INSTRUCTION PAMPHLET No. T 5002

NOVEMBER, 1918.

(SUPERSEDING ISSUE OF AUGUST, 1911)

MOTOR-DRIVEN AIR-COMPRESSORS

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PITTSBURGH, PA.

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Motor-Driven Air Compressors

NOTE. The reference numbers shown herein are for convenience only and are not to be used when ordering repair parts. See Part Catalogs, giving Piece Numbers, Prices, etc.

Motor driven air compressors as used on electric motor cars and locomotives are for the purpose of furnishing a supply of compressed air for the operation of the air brakes and other air operated devices. The Westinghouse line of compressors has been on the market for many years and represents 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.

The governors for the compressors described herein, are covered in Instruction Pamphlet No. T 5042 which can be obtained, together with any additional information, if desired, from our nearest District Office.

"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 overall efficiency and large capacity motor.

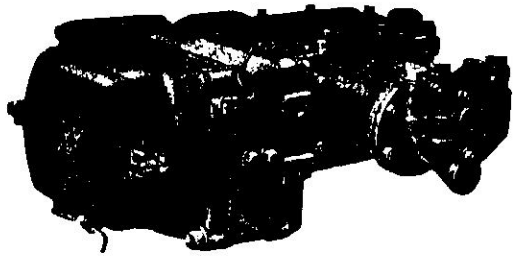


Fig. 1. "Bungalow" Type DH Compressor

This compressor, Figs. 1 and 2, is of the horizontal duplex air cylinder type, single acting (that is, the air is compressed on only one side of the piston), and is driven by a motor through herringbone gearing. As can be seen from Figs. 1 and 2, however, the DH compressor is different in general design from preceding types. The motor is at the side of the compressor portion instead of behind it, 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. 6, 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 on page 15, and also eliminating the possibility of oil reaching the commutator from that source.

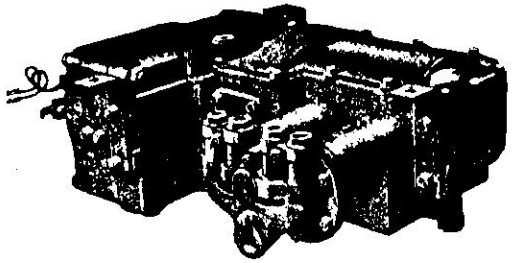


Fig. 2. "Bungalow" Type DH Compressor in Suspension Hangers

These compressors are built in three sizes, viz.: DH-10, DH-16 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 6): 2, Cylinder and Crank Case; 3, Cylinder Cover; 4, Inlet Valve; 5, Inlet Valve Chamber Cap; 6, Discharge Valve; 7, Discharge Valve Chamber Cap; 8, Piston; 9, Piston Ring; 10, Crank Shaft; 11, Connecting Rod; 12, Wrist Pin; 13, Gear; 14, Pinion; 15, Cylinder Cover Gasket; 16, Rear Crank Shaft Bearing; 17, Front Crank Shaft Bearing;

18, Small Motor Bearing; 19, Motor Bearing; 21, Oil Filling Elt; 22, Oil Filling Plug; 26, Hand Hole Cover; 27, Hand Hole Cover Gasket; 29, Crank Case Top Cover; 30, Crank Case Top Cover Gasket; 35, Crank Shaft Key; 36, Crank Shaft Castle Nut; 38, Bearing Cap (Rear End); 39, Bearing Cap (Front End); 40, Bearing Cap

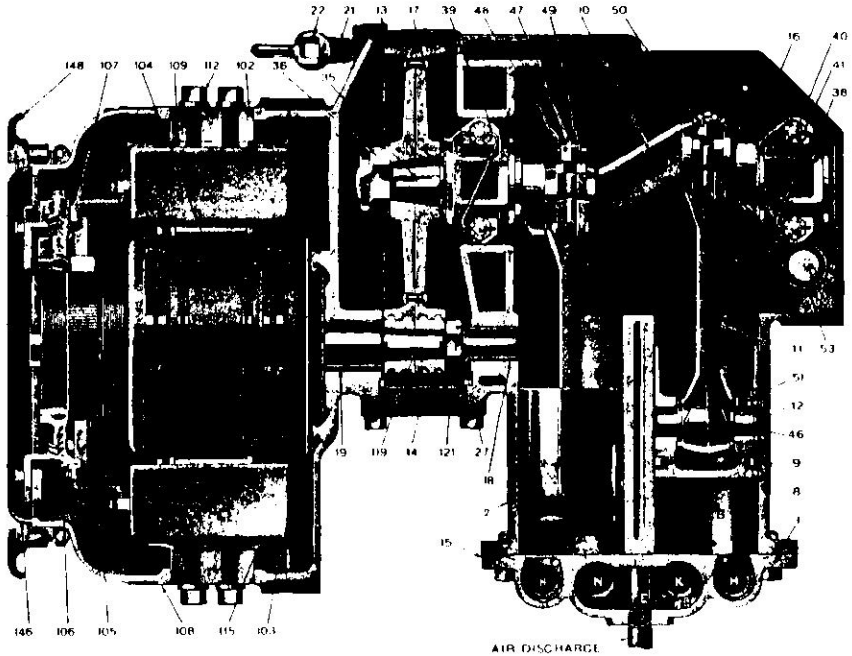


Fig. 3. Sectional View Type DH Compressor

Bolt; 41, Castle Nut; 43, Connecting Rod Bush; 44, Connecting Rod Cap; 45, Connecting Rod Cap Bush; 46, Wrist Pin Bush; 47, Eye Bolt; 48, Castle Nut; 49, Alignment Washer; 51, Wrist Pin Set Screw; 53, Crank Case

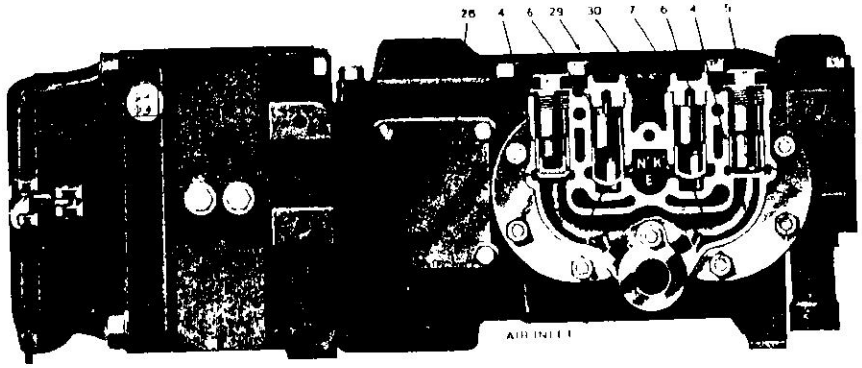


Fig. 4. Type DH Compressor with Cylinder Cover in Section

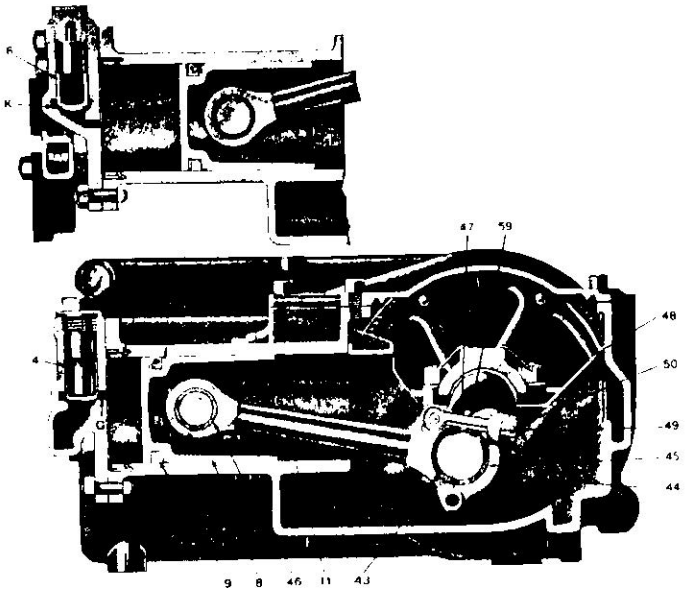


Fig. 5. Sectional Views Type DH Compressor

Vent Fitting; 59, Washers; 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; 119, Key for Pinion; 121, Pinion Castle Nut; 116, Commutator Door; 117, Hinge Pin; 118, Latch.

Compressor

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, containing the valves, and may be easily removed. It is tapped for the suction and discharge pipe connections, the suction opening usually being piped to an air strainer located in the motorman's cab or on the roof of the car. These openings have sufficient wall to permit of tapping one size larger should the threads become worn.

The air valves, 1 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 stops 5 and 7, are of such a design as to reduce clearance and prevent sluggish action of the valve.

The pistons 8 and connecting rods 11 have been made unusually long with a view to 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 a three-segment packing ring 9, a special quality of cast iron being used so as to give minimum and uniform wear. Each segment is composed of two pieces, a square section fitting into an "L" section riveted together in such manner as to produce an overlap at each end of each segment. The piston ring when in position is expanded by means of coil springs of piano steel wire fitted in recesses in the ends of the segments which force the segments against the cylinder wall, the overlapping segments maintaining an air tight joint.

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 and 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 16, 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 14, to take up wear quickly and readily by removing liners and again tightening the nut 18 on eye bolt 17, 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 11, 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 36 and cotter. This arrangement, combined with a steep taper on the crank shaft, makes removal of the gear easy.

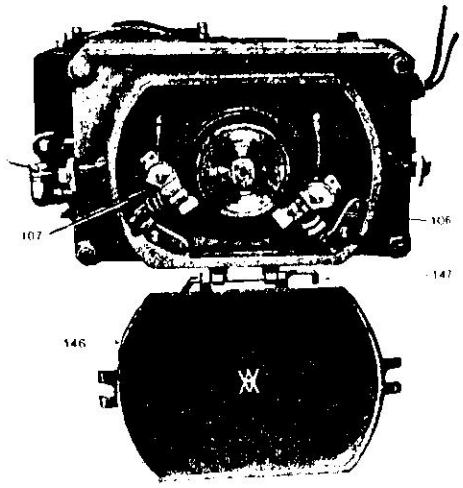


Fig. 6. Type DH Compressor. Commutator Door Open

Motor

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

The field yoke, 102, 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.

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 101 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 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. 7, 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 tension of the brush holder springs is adjusted without removing them and without the use of tools. By merely moving a small wire lever from notch to notch on a dial provided on the carbon holder,

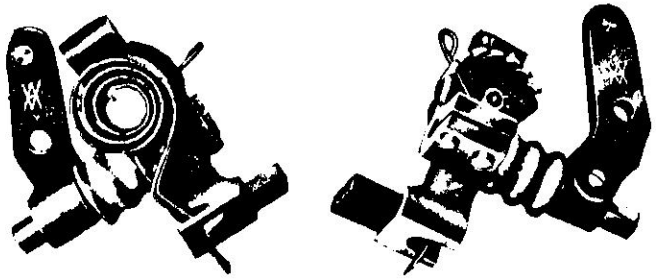


Fig. 7. Carbon Holder

the tension of the spring may be changed in small steps at will. 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.

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.

Operation

Referring to Fig. 3 and the lower view in Fig. 5, the right-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 1 and passes into the 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 and thence through the discharge pipe into the reservoir. The same operation takes place in the left-hand cylinder B except that it is compressing (see upper view, Fig. 5), while the right-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. A circumferential groove *b* is cut in the piston immediately back of the packing ring. When the piston is at the end of its stroke, compressed air trapped in the clearance space by-passes the packing ring, reaching the groove and then "blows back" into the crank case any excess oil that may have crept along the piston.

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 simply of a vent fitting 53 connecting the interior of the crank case to the atmosphere. The fitting has been made long enough to insure that no dirt will be drawn into the compressor due to pulsations of air when there is a vacuum and is protected against loss of oil due to direct splash from the crank case.

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 22 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, incidentally 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 116, Fig. 6, covers prac-

tically 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. 8. Then withdraw the cotter 122 and place a wrench on the castle nut 121 to keep it

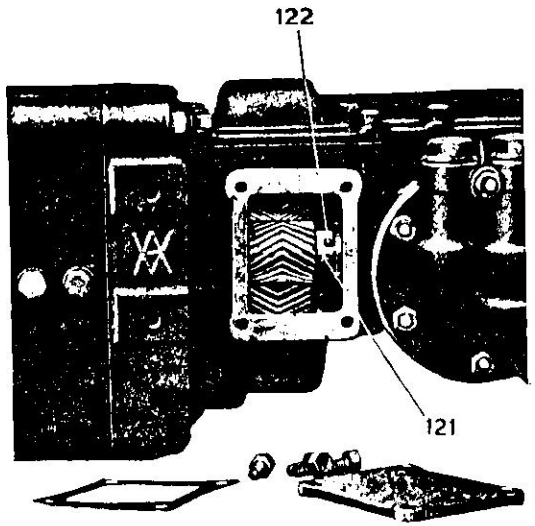


Fig. 8. Hand Hole Cover Removed, Showing Pinion

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.

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. 9, 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 act 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 17 up solidly; then fasten the brackets 12 and 19 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 $\frac{5}{8}$" bolts for

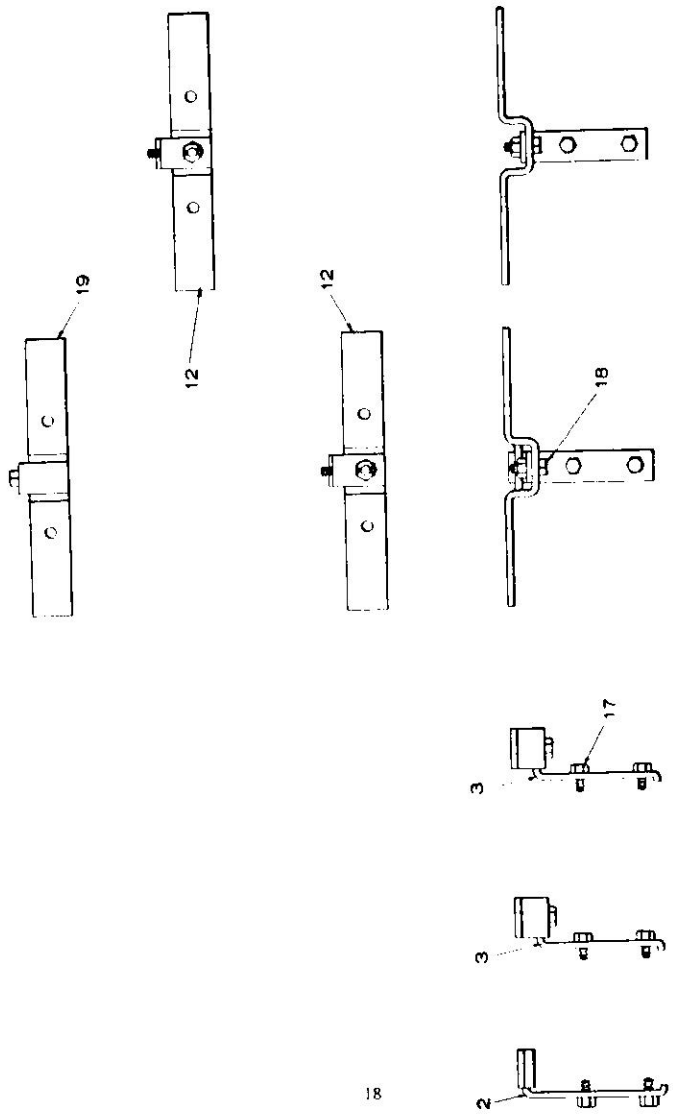


Fig. 9. Type DH Compressor Suspension Hangers

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 18 are set up solidly. A compressor with this form of suspension is shown in Fig. 2.

