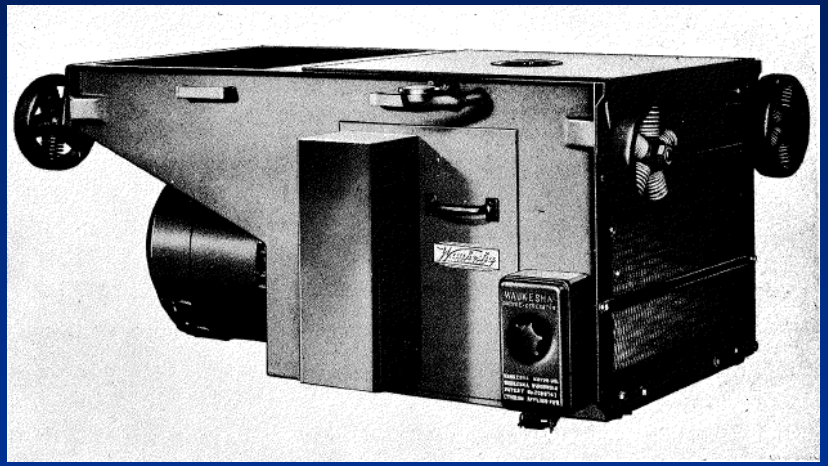
# Waukesha Propane Electrical & A/C Systems

Seminar 312

# Waukesha Propane Products

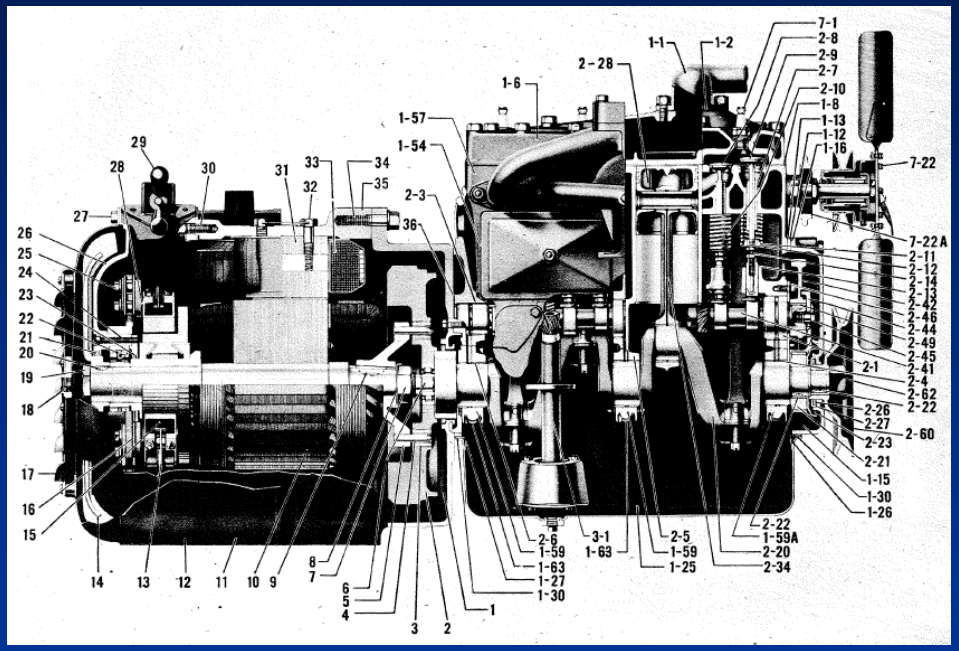
- 7.5 kilowatt engine-generator units (Including control panels)
- “Ice Engine” engine-compressor-condenser units
- Supplementary wet condenser units
- Roll-out mounting rails
- Fuel cabinets

# 7.5 Kilowatt Engine-Generator



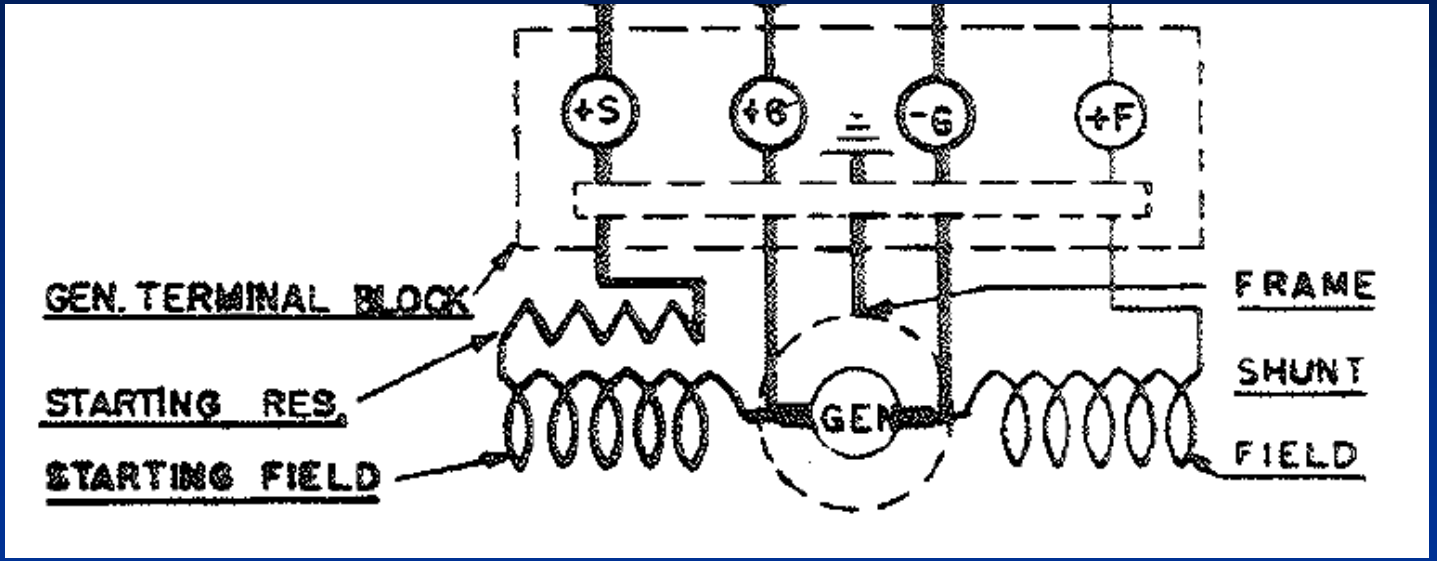

- 4-cylinder Waukesha ‘FC’ engine
- Roll-out wheels include vibration dampening
- Basic engine protection: Low oil & overheat
- Local start/stop in control box

# 7.5 Kilowatt Engine-Generator



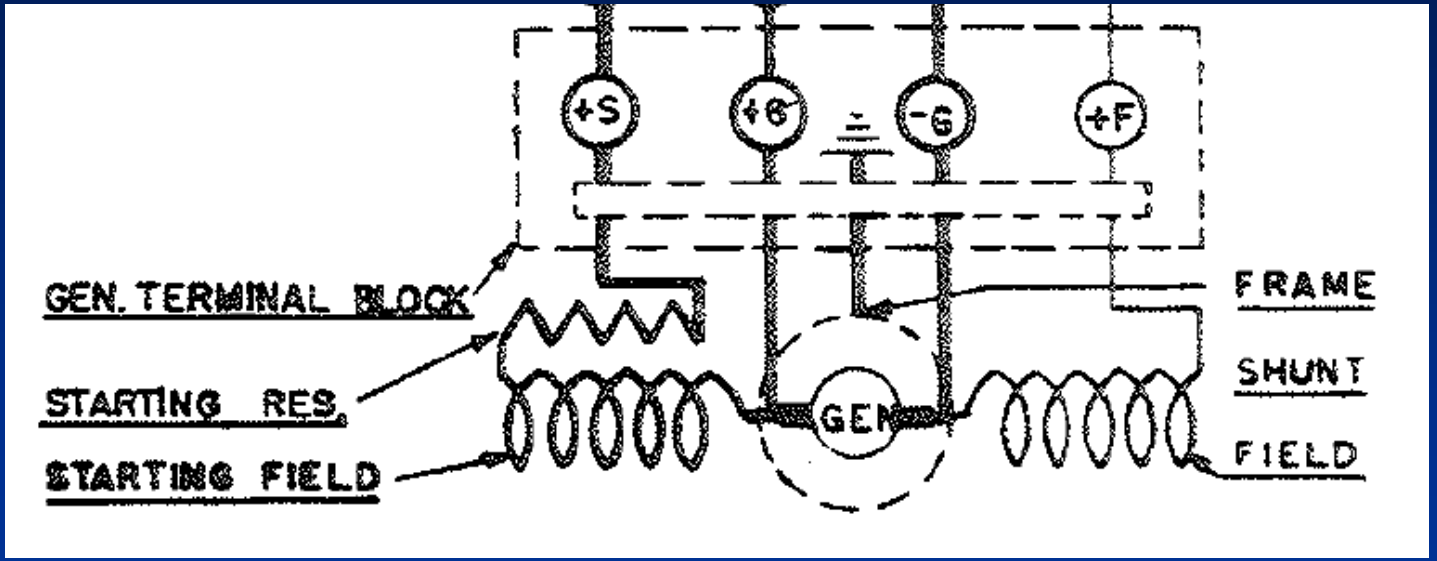

- DC Generator directly coupled to engine
- Output controlled by varying strength of field windings
- No starter – uses separate starting windings in the generator

# Generator Internal Wiring




- Battery across +S & -G to start engine
- Generator output between +G & -G
- Output proportional to field current between +F & -G
- Generator frame grounded to car's frame

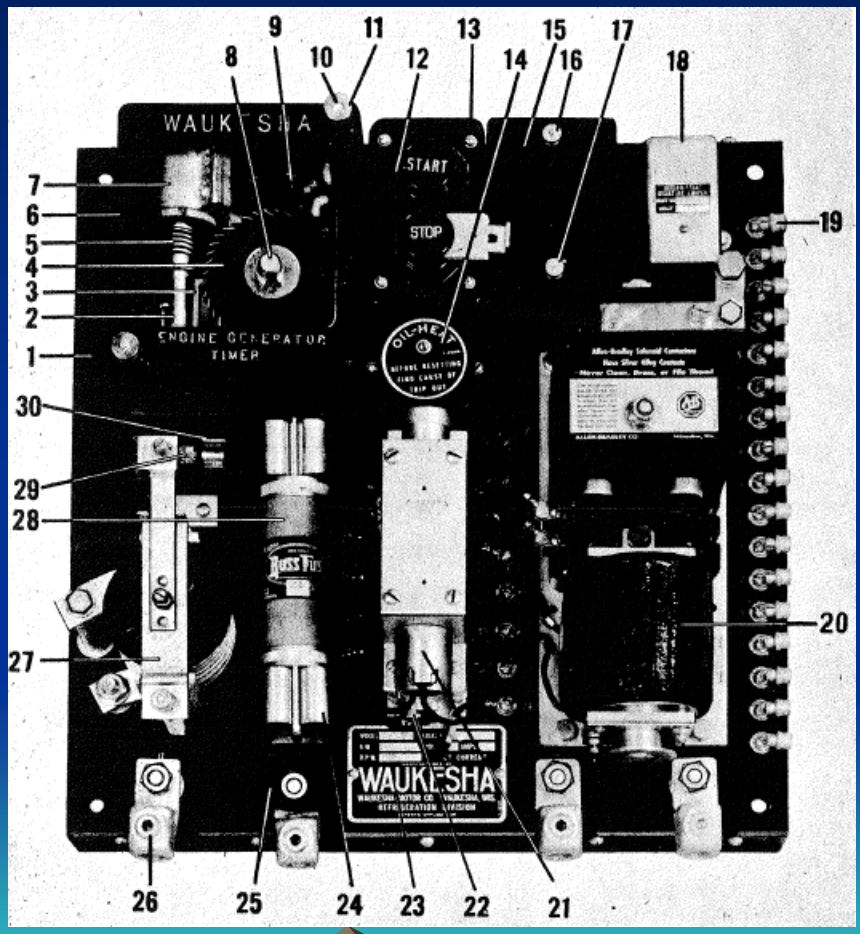
# Generator Connections




- +S from Waukesha generator control panel
- +G to Waukesha generator control panel, then Safety generator regulator, then Safety reverse current relay
- +F from Safety generator regulator

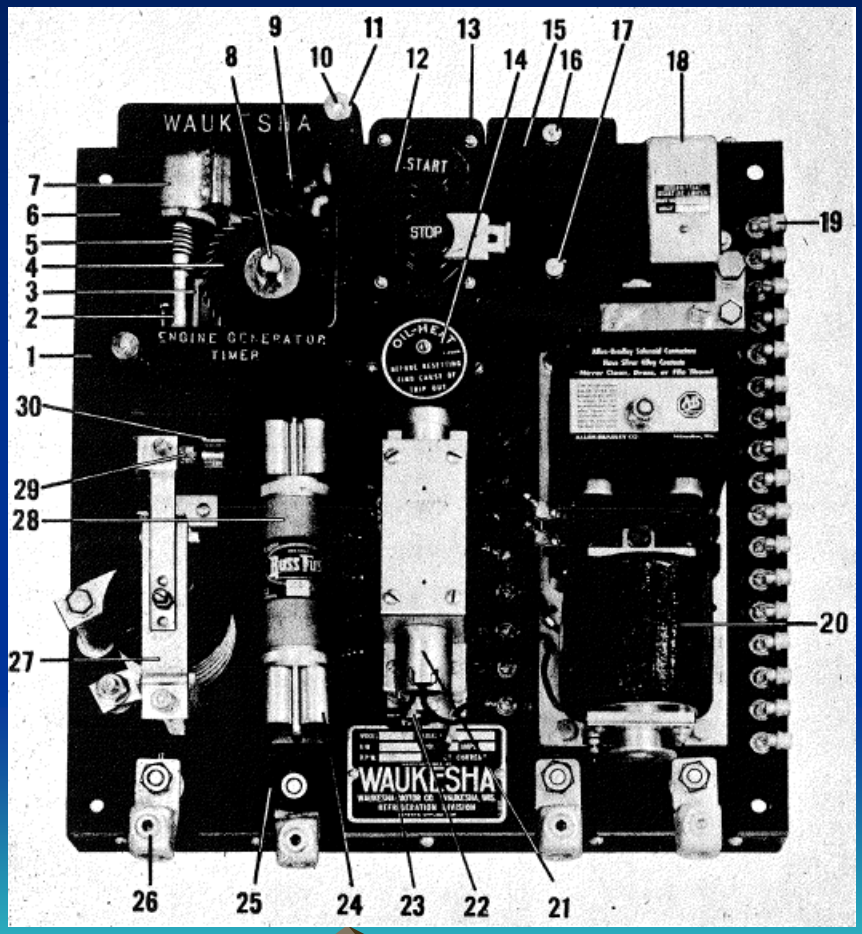
# Engine-Generator Control

- Mounted in Electrical Cabinet
- Controls start, run & shutdown. Includes engine protection and some automation
- Control fuse (30) is 10 amp, 250 volt



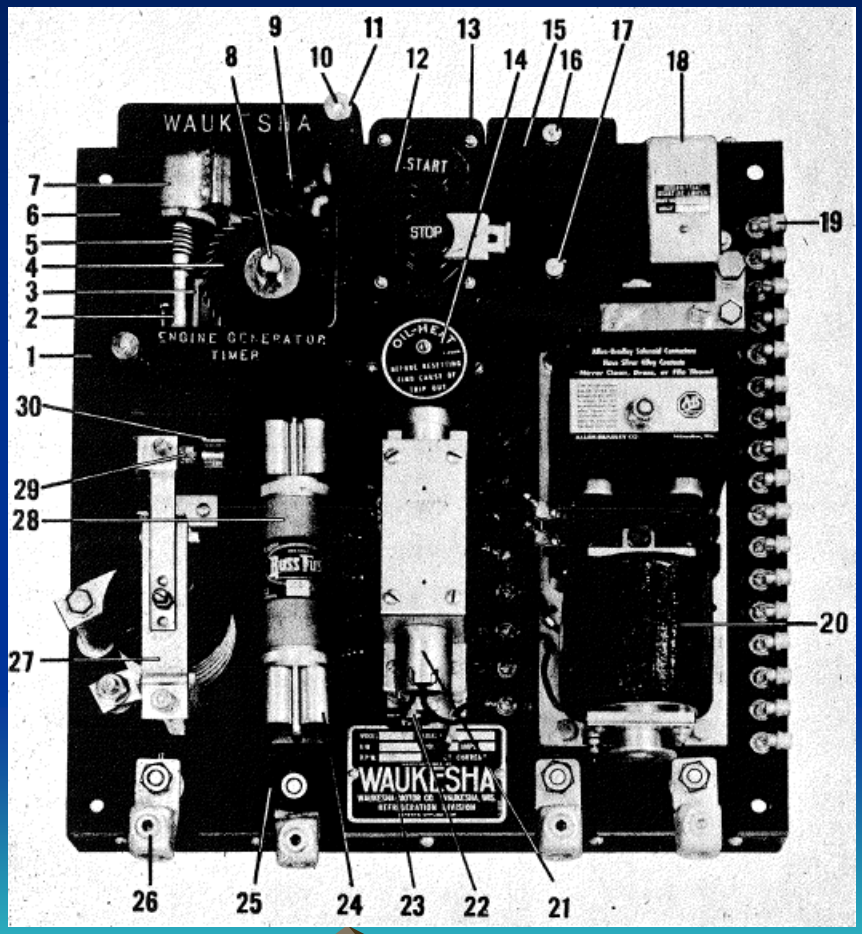
# Manual Starting

- Use panel start button (12) or start button in engine-generator control box
- Control circuit relay (16) enables run circuits
- Starting contactor (20) cranks engine
- Starting fuse (28) is 150 amp for 40vdc / 125 amp for 80vdc

