MAINTENANCE MANUAL

FOR

WAUKESHA LIGHTING

AND

AIR-CONDITIONING UNITS

Victor Roberts

THE PULLMAN COMPANY

YARD DEPARTMENT

CHICAGO

FEBRUARY, 1944

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WAUKESHA FUEL SYSTEM

CHART NO. 1

FUEL.

Propane is the fuel used in the Waukesha engine. Under atmospheric pressure it is a gas because of the liquid having a boiling point of 48.1°F. below zero. Propane itself is colorless and odorless, but a tracer gas having a characteristic unpleasant odor is added to make it easy to detect a leak in the fuel system.

Propane exists as a liquid in the fuel tanks at a pressure of 125 lbs. per square inch at 70°F. At 90°F. the pressure is 167 lbs. per square inch.

FUEL TANK.

The fuel tank is a cylinder approximately 42" long and 16" in diameter. This tank is built to withstand operating pressures of over 260 lbs. Each tank is capable of holding 100 lbs. or 23.6 gallons of liquid propane.

As propane gas is drawn from the tank, the pressure within the tank is reduced causing the liquid propane to boil. This boiling continues until such time as the pressure within the tank corresponds to the boiling point of the liquid propane at that pressure and temperature. When liquid propane boils, it absorbs heat from the metal tank and the surrounding air, therefore, the tank feeding fuel to the engine will feel colder than the other tanks in the system. Under some weather conditions the tank will sweat or frost.

CYLINDER VALVE.

The cylinder valve is attached to the top of the fuel tank and has a curved pipe extending inside of the fuel tank towards the top of the tank so that gas and not liquid is admitted to the valve. For this reason, there is a definite position in which the fuel tank must be placed in fuel cabinet. Attached to the cylinder valve is a high pressure release valve, in other words, a safety valve. This valve is approximately 1½" in diameter and 4" long. At one end are several small holes to allow for escaping gas. This valve is spring loaded so that at 400 lbs. pressure it automatically opens and allows gas to escape. Excessive pressure within the tank may be caused by overfilling or overheating the tank.

The slug valve is a small metal piston contained within the cylinder valve. It is spring loaded and will automatically close if more than 300 cu. ft. per hour of gas tries to pass.

The hand shut-off valve portion of the cylinder valve has a diaphragm separating the gas chamber from the valve handle stem. This is to prevent gas from leaking past the thread of the valve handle stem.

Also contained in the cylinder valve is a safety valve, which is normally closed until a special fitting is inserted in the valve outlet which forces this valve back into the open position allowing the gas to flow into the flexible hose connection.

FLEXIBLE HOSE.

A flexible hose connects the fuel tank to the main fuel line. At one end of this hose is a special fitting which has left hand threads and screws into the cylinder valve. As this fitting is screwed into the cylinder valve it forces the safety valve back off of the seat allowing the gas to pass into the hose.

Connected into the main fuel line are the following valves and regulators:

CHECK VALVE.

This valve is approximately 2" in diameter and allows the gas to flow in one direction only. When the flexible hose is disconnected from the fuel tank, this valve is normally closed. As the fuel enters this valve it must first pass through a fine mesh wire screen. The pressure of the fuel on the inlet side forces the valve piston back against the spring opening the valve seat. This allows the gas to pass around the piston to the outlet side of the valve.

HIGH PRESSURE REGULATOR.

This regulator reduces tank pressure which may run as high as 200 lbs. down to 10, 20, 30 or 40 lbs. This valve operates as follows:

As the pressure on the lower side of the diaphragm is reduced, the spring on the top side of the diaphragm forces it down. The valve seat being attached to the diaphragm by the valve stem will open, allowing the gas to flow from the inlet side, past the valve seat, up around the valve stem and out the outlet side of the valve. As the pressure builds up on the outlet side and the pressure is thus increased on the lower portion of the diaphragm this back pressure gradually overcomes the pressure exerted by the spring above the diaphragm and the valve will close. The pressure adjustment screw on the top of this regulator increases or decreases the spring pressure on the top side of the diaphragm thereby increasing or decreasing the gas pressure necessary on the lower side of the diaphragm in order to open or close the valve. Adjustment must be made with the engine running.

HIGH PRESSURE EXCESS FLOW VALVE.

This is a safety feature that will shut off automatically if the flow of gas is in excess of that required to run both engines at full load. This is placed in the line in case a leak should develop between this valve and the next excess flow valve. It operates as follows:

As the fuel enters this valve it must flow through small holes drilled in a movable piston which is spring loaded open. As the flow of gas becomes excessive this piston is forced against the spring, compressing the spring until this piston closes against the valve body thus stopping the flow of gas.

SHUT-OFF VALVE.

This is a hand operated valve used mainly when adjusting the high pressure regulator or changing fuel tanks. This valve has a metal diaphragm which prevents the gas from leaking around the valve handle stem.

HIGH PRESSURE GAUGE.

This gauge indicates the pressure in the fuel header dependant upon the pressure setting of the fuel tank which is then supplying fuel for the engines.

LOW PRESSURE REGULATOR.

The purpose of this regulator is to provide another reduction in pressure which is more closely controlled than the first stage regulator. In this regulator the gas pressure is reduced from pounds on the inlet side to ounces on the outlet side. At the bottom of this regulator is a screw which adjusts the spring pressure on the diaphragm thereby regulating pressure of the gas leaving this regulator. When the gas pressure above the diaphragm is lower than 3 or 5 oz. the spring forces the diaphragm up actuating the lever arm, which in turn opens the valve seat. As the pressure builds up above the diaphragm , it forces the spring down, also pulling down the arm which regulates the lever closing the valve. Should the main diaphragm break and the pressure rise above a few lbs., the pressure release valve at the top of this regulator will open allowing gas to escape and indicating by odor a defective regulator.

As in the case of the high pressure regulator the closing of the regulator valve is controlled by back pressure on the discharge side of the regulator.

LOW PRESSURE EXCESS FLOW VALVE.

This valve serves the same purpose as the high pressure excess flow valve and provides a similar protection for the low pressure line. It automatically shuts off if more than 125 cu. ft. of gas per hour tends to flow. This valve, unlike the high pressure excess flow valve, is operated by a diaphragm and is much more sensitive to the flow of gas. As the gas enters the valve it must flow through the valve plunger which in turn is attached to the diaphragm. At one end of the valve plunger is a baffle past which the gas must flow. As the flow of gas becomes excessive, such as would occur if a leak developed, pressure on this baffle increases forcing the plunger against the valve seat and stops the flow of gas. In this plunger a hole has been drilled to allow a small amount of gas to pass to the outlet side of the valve. As the flow of fuel from the outlet of this valve stops, (by repairing leak, etc.), the bleeder hole allows the pressure to increase on the outlet side automatically opening the valve. The locking pin shown at the lower portion of this valve locks the adjustment nut in place. This nut can be moved so as to increase or decrease the spring pressure on the valve diaphragm. Do not attempt any adjustment on this valve, replace if defective.

THE MANOMETER.

This gauge is connected to the Ensign regulator and registers the pressure in the line between the low pressure regulator and the Ensign regulator, showing 3 or 5 oz., depending on the regulator then in use.

THE ENSIGN REGULATOR.

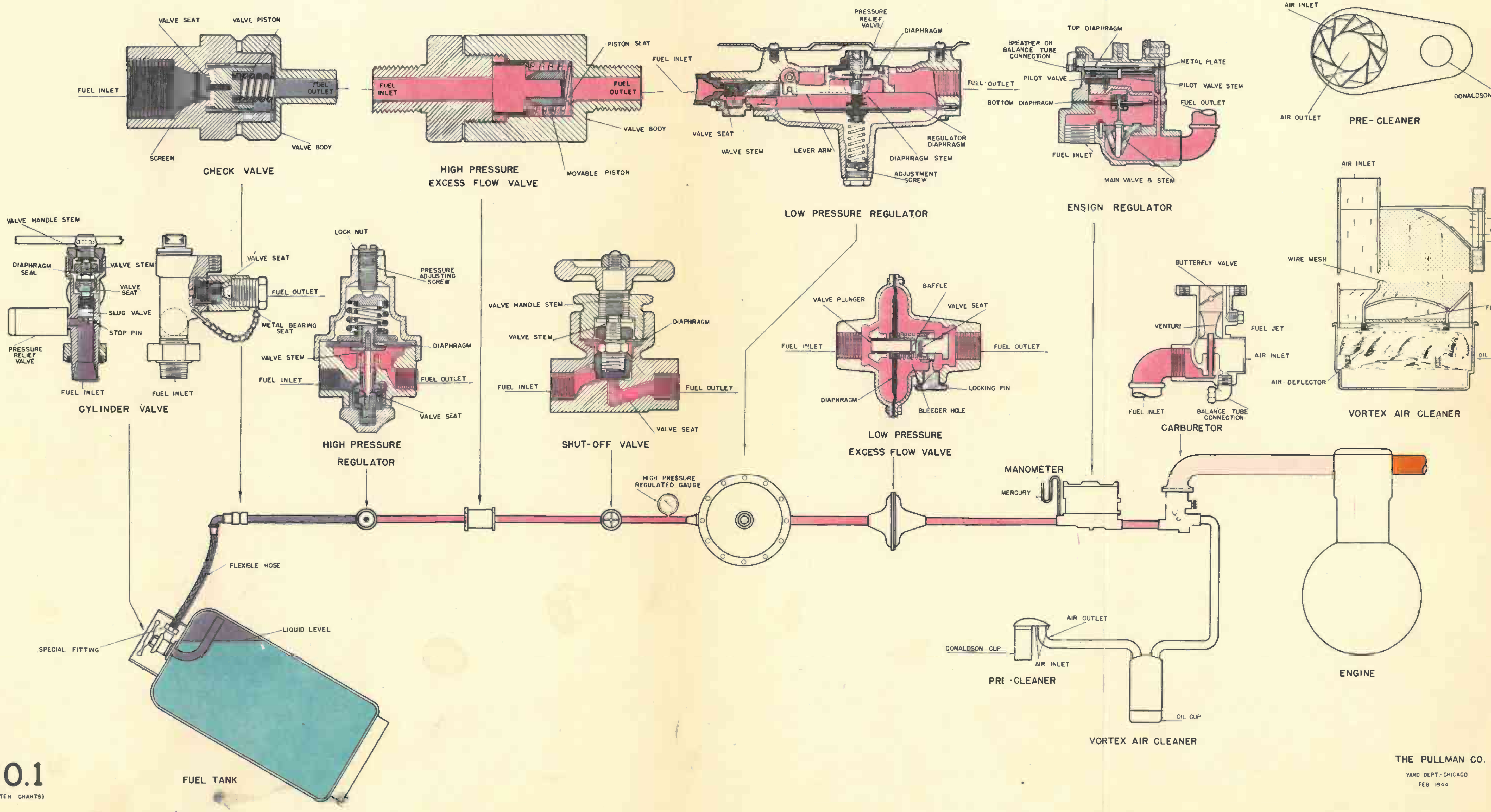
This regulator serves the same purpose as the float valve in an automobile carburetor. It automatically shuts off the flow of gas when the engine stops, and also meters the amount of gas to the carburetor depending upon the requirements of the engine. The Ensign Model "B" regulator operates as follows:

As the pressure on the outlet side of the regulator is reduced by the engine in cranking it draws the top diaphragm down opening the pilot valve by action of the pilot stem. When the pilot valve opens, the pressure on the top side of the lower diaphragm is reduced causing the diaphragm to be drawn up against the action of a spring. As the top diaphragm is drawn up, the valve opens, allowing fuel to flow from inlet side through the regulator and to the outlet side. When the engine stops the pressure builds up on the outlet side thereby forcing the top diaphragm up closing the pilot valve. The pressure above and below the lower diaphragm is soon equalized due to a small hole in the center of this diaphragm. The spring above the diaphragm forces the valve stem down closing the valve.

THE CARBURETOR.

It is nothing more than a mixing chamber for the fuel and air. They are mixed in the proper proportion for combustion. The amount of gas entering the carburetor is adjusted by a screw on the side of the carburetor. Gas enters the carburetor through a jet which

WAUKESHA FUEL SYSTEM



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extends into a Venturi. Air and gas are drawn through this opening together. We have, at the present time, three carburetors with internal differences depending upon the unit on which each is used. They are stamped "ICE", "GEN" or "STR" on the mounting flange. The butterfly valve regulates the total amount of air and gas mixture flowing to the engine thereby regulating the speed of the engine. In some installations we have a balancing tube connecting the carburetor and the top diaphragm chamber of the Ensign regulator. With this arrangement should the Vortex air filter become clogged, the Ensign regulator is also affected so that it will still only allow the proper amount of gas to enter the carburetor minimizing the effect of the restricted air filter.

VACUUM GAUGE.

Mounted on the engine control panel is a vacuum gauge which registers the amount of vacuum the engine is drawing in the intake manifold. The carburetor should be so adjusted as to obtain the highest reading possible on the vacuum gauge with engine operating under a steady load which indicates that the engine is receiving the proper ratio of fuel and air. Under ordinary conditions this gauge should register 10" to 12" of vacuum indicating a properly adjusted carburetor. The vacuum reading is highest with the engine idling or running under a light load. The vacuum is lowest when the throttle is open wide and the engine heavily loaded.

THE PRE-CLEANER.

The air for the engine first enters the pre-cleaner where it is whirled in such a manner that the larger particles of dirt are thrown to the outer portion of the cleaner and settle in a small cup at one side of the cleaner. The air then passes through a pipe and enters the vortox air cleaner.

VORTOX AIR CLEANER.

Upon entering the vortox air cleaner the air passes downward striking the baffle at the lower portion of this cleaner. The air strikes this baffle in such a manner that it gives the air a whirling motion. The baffle is set in a cup which contains oil to a certain level. With the whirling of the air, oil is picked up and some dirt particles which may be contained in the air are settled out by action of the oil. The air then changes its direction of flow starting toward the top of the cleaner where it first must pass through a fine mesh screen just above the oil compartment. This filter will tend to catch the oil and dust and drop the dirty oil back into the cup where the dirt settles out and the oil is free to be picked up again. The air and oil mist continues past this filter and then must pass through a coarse mesh screen where more dust and oil is caught and returned to the lower oil cup. From this cleaner the air passes into the inlet side of the carburetor.

WAUKESHA 6 TANK FUEL SYSTEM

CHART NO. 2

It is common practice to use two fuel cabinets, each containing three or four fuel tanks. Connected between the common fuel line and each Propane tank are the following items as described in detail in Chart #1.

Cylinder valve, special fittings, flexible hose, check valve, high pressure regulator, high pressure excess flow valve and shut-off valve.

SEQUENCE OF EMPTYING FUEL TANK.

In each fuel cabinet the high pressure regulators are adjusted as follows: #1 tank, 30 lbs.; #2 tank, 20 lbs.; and #3 tank, 10 lbs. With this adjustment we draw fuel from the regulator having the highest setting first, and so on. The #2 and #3 tank regulators are closed when #1 tank is feeding fuel to the common line because the back pressure is higher than the pressure for which they are set. The pressure in the common line is indicated on the gauge connected between the tanks and the low pressure regulator. Number two tank will feed after #1 tank pressure has dropped to 20#, and the #3 tank will start to feed when the pressure in the common line has dropped to 10 lbs. With this arrangement it is possible to empty first one tank, then another and so on, successive tanks being prevented from emptying until the tank set for the higher pressure has fallen off allowing the lower regulator to open. The tanks in the second fuel cabinet are connected in the same manner with the regulators adjusted the same as in the first cabinet.

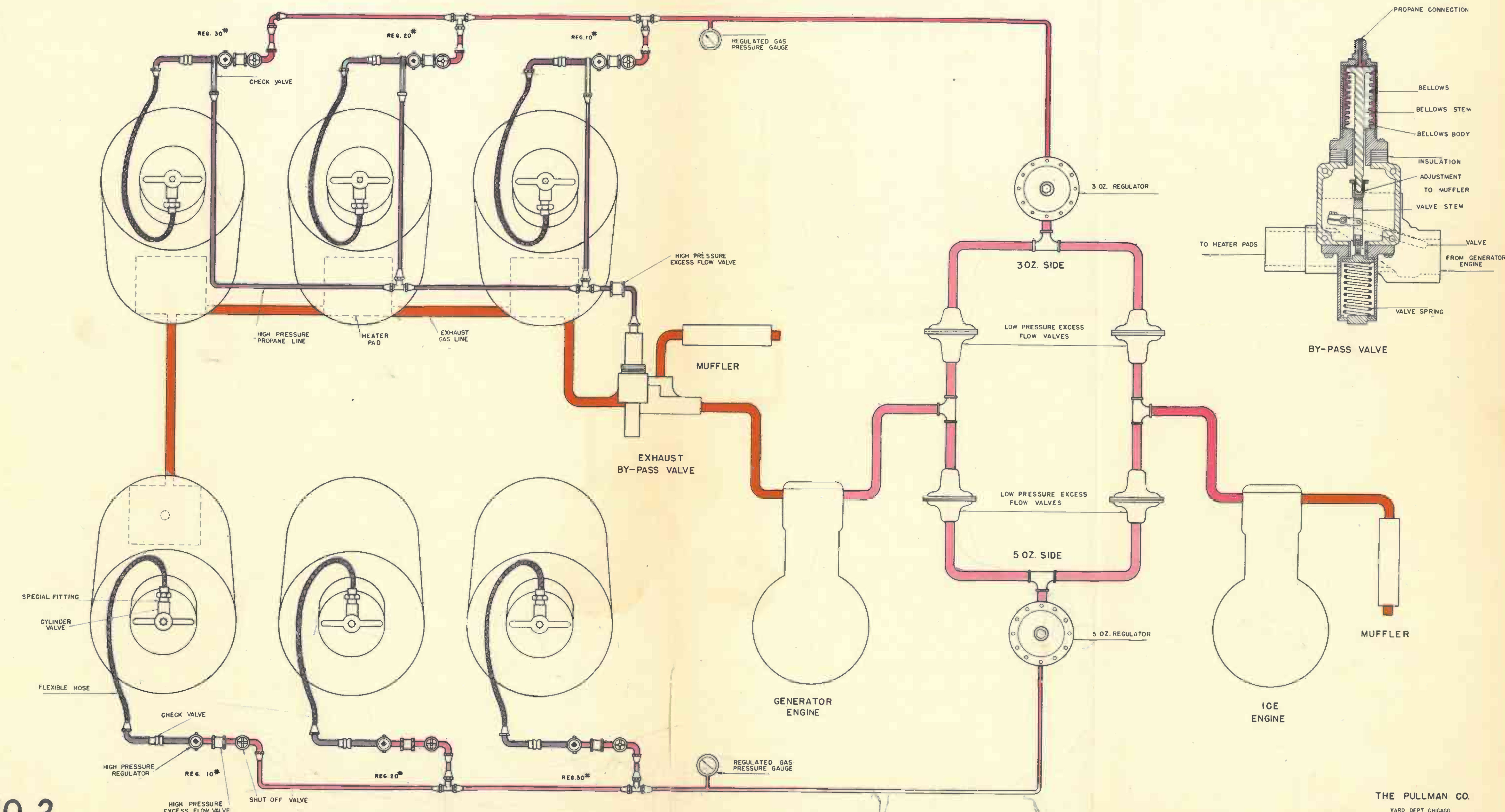
SEQUENCE OF EMPTYING FUEL CABINETS.

Each tank must contain at least 3 lbs. of fuel in order to maintain the various pressures. It is usually convenient to have the fuel drawn from one cabinet first until all cylinders in one cabinet are empty. This can be accomplished regardless of the number of fuel cylinders in each cabinet by setting the second stage regulator in one fuel cabinet to maintain 2 oz. higher pressure to the engine than that from the other cabinet. By setting one regulator to maintain 5 oz. and the other 3 oz. the fuel will flow from the cabinet maintaining the higher pressure until all fuel cylinders in this cabinet are approximately empty. Connected in the line between each low pressure regulator and the engine compartment are two low pressure excess flow valves. The purpose of these valves is to shut off the fuel to the flexible tube connecting ice and generator units to the car should this tube break.

HEATER PADS.

To maintain the proper pressure in the tank in cold weather there are heater pads under each of the tanks in the cabinet

WAUKESHA 6 TANK FUEL SYSTEM



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having a 3 oz. second stage regulator. These pads are heated by the exhaust gas from the generator engine. The flow of exhaust gas is directed through the heater pads or through the muffler by the use of an exhaust by-pass valve. This valve will allow all the exhaust gas to pass through the pads if the pressure in the tanks falls below 75 lbs. and will exhaust all through the muffler if the pressure is above 125 lbs. (125 lbs. Propane pressure corresponds to about 70^{o} outside temperature.)

EXHAUST BY-PASS VALVE.

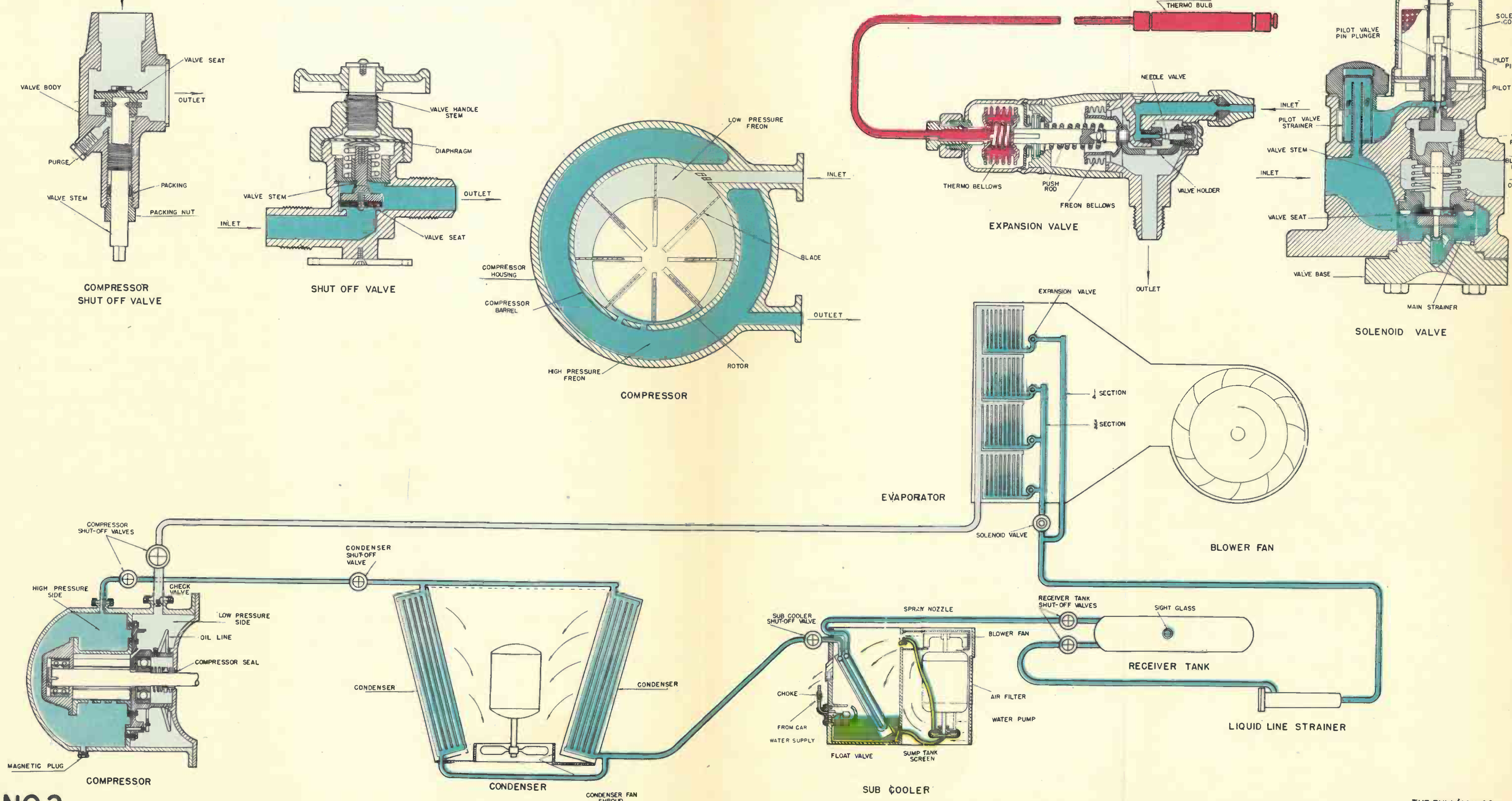
The by-pass valve is so connected that the pressure on its operating bellows is equal to the highest tank pressure of any tank in the cabinet having heater pads. Should a leak develop at the operating bellows of the by-pass valve, an excess flow valve connected in this line will automatically shut off the flow of gas. In each of the lines connecting the tanks to the by-pass valve there is a check valve. The purpose of this reverse flow check valve is to allow the gas to flow in only one direction, i.e., from the tank to the by-pass valve. As the #1 tank is emptied, the check valve closes and the pressure on the by-pass valve bellows is maintained by the other two tanks.

