Effect of low load operation below specified minimum load.

High speed diesel engines (>1200 rpm) suffer from what is commonly referred to as **"slobbering"** at low load levels. This condition is created by low combustion temperatures and pressures, as compared to a fixed oil flow entering the combustion arena. Minimum load levels vary between engine designs. Advent of common fuel rail injection systems and other high accuracy means of fuel into higher combustion efficiency arenas have lowered the minimum load rule of thumb of 50% of rating plate. Some engine data sheets state 25%, others 30% and so on. Always verify.

Oil flows to the combustion arena via two principle constant flow sources. 1) Oil directed to the underside of the piston for cooling purposes and for lubrication of the cylinder wall via oil control piston rings and 2) Oil flowing between valve guides and valve stems for lubrication purposes. Note: The valve stem seal, where fitted, plays a part in controlling extent of flow. Valve seal failure will exasperate the problem.

Note: A diesel engine consumes oil. Oil consumption is traditionally expressed as a percentage of fuel consumption. Typical oil consumption values are between 0.2 and 0.5%. The writer experiences lower oil consumption than advised by some engine manufactures with certain well maintained engines. Note: Too little consumption is a problem indicative of an oil supply issue to combustion related components.

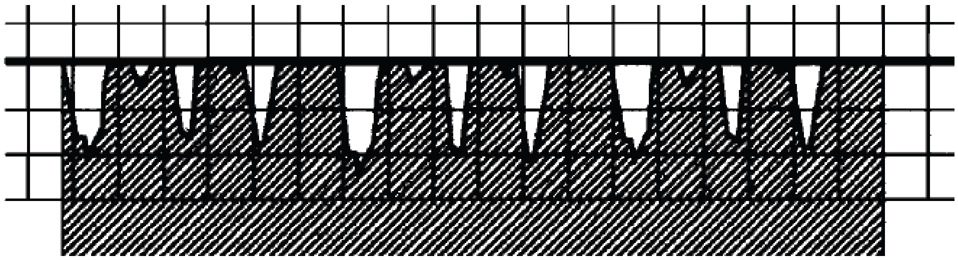
At too low a load, combustion temperature and pressure can be insufficient to effectively burn lubrication oil entering the combustion arena. This unburnt oil enters the exhaust system and air induction system when at low boost levels during valve overlap. Air induction fouling is a particular issue for naturally aspirated engines.

Partially burnt or unburnt material enters the upper cylinder region and deposits as a sludge in the cooler areas - manifolds and turbocharger and hard carbon in the hotter exhaust valve and piston crown regions. Exhaust stack fires as a result are not uncommon. Carbonized oil on top of pistons creates an abrasive compound resulting in the carbonized pistons polishing the cylinder walls when travelling within the cylinder, resulting in a condition referred to as 'glazed liners/ cylinders'. Obviously exhaust PM emissions increase with consequent loss of performance.

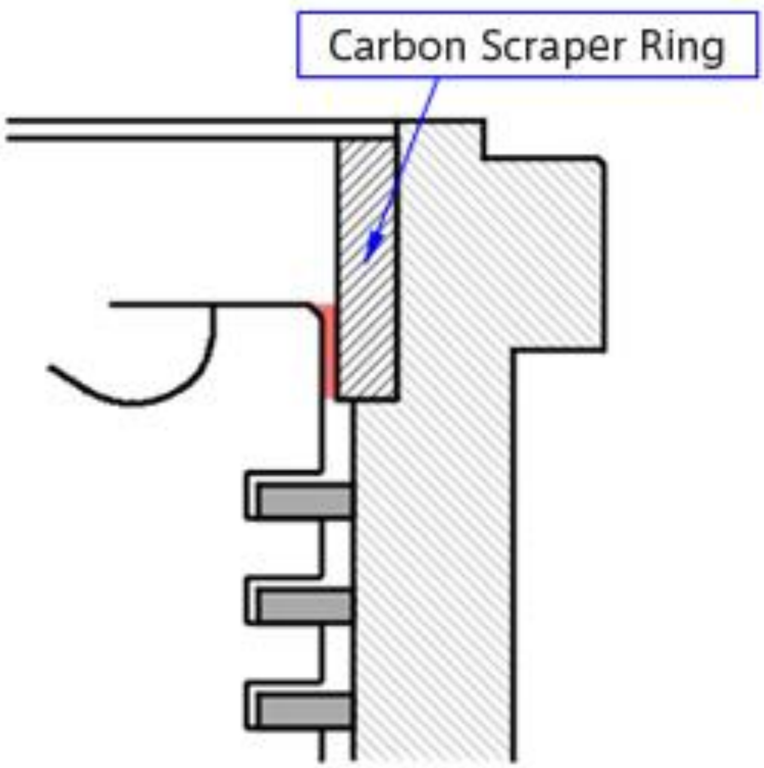
As part of oil control into the combustion arena; the cylinder walls in which the piston travels, have an abraded cross hatch pattern (see Fig 1) to retain oil on the cylinder wall for lubrication purposes. An oil control piston ring deposits oil into the cross hatch crevices (see Fig 2). Excess oil above cross hatching retention capacity is 'scraped' from the cylinder surface by the 'oil control' / 'scraper' ring and returns to the oil sump via the same oil control ring. The absence of this cross hatching as a result of 'polishing' / 'glazing' causes diminished oil control ring performance and exponentially increases oil into the upper cylinder region which at low load will exasperate the issue further.