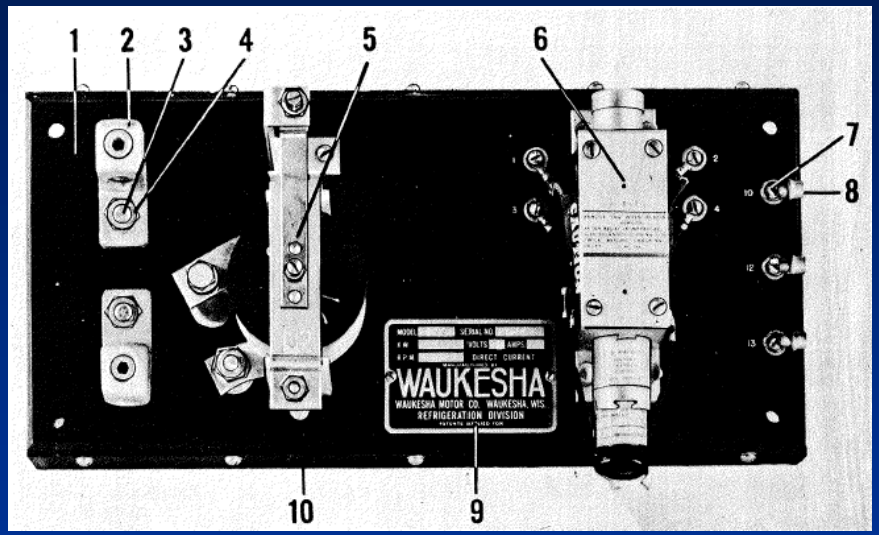


# Periodic Starting

- Starting timer (6) starts generator regularly for “maintenance” charging
- Timing wheels (8) for 15-, 30- or 60-minute interval
- Timing relays (21) and (22) pulse the starting timer one notch every three minutes
- Disable by removing link between “A” and “B” terminals at upper left



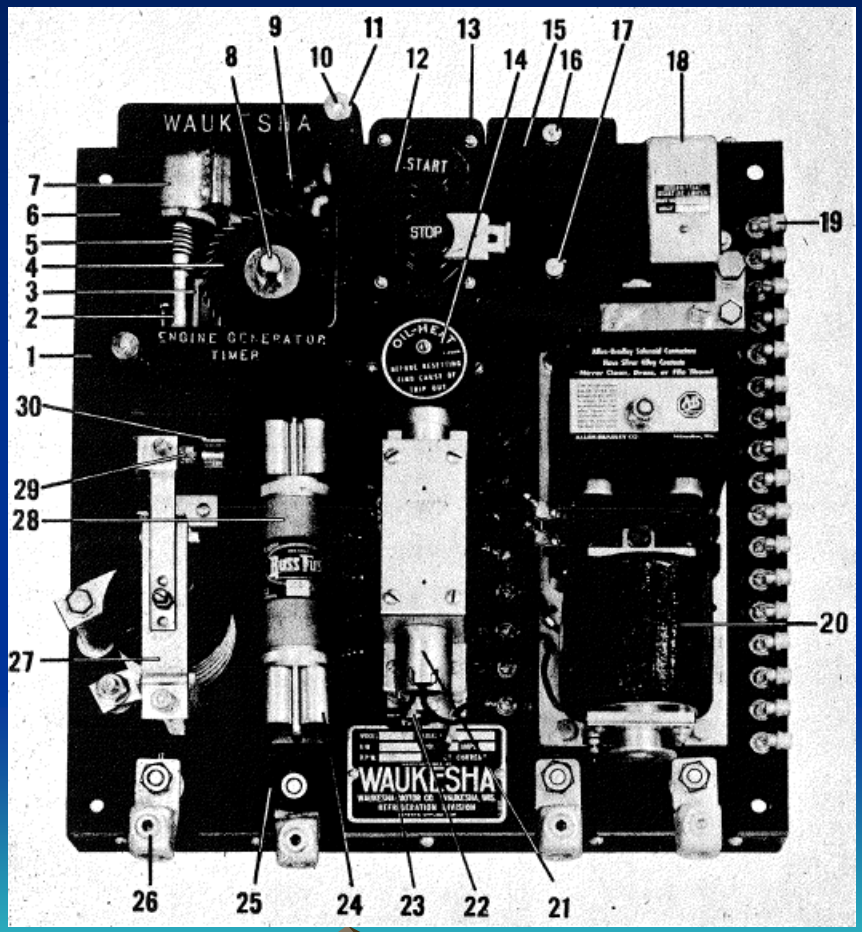
# Demand Starting




- Optional module
- Starts generator when car's demand rises
- Has short starting delay – to ignore momentary spikes in demand

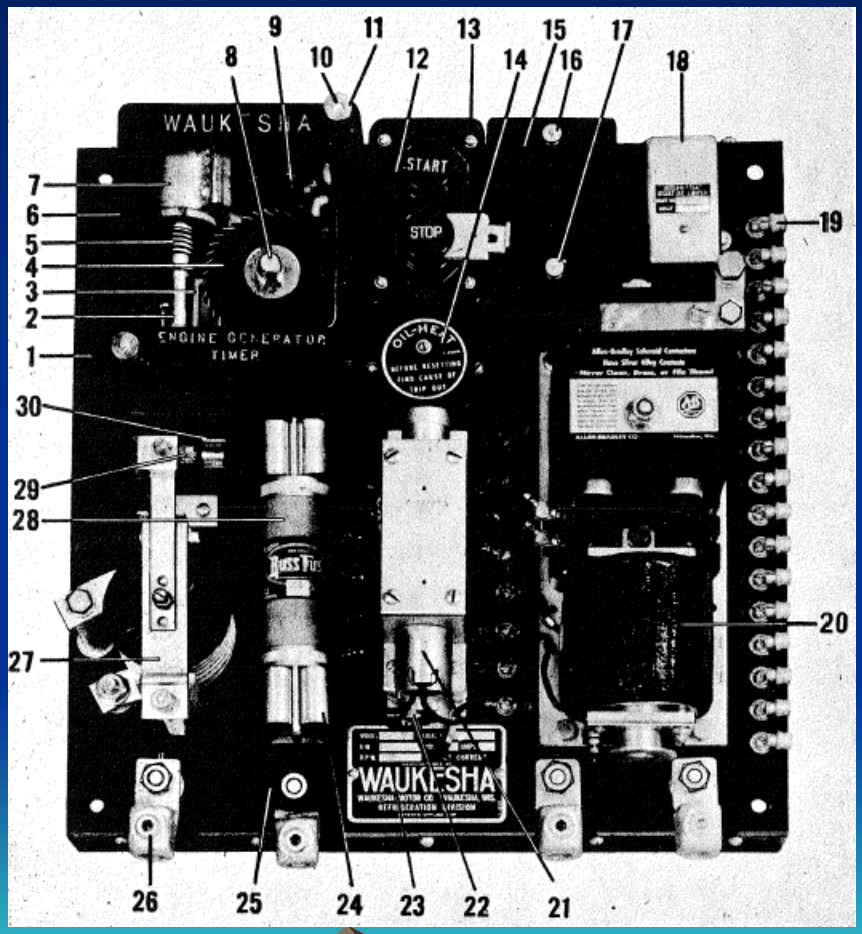
# Engine Protection (Over-Crank)

- If it takes longer than 15-20 seconds to start the engine, the Intermittent Starting Switch (18) cancels the attempt



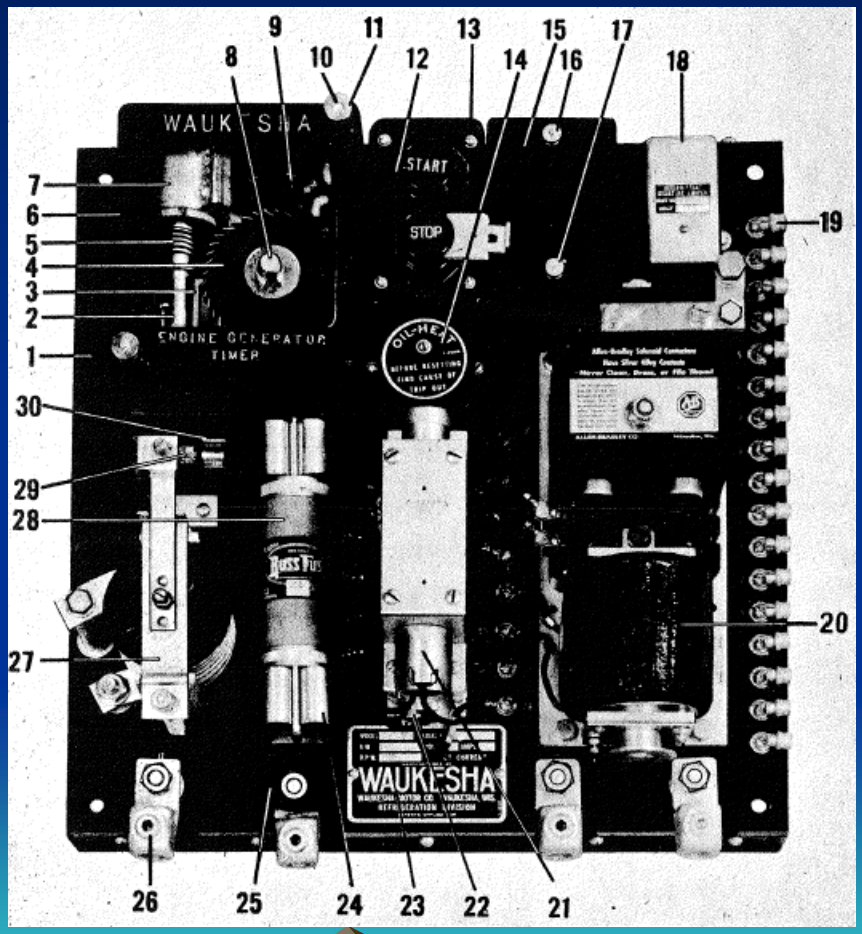
# Manual Shutdown / Lockout

- Stop via button on control panel (12) or in engine's control box
- Control circuit relay (17) grounds magneto to stop engine (no spark) and resets "run" circuit for starting



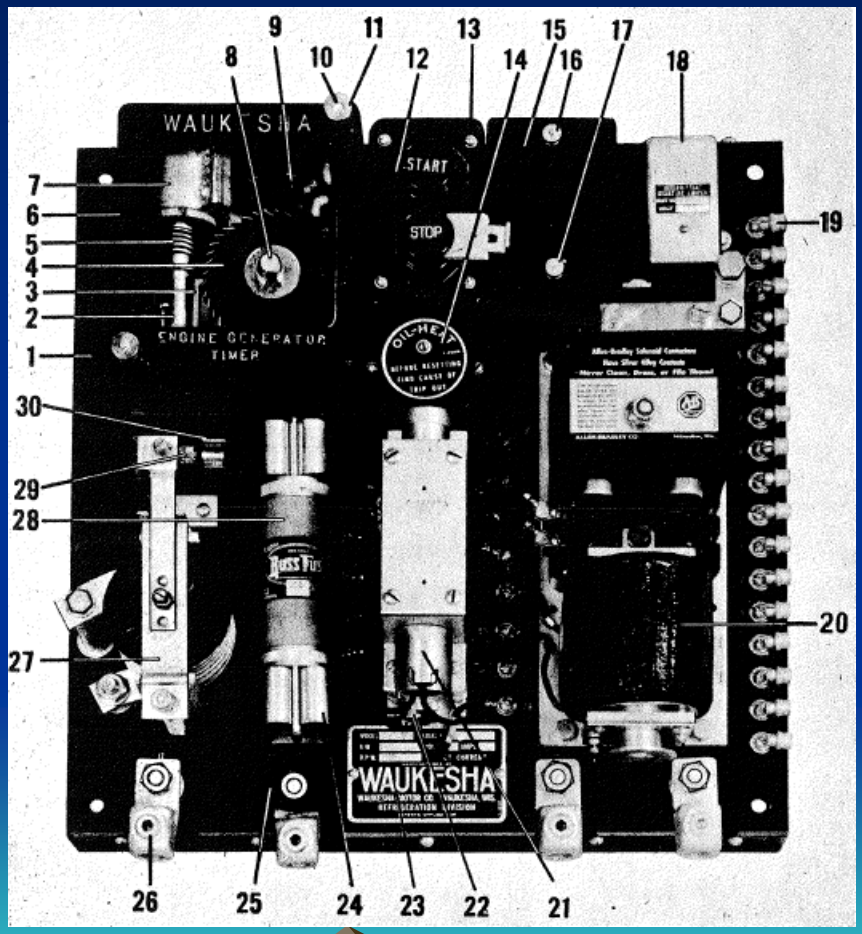
# Low-Demand Shutdown

- Low Current Relay (27) stops generator when car's current draw approaches battery fully charged



# Engine Protection (Oil / Heat)

- If the engine's coolant temp exceeds ~245° for 90 seconds, or the oil pressure drops below 4 lbs for 90 seconds, the OIL-HEAT safety(14) will trip, shutting down the engine



# Control Panel Connections

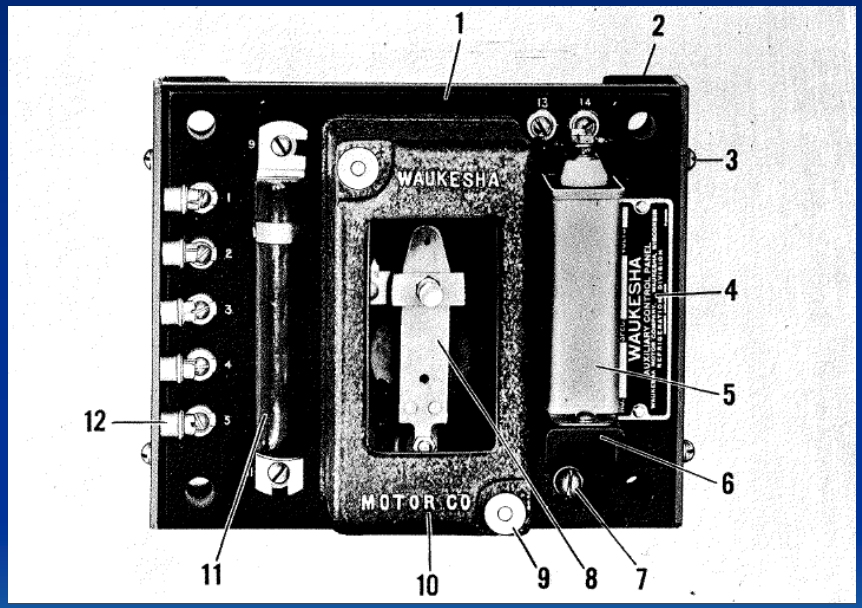
- 1, 8 & 9 to auxiliary contacts on reverse current relay to detect generator running:
  1 = run, 8 = common, 9 = stopped
- 1 & 2 connect to both hot engine and low oil pressure sensors: Normally open
- 3 to engine block, 4 to magneto: Grounds magneto to stop engine
- 5, 6 & 7 to generator local control:
  Close 5 & 7 to start, open 6 & 7 to stop

