends are slipped over the blade at the desired point, and the bolt tightened until the desired amount of twist has been put in the blade.

A type of valve gear known as the Walschaert has of late years been applied extensively to American locomotives, due chiefly to the desire to improve the locomotive structurally rather than improve the steam distribution. While it differs radically in appearance from the ordinary link motion, it has many parts similar in construction, and the method of performing the various operations in repairing this gear are the same as have been described in the foregoing. A detailed description of this gear will be found elsewhere.

CHAPTER VIII.

Erecting Shop Work—Hanging or Lining Guides.

The function of the guides and crosshead is to compel the piston rod to move in a straight line coincident with the center line of the cylinder bore. For this reason the guides should be set with great care so as to be exactly parallel with the center line of the cylinder, so that the crosshead will slide in a path exactly parallel to the path in which the piston rod will move, if it moves in a straight line.

Guide bars are generally set, or lined, to a fine line set central in the bore of the cylinder by measuring from the counterbore at the front end, and by the stuffing box at the back end. Sometimes a template, similar in form to the cross section of the crosshead, sliding upon a long piece of tubing centered in the cylinder, is used.

Before beginning the operation of hanging the guides, they should be faced to a face plate and the wearing surfaces made a right angle to the side faces. The ends bearing on the guide blocks should be planed slightly below the wearing surfaces, or grooves cut across the guides near the ends, in such a position that the cross head will travel over them at each end of the stroke, and thus avoid wearing shoulders at the ends of the travel. Steel and wrought iron guides can be made nearly straight by springing them under a press, and if not too badly worn can be finished by filing. The final finish should be done by draw filing with a fine file in the direction of the length.

In lining the guides loose bolts should be used, but they should nearly fill the holes. They should be long enough to reach through the top and bottom guides, and when lining the bottom guides, which should be done first, pieces of pipe as long as the thickness of the top guides should be placed between the bolt heads and the top of the guide blocks. The center line should be run through the cylinder at this stage of the operation. Use a fine line and stretch it tight.

In order to set the guides the correct height from the cylinder line, a tool called the guide gauge is necessary. It is set in the following manner. The hole in the crosshead for the piston rod should be centered by fitting in it a piece of copper, lead or wood stick, as shown in Fig. 1. With the hermaphrodite calipers locate the center of the hole, marking it with a small prick punch mark. Two parallel strips or straight edges should be placed on the bottom wearing surfaces of the crosshead, and the guide gauge applied to the straight edges as shown, setting the needle or pointer in the gauge to the center of the hole.

The guides are set the correct distance above the cylinder line with the guide gauge applied at each end as in Fig. 2, being correct when the pointer just touches the line. Now it is possible for the pointer to touch the line when applied in this manner and yet the setting of the guides will not be correct. There are two methods of checking this. An adjustable level may be set to the valve seat, or to a straight edge laid across the frames, and then applied to the guides at each end as shown in Fig. 3, testing them at the same time to see that the top faces lead true, one to the other. Thus, in Fig. 4, *a* and *b* are the bars and *c* the straight edge, which, by being pressed firmly to the surface of *a*, shows that the surface of *b* is not in line with *a*, because if it were so the straight edge would meet the face of *b* as shown on Fig. 5. We might place a straight edge across the frames just back of the front guide blocks, resting it on parallel pieces as shown in Fig. 6, and caliper the distances *c* and *d* from the guides to the straight edge. Suppose the outside guide shows $\frac{1}{16}$ inch lower than the inside one. If we raised the low one $\frac{1}{16}$ inch or lowered the high one $\frac{1}{16}$ inch we would find on applying the guide gauge that the guides would be $\frac{1}{32}$ inch too high in the first case and would be $\frac{1}{32}$ inch too low in the second case. Hence to maintain the height of the bars correct, we should lower the high one $\frac{1}{32}$ inch and raise the low one $\frac{1}{32}$ inch. Test them at the back end in the same manner and make the necessary changes. As changing one end will alter the setting at the other end, the process must be repeated. Sufficient liners should be placed between the guides and the guide blocks to hold the guides in this position when the nuts on the bolts are tight. If there is room one liner about $\frac{1}{16}$ inch thick should be used, filling up the balance of the space with thin liners.

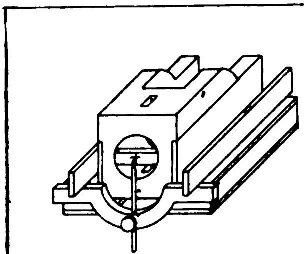


Fig. 1.

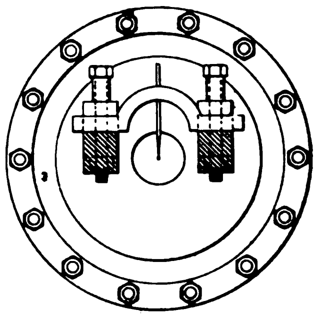


Fig. 2.

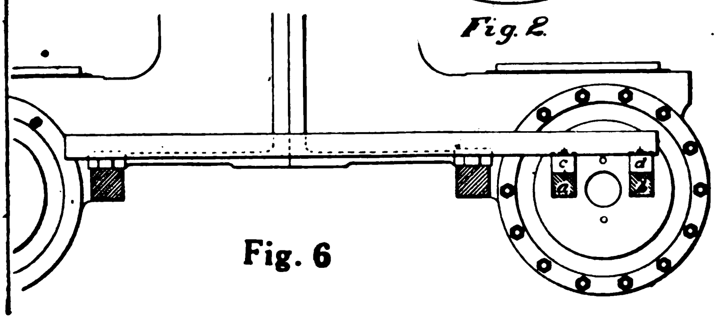


Fig. 6

The guides are set in line horizontally by calipering from the cylinder line as shown in Fig. 7, the calipers being set to one half the distance between the flanges on the crosshead. The crosshead should have about $\frac{1}{32}$ inch side motion. They may also be set in this direction by using a square and straight edge in the following manner; see Fig. 8. On a straight edge mark two lines, *a* and *b*, a distance apart equal to the distance between the flanges of the crosshead. Midway between *a* and *b* mark the line *c*. Place the straight edge across the bars as shown, and when the edge of the square placed on the straight edge coincides with *c* and the cylinder line, and the marks *a* and *b* coincide with the inside edges of the guide bars, the latter are set true in this direction, supposing the hole for the piston rod is exactly central between the crosshead flanges. If such is not the case, the distance from *a* to *c* and *b* to *c* must be made to suit the crosshead.

If for any reason the guide bars do not bed properly on the guide blocks and liners, the bars will be sprung in bolting them up. The way to test them in this respect is, after the above operations place a long straight edge lengthways along each bar and move it laterally at one end. If it swings from the center, the bar is rounding, while if it shuffles across first at one end and then at the other, the bar is hollow in its length. To find at which end this spring exists, slacken the bolt or bolts at one end, and again apply the straight edge. If the spring is removed the error lies in the bedding of the bar at the loose end. If not removed, tighten the bolts again and slacken those at the other end, and again apply the straight edge. In this way it may be determined how much of the spring is due to each end. The guides may be sprung up or down in the center by using narrow liners either in front or back of the bolt. If the guides are sprung up in the center, the strip should be placed between the bolt and the center of the guide and a liner of the thickness of the strip should be taken out; otherwise the guide will be the thickness of the strip too low when tightened up. If the guides are sprung down, the strip should be placed between the bolt and the end of the guide. In this case no liners will need to be taken out. Experience will teach the machinist more about the effect of these strips in straightening guides than anything that can be written.

With some forms of four bar guides, the guide yoke is fastened to the top guide and the bottom guide is fastened to the top one at the rear end by the guide blocks. With this construction it will be necessary to line the top guides first. Otherwise the operation is the same as described.

After the bottom guides have been lined, the crosshead should be placed on them and moved from one end to the other, and examined to see if there is any "rock" in it; also where it bears on the guides. It may be that the wings of the crosshead were not planed exactly the same height, in which case the guides must be lined to suit by raising the low one or lowering the high one. If the difference is very much one guide should be lowered and the other one raised, otherwise they would be thrown too much out of line. The guides should be tested at both ends in this manner, the idea being to have them perfectly parallel with the crosshead laterally, so that the bearing will be equal on both wings, otherwise the guides are liable to cut and run hot. If the bearing of the crosshead is shown to be on one edge of the guides, the high side must be let down by putting strips

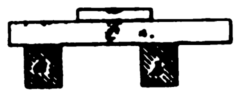


Fig. 3.

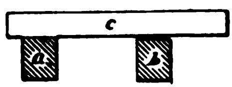


Fig 4.

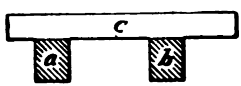


Fig. 5.

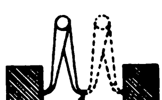


Fig. 7.

between the guide and block on the high side, or removing them from the low side. These changes will probably somewhat destroy the perfect alignment of the guides, but not enough to do much harm. After setting the bottom guides, scribe lines on the cylinder head and guide yoke fair with the edges of the guides so that they can be placed back in position in case they move while putting up the top guides. The liners projecting beyond the ends of the guide blocks should be chipped off flush with the blocks, as it will be hard to get at them after the top guides are in place.

Place a jack or support of some kind under the inside bottom guide and take out the bolts and place the top bar in position, lining it down to within about $\frac{1}{64}$ inch of the crosshead. It can be sprung up or down in the center as may be necessary in the same manner as the bottom ones. The edge of the top guide should be set in line with the inside or outside edge of the bottom guide, depending on the style of crosshead. In the particular construction illustrated, the top guides do not guide the crosshead laterally, hence are set with the outside edges in line with the outside edges of the bottom guides. The top guide should be set parallel laterally with the bottom one. Proceed in the same manner with the outside guide and the job is done, unless the bolt holes are to be reamed. In this case clamps should be applied in such a manner as not to spring the guides, the bolts taken out and the holes reamed. If the guides should move, they may be re-set to the lines scribed on the cylinder head and guide yoke. The bolts should fill the holes but should not be too tight.

It is the practice in some shops to mark the guides and crosshead after lining, so that the roundhouse machinist will have something to go by when it is necessary to close the guides to take up the wear. See Fig. 9. Here center punch marks *a* and *b* are made at each end of the crosshead, inside and outside, the same distance from the face of the bottom guide. Center punch marks *c* and *d* are also made on faces of the guide blocks, inside and outside, the same distance from the face of the bottom guide that marks *a* and *b* are. In closing the guides, if the roundhouse man will bring these four marks, inside and outside, in line when tested with a straight edge, the crosshead will be the same height it was originally.

To line two bar guides, the crosshead should be centered as before described and a pair of calipers or suitable gauge set from the face of the bottom gib to the center, using a straight edge as shown in Fig. 10. Both guides should be bolted up and the cylinder lined. The guides should be set parallel and central to the cylinder line, using an adjustable square as shown in Fig. 11. The bottom guide should be set the correct distance below the cylinder line at each end by using the calipers or gauge as shown in Fig. 12. They may be sprung up or down as may be necessary as was before described. Set both guides perfectly square laterally by using a straight edge across the frames at each end as shown in Fig. 12, making the distances *c* and *d* equal, or they may be set in this direction by using an adjustable level. Calipers should be set to the distance between the crosshead gibs and the top guide lined to give about

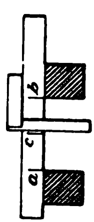


Fig. 8.

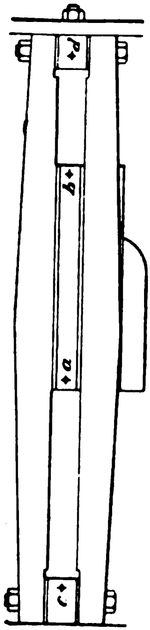


Fig. 9.

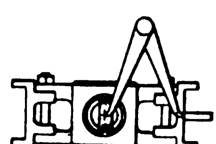


Fig. 10.

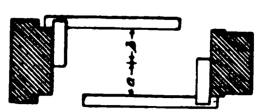


Fig. 11.

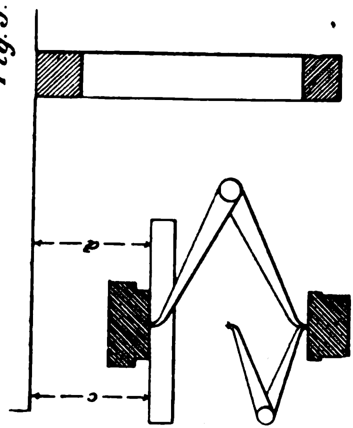


Fig. 12.

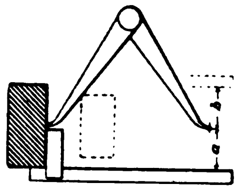


Fig. 13.

$\frac{1}{64}$ inch clearance. The crosshead should now be put up and moved from one end of the guides to the other and the bearing tested. If everything is correct, ream the holes and fit the bolts.

With the "Laird" type of crosshead both guides are above the cylinder center and generally it will be necessary to line the top guide first. The crosshead should be centered and the calipers, or gauge, set to the distance from the center to the top of the gib. Set the top guide parallel to and central with the cylinder line by using a square as shown in Fig. 13, and the correct distance above the line by using the calipers or gauge. It should be squared up laterally by means of a level or by measuring from a straight edge across the frames as in Fig. 12. The bottom guide should be set central with, and the thickness of the gib plus about $\frac{1}{64}$ inch from the top guide. Keep it square laterally. Place the gib between the guides and see that it moves freely from one end to the other, after which the crosshead should be bolted up.

In closing guides it is sometimes difficult to determine whether they should be closed up or down. With light power, generally running ahead, it is safe to assume that the greatest wear will be on the top gib of the crosshead, hence the top guide should be lowered. With heavy power this may not be the case, owing to the greater weight of the parts resting on the guides. If the piston is kept central in the cylinder (as it should be), the guides may be tested in the following manner. Place the crosshead with the piston attached at the back end of the guides, and caliper from the bottom guide to the piston rod at the front end and also near the crosshead. If the distance from the guide to the rod at the front end is greater than that near the crosshead, the bottom guide should be raised sufficient to bring the piston rod parallel to it. Good judgment must be used in closing guides, to the end that the piston rod will be kept in a path in line with the center line of the cylinder.

CHAPTER IX.

ERECTING SHOP WORK—FITTING UP RODS.

In fitting up rods the following conditions must be obtained. The axial lines of the brass bores must be at right angles to the center lines *A*, *B* and *C*, *D* of the rod, (see Fig. 12), and parallel to each other, as the pins on which the brasses run are parallel. The flanges of the brasses must be the correct thickness for the length of the pins and divided equally each side of the center line *A*, *B* of the rod. The center to center distance between the brass bores must be equal to the center to center distance between the pins on which the rod works.

In the case of a new rod the steps in fitting it up are generally as follows:

1. The rod is planed or milled.
2. The straps are planed or milled.
3. The straps are fitted to the rod.
4. The straps and rod are drilled, reamed and bolted together.
5. The key ways, if any, are cut and finished.
6. The side faces of the straps are planed to correct thickness while bolted to the rod.
7. The brasses are planed or milled and fitted to the straps.
8. The rods are laid off for length and the brasses bored.
9. The brasses are fitted to the pins.

As the first, second, sixth and first half of the seventh steps constitute work not generally done by the man fitting up the rods they will not be described at this time.

If the two ends of the rod have been made and machined as separate pieces and afterwards welded to the body of the rod, or in case one new end has been made, the two ends will have to be aligned by the following process. This must also be done where the rod has been bent in service.

The rod is first laid on its side as shown in Fig. 1, two straight edges or winding strips *A* and *B* being placed on the side faces *C* and *D*, and the rod set in this direction until the straight edges appear parallel when sighted by the eye. The straight edges should be placed square across the rod and parallel to each other. The rod is then placed on edge to test the alignment of the side faces *C* and *D*, Fig. 2. The straight edge is held firmly against one of the faces, as *C*, with the other end slightly elevated as shown. The elevated end is then lowered, the motion tending to keep the end fairly against the face *C*. The distance *a*, *b*, Fig. 3, is measured and the straight edge is then placed on the opposite side as shown by the dotted lines, and the distance *c*, *d* measured. The rod is set until these two measurements are equal. The straight edge is next applied to the edge faces *E*, *F*, *G* and *H*, Fig. 4, and the distances *e*, *f* and *g*, *h* made equal. Next the straight edge is applied to the edge faces of the small end as shown in Fig. 5, and the lines *i*, *j* and *k*, *m* scribed along the straight edge, and the rod set in this direction until the distances *n*, *o* and *p*, *r* are made equal. During these various operations a straight edge should be placed along the body of the rod, and if the body is straight, the adjustment, or set, should be made near the end at which the straight edge is pressed to the rod. The winding strips should also be applied to the side and edge faces as shown in Fig. 1, from time to time, and as making one setting may alter another, the whole process must be repeated until the whole of the tests prove the setting correct.

If the rod is forged solid and the ends finished by planing or milling, they will probably be correct (but should be tested as above) and the first operation will be the fitting of the straps to the rod ends.

The straps should be tested as shown in Fig. 6, to determine if the jaw faces are square, and the face *E* of the rod end should be surfaced true and made a right angle to the side face *C*, Fig. 7. The opposite face *G* of the rod end should be made parallel to *E*, and both of these faces should be at right angles to the end face *H*, unless the dimension *b* is less than *a*, in which case the angle of face *E* and the opposite one *G* should be equal with reference to *H*, a square and surface plate being used to test them. To fit the strap, place it on the rod (having first put marking on the rod end) and move it end ways and side ways, observing

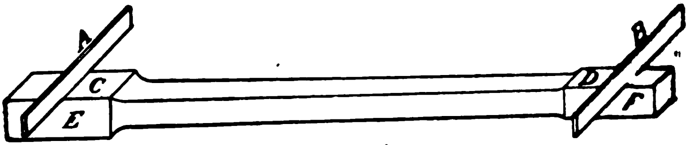


Fig. 1

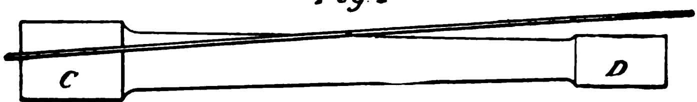


Fig. 2.

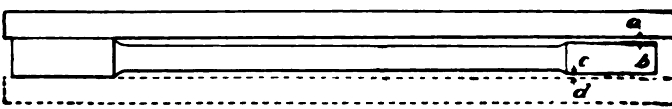


Fig 3.

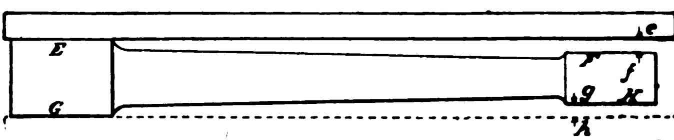


Fig. 4.

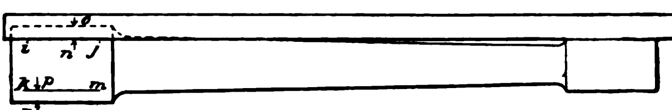


Fig. 5.

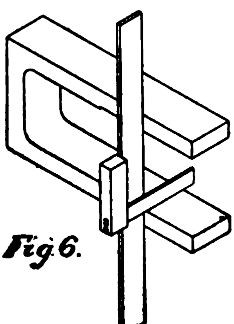


Fig. 6.

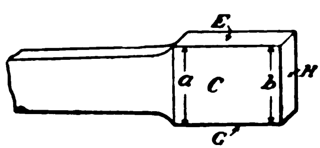


Fig 7.

where the least motion takes place when the strap is moved side ways by pressing the crown end, for the point of least motion is where it fits the tightest. When the strap shows to bed well on the rod and its motion is an ambling one, and not a pivoted one, it fits properly. The inside faces of the straps and the faces of the rod end should be made slightly taper, being smaller at *b*, Fig. 7, than at *a*, for the reason that the brasses can be made a tighter fit in the strap without destroying the fit of the strap to the rod.

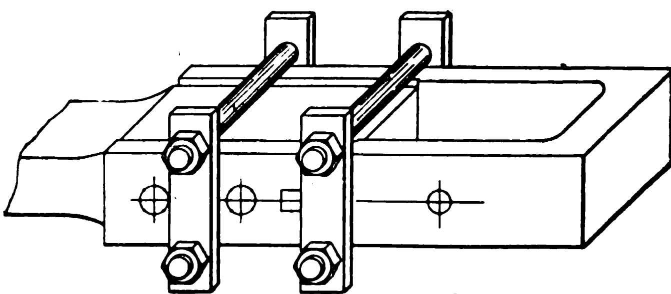


Fig. 8

The holes for the strap bolts should be laid out and the strap placed in position on the rod and clamped as shown in Fig. 8. In doing this the rod should stand with the side faces vertical. The strap should be set central side ways and in line with the rod length ways. The clamp bolts should be tightened gradually, first one a little and then another, going over all four once or twice before they are fully tightened up. If the strap is not fair when they are all tight, they must all be loosened before the strap is again adjusted, or the pressure of the clamps will cause the strap jaws to spring out of true, and the holes will not come fair when the clamps are removed. After clamping the straps to the rod it should be sent to the drill press and the holes drilled and reamed, after which the straps should be removed and the key ways drilled in the strap and slotted in the end of the rod. The straps should then be bolted to the rod and the key ways finished by filing. The sides of the key ways should be filed parallel to the side faces of the strap and should be of equal width throughout. A suitable gauge will probably be furnished for this as well as to test the correctness of the taper. The keys should fit the key ways tight enough so that they will stay in any position in the key way of the strap or rod when standing vertical.

The straps should now be bolted to the rod and the side faces of the straps planed to the correct thickness, after which the brasses should be planed to fit the straps. The width for the brasses should be measured while the strap is on the rod, because the width between the jaws of the strap is greater when the strap is in place on the rod end than when off.

The brasses are generally soldered together for planing, and as they should be fitted to the strap separately they must be separated, and this can best be done by driving a thin chisel between the joint faces. The back brass should be fitted first. The corners of the ways in the brass for the strap should be eased clear with a half round file in case they were not cut down by the machine hand. The brass should be driven in and out of the strap while fitting, with a block of wood, otherwise the bore of the brass will be pened, and when bored out will close in at the sides and hence be a loose fit in the strap. As a guide when fitting the bottom brass, the strap should be placed on the rod as shown in Fig. 9, with the edges overlapping the rod so that the calipers may be set as shown.

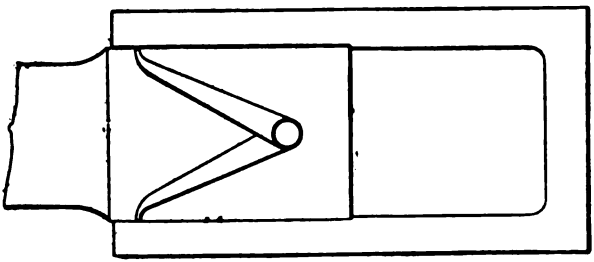


Fig. 9

Each time the brass is placed in the strap to try the fit, the calipers so set should be tried in the strap until the brass has been reduced sufficiently as not to spring the strap jaws too wide open. The brass should be left a little tight, as after being bored out it will close slightly across the sides, thus easing the fit. In fitting the brass it should be tested with a square as shown in Fig. 10, keeping the sides as well as the flanges square with the joint face. The crown of the brass should bed very finely to the bottom of the strap. The second brass should be fitted in the same manner, but should just fill the strap when the back brass is in place; otherwise it will spring the strap open and destroy the fit of the back brass and also the fit of the strap to the rod. The brasses should be planed to such length that a plate at least ¼ inch thick can be placed between the brass and key. After the brasses have been fitted, and before placing them in the straps, two lines, *a* and *b*, Fig. 11, should be marked

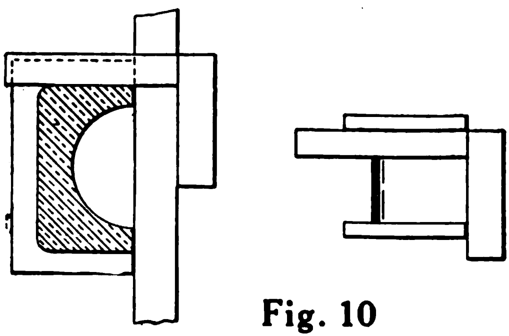


Fig. 10

on the outside face of the top brass in line with the faces which fit against the inside jaws of the strap.

The brasses should now be placed in the straps and the straps bolted to the rod. Center pieces *E* and *F*, Fig. 12, should be placed in the bores and upon them lines *c*, *c* and *d*, *d* scribed parallel with and central between the lines *a* and *b* on the brass. Across one of the center pieces scribe the line *e*, *e* in line with the joint faces of the brass, intersecting the line *c*, *c* at *f*.

The trams are now set to the length of the rod, and from center *f* an arc is scribed across the center piece in the opposite brass at *g*, *g*. If the point of intersection *h* does not come in line with a line drawn across the joint of the brass, the two centers should be changed so as to divide the difference between the two brasses. If very much out, the brasses should be lined up in the straps to suit. From the centers *f* and *h*, thus located, a circle, somewhat larger than the bore of the brass is to be, should be

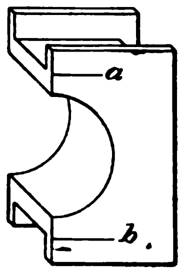


Fig. 11

scribed on the face of the brass and located permanently by prick punch marks. This circle is for the lathe or boring mill hand to set the brass for boring. The straps should now be removed from the rods and the keys driven in to hold the brasses in place, after which they are sent to the lathe or boring mill.

In laying off rods for length they should be placed in such a position that the trams will be applied to them in the same position which the trams occupied when set. When traming for the length of the side rods, if the construction of the engine is such that the fire box extends down between the frames, the trams should be set about $\frac{1}{32}$ inch longer than the distance between the centers of the axles. This for the reason that when the engine is hot the frames will expand about this amount. To get the correct length of the main rod the crosshead should be placed exactly central between the striking points. Then if a stick is placed against the crosshead pin and a line scribed

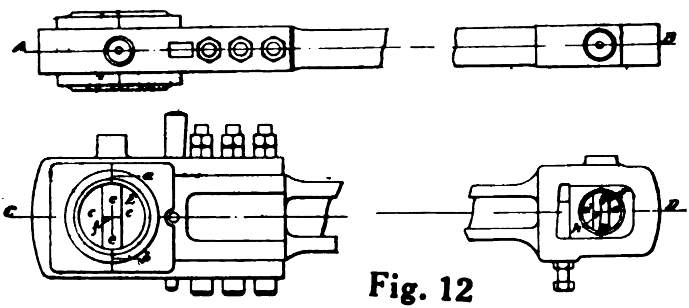


Fig. 12

across it in line with the center of the main driving axle, this length plus one half of the diameter of the crosshead pin will be the length of the main rod. See Fig. 13.

With rod ends of the style shown at the small end of the rod in Fig. 12, the brasses should be left soldered together during the process of fitting, as the brass must be chucked by itself for boring. The recess in the rod should be filed square all around with the side face, or preferably slightly taper, in which case each

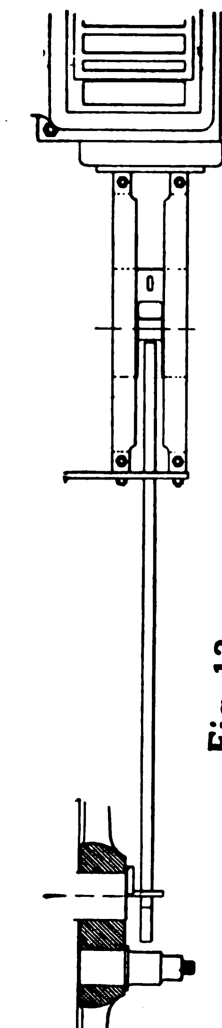


Fig. 13

inside face, except the one where the key bears, should be an equal degree of taper to the side face. By making the faces slightly taper it will be much easier to make the brass a good fit, as it can be tried in its place while being fitted before being reduced to finished size. With brasses of this style too good a fit in the rod cannot be had.

The foregoing remarks apply to the fitting up of side rods having strap ends. With rods of the style shown in Fig. 14, there are no straps at the front and back ends, the rod being forged in one piece, the ends bored out, and brass bushings pressed in. The bushings are kept from turning, in case they should become loose, by a dowell pin screwed in from the oil cup. There should be a groove turned in the outside of the bushing in line with the oil hole so that in case the dowell should break off and the bushing turn, the oil supply will not be cut off. As the center to center distance between the brass bores admits of no adjustment, it is evident that the shoes and wedges must be laid out very accurately so that the centers of the axles will be the same distance apart that the centers of the rod bushings are.

Sometimes these rod ends are made and finished separately and afterward welded to the rod body. In such cases the rod will require setting as previously described. In making repairs it will be found that the holes for the bushings get badly out of round, in which case it will be necessary to have them trued up.

In some shops it is customary to bore and turn the bushings and then press them into the rod ends. If this is done allowance must be made in boring the brass for the amount the bore will close in pressing it in. Generally when the bushing is in the rod the bore should be from $\frac{1}{64}$ inch to $\frac{1}{32}$ inch larger than the pin. The bushings should be pressed in with a pressure of about one and one-half tons for each inch of outside diameter of the bushing. The side rod brasses should have from $\frac{1}{64}$-inch to $\frac{1}{32}$-inch lateral or side motion, and the fillet in the brass should be such that it cannot bear on the pin.

Side rods for an engine having three pairs of driving wheels are shown in Fig. 14. In the particular construction shown the middle connection brass is of the strap form, and the two end brasses are of the solid type. The middle connection brass has two keys in order that the brass may be keyed and still maintain the center distances *A* and *B* correct as closely as possible. It is a good practice when laying out rods of this kind for length to scribe lines *a*, *a* and *b*, *b*, Fig. 15, across the middle connection strap at the center of the bore. When this is done whenever it is required to key up the brass, or after it has been filed, all that is necessary to maintain the rods the correct length is to see that the joint faces of the brass come fair with the lines *a*, *a* and *b*, *b* when the brasses are keyed up.

The knuckle joint *C* is shown in detail in Fig. 16. The pin has a taper fit in the jaws of the rod, and is kept from turning by the dowel

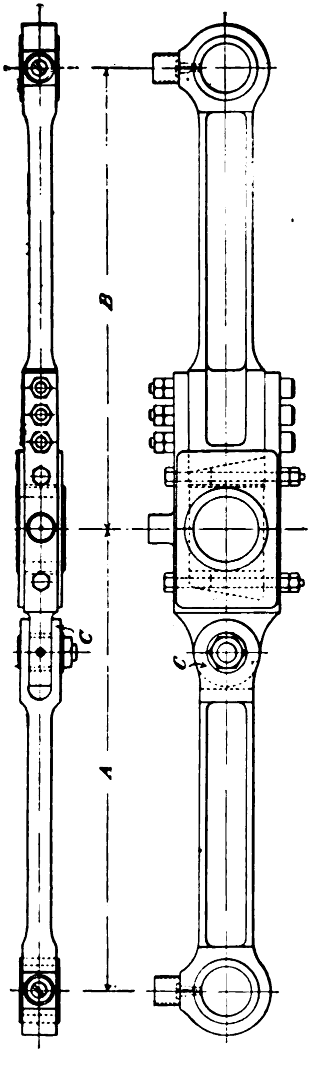


Fig. 14.

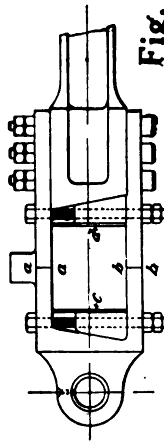


Fig. 15

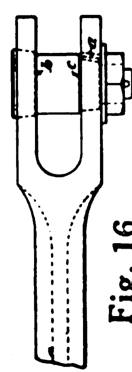


Fig. 16

at *a*. The pin is generally made of wrought iron and case hardened. The bushing in the strap in which the pin works is generally made of wrought iron, case hardened, but is sometimes made of hard brass. If the pin wears loose in the rod, and the holes are in good shape, it can be tightened by cutting back the shoulders at *b* and *c*, thus letting the pin further into the rod.

In repairing rods the following work will generally be required:

1. The straps refitted and probably bolt holes reamed and new bolts fitted. Also new keys.

2. The side of the straps planed up, brasses lined to make them fit the straps, rods lined to length, and brasses fitted to the pins.

If the strap has been loose on the rod end the faces of the rod will need to be trued up to a surface plate and made square with the side faces, and also made parallel or the correct taper with reference to the end of the rod as the case may be. After this is done the straps will need to be closed. If the inside of the straps are taper they can be closed by pening the outside of the back, but as this method will only take care of a slight misfit, the chances are that the straps will have to go to the blacksmith for closing. If this is done they should be tested by winding strips applied as shown in Fig. 17, to insure that the side faces are true. The inside of the jaws should be filed up, also the faces bearing on the brass, and the strap fitted to the rod as previously described. If the side faces of the strap are badly worn by the brass working in the strap, the straps should be bolted to the rod to have the side faces planed.

If the old brasses are to be used again, the inside of the wings and also the top face of the brass where it bears against the strap should be tinned and loaded with babbit or solder, after which they are fitted to the strap as before described.

All bolts should be examined and those having poor threads discarded. Holes should be reamed where necessary and the old bolts refitted by turning off the under side of the head, or new bolts made.

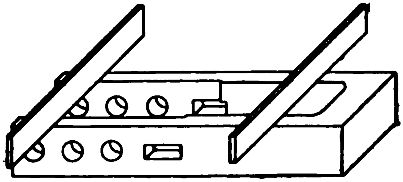


Fig. 17.

In order to make the brasses fit the pins, the joint faces must be filed or planed off, and the following points should be observed. If the brasses are to come brass to brass, that is, butt together when the bore is the size of the journal, these faces must be filed away until the bore is the correct size when measured with calipers as shown in the upper left hand corner of Fig. 18. In doing this each half of the brass should be filed so that it will embrace one-half of the pin. This will be the case when the two halves measure correctly as above, and alike when tested as shown in the upper right hand corner of Fig. 18, in which the brass is shown resting on a surface plate. During the process of filing, the joint faces should be tested with a square as shown in the two lower figures of Fig. 18, in order to keep the joint square both ways. This is necessary, for unless these faces are square the pressure of the key will tend to either twist the brasses in the strap or spring the strap open, depending on which way the faces are out.

In lining the rods for length, bear in mind the fact that one of the liners only adjusts the length of the rod, the other one simply serves to raise the key up to its proper height. With locomotive rods as generally constructed, the liner next to the strap, or liner *c*, in Fig. 15, is the one which adjusts the length of the rod, and is therefore the one to be fitted first. If with the brasses in place the rod is say $\frac{1}{8}$ inch too long, the thickness of the back liner *c* would be increased $\frac{1}{8}$ inch. The thickness of the key liner *d* should be sufficient to raise the key up as high as it will go. In the particular construction shown the key would be lowered, as it is raised to key the brass.

