INSTRUCTION PAMPHLET

No. T 5002

JANUARY, 1938

MOTOR DRIVEN AIR COMPRESSORS

for

ELECTRIC RAILWAY SERVICE

WESTINGHOUSE
AIR BRAKE COMPANY
TRACTION BRAKE DIVISION
PITTSBURGH, PA.
U. S. A.

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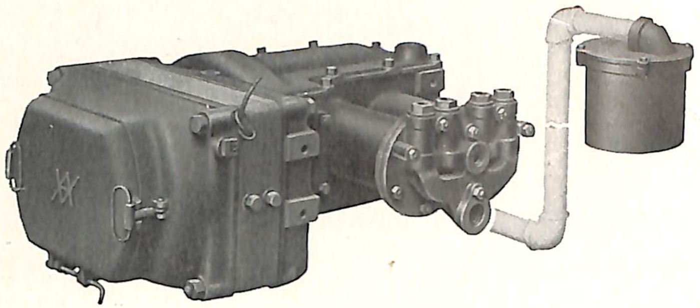
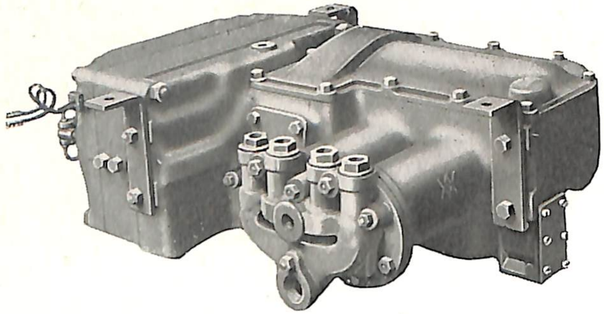


Compressor with 8″ Suction Strainer



Compressor in Suspension Hangers

Fig. 1. Exterior Views of the Type "DH" Air Compressor

Motor Driven Air Compressors

Motor driven air compressors are used on electric motor cars and electric locomotives as a part of the air brake equipment to supply compressed air for operation of the brake and other air operated devices.

Westinghouse compressors have been on the market for many years and represent advanced engineering practice in design and construction as well as painstaking care in manufacture. Every effort has been made to produce compressors that are reliable, durable, efficient, quiet in operation, easy of access, and as free from operating troubles as possible. These characteristics, together with low maintenance cost and little attention required, make certain types of Westinghouse compressors particularly suitable for industrial service as well.

Inasmuch as the compressors discussed in this pamphlet have many points in common, in order to avoid repetition, the DH and D-EG have been selected as representative of the most widely different types and have been fully described. The sections devoted to the other types include brief descriptions of their salient characteristics and designation of the class of service for which they are adapted, while only those details of design and construction in which they are different from the DH and D-EG types are discussed, the other features being referred to the DH or D-EG for explanation. Thus, the "blow back" feature is described for the DH type of compressor and thereafter is only mentioned.

It should be noted, moreover, that the operation of all types of compressors is practically identical, and for that reason, the instructions for care and maintenance found in the chapters for the DH and D-EG types and at the end of the pamphlet apply to all the types unless the contrary is stated.

Before leaving the factory each compressor is worn in and tested to determine its efficiency and accurate adjustment of its parts. The compressor must show a high cylinder efficiency before it is allowed to pass. The operation is carefully noted with regard to connecting rod adjustment, meshing of gear and pinion, proper circulation of oil, smooth and quiet running, etc.

Motors are thoroughly tested to insure their performance meeting certain rigid requirements. The motors are tested for open circuit, short circuit, ground, proper speed at rated load, temperature rise, satisfactory commutation, end thrust and efficiency.

Electric Compressor Governors, which control the operation of the air compressors, are described in separate instruction pamphlets as follows:—

No. T 5042 Electric Compressor Governors J Types and G-1-D.

No. T 5042-1 Type S Electric Compressor Governors and Governor Synchronizing System.

Choice of Compressor

In choosing the proper size of motor-driven compressor, several points should be considered, as follows:

1st. *In street railway work* the weight of car determines the size of brake cylinder, which, with the number of stops made in a certain length of time, will determine the quantity of air used. The compressor should be chosen for the conditions requiring the most frequent stops.

2nd. *The use of air whistles or horns* requires additional compressor capacity in proportion to the size of whistle (or horn) and the frequency with which it is used.

3rd. *The Westinghouse Electro-Pneumatic Multiple-Unit Control System* requires a very small additional compressor capacity, depending on the size of equipment and frequency of operation.

4th. *Pneumatically operated doors* and other such devices require additional capacity depending on the size of equipment and frequency of operation and maintenance.

5th. *A motor car (or locomotive) hauling trailers*, requires considerable extra compressor capacity in proportion to the number of trailers handled, and the size of brake cylinders used in their equipment as well as the frequency of stops.

6th. *For compressors in stationary plants,* the quantity of air required can readily be computed from the use to which it is put, and this should represent the minimum capacity of the compressor chosen to supply the air.

There is nothing gained by installing a compressor that is too small for a given service since the extra effort required to produce the necessary volume of air will cause overheating, loss in efficiency, and probably serious damage, resulting in excessive maintenance.

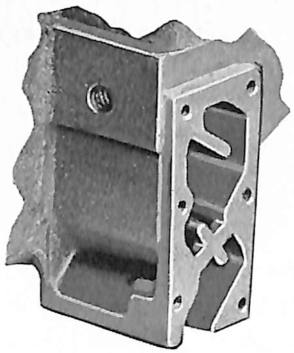


Fig. 2. View of the Crank Case Vent with Cover Removed showing Baffles in the Air Passage

"Bungalow"
Type DH Compressor

The DH or "Bungalow" type of motor driven air compressor is a light weight, low height compressor developed especially for use on low-built, light weight cars, but is none the less adaptable to all types of cars.

It embodies the following important features: Provision for preventing oil passing into the brake system; few bolts throughout, facilitating taking apart and assembling; easily removed armature; easily adjusted brush pressure; perfect alignment, which is fixed—not adjustable; accessibility of all working parts; direct "three point" suspension; minimum height over-all; minimum weight; high over-all efficiency and large capacity motor.

This compressor is of the horizontal two cylinder type, single stage, single acting (that is, the air is compressed only on one side of the piston), and is driven by a motor through herringbone gearing. As can be seen from Fig. 1, the DH compressor motor is at the side of the compressor portion and the motor pinion is in front of the gear, as shown in Fig. 3, thereby giving greater compactness.

The low height of the compressor makes it particularly adapted to the "Easy Entrance, Easy Exit" type of car, in which track clearance has been reduced to a minimum.

The motor is provided with a large door at the commutator end, shown in Fig. 7, giving easy access to the commutator for inspection, adjustment of brushes and cleaning. The armature shaft has no bearing on the commutator end, thereby facilitating the removal of the armature as described later, and also eliminating the possibility of oil reaching the commutator from that source.

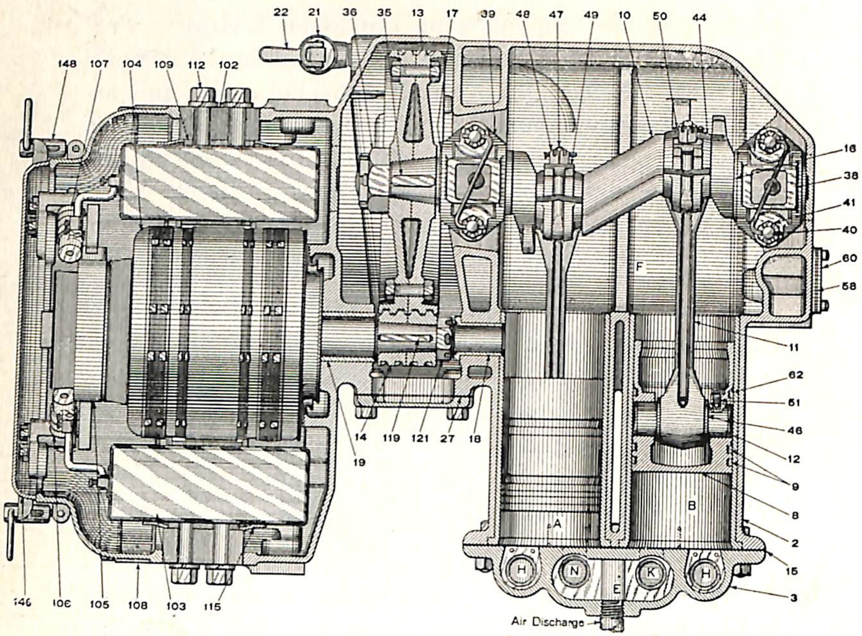


Fig. 3. Sectional View Type DH Compressor

These compressors are built in four sizes, viz.: DH-10, DH-16, DH-20, and DH-25, the numeral portion of each designation indicating the displacement in cubic feet per minute.

The parts with which we are chiefly concerned in this pamphlet are as follows (Figs. 3, 4 and 5):

2 Cylinder and Crank Case
3 Cylinder Cover
4 Inlet Valve
6 Discharge Valve
7 Valve Chamber Cap
8 Piston
9 Piston Ring
10 Crank Shaft
11 Connecting Rod
12 Wrist Pin
13 Gear
14 Pinion
16 Rear Crank Shaft Bearing
17 Front Crank Shaft Bearing
18 Small Motor Bearing
19 Motor Bearing
21 Oil Filling Ell
26 Hand Hole Cover
29 Crank Case Top Cover
35 Crank Shaft Key
38 Bearing Cap, Rear End
39 Front End Bearing Cap
44 Connecting Rod Cap
46 Wrist Pin Bush
47 Eye Bolt
48 Eye Bolt Castle Nut
51 Wrist Pin Set Screw
60 Vent Cover
62 Oil Ring
102 Field Yoke
103 Field Coil
104 Armature
105 Commutator
106 Right Carbon Holder
107 Left Carbon Holder
108 Front End Bell
109 Salient Pole
112 Salient Pole Cap Screw
115 Field Coil Spring
121 Pinion Castle Nut
122 Cotter Pin
146 Commutator Door
148 Door Latch

Compressor Portion

The cylinders, crank case, motor housing, and bearing brackets are cast in one piece, thus eliminating the necessity for a bed plate, or adjustment to obtain proper centers of gear and pinion, and providing a construction which is rigid and of few parts.

The cover 3, Fig. 3, for both cylinders is in one piece, and may be easily removed. It is tapped for the suction and discharge pipe connections and contains the air valves.

The air valves, 4 and 6, (four in number)—one suction and one discharge valve for each cylinder) are located close to the cylinder to reduce valve clearance. The valves are accurately machined hydraulic forgings, giving longer life than valves turned from cold rolled commercial stock. These valves require little or no attention. Placed vertically, they close by gravity so that there are no springs to break, corrode or lose their temper. They are easily accessible by simply removing the caps. The valve chamber caps 7, are of such a design as to reduce clearance and prevent sluggish action of the valve.

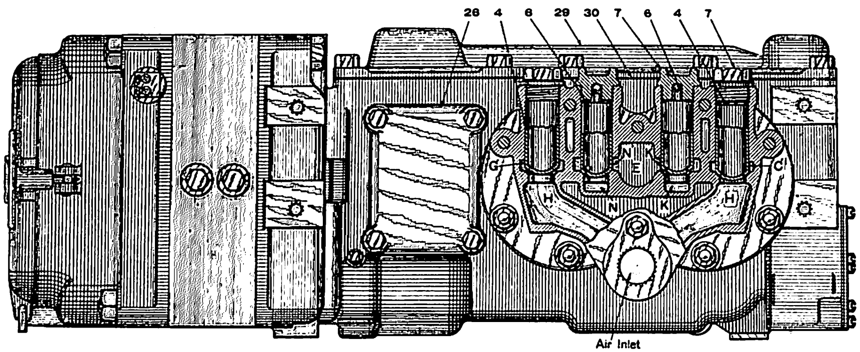


Fig. 4. Type DH Compressor with Cylinder Cover in Section

The pistons 8 and connecting rods 11 have been made unusually long with a view of insuring minimum and even wear on the cylinders, wrist pins, wrist pin bearings and pistons themselves. The pistons are of the trunk type and are carefully turned to fit the bore of the cylinders. Each piston is provided with three snap rings of standard form, a special quality of cast iron being used

so as to give minimum and uniform wear. The two outer rings 9 are compression rings, and the inner ring 62 is an oil ring designed to prevent passage of excess oil into the air cylinder.

The wrist pins 12, are of hardened steel, carefully ground. They are pressed into the pistons and held in place by set screws.

The connecting rods 11 and the crank shaft 10, are drop forgings of high grade steel, the latter being specially heat treated. The wrist pin ends of the connecting rods are provided with liberal special bearing metal bushings 46, which can be readily replaced when worn. The crank shaft ends of the connecting rods are provided with split bearings of special bearing metal, allowance being made between the connecting rods and bearing caps 44, to take up wear quickly and readily by removing liners and again tightening the nut 48 on eye bolt 47, which is hinged to the connecting rod.

All bearings are of our special bearing metal mixture and may be easily renewed.

The crank shaft is designed to make a center or thrust bearing unnecessary.

The power is transmitted from motor shaft to crank shaft by a herringbone pinion 14, and gear 13. These gears have a large number of fine teeth which makes for quiet running for a long time. The gear is forced on to the taper shaft over a square key 35, and secured by a castle nut and cotter. This arrangement, combined with a steep taper on the crank shaft, makes removal of the gear easy.

Operation of Compressor

Referring to Fig. 3 and the lower view in Fig 5, the left-hand piston being assumed to be on its backward stroke a suction is created in that cylinder (A). This draws air through the suction strainer and inlet pipe into chamber H where it lifts inlet valve 4 and passes into the

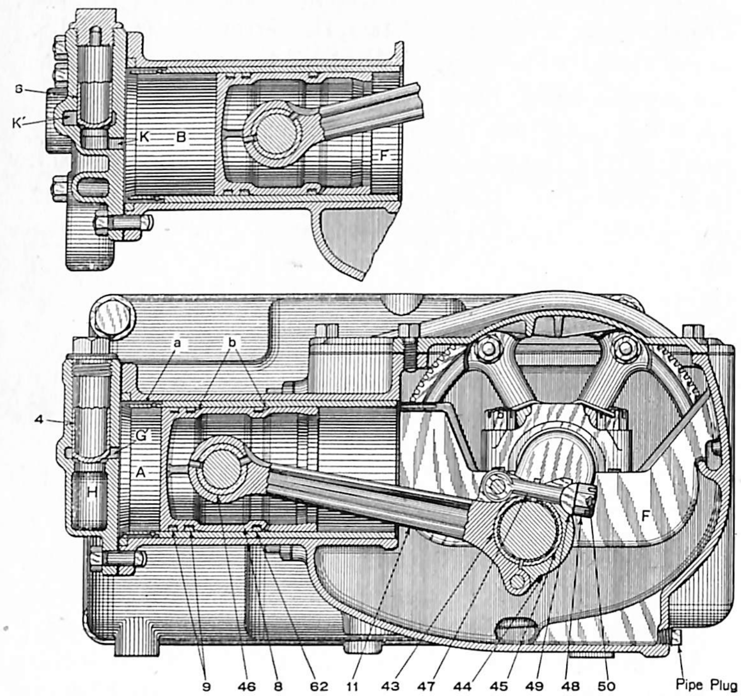


Fig. 5. Sectional Views Type DH Compressor

cylinder A. On the return stroke, the inlet valve closes and the compressed air lifts the discharge valve 6 and passes through ports K and K′ into chamber E, Fig. 4, and thence through the discharge pipe into the reservoir. The same operation takes place in the right-hand cylinder B except that it is compressing (see upper view, Fig. 5), while the left-hand cylinder is drawing air in, and vice versa.

Fig. 5 shows the method of preventing oil from passing into the discharge pipe. Two "blow back" passages *a* are provided in the walls of each cylinder at the pressure end. Circumferential beveled grooves *b* are cut in the piston immediately back of the second compression ring and the oil ring. When the piston is at the end of its stroke, compressed air trapped in the clearance space by-passes the two compression rings, reaching the groove back of the second ring and then "blows back" into the crank case any excess oil that may have crept along the piston. The wiping action of the oil ring also assists in preventing the passage of oil.

Inasmuch as there might at times be a slight vacuum or pressure in the crank case, due to ring leakage and the movement of the pistons, a vent or "breathing" opening is made to the atmosphere. This consists of a passage cast in one corner of the crank case, opening into the crank case at the top and to the atmosphere at the bottom, see Fig. 2. Baffle plates are cast in the passage for the purpose of preventing the entrance of dirt with air flowing into the crank case. The baffles are so arranged that any air entering the vent must come in contact with the baffles, which tends to separate the dirt from the air and cause it to drop back to the atmosphere.