On Chart #2 is shown a cross section of the exhaust by-pass valve, When the propane pressure is low, the spring in the lower portion of this valve forces the valve stem up, placing the valve in the position shown thereby allowing exhaust gas from the generator engine to flow through this valve to the heater pads. When the tank pressure exceeds 125 lbs. the bellows of the by-pass valve is forced down, moving the bellows stem against the valve stem forcing the valve to the opposite position, thereby allowing the exhaust gas to flow from the generator engine out through the muffler. The operating bellows tends to become hot due to the exhaust gases passing near it, therefore insulation is provided between the bellows body and the valve body as shown. The length of the bellows stem may be varied by the adjustment screw. By this adjustment screw we may vary the opening and closing pressure of the valve.

OTHER TANK ARRANGEMENTS.

The six tank fuel system as shown is used on Streamliner equipment. Please note that one tank in the bank governed by the 5 oz. second stage regulator is, in this case, also equipped with a heater pad for winter operation. Other six tank systems have only 3 tanks in the cabinet nearest the generator unit so equipped. In the eight tank systems the same general arrangement is used and 4 tanks in the cabinet nearest the generator unit are provided with heat when necessary.

FREON CYCLE- MODEL "E"



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some heat from the liquid freon. There is also a snap action float valve connected to the car water system for the purpose of adding water to the tank to make up for water lost by evaporation. In the water line between the car water tank and the tank of the sub-cooler is a choke. This has been added to allow only a small amount of water to flow to prevent the car from being drained of water in case of a failure of the float valve.

RECEIVER TANK.

After the sub-cooler the freon then goes to the receiver tank which is a metal drum capable of holding about 30 lbs. of liquid freon. There is a sight glass on each side of the tank so that the liquid level may be observed. This level should be approximately one-half way up in the tank when the cooling system has been working for 1/2 hour.

LIQUID LINE STRAINER.

The liquid line strainer is a metal cylinder about 5" in diameter and 18" long. On entering the cylinder the freon must pass through a fine copper screen, a felt cloth and then another fine copper screen. The purpose of this strainer is to remove any foreign matter from the freon that would tend to stop up the expansion valves or any other valves in the system.

SOLENOID VALVE.

The solenoid valve is an electrically controlled shut-off valve. This valve is controlled by the cooling pilot relay so that when the temperature in the car has reached that of cooling thermostat, the pilot relay is de-energized which in turn opens the electrical circuit to the solenoid valve, stopping the flow of the freon to the expansion valve.

EXPANSION VALVE.

The expansion valve meters the flow of liquid freon to the evaporator in the proper amount according to the temperature of the air passing over the evaporator.

EVAPORATOR.

The evaporator is a series of tubes in which the liquid refrigerant,at a low pressure,boils and becomes a vapor, absorbing the heat necessary to change it to a vapor from the air blown over it by the blower fan of the car.

The low pressure freon gas is then returned to the compressor, and the cycle is repeated.

SOLENOID VALVE.

Operation of the solenoid valve is based upon the by-pass principle where the main valve opens by the pressure difference between the refrigerant above and below an operating piston. The solenoid is used only to open the small by-pass with consequent low electrical power consumption. When the solenoid is energized the plunger is pulled upward a short distance to gain momentum before raising the valve stem. When the by-pass is thus opened it allows the refrigerant to pass into the chamber above the piston connected directly to the main valve. The area of the piston is greater than the area of the main valve, and the piston is, therefore, forced downward, automatically opening the main valve. When the solenoid is de-energized, the needle comes down closing the by-pass valve. Since the main valve is held open against the coil spring, it now returns to the closed position. The valve closes with the flow of the liquid, forming a tight seal. Any refrigerant remaining above the piston bleeds out through a small hole in the piston into the discharge side of the valve. The small by-pass valve is called a pilot valve.

EXPANSION VALVE.

The thermostatic expansion valve is a pressure reducing valve, thermostatically controlled, and located between the solenoid valve on the high pressure side and the evaporator on the low pressure side of the refrigeration system. The thermostatic bulb attached to the evaporator outlet is charged with a refrigerant which creates a vapor pressure on the thermostatic element, increasing as the temperature of the bulb increases. This pressure on the power element acting through the push rod tends to open the needle valve. It is opposed by the pressure of the refrigerant at the expansion valve outlet acting against the bellows seal in the body of the valve. It results, therefore, that if the pressure on the bellows seal is less than the pressure corresponding to the temperature of the thermostatic bulb, the needle valve will open and if the pressure is greater the valve will close. The valves are set so that it requires more pressure on the power element than the pressure on the bellows seal to open the valves. The thermostatic expansion valve feeds to the evaporator at all times exactly the amount of refrigerant required to meet the load on the evaporator and keep the entire coil at a uniform temperature without any possibility of liquid passing through the coil into the suction line.

OPERATING PRESSURES.

Normal operating pressure for the Waukesha Type of cooling system is 20 to 45 lbs. on the low side; the high side pressure in pounds will be approximately double the outside air temperature in degrees.

MODEL "E" ICE UNIT
CHART 3

The principal parts of the Model "E" Ice Unit are: (1) a four-cylinder internal combustion engine, (2) a direct connected rotary type refrigerant compressor, (3) a starter generator direct connected between the engine and the compressor, (4) electric driven air condensing unit, (5) a sub-cooler unit.

CONDENSER.

The condenser for this model is a remote electric driven air condenser. The air flows into the unit through the side condenser coils and out the bottom of the unit. The special condenser fans are driven by two 1/2 H.P. electric motors. The motors are energized by the ice unit generator under normal load and by the car batteries under excessive refrigeration load. The air deflector vanes under the fans are fixed in the shroud ring and turned so as to deflect the air to the rear of the train.

EVAPORATOR.

The evaporator is divided into two parts - - 1/4 and 3/4 sections. When the car cools down to the setting of the high cooling thermostat tube, the solenoid valve closes. When this valve closes, the freon flow to three of the expansion valves is shut off. The evaporator now operates on only one expansion valve, reducing the load on the ice unit while maintaining an even car temperature. When the second cooling thermostat tube is satisfied, the engine stops.

ROTARY COMPRESSOR.

This model unit has a rotary compressor. NEVER PUMP A VACUUM WITH THIS TYPE COMPRESSOR. The ice engine unit must never be operated below 5 lbs. suction pressure or without pressure differential between the high side and the low side to insure lubrication and a sufficient flow of gas to cool the compressor. When removing freon from the system, it is necessary to use a separate evacuating pump connected anywhere in the system, preferably to the discharge valve at the compressor.

The rotary type compressor is a cylinder closed at each end within which is located a rotor that is mounted off center. In this rotor are ten longitudinal slots in which vanes float. As the rotor turns these vanes are thrown out against the cylinder forming chambers enclosing the freon. The freon inlet is at that point where the vanes are most extended. These vanes are then forced toward the center of the rotor as it turns, which by its eccentricity reduces the space in which the freon is held until such time that the freon has been compressed and is discharged through ports in the cylinder into the high side of the compressor.

SHUT-OFF VALVE.

This drawing shows a cross-section of the common Kerotest valve used in our refrigeration system. It is a common shut-off valve, hand operated, with a metal diaphragm to prevent the freon from leaking past the valve stem. Valve must be piped with freon inlet from bottom side of valve stem. If piped in the reverse direction, flow of freon can cause valve to close.

THE COMPRESSOR SHUT-OFF VALVE.

When this valve is in the open position the freon is free to flow from the inlet to the outlet side, and the purge valve may be opened without allowing gas to escape. When in the closed position the purge opening is opened to the discharge side of this valve which will allow the passage of freon. Similar valves are used on both compressor suction and discharge lines.

REVERSE FLOW CHECK VALVE.

A reverse flow check valve is built in between the compressor and the suction line valve to prevent reverse flow of gas when the compressor stops.

MODEL "D" ICE UNIT

CHART 4

The principle parts of the Model "D" Ice Engine Unit are:

(1) A four cylinder internal combustion engine,

(2) A four cylinder "V" type refrigerant compressor connected to the engine drive shaft by multiple V belts,

(3) A belt driven condenser fan also driven from the engine drive shaft,

(4) A sub-cooler unit.

CONDENSER.

Two condensers, one mounted on each side of the compressor form the sides of the compressor compartment. A condenser fan driven by V belts from the engine drive shaft occupies all of the space at the rear end of the unit. The fan draws air into the compressor box, through the condensers on either side, and forces it out back of the unit. It is important that the top and bottom compressor compartment covers be in place and fit properly so that all air discharged by the fan is obliged to enter the compressor compartment through either condenser.

Tension on the condenser fan belts is maintained by a spring loaded idler pulley.

EVAPORATOR.

The evaporator used with the Model "D" Unit is divided into one-third and two-third sections, each controlled by a solenoid valve. When the car cools down to the setting of the high cooling thermostat tube, the two-thirds section solenoid valve closes, thereby stopping the flow of freon to two expansion valves. When the car has further cooled down, and the second cooling thermostat tube is satisfied, the other solenoid valve closes, completely stopping the flow of freon to the evaporator. With the flow of freon stopped, the compressor will pump down the system reducing the freon pressure on the low side to 7½ lbs., which causes the low pressure switch to close a circuit, grounding the magneto and stopping the engine.

COMPRESSOR BY-PASS SOLENOID VALVE.

The compressor by-pass solenoid valve is similar to the evaporator solenoid valve, and in this case is connected between the high pressure chamber on the compressor head and the low side of the freon system - - the crankcase of the compressor. The valve is energized open during the cranking cycle unloading the engine starting motor from having to handle pumping of freon by the compressor in addition to turning over the engine. After the engine starts to run, the by-pass valve closes and the compressor pumps freon in the usual manner.

REVERSE FLOW CHECK VALVE.

A reverse flow check valve, one for each compressor head, is located in the high side freon line a short distance from the compressor discharge shut-off valves. The purpose of these check valves is to prevent freon from backing up from the condensers when the unit is stopped and when the by-pass valve is opened during the starting cycle.

HIGH PRESSURE RELIEF VALVE.

Should a high pressure be built up on the discharge side of the compressor, and because the compressor continues to turn over a few revolutions after the magneto has been grounded by the high pressure switch, a spring loaded pressure relief valve attached to the high pressure chamber in the compressor head, will open at 400 lbs. and discharge high pressure gas into the crankcase. When the head pressure has been reduced to 350 lbs. this valve will close automatically.

THE FREON CYCLE

CHARTS NOS. 3 & 4.

REFRIGERATION.

Refrigeration means simply a reduction in temperature, and regardless of the mechanism used, the final result is nothing more than the extraction of heat. Heat always flows from a warmer substance to a colder substance, and in doing so the warm substance gives up heat and the colder one receives it. The heat the cooler substance receives may cause its temperature to rise, or it may cause its state to change; that is, melt or boil. Likewise, the substance losing heat will lower its temperature, change state, or both.

FREON.

A refrigerant acts the same as water in that it can be changed from a liquid to a gas by adding heat. Most refrigerants exist as a gas under atmospheric pressure and do not become a liquid except under very low temperatures or at high pressures. Freon, the refrigerant used in our Waukesha system, boils or becomes a gas at 22° below zero under atmospheric pressure.

The freon system is a completely sealed unit where the state of the freon is changed from a gas to a liquid and back to a gas repeatedly. This is done as follows:

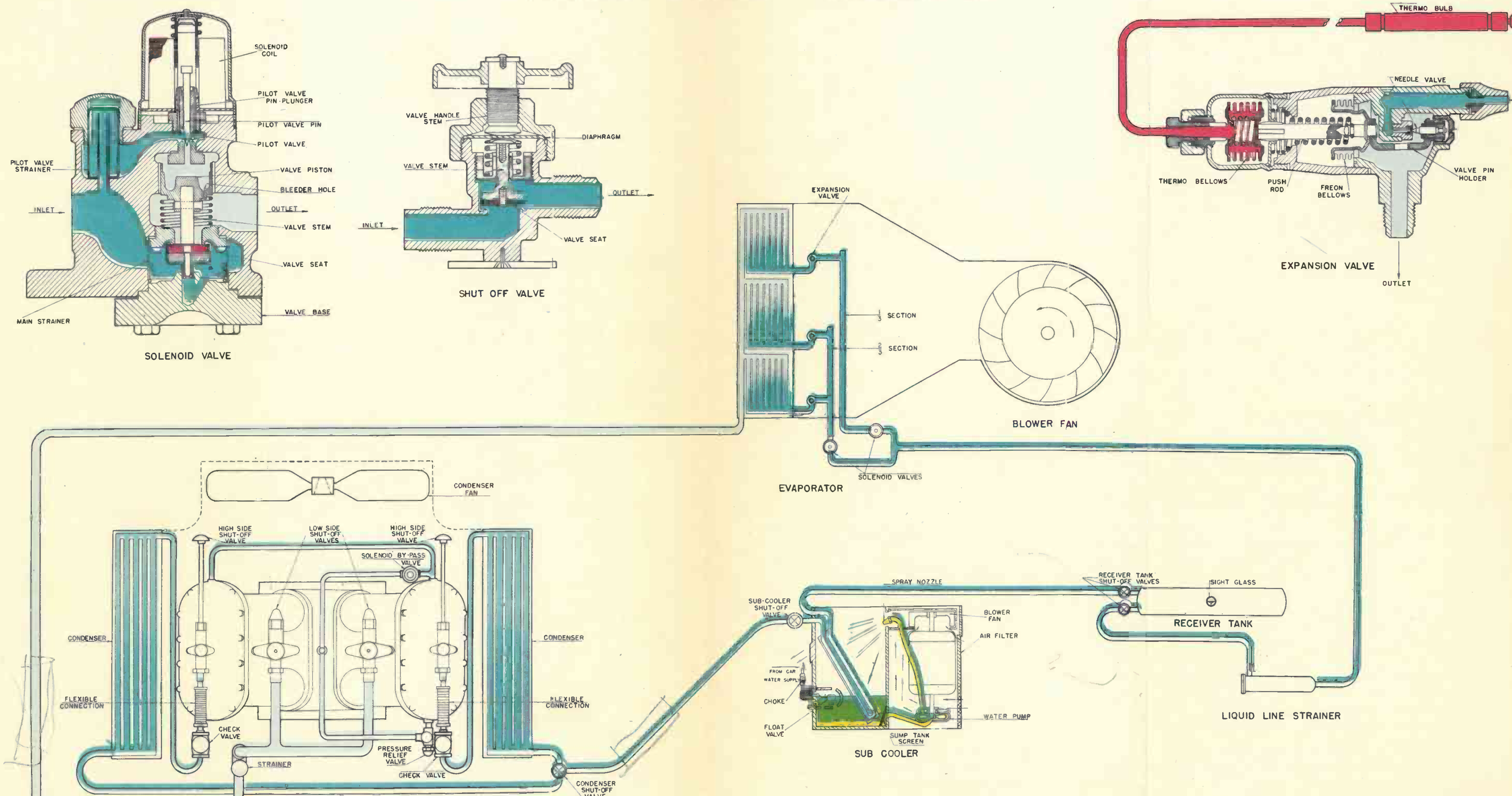
CONDENSER.

The freon leaves the compressor as a high pressure gas; it then enters the condenser unit where the gas is cooled and changed to a liquid. This unit is made up of two large condensers, which is a series of tubes through which the freon flows. Air is drawn over the tubes,reducing the temperature of the freon within the tubes. This cooling of the freon gas and the pressure within the condensers cause the freon to change its state from a gas to a liquid.

SUB-COOLER.

In extremely hot weather it is necessary to provide for an additional method of cooling the freon to reduce pressure and temperature of the liquid. For this is provided a sub-cooler. This unit consists of a tank of water, a finned coil, a 1/2 H.P. motor with a blower fan attached to one end, and a water pump to the other end. These are so connected that the water is sprayed through a nozzle, mixed with the air of the blower fan, and blown over the condenser. The evaporation of the water with the air blown over it reduces the temperature of the coil and absorbs

FREON CYCLE - MODEL "D"



COMPRESSOR - CONDENSER

NO. 4
(OF TEN CHARTS)

THE PULLMAN CO.
YARD DEPT - CHICAGO.
FEB. 1944

ENGINE COOLING SYSTEM

CHART 5.

The heat from combustion of fuel in an engine can be divided up in the following manner:

1. Heat which turns the engine and drives the compressor or generator attached to the engine.

2. Heat which passes through the cylinder walls into the water jacket and is lost finally to the atmosphere.

3. Heat which is transmitted to the oil as it runs down off piston and cylinder walls.

4. Heat which passes out of the engine as hot exhaust gases.

It is heat lost to the water jacket with which we are most concerned and over which as maintenance men we have most control.

WATER PUMP.

The water pump is the heart of the water circulating system. It is gear driven from the crankshaft at engine speed. Water enters near the center of the pump casing and the impeller's rotation causes the water to be thrown outward where a discharge opening is provided, through which the water is piped to the water jacket.

Packing glands are provided where water pump shaft passes through the pump housing to prevent the loss of water, and also to prevent air being drawn in by the suction of the pump when it is in operation. A grease cup which must be turned down periodically is used to lubricate the pump bearing. A small copper tube connection is provided between the top of the pump and the water jacket to allow air to escape from the pump when the system is refilled after draining, and in some cases as shown on Chart #5, a stream of water is directed against the temperature bulb of the oil heat switch by a nozzle in the engine head.

Advantage is taken of the natural circulation of heated water in that the water delivered to the water jacket enters the jacket at its lowest point, and leaves the engine after passing upward through the jacket and through the cylinder head.

RADIATOR.

After leaving the cylinder head, the water which has been heated in passing through the engine is brought into the top of the radiator, which is of tubular core construction, that is, has a top header or expansion tank which is connected to the lower header with numerous tubes having a cross section of about 1/8" by 3/4". Cooling fins running horizontally across the radiator and attached to the tubes present a large area to the air, which is drawn through the radiator by the engine fan. In passing from the top of the radiator to the bottom header, the heat picked up by the water in the water jacket is transmitted to and dissipated in the atmosphere.

It is very essential that both the exterior surfaces of the radiator and the interior surface of the tubes be kept as clean as possible, as any formation of rust, scale or grease will slow up the rate at which heat can be transferred from the water to the air, and will result in an overheated engine.

Inspection plates are provided in the top radiator header, which when removed afford access to the top ends of the radiator tubes for inspection or repair purposes. Clean out connections are provided on the lower radiator header and the use of these fittings will be described in detail in connection with cleaning the radiator with a flushing gun as shown on Chart #10.

Because of the low overall height of Streamliner Units, and the lack of water capacity in the top radiator header, it was necessary to add a 10 gallon expansion tank mounted directly above the unit and connected to the radiator with lengths of hose.

RADIATOR FILLING CAP.

The engine cooling system on Waukesha Units is like that found on many modern cars - - a sealed system, that is, one in which a slight pressure can be built up, in this case 5 lbs., in order to raise the boiling point and prevent the loss of cooling solution. The radiator filling cap provides the final seal against atmospheric pressure. You will note from the detail drawing of this cap that the lower disk seals against the gasket in the radiator filling device, and is spring loaded. It requires a pressure of 5 lbs. per square inch to lift this main disc and allow excessive pressure to be relieved out the small hole provided in the side of the filling device. During an off cycle of the unit, and as the solution cools down, a partial vacuum is created within the radiator, and to prevent atmospheric pressure from crushing the radiator tubes, a smaller valve in the center of the main valve disc opens in the reverse direction to allow air to enter the radiator and equalize the pressure.

We all know that water boiling in an open vessel does so at a temperature of 212° at sea level. Under 5 lbs. pressure in a closed system boiling will not take place until 227° F. Therefore, it is possible to set the temperature element of the oil-heat switch to operate at 220° F. and thereby increase the operating temperature range of the engine.

In addition to this advantage of a sealed system, there is also a disadvantage in that it is possible to pump water out of the radiator filling device through cycling of the unit. Each time the unit is started and run, the water and air trapped in the radiator will expand and the water splashed into the filling device by motion of the unit will be forced out the relief hole. While only a little is lost each time, this amount becomes considerable when the unit cycles frequently. It was found that it was possible to drill a number 52 hole in the top inspection cap of Model B generator radiators, and a similar hole in the top radiator header of Model D Ice Engines, and still retain the advantages of a closed system. The number 52 size hole is large enough to equalize the pressure inside and out of the radiator under normal conditions, and is small enough so that pressure will build up when the water approaches the boiling point, and only a very small amount of water in the form of steam will be lost through the hole.

USE OF ANTI-FREEZE.

Anti-freeze solutions of permanent type are used in all units during the winter season when freezing protection is required. A solution strength of approximately 50% is maintained.

Anti-freeze preparations of the permanent type also have the property of raising the boiling point of a radiator solution, and because of the enclosed mounting of Streamliner Units, it is necessary that we take advantage of this property. Therefore a solution strength of approximately 75% is maintained in these units during the summer.

Capacities of the various engine cooling systems will be found in the tabulated data on pages and

RADIATOR HOSE.

Heat and oil causes deterioration of radiator hose. Many cooling system failures are due to rotted, swollen, age-hardened, or cracked hose. When the lining of the hose disintegrates, it can deposit in the narrow water passages of the radiator core, and clog up these tubes until a good portion of the radiator is ineffective because there is no flow through the clogged tubes. The time to renew radiator hoses is before this condition occurs and they should be watched carefully for exterior signs of failure and when the radiator core upon inspection shows a soft brownish sludge, the hoses should be suspected as the source of contamination.

We are using at the present time synthetic hoses which have better resistance to heat and oil than natural rubber.

ENGINE RADIATOR FAN.

The engine radiator fan is mounted on the engine back of the radiator core and is used to draw air through the core in order to carry away heat from water passing through the radiator. On Streamliner Units this fan is gear driven, on all others it is belt driven. It is necessary that the fan be in good physical condition and operate properly or the engine will rapidly overheat. It is important that the pitch or curvature of the fan blade be maintained or the required amount of air will not be drawn through the radiator, and it is likewise important that the fan belt and fan drive gears be properly maintained.

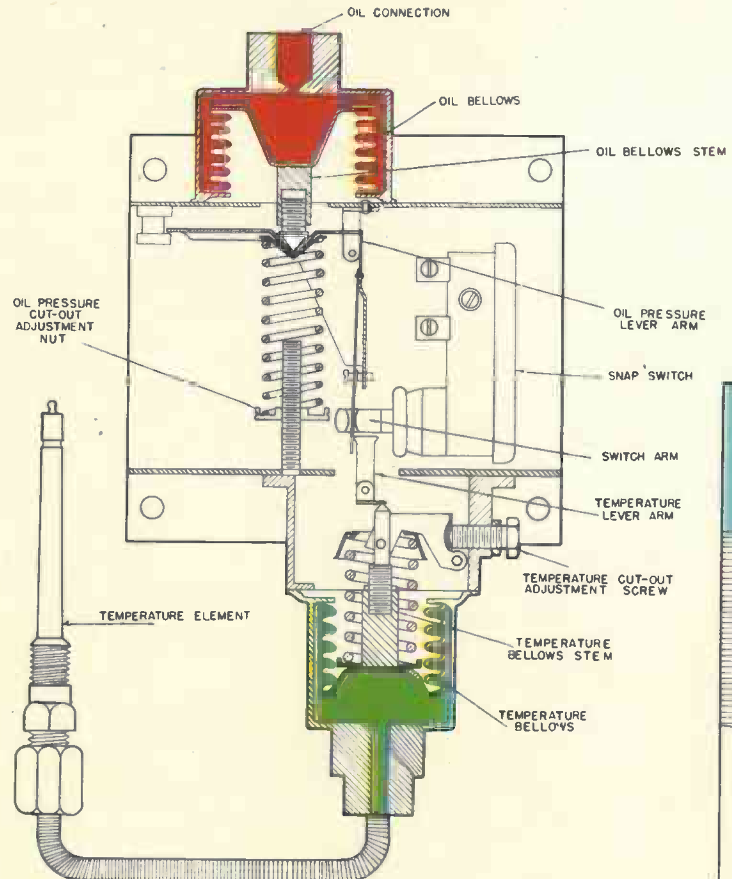
OIL-HEAT SWITCH.