Main rod brasses for the back end should be bored out about $\frac{1}{64}$ inch larger than the pin, and given from $\frac{1}{64}$ inch to $\frac{1}{32}$ inch lateral or side motion. The front end main rod brass should be so bored that when fitted to the pin the brass will stand open at the joint about $\frac{1}{16}$ inch. In order to do this a liner of sufficient thickness should be placed between the joint faces when the brass is sent to the lathe, and after boring taken out. Rod brasses should have a good bearing front and back, but should not bear much top and bottom, and should have no bearing on the fillet. After fitting a brass to the pin it should be placed in the strap and keyed up brass to brass and whirled on the pin to test it. It should be perfectly free at all points but without lost motion. As the front end brass should be left open, it should be keyed up where it will be free on the pin and the key marked.

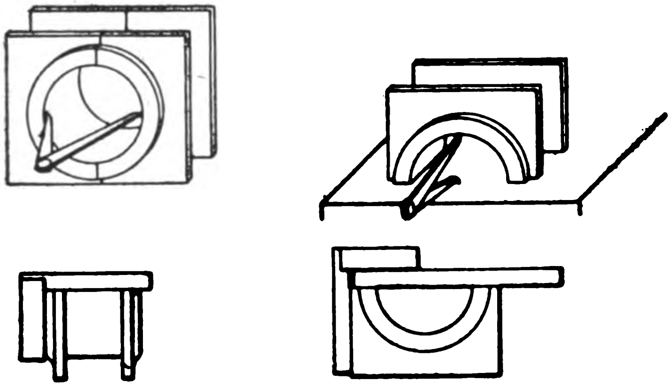


Fig. 18

Sufficient care is not often enough taken in fitting up main rods, especially on the larger engines. The number of back end brasses reported to the roundhouse as running hot is evidence of this. The point so often neglected is the proper alignment of the main rod, and as a result, while the brasses may fit the pin perfectly when tested, still they may be enough out of line so that when the straps are connected to the rod the brasses will be twisted on the pins and thus cause heating. To test the alignment of the rod the front end brass should be keyed up tight on the wrist pin and the position of the back end of the rod examined with reference to its alignment with the crank pin. It should line central with the pin. If it does not the front end brass should be refitted until it does. Then the crank pin brass should be placed on the pin and the strap put on and keyed up tight. Swing the strap up in line with the rod and see if the faces of the strap are square with the side faces of the rod. If not the brass should be refitted until they so show. Then the strap should be connected to the rod and the brass keyed up tight, and the alignment of the front end of the rod examined with reference to the wrist pin. The rod should point straight to the center of the pin. If it does not the back end brass should be refitted until it does. If the rod is thus put up perfectly in line at both ends and without any vertical twist, it will probably cause no trouble. It may be said in passing that the almost universal use of grease as a lubricant for crank pin brasses covers a multitude of sins in the way of poor fitting up of rods.

CHAPTER X.

ERECTING SHOP WORK—SETTING VALVES.

(Stephenson Link Motion.)

To many the operation of setting the valves on a locomotive seems a complicated matter. The contrary is however the case, and it may be said that the operation is more an exercise of common sense than of rule. If the principles underlying are fully understood there should be no difficulty experienced.

Before proceeding to a discussion of the matter it will be well to set down the definition of some of the terms that will be used.

LAP.—Referring to the upper figure of Fig. 1, the *lap* is the amount which the edge of the valve overlaps the adjoining edge of the steam port when the valve stands centrally on the valve seat. The portion shown by the cross shading is called the *outside lap* or *steam lap*, while the portion shown by the solid black is called the *inside lap* or *exhaust lap*. Ordinarily when lap only is mentioned it refers to the steam lap. The author prefers the terms *steam lap* and *exhaust lap* for the reason that with the inside admission piston valves the steam lap is inside while the exhaust lap, if any, is outside.

EXHAUST CLEARANCE.—If, as shown in the middle figure of Fig. 1, the inside edges, or exhaust edges, of the valve do not cover the steam port, the distance *c* which the port is open is called the *exhaust clearance.*

LEAD.—Lead is the amount the steam port is open at the beginning of the piston's stroke. It is the distance *d* shown in the lower figure of Fig. 1.

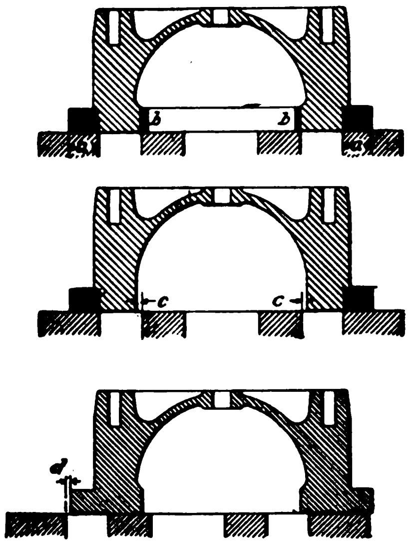


Fig. 1

TRAVEL OF THE VALVE.—The travel of the valve is the distance the valve moves forward and backward over the valve seat. It is a relative term to the stroke of a piston.

THROW OF ECCENTRIC.—The throw of an eccentric is the diameter of the circle described by the center of the eccentric as it makes a revolution with the shaft. Sometimes throw is used to designate the eccentricity which is the radius of the circle described above. It should never be used in this sense. If there is no rocker arm between the eccentric and valve which increases or decreases the action of the eccentric, the throw of the eccentric will be equal to the travel of the valve.

THE ANGLE OF ADVANCE.—The angle of advance of an eccentric is the angle by which the center line of the eccentric stands away from a line at right angle to the center line of motion of the valve gear. It is equal to the angle due to the lap plus the angle due to the lead.

THE CENTER LINE OF MOTION.—The center line of motion of a valve gear is a line drawn through the center of the axle and center of the eccentric rod connection to the valve rod. In a locomotive with a reversing rocker it is a line drawn through the center of the axle and the center of the lower rocker pin hole. The angular advance of the eccentrics is laid off from a line at right angles to this line. More will be said about this matter later.

Fig. 2 shows an inside admission piston valve. The action of this valve is different from that of the valve shown in Fig. 1, inasmuch as the admission of steam to the cylinder is controlled by the inside edges and the exhaust by the outside edges. The *steam lap* of this valve is the distance *a* which the *inside* rings overlap the *inside* edges of the steam ports. If this valve had *exhaust lap*, the outside rings would extend over the *outside* edges of the steam ports. If the valve had exhaust clearance the edges of the outside rings would not close the ports. To properly perform its functions this valve must move in an opposite direction to the valve shown in Fig. 1. This will be taken up fully later on.

The direction of rotation of an engine depends on two things—the way the eccentric is con-

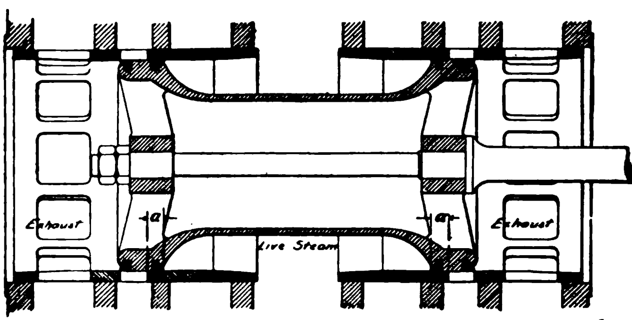


Fig. 2

nected to the valve spindle and the location of the eccentric relative to the crank pin. The valve may receive its motion in three ways: FIRST, the eccentric rod may be connected directly to the valve spindle; SECOND, the eccentric may be connected to the valve spindle by a rocker pivoted at one end; THIRD, the eccentric may be connected to one end of a rocker pivoted at or near its center with the valve spindle connected to the other end. In this case the valve will have a direction of motion opposite to that of the eccentric, while in the first and second cases the valve and eccentric will move in the same direction. With the connection made as in the first and second cases the motion is said to be *direct* and the *eccentric* will always lead the crank in the direction in which the crank is to turn, by an angle approximately equal to 90° plus the angle of advance. In the third case the eccentric will follow the crank by an angle approximately equal to 90° minus the angle of advance. The above is true for valves having outside admission only. In case the valve has inside admission, the position of the eccentrics will be reversed, i. e., with the connection direct, the eccentric will follow the crank by an angle approximately equal to 90° minus the angle of advance, and if the connection is indirect the eccentric will lead the crank by an angle approximately equal to 90° plus the angle of advance. These distinctions should always be borne in mind.

In locomotive practice when an engine is equipped with slide valves or outside admission piston valves, the valve motion is generally of the indirect type. When equipped with inside admission valves the motion is generally of the direct type.

To simplify matters as much as possible the problem of setting the valve on a stationary engine which is to run in one direction only will be taken. But in order to approximate

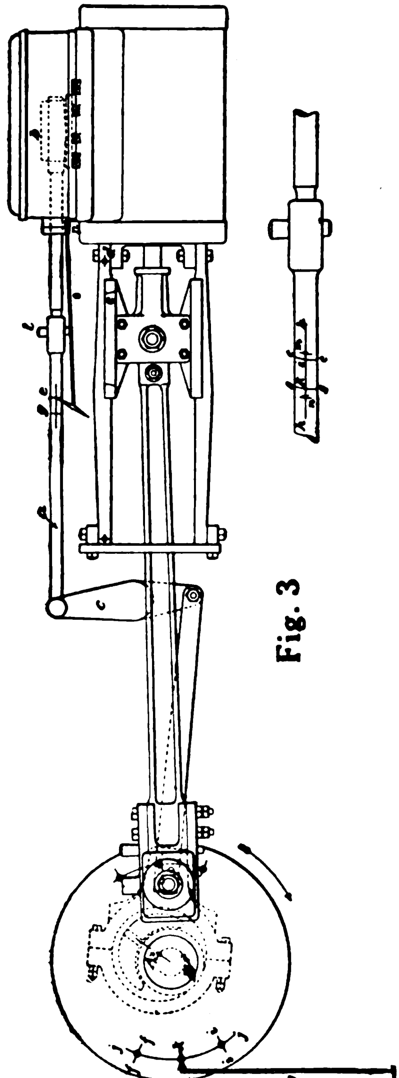


Fig. 3

locomotive conditions, the valve will be driven through a reversing rocker, hence the motion will be of the indirect type. Fig. 3 shows such an engine.

An inspection of this drawing will show that after the valve and connections are erected there are two available means of adjustment—the eccentric rod can be lengthened or shortened, and the eccentric can be turned about the shaft. As was explained in the chapter describing the fitting up of the valve motion, when the valve

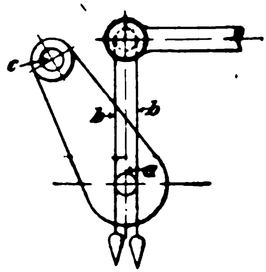


Fig. 4

gear is erected, the length of the valve rod *a* is so adjusted that the valve *b* will stand centrally on the valve seat when the upper rocker arm *c* is square with the valve seat. While the valve gear was being erected and before the steam chest cover was put on, two lines, *e* and *g*, called port marks, were placed on the valve stem. The method of locating these lines is as follows:

See that the valve spindle key *l* is properly tightened. Set the rocker arm *c* square with the valve seat. If the valve seat is level the rocker arm should stand vertical when tested with a plumb line thrown over the pin. Examine the valve to see that it stands central on the seat, which it should do when the rocker arm is square. If it does not, the valve rod *a* must be lengthened or shortened as the case may be.* Generally this will have to be done by the blacksmith. Examine the valve and see that its steam edges are parallel with the edges of the steam ports, and if they are not the valve stem or spindle will have to be sprung. See if there is any lost motion between the valve and yoke. If there is take it up by placing suitable liners between the front of the valve and yoke as at *a*, Fig. 5. With the eccentric rod disconnected move the valve forward until it opens the back port *f*, until a piece of paper or thin tin can be placed between the valve edge and edge of the port at *c*. The valve is now in a position to scribe the back port mark on the valve rod. With a prick punch mark a center on some suitable *fixed* portion of the engine cylinder, as at *d*, and from this point, with the three pointed valve tram, scribe the line *g*, *g* on

* A method of determining whether the valve rod is the correct length or not, and whether it should be lengthened or shortened and how much, is shown in Fig. 4. Disconnect the valve rod and turn the rocker as shown. From the center of the shaft scribe the circle *a*, having a diameter equal to the diameter of the pin hole *c* in the rocker arm. Place the pin in the valve rod and place the valve central on the seat. Throw a plumb line over the pin on the inside of the valve rod as shown at *b*, *b*. If the valve rod is the correct length, the lines *b*, *b* will coincide with the circle *a*. If not, the valve rod must be lengthened or shortened, as the case may be, until they will do so.

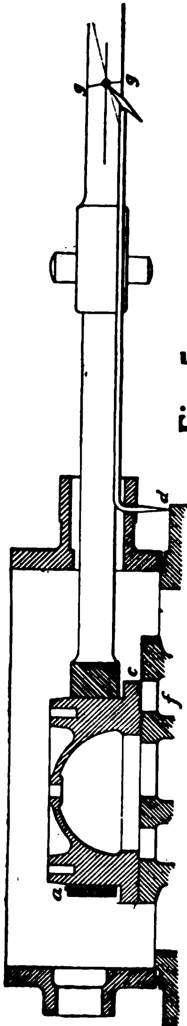


Fig. 5

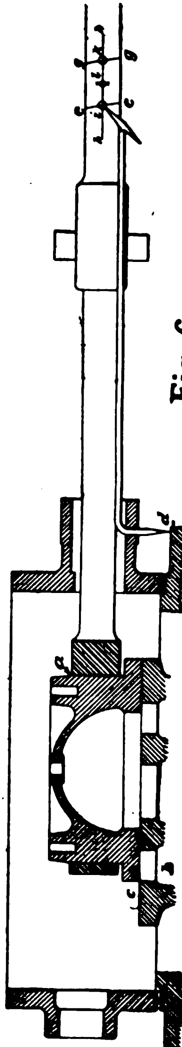


Fig. 6

the valve rod. Remove the liners between valve and yoke, if any, and place them back of the valve at point *a*, Fig. 6, and move the valve backward until port *b* is opened, so that the paper or tin can be slipped between the edge of the valve and the edge of the port at *c*, as before. From the point *d* on the cylinder with the valve tram scribe the line *e*, *e* on the valve rod. With a box square scribe the line *h*, *h* intersecting lines *e*, *e* and *g*, *g* and at the points of intersection make the two small centers *i* and *k*. The center *i* is the front port mark and center *k* is the back port mark.

If with the dividers the center *l*, between the points *i* and *k*, is found, this point will represent the central position of the valve upon its seat. The points *i* and *k* are points of admission and cut off, and point *l* will be the point of both release and compression if the valve has neither exhaust lap nor exhaust clearance.

When the valve motion was assembled there were two dimensions lacking—the correct length of the eccentric rod and the angular location of the eccentric relative to the crank. As was before mentioned the eccentric rod is capable of adjustment at its connection to the eccentric strap by means of slotted holes in the rod or blade, and the eccentric can be moved to any position around the shaft. The setting of the valve consists of adjusting the eccentric rod so that the valve will travel at the proper place on the seat, and the locating of the eccentric at such a point on the shaft relative to the crank

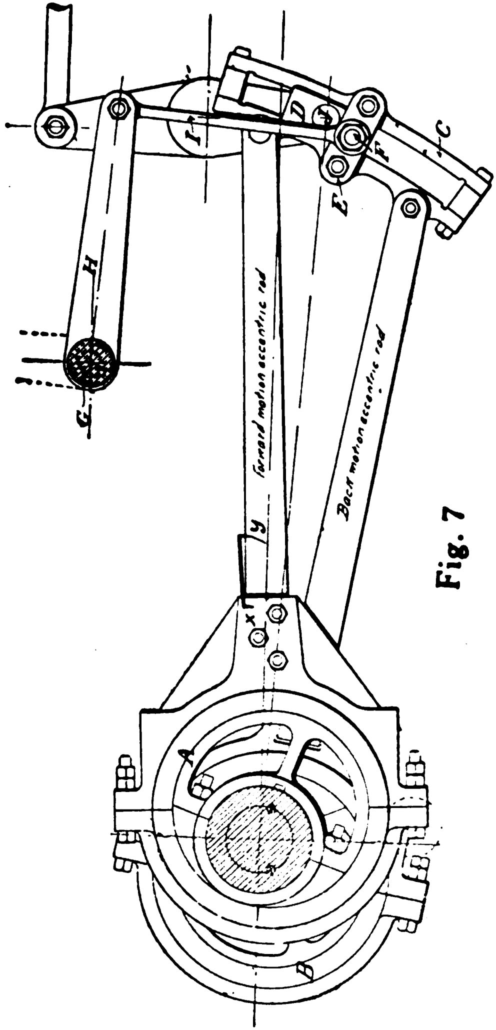

Forward motion eccentric rod
Back motion eccentric rod
A
B
C
D
E
F
G
H
I
y
x

Fig. 7

pin that the admission of steam to the cylinder will take place at the proper time. There are two distinct steps necessary.

I. Locating the engine exactly on the two dead centers.

II. Adjusting the length of the eccentric rod and locating the eccentric.

We will assume that the engine in question has the following dimensions:

Diameter of cylinder	19″
Stroke of piston	26″
Throw of eccentric	$5\frac{1}{2}$″
Travel of valve	$6\frac{9}{16}$″
Length of upper rocker arm	12″
Length of lower rocker arm	10″
Lap of valve	$1\frac{1}{4}$″
Lead of valve	$\frac{1}{16}$″

To find the dead centers proceed as follows. (See Fig. 3.) Turn the crank to any convenient position above the front center. Then turn in the direction of the arrow (which is also the direction in which we wish the engine to run) until the cross head has approached to within about 1 inch of the end of the stroke. Stop, and from a small center *d*, in any convenient position on the guide, with a suitable tram scribe the arc *e* on the crosshead. Upon the face of the crank disc scribe an arc *f*, *f* by means of a tram *g* from any convenient *fixed* point, as *h*. Turn the engine in the same direction until the crosshead has reached the end of its stroke and has traveled back until arc *e* is beyond the point it occupied when scribed.

Then move the engine in the opposite direction until the tram when held in point *d* will fall exactly in the arc *e*. This reversal of motion is necessary to cut out any error that might occur from looseness in the crank and wrist pin brasses. When moving the crosshead to the second tram position the crank and wrist pins should press against the same brass that they did when the arc *e* was scribed. With the engine in this position, with the tram *g* from point *h* scribe arc *i*, *i* on the crank disc. From the center of the shaft, or with the hermaphrodite calipers from the edge of the disc, if it is turned, scribe the arc *j*, *j*. Bisect the arc *j*, *j* between arcs *f*, *f* and *i*, *i* at *k*. It will be seen that when point *k* is brought fair with tram *g* the engine will be exactly on the front center as shown. Too much care can not be used in locating the dead centers, as on their correct location depends the accuracy of the remainder of the work.

As this engine is to run in the direction of the arrow it will be necessary to turn the crank back past the center and then come ahead in the direction of the arrow until tram *g* exactly coincides with point *k*. With the engine in this position, with the valve tram *o* scribe a line on the valve rod as shown at *m*, *m*. See the enlarged view of the valve rod in the lower right-hand corner of Fig. 3.

In the same manner as described, locate the rear dead center and place the engine on that center, moving it, when coming to the center, in the direction of the arrow. With the tram *o* scribe the line *n* on the valve rod.

An inspection of the lines on the valve rod shows that line *m* is $\frac{1}{2}$ inch from the front port mark *i*, and line *n* is $\frac{3}{4}$ inch from the back port mark *k*, both of them being outside. Therefore the valve has $\frac{1}{2}$-inch lead on the front center and $\frac{3}{4}$-inch lead on the back center. If the eccentric rod was the correct length these two leads would each be equal to one-half their sum or $\frac{5}{8}$ inch. If we take a pair of small dividers set to $\frac{5}{8}$ inch, and from the port marks scribe small arcs cutting the horizontal line as shown, it will be seen that the valve rod is traveling too far ahead and must be moved back $\frac{1}{8}$ inch.

If the rocker arms were of equal length the eccentric rod would be shortened $\frac{1}{8}$ inch. As the upper rocker arm is longer than the lower one the eccentric rod will need to be shortened less than $\frac{1}{8}$ inch. With any rocker the amount the eccentric rod is to be moved bears the same relation to the amount the valve rod is to be moved, as the length of the rocker arm to which the eccentric rod is connected bears to the length of the rocker arm to which the valve rod is connected. Thus if

a = amount valve stem is to be moved,

b = amount eccentric rod is to be moved,

c = length of rocker arm to which the eccentric rod is connected,

d = length of rocker arm to which the valve rod is connected,

we get the following proportion:

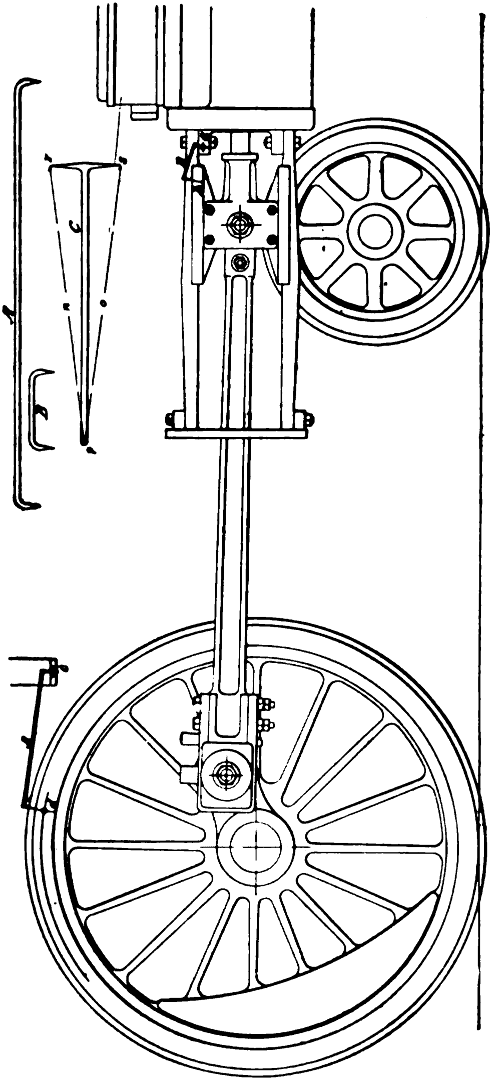


Fig. 8

(1) b : a :: c : d, whence

(2) b = ac ÷ d.

Substituting the values of the letters in equation 2, we get

$$b = \frac{\frac{1}{8}'' \times 10''}{12''} = \frac{7''}{64} \text{ nearly.}$$

Shorten the eccentric rod $\frac{7}{64}$ inch, and if the engine is run over again it will be found that the lines *m* and *n* will come $\frac{3}{8}$ inch outside the port marks and the valve will have $\frac{3}{8}$-inch lead. As the valve is to have $\frac{1}{16}$-inch lead it is evident that the eccentric has too much angular advance and in this case will have to be moved away from the crank pin. To set it in the correct position, place the engine on one of the dead centers, say the back one, and move the eccentric away from the pin until the valve tram falls inside the port mark *g*, then move the eccentric toward the pin until the valve tram comes $\frac{1}{16}$ inch outside the port mark *k*. Place the engine on the forward center and if the work has been correctly done, the tram point will fall $\frac{1}{16}$ inch outside the port mark *i*. If the eccentric was very much out of position it will be likely that the lead will not be correct on the forward center on account of the fact that the length of the eccentric rod must be adjusted *with the eccentric very near its correct position.* Again, after adjusting the length of the eccentric rod the second time it may be necessary to change the location of the eccentric to get the leads correct. Two or three trials should be sufficient, and this completes the setting.

If the engine is to run in the opposite direction to that shown, the center of the eccentric would be located in the same relative position to the crank pin, but on the opposite side, as at *B*, in order to fulfill the condition previously laid down of following the crank pin when the eccentric rod is connected to a reversing rocker, and the valve has outside admission.

Now if the engine is to rotate at one time in the direction of the arrow, and at another time in the opposite direction, or in other words if the engine is to be reversed, there must be some means provided for moving the eccentric from position *A* to position *B*, or there must be two eccentrics fixed in these two positions on the axle. If the latter method is used there must be some means provided for disengaging one eccentric rod when the other one is engaged with the rocker. This is done in locomotive practice by means of the link, shown in Fig. 7. One end of each eccentric rod is attached to the link *C*, the rod from the go-ahead eccentric to the top of the link, and the rod from the back-up eccentric to the bottom. The link has a slot extending lengthwise in which the block *D*, called the link block, can move freely from one end to the other of the link. This block is connected to the rocker by means of the link-block pin *J*. At the center of the link is a piece *E*, called the link saddle, extending across it, to which is forged a pin *F*, called the saddle pin. The shaft *G*, extending across the frames, is called the lifting shaft, or tumbling shaft, and the arms *H* are called the lifting shaft arms. To the ends of the lifting shaft arms the piece *I*, called the link hanger, is pivoted at one end while the opposite end is fastened to the saddle pin. The lifting shaft has at one end another arm generally extending upward at right angles to the lifting shaft arms *H*, to which the reverse lever in the cab is connected by means of the reach rod. It will be seen that, as the link is suspended from the lifting shaft arms, if they are raised or lowered they will carry the link with them. If the link is lowered until the end of the forward motion eccentric rod is brought opposite the link block, it is evident that the rocker will receive its motion from the forward-motion eccentric in exactly the same manner as if the connection was made as in Fig. 3. If the link is raised until the end of the back-up eccentric rod is opposite the link block, the rocker will receive its motion from the back-up eccentric exactly as if it were connected directly to the rocker arm. If the link is placed in some intermediate position as shown in Fig. 7, the rocker will receive a motion partaking somewhat of that of the upper and also that of the lower eccentric rod. So long as the link block is above the center of the link, the motion will be controlled more by the upper rod and the engine will run forward. If below the center the engine will run backward. At the intermediate points of the link, the travel of the valve is less than full stroke and the steam port is open for the admission of steam a shorter period than when the link is in either extreme position,

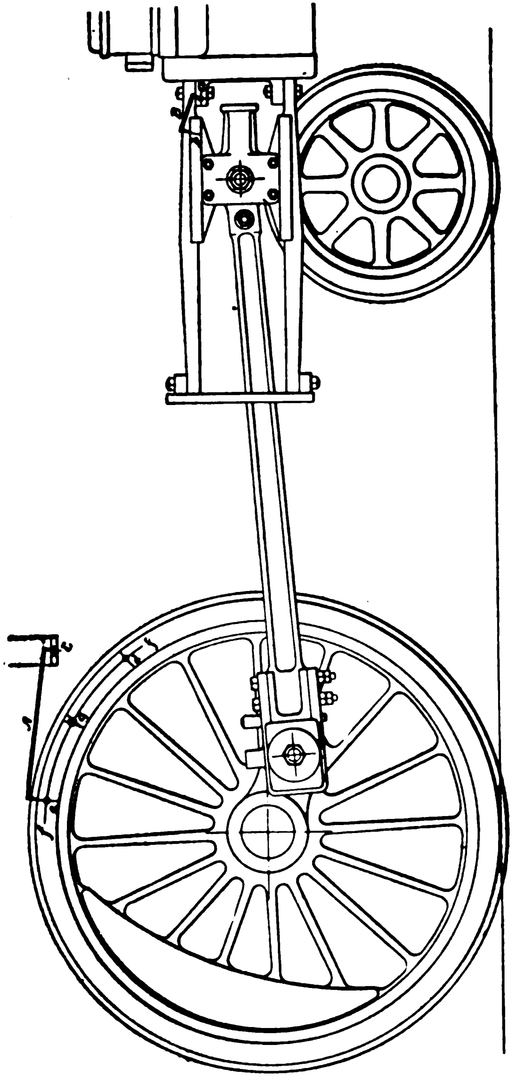


Fig. 9

the travel becoming shorter as the link is "hooked up."

Having briefly explained the relationship existing between the simple valve gear of Fig. 3 and the locomotive link motion, we will proceed to the discussion of the problem of setting the valves on a locomotive.

We will assume that the engine is of the ordinary "American" or 2-8-0 type, having the following dimensions relating to the valve gear:

Diameter of cylinder	19 "
Stroke of Piston	26 "
Travel of Valve	7 "
Steam lap of valve	1¼"
Exhaust lap of valve	0 "
Exhaust clearance of valve	0 "
Lead of valve in full gear	0 "
Throw of eccentrics	5½"
Length of upper rocker arm	12⅞"
Length of lower rocker arm	10 "
Radius of link	60 "

Before proceeding to adjust the valves the following points should be looked after.

1. See that the engine is perfectly level both lengthways and crossways.

2. See that the main driving boxes are central in the jaws in a vertical direction and also that the wedges are set up snugly.

Some form of rollers is generally used under the main drivers, and where these are used the weight of the engine is carried on jacks, care being exercised that the above two conditions are met.

As mentioned elsewhere the valve setter will generally find the valve gear assembled and the main rods up. Generally the port marks are taken, as before described, by the man who puts up the chests, and the valve rods have been made the correct length. In case the port marks have not been taken, or there is any reason to doubt their correctness, they should be marked as described. To do this with everything connected up it will be necessary to place the main drivers in such position that the crank pin will be at or near the quarter, or at such a point that the valve can be made to open both ports by moving the reverse lever from full gear forward to full gear backward. Take up any lost motion between the valve and yoke with liners as was described, and move the reverse lever to such position that the port desired will be entirely covered. Then move the lever in such direction that the valve will open the port. When the port is just open so that a piece of paper or thin tin can be slipped between the edge of the valve and the edge of the port, the lever should be held in that position until the port mark is scribed on the valve rod. Secure all four port marks in this manner. If the eccentrics or eccentric rods are "out" so much that the ports cannot be uncovered in this manner, the link block pin should be disconnected so the rocker can be moved to get the valve into proper position for scribing the port marks.

Besides the usual equipment of tools the valve setter will need the three trams shown in Fig. 8.

Tram *A* is a double pointed tram for locating the dead center points on the wheel tire and may be of any convenient length, say about three feet. Tram *B* is a short double-pointed tram for scribing the lines on the crosshead and may be from six to eight inches long. Tram *C* is a three-pointed tram for scribing the valve rod and is made so that the distances *n* and *o*, from point *p* to points *r* and *s*, are exactly equal. Generally each railway has a standard dimension for *n* and *o* and all valve trams are maintained to this dimension, so that port marks once obtained may be used again and at any shop, without the necessity of taking up the chest covers and re-marking the rods.

Referring to Fig. 8, suppose the engine is standing with the right pin on the upper forward eighth. Move the engine forward until the cross head has approached to within about one inch of the end of the stroke. Stop, and with tram *B*, from center *a*, located in a convenient position, scribe the arc *b* on the cross head. Go to the driver, and with tram *A* from some convenient *fixed* point *c* (in this case *c* is located on one of the running board brackets) scribe the arc *d* on the face of the tire. Move the engine forward until the cross head passes the center, and arc *b* passes beyond the tram *B*. Then back up until tram *B* falls exactly in arc *b*; see Fig. 9. With the engine in this position, with the tram *A*, from center *c*, scribe arc *e* on the tire. With the hermaphrodite calipers from the *inside* of the tire scribe the line *f*, *f*. Bisect

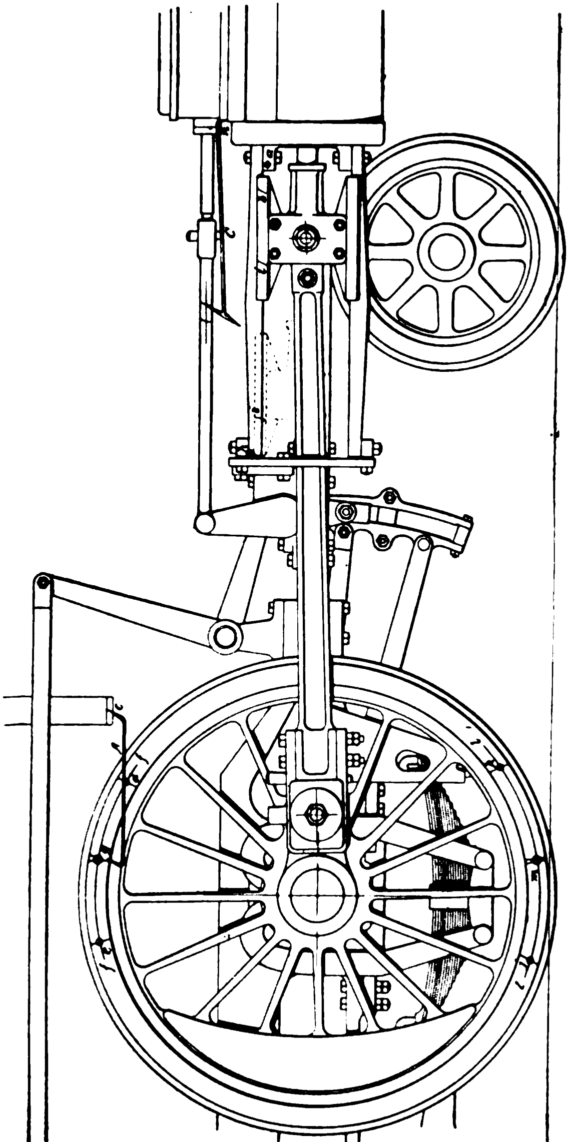


Fig. 10

this line between the arcs *d* and *e* at *g*. Point *g* will be the tram point for the forward center.

As the crank pin is now below the center, place the reverse lever in full back gear, marking the notch the latch is in so that the lever can be placed in this same position again. Move the engine ahead about six inches and then move back until tram *A* will fall exactly in point *g*; see Fig. 10. The engine will now be on the front dead center. Mark a line on the guides at front or back end of crosshead which will denote the limit of travel. Now with the valve tram *C*, from the point *n*, on the cylinder casting (this point is the same as point *d*; Figs. 5 and 6), scribe a line on the valve rod as *1*; Fig. 11. Place the reverse lever in full gear forward, marking the notch, and move engine on backward about six or eight inches. Then move the engine ahead until tram *A* again coincides exactly with point *g*; Fig. 10. With the valve tram scribe a line on the valve rod which will appear as 2, Fig. 11.

Go to the left side of the engine and proceed in exactly the same manner, which will give us two lines on the left valve rod corresponding to 5 and 6; Fig. 11.

In scribing the lines on the valve rod always scribe the ones for the forward motion from slightly *below* the horizontal line *h, h, upward,* and the lines for the back motion from slightly *above* the line *h, h, downward.* By doing this they are easily distinguished.