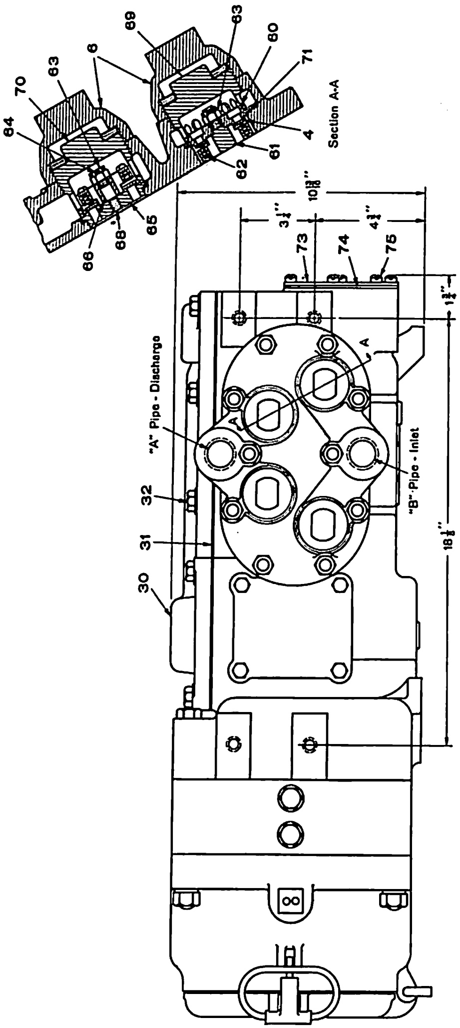


Fig. 6 DH-10-D Air Compressor with Disc Type Valves

A plate 60 (Fig. 3) held in place by six cap screws provides access to the baffles for cleaning purposes.

The DH-10 size compressor is supplied either with bottle type valves (as above described and illustrated by Figs. 4 and 5) or with disc type valves, Fig. 6. Each disc valve unit is a complete assembly which may be readily removed for inspection or replacement by the removal of valve cap 6 and the cage (inlet 69 or discharge 70). The valve 4 is a thin washer of stainless steel, accurately ground on both sides. With a small lift and spring weighted, the disc type of valve is capable of long, quiet service. The DH-10 Compressor does not have the blow-back holes, but does have the circumferential grooves.

The DH-16 and DH-20 air compressors can also be supplied with *disc valve cylinder covers.*

Motor Portion

The motor is of the enclosed, four pole, direct current series wound type, with two field coils.

The field yoke, 102, (Fig. 3) is made up of laminated soft steel punchings, insuring uniformity of section and minimum weight. The yoke fits between milled surfaces of the motor housing, being supported firmly in place by means of long bolts and studs which hold the two parts of the motor housing together.

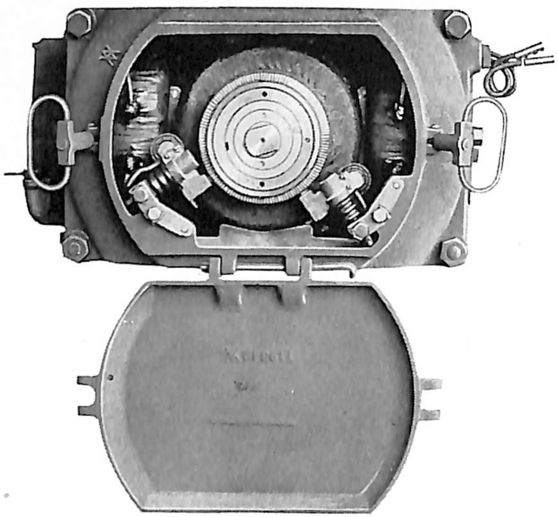


Fig. 7. Type DH Compressor, Commutator Door Open

The pole pieces 109 are each held in place by two cap screws 112, and may, therefore, be very easily removed. The field coils are impervious to oil and water to a high degree. The consequent poles are a part of the field yoke. To prevent injury due to vibration, the coils are held firmly in place by a flat steel spring 115, which presses them against the pole tip guards.

The armature 104 is of generous proportions and is built up of soft sheet steel punchings keyed to a spider. The coils are form-wound and of uniform size. The commutator 105, is of liberal dimensions, using $\frac{1}{32}$″strips of the best grade of mica. The mica insulation between the commutator bars is undercut. In order to prevent possibility of any movement that might damage the leads, special care is taken in supporting them from coil to commutator by a heavily insulated steel coil support fastened securely against the armature core, while the coils are banded in the core and on the ends to prevent any movement. The oiling system is designed with extra precautions to prevent entrance of oil into the motor, as described later.

The brush holders, Fig. 8, are permanently located in a position slightly back of the mechanical neutral position which is the most efficient location on account of the fact that the armature always rotates in one direction; they are, however, arranged for easy radial adjustment by means of a set screw which secures the brush holder stud in the clamp. The holders are fastened to the motor case with one cap screw and one dowel pin, giving accuracy of location but easy removal. The brushes are held in contact with the commutator by a combination of a coiled spring and a flat spring fastened at the uncoiled end of the former, thus providing a spring of double amplitude. The flat uncoiled spring exerts only a light pressure upon the brush and, therefore, takes care of the small vibrations. This tends to eliminate chattering and improves commutation.

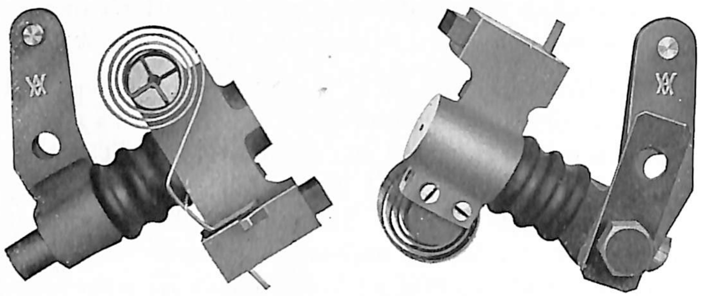


Fig. 8. Photographic Views of the Brush Holder

The brushes are located on the lower quadrant of the commutator. This position is most accessible from the pit and in itself tends to keep the brushes and commutator clean.

Lubrication

The lubrication of the compressor is entirely automatic and is effected by the splash system, as shown in Fig. 3.

Oil is poured into the crank case through the oil fitting 21 until the level maintained by the fitting is reached. As the crank rotates, the connecting rods dip into oil, splashing it onto the interior surfaces, lubricating the cylinders and crank shaft and connecting rod bearings. The oil splashed into the trough on the rear wall of the crank case, flows through a passage into the gear case

chamber where it is carried up by the gears and into the armature shaft bearings.

This arrangement allows the oil to lubricate the teeth of the gear without having the gear run in oil, incidently reducing the amount of heat generated by churning the oil in the gear case.

The main motor bearing is provided with cored passages leading to the bottom of the gear case through which the excess oil returns. The ends of these passages are sealed by oil against vapor getting into the motor.

As there is only one place to oil the compressor, lack of lubrication is not likely to occur. The fitting has a large opening through it so that it is not likely to become clogged and give false oil level. The plug covers the end of the fitting so that dirt cannot enter the fitting when removing plug for filling.

Adjustments and Repairs

The construction of the compressor is such that all parts are easily accessible for inspection or repairs. The gear, crank shaft, crank shaft bearings and connecting rods are exposed for examination by taking off the crank case top cover 29. The commutator door, Fig. 7, covers practically the whole end of the motor, so that when the door is open, the commutator, brushes and interior are entirely exposed to view and easy of access.

To remove the armature, open the commutator door and remove the brush holders. Take off the hand hole cover 26, as shown in Fig. 9. Then withdraw the cotter 122 and place a wrench on the castle nut 121 to keep it from turning. With a wrench on the flats on the outer end of the armature shaft, turn the shaft to the left until it is unscrewed from the castle nut, after which the armature can be easily withdrawn from the motor.

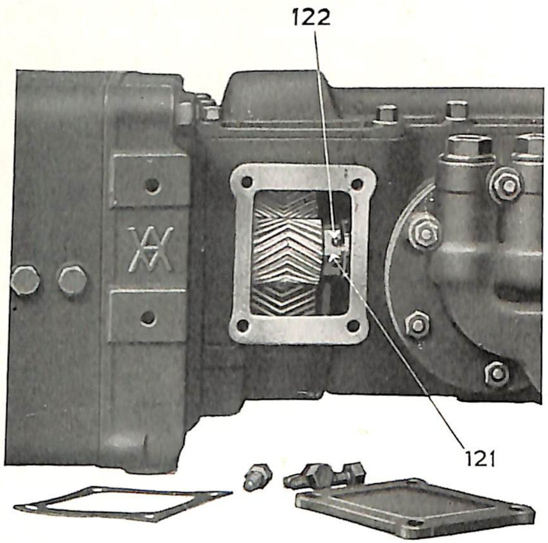


Fig. 9. Hand Hole Cover Removed, Showing Pinion

The procedure is simply reversed to replace the armature. Make the electrical connections as before and replace the brushes as they were, in order that the bearing between the brushes and commutator be not destroyed. If the brushes are interchanged, they should be ground to a bearing by using a strip of sandpaper on the commutator under the brushes with the sand toward the brush until a full bearing is obtained. This will prevent the excessive sparking which would result from an improper brush bearing and thus preserve the commutator glaze.

With the hand hole still open, turn the armature by hand a few times to make sure that the gears run freely, then replace hand hole cover and start compressor.

Suspension

The suspension used with the compressor is direct and of the "three-point" type which not only contributes to light weight but facilitates mounting and dismounting of the compressor and provides accessibility.

This type of suspension consists of three light-weight steel hangers, Fig. 1, fastened by two bolts each to lugs cast upon the compressor, the weight of the compressor being actually supported by the ends of the hangers which are bent sharply underneath these lugs. The upper ends of two of these hangers are bolted by one bolt each to brackets bolted to the car body. No bolt is needed for the third hanger since the other two hangers serve to hold it in place. This method of suspension requires the removal of only two bolts to disengage the compressor from the car body.

To install the suspension, fasten the hangers to the sides of the compressor and be sure to set the cap screws up solidly; then fasten the brackets securely to the car framing, at the proper distance apart, utilizing, if practicable, an existing timber for one of them and putting in a suitable piece for the other. Use ⅝″ bolts for each bracket. *Do not use lag screws.* If desirable, the ends of the bracket may be straightened up and bolted to the side of the sill. The compressor, with the hangers attached, is then raised and the bent part of the hangers slipped into place. Then the two bolts are set up solidly. A compressor with this form of suspension is shown in Fig. 1.

Type DH Air Compressors—Sizes and Performance Data Based on 100 Pounds Air Pressure

Compressor	Dis. Cu. Ft. per M	Voltage	Amperes Operating	Amperes Fuse	Approximate Weight Net	Approximate Weight Ship.	R. P. M. Compressor	R. P. M. Motor	Approximate Dimensions Length	Approximate Dimensions Width	Approximate Dimensions Height	Pipe Size Inlet	Pipe Size Discharge	Valve Lift Inlet	Valve Lift Discharge
DH-10	10	220	7.1	10	435	525	226	1200	25¼"	30¾"	10¾"	1"	1"	7/64"	7/64"
		600	2.6	10											
DH-16	16	230	12.3	20	650	760	217	1120	24¾"	34"	12½"	1¼"	1"	5/32"	1/8"
		600	4.75	10											
DH-20	20	37	92	150	650	760	273	1400	24¾"	34"	12½"	1¼"	1"	5/32"	1/8"
		64	50	75											
		600	5.35	10											
DH-25	25	32	131	200	990	1050	200	1080	29½"	39¾"	15¾"	1¼"	1"	5/32"	1/8"
		64	65.5	100											
		115	36.6	60											
		400	10.5	15											
		600	7	10	990	1050	200	1080	28½"	39¾"	15¾"				
		1200	3.5	10	1075	1150	200	1080							
	27	1500	2.8	10	1075	1150	216	1160							

Type D-EG Compressor

In design, this compressor is of the duplex air cylinder type, driven by a totally enclosed series wound motor, both motor and compressor being mounted on a common bed plate and connected by herringbone gearing.

Compressor Portion

The functions of the compressor portion, as shown in Figs. 11, 12 and 13, are identical with those of the DH, the air being drawn past the inlet valves into the cylinders, compressed, and discharged through the discharge valves into the reservoir. The mechanical construction

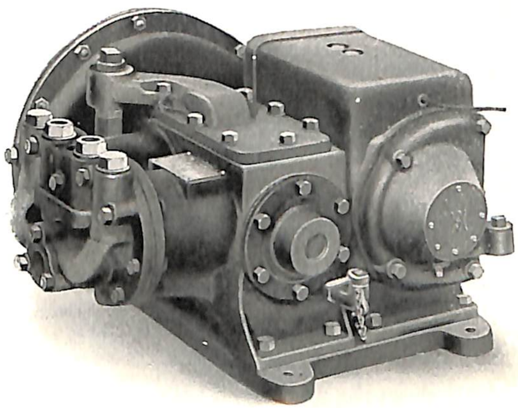


Fig. 10. Type D-EG Air Compressor

is somewhat different, however, for in addition to the bed plate 82, the motor is located directly back of the compressor, instead of at the side, with an air space between for securing ventilation. The gear 28 and pinion 98 are enclosed in a gear case 9 which is attached to the com-

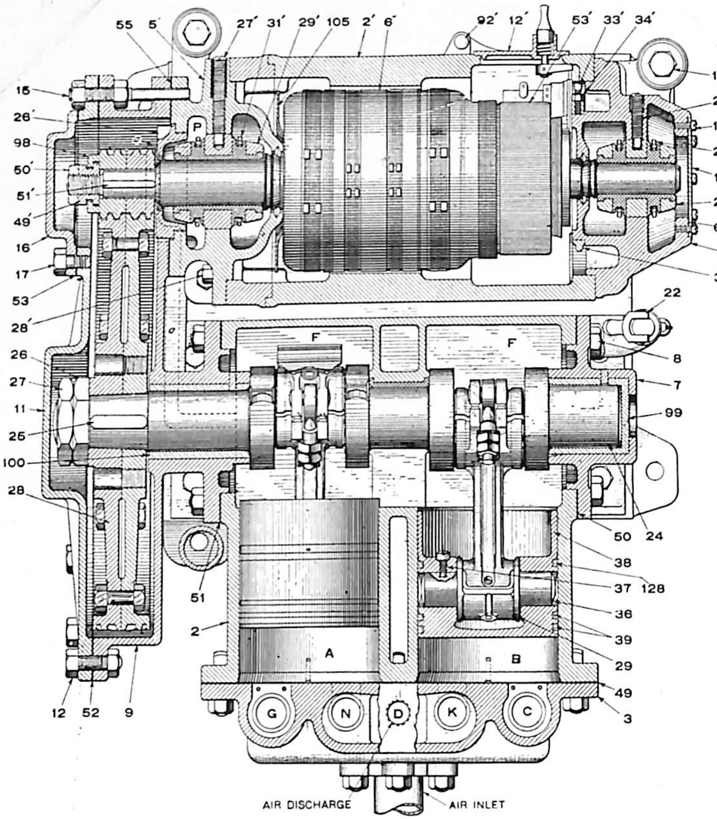


Fig. 11. Sectional View Type D-EG Compressor

pressor and motor. It protects the gearing from injury and carries the necessary lubrication. This gear case is known as the EG type and is provided with a cover 11

which is bolted to it. The crank shaft 24 has two end bearings in brass bushings, 99 and 100, and a middle bearing of babbitt.

In other respects the compressor is practically the same as the DH type, the pistons 38, connecting rods 29,

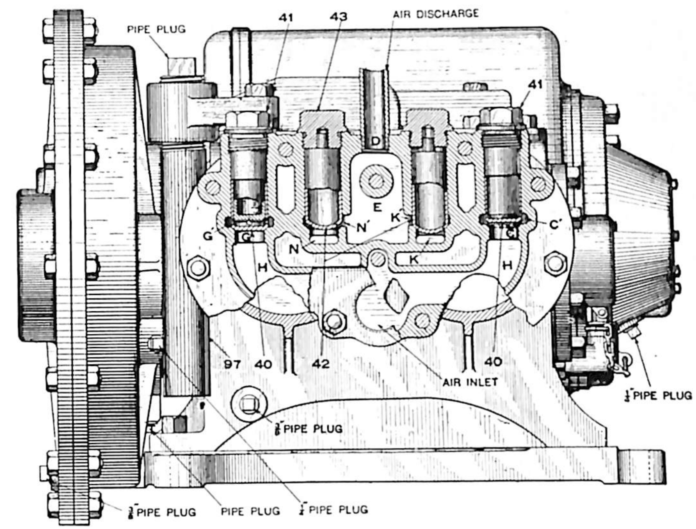


Fig. 12. Type D-EG Compressor with Cylinder Cover in Section

packing rings 39, oil ring 128, valves 40 and 42 and wrist pins 36 being of the same design. It also has the "blow back" feature and crank case vent to the atmosphere. The crank case vent, however, is through the pipe 97 on the outside of the compressor. It should be noted that the center line of the cylinders is slightly above that of the crank shaft in order to reduce the vertical component of the thrust and consequent wear during the compression stroke. For that reason, *the crank shaft should always rotate in a clockwise direction when viewed from the gear end.* This instruction also holds good for all the other types of compressors covered in this Instruction Pamphlet.