Sizes and Performance

As previously stated, the compressor is furnished in the following sizes: DH-10, DH-16 and DH-25, the numerals (10, 16 and 25) representing the displacement in cubic feet per minute. The motor is wound for operation at 600 volts direct current, and the cylinders are not water-jacketed.

The data for performance and dimensions are as follows, the performance data being based on an operating air pressure of 100 lbs. per square inch:

Designation	Displacement Cu. Ft. per Min.	Size of Cylinder in Inches	Speed in R. P. M.		E. H. P. Input	Volts	Fuse Amperes
			Crank Shaft	Motor			
DH-10	10.0	$3\frac{5}{8}$x$3\frac{3}{4}$	226	1200	2.0	600	4.0
DH-16	16.0	$4\frac{1}{4}$x$4\frac{1}{2}$	217	1110	3.4	600	6.0
DH-25	25.0	5x$5\frac{1}{2}$	200	1080	5.65	600	10.0

Designation	Size of Piping in Inches		Lift of Valves in In.		Dimensions in Inches			Weight Lbs.	
	Suction	Discharge	Inlet	Discharge	Length	Width	Height	Net	Shipping
DH-10	1	$\frac{3}{4}$	$\frac{7}{64}$	$\frac{7}{64}$	$25\frac{1}{8}$	$30\frac{11}{16}$	$10\frac{3}{4}$	400	490
DH-16	$1\frac{1}{4}$	$\frac{3}{4}$	$\frac{5}{32}$	$\frac{1}{8}$	$25\frac{3}{8}$	$33\frac{25}{32}$	$12\frac{1}{2}$	580	675
DH-25	$1\frac{1}{4}$	1	$\frac{5}{32}$	$\frac{1}{8}$	$28\frac{7}{32}$	$39\frac{11}{16}$	$15\frac{11}{16}$	925	1050

Type D-EG Compressor

The D-EG Compressor, Fig. 10, has been manufactured for many years and there are at the present time thousands of them in service throughout the country, both in railway and industrial work. In design, the compressor

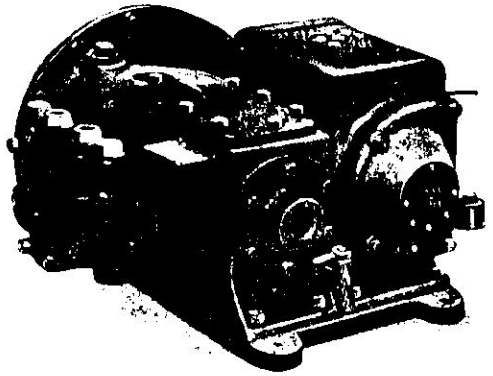


Fig. 10. Type D-EG Compressor

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

The functions of the compressor portion, as shown in Figs. 11, 11A and 12, 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

is somewhat different, however, for in addition to the bed plate 29, the motor is located directly back of the compressor, instead of at the side, with an air space between

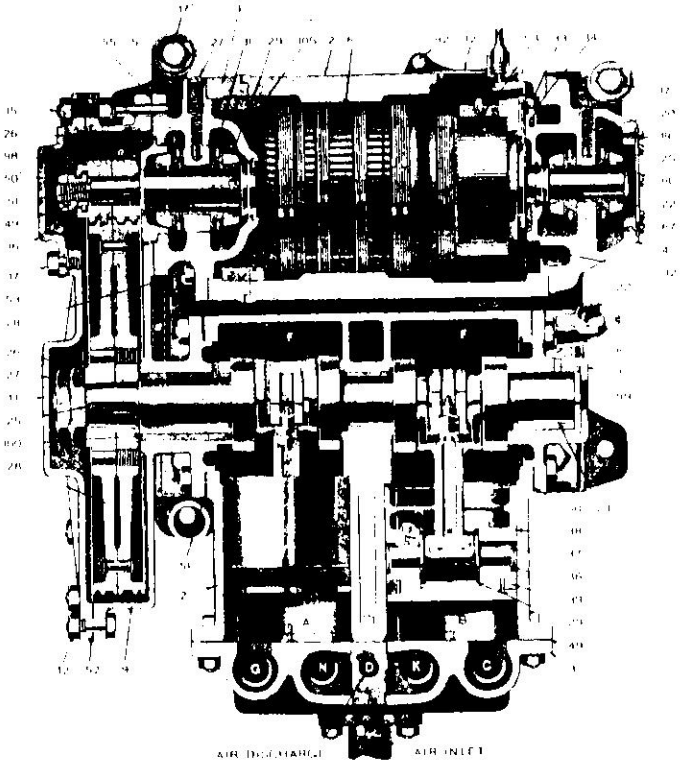


Fig. 11. Sectional View Type D-EG Compressor

for securing ventilation. The gear 28 and pinion 98 are enclosed in a gear case 9 which is attached to the compressor 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 21 has two end bearings in brass bushings, 99 and 100, and a middle bearing of babbitt.

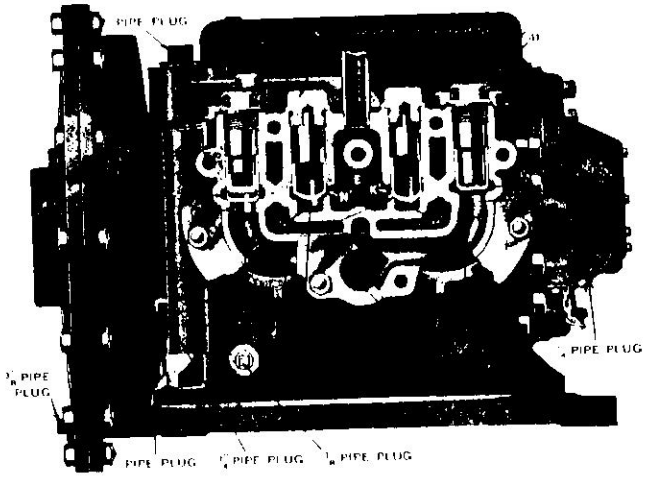


Fig. 11A. Type D-EG Compressor with Cylinder Cover in Section

In other respects the compressor is practically the same as the DH type, the pistons 38, connecting rods 29, packing rings 39, 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*

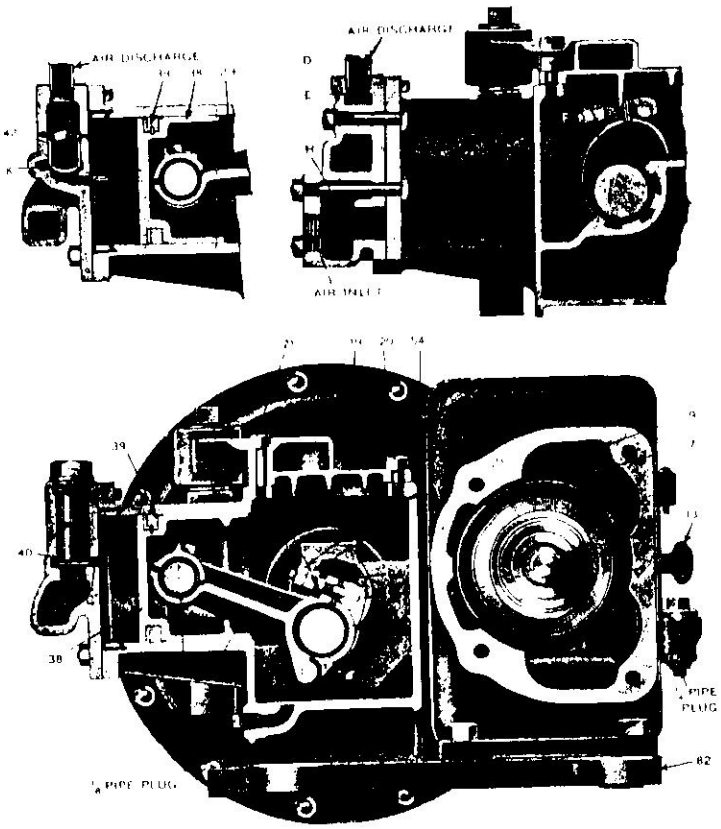
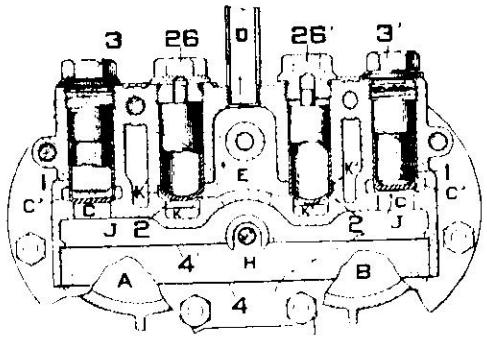


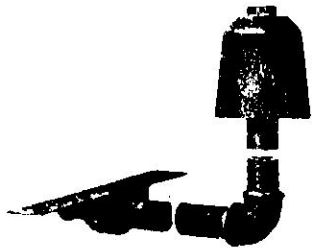
Fig. 12. Sectional Views Type D-EG Compressor

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.



Old Standard Cylinder Cover

NOTE. The Type D-EG compressor was originally supplied with a cylinder cover having a perforated plate 44, perforated slide 45 and curled hair suction, as illustrated in section above. Later a suction plate and suction strainer, as illustrated below, replaced the perforated slide. Both of these arrangements have, however, been superseded by the cylinder cover shown in Fig. 10.



Old Standard Suction Plate and Strainer

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, 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, 1', 3' 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'.

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

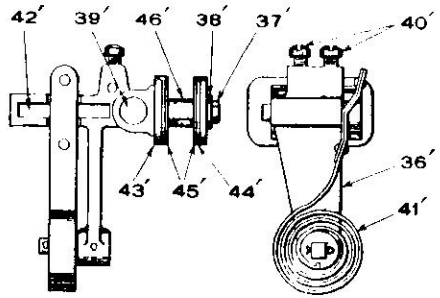


Fig. 13. Type D-EG Compressor Carbon Holder

coils. The two brush holders, Fig. 13, mounted on the adjustable cast iron rocker arm 32', Fig. 11, are of cast brass, with a tap bolt 34', 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 25 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

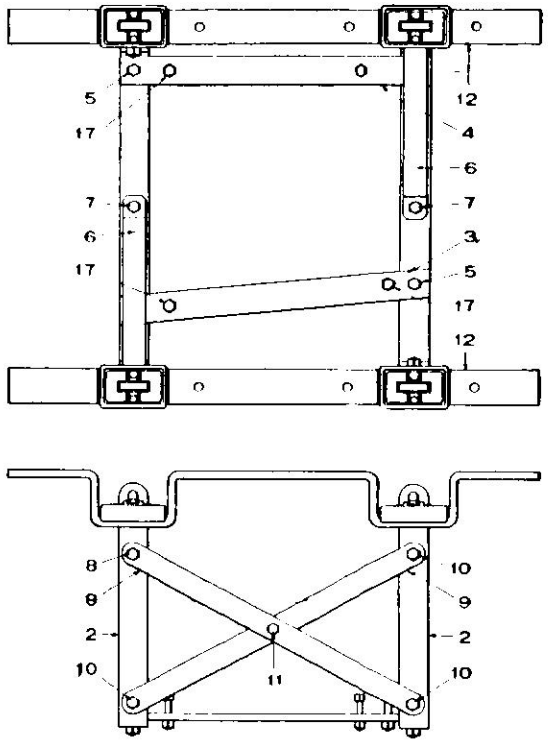


Fig. 14. Type of Suspension Cradle for D-2-EG, D-3-EG and D-4-EG Compressors

holes 17′, Fig. 11, and are supplied with constant lubrication by means of the oil rings.

Suspension Cradle

For electric railway service a suspension cradle, illus-

trated in Figs. 14, 14A and 15, is used, which combines compactness with great stability and affords ready access to all bolts and parts of the compressor requiring attention, when in position under the car.

This device consists of two parts, the cradle 2, 3 and 4, Fig. 14, which is bolted to the base of the compressor, and thereby becomes an integral part of it, and the brackets 12, by which the cradle is secured to the car. The two brackets have two pockets, each containing a rubber cush-

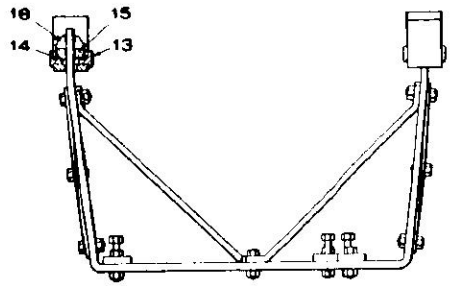


Fig. 14A. Type of Suspension Cradle for D-2-EG, D-3-EG and D-4-EG Compressors

ion 14, fitted in an iron casing 13, with a suitable cover, 15, 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 16, 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.

In order to install the suspension, secure the cradle to the base of the compressor and be sure to set the cap screws and nuts up solidly; then fasten the brackets solidly

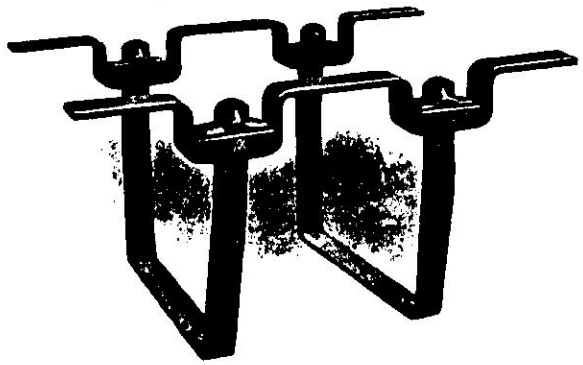


Fig. 15. Suspension Cradle for D-4-EG Compressor

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 four 5/8"

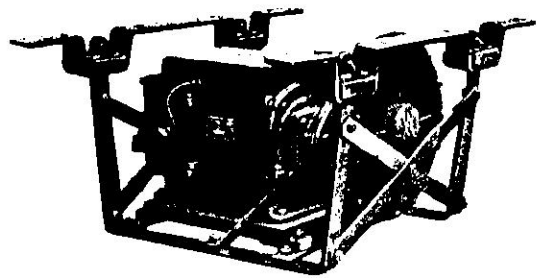


Fig. 16. Type D-EG Compressor in Suspension Cradle

bolts for each bracket. *Do not use lag screws.* If desirable, the ends of the brackets may be bent up and bolted

to the side of the sill. Place the boxes containing the rubber cushions in the hanger pockets and raise the compressor until the ends of the cradle pass through the cushions far enough for the keys to be put in; then lower the compressor until the cradle ends are seated in the notches of the keys.

