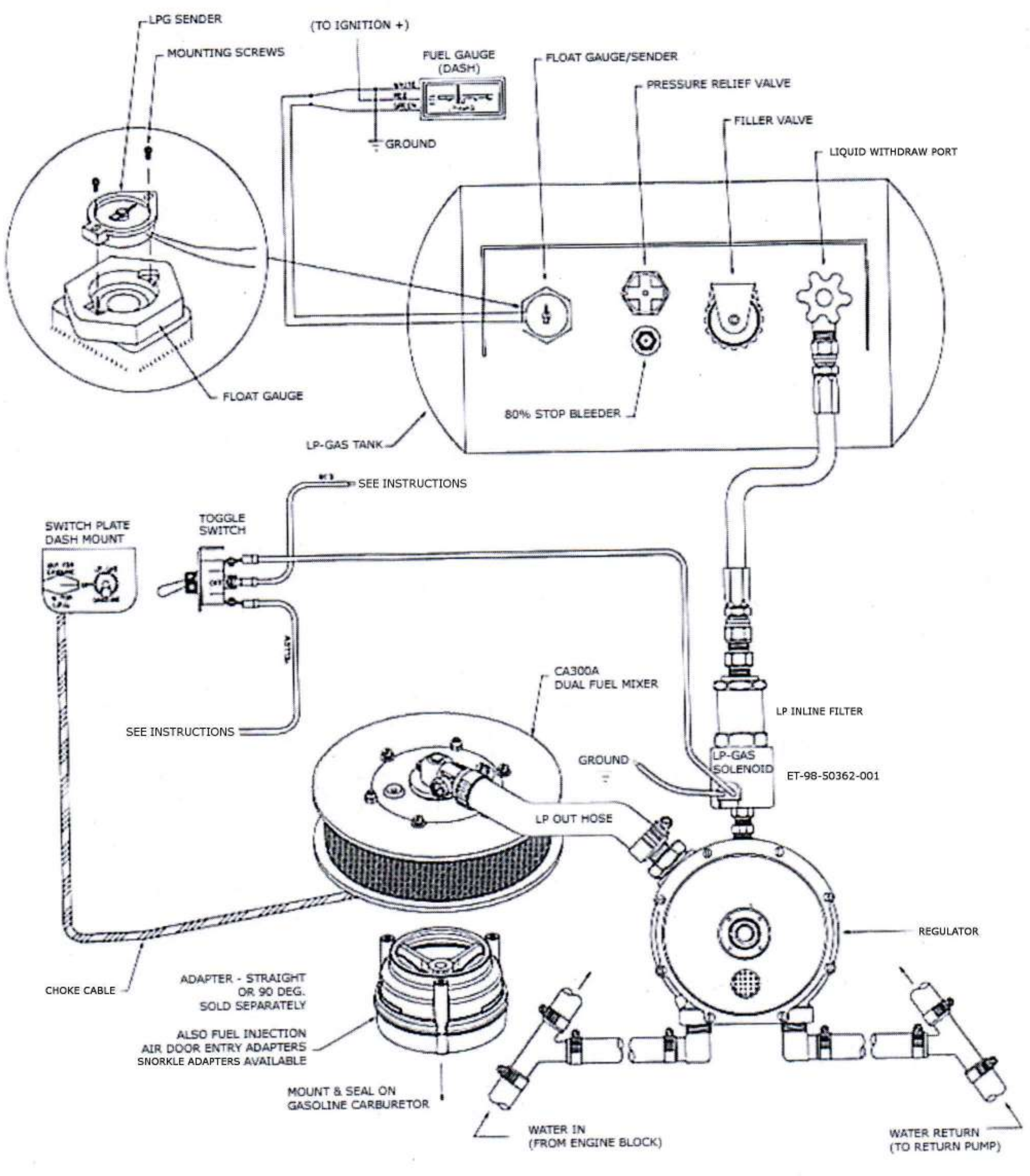
AUTOMOTIVE DUAL FUEL SCHEMATIC
LPG & GASOLINE CA300



IMPCO FUEL SYSTEM ADJUSTMENT INSTRUCTIONS

1. BE SURE THAT WATER HOSES, FUEL HOSES AND WIRES ARE PROPERLY FASTENED IN PLACE. THEY SHOULD BE CLEAR OF THE EXHAUST SYSTEM AND SHARP OBJECTS.

2. THE FUEL CYLINDER MUST BE LOCATED WITHIN THE OUTER LIMITS OF THE MACHINE.

CHECK FOR FUEL SYSTEM LEAKS

1. PRESSURIZE THE FUEL SYSTEM BY OPENING THE FUEL CYLINDER HAND VALVE SLOWLY AND CONTINUE AS FOLLOWS:

   A. SYSTEMS WITH VACUUM OPERATED SHUTOFF VALVES SUCH AS THE IMPCO VFF30 MUST HAVE VACUUM APPLIED TO THE VALVE TO ALLOW FUEL TO PASS THROUGH TO THE CONVERTOR (VAPORIZER-REGULATOR). THIS CAN BE DONE BY OPERATING THE ENGINE CRANKING MOTOR.

   B. SYSTEMS WITH ELECTRICALLY OPERATED SHUTOFF VALVES MUST HAVE CURRENT TO THE VALVE BEFORE IT OPENS AND ALLOWS FUEL TO PASS THROUGH. A VACUUM SWITCH OR OIL PRESSURE SWITCH MUST BE USED AS AN ADDITIONAL SAFETY AND WIRED IN SERIES WITH THE ELECTRIC SOLENOID. ACTUATING EITHER OF THESE CAN BE DONE WITH THE CRANKING MOTOR. IT MAY TAKE MORE CRANKING TO ACTUATE THE OIL PRESSURE SWITCH.

2. CHECK ALL OF THE FUEL CONNECTIONS FOR LEAKS WITH AN APPROVED LEAK CHECK SOLUTION WHILE THE SYSTEM IS UNDER LP GAS PRESSURE OF NOT LESS THAN 90 PSI. ALL LEAKS MUST BE REPAIRED.

BEFORE YOU MAKE ANY FUEL ADJUSTMENTS:

1. THE AIR CLEANER SHOULD BE INSTALLED.
2. IGNITION TIMING MUST BE CHECKED AND ADJUSTED PER THE ENGINE MANUFACTURER'S SPECIFICATIONS. PROPANE BURNS SLOWER THAN GASOLINE. RETARDED TIMING WILL REDUCE HORSEPOWER AND INCREASE EXHAUST EMISSIONS. MOST MANUFACTURERS RECOMMEND ADVANCING THE TIMING 3 TO 5 DEGREES. THIS WILL INCREASE LOWER END TORQUE HORSEPOWER; HOWEVER YOU MAY EXPERIENCE A LOSS OF POWER UNDER EXTREME HEAVY LOAD CONDITIONS. WHEN MACHINES ARE WORKED VERY HARD, BE CAREFUL NOT TO ADVANCE THE TIMING BEYOND THE MANUFACTURER'S RECOMMENDATION. THIS WOULD CAUSE UNNECESSARY STRESS ON THE ENGINE.
3. CONVERTING ENGINES TO BURN PROPANE MAY CAUSE THE GOVERNED ENGINE SPEED TO CHANGE. TO MAINTAIN THE TRUCK'S "NO LOAD" AND "LIGHT LOAD" DRIVABILITY, IT MAY BE NECESSARY TO RESET THE GOVERNOR TO FACTORY SPECIFICATIONS. THE ENGINE AND TRANSMISSION MUST BE AT ITS NORMAL OPERATING TEMPERATURE PRIOR TO MAKING ANY ADJUSTMENTS.