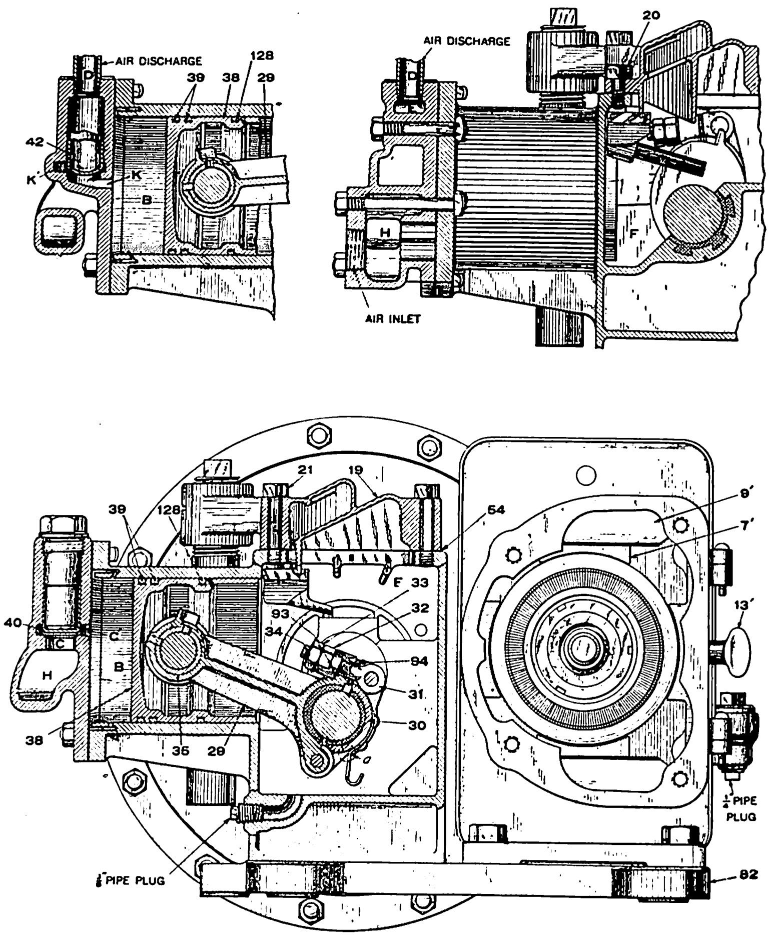


Fig. 13. Sectional Views Type D-EG Compressor

Motor

The motor is of the enclosed, series wound, four pole type, with two field coils. It has an annealed cast steel magnet frame 2, (Fig. 11) having a prolongation on the commutator end, which is provided with an opening or doorway to permit of ready access to the brushes and commutator. This opening has a door 12, hinged to the frame, which is tight fitting, excluding rain and dust. In the ends of the frame are centered housings, 4′ and 5′, which carry the armature bearing. Cast iron bearing shells 22′ and 29′, of ample proportions, with babbitt insets are centered in the housings and secured by means of set screws 20′ and 27′.

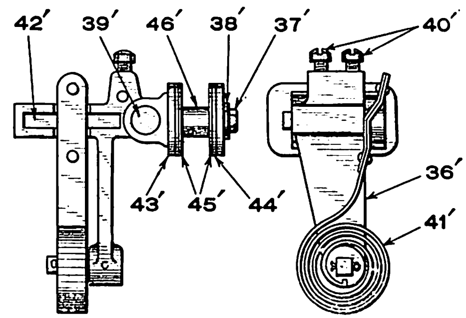


Fig. 14. Type D-EG Compressor Brush Holder

Two of the four field poles are a part of the frame, the other two being made of laminations of soft sheet steel and are bolted to the frame, thus also securing in place the field coils. The two brush holders, Fig. 14, mounted on the adjustable cast iron rocker arm 32′, Fig. 11, are of cast brass, with a tap bolt 37′, threaded into a steel plug

39′ in the holder to secure them in position, and are insulated from the yoke by fibre, fullerboard and mica washers, 43′, 44′ and 45′, respectively, and tube 46′, so that ample insulation has been provided at this point. The carbon brushes 42′ slide in machined holders and are held in contact with the commutator by a coiled spring 41′ of bronze ribbon, thus giving a uniform pressure during the life of the brush. The screws 40′ are binding screws to secure the leads firmly to the brush holder. The armature shaft is provided with a deflector 105 which prevents excess oil from the rear motor bearing coming in contact with the armature.

The other electrical details are similar to those of the DH motor, the functions being the same, and the only differences being those due to variation in mechanical construction.

Lubrication

The lubrication of the compressor is entirely automatic and requires no attention other than to replenish the oil supply when needed. The crank shaft bearings, connecting rods and pistons are lubricated by the splash system, the oil being poured into the crank case through the fitting 22, Fig. 11. As the crank shaft rotates, oil is splashed into the cylinders and into the crank shaft bearings. Some of the oil splashed into the rear crank shaft bearing seeps through the bearing and enters the gear case where it serves to lubricate the gear teeth. Part of this oil is carried up by the gear to the pinion and thence into the rear bearing oil well of the motor. This oil cannot, however, flood the motor, for there is a direct connection through a cored passage *a* between

the oil well and the crank case, whereby any overflow returns to the latter. The motor bearings each have an oil well filled through holes 17′, Fig. 11, and are supplied with constant lubrication by means of the oil rings.

Suspension Cradle

This device consists of two parts, the cradle, Fig. 15, which is bolted to the base of the compressor (and thereby becomes an integral part of it) and the brackets by which the cradle is secured to the car. The two brackets have two pockets, each containing a rubber cushion, fitted in an iron casing, with a suitable cover, and these parts are provided with a slot through which the ends of the uprights may pass. These ends also have slots for notched keys which latter, when in place, support the cradle with its compressor and cannot work out. Thus the compressor is firmly supported on rubber cushions which prevent the vibrations from being transmitted to the car body, and at the same time, by first raising the compressor one-half inch and slipping out four keys, the compressor may readily be lowered from the car.

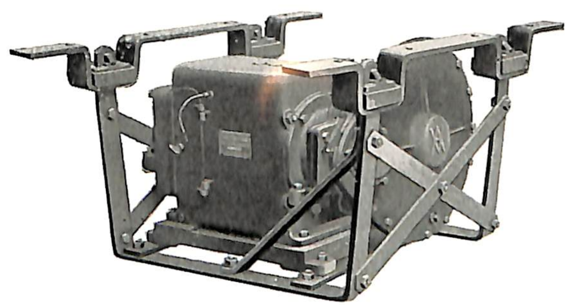


Fig. 15. Type D-3-EG Compressor in Suspension Cradle

Adjustment and Repairs

To remove the armature, first take out the four cap screws which secure the housing at the commutator end of the motor, and, after disconnecting the brush holder leads and removing the brushes, withdraw the housing. Then take out the three screws which secure the cap 16, Fig. 11, on gear case; block the crank shaft with a wooden block, remove the lock nut 50′ from the end of armature shaft, using the special box wrench provided for this purpose. Then unscrew the next nut 49′, which at same time pulls off the pinion. As the pinion cannot move outwardly on account of the gear teeth, it is necessary that the armature should be free to move in the opposite direction before attempting to unscrew nut. The armature can so move when the housing is removed as above indicated. The armature may now be withdrawn from the motor, care being taken to prevent it from dropping on the pole pieces and thereby damaging the armature coils.

To put in an armature, slide it carefully into the field until the threaded end projects from the bearing, having the key uppermost. Now put in the pinion, with keyway at top, and with a small lever pry the pinion into line with the shaft. In motors of early construction it is necessary to lift the remaining oil ring by means of a scriber or similar implement passed through the pinion, and push the armature into place. Before sliding the shaft through the pinion it is necessary to place the special pinion nut in its position against the pinion with its collar within the flange on the latter by which it is drawn off when the nut is unscrewed. As the shaft is pushed through the

pinion, the nut must be turned until the pinion is pressed firmly to its bearing, then it must be locked with the additional nut provided for that purpose. Put back the housing with the commutator end bearing, having, in the case of the older machines, removed the plate at the end to admit of lifting the oil rings, and bolt in place. Make the electrical connections as before and replace the brushes exactly as they were, in order that the bearing between brushes and commutator may not be destroyed. While the pinion hole in gear case cover is still open, turn the armature by hand to make sure that the gears run freely, then replace pinion cover and start the compressor.

Sizes and Performance Data

Designation	Displacement Cu. Ft. per Min.	Lift of Valves in In.		Speed in R. P. M.		Volts	Fuse Amperes	Air Pressure per Sq. In.
		Inlet	Discharge	Crank Shaft	Motor			
D-1-EG	14.5	$\frac{5}{32}$	$\frac{1}{8}$	214	1350	600	10	100 lbs.
D-2-EG	25.0	$\frac{5}{32}$	$\frac{1}{8}$	217	1200	600	10	100 lbs.
D-3-EG	38.0	$\frac{5}{32}$	$\frac{1}{8}$	170	875	600	15	100 lbs.
D-4-EG	50.0	$\frac{3}{16}$	$\frac{5}{32}$	183	1110	600	20	100 lbs.

Type D-F Compressors

These compressors are *light weight, compact, rigid machines* developed from the D-EG type. The crank case, cylinders, motor end bells, and half the gear case are all cast in one piece, thus eliminating the bed plate and securing perfect alignment.

Compressor Portion Type D-2-F

The compressor portion is of the two cylinder type, similar to the D-EG except that a two bearing crank shaft is used, and the pistons and the piston rods are made longer to insure minimum and even wear on the cylinders, wrist pins and pistons.

The gear case cover is in reality half of the gear case, and when removed exposes the entire gear and pinion. There is also a small removable cover over the pinion, so that the armature may be removed without taking off the gear case cover.

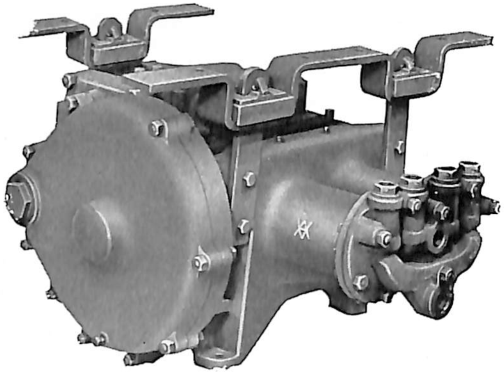


Fig. 16. Photographic View of the D-2-F Air Compressor with Suspension

In other respects the compressor is practically identical with the D-EG type, and the description of the latter will apply.

D-2-F Compressor Motor

The motor is of the enclosed, series wound, four pole type, with two field coils and a laminated field yoke. The field yoke fits between the milled surfaces of the motor housing and is held firmly in place by long cap bolts. The motor is provided with a commutator door which, when open, gives access to the brushes. This door is supported by a new type of hinge, which facilitates opening, and which, when closed, makes the motor entirely dust proof. The armature itself is of generous proportions to prevent overheating. The construction is in accordance with the best railway practice, and is similar to that of the DH. The brush holders are permanently mounted on the motor frame and are well insulated from it. The brushes are given a position of slight backward lead, which is best suited for good commutation.

Lubrication

The lubrication system is like that of the D-EG, the pistons and crank shaft bearings being lubricated by oil splashed from the crank case while the motor bearings are provided with separate oil wells and rings. As with the D-EG, some of the oil seeps over into the gear case and is carried by the gears to the rear motor bearings. A passage between its oil well and the crank case prevents the motor being flooded from that source, however. The oil level in the rear bearing is maintained from the gear case after once being filled, the excess returning direct to crank case.

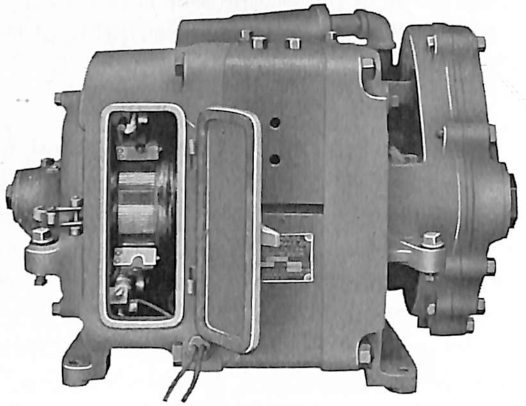


Fig. 17. View of the D-2-F Air Compressor with Commutator Door Open

Suspension

The compressor has feet for use when it rests upon the floor of the car or locomotive, and when suspended beneath the car it is supported by three steel hangers as shown in Fig. 16. These hangers are fastened to brackets which in turn are attached to the car, and are held in place by notched keys as with the D-EG type. This method of suspension makes it easy to remove the compressor from the car, it being necessary only to raise the compressor slightly and drive out the keys.

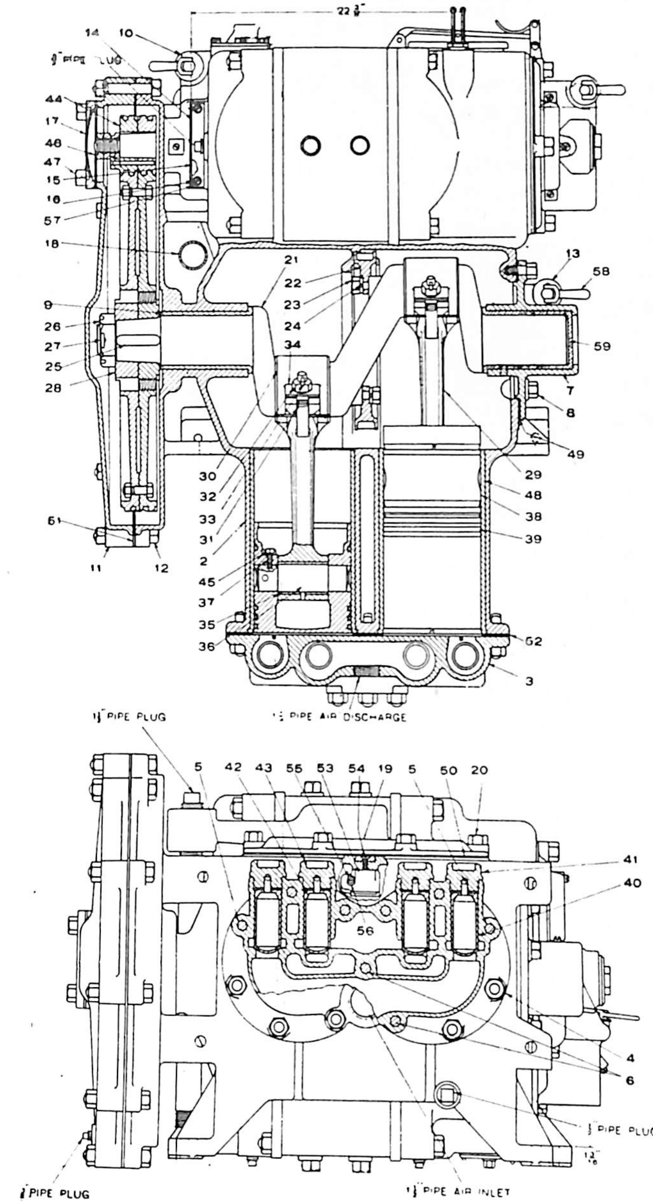


Fig. 18. Outline and Section Views of the D-3-F Air Compressor

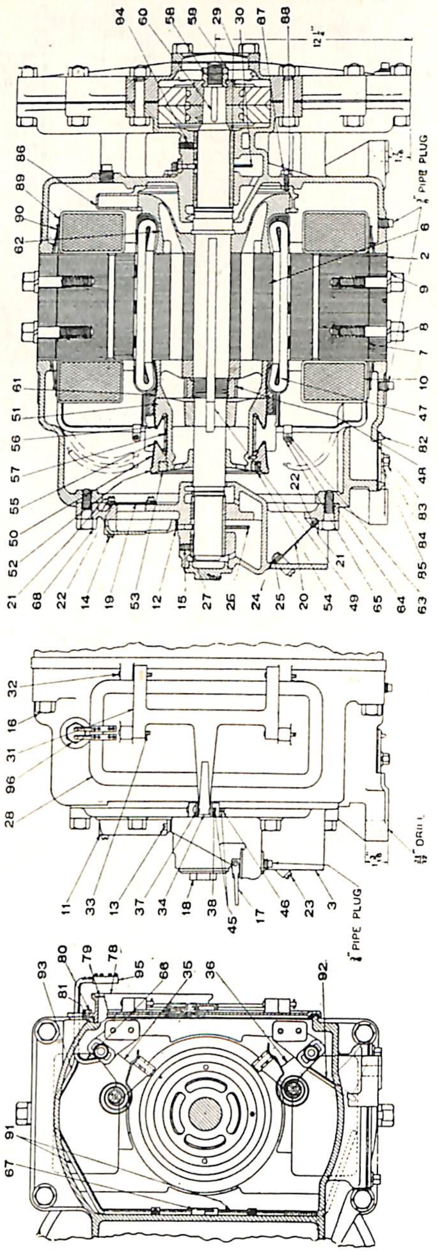


Fig. 19. Motor Portion of the D-3-F Air Compressor

Type D-3-F Air Compressor

This compressor, which is intended for use on large motor cars and small electric locomotives, has a displacement of 35 cu. ft. against 100 pounds air pressure and is capable of continuous operation without exceeding safe temperature limits.

The *compressor portion* is similar in design to that of the D-2-F type except the cylinders are provided with bushings which can be renewed when worn, and the pistons are fitted with four rings, three of which are compression rings (39) while the fourth (inner ring) is an oil ring. The method of lubrication is also somewhat different. An oil wheel, mounted on the crank shaft between the connecting rods, picks up oil from the crank case and with the aid of deflectors on the crank case cover and ribs on the crank case wall, distributes the oil to the crank shaft and connecting rod bearings.

