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Diesel Engine Valve Construction

The material selection and construction of diesel engine valves varies in engine makes depending on engine specific operating requirements, country of manufacture, current technology and cost. Intake valves typically operate at temperatures of about 650°C, however in turbocharged engines that can be up to 700°C. Exhaust valves typically operate at temperatures of about 800 - 850°C. The maximum temperature in valves is often not at the head, but in the centre of the valve at the fillet. The contact angle and width between the valve face and seat must be sufficient to allow sealing of combustion pressures and gases and the dissipation of heat from the valve head to the valve seat and cylinder head. It is estimated that 75% of the heat in a valve is dissipated through the valve seat and 25% through the stem to the valve guide. Both inlet and exhaust valves receive some cooling from airflow entering the cylinder during the intake stroke, however, the inlet receives more cooling, while the exhaust is heated more with the exhausting of combustion gases. Poor contact between the valve face and valve seat can result in the valve running several hundred degrees hotter, causing significantly shorter valve life.

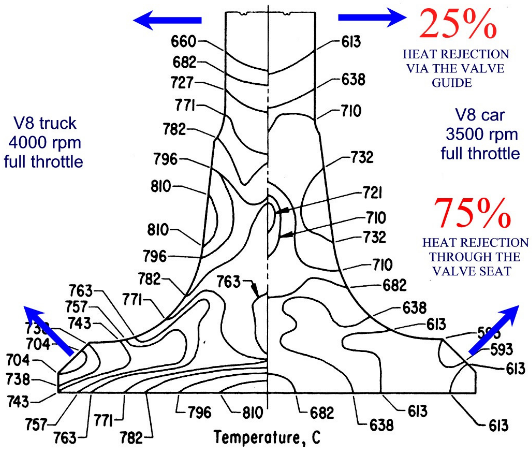

Diagram 1. Two examples of heat distribution in valve heads

The material selected for a valve must possess a wide range of properties. Valves must maintain a high hardness at elevated temperatures to withstand the forces generated when hard particles are trapped between the valve face and seat. Both the valve head and stem must be strong enough to withstand the seating forces at high revs and temperature. It must have good thermal fatigue properties. It must withstand stem, face and tip wear and high temperature corrosion. The valve tip must be able to withstand the high loads generated in opening the valve, especially for exhaust valves opening against the cylinder combustion pressures.

Inlet valves in diesel engines are commonly made from Si-Cr-Mo steel JIS SUH3, Si-Ni-Cr steel JIS SUH4 (EN59), Ni-Cr-Mo steel JIS SNCM8 (EN24) and Si-Cr Steel JIS SUH11 (EN52). JIS SUH3 is the most common diesel inlet valve material in the aftermarket. It is a martensitic, magnetic material that has a standard hardness of approximately 26 - 28 HRC. SUH3 valves are not usually tipped as the valve tip can be heat treated to produce a hardness of 50 - 59 HRC. Inlet valves usually do not require special face treatments, however in turbocharged engines the inlet valve will often be stellite faced. Stellite facing gives a face hardness of about 55 - 59 HRC, has excellent corrosion resistance and can withstand heavy valve spring pressures. SUH3 has a tensile strength of approximately 62 kg/mm^2 at 500°C, 43 kg/mm^2 at 600°C, 22 kg/mm^2 at 700°C and 10 kg/mm^2 at 800°C. Clearly inlet valves will fail at temperatures much over 600°C. Triballoy intake valves are an option for longer service life and severe-duty applications.

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Exhaust valves in diesel engines are commonly made from Mn-Ni-Cr steel JIS SUH35 (21-4N) or Ni-Cr-Mo steels JIS CRK22 and 21-12N. JIS SUH35 is the most common diesel exhaust valve material in the aftermarket. It is an austenitic, non-magnetic material that has a standard hardness of approximately 38 - 45 HRC. SUH35 cannot be heat treated and is much more expensive than SUH3. Therefore, it has been very common to see manufacturers friction weld a SUH3 stem to a SUH35 head (bi-metallic valves) to make a cheaper valve and allow hardening of the tip by heat treatment. However, it is becoming more common for O.E. and aftermarket manufacturers to make the entire exhaust valve from SUH35 and either wafer tip or stellite weld the tip. Both processes produce a tip hardness of approximately 50 - 59 HRC. Stellite facing of exhaust valves is also very common. SUH35 has a tensile strength of approximately 75 kg/mm^2 at 500°C, 68 kg/mm^2 at 600°C, 58 kg/mm^2 at 700°C, 40 kg/mm^2 at 800°C and 34 kg/mm^2 at 850°C. Many of the larger capacity, high horsepower output engines have Nimonic 80A (Ni-Cr20-Co18-Ti-Al), Nimonic 81 or Inconel valve heads that are highly heat resistant and an option for longer service life, severe-duty applications.

To improve performance properties of the valve stem, manufacturers choose either nitriding (tufftriding) or hard chroming. Both processes are used for similar outcomes. American and European manufacturers tend to favour hard chroming, while Japanese manufacturers favour nitriding. However, there are many opposite examples. Both processes increase hardness, significantly improve wear and seizure resistance, improve fatigue endurance, and increase resistance to corrosion and pitting. In general, nitriding is harder (approximately 60 HRC), thinner, less expensive, more environmentally friendly and has a slightly rougher finish. The nitriding process produces a surface layer of iron nitride and leaves the entire valve with a dark grey to black appearance. It is a heat treatment process that usually requires final machining afterwards. The surface hardness approaches double that of the base material, but is only 10 to 20 μm thick. For the rpm range of most diesel engines, nitriding is an excellent choice. Hard chroming is a slightly softer finish (approximately HRC 55), thicker, usually more expensive, a more environmentally unfriendly process and typically has a smoother finish. Hard chroming is usually the choice for higher revving and performance vehicles that run smaller valve guide clearances and higher valve speeds.