# Control Panel Connections

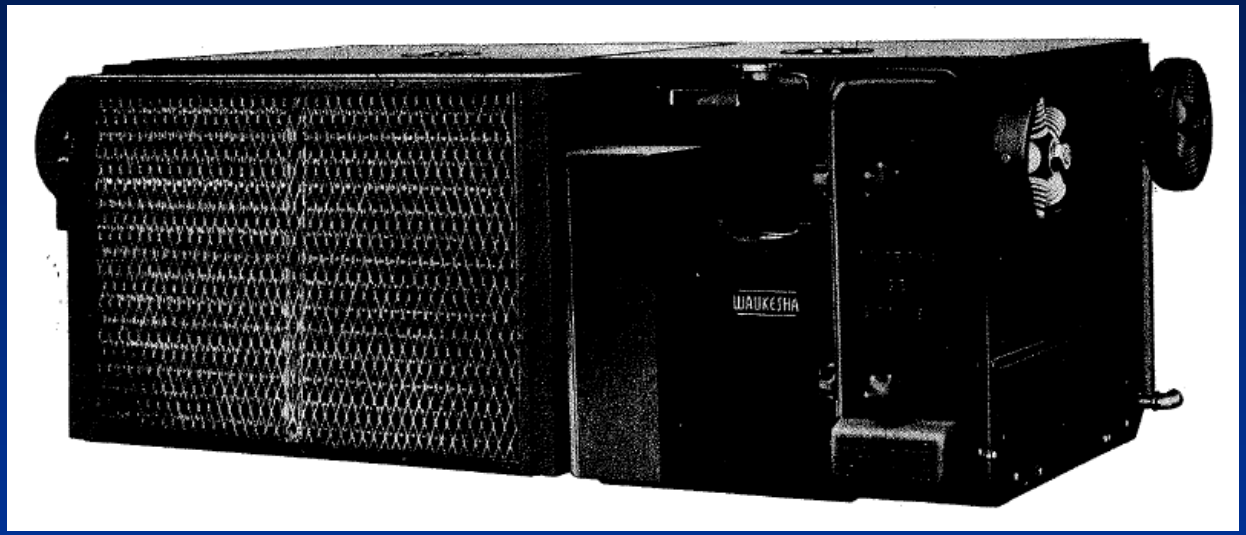
- 10, 12, 13 & 18 connect to like-numbered terminals on the optional load current relay panel (demand-starting feature)
- 11 to battery negative (unregulated)
- 14 to engine-generator +S starting winding
- 15 to battery positive (unregulated)
- 16 to engine-generator +G output
- 17 to generator regulator's +G generator output terminal

# Edison Batteries

- Edison batteries (Nickel-Iron) have different charging needs than lead-acid
- This aux panel was added when Edison batteries were used
- Exide stopped production in 1975 – still made in China
- Durable, less efficient

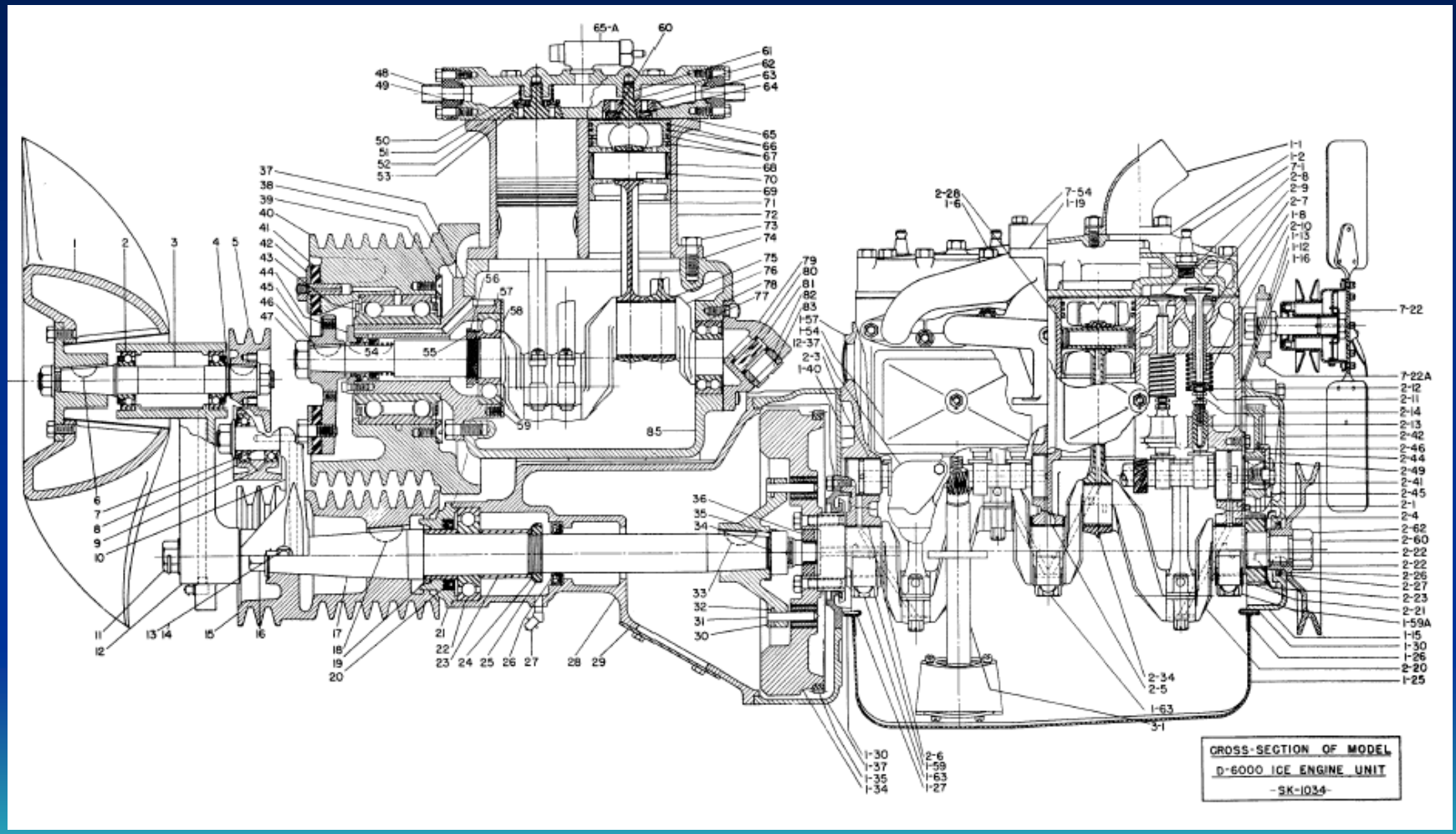


# Ice Engine




- 4 cylinder Waukesha ‘FC’ engine
- V-4 reciprocating compressor
- Dual air-cooled Freon condenser coils
- Refrigerant fill point
- Self-contained starting, safety & shut-down controls

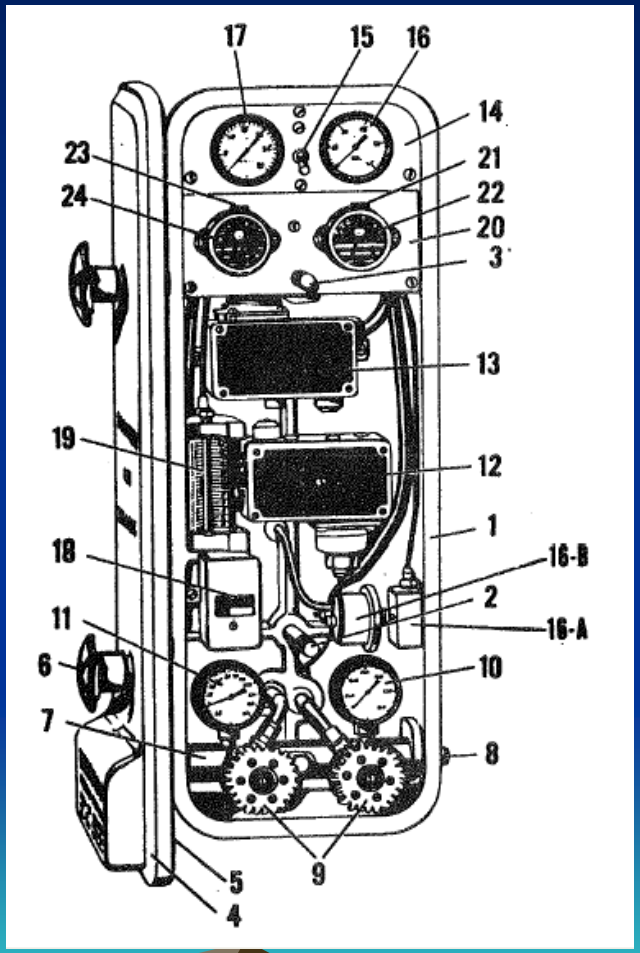
# Ice Engine



# Ice Engine Controls

Top Row:

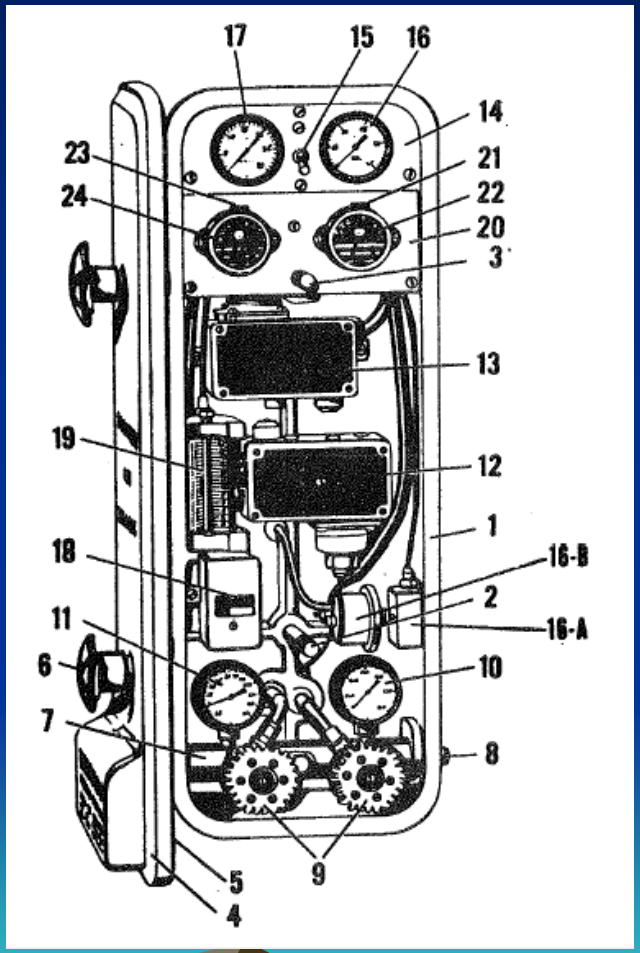
- 17 – Vacuum Gauge shows engine intake manifold vacuum
- 15 – Momentary start switch simulates cooling demand (and opens solenoid valve so that refrigerant can circulate)
- 16 – Oil gauge shows engine lubricating oil pressure



# Ice Engine Controls

2nd Row:

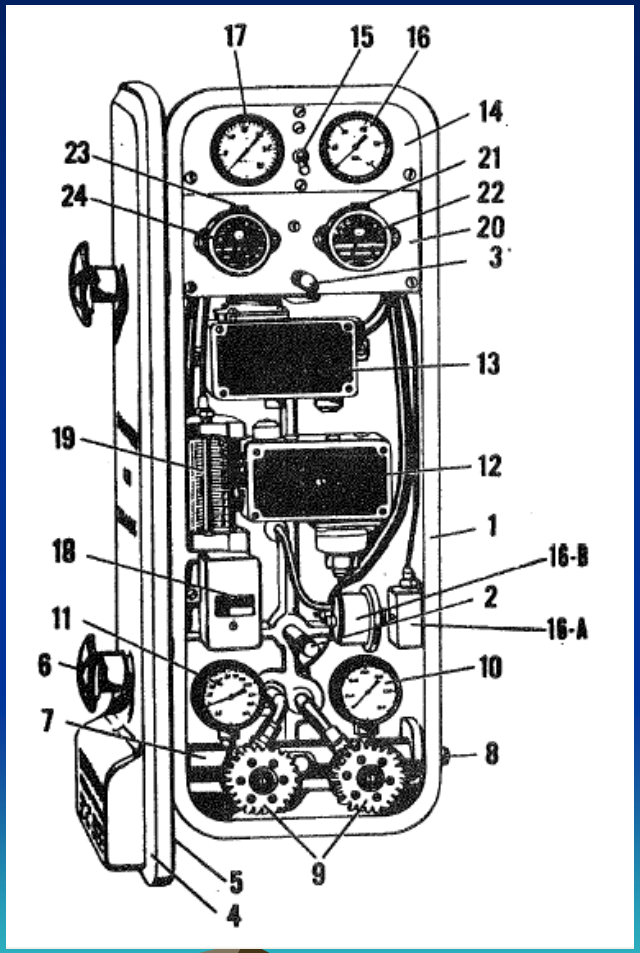
- 24 – Low oil pressure / engine overheat time-delay shutdown
- 22 – Cranking time-delay shutoff



# Ice Engine Controls

3rd Row:

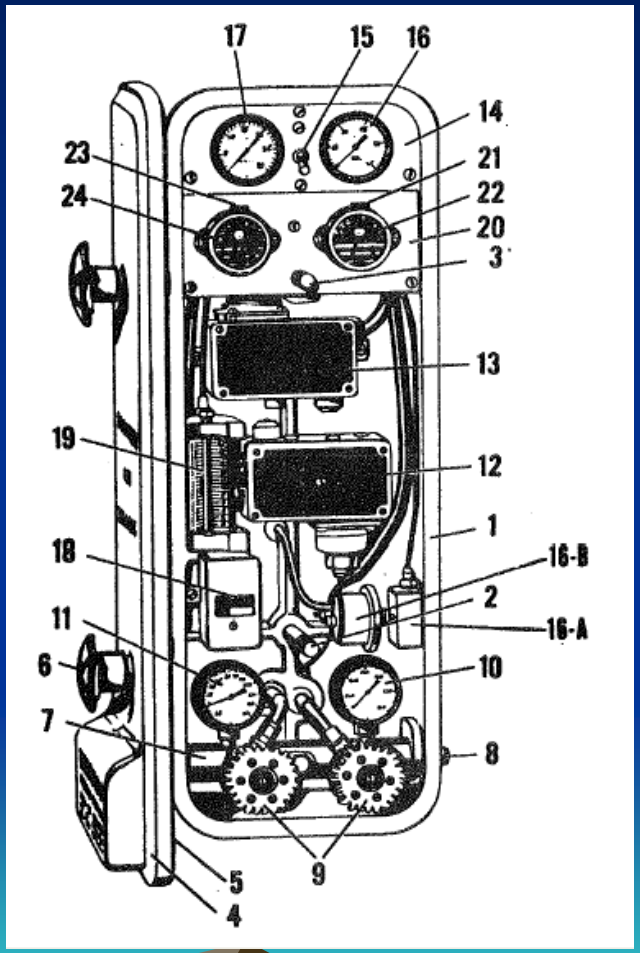
- 13 – Compressor output safety shutdown switch – senses excess pressure



# Ice Engine Controls

4th Row:

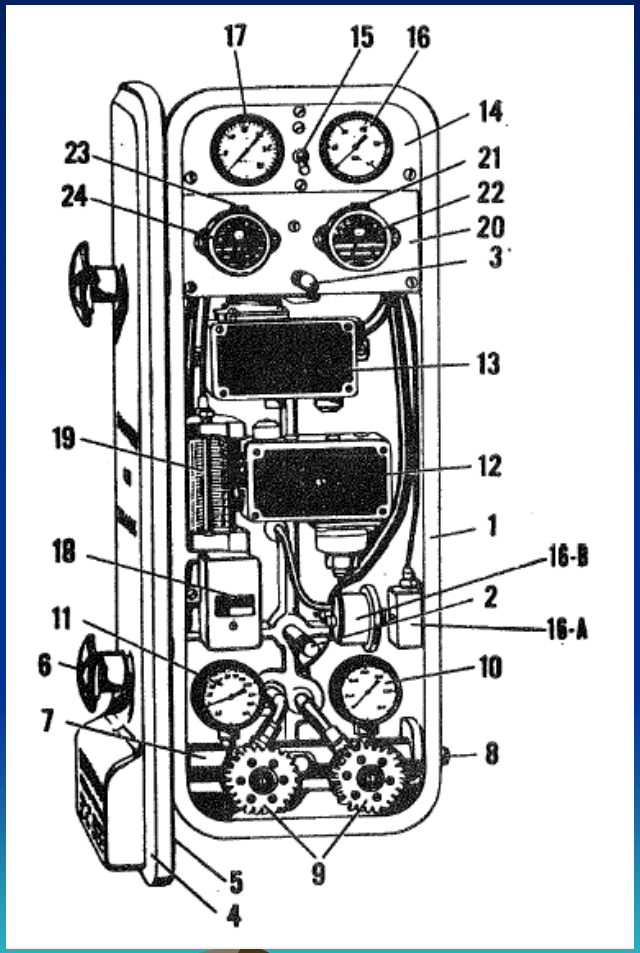
- 19 – “Manometer” fuel pressure gauge
- 12 – Compressor input safety shutdown switch – senses excess vacuum (by design, stops Ice Engine after car is cool.)