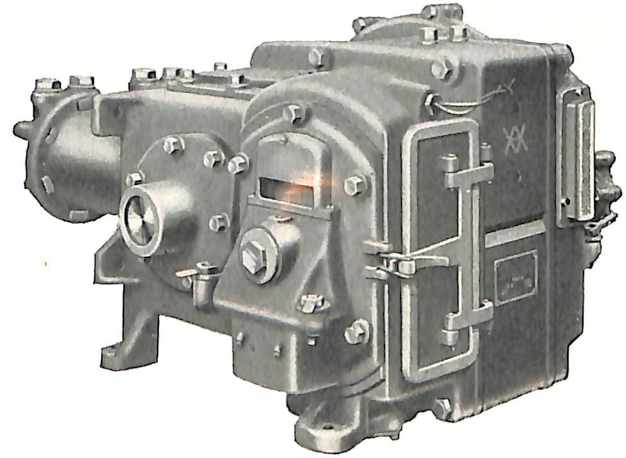


Fig. 20. Photographic View of the D-3-F Air Compressor

The *motor portion* is provided with a ventilating system which enables it to drive the compressor continuously as before stated. A fan on the rear end of the armature draws air through screened openings in the front end of the motor, through ducts in the commutator bushing and armature core, and is blown out through a fan housing and nozzle. This nozzle is so designed that the air from the fan induces a flow of air across the surface of the armature and between the field coils.

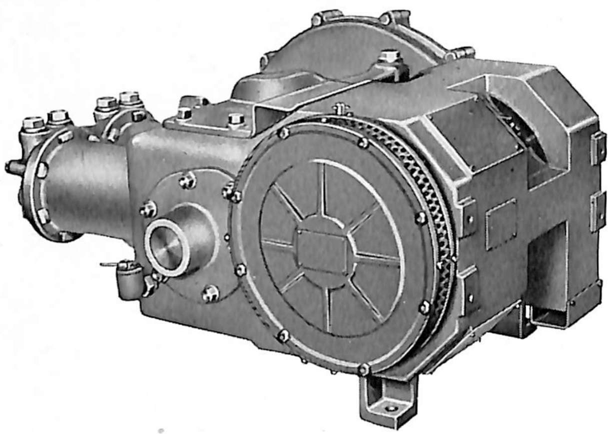


Fig. 21. Photographic View of the XD-3-F Air Compressor

XD-3-F Air Compressor

This compressor is quite similar to the D-3-F just described except that it is provided with an A.C. motor which is designed for operation on 25 cycles, single phase alternating current at 100 volts.

The rated motor speed of 1000 R.P.M. provides for displacement of 35 cubic feet per minute, and continuous operation at 100 pounds air pressure will not cause dangerous overheating.

The rotor runs on ball bearings which contribute to a cool running rotor shaft while a motor ventilating system comprising a fan, air ducts and screened openings, insures against overheating of the rotor and stator windings.

An alemite fitting is used to lubricate the front motor bearing while the rear motor bearing is lubricated by the circulation of oil in the gear case. The crank case is filled with oil (through the oil fitting 13) which, when filled to the proper level, provides for the lubrication of the compressor portion as described for the D-3-F compressor, and also the rear motor bearing as above stated.

The rotor is readily accessible upon removal of the cover, the fan and the bearing housing, and if the pinion is loosened the rotor can then be easily withdrawn from the motor.

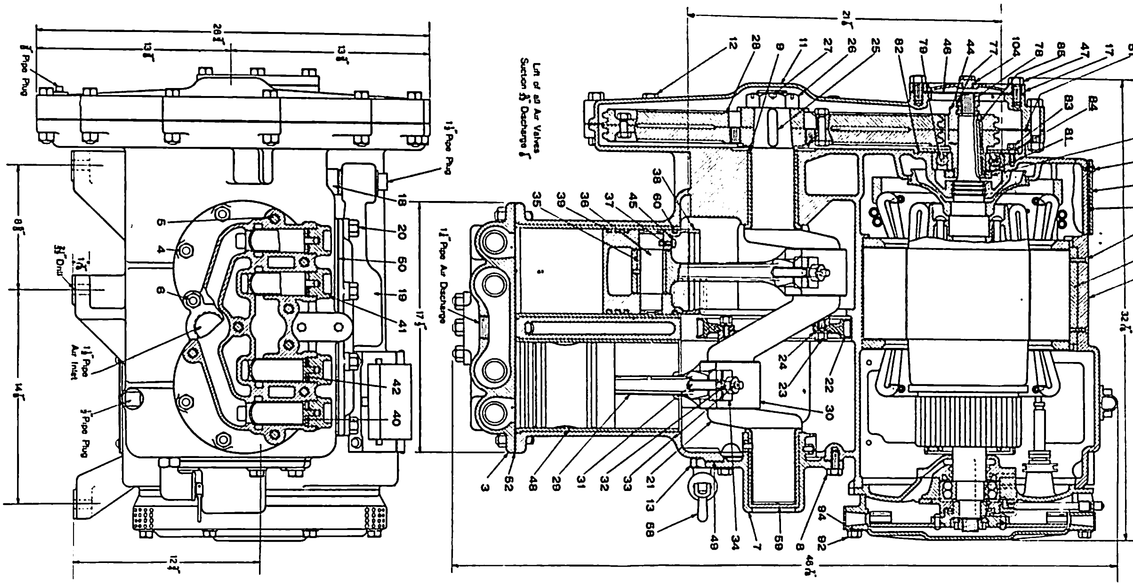


Fig. 22. **Outline and Sectional Views of the XD-3-F Air Compressor**

Type DF Air Compressors—Sizes and Performance Data Based on 100 Pounds Air Pressure

Compressor	Dis. Cu. Ft. per Min.	Voltage	Amperes		Approximate Weight		R. P. M.		Approximate Dimensions			Pipe Size		Valve Lift	
			Oper-ating	Fuse	Net	Ship.	Com-pressor	Motor	Length	Width	Height	Inlet	Dis-charge	Inlet	Dis-charge
D-2-F	25	600	7.0	10	975	1075	200	1150	37¾″	29¾″	21½″	1¼″	1″	5/32″	⅛″
		32	170	250											
		64	85	125											
		125	44	75											
D-3-F	35	230	23.7	40	1430	1615	179	1100	42″	34⅜″	24½″	1½″	1¼″	5/32″	⅛″
		600	9.1	15											
		1200	4.55	10											
		1500	3.63	10											
XD-3-F	35	100	90	150	1470	1660	179	1000	45″	33″	27″	1½″	1¼″	5/32″	⅛″
D-4-FS	50	500	15.5	20			225	1575	42″	34⅜″	24½″	1½″	1¼″	5/32″	⅛″

D-K Type Compressors

The D-2-K and D-3-K compressors were designed for use in *high voltage* railway service while the D-4-K was developed to supersede the D-4-EG compressor. The D-4-K has in turn been superseded by the D-4-P compressor and the D-2-K and D-3-K by the DH and D-F types.

The design of the compressor portion is very similar to that of the D-EG. The dimensions of various parts, such as the crank shaft bearings, wrist pins and connecting rods have been increased in order to give a more rugged construction. The principal difference in appearance is in the gear case which is divided on a horizontal instead of a vertical plane, the top being removable for inspection of the gears. This form of gear case is known as the K type.* The pistons have been lengthened and the thickness of the cylinder walls has been increased so as to permit a greater number of reborings. The distance between the centers of the cylinders has also been increased.

The construction of the motor is practically identical with that of the D-EG except for the necessary modifications in winding for the D-2-K and D-3-K, due to the high voltage for which they are designed.

The lubrication and suspension of the compressor are exactly the same as for the D-EG, and will be found described in the section devoted to that type.

*NOTE:—The D-2-K 1500 volt compressor has the F type of gear case.

The performance data based upon an operating air pressure of 100 lbs. per square inch, for all three sizes is as follows:

Designation	Displacement Cu. Ft. per Min.	Lift of Valves in In.		Speed in R. P. M.		Volts	Fuse Amperes
		Inlet	Discharge	Crank Shaft	Motor		
D-2-K	26.0	5/32	1/8	221	1200	1200	10
D-2-K	26.0	5/32	1/8	221	1200	1500	10
D-3-K	38.6	5/32	1/8	173	875	1200	10
D-4-K	50.0	3/16	5/32	183	1100	600	20

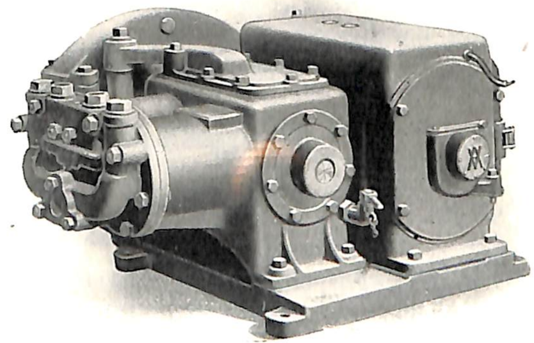


Fig. 23. Photographic View of the D-2-K Air Compressor

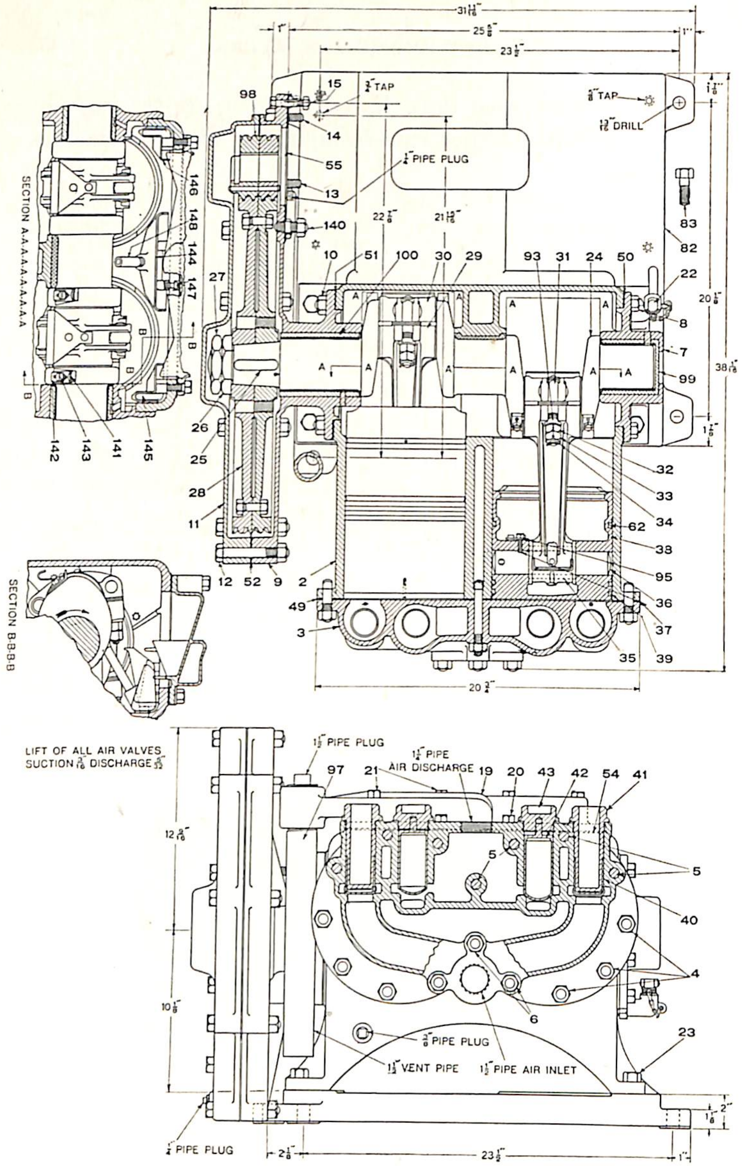


Fig. 24. Outline and Sectional Views Type D-4-P Compressor

D-4-P Air Compressor

The D-4-P Compressor supersedes the D-4-K and was developed in order to provide that size of compressor with a motor of such design as will have a greater margin against overheating and will give good commutation

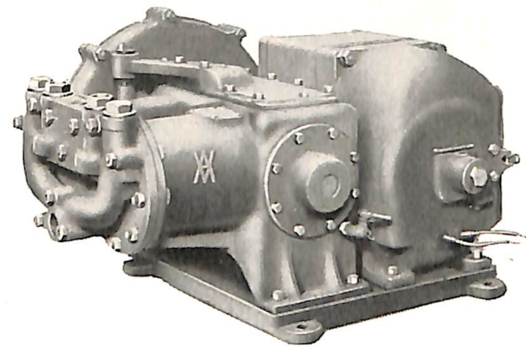


Fig. 25. Photographic View of the D-4-P Air Compressor

under a wider range of operating conditions. Like the D-4-K, the compressor portion and the motor are of separate construction, being mounted on a common bed plate and supported by the cradle form of suspension, as described for the D-EG type.

The compressor portion, Fig. 24, is identical with the D-4-K except that the F type of gear case is used, and a larger bed plate is required on account of the increased size of the motor.

The motor, Fig. 26, is larger than that of the D-4-K and can be supplied for operation at various voltages as specified in the table.

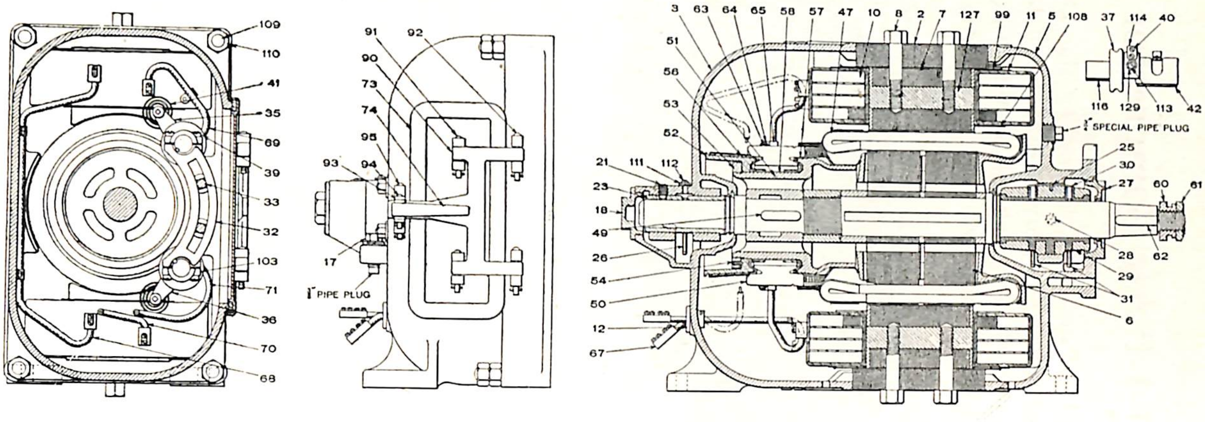


Fig. 26. Type D-4-P Compressor Motor

Type D-4-P Air Compressors—Sizes and Performance Data Based on 100 Pounds Air Pressure

Dis. Cu. Ft. per Min.	Voltage	Amperes		Approximate Weight		R. P. M.		Approximate Dimensions			Pipe Size		Valve Lift	
		Operating	Fuse	Net	Ship.	Compressor	Motor	Length	Width	Height	Inlet	Discharge	Inlet	Discharge
50	90 115 235 480 600 1200 1500	86 67.5 33 16.2 12.9 6.45 5.15	125 100 50 25 20 10 10	1650	1875	184	1000	41″	34½″	25″	1½″	1¼″	3/16″	5/32″

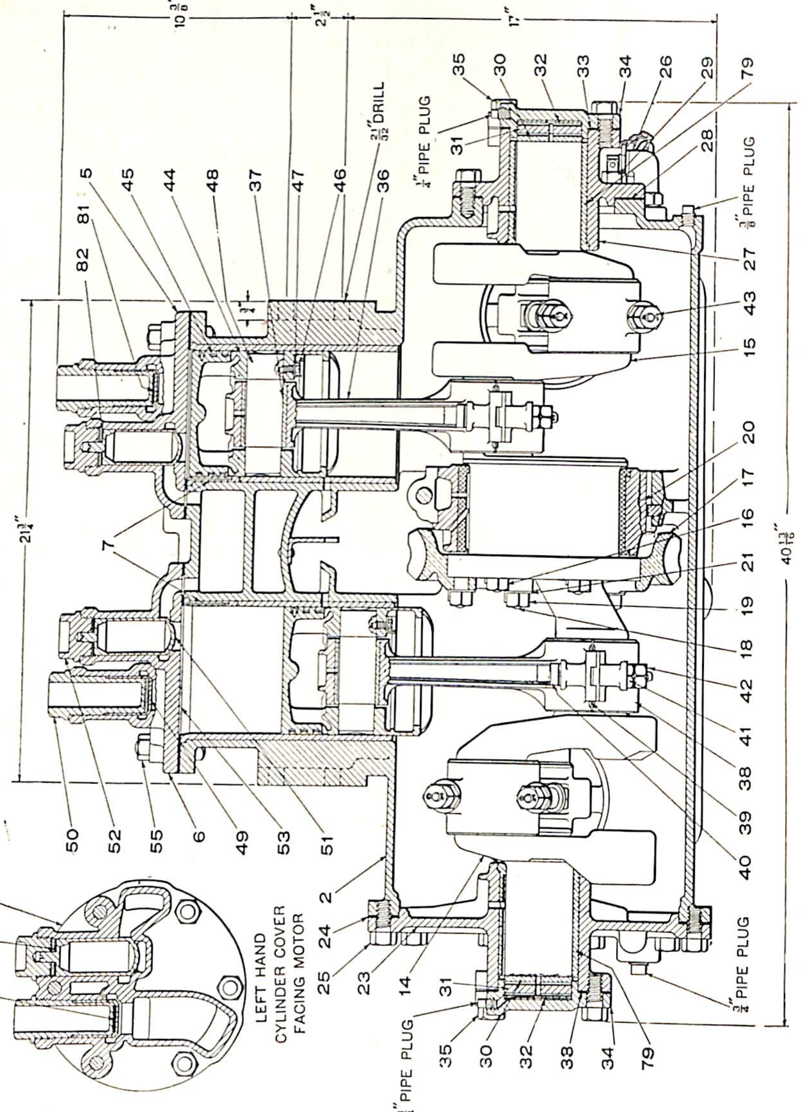


Fig. 27. XQ-27 Air Compressor, Section through Vertical Cylinders

XQ-27 Air Compressor

This is a four cylinder single stage air compressor driven through worm and gear by a single phase motor. The frames of the motor and compressor are bolted together and suspended by hangers from the car body. Two cylinders are horizontal and two vertical, and each cylinder has a cylinder cover containing a bottle type discharge valve 51 and a similar type inlet valve 49, Fig. 27. The two piece crank shaft, 14 and 15, is bolted at the center to the worm wheel 17 which is driven by a worm on the armature shaft 30 of the motor, Fig. 31. Each of the four pistons has three rings, two compression (outer) rings 45, and an (inner) oil ring 85, Fig. 29.