POWER ADJUSTMENT:

FULL POWER MIXTURES ARE CONTROLLED BY THE MIXTURE ADJUSTMENT AT THE FUEL INLET OF THE MIXER. THE FUEL MIXER CASTING IS MARKED WITH AN "R&L" INDICATING THE FULL, RICH AND LEAN POSITIONS OF THE VALVE. THIS ADJUSTMENT WILL CONTROL THE FULL LOAD FUEL MIXTURE AND MUST BE MADE WITH THE ENGINE UNDER FULL OR WORKING LOAD.

IDLE ADJUSTMENT:

TURNING THE SCREW "IN" WILL MAKE THE FUEL MIXTURE RICHER AND TURNING IT "OUT" WILL MAKE IT LEAN. THIS ADJUSTMENT MUST BE MADE AT THE MANUFACTURER'S RECOMMENDED IDLE RPM.

WE STRONGLY RECOMMEND THAT YOU USE A CARBON MONOXIDE FUEL ANALYZER TO ADJUST THE FUEL MIXTURE.

READINGS USING CARBON MONOXIDE ANALYZER

POWER MIXTURE - .5% +/- .25%
IDLE MIXTURE - .5% TO .75%

READINGS USING AIR FUEL RATIO ANALYZER

POWER SETTING - 15.5 - 16 TO 1
IDLE SETTING - 14.5 TO 1

NOTE: WHEN EXHAUST ANALYZERS ARE NOT AVAILABLE, A TACHOMETER MAY BE USED. MAKE FUEL ADJUSTMENTS TO OBTAIN MAXIMUM RPM READING, THEN LEAN FUEL MIXTURE TO LOWER READINGS 10 - 20 RPM.

IMPORTANT !

Carbon Monoxide - what service personnel should know!

OSHA Requirement

The CO level shall NOT EXCEED 50 PPM measured over an 8 hour period in the work environment.

How does parts per million (PPM) relate to percentage numbers?

One million parts per million equals one hundred percent of the engines exhaust gases.

10% CO	equals	100,000 PPM
1% CO	equals	10,000 PPM
.1% CO	equals	1,000 PPM
.01% CO	equals	100 PPM

For Each One One-hundredth of One Percent You Will Have 100 PPM.
Example: .01 % X 1,000,000 PPM CO = 100 PPM CO.

With Adequate Ventilation and Following the Enclosed Adjustment Instructions, You Should Be Able to Keep the Carbon-monoxide Level below the OSHA Requirement.

WE STRONGLY RECOMMEND THE USE OF A CARBON MONOXIDE ANALYZER

RECOMMENDED SAFETY MAINTENANCE PROCEDURE FOR LP GAS FUELED FORKLIFT TRUCKS

WARNING: *All fuels used in internal combustion engines are flammable and should be treated with caution. All cigarette smoking and open flames should be prohibited. Sparks should be avoided. The fuel cylinder should be mounted so that it does not extend outside the truck and should also be properly positioned by using the locating pin or key way.*

The fuel valve should be turned off when the machine is not in service.
Cast fittings should not be used in the LP-GAS system.
Use only Underwriters Laboratories or Factory Mutual listed LP-GAS hose assemblies where pressure fuel lines are required.
All pipe threaded fittings should be installed using an approved sealing compound.
Fuel lines should be supported by clamps to minimize chafing and wear.
The LP-GAS solenoid valve should be wired to an automatic shut off switch (oil pressure or vacuum) to prevent leakage of gas in the event the ignition is on without the engine running.

Check the propane solenoid or vacuum shutoff valve for leakage as follows:

1. *Turn fuel cylinder valve off, start and run engine until it stops.*
2. *Install a 0 to 30 PSI pressure gauge per instruction A or B.*
   A. *For propane systems with a single unit consisting of primary and secondary regulators, install at the primary test port.*
   B. *For propane systems consisting of two separate regulators, install between the primary and secondary stages.*
3. *Turn cylinder fuel valve on. The pressure gauge should maintain a zero reading.*
   If it does not, the solenoid valve or vacuum shutoff valve must be repaired or replaced.

An odor is added to LP-GAS to help detect leaks. If the gas odor is detected the fuel cylinder supply valve and engine should be turned off. Remove all sources of ignition, and ventilate the area. Make all of the necessary repairs before you turn the fuel supply on.
The complete LP-GAS system should be inspected periodically. Check all hoses for wear, connections for leaks and all parts for damage.

NOTE: Fuel hoses have a limited life expectancy. They should be checked for cracking and drying due to age. Hoses with visible signs of age should be replaced. Use only Underwriters Laboratories or Factory Mutual listed LP-GAS parts for replacements.

NOTE: The above information is provided as a guide. Consult the National Fire Protection Association pamphlet 58 for the safe storage and handling of liquefied petroleum gases. Governmental safety regulations in your locality could vary. Check with the authority having jurisdiction to be sure that you meet all of their requirements. Contact the manufacturer for detailed service information.

INSTALLATION INSTRUCTIONS FOR MODEL "E" AND "E-2" VAPORIZERS

- Select mounting location below water level of radiator (to avoid air lock) and within close proximity to the mixer to allow for the shortest length of vapor hose to the mixer. Do not mount on engine due to excessive vibration. Position can be anywhere from level to 90 degrees down with the vapor port in the downward position.
- Check bottom of vaporizer for port identification. (Water, fuel inlet, fuel vapor inlet)
- Install all fittings and lock off valve (if electric lock off) in appropriate ports, pointing them in the most convenient direction for final hookup. Use a thread sealer. NOTE: Do not over tighten fittings, especially the lock off valve, in order to avoid cracking the main housing. Cracked housings due to over tightening will not be covered by warranty.
- Select inlet & outlet sources for hot water from vehicle cooling system. (Direction of water flow is not important.) **Suggestions:** Heater hoses, threaded ports in thermostat housing, water pump, engine block, cylinder head or intake manifold. Optional "Y" tubes can be used in heater hoses to create a separate water circuit if desired. If water ports are difficult to access or locate, you may choose to purchase a hose tap kit from **NASH FUEL – Phone # 859-881-0509.** This will include 2 hose taps that can be used to tap into the upper and lower radiator hoses for a 5/8" hose connection that can then be routed to the vaporizer. **Part # HTC625ST** for a set of straight hose taps or **HTC62545deg** for a set of taps that come out of the heater hose at a 45 degree angle. Can be a great time saver.
- **ELECTRICAL:** Connect one wire of the electric lock off (if used) to frame ground, and the other to the positive terminal on the ignition coil or ignition terminal of the key switch. If a vacuum switch is used, connect this circuit to energize the lock off when vacuum is present.
- **LPG PRESSURE HOSE:** Select the most convenient routing to the fuel tank. Avoid hot exhaust system components, moving components such as drive shafts, and sharp surfaces such as sheet metal.
- **VAPOR HOSE:** Follow the shortest route to run this hose from the vaporizer to the mixer, clamping both ends securely.
- **OPTIONAL EQUIPMENT AVAILABLE:** Cold start assist kits – electrical or manual, Hot water thermostat kits to control the temperature of the vaporizer - to help eliminate tar buildup in the vaporizer, Power boost valve – vacuum operated. Available from **NASH FUEL 859-881-0509**

Carburetor Adjustments

There are three carburetor adjustments. The idle *speed* adjustment controls the degree of opening of the butterfly at idle, the same as the adjustment on a gasoline carburetor. The *idle* mixture adjustment controls mixtures at idle and slightly above, while the *power* mixture adjustment controls full-power/high-RPM mixtures.