# Ice Engine Controls

5th Row:

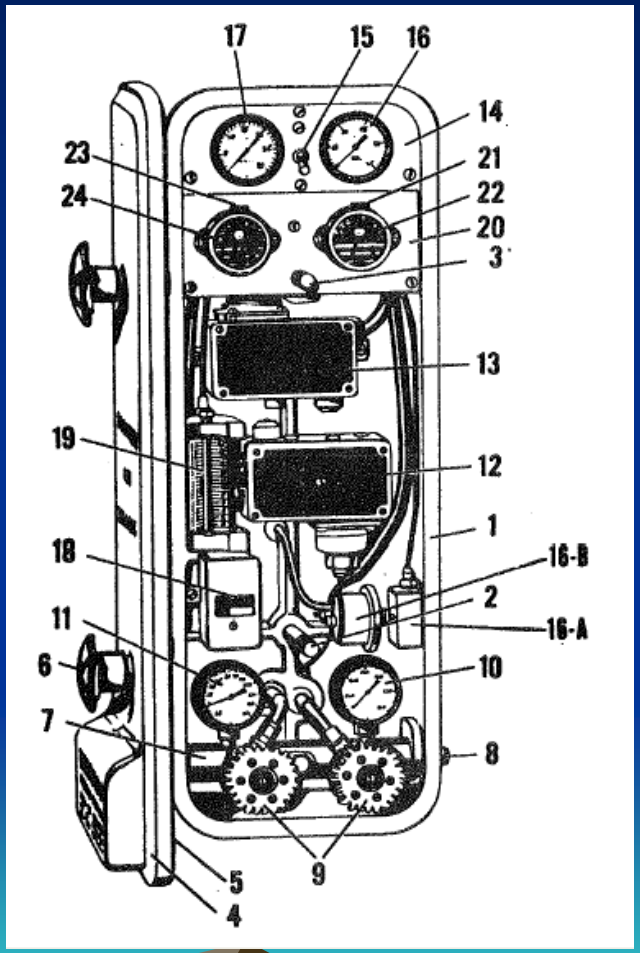
- 18 – Intermittent start switch (optional)
- 16 – Low oil pressure sensor



# Ice Engine Controls

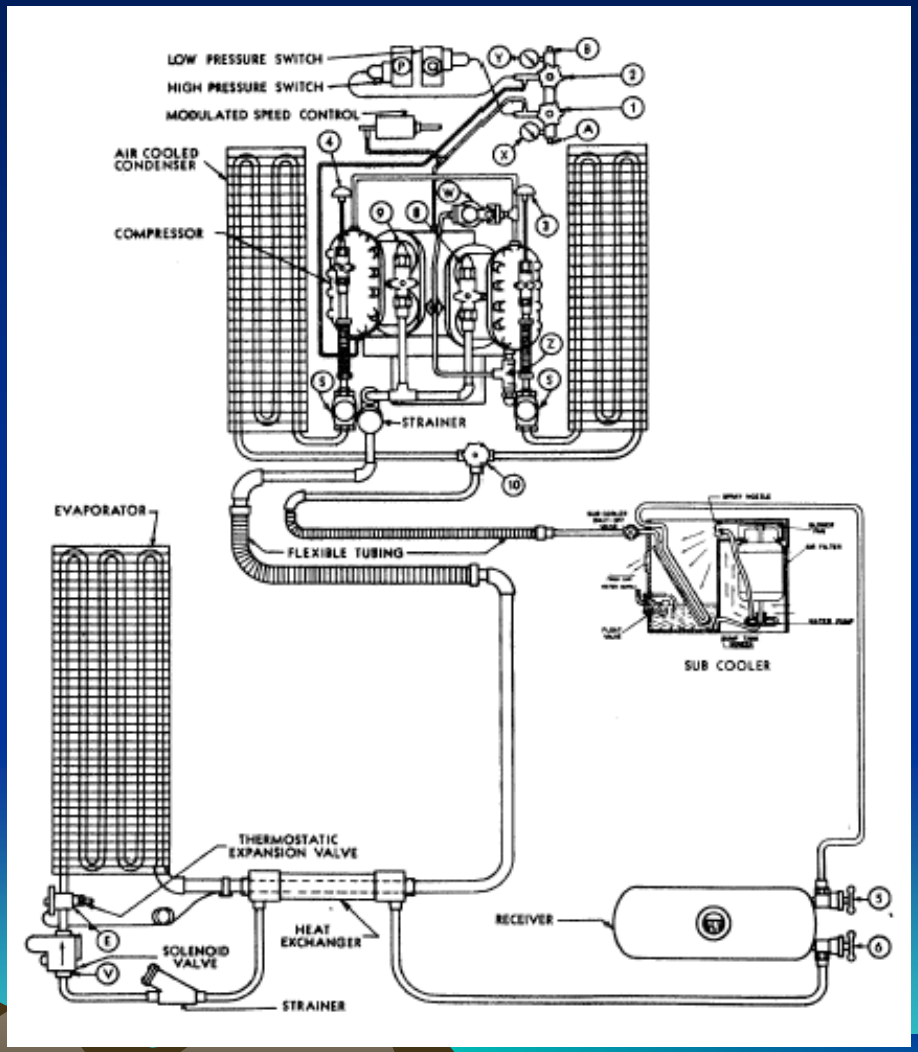
Bottom Row:

- Compressor input vacuum gauge & output pressure gauge
- Refrigerant fill manifold – hoses connect on left & right, close shutoff valves except when service equipment is connected



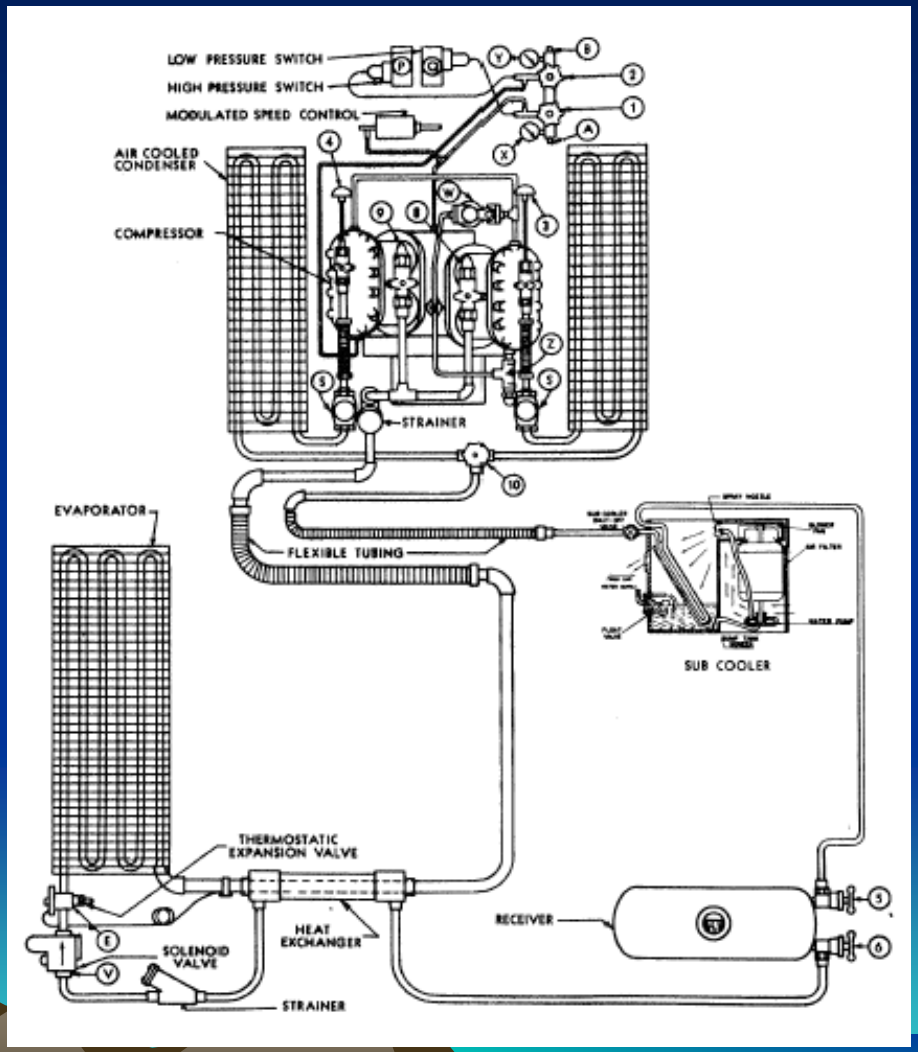
# Refrigerant Loop - Compressor

- Dual compressors pressurize refrigerant vapor
- Increased pressure => hotter gas
- R12 on 90° day: 140 psi / 176° f (Depends on refrigerant type & air temperature)



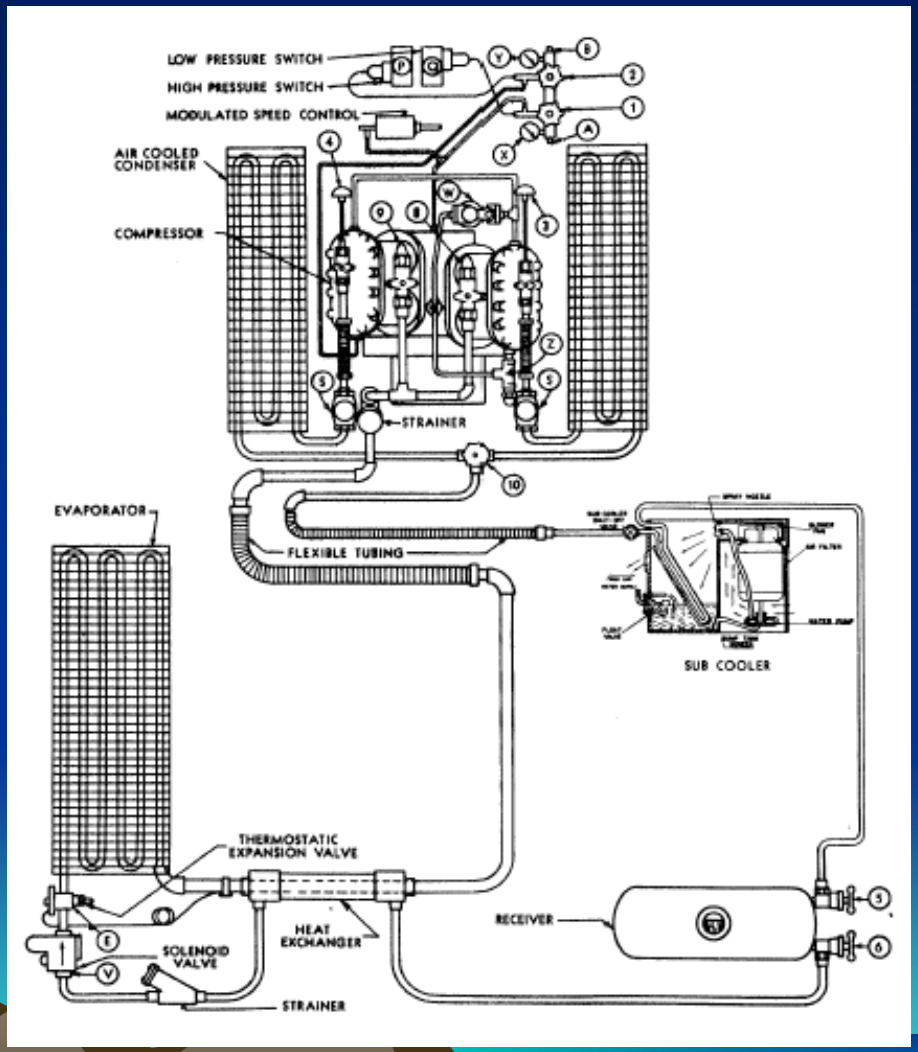
# Refrigerant Loop – Controls

- High pressure gauge, safety shutdown, and evacuation fitting connected to compressor output
- Safety closes solenoid valve at 300 psi and stops engine at 350 psi



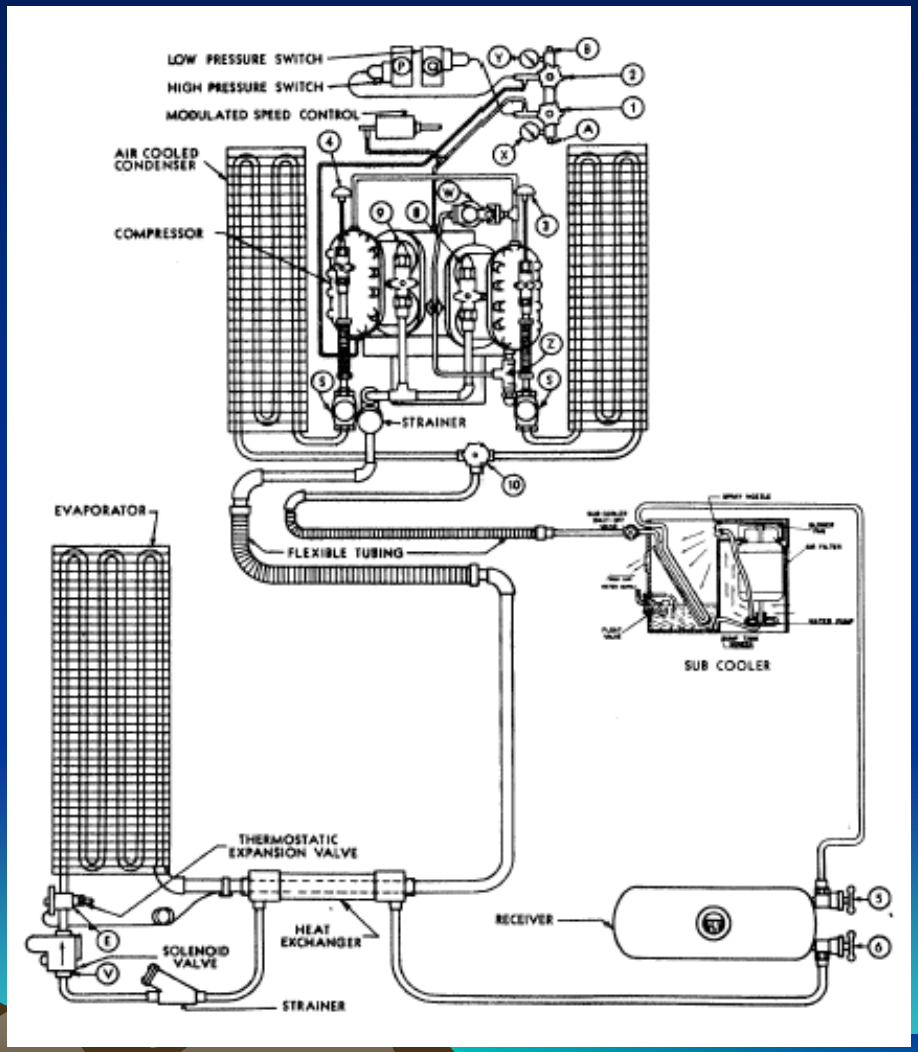
# Refrigerant Loop - Condenser

- Air-cooled condenser coils on ice engine extract heat from refrigerant vapor, which condenses into a liquid
- Optional evaporative sub-cooler blows water spray over refrigerant coils, extracting even more heat