The compressor is single acting, air being drawn into each cylinder past the suction valve on the suction stroke and compressed on the pressure stroke, seating the suction valve and lifting the discharge valve, and passing

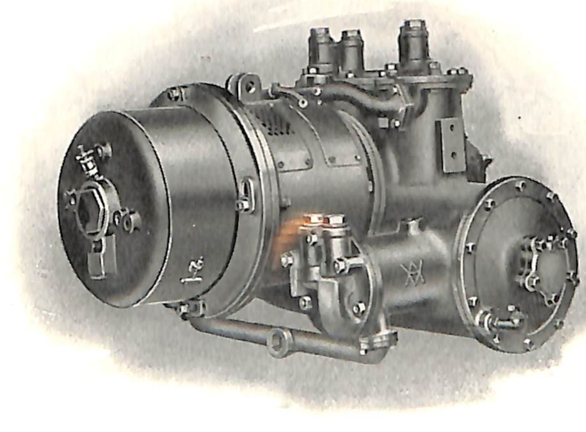


Fig. 28. Photographic View of XQ-27 Compressor

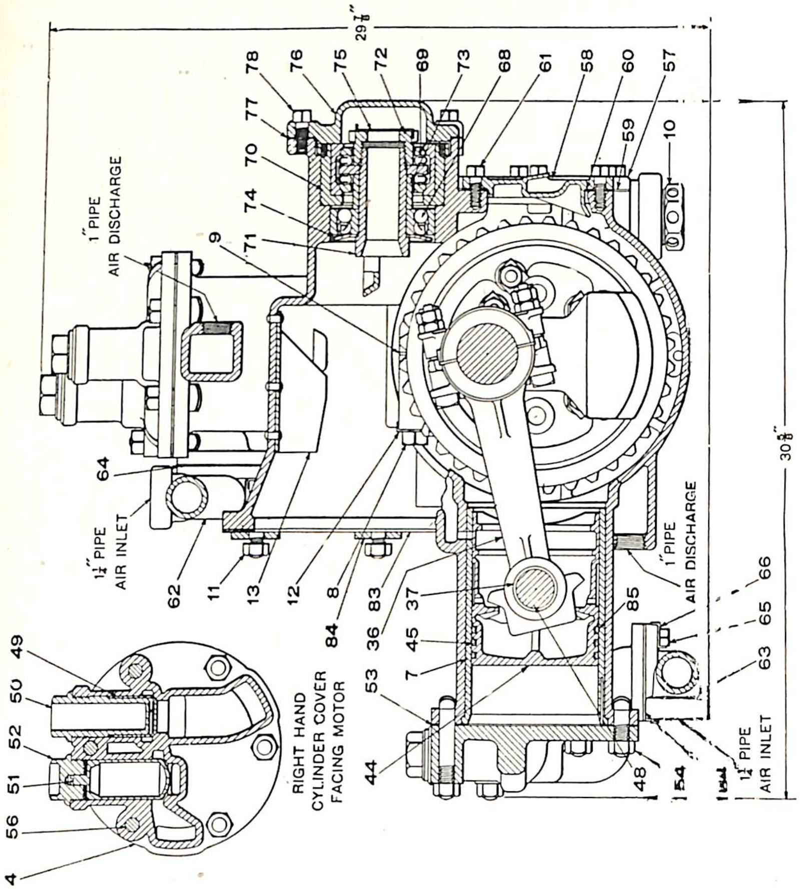


Fig. 29. Sectional Views of the XQ-27 Compressor

directly to the main reservoirs. Special features contributing toward quiet operation are: worm and gear drive, slow speed, balanced crankshaft, 90 degree angularity of cylinders, generous compressor end bearings, self aligning thrust bearing for armature shaft, and ball motor bearing.

Lubrication is by the splash system, crank shaft splashers distributing oil to all parts of the crank case, cylinders, etc. Baffle, 13, assures a constant supply to the worm gear and its bearing. Oil level should be kept to the top of the oil fitting, 26, and should be renewed at regular intervals.

The motor bearings are of the ball bearing type, the commutator end bearing being lubricated by a grease cup and the worm end bearing by the splash system.

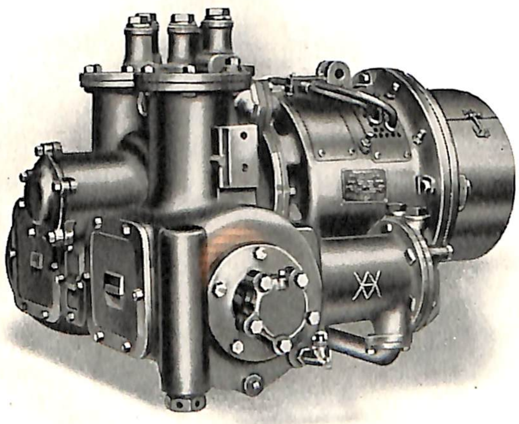


Fig. 30. Photographic View of XQ-27 Compressor

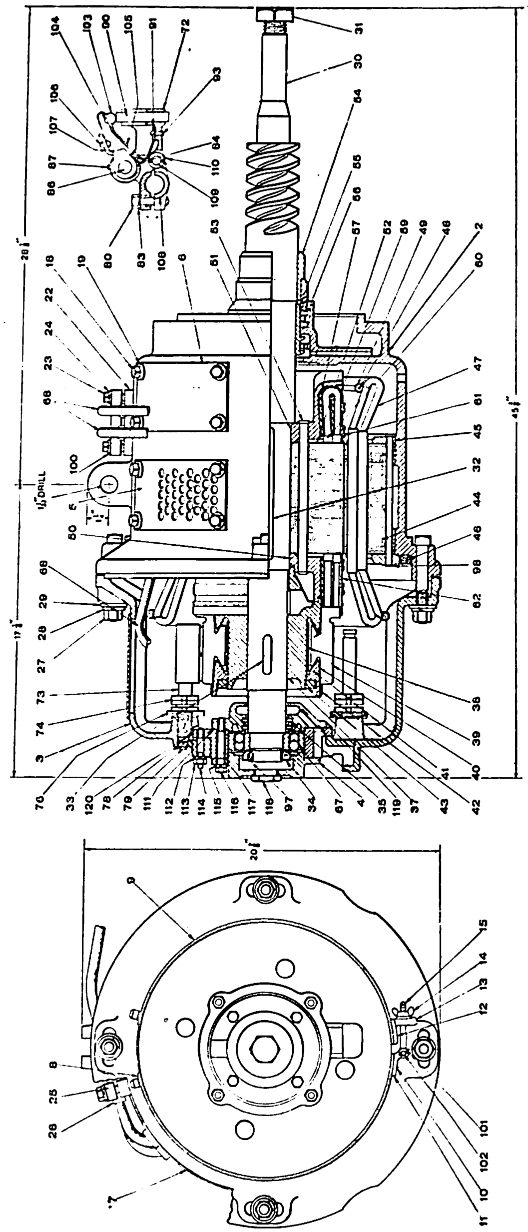


Fig. 31. Motor Assembly for XQ-27 Compressor.

The air strainer should be cleaned at regular intervals. If a pounding develops it is probably due to a loose connecting rod. Locate the guilty rod and remove a shim from between the halves of the bearing and tighten the bolt to remove all play. Do not remove too many shims and leave an unfilled gap as the rod will bind under these circumstances.

To Remove the Armature:

First remove the bolts, attaching the motor and compressor frames; remove compressor thrust bearing cover, 76, exposing worm shaft nut 31, Fig. 31; remove this nut and insert bearing cover cap screws in tapped holes of thrust bearing ring 70, and pull out thrust bearing 69, and radial bearing 68. Motor portion may then be backed off by worming the shaft worm out of engagement with compressor worm wheel.

Now loosen lead clips from carbon holders. Then, tie to the motor eye bolt and pick the motor up and stand it on end with the end bell down; remove the four bolts securing end bell to motor frame and lift off the motor frame. Remove commutator end bearing housing, 3, and its cap 4, and then drop the motor ball bearing. Remove the armature.

When reassembling, the notch on gear must coincide with notch on crank case when arrow on end of worm shaft points down.

C Type Air Compressors

This type compressor, which was developed to supply 130 to 140 pounds of air pressure in electric locomotive service, is of the *two stage three cylinder type* with compressor portion and motor mounted on a common bed plate.

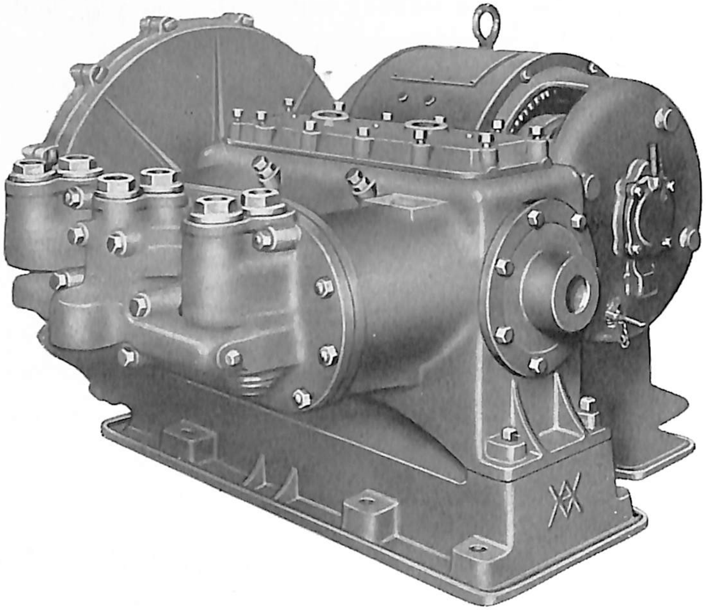


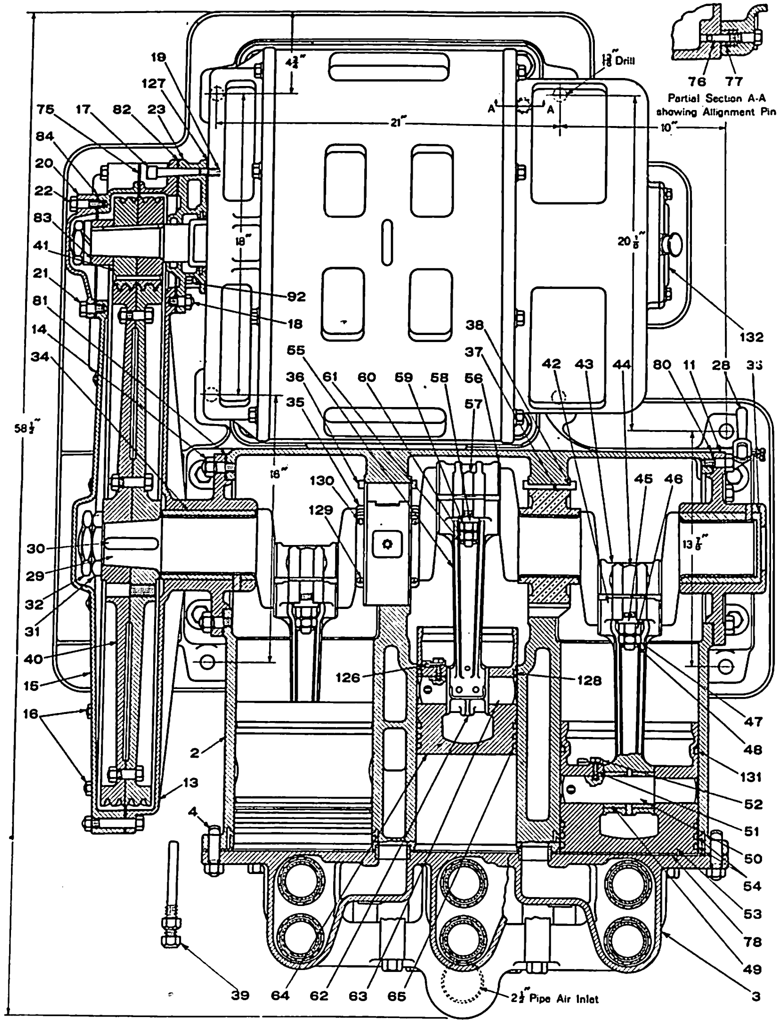
Fig. 32. Photographic View of the XC-75 Air Compressor

The compressor portion, Figs. 33 and 34, has two low pressure and one high pressure cylinder, the latter being located between the other two. The low pressure cylinders receive air from the atmosphere through the suction inlet, compress it to the first stage, and discharge it into an intercooler. From there it passes into the high pressure

cylinder where it is raised to the final pressure and discharged into the reservoir. The intercooler should consist of the equivalent of 100 feet of 2-inch pipe, arranged for rapid radiation of heat. It serves to cool the air from the high temperature incidental to its initial compression; in this way the volumetric efficiency is increased and the compressor is enabled to operate for longer periods without overheating. The intercooler and final discharge pipe connections are made on the cylinder casting itself so as to be independent of the cylinder head, which can be removed for inspection by breaking only the suction pipe joint.

The six discharge valves 72, Figs. 33 and 34, are of the "bottle" type while the three inlet valves 66 are of the "toadstool" type. They are all made of chrome vanadium steel forgings and are double oil tempered to give the greatest strength and resistance to wear and distortion. The valve seats 69 and 73 are of brass, and are so arranged that they are readily renewable. The crank shaft is of ample proportions and is forged from shaft steel and heat treated. It is supported by two end and two intermediate bronze bearings. The low pressure cranks are 45 degrees apart and the high pressure crank 180 degrees from one low pressure crank, thus giving uniform turning effort. The crank case is vented to the atmosphere through two holes in the top cover 24, which should be piped to the outside of the locomotive. The gear case is of the K type.

The lubrication of the compressor is like that of the D-EG type except that the motor bearings are packed with waste instead of using oil rings, the oil being drawn from the oil wells by capillary attraction. No suspension



Lift of all Air Valves 1/8" except Intermediate Inlet Valve of XC-60 Compressor Complete Pc. 80518 which has 1/8" Lift

When Compressor is used with XB-650 Motor, capacity is as follows.-

125 Volts - 60 Ft. Displacement
145 Volts - 75 Ft. Displacement

Fg. 33. Sectional View of the XC-75 Air Compressor with XB-650 Motor

is furnished with the compressor as it always rests on the floor of the car or locomotive.

The compressor is driven by either A.C. or D.C. motors designed to run continuously and for compressor displacements of 60 or 75 cubic feet of air per minute at 140 pounds pressure. The 60 cubic foot compressor is designated at the "C-60" while the 75 cubic foot compressor is designated as the "C-75" with D.C. motor and as the "XC-75" with Single Phase A.C. motor.