A compressor installed in a cradle is shown in Fig. 16.

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.

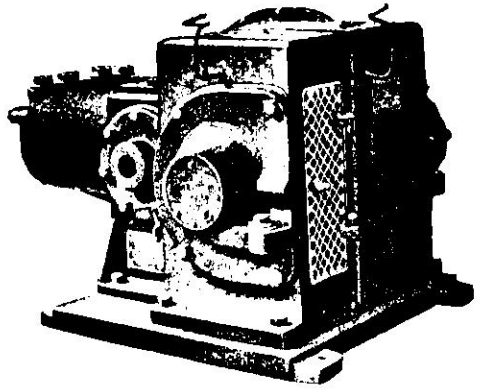


Fig. 17. Type D-EGW Compressor Water-Jacketed and with Ventilated Motor

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

The compressor is manufactured in the following sizes: D-1-EG, D-2-EG and D-3-EG. The D-1-EG, formerly manufactured, is now obsolete, having been superseded by the D-1-K and it in turn by the D-1-P, which is now standard. The compressor is furnished for railway service with either a direct current or a single phase alternating current motor. When used for industrial purposes it is supplied with a direct current motor, ventilated (except the D-1 size) by means of holes in the door and perforated plates on the top and side which give a free circulation of air. When used for continuous service, the cylinders and cylinder cover are water-jacketed, and the next larger size of motor is used, thus: a D-1 compressor would have a D-2 motor, etc. A compressor so equipped is shown in Fig. 17.

The data for performance and dimensions are as follows, the performance data being based upon an operating air pressure of 100 lbs. per square inch:

Designation	Displacement Cu. Ft. per Min.	Size of Cylinder in Inches	Speed in R. P. M.		E. H. P. Input	Volts	Fuse Amperes
			Crank Shaft	Motor			
D-1-EG	14.5	5x3	214	1350	3.54	600	5
D-2-EG	25.0	$5\frac{1}{2}$x$4\frac{1}{4}$	217	1200	6.35	600	10
D-3-EG	38.0	7x5	170	875	8.46	600	15
*D-4-EG	50.0	$7\frac{3}{4}$x5	183	1110	12.1	600	20

Designation	Size of Piping in Inches		Lift of Valves in In		Dimensions in Inches			Weight Lbs.	
	Suction	Discharge	Inlet	Discharge	Length	Width	Height	Net	Shipping
D-1-EG	$1\frac{1}{4}$	$\frac{3}{4}$	$\frac{5}{32}$	$\frac{1}{8}$	$27\frac{1}{16}$	$23\frac{9}{16}$	18	660	750
D-2-EG	$1\frac{1}{4}$	1	$\frac{5}{32}$	$\frac{1}{8}$	32	$27\frac{7}{16}$	$20\frac{13}{16}$	975	1100
D-3-EG	$1\frac{1}{2}$	$1\frac{1}{4}$	$\frac{5}{32}$	$\frac{1}{8}$	$34\frac{9}{16}$	$29\frac{7}{16}$	$22\frac{1}{4}$	1250	1400
*D-4-EG	$1\frac{1}{2}$	$1\frac{1}{4}$	$\frac{3}{16}$	$\frac{5}{32}$	$36\frac{5}{16}$	$30\frac{3}{4}$	$23\frac{3}{4}$	1450	1600

*NOTE Superseded by the D-4-P. See Page 50.

TYPE D-F COMPRESSOR

The D-F compressor, Fig. 18, was developed from the D-EG in order to supply a light weight, compact and rigid compressor. The cylinders, crank case, motor housings and gear case are cast in one piece, thus eliminating

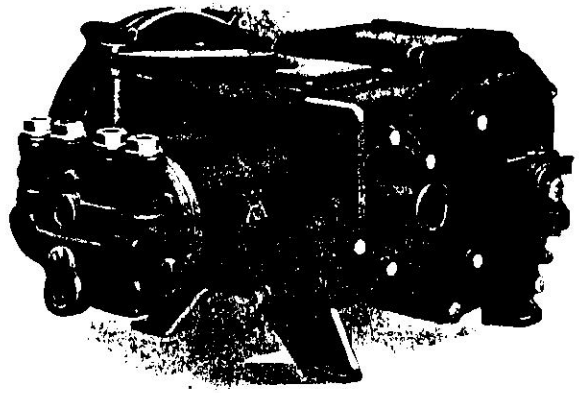


Fig. 18. Type D-F Compressor

the need of a bed plate and securing perfect alignment; the suspension is direct and of the "three-point" type; the field yoke is made of laminated steel sheets; the motor is of large capacity. A number of other refinements are detailed later.

Compressor

The compressor portion, Figs. 19 and 20, is of the duplex type and, as can be seen, resembles the D-EG very closely. It has a two bearing crank shaft 24, there being

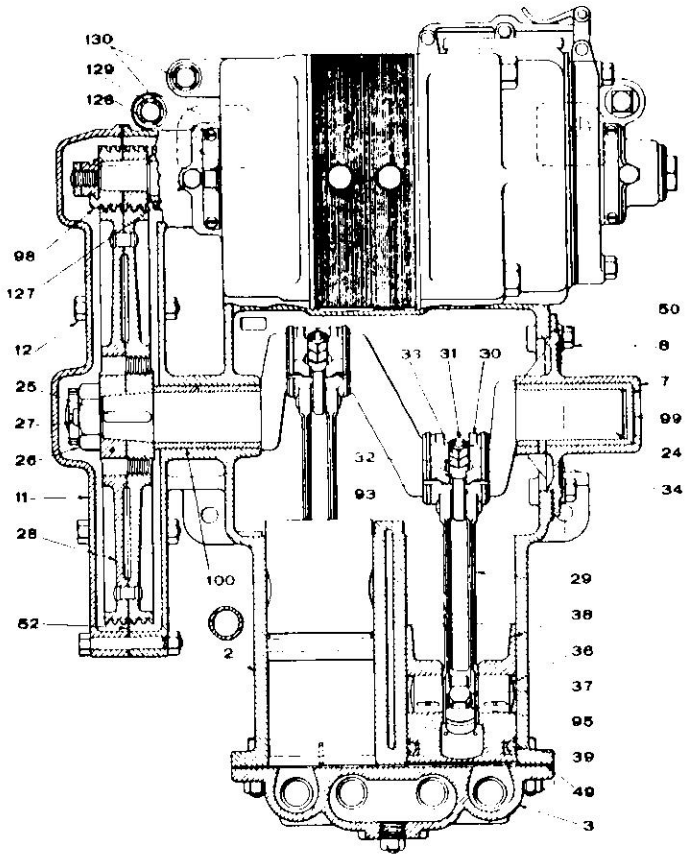


Fig. 19. Sectional View Type D-F Compressor

no middle bearing and the pistons 38 and connecting rods 29 have been made long with a view to insuring minimum and even wear on the cylinders, wrist pins and pistons themselves. The wrist pins 36 are rigidly fastened to the connecting rods so that the pin rotates in the piston. The gear case cover 11 is, in reality, half of the gear case. This form of gear case is known as the type F. In other

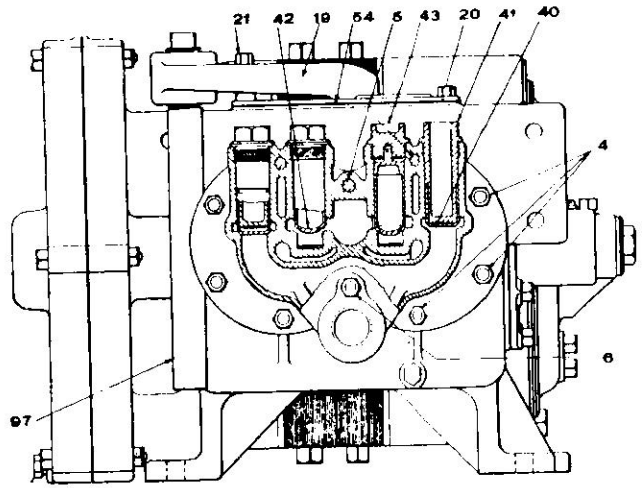


Fig. 20. Type D-F Compressor. Cylinder Cover in Section

respects the compressor is practically identical with that of the D EG, and the description of the latter will apply here also.

Motor

The motor, Figs. 21 and 22, is of the enclosed, series wound, four pole type, with two field coils and a

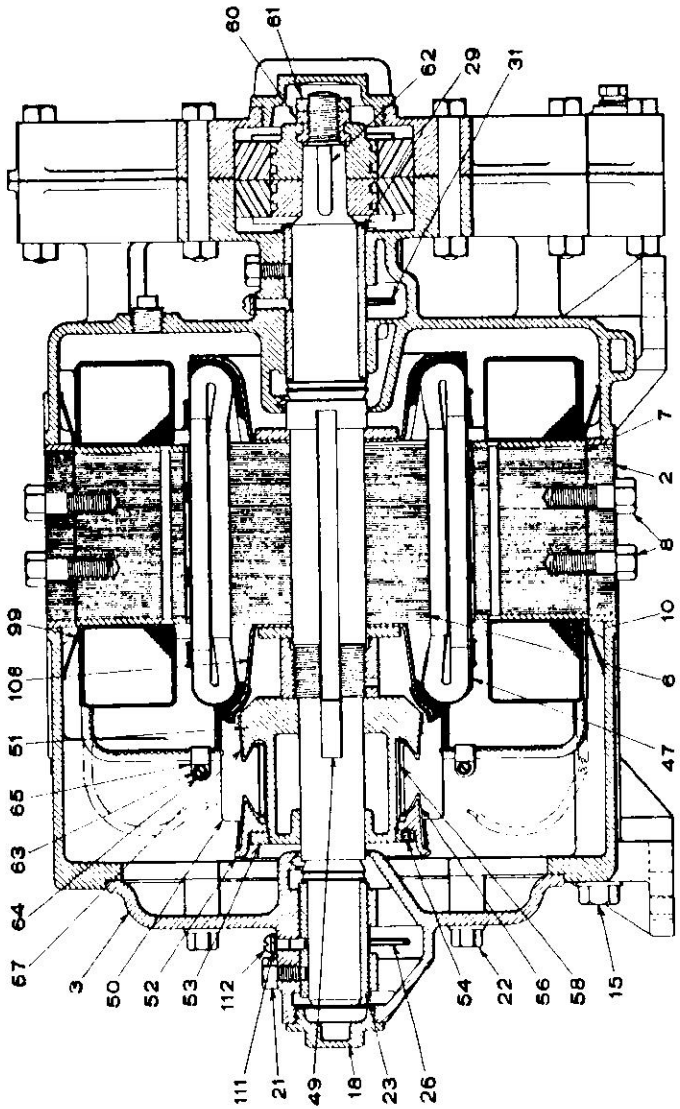


Fig. 21. Type D-F Compressor Motor

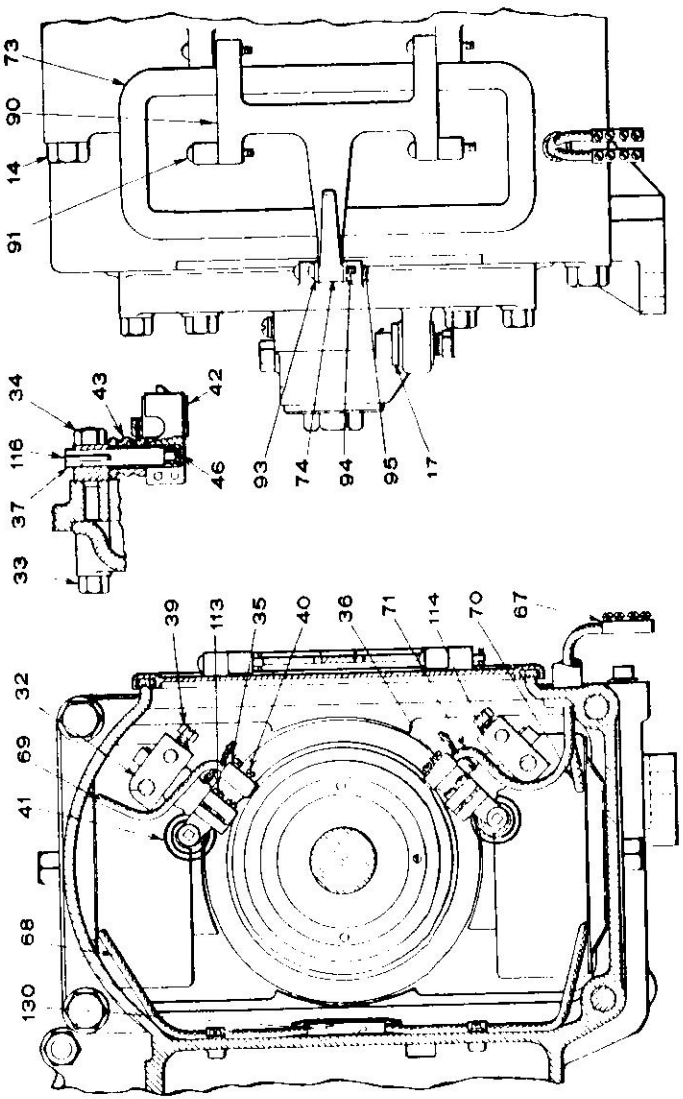


Fig. 22. Type D-F Compressor Motor

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 73 which, when open, gives access to the brushes. This door is supported by a new type of hinge 90, 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 32 and 36 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.

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 Figs. 23, 23A and 24. 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

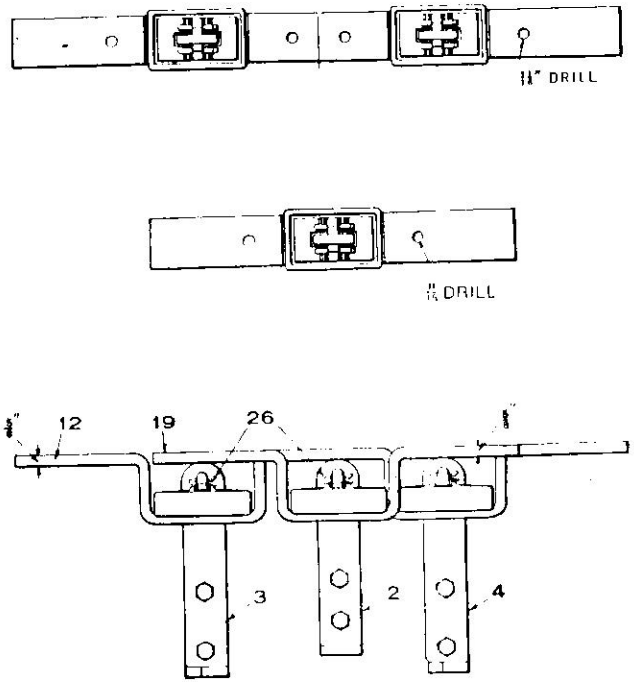


Fig. 23. Suspension for Type D-F Compressor

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.