Go to the right side of the engine and move forward until the right crosshead comes to within one inch of the end of the back stroke. With the tram *B* from center *h* scribe the arc *i* on the cross head, and with tram *A* from center *c* scribe arc *j* on the tire; see Fig. 10. Move the engine forward until the cross head passes the end of the stroke and returns past the position it occupied when arc *i* was scribed. Then move backward until tram *B* falls exactly in arc *i*,

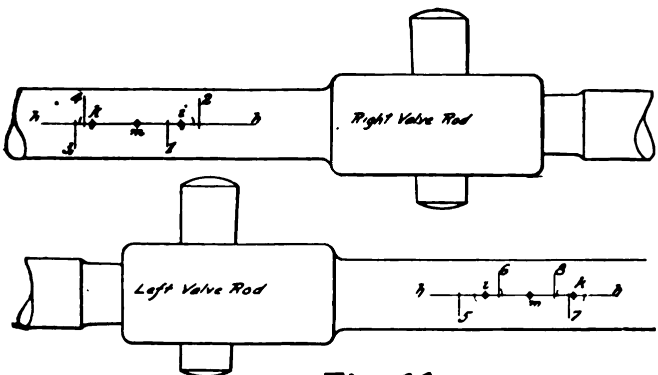


Fig. 11

and with tram *A*, from center *c*, scribe arc *k* on the tire. With the hermaphrodite calipers from the *inside* of the tire scribe line *l*, *l* and locate point *m* midway between arcs *j* and *k*. Point *m* will be the tram point for the back center. This leaves the crank pin above the back center, so we will place the reverse lever in full back gear and move the engine ahead about six inches; then come ahead until tram *A* coincides with point *m*. With the engine in this position the valve tram will scribe line 3 on the right valve rod; see Fig. 11. Move the engine about six inches further back, place the reverse lever in full gear forward, and move the engine ahead until tram *A* again coincides with point *m*. Scribe line 4 on the valve rod; see Fig 11.

Go to the left side and repeat the operation for the back center of the left pin. This will give us lines 7 and 8 on the left valve rod. We have run the engine over once.

We will now examine the marks we have on the valve rods. Referring to the right valve rod we find that line 2, which was scribed on the front center with the valve in full gear forward, is ½ inch outside the port mark *i*. This shows that the valve has ½ inch lead in forward motion on the front center. Line 4, which was scribed on the back center with the valve in full gear forward, is ¼ inch outside the port mark *k*, which shows that the valve has ¼ inch lead on the back center. Now it is evident that if the forward-motion eccentric rod was the correct length the two leads would be the same, and equal to one-half the sum of the two leads given, or ⅜ inch. If from the port marks *k* and *i* we set off ⅜ inch lead, we find that the valve rod must be moved ahead ⅛ inch in order to bring the tram marks 2 and 4 in line with the ⅜ inch lead marks. As the valve rod and eccentric rod are coupled together by a reversing rocker, the eccentric rod must be shortened in order to move the valve rod ahead. If the rocker arms were of equal length we would shorten the eccentric rod the same amount that we wish to move the valve rod ahead. As the rocker arms are of unequal length we can find how much to shorten the eccentric rod by substituting the known values in equation No. 2, given before, which will give us:

$$b = \frac{\frac{1}{8}'' \times 10''}{12\frac{7}{8}''} = 3\text{-}32''.$$

Referring to the back motion marks on the right valve rod, we find that on the front center the line *1* is $\frac{3}{8}$ inch inside the port mark *i*, which shows that the valve covers the port $\frac{3}{8}$ inch or is $\frac{3}{8}$ inch blind. On the back center we find line 3, $\frac{1}{2}$ inch outside the port mark *k*, which shows the valve has $\frac{1}{2}$ inch lead. Subtracting the blind from the lead gives us $\frac{1}{8}$ inch lead to be divided equally front and back. Measuring $\frac{1}{16}$ inch from the port marks, we find that the valve rod must be moved back $\frac{7}{16}$ inch to accomplish this. By the formula given we find that the right back eccentric rod must be lengthened $\frac{11}{32}$ inch.

Referring to the left valve rod, we find on the forward center, with the valve in full gear forward, that the valve is $\frac{3}{8}$ inch blind and on the back center it is $\frac{9}{16}$ inch blind. Adding the blinds together gives us $\frac{15}{16}$ inch total blind to be equalized, or $\frac{15}{32}$ inch at each end. Setting off the $\frac{15}{32}$ inch inside each port mark, we find that the valve rod must be moved $\frac{3}{32}$ inch ahead. This will require the left go-ahead eccentric rod to be shortened $\frac{1}{16}$ inch. Referring to the back motion marks, we find on the front center the valve has $\frac{3}{4}$ inch lead and on the back center it is $\frac{1}{8}$ inch blind. Subtracting the blind from the lead leaves $\frac{5}{8}$ inch lead to be equalized. Laying off the $\frac{15}{16}$ inch lead from the port marks, we find that the valve rod must be moved ahead $\frac{7}{16}$ inch. This requires the eccentric rod to be shortened $\frac{11}{32}$ inch.

We will now go under the engine and adjust the blades as determined. Before loosening up the bolts holding the blade to the strap, take the

Fig. 12

short crosshead tram and from a center x on the eccentric strap scribe an arc y on the blade; see Fig. 7. Then loosen up the bolts and adjust the blade longer or shorter as the case may be, the amount called for. This will be when a second arc scribed on the blade measures the called for distance from the first arc y.

Having adjusted the blades, if we were to run the engine over the second time and mark the valve stem we would find our marks would show as in Fig. 12. On the right side the forward motion shows $\frac{3}{8}$-inch lead on each center, and $\frac{1}{16}$-inch lead in the back motion. On the left side the valve is $\frac{15}{32}$-inch blind in the forward motion and has $\frac{5}{16}$-inch lead in the back motion. As the valves are to be set with no lead or "line and line" all around it is evident that all the eccentrics must be moved.

On the right side the go-ahead eccentric must be moved in a direction to reduce the lead $\frac{3}{8}$ inch, and the back-up eccentric must be moved to reduce the lead $\frac{1}{16}$ inch. On the left side the go-ahead eccentric must be moved to increase the lead $\frac{15}{32}$ inch and the back-up eccentric moved to reduce the lead $\frac{5}{16}$. There are two ways of doing this part of the work.

1. The eccentrics may be moved on the axle the proper amount as denoted by tramming the valve rod and the keys fitted.

2. The amount of off-set for the keys may be calculated and the keys planed up accordingly.

The first method will be the better one if the eccentrics were placed on the axle by the erecting gang without keys, and the second will probably be the quicker if the eccentrics were placed with straight keys in them when erected.

If the first method is to be used, the inside eccentrics will be moved out of the way. Generally the go-ahead eccentrics are the inside ones, the back-up ones being placed next to the driving boxes. Place the engine on either center and move the eccentric in a direction opposite to that in which it would turn were the engine moving in the direction controlled by it, until all lead is taken off as shown by the valve tram. Then move it in the direction of the rotation it controls until the valve tram coincides with the port mark for the center upon which the engine is standing. Fasten it securely in this position by means of the set screws. If the engine was to have say $\frac{1}{16}$-inch lead the eccentric would be moved until the tram was $\frac{1}{16}$ inch outside the port mark. *Always remember that in setting eccentrics the final movement should be in the direction of the rotation*

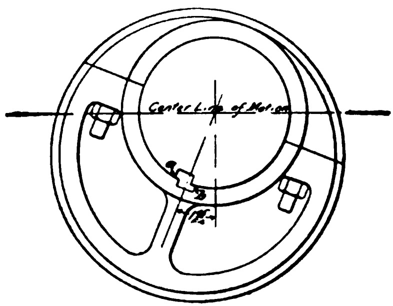


Fig. 13

governed by that eccentric. Place the engine on the opposite center and try the port mark with the tram. If this mark trams, the eccentric position is correct. As before stated, sometimes when the eccentric is out of position badly it may be necessary to adjust the length of the eccentric rod again, in which case the eccentric will have to be moved slightly. Set the other back-up eccentric in the same manner. Looking at the right eccentric from the inside, supposing the engine stands on the front center, the axle and eccentric would appear as in Fig. 13. Examining the key ways, we find that the key must be offset $\frac{3}{32}$ inch, as the key ways caliper $1\frac{3}{32}$ inches from the corners *a* and *b*, and the key ways are each 1 inch wide. Looking at the left back-up eccentric from the inside, supposing the engine is standing on the left front center, the eccentric and axle will appear as in Fig. 14. Here the key ways caliper

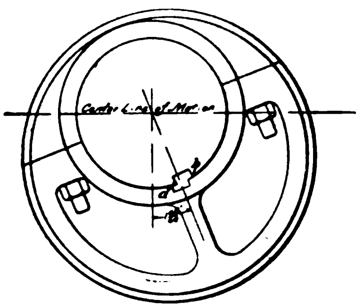


Fig. 14

$1\frac{9}{32}$ inches from *a* to *b*, and as they are each 1 inch wide, the key will be off set $\frac{9}{32}$ inch. Have these keys planed up to these dimensions and put them in. Before loosening up the eccentrics to fit the keys they should be marked with a "V" chisel or three-pointed tram so that their position can be checked when the keys are fitted.

The forward-motion eccentrics will now be set in the same manner, and after doing so, when looked at from the inside with the engine on the front centers, they will appear as shown in Figs. 15 and 16. Fig. 15 shows the right one and we find the right key will be off set $\frac{15}{64}$ inch as shown, and the left one $\frac{17}{64}$ inch. Have these keys planed up and fit them to the eccentrics. Be sure the keys are marked to indicate the way they go, to avoid getting them in wrong side up or turned end for end.

If the second method of locating the eccentrics is used, proceed as follows:

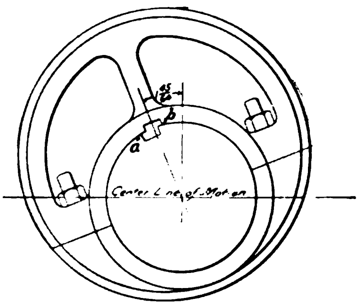


Fig. 15

Calculate the required angular advance of the eccentric referred to the surface of the axle by the following formula:

(3.) A = bcd ÷ ef, where

A = angular advance.

b = the amount the valve is to be moved = lap plus lead.

c = length of lower rocker arm.

d = diameter of axle.

e = length of upper rocker arm.

f = throw of eccentric.

This formula is not exactly correct, inasmuch as it assumes that the sine of the angle that the center line of the eccentric makes with the line at right angles to the center line of motion, is equal to the chord of the arc at the surface of the axle enclosed by this angle. In this particular case the error amounts to about one per cent.

First figure the angular advance which the eccentrics must have to fulfill the conditions,

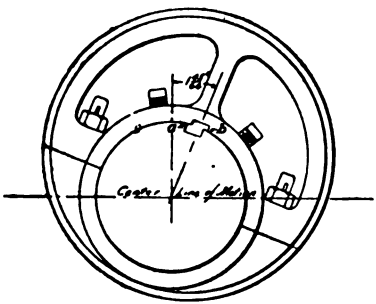


Fig. 16

viz. The valve is to be set line and line all around, hence at the beginning of the stroke the valve will be moved $1\frac{1}{4}$ inches from the central position. Substituting this value, as well as the other known quantities, in the equation we have

$$A = \frac{1\frac{1}{4}'' \times 10'' \times 9''}{12\frac{7}{8}'' \times 5\frac{1}{2}''} = 1\frac{19}{32}''.$$

Now, beginning with the right go-ahead eccentric, figure the actual advance that the eccentrics have. In forward motion the right valve has $\frac{3}{8}$ inch lead, hence b would equal $1\frac{1}{4}$ inches plus $\frac{3}{8}$ inches $= 1\frac{5}{8}$ inches. Substituting this in the formula, we have

$$A = \frac{1\frac{5}{8}'' \times 10'' \times 9''}{12\frac{7}{8}'' \times 5\frac{1}{2}''} = 2\frac{1}{16}''.$$

In the back motion the right valve has $\frac{1}{16}''$ lead, hence b equals $1\frac{5}{16}''$, and the equation becomes

$$A = \frac{1\frac{5}{16}'' \times 10'' \times 9''}{12\frac{7}{8}'' \times 5\frac{1}{2}''} = 1\frac{43}{64}''.$$

In the forward motion the left valve is $\frac{15}{32}$ inch blind and b will be equal to $1\frac{1}{4}$ inch $-\frac{15}{32}'' = \frac{25}{32}''$, and the equation becomes

$$A = \frac{\frac{25}{32}'' \times 10'' \times 9''}{12\frac{7}{8}'' \times 5\frac{1}{2}''} = 1''.$$

In the back motion the left valve has $\frac{5}{16}$ inch lead and b will be equal to $1\frac{9}{16}$ inch and the equation becomes

$$A = \frac{1\frac{9}{16}'' \times 10'' \times 9''}{12\frac{7}{8}'' \times 5\frac{1}{2}''} = 1\frac{63}{64}''.$$

Comparing these advances with the required ones, we have

	Actual Inches	Required Inches	Difference Inches
Right front......	$2\frac{1}{16}$	$1\frac{19}{32}$	$0\frac{17}{32}$
Right back......	$1\frac{43}{64}$	$1\frac{19}{32}$	$0\frac{5}{64}$
Left front.......	1	$1\frac{19}{32}$	$0\frac{19}{32}$
Left back.......	$1\frac{63}{64}$	$1\frac{19}{32}$	$0\frac{25}{64}$

As the actual advance of the right front, right back and left back eccentrics is greater than that required, it is evident that these eccentrics must be moved away from the crank pin the amounts shown under the heading of "difference." As the left front eccentric does not have the required amount of advance, it will be necessary to move it toward the pin. If the eccentrics were placed on the axle with straight keys all we have to do is to tell the planer man to plane up a set of keys with the off set given. These keys will be as shown in Fig. 17.

We have now adjusted the valve gear so far as setting the eccentrics and making the eccentric rods the correct length is concerned. If all of the parts were constructed and erected as the motion was designed, this would be all that would be necessary. However, as engines go through the shops various changes are made, especially in the links. As these are closed to take up the wear, the centers of the blade pin holes become closer to the link arc and, unless great care is used, the position of the saddle pin with reference to the link arc changes. These various changes will affect the equality of the motion imparted to the valve rod by the link and it will be necessary to examine the valve events for a cut off at half stroke and the point where the engine will do the greater part of its work. Generally speaking, the link motion is designed to cut off equally front and back at half stroke. If it can be made to do this it will not be far off at all other points.

To test the cut off at half stroke proceed as follows. Suppose the engine to be standing on the right front center. Move the engine ahead until the crosshead has traveled back one half the stroke as determined by measuring from the front travel mark to the edge of the crosshead. The reverse lever should be in full gear forward. Then move the reverse lever back until the point

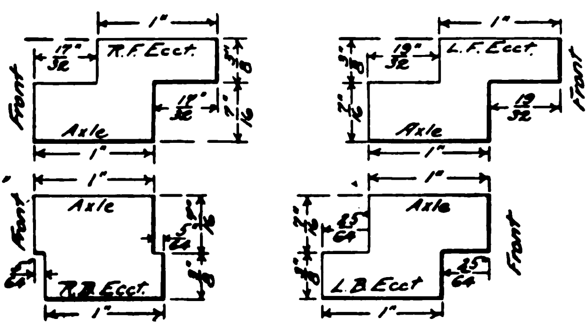


Fig. 17

of the valve tram will coincide with the front port mark *i*, Fig. 11. If the lever in this position will not latch in the quadrant latch it in the nearest notch back. Move the engine backward about six or eight inches and then move ahead until the valve tram again coincides with the port mark *i*. Measure the distance the crosshead has traveled from the front travel mark. We will suppose that it measures 13 inches.

Chalk this down on the front end of the guides. Go to the left side of the engine and move ahead until the left crank pin passes the front center and the valve tram coincides with the front port mark *i* on the left valve rod. Measure the distance the left crosshead has traveled back from the front travel mark. We will assume it is 12 inches and will chalk this down on the front of the left guides. Go to the right side of the engine and move ahead until the right crosshead passes the back center and the valve tram coincides with the back port mark *k*. Measure the distance the crosshead has traveled ahead from the back port mark. We will assume that it is 13¾ inches, so will mark this down on the back end of the guides. Go to the left side of the engine and move ahead until the left crosshead passes the back center and the valve tram coincides with the back port mark *k*, on the left valve rod. Measure the distance the left crosshead has traveled ahead from the back travel mark. We will assume that it measures 13 inches and will mark this down on the back end of the left guides. In the same manner the cut off for the back motion could be tried by turning the engine in the opposite direction and placing the reverse lever back of the center of the quadrant. As this engine is a passenger engine and will run in a forward direction the greater part of the time, we may neglect the back motion.

An inspection of our marks shows that the cut off takes place at the following points:

Right side.		Left side.	
Front center	13″	Front center	12″
Back center	13¾″	Back center	13″
	2) 26¾″		2) 25″
Average	13⅜″	Average	12½″

Owing to the space that the piston rod takes up on the rear side of the piston there should be a difference between the front and back cut-off of from ⅜ inch to ½ inch, being that much longer at the back end. On the right side we find the difference is ¾ inch, and we can equalize this by changing the length of the go-ahead eccentric rod. As the average cut-off on this side is 13⅜ inches and we wish a difference of one-half inch, the cut-off at the forward end should take place at 13⅛ inches, and at the back end at 13⅝ inches. As our cut-off takes place at 13 inches at the forward end it shows that the valve rod is ahead of the position it should be in, and therefore we can bring it into the correct position by lengthening the go-ahead eccentric rod. As a change of $\frac{1}{32}$ inch in the length of the rod will make a change of about ½ inch in the cut-off, and as we want a change of ⅛ inch, we will lengthen the rod a scant $\frac{1}{64}$ inch. This should bring the cut-off at approximately 13⅛ inches at the front end and 13⅝ inches at the back end. Referring to the left side, the average cut off is 12½ inches, and if we make a difference of ½ inch between the ends, the cut off at the front end should take place at 12¼ inches, and at the back end at 12¾ inches. As the cut off takes place at 12 inches the eccentric rod should be lengthened enough to change the cut off ¼ inch, or $\frac{1}{64}$ inch. After making these changes the sum of the cut offs will be 26¾ inches on the right side and 25 inches on the left side. This shows that the total cut off on the right side is 1¾ inches longer than on the left. This shows that the right link is lower with reference to the link block than the left. This may be due to any one of the following causes:

1. The link hangers may not be the same length.
2. The centers of the rockers may not be at equal heights from the top of the frames.
3. The tumbling shaft arms may be sprung up or down.
4. The tumbling shaft may not be the same height at both ends.

An examination of these parts should be made and the trouble located if possible. In this particular case we can shorten the right link hanger, or raise the right tumbling shaft box or line the right rocker box down. If the link hangers are of equal length, the better way will be to line the right rocker box down, if possible. If we cannot do this, then line the right tumbling shaft box up. A change of $\frac{1}{16}$ inch in the height of the link will make a change of about 1 inch in the cut off on that side, so we can line the right rocker box down, or the left rocker box up $\frac{7}{64}$ inch. We might line the right tumbling shaft box up about

$\frac{7}{32}$ inch, or the left one down this same amount and get the same result. Judgment should be used in these matters, as no definite instructions can be given.

It is the practice at some shops, after setting the valves on a new engine, or one having had a thorough overhauling, to shorten all four eccentric rods $\frac{1}{64}$ inch. Then after the engine has been broken in and the wedges set up, the length of the rods will be correct.

As will be seen, in order to get the cut offs equal, we destroyed the equality of the leads in the forward motion. We could have avoided this by changing the lengths of the back up eccentric rods instead of the forward motion ones, and where the equalization is done for the forward gear only, this is the better practice.

In the foregoing nothing has been said about the proper amount of lead to be given for the reason that it is a matter upon which the working machinist has, as a general thing, nothing to say. Such information will be furnished by the master mechanic or foreman. On some roads it is the custom to require valves to be set with a certain lead in full gear and a certain lead at some designated point of cut off. When this is done, the method of valve setting is the same as described above, except that with the reverse lever in the proper notch to give the cut off called for, the angular advance of the back up eccentric is adjusted until the lead called for at that point is secured.

Sometimes an attempt is made to adjust the length of the eccentric rods without locating the engine on the dead centers. This is done by moving the engine slowly and marking the extreme travel of the valve rod, then adjusting the eccentric rods so that the valve will travel equally each side of the port marks. The correct length of the eccentric rods cannot be determined in this manner for the reason that the valve does not travel equally forward and back of the center when the eccentric rods are the correct length. With a reversing rocker the travel of the valve will be greater to the rear of the central position, hence if the length of the eccentric rods were adjusted to make the travel equal, the equality of the lead openings would be destroyed. In the particular engine under discussion, this difference would amount to about ¼ inch. Of course if an engine is out very badly and time is limited, an approximate adjustment may be made, bearing the above fact in mind.

With the heavy power now in use on the majority of railways, the engineer's work report of "Square valves, engine is so lame that she cannot handle her tonnage," is a very common one. Generally the demand for engines is so great that the time cannot be spared to properly run the engine over, and even were this possible, owing to the wear of the various parts, the results obtained would hardly be such as to warrant the expense. In such cases good results may be had by setting the valves by sound. The engine should be taken outside on a suitable piece of track, the lubricator set to furnish an extra supply of oil, the reverse lever hooked up to the point where the engine is generally worked and the brake set enough to make the exhausts sound loud and distinct. If the lameness is caused by the wear of the parts and not by slipped blades, there will probably be two heavy exhausts just before the crossheads reach the back end of the stroke. If such is the case, all the eccentric rods should be shortened an amount depending on the circumstances. This applies to indirect motion only.

If the engine has one heavy exhaust you may look for a slipped blade. If the engine is square in the corner going ahead, but goes lame as the reverse lever is hooked up, it is evidence that one of the back up eccentric blades has slipped. It will be on the side that the heavy exhaust comes from, which can be determined by watching the crossheads. Place the engine in the motion which the slipped blade controls and if the heavy exhaust comes on the forward center, lengthen the blade, but if it comes on the back center shorten it.

If the engine has two loud exhausts with a lighter one between them it indicates that the engine has a slipped eccentric, in case you find nothing else wrong such as loose rocker arm pin, rocker box working, etc. The loud exhausts may or may not come from the side the trouble is on, depending which way the eccentric has slipped. If it has moved so as to increase the lead, the loud exhausts would come from the side affected, while if it has moved to decrease the lead, the loud exhausts would come from the opposite side. Considerable experience is necessary to enable one to do this work correctly, but close attention and a reasoning from cause to effect should assist the novice in this matter.

The setting of piston valves will differ from that of the valve described, depending on the style of valve. An outside admission piston

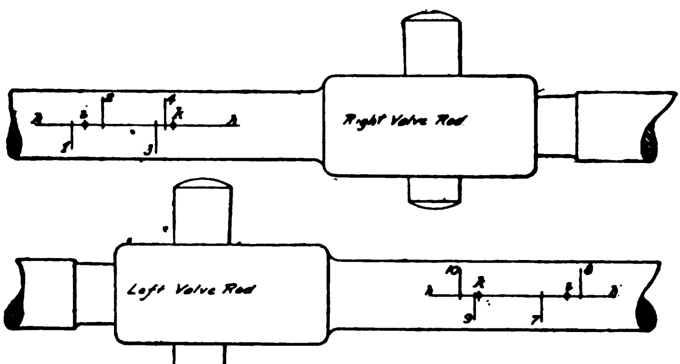


Fig. 18

valve, driven by means of a reversing rocker, or indirect connection, will be set in exactly the same manner. If it is direct connected, the method will be the same, but the position of the eccentrics will be changed. If it is an inside admission valve, direct connected, the position of the eccentrics will be the same as in the valve gear just discussed, but the fact that the valve travels in an opposite direction must be borne in mind, as it affects the relative position of the marks on the valve rod. Refer to Fig. 18, which shows the right and left valve rods marked for an engine having inside admission valves. The letters and figures refer to the same marks designated by the same letters and figures in Fig. 11. Comparing these two figures, it will be seen that the front port marks *i*, *i* are back of the back port marks *k*, *k*. The marks 2 and 4, on the right valve rod, denoting lead in the forward motion, are *inside* the port marks instead of outside as in Fig. 11. The mark 1, denoting lap in the back motion, is outside the port mark *i* instead of inside, as in Fig. 11. Comparing the left valve rod with the one shown in Fig. 11, will show the same relative changes in the marks. As this valve would probably be connected to the link by means of a rocker which would not reverse the motion, the eccentric rod, in adjusting the length, would be moved in the same direction that we would wish to move the valve rod.

The method of getting the port marks *i* and *k* will depend on the construction of the cylinders. Generally there is a peep hole about 1¼ inches in diameter located in the steam port, so that you can look directly down into the port and see the edge of the valve rings as they pass over the port. The valve is placed in the cylinder and a lighted taper or thin torch is inserted in the peep hole. This will light up the opening in the valve bushing forming the edge of the port, and by moving the valve until the inside edge of the valve ring is even with the inside edge of the bushing, the exact position of the valve at the time of closing or opening the port is seen. With the valve in this position the port mark is located with a tram in exactly the same way as has been described. The operation is repeated for the other end of the valve and you have your two port marks.

If the cylinder is not provided with the peep holes, the position of the valve relative to the

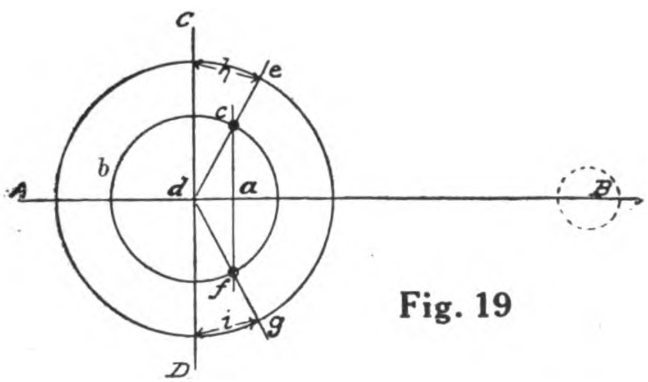


Fig. 19

ports must be determined by careful measuring.

As the position of the eccentrics on the axle relative to the crank pin is fixed for a given lap and lead of the valve, there is no reason why they should not be located in the correct position and permanently fastened before the wheels are placed under the engine. By doing this the hardest and most disagreeable part of valve setting will be avoided. There are two methods of doing this work.

1. The position of the eccentrics may be laid down graphically and the measurements thus determined transferred to the axle.

2. The position of the eccentrics may be calculated and laid off directly on the axle.

Suppose it is required to locate the eccentrics on the axle for an engine having the following characteristics: The rocker arms are of equal length; the horizontal center line of the cylinders passes through the center of the main driving axle; the center line of motion of the valve gear coincides with the cylinder center line; the throw of the eccentrics is 5½ inches; the diameter of the eccentric fit on the axle is 9 inches; the valve has 1¼ inches lap and is to be set line and line in full gear for both motions. If the first method is used proceed as follows:

On a piece of tin or other smooth surface of suitable size, draw the lines *A*, *B* and *C*, *D*, at right angles; see Fig. 19. From the point of intersection *d* scribe the circle *b*, *c*, *f*, having a diameter equal to the throw of the eccentrics, in this case 5½ inches. Also from the same center scribe another circle with a diameter equal to the diameter of the axle, in this case 9 inches. From the center *d* on line *A*, *B* lay off the distance *d*, *a* equal to the lap and lead of the valve, in this case 1¼ inches. Through *a* draw the line *f*, *a*, *c* at right angles to *A*, *B*. Point *c* where this line intersects the throw circle will be the center of the forward motion eccentric, and point *f* the center of the back motion eccentric, assuming that the crank pin is located at *B*. From center *d* draw the lines *d, c, e* and *d, f g*, representing the center lines of the eccentrics until they intersect the circumference of the axle at *e* and *g*. Now if the line *C, D* is located on the axle and from it the distances *h* and *i* laid off toward the crank pin, the two points *e* and *g*, through which the center lines of the eccentrics must pass, will be located.

To locate the line *C, D* on the axle, place

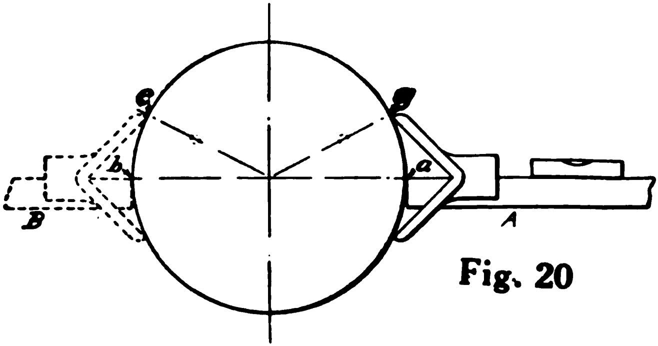


Fig. 20

the wheels in such position that the crank pin will be vertically over the center of the axle. This may be done by scribing on the end of the axle the circle *a, a*, Fig. 21, with a diameter equal to the diameter of the crank pin, or crank pin collar next to the hub. Throw the plumb line *b, b* over the pin and adjust the wheels until lines *b, b* exactly coincide with the circle *a, a*.* Block the wheels securely in this position. Take a center square and place it as at *A*, Fig. 20, and with a level placed on it as

*Do not use nuts for plumb bobs.

shown, adjust it until it is exactly level. The square is now exactly at right angles to a line drawn through the center of the crank pin and center of the axle. At point *a*, where the square

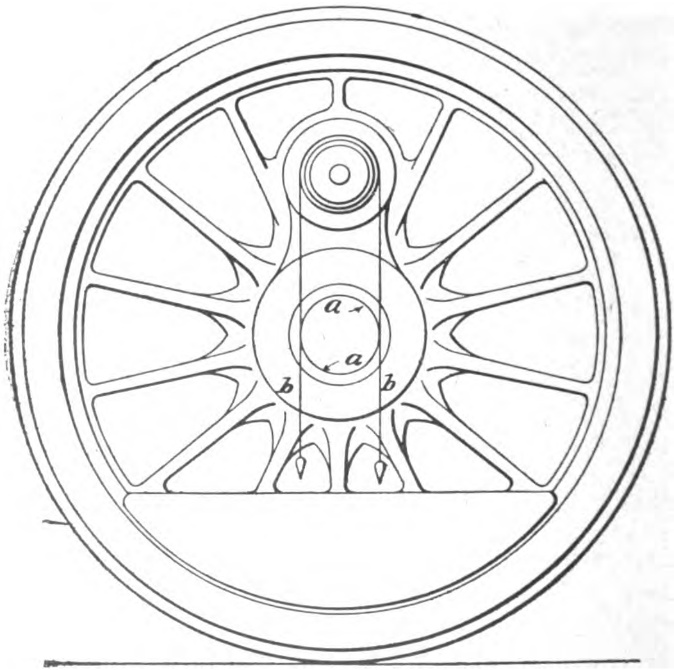


Fig. 21

blade touches the surface of the axle, scribe a line which will be one end of line *C*, *D*, Fig. 19. Place the square on the opposite side, as shown by the dotted lines, adjusting it perfectly level, and scribe a line at *b*, which will be the other end of line *C*, *D*, Fig. 19. Set a pair of dividers to the distance *h*, Fig. 19, and from point *b*, Fig. 20, set off this distance toward the crank pin which will locate point *e* with which the center line of the forward motion eccentric must coincide. In the same manner set off distance *i*, Fig. 19, from point *a*, Fig. 20, locating point *g* with which the center line of the back motion eccentric must coincide. By means of a box square the points *e* and *g* may

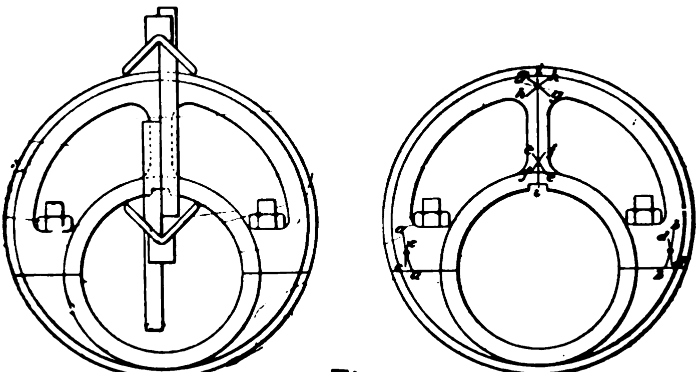


Fig. 22

be carried to the proper location longitudinally on the axle and the key ways laid off. In a similar manner lay off the key ways for the opposite end of the axle.

The key ways in the eccentrics should be cut exactly on the center line to avoid the use of offset keys. This center line may be located on the eccentric in two ways. The left hand figure of Fig. 22 shows a method of doing this with two center squares and is so plain as to call for no further explanation. The right-hand figure shows a method of locating this line by means of arcs. With the hermaphrodite calipers, from the outside of the eccentric, scribe the lines *a, a* and *b, b,* and from the bore scribe the lines *c, c* and *d, d* as shown. From the points of intersection, with the dividers set to any convenient distance, scribe the arcs *e, e* and *f, f*. With a larger setting scribe the arcs *g, g* and *h, h*. Through the points of intersection of arcs *g, g* and *h, h*, and *e, e* and *f, f*, draw the line *i, i*, which will be the center line of the eccentric.

In locomotive practice it is not uncommon to find that the horizontal center line of the cylinders does not intersect the center of the main driving axle, but is located above it, the distance varying from ½ inch to 3½ inches. Also the center of the link block pin hole in the lower rocker arm will be more or less below the center of the axle. When such is the case the relative positions of the eccentrics and crank pin will be as shown in Fig. 23. The line *A, B* is the horizontal line through the center *d* of the driving axle. Line *d, H* is the center line of the crank arm, and it will be noticed that it intersects the surface of the axle at a distance *m* above the line *A, B*. The distance *m* will depend on the length of the stroke diameter of the axle, length of the connecting rod, and the distance the center line of the cylinder is above the line *A, B*. Line *d, G* is the center line of motion, intersecting the surface of the axle at a distance *n* below the line *A*, *B*, depending on the diameter of the axle, radius of the link and the distance the center of the link block pin is below the line *A*, *B*. The advance of the eccentrics is laid off from the line *C*, *D* at right angles to line *d*, *G*. Line *E*, *F* is at right angles to the crank arm *d*, *H*. The distance *j*, which the line *C*, *D* is from the line *E*, *F*, is equal to the sum of the distances *m* and *n*.