Light load or cruise mixtures are controlled by the contour of the gas metering valve. These are not adjustable at the carburetor. Power mixture adjustment must be set under full load. This adjustment has no effect at idle or in the light-load range. A CO meter or exhaust analyzer is highly desirable for making the power mixture adjustment. If an exhaust analyzer of the Wheatstone Bridge type must be used, care should be exercised to limit exhaust pressure into the instrument as it can give a false rich reading. The analyzer must be kept reasonably dry with a water trap as well. An infra-red CO meter is a more accurate instrument; however most of these operate on 110 AC voltage and require an inverter to 12 volts if they are to be used in a moving vehicle.

Proper CO reading for the power adjustment depends on the type of vehicle and its use. A heavy-duty truck operating under continuous full-load conditions should be adjusted no leaner than 1.5 to 2.0 percent CO for safety. A light duty vehicle can operate safely as lean as 1.0 or 1.5 percent CO, since it will not be operating "flat out" for long periods of time. The slightly richer mixtures for trucks will help avoid detonation, without being rich enough to elevate exhaust gas temperature unreasonably.

Extremely lean mixtures during acceleration, possibly caused by a restricted balance line from the carburetor to the converter, or lean mixtures under load, place a high voltage requirement on the ignition system which may cause missing or crossfire with resultant backfires.

Maximum richness for optimum performance is close to 3.0 percent CO. Horsepower will begin to drop as the mixture is richened beyond this point. There is not much change in power from 1.0 percent CO to 3.0 percent CO.

If the engine does fall off in power with a power mixture leaner than 3.5 percent CO, it is a sign of poor fuel distribution in the air stream to the intake manifold. In an eight-cylinder engine, for example, four may be rich and four lean. Mileage would be poor.

Spark Plugs

Spark plug electrodes should have sharp and square edges. When electrodes become worn, rounded, or burned, the voltage requirement increases. Also, as electrodes erode away with use, gaps begin to widen.

The wider the spark plug gaps, the more voltage necessary to bridge the gap. Impco recommends a .028 gap on a standard ignition system and .035-inch gap on HEI and electronic ignitions. Beyond these gaps, the voltage requirement in a propane engine becomes too high.

Heat Range. Plugs are available in a variety of heat ranges. A *hot plug* transfers heat slowly, causing the plug to operate at a higher temperature. A cold plug has a faster rate of heat transfer, thus it operates at a cooler temperature.

As a colder spark plug heat range is utilized, greater voltage is required for a spark to jump the plug gap. Mechanics, knowing the fuel is a dry gas which causes very little carbon deposit, often decide to run a very cold range spark plug and expect no adverse effects from fouling. Frequently, plugs used are of such a cold heat range that the voltage requirement is extremely high all the time. With such a plug, even a fine ignition system will misfire in a very few thousand miles. This happens from the minute oxide begins to build on the electrodes.

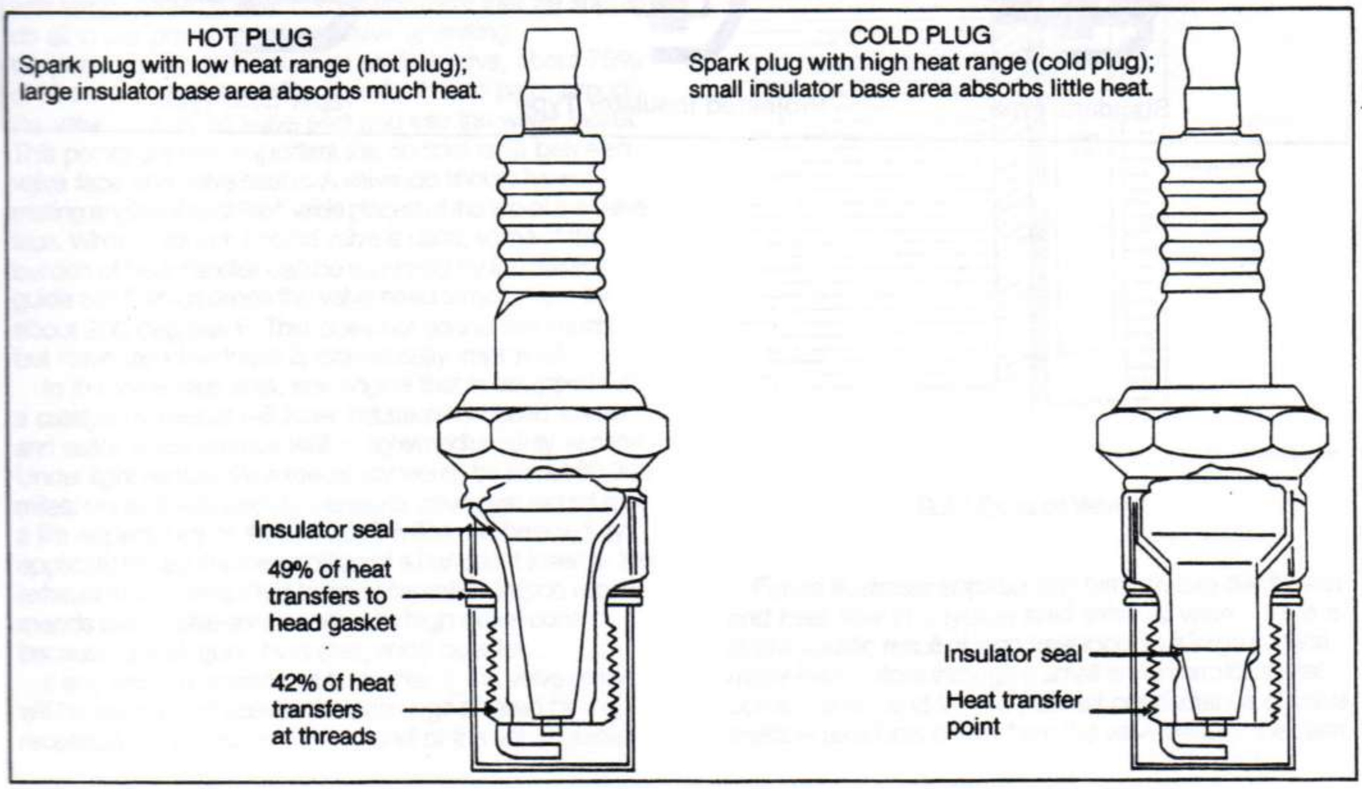
Oxide buildup on plug electrodes is usually caused simply by the spark going across the electrode gap. After a few thousand miles there is a burn somewhat similar to that seen on an arc welder's electrode. There is quite a bit of heat caused by ignition itself and it eventually does burn electrodes.

Selecting Proper Heat Range. To select a proper heat range plug, first check the ignition timing to be sure that spark advance is set correctly. Then pull a plug to look for signs of overheating. Close examination of spark plugs, using a magnifying glass, will often indicate developing trouble before it occurs. Tiny "pepper" spots on the ceramic insulator around the center electrode indicates detonation, even if it cannot be heard. Bubbled cement around the center electrode, or in extreme cases, speckles of white aluminum and blue center electrodes and ground straps indicate excessive heat in the combustion chamber.