The oil-heat switch is a combination oil pressure and engine temperature switch. If the engine oil pressure acting on the bellows of the switch should be less than 5 lbs., the spring loaded arm will force the bellows upward, and through the lever arrangement, cause a small snap-action switch to close its contact. The snap-action switch closes an electrical circuit to the heater element of the oil-heat stop switch, which in turn stops the engine before damage can occur to the engine bearings because of lack of lubrication.

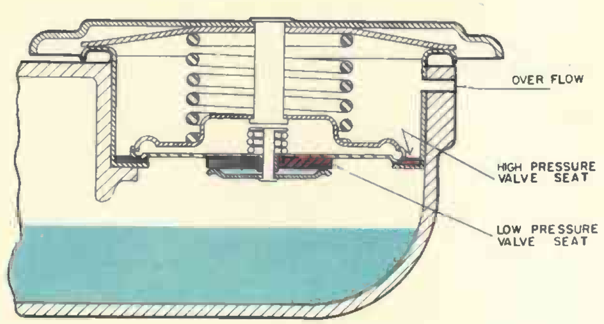
Should the engine temperature go above the pre-determined temperature, (220° on all units except Streamliners, which are set at 265°), the temperature bulb in the engine cylinder head will cause expansion of the gas in the temperature power element to trip the same snap switch and stop the engine by heating the element of the oil-heat stop switch the same as would low oil pressure.

Regular inspection of the oil cut-out point and temperature cut-out point is necessary to prevent damage to the engine from lack of oil or excessive temperatures.

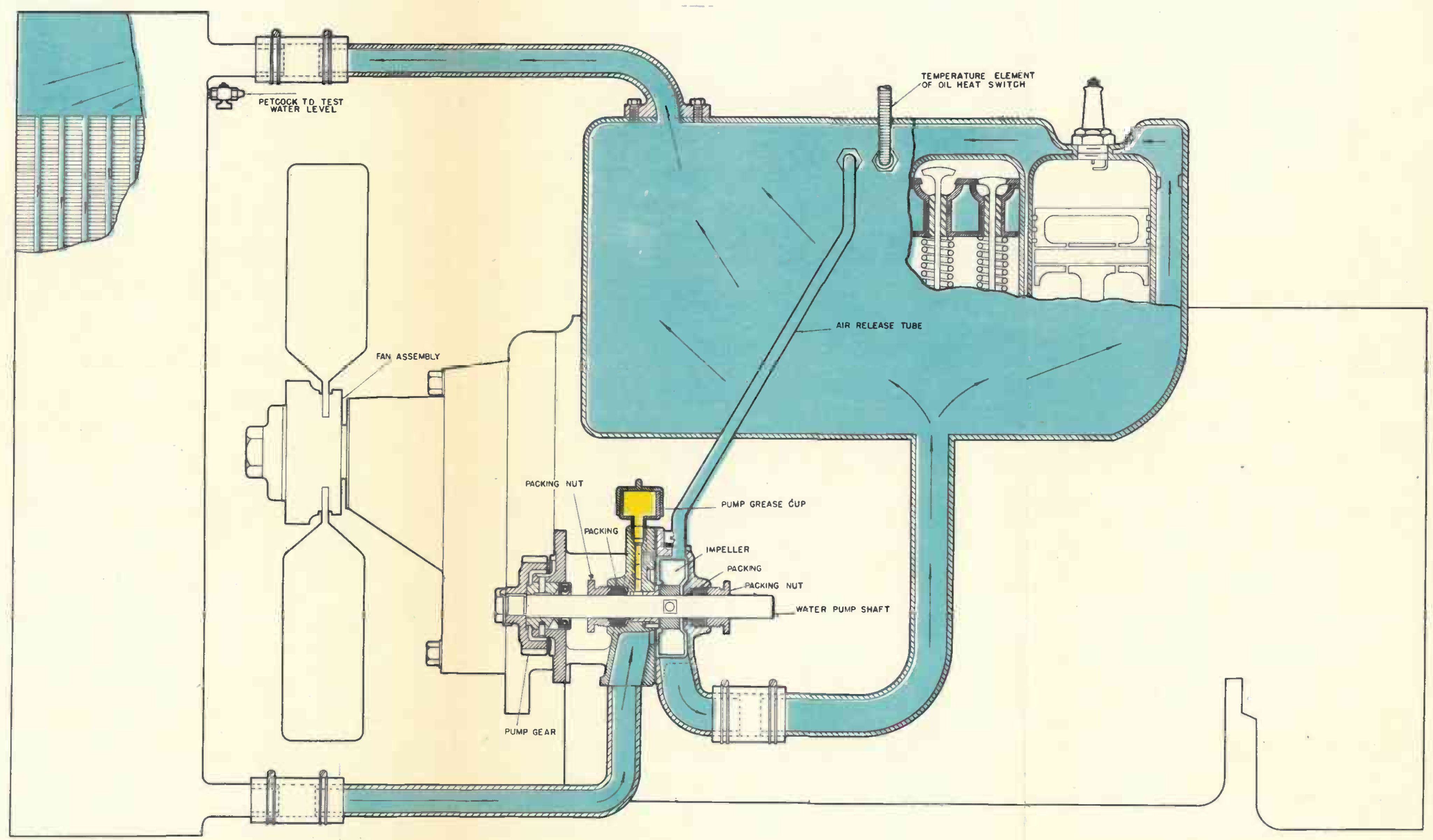
ENGINE COOLING SYSTEM



OIL-HEAT SWITCH



RADIATOR CAP



NO. 5
(OF TEN CHARTS)

THE PULLMAN CO.
YARD DEPT-CHICAGO
FEB. 1944

TIMING AND IGNITION

CHART #6

The ignition system produces and delivers high voltage surges of up to 20,000 volts to the correct spark plug at the correct time with respect to the pistons, valves, etc. Each high voltage surge produces a spark at the spark plug gap to which it is delivered so the mixture of air and fuel in the cylinder is ignited.

The ignition system consists of a magneto, spark plug wiring and spark plugs.

MAGNETO.

The magneto is made up of a permanent magnet, a laminated armature, a primary winding of a few hundred turns of relatively heavy wire and secondary winding of many thousands of turns of very fine wire. With rotation of the armature a low voltage current is generated in the primary coil. This current flows from ground through the primary to the breaker points and back to ground. The flow of current (at approximately 6 volts) through the primary winding is stopped when the breaker points open.

BREAKER POINTS.

Current attempts to continue to flow across the contact point because of the self induction of the coil. Self induction opposes any change in the amount of current flowing in a winding, thus the coil primary attempts to keep the current flowing in the circuit, and if it were not for the condenser it would continue to flow and would form an arc across the breaker points. This arc would not only burn the points, but it would also drain off the energy of the coil so that there would not be enough energy remaining to induce a high voltage surge in the secondary winding of the coil.

CONDENSER.

However, the condenser momentarily provides a place for the current to be stored. The current flows into the condenser instead of arcing across the breaker points. The current which can flow into the condenser is, however, limited so that the condenser is very quickly charged. The condenser acts in effect like a check spring and quickly checks or brings to a stop the flow of current in the primary winding. Consequently the magnetic field which was produced and sustained by the flow of current quickly collapses.

HIGH TENSION COIL.

The collapse of the magnetic field is sufficiently rapid to induce a high voltage in both the primary and secondary windings. The voltage induced in the primary winding may be as high as 250 volts. The only immediate effect of this voltage on the primary winding is to merely further charge the condenser.

The voltages produced in the primary and secondary windings are proportional to the number of turns in the two windings. Since the secondary winding has up to 100 times as many turns as the primary, the voltage could go as high as 25,000 volts in the secondary, but the voltage does not normally reach this value. It only increases to a value sufficient to produce a spark at the spark plug gap, somewhere between 4,000 and 18,000 volts. Variations in the voltage required are due to such factors as engine compression, speed, fuel mixture ratio, width of spark plug gap, spark plug temperature, etc.

After the spark is produced, the energy in the coil,stored in the form of magnetic flux begins to drain from the coil through the secondary, sustaining the spark at the spark plug gap. The spark is sustained for several degrees of crankshaft revolution. During this time the condenser discharges back through the primary circuit producing an oscillation of current flow in the primary until the primary circuit returns to a state of equilibrium. The condenser does not discharge until after the spark has occurred at the spark plug gap.

DISTRIBUTOR.

In addition to closing and opening the breaker points so that high voltage surges are produced, the ignition distributor also serves to deliver high voltage surges to the correct spark plug at the correct instant.

It delivers the high voltage surges to the correct spark plug by means of a distributor cap, a distributor disc and an ignition cable. After the high voltage surge has been created it is carried from the coil by the high tension lead to the center brush of the distributor cap. From there it passes through the metal insert in the rotor to one of the four brushes opposite which the rotor has been positioned. The high voltage surge is then carried through the ignition cable to the correct spark plug.

While it is not entirely correct, the magneto primary can be thought of as a source of 6 volt power like a battery in an automobile. The breaker points and condenser serve the same purpose in a magneto as in your automobile. Likewise, the magneto secondary circuit is like a high tension coil and the distributor rotor and distributor caps perform the same function in each case.

IMPULSE STARTER.

The impulse starter is a spring mechanism at the drive end of the magneto to facilitate starting by turning the magneto shaft much faster than the engine cranking speed, at the same time retarding the spark automatically.

When a magneto with an impulse starter is rotated, a latch dog (or stop device) operates to hold the magneto shaft from turning. Nevertheless, the driving member of the starter may continue to be turned, since it is free to rotate about the magneto shaft. The continued turning of the driving member while the magneto shaft remains locked, winds up a spring in the device. It is apparent that continued rotation eventually brings the drive member of the starter into a position where, if the machine is timed to an engine, some one piston reaches top center and is ready for a starting spark. The drive member of the starter is fitted with a cam so designed that, when rotation has proceeded to the position where a starting spark is needed, the cam disengages the latch dog which has been holding the magneto shaft. Under the influence of the wound up spring, the magneto shaft and rotor now turn at high speed until they catch up with the driving member which has been turned by cranking the motor. During this period of high speed, the magneto produces a hot spark. The spark is a retarded, or safe starting spark, because the magneto shaft was not released at all until the drive member (and, of course, the engine crankshaft) has proceeded far enough around to be in the retarded position. The time of the spark is governed entirely by the time when the cam of the drive member releases the latch, or stop. Since these are both parts of the impulse starter, it is clear that the proper timing of the starting, or impulse, spark must be provided for in the impulse starter.

The timing detail of an impulse starter is described as its "lag angle." The lag angle of an impulse starter is the number of degrees, measured at the impulse starter (or magneto shaft), between the time of the occurrence of the fully advanced spark with the magneto running at fair speed, and the time of the occurrence of the starting (or impulse) spark when the machine is turned slowly with the impulse starter in engagement. We use a 15° lag angle. When the impulse starter rotates at a speed over 250 R.P.M., such as after the engine starts, the dogs are centrifugally thrown out against the outer shell; thus they do not engage in the stop pin on the magneto. So, at engine running speed the impulse starter dogs do not engage, and the impulse starter is a means of direct drive for the magneto armature.

SPARK PLUGS.

Spark plug wear is just as natural as the wear of any other part of the motor. When we consider the conditions under which the plugs operate, it is easy to understand that normal wear cannot be avoided. Spark plugs are made in a variety of designs, adapted to the different temperature conditions under which they are required to operate. This is called the heat range. The important factor which determines the heat dissipating properties of a spark plug is the length of the insulator within the combustion chamber of the engine. The shorter the insulator or heat path, the colder the plug. The longer the insulator or heat path, the hotter the plug. Hot running or high compression engines require cold spark plugs.

A cause of spark plug failure is a carbon coating that forms on the center electrode insulator from the burning of the fuel which becomes a conductor of electricity and shorts the plug. The ignition current follows the deposit instead of jumping the gap. The remedy is to remove the plugs and clean them. A normal plug develops an even brown glaze on the center electrode porcelain.

Correct gap setting cannot be overemphasized at the time of installation of new plugs and plugs in service. The recommended gap setting for the Waukesha motor is .015". When making adjustment never move or bend the center electrode as insulator breakage will result. When setting the gap on worn plugs, using a flat feeler gauge, always take into account the curvature of the worn electrodes.

<u>TIMING.</u>

Stamped on the flywheel 12° before top dead center of piston #1 is the word "FIRE", which when lined up with a mark on the flywheel housing indicates the correct instant of ignition timing for cylinder #1. A deep groove is provided at this point which can readily be seen through the inspection hole in the flywheel housing. The magneto is held in place by two capscrews, and it is connected to the drive shaft through an adjustable coupling so that it is easily disconnected and re-timed when necessary. Before loosening this coupling, mark the exact shaft position to simplify timing the magneto when it is replaced. Always refer to the fly wheel markings or to the piston position as a final check as to the correctness of the ignition timing.

<u>CAUTION</u>: Since the magneto fires only every other time the #1 piston is up, it is extremely important that spark occurs on the proper stroke. To check this, remove spark plug #1 and turn the engine until air blows out of the spark plug opening. Ignition should occur 12° before the piston reaches the top dead center on this compression stroke.

With the #1 piston in the proper position for ignition, proceed as follows to check or time the magneto.

1. Loosen the hexagonal lock nut on the drive coupling. This loosens the coupling on the shaft of the pump and permits the magneto to be rotated without disturbing the engine.

2. Rotate the magneto clockwise by hand, facing the drive end, until the impulse coupling trips and sparks occur at #1 plug. The impulse coupling automatically retards the spark 15° on starting; hence, do not tighten magneto coupling at the position where the above spark occurs but proceed as directed in the next paragraph.

3. Now slowly rotate the impulse coupling counterclockwise until a strong magnetic pull is felt, but not far enough to again engage the impulse coupling. The spark occurs at the point of highest magnetic pull and can readily be seen or felt. With the magneto held in this position, tighten the hexagonal lock nut on the drive coupling.

The timing of the magneto may also be set by rotating the impulse starter shell so that the marking on the shell and the marking "R" on the magneto frame correspond when the rotor is at the #1 high tension lead brush. The marking on the flywheel must also be at #1 fire with the #1 piston on the compression stroke. When all these conditions are correct lock the drive coupling nut in place with lockwasher.

After timing the engine it is advisable to check it by the use of the timing light as described on page 56 and illustrated on Chart #10.

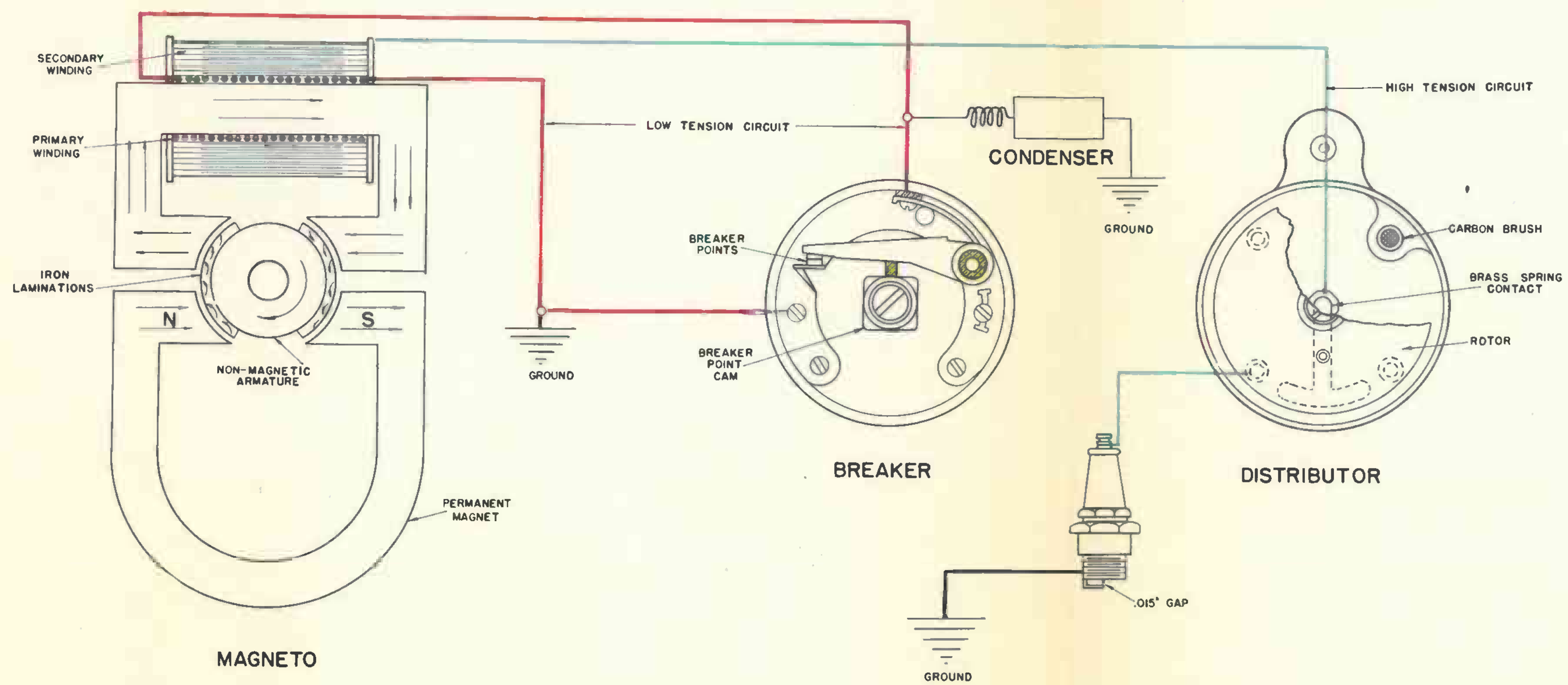
Be sure that the ignition cables make good clean metallic contact to the distributor on the magneto. Any green corrosion on these points indicates arcing due to poor metallic contact, which in turn seriously impairs the spark intensity plus overburdening the magneto.

FOUR CYCLE ENGINE.

The Waukesha Engine operates on a four cycle principle, that is, a power stroke occurs every second revolution in any one cylinder. As shown on the chart, an intake stroke occurs during the period of a downward moving piston. The intake valve is open at this time and the exhaust valve is closed. As the piston passes its lower dead center, the intake valve closes, and the combustible mixture is compressed as the piston moves upward. Twelve degrees before top dead center a spark occurs, firing the fuel mixture resulting in a strong downward thrust on top of the piston. This period is known as the power stroke. As the piston approaches its lower dead center, the exhaust valve opens and remains open while the piston again moves upward in an exhaust stroke, pushing out of the cylinder all burned gases. The exhaust valve then closes and the cylinder is ready to admit a fresh charge of fuel and air in another intake stroke and the cycle is repeated.

You know from experience, that the intake and exhaust valve are both operated off the same camshaft and are on the same side of the engine. For sake of explanation on Chart #6, the intake and exhaust valve have been shown on opposite side of the cylinder so that the flow of gases through the cylinder and the operation of the valves with respect to the position of the piston can be more readily observed.

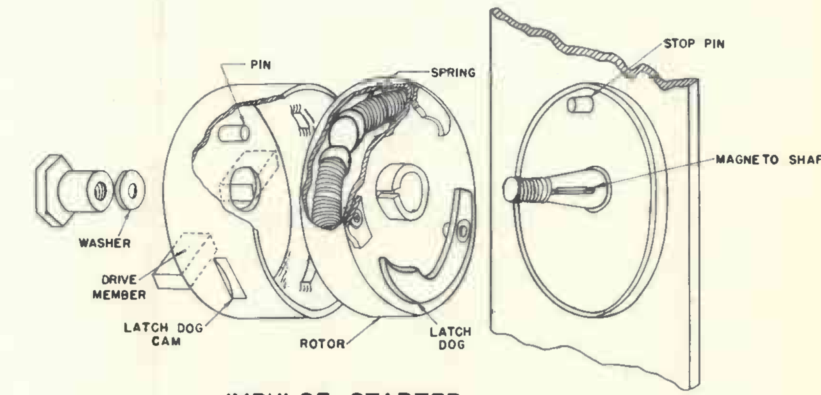
TIMING & IGNITION



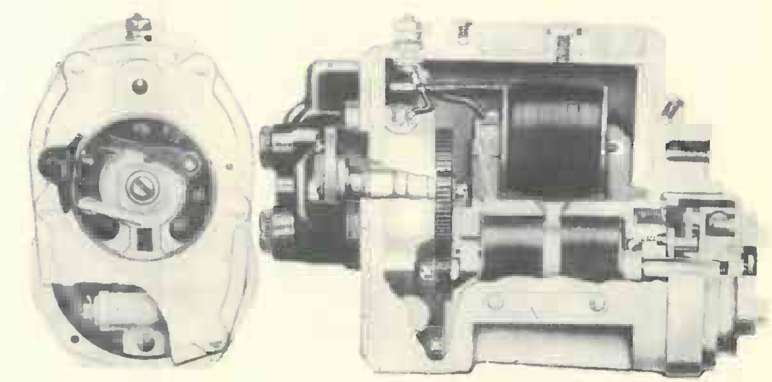
MAGNETO

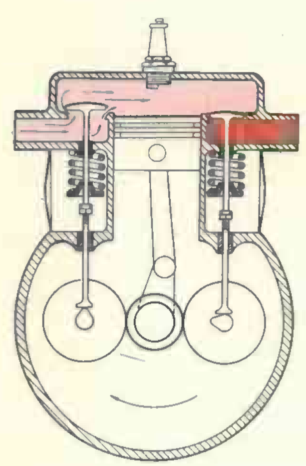
BREAKER

DISTRIBUTOR

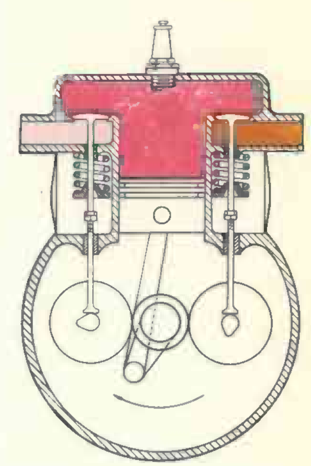


IMPULSE STARTER

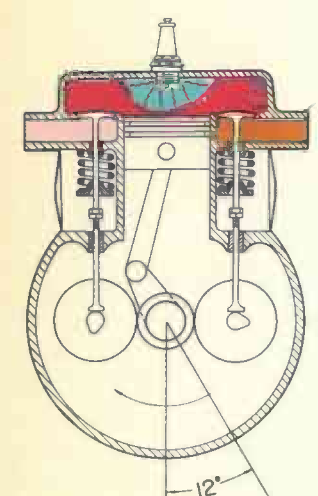




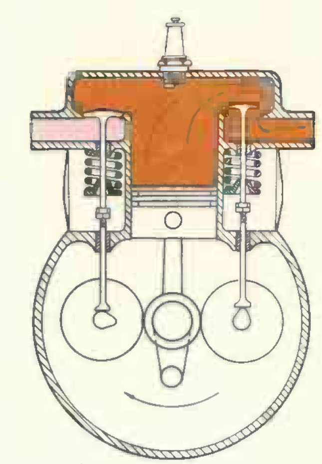
INTAKE



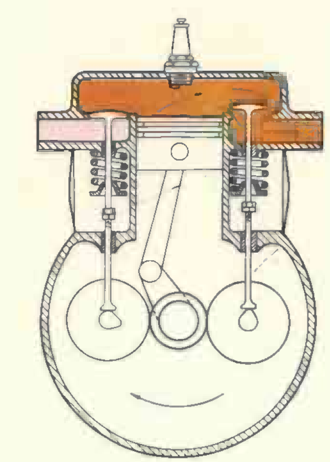
COMPRESSION



FIRE



EXHAUST



EXHAUST

NO. 6
(OF TEN CHARTS)

THE PULLMAN CO.
YARD DEPT. - CHICAGO
FEB. 1944

MODEL "C" GENERATOR ENGINE CONTROL CIRCUIT

CHART NO. 7

AUTOMATIC STARTING TIMER. (Pictured on Page #36.)

When the control circuit is energized for the first time the three-minute timing relay coil and the automatic starting timer coil are energized. The automatic starting timer coil advances the automatic starting timer cam one step, and the three-minute timing relay coil closes its contacts. This energizes the relay coil of the five-second timing relay, and after five seconds this relay opens its contacts which then de-energizes the three-minute timing relay coil and also the automatic starting timer coil. Since the three-minute timing relay is slow opening it will take approximately three minutes to open; when it opens it de-energizes the five-second timing relay coil, closing its contacts and energizing the three-minute timing relay coil and the automatic starting timing coil. The cycle is then repeated.