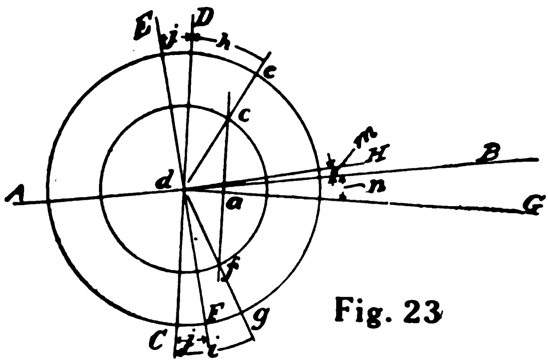


Fig. 23

To lay off the key ways for these eccentrics we must know the distance *m* which the crank arm is above the line *A*, *B*, and the distance *n* which the center line of motion is below the line *A*, *B*, both measurements being taken at the surface of the axle.

Let A = distance the center line of the cylinder is above the center of the axle.

B = length of the connecting rod.

C = length of crank arm = one-half stroke.

D = diameter of axle.

Then

(4). $m = A\ D \div 4\ (B + C)$.

Assuming that $A = 3''$, $B = 90''$, $C = 13''$, $D = 9''$, then

$m = 3 \times 9 \div 4\ (90 + 13) = \frac{1}{16}''$.

If D = diameter of axle.

E = distance link block pin is below center of axle,

F = radius of link,

then

(5). $n = DE \div 2F$.

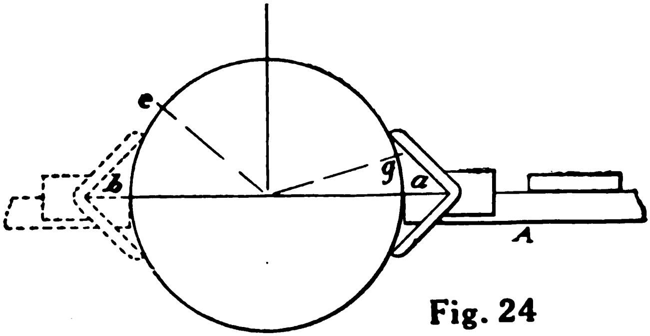


Fig. 24

Assuming that $D = 9''$, $E = 2\frac{1}{2}''$, $F = 60''$,

$n = (9 \times 2\frac{1}{2}) \div 2 \times 60 = \frac{3}{16}''$.

$j = m + n = \frac{1}{4}''$.

If the other conditions were the same as in Figs. 19 and 20, we would lay off from point *b*, Fig. 24, the point *e*, distant from *b* the sum of the distances *j* and *h*, Fig. 23, locating the center line of the forward motion eccentric. From point *a*, Fig. 24, the point *g* would be laid off, distant from *a* the difference between the distances *j* and *i*, Fig. 23, locating the center line of the back motion eccentric.

Instead of doing this work graphically, the angular advance of the eccentrics may be calculated by formula (3), and if the cylinder center line and the center line of motion do not coincide with line *A*, *B*, the distance *j*, which advance of the forward motion eccentric must be increased, and the advance of the back up eccentric reduced with reference to the line at right angles to the crank pin, may be calculated by formulas (4) and (5).

CHAPTER XI.

ERECTING SHOP WORK—SETTING VALVES—WALSCHAERT VALVE GEAR.

The type of valve gear known as the Walschaert is coming into extensive use on American locomotives, especially those of the heavier type.

As will be seen from the figure, this gear combines two entirely distinct motions—that derived from a single eccentric and the other from the crosshead—in such a manner that the combined effect is quite analogous to the motion obtained from a stationary link driven by two eccentrics.

The eccentric is usually applied in the form of a return crank from the main crank pin, its center being located on a line approximately at right angles to the main crank arm. Thus the eccentric has no angular advance and the link gives the valve no lap or lead. The link oscillates about a fixed axis, and its radius is the length of the radius rod. A union link, fastened to a short arm rigidly secured to the crosshead, is fastened to the lower end of the combination lever, the top end of which is connected to the radius rod and also to the valve spindle. This connection combines the

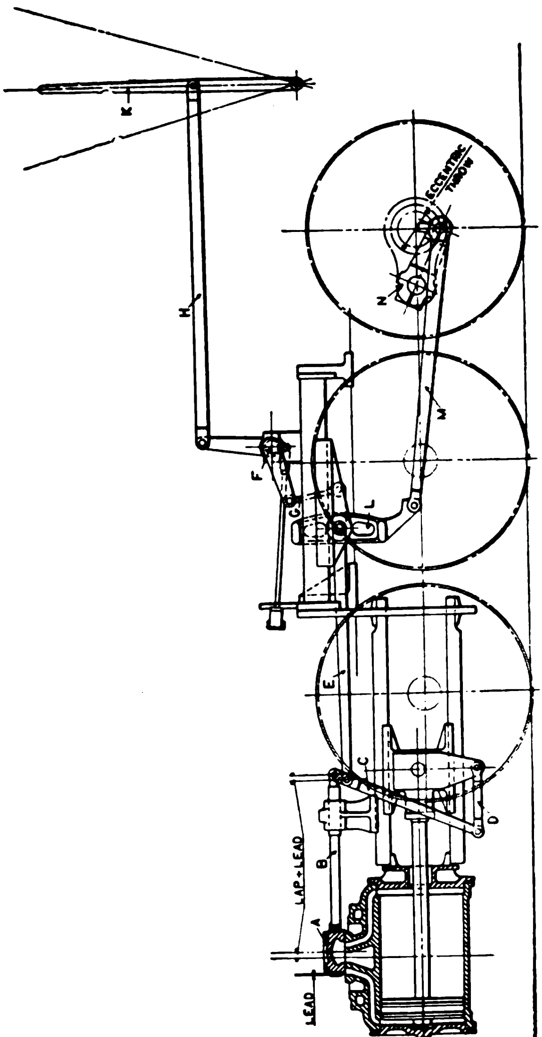


Fig. 1

eccentric and crosshead motions and provides the angular advance necessary to give the valve the required lap and lead, the two lever arms of the combination lever being so proportioned that the full travel of the crosshead will move the valve twice the amount of the lap and lead. From this it will be seen that the lead will be constant for all positions of the link block. In the construction shown, the end of the radius bar is connected to the lifting arm by a link. In other constructions this connection is made by means of a slip joint on the end of the lifting arm, in which case the lifting shaft is located to the rear of the link with its center at about the same height as the center of the link.

With the reverse lever in the central notch, the link will impart no motion to the valve, therefore all the motion the valve will get will be that derived from the crosshead through the medium of the combination lever which is, as before stated, twice the amount of the lap and lead. By moving the reverse lever forward the link block is lowered and the motion of the return crank is brought into combination with the motion from the crosshead, producing a valve movement suitable for moving the engine forward. By moving the reverse lever backward the link block is raised to the opposite end of the link, resulting in a valve movement suitable for moving the engine backward.

SETTING OUTSIDE ADMISSION VALVES WITH WALSCHAERT GEAR.

A design of the Walschaert Valve Gear used with outside admission valves is shown in Fig. 1. The names of the various parts of the gear are as follows: A, valve; B, valve stem; C, combining lever; D, crosshead link; E, radius rod; F, reverse shaft; G, lifting link; H, reach rod; K, reverse lever; L, reverse link; M, eccentric rod; N, eccentric crank.

The main pin is shown on the forward dead center, and the reverse lever is in its middle position, with the link block in the center of the link. A careful study shows that with a valve having outside admission the valve rod is connected to the combining lever at a point above the latter's connection to the radius rod. If the block is in the lower half of the link when in forward gear, the eccentric crank leads the main pin. If the block is in the upper half of the link when in forward gear, the eccentric crank follows the main pin.

With a valve having inside admission the valve rod is connected to the combining lever at a point below the latter's connection to the radius rod. If the block is in the lower half of the link when in forward gear, the eccentric crank follows the main pin. If the block is in the upper half of the link when in forward gear, the eccentric crank leads the main pin.

Since the position of the valve, when the piston is at the end of its stroke, is dependent on the combining lever only, it is evident that the lead given by the Walschaert gear is the same for all points of cut-off.

This is the principal feature which distinguishes this gear from the Stephenson motion as far as steam distribution is concerned. All parts of the Walschaerts motion should be correctly laid out and constructed from a diagram, and the gear designed to give the lead most desirable for the usual running speed. The parts having been correctly made, it is impossible to alter the lead without seriously deranging the motion. In this respect the Walschaerts gear is less flexible than the Stephenson; but when the correct steam distribution is obtained it is less liable to derangement, and the engine is more easily kept "square."

Assuming that all detail parts have been checked with their respective drawings and that the main rod is up and the gear fully connected, the procedure is as follows:

1. Block the main driving boxes, allowing one-half inch over the central position for settling, viz.: add one-half inch to the dimension between the top of the frame and the center line of the driving journal, as given on the erecting diagram.

2. Obtaining exact dead centers. Place the main crank approximately six or eight inches below the forward dead center. Put a prick punch mark on any convenient place on the crosshead gib (Fig. 2), and scribe with a tram or a pair of dividers the line A-A on the guide.

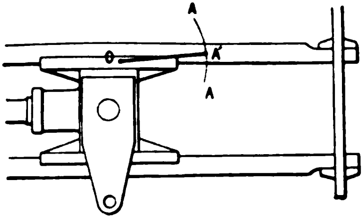


Fig. 2

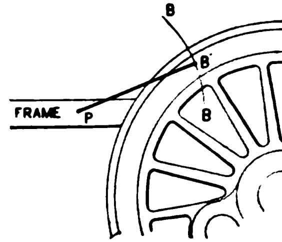


Fig. 3

Next prick punch the engine frame at any convenient place ahead of the driving wheel, and with a long tram scribe the line B-B on the tire (Fig. 3). Prick punch the Point B′ at a definite position (say one inch from edge of tire) on this line.

Now revolve the wheel backwards until the main crank comes above the forward dead center, stopping it when the tram used in Fig. 2 reaches exactly from the point O on the crosshead to the point A′ on the guide. Then re-tram the frame to the tire as in Fig. 4, using the same tram and the same point P as in Fig. 3. Scribe the line C-C and punch the point C′ at exactly the same distance from the edge of the tire as B′. This operation will place the point B′ (previously obtained) at a distance Q from point C′.

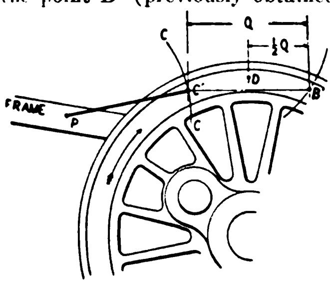


Fig. 4

Now prick punch the point D at a position exactly central between C′ and B′ and at the same distance from the edge of the tire as C′ and B′.

Now if the wheel be revolved forward until the long tram reaches exactly from point P to point D, the main crank will be on the exact forward dead center. Proceed in like manner to obtain the exact backward dead center, reversing the operation and using the same point on the crosshead and frame, and a new point (forward of the crosshead) on the guide. A good method for marking these center is shown on Fig. 5. The trial points are indicated by a single punch mark only, while the final points are indicated by three punch marks, the outermost ones being the actual tram points (D-D′). The points S and S′, Fig. 5, are indicated in a similar manner, the outermost punch marks representing the actual tram points used for marking the half stroke positions.

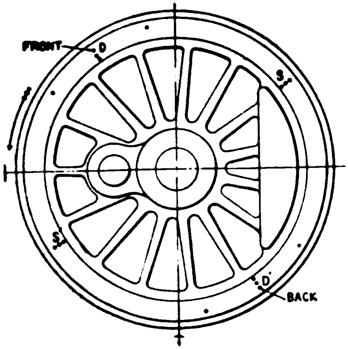


Fig. 5

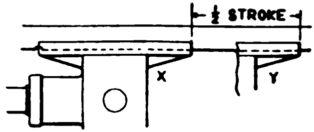


Fig. 6

To obtain the points S and S′, set the crosshead on the forward dead center and measure back on the guides one-half the piston stroke, Fig. 6.

Then revolve the wheel forward until the crosshead moves from position X to position Y. Now with the long tram obtain point S by tramming from point P on the frame (Figs. 3 and 4), prick punching point S at the same distance from the edge of the tire as point D.

The opposite half stroke point S′ may be obtained by the same method, preferably revolving the wheel in the same direction (arrow on Fig. 5) so that the influence of lost motion in the parts may be minimized.

The four important points on the stroke are now definitely established on the wheel, and are ready to be used for valve setting.

If desired, any other positions of the stroke can be marked on the wheel by using the long tram and the method of procedure described above.

1. With the ports exposed, place the valve with its steam edge just cutting off the ports (at each end successively), and prick punch the valve stem at points F and F′, obtained by tramming from any convenient place on the valve seat or shelf (see Figs. 7 and 8). The distance between points F and F′ will be equal

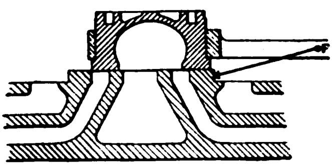


Fig. 7

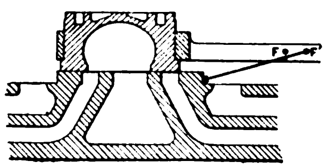


Fig. 8

to twice the lap of the valve. When the valve is leading (main crank on either dead center) the port should be open by an amount equal to the desired lead (see Fig. 9). If the tram is used with the valve on its lead, then the distance between the point so found and the point F on the valve stem will be equal to the lead (V on Fig. 9).

With this statement in mind, proceed as follows:

2. Hook up the gear so that the link block is exactly central with the link, place the main crank on the forward dead center, and tram to the valve stem. Revolve the wheel to the backward dead center, and again tram to the valve stem. Measure the distance between the points so obtained, and compare the same with the specification. The distance should be equal to twice the sum of the lap and lead. Variation from the specified figures means that an error exists in the combining lever, the upper and lower arms of which are made respectively proportional in length to twice the lap and lead and to the stroke of the piston, Fig. 10.

Assuming that the distance L, Fig. 10, as trammed on the valve stem, is found correct, the procedure is now as follows:

3. Place the gear in forward motion, with the link block at a point in the link that will give the specified maximum valve travel when the wheels are revolved in a forward direction (this position of the link block is obtained by experiment).

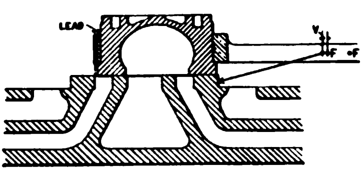


Fig. 9

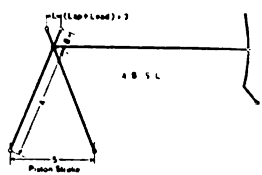


Fig. 10

4. Place the main crank on the forward dead center, by tramming from P to D, and with the same tram as used for marking the valve stem (Figs. 7 and 8) scribe on the stem, measuring the distance between the points so obtained and the punch mark F. This distance should be exactly equal to the specified lead.

5. Revolve the wheel in a forward direction until the main crank is on the back dead center (tram from P to D′), and similarly scribe on the valve stem, measuring the distance between the point so obtained and the punch mark F′. This distance should also be exactly equal to the specified lead.

6. Place the gear in backward motion (as instruction No. 3) and examine for lead at the front and back exactly as described in instruction 4 and 5, except that the wheel must be revolved in a backward direction.

7. If all the points so found are exactly to specification, the valve setting is square. A check should now be made by placing

the piston on the forward dead center, and moving the link block through its entire travel in the link. This should in no way disturb the position of the valve.

8. With the gear set for full stroke forward and full stroke backward the maximum valve travel should be examined with the piston at half stroke; placing the wheel with the long tram between the points P and S and P and S′, respectively (see Fig. 5). The travel so measured will not be exactly square at the front and back, as the points S and S′ represent half stroke measured from the piston travel, and do not take into consideration the angularity of the main rod.

Travel Irregularities.—The Walschaerts gear has inherent peculiarities that frequently cause slight irregularities in the travel of the valve. If, in full gear, this irregularity does not amount to more than one-quarter inch out of the square between the front and back positions of the valve it may be ignored, and the squaring of the travel may be considered as nearly perfect as the design will allow.

In special cases it may be desirable to square the valve travel when the gear is hooked up to give the cut-off at which the engine is most frequently worked. Thus, on a passenger locomotive, the most satisfactory results may be secured when the travel is squared at one-third or one-half stroke cut-off. In such a case, a slight irregularity at full stroke will probably be unavoidable, but will not prove detrimental. In any event, the particular circumstances under which the engine is to work must determine at what point of cut-off the valve travel shall be squared.

9. In marking the forward and backward gear positions on the reverse quadrant of a "cold engine" an allowance toward the front of the quadrant must be made on each end, to correct for expansion when the engine is under steam. The amount of such allowance is a matter of judgment, but one-quarter to three-eighths inches can be considered sufficient for ordinary standard gauge engines.

CORRECTIONS.—If on trial the valve gear is found to be out of square on the lead points the following hypothetical cases will serve to explain the corrections that should be made.

For example, suppose the specification calls for the following: Maximum valve travel, 5½ inches; eccentric crank throw, 11 inches; constant lead, ¼ inch; outside lap of valve, 1 inch; link block below link center in forward gear.

It is very important that the following dimensions check exactly with the drawings:

1. Length of combining lever between central fulcrum and upper and lower arm centers (Fig. 10, dimensions B and A).

2. Eccentric crank throw and length of crank arm.

In the case under consideration the prick punch marks on the valve stem (Figs. 7 and 8) will be two inches from center to center (this is twice the valve lap).

3. A change in the length of the eccentric rod results in a change in the position of the valve, approximately in proportion to the eccentric throw and valve travel. In the present case this is as eleven to five and one-half, or as two to one. In other words, a change of one-quarter inch in the length of the eccentric rod will move the valve approximately one-eighth inch when the link block is in full gear and the main crank is on the dead center.

4. The influence of eccentric rod changes on the direction (ahead or back) of the movement of the valve is shown in Fig. 11, which will show that if the eccentric rod E is lengthened to E′, then the radius rod R will be moved ahead to the position R′, and the valve stem will be moved a distance X in the direction of the arrow, thus displacing the valve from position V to position V′.

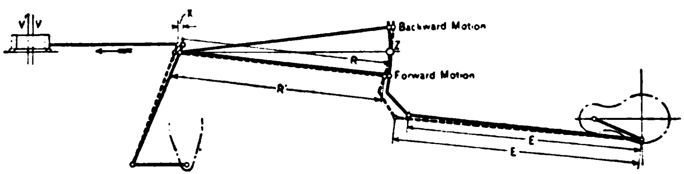


Fig. 11

5. The following rules can thus be formulated.

If the link block is below the link center when running ahead, in forward motion, the eccentric rod is lengthened, the valve is moved ahead.

If the eccentric rod is shortened, the valve is moved back, in backward motion, the eccentric rod is lengthened, the valve is moved back.

If the eccentric rod is shortened the valve is moved ahead. If the link block is above the center when running ahead, then, in each case, the valve will be moved in the direction opposite to that stated above.

6. Corrections made to the link radius rod will have approximately full influence on the movement of the valve, viz.: any variation in the radius rod will produce approximately the same variation in the movement of the valve.

7. The link fulcrum Z (Fig. 11) is a fixed point, therefore the direction of movement due to changes in the radius rod will vary directly with such changes, and the following rules can be formulated.

In either forward motion or backward motion, to move the valve ahead, lengthen the radius rod the amount desired. To move the valve back shorten the radius rod the amount desired. This is true whether the link block is above or below the link in forward gear.

8. With these facts in mind, two hypothetical cases will be considered.

HYPOTHETICAL CASE NO. 1.—Let it be assumed that, on tramming to the valve stem with the main crank on the dead centers, the following irregularities in the lead are noticed for the engine under consideration. The dots on the diagrams represent the prick punch marks F and F′ (Fig. 8) on the valve stem while the crosses represent the irregularities in the lead when trammed to the valve stem (Fig. 12).

9. The first procedure will be to divide the error between the forward and backward motions as follows:

Error in forward motion—
Front, 3/8″—1/4″=1/8″ error } To square the lead, the valve must
Back, 1/4″ lead—1/8″=error } be 1/8″ ahead.

Error in backward motion—
Front, 7/16″—1/4″ lead=3/16 error } To square the lead, the valve
Back, 1/4″ lead—1/16″=3/16″ error } must be moved 3/16″ ahead.

As the errors in the two motions occur in the same direction, it follows that the greater one partially counteracts the effect of the lesser, and that the combined or average error will be the difference between the two, viz.: three-sixteenth inch average error.

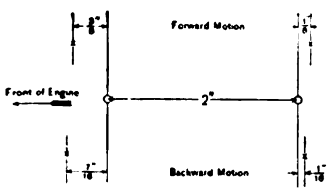


Fig. 12

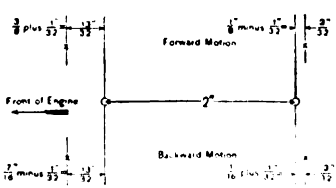


Fig. 13

10. To divide an average error of one-sixteenth inch equally about a central point, it will be necessary to move the valve one-half this amount or one-thirty-second inch (in this case one-thirty-second inch back in forward motion).

According to rule 3, the eccentric rod must be shortened one-sixteenth inch (in the proportion of two to one) to move the valve one-thirty-second inch. When this has been done the valve stem points will tram as shown in Fig. 13.

11. The errors in forward and backward motion have thus been equalized, and it remains only to square the lead front and back for both motions. The valve as now standing is five-thirty-seconds inches too far back to equalize the lead, viz.:

13/32″—1/4″ lead=5/32″ error front.
1/4″ lead—3/32″=5/32″ error back.

12. As the influence of the radius rod is direct (see rules 6 and 7) it follows that by lengthening this rod the amount required (five-thirty-seconds inches) the valve will be squared, and can be trammed to the dimensions shown by Fig. 14. These dimensions are the ones required by the specification.

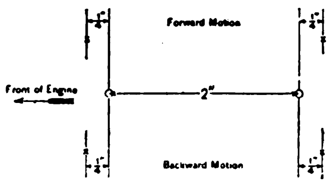


Fig. 14

13. The valve has thus been squared and the errors corrected in hypothetical case No. 1 by the changes noted below:

Eccentric rod shortened 1/16″.

Link radius rod lengthened 5/32″.

14. A final trial of the valve and cut-off, etc., can now be made in the previously described manner.

Hypothetical Case No. 2.—Let it be assumed that on tramming for lead results are obtained as represented by Fig. 15.

15. Divide the error between the forward and backward motions, as follows:

Error in forward motion—

Front, $\frac{7}{16}''$—¼″ lead=$\frac{3}{16}''$ error } To square the lead the valve
Back, ¼″ lead—$\frac{1}{16}''$=$\frac{3}{16}''$ error } must be moved $\frac{3}{16}''$ ahead.

Error in backward motion—

Front, ¼″ lead—$\frac{3}{16}''$=$\frac{1}{16}''$ error } To square the lead the valve
Back, $\frac{5}{16}''$—¼″ lead=$\frac{1}{16}''$ error } must be moved $\frac{1}{16}''$ back.

As the errors in the two motions occur in opposite directions it follows that they increase each other, and that the combined or average error will be the sum of the two, viz.: three-sixteenths inches plus one-sixteenth inch equals one-quarter inch average error.

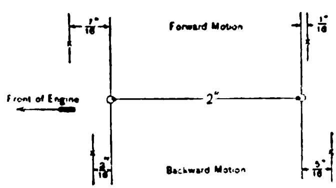


Fig. 15

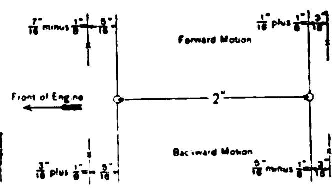


Fig. 16

16. To divide this error equally about a central point, it will be necessary to move the valve one-half the amount, or one-eighth inch (in this case one-eighth inch ahead in forward motion).

According to rule No. 3, the eccentric rod must be lengthened one-quarter inch (in the proportion of two to one) to move the valve one-eighth inch. When this has been done, the valve stem will tram as shown in Fig. 16.

17. The errors in forward and backward motion have thus been equalized, and it remains only to square the lead front and back for both motions. The valve as now standing is one-sixteenth inch too far back to equalize the lead, viz.:

5/16"—¼" lead=1/16" error front.
¼" lead—3/16"=1/16" error back.

18. To move the valve ahead one-sixteenth inch the link radius rod must be lengthened one-sixteenth inch (see rules 6 and 7) and the lead will then be squared. When trammed for lead, the results will be as shown on Fig. 14. These dimensions are the ones required by the specification.

19. The lead has been squared and the errors in Hypothetical Case No. 2 have been corrected by the changes noted below:

Eccentric rod lengthened ¼ inch; link radius rod lengthened 1/16 inch.

20. Trial of the valve travel and cut-off, etc., can now be made in the manner previously described.

From the above it is evident that the errors in forward and backward motion are equalized by changing the length of the eccentric rod, and the lead is then squared by changing the length of the radius rod. Theoretically the radius rod should not be changed, but the amount necessary is so slight that it makes practically no difference in the movement of the valve.

SETTING OF INSIDE ADMISSION PISTON VALVES.

The method of setting inside admission piston valves is generally similar to that described above. Fig. 17 shows a design of the Walschaert gear used with inside admission valves.

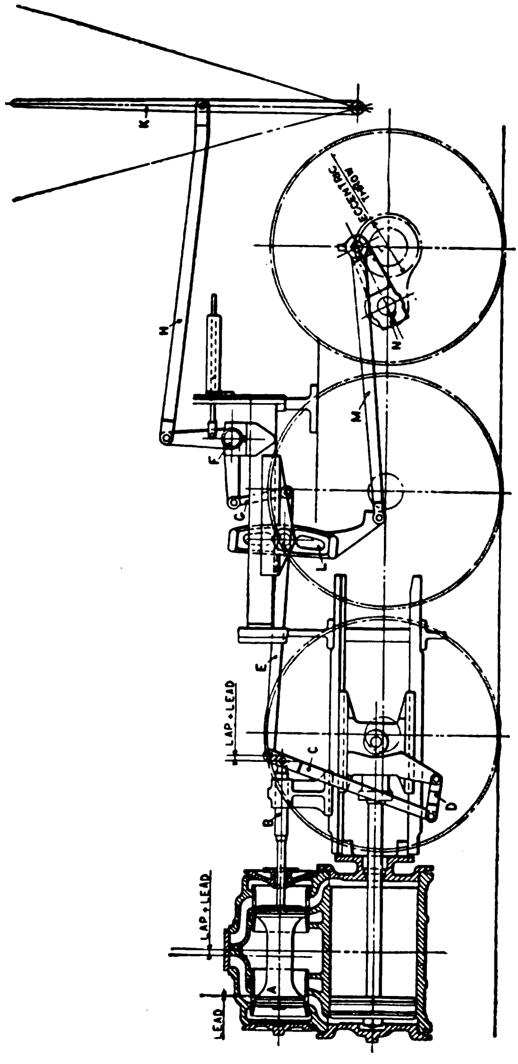


Fig. 17

It must be remembered, however, that to perform corresponding functions this valve moves in a direction opposite to that of the slide valve. When setting piston valves the steam chest heads should be removed for the sake of convenience. The line and line positions of the valve are determined by observation through peep holes provided for the purpose. In this way the points F and F′ are located on the valve stem, by tramming from any convenient point on the back wall of the steam chest. (Figs. 18 and

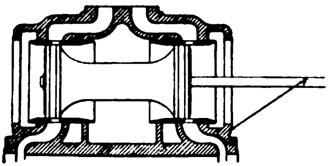


Fig. 18

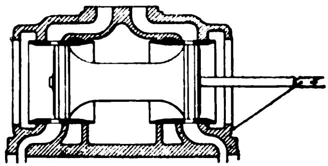


Fig. 19

19.) The lead points on the valve stem can thus be obtained by placing the crank on the dead center, and again tramming from the steam chest wall. (Fig. 20.) The test for lead is made as previously explained, the combining lever occupying positions as shown in Fig. 21.

The lead in full gear with this style of valve is examined precisely the same as already described, reference being made to Figs. 17 and 18.

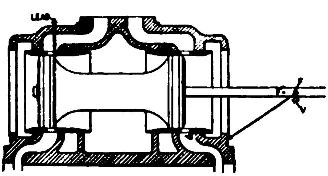


Fig. 20

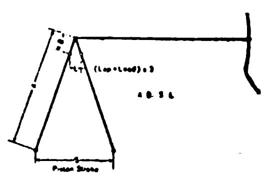


Fig. 21

Corrections.—The following two hypothetical cases will best explain the method for correcting errors. For example, suppose the specification of a locomotive having inside admission piston valves calls for the following:

Maximum valve travel 5¾ inches; eccentric crank throw, 15½ inches; constant lead, ¼ inch; steam lap of valve, 1 inch; link block below link center in forward gear.

The influence of eccentric rod changes on the direction (ahead or back) of the movement of the valve is shown on Fig. 22. An examination of this figure will show that if the eccentric rod E is lengthened to E′, then radius rod R will be moved ahead to the position R′, and the valve stem will be moved a distance X in the direction of the arrow, thus displacing the valve from position V to position V′. Therefore, the rules applying in the case of

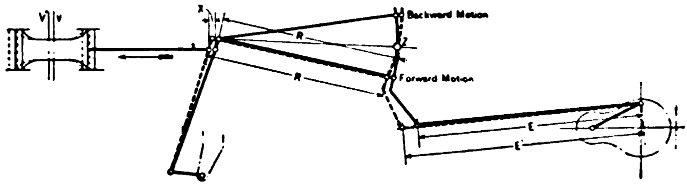


Fig. 22

outside admission slide valves also applies to this style of valve, as follows:

In forward motion, if the eccentric rod is lengthened, the valve is moved ahead. If the eccentric rod is shortened, the valve is moved back.

In backward motion, if the eccentric rod is lengthened, the valve is moved back. If the eccentric rod is shortened, the valve is moved ahead. If the link block is above the center when running ahead, then, in each case, the valve will be moved in the direction opposite to that stated above.

In any case, regardless of whether the gear is in forward or backward motion, to move the valve ahead lengthen the radius rod the amount desired. To move the valve back, shorten the radius rod the amount desired.

It must be remembered that with an inside admission valve the front port opening is increased if the valve is moved ahead, and the rear port opening is increased if the valve is moved back.

Bearing these facts in mind, two hypothetical cases will now be considered.

Hypothetical Case No. 1.—Let it be assumed that, on tramming to the valve stem with the main crank on the dead centers, the following irregularities in the lead are noticed for the engine under consideration. The dots on the diagram represent the prick punch marks F and F′ (see Fig. 19) on the valve stem, while the crosses represent the irregularities in the lead when trammed to the valve stem (Fig. 12). These irregularities are the same as those used in the corresponding case for slide valves, therefore the same diagrams are referred to.

1. The first procedure will be to divide the error between the forward and backward motions, as follows:

Error in forward motion—

Front, 3/8″—1/4″ lead=1/8″ error } To square the lead, the valve
Back, 1/4″ lead—1/8″=1/8″ error } must be moved 1/8″ back.

Error in backward motion—

Front, 7/16″—¼″ lead=3/16″ error Back, ¼″ lead—1/16″=3/16″ error	To square the lead, the valve must be moved 3/16″ back.

As the errors in the two motions occur in the same direction, it follows that the greater one partially counteracts the effect of the lesser, and that the combined or average error will be the difference between the two, viz.: three-sixteenth inches minus one-eighth inch equals one-sixteenth inch average error.

2. To divide an average error of one-sixteenth inch equally about a central point, it will be necessary to move the valve one-half the amount or one-thirty-second inch (in this case, one-thirty-second inch ahead in forward motion).

In the engine now under consideration, the eccentric crank throw is fifteen and one-half inches and the valve travel five and three-quarter inches. Hence the ratio of eccentric throw to valve travel is approximately as two and seven-tenths to one. Therefore, the eccentric rod must be lengthened two and seven-tenths times one-thirty-second, as previously stated, or approximately five-sixty-fourths inches to move the valve ahead one-thirty-second inch. When this has been done, the valve stem points will tram as shown in Fig. 13.

3. The errors in forward and backward motion have thus been equalized and it remains only to square the lead front and back for both motions. The valve as now standing is five-thirty-seconds inches too far ahead to equalize the lead, viz.:

13/32″—¼″ lead=5/32″ error front.

¼″ lead—3/32″=5/32″ error back.

As the influence of the radius rod is direct it follows that by shortening the rod five-thirty-seconds inches the valve will be moved back that amount and the lead squared. The valve stem can then be trammed to the dimensions shown in Fig. 14. These dimensions are the ones required by the specification.

4. The valve has thus been squared and the errors corrected in Hypothetical Case No. 1 by the changes noted below:

Eccentric rod lengthened 5/64 inches; radius rod shortened 5/32 inches.

5. A final trial of the valve and cut-off, etc., can now be made in the previously described manner.

Hypothetical Case No. 2.—Let it be assumed that on tramming for lead results are obtained as represented by Fig. 15.

6. Divide the error between the forward and backward motions, as follows:

Error in forward motion—

Front, 7/16″—¼″ lead=3/16″ error Back. ¼″ lead—1/16″=3/16″ error	To square the lead, the valve must be moved 3/16″ back.

Error in backward motion—

Front, ¼″ lead—3/16″=1/16″ error Back, 5/16″—¼″=1/16″ error	To square the lead, the valve must be moved 1/16″ ahead.

As the errors in the two motions occur in opposite directions they increase each other, and the combined or average error will be the sum of the two, viz.: three-sixteenths inch plus one-sixteenth inch equals one-quarter inch average error.

7. To divide the error equally about a central point it will be necessary to move the valve one-half the amount, or one-eighth inch (in this case one-eighth inch back in forward motion).

According to a rule given, the eccentric rod must be shortened two and seven-tenths times one-eighth inch, or approximately eleven-thirty-seconds inches, to move the valve one-eighth inch. When this has been done, the valve will tram as shown in Fig. 16.

8. The errors in forward and backward motion have thus been equalized, and it remains only to square the lead front and back for both motions. The valve as now standing is one-sixteenth inch too far front to equalize the lead, viz.:

5/16"—¼" lead=1/16" error front.
¼" lead—3/16" lead=1/16" error back.

11 Trial of the valve travel and cut-off, etc., can now be made in the manner previously described.

SETTING OF OUTSIDE ADMISSION PISTON VALVES.

With valves of this type, the arrangement of the gear is the same as that used with outside admission slide valves, and the method of setting is the same. The line and line positions of the valve. however, must be observed through peep holes, as in the case of the inside admission piston valve.

ERECTING SHOP WORK

CHAPTER XII.

Erecting Shop Work — Erecting Engine Trucks.