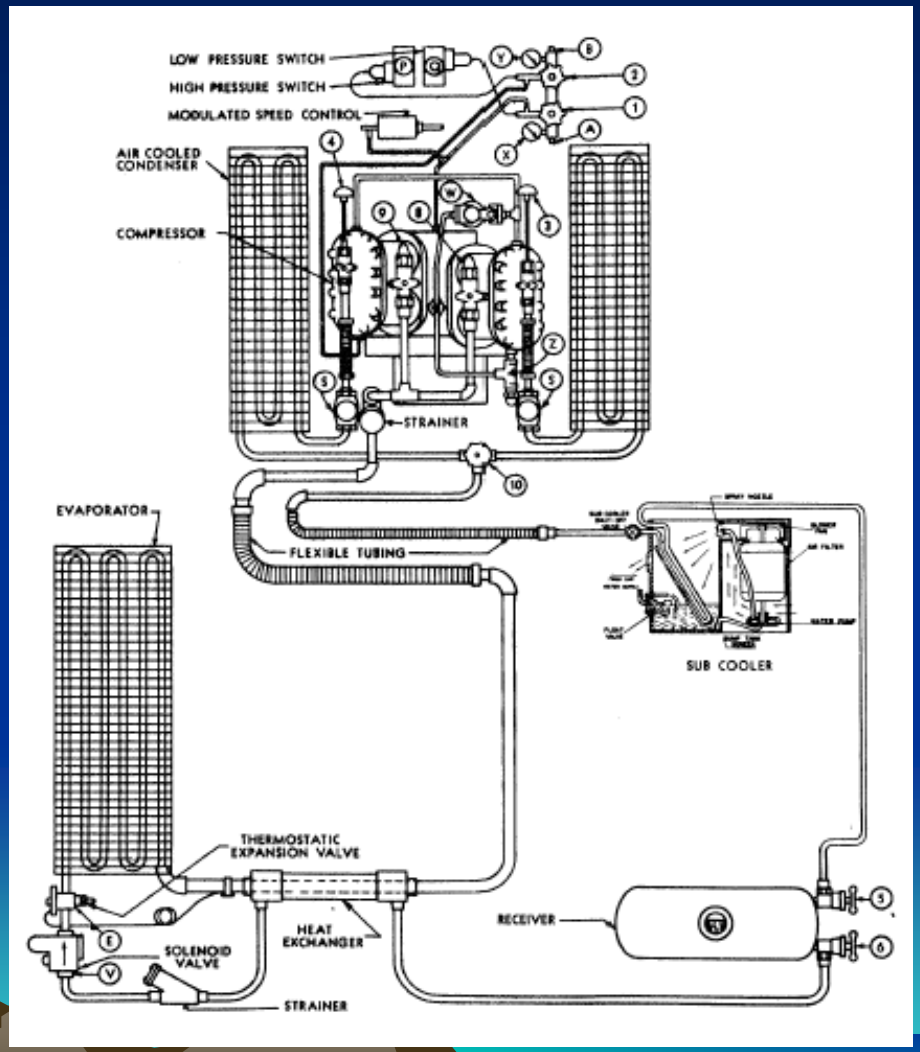
# Refrigerant Loop - Receiver

- Receiver is reservoir for excess refrigerant (capacity ~50 lbs)
- Liquid level should be in sight glass when system is cooling
- Liquid refrigerant is tapped from bottom of receiver
- R12 on 90° day: 140 psi / 110° f



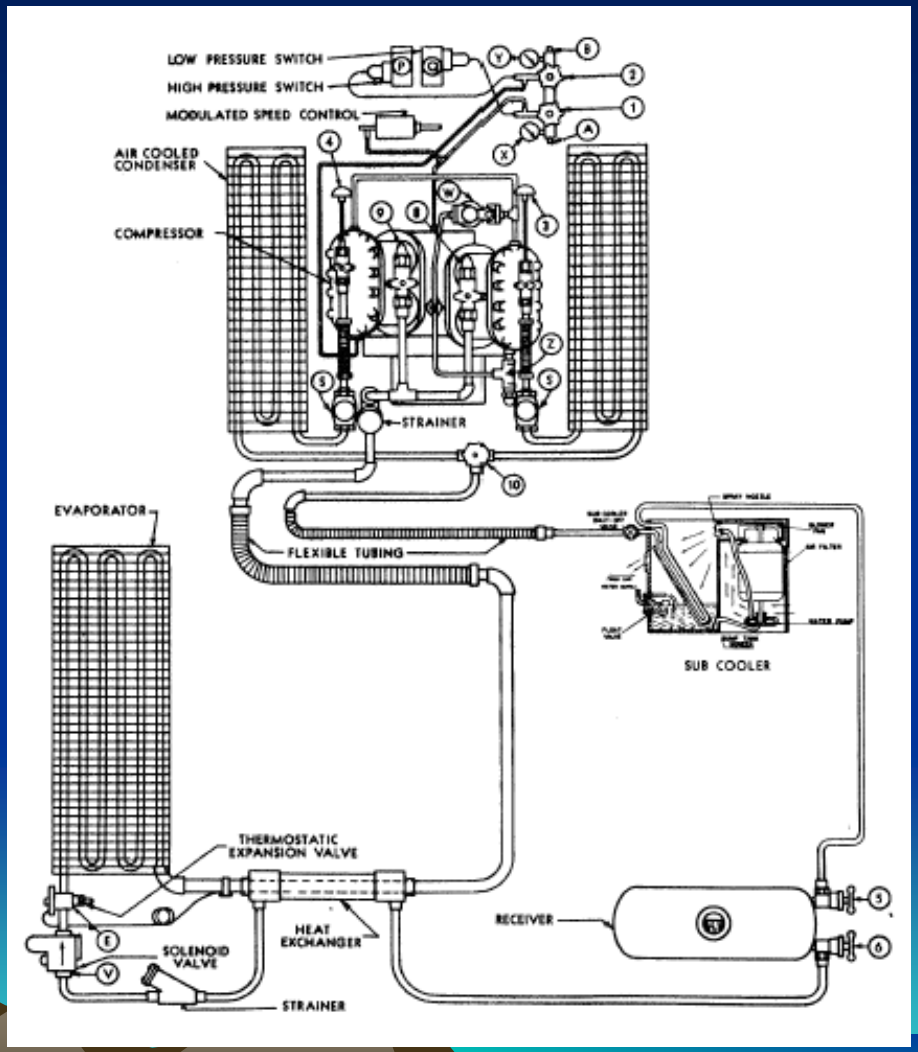
# Refrigerant Loop – Heat Exchanger

- Liquid to overhead unit is 110° on a 90° day
- Vapor from overhead is 47° on a 90° day
- Heat exchanger uses vapor to cool liquid – free efficiency gain



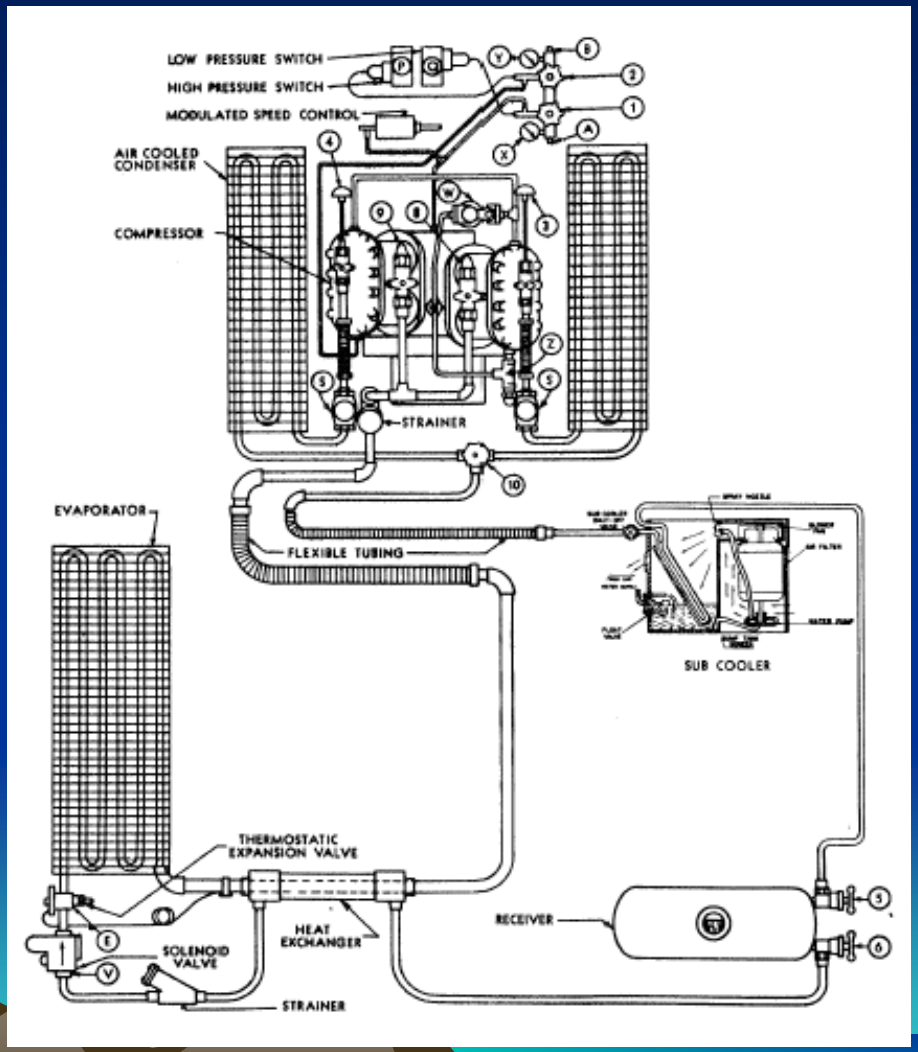
# Refrigerant Loop - Strainer

- Strainer keeps chunks out of expansion valve
- May eventually get plugged, impacting fuel consumption and system's ability to cool the car



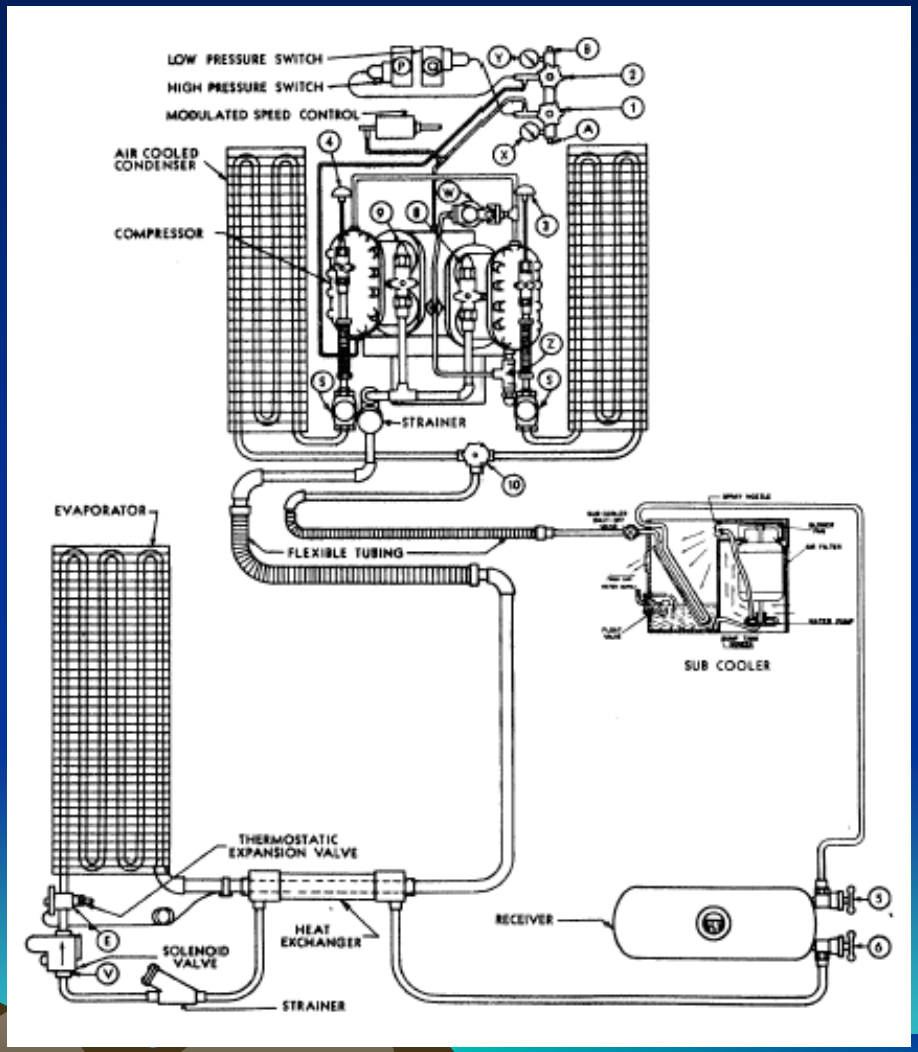
# Refrigerant Loop – Solenoid Valve

- Solenoid valve is how control system turns cooling on & off
- After valve closes, low pressure switch stops compressor
- Many cars have dual evaporator coils, expansion valves, and solenoid valves



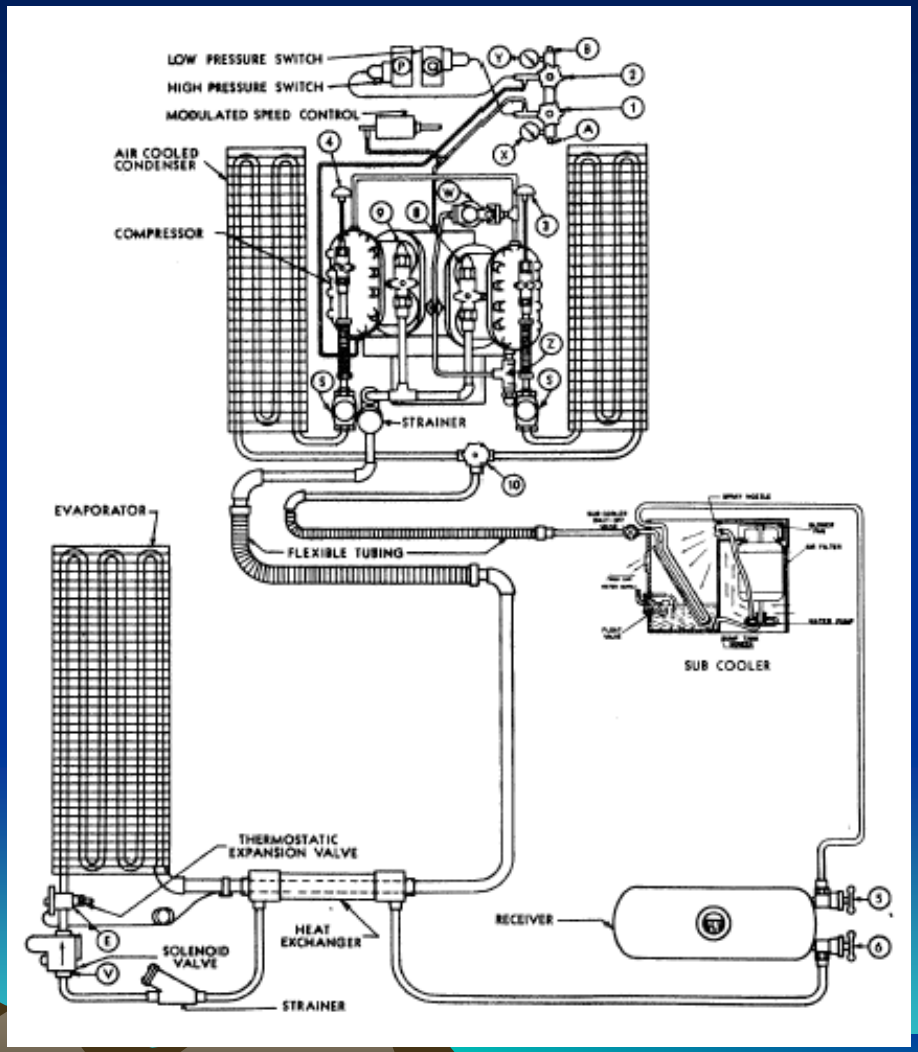
# Refrigerant Loop – Expansion Valve

- Expansion valve is where hot, pressurized liquid expands into cold, low-pressure vapor
- Rate of expansion is controlled thermostatically to match air temp
- Vapor to overhead unit is 34 psi / 37° f on a 90° day