When the automatic starting timer coil is energized, it moves the automatic starting timer cam one step. Assuming the operation is for a 15-minute interval, after five impulses or steps the cam is moved to position where contact is made, energizing the control circuit relay.

STARTER CAM.

The toothed wheel seen through the glass front in timer case is the device which is indexed or turned one notch every time the automatic starting timer coil is energized. Directly behind the teeth is a cylindrical surface having two depressions for a "one hour cam" or eight depressions for a "fifteen minute cam." A follower riding on this cam holds the contacts of the timer switch open until such time as the follower drops into one of the depressions.

In the wiring diagram, the contacts which are closed by the cam are shown with the auto-timer coil just like any other relay; but it must be remembered that the auto-timer coil must be energized a number of times, depending upon the number of notches in the cam, before its contacts close.

A two-point timer cam is used for summer operation giving the engine a starting impulse every hour if the unit is not already running. An eight-point cam is used in cold weather to start the engine every fifteen minutes to insure easy starting.

CONTROL RELAY

The control circuit relay when energized by the automatic starting timer energizes the starting contactor, and also opens the ground circuit to the magneto. The third set of contacts on the control relay close when the relay is energized, and provide a holding circuit to keep the control relay coil energized.

STARTING CONTACTOR.

The starting contactor when energized through the control relay, intermittent starting switch, and auxiliary top contacts on reverse current relay, closes a circuit to the series starting field in the generator. The generator then motors, cranking the engine. As soon as the engine starts and the generator voltage builds up to 1/2 volt above battery voltage, the reverse current relay closes and at the same time de-energizes the starting contactor by breaking starting contactor coil circuit at the auxiliary top contact. The series starting field circuit in the generator is then broken, and the generator being driven by the Waukesha Engine, is then controlled by its shunt field alone.

INTERMITTENT STARTING SWITCH.

The intermittent starting switch serves two purposes. One, it permits the generator to crank the engine for approximately 15 seconds, and then breaks the starting circuit for 45 seconds, re-cycling until the engine starts or until the automatic starting timer advances off its starting position, in approximately three minutes. Two, its second purpose is to open the control relay circuit to stop the engine generator when the low current relay reaches its cut-out point.

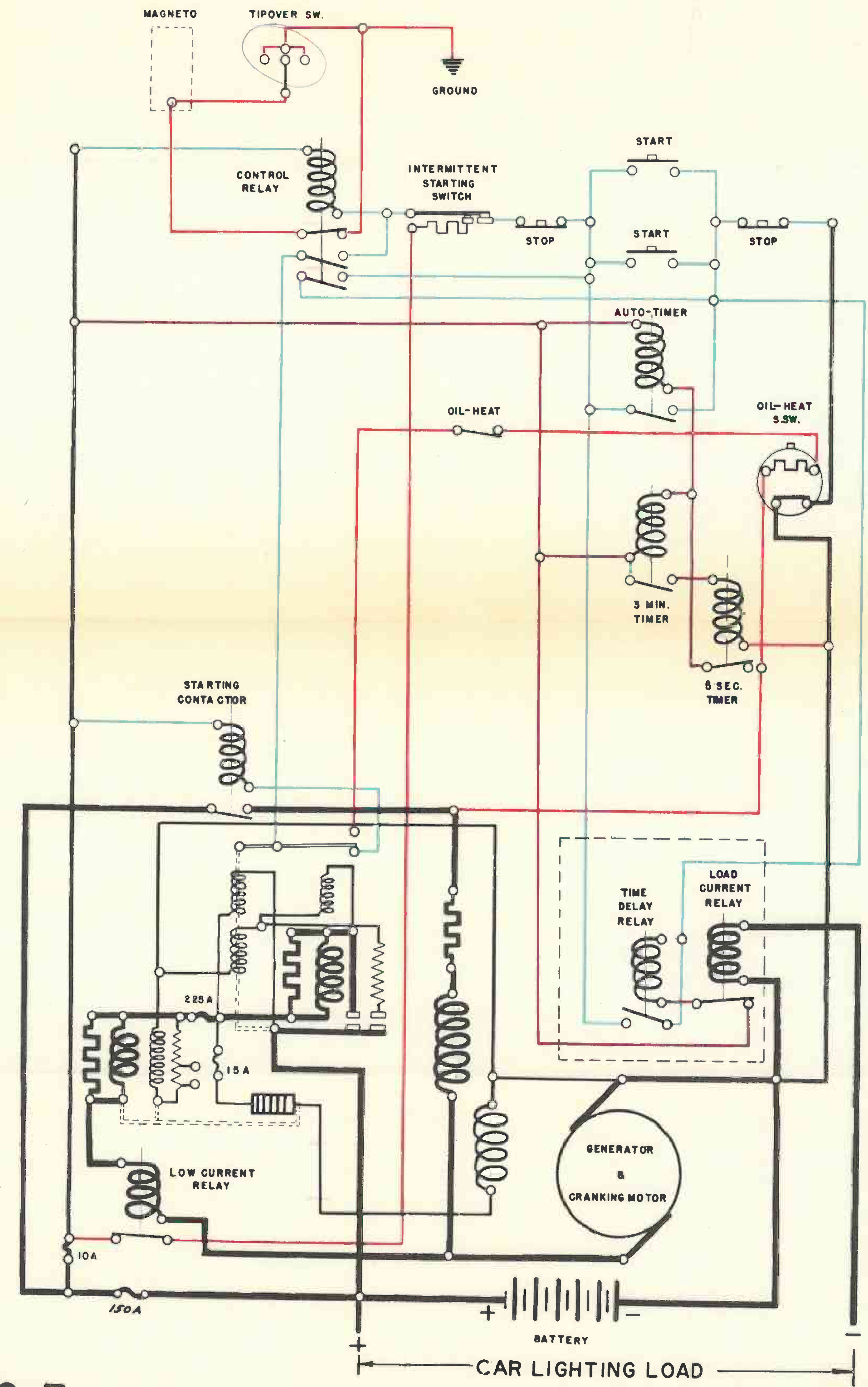
LOW CURRENT STOP RELAY. (Pictured on Page #32)

The operating coil of a low current stop relay is connected in series with the output of the generator. As the batteries approach a charged condition, the amount of current they will accept from the generator falls off. When the car lighting load and the electrical demand of the battery falls below a predetermined setting (45 amps.) the low current stop relay closes its contacts completing a circuit to the heater element of the intermittent switch. After the heater element is energized, for approximately 15 seconds, its contacts open to de-energize the control relay circuit, which in turn, stops the engine. As the generator comes to rest the polarity through the starting field changes, energizing the starting timer until the 5 second relay opens its contacts. This in turn advances the cam one notch to open the starting circuit.

LOAD CURRENT RELAY PANEL.

The load current relay panel will automatically start the engine generator on a pre-determined load on the battery of

MODEL "C" GENERATOR ENGINE CONTROL CIRCUIT



NO. 7
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60 amps. regardless of the position of the automatic timer. Where small capacity batteries are used, the generator is started in this manner before the battery can be exhausted.

The panel operates when the load on the battery is sufficient to open the contacts of the load current relay whose coil is connected in series with the car lighting load. This de-energizes the coil of the mercury time delay relay which closes its contacts in about 10 seconds. The contacts of the delay relay parallel those of the "start" buttons and the automatic timer to give the unit a starting impulse.

The delay relay also has a 10 second lag on opening. This time delay eliminates any false starting of the engine generator due to sudden fluctuations in the load current.

OIL-HEAT STOP SWITCH.

Should the engine for any reason become overheated, causing the engine head temperature to go above 220° (265° on streamliners) or should the oil pressure go below 5 lbs., an oil-heat switch located in the unit will make contact to energize the oil-heat stop switch located on the control panel. In about one and one half minutes, this switch will trip open, stopping the engine by opening the circuit to the control relay coil.

A stop switch of the type used on all Waukesha panels is shown on Page 32 , as it would appear with the cover removed. It is shown in the tripped or "off" position, with contacts open. When the reset plunger is pushed down, a flat spring attached engages in the toothed wheel shown on the right. The toothed wheel is soldered on its shaft with a low temperature melting solder. Mounted on the reverse side of the stop switch and on the same shaft as the toothed wheel is a heater element which is energized, in this case, by closing the oil-heat switch. When the solder softens, the wheel is free to turn releasing the stop spring. The reset plunger which is spring loaded, moves upward opening the stop switch contacts. The heater circuit, which is interrupted when the unit stops, then allows the solder to solidify and the reset may again be engaged.

Always investigate the reason for a stop switch found in the "Off" position.

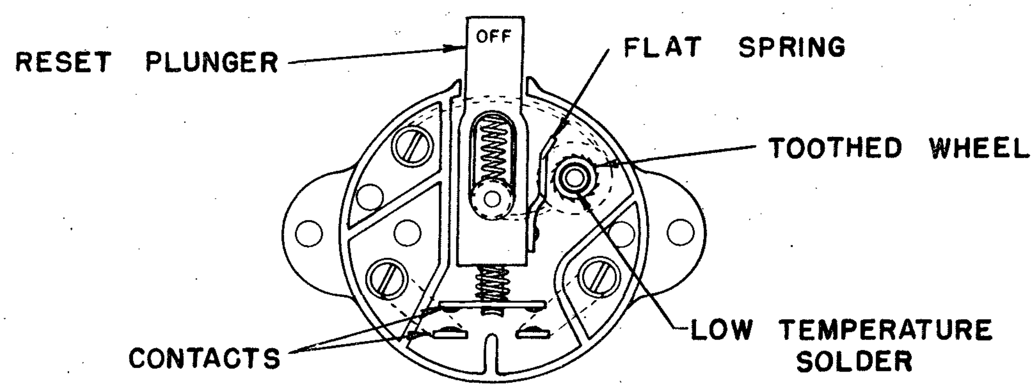
MANUAL STOP-START BUTTON.

A generator engine can be started or stopped manually either at the unit or at the panel by pushing either of the above mentioned buttons. The start buttons are connected in parallel with the automatic timer contacts and the contacts of the time delay relay on the load current relay panel. The stop buttons are connected in series with the control relay coil and serve to de-energize the control relay to stop the engine.

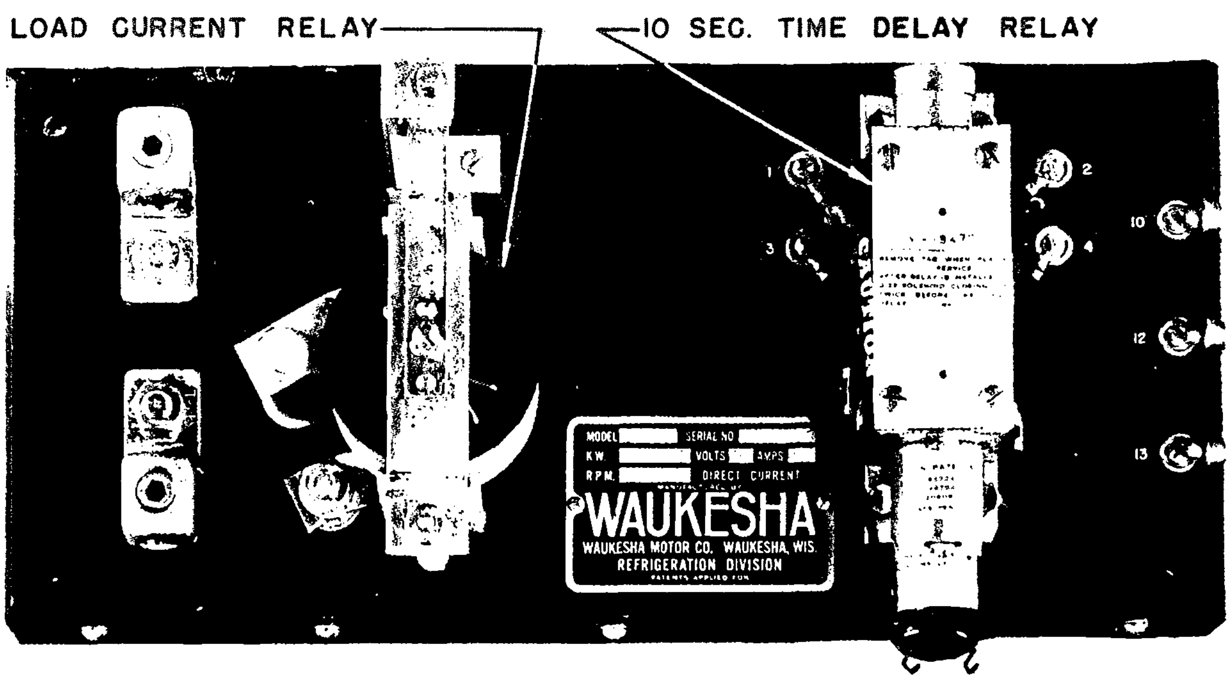
TIP-OVER SWITCH.

A tip-over switch is mounted inside the control box on the generator unit and will ground the magneto primary circuit in case the unit tips more than 45° to either side.

STOP SWITCH



LOAD CURRENT RELAY PANEL



MODEL "B" GENERATOR ENGINE CONTROL CIRCUIT

CHART NO. 7 A

The Model "B" generator engine control circuits are similar to those of the Model "C", but have the following differences:

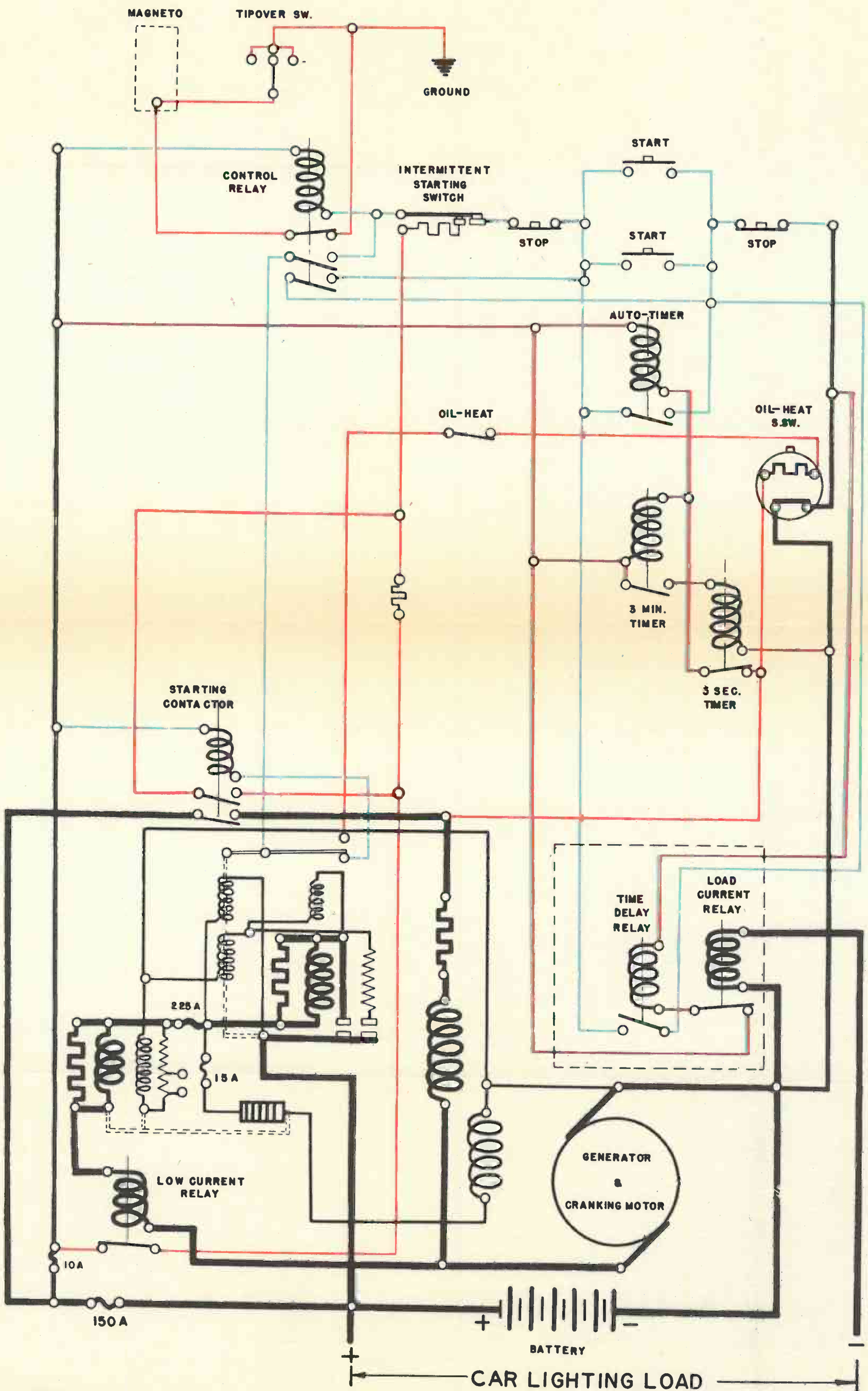
The starting contactor has a set of auxiliary contacts which are connected in parallel with a limiting resistor in the intermittent starting switch heater circuit. When the starting contactor is energized and engine is cranking, this additional resistance is shunted out by the auxiliary contacts on the starting contactor and full battery voltage is applied across the heater element of the intermittent starting switch. After the unit is in operation, and when stopping under regulation of the load current stop relay, the limit resistor is then in the circuit and serves to cut down the generator operating voltage, which is 38 volts, so that only 32 volts is impressed across the heater element of the intermittent starting switch. This circuit has been added for cars that may at sometime use Edison batteries. For Edison batteries the generator voltage is 43 volts, which is sufficiently high to burn out the heater element of the intermittent starting switch if no protection is provided.

The other change involving the Model "B" scheme of controls is a separation in the negative feed to the coil and contact of the time delay relay on the load current relay panel. The time delay relay coil is now connected to negative battery after first passing through the contacts of the oil-heat stop switch as shown. This change adds another terminal (#18) to the load current relay panel, which is not shown on the panel pictured on Page 32.

TIP-OVER SWITCH

The tip-over switch for this model unit is mounted on the back of the motor compartment and serves the same purpose as explained for the Model "C".

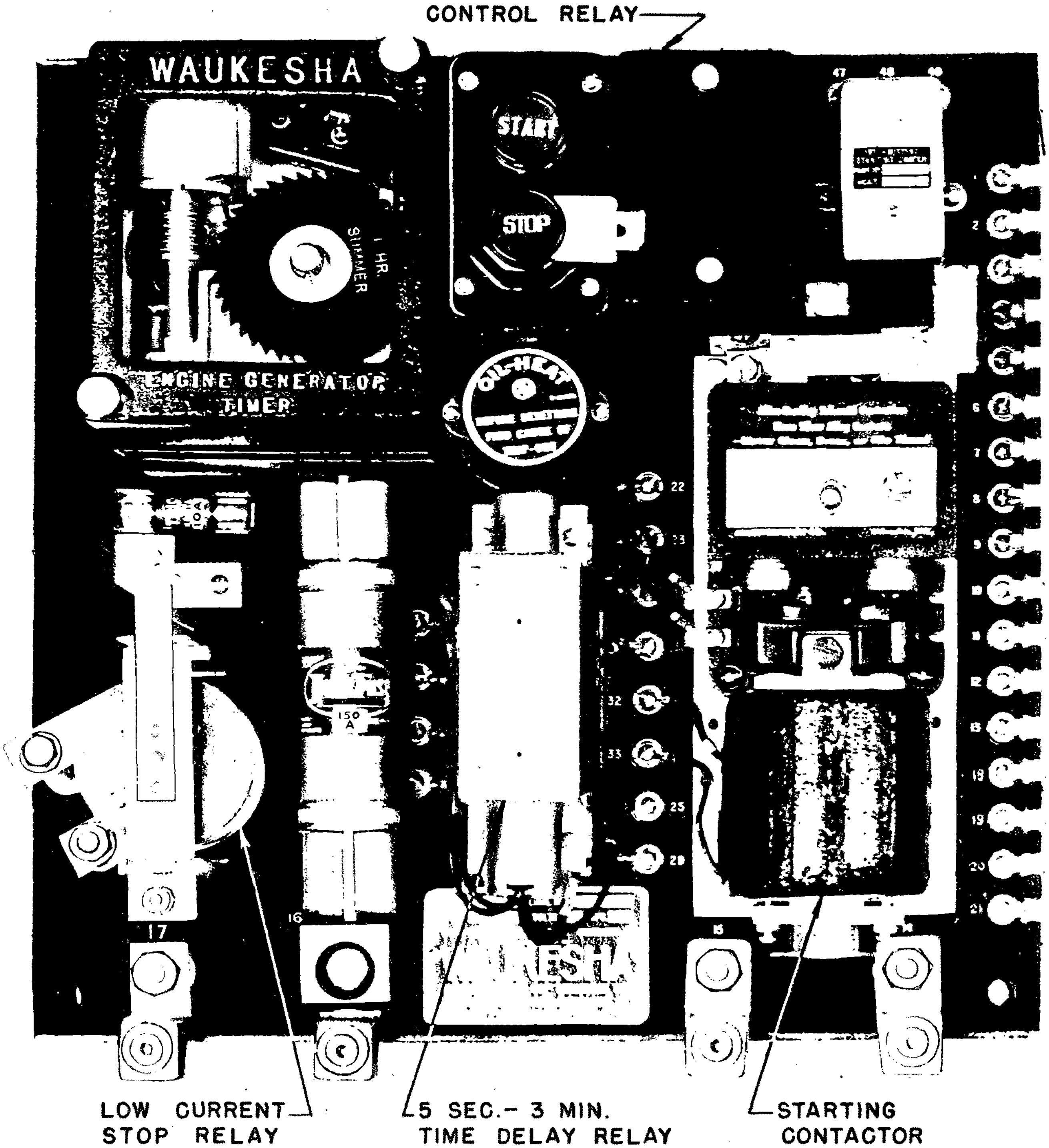
MODEL "B" GENERATOR ENGINE CONTROL CIRCUIT



NO. 7A
(OF TEN CHARTS)

THE PULLMAN CO.
YARD DEPT.-CHICAGO
FEB. 1944

GENERATOR CONTROL PANEL



MODEL "E" ICE ENGINE CONTROLS

CHART 8 A

STARTING IMPULSE.

When either the starting button in the Ice Engine Unit Control Box or the button on the Ice Engine Panel, located in the electric locker, is operated; or the cooling pilot relays on the Vapor control panel are energized, a circuit is completed to the control relay coil. When the unit is started from either of the start buttons, the button must be held in if the unit is to continue to run.

The cooling pilot relays, of which there are two since these cars have sectional evaporators, are located on the Vapor panel and have two sets of contacts. One set of contacts on both cooling pilot relays is connected in parallel with the start push buttons. To simplify the wiring diagram, only one cooling pilot relay is shown, and that relay having only a starting contact. Actually, the cooling pilot relay which is controlled by the higher thermostat tube setting, and which is satisfied first as the car cools down, also controls a solenoid valve and in the freon line to the 3/4 section evaporator. The second cooling pilot relay controlled by the low temperature thermostat tube setting, immediately stops the Ice Engine when this thermostat tube has been satisfied, by opening the circuit to the control relay coil.

CONTROL RELAY.

Upon completion of the control relay coil circuit, its contacts operate as follows:

One set of contacts closes to energize the condenser fan and starter contactor, another set of contacts closes in the generator shunt field circuit. The third set of contacts opens to remove the ground from the primary circuit of the magneto. This last mentioned circuit, the magneto grounding circuit, is the one which stops the unit when the control relay is deenergized for any reason.

CONDENSER CONTACTOR.

The condenser contactor when energized opens the circuit to both condenser fan motors and the sub-cooler motor, and does not close again until the low vacuum switch is operated. In this manner the electrical load of the condenser fans and sub-cooler is delayed until the engine has been cranked.

STARTING CONTACTOR.

The starting contactor when energized by the control relay completes a starting circuit through the series field of the starter generator which now begins to motor. At the same time, a second set of contacts on the starting contactor opens the generator shunt field circuit. In normal operation the starting contactor remains energized until the high vacuum switch operates.

LOW VACUUM SWITCH.

The engine has now been cranked and is in operation. As the engine manifold vacuum develops, the low vacuum switch which is connected to the manifold, opens its contacts at 1⅛" of manifold vacuum; de-energizing the condenser contactor, which in turn closes its contacts to energize both condenser fan motors and also the sub-cooler motor if the sub-cooler pressure switch is closed.

HIGH VACUUM SWITCH.