Fig 1

Fig 2 Microscopic cross section of cross hatch honing pattern



Note: Some engine designs incorporate an 'anti-polishing ring' installed to the top of the liner wall whose diameter is less than that of the cylinder but greater than the piston top diameter and stops short of the top piston ring. This ring scrapes carbon deposits off the piston sides as the piston noses through on each stroke. See below.



"The anti-polishing ring is a good deterrent and a useful feature but does not solve all of the effects of low load operation", we need to consider all and make valued judgment against the back drop of all the information and project circumstances. Food for thought!

Effects of low load operation on a diesel generating set

In standby duty generator applications this condition normally occurs however lack of operating hours (typ less than 50 PA) is a savior. Annual 100% load testing for a healthy duration, (>4 hrs.) as part of planned maintenance, assists with burning off oil residues before harm sets in (a relative term given the low operational hours expected of an emergency generator).

In prime power applications where the load profile often varies, it is reasonable to contemplate that operation at higher loads will 'burn off' accumulated residues from operation at lower loads. The writer prefers to assess this aspect using energy produced in a 24 hr. cycle.

E.g. stated minimum load = 40%. A 1000 kWe generator at 40% average load produces 9600kw-hr per 24 hr. period. This is to be considered the absolute minimum energy level that can be produced without counter measures such as routine high load operation and or adjustment of normal operation maintenance schedules to suit operating condition specifics… provided power peaks are at least 20% above the 40% value. Where daily cyclic load peaks are only 10% above lower kWe levels minimum energy production should be proportionality higher to compensate. See also generator sizing for further elaboration.

Generator engine sizing is important. Operation below recommended minimum kWe load level should see corresponding operational hours, or greater, at a higher level of load of >50% of rating plate to counter the effects. E.g. operation at 30% load for 2 hrs. Should see operation for 2 hrs. at 60%. This is not a black or white subject. This commentary is 'rule of thumb' for guidance; many specifics enter the appraisal for final recommendation. Higher ambient temps by example promote higher exhaust temps which can aid the problem. Intercooled engines however will not reap the same benefit in this equation.

Note: The writer adopts a sizing policy of 65 to 70% of prime power rating x 24hrs as an ideal kWh/day rating for prime power applications. In short there is a lot to consider, and proper due diligence "shall be undertaken".

Often asked: How long before damage sets in? Damage in this context will most likely be liner glazing or possibility of exhaust fire. The answer is of course variable based on potentially many unknowns; as a rule of thumb 50% reduction in service life of affected components would be a reasonable consideration, at least as a starting point. Exhaust fires are unpredictable and operators should be particularly diligent in routine inspections of the exhaust system internals and react accordingly.

Affected components in typical order of adverse operation. Note: every circumstance is different, many variables.

1) Carbonized injector nozzles - resulting in poor combustion which will exasperate the fundamental issue.
2) Fouled turbocharger turbine – loss of turbine speed and therefore boost pressure which will affect combustion efficiency.
3) Heavy carbon build up on valves and seats. Uneven deposits on seat will result in angular valve landings leading to stem fatigue which could lead to separation the of the valve head from the stem.
4) Loss of cross hatching to cylinder liner walls. Stop and replace.

Practicing of condition monitoring techniques is in the writers view is ESSENTIAL. "To track and monitor measurements and observations from routine interventional inspections will allow safe modification of scheduled maintenance activities and will often avoid catastrophic failure; for properly sized installations such practice will allow extension of originally envisaged major interventions for cost control and uptime benefits".