Before choosing a spark plug, determine how hard the engine will work 90-percent of its lifetime. Will it be running under light-, medium- or heavy-load conditions? When you can determine this, then you will have a good idea of how high temperatures will be in the combustion chamber.

At that point, there are two considerations in choosing a plug for propane application. The plug must operate hot enough to keep voltage requirements to a minimum and cold enough to prevent preignition and detonation.

If you need additional guidelines, refer to the



Spark Plugs

engine manufacturer's spark plug recommendations for gasoline engines. For light-duty propane applications, use the plug that is specified. For medium- or heavy-load operation, choose a plug that is one or two steps colder than the recommended plug.

Plug Polarity. Reversed polarity of the current to the spark plugs requires 30 percent to 40 percent greater voltage to fire the plugs. Effects of reversed polarity may be seen in spark plugs with a dished side electrode opposite the center electrode.

If there is doubt as to correct polarity, remove a plug wire and hold it approximately 3/16″ from the plug terminal. Insert the tip of a lead pencil in the gap. A more visible spark will jump from the pencil tip to the plug terminal if polarity is correct. If it is reversed, the brighter flash will be to the wire terminal.

Polarity may be corrected by reversing the primary wires to the coil.

Spark Plug Life. Plugs can live for 30,000 miles or so with propane as fuel. However, every ten thousand miles, the plugs should be removed and a file run across the electrodes to break through the oxide, getting back down to the parent metal. Then the ground strap and center electrode should be filed back to a nice square configuration and regapped. When this is done, the spark plugs give excellent service for 30,000 miles or longer. If plugs are the proper heat range, there does not seem to be any deterioration of the porcelains.

Gap Styles of Spark Plugs

Standard Type — Projected Insulator Type — Taper Seat Type

Ignition System

Ignition–Primary Side. First, there is the voltage source. This would be the battery at cranking to start the engine, or the alternator when the engine is running. The current or voltage is transferred through an ignition switch. Along the line between the ignition switch and the primary side of the coil there is resistance in the primary wire or a separate external resistor, depending on the vehicle type. There are both types in use. Current flows from the ignition switch through the resistor and the primary side of the coil to the distributor. Within the distributor, points serve as a grounding switch. They cycle open and closed. When they are closed, the current flows through the primary side of the coil. This builds a magnetic field around the secondary windings of the coil. When the points open, the current is interrupted and the magnetic field collapses, generating a high voltage current in the secondary winding of the coil. There is an ignition condenser across the points whose sole function is to prevent arcing at the points when they begin to open. This is necessary because as the points open and the magnetic field around the primary winding collapses, voltage is generated in the primary winding as well as the secondary. If there was no condenser, there would be a large arc across the points. This would sustain the current flow and keep the magnetic field from collapsing rapidly. This condition would not only destroy the points but would also keep the secondary from building the voltage required in the system. The condenser is a storage tank into which excess current flows momentarily while the points are getting a few thousandths-inch air gap.

Ignition–Secondary Side. The secondary side of the ignition system may be described as the high pressure side. It is very important, especially with propane operation where elevated plug voltages are required all the time. Voltages will consistently run higher than a comparable gasoline operation. With a high voltage requirement, there is a greater chance of spark jump inside the distributor cap to the next segment, which will cause backfiring. Most late model engines use a brown alkyd distributor cap which is much superior to the old black bakelite cap. Bakelite loses dielectric strength rapidly as temperatures rise above 175 degrees F, and is subject to carbon tracking in damp weather.

Spark Plug Boots. Spark plug boots must be maintained in good condition or the spark will leap out of the boot to the nearest grounding object such as the metal heat shield or the exhaust manifold.

A worthwhile investment, especially in engines in a poorly ventilated underhood area, is the installation of silicone rubber spark plug boots. These are available from Belden, Autolite and others. They will outlast stock boots 10 to 1 while preventing spark jump as well. Silicone boots are most effective in extremely cold weather, as they retain flexibility and will not shatter when removed from a spark plug.

Spark Plug Wires. The spark plug wires must be in good condition. Wire can be of the IRS type with no malfunctions as long as it is in good shape. IRS wiring is wire now used universally on motor vehicles in the United States to reduce interference with television and radio reception. Many think it reduces the ignition performance; however, if the wire is in good condition (not broken internally) there is no difference in the performance of resistance wire compared to the standard metallic wire used previously. However, the IRS wire is highly susceptible to natural breakage and to extreme low or high temperature conditions when it becomes brittle and may easily break internally. This becomes a possible problem area and must be watched carefully. Silicone insulated premium IRS wire (such as Autotronics or Jacobs) is availabie for installation in extremely hot conditions such as cabover trucks and vans.

Ignition Coil. The ignition coil maintains a system that puts out high voltage potentials. There must be at least 28,000 to 32,000 volts available to give enough margin so there will be no misfiring if the ignition system deposits oxide on tne plug electrodes. This potential involves not only the coil, but the input voltage to the coil as well. Occasionally, a good coil may not put out very high secondary voltage, perhaps just 22,000 volts output on an open circuit, and upon examination, one will find that the input voltage is low. Input voltage at idle should be approximately 10 volts.

It is a general rule that a loss of one volt on the input side will cause a loss of 5,000 volts on the output side. If an alternator system is set very low on the voltage, or if the primary resistor on the input side of the coil has too much resistance, primary voltage drops and consequently the secondary will suffer badly. Changing a coil will not remedy this situation.

Extremely cold weather lowers resistance in the primary coil windings. As a result, more current will flow until the coil heats. This condition will cause points to burn prematurely. Since cold conditions also lower resistance in the starter windings, a tremendous amperage draw is placed on the battery, wires, terminals, and relays, all of which must be kept in excellent condition for cold weather starts.

Detonation & Preignition (from incorrect spark advance). Correct combustion is a controlled flame front which progressively burns across the combustion chamber. Detonation, on the other hand, occurs when the flame compresses and heats the unburned charge to the point of spontaneous combustion.

The effects of light detonation may be overheating of the engine, broken spark plugs, overloaded bearings, high fuel consumption, loss of power, etc. In extreme cases, pistons have been shattered, cylinders burst, or cylinder heads cracked. At times, the temperature resulting from detonation may reach the point where the piston is actually melted.

A knock or ringing sound, produced by the intense vibration of the combustion chamber walls, usually accompanies detonation. But the ringing might go unnoticed, drowned out by engine noises. Intermittent puffs of black smoke may also be observed coming from the exhaust pipe.

(Continuous black smoke indicates the engine is burning oil.) This smoke becomes heavy during severe detonation.

Preignition is so similar to detonation that they are often confused. Much of the same engine damage can result. But preignition begins when some part of the combustion chamber becomes hot enough to actually preignite the fuel mixture before the spark occurs. This can then lead to detonation.

Too much total spark lead to top end can create back-firing in the intake manifold. Detonation or preignition may cause a part of the combustion chamber to become extremely hot. This hot spot can ignite the fuel charge as it's entering the cylinder. This will actually explode back into the manifold, severely damaging the intake system.

Effects of Altitude. As elevation increases, atmospheric pressure decreases, causing comparable decrease in both combustion chamber pressure and burn rate. This means that the spark is no longer timed to draw maximum power from the engine.