When the manifold vacuum rises above 7", the high vacuum switch contacts open to de-energize the starting contactor, which in turn opens the circuit through the series field of the starter generator and also completes the generator shunt field circuit. The starter generator now builds up voltage as a generator and furnishes power to operate the condenser fan motors and the sub-cooler motor. There no longer is any electrical connection between the starter generator and the car batteries, except that the generator shunt field is excited by the car batteries.

As explained under the heading of Vacuum Gauge, Page 5 , the engine intake manifold vacuum varies with the load on the engine, being lowest when the engine is heavily loaded. The high vacuum switch provides a means for relieving the engine of the power required to operate the condenser fans and sub-cooler in the following manner: Any time that the refrigerant load becomes excessive so that the engine manifold vacuum falls below approximately 3" the high vacuum switch contacts close; energizing the starting contactor, and also de-energizing the generator shunt field. The electric load which was formerly carried by the 2KW Generator, is now supplied from the battery through the starter generator series field. The starter generator will remain unloaded until the engine again attains an intake manifold vacuum of over 7".

INTERMITTENT STARTING SWITCH.

In the foregoing has been described a normal starting cycle. If the ice engine for any reason, does not start within 15 to 20 seconds, the intermittent starting switch contacts which are connected in series with the starting contactor coil will open; de-energizing the starting contactor and also open its own heating circuit. As the intermittent starting switch cools off, its contacts will close in approximately 45 seconds; the engine will be cranked again for 15 seconds and the cycle repeated.

CRANK LIMIT STOP SWITCH.

The heater element of the crank limit stop switch is energized through the low vacuum switch and the control relay during a starting cycle. Under normal starting conditions the low vacuum switch will open before the heater element in the crank limit switch can operate the contact release. Should the engine fail to start within approximately 3 minutes, the crank limit stop switch will open its contacts breaking the circuit to the control relay coil, and preventing further cranking of the unit until the crank limit reset is operated manually.

OIL-HEAT STOP SWITCH.

The heater element of the oil-heat stop switch is energized anytime during engine operation should the oil pressure fall below 5 lbs., or the engine temperature go above 265° F. The oil-heat stop switch reset is tripped out in approximately 1½ minutes after the contacts of the oil-heat switch on the engine close.

HIGH-LOW STOP SWITCH.

The high-low stop switch heater element is energized through the contacts of a freon dual pressure switch. Should the high pressure on the compressor discharge side go above 290 lbs., or the freon suction pressure fall below 7½ lbs., the high-low pressure switch contacts close to energize the heater element of the high-low stop switch. The high-low stop switch reset trips out approximately 1½ minutes after the high-low pressure switch contacts are closed.

TIP-OVER SWITCH.

A tip-over switch mounted on the ice engine unit will automatically ground the magneto primary circuit and stop the engine should the unit be tipped at an angle of more than 45°.

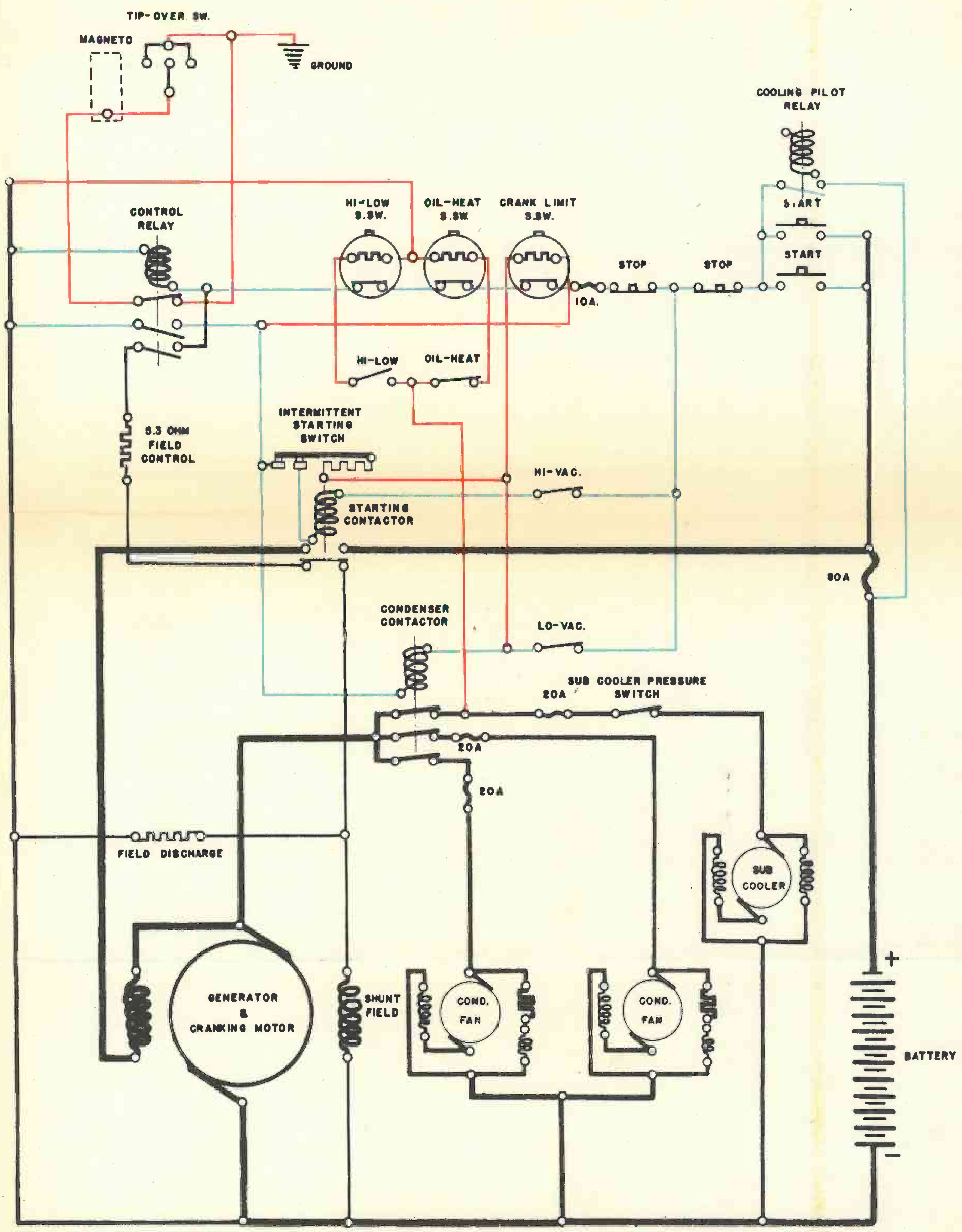
SUB-COOLER PRESSURE SWITCH.

The operation of the sub-cooler motor depends finally upon the sub-cooler pressure switch which closes its contacts at 175 lbs. high side freon pressure, and opens its contacts at 150 lbs. pressure.

PILOT LIGHT.

A pilot light is provided in the electric locker for the guidance of the repairman and indicates the condition of the evaporator. When cooling is turned on, the pilot light circuit is open until the contacts of a temperature switch close. The thermal bulb of the temperature switch is connected to the evaporator freon suction line where it is influenced by the temperature of gas returning to the compressor. When the suction line is cold, the temperature switch closes, lighting the pilot light as an indication that refrigeration is taking place in the evaporator. It is principally for the benefit of a repairman riding the train.

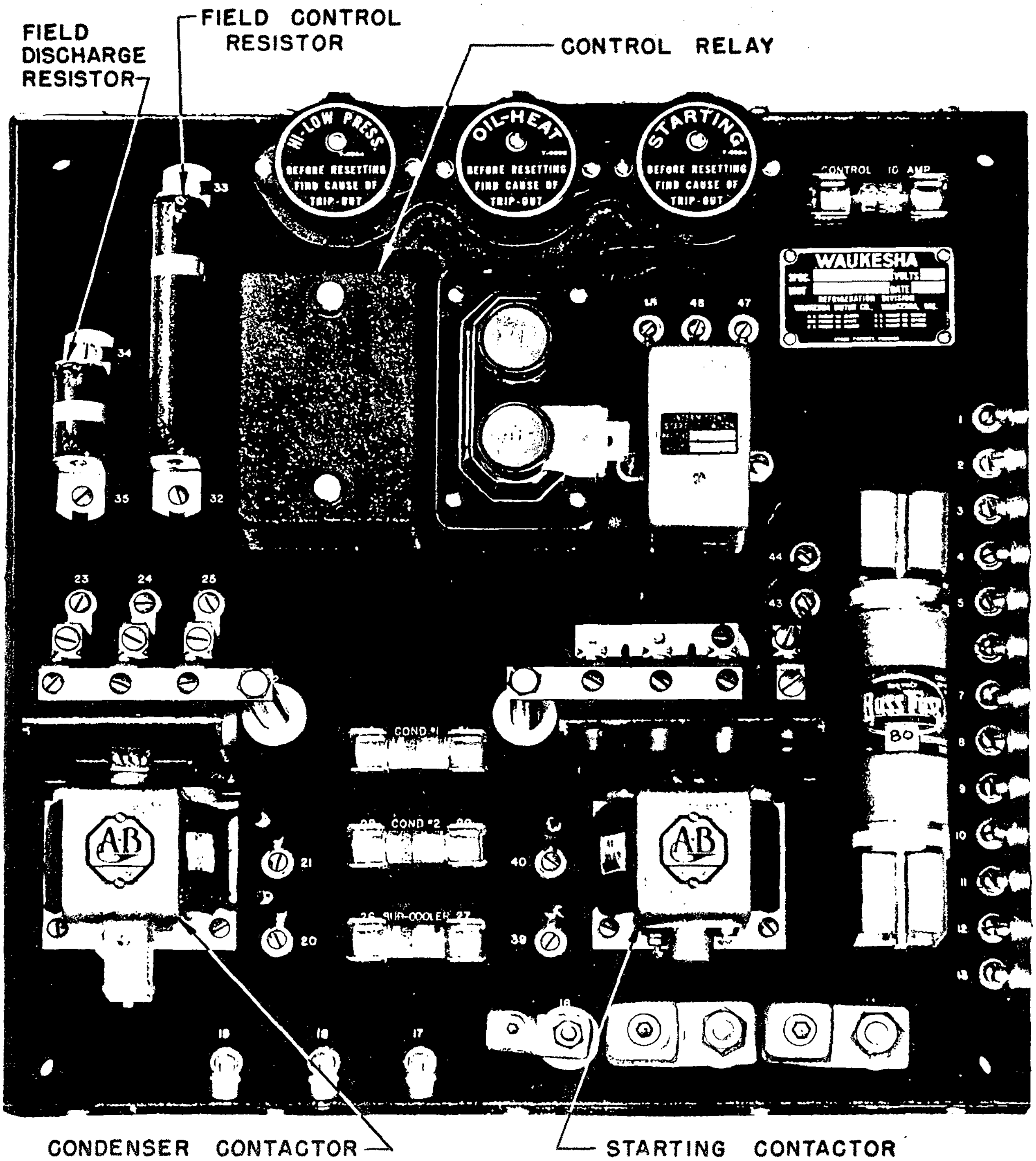
MODEL "E" ICE ENGINE CONTROL CIRCUIT



NO. 8A
(OF TEN CHARTS)

THE PULLMAN CO.
YARD DEPT - CHICAGO
FEB. 1944

ICE ENGINE CONTROL PANEL MODEL "E"



MODEL "D" ICE ENGINE CONTROL

CHART No. 8 B

STARTING IMPULSE.

The Model "D" Ice Engine controls differ from that of a Model "E" in that the Model "D" Ice Engine Unit normally stops by pumping down the freon system, and cutting out on low freon pressure. By pumping down the freon system, the compressor is relieved of handling any freon during the starting cycle. The scheme of controls for this unit requires an unusual number of control devices whose contacts are connected in series. The function of each device will be described first in the order of progression of a starting impulse and later in detail.

The cooling pilot relays of which there are two since these cars have sectional evaporators, are located on the Vapor panel and have two sets of contacts. One set of contacts on both cooling pilot relays is connected in parallel and carry the main control circuit. The other set of contacts on both cooling pilot relays each control an evaporator freon solenoid valve. Number One cooling pilot relay controls the evaporator freon solenoid valve to the one-third section evaporator, and is in turn controlled by the lower thermostat tube setting. The Number Two cooling pilot relay controls the two-thirds section evaporator freon solenoid valve, and is controlled by the higher value thermostat tube setting which is satisfied first as the car cools down.

On a few cars with Waukesha equipment the evaporator is actually divided so that one half of the evaporator is responsible for cooling the air for one section of the car such as a lounge section, the other half of the evaporator cools the air for the room space. In this case there is no higher or lower setting between the thermostat for each section, and the ice engine unit will continue to run as long as either cooling thermostat requires cooling.

When either of the cooling pilot relays is closed, an electrical circuit is completed from negative light through the cooling pilot relay contacts, the contacts of the high pressure switch, the contacts of the oil-heat and crank limit stop switches, through the vacuum switch contacts to the low pressure switch. Since the unit has stopped by pumping down, the top contacts of the low pressure switch do not close until the low side freon pressure builds up to approximately 15 lbs. The pressure builds up with but a few seconds delay since a freon solenoid valve is also energized on the closing of a cooling pilot relay. Upon closing of the upper contacts, the low pressure switch cranking circuit then continues through the contacts of the intermittent starting switch to the starting contactor, which upon closing its contacts, connects the cranking motor directly across the battery. The compressor by-pass solenoid valve is also energized at the same time as the starting contactor, thereby unloading the compressor. After the engine has been cranked and is running, and approximately $1\frac{1}{2}$" of vacuum has been developed in the engine intake manifold, the contacts of the vacuum switch open, de-energizing both the starting contactor and the compressor by-pass solenoid valve.

The unit now runs subject only to action of the cooling pilot relays and the oil-heat and freon pressure protective devices.

MANUAL START TOGGLE SWITCH.

The unit can be started and controlled from the gauge box by first turning on the blower fan in the car, putting a jumper across "Yard Test" posts on the panel, and lifting the manual start toggle switch in the unit control box. A circuit is again completed through the various pressure switches and protective devices with the following exceptions:

The circuit through the manual start toggle switch is from negative battery rather than negative light. This necessitated a current limiting resistor being connected in series with the manual start toggle switch to prevent the 10 amp CC fuse from blowing should the toggle switch be lifted while the Vapor control panel is calling for cooling.

The functions of the various control devices will now be described in detail.

LOW PRESSURE SWITCH.

The low pressure switch is actuated by the low side freon pressure. It has an upper and a lower contact. The upper contact which carries the cranking circuit, closes at a pressure of 15 lbs. The lower contact which serves to ground the magneto primary and stop the engine closes at $7\frac{1}{2}$ lbs. The low pressure switch has an active part in the scheme of controls since it is always responsible for stopping the engine after the freon solenoid valves close and the system pumps down.

HIGH PRESSURE SWITCH.

The high pressure switch is actuated by the freon pressure on the discharge side of the compressor, and like the low pressure switch has an upper and a lower contact.

The upper contacts carry the cranking control circuit and also the negative feed for both evaporator freon solenoid valves. In order to prevent intermittent starting and stopping of the unit under control of the high pressure switch, the high pressure switch is so located in the circuit that upon opening its upper contacts at 300 lbs. the evaporator solenoids are de-energized permitting the system to begin to pump down. This reduces the head pressure without stopping the unit. If the high pressure should continue to increase to 350 lbs., the lower contact is made grounding the magneto and stopping the engine.

VACUUM SWITCH.

The operation of this switch is dependent upon engine manifold vacuum. After the engine has started and $1\frac{1}{8}$" of vacuum has been created in the engine intake manifold, the switch opens. The opening of this switch breaks the negative control circuit for the starting motor solenoid, the compressor by-pass solenoid, the heater element of the intermittent starting switch and the heater element of the crank limit stop switch.

Failure of the vacuum switch to open will result in damage to the starter motor and gears.. Failure of the switch to close will prevent cranking the engine .

INTERMITTENT STARTING SWITCH.

In order to avoid burning out the cranking motor, through excessive cranking, an intermittent starting switch is used. It consists of a bi-metallic contact arm, two sets of contacts, and a heater element. At the time a starting circuit is completed to the starting contactor, a circuit is also completed to the heater element of the intermittent starting switch, which heats the bi-metallic contact arm causing it to break the starting circuit in approximately 15 seconds. Forty-five seconds later, the contacts of the intermittent starting switch close again, allowing the engine to crank for approximately 15 seconds. This intermittent action continues until the engine starts, or until the reset on the crank limit stop switch is tripped.

CRANK LIMIT STOP SWITCH.

A stop switch of the type used on all Waukesha panels is shown on page 32 , as it would appear with the cover removed. It is shown in the tripped or "Off" position with contacts open. When the reset plunger is pushed down, a flat spring attached engages the toothed wheel shown on the right. The toothed wheel is soldered on its shaft with a low temperature melting solder. Mounted on the reverse side of the stop switch, and on the same shaft as the toothed wheel, is a heater element which is energized as long as the unit is cranking. When the solder softens and the wheel is free to turn, releasing the stop spring; the reset plunger which is spring loaded, moves upward opening the crank limit stop switch contacts. This breaks the starting contactor circuit and the engine will not crank until the reset plunger has again been engaged. The heater circuit which is also interrupted when the control circuit is opened, then allows the solder to solidify and in a few minutes the plunger may be reset. This switch has a three minute heater element.

Always investigate the reason for a stop switch found in the "Off" position.

OIL HEAT STOP SWITCH.

The oil heat stop switch is identical in construction with the crank limit stop switch except that it has a four minute heater element, and therefore requires four minutes of heating before the reset plunger is tripped. In this case, the heater element is energized by closing of the oil-heat switch on the unit, which closes its contact should the engine heat go above 220 $^{\circ}$ or the oil pressure fall below 5 lbs. The oil-heat stop switch has a four minute heater element because it is also energized during the cranking period as the oil pressure of an engine under cranking speed is not sufficient to open the oil-heat switch contact.

Again, always investigate the reason for a stop switch tripped in the "Off" position.

STARTING CONTACTOR.

The starting contactor has two functions, one, to engage the cranking motor pinion gear with the flywheel ring gear, and two, to complete the cranking motor circuit. The starting contactor solenoid has two windings a pull-in coil and a hold-in coil. The pull-in coil is shunted out when the starting contactor contacts close.

The contactor will be explained more fully in connection with the sketches on Chart #9.

An electrolytic condenser is connected across the starting contacts to prevent burning of contacts when opening. This condenser must be connected, red lead to positive, and black led to negative sides of the contactor in order to be effective.

COMPRESSOR BY-PASS SOLENOID VALVE.

This valve is identical with one of the evaporator solenoid valves. It is energized during the time the engine is cranking and is de-energized by opening of the vacuum switch after the engine is running.

When energized, the valve opens allowing freon in the compressor heads to return to the crankcase, preventing the compressor from pumping, thereby reducing the load on the cranking motor.

SUB-COOLER RELAY AND PRESSURE SWITCH.

The sub-cooler relay is simply a load relay to connect the sub-cooler motor to the car battery.

The sub-cooler pressure switch controls the sub-cooler relay coil, and is in turn governed by high side freon pressure. The pressure switch closes its contacts at 175 lbs. and opens when the pressure drops below 150 lbs..

TIP OVER SWITCH.

The tip over switch is a mercury type switch that will ground the magneto and stop the engine if the unit is tipped 45° from the vertical to either side.

REMOTE CONTROL PANEL.

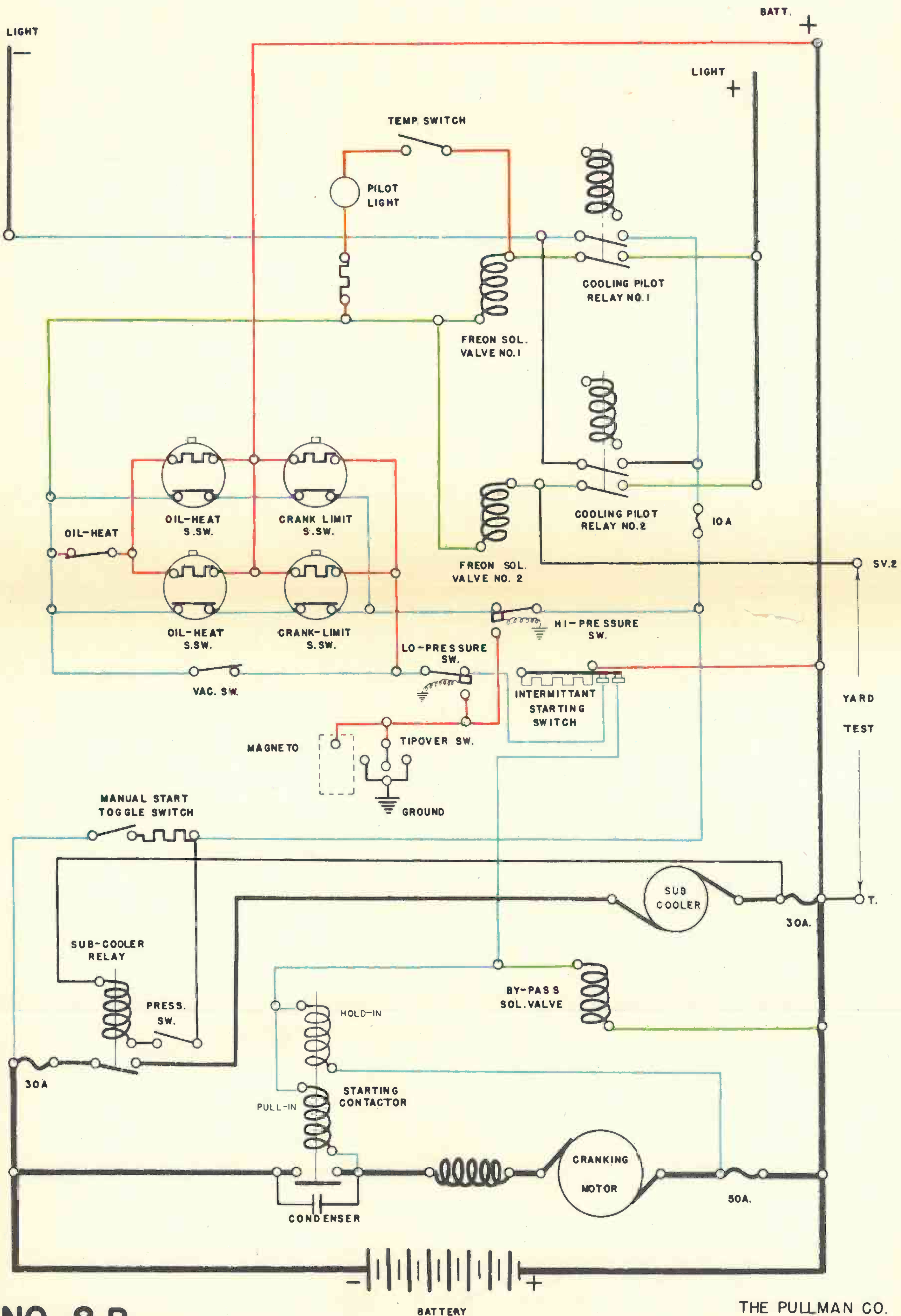
In order to make it possible for a repairman to operate the engine on the road, and in case either the crank limit or oil-heat stop switches on the unit were tripped out; these protective devices have been duplicated on a remote control panel in the car electric locker. The heater elements and contacts have been respectively connected in parallel so that to stop the engine or prevent continued cranking both oil-heat stop switches or both, crank limit stop switches must be tripped "Off".

In order to resume operation after taking corrective measures, it is only necessary to reset a stop switch either on the remote control panel or at the unit.

PILOT LIGHT.

A pilot light is provided in the electric locker for the guidance of the repairman, and indicates the condition of the evaporator. When cooling is turned on, the pilot light circuit is open until the contacts of a temperature switch close. The thermal bulb of the temperature switch is connected to the evaporator freon suction line where it is influenced by the temperature of the gas returning to the compressor. When the suction line is cold, the temperature switch closes, lighting the pilot light as an indication that refrigeration is taking place in the evaporator. It is principally for the benefit of a repairman riding the train.

MODEL "D" ICE ENGINE CONTROL CIRCUIT



NO. 8 B

(OF TEN CHARTS)

THE PULLMAN CO.
YARD DEPT-CHICAGO
FEB 1944

MISCELLANEOUS DETAIL

CHART 9

LUBRICATION SYSTEM.

The Waukesha Engine is lubricated under pressure from a gear type oil pump. A bottom view of the oil pump, as shown on the chart, indicates how this pressure is developed. A small quantity of oil is trapped between each tooth and the pump casing as the gears revolve, and is delivered up the pump shaft housing through channels to the crank shaft and camshaft bearings. Since the speed of rotation of the oil pump depends upon the speed of the engine, and the pressure developed depends upon the engine speed and viscosity of oil, it is necessary to provide an oil pressure adjustment.