The ordinary four-wheeled engine truck consists of the frame of wrought iron or cast steel, the center casting (either of the rigid or swing center type) and the pedestal jaws with their binders and cross braces. The problem of erection is to locate these various members

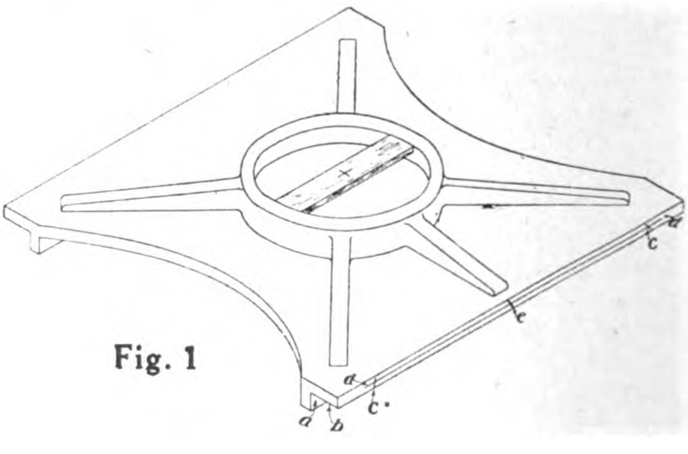


Fig. 1

so that the axles will be parallel to each other and the required distance apart, with the center casting located midway between them.

The center casting will be received from the machine shop with the frame fits at *a* and *b*,

Fig. 1, planed so that the center of the recess for the center pin will be central. The first step will be to locate the transverse center line. This may be done in several ways, but as good a one as any will be to place a stick across the recess and find the center with a center square or pair of hermaphrodite calipers. Then with a pair of trams set to any convenient distance scribe short arcs across each edge of the casting as shown at *c, c*. Draw the lines *d, d* on both sides of the casting parallel with the finished surface of the frame fit and the same distance from it. The center of this line between the arcs *c, c,* as at *e,* will be a point on the center line. Carry this line across the frame fit and from it lay off the necessary holes for the frame bolts. Have these holes drilled, leaving stock for reaming to size.

The frame bars will be received from the machine shop finished all over. Place them side by side as shown in Fig. 2, and draw the line *a, a* across them at the center of their length. From this line lay off the lines *b, b* and *c, c* at a distance equal to one-half the required distance between the axles. Draw the lines *f, f* parallel to and at the distance from the edge of the frame that the blue print shows the center of the bolt holes to be. On the lines *f, f,* using the lines *a, a, b, b,* and *c, c* as starting points, lay off all holes in the bars and have them drilled, leaving stock for reaming.

After the center casting and the frame bars are returned from the drill press, place the bars in position so that the distance from the points *e*, on the casting, to the four points *g*, *g*, *g*, *g* on the bars will tram the same. Clamp firmly in this position, ream the holes to size and have bolts fitted a good driving fit. The cross pieces at the ends should now be laid out, drilled and

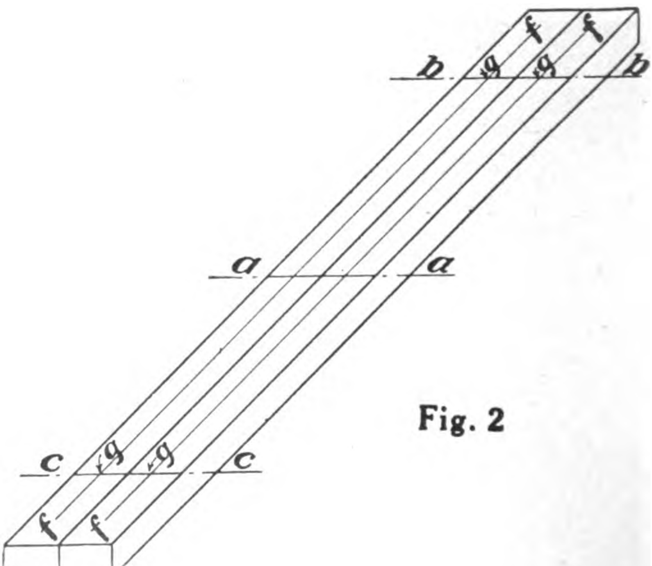


Fig. 2

bolts fitted. If the truck has a swing center, the center of the recess for the center pin should tram equally to the four points *g*, *g*, *g*, *g* when the truck frame is level. This for the reason that the weight of the engine on the center casting will bring the casting central with the hanger pins, and if these are not central with the frame the tendency will be to cut the flanges of the wheels on the side furthest from the centre.

The holes for the frame bolts in the pedestal jaws should be drilled in a jig so as to be interchangeable. Get the size of the truck boxes (they should all be the same) and clamp the four corner jaws in place with the face of each jaw one-half the size of the box distant from the center lines *b*, *b* and *c*, *c* and opposite jaws true across their faces when tested with a long straight edge. The face of the jaws should be

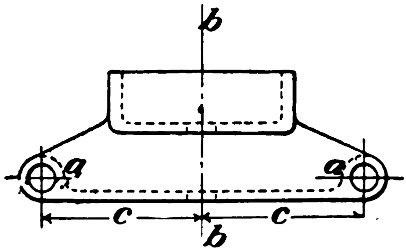


Fig. 3

square with the frame. Place the remaining four jaws and the truck boxes in position with a strip of tin between the jaw and the box and clamp firmly in position. Ream all holes through the frame and jaws and have jaw bolts fitted a good driving fit, but be careful that they are not too tight, as it is sometimes necessary to remove jaws in the round house.

If care is exercised in laying out the frame as described everything should be square and stay so during the life of the truck.

The wheels and boxes should now be placed in position, also springs and equalizers and the binder braces and bottom cross braces bolted to place, and the truck is finished.

Trucks having a single pair of wheels have the center pin located to the rear of the frame and always have the center casting supported on some system of swing links. The designs of this form of truck are so varied that attention will be called to the following points only.

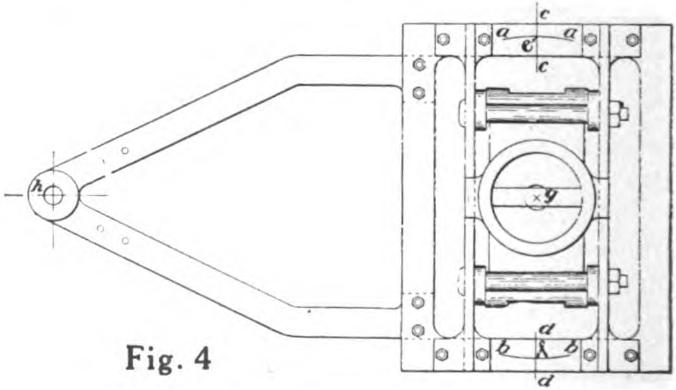


Fig. 4

The center casting should be laid out so that the distance *c, c* from the center line *b, b,* Fig. 3, to the centers of the holes for the hanger pins will be equal. With the center casting in place supported by the swing links and the truck frame level, short arcs *a, a* and *b, b,* Fig. 4, should be struck from the center of the recess in the center casting, intersecting the center lines *c, c* and *d, d* of the pedestal jaws at *e* and *f.* The center of the hole *h* for the radius pin should tram equally from these points *e* and *f.*

CHAPTER XIII.

ERECTING SHOP WORK—INJECTORS.*

The explanation of the action of an injector is as follows: (see Fig. 1). While in action the injector makes use of the velocity of the steam coming directly from the boiler *A* through a pipe *B* of the required area to insure sufficient velocity according to the amount of water to be delivered per hour. The steam entering the injector is controlled by the valve *C* and passes through the steam nozzle *a*, which is shaped in the best possible form to insure the maximum velocity of the steam, and creates a partial vacuum in the suction pipe *b*. The atmospheric pressure on the water in the tank forces the water into the injector. The water coming into contact with the steam jet in the combining tube *c* condenses the steam, and a part of the velocity of the steam is imparted to the water, giving the water sufficient momentum to raise the boiler check *f* and enter the boiler. As will be noticed, there is an opening between the combining tube *c* and delivery nozzle *d* which is in communication with the atmosphere through the medium of the overflow pipe *g*. This is necessary to allow the water to escape until the jet acquires sufficient momentum to

* For a full description of the various types of locomotive injectors see the Volume Locomotive Appliances.

raise the boiler check. With properly shaped and proportioned nozzles, the final velocity of the moving mixture of steam and water will be greater than the velocity at which water from the boiler would issue from the same opening through which the moving jet of steam and water enters the delivery pipe, and this difference in velocities explains the action of the injector.

Generally injectors may be divided into three classes:

1. Single tube injectors containing a single set of nozzles. These may have a central lifting nozzle attached to the operating lever or handle, or may have an independent lifting jet.

2. Re-starting injectors.

3. Double tube injectors, containing two distinct and separate sets of nozzles. These are commonly called inspirators.

The first two classes may be either lifting or non-lifting, according as to whether it is necessary to place them above or below the level of the water supply. The second class may be with or without self-regulation.

While the injector is not a sensitive or delicate instrument, it does require care to keep it in good working order and is subject to defects and failures if not properly attended to. Generally speaking, the failure of injectors may be classed under either of the following heads:

1. The injector refuses to prime promptly, or to prime at all.

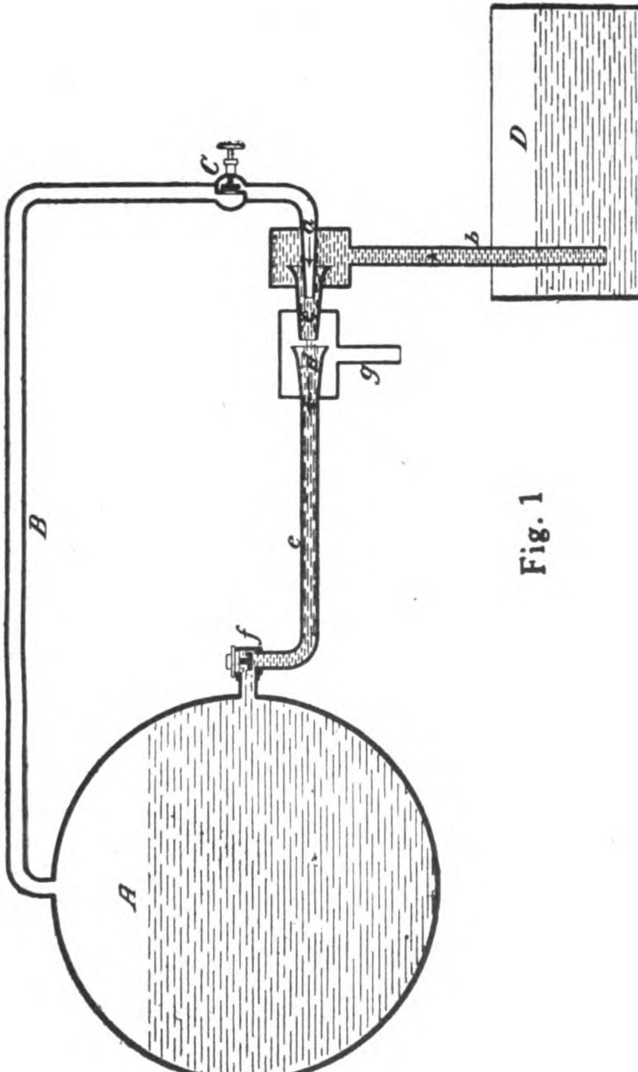


Fig. 1

2. The injector primes but will not force the water into the boiler, or forces it partly into the boiler and partly through the overflow.

As a general proposition, the trouble in the first case may be looked for between the overflow and the tank and would be due to any one or more of the following causes:

(a.) *Suction Pipe Stopped Up.* This may be due to a clogged strainer, dirt and coal around the tank valve, feed pipe or hose being stopped up, collapsed hose lining, or the tank valve shut. Any of these defects prevents water coming through and is probably the most frequent cause of the failure of the injector to prime. Take down the hose and examine the strainer and clean same, if necessary. Open the tank valve and observe if there is a strong flow of water from the hose. If not, the valve is probably choked with coal, waste, bird's nests, small fish, etc., collecting around it, and the water will have to be let out and the tank thoroughly cleaned. If the obstruction is in the hose itself, it can generally be found by inspection. A collapsed hose lining is sometimes hard to detect, as it will allow a free flow of water from the hose under tank pressure, but the minute the injector is put on, it will roll up and shut off the water. This will require a new hose. If the obstruction is in the suction pipe, close the over-flow valve, open the steam valve and blow steam back through the pipe, which will generally force the obstruction out.

(b.) *Leaky Suction Pipe.* This allows air to enter and will prevent the injector forming the vacuum necessary to raise the water. By closing the tank valve and putting the injector on as a heater, steam will blow out of any loose joints. In doing this do not turn the steam on hard, or you will blow the hose off the goose necks. The remedy is evident. With the syphon style of tank valve, if the plug or valve at the top of the syphon, which is placed there to stop the flow of water in case the hose is disconnected, is open or leaks, the injector cannot prime.

(c.) *Water in the Suction Pipe too Hot.* This may be due to a leaky boiler check valve, or steam valve allowing steam to blow back into the tank. The reason why an injector will not raise hot water is as follows: The temperature at which water boils depends on the pressure upon it, the lower the pressure the lower the temperature at which it will turn into steam. Under a gauge pressure of 180 pounds per square inch, water boils at a temperature of about 380° F., under the pressure of the atmosphere it boils at about 212° F., and if in a vacuum of 22 inches of mercury it will boil at a temperature of only about 153° F. When an injector is put to work a vacuum is formed in the suction pipe, and if the water is heated to a temperature of 150° or 160° F. it will boil, giving off steam which will destroy the vacuum. The remedy is to remove the cause of the heating.

(d.) *Obstruction in the Tubes.*—If the overflow passages, lifting jet, etc., are clogged with dirt and lime, the free passage of steam to the overflow will be interfered with, preventing the formation of a vacuum in the suction pipe. These passages, if clogged with lime, may generally be cleaned by removing the overflow valve and washing the overflow chamber with acid.

Where an injector primes but will not force the water into the boiler, or forces it partly into the boiler and partly through the overflow, it may be due to any of the following causes.

(a.) *Suction pipe or strainer partially stopped up; partially closed tank valve; collapsed hose lining or a kink in the hose.* Any one, or a combination of the above causes, will prevent the injector lifting sufficient water to condense all of the steam, and as a consequence the jet of combined steam and water will not have sufficient momentum to raise the boiler check, and will be forced out of the overflow. The uncondensed steam will gradually decrease the vacuum until the injector will break. The remedy in this case is the same as for a suction pipe stopped up.

(b.) *Leaky suction pipe.* A leak in the suction pipe may not be of sufficient size to prevent the injector from priming, but it will cut down the quantity of water raised so that the steam will not be entirely condensed. This will cause the injector to break on account of the destruction of the vacuum. If the injector is of the re-starting type it will go to work as soon as the water coming to the injector becomes solid again. With the other types the injector will have to be shut down and started again. Generally an injector will work noisily if there is a leak in the suction pipe that is not great enough to prevent working entirely.

(c.) *Boiler check stuck.* If the boiler check is stuck shut, the injector will prime all right, but will break as soon as the steam valve is opened. If it sticks partially open, or does not have sufficient lift, a part of the water will go to the boiler and the balance out of the overflow. A closed overflow injector will break and the steam blow back into the tank. In this case the injector may be made to work by cutting down the water supply and throttling the steam until the waste at the overflow is a minimum. A stuck boiler check may sometimes be opened by putting on the injector and at the same time jarring the check body smartly with a piece of wood.

(d.) *Obstruction in the tubes.* Any obstruction in the delivery tube, such as coal, scale, etc., will either cause the injector to break as soon as steam is turned on, or will cause a large amount of water to be thrown from the overflow. By taking out the main steam valve bonnet, in most injectors, a piece of wire may be run through the tubes, thus dislodging any obstruction.

(e.) *Injector limed up.* Failure from this cause is seldom sudden, as the lime collects on the tubes slowly. It is necessary for the tubes to be clean in order that the injector may work properly, and as they lime up the capacity of the injector will be cut down until finally it will refuse to work at all. Injectors should be cleaned frequently by placing them in a bath of muriatic acid. They should be removed from the acid as soon as the gas bubbles cease to be given off. As thc acid combines with the lime and forms a gas, as long as there is lime for the acid to combine with it will not attack the metal.

(f.) *Loose or worn tubes.* A loose tube will, in most cases, entirely prevent an injector working and will, in any event, seriously affect it. If the tubes are worn too large or out of shape, or cut, the injector will not work properly. The remedy is to replace the worn tubes by ones of standard size.

In repairing injectors the requirements to perform the work successfully are a thorough knowledge of the construction and the principle of the operation of the injector, a skilled workman with a proper equipment of tools and necessary repair parts. Following is a description of the method of overhauling a Monitor injector and in a general way is applicable to all injectors. Fig. 2 shows a sectional view of the Monitor injector, together with the names of the various parts.

1. Remove the line check body, heater cock, steam valve and jet valve.

2. Put the injector in a pickle of boiling caustic soda, made of 1 pound of caustic soda to 3 gallons of water, and leave for about two

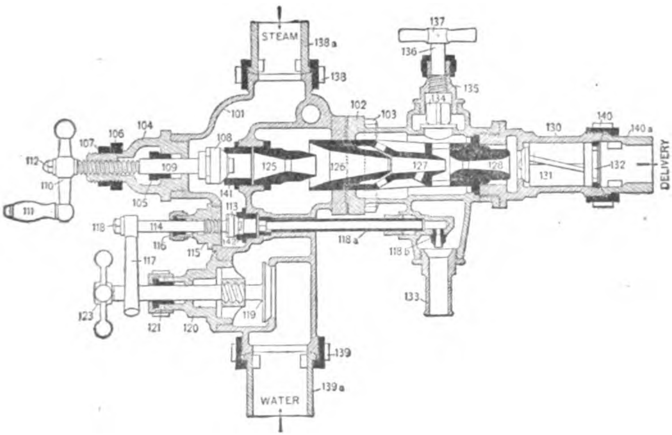


Fig. 2

Nathan Monitor "XX" Injector. (Sectional View.)

LIST OF PARTS.

1. Body (Back Part).
2. Body (Front Part).
3. Body Screw.
4. Yoke.
5. Yoke Gland.
6. Yoke Packing Nut.
7. Yoke Lock Nut.
8. Steam Valve Disc and Nut.
9. Steam Valve Spindle.
10. Steam Valve Handle.
11. Steam Valve Rubber Handle.
12. Steam Valve Top Nut.
13. Jet Valve Disc and Nut.
14. Jet Valve Spindle.
15. Jet Valve Bonnet and Nut.
16. Jet Valve Gland.
17. Jet Valve Lever Handle.
18. Jet Valve Top Nut.
18a. Jet Tube.
18b. Lifting Nozzle.
19. Water Valve.
20. Water Valve Bonnet and Nut.
21. Water Valve Gland.
23. Water Valve Handle.
25. Steam Nozzle.
26. Intermediate Nozzle.
27. Condensing Nozzle.
28. Delivery Nozzle.
30. Line Check Casing.
31. Line Check Valve.
32. Stop Ring.
33. Overflow Nozzle.
34. Heater Cock Check.
35. Heater Cock Bonnet and Nut.
36. Heater Cock Spindle.
37. Heater Cock T Handle.
38. Coupling Nut—Steam End.
38a. Tailpiece—Steam End.
39. Coupling Nut—Water End.
39a. Tailpiece—Water End.
40. Coupling Nut — Delivery End.
40a. Tailpiece—Delivery End.
41. Steam Valve Seat.
42. Jet Valve Seat.

hours; then put into a bath of muriatic acid until such time as gas bubbles cease to be given off. This will take from one to five hours, depending on the amount of scale in the injector and the strength of the acid. Wash well with cold water.

3. Place the injector in the vise, remove the delivery nozzle with a trimo wrench, and with a proper stud draw out the condensing and intermediate nozzles. It should not be necessary to separate the front and back bodies unless the joint is leaking, or the nozzles are so badly scaled up that they cannot be drawn out, or to renew the front body. The steam nozzle may be removed with a long socket wrench if necessary to renew it. In some waters the condensing nozzle No. 27 and intermediate nozzle No. 26 lime up solid, in which case they should be removed from the body before putting into the acid.

4. Re-seat all valve seats if necessary. If the inside bore of the body is worn too large for the nozzle fit, apply solder to the inside of the body and bore to fit the nozzle, or bush the body if necessary. If the jet valve or heater cock body bonnet fit in the body becomes too loose in the No. 7, 8 or 9 injectors, tap out the body for a No. 10 bonnet. If the jet valve or heater cock bonnet fit in the body of a No. 10 injector becomes too loose, clean up the thread and make a new bonnet. If the steam valve yoke fit in the body becomes too loose, draw back to place as much as possible and shrink an iron band on

to hold it in place, and tap to size. If the jet valve seat becomes worn through it may be cut out and a plug screwed into the body.

5. In assembling injectors, *use oil and graphite on all threads and joints*, so that when necessary to take apart again they will start easily. Screw in the steam nozzle No. 25, with a socket wrench, and then screw nozzles Nos. 26, 27 and 28 together and slip into place in the body. Screw in the line check body, making sure that it makes a tight joint with the nozzle and front body by spotting both joints. Put in the heater cock, steam valve and jet valve, and see that the stems are well packed with prepared packing or asbestos wick soaked in valve oil and graphite. See that the water valve works easily and can be regulated.

When renewing nozzles Nos. 26, 27 and 28, always renew the steam nozzle No. 25. Nozzles Nos. 25, 26 and 27 will usually wear out two of No. 28.

Do not dismantle an injector entirely when only a new delivery nozzle is required, or when it simply needs liming out, unless it is so badly limed up that it is necessary to take the nozzles out in order to get them clean.

Do not heat an injector to loosen up the scale, for the removal of nozzles, etc.

Do not try to bush nozzles. It is better to apply a new one.

Do not throw any usable parts into the scrap.

After an injector has been repaired and cleaned it should be given a thorough test to insure that it is in proper working condition. For this purpose some form of a testing plant is necessary. A very convenient plant of this kind, and one that is inexpensive to erect, is shown in Fig. 3. In order to get the best results from this plant in cases where the shop

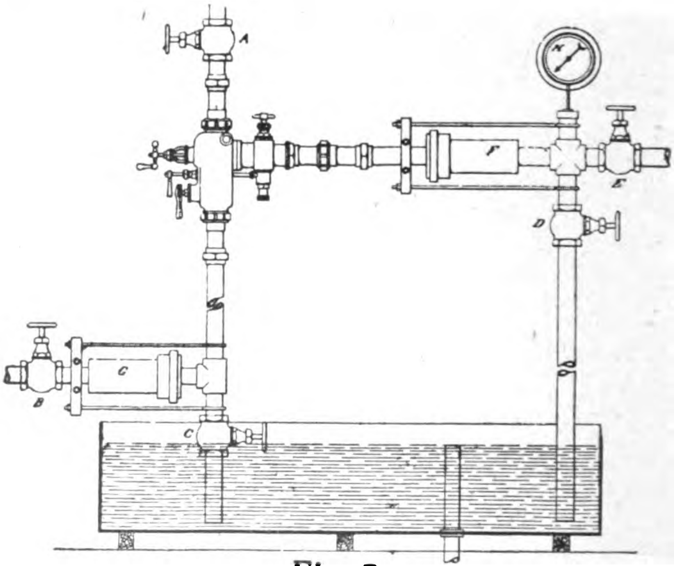


Fig. 3

boilers do not carry as high a steam pressure as do the locomotives, a small, high pressure vertical boiler should be installed, as an injector will sometimes work all right with a low steam pressure and give very poor results if the pressure is materially increased, and vice versa.

Referring to Fig. 3, the water supply to the injector should be connected so that the water will flow to the injector under slight pressure, as will be necessary when testing non-lifting injectors, and also arranged to take water from a tank as shown, lower than the injector a distance equal to about the average height of lift that the injector will work under when in place on the locomotive, in case it is of the lifting type. Steam comes to the injector at the top, being controlled by valve A. The water comes from the bottom, being controlled by valves B and C. The discharge is at the end and is controlled by valves D and E. In order to adapt the plant to the testing of injectors of different sizes and makes, the water connection and the discharge pipe should be made adjustable by means of the expansion joints at F and G. Each pipe should also be supplied with short nipples as shown, one end having a ball joint union to connect with the fixed pipes, the other end having the standard sleeve and nut for the injector to be tested. If desired these sleeves may be made the correct length for the various injectors to be tested and thus do away with the necessity of the expansion joints. A gauge H should be applied to the discharge pipe as shown in the figure. The discharge from the injector under test may be disposed of as is most convenient.

To test an injector, couple it onto the plant and proceed about as follows:

Test No. 1. Close the injector overflow and all valves except the steam valve A, and put on full boiler pressure for a minute or two. This will show up any leaks there may be in the body or joints.

Test No. 2. Close steam valve A and open valve B and the injector overflow and let the water run through to cool off the injector. Open valve E or D, in the discharge pipe, and with the water flowing from the tank open the steam valve A and start the injector. If it starts, gradually close the valve in the discharge pipe until pressure shows on the gauge H, which will denote the pressure in the discharge pipe. This should be at least 20% higher than the boiler pressure to insure satisfactory working. The valve in the discharge pipe should not be entirely closed, or the injector will break. If the injector will not show the desired pressure, or if it breaks before boiler pressure is reached, you are safe in assuming that the tubes are worn out of proportion, probably the discharge nozzle is worn too large, or possibly the combining nozzle is cut.

Test No. 3. If the injector is of the lifting type, close the direct water supply valve B, and open valve C. Put on the lifter and if the injector primes and goes to work, maintaining a pressure in the discharge pipe 20% higher than boiler pressure, you know that it is in good condition and will work when placed on the engine. If it should not work when placed on the engine you know that the trouble is not in the injector, but must be looked for at some other point.

This testing plant may be modified or elaborated to suit individual requirements. Thus thermometers may be placed in the supply and discharge pipes to test the temperature of the feed water and discharge. A vacuum gauge may be attached to the feed pipe to test the lifting capacity. The tanks may be measured and the capacity of the injectors determined under various conditions, etc.

Engineers, as a rule, are not very careful about reporting work on injectors in the way of giving the roundhouse man the necessary information as to the probable cause of the trouble. The usual report is something like this: "Right injector will not work. Left injector O. K." As the proper working of an injector depends on the condition of the engine with regard to steam pressure, the machinist who is responsible for this work should lose no time in getting to the engine in order to determine just what the trouble is. Take the above report; it may cover work upon all the connections from the tank to the boiler check, including the injector itself. With the rush that is generally upon the roundhouse machinist he should naturally seek at once for the seat of the trouble in order to save time. By working the injector while the engine is "hot," you may be able to determine whether the injector does not prime, wastes water at the overflow, or whether the boiler check is leaking, etc. If the trouble is in the injector there is no use in taking down the hose, while if it is the hose, tank valve, or boiler check, it would do no good to change the injector. And just because you are able to get an injector to work after it has been reported as failing on the road, does not mean that you are justified in declaring the injector to be in good condition. For instance, the suction pipe might have a loose joint which might not prevent the injector from working while the engine is standing, but when running the vibration may cause it to open up enough to put the injector entirely out of business. Too much depends on the *positive* working of an injector for the roundhouse man to take any chances. He *must* find and repair the defect.

CHAPTER XIV.

ERECTING SHOP WORK—PIPE FITTING.

While the work of erecting pipes does not, strictly speaking, come under the head of machinist's work, still there are times, especially

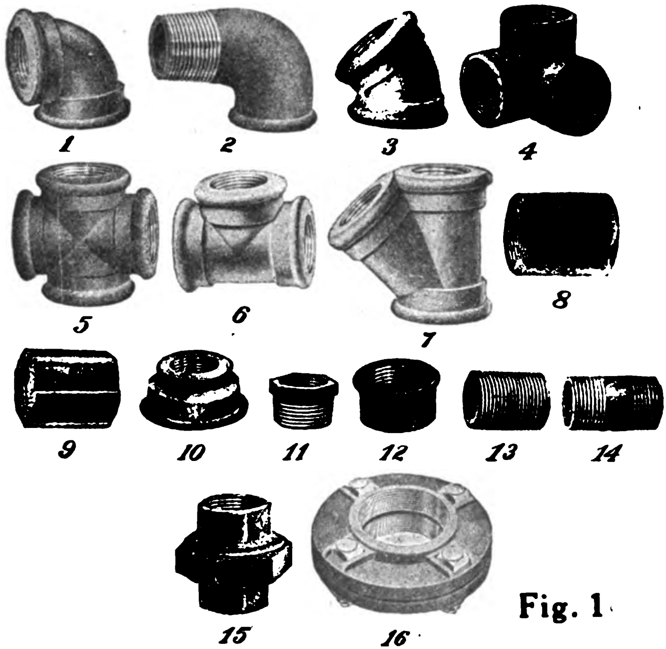


Fig. 1

in the round house, when the machinist will be called upon to do pipe work.

Common iron pipe, or "gas pipe," as it is generally called, is made by rolling a long sheet of flat iron transversely into a cylinder and welding the edges. These edges are butt welded in pipes from ¼ inch to 1¼ inches in diameter, and are lap welded in pipes from 1½ inches in diameter up. In addition to the common pipe, wrought iron pipes are manufactured of an extra thickness known as extra strong and double extra strong.

Iron pipe is designated by the nominal inside diameter, not by the outside diameter. Copper and brass tubing are designated by the outside diameter. The following tables give the actual inside diameter, the actual outside diameter, the number of threads per inch and the length of the perfect screw for all sizes of pipe up to six inches in diameter.

A comparison of the tables for the extra strong and double extra strong pipe with the

TABLE I.

STANDARD WROUGHT IRON STEAM, GAS AND WATER PIPE.

Nominal Inside Diameter. Inches.	Actual Inside Diameter. Inches.	Actual Outside Diameter. Inches.	Number of Threads per Inch.	Length of Perfect Screw. Inches.
⅛	0.27	0.405	27	0.19
¼	0.364	0.54	18	0.29
⅜	0.494	0.675	18	0.30
½	0.623	0.84	14	0.39
¾	0.824	1.05	14	0.40
1	1.048	1.315	11½	0.51
1¼	1.38	1.66	11½	0.54
1½	1.61	1.9	11½	0.55
2	2.067	2.375	11½	0.58
2½	2.468	2.875	8	0.89
3	3.067	3.5	8	0.95
3½	3.548	4.0	8	1.00
4	4.026	4.5	8	1.05
4½	4.508	5.0	8	1.10
5	5.045	5.563	8	1.16
6	6.065	6.625	8	1.26

TABLE II.

EXTRA STRONG AND DOUBLE EXTRA STRONG WROUGHT IRON PIPE.

Nominal Inside Diameter. Inches.	Extra Strong.		Doule Extra Strong.	
	Actual Inside Diameter. Inches.	Actual Outside Diameter. Inches.	Actual Inside Diameter. Inches.	Actual Outside Diameter. Inches.
⅛	0.205	0.405		
¼	0.294	0.54		
⅜	0.421	0.675		
½	0.542	0.84	0.244	0.84
¾	0.736	1.05	0.422	1.05
1	0.951	1.315	0.587	1.315
1¼	1.272	1.66	0.885	1.66
1½	1.494	1.9	1.088	1.9
2	1.933	2.375	1.491	2.375
2½	2.135	2.875	1.755	2.875
3	2.892	3.5	2.284	3.5
3½	3.358	4.0	2.716	4.0
4	3.818	4.5	3.136	4.5
5	4.813	5.563	4.063	5.563
6	5.75	6.625	4.875	6.625

table for the common pipe shows that the extra thickness is obtained by decreasing the inside diameter of the pipe, thus making the walls thicker. The inside diameter of a 1½-inch pipe is 1.61 inches, that of an extra strong pipe is 1.49 inches, and that of the double extra strong pipe is 1.088 inches, the outside diameter of all three being 1.9 inches. Hence it will be seen that the same nominal size of the extra strong or double extra strong pipe may be used with standard fittings, but the capacity of the pipe will be cut down.

Pipe comes from the mills in lengths of from 15 to 20 feet and is threaded on both ends with a coupling screwed on one end. The larger sizes of pipe will also have a ring screwed on the other end to protect the threads during shipment.

For joining the different pieces of a line of piping various fittings are used, the more common ones being shown in Fig. 1. These various pieces are designated as follows:

1. 90 degrees elbow.
2. Street elbow.
3. 45 degrees elbow.
4. Side outlet elbow.
5. Cross.
6. Tee.
7. Y Branch.
8. Coupling, right hand.
9. Coupling, right and left hand.
10. Reducing coupling.
11. Bushing.
12. Cap.
13. Close nipple.
14. Shoulder nipple.
15. Union.
16. Flange union.

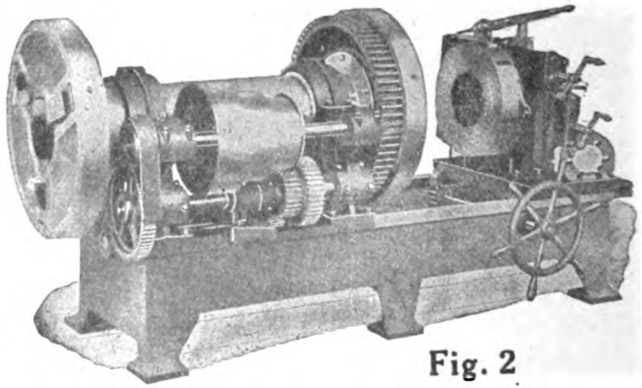


Fig. 2

The majority of these fittings are made of both cast and malleable iron, and all of them, except caps and plugs, are threaded for two, and in some cases more than two connections; both threadings are usually right hand, but they are also furnished, on special order, with right hand threads on one side and left hand threads on the other.

Ordinarily in laying a line of pipe, the different sections are united by means of couplings. Each section put down has a coupling already tightened on the projecting end, to which the next section is connected by screwing it into the coupling. Where two sections meet the connection is made by using a right and left hand coupling, one of the sections having a left hand thread cut on it. This connection may also be made by using one of the unions No. 15 or 16.

When it is necessary to increase or decrease the continuation of a pipe line, a reducing coupling is used, or a reducing bushing is screwed into a common coupling.

The nipples, Nos. 13 and 14, are simply short pieces of pipe threaded on each end. Both threads may be right hand, or one right hand and one left hand. These nipples may be secured in various lengths.

Where a line of piping ends with a pipe end it is closed with a cap, or a plug screwed into a coupling.

In order to avoid mistakes in ordering tees, crosses, Y branches, etc., where the openings are of different sizes, be governed by the following rule: Give the sizes of the ends of the run first, then the size of the outlet or branch. Suppose you want to branch off from a line of 1-inch pipe with a ½-inch pipe, using a tee. The tee would be as follows, "1 **T** 1", and would be
½"
ordered as a 1"×1"×½" tee. A Y-branch,

cross or side outlet elbow would be ordered in the same manner.