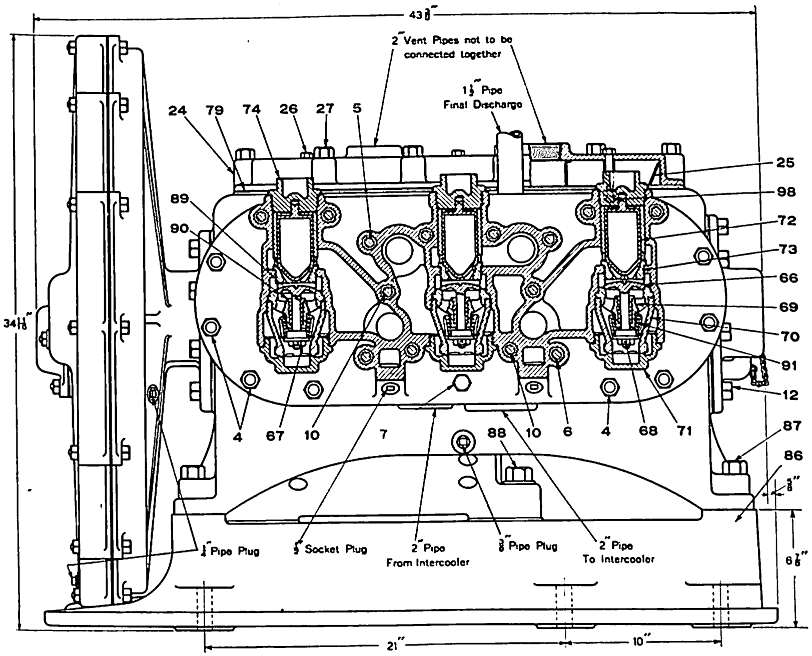


Fig. 34. End View of the XC-75 Compressor with the Valves in Section

Type C Air Compressors—Sizes and Performance Data Based on 140 Pounds Air Pressure

Compressor	Dis. Cu. Ft. per Min	Voltage	Amperes		Approximate Weight		R. P. M.		Approximate Dimensions			Pipe Size		Valve Lift	
			Operating	Fuse	Net	Ship.	Compressor	Motor	Length	Width	Height	Inlet	Discharge	Inlet	Discharge
C-60	60	600 DC	18.5	30	2475		176	800	48"	43"	27"				
C-75	75	115 DC	109	150	2475		222	1000	49½"	43"	26¾"				
		1500DC	8.7	15	2475		222	1190	58½"	44"	34½"	2½"	1½"	3/32"	3/32"
XC-75	75	145 AC	140	200	3360		222	1190	58½"	44"	34½"				
		290 DC	49	75											

CA-150 Air Compressor

The CA-150 air compressor is of the cross compound double-acting type, the low pressure cylinder being 14½" in diameter, the high pressure 8" in diameter, with an 8" stroke. An intercooler is used between the two stages of compression.

The compressor operates at a normal speed of 100 RPM, and is driven by either a D.C. or an A.C. motor through a worm and wheel having a ratio of 12 to 1.

Where the motor design does not lend itself to integral mounting, this compressor can be supplied with flexible coupling for drive by separately mounted motor.

Integral Worm Shaft and Armature Shaft:

The worm shaft, reference 77, and armature shaft are of one piece construction and are supported by self-aligning radial ball bearing 75 and a sleeve bearing between the armature and the worm. The end thrust on the worm shaft is taken by a two-direction self-aligning thrust bearing 76.

It is intended that the armature shaft turn clockwise as viewed from the commutator end of the motor. However, if by accident it should run in the opposite direction, the worm shaft will be held in place by the two-direction, self-aligning thrust ball bearings.

No bearing adjustment is required, but if a thicker gasket than is now used is applied to make the joint on the cover for the thrust bearing housing oil tight, the thrust bearing will have space to permit its moving endways back and forth when the worm rotates backwards a fraction of a revolution due to the pressure on the pistons equalizing when the compressor is stopped. On the other hand the thrust bearing should not be gripped too tightly. All that is needed is to prevent end movement of it.

It is important to note before starting to remove the worm shaft that there is an arrow on the end which is seen when the cover is removed from the thrust bearing housing. When the arrow is pointing downwards, a rough measurement should be made from the bottom edge of the large rectangular doorway to any convenient tooth

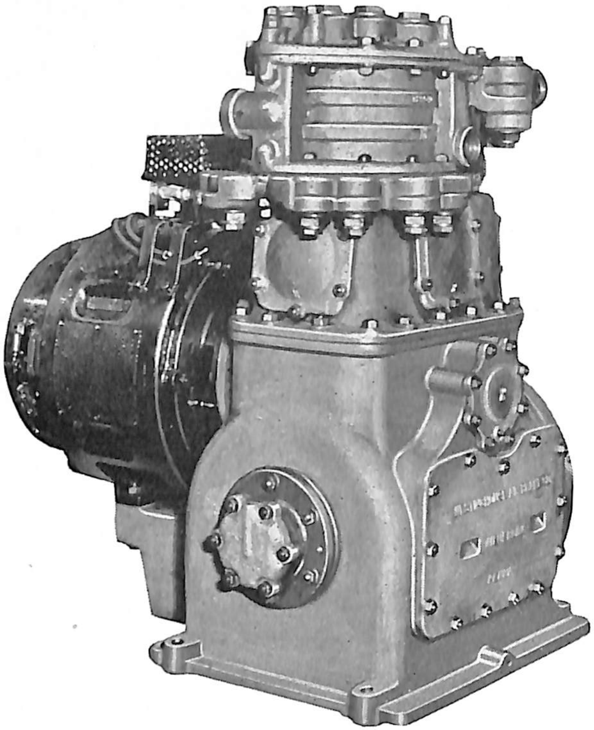


Fig. 35. Photographic View of the "CA-150" Cross Compound Air Compressor with Integral Worm Shaft and Armature Shaft

on the wheel. Mark this tooth permanently. These positions of the worm shaft and wheel should obtain when the worm is put back again, and this relation must be observed whether it is the worm only, or the wheel or both, which are to be removed. This insures the same thread engaging with the same teeth in the wheel which have either been worn or were scraped to a good bearing.

To remove the worm shaft proceed as follows:

Remove bearing cap 88, pull out cotter 150 and pin 82 (Fig. 36) then back off nut 81. Remove bearing 76 and disconnect the motor by removing the bolts attaching it to the compressor. The motor and worm shaft can then be pulled out by rotating the armature until the worm is disengaged from the gear. When re-assembling, rotate the crank shaft until the notch chipped across the face of the worm gear is horizontally in line with the groove chipped across the left hand inside edge of the large door in the base. Assemble the worm shaft so that when it is in place, and the gear is in the above described location, the arrow on the end of the worm shaft is pointing downward.

Separate Worm and Armature Shafts with Flexible Coupling:

The worm may be removed from the compressor without taking off the ball thrust bearing or the radial bearings. After the flexible coupling is taken off and cover on the thrust bearing housing removed, the worm shaft should be rotated counter clockwise, as viewed from the thrust bearing end, until it comes to a stop, caused by the ball bearing at the coupling end fouling with the wheel teeth. The outer ball race being spherical, this race may be tilted from its normal vertical plane so as to stand with the top towards the thrust bearing and the bottom

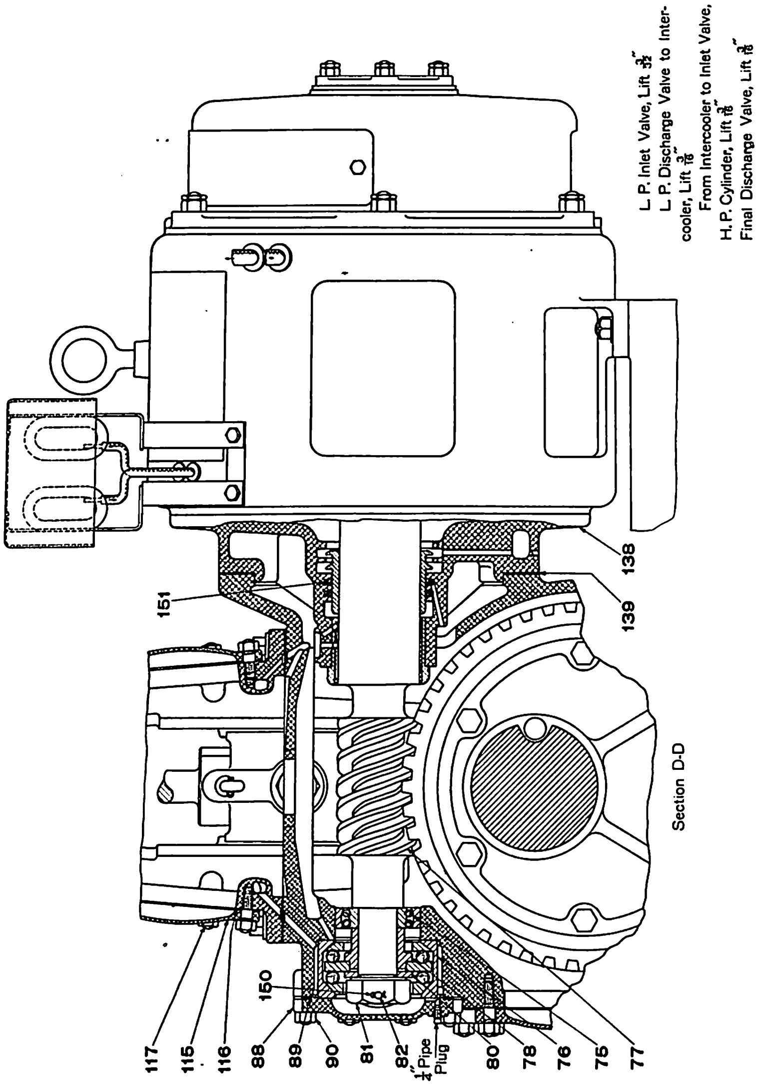


Fig. 36. CA-150 Compressor, Sectional View Showing the Worm Drive

towards the coupling. In this position the race will clear the wheel teeth and the worm can be unscrewed from the wheel. However, it is necessary to rotate the wheel a little at the same time. The race can be reached through a small doorway in the centerpiece above the large rectangular door. Using the end of a hammer handle the race should be tapped at the top so as to cause it to lean backwards, then rotate it by hand 180° when it will lean in the opposite way. The reason for this is the difficulty to get at the underside of the race.

CRANK SHAFT:

The worm wheel rim 62, see Fig. 37, is secured to the disc on the crank shaft 61 by six bolts 63. The nuts on these bolts, and the flange on the inner rim of the wheel are to the left looking in at the large rectangular doorway on the crank case. This arrangement should be adhered to in re-assembling the compressor, for the reason that the wheel teeth will have the best bearing and the end thrust of the wheel rim will be resisted by the flange instead of the nuts.

The crank shaft is supported by two bronze bearings (babbitt lined) pressed into housings fastened to the crank case. End movement of the shaft is resisted by a thrust bearing at each end, consisting of one hard bronze disc 71 and one hardened steel disc 72. The bronze disc, next to the shaft, is free to rotate, while the steel disc is prevented from rotating by two dowel pins.

Between the steel disc and the bearing housing cover are several thin disc liners 73. They are also kept from rotating by the dowel pins. More liners should be added as the discs and the end of the shaft wear, and this can easily be determined by measuring the end play of the

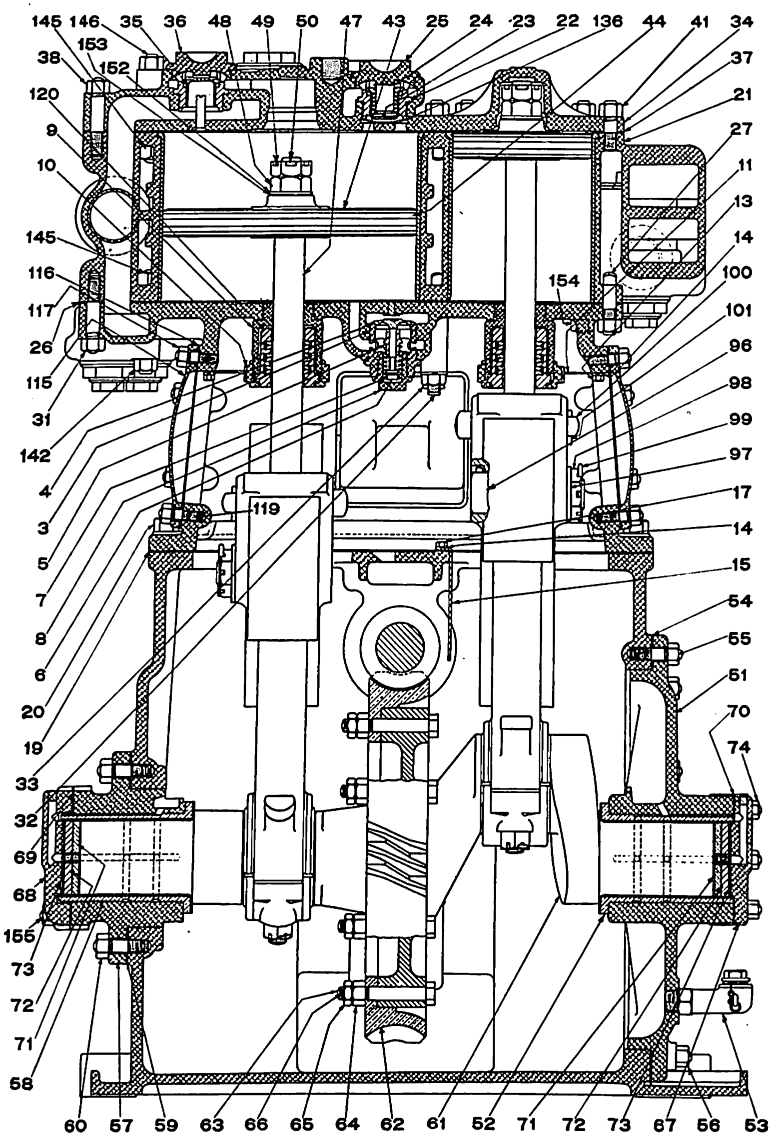


Fig. 37. CA-150 Compressor, Section through Air Cylinders and Crank Shaft Main Bearings

shaft, as there is only .002″ end play allowed when the compressor leaves our factory. This should be maintained as closely as practicable, because when once the wheel teeth are fitted to the shape of the worm thread, that is, the teeth have become a matrix of the threads, endwise adjustment of the wheel will cause a reduction of the bearing area to practically a line contact, depending upon the amount the bearing has worn. However, the unit bearing pressure on all the bearings is comparatively low, so that it will be a long time before the wear is enough to need a liner .005″ thick. Liners not exceeding this thickness should be kept on hand and one added as soon as the wear is this amount, and care should be taken to see that it is put into that thrust bearing which carries the load, that is, the bearing in the large circular cover.

Another reason for limiting the end motion of the crank shaft is on account of the shaft being pushed over against the opposite thrust bearing, due to reversal of rotation of the crank shaft caused by the pressure on the pistons equalizing when the power is thrown off. This also occurs when the air pressure is so low that compression takes place only in the low pressure cylinder. There is no reversal when operating on air pressure above 50 lbs. and the valves are seating properly.

To remove the crank shaft proceed as follows:

After disconnecting and removing the connecting rods 102 (see Fig. 38) from the crankpins, and the large circular cover 51 (Fig. 37) which is also the housing for one of the main bearings 52, is taken off, the worm shaft, and a rib on the base which makes the waste oil tray, are both in the way of the crank shaft being removed from the other bearing and the crank case. To get the crank

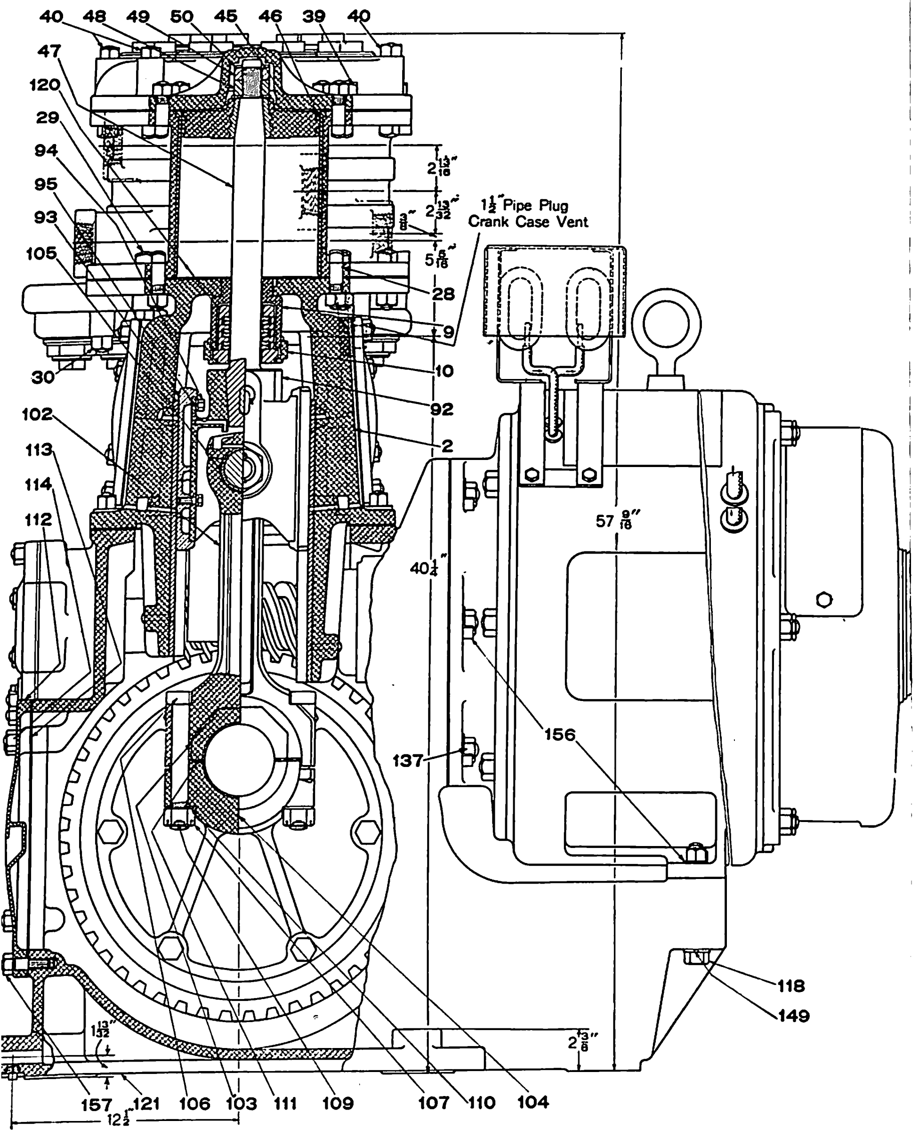


Fig. 38. CA-150 Compressor, Section through the High Pressure Cylinder Showing Crosshead and Connecting Rod Details

shaft out, therefore, either the worm shaft must first be taken out and the other main bearing housing loosened up, at least pulled out as far as the close fitting part keeps it from being oscillated slightly, or it also should be entirely removed and not disturb the worm shaft. The latter method is the better of the two.