The simplest method of compensating for increased elevation is to advance the initial spark lead. This is largely a trial and error method. But, it is safe to say that for every 5,000 feet, spark should be advanced approximately four degrees. If a timing adjustment is not made to allow for the effects of high altitudes on ignition, the slower burn rate can once again result in overheated exhaust valves and horsepower losses.

Gasoline engines are not affected as much as propane engines because as gasoline mixtures richen in high altitudes, the voltage required to jump the gap at the plug decreases, compensating for the loss of insulation. The gasoline engine suffers performance-wise due to the richened mixtures but spark jumping is controlled.

Propane fuels, however, have a high voltage requirement at the spark plug--far greater than gasoline. With propane carburetion, fuel mixtures do not richen as elevation increases, so voltage requirement remains high. Because fuel mixtures are constant, propane engines perform better than gasoline engines at high altitudes. But with the extreme voltage requirement, the low density of the air cannot provide enough insulation to prevent spark jumping.

Distributor Timing & Adjustment

There are three different considerations to think about in the distributor. First is initial timing. This occurs at idle in relationship to the crankshaft degrees before top-dead-center. Second is the flyweight curve, which is ignition timing mechanically advanced by increased RPM. Finally there is the vacuum advance system, which gives a high rate of advance for part-throttle cruising.

Each distributor should be checked for total advance, either on a distributor test machine, or with an adjustable timing light. Setting initial spark lead is possible with any timing light; however, most timing marks on the flywheel or vibration dampener are insufficient to show total advance. A timing light such as Sun furnishes with its console, or a portable light, such as the one manufactured by Fox Valley, may be used to set initial timing. Then, with the engine at peak RPM, an adjustment on the light allows the mechanic to synchronize the initial reading with the new RPM and read total advance on the adjustment.

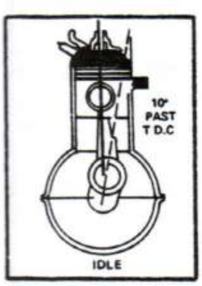
Heavy duty operations require fully advanced ignition by 2000 or 2200 rpm's. Accepted practice in LPG truck applications calls for 10 to 20 percent more initial spark lead (approximately 10 degrees) and 10 to 20 percent less total spark lead (usually 27 to 30 degrees than factory specification for gasoline in the same engine.

If spark lead is not advanced far enough, combustion will occur so late in the engine cycle that the fire will still be burning when the exhaust valve opens. Exhaust temperatures climb steadily until they result in the cracking of the exhaust manifold and burning of the exhaust valves.

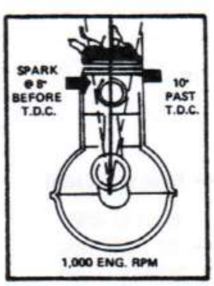
Should the exhaust valve itself become hot enough to ignite the incoming charge, backfiring will develop. Such destructive effects, due to underadvancing the spark, will also be accompanied by poor gas mileage and loss of horsepower.

It should be noted that, in certain states, it is illegal to modify the factory-specified initial spark setting or spark advance curve.

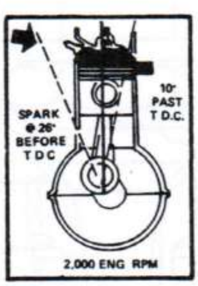
Centrifugal Advance. The centrifugal advance mechanism times the high voltage surge produced by the ignition coil so that it is delivered to the engine at the correct instant, as determined by engine speed.



IDLE



1,000 ENG. RPM



2,000 ENG RPM

When the engine is idling, the spark is timed to occur in the cylinder just before the piston reaches top-dead-center. At higher engine speeds, however, there is a shorter interval of time available for the fuel-air mixture to ignite, burn, and give up its power to the piston. Consequently, in order to obtain the maximum amount of power from the mixture, it is necessary at higher engine speeds for the ignition system to deliver the high voltage surge to the cylinder earlier in the cycle.

To illustrate this principle, assume that the burning time of a given gas mixture in an automotive engine is .003 of a second. To obtain full power from combustion, maximum pressure must be reached while the piston is between 10 degrees and 20 degrees past top dead center. At 1,000 engine r p m the crankshaft travels through 18 degrees in .003 a second, at 2,000 rpm the crankshaft travels through 36 degrees. Since the maximum pressure point is fixed, it is easy to see why the spark must be delivered into the cylinder earlier in the cycle in order to deliver full power, as engine speed increases.

NO ADVANCE

FULL ADVANCE

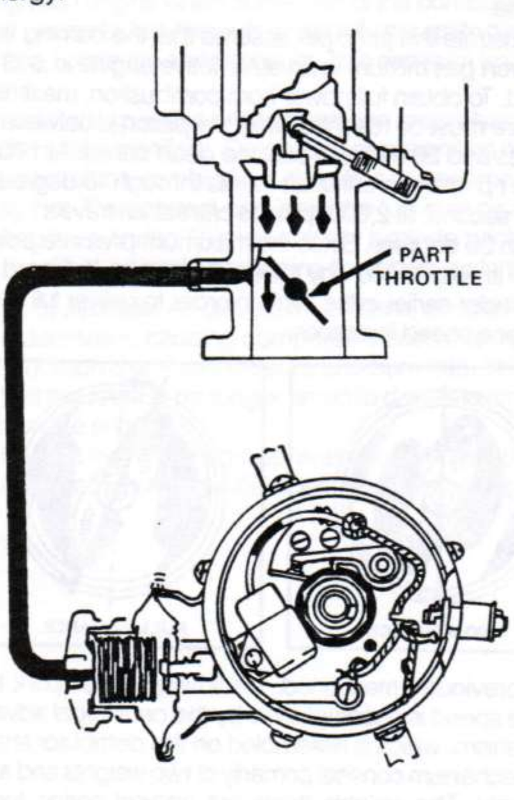
As previously mentioned, the timing of the spark to engine speed is accomplished by the centrifugal advance mechanism, which is assembled on the distributor shaft. The mechanism consists primarily of two weights and a cam assembly. The weights throw out against spring tension as engine speed increases. This motion of the weights turns the cam assembly so that the breaker cam is rotated in the direction of shaft rotation to an advanced position with respect to the distributor drive shaft. The higher the engine speed, the more the weights throw out and the further the breaker cam is advanced.

Modification of the centrifugal weight advance can be made easily with advance limiting plates manufactured by Gann Products Company, Downey, California. Its installation in the distributor restricts the flyweight travel to a given number of degrees. Since flyweight advance doubles at the crankshaft, total spark lead is easily computed. For example, should the use of a Gann plate allow 9 degrees of flyweight travel, advance automatically doubles to 18 degrees at the camshaft. This figure, added to the initial spark lead at idle, equals total advance.

Vacuum Advance. Cruising at light loads and small throttle openings produces high manifold vacuum which reduces the cylinder pressures. At the same time, lean mixtures are maintained. Because of these two factors, the fuel-air mixture burns very slowly. Additional spark advance (over and above advance provided by the centrifugal advance mechanism) will increase fuel economy. The extra advance is required to start the "fire" early enough to achieve suffi-

Distributor Timing & Adjustment

cient burning of the fuel by top-dead-center. Otherwise, most burning occurs on the way down after top-dead-center, greatly elevating exhaust temperature and wasting fuel energy.