The oil pressure adjustement is tapped off the main oil line and operates as follows:

A spring loaded ball is held against a seat, and when the oil pressure exceeds thirty pounds, the ball is forced away from its seat allowing a sufficient amount of oil to return directly to the crankcase to relieve the excess pressure. No adjustment should be made to oil pressure unless the engine has operated at least one half hour and the oil is thoroughly warmed up.

An oil pressure gauge is also tapped into the main oil line from the pump, and indicates the pressure being maintained by the pump.

The oil filter used is of the by-pass type, that is, only a small part of the oil delivered by the pump is by-passed through the oil filter to be cleaned and returned to the crankcase. Filtering is done by a cotton waste pack. Should this filter be packed too tight, or if it were to become plugged, no oil would pass through it, but the bearings would still receive sufficient oil. A loosely packed filter will allow too much oil to by-pass and can be a reason for low oil pressure.

The oil filter is repacked on every oil change.

MODEL "F" ENSIGN REGULATOR.

The Model "F" Ensign Regulator serves the same purpose as the Model "B" Ensign Regulator, as described on Page 4. The Model "F" Regulator is not as sensitive to opening pressure as is the Model "B" and therefore, is used exclusively on generator units, which crank faster and therefore quickly develop a manifold vacuum.

It operates as follows:

When the engine is cranked, the vacuum drawn in the engine intake manifold reduces the pressure on the lower side of the operating diaphragm which in turn pulls down against a lever arm and raises the valve seat. Again the amount of opening depends upon the load on the engine. When the engine stops, the pressure on each side of the regulator diaphragm equalizes, which allows the spring loaded lever arm to force the diaphragm upward closing the valve.

This type of regulator has two features which are not used in our service; one, a plunger extending through the top plate of the regulator which can be depressed manually to open the valve seat; and two, an idling adjustment which is shown in the lower half of the regulator casting, and which in our case, is closed off with a pipe plug.

THE MODULATOR.

The Modulator is a device which will vary the speed of the engine depending upon low side freon pressure, which also varies with the refrigeration load. When the pressure is low, the speed of the engine is decreased proportionately, reducing the compressor capacity and therefore reducing the rate of cooling in the car. This evens out the temperature and also the humidity in the car and prevents frequent cycling of the unit. If the low side freon pressure rises, which indicates a demand for more cooling, the engine speed is increased and the compressor capacity restored.

The low side freon pressure operating through a bellows presses against the Modulator stem, which increases or decreases the spring tension on the governor arm as required. The adjustment of the Modulator will be explained along with the adjustment of the governor to which it is attached.

THE GOVERNOR.

The governor regulates the maximum speed of the engine by operating a carburetor butterfly valve. The governor shaft is driven from the engine timing gear train. To this shaft are attached two small flyweights so that when the shaft revolves, the weights are thrown out centrifically in such a manner to exert pressure on a plunger on the shaft. The plunger in turn operates a fork attached to the pivot of the governor control arm. An adjustable link connects the governor control arm on the carburetor butterfly. The linkage is so connected that as the flyweights revolve faster and faster, the force exerted tends to close the carburetor butterfly valve and slow down the engine.

The following procedure must be followed in installing or readjusting the modulated control using the electric tachometer and speed-pressure curves:

1. Adjust the governor damping screw so it protrudes 1/8" beyond the lock nut.

2. Remove the pin from the governor arm.

3. The minimum speed of the engine is determined only by the screw on the carburetor and the load on the engine. Therefore, first start the engine and obtain 18 to 22 lbs. low side freon pressure for the Model "E", or 14 to 15 lbs. for the Model "D" Unit throttling the compressor suction line valve. Then adjust the screw on the carburetor until the desired speed is obtained.

4. With the idling screw against the stop, adjust the carburetor arm so that it is about 15° to the right of a vertical position.

5. Turn the large adjusting nut at the bottom of the modulator until the modulator stem just starts to move at 18 to 20 lbs. for Model "E" or 14 to 15 lbs. for Model "D", rising pressure. As the large adjusting nut is turned up the tension is increased on the spring requiring a higher pressure to move the modulator stem. The movement must be checked on a rising suction pressure obtained by throttling the suction valve until the pressure is below 18 lbs.for the Model "E" and 15 lbs. for the Model "D", then opening the valve again.

6. With the engine running at the proper minimum speed and with a suction pressure of 18 lbs. for the Model "E" and 15 lbs. for the Model "D", just remove the slack in the governor spring.

7. Now adjust the length of the governor rod so that it lacks 1/16" of reaching governor arm when the engine is running at minimum speed.

8. When running the engine at a suction pressure of 40 lbs. the speed should be 1400 R.P.M. for the Model "E", and 1225 R.P.M. for the Model "D". If the speed does not check within plus or minus 50 R.P.M., adjust the governor spring tension.

STARTER MOTOR.

A starter motor is a special type of electric motor designed to operate under great over-load and produces a high horsepower for its size. It can do this for short periods of time only, as in order to produce the necessary amount of horsepower, a high amperage current is required. The high current creates considerable heat, and if the cranking motor operation is continued for any length of time without pause to allow for cooling, the accumulated heat would cause serious damage to the motor.

The cranking motor drive mechanism has two jobs; one, to transmit the cranking torque to the engine when the cranking motor is operated, and to disconnect the cranking motor from the engine after the engine has started. The second job is to provide a gear reduction between the cranking motor and the engine so that there will be sufficient torque to turn the engine over at cranking speed. The gear ratio of the cranking motor to the engine is approximately 18 to 1, thus to turn the engine over at 100 R.P.M., the cranking motor must turn at 1800 R.P.M. After the engine begins to run, it may increase in speed up to 1400 R.P.M. If the cranking motor drive were to remain meshed with the flywheel ring gear, the cranking motor armature would be driven at 25,200 R.P.M and would be damaged by this high speed.

To avoid such a condition, the cranking motor drive mechanism must quickly disengage the pinion from the flywheel, or the pinion from the cranking motor armature, the instant the engine begins to operate and increase in speed. The over-running clutch drive provides positive meshing and disengaging of the drive pinion and the flywheel teeth. The over-running clutch uses a shift lever to actuate the drive pinion which together with the over-running clutch mechanism, is moved endwise along the shaft and into or out of mesh with the flywheel teeth.

When cranking begins, the shift lever forces the over-running clutch assembly endwise along the shaft until the pinion meshes with the flywheel ring gear. If the pinion and the ring gear teeth should butt instead of mesh, all that happens is the pinion is held tightly against the ring gear as the shift lever movement continues and compresses the clutch spring; then after the cranking motor switch closes, the pinion need only rotate the width of 1/2 tooth before an alignment takes place and the pinion drops into mesh.

<u>OVER-RUNNING CLUTCH.</u>

The over-running clutch consists of a shell and sleeve assembly, which is splined internally to match splines on the drive shaft. The pinion and collar assembly fits within the shell. Four notches are cut into the shell into which are assembled four hardened steel rolls. The notches taper inward slightly. The pinion collar can rotate freely in the direction in which the roll tends to move against the spring. However, when the pinion is meshed with the flywheel teeth and the armature begins to rotate, the shell rotates in the direction for cranking. The rolls also rotate between the shell and collar and are forced tightly into the smaller part of the notches where they jam between the collar and the shell and force the pinion to rotate with the shell.

When the engine begins to operate, it attempts to drive the cranking motor armature through the pinion faster than the armature rotates. This spins the rolls back to the larger part of the slots where there is adequate room for them and the pinion can rotate freely with respect to the shell. In other words, the pinion over-runs the remainder of the assembly.

STARTING SOLENOID CONTACTOR.

On cranking motors which use an over-running clutch, the clutch is engaged and the motor circuit completed by an electro-magnetically operated switch mounted on the starter motor. The solenoid shifts the pinion into mesh with the ring gear and also connects the cranking motor to battery through a pair of contacts. Cranking motors draw approximately 120 amps at instant of engagement, and 35 amps while cranking the engine. Heavy contacts are required to handle this amount of current with minimum voltage drop and without damage. The switch part of the contactor consists of a movable disc attached to a plunger, and a pair of heavy fixed contacts. You will note from the sectional view of the solenoid that the solenoid armature must move a considerable distance before striking the plunger carrying the movable disc contact. The plunger is so connected with the clutch engagement linkage,so that pinion and ring gears are brought into mesh before an electrical circuit is made to rotate the starter.

The solenoid has two windings as shown; one, the pull-in winding consists of relatively few turns of heavy wire. The other, the hold-in winding, consists of many turns of fine wire; together they provide sufficient magnetic pull to engage starter gears and operate the disc contact. A strong magnetic field is required to pull the solenoid plunger into the coil, and after the plunger has been pulled in, less magnetism is required to hold it in. Therefore, the pull-in winding is connected across the solenoid switch contacts so that as the plunger forces the disc contact against the fixed contacts to complete the cranking motor circuit, the pull-in winding is shunted out of the circuit. This eleminates burning out the heavy pull-in winding without sacraficing a strong initial pull necessary to engage the pinion and close the contacts in the cranking motor circuit.

As soon as the engine has cranked and begins to run, the vacuum created in the intake manifold operates a vacuum switch which opens the circuit to the solenoid contactor coil, which allows the shift lever spring to disengage the starter motor pinion and also break the electrical circuit to the starter motor.

In order to minimize arcing of the solenoid contacts, under their heavy loading, an electrolytic condenser, not illustrated, is connected across the switch contacts. An electrolytic condenser has a very definite polarity and must be connected with the black or negative lead to that fixed contact which is negative while the starter contactor is open. The condenser lead which is red, or white with a red tracer, must be connected to that fixed contact which is positive when the contactor is open.

Whenever it is necessary to change a starting motor solenoid or a starting motor complete, the following adjustment must be made:

With the starter solenoid energized, the starter pinion should come to within 1/8" of the nose of the starter drive casting. Adjustment is made by turning in or out on the solenoid armature after disconnecting the link arm and dust cover. If through the engagement linkage, the starter pinion is allowed to strike the end housing, the housing will break under repeated impacts, and if the pinion is allowed too much clearance, its engagement with the ring gear on the flywheel is shallow resulting in eventual damage to the gears. Adjustment can only be made with the starter motor and solenoid removed from the unit, and no attempt should be made to replace the solenoid only without removing the starter motor and adjusting the solenoid plunger travel to the proper limit. It is difficult to make this adjustment by pushing the solenoid plunger in by hand because of the slotted joint in the engagement linkages.

VACUUM SWITCH.

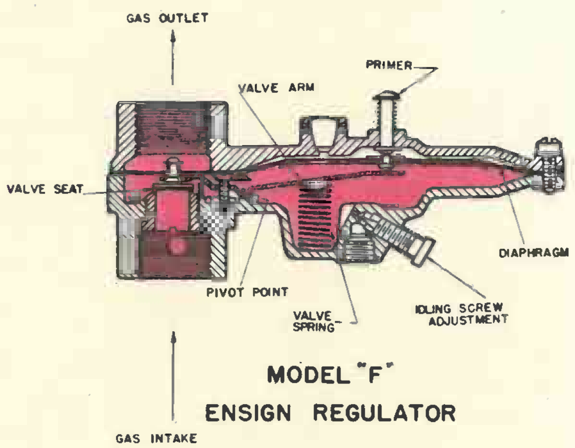
A cross section of a vacuum switch is shown on Chart #10. A vacuum switch is used on the Model "D" Ice Engine to de-energize the starting contactor after the engine begins to run. Two vacuum switches are used in the Model "E" Ice Engine control circuit; one to operate the starting contactor, and the other to de-energize the condenser contactor. The electrical functions of the vacuum switches has been explained in detail in connection with Charts Nos. 8 A and 8 B describing controls for the Model "E" and Model "D" Ice Engines respectively.

The top chamber of the vacuum switch is connected to the engine intake manifold and the operating diaphragm and plunger are pulled upward as a vacuum is developed. Their movement is opposed by action of a spring.

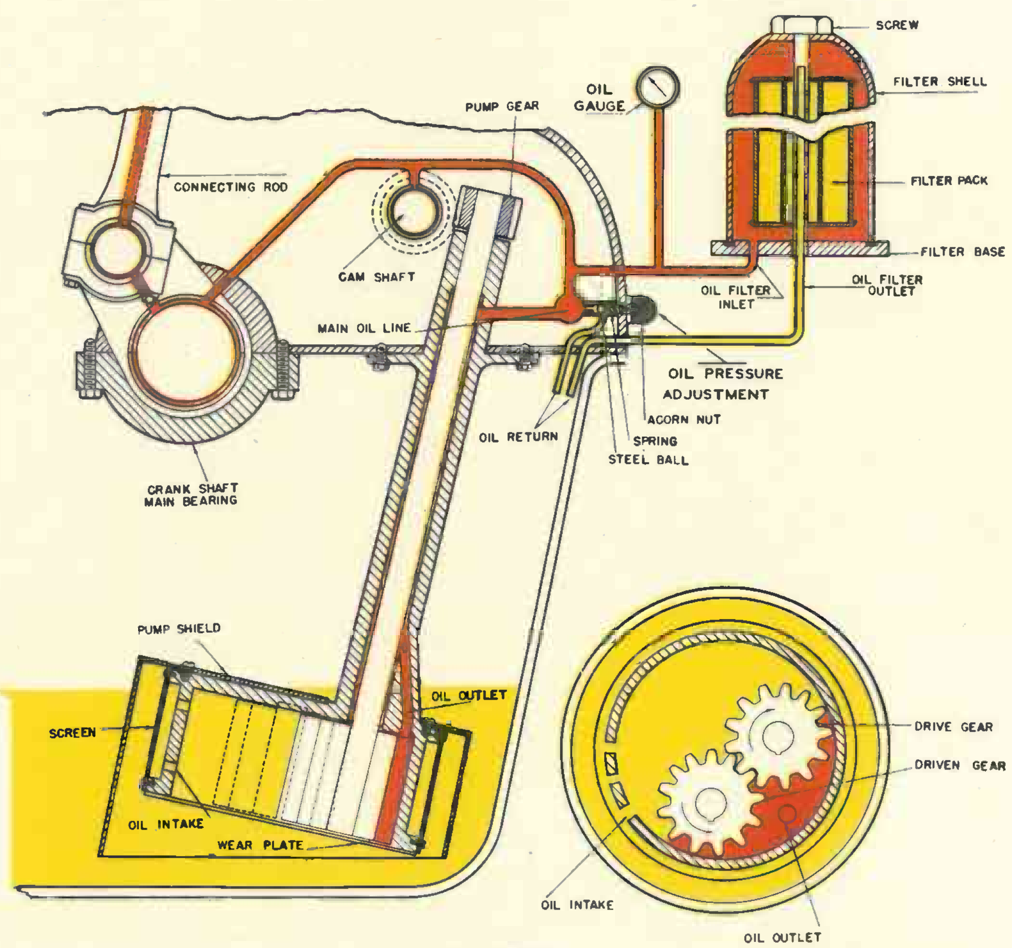
There are two vacuum switches now in use, the difference being in the size of the spring and consequently the degree of vacuum necessary to actuate the switch. The high vacuum switch has the heavier spring and requires the greater vacuum in the top diaphragm chamber in order to open.

The diaphragm plunger is connected to a snap switch whose contacts are normally closed and are only open when the pull of the vacuum exceeds that of the spring.

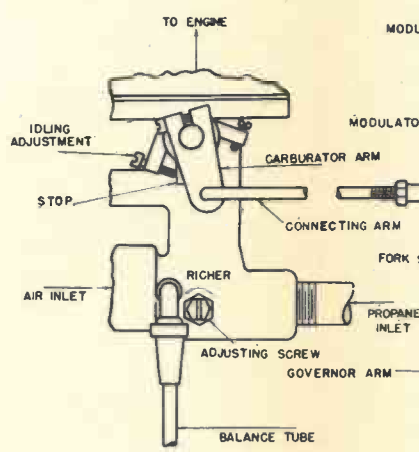
MISCELLANEOUS DETAIL



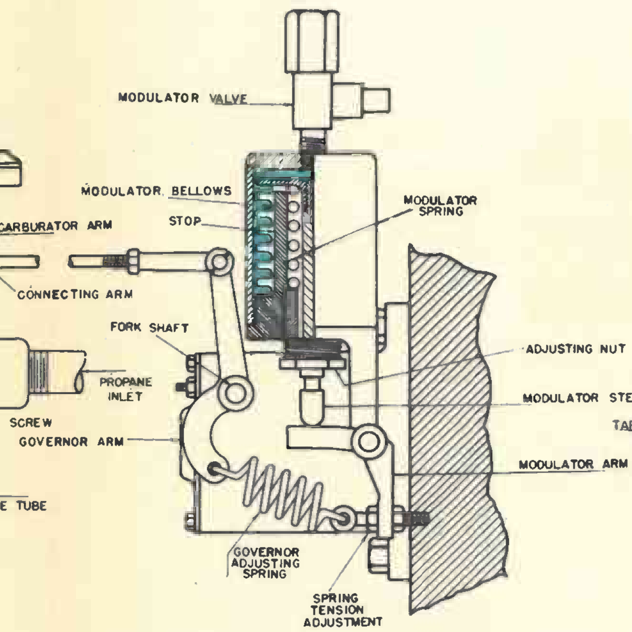
MODEL "F"
ENSIGN REGULATOR



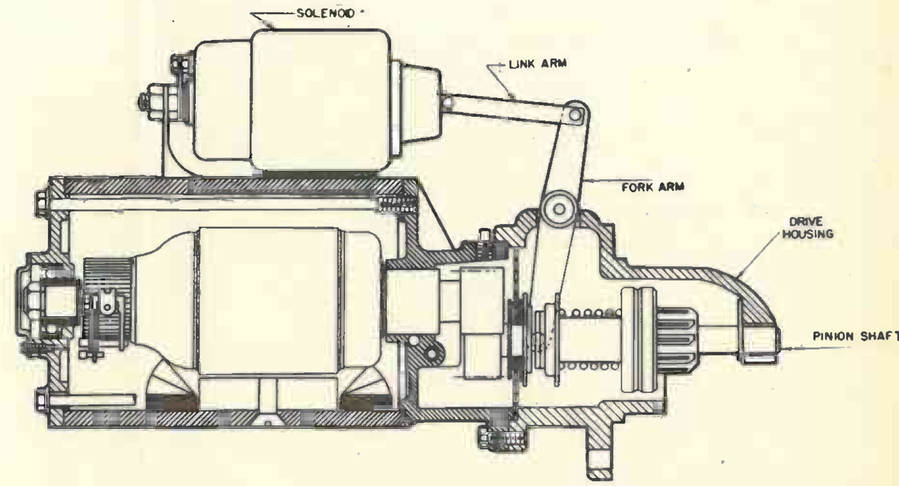
OIL PUMP



CARBURATOR



MODULATOR AND GOVERNOR



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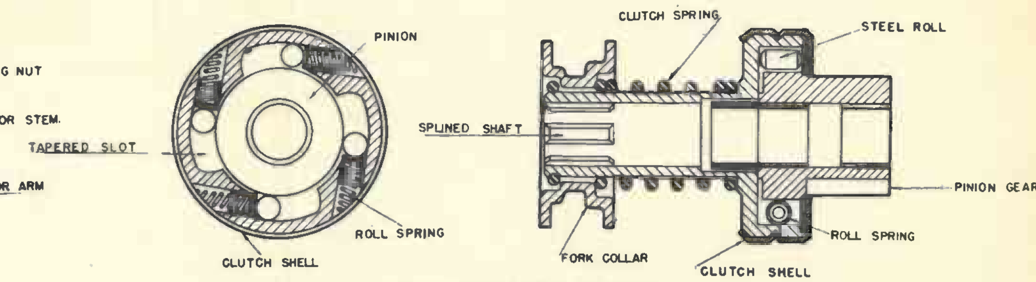

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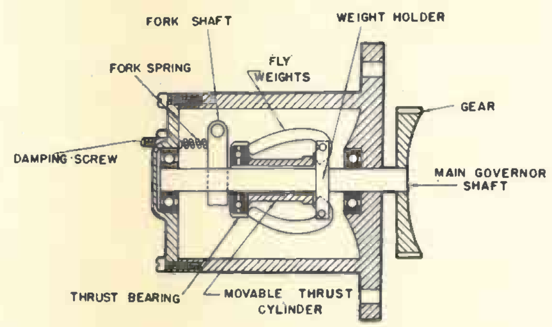
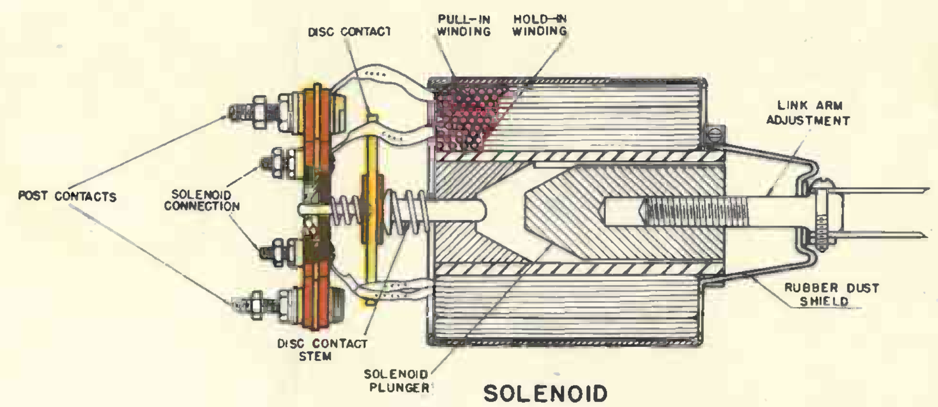


GOVERNOR



SOLENOID

NO. 9
(OF TEN CHARTS)

THE PULLMAN CO.
YARD DEPT. CHICAGO
FEB. 1944

WAUKESHA TEST AND MAINTENANCE

CHART 10

The purpose of this chart is to show the use of various test and servicing equipment used in Waukesha maintenence.

TIMING LIGHT.

After an engine has been timed, as explained on Page 26, the timing light must be used as a check on timing accuracy.

The timing light has a power pack made to operate on 32 volts D. C., which can be obtained by connecting across terminals of generator terminal blocks, or across brushes of 2KW armatures on streamliner ice engine units, and on Model "D" Ice Engine Units, 32 volts can be obtained across the contacts of the starter contactor. Another method for obtaining power to operate the timing light is to extend the 32 volt leads and equip them with a battery charging plug which can be plugged into the car receptacle. The third, or single lead, from the timing light is connected to either number one or number four spark plug cable. A flash is obtained at each firing impulse of spark plug, which in effect, stops the motion of the flywheel so that the timing mark can be plainly seen.

It is suggested that a white line be painted on the flywheel on either side of the timing mark so that the timing mark may be readily identified, as it is not always easy to see because of the limited opening in the unit frame and flywheel housing.

TACHOMETER.

The tachometer is used to check engine speed and indicates revolutions per minute directly on a dial. One lead from the tachometer is connected to the grounding terminal on the magneto and the other lead to ground any place on the unit frame. The magneto grounding terminal connection can also be picked up at the terminal block on Model "E" Ice Engine Units, or on the lower contacts on the high or low pressure switches in the control box of Model "D" Ice Engine Units; so that it is not necessary to go behind the unit to make connections.

Select the 4500 R.P.M. scale on the meter, and turn the selector switch to battery check. The indicator on the instrument should then swing over to the extreme right hand blue colored segment of the scale marked "battery check." If the needle does not swing into the blue area, replace the two flashlight batteries under separate covers in the left-hand side of the Tachometer case. After the batteries have been checked, and found to be serviceable, the selector should be set to the "eight lobe" position.

The engine is then started and its speed read directly on the meter. All generator units should operate at 1100 R.P.M. full load speed. The speed of Model "D" and Model "E" Ice Engines depend upon low side freon pressure, because of the effect of the modulator on the governor. Engine speed corresponding to various suction pressure gauge readings are shown on the chart cemented in the cover of the tachometer case.

RADIATOR FLUSHING GUN.

The radiator flushing gun consists of a "Y" fitting, a quick opening trip valve, an air chamber consisting of a 1½" diameter pipe nipple 3½" in length with an orifice plate having 1/8" opening on the inlet side, and pipe fittings to connect the gun to the radiator header and to air and water supply.