In any pipe installation various lengths of pipe will be required, so it will be necessary to cut the full lengths to the required dimensions.

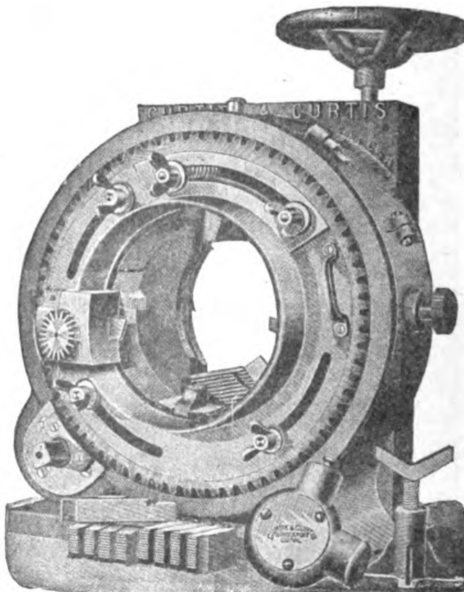


Fig. 3

Shops where a large amount of this work is done are usually provided with some sort of a power pipe cutting and threading machine, one style of which is shown in Fig. 2. A hand power machine for large pipe is shown in Fig. 3. This machine cuts off and threads all sizes of wrought iron pipe from 2½ inches to 10 inches right hand. The pipe is inserted from the back of the machine and is clamped by a self-centering vise attached to the machine. As the large die carrying gear is revolved by means of the small pinion embedded in the side of the shell, it is drawn toward the end of the pipe by a lead screw on its back and the dies are thus fed to the pipe. When the required length of thread is obtained the dies are thrown back and the pipe taken out, without running back over the thread. Only three sets of dies are used for the full range of the machine, and they are all

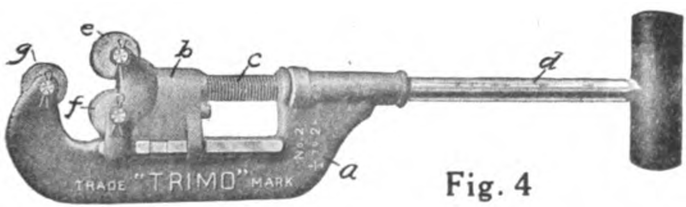


Fig. 4

made opening and adjustable to any variations of the fittings. This machine is also fitted when desired with a power base and countershaft. It can then be used either as a power machine in the shop, or taken from its base and carried out on a job as a hand machine. In the absence of these machines pipe larger than about 4 inches is generally cut and threaded in a lathe. The majority of small pipe is cut with a pipe cutter shown in Fig. 4. The body *a* carries the slide *b*, which is operated by the screw *c* on the handle *d*. The hardened steel cutting wheels *e* and *f* are set in the slide and the wheel *g* in the frame or body. The slide *b* is drawn back by means of the screw to allow the pipe to go in between the cutters, after which they are forced into the pipe by turning the handle *d*, and at the same time rotating the tool around the pipe. Some cutters of this type have but one cutting wheel, which is located in the slide, the other cutters being replaced by plain rollers. A cutter of this type always throws up a burr on the end of the pipe, both inside and outside, which should be re-

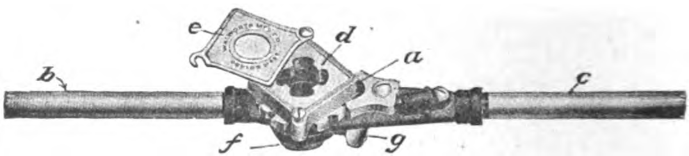


Fig. 5

moved by filing the outside and reaming the inside.

The thread is cut by means of the stock and dies, shown in Figs. 5 and 6. The ordinary stock is shown in Fig. 5, and consists of a body *a* into which handles *b* and *c* are screwed. The body has a square recess in the top to hold the die *d*, the cover *e* sliding over it to hold it in place. For threading the larger sizes of pipe, from 1 inch to 2 inches, the back of the stock is threaded internally with a 11½ per inch thread, and the bushing *f* is screwed into it. This bushing has various thimbles having holes through them the size of the outside diameter of the pipe to be threaded, which bushing and thimble are slid over the end of the pipe so that the die rests on the end of the pipe. The bushing is then made fast to the pipe by means of two set screws *g* and the stock given a few turns to start the die on the pipe. The screw on the bushing and the thread in the stock act as a lead screw and draw the die on. As soon as the die has taken a good hold, the set screws

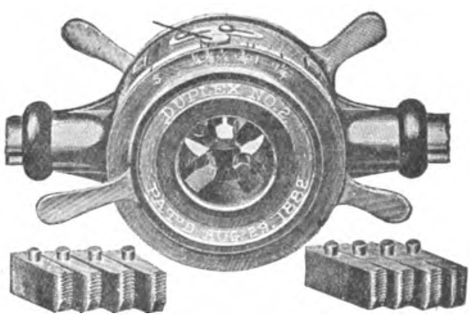


Fig. 6

are loosened up and the thread finished. This stock is generally furnished in five sizes to cut threads on pipe from $\frac{1}{8}$ inch to 3 inches in diameter.

The stock shown in Fig. 6 has adjustable dies and is very convenient for threading the larger sizes of pipe by hand, as the dies or chasers may be opened more or less and several cuts taken to bring the thread down to size. The dies cut the correct size when the pointer *a* is set opposite the figure denoting the diameter of the pipe being operated on. These stocks are made in eight sizes, threading pipe up to 8 inches in diameter.

For threading the inside of pipe fittings, valves, reservoirs, or anything that is to be threaded inside for pipe connections, two tools are used. Fig. 7 shows a pipe reamer which is used to enlarge holes where they are too small to receive the tap, and also to give the hole the required taper of $\frac{3}{4}$ inch per foot, which is the standard taper of pipe threads. The pipe tap, Fig. 8, cuts the thread, and one is needed for each different pipe size.

Fig. 7

For holding the pipe while cutting and threading, various kinds of pipe vises are used, one style of which is shown in Fig. 9.

For screwing the pipe together various kinds of pipe tongs and wrenches are used. Fig. 10 shows the well known Trimo wrench, which is one of the best of this type of wrench. They are suitable for all sizes of pipe up to 2 or 3 inches in diameter. Fig. 11 shows a new style of pipe wrench known as the Bullard Automatic which is a very convenient tool for all work within its capacity. It is made in five sizes up to 3-inch. Fig. 12 shows a form of chain tongs which are made in various sizes. For medium and large work these are the most rapid and handy tools of their kind. Fig. 13 shows the common form of adjustable pipe tongs, the adjustable jaw allowing one pair to take two sizes of pipe. These tongs are also made non-adjustable, in which case a pair of tongs must be provided for each size of pipe. In cases where a suitable wrench or tongs is not available, a rope may be used as shown in Fig. 14. The rope is first doubled as shown at *a*, and then given enough turns around the pipe to insure its gripping. A bar *b* is thrust through the loop end of the rope and the two loose ends

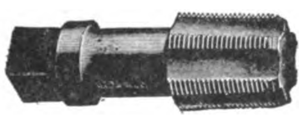


Fig. 8

are bought together and held as at *c*. Enough pull is exerted at *c* to prevent the rope slipping and the pipe is turned by the bar, the same as with any wrench. If the location of the work is such that a complete turn cannot be made, the rope may be slacked off and the bar and rope turned back to get a new hold.

When given a pipe job to erect, the first thing to do is to carefully go over the lay out and figure on just what will be required in the way of fittings, valves, etc., and order these from the store room. In erecting pipe work care must be taken to have it align as true as possible, as well as to have the joints tight enough to stand the required pressure without leakage. Sometimes elbows, tees or other fittings will be found that are not threaded true, in which case, if the pipe is threaded true, the alignment will be defective and the job will look unsightly. In such cases the defective fitting should be thrown away or the thread on the pipe cut to correct the error in the fitting. To cut a pipe thread out of true to suit a de-

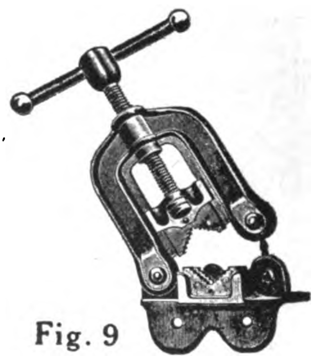


Fig. 9

fective fitting, a very good plan is to cut the end of the pipe off at an angle instead of square, which will cause the die to cant over and thus cut the thread at an angle with the axis of the pipe. No definite rule can be given for determining the angle at which the end of the pipe should be cut, considerable practice being required to educate the judgment as to how much to do this to suit any given amount of error.

In erecting pipe it is best to begin at one end and screw each piece firmly to its place before attaching another, so that the lengths of the pieces may be accurate. In measuring for the length of pipe do not forget to make allowance for the distance the pipe will enter the fittings. The fit of the joints should in all cases be made by tightness of thread fit, and not by the fitting jambing against the end of the thread on the pipe, as joints in which this is the case will usually leak. The thread of the pipe should be covered with plumbago and oil before screwing to place in preference to coating it

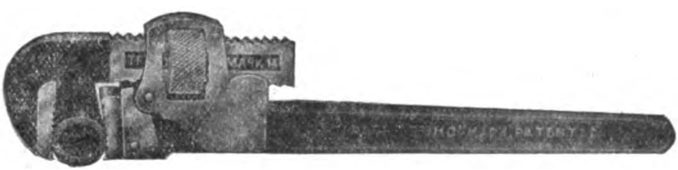


Fig. 10

with white or red lead, as a plumbago joint will never stick. All pipe should be thoroughly blown out before erecting in order that there will be no scale or dirt left in them to be carried by the steam or water to the valves, and by getting between them and their seats cause them to leak.

In screwing a valve or cock of any kind onto a pipe or other fitting always place the wrench on the side of the valve next to the pipe that the valve is being attached to, for if the wrench is placed on the side away from the pipe, the pressure exerted on the wrench will strain the valve body and distort the seat so that the valve will probably leak. Valves should always be so placed in the pipe that the opening from the under side of the valve seat will be toward the direction of the pressure supply; in other words, the valve should close toward the pressure. If this is done, when the valve is closed, there will be no pressure against the valve stem packing and it will wear longer, and when closed the valve can be packed under pressure.

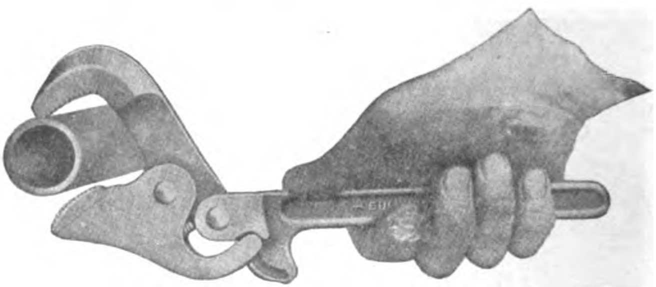


Fig. 11

Some valves are so constructed that when the valve is *wide open,* the top side of the valve disc makes a tight joint with the under side of the bonnet. Such valves may be packed while pressure is on and the valve open, *provided it is wide open.* All valve stems should be well packed with some form of prepared packing, or with cotton or asbestos wicking plaited to fill the packing space and well saturated with valve oil and plumbago.

All cut-out cocks used in the air brake and signal piping of locomotives and cars are so constructed that when the handle is lying *lengthwise* of the pipe the cock is closed, and when the handle stands at right angles to the pipe, the cock is open. This is opposite to the way the handles are attached to regular stock cocks. The only air brake cock differing from the above is the angle cock placed on the ends of the train line and to which the hose is attached. With this cock the handle and port are parallel and when open the handle is parallel with the pipe.

In taking old pipe down a joint which sticks may sometimes be loosened by striking it

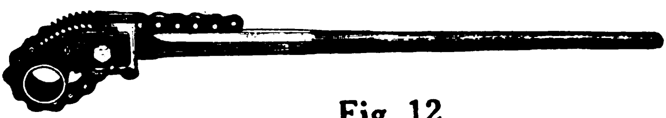


Fig. 12

smartly with a hammer while it is under full pressure from the pipe tongs; or these means failing, the fitting may be heated, which should be done as quickly as possible, so that the fitting may be hotter than the pipe. If it is not important to save the fitting, it may be split by a flat chisel, or in the case of cast iron fittings they are easily broken by striking with a hammer.

The piping of locomotives and cars is subjected to such severe usage that every expedient should be adopted that will reduce the leakage and loss from friction, hence pipe fittings for changing the direction of any pipe should be avoided wherever it is possible to bend the pipes and get them into position when bent. Many of the pipes on locomotives will be found so crooked that they will scarcely lie still when placed on the floor and the task of duplicating some of these examples of pipe bending is, to say the least, difficult.

Where large numbers of pipes are to be bent to the same shape and radius, a pipe bending machine will soon pay for itself. Such a machine is shown in Fig. 15. When pipes are bent for a special job and to a variety of radii, it would not pay to set up the machine, hence

Fig. 13

in the following it will be assumed that the work is to be done by hand.

While considerable experience is required before the best results can be obtained in hot pipe bending, the method to be pursued is simple. The most practical method is to fill the pipe to be bent with perfectly dry sand and plug or cap the ends so that the filling will be retained. The pipe should be well filled and care taken that nothing damp or inflammable gets into it, or the necessary heating is liable to cause an explosion. The heating may be done in an ordinary forge and should be restricted to the part of the pipe where the bend is to be made. Over heating should be avoided, as it will cause the pipe to scale, which will have quite an effect in reducing the strength of the pipe to resist bursting. The best results will probably be attained with the heat not carried above a full red, as the liability to kinking is less, and generally it will be necessary to take two or three heats before a sharp bend can be

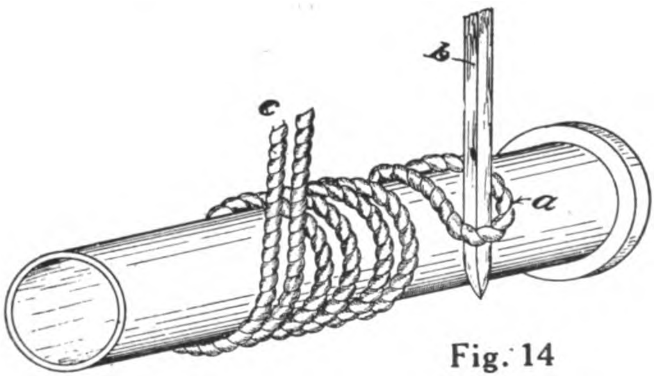


Fig. 14

satisfactorily made. A can of water should be provided having a spout so that a small stream can be directed exactly where needed. The proper use of water is important in securing bends without kinks, and as kinks look badly and also reduce the cross section of the pipe, they should be avoided.

After the pipe has been raised to the proper heat, it should be clamped in the vise as close to the location of the bend as possible without touching the heated portion, and the bend started. When bending the cheaper grades of butt welded pipe, care should be taken that the seam comes on the inside or the outside of the curve and not on the sides, as it is liable to open in the weld if it comes in the latter position. The portion of the pipe which will form

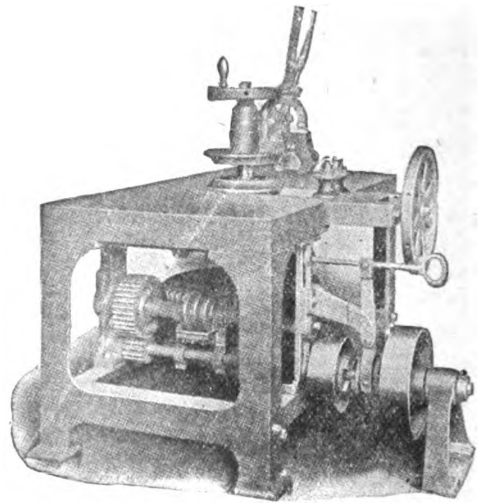


Fig. 15

the outside of the curve should be cooled with water, carefully applied from the can. In making the bend, the inside portion, being hot and plastic, will be compressed as the bend is made, with very little tendency towards flattening. If such a tendency should develop, it may be corrected by loosening the pipe and using the vise jaws to bring the flattened portion back to approximately a circular section. Another reason for applying the water to the outside of the curve is that by forcing the bend to take place on the inside of the curve, the pipe walls will be better supported by the filling, for the reason that the cubic contents will be slightly reduced by the compression, but if the outer part of the curve is allowed to stretch, the cubic contents of the pipe will be increased slightly, thus allowing a small amount of slackness in the filling, and a consequent lack of support to the walls of the pipe. When bending pipe without formers it is necessary to have a template, which may be made of ¼ inch rod, bent to the desired curve, and which is laid on the pipe while bending as a guide. As fast as the pipe attains the correct curve, that portion should be cooled, leaving the remainder in a condition to continue the bend as desired.

When pipes are bent it will generally be necessary to connect the various sections with unions, or right and left hand couplings, both of which are more likely to leak than the ordinary right hand coupling. However, if they are properly put together there should be no trouble, and furthermore, such a construction will be much easier to take down for repairs, which is a matter of importance in locomotive work.

After bending, the pipe should be thoroughly blown out, as the inside of a pipe seems to have a sort of skin which the bending breaks and loosens, and unless blown out, these pieces of scale are liable to get into the valves and cause trouble. It should also be tested for leaks.

All pipe work about locomotives and cars should be firmly clamped in position, as the majority of the loose joints, etc., are caused by the pipe shaking loose.

CHAPTER XV.

ERECTING SHOP WORK—AIR PUMP REPAIRS.

As it is the general practice in the majority of shops and roundhouses to have all air brake repairs attended to by one man, or set of men, the opportunity for the general machinist to acquire a knowledge of these repairs is limited. Hence the excuse for treating this subject in a way which, to many, may seem too detailed.

The air pumps in general use are the Westinghouse 8 inch, 9½ inch, 11 inch and compound pump, and the New York pumps Numbers 1, 2 and 5. Following is a brief description of the operation of each, a full understanding of which must be had before the question of repairs can be taken up.

The Westinghouse 11 inch and 9½ inch pumps are identical, so far as the principle of operation is concerned, so that the following description of the operation of the 9½ inch pump will answer for both.

Referring to Figs. 1 and 2, the valve motion of the pump consists of two pistons, 77 and 79, of unequal diameters, mounted on a rod 76, while a slide valve 83, of the "D" type, held in position between them by collars on the same rod, provides for the distribution of steam to the upper and lower sides of the main steam piston 65, as required. Steam enters the pump at *X*, where a suitable stud and nut admits of the direct connection of the pump governor, and by means of passages a, a_1 and a_2, is admitted to slide valve chamber A, between the two pistons, 77 and 79, and by reason of the greater area of the piston 77, tends to force it to the right, to the position in which the main valve is shown in Fig. 1, thus admitting steam to the under side of the main piston 65, through port b, and passages b_1 and b_2, forcing it upward, while the steam previously used on the opposite side in forcing the main piston downward is exhausted to the atmosphere through passage c, port c_1, cavity B of the slide valve, port d, and passages d_1 and d_2, to the connection Y, from whence it is conveyed by a suitable pipe to the smoke box of the locomotive and the atmosphere.

In Fig. 3 is illustrated an outside view of the main valve bushing 75, showing the relative arrangement of the ports therein, and of which port t communicates between chamber E in the main valve head 85, and exhaust passage f_1, and hence is in constant communication with the outside atmosphere, relieving the pressure on the surface of main valve piston 79, exposed to chamber E. A reversing valve 72 operates in chamber C, in the center of the steam cylinder head, steam being supplied thereto from slide valve chamber A, through ports e and e_1, and which is given motion through the medium of a rod 71, extending into the space k, of the hollow main piston rod. The duty of this valve is merely that of admitting steam to, and ex-

NINE AND ONE-HALF-INCH AIR PUMP.

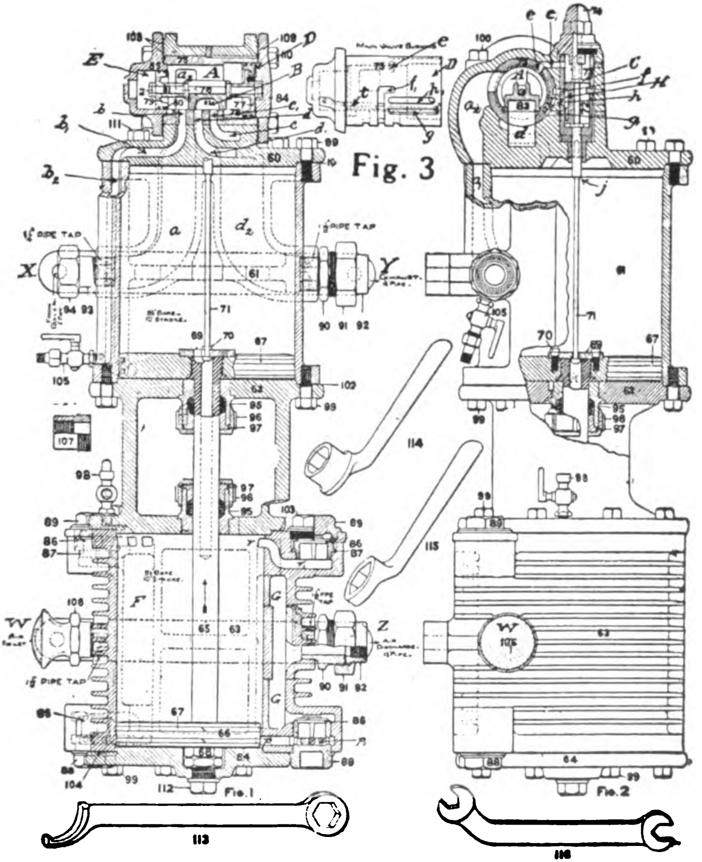


Fig. 1

Fig. 2

hausting it from space *D*, between the main valve piston 77 and main valve head 84, and is shown in Fig. 1, in position to exhaust the steam previously used, from the space *D*, through ports *h*, h_1, reversing valve cavity *H*, and ports *f* and f_1, to the main exhaust passages *d*, d_1 and d_2.

It will at once be apparent, having described how the surface of the main valve pistons 77 and 79, exposed in chambers *D* and *E*, respectively, being free from pressure other than that of the outside atmosphere, that the steam on their opposite sides in chamber *A* is exerting a force in both directions, but the total force to the right is greater by the sum of the steam pressure in chamber *A*, multiplied into the difference between their areas. This effect, however, is reversed when the main piston, approaching the upward termination of its stroke, strikes the shoulder *j*, of the reversing valve rod 71 (forcing the rod and its valve 72 upward), and causes the admission of steam from chamber *C* to chamber *D*, through ports *g* and *g*1, thus practically balancing the pressure *on both sides* of main valve piston 77, when the steam in chamber *A*, acting upon the effective area of main steam valve piston 79, forces the entire main valve structure to the left, causing the steam used in pushing the main piston upward on its previous stroke to be exhausted to the atmosphere and the admission of live steam to the upper side of the main piston, which forces it downward, until near the termination of its stroke, the plate 69 engages the button head on the lower end of the reversing valve rod 71, which moves the reversing valve 72 to the position shown in Fig. 2, thus completing the cycle of one double stroke or revolution of the pump.

Coincident with the reciprocal movements of the main steam and air pistons, air from the outside atmosphere is drawn alternately into the respective ends of the air cylinder 63, through the screened inlet 106, at *W*, chamber *F*, and receiving valves 86, and from thence is forced through ports *r*, and r_1, *p* and p_1 and discharge valves 86, to chamber *G* and the main reservoir, to which latter the pump should be connected by 1¼-inch pipe at *Z*.

The construction of the 8-inch air pump is clearly shown in Fig. 4. The main valve 7 controls the admission of steam to the main piston of the pump and its exhaust through a series of ports in the cylindrical bushings 25 and 26, that are suitably opened and closed by a reciprocating movement of this valve, which is composed of two pistons of unequal diameters mounted on the opposite ends of a suitable rod—the upper piston occupying bushing 25 and the lower one bushing 26.

The pump governor is attached to the pump by the union nut 54. Steam pressure present in chamber *m* will force main valve upward, by reason of the greater area of its upper piston, unless other mechanisms in the construction of the pump resist its movement, as will be

EIGHT INCH AIR PUMP.
PLATE F 5

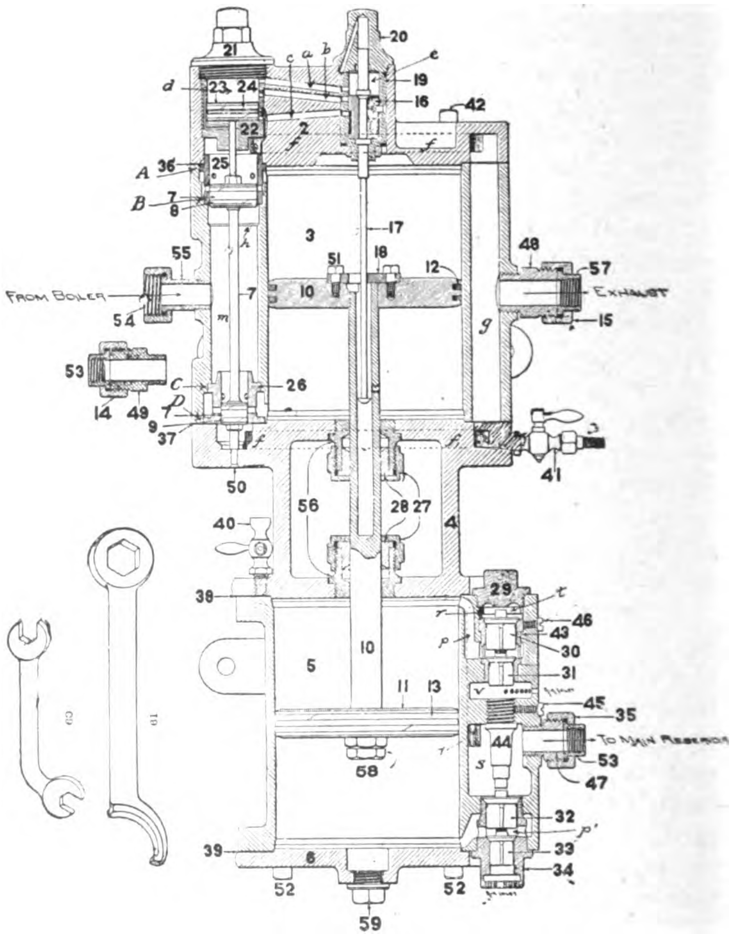


Fig. 4

described later. The opposite, or downward, movement of this valve is accomplished at the proper moment by the combined action of steam pressure on the upper surface of its lower piston and reversing piston 23, the stem of the latter extending through bushing 22, in which it operates, and bearing on the top of the main steam valve. Pressure on the upper side of reversing piston 23 is regulated by a small slide valve 16, in the central chamber *e*, of the upper steam cylinder head 2, to which steam pressure is conducted from chamber *m*, through port *h*. This valve is given motion by rod 17, which extends through bushing 19, in the upper head of the pump and into the hollow main piston rod 10, and is provided with a button-head on its lower end and a shoulder just below the top head which come in contact with plate 18 (attached to the steam piston), as the latter approaches the end of its stroke in either direction.

Steam from the boiler being admitted to chamber *m*, forces the main valve upward, opening the lower series of ports in bushing 25 and entering the steam cylinder above main piston 10, drives it downward, while the steam used in making the previous upward stroke is discharged from its under side through the lower series of ports in bushing 26, which are also uncovered by this upward movement of the main valve, thence through a suitably arranged passage *f*, *f*, shown in dotted lines, communicating with exhaust chamber *g*, whence it is discharged by a pipe connected at union swivel 57, through the smoke box and stack to the atmosphere. As the main piston reaches the termination of its downward stroke, plate 18, striking the button-head on the lower end of the reversing valve rod 17, draws the rod and its valve 16 downward, uncovers port *a* and admits steam to chamber *d*, which forces reversing piston 23 and main valve 7 downward to the position shown in the cut and permits steam from above the main piston 10 to be discharged through the upper series of ports in bushing 25, thence through passage *f*, *f* to exhaust chamber *g*, and to the atmosphere, while live steam is admitted from chamber *m*, through the upper series of ports in bushing 26, to the under side of main piston 10, driving it upward until plate 18 strikes the shoulder *n* of reversing valve rod 17, which pushes valve 16 upward and brings the small exhaust cavity in its seat opposite ports *b* and *c*, exhausting the pressure from above, reversing piston 23, into passage *f*, *f*, permitting the main valve to again move upward as previously described.

The upward movement of air piston 11 causes the lower receiving valve 33 to lift, and air from the atmosphere to be drawn through the series of inlet ports in the under side of valve chamber cap 34, thence past the valve and through port p^1 to the air cylinder; on the downward movement of the air piston, receiving valve 33 closes by gravity and the air contained in the cylinder is compressed to a pressure slightly in excess of that which may already be stored in the main reservoir, and lifting discharge valve 32 is forced into chamber *s*, and thence into the main reservoir through pipes connected at union swivel 53. The downward movement of the air piston similarly causes air to be drawn into the upper end of the air cylinder, through the upper inlet ports, to chamber *v*, upper receiving valve 31, and passage *p*. The receiving valve closing, air on this side of the piston in being compressed during the upward stroke raises the upper discharge valve 30, and is forced into chamber *t* and thence through communicating port *r* to chamber *s* and the main reservior.

Of the compound pumps the Westinghouse design known as the 8½-inch Cross Compound will be described. It is of the siamese type, having two steam and two air cylinders arranged side by side, respectively, the steam cylinders being at the top, as is the usual Westinghouse practice. The high-pressure steam cylinder is 8½ inches in diameter; the low pressure 14½ inches in diameter, both having 12-inch stroke. The low pressure air cylinder, located under the high pressure steam cylinder, is 14½ inches in diameter and the high pressure air cylinder, located under the low pressure steam cylinder, 9 inches in diameter. The valve gear is in the top head of the high pressure steam cylinder and is of a design similar to that of the 9½ and 11-inch pumps.

The high pressure steam piston, with its hollow rod, contains the reversing valve rod which operates the reversing valve, and it in turn the main valve and its slide valve, which controls steam admission to and exhaust from both the high and low pressure steam cylinders.

The low pressure steam and high pressure air pistons are connected by a solid piston rod, having no mechanical connection with the valve gear, being simply floating pistons.

The operation of the steam in the steam cylinders is on the same principle as in two cylinder compound engines generally, steam from the boiler being admitted to the high pressure cylinder; then, after doing its work, expanded to the low pressure cylinder, and from thence exhausted to the atmosphere, the two pistons being in motion at the same time, but moving in opposite directions.

Free air is taken into the larger air cylinder and by compression forced into the smaller or high pressure one; then, in turn, recompressed and discharged into the main reservoir.

As already stated, the valve gear and its operation is essentially the same as that of the 9½ and 11-inch pumps. The reversing valve performs the same duties and is operated by the reversing valve rod in the same manner as that of the 9½ and 11-inch pumps.

Referring to Fig. 5, which shows a diagrammatic section through this pump, the main slide valve is provided with the usual exhaust cavity, and in addition has four elongated steam ports in its face. The two outer and one of the inter-

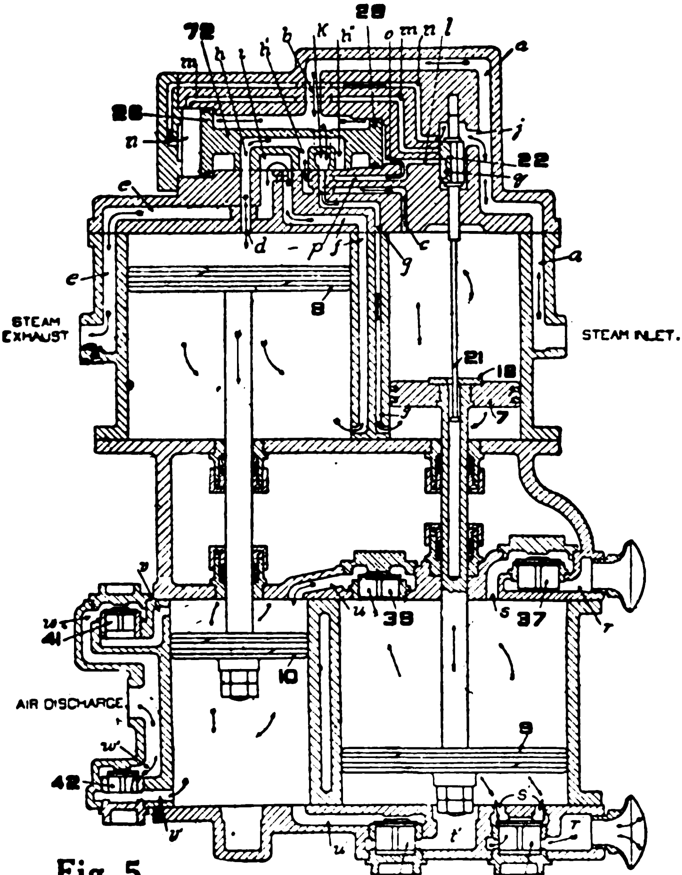


Fig. 5

DIAGRAM OF THE CROSS COMPOUND PUMP UP-STROKE, HIGH-PRESSURE-STEAM SIDE mediate ports communicate with two cored passages extending longitudinally in the valve and serve to make the proper connection between the high and low pressure cylinders during the expansion of the steam from one to the other. The remaining port controls the admission of steam to the high pressure cylinder. The cavity governs the exhaust from the low pressure cylinder to the atmosphere.

The valve seat has five ports. Of these the two back ones lead to the bottom and top ends respectively of the high pressure cylinder; the first and third ports to the top and bottom ends of the low pressure cylinder, and the second port to the exhaust. Figs. 5 and 6 show the parts in their relative positions while the pump is making an up and down stroke, the ports and passages being arranged to clearly indicate the passage of steam through them.