Sizes and Performance

The compressor is furnished in two sizes, the D-1-F and the D-2-F, and the motors for each size are rated at

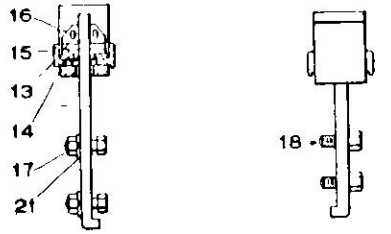


Fig. 23A. Suspension for Type D-F Compressor

600 volts with a maximum of 750 volts on peak. The cylinders are not water jacketed. The data for perform-

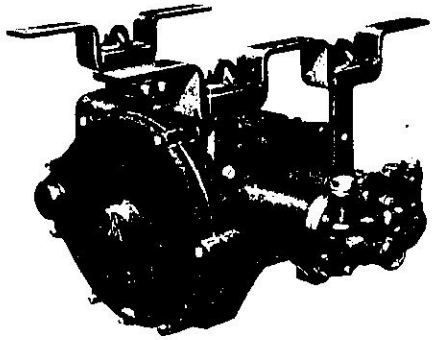


Fig. 24. Type D-F Compressor Suspended

ance and principal dimensions are as follows, the performance data being based upon an operating air pressure of 100 lbs. per square inch:

Designation	Displacement Cu. Ft. per Min.	Size of Cylinder in Inches	Speed in R. P. M.		E. H. P. Input	Volts	Fuse Amperes
			Crank Shaft	Motor			
D-1-F	15.7	$4\frac{1}{4}$x$4\frac{1}{4}$	225	1490	3.42	600	6
D-2-F	25.0	5x$5\frac{1}{2}$	200	1150	5.63	600	10

Designation	Size of Piping in Inches		Lift of Valves in In		Dimensions in Inches			Weight Lbs.	
	Suction	Discharge	Inlet	Discharge	Length	Width	Height	Net	Shipping
D-1-F	$1\frac{1}{4}$	$\frac{3}{4}$	$\frac{5}{32}$	$\frac{1}{8}$	$33\frac{1}{4}$	$24\frac{15}{16}$	$17\frac{9}{16}$	625	725
D-2-F	$1\frac{1}{4}$	1	$\frac{5}{32}$	$\frac{1}{8}$	$37\frac{3}{4}$	$29\frac{3}{4}$	$21\frac{7}{16}$	975	1110

TYPE D-K COMPRESSOR

The D-K type of compressor, Figs. 25 and 26, is a modification of the D-EG and is manufactured for two separate classes of service. The D-2-K and D-3-K are intended for operation on high voltage railway service while the D-1-K was developed to supersede the D-1-EG, and has in turn been superseded by the D-1-F.

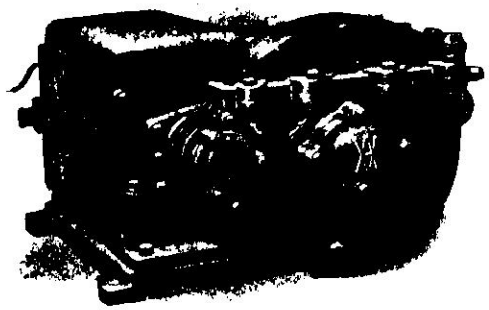


Fig. 25. Type D-K Compressor

The design of the compressor portion, as shown in Figs. 27 and 28, is very similar to that of the D-EG except for changes in certain details, as will be described. 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 11 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.

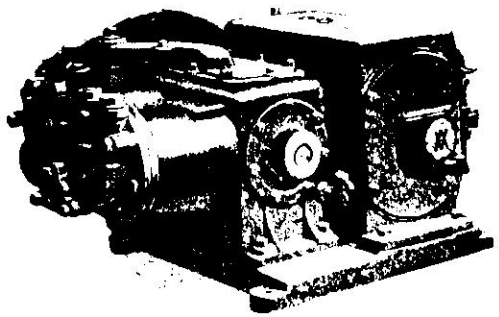


Fig. 26. Type D-K Compressor

The construction of the motor, Figs. 29 and 30, 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 armature is made in accordance with best railway practice. The commutator door gives access to the brushes which are supported on a rocker arm. The door is fastened by a hinge of the same type as that used for the D-F type compressor.

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.

* Crankshaft jam nuts are LH Thread - 3/4" Hex Head - Special Tool exists

The D-2-K is furnished for direct current operation at 1200 and 1500 volts; the D-3-K at 1200 volts; and the D-1-K type has been furnished at 110, 220, 440 and 600

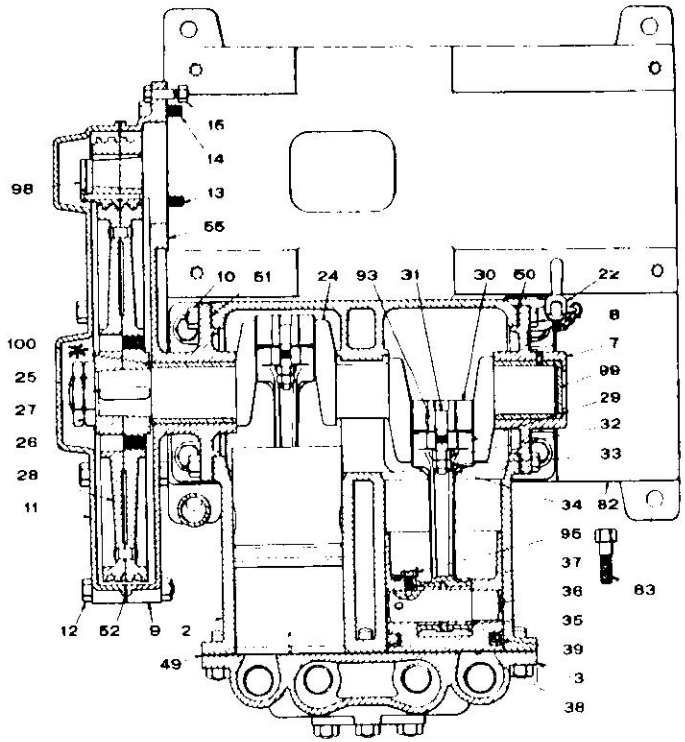


Fig. 27. Type D-K Compressor. Sectional View Compressor Portion

volts. The D-2-K and D-3-K are not furnished with water-jacketed cylinders or ventilated motor.

The data for performance and principal dimensions for all three sizes are as follows, the performance data being based upon an operating air pressure of 100 lbs. per square inch:

Designation	Displacement Cu. Ft. per M.n.	Size of Cylinder in Inches	Speed in R. P. M.		H. P. Input	Volts	Fuse Amperes
			Crank Shaft	Motor			
D-2-K	26.0	$5\frac{1}{2}$x$4\frac{1}{4}$	221	1200	6.35	1200	5
D-2-K	26.0	$5\frac{1}{2}$x$4\frac{1}{4}$	221	1200	6.35	1500	5
D-3-K	38.6	7x5	173	875	8.44	1200	8
*D-4-K	50.0	$7\frac{3}{4}$x5	183	1100	12.1	600	20

Designation	Size of Piping in Inches		Lift of Valves in In.		Dimensions in Inches			Weight Lbs.	
	Suction	Discharge	Inlet	Discharge	Length	Width	Height	Net	Shipping
D-2-K	$1\frac{1}{4}$	1	$\frac{5}{32}$	$\frac{1}{8}$	$35\frac{3}{16}$	$30\frac{3}{8}$	$19\frac{7}{8}$	1275	1400
D-2-K	$1\frac{1}{4}$	1	$\frac{5}{32}$	$\frac{1}{8}$	$35\frac{3}{16}$	$31\frac{3}{16}$	$22\frac{1}{2}$	1350	1475
D-3-K	$1\frac{1}{2}$	$1\frac{1}{4}$	$\frac{5}{32}$	$\frac{1}{8}$	$39\frac{5}{8}$	$32\frac{1}{8}$	23	1500	1800
*D-4-K	$1\frac{1}{2}$	$1\frac{1}{4}$	$\frac{5}{32}$	$\frac{5}{32}$	40	$31\frac{7}{8}$	$23\frac{5}{16}$	1600	1925

*NOTE—Superseded by the D-4 P.

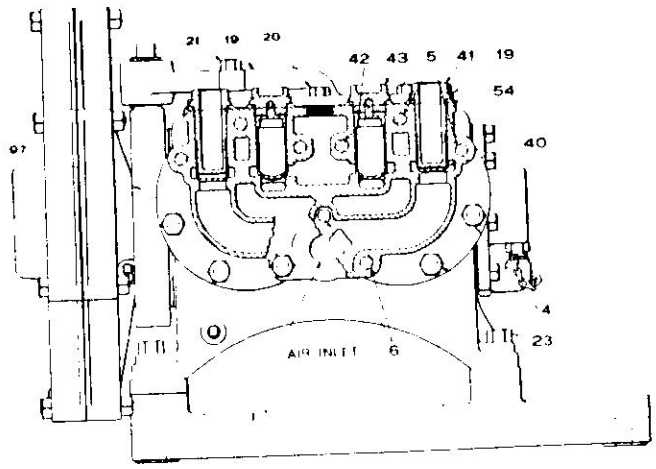


Fig. 28. Type D-K Compressor, showing Cylinder Cover in Section

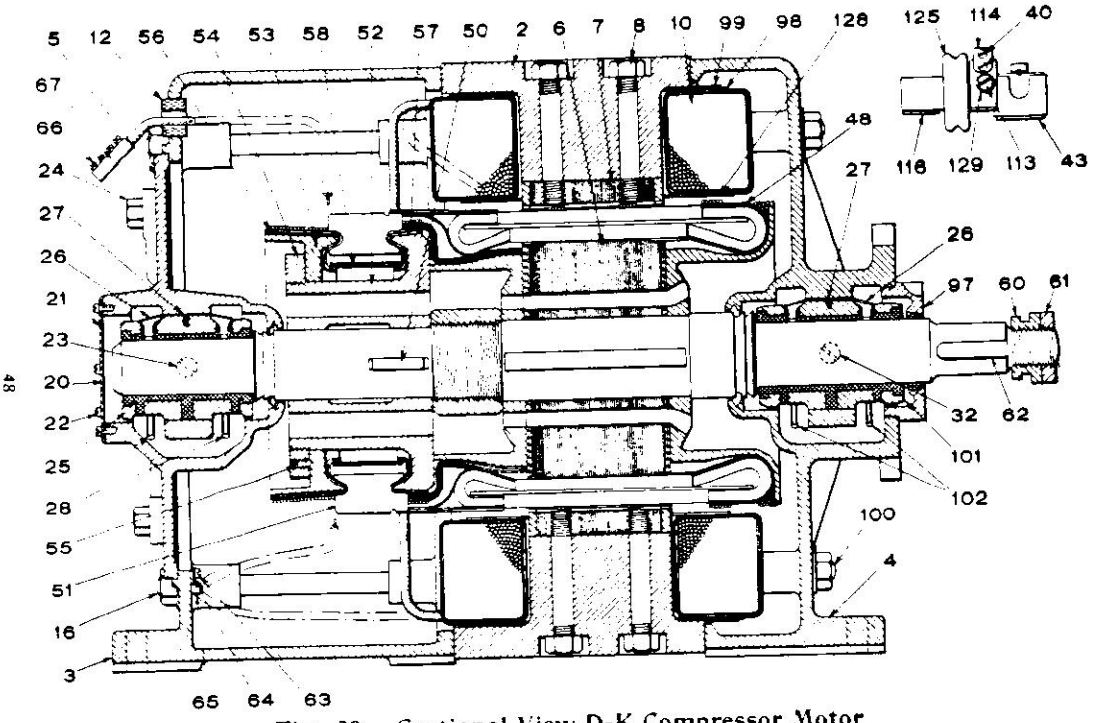


Fig. 29. Sectional View D-K Compressor Motor

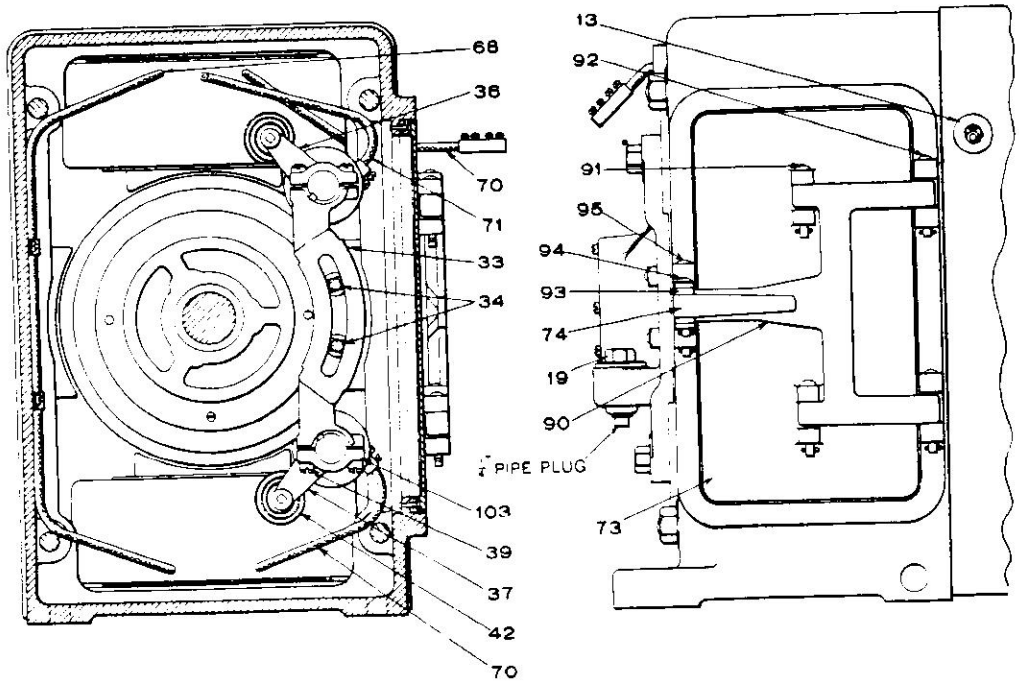


Fig. 30. Type D-K Compressor Motor

D-4-P COMPRESSOR

The D-4-P Compressor, Fig. 31, supersedes the D-4-K and has been 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

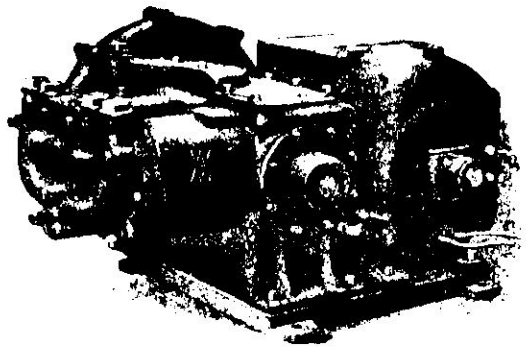


Fig. 31. Type D-4-P Compressor

commutation 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, Figs. 32 and 33, 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, Figs. 31 and 35, is larger than that of the D-4-K and can be supplied for operation at 235, 480 or 600 volts. The 235 volt winding is used instead of the

usual 220 so that the motor will operate satisfactorily on a line having a nominal voltage of 250 volts.