Care should be taken when working the crank shaft out or into the crank case not to mar the crank pins or the main bearing journals.

Connecting Rods:

The wrist pin bearing is a bronze bush 105, Fig. 38, pressed into a suitable bored hole in the cast steel rod 102. There is no take up for wear at this end of the connecting rod, but there is at the crank end which is effected in the usual way by removing a liner from under the cap 104 which forms one-half of the bearing. The other half of the bearing 103 is removable and its shape and method of holding in the rod permits adjusting the rod length to compensate for wear by adding a liner on the back of the half bearing, that is, between it and the rod. Note that it is not necessary for this liner to extend down on the two slanting sides of the half bearing.

Both the half bearing shell and the cap are lined with high grade babbitt metal held in by cored dovetail recesses.

The normal length of the rod between centers of bearings is 16″, but what is more important, and is easier gaged, is the distance between the bearings as measured from the bottom (inside) of the wrist pin bearing to the top (inside) of the crank pin bearing, which is 12.877″.

In addition to spring cotters in the ends of the bolts, which will prevent the jam nuts dropping off, sheet iron

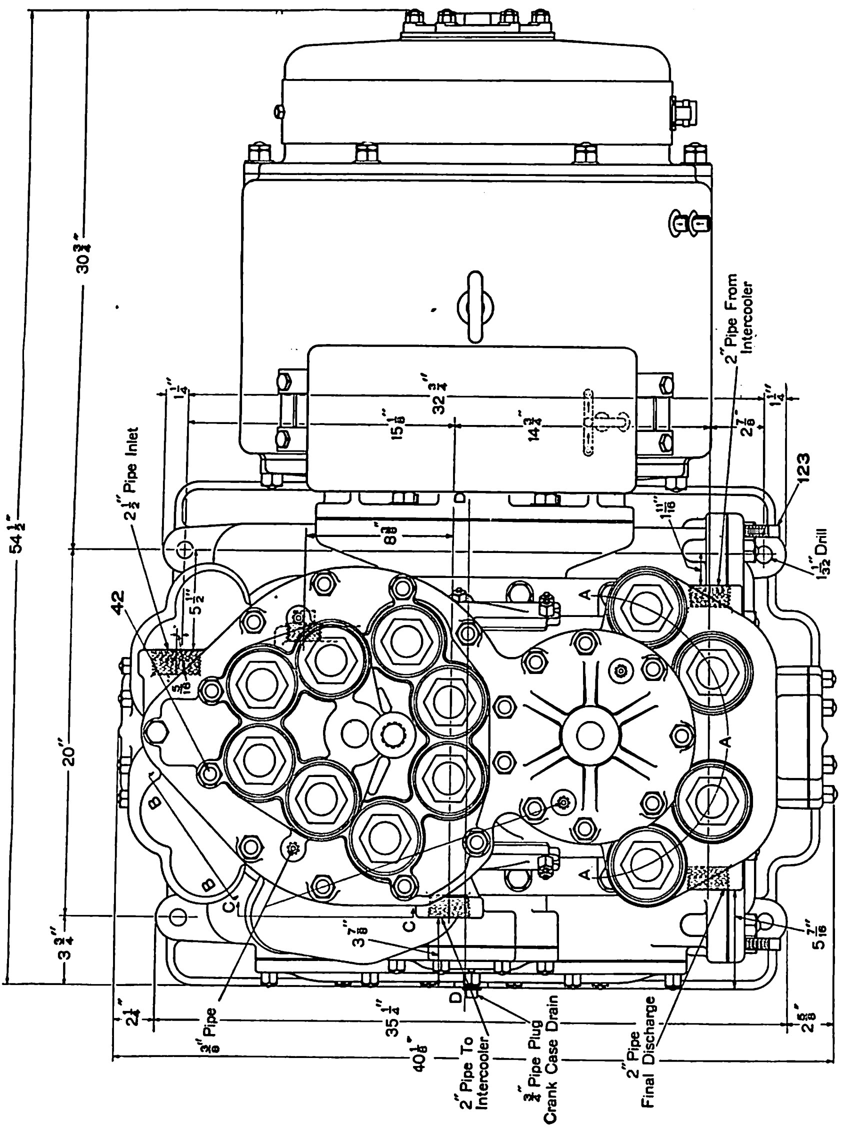


Fig. 39. Top View of the CA-150 Air Compressor

nut locks under the thick nuts are used. It is important to see that they are not omitted at any time.

Cross Heads:

Since the crank shaft rotates only one way, only one side of the guides for each cylinder and one of the shoes 93, Fig. 38, on each cross head are subject to wear, namely, those on the motor side of the compressor. When the compressors leave the factory the cross heads fit easily, but with no perceptible clearance between the guides. Whatever wear occurs and has to be compensated for, can easily be determined with "thickness gages" inserted between the shoe and the guide. Wear should be taken up when it amounts to .005", by inserting a liner this thickness between the shoe and the cross head on the side towards the motor. It will be a long time before this thickness of liner is needed, but the reason for this refinement is to avoid the crossheads being slapped against the back guides due to reversal when the compressor is stopped. Of course it is also better for the piston rod packing to have the rods centrally maintained.

To remove the cross heads, first remove the pistons and disconnect the connecting rods from the crank shaft. The cross heads with the piston rods can then be lowered into the crank case and passed out through the large rectangular doorway.

The cranks, of course, will have to be set so they will not obstruct the doorway.

Pistons and Packing Rings:

The pistons and rings are the same type as are employed in the 8½" cross compound steam-driven compressor, in fact, the low pressure piston is identical except that it is made a closer fit in the cylinder. On account of

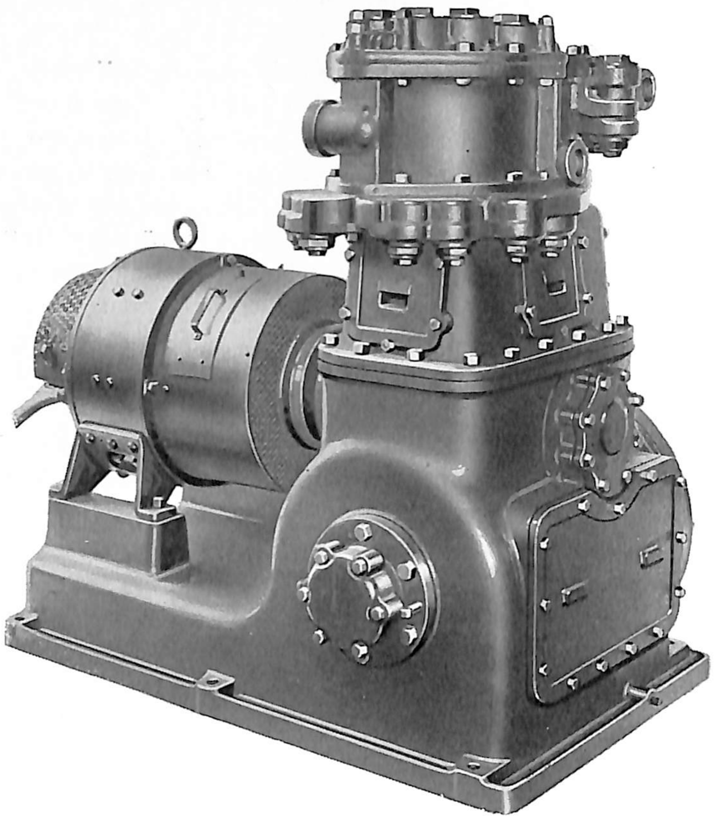


Fig. 40. The "CA-150" Cross Compound Air Compressor with Separate Worm and Armature Shafts and Flexible Coupling

the stroke being positive and the small clearance space between the piston and cylinder heads it is important to see, should a new piston be applied, that the distance from the boss on the piston to the boss on the crosshead is 13.034″.

If new rings have to be applied, the pistons must be pulled off the rods, jack screw holes in the pistons having been provided for that purpose.

PISTON ROD PACKING:

This is a metallic packing and was designed especially for this compressor. It does not fit the standard 8½″ cross compound compressor piston rod packing box, but the threaded portion in the cylinder head is standard, so that standard boxes can be used. However, none of the ordinary metallic packings which were tried could be made air tight and maintained so without more or less frequent tightening.

Our experience with the packing employed bears out the manufacturer's claim which is—long service with no attention needed when properly applied and lubricated. The latter is especially good on this compressor, in fact a baffle is installed above the worm to prevent too much oil being thrown from it to the rods.

Sheet iron brackets are attached with screws to the inside of the centerpiece above the end doors. They are to prevent the packing box nuts from turning loose. If much vapor is noticed at the vent in the centerpiece it is evidence of the packing leaking. The nut should be tightened if leakage occurs from the nut having loosened, but this will not stop a leak due to any other cause.

Lubricating System:

The lubricating system is entirely automatic, requiring no attention other than to replenish the oil supply in the crank case through the fitting 53, Fig. 37, which also serves to indicate the oil level. The connecting rods dip into the oil and splash a generous amount into the crank shaft bearings and onto the connecting rod journals. The worm wheel revolves in the oil and carries it up onto the worm which throws it off in all directions—onto the cross heads and into troughs suitably arranged to direct the oil into all worm shaft bearings. The cylinders are adequately lubricated with the oil which adheres to the

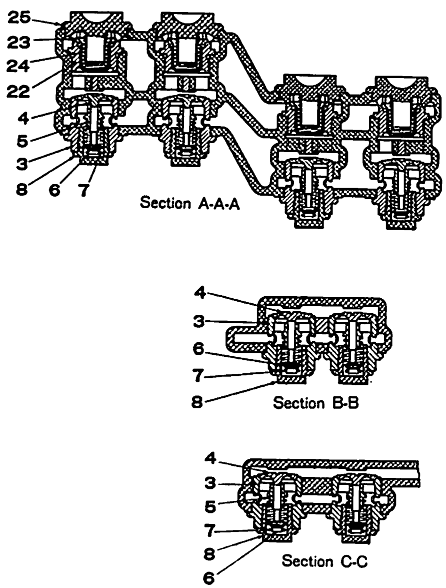


Fig. 41. Sectional Views of Air Valves

piston rods and is carried into the cylinders. There are tapped holes in the cylinder heads for oil cups if they are found to be necessary. The oil should not be permitted to get below the bottom of the filling fitting.

Valves—General:

There is a total of twenty-four air valves, twelve for the top of the two cylinders and twelve for the bottom ends. All valves are of the same diameter, but there are three different types, viz., mushroom, cup and inverted cup. All valves are spring loaded except the upper low pressure inlet valves. The lift of each low pressure inlet valves is $\frac{3}{32}''$, while the lift of all other valves is $\frac{3}{16}''$.

There are twelve *mushroom type* valves (all spring loaded); four of these are the lower low pressure inlet valves, located at the bottom of the low pressure cylinder; four are high pressure inlet valves (two connected to the upper and two to the lower end of the high pressure cylinder), located at the lower end of the high pressure cylinder, and four low pressure discharge valves located at the bottom of the low pressure cylinder.

There are eight *cup type* valves (spring loaded); four are low pressure discharge valves located at the top of the low pressure cylinder, and four are high pressure discharge valves (two connected to the upper and two to the lower end of the high pressure cylinder) located at the upper end of the high pressure cylinder.

There are four *inverted cup type* valves (not spring loaded); these are low pressure inlet valves located in the top head.

GASKETS:

When new gaskets are applied or the old ones put back, if removed temporarily, care should be taken to see that no oil holes are covered. Better joints will be made if all bolts are tightened lightly first, then make each as tight as the bolt will stand without straining so much as to stretch them.

FLEXIBLE COUPLING (SEPARATE WORM AND ARMATURE SHAFTS):

The flexible coupling, consisting of two flanges with hubs bored tapered to suit the worm and armature shafts, a middle piece with a flange at each end, and fibrous discs gripped by bolts between the double flanges and single flanges, must be disconnected before either the worm shaft or the armature shaft can be removed. If it is the former, unbolt only the pair of flanges next the compressor; then lift the motor and turn it around far enough to get at the nuts on the end of the worm shaft. The flange can then be removed with a jack consisting of a straight clamp and two studs and nuts. There are two tapped holes in the hub of the single flanges for the pull off studs and clamp. It may be necessary to hammer the clamp while the stud nuts are tightened.

To remove the flange on armature shaft, the outer screen on the fan housing must first be removed. This is done by unscrewing the six ¼″ button head screws, when the screen can be passed over all the flanges towards the compressor. The bolts in the flanges are then accessible.

AFTER REASSEMBLING:

After putting the compressor together again, having had it apart for any cause, at least one revolution should be made by hand to see that nothing is fouling. This is also a test to insure that there is no binding anywhere due to too close fits or improper alignment.

The displacement of the CA-150 Compressor is 150 cubic feet per minute working against 140 pounds air pressure. Net weights, dimensions, and operating characteristics are as follows:

R. P. M.—Compressor	100
Motor	1200
Approximate Dimensions—Length	55″
Width	40″
Height	58″
Pipe Size—Inlet	2½″
Intercooler	2″
Discharge	2″
Valve Lift—Low pressure inlet	$\frac{3}{32}$″
All others	$\frac{3}{16}$″

VOLTAGE	AMPERES	FUSE AMPERES	APPROXIMATE NEW WEIGHT
90 D. C.	306	450	4575
125 D. C.	220	325	
190 A. C.	193	300	
245 A. C.	165	250	4680
330 A. C.	105	150	5365
530 D. C.	60	90	5060
650 D. C.	60	90	

Air Strainers

In order to avoid having dirt and other foreign matter enter the compressor through the inlet, it is necessary to supply the suction pipe with a strainer which will insure a supply of clean dry air. The strainer should be piped, if possible, to the cab or top of car.

The 8″ suction Strainer, as illustrated in Figs. 1 and 42, is used for compressors of 50 cubic feet displacement or under, and the No. 54 Suction Strainer is used for larger compressors.

8″ Suction Strainer

The ample cross-sectional area provides for a slow rate of flow into and through the strainer, together with sufficient capacity to retain dirt and dust drawn into it without noticeable restriction to the flow of air. A compact layer of pulled curled hair prevents the passage

Fig. 42. 8″ Suction Strainer, Sectioned View

through it of even the finest dust, the construction being such that all the air must filter through the entire thickness of the bed of hair. When the strainer is installed with the opening downward, as it should be, any dirt or dust which might be drawn into it when the compressor is running tends to be shaken out by the jolting of the moving car after the compressor stops.

No. 54 Air Strainer

The large capacity of this strainer permits the air to be drawn through it gently and without compelling the compressor to "pull" hard to get it. The dust and dirt is thus stopped at the outer surface of the strainer proper and most of it is then jolted out at the lower speeds with the vehicle moving.

As will be seen from Figs. 43 and 44, this is a very large double cylindrical strainer (overall dimensions approximately 10″x14″) with an inner strainer of perforated sheet steel, galvanized, and an outer strainer of coarse

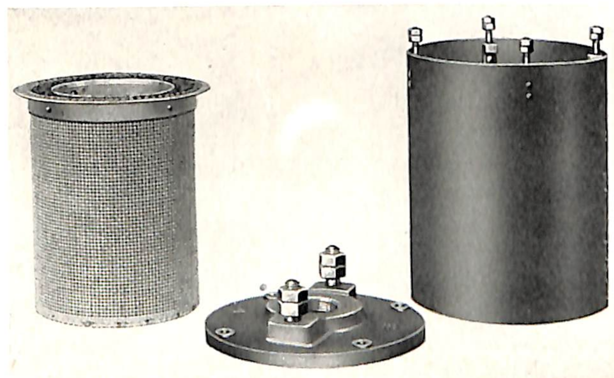
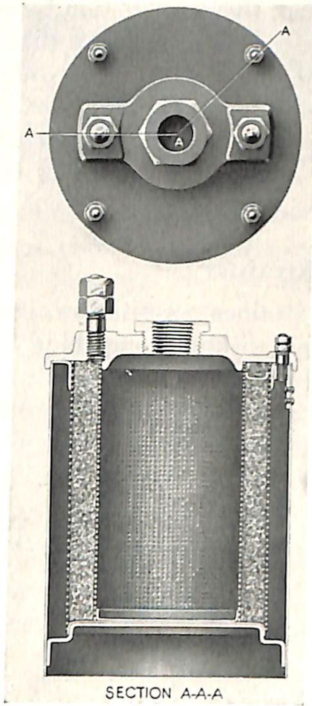


Fig. 43. Disassembled View No. 54 Air Strainer



galvanized wire mesh, the intervening space being well packed with curled hair. A galvanized iron shell encircles the strainer proper, preventing dirt, oil and water from striking directly against the strainer and thereby reducing the possibility of trouble from clogging. The strainer may be quickly and conveniently taken apart, without disturbing any pipe connections, by removing the nuts from the four studs. This strainer should be installed vertically with the large opening downward.