While steam is being admitted to the bottom end of the high pressure cylinder, carrying its piston upward, the main slide valve cavity opens the bottom end of the low pressure cylinder to the exhaust and at the same moment its cored passages connect the top end of the high pressure cylinder with the top end of the low pressure cylinder, thus expanding the steam from above the high pressure piston to the top end of the low pressure cylinder, moving the piston of the latter downward. During this time free air is being taken into the bottom end of the low pressure air cylinder, while that in the top end is being compressed into the high

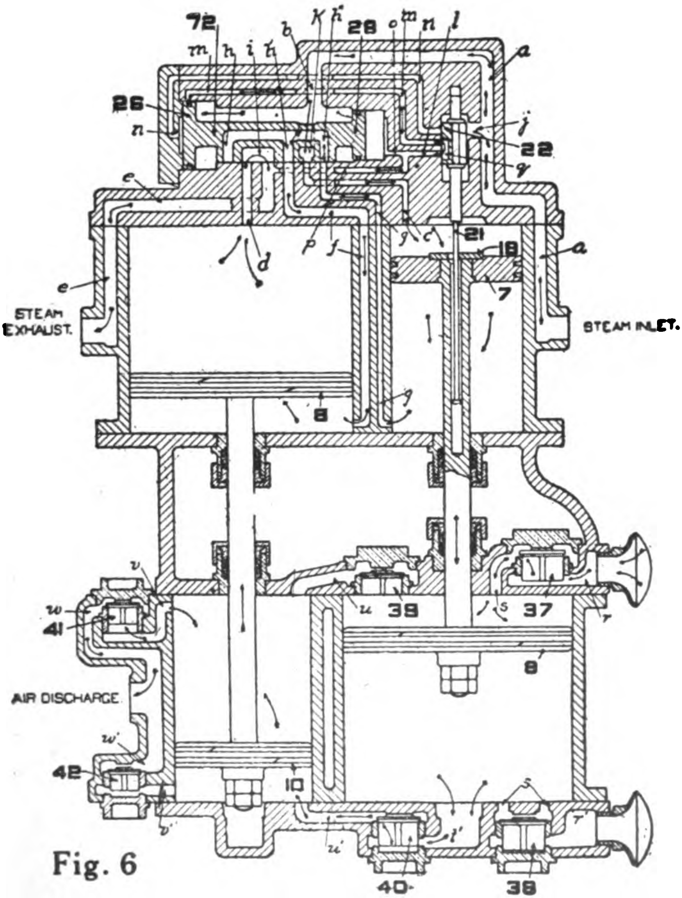


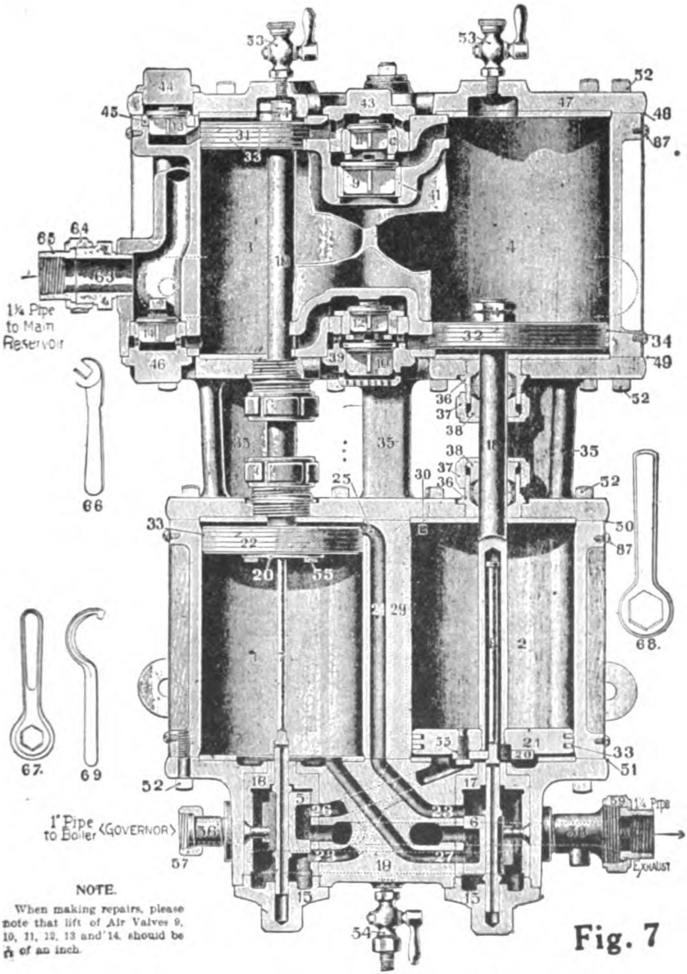
Fig. 6

DIAGRAM OF THE CROSS COMPOUND PUMP DOWN-STROKE HIGH-PRESSURE-STEAM SIDE pressure air cylinder. During the piston stroke this intermediate pressure is being built up from the atmosphere to about 40 pounds, a result of compressing the air from the large to the small air cylinder, a similar increase obviously taking place above the high pressure air piston and which exerts a downward force on that piston the same as does the steam above the low pressure steam piston. On the opposite or lower side of the high pressure air piston, the intermediate air under compression to the main reservoir is exerting a resistance equal to the area of the piston plus the main reservoir pressure and which is greatly less than the combined steam and air pressures on top of the respective pistons.

When the pump mechanism is reversed, the action is simply a repetition of that above described.

The New York pumps differ radically in construction and operation from the Westinghouse pumps. Fig. 7 shows the No. 2 pump, the No. 1 being smaller and the No. 5 larger, differing from it only in the matter of size. Referring to the figure, it will be seen that the pump has four cylinders, two steam and two air. The two steam cylinders 1 and 2 and the high pressure air cylinder 3 are 7 inches in diameter, but the low pressure air cylinder 4 is 10 inches in diameter, being twice the capacity of the steam cylinder actuating it and also twice the capacity of the high pressure air cylinder 3. In this pump the steam cylinders are at the bottom, with the air cylinders above.

No. 2 Duplex Air Pump.



NOTE.

When making repairs, please note that lift of Air Valves 9, 10, 11, 12, 13 and 14 shoud be $\frac{1}{16}$ of an inch.

Fig. 7

Steam and Exhaust openings are now provided on both sides of the pump so that it can be placed on either the right or left side of the locomotive, by simply changing plugs. It is arranged for the right hand side, unless otherwise specified.

Steam being shut off from the pump, pistons 21 and 22 together with main steam valves 5 and 6 will be in their lowest positions. Port 23, 24 and 25, leading to cylinder 1, and port 26 leading to cylinder 2, will be open. On opening the throttle live steam will enter the pump through the governor connection 56, filling the chests, and enter ports 23, 24, 25 and 26. As piston 22 is down the steam entering port 23, 24 and 25 will have no effect other than to hold it down. Steam entering port 26 will cause piston 21 to make an up stroke, piston 32, in cylinder 4, discharging air through valve 11 into cylinder 3, and at the same time air will be drawn into the lower end of cylinder 4 through valve 10. On reaching the end of the upward stroke the plate 20, on piston 21, will come in contact with the button on the end of valve rod 8, moving valve 6 up, thus opening port 27 to live steam and placing ports 23, 24, 25 in communication with the exhaust passages through the cavity in valve 6. Piston 22 will now make an up stroke, discharging the air in cylinder 3, through the upper final discharge valve 14, into the main reservoir. At the same time air from the atmosphere will be drawn through valves 10 and 12 into cylinder 3, under piston 31. As piston 22 reaches the end of its upward stroke, plate 20 will come in contact with the button on valve rod 7, moving valve 5 to the position shown in Fig. 7. This will admit steam to the upper side of piston 21, through ports 28, 29, and place port 26, in communication with the exhaust passages. Piston 21 will make a down stroke, discharging the air in cylinder 4, through valve 12, into cylinder 3. At the end of this stroke plate 20 will strike the shoulder on valve rod 8, moving valve 6 to its lowest position. This will admit steam through ports 23, 24, 25, to the upper side of piston 22, causing that piston to descend and discharge the air in cylinder 3, through the lower discharge valve 14, into the main reservoir. As will be seen from the foregoing, *each air cylinder fills with free air at every stroke.* The first operation forces air from the larger cylinder to enter the smaller one, in addition to the free air already in it, thus compelling the smaller cylinder to contain three times its volume of free air, compressed to about 40 pounds. The high pressure piston then completes the compression and forces this air into the main reservoir.

Air pump repairs may be divided into two classes, viz.:

1. General or thorough.
2. Roundhouse, or running.

General repairs should mean the re-building of the pump, making it practically as good as new. Roundhouse, or running repairs, should be confined to the correction of minor defects, such as renewing worn packing rings in the air cylinder, repairing air valves, etc.

Following are the more common indications of defects as reported by engineers, and the probable trouble. In the majority of these cases the remedy is self-evident once the cause is determined. For information as to the proper method of correcting these defects the reader is referred to the latter part of this chapter, which covers making general repairs to pumps.

When possible it is best for the repair man to test the defective apparatus and locate the direct trouble, thus using his head first and his hands and tools next. This will result in the work being done more quickly and satisfactorily. The work reports turned in by the engineers are often defective in that they fail to give enough information as to the symptoms to enable the repair man to tell exactly what the trouble is without making a test, and they lose sight of the fact that by the time the repair man may get to the engine it may be cold and no opportunity given to make a test of the defective apparatus.

The roundhouse air-brake man should have a complete equipment of tools for carrying on the work rapidly, as well as such complete parts as are liable to give out, which will allow the necessary changes to be made with the minimum loss of time. A suggestive list of tools which the roundhouse man should possess, or have access to, is included in the following:

1. One air pump hoist.
2. One device for lifting air pump.
3. One top head lifter.
4. One packing nut compressor.
5. One discharge valve stop wrench, 8-inch pump.

6. One air piston and head disconnector.
7. One piston holder, while tightening nuts.
8. One 8-inch valve case remover.
9. One main valve and reversing piston remover.
10. One air lift gauge.
11. One tool for cutting off the top of air valves for the proper lift.
12. One pair of small sized tongs.
13. One brake valve separating tool.
14. One equalizing piston and valve seat reamer.
15. One feed valve piston remover.
16. One hose gasket and coupling cleaner.
17. Set of fittings for applying test gauge.

Some of these tools are shown in Plate No. 1, and bear the numbers given above. In addition to the above special tools, the repair man should have a tool box for carrying small tools. These small tools should include one hammer, one 12-inch monkey wrench, small scrapers, several chisels, packing hooks, one 8-inch and on 18-inch Trimo or Stilson pipe wrench, one steel bar, and the proper sized well fitting wrenches for the different sized finished nuts.

PUMP DEFECTS.

WESTINGHOUSE PUMPS.—*Pump Pounds.*—This may be the result of too light a frame, frame loose, or the pump loose on the frame; air valves having too much lift; worn or tight packing rings in the main valve or the reversing piston of the 8-inch pump; air or steam piston head loose on the piston rod.

Pump Runs Hot or Does Not Pump Up Pressure Rapidly When Run at Proper Speed.—This trouble has increased during the last few years owing to the introduction of the high-speed brake and the duplex method of control with their higher pressures. It is the symptom of the air cylinder being in poor condition due to worn packing rings, leaking air valves, or choked air passages. To locate the defective parts proceed as follows. Pump up the main reservoir to 90 pounds or more. If, with the pump running at a moderate speed, the suction is complete for each stroke, or nearly so, it is good evidence that there is no leakage. In this case the trouble will probably be found in choked air ports and passages, due to dirt and the use of too much oil in the air end of the pump. If the suction is poor, stop the pump, open the oil cup and remove the plug from the bottom head. Any flow from these openings will indicate leakage past the discharge valves or their bushings. If none is apparent it is evidence that the cylinder packing rings are in poor condition. If the trouble is with the packing rings and the cylinder is in good condition and not more than $\frac{1}{32}$ inch larger at the ends than at the center, new rings should be fitted. If the cylinder is found in poor condition, the pump should come off and be sent to the repair room. If the trouble is with the valves or valve bushings they should be refitted. In case the trouble is found to be due to choked air passages and ports they should be cleaned out thoroughly by working a hot solution of lye through the pump. Run the pump slow and allow the solution to go to the main reservoir (if there is no hose between the pump and the reservoir). Use two or three buckets of the solution. After working this through the pump, dividing it about equally between the upper and lower ends, thoroughly rinse the pump with clean hot water. Tighten up, or renew all gaskets between the pump and reservoir and give the pump a good oiling. This does not mean a large quantity of oil but rather to see that what oil is used gets to the proper place. *Never use kerosene to clean the air end of a pump, as the heat of compression is liable to cause a serious explosion.*

Pump Runs Too Slow.—This is the symptom of small or clogged discharge pipes; a small or clogged exhaust pipe; too little lift to the discharge valves. With the first and last cause it is generally accompanied by heating. The proper remedy in each case is evident.

Pump Has Unequal Stroke.—This is an indication of unequal lift of the discharge valves (the slow stroke will be toward the valve having the least lift); a broken or stuck valve; leakage past a discharge valve or bushing; or defective valve motion. Any trouble with the receiving valves is apparent by an examination of the suction inlets. If a discharge valve is stuck or broken there will be defective suction at that end. Leakage past a discharge valve or bushing will wholly or partially destroy the suction at the end having the defective valve. If the trouble seems to be with the valve motion, the pump should be taken off and sent to the repair room, as it is sometimes very difficult to locate the exact cause of the trouble.

Pump Stops.—In case a pump is reported as stopping, first see that it is receiving steam, as the trouble may be with the governor. This may be done by disconnecting the governor at the governor union stud. If an 8-inch pump, remove the reversing cylinder cap 21, and if on opening the throttle, steam comes from the port *a*, it indicates that the reversing valve is getting steam. Examine this piston to see if it is properly lubricated, and that it is in good condition. On account of its position it frequently fails to get a sufficient quantity of oil. A frequent cause of stoppage is a leak past the reversing cylinder from port *a* to port *b*, making the pressure on top of the reversing piston insufficient to force the main valve down. With the 9½ and 11-inch pumps, excessive leakage past the small main valve piston head 79 will, on account of the small size of the port leading from the left main valve cylinder head 85 to the exhaust passages, prevent the main valve moving to the left. In this case the pump will stop at the top end of the stroke. If the piston rod nuts 58 or 68 work off or split they will generally cause the pump to stop at the bottom. By taking out the bottom plug the condition of these nuts may be seen. A loose or badly worn reversing plate will cause stoppage at the bottom, while if one of the reversing plate bolts works up it will cause stoppage at the top. A broken reversing valve rod will generally cause stoppage at the bottom. A broken main steam valve stem will generally cause the pump to stop on the bottom. If the stop pin 50 is too short it will allow the main steam valve to drop down low enough to let the lower packing ring 9 catch on the bottom of the bushing 28. This will cause stoppage at the top of the stroke.

Pump Dances or Short Strokes.—If a pump dances or short strokes the reversing valve rod will generally be found bent in case the steam pressure is full. Sometimes in starting a pump the pressure will be insufficient to hold the reversing valve to its seat with force enough to prevent its dropping down and reversing the pump before the piston has made a full stroke. This also may happen when the governor shuts the pump down.

In removing the top head, always take out the reversing valve rod first, and this may be done by holding the main piston about half way up in the cylinder. In putting on a new head never place the reversing valve and rod in position until the head is in place, and be sure the reversing valve is in right. With the 8-inch pump it is a very easy matter to put this valve in so that it will leave all the ports open, in which case the pump will not start.

New York Pumps.—*Pump Pounds.*—The causes are the same as were given under this heading for Westinghouse pumps, and in addition worn steam valves, reversing rods or plates.

Pump Runs Hot or Does Not Pump Up Pressure Rapidly When Run at Proper Speed.—The causes are the same as were given for the Westinghouse pumps. However, owing to the difference in the construction of the pumps a different method of testing for leakage must be used. In testing the New York pump for leakage, first ascertain if all air valves are tight and that no leakage takes place past the seats or chambers. If receiving valves 9 and 10 leak, air will be discharged from them when piston 32 makes a stroke toward the defective valve. If these valves are found tight, or repaired if found defective, valves 11 and 12 should be tested. The main reservoir should be pumped up to at least 90 pounds. If either of these valves or their seats leak, the low pressure piston will make a quick stroke away from the end in which the defective part is located, and the receiving valve at that end will fail to lift promptly. A defective cylinder head gasket between the low and high pressure cylinders will have the same effect, but should be of rare occurrence if proper care is exercised in assembling the pump. To test for leakage past the final discharge valves, stop the pump and allow the pistons to settle to the bottom of their cylinders. Open both oil cups, and if a continuous flow exists from the high pressure cup, the piston remaining stationary, the upper discharge valve 13 is leaking. If the piston 31 should rise, the lower discharge valve 14 is probably leaking. To test for leaking packing rings it should be known that the air valves are in good condition. If, with the pump running at about 30 strokes per minute (double), the suction is weak and ceases shortly after the piston has commenced its stroke, it is evidence that the packing rings are leaking. If there is a flow from either oil cup when the piston in its cylinder is moving down, the packing rings in that cylinder are leaking. In general, leaking packing rings, air valves and gaskets cause the pump to make irregular strokes and to heat up quickly.

If the air passages are found to be dirty, the pump should be washed out as was described for the Westinghouse pumps.

Pump Runs Too Slow.—This will be the result of choked discharge ports, or too little lift to the valves. If the trouble is with the intermediate valves, the low pressure piston will be sluggish, while if it is the final discharge valves or ports, the high pressure piston will be affected.

Pump Lame.—With the New York pump this trouble is almost entirely the result of derangements in the air cylinders, such as leaking valves, packing rings, unequal lift of valves and valves stuck or broken.

Pump Stops.—This may be caused by piston rod nuts 74 working off or breaking; reversing plates badly worn; loose reversing plates or reversing plate bolts 53 working out; valve rods 7 and 8 badly worn or broken. If the trouble is not in the governor and on opening the throttle the low pressure piston makes a stroke up and stops at the top, the high pressure piston remaining stationary, the trouble will be the failure of the high pressure valve 6 to move. If under the same circumstances both high and low pressure pistons make the up stroke and stop at the top, the trouble will be found to be the failure of the low pressure valve 5 to move, due to any of the causes mentioned above.

In locating air pump troubles good judgment must be exercised and a little thought given to cause and effect, otherwise a great amount of unnecessary work will be done.

AIR PUMP GENERAL REPAIRS.

For the purpose of describing the method of making general repairs to an air pump the 9½-inch pump will be taken as an example, as at the present time there are more of these pumps in use than of any other type.

Preparatory to thoroughly overhauling a pump it should be completely dismantled and placed in a suitable lye tank. If several pumps are being attended to at one time, keep the parts of the different pumps separate. The lye solution should be heated, but the steam should not be admitted directly into the tank, as with this method the solution is rapidly diluted; a coil of pipe with a suitable drain should be used. The pumps should be allowed to remain in the lye until all grease and dirt have been removed. After removal from the lye, blow off with a steam jet, paying particular attention to see that all ports are perfectly clean. It will sometimes be necessary to use scrapers to remove the accumulation of dirt from the discharge ports of the air cylinders, and these should be cleaned down to the iron. After the cleaning examine all parts carefully, returning those suitable for further service to the pump, and scrapping all defective parts. Do not allow a lot of partially worn out parts to accumulate around the shop, but a small number of second-hand valve bushings or cages, reversing cylinders, pistons, etc., may be kept on hand, which, while not good enough to place in a re-built pump, will answer for renewals in making running repairs. In making repairs to pumps, as well as all air brake apparatus, there are two very important things to bear in mind, viz., *workmanship* and *standards.*

Top Head.—The portion of the main valve bushing 75 forming the cylinder for the large main valve piston 77 has a tendency to wear quite rapidly, forming a shoulder at each end, which must be removed by filing or scraping before new packing rings can be fitted. If worn $\frac{1}{32}$-inch larger than standard it will require a new main valve bushing, or the old one bushed. The practice of scrapping this bushing and applying a new one for this reason alone is to say the least extravagant. This main valve bushing should be pressed out of the head, put in a lathe and bored out to $3\frac{5}{16}$ inches, after which a bushing should be turned to fit the bore of the main valve bushing, pressed into position and bored to standard size, properly faced and ports drilled. It should be secured from turning by a taper dowell pin as shown in Fig. 8. The main valve bushing is now ready to be pressed back into the head. Care should be used that the bushing is not made too tight, as it simply needs to be tight enough to prevent steam leakage, and as the main valve bushing will be quite thin, if the small bushing is too tight it will either spring the main bushing so it will not fit the head, or will crack it. This work should be done for not to exceed $1.00, while a new main valve bushing will cost $4.75. In a similar manner the left main valve cylinder head 85 should be placed in a lathe and bored to 2⅜ inches, after which a bushing should be turned and pressed into the head, bored and faced to standard size, and ports properly drilled as shown in Fig. 9. The large and small main valve packing rings Nos. 78 and 80 should be removed and new ones applied and properly fitted. These rings should be a neat fit in the grooves, but not too tight. The main slide valve 83 and its seat should be properly faced. If this valve has $\frac{3}{64}$ inch play between the shoulders of the main valve stem 76, either a new valve should be applied, or a new stem, depending on which one is worn, the idea being to maintain the parts standard.

Reversing valve, chamber bush 73 should be removed and a new one applied, also a new reversing valve 72. This valve should be "spotted" to

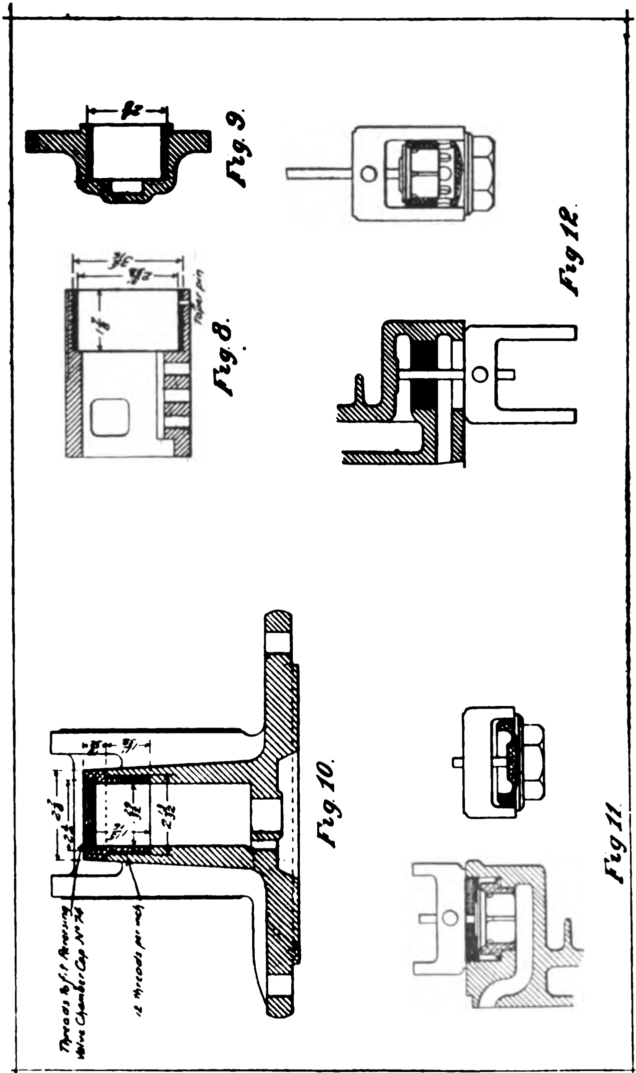


Fig. 8. Fig. 9. Fig. 10. Fig. 11. Fig. 12.

its seat in the reversing valve chamber bushing. An old valve will not give good results if applied to a new bushing. If there is $\frac{3}{64}$ inch play between this valve and the shoulders on the reversing valve rod, if the valve is new, a new rod should be applied; if the rod is new a new valve is called for. Great care should be also taken that the distance between the shoulder and the button head on the reversing valve rod is correct, and if not, the rod should be scrapped. If the threads by which the reversing valve cap 74 is held are stripped or in poor condition, the head should be scrapped, or preferably repaired as shown in Fig. 10. Here the head is bored out to a diameter of about $2\frac{13}{16}$ inches for a depth of $1\frac{15}{16}$ inches, and a 12 pitch thread cut in same. The top of the head is cut off about $\frac{11}{32}$ inch and a bushing made as shown. The top of this bushing is threaded to take the reversing valve chamber cap. After the bushing is screwed into position a light cut is taken through it to true up the chamber for the reversing valve bushing. As the latter is made large to allow repair men to turn to fit, a light cut taken through the chamber does not make any difference. The port by which the main valve chamber and the reversing valve chamber are connected is drilled after the bushing is in position. The reversing valve chamber cap 74 should be fitted so that the two joints (the one on top of the bushing and the joint with the head) are made at the same time. They should both be perfect joints, the one with the bushings being lighter than the one with the head.

Center Piece.—The packing glands 95 should be examined to see that they are tight in the center piece, and that the threads for the packing nuts 96 are in good condition. If not the glands should be renewed. The thread in the center piece should fit air tight, and the glands be drawn down tight to a bearing on the center piece. Use white or red lead on the joints and threads. The oil cup 98 should be examined and repaired or renewed as may be necessary. The stuffing box nuts should fit neatly and if the threads are not in good shape, the nuts should be renewed.

Air Cylinder.—If the air cylinder is worn $\frac{1}{32}$ inch or more larger at the ends than at the center, it should be re-bored. Some repair men simply true them up; some bore them out by $\frac{1}{16}$ inch and others make them $\frac{1}{8}$ inch larger than the orignial size. Which method is the better will depend on local conditions. The seats in the cylinder casting for the air valve seats 87 should be cleaned so that the seats will have a good bearing and be air tight. The lower air valve cages 88 should be a tight fit in the thread where screwed into the cylinder, as the tightness of this fit must be depended upon to prevent leakage from the main reservoir, in the case of the discharge valves. These caps must also make an air tight joint with the face of the cylinder. If the parts of the cages which form the guide for the valve wings are not too much worn, and they are otherwise in good condition, the valve seats should be trued up and new valves fitted. It will generally be found necessary to do quite a little filing on steel valves before attempting to grind them, on account of their having high spots on the seat in line with the wings. The upper valve chamber caps 89 should have the under surface, which acts as a valve stop, trued up before facing the valves off for lift. All the valves in the 9½-inch and 11-inch pumps should have $\frac{3}{32}$-inch lift, which may be secured most conveniently by means of the gauges shown in Figs. 11 and 12. These gauges are the design of Mr. M. H. Shepard, Foreman of Air Brake Repairs of the New York Central, at West Albany. These may be made in a variety of forms to suit the individual taste of the man using them; the only essential point is that the length of the movable post must be $\frac{3}{32}$ inch, the lift of the valves, longer than the height of the body of the gauge. The method of using it is shown by the illustrations and needs no further explanation.

Pistons and Piston Rod.—The air piston head 66 should be a neat sliding fit in the cylinder, and should fit the piston rod an easy driving fit. A large number of loose air piston heads is caused by the piston being a loose fit on the rod. The packing rings 67 should fit the grooves without any lost motion, but loose enough to be easily moved by hand. They should be larger than the cylinder by about $\frac{3}{32}$ inch to $\frac{1}{8}$ inch, and after sawing in two and fitting the ends, should be placed on a suitable mandrel or chuck and turned to the exact size of the cylinder. When a spring ring having a diameter greater than the cylinder is cut and placed in the cylinder it will fit about as shown in Fig. 13. From this figure it will be seen that the ring bears on the cylinder for about one half the circumference from *b* to *c* and again at the point *a*, where the ring is cut, and does not touch the cylinder walls from *a* to *b* and *a* to *c*.

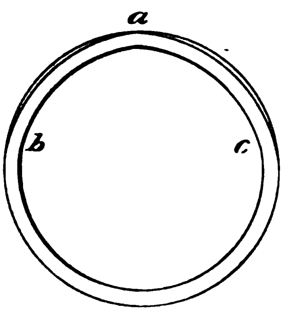


Fig. 13

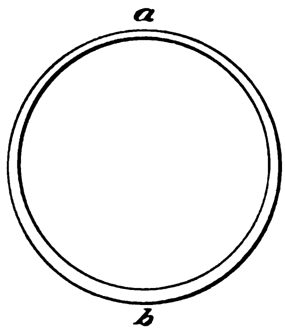


Fig. 14

If the rings are not turned after cutting they must be filed at the point *a*, each way toward points *b* and *c* until a good bearing is had. Fig. 14 shows a form of ring which is very suitable for running repair work. This ring is the usual depth at *b*, and one-half this depth at *a*, where the cut is made. Owing to its shape it is much easier fitted than the usual form. The steam piston head should not be more than $\frac{1}{16}$ inch smaller than the steam cylinder, and if metallic packing is used the rod should not be more than $\frac{1}{16}$ inch below the standard size. The lower end of the rod, in case it is not turned up in the lathe, should be filed down to the same size as the balance of the rod. Run a solid die of standard size over the threads for nuts 68 and see that they are in good condition. These nuts should be a tight fit on the rod. Reversing plate 69 should be removed and examined for wear and renewed if necessary. These plates wear much faster on the under side than on the upper. See that new reversing plate bolts 70 are used, for as these are small they are generally strained more or less in tightening down and are very liable to fail if used the second time. They should be secured from turning by some form of a locking device. The packing rings 67 should be fitted in the same manner as was described for the air end.

Steam Cylinder.—If the steam cylinder is worn $\frac{1}{16}$ inch larger at the ends than in the center it should be re-bored. The one-inch steam pipe stud 93 should be examined to see that it is tight in the cylinder, and that the threads in nut 93 are in good condition. The one and one-fourth-inch union stud 90 should be similarly examined. All drain cocks should be examined and repaired or renewed where necessary.

Assembling.—All joint surfaces on cylinders and center piece should be cleaned perfectly with emery cloth; also all gaskets must be thoroughly annealed and cleaned. Paint the joint surfaces with a mixture of white lead, plumbago and varnish and bolt together, using annealed bolts. See that the bolts do not extend beyond the surface of the cylinder flange, for if they do they will probably stick and be broken when necessary to take the pump apart again. Use plumbago and lard oil on all bolts and caps. After bolting the cylinders to the center piece, place the piston in position and secure the air piston head. Before doing this see that all piston packing, glands, nuts, etc., are in proper position. Draw the nuts 68 up firmly with a wrench of suitable length so that you can judge correctly how tight they are. In addition they should be secured by some form of lock nut. Try the piston by moving it in the cylinder a few times and leave it in about the center of the cylinders. Bolt on the top head and place the reversing valve and rod in place and put on the bottom head. The pump is now ready for the testing rack, where it should be run long enough to develop any defects and assure its efficiency when placed in service. If any of the gaskets show a tendency to leak they can generally be fixed by lightly caulking with a thin tool, but care must be exercised in doing this not to close in any of the ports through the top gasket.

In general the foregoing directions apply equally to the eight-inch pump, except as to some of the details covered in the following.

Air Cylinder.—The seats for the upper air valve chamber bush 43 should be carefully cleaned, using a reamer similar to that shown in Fig. 15. The two seats *a* and *b* of this bushing, Fig. 16, must be ground to an air-tight bearing. See that the set screw 46 enters the counter bore in the bushing enough to keep it from turning, but that the point does not touch the bushing when the screw is up tight. You should be able to move the bushing slightly with the set screw tight. The upper valve chamber cap 29 must make an air-tight joint on the

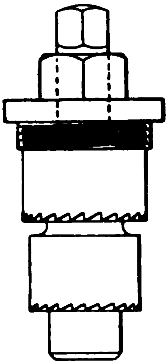


Fig. 15.

cylinder, its under surface bearing evenly, but not too hard, on the top of the valve bushing. If this cap bears unevenly on the bushing it will spring it, causing leakage, and the upper end will probably break off. After fitting the bushing and cap, grind in the valves 30 and 31. They should have a good bearing on the seats, but not too wide, or they will stick. The seats should be reamed with a reamer as shown in Fig. 17 and the width of the

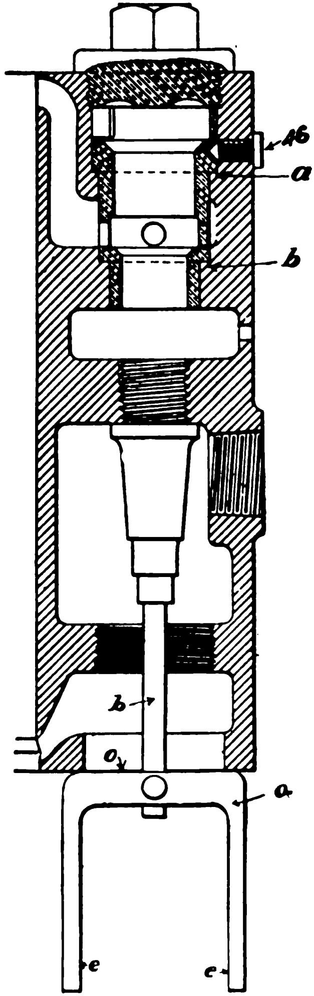


Fig. 16

seat and the clearance for the valve cut by placing the bushing in a lathe. As the bottom of valve 30 forms the stop for valve 31, it should be filed off square. In filing off the tops of these valves to get the required lift, get them square so they will have a full bearing against the stop. Give the discharge valves $\frac{1}{16}$-inch lift, and the receiving valves $\frac{3}{32}$ -inch lift. Examine the discharge valve stop 44, and if the end is much

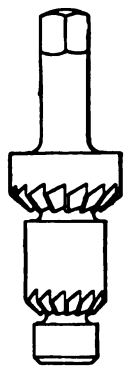


Fig. 17

worn it should be taken out and a new one used. It should be a snug fit in the cylinder, otherwise there will be leakage past it to the atmosphere under the upper receiving valve. The lower valve chamber cap 34 should be a tight fit where it screws into the cylinder, in order to prevent back leakage from the main reservoir into the cylinder. It must also fit air tight against the lower face of the cylinder. For determining the lift of the receiving valves and discharge valves, use a tool as shown in Fig. 10, Plate I, also in Figs. 16, 18, 19, 20 and 21. The first one consists of the body *a*, movable post *b*, with a nut for securing the post in position; also the piece *d*, one end being the thickness of the lift for the receiving valves, or $\frac{3}{32}$ inch, and the other end the thickness of

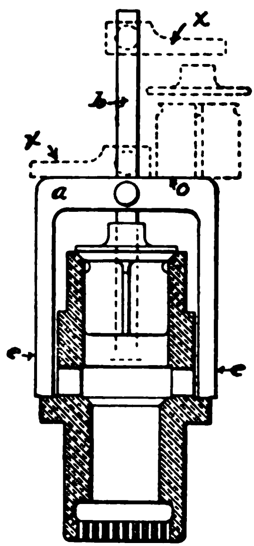


Fig. 18

the lift of the discharge valves, or $\frac{1}{16}$ inch. A similar gauge should be made for the $9\frac{1}{2}$-inch pump and the New York pumps. A table of the dimensions suitable for all three gauges is given. To use the gauge to get the lift of the lower discharge valve of an 8-inch pump, place the face *o* against the face of the cylinder and raise the post until it strikes the stop, securing it in this position. With the discharge valve on its seat, place the legs *e*, *e* on the cap joint and when the lift is correct the lift gauge *d* will just pass between the post and the valve, as shown in Fig. 18. To get the lift of the upper discharge valve the operation will be reversed. See Figs.