To use the gun the top radiator hose connection and radiator inspection covers are removed and also the pipe plug in the radiator flushing fitting. The gun is then threaded into the radiator fitting and a water hose and high pressure air line connected as shown on Chart. With the trip valve on the gun in the "off" position, water is then turned on and the rate of flow adjusted so that it slowly spills out of the radiator inspection cover and top hose connection. The trip valve is then opened and immediately closed, which allows the high pressure air stored in the 1-1/2" pipe nipple to rapidly expand in the lower radiator header, forcing high velocity jets of water up through the radiator core dislodging insoluble foreign matter from the core. A piece of sheet metal should be held up to the side of the radiator inspection cover to protect the operator from being splashed by the water as it is blown out of the radiator. As the water fills up the radiator and again begins to overflow, foreign matter can be seen washing out and the trip valve is again opened and the process repeated until it is reasonably certain that the core is free of foreign matter.

TESTING OF ENGINE TEMPERATURE SWITCH.

The engine illustrated on Chart #10 is shown with a test thermometer inserted in the engine head alongside of the temperature bulbs of the oil-heat switch. With the exception of streamliner units, the cut-out temperature can easily be reached by blocking off the inlet side of the engine radiator, and allowing the engine to operate.

After inserting test thermometer in engine head, cover the radiator so the engine temperature will rise. With the engine operating, connect a bell test set across the contacts of the snap switch in the oil-heat switch case. When the engine temperature reaches 220° set the temperature adjustment of the oil-heat switch so that the snap switch will close. The closing of the snap switch will be indicated by ringing of the bell test set.

For streamliner units which are set at 265° it is necessary to remove temperature bulb from the engine head and after blocking the snap switch open by inserting a wedge under the lever arm actuated by the oil pressure bellows, and connecting a bell test set as outlined above; the temperature bulb is then inserted in an oil bath which is heated with a torch. The test thermometer is also inserted in the hot oil bath and the oil stirred constantly to obtain a uniform temperature. The snap switch is set to close at 265° under these conditions. A 1/8" pipe coupling drilled for free circulation is applied to the end of the test thermometer to prevent breaking the mercury bulb when used in an open bath.

COMPRESSION GAUGE.

The gauge furnished for reading the compression in the engine cylinders is of the maximum reading type, that is, the gauge indicator will register and hold the highest pressure obtained until reset by a relief button on the gauge case. A compression gauge reading indicates the internal condition of the cylinder in which it is installed. For a good compression reading, it is necessary that the intake and exhaust valves seat properly and the cylinder walls, piston and piston rings be in good condition. An unusually low compression reading indicates that additional attention to the engine is required.

The lowest compression pressure that would be called acceptable is 75 lbs. when read under the following conditions:

1. All of the spark plugs removed to increase the cranking speed.

2. The maximum reading type of gauge used.

3. Reading observed after 10 to 12 compression strokes. (Take reading after the same number of compression strokes on all cylinders for comparative results.)

4. Engine warm and properly lubricated.

5. A cranking speed of 125 R.P.M. or more.

On a new or overhauled engine which has been properly broken in and properly lubricated, you should get a pressure reading range from 115 to 140 lbs. when warm.

Another factor almost as important as the actual pressure measured, is the variation in pressures obtained on the four cylinders of the same engine. When a reading is obtained 10 to 20% lower than the highest reading obtained, even though the lowest reading may be above 75 lbs., the cause for the low reading should be investigated. The next step is to inject some heavy oil around the piston and cylinder walls to properly seal the piston. Then after cranking the engine a few times to properly distribute the oil on the cylinder wall, another pressure reading should be taken and if the pressure reading is still considerably below the average reading, it indicates, of course, that most of the compression loss is through either of the valves instead of past the piston.

TENSION INDICATING WRENCH.

A tension indicating wrench must be used when tightening engine head bolts and connecting rod bearing cap bolts. Although the tension indicating wrench is sturdy, it must be treated as an instrument and not as you would an ordinary socket extension handle. Do not use this wrench as a general purpose wrench and do not use it beyond its range.

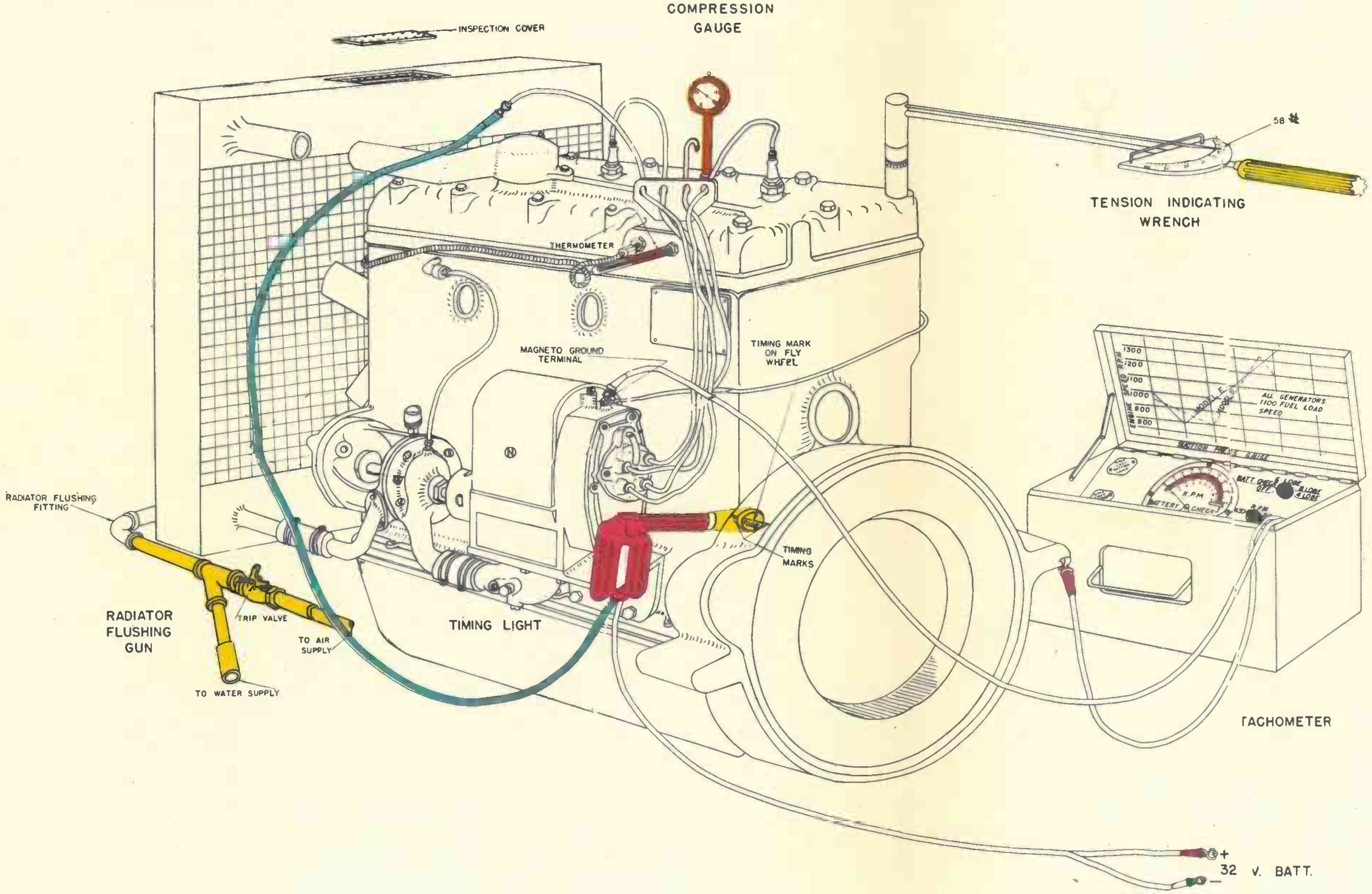
Torque wrench recommendations for various applications may be found on Page 74 .

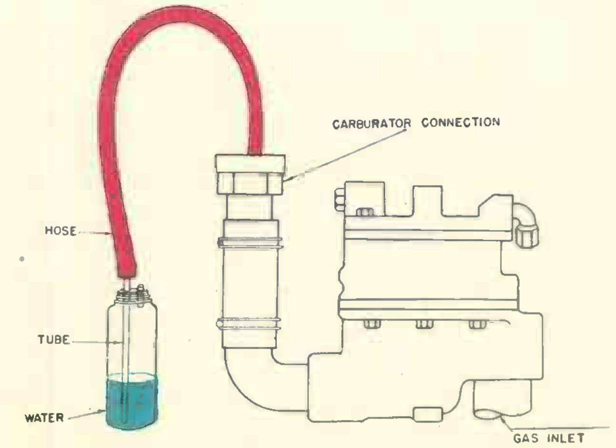
TEST FOR ENSIGN REGULATOR SHUT-OFF.

After not having run for a length of time some units experience difficulty in cranking. Some of the troubles have been traced to failure of the Ensign regulator to shut off completely. This condition is identified by observing the cranking of an engine that has been shut down for a time. The engine may have a long cranking period and then run "rough" upon starting until the rich mixture due to propane accumulated in the engine air filter and manifold has been scavenged out. If the unit is stopped and started again immediately, it will start normally.

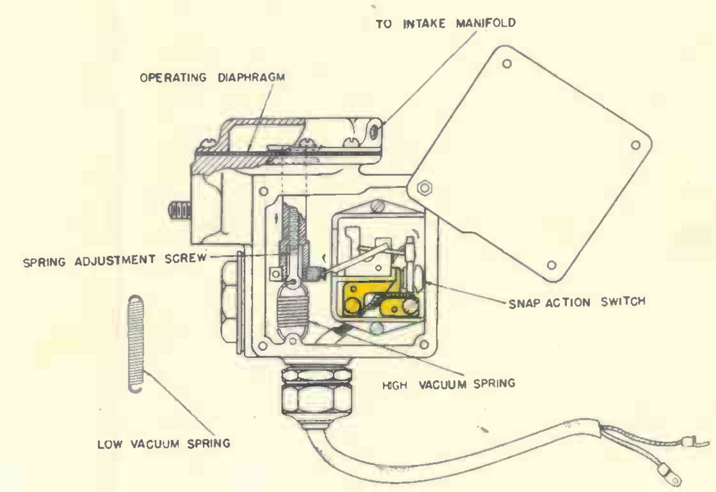
For a quick check when the Ensign regulator is suspected of leaking, and as part of a monthly inspection, a tester consisting of a jar, tubing, and fitting, as shown on the chart, should be made up locally. Break the fuel line union at carburetor and holding fitting against half union, observe if bubbles appear in water filled jar. Blow gently against top regulator diaphragm through breather or equalizer opening, and see if regulator again shuts off. Should bubbles appear when regulator is closed, the top half of regulator body will be removed after shutting off fuel lines and the main valve and seat inspected.

WAUKESHA SERVICE & TEST





TESTING OF ENSIGN REGULATOR SHUT-OFF



DETAILS OF VACUUM SWITCH

NO. 10
(OF TEN CHARTS)

THE PULLMAN COMPANY
YARD-DEPT. CHICAGO
FEB. 1944

INSPECTION PROCEDURE MODEL "D".

The following procedure will be followed in servicing of Waukesha Ice Engine Units. In addition, the present instructions as called for in "Maintenance Instructions - Air Conditioning Equipment - District Yards" are to be followed in servicing parts of this equipment that are common to all types, such as blower fans, filters, etc.

DAILY INSPECTION

1. Turn blower fan "On" and set selector switch for cooling. Observe if unit starts by indication of pilot light. Turn selector switch to "Off" position, allowing blower fan to continue to run. Put a jumper across "Yard Test" posts.

2. Remove front cover from engine compartment. Blow out compartment and engine radiator thoroughly.

3. Check oil level in crankcase, adding oil if necessary. Use SAE #30 for summer and SAE #10 for winter operation. Summer grade oil will be used only during period of April 1st to November 1st. Remove bottom assembly of engine air cleaner, drain dirty oil, clean out cup with solvent Catg. L-3 and fill to proper level with clean engine oil of the same SAE number as used in crankcase. Clean engine oil bath breather in a similar manner. Empty cup on air pre-cleaner on units so equipped. Check water level in engine radiator.

4. Start equipment from control box by lifting toggle starting switch. Observe engine operation. Check fuel pressure to engine regulator at mercury manometer. With engine operating this should be approximately 3 to 6 ounces.

5. Observe compressor operation. Check cooling effect by feeling compressor flexible freon lines and observing high and low pressure gauge readings.

6. Wash out sub-cooler air filter during season when in use, Sub-cooler sump drain plug is to be applied and make up water turned on only after danger of freezing weather has passed. Sump drain plug must be removed and water shut off before freezing weather is encountered. The sub-cooler motor is to be disconnected when sub-cooler is drained for winter service to prevent pump shaft from being scored. For cars operating in dusty territory it will be necessary to flush out sub-cooler as outlined in Item 6 under Weekly Inspection.

WEEKLY INSPECTION

1. Roll unit out on track extensions. Remove all covers from both engine and compressor compartments. Blow or wash out both compartments. If condensers or engine radiator is caked with foreign matter, same should be washed clean with water. When water is used, avoid soaking magneto and ignition cables and keep water off manifolds when hot.

2. Check entire engine assembly for oil or water leaks. Check radiator filling cap gasket.

3. Turn grease cup on engine water pump one half turn. Use lubricant Pullman Cat. K-6362, for water pump. Check water pump packing gland. Gland pressure should be just tight enough to prevent leaks.

4. Start equipment from control box by lifting toggle starting switch. Observe operation of starting motor, engine vacuum switch, engine modulator, compressor by-pass valve, engine oil pressure and oil pressure switch, low pressure switch and engine manifold vacuum.

5. Check freon level in receiver tank; also flow of freon through liquid line strainer.

6. Drain and flush out sump of evaporative sub-cooler. See that make-up water line from car water tank to sub-cooler sump is open. Clean water strainer and refill sump. Clean sub-cooler air intake filter by washing off with water.

SEMI-MONTHLY INSPECTION

(In addition to Weekly Inspection Features)

1. Check all belts for physical condition and proper tension.

2. Check visually magneto and ignition wiring. Ignition cables should be as far removed from hot manifolds as possible. Check magneto fiber coupling for proper clearance of approximately .015" between coupling and drive member. See that magneto drive shaft coupling nut is tight.

3. Remove, clean and set gap on spark plugs to .016". Allow no dirt to enter engine through plug openings. Replace plugs having cracked porcelain, or when gap is beyond adjustment. Gap adjustment is made by bending side electrodes only.

4. Check unit and suspension by visual inspection for loose bolts, fittings, or fractured parts.

MONTHLY INSPECTION

(In addition to semi-Monthly Inspection Features)

1. Remove upper half of engine air intake filter, air connection to carburetor, and carburetor. Clean in Solvent #L-3. Reapply after blowing dry with compressed air. Test ensign regulator for shut off.

2. While carburetor is removed for cleaning, take off valve cover plates and set tappets to .010" for intake and .012" for exhaust valves with engine cold.

3. Check for freon leaks.

4. Check for propane fuel leaks by odor of tracer gas. Leak can be located by soap bubble test, painting suspected lines with soap water.
CAUTION: Do not use any flame around fuel cabinet until all traces of gas have been blown out of the fuel lines.

5. Check settings of pressure regulators by shutting off all cylinders individually, with the exception of the low pressure cylinder in cabinet governed by the 3 ounce regulator. With engine in operation the fuel pressure gauge on cabinet manifold should show 10 lbs.. Open cylinder valves progressively from low pressure position to high pressure position. Pressure should increase to 20, 30, and finally 40 lbs.. Open Cylinder valves in second fuel cabinet governed by 5 ounce regulator in a similar manner. Pressure will again increase progressively, as before. All valves must be left in open position. Valves must be opened slowly to prevent slugging.

6. Check engine fuel mixture adjustment. Turn fuel adjustment screw clockwise until engine loses speed, then turn counterclockwise until highest vacuum is obtained. Adjustments must be made with engine under a steady load.

7. Check engine operating speed with electric tachometer.

8. Test operation of crank limit switch by grounding magneto and holding starting toggle switch in starting position, allowing starter to crank engine until crank limit switch trips out. This limit should be approximately three minutes. During this period the intermittent starting switch should allow the engine to crank for 15 seconds with 45 second off-cycle intervals. Clean magneto rotor and wipe out distributor cap.

9. Set low pressure switch to stop engine at 7½ lbs. and start engine at 15 lbs., using Pullman low pressure test gauge. Check low pressure gauge against test gauge. Set high pressure switch to open upper contacts at 300 lbs.. Upper contacts should close at 295 lbs.. Set high pressure switch to close its lower contact at 350 lbs.. Use Pullman high pressure test gauge to check settings up to 300 lbs.. For higher pressure use gauge in control box if it is found to be accurate at 300 lbs. as checked against test gauge. On streamliner units the high pressure switch is set to stop engine at 290 lbs. and to cut in at 270 lbs. Set sub-cooler pressure switch to start motor at 175 lbs. and to stop motor at 150 lbs.

10. Check oil level in compressor crankcase after unit has run for 1/2 hour.

11. Using lubricant, Pullman Cat. K-6939, grease sparingly the six lubricating points on compressor and condenser fan drive which are equipped with Alemite fittings.

12. While engine is warm, remove oil filter and crank engine (with ignition grounded) sufficiently to cause oil to flow at oil filter base, showing oil line to be open. Change oil in crankcase. Allow about 1 qt. of oil additional for saturating new waste in filter element. Repack oil filter element with clean waste, Cat. M-1193. Do not pack filter too tightly. A loosely packed filter will handle more oil because of its low resistance, consequently removing more foreigh matter. In correctly packed filter, old waste will fall away from the shell when inner tube is removed.

13. While spark plugs are removed, check compression in each cylinder following procedure as outlined on page 57.

14. Apply one drop of engine oil to each bearing on starting motor. Apply one drop of engine oil to governor and modulating linkages on carburetor control.

15. Rotate unit mounting wheels 1/4 turn to change loading on springs.

3-MONTH INSPECTION

(In addition to Monthly Inspection Features)

1. Using lubricant, Pullman Cat. K-6939, grease compressor pulley bearings and sub-cooler motor bearings.

2. Wash exterior of condensers, engine radiator and sub-cooler coils with Oakite Penetrant. Straighten any bent fins on engine radiator.

3. Remove magneto for thorough inspection on magneto test rack.

4. Test operation of oil-heat switch, adjust oil pressure switch to open at oil pressures above 5 lbs. (by varing oil pressure at adjusting screw on engine block at low engine speed.) By blocking inlet side of engine radiator and inserting test thermometer into engine head alongside of temperature bulb, set temperature switch to close at 220°. (Streamliners set to 265° in hot oil bath.)

5. Remove electrical plugs and inspect for corrosion in receptacles.

6-MONTH INSPECTION.

(In addition to 3-Month Inspection Features)

1. Clean propane line filter located ahead of intake to Ensign regulator.

2. Overhaul and test vacuum switches.

3. Remove top of Ensign regulator, inspect pilot diaphragm and pilot valve. Replace any diaphragm that has a hard glazed spot on an oil spot.

4. Remove radiator inspection plates and examine interior of radiator for rust, scale, and grease clogged tubes. Wash out radiators when necessary, using radiator flushing gun and cooling system cleanser.

SAFETY PRECAUTIONS:

While servicing Ice Engine Units, remove control cable plug from car receptacle to prevent engine from being cranked. On cars with remote control features, remove cables carrying starting circuit.

INSPECTION PROCEDURE MODEL "B"

The following procedure will be followed for servicing of Waukesha engine generator units. In addition, the present instructions as called for in "Instructions for Car Lighting Maintenance Pullman Cars" are to be followed in servicing parts of equipment that are common to all types such as reverse current relays, regulators, etc.

DAILY INSPECTION

1. Incoming test.

2. Without rolling unit from under car, remove front engine cover and blow out engine compartment and radiator.

3. Check oil level in crankcase, adding oil if necessary. Use SAE #30 for summer and SAE #10 for winter operation. Summer grade oil will be used only during period of April 1st to November 1st. Remove bottom assembly of engine air cleaner drain dirty oil, clean out cup with solvent Cat. #L- 3, and fill to proper level with clean engine oil of the same SAE number as used in crankcase. Clean engine oil bath breather in a similar manner. Empty cup on air pre-cleaner on units so equipped. Check water level in engine radiator.

4. Start engine from control box and observe engine operation. Check fuel pressure to engine at mercury manometer. This should be from 3 to 6 oz. with engine in operation.

5. Shut off engine from control panel inside of car. Observe one 3 minute cycle of automatic starting timer.

WEEKLY INSPECTION

(In addition to Daily Inspection Features)

1. Roll unit out on track extensions. Remove, top, front and rear engine compartment covers. Inspect engine for oil or water leaks, wash or blow out unit, paying particular attention to radiator core. If water is used, avoid soaking magneto and keep water off manifolds when hot.

2. Blow out ventilating fins in generator shell. Remove generator hand hole cover and blow carbon dust out of interior of machine. See that brushes are free in brush boxes.

3. Turn grease cup on engine water pump one half turn. Use lubricant, Cat. K-6362, for water pump. Check water pump packing gland. Gland should be tightened only enough to prevent leaks.

4. See that auxiliary top contact on reverse current relay is clean and free of dust.

5. Test radiator filling cap gasket.

SEMI-MONTHLY INSPECTION

(In addition to Weekly Inspection Features)

1. Check engine fan belt for tension and physical condition. Belt should have about 1" total movement midway between the two pulleys when pressed between fingers.

2. Check visually magneto and ignition wiring. Ignition cables should be as far removed from hot manifolds as possible. Check magneto fiber coupling for proper clearance of approximately .015" between coupling and drive member. See that magneto drive shaft coupling nut is tight.

3. Remove, clean and set gap on spark plugs to .016". Allow no dirt to enter engine through plug openings. Replace plugs having cracked porcelain, or when gap is beyond adjustment. All adjustments should be made by bending side electrodes.

4. Check unit and suspension for loose bolts, fittings, or fractured parts.

MONTHLY INSPECTION

(In addition to Semi-Monthly Inspection Features)

1. Remove upper half of engine air intake filter, air connection to carburetor, and carburetor. Clean in Solvent #L-3. Reapply after blowing dry with compressed air. Test Ensign regulator for shut off.

2. While carburetor is removed for cleaning, take off valve cover plates and set tappets to .010" for intake and .012" for exhaust valves with engine cold.

3. Check engine fuel mixture adjustment. Turn fuel adjustment screw clockwise until engine loses speed, then turn counterclockwise until highest vacuum is obtained. Be sure to fasten lock nut securely. Adjustment must be made with engine under a steady load.

4. Check for propane fuel leaks by odor of tracer gas. Leak can be located by soap bubble test, painting suspected lines with soap water.
CAUTION: Do not use any flame around fuel cabinet until all traces of gas have been blown out of fuel lines.

5. Check settings of pressure regulators by shutting off all cylinders individually, with the exception of the low pressure cylinder in cabinet governed by the 3 ounce regulator. With engine in operation the fuel pressure gauge on cabinet manifold should show 10 lbs.. Open cylinder valves progressively from low pressure position to high pressure position. Pressure should increase to 20, 30 and finally 40 lbs.. Open cylinder valves in second fuel cabinets governed by 5 ounce regulators in a similar manner. Pressure will again increase progressively, as before. All valves must be left in open position. Valves must be opened slowly to prevent slugging

6. While engine is warm, remove oil filter and crank engine (with ignition grounded) sufficiently to cause oil to flow at oil filter base, showing oil line to be open. Change oil in crankcase. Allow about 1 qt. of oil extra for saturating new waste in filter element. Repack oil filter element with clean waste, Cat. M-1193. Do not pack filter too tightly. A loosely packed filter will handle more oil because of its low resistance, consequently removing more foreign matter. In a correctly packed filter, old waste will fall away from the shell when the inner tube is removed.

7. While spark plugs are removed, check compression in each cylinder following procedure as outlined on page 57.

8. Remove distributor cap and magneto distributor rotor. Wipe cap and rotor to remove carbon dust. Inspect magneto breaker contact. Contacts are in perfect condition when surfaces are clean, even, and show a fine grained or frosty appearance. Dirty or slightly pitted contacts can be dressed with fine sandpaper or crocus cloth. Check gap setting Check engine timing with timing light.