Fig. 44. Sectional View No. 54 Air Strainer

Filter Type Air Strainer

This Air Strainer is of the "cartridge type" which permits removal of the strainer element for cleaning without the necessity of disconnecting the strainer from the compressor. Fig. 45 illustrates the strainer element and the exterior view of the air strainer while Fig. 46 is a sectional assembly view showing the construction.

The inlet opening is formed in the under side of the cover as an annular ring around the shell. As the air

enters this opening it passes upward and inward to the inside of the shell where it strikes a baffle and is directed downward before passing through the filter element into the discharge opening. Some of the heavier particles of dirt are carried downward and deposited at the bottom of the shell cavity.

The cover is centrally threaded for a 2″ pipe outlet to the compressor and it is also provided with two mounting studs by which the unit can be secured to any bracket. The shell is of pressed steel and is attached to the cover by means of a clamping bolt and nut. This shell houses the filter element and acts as a dirt chamber. In the bottom are several small holes to permit moisture to drain from the chamber. When it is necessary to dismantle the strainer for cleaning or changing the filter element the only labor involved is to loosen the nut on

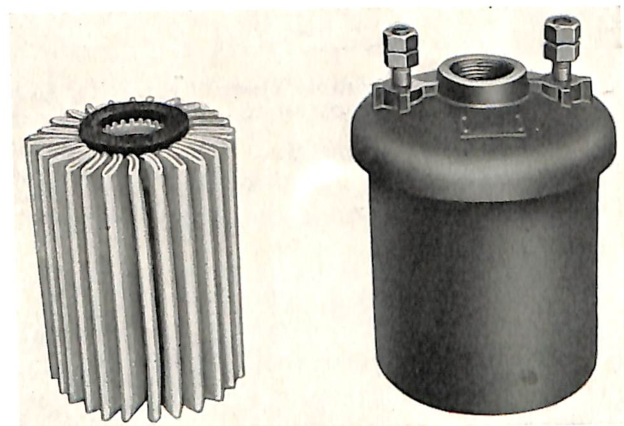


Fig. 45. Photographic Views of the Filter Element and the Complete Filter Type Air Strainer

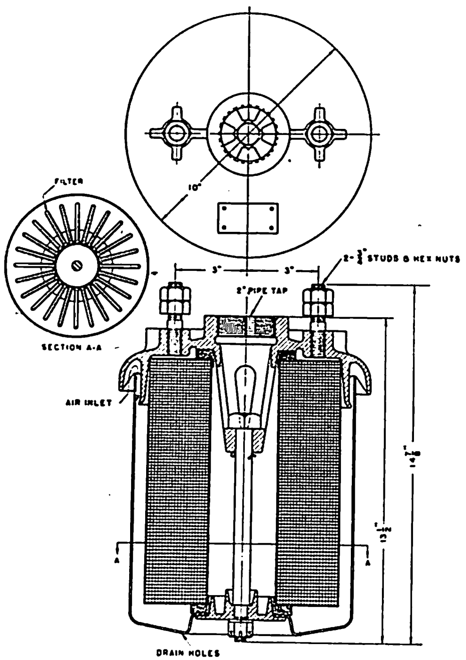


Fig. 46. Sectional Assembly Views of the Filter Type Air Strainer

the clamping bolt which will allow the bottom cap and shell to be removed exposing the filter element for examination and cleaning.

The filtration element comprises a corrugated and radial wire mesh assembly, covered with a layer of thick felt so constructed that the actual filtration area is many times the inlet or outlet passage areas. This element is also provided with large felt washers on each end to seal on shoulders surrounding the outlet passage on the upper end and with the bottom cap nut and shell on the lower end.

Installation

In the selection of a position for a motor compressor on a car, it is important that the position be such as to allow a free circulation of air around the compressor cylinders. Also, the oil fitting in the compressor crank case should be easily accessible from the street.

The discharge opening should be connected by not less than 25 feet of pipe to the main reservoir. The function of this pipe is to afford ample cooling surface for the compressed air. It should be one or two sizes larger than that for which the compressor outlet is tapped and should be placed under the car in a manner to insure proper cooling of the air and consequent precipitation of moisture. It should be low enough for a good circulation of air all around it and should be placed along the side under the car as near the outside of the frame as practicable, where it will get the benefit of the rapidly changing air at that point but be in no danger of striking platforms or objects in the track or street. Avoid, if possible, hanging such pipe under the car inside of the outside width of trucks as the air at that point has comparatively little circulation.

All other connections to the main reservoir must be made at the end opposite to that at which the discharge from the pump enters so that all air will pass through the reservoir and deposit the water that is necessarily precipitated in the cooling of compressed air, as well as any oil or dirt that may have been entrapped by it.

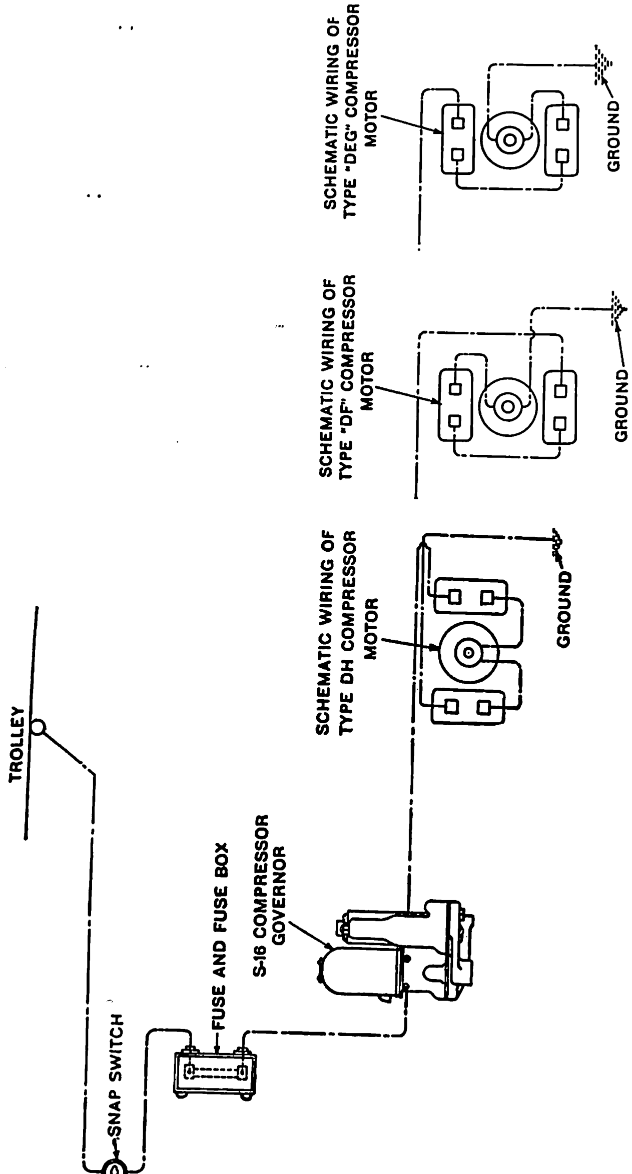


Fig. 47. Typical Wiring Diagram for Motor Driven Air Compressor

When installing a motor driven compressor for ordinary industrial purposes, it can be bolted to a substantial floor, set in a cement foundation, or suspended if necessary. *It should always be placed in as cool a location as possible and the suction piped to a point where cool, clean, dry air is always available.* We do not usually recommend suspending the compressor from a point near the ceiling as the temperature of that locality is usually considerable above that which is suitable for satisfactory operation. The location of the compressor should be where it can be easily dismantled when occasion requires and where all important parts are easily accessible.

The wiring diagram for all types of compressors is shown in Fig. 47. The point at which the compressor circuit should be tapped to the main trolley line is determined by the conditions of each individual case, but we recommend connecting between the choke coil and circuit breaker in order to obtain lightning protection, and at the same time be independent of the circuit breaker.

For all types, run the wire from the trolley connection to the switch, making sure that when it is open, the dial shows the words "Off" and when closed "On"; thence it is run through the fuse box to the governor where connections may be made to whichever terminal is more convenient.* Carry the wire from the remaining terminal to the motor where connection must be made to the field lead at the point where it comes out of the frame. The other lead should be connected to the main motor ground wire. In making the connections to the motor use the

*NOTE:—For wiring in connection with Synchronizing System, see Instruction Pamphlet No. T-5042-1.

brass terminals which accompany it, being sure to tighten the set screws solidly and cover the entire connection with insulating tape.

The switch in the compressor circuit should be placed in an accessible location. The fuse box should be connected between this switch and the governor. It ought to be placed so that a screw driver or other implement is not needed to get at it, but it should be easily accessible, in a dry place, with its box well removed from any ground connection. The size of fuse designated for the compressor should always be used and under no circumstances should one with a larger capacity be installed. If the fuse repeatedly blows, examine the motor and compressor for disorders.

The direction of rotation of the crank shaft must be clock-wise when viewed from the gear end. If necessary to change the direction of rotation, reverse the brush holder connection.

Inspection and Maintenance

The compressor should be regularly lubricated by unscrewing the cap nut from the crank case oil fitting and from the oil filling elbows at the motor end (except the DH type) and filling the receptacles with a good grade of air compressor oil. The DH type has only one oil fitting located at the back of the crank case. Cap nuts should always be replaced after oiling to prevent dirt getting inside the compressor. Inspection and oiling should occur at sufficient intervals to see that the oil level at any filling place does not get more than ¼-inch below the top of the fitting. Approximately every six months, all oil should be drained from the compressor, and the crank case thoroughly cleaned with gasoline and re-supplied with fresh oil. At the same time, remove the valves and clean them and their cavities. *Keeping the crank case oil clean is the surest way of keeping down maintenance costs.*

Special precautions should always be observed to replace the packing rings on the same pistons from which they were removed and in the same position. The pistons should also be replaced in the same cylinders from which they were removed. To facilitate this, a letter is stamped at the top of the outside flange of each cylinder, and on the outside face of each piston.

Piston rings are now supplied without dowel pin holes, consequently, when installing new rings on pistons with the dowel pins, the pins must be removed.

One oil ring is now used on each piston in the ring groove nearest the crank case. The outside bearing surface of this ring, that is, the surface bearing against the cylinder wall, is slightly tapered so that one edge of the ring is relatively sharp. The ring must be installed with the sharp or scraping edge towards the crank shaft, to scrape the oil back toward the crank case during the suction stroke. This sharp edge of the ring is not readily determined by the eye and for identification purposes, the opposite edge of the ring has a $\frac{1}{32}''$ 45 degree chamfer. Therefore, when correctly installed, the oil ring will be in the groove nearest the crank case and with the chamfered edge toward the cylinder head.

The commutator should be kept clean. The brushes should have a close, sliding fit in their holders and the door tightly closed that dust may not penetrate to the interior of the motor. Occasionally blow the carbon dust out of the motor to avoid possibility of short circuits.

The air gap should be checked at intervals in order to preclude any possibility of bearings wearing sufficiently to permit the motor to get down on the field and damage, or perhaps destroy, the winding.

The removal of the armature of the DH compressor is described under that heading. The removal for the other types is as described for the D-EG.

To remove a field coil, the compressor should be taken from the car.

We strongly recommend that railways using our equipment provide themselves with one or more extra compressors so that a defective one may be promptly replaced. Repairs can be made at a bench in the day time to far better advantage than is possible under the cars at night. With such equipment, all but the very minor repairs can be profitably handled in this way, and with the cars in the barn a minimum length of time.

Keep the suction strainer clean. If it is permitted to become choked with dirt the efficiency of the compressor is greatly reduced.

If a pounding develops in the compressor, take off the crank case cover, examine the connecting rod caps where lost motion is most likely to occur, and remove the necessary liners to take up the wear in the bearing. Never leave an unfilled gap between the cap and the rod, as in that case the bearing may bind on the crank pin. Be sure and tighten the lock nuts and replace the cotter pins.

To get at the piston packing rings or wrist pin, it is necessary to detach the connecting rod from the crank shaft, and after removing the cylinder head, draw the piston out. Wrist pin bushes should last for years; lost motion at this point requires replacement of bushes.

The best results are obtained with the lifts of the valves as given in the table of dimensions for each type of compressor, and they should always be adhered to.

Three sizes of repair pistons, $\frac{1}{16}$-inch, $\frac{1}{8}$-inch and $\frac{3}{16}$-inch larger than the original size can be supplied for re-bored cylinders. Rebored and bushed cylinders to original size are recommended in preference to larger sizes of cylinders and rings.

Disorders

Causes and Remedies

COMMUTATION IS NOT GOOD. Cause:—(1), commutator may be dirty or rough. Remedy:—(1), if simply dirty, clean by holding a clean piece of cloth against the commutator while the armature is rotating. If commutator is rough or uneven (detected by holding a long pencil lightly against it while rotating), sandpaper thoroughly. Never use emery cloth. If this does not make the commutator smooth and even, tighten the commutator nut and then turn the commutator. The chattering of brushes due to rough commutator would cause poor commutation. Cause:—(2), brushes may be sticking in holders. Remedy:—(2), stop motor and make sure brushes are free in holders, and that their bearing on the commutator is good. To insure good bearing, place a strip of sandpaper the width of the commutator under one brush at a time, the carbon resting on the rough side of the sandpaper. Hold the brush down firmly on the paper and move paper around circumference of commutator until the brushes bear on the commutator the full thickness of the brush. Do not draw paper under brush tangential to commutator surface. Cause:—(3), rocker arm, which carries both brush holders, may not be properly located. Remedy:—(3), adjust rocker arm so that line on rocker arm and on motor housing form one line. The adjustment of the rocker arm will ordinarily be backward against rotation an amount of approximately two commutator bars.

ARMATURE TROUBLE. Cause:—Open circuit in armature, shown by ring of fire around commutator. Remedy:—Open coil is shown by pitting at edge of commutator segments to which open coil is connected. Armature should be repaired at once.

SHORT-CIRCUITED COIL. Armature heats excessively. Insulation becomes burnt and may blow fuse. Armature should be removed and repaired at once.

GROUNDED FIELD OR ARMATURE. Fuse blows or motor smokes. If the fuse blows, replace fuse and reduce air pressure and if possible lower voltage; close switch, raising both voltage and pressure gradually. If at full voltage and full pressure the fuse holds and operates satisfactorily, blowing of fuse was due to defective fuse or to too light a fuse, or due to hot bearing. If bearings are in good order and fuses hold, fuse blowing would indicate a grounded motor, if the power circuit is a grounded one. Motor must be repaired. If motor is grounded, the fuse will blow before full voltage is reached. If motor smokes, stop compressor and make examination of motor; the ground or short circuit causing smoke may be located if examination is made promptly.

COMPRESSOR POUNDS. Cause:—Probably caused by slight wear in connecting rod bearing on crank pin. Remedy:—Take out one liner between connecting rod cap and rod, and re-fasten cap. This will take up slack and stop pounding.

SLOW IN COMPRESSING AIR. Cause:—(1), air intake strainer clogged; (2), valve not seating properly, due to an accumulation of burnt oil or entrance of dirt; (3), excessive leakage past piston rings. Remedies:—(1), clean strainer; (2), clean valves, seats and passages; (3), remove pistons and clean rings and grooves. Rings may have been stuck in grooves. If cylinders show excessive wear, particularly out of round, have them rebored $\frac{1}{16}$-inch larger, and replace old rings and pistons with new rings and pistons. Where reboring has been repeated until last reboring makes cylinders $\frac{3}{16}$-inch larger than the original diameter, bush cylinders and use new pistons and rings of original diameter. The practice of reboring cylinders and using new rings is not recommended, however, for severe service conditions as rebushing to original size is to be preferred.

Compressor heats excessively. Cause:—(1), improper operation of water control system (where water-jacketed compressor is used); (2), lack of oil in crank case; (3), air passages clogged with burnt oil; (4), piston packing rings worn or cut; (5), discharge valves have insufficient lift. Remedy:—(1), investigate for stoppage in pipes or insufficient water supply; (2), replenish crank case with oil; (3), remove the cylinder head, take out valves, and thoroughly cleanse air passages by submerging head in a hot solution of potash, afterwards removing all traces of potash by hot water; (4), renew air piston rings; (5), regulate lift of discharge to height given in table by the use of a new or machined valve cap.

Cylinder cover gasket blows. If this gasket blows at any point, allowing air to escape, shut compressor down at once and do not start again until new gasket has been applied; in a water-jacketed compressor, if any water is in the cylinder when starting, it might cause serious damage to the compressor.

WESTINGHOUSE AIR BRAKE COMPANY

TRACTION BRAKE DIVISION

Pittsburgh, Pa., U. S. A.

General Office and Works at Wilmerding, Pa.

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