The compressor is also furnished for industrial pur-

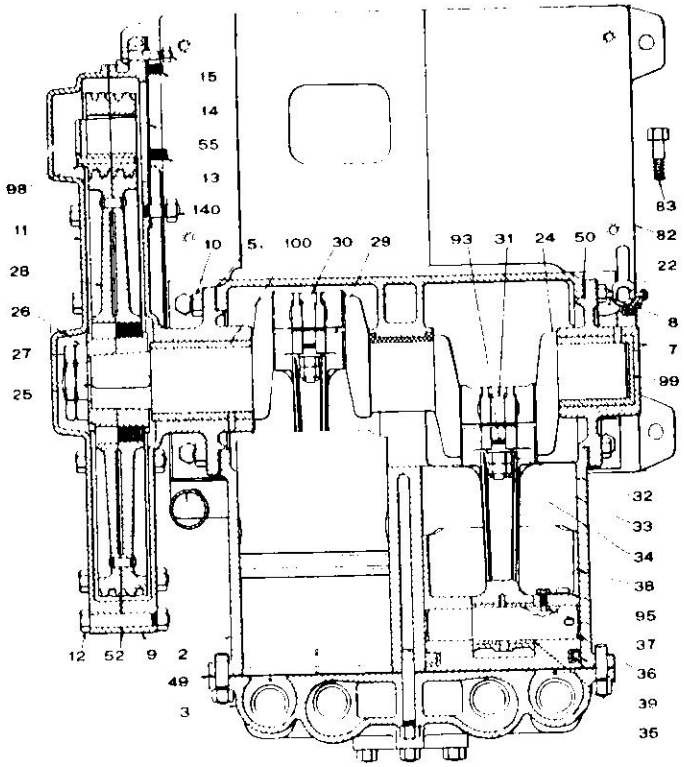


Fig. 32. Sectional View Type D-4-P Compressor

poses with water-jacketed cylinders and a ventilated motor which is wound for either 235 or 600 volts, and in this case is known as the D-4-PW.

The data for performance and dimensions are as fol-

lows, the performance data being based on an operating air pressure of 100 lbs. per square inch:

Designation	Displacement Cu. Ft. per Min.	Size of Cylinder in Inches	Speed in R.P.M.		E. H. P. Input	Volts	Fuse Amperes
			Crank Shaft	Motor			
D-4-P	50.0	$7\frac{3}{4}$x5	184	1000	10.5	600	20

Designation	Size of Piping in Inches		Lift of Valves in In.		Dimensions in Inches			Weight Lbs.	
	Suction	Discharge	Inlet	Discharge	Length	Width	Height	Net	Shipping
D-4-P	$1\frac{1}{2}$	$1\frac{1}{4}$	$\frac{3}{16}$	$\frac{5}{32}$	$40\frac{13}{16}$	$34\frac{3}{8}$	$24\frac{11}{16}$	1650	1875

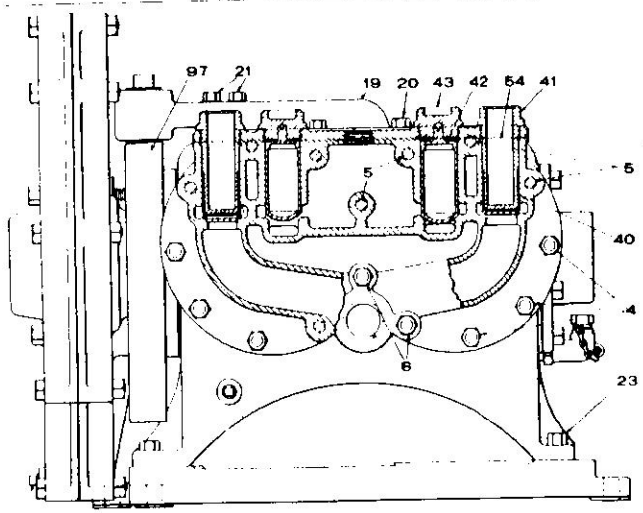


Fig. 33. Type D-4-P Compressor. Cylinder Cover in Section

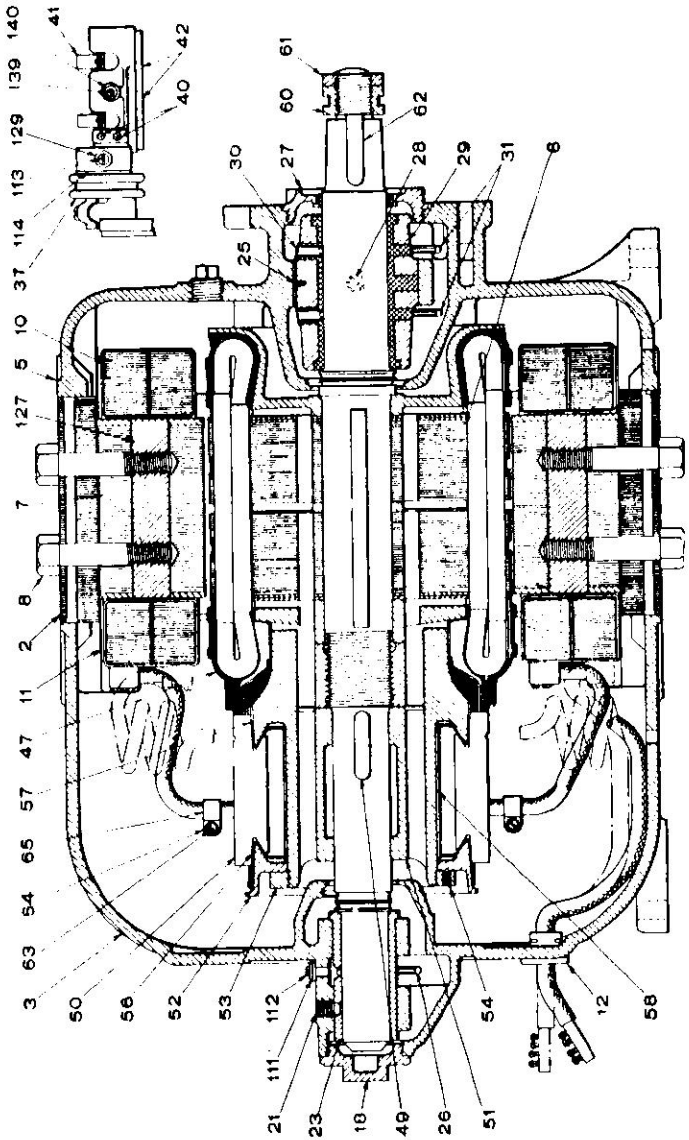


Fig. 34. Type D-4-P Compressor Motor

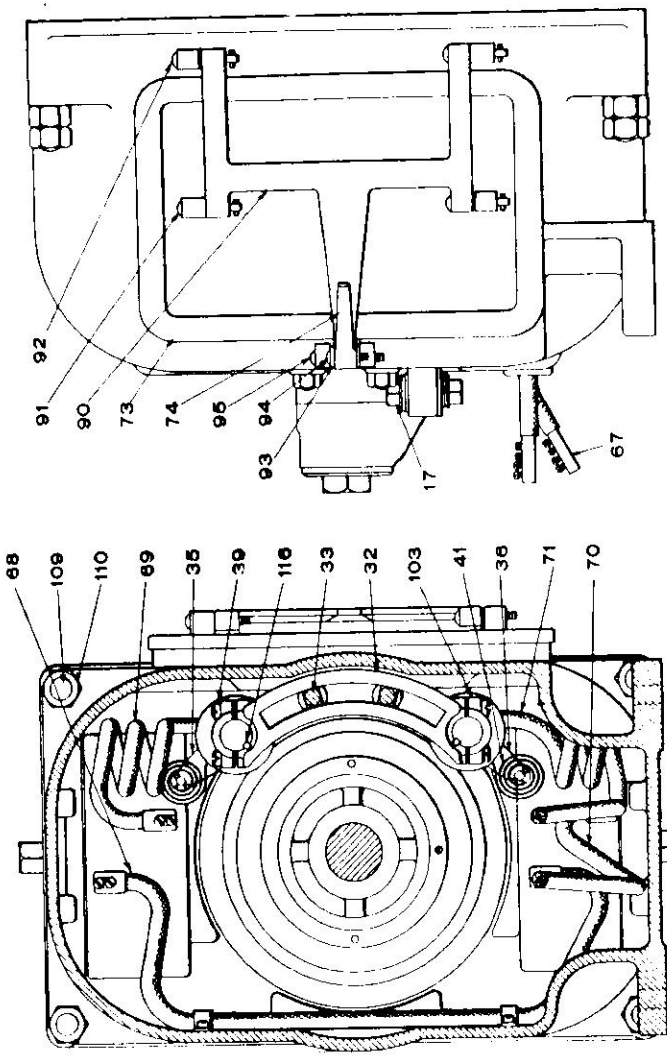


Fig. 35. Type D-4-P Compressor Motor

TYPE D-L COMPRESSOR

The D-L Compressor, Fig. 36, was brought out several years ago, incorporating a number of special features as compared with the D-EG type as it then existed.

The bed plate is eliminated, the motor and compressor

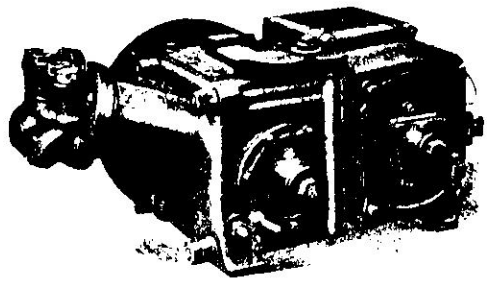


Fig. 36. Type D-L Compressor

portion being fastened together by long bolts and alignment is secured by machined shelves on the motor which engage with corresponding ones on the compressor. The suspension is of the "three point" type and no cradle is necessary.

Referring to Fig. 37, it will be seen that the crank shaft has two bearings, the middle one being provided for but not babbitted unless specified. The cylinders are bushed so that reboring is unnecessary and the original size of the cylinder can be maintained by replacing the worn bushings as required. The gear case, as shown in Fig. 38, is of the K type, but is divided at an angle to the horizontal. The crank case cavity is somewhat larger than

that of the type D-EG, thus providing for a larger supply of oil and permitting longer intervals between inspections.

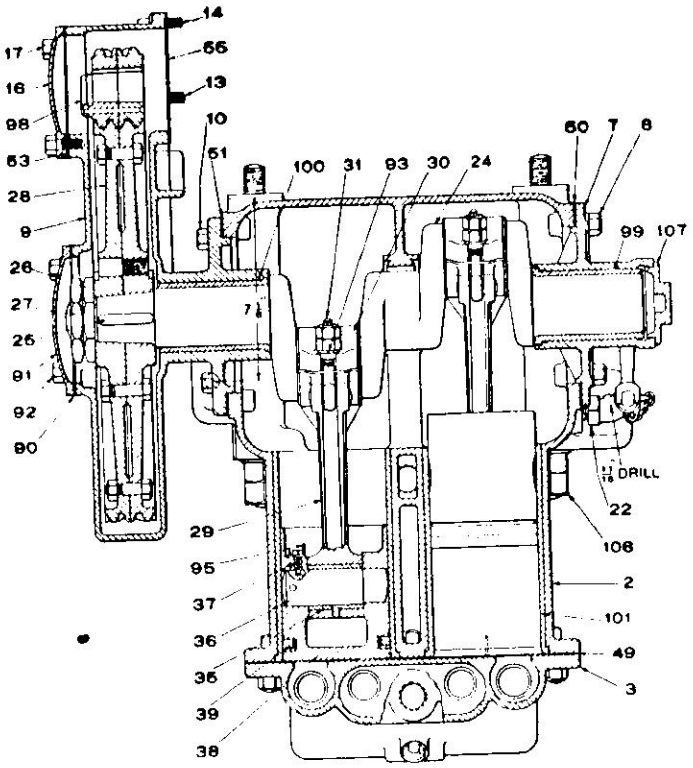


Fig. 37. Type D-L Compressor. Sectional View Compressor Portion

By virtue of the cylinders being at an angle to the horizontal and the valves vertical, valve clearance is reduced