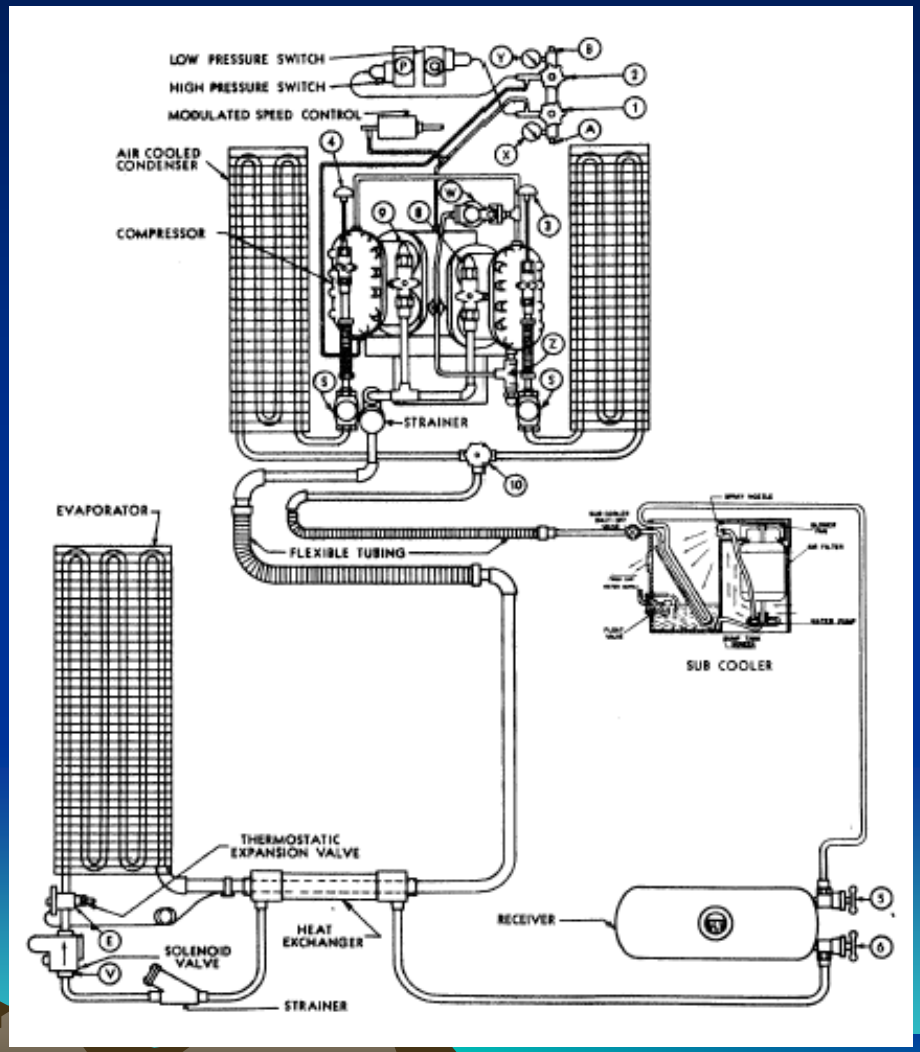
# Refrigerant Loop - Evaporator

- Cold refrigerant vapor (& some liquid) in evaporator coils cool car air – remaining liquid boils
- Vapor from overhead unit is 34 psi / 47° f on a 90° day



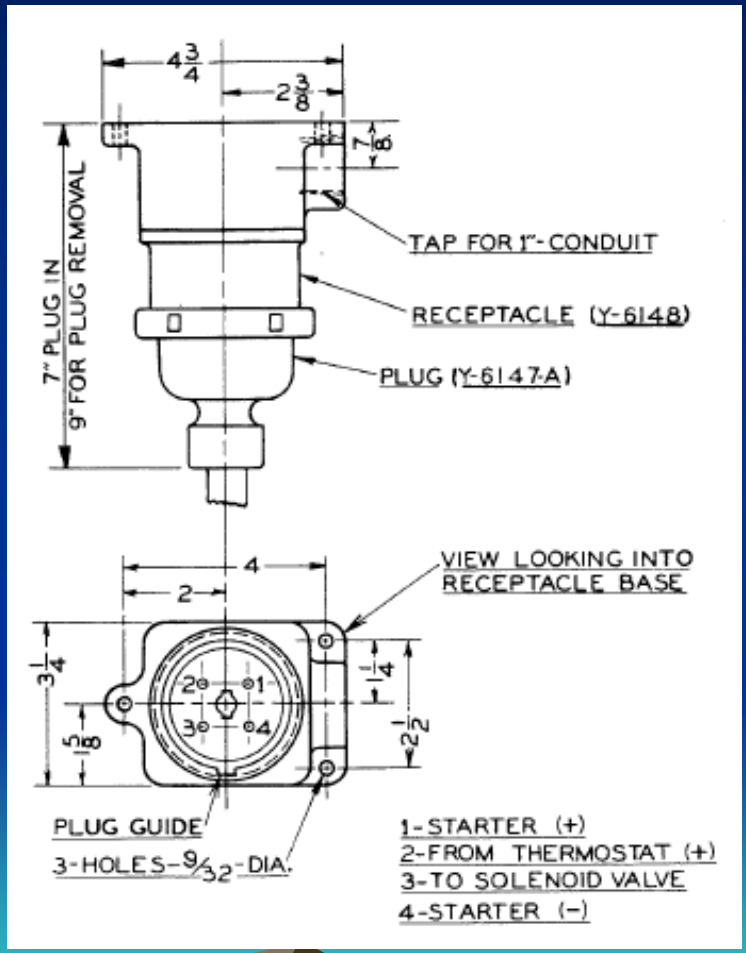
# Refrigerant Loop - Controls

- Temperature & pressure of “used” vapor reflect work to cool the air
- Ice Engine governor setting is influence by low-pressure side
- Low-pressure safety switch doubles as auto stop after car is cool (closes at ~7 ½ lbs)
- Gauge & fill point are on compressor intake



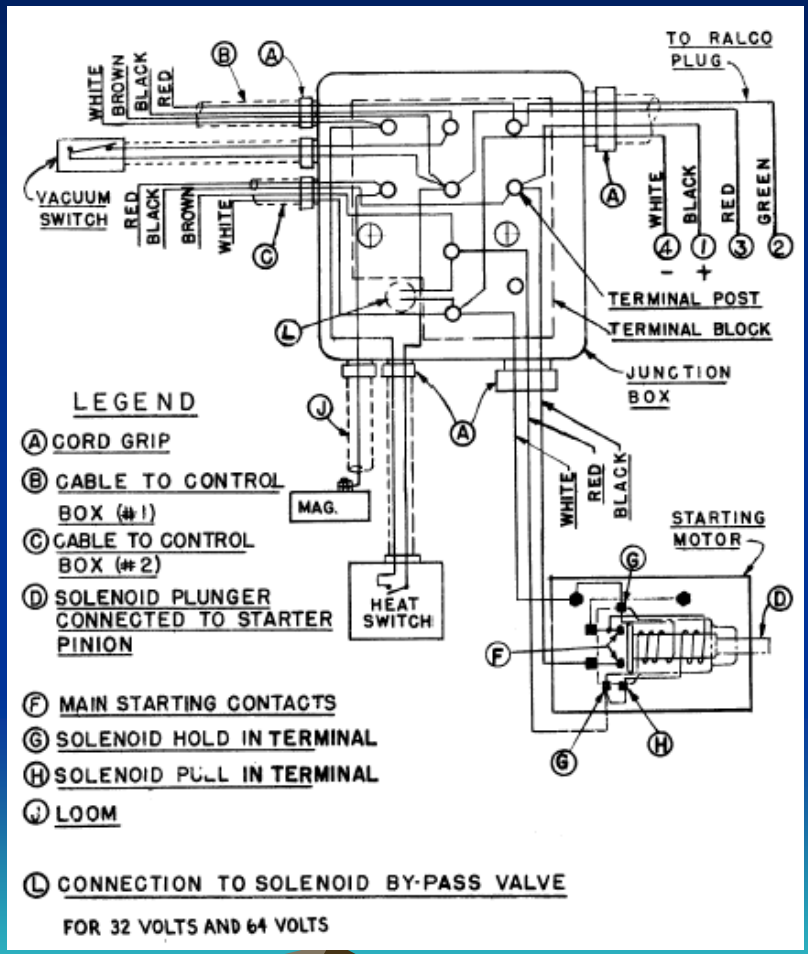
# Connection to Car

- Pins 1 & 4 are control & starting power from car's main DC bus (often via blower circuit breaker)
- Pins 2 & 3 splice in between Vapor control panel and solenoid valve to detect cooling demand
- Ice Engine toggle switch energizes pin 3 to open solenoid valve
- High-pressure shutdown opens pin 3

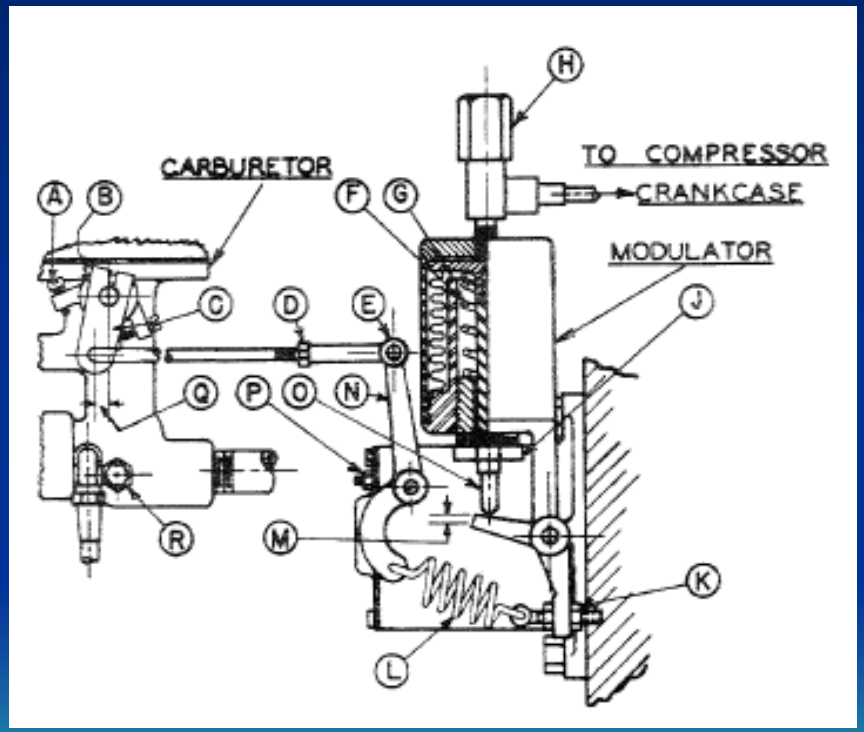


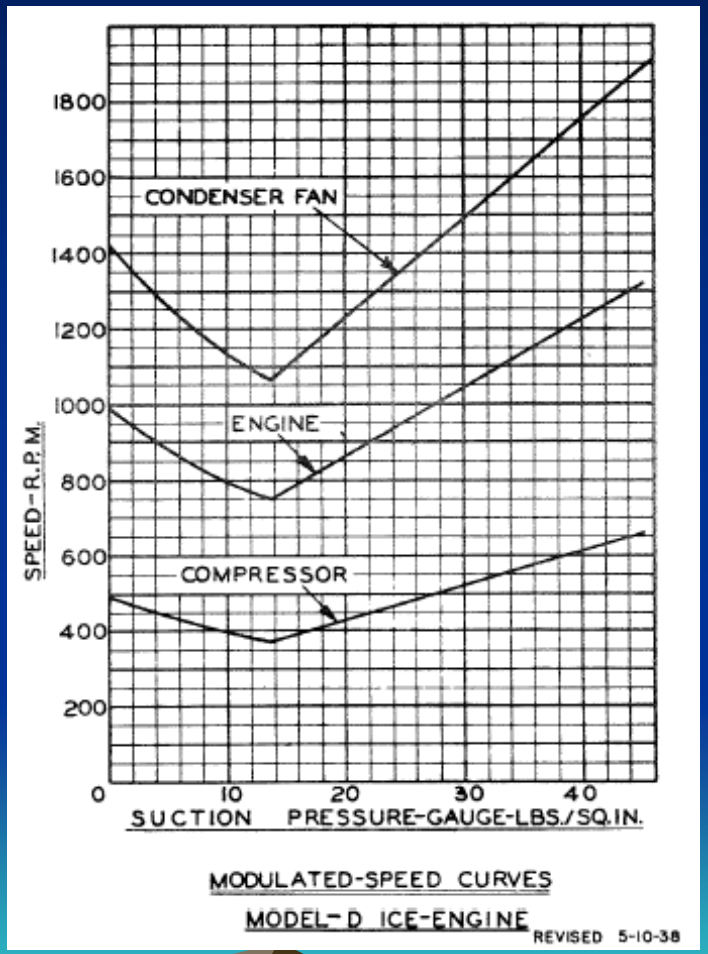
# Ice Engine Starting

- Demand on 2 & 3 (or toggle switch) picks starter solenoid
- Engine intake manifold vacuum switch proves engine running
- Cranking limit: 3 min. with 15 on/45 off intermittent starting, 1 ½ min. without
- By-pass valve “W” unloads compressor while engine is starting
- Check valves “S” assist in keeping it unloaded



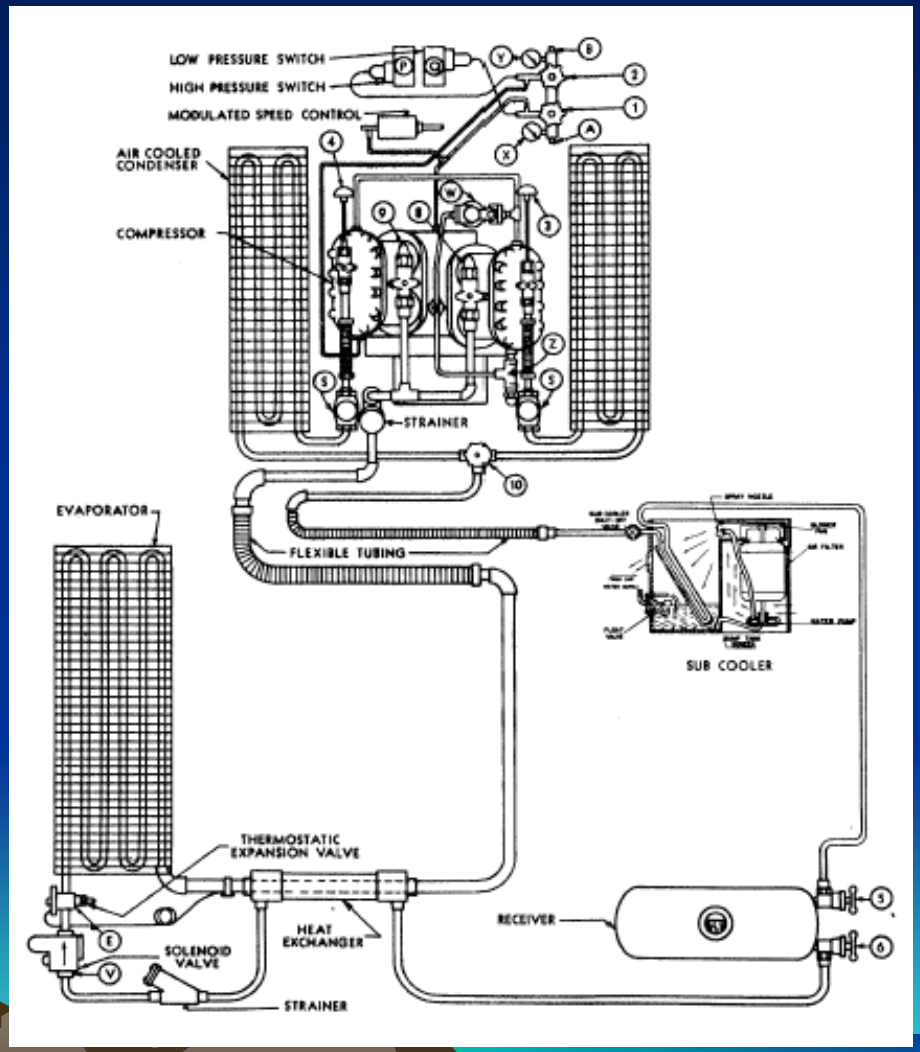
# Low-Side Pressure vs. RPM



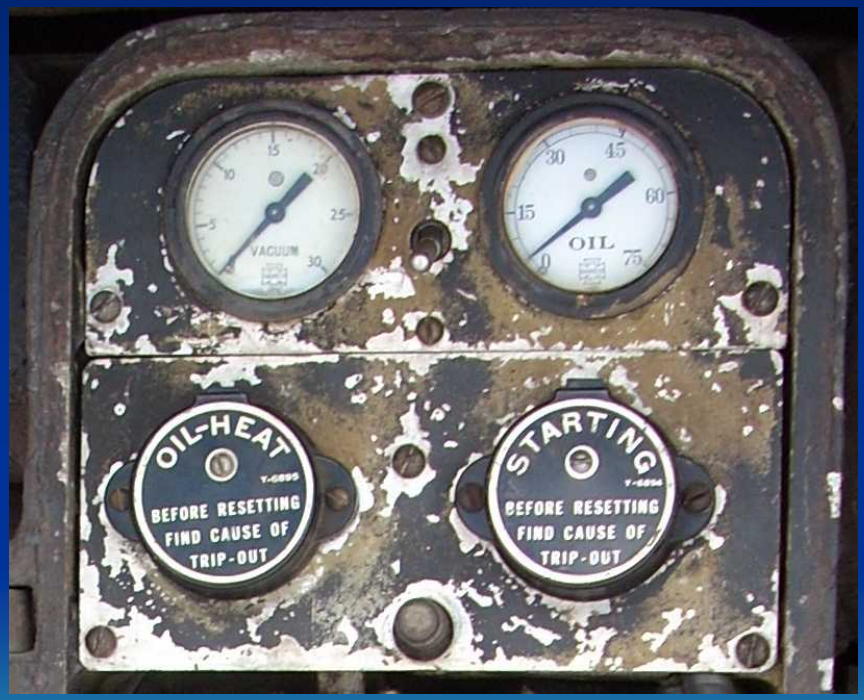
# Normal Shutdown

- Controls decide its cool enough, and close the solenoid valve
- Low pressure side is evacuated by compressor
- Low pressure safety switch grounds engine magneto
- (Therefore, must block switch open to bench-test an Ice Engine)