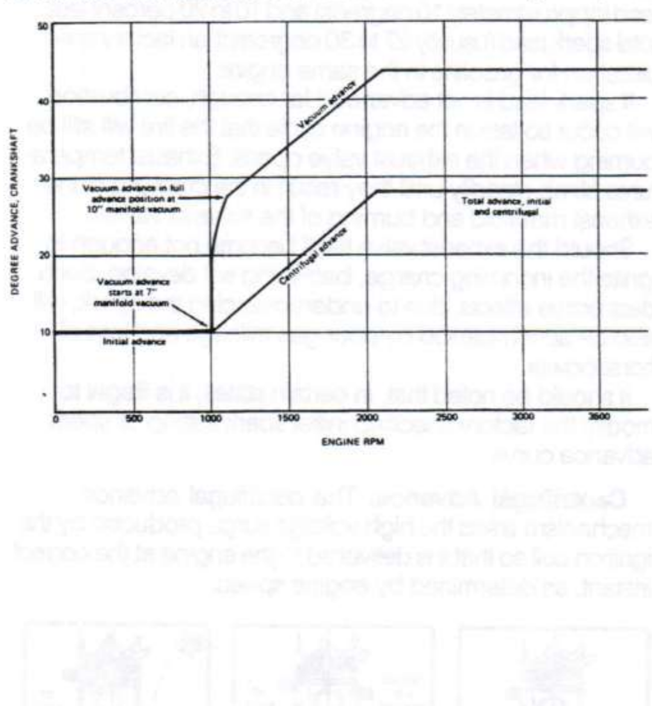


To provide advance based on intake manifold vacuum conditions, most distributors are equipped with a vacuum advance mechanism. This mechanism has a spring-loaded diaphragm connected by linkage to the distributor.

The spring-loaded side of the diaphragm is airtight, and is connected in many cases by a vacuum passage to an opening in the carburetor. This opening is on the atmospheric side of the throttle when the throttle is in the idling position. In this position, there is no vacuum in the passage.

When the throttle is partly opened, it swings past the opening of the vacuum passage. Intake manifold vacuum then can draw air from the airtight chamber in the vacuum advance mechanism and this causes the diaphragm to be moved against the spring. This motion is transmitted by linkage to the distributor breaker assembly, causing it to rotate. The amount of distributor breaker assembly rotation is governed by the amount of vacuum in the intake manifold up to the limit imposed by the design of the vacuum advance mechanism.

You must be sure that the vacuum spark advance does not put the total spark lead beyond 45 degrees. This is of no benefit to mileage and could cause severe detonation. Often the degrees of vacuum advance cannot be precisely controlled. In that case, it is best to disconnect the mechanism, rather than take the chance of overadvancing the spark.



Valve Theory & Problems

Under extreme heat conditions, exhaust and intake valve materials lose their hardness and tensile strength at a very rapid rate. This leaves the valve face in a softened condition, so it is vulnerable to rapid wear or welding against the valve seat.

On intake valves, an overheat condition will show up as a tuliped valve. On exhaust valves, we will have valve recession, which is a wearing process between valve face and valve seat. This wear is caused by valve movement in a circular direction against the valve seat. With the valve face being soft, wear takes place at a rapid rate. Recession wear can take place on the valve face or the valve seat or both. If any welding takes place between valve face and valve seat, a rough surface will result which aggravates the recession process.

The tendency for valves to suffer recession is greatly increased by engine rpm and load, as these factors add to valve heat and valve rotation against the seat.

The basic difference between operation on gasoline and propane or natural gas is the fact that there are no protective deposits left by the fuel on the valve face or valve seat, so any rotational movement between the two will cause wear. Every effort should be made to prevent rotational movement between valve and seat. Mechanical valve rotators should be made inoperative by small tack welds, free floating valve keepers ground so they fit the valve stem tightly and prevent valve rotation, and valve springs carefully checked to manufacturer's specs on height and tension.

We have mentioned the rapid loss of valve steel hardness with temperature, so it becomes apparent that we should do all in our power to reduce valve operating temperature. On a non-sodium cooled valve, about 75% of all the heat that the valve absorbs has to pass through the valve face to the valve seat and into the water jacket. This points out how important the contact area between valve face and valve seat is. A valve job should have mating angles at least 3/32" wide placed at the top of the valve face. When a sodium cooled valve is used, some of the burden of heat transfer can be assumed by the valve guide area, which drops the valve head temperature by about 200 degrees F. This does not sound like much, but valve face hardness is dramatically improved.

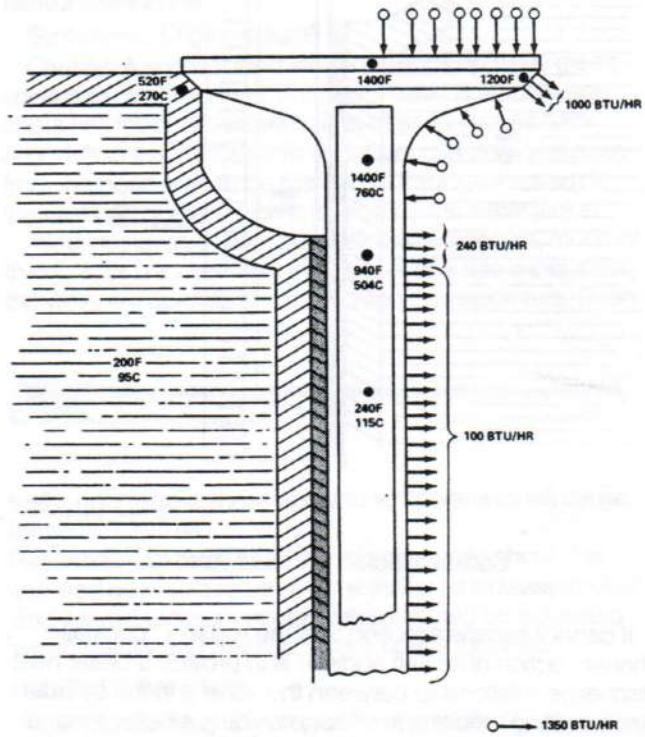
In the valve seat area, any engine that is equipped with a catalytic converter will have induction-hardened valves and seats which operate well in light/medium-duty service. Under light service, life expectancy would be about 80,000 miles; under medium-duty the same valve seat would give a life expectancy of 40 to 60,000 miles. All heavy-duty applications require the addition of a hard seat insert in the exhaust side if valve life is to be acceptable. Impco recommends using valve seat inserts with high nickel content because of their good heat dissipation qualities.

If any valve recession has taken place, the valve guide will be destroyed because the grindings created by the recession will be blown into the end of the valve guide.

If valve guides need to be replaced, guides of premium material should be used. Steel or bronze give good results. Valve guide clearances should be halfway between the minimum and maximum recommended by the engine manufacturer. Please note clearances will be larger if a sodium cooled valve is used due to the greater stem expansion. One note of caution: Some exhaust valve guide failures have been due to poor lubrication caused by high exhaust back pressure which prevents oil from going down the guides. When you have valve problems on an LPG- or natural gas-fueled engine in a short number of operating hours, about 99.9% of the time poor workmanship on the valve job is the culprit, not lean mixtures. LPG and natural gas fuels are a neat scapegoat for poor workmanship.