9. Check operating speed by using electric tachometer. Engine should operate at 1100 R.P.M. at any load.

10. Rotate unit mounting wheels 1/4 turn to change loading on springs.

11. Test operation of engine exhaust by-pass valve.

12. Inspect generator control panel relays and, if necessary, clean contacts.

3-MONTH INSPECTION

(In addition to Monthly Inspection Features)

1. Grease the ball bearing in commutator end of generator, using lubricant, Pullman Cat. K-6940.

2. Remove magneto for thorough inspection on magneto test rack.

3. Test operation of oil-heat switch. Adjust oil pressure switch to open at oil pressures above 5 pounds (by varying oil pressure at adjusting screw on engine block) at low engine speed. By blocking off air to inlet side of engine radiator and inserting test thermometer into engine head alongside of temperature bulb, set temperature switch to close at 220°. (Streamliners set to 265° in hot oil bath).

4. Wash exterior of engine radiator with Oakite Penetrant. Straighten any bent fins.

5. Remove electrical plug and inspect for corrosion in control receptacle

6. Check settings of load current and low current stop relays.

6-MONTH INSPECTION

(In addition to 3-Month Inspection Features)

1. Clean propane line filter located ahead of intake to Ensign regulator.

2. Remove top of Ensign regulator and inspect pilot diaphragm and pilot valve. Replace any diaphragm that has a hard glazed spot or an oil spot.

3. Remove radiator inspection plates and examine interior of radiator for rust, scale, and grease clogged tubes. Wash out radiators when necessary, using radiator flushing gun and cooling system cleanser.

SAFETY PRECAUTIONS:

Your attention is called to the possibility of cranking of engine generator unit through someone accidently closing the reverse current relay. While the lock-out feature on the stop button is entirely adequate for most service conditions, if a repairman is required to place himself in a position as to be injured should the engine be started accidently, he will remove both the main generator and motor cranking fuses, the former from the reverse current relay panel and the latter from the Waukesha control panel. These fuses are to be retained in his possession until his work on unit is completed.

INSPECTION PROCEDURE MODEL "E" AND "C". STREAMLINER UNITS.

The preceding instructions for inspection procedure for Model "D" Ice Engine Units and Model "B" Engine Generator Units apply, with few exceptions, to similar units on Streamliner cars. Because of differences in the mounting of units under the cars, differences in engine assemblies, and differences in scheme of controls; the following items will be added to inspection procedures in addition to items already listed which are common to Streamliner and other lightweight cars.

DAILY INSPECTION

1. See that level in radiator expansion tank is 1/2 full as indicated on gauge glass and that there are no leaks at hoses or fittings.

WEEKLY INSPECTION

1. Inspect for broken or missing springs in engine fan drive. Check for excessive play in engine fan gears.

2. Test strength of engine radiator solution with anti-freeze tester. Maintain a 75% solution strength in summer and 50% in winter.

3. (Ice units only). Check operation of both vacuum switches by observing sequence of starting and condenser contactors.

4. Check operation of condenser fan and sub-cooler motors.

5. Blow out interior of 2 K.W. generator. Check condition of brushes and commutator.

SEMI-MONTHLY INSPECTION

1. Test torque at which engine fan slips using a spring scale with hook inserted in hole provided in one fan blade. With steady pull at right angles to fan blade, slippage should occur at 10 lbs. as read on scale. Adjust fan drive spring compression with nut on fan shaft if necessary.

2. Check condition of control cables.

3. (Ice units only). Measure voltage generated by 2 K.W. generator with engine speed of approximately 1400 R.P.M. and condenser fans and sub-cooler operating, voltage across terminals #13 and #16 on ice engine control panel should measure 30 to 32 volts.

4. Check condition of relay contacts on panel.

MONTHLY INSPECTION

1. Inspect Propane cabinet for physical condition especially tank cradles and fastening devices. Lubricate pivots and fittings.

2. (Ice units only). Ring out control cable from plug contacts to unit terminal board with bell test set at time of inspection of plug and receptacle.

3. Test time of trip out of oil-heat, crank limit, and hi - low stop switches.

4. Set low pressure switch to stop engine at 5 lbs. Set high pressure switch to stop engine at 290.

WAUKESHA LUBRICATION CHART

WHERE USED	MODEL	LUBRICANT: WINTER SAE 10 SUMMER SAE 30 M-885	K-6939	K-6362	K-2821	K-6940	M-1532	K-10609	K-11001
COMPRESSOR (CHECK OIL)	D				M				
COMPRESSOR DRIVE SHAFT	D		M						
COMPRESSOR PULLEY	D		3 MO.						
COMPRESSOR FAN	D		M						
ENGINE CRANKCASE (CHECK OIL) (CHANGE OIL)	All	D M							
ENGINE AIR CLEANER	All	D							
ENGINE RADIATOR FAN	D-B								6 MO.
ENGINE WATER PUMP	All			W					
ENGINE STARTER MOTOR	D	M							
MAGNETO	All		(AT TIME ON TEST RACK)					3 MO.	
GENERATOR, 7½ KW	All					3 MO.			
SUB-COOLER MOTOR	D-E		3 MO.						
UNIT WHEELS	All		OVER-HAUL						
GOVERNOR & CONTROL LINKAGES	All	M							
BELT TENSION SCREWS	D						M		
CONDENSER FANS	E		3 MO.						
COMPRESSOR (ROTARY)	E	60 AUTOMOTIVE OIL IN SEALED CANS M885							

TABULATED DATA
MODEL "D" ICE AND MODEL "B" GENERATOR UNITS

Engine Model	FC
Bore	3 1/4"
Stroke	4"
Oil capacity with filter	5 quarts
Oil pressure (lbs. per sq. in.)	15-35
Valve tappet clearances cold - Exhaust	.012"
Valve tappet clearances cold - Intake	.010"
Spark plug gap	.016"
Magneto breaker point gap	.017"
Cooling water capacity - Ice Unit	16 quarts
Cooling water capacity - Generator Unit	13 quarts
Anti-freeze protection - winter - test good for	-30° F
Oil-heat switch contacts close - below 5 lbs. oil pressure	
Oil-heat switch contacts close - above 220° engine temp.	
Generator KW	7 1/2
Field poles	4
Interpoles	4
Load current relay opens contacts	60 amps.
Load current relay closes contacts	55 amps.
Low current stop relay closes contacts	45 amps.
Compressor Oil capacity (300° viscosity)	6 quarts
Bore	3 1/2"
Stroke	2 1/2"
Displacement	96 cu. in.
Speed ratio Engine to Compressor	2
Speed ratio Condenser Fan to Engine	1.5
Sub-cooler motor	1/2 H.P.
Volts	32
Amperes	16
Speed	1725 R.P.M.
Sub-cooler pressure switch contacts close	175 lbs.
Sub-cooler pressure switch contacts open	150 lbs.
Sub-cooler choke: water flow at 25 lbs. pressure	1 gal.in 5 min.
Intermittent starting switch: 15 sec."on" - 45 sec."off".	
Crank limit stop switch trips - Ice Unit	3 min.
Oil-heat stop switch trips - Ice Unit	4 min.
Oil-heat stop switch trips - Generator Unit	1 1/2 min.
Freon low pressure switch closes upper contact	15 lbs.
Freon low pressure switch closes lower contact	7 1/2 lbs.
Freon high pressure switch opens upper contact	300 lbs.
Freon high pressure switch closes lower contact	350 lbs.
Vacuum switch contacts open at Engine manifold vacuum of	1 1/2 "
Generator Engine speed	1100 R.P.M.
Ice Engine speed maximum at 40 lbs.freon suction pressure	1225 R.P.M.
" " " minimum " 14 " " " "	750 R.P.M.

TABULATED DATA
MODEL "E" ICE AND MODEL "C" GENERATOR UNITS

Engine Model	FCX
Bore	3 3/8"
Stroke	4 "
Oil capacity with filter	5 quarts
Oil pressure (lbs. per sq. in.)	15-35
Valve tappet clearances cold - Exhaust	.012"
Valve tappet clearances cold - Intake	.010"
Spark plug gap	.016"
Magneto breaker point gap	.017"
Engine Cooling solution capacity with 1/2 full expansion tank	9 gal.
Anti-freeze protection - winter - test good for	-30° F
Anti-freeze solution strength - summer	75%
Oil-heat switch contacts close - below 5 lbs oil pressure	
Oil-heat switch contacts close - above 265° engine temp.	
Generator KW	7 1/2
Field poles	4
Interpoles	4
Load current relay opens contacts	60 amps.
Load current relay closes contacts	55 amps.
Low current stop relay closes contacts	45 amps.
Starter Generator KW	2
Voltage	32
Field poles	8
Compressor	
Oil capacity	7 pints
Condenser fan motor, each	1/2 H.P.
Volts	32
Amperes	16
Speed	1725 R.P.M.
Sub-cooler motor	1/2 H.P.
Volts	32
Amperes	16
Speed	1725 R.P.M.
Sub-cooler pressure switch contacts close	175 lbs.
Sub-cooler pressure switch contacts open	150 lbs.
Sub-cooler choke: water flow at 25 lbs. pressure	1 gal. in 5 min.
Intermittent starting switch: 15 sec. "on" - 45 sec. "off".	
Crank limit stop switch trips - Ice Unit	3 min.
Hi-low stop switch trips - Ice Unit	1 1/2 min.
Oil-heat stop switch trips	1 1/2 min.
Low vacuum switch contacts open at engine manifold vacuum of	1 1/2 "
High " " " " " " " " "	7 "
Generator engine speed	1100 R.P.M.
Ice engine speed maximum at 40 lbs. freon suction pressure	1400 R.P.M.
" " " minimum " 14 " " " "	800 R.P.M.

Overhauling Tolerances for Waukesha Engines and Compressors.

A-Manufacture Std. B-Serviceable C-Repair or Replace

	A	B	C
Cylinder taper	.0005	.008	.010
Out of round	.0005	.002	.005
Maximum oversize	.0015	.010	.015
Crankshaft			
Straightness	.001	.004	.005
Journals taper	.0005	.004	.005
Journals out of round	.0005	.004	.005
Bearing Clearance	.0015-.0035	.005	.008
End play	.003 -.008	.010	.015
Camshaft Bearings			
Straightness	.001	.003	.005
End play	.003-.006	.008	.015
Connecting rods.			
Bearing clearance	.001-.003	.004	.005
End play	.005-.008	.015	.020
Piston Clearance	.003	.005	.007
Piston Ring Clearance			
Ring Clearance	.002	.004	.006
Gap top ring	.010-.017	.025	.040
Gap 2nd ring	.007-.017	.025	.040
Gap oil ring	.007-.015	.025	.040
Valve Clearance in Guides			
Intake	.002-.003	.004	.006
Exhaust	.003-.004	.005	.007

Valve spring Compression: 36 lbs. plus or minus 4 lbs. at 1 29/32" or 71 lbs. plus or minus 6 lbs. at 1 5/8".

	A	B	C
Piston Pin Clearance	.0002-.0008	.0015	.003

Torque Wrench Recommendations

	Size	Wrench Torsion
Engine head	7/16" - 14	58 foot lbs. - 63 Ft. lbs. on steel head gaskets.
Connecting rods	3/8" - 24	58 foot lbs.

Tighten bolts and nuts in a staggered fashion - a little at a time on each until drawn up as indicated by torque wrench.

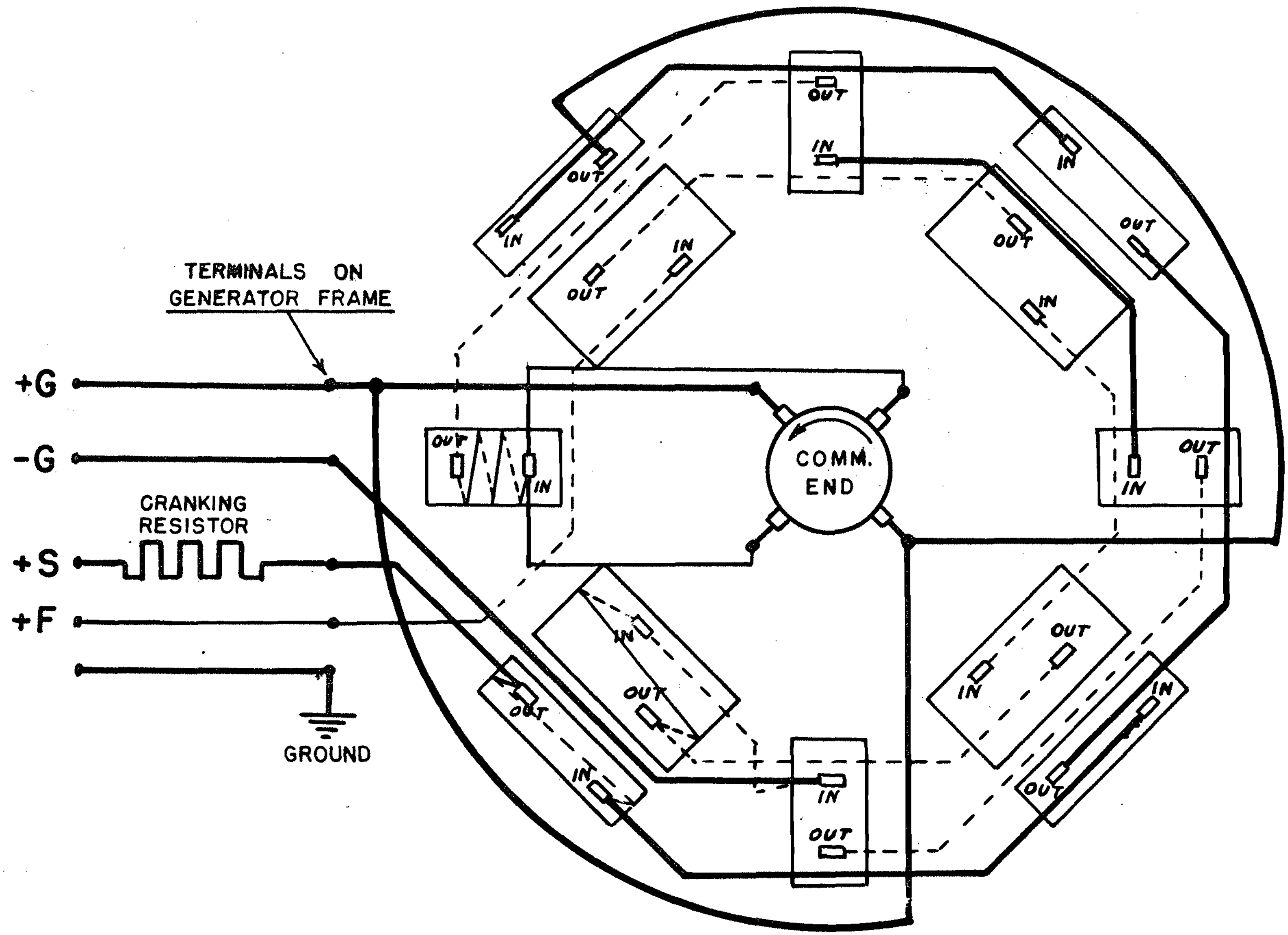
Overhauling Tolerances for Waukesha Engines and Compressors.

7-Ton Reciprocating Freon Compressor

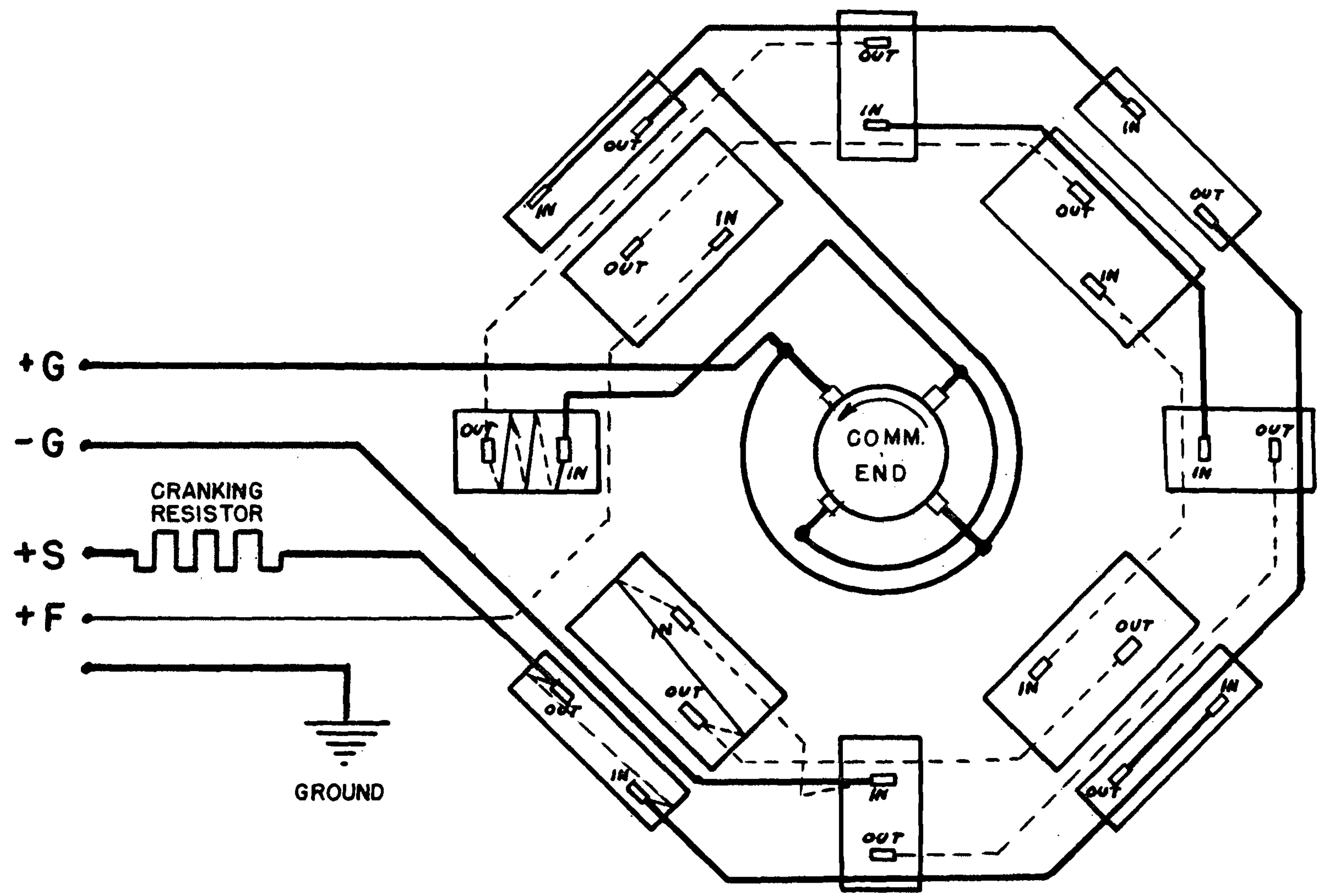
Initial and Permissible Clearances before renewing parts.

LOCATION	INITIAL FIT CLEARANCE	MAX. ALLOWABLE CLEARANCE
Piston in Cyl.	.002" to .003" on dia.	.006" on dia.
Ring side Clearance in Grooves	.0005" to .002"	.005"
Ring Gap	.0005" to .010"	.030"
Conn.Rod Lower End on Dia.	.001" to .0015"	.0025"
Conn Rod Upper End on Dia.	.0002" to .0004"	.001"
Conn. Rod Lower End Both Rods - Side Clearance	1/32"	1/16"
Piston Pin in Piston	.0001" to .0004"	.001"

BALL BEARINGS	Maximum parallel movement of races when subjected to reversing end thrust .008".
VALVES	If valve plate is grooved 1/64" deep or more, the entire assembly should be replaced as other parts will have deteriorated at this time so that they will not give further dependable service.
GASKETS	All gaskets should be carefully examined when removed, and unless obviously in excellent condition, should be replaced.

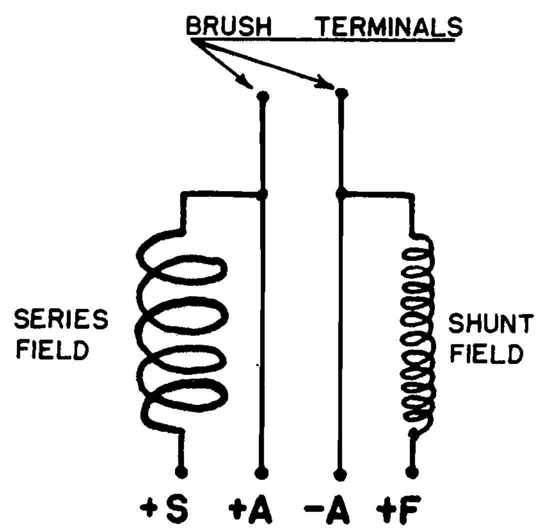


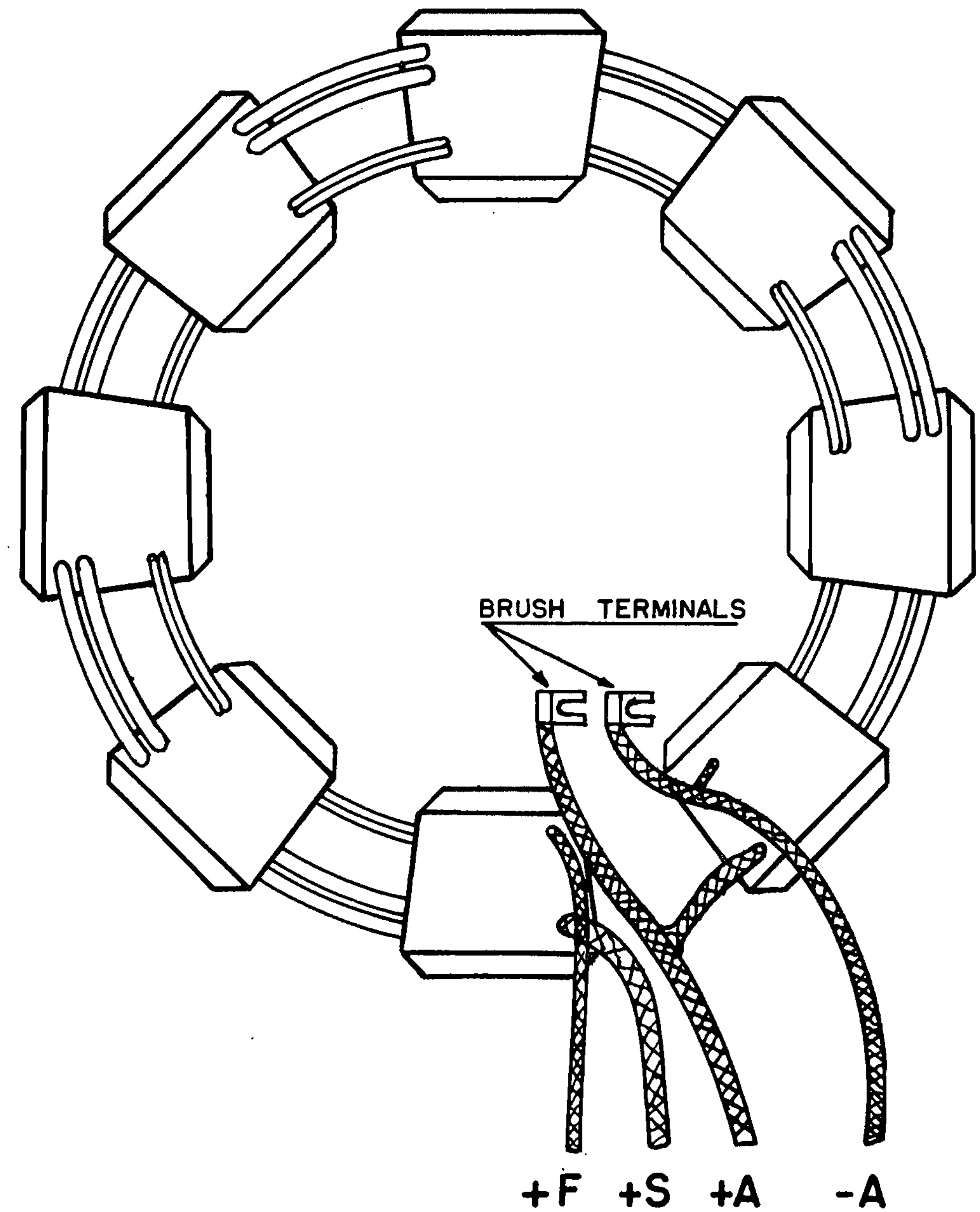
WIRING DIAGRAM FOR GENERATOR WITH 5 WIRES CONNECTED TO BRUSH RIG



WIRING DIAGRAM FOR GENERATOR WITH 3 WIRES CONNECTED TO BRUSH RIG

TO CHANGE ROTATION OF MOTOR
REVERSE BRUSH TERMINALS.





FIELD COIL ASSEMBLY FOR MODEL "E" ICE ENGINE