# Engine Protection

- Over-crank limit trips if engine cranks but will not start
- Oil-heat trips if low oil pressure or high coolant temp persist
- Model “D” Ice Engines also have a tip-over shutdown switch
- All ground magneto

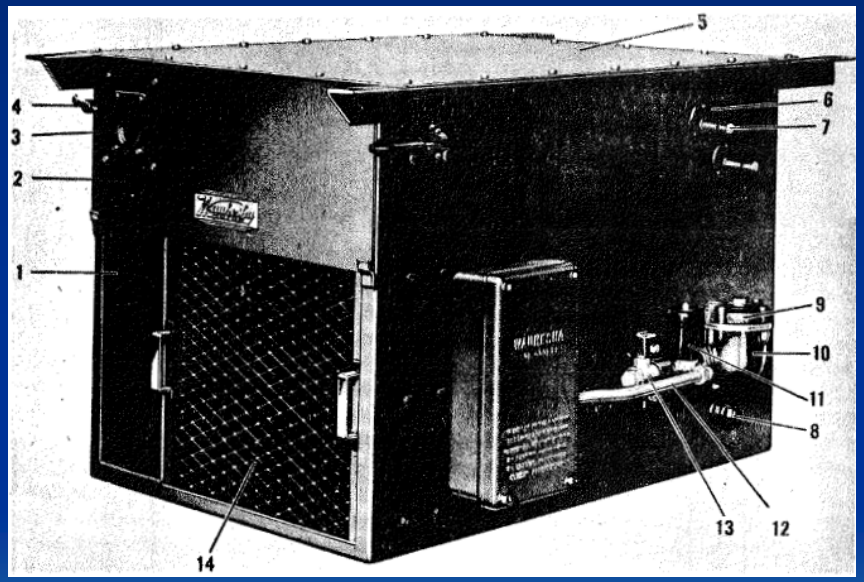


# Remote Engine Protection

- Optional remote puts extra overcrank and oil-heat trips inside car
- Both in pair must trip to stop engine
- Resetting either allows operation

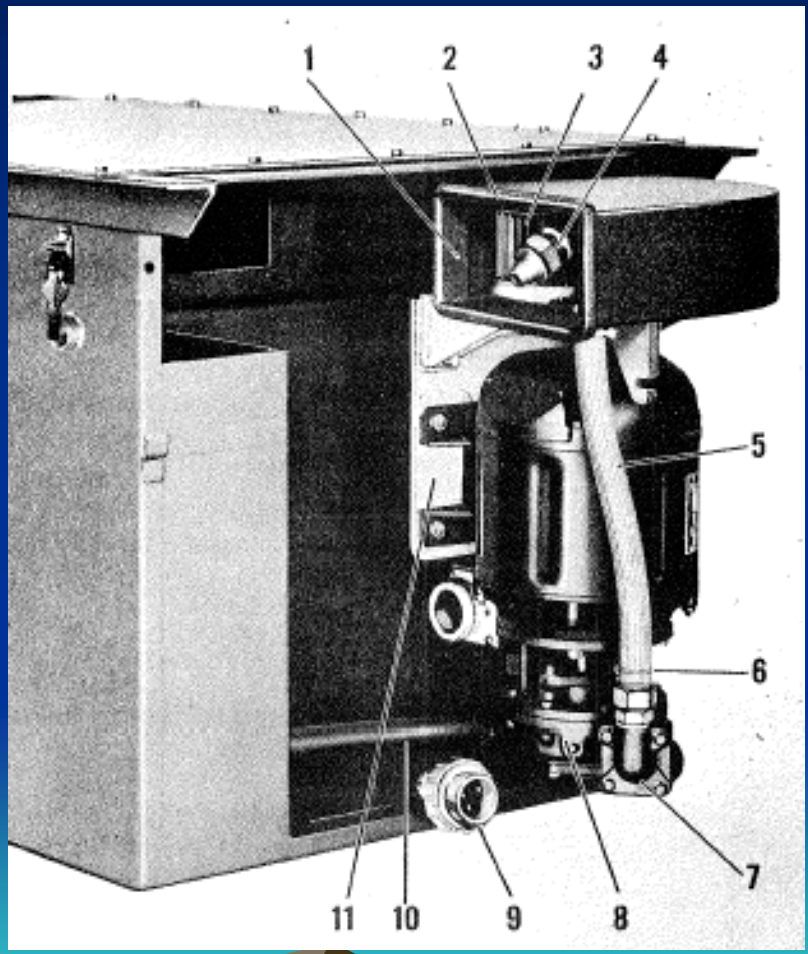
# Wet Condenser ("Subcooler")

- Extra cooler installed between compressor outlet and receiver tank
- ~40 gal capacity
- Can auto-fill from evaporator condensate drain or water raising system
- May be arranged with separate switch, tied to blower switch, or auto start/stop via pressure or temperature sensor



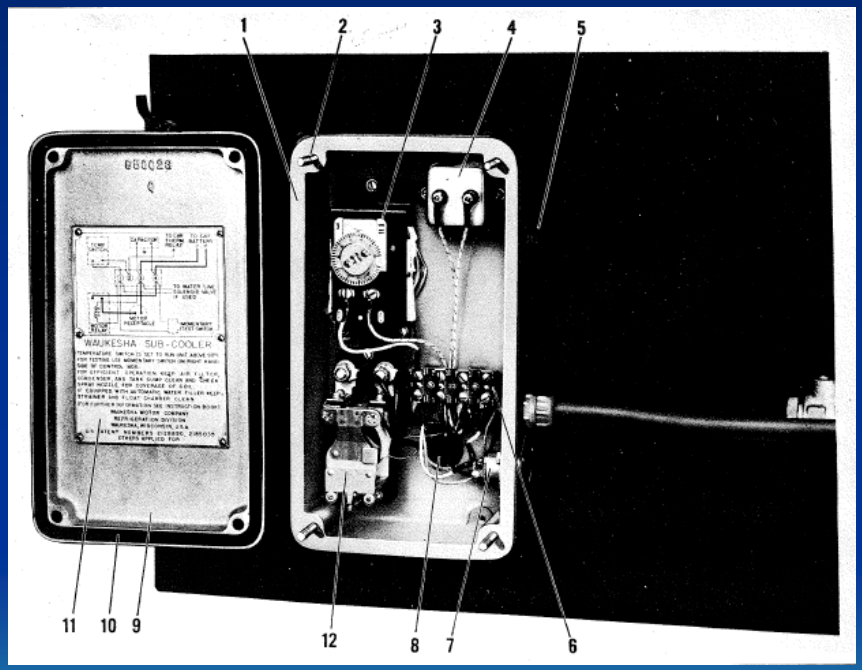
# Subcooler Air/Water Spray

- Combined blower & water pump assembly swings out for servicing
- Easily replaced
- Disconnect pump inlet hose when draining tank for winter!



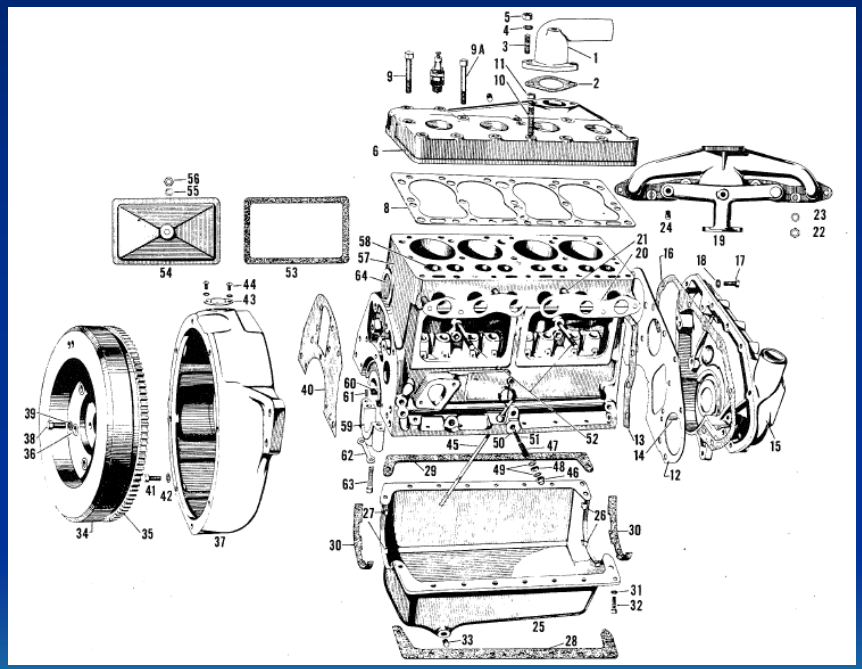
# Subcooler Control

- Control box contains pressure or temperature switch, parallel local test pushbutton, and motor starter relay



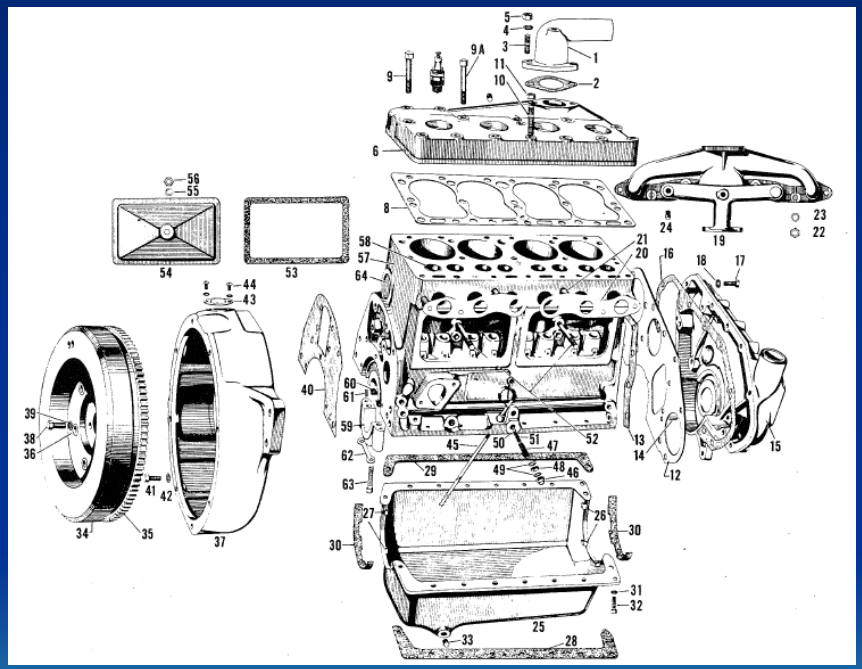
# FC Engine

- Propane fuel
- Straight-four flathead
- Water-cooled
- Four-cycle
- Magneto ignition
- Pre-WWII design



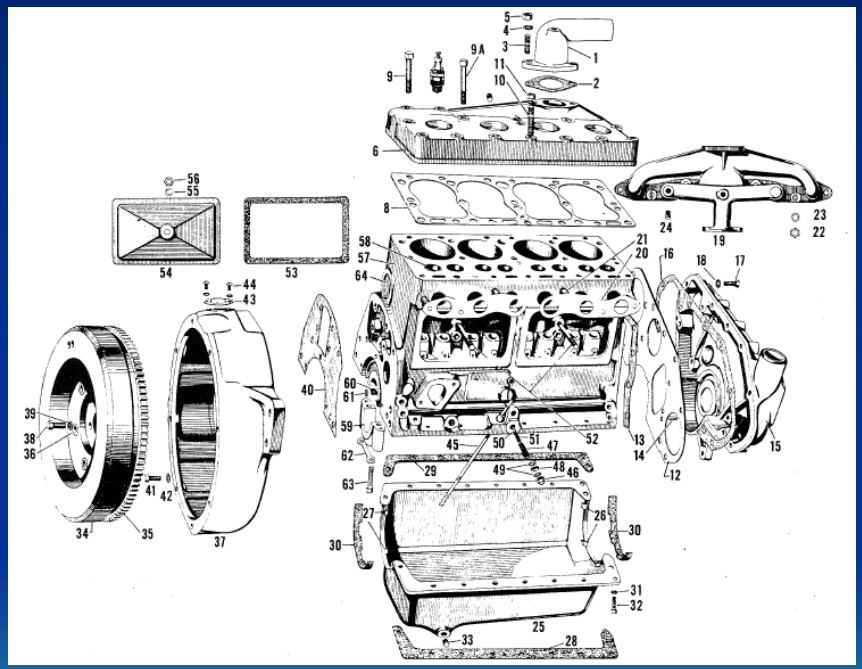
# Head Repairs

- Cast iron head – can be welded with special rod, preheat, & slow cool-down
- Only connections are water outlet & spark plugs
- Never reuse gaskets – Victor Reinz 1342G is a physical fit



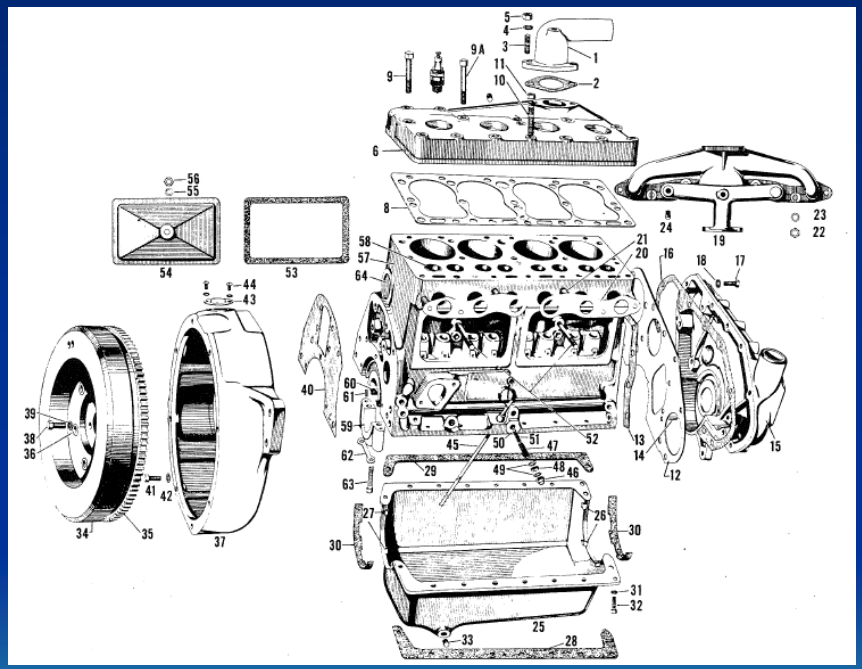
# Good Compression

- Requires 75 to 140 psi each cylinder
- All 4 should be about the same
- To test, run until warm then remove all plugs
- Have a good battery
- Take max reading over 10+ pumps



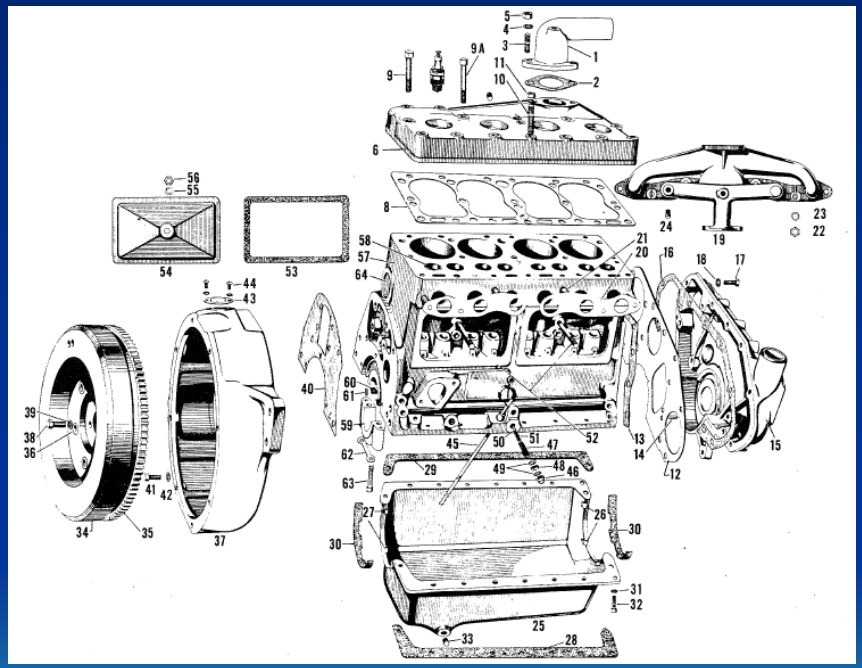
# Bad Piston Rings

- Poor compression
- Oil lost to combustion
- Maybe vertical scratching of cylinder walls
- Use cylinder hone to clean minor damage
- Source for new rings is ???