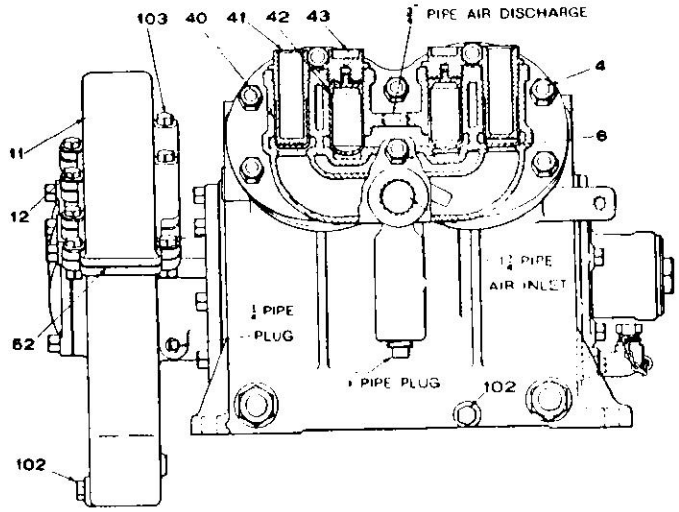


Fig. 38. Type D-L Compressor. Cylinder Cover in Section

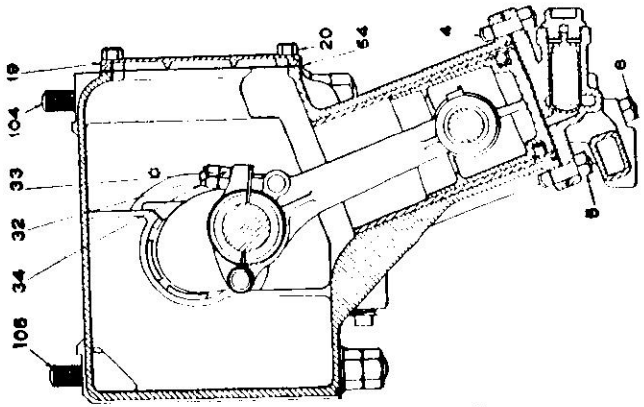


Fig. 39. Sectional View Type D-L Compressor

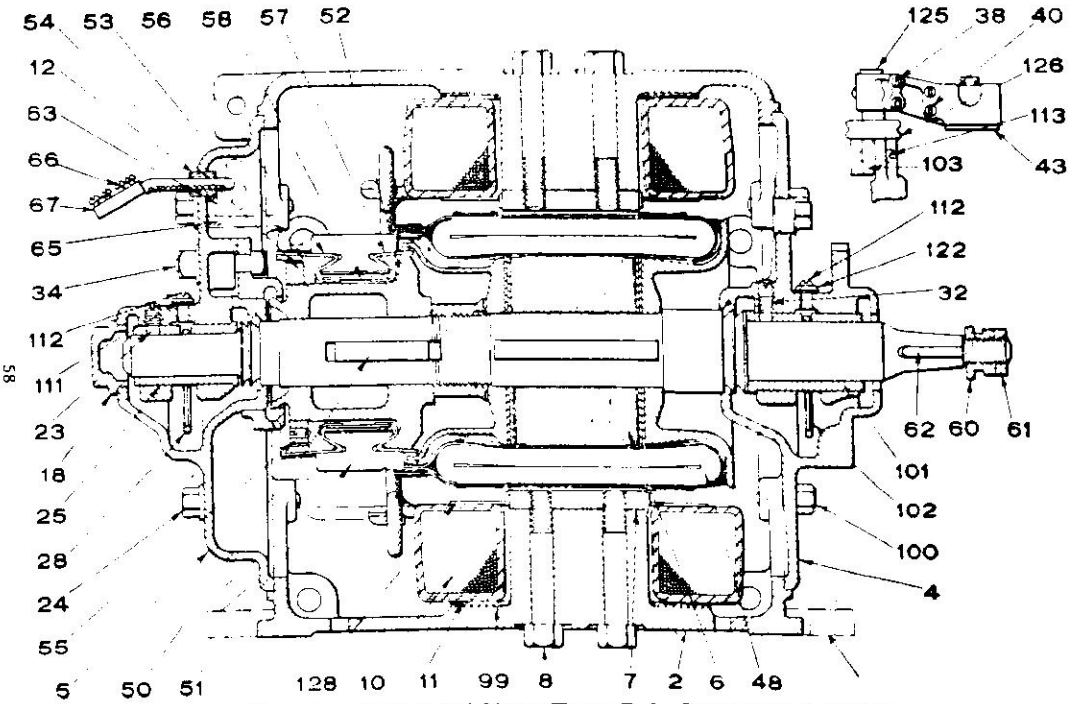


Fig. 40. Sectional View Type D-L Compressor Motor

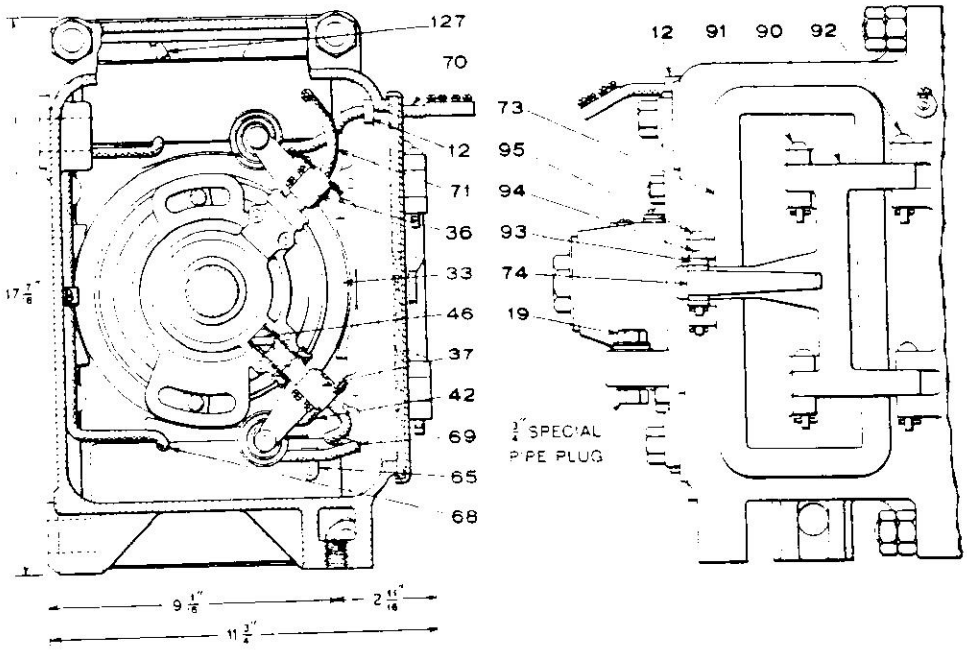


Fig. 41. Type D-L Compressor Motor

to a minimum and high volumetric efficiency is obtained. The piston, connecting rod and stroke are all longer than in the D-EG.

The motor, Figs. 10 and 11, is of the enclosed, four pole series wound type, with two field coils. The field yoke of the D-1-L is a steel casting, while that of the D-2-L is made of laminated sheet steel. The armature is unusually large and the motor as a whole is larger than the corresponding sizes of the D-EG, thus reducing the chances of overheating. As with the D-EG, the brushes are mounted on rocker arms. The commutator door gives access to the brushes and is mounted upon the same type of hinge as the D-F.

In other respects, both the compressor and motor are of the same general construction as the D-EG, the operation and lubricating systems being identical.

The suspension is of the "three-point" type and the hangers are fastened to the brackets by keys in a manner similar to the D-F type of suspension.

The compressor is furnished in two sizes: D-1-L and D-2-L, both being wound for operation at 600 volts direct current. The data for performance and dimensions are as follows, the performance data being based upon an operating air pressure of 100 lbs. per square inch:

Designation	Displacement Cu. Ft. per Min.	Size of Cylinder in Inches	Speed in R. P. M.		E. H. P. Input	Volts	Fuse Amperes	
			Crank Shaft	Motor				
D-1-L	15.7	$4\frac{1}{4} \times 4\frac{1}{4}$	222	1475	3.58	600	5	
D-2-L	26.0	$5 \times 5\frac{1}{4}$	218	1200	6.35	600	10	

Designation	Size of Pipes in Inches		Lift of Valves in In		Dimensions in Inches			Weight Lbs.	
	Suction	Discharge	Inlet	Discharge	Length	Width	Height	Net	Shipping
D-1-L	$1\frac{1}{4}$	$\frac{3}{4}$	$\frac{5}{32}$	$\frac{1}{8}$	$31\frac{1}{16}$	$26\frac{1}{4}$	$19\frac{13}{16}$	675	825
D-2-L	$1\frac{1}{4}$	1	$\frac{5}{32}$	$\frac{1}{8}$	$38\frac{1}{4}$	$30\frac{7}{16}$	$20\frac{3}{4}$	1200	1400

TYPE D-N COMPRESSOR

The development of interurban traction systems employing direct current at 1200 to 1500 volts in rural districts and at 600 to 750 volts within city limits has created a demand for a compressor that will operate with the same displacement at either voltage. With the ordinary type of compressor, if the motor is designed to run at normal speed with, say 1200 volts, when the 600 volt zone is reached, the speed, and hence the displacement, will be reduced approximately one-half. The D N compressor, Fig. 42, has been developed to meet this condition, and as can be seen from Fig. 43, is of the double commutator type. The motor has a single armature with two sets of windings, each winding being connected to its individual commutator. For high voltage service, the windings are

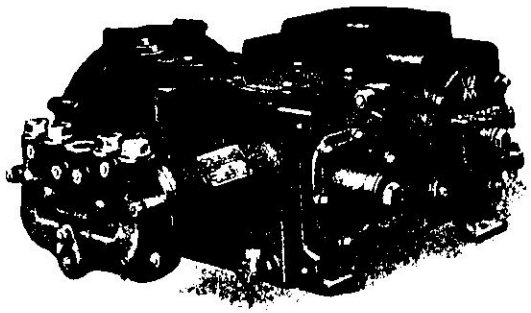


Fig. 42. Type D-N Compressor

connected in series, and for low voltage in parallel and hence, under either condition, the speed will be the same.

This type of compressor requires no bed plate, the motor and compressor portion being bolted together, and alignment is secured by machined shelves, as with the type D-L. An additional means of alignment is provided by a key which is fitted between the two portions. Direct

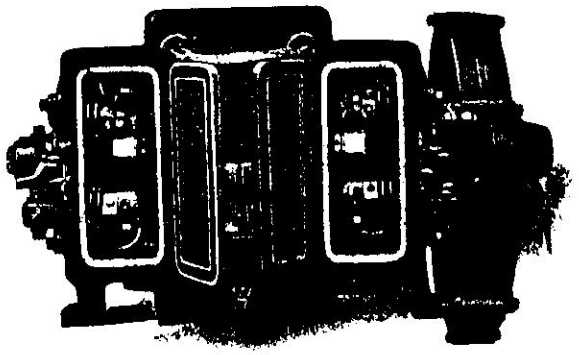


Fig. 43. Type D-N Compressor. Rear View showing Commutators

"three-point" suspension is used and the hangers are secured to the car in the same manner as with the D EG.

The compressor portion, Figs. 44 and 45, is almost identical with that of the D-F, a two bearing crank shaft and the F type of gear case being used. The wrist pins, however, are arranged the same as with the DH or D-EG types.

The motor, Figs. 46 and 47, is of the enclosed, four pole type, with two salient poles. The armature, as previously stated, has two sets of windings which are embedded in the same slots in the core, one set on top of

the other, with ample insulation between. Each of the salient poles, instead of a single coil, has two, and a pair of these, one from each pole, is connected in series to one

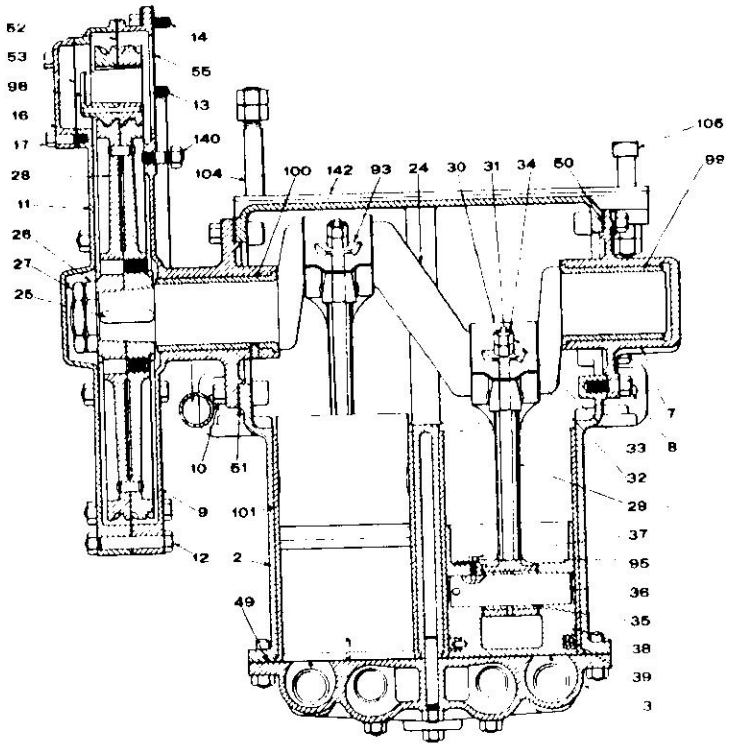


Fig. 44. Type D-N Compressor. Sectional View Compressor Portion

armature winding while the remaining pair is connected to the other winding. As each winding is connected to its own commutator, this arrangement constitutes prac-

tically two complete motors which have separate leads brought out near their respective commutator doors. These leads are connected to the main motor switch or to an automatic change-over switch which makes the proper

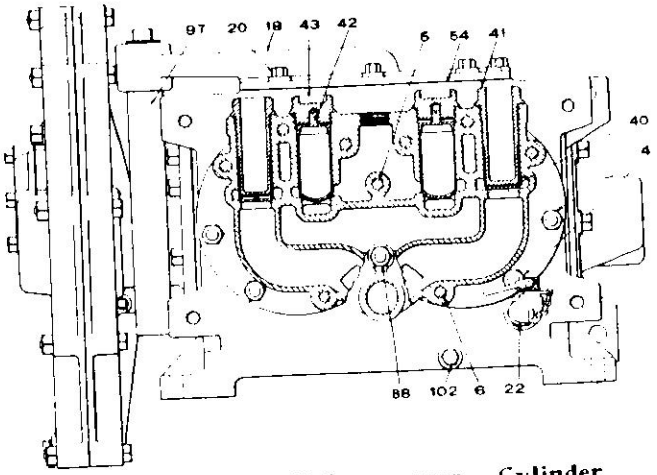


Fig. 45. Type D-N Compressor. Cylinder Cover in Section

connections so that in the high voltage zone, the two windings are in series, and in the low voltage zone, in parallel.

In other respects the motor resembles those already described, the construction throughout being in accordance with the best railway practice. The field yoke for the D-2-N and D-3-N is a steel casting, and for the D-1-N is made of laminations of steel sheets. The door is supported by the same kind of hinge as the D-F. The carbon holders are arranged on a rocker arm that permits a wide