Valve Temperature

Heat Flow and Temperature Distribution in a Solid Exhaust Valve



Solid Exhaust Valve

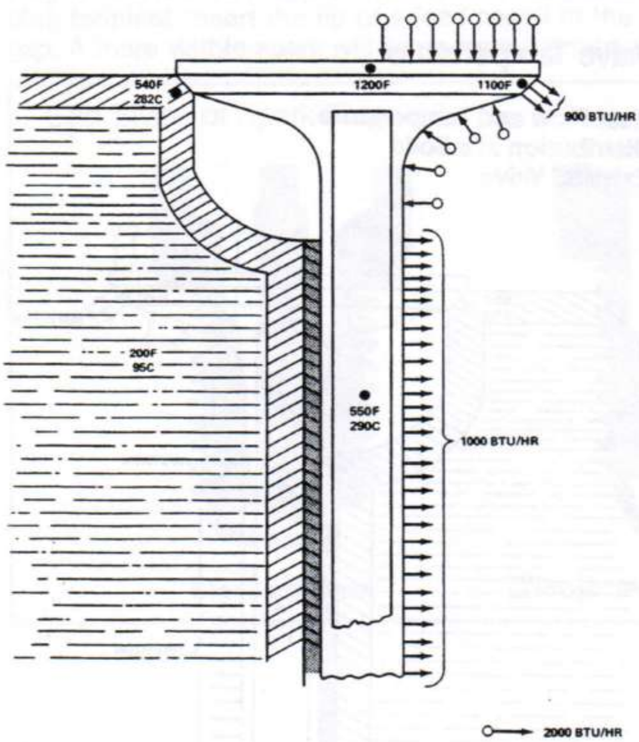
Figure illustrates approximate temperature distribution and heat flow in a typical solid exhaust valve. This is a characteristic result of high heat input to a large surface, major heat output through a small and intermittent seat contact area, and limited thermal conductance of valve material as a heat carrier from the valve head to the stem.

Valve Theory & Problems

Heat Flow and Temperature Distribution in a Sodium Cooled Exhaust Valve

The addition of an axial cavity half filled with sodium changes the heat flow pattern significantly. The effects of adding a sodium cavity are:

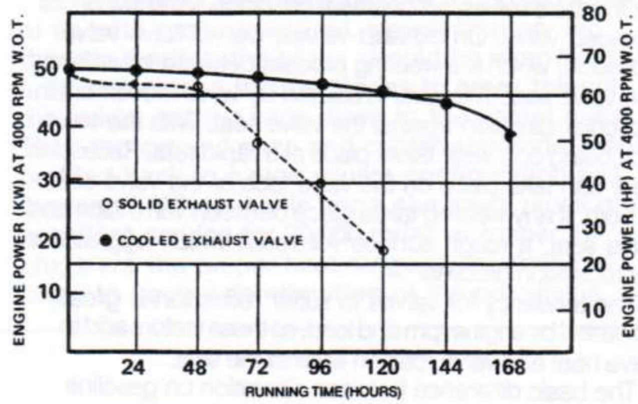
1. Axial thermal conductance is greatly increased.
2. The valve head runs cooler.
3. Stem temperature increase causes more heat discharge through the valve stem-guide contact.
4. Heat released through the valve seat-cylinder head contact is reduced, as is the temperature of this interface.



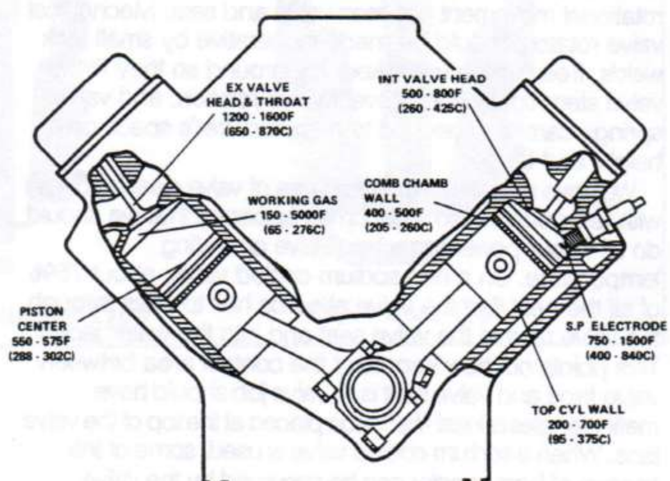
Sodium Cooled Exhaust Valve

It cannot escape attention that the result of "cocktail-shaker" action of molten sodium is to provide a better heat discharge relationship between the valve and the cylinder head cooling medium, in effect providing a better thermal connection between the exhaust valve and the engine cooling system. Quantitative heat flow to and through the valve is increased by the action of sodium, since the cooler valve head offers a greater temperature differential with the surrounding environment of hot turbulent gases.

Although valve cooling by "cocktail-shaker" sodium action seems to increase heat input to the engine coolant by about 1000 BTU/HR (300W) per exhaust valve (an added 8000 BTU/HR (2400W) for the exhaust in a V-8), this is not really a significantly increased burden on the engine cooling system. The test engine used for valve heat flow studies illustrated has a total heat flow to the water jackets of about 400,000 BTU/HR (12000W), of which 8000 (2400W) BTU/HR is about 2%.



Engine Power Loss As A Function Of Valve Cooling(s)



Significant Combustion Chamber Temperatures

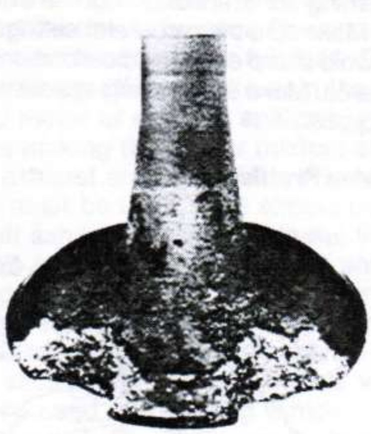
Valve Problems

Valve Failure From Leakage

Symptoms: Engine "miss." This type of failure will always show up on a leakdown test.

Causes: A small leak in the exhaust valve, caused by a deposit on the seat or slight wear or distortion will allow hot gases to escape. As the gases flow through the small opening, under extreme pressure, they will begin to erode the valve face. Eventually, a particular path, or "gutter" will begin to form in the leaking area. The gases will then seek the path of least resistance, and concentrate their flow on this gutter, causing it to grow until a definite problem is noted in engine operation.

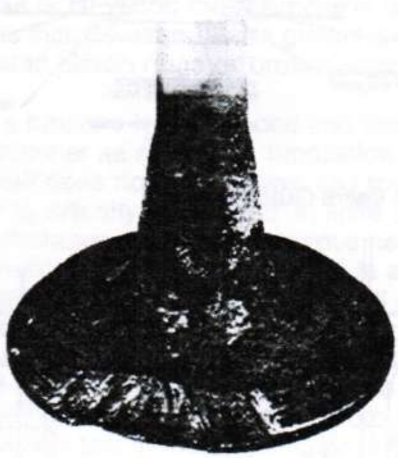
Remedies: The normal "fix" for this type of problem is a valve job. The seat in the head is usually not damaged extensively by this type of failure. It is cooled via the water jacket, thus the material does not erode nearly as bad as the valve material. The failed valve is replaced and the seat is faced.



There is no particular mode of operation that causes such failures, although extreme temperatures do not help the situation. When doing a valve job, make certain that the valves are seating well, and that the guides are sized correctly. Stem deposits may hold the valve crooked in the guide, thus not allowing proper seating, if guide clearances are extreme or the guide is bell-mouthed.