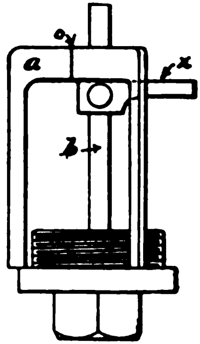


Fig. 19

19 and 20. The legs *e*, *e* will be placed on the joint face of the upper valve chamber cap, and the post adjusted to the stop, and the adjustable piece *x* placed against the under side of the gauge and secured. Then with the surface *o* resting on the cylinder joint, the valve should be filed until the lift gauge will pass between the piece *x* and the body of the gauge, as shown in Fig. 20. In case it is desired to get the lift of the upper receiving valve without

removing the bushing, place the upper discharge valve on its seat and with face *o* resting on the cylinder joint, lower the post until it rests on the top of the discharge valve. Secure it in this position and adjust the piece *x* on the post with the flat surface resting against the face *o*. Loosen the sliding post and move it until,

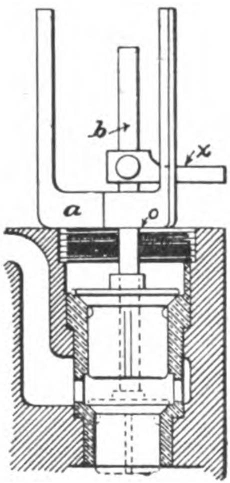


Fig. 20

with the discharge valve resting on *o*, Fig. 18, the lift gauge for the receiving valve will just pass between the valve and piece *x* and secure the post in this position. Remove the piece *x* and if the lift of the receiving valve is correct the end of the sliding post will rest on the receiving valve when face *o* of the gauge is on the cylinder joint. Be sure the bottom of the discharge valve has not been worn by the receiving valve striking it; if it has it should be filed up square.

Center Piece.—Repairs to the center piece for the 8-inch pump are the same as for the 9½-inch pump, except that from the face of the center-piece to the top of stop pin 50 should measure exactly $\frac{25}{64}$ inch. If not correct a new pin should be put in. This may be done by drilling out the old pin, making the hole about ½ inch. Make a new pin out of ⅝ inch round iron to go in the hole a tight driving fit.

Steam Cylinder.—Bushings 25 and 26 should be carefully calipered and if worn new ones should be fitted. In fitting these bushings they should be a fair driving fit at *A* and *B* and *C* and *D*, as they must be steam tight, and faced to such length as will bring them flush with the face of the cylinder. Main steam valve 7 should be examined to see that the stem is straight and of standard length and that the nuts on the top and bottom heads are tight and properly secured. Care should be used in fitting packing rings 8 and 9 to see that they fit the grooves in the heads and that they have a good bearing in the bushings. You should be able to move the main valve by hand.

Steam Head.—Generally if a pump has been in service any length of time, the reversing valve bushing 19 will need renewing, both on account of the wear of the reversing valve 16 and the reversing valve rod 17. This bushing should fit the head a tight driving fit. In turning it in the lathe, nothing should be faced off the top or bottom, they being just trued up in case they run out. The reversing valve rod should fit this bushing, and the cap 20, a neat sliding fit. The joint surface on the head for caps 20 and 21 should be scraped to a surface plate. After bushing 19 and reversing cylinder 22 are in position, the caps should be fitted so that the two joints (the one on top of the bushings, the other with the head) are made at the same time. They should both be perfect joints, the one with the bushings being lighter than the one with the

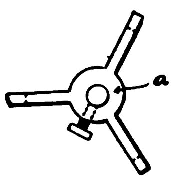


Fig. 21

head. The reversing cylinder should be examined as to the fit of the piston stem, which should be a neat sliding fit. If the cylinder is not worn over $\frac{1}{64}$ inch larger than standard size, the top and bottom part of the bore which the packing rings do not cover should be filed or scraped to the same size, or trued up in a lathe. The reversing piston packing rings should be carefully fitted to the cylinder so that they show a good bearing for their entire circumference. The cylinder must be a good fit on the tapered portion or there will be leakage from steam port *a* to the exhaust passages, in which case the pump would be liable not to reverse. On cylinders where this fit is defective it may be remedied by turning a small groove as shown in Fig. 22, and fitting a $\frac{1}{16}$ inch copper wire gasket. In case the top of the cylinder where the reversing valve chamber cap screws in is defective, it may be repaired in a similar manner to that described for the 9½-inch pump.

The extended use of the high speed brake with its train line pressure of 110 pounds and reservoir pressure of 130 pound, sand also the

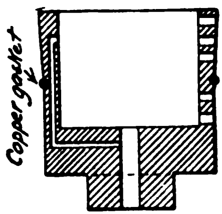


Fig. 22

increase in reservoir pressure on freight engines, requires that the repair work on the air end of pumps must be of a better quality than was the practice with the lower pressures. More care must be used in fitting packing rings, valves and bushings; cylinders must be re-bored and packing rings renewed oftener than has been the custom in the past. Under the hard usage of to-day the air cylinder packing rings will last about three months, and by this time it will generally be found that the valves will have excessive lift. It should be borne in mind that the air pump is the backbone of the whole air-brake system, and a failure of the pump to properly perform its work means the failure of the entire apparatus.

The foregoing instructions will apply to the repair of the New York pumps, and the Westinghouse compound pumps, with such variations as may be necessary due to the difference in the detail construction.

POINTS IN REPAIRING.

All pump bolts and the air ends of piston rods should be annealed by heating to a dull red, and placing in lime until cool. When removed from the fire they should be carefully examined for cracks, as any such can then be easily seen. Do not heat too hot or they will scale.

Copper gaskets should be annealed by heating to a red heat and quenching in water. If they are wet and sprinkled with common salt on each side before heating, they will come out of the water almost as clean as new material.

Make gauges from new parts as follows and use them regularly in repairing, so that standards will be maintained. These gauges should be made for each one of the several styles and sizes of pumps.

1. A gauge for the thickness of the main piston heads.

2. A gauge for the distance between the main piston heads.

3. Gauges for the lengths of the cylinders and center pieces.

4. Gauges for all dimensions of the reversing valve rod.

5. Gauges for the main steam valve of the 8-inch pump.

6. Gauge for the thickness of the reversing plates.

7. Gauge for the distance from the face of the steam cylinder head of the 8-inch pump to the lower end of the reversing piston stem when the piston is at the bottom of the reversing cylinder.

8. Gauge for the distance from the upper face of the steam cylinder of the 8-inch pump to the bearing point for the reversing piston stem on the main steam valve, when the main valve is pushed down onto the stop.

9. Gauge for the distance from the upper face of the cylinder to the top of the main valve stop.

10. Gauge for the distance from the face of the center piece to top main valve stop, this being $\frac{25}{64}$ inch.

In the measurements given under 7, 8, 9 and 10, the gaskets should be removed.

Be sure that the air piston nuts are drawn up tight. Also see that the air piston head is a good fit on the piston rod.

Do not fail to examine the reversing plates in all pumps passing through the shop, as the underside almost always wears much faster than the top.

Re-bore all air cylinders when worn $\frac{1}{32}$ inch larger at the ends than in the center.

Maintain the seats for all air valves at the standard taper of 45°, a suitable reamer being used for this purpose. The proper width of the seats and clearance at the sides of the valves should be obtained in the lathe after reaming.

After the work on the air valves and cages is completed and same are in place, attach the shop pressure to the discharge of the pump. Any poor work that would cause back leakage from the main reservoir can thus be detected and remedied before the pump is assembled.

The only permissible deviations from standards are as follows:

1. Slightly worn packing ring grooves in the main pistons may be trued up.

2. The reversing cylinders and main valve bushings of the 8-inch pump may be trued up if it will not increase the diameter over $\frac{1}{64}$ inch above the standard.

3. The cylinders for the main valve pistons of the 9½-inch pump may be trued up if it does not increase their diameters over $\frac{1}{32}$ inch above standard.

4. The slide valve bushings of New York pumps may be bored out, using new valves larger than standard size to fit the increased diameter of the bushings.

5. The steam and air cylinders may be trued up without fitting new pistons, if not more than $\frac{1}{16}$ inch larger than the pistons.

After receiving general repairs, air pumps should be tested in order that their efficiency may be assured. One prominent railway requires all repaired pumps to pass the following tests, the main reservoir capacity being 22,200 cubic inches, the steam pressure 160 pounds, and the leakage diaphragm not more than $\frac{1}{8}$ inch thick.

Westinghouse 11-*inch pump.*

No. 1: With the throttle wide open, to raise the reservoir pressure from zero to 150 pounds in 3 minutes.

No. 2: With the throttle opened to give a speed of 52 cycles per minute, to maintain a constant reservoir pressure of 75 pounds for 60 minutes against a leakage through a $\frac{13}{64}$-inch hole.

No. 3: With the throttle wide open, to raise the reservoir pressure from 75 pounds to 85 pounds in 2 minutes against a leakage through a $\frac{13}{64}$-inch hole.

Westinghouse $9\frac{1}{2}$-*inch pump.*

No. 1: With the throttle wide open, to raise the reservoir pressure from zero to 150 pounds in 5 minutes.

No. 2: With the throttle opened to give a speed of 52 cycles per minute, to maintain a constant reservoir pressure of 100 pounds for 60 minutes against a leakage through a $\frac{1}{8}$-inch hole.

No. 3: With the throttle wide open to raise the reservoir pressure from 100 pounds to 120 pounds in 5 minutes against a leakage through a $\frac{1}{8}''$ hole.

Westinghouse 8-*inch pump.*

No. 1: With the throttle wide open, to raise the reservoir pressure from zero to 150 pounds in 5 minutes.

No. 2: With the throttle opened to give a speed of 65 cycles per minute, to maintain a constant reservoir pressure of 100 pounds for 60 minutes against a leakage through a $\frac{3}{32}$-inch hole.

No. 3: With the throttle wide open, to raise the reservoir pressure from 100 pounds to 120 pounds in 2 minutes against a leakage through a $\frac{3}{32}$-inch hole.

New York Pump No. 5.

No. 1: With the throttle wide open, to raise the reservoir pressure from zero to 150 pounds in 2 minutes.

No. 2: With the throttle opened to give a speed of 38 cycles per minute, to maintain a constant reservoir pressure of 70 pounds for 60 minutes against a leakage through a $\frac{15}{64}$-inch hole.

No. 3: With the throttle wide open, to raise the reservoir pressure from 70 pounds to 80 pounds in 19 seconds against a leakage through a $\frac{15}{64}$-inch hole.

New York Pump No. 2.

No. 1: With the throttle wide open, to raise the reservoir pressure from zero to 140 pounds in 3 minutes and 10 seconds.

No. 2: With the throttle opened to give a speed of 52 cycles per minute, to maintain a constant reservoir pressure of 70 pounds for 60 minutes against a leakage through a $\frac{1}{8}$-inch hole.

No. 3: With the throttle wide open, to raise the reservoir pressure from 70 pounds to 80

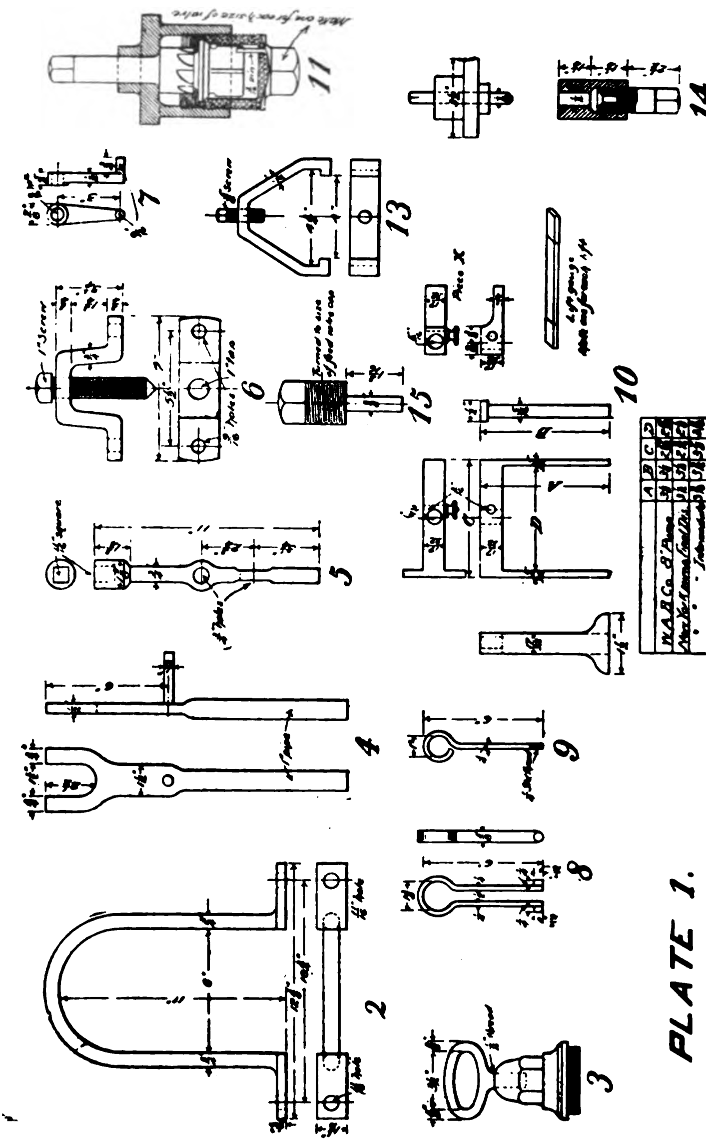


PLATE 1.

pounds in 1 minute against a leakage through a $\frac{1}{8}$-inch hole.

These tests are severe and only the best workmanship will enable the pumps to pass them.

CHAPTER XVI

ERECTING SHOP WORK—BRAKE VALVE REPAIRS.

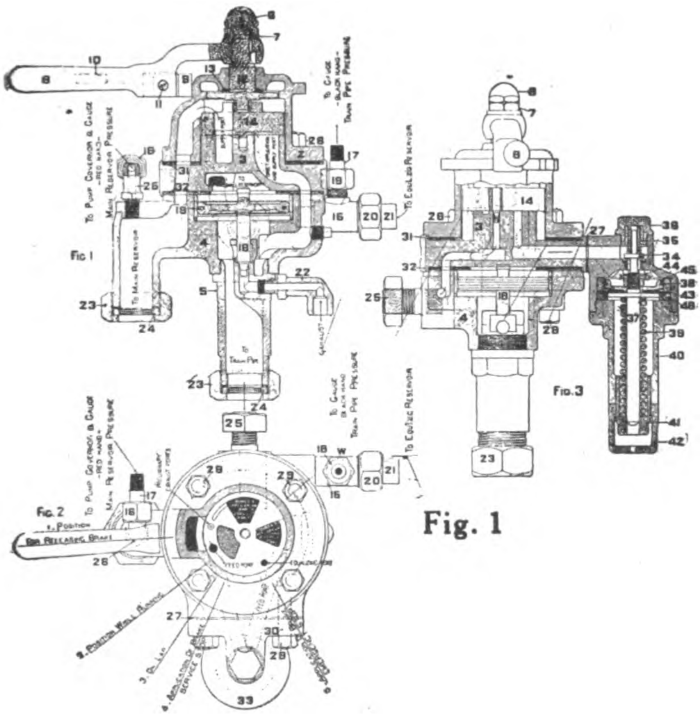
For a full description of the construction and operation of the various forms of brake valves, the reader is referred to the volume of The Science of Railways devoted to the air brake, its construction and working, wherein these matters are set forth in a very complete manner.

In this chapter the method of thoroughly overhauling a brake valve will be discussed and will therefore cover the correction of all defects as ordinarily reported by engineers, and as are set forth in the volume above mentioned.

Generally speaking, when a brake valve is reported as being defective, it is the better plan for the roundhouse machinist to remove the defective valve and replace it with one known to be in good order. The removed valve should then have a tag affixed on which is noted the reported defects, and be sent to the repair room, where it should be tested and put in good order.

Assuming that a brake valve that has been in service for a long period has been turned into the repair room, the method of procedure will be about as follows.

The valve should be taken apart and all gaskets removed, after which it should be loosely bolted together and placed in the lye tank and thoroughly boiled out. On removal from the lye it should be blown out with steam and examined to see that all ports and passages are perfectly clean.



In looking over the valve we will probably find that the handle 8, Fig. 1, is quite loose on the rotary key 12, and also that the key is very loose in the valve body 2. Also the seat on the valve body for the key washer 13 is badly worn, as well as the seat for the washer on the rotary key. The key should be placed in a lathe and a light cut, just sufficient to true it up, taken over the stem, and the surface where the key washer bears trued up. The fit of the handle to the key is restored by either sweating a piece of sheet brass to the key or to the handle, and refitting the parts.

The hole for the key stem in the valve body 2 should be bored out to about 1¼ inches, and a bushing pressed in. The bushing should be bored out to fit the key stem, and faced off to

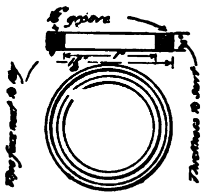


Fig. 2

length, the facing cut to extend far enough to true up the bearing for the key washer. The washer should be made of babbit metal in a form about as shown in Fig. 2. It should be a snug fit on the stem and should be "spotted" to a perfect bearing on both the valve body and the key by scraping. The thickness of this washer will depend on the amount the rotary valve and its seat have been faced off, as it should be of such thickness as will keep the key well down in the rotary valve.

If the valve is one of the D8 type, it will probably be found that the stop for the handle spring, separating the running position from the lap position, will be badly worn. If such is the case it should be repaired by dovetailing and sweating in a piece of brass as shown in Fig. 3, filing it up to shape by using a template, Fig. 4, made to fit a new valve. These stops, together with the handle spring and dog, should be kept in first-class condition so that the engineer can determine the position of the valve by feeling

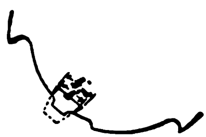


Fig. 3

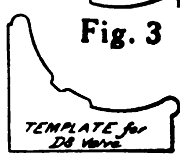


Fig. 4

the resistance of the stops. He can do better braking if this is done.

The rotary valve 14 and its seat 3 should be faced either by means of a well made facing tool as shown in Fig. 5, or in the lathe. If done in the lathe, it should be a good machine and the operator should see that all end motion is taken out of the spindle. The valve and seat should be accurately chucked and a light cut, with a fine feed, should be taken with a *sharp*, narrow-nosed tool. If too heavy a cut, or coarse feed be taken, the spring of the tool and machine will result in the surface of the valve and seat being too low between the ports where they are close together. It is better to take several cuts if necessary. After facing, the valve and seat should be scraped to a good bearing with an accurate surface plate and then ground together with oil. Do not use any grinding material if the best job obtainable is desired. If grinding material is used let it be nothing but the finest grade of Trojan grinding compound. A properly

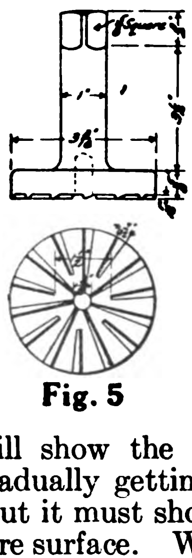


Fig. 5

seated rotary will show the heaviest bearing at the center, gradually getting lighter toward the outer edge, but it must show a perfect contact over the entire surface. When the pressure is on the valve, the rotary will be deflected, thus making the bearing at the outer edge equal to that at the center. If the outer bearing is too heavy the valve will handle hard. The preliminary exhaust port should be exactly

$\frac{5}{64}$ inch in diameter, and if not correct should be made so.

The bushing for the equalizing piston 18, in the bottom case 4, should be examined to see that there are no shoulders at the top and bottom (the latter especially) which will interfere with the piston raising or seating. Such a worn bushing is shown in Fig. 6. With a bushing

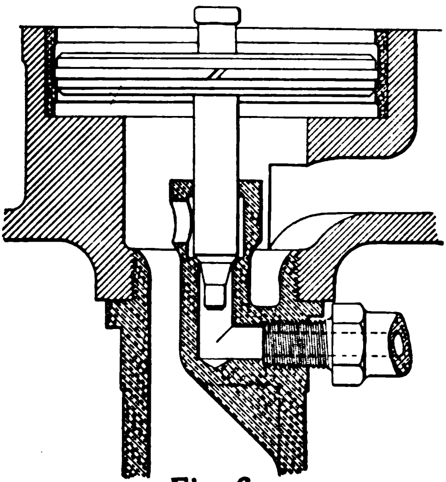


Fig. 6

worn as shown, if the packing ring is fitted tight to the upper part of the bushing it will gap open when the piston reaches the worn part, thus allowing air to leak past it from the train line to chamber D, when a reduction is made. If the seat and stem have been re-seated, the shoulder at the bottom will probably prevent the valve seating tight. If the bushing is worn as shown, it should be renewed, or it may be taken out and a strip of about No. 27 tin placed around it and the bushing pressed into place again. The tin will close the bushing enough so that it may be bored out to standard size. Piston ring 19 should be put in the bushing somewhat tight to allow it to be fitted accurately to the bushing by filing and grinding in the same manner that a triple valve piston ring is fitted. If the ring is too loose in the groove, the piston should be placed under a press and the groove closed on the ring. The ring should be free in the groove, but not loose enough to shake.

The end of the stem 18, forming the train line exhaust valve, should be reamed with a tool similar to Fig. 7, and the seat for this valve in the bottom cap 5 should be re-seated with a tool similar to that shown in Fig. 8, after which they should be ground to a perfect bearing.

The brake valve proper is now ready to be assembled. Upper and lower body gaskets 31 and 32 should be examined and renewed if necessary. In putting the valve together use graphite or plumbago on both sides of these gaskets, and they will not stick. Owing to the general location of the brake valve in close proximity to the boiler head, these gaskets become hard and dry and should be softened up, soaking them in Marvin's brake cylinder grease. Examine all gauge pipe fittings and see that they are tight and have good threads. The equalizing piston should be oiled with a small quantity of non-gumming oil and should move perfectly

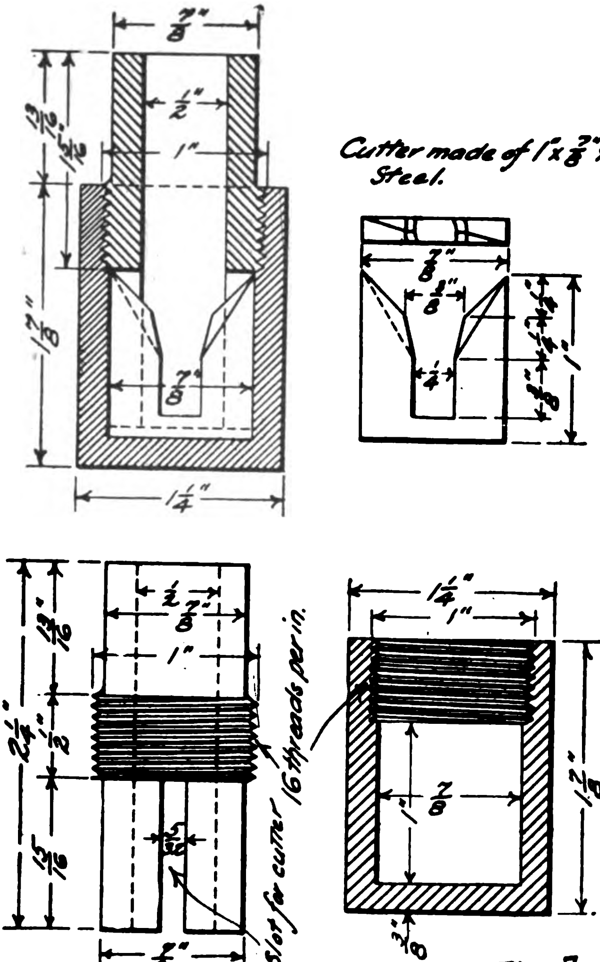

Cutter made of 1" x 7/8" x 5/32" Steel.
Slot for cutter
16 threads per in.

Fig. 7

free in the bushing. The rotary valve and key washer should be oiled with vaseline or a lubricant made of about one part beeswax and two parts tallow. Be careful not to draw the handle down too tight.

Feed Valve Attachment.—The feed valve attachment should be overhauled, and we will

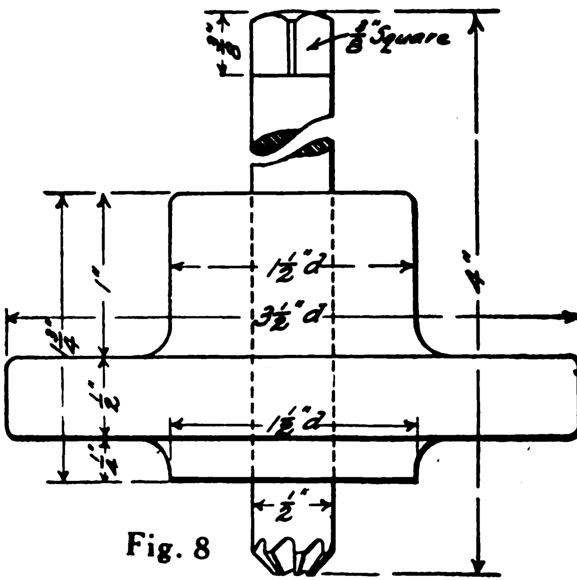


Fig. 8

assume that it is one of the old-style ones. To keep all the parts standard, a gauge similar to that shown in Fig. 9 should be made and used as follows: The edge *A* is trued up for use as a straight edge to test the collar on the piston rod, to see that it is not sprung down, as may easily be done by trying to tighten nut 44 to position with too thick a diaphragm. If the collar is true the gauge should be applied as in Fig. 10, to gauge the distance from the lower face of the collar to the top of the piston rod, which should be $\frac{15}{16}$ inch. Then with the nut in position, use the flat part of the gauge with the protruding pin to gauge the distance from the top of the rod to the three striking points

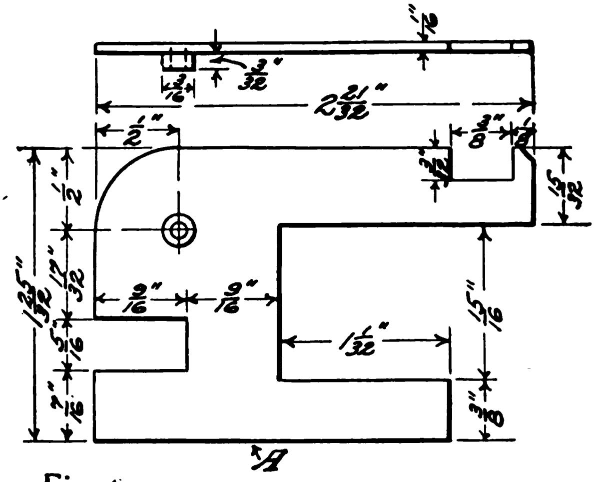


Fig. 9

on the nut, as shown in Fig. 11. This should be about $\frac{3}{32}$ inch, but should not exceed $\frac{1}{8}$ inch. Next use the gauge, as shown in Fig. 12, to determine the distance from the finished face where the piston rod nut strikes to the top of the valve seat on the brass bushing, which should be $\frac{3}{8}$ inch. If this seat has been faced off it should be brought to the correct height by shimming under the collar with paper washers. The width of the seat should also be kept standard. The length of the lower stem of the supply valve should be gauged as shown in Fig. 13, and should be $\frac{9}{16}$ inch. The cap nut 36 should be examined to see if the guide for the upper stem of the supply valve is sprung, as this is a common defect caused by striking the top of the nut with a hammer. The supply

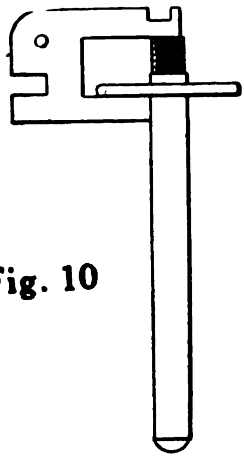


Fig. 10

valve stem should be a neat sliding fit in the guide.

All parts of the feed valve should be thoroughly cleaned, especially the ports. No metal should be used in cleaning the supply valve and seat. When difficulty is experienced in removing the piston, a tool similar to that shown in Fig. 14 will remove it without damage. To grind the supply valve and seat use a tool as shown in Fig. 15, which is a round piece of hardened steel with the end ground true, and having a removable center pin. If these parts require more than a rubbing down with oil, use the finest grade of Trojan grinding compound, or pumice stone, and if ground very much it will probably be necessary to raise the seat as before described.

The packing ring 38 should be a neat fit

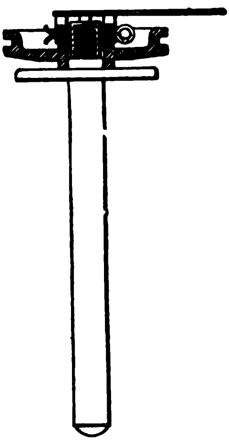


Fig. 11

in the piston groove, and also a perfect fit to the cylinder. The piston should move free. In replacing the diaphragms (which should be done if they are distorted or damaged on account of the spring box 40 being screwed up too tight) place them on the piston and enter the rod through, holding them firmly until the nut is well down. They should be tested to see that they are central, by placing the diaphragm ring in place and observing that the lower or smaller diaphragm fits in the recess of the ring, and that the upper one is true with the outside of the ring. The spring box should be screwed up against the diaphragm but little harder than can be done by hand, and care should be used that it is not unduly tightened when setting up the check nut. A good way to guard against this is to place a

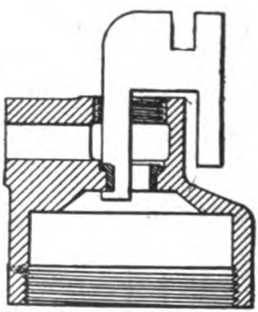


Fig. 12

washer, or washers, of sufficient thickness between the valve body 33 and the spring box so that the spring box may be drawn up tight against the washers without pinching the diaphragm too tight. By setting up the spring box too tight the diaphragm will be damaged, and the supply valve may be held off its seat. The regulating spring should be examined to see that it does not bind on the piston rod, and the rod examined to see that it is perfectly free in the regulating nut. With the piston and regulating nut in place, the piston should move free. The cap nut 36 should not be tightened down too tight. In bolting the attachment to the brake valve, see that the gasket is in good condition so that there will be no leakage across the ports or to the atmosphere.

The adjustment of this attachment will depend on the condition of the train line; hence, in making a shop adjustment, or one on a light engine, the main reservoir pressure should be

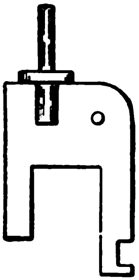


Fig. 13

pumped up to the maximum and a leak made from the train line about equal to that from an average train. This may be done by opening about full the release valve on either the driver brake or tender auxiliary, or by using a hose coupling on the train line with a $\frac{3}{64}$-inch or $\frac{1}{4}$-inch hole. After each alteration of the regulating nut, make about a 15-pound reduction and return the valve handle to the running position, thus allowing the train line to feed up through the feed valve. When set to carry the correct pressure, place the valve handle in full release position for two or three seconds, return to running position, and after the train line has leaked down to a point where the feed valve is supplying the train line, notice the difference the gauge shows from the first setting. There will probably be a difference, but it should not exceed four or five pounds. If the difference is greater than this, it shows that the piston does not move easily, due to binding of the

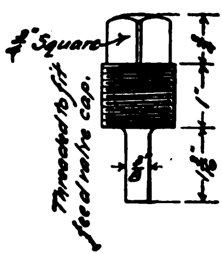


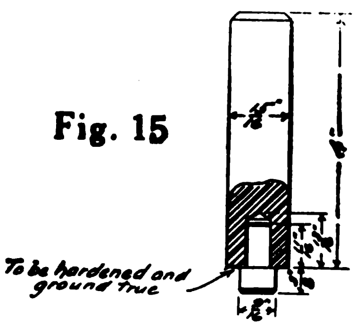
Fig. 14

adjusting nut or adjusting spring on the piston rod, piston too tight in the cylinder, or the collar of the piston binding on the diaphragm ring. If after regulating, as described, the leak from the train is stopped, and the train line pressure increases several pounds and stops, this indicates that probably the spring box is screwed up too tight or the diaphragm is distorted.

With the slide valve feed valve attachment the foregoing directions apply in so far as the governing part of the attachment is concerned. In addition, the slide valve and seat should be faced and brought up to a perfect bearing. The piston should move perfectly free. In the old style of this attachment, where the piston has no packing ring, it should not be allowed to get too loose. With the new style, the packing ring should be a good fit and the equalizing hole through the piston kept standard size.

With the D8 brake valve, having the excess

Fig. 15



pressure valve instead of the feed valve attachment, the excess pressure valve and seat should be ground to a perfect bearing and the spring adjusted to carry the required excess pressure, generally from 20 to 30 pounds. If the spring is too light, increase the tension by placing thin washers between the spring and cap. If too stiff, lessen the tension by removing some of the washers, or in case there are no washers, by filing or grinding off the end of the spring.

Never attempt to regulate the spring by closing it or stretching it out, as this will ruin it.

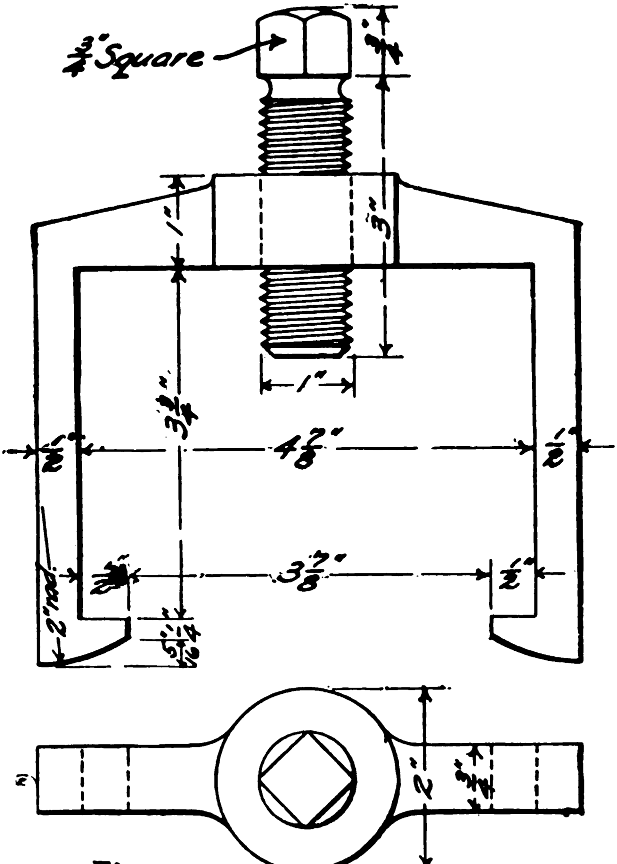


Fig. 16

Fig. 16 shows a very convenient tool for separating the brake valve body from the valve seat.

(End of Volume I.)