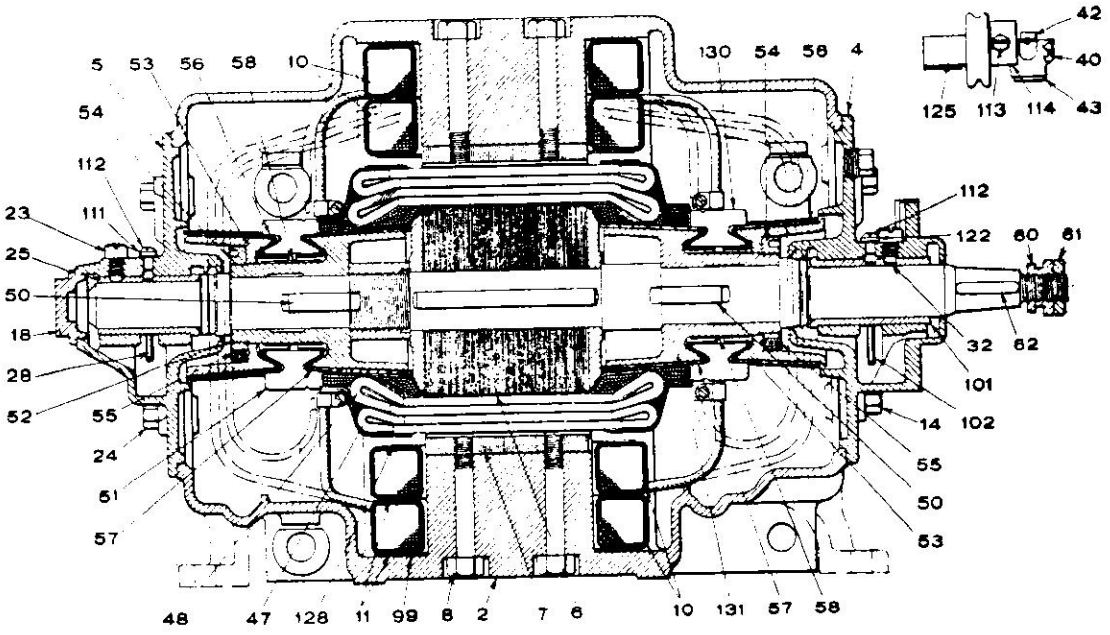


Fig. 46. Type D-N Compressor Motor

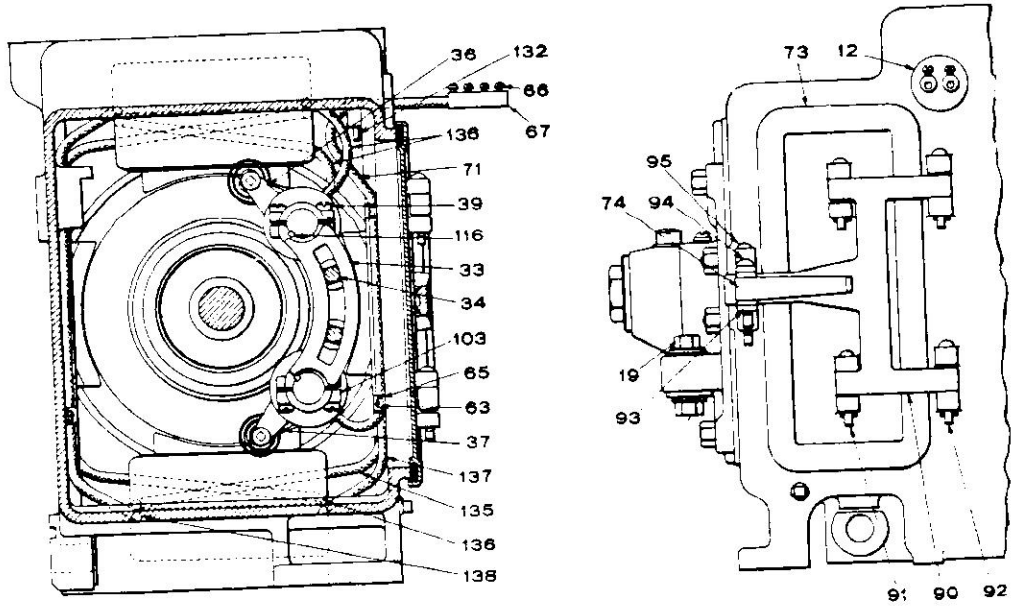


Fig. 47. Type D-N Compressor Motor

variation of location of carbons relative to their neutral position and the commutators have large creepage surfaces.

The lubricating system is the same as that of the D-EG, described on page 20.

The compressor is furnished in the following sizes: D-2-N, D-3-N and D-4-N, all of which are wound for operation at either 600-1200 volts or 750-1500 volts direct current. The data for performance and dimensions are as follows, the performance data being based on an operating air pressure of 100 lbs. per square inch:

Designation	Displacement Cu. Ft. per Min.	Size of Cylinder in Inches	Speed in R. P. M.		E. H. P. Input	Volts	Fuse Amperes
			Crank Shaft	Motor			
D-2-N	27.0	5x5½	216	1200	6.0	1200-600 1500-750	*10
D-3-N	38.0	6x5½	212	1400	8.5	1200-600 1500-750	*15
D-4-N	50.0	7x6	188	1020	11.5	1200-600 1500-750	*20

Designation	Size of Piping in Inches		Lift of Valves in In.		Dimensions in Inches			Weight Lbs.	
	Suction	Discharge	Inlet	Discharge	Length	Width	Height	Net	Shipping
D-2-N	1¼	1	5/32	1/8	39 3/8	32 5/8	20 5/8	950	1200
D-3-N	1½	1¼	5/32	1/8	41	34½	23¾	1275	1550
D-4-N	1½	1¼	7/16	5/32	43 7/16	40 5/32	24⅜	1675	2000

See Note on following page.

*NOTE. The fuses for a double commutator motor must have sufficient carrying capacity for low voltage operation, which means that on high voltage operation the fuse capacity will be much in excess of that which would be used if high voltage operation only were considered. For example, on 600 volt operation the running current may be 7 amperes, which would require a 10 ampere fuse; on 1200 volt operation, the running current would be less than 4 amperes, from which it can be seen that the 10 ampere fuse is in excess of requirements for the low voltage operation. However, as the use of separate fuses for each winding does not actually safeguard the motor to a great enough degree, as compared with the one large fuse, to warrant their use, the one large fuse is recommended in the interest of simplicity and economy.

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 motor, Figs. 62 and 63, is of the series wound, four pole type, with four field coils, and is ventilated. The carbon holders are mounted on a rocker arm and are arranged for double carbons, each carbon having its own spring. The carbons rest on the top of the commutator and are easily accessible for adjustment. The field yoke is a solid steel casting, the pole pieces being made of laminations of sheet steel. The design of the motor is such that no door is necessary.

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

The compressor is furnished in only one size, having a capacity of 60 cubic feet per minute, and is driven by a 600 volt direct current motor. It can be started on any voltage up to 750 volts without the use of a starter. The data for performance and dimensions are as follows, the performance data being based upon an operating air pressure of 110 lbs. per square inch;

Designation	Displacement Cu. Ft. per Min.	Size of Cylinder in Inches	Speed in R. P. M.		E. H. P. Input	Volts	Fuse Amperes
			Crank Shaft	Motor			
C-60	60.0	H. P. 6x5½ L. P. 8½x5½	176	800	11.75	600	25.0

Designation	Size of Piping in Inches		Lift of Valves in In.		Dimensions in Inches			Weight Lbs.	
	Suction	Discharge	Inlet	Discharge	Length	Width	Height	Net	Shipping
C-60	2½	1½	3/16	3/32	49½	43	26 11/16	2475	2800

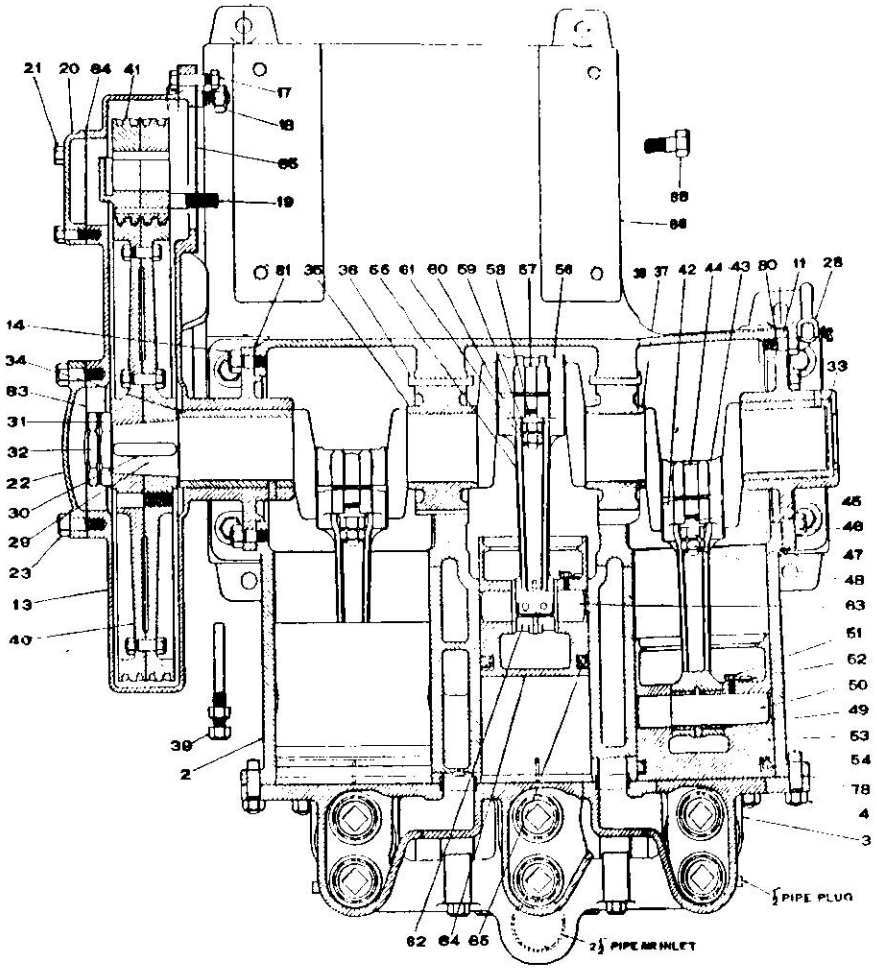


Fig. 60. Sectional Views C-60 Compressor Portion

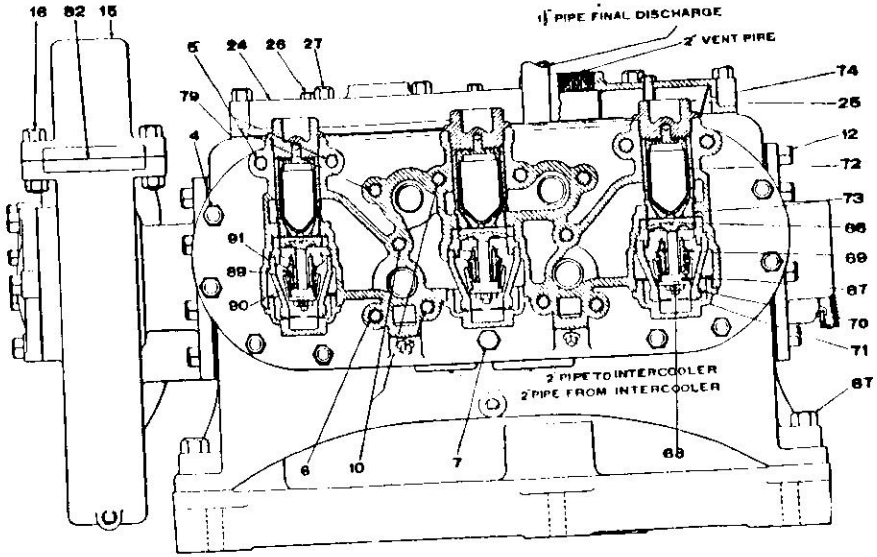


Fig. 61. C-60 Compressor, showing Valves in Section

C-75 COMPRESSOR

The C-75 compressor has been developed from the C-60 for service conditions requiring a greater displacement than the latter. The compressor portions of the two machines are identical but the C-75 in installations to date has been driven by a phase converter through a pneumatic clutch, similar to that described on page 76. At a rated speed of 220 revolutions per minute, it compresses 75 cubic feet of air against 140 pounds pressure, a proportionate increase in size of intercooler maintaining practically the same temperatures as with the C-60.

The function of the phase converter is to convert single phase alternating current into three phase current for use in the electric apparatus on the locomotive and to drive the compressor as required.

DYNAMOTOR COMPRESSOR

The dynamotor compressor, Fig. 50, is designed for high voltage railway service and is a combination consisting of a duplex air compressor portion and a direct current self-contained dynamotor, the compressor portion being operated by the dynamotor through the action of a clutch and herringbone gearing. The function of the dynamotor is two-fold: 1st, to supply current at reduced voltage for

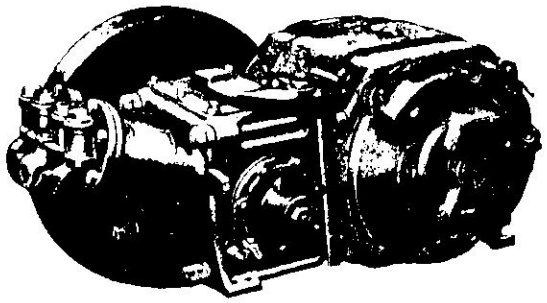


Fig. 50. Dynamotor Compressor

lighting and control circuits and 2nd, to drive the compressor as required.

The compressor portion is furnished in the following sizes: D-2, D-3 and D-4. For the first two sizes, the D-E, type is used, while the D-K type has been supplied for the last. They are identical with those furnished for standard compressors except for changes in the gear case due to the clutch. The D-E, type compressor is bolted to the dynamotor and direct "four-point" suspension is used, while the D-K requires a bed plate and is suspended by a cradle. The lubricating system is the same as that described for the D-EG, the oil being poured into the crank

case and the motor bearing oil wells. The clutch requires no additional attention, for it receives its supply of oil from the gears.

The dynamotor is of the YE type, series wound, with two armature windings and two commutators. When operating on high voltage, the windings are in series and the control circuit is taken off at a point half-way between the trolley and the ground. When operating on half voltage, as in city service, the connections are changed so that the control circuit is taken direct from the trolley and only one winding is used in the dynamotor for driving the compressor.

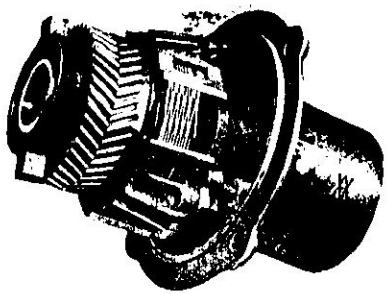


Fig. 51. Clutch for Dynamotor Compressor

As it is necessary to run the dynamotor continuously in order to furnish current for the control circuits and lighting, a clutch must be provided so that the compressor can be stopped when the air pressure in the reservoir has reached a pre-determined point. The clutch is shown in Figs. 51 and 52, the operation being as follows: Referring to Fig. 52, the driving bracket 11 is keyed to the dynamotor shaft 13, and revolves with it. The pinion bracket 2 is free to rotate on the sleeve 42, and carries the pinion 11, which is fastened to it by the dowel pins 40. The pinion meshes with the compressor gear of which only a portion is shown. The driving bracket 11 has a hexagonal periphery, and on it are mounted twenty-one discs, ten of the type marked 8, and eleven of those marked 9 and 10, which are left and right hand respectively. The discs 8 have hexagonal holes and consequently rotate with the driving bracket, while the discs 9 and 10 have round holes which permit the bracket to turn freely without driving them. They have, however, three projections on their outside rims which fit into corresponding slots in the pinion bracket so that any motion of the discs is transmitted to the bracket and thus to the pinion. They also have small tongues cut in the projections, these tongues being bent outward, as shown.