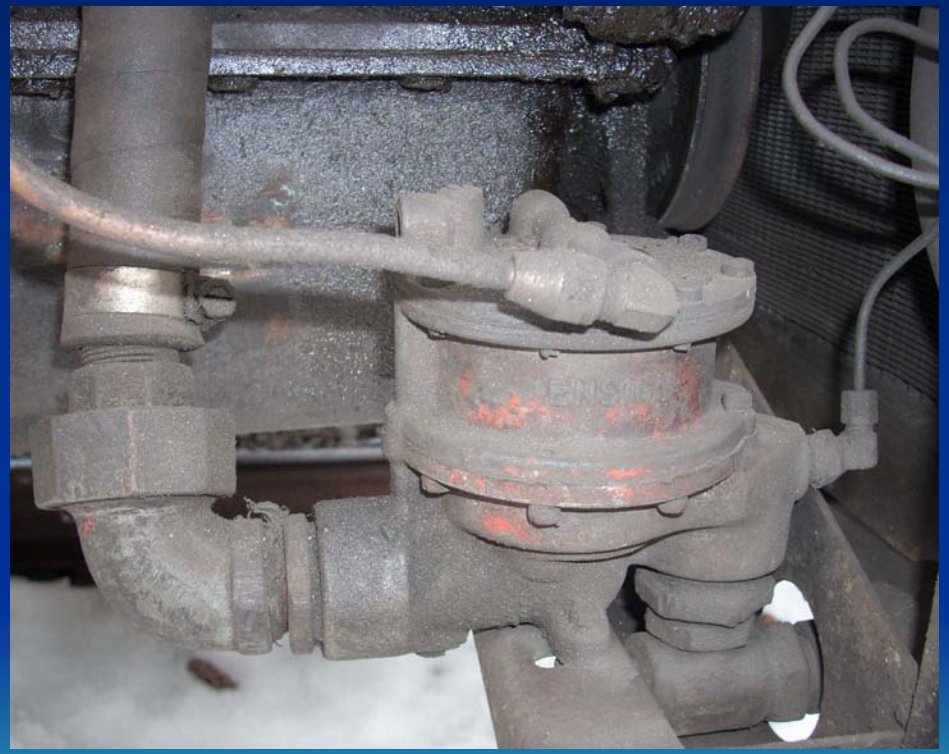
# Bad Valves

- Poor compression
- Violent fluctuation of vacuum gauge
- Cracked valve = toss
- Bad seat = lap or grind
- Bent stem = toss
- Sticky movement = new guides?



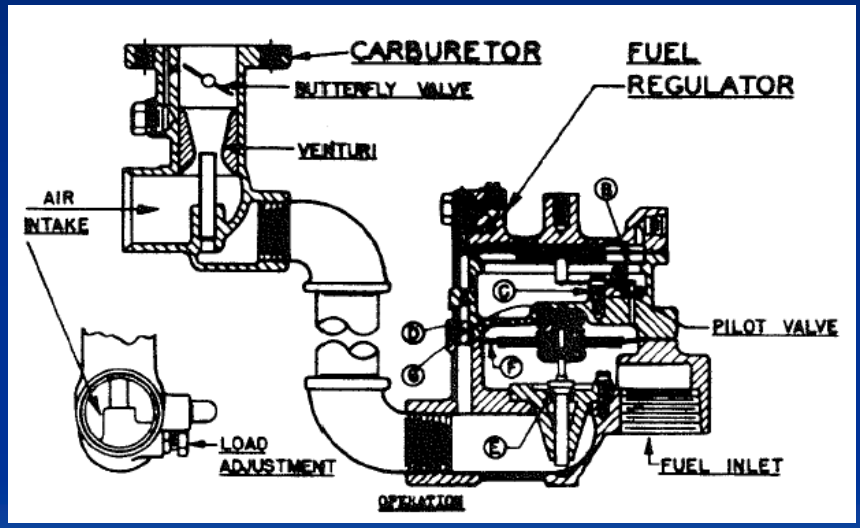
# Propane Regulator

- Propane supplied as a gas, not liquid
- Mercury manometer in control box shows pressure at regulator inlet (should read 3 to 5 oz)
- Regulator provides proper inlet pressure to carburetor for correct fuel/air mix



# Propane Carburetor

- Mixes fuel & air – adjust mixture via needle valve on side for best combustion
- Too lean – power loss
- Too rich – carbon monoxide danger
- Stamped “GEN” or “ICE” – specific to application



# Propane Carburetor

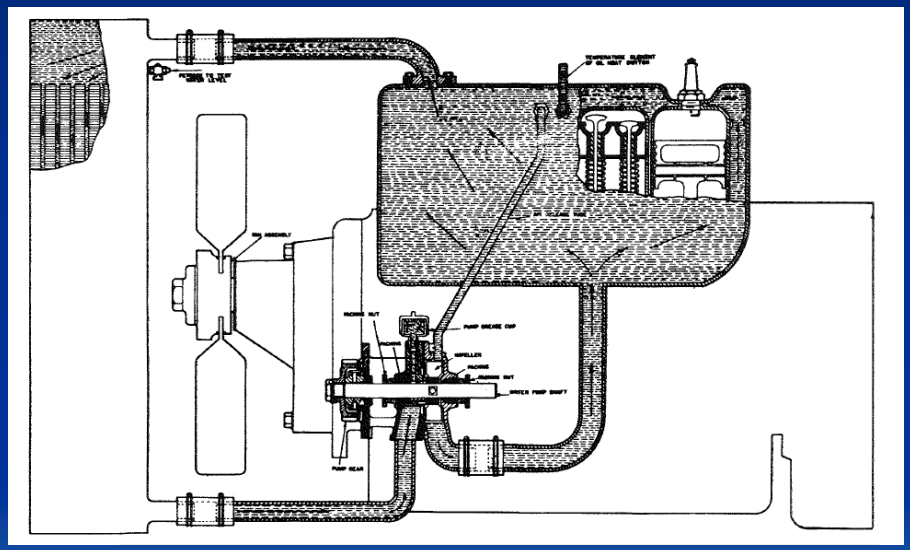
- Governor sets engine speed via butterfly valve (throttle)
- May have a small pipe to regulator – compensates for partly-plugged air filter
- Gum deposits need periodic washing out

# Air Filter

- Vortex type – air is drawn in top & swirled around
- Heavy dirt particles drop out
- Oil in bottom cup captures particles

# Cooling System

- Cool water pumped into bottom of jacket
- Hot water exits at top
- Not pressurized
- No thermostat
- Use 50/50 distilled water & automotive antifreeze

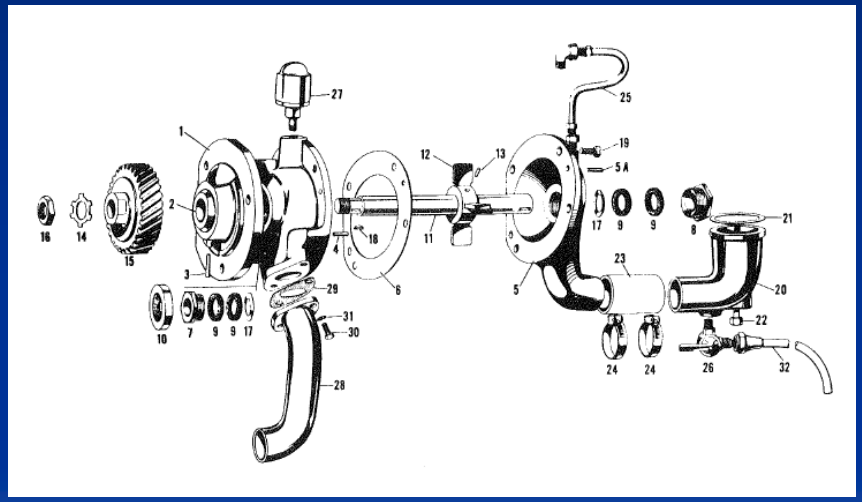


# Overheating

- Overheating possible if no coolant, water pump not pumping, radiator plugged, fan not turning, or bad head gasket allowing burning gas into water jacket
- Typical damage: cracked or warped head
- If OIL-HEAT keeps tripping, measure head temperature (handheld optical is nice) – over 240° is bad
- If head temp and oil pressure OK, disconnect wires from sensor in head & check sensor.
- Do not disable OIL-HEAT!

# Water Pump

- Gear-driven impeller
- Tube at top let air out when filling
- Water seals most common failure
- Oil seal: SKF 7572
- Inverted flare: NAPA 202x4
- Complete disassembly required to change gear-side seal
- When changing, careful not to change timing by turning the magneto!



# Radiator Fan

- Belt-driven from crankshaft
- Belt must be tight enough to roll engine when fan blade is turned by hand
- Lever-type belt tightener, with lock nut
- Use 5L310 V-belt

# Magneto

- Bosch (more common) or Edison
- Driven through water pump
- Check operation by removing spark plugs & laying them on the head
- Can also check with a timing light (2 lantern batteries will power)
- Use wire-core plug wires, not high-resistance carbon – a magneto puts out less energy than a distributor
- Look for rebuilders under 'aviation'

# Spark Plugs

- We've used NKG A-7, Champion D16-J, Champion 514...
- Correct gap is most important.

# Firing Order

- Cast into block: 1-3-4-2
- Cylinder #1 closest to fan
- Standing at radiator, magneto spins counter-clockwise
- Good idea to mark magneto w/paint marker when removing
- Looking at wire-connection end of magneto:  2  1
  4  3

# Timing

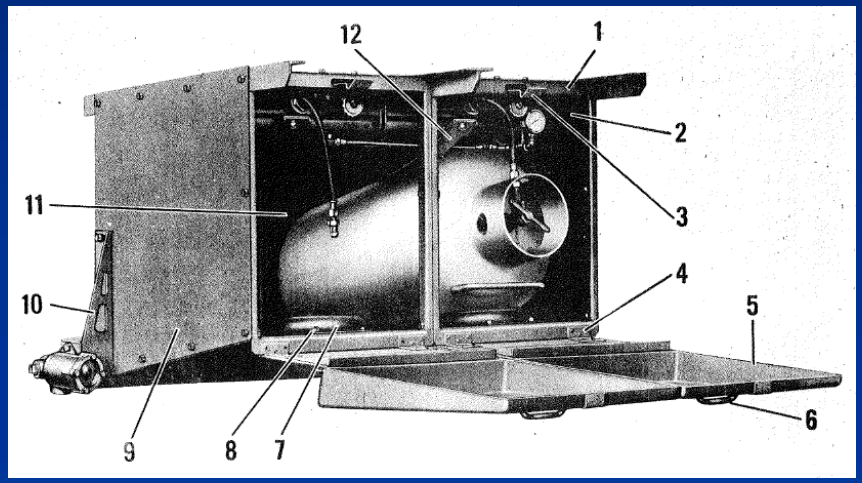
- Engine will not start if timing is off
- Manual says roll engine by hand until “fire” mark on flywheel visible, then set magneto to #1 firing position (Cylinder #1 is closest to fan)
- Fine adjustment via worm gear in magneto coupling.
- If won’t start, can use timing light to verify – clamp on #1 plug wire, flash should illuminate flywheel “fire” mark in window. (Trick: Two 6v lantern batteries will power timing light)

# Engine Oil

- Will stay fairly clean because propane doesn't produce soot
- Use good automotive engine oil
- Oil pressure is adjustable – should be 15 to 35 lbs on control box gauge
- Oil pressure under 4-6 lbs for 90 seconds will trip OIL-HEAT engine shut-down
- Uses an external cotton-waste oil filter (if any) – or try NAPA 1108 or Baldwin Filters T51-M
- Most oil is pumped into engine – only a portion gets filtered

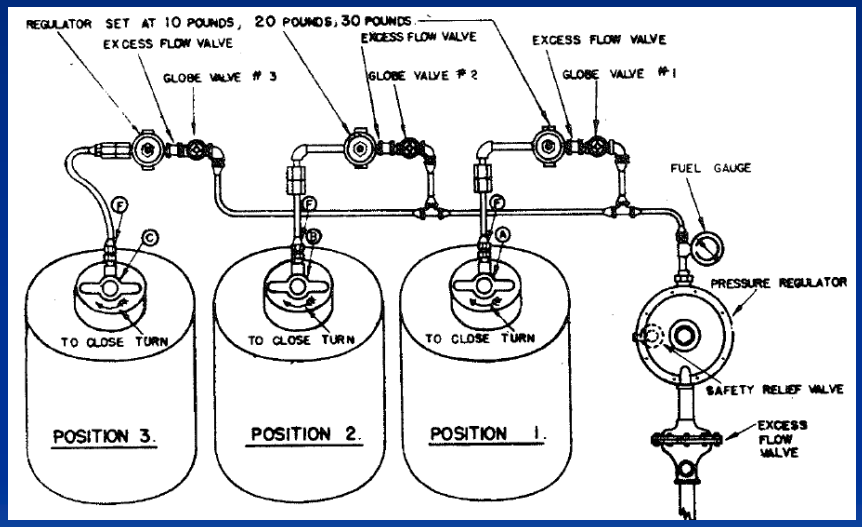
# Propane Bottles

- Bottles contain 100 lbs liquid propane
- Shorter, fatter, & better built than commercial 100-lb
- Up to 135 lbs empty, 235 lbs full – two man carry
- “J” snorkel draws propane gas off top



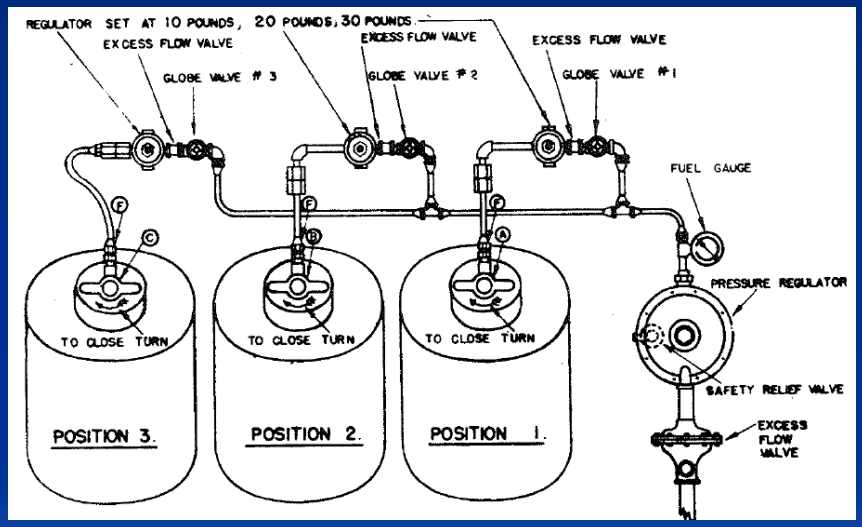
# Fuel Manifold

- Not a true manifold – each bottle regulated separately
- Each regulator set to a different pressure: 10 lbs, 20 lbs, etc
- Bottles empty from highest pressure to lowest



# Safety Features

- Shutoff valve for each propane bottle
- Regulator also functions as a check valve to prevent back-flow into bottle
- Excess flow valves prevent uncontrolled dumping
- Heavy construction



# Fuel Cabinet Features

- Built to snuggle under center sill
- Bottle tilted to keep it from sliding out
- Available in multi-bottle cabinets or sectional cabinets
- Cradle keeps bottle from rolling
- Cradle available as unheated, steam-heated, or exhaust-heated

# Surge Chamber

- Fuel line must have a 400 cubic inch surge chamber between fuel cabinet and FC engine
- Allows engine to rev without drawing liquid propane

# Roll-Out Rails

- Lower rail nests in structural channel – separated by rubber vibration dampeners
- Upper rail prevents tip-out

# Roll-Out Stops

- Fit either side
- ¾” Box Wrench
- Adjust upper stop bolt to keep unit from shifting
- Engine-generator shown, Ice Engine uses outer holes

# Rail Extensions

- Should be a pair of extensions hung next to one roll-out rail
- Drop over pins in roll-out rail
- Not long enough to lift unit out vertically

# That'll Do


- Questions?