Guttering Of Exhaust Valves

Symptoms: Lack of compression and engine miss on cylinders with valves that look like the one illustrated. This failure will definitely show up on a cylinder leakage test.



Causes: Preignition! The extreme temperatures encountered with preignition actually blew away the valve material in this case. Slight valve leakage probably started the erosion. The slight leak was a path of escape for the tremendously hot gases formed in the combustion chamber. Focusing these temperatures at the small leak was very similar to using a blow torch on the valve head. As soon as the edge became molten, the gases "blew" the material away. This continued until the valve was in the condition shown.

Remedies: Preignition may be eliminated if the various causes can be controlled:

A. Keep engine operating temperature within the recommended range.

B. Keep valve temperatures down. Do not grind valves to the point of having sharp edges or ultra-thin seats. Watch stem clearances.

C. Use fuel of octane level compatible with engine use.

D. Keep initial and total spark advance within specs.

E. Make sure carburetor calibration is within spec.

F. Use spark plugs of the proper heat range.

Sodium Cooled Valve Stem Failure From Excessive Guide Clearance

Symptoms: Engine failure!!

Causes: A sodium filled valve depends on valve guide contact to dissipate heat. A sodium valve is actually only about half filled with sodium. This material moves back and forth in the cavity within the valve, carrying heat away from the head area to be dissipated through the stem to the cast iron guide, which is cooled by the water jacket.

When excessive valve guide clearance occurs, much of the contact area between the stem and guide is lost, thus the valve will operate at a much higher temperature. Eventually, operating at these elevated temperatures will cause failure as illustrated.

Remedies: Obviously, valve guide clearance should be checked on all engines every time the head is disassembled. Engines with sodium cooled valves should be inspected very carefully and manufacturers' specs followed.

Scuffed Valve Stem

Symptoms: When the stems become scuffed badly enough, the valves will begin to stick in the guides, causing the engine to "miss." A cylinder leakdown test will show valve leakage if the galling has progressed to the point of holding the valve off the seat.

Causes: Four things can cause stem scuffing as illustrated here: 1) Valve to rocker arm misalignment, 2) Lack of lubrication, 3) Lack of prelube, 4) Lack of clearance between the stem and the valve guide.

Valve to rocker arm misalignment forces the valve to one side of the guide, causing high friction and scuffing.

Valve Theory & Problems

Lack of lubrication will obviously cause scuffing problems, especially when coupled with misalignment. Low and no-lead fuels have particularly emphasized this problem. The lead acted as a stem lubricant, thus the removal of this additive brought many scuffed stems to modern engines.

Dry assembly of the valve in the guide may lead to scuffing, since it will take some time for lubricant to reach

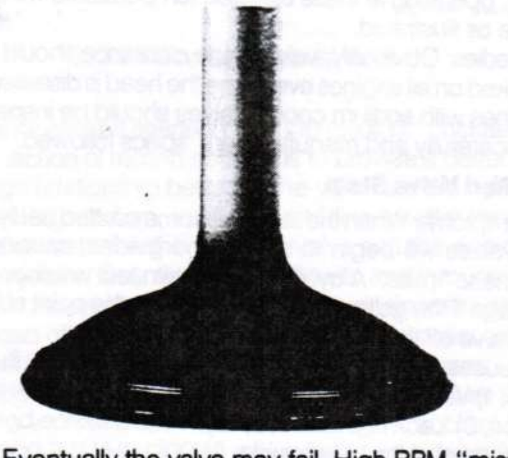
this area. Once again, a slight misalignment of the stem and rocker arm will accelerate this type of failure.

Manufacturers' recommended clearances should always be adhered to when doing valve work. Extremely loose clearances can cause valve failures due to the lack of temperature removal from the stem by the guide. This is especially true in sodium cooled valves. Tight clearances can cause scuffing.

Remedies: Be extremely careful when doing valve work that rocker arm geometry and alignments are not altered. When valves are faced, the tip of the stem should also be faced to maintain geometry. Clearances recommended by the manufacturers must be maintained and valves of the proper materials must be used. Chrome-plated valve stems were introduced by many manufacturers in the early '70s. Although there are identical valves without the chrome available at a substantial savings, the chrome stem valves should be used whenever possible to guard against failures from poor lubrication.

Intake Valve Tuliped From Heat of Preignition

Symptoms: As can be seen from the photo, the head of this valve is distorted extensively. This distortion will diminish valve spring loads and close up valve-to-rocker arm clear-

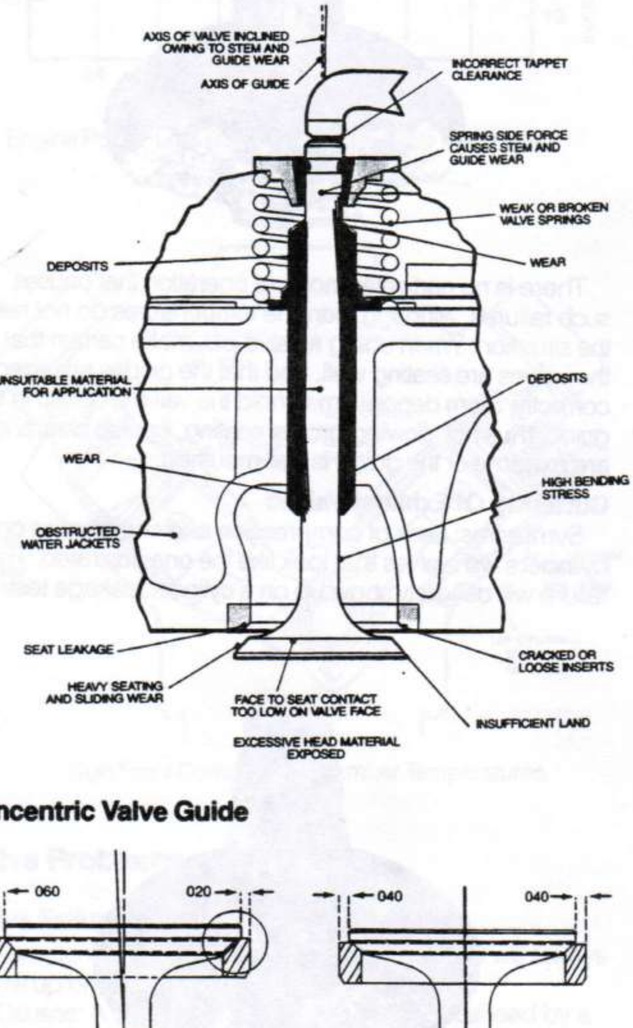


ances. Eventually the valve may fail. High RPM "miss" may occur. Audible knock (ping) will normally be noticed.

Causes: High coolant temperature (above 195 degrees F.) and the extreme heat of the combustion process when preignition and detonation are encountered resulted in the valve stretching in the head area. Igniting the air/fuel charge prior to the designated ignition timing causes the engine to compress already burning gases. This pushes the maximum combustion temperature well above the design criteria for the valve material, softening it; thus the distortion.

Remedies: Avoid preignition. Keep octane ratings up and ignition timing within spec. Do not use extremely hot spark plugs. Make sure the carburetor settings are within calibration. Avoid sharp edges and carbon deposits in the combustion area. Make sure cooling system and coolant flow are adequate.

Common Valve Problem Areas



Concentric Valve Guide