The right and left hand discs are arranged along the driving bracket alternately, being separated from each other by the plain discs. When the clutch is open, the tongues force them far enough apart to allow the plain discs to rotate between them without touching, but if pressure is applied along the axis of rotation, the tongues straighten out and the surfaces of the discs grip each other. As the plain discs revolve continuously with the dynamotor shaft, this means that the right and left hand discs, and hence the pinion bracket, will also revolve. The pressure necessary to straighten the tongues is obtained from spring 13, which moves spring follower 16 to the right (when there is no air pressure in cylinder A), thereby transmitting the force through the clutch levers

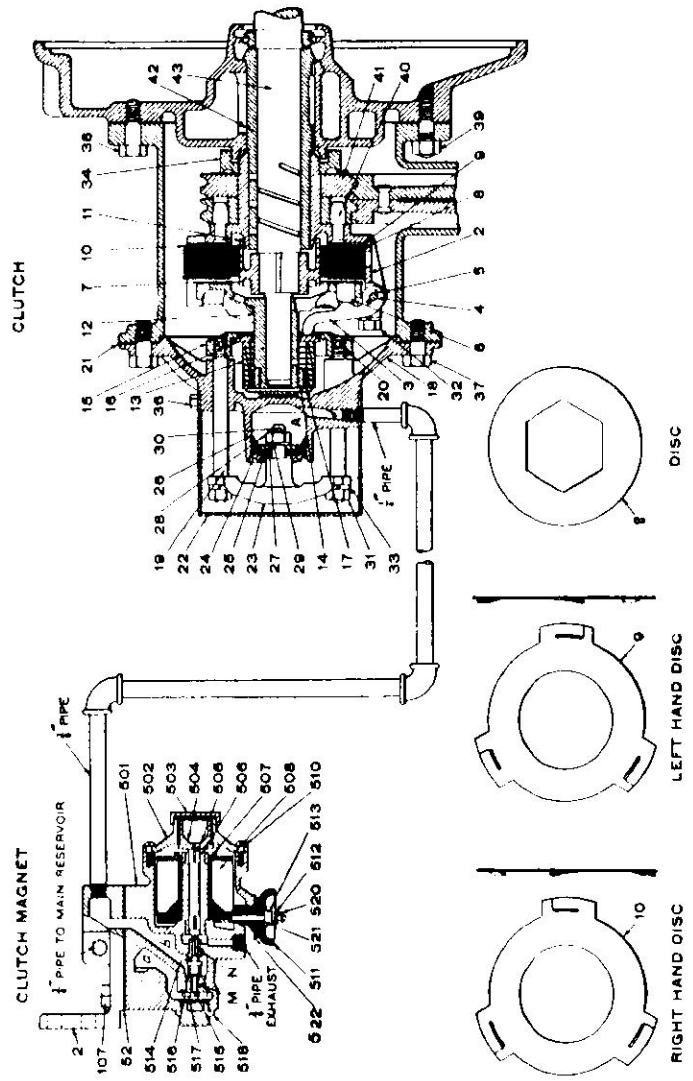


Fig. 52. Clutch and Clutch Magnet for Dynamotor Compressor

3 to the plate 7 which in turn presses against the discs and causes them to be forced together with the results above described.

In order to open the clutch, air is admitted to the cylinder A causing the piston to move outward. This motion is transmitted through the piston arm 23 and the rods 19 to the yoke 15, which moves to the left, thus compressing the spring and relieving the pressure on the discs. The tongues then force them apart as explained.

Air is admitted to the cylinder through either a type N governor*, which is actuated directly by the reservoir pressure, or by a clutch magnet†, which is energized by the synchronizing system.

*NOTE. The Type N Governor is nothing more than the pneumatic portion of the Type J Governor and if the operation of this governor as described in Instruction Pamphlet No. T-5042, is understood, it can readily be seen how the Type N Governor operates to cut in and out the clutch of dynamotor compressors.

†NOTE.- The clutch magnet is actuated by the cutting in and out of the compressor governor. When the magnet is de-energized by the cutting out of the compressor governor, main reservoir air entering at the pipe tapped opening marked "To Main Reservoir" flows through passage *a*, then through passage M around the stem of admission valve 515 to passage *b* whence it flows to the clutch cylinder A, throwing the clutch out and stopping the compressor. When the magnet is energized by the cutting in of the governor, armature 504 is drawn toward magnet core 506, thereby pushing armature stem 505 inward and seating supply valve 515. This action cuts off communication between passages *a* and *b* and opens the clutch cylinder A to the atmosphere through passage *b* and N and the exhaust opening. This permits the clutch to cut in and connect the compressor to the dynamotor.

The dynamotor compressor is furnished in the following sizes and voltages:

Dynamotor	Compressor	Displacement	Voltage
YE-7	D-2-LA	25	600-1200
YE-8	D-2-LA	25	600-1500
YE-7	D-3-LA	38	600-1200
YE-10	D-3-LA	38	750-1500
YE-4-B	D-4-K	50	600-1200
YE-6-B	D-4-K	50	750-1500

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

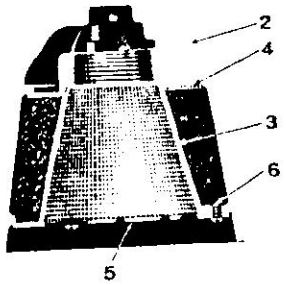


Fig. 53. Type G Suction Strainer

a supply of clean dry air. The strainer should be piped, if possible, to the cab or top of car.

Fig. 54. Special "Fifty-Four" Air Strainer

Fig. 53 shows the Type G strainer regularly furnished with the compressor. When a strainer of greater capacity and efficiency is desired, however, the Special "Fifty-Four" Air Strainer, Figs. 54, 55 and 56, is used. As will be seen this is a very large double cylindrical strainer (over-all dimensions approximately 10" x 11") with an inner strainer of perforated sheet steel, galvanized, and an outer strainer of coarse galvanized wire mesh, the in-

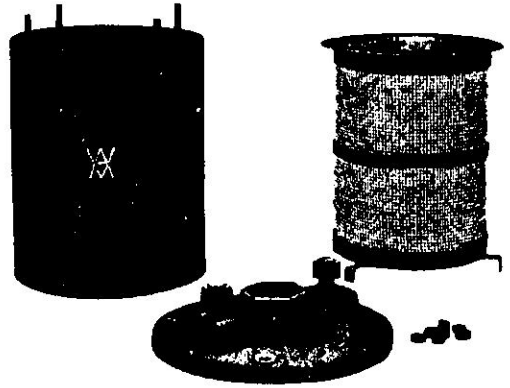


Fig. 55. Special "Fifty-Four" Air Strainer Disassembled

tervening space being well packed with curled hair. A galvanized iron shell 3 encircles the strainer proper, preventing dust, dirt, etc., from striking directly against the strainer portion. This strainer has a greater amount of curled hair than the type G strainer. It can be quickly and conveniently taken apart without disturbing any pipe connections by removing the nuts from the four studs. It should be installed in a vertical position with the large opening downward.

Another type of strainer, known as the "Lord Screenless Air Cleaner," Fig. 57, is also used on some roads. The principle of operation of this cleaner is that incoming air at K in expanding through the slot in the bottom

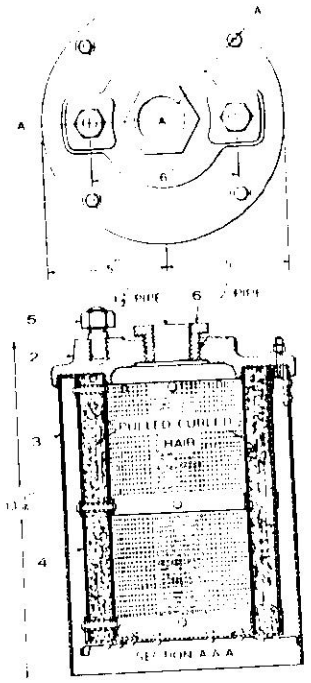


Fig. 56. Sectional View of Special "Fifty-Four" Air Strainer

of the tube L is deflected sharply by the surface of the oil in chamber M. This contact with the surface of the oil causes the dirt in the air to adhere to the oil, thus allowing the clean air to flow without restriction through

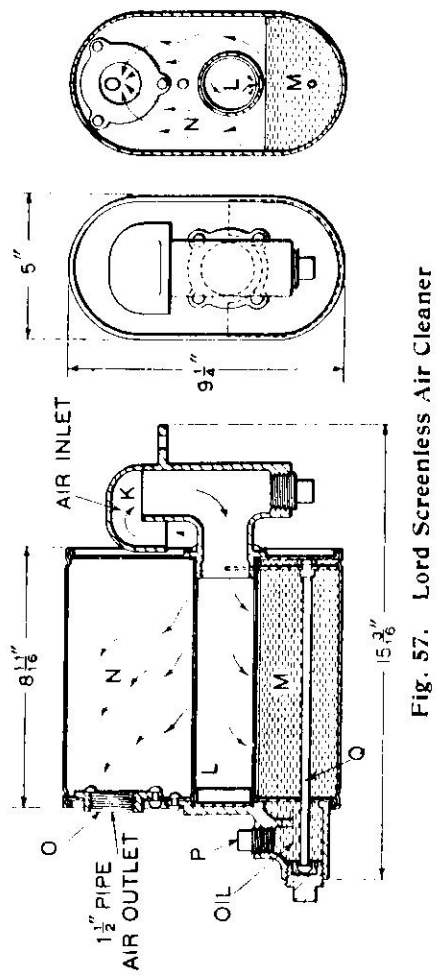


Fig. 57. Lord Screenless Air Cleaner

the expansion chamber N, thence through outlet O to the compressor. The dirt deposited in the oil accumulates in the bottom of chamber M, so that a clean surface of oil is always exposed to the incoming air. The oil chamber is cleaned by removing plug and pulling out on the rod Q, causing the plate at the end of the rod to push the dirt out ahead of it.

MOTOR DRIVEN COMPRESSOR TESTS

Motor and Compressor Test

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, good commutation, 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.

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 requires additional compressor capacity in proportion to the size of whistle 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.

INSTALLATION OF THE MOTOR DRIVEN COMPRESSOR

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 entrained by it.

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 con-

siderably 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 except the D-N is shown in Fig. 58; that of the D-N is shown in Fig. 59. 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 except the D-N run the wire from the trolley connection first to one compressor snap switch and then to the other, connecting them in series, and making sure that when they are open, their dials show the words "Off" and when closed "On"; thence it is run through the fuse box to the governor where connection 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 this way a grounded field coil or lead cannot cause damage to the armature. The D-N compressor has two sets of leads, one on each end of the motor, and the wiring should be done in accordance with Fig. 59. In making the connections to the motor use the brass terminals which accompany it, being sure to tighten the set screws solidly and cover the entire connection with insulating tape.

*NOTE. For wiring in connection with synchronizing system, see Instruction Pamphlet No. T 5042.

The compressor snap switch should be placed in an accessible location. The fuse box should be connected between the compressor snap 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 cir-

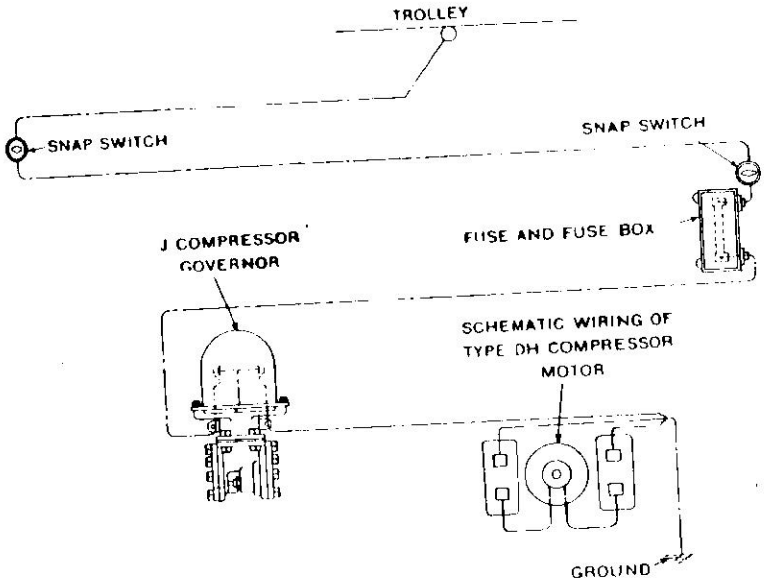


Fig. 58. Typical Diagram for Motor Driven Air Compressor, all Types except Type D-N

NOTE: For wiring diagram when the Governor Synchronizing System is used, see Instruction Pamphlet No. T 5042.

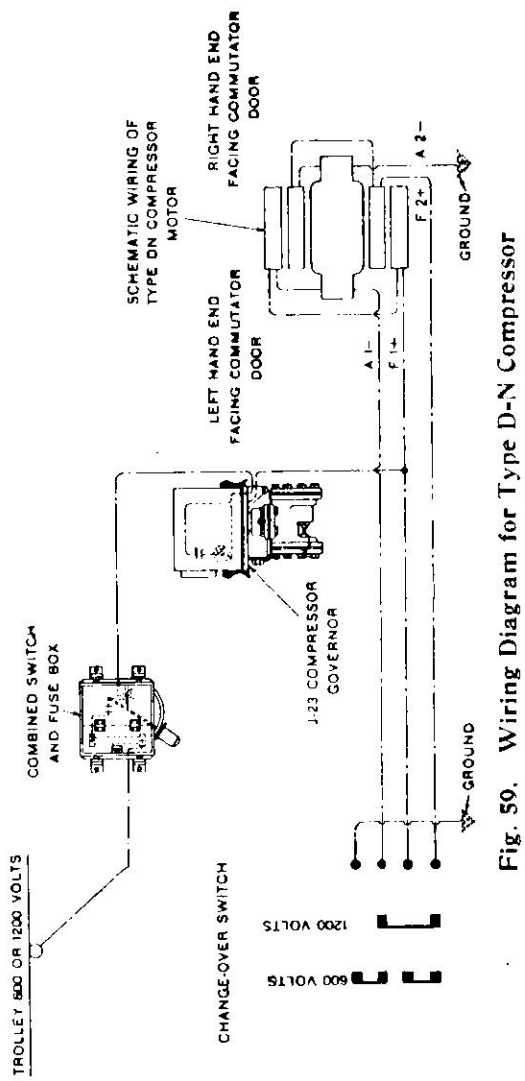


Fig. 59. Wiring Diagram for Type D-N Compressor

cumstances 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

Cleaning and Repairing the Motor Driven Compressor

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 Galena air compressor oil or its equivalent. 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 $\frac{1}{4}$-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, on the outside face of each piston, and on the inside face of the joint of each packing ring segment. In addition to this letter, a figure is stamped on each end of the segments to show how they are to be joined. A dowel pin is located in the bottom of the packing ring groove and if the segments are joined correctly so that the same figure is on each side of the joint, viz., 1-1, 2-2, 3-3, it will be found impossible to place them in the groove in other than the proper position. It is also essential that the packing rings should be installed with the square segment of the ring next to the wrist pin, as shown in Fig. 5.

The commutator should be kept clean. The brushes should be free 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-EC.

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 that a defective one may be promptly replaced and the repairs made at a bench in the day time to far better advantage than is possible under the cars at night.

With such an 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.

If a compressor blows its fuse frequently, and the motor is found to be in good order it may be assumed that the compressor is not working freely. It should be examined for stuck valves, hot bearings and tight pistons and the trouble remedied. Under no circumstances should the car be sent out with a heavier fuse; such a practice is almost sure to result in burning out a motor. All the compressors are started without the use of a rheostat.

Three sizes of repair pistons, 1-16-inch, 1-8-inch and 3-16-inch larger than the original size can be supplied for re bored cylinders. Packing rings .006 inch and .012

inch wider than the standard are also furnished for each size of piston. 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 hard ball of slightly oily waste 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, it should be turned down. 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 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 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.