Piston Failure on Diesel Engines

The AERA Technical Committee offers the following information regarding piston failure in diesel engines. It is imperative to determine the cause of piston failure and addressing the cause before simply replacing the damaged parts and re-assembling the engine. Otherwise, similar damage will occur shortly after the engine is placed back in service.

Diesel engine injection principles and operation
The piston and ring assembly of a diesel engine fit tightly in the cylinder bore to provide high compression, in order to cause ignition of the injector fuel. The fuel is delivered at a precise moment, in an exactly metered quantity and is metered by the injection system. This fuel is delivered to the cylinders at a very high pressure and is broken up into a very fine spray with droplets diameters of a few microns.

This is achieved by forcing the fuel through very small orifices at extremely high pressures. In the modern diesel engine, the tendency is to increase the numbers of these orifices and thereby making them smaller as well as increasing the pressure. In some of the modern diesel engines the injection pressure is in the range of as much as 29,000 psi (200 MPa). This is typically 10 times higher than the older generation of diesel engines, which got worse fuel economy.

The result of the higher pressure and smaller orifice sizes is that the droplets are significantly smaller and the exposed area is therefore significantly bigger. This results in a smoother, faster and more complete combustion as well as better fuel economy. In simple terms it is making the engine more efficient.

In the hot air caused by compression, the fuel starts burning and due to the heat release, the pressure rises. The piston is then forced down, to produce the power of the engine. It must be kept in mind that the injection is not an instantaneous happening. The injection process has certain duration and the more fuel that has to be injected, the longer the process takes. Some injection processes consist of an initial pilot injection to start the flame burning, with a secondary higher volume injection where the majority of the fuel is delivered. The injection process starts when the needle lifts off the seat and opens the orifices for the fuel to be squirted out under very high pressure.

As an example, in a particular engine the combustion process from about 7º Before Top Dead Centre, (BTDC) to 30º After Top Dead Centre (ATDC). From testing it has been observed and determined that the biggest flame is present just after 13º. Thus, it is typically the position namely between 15º and 20º (ATDC), when the biggest pressure is needed on the piston crown.

If excessive fuel is being delivered, or continues to be supplied the heat from combustion continues to rise. It's hard to stop a fire when there is fuel still being supplied. Here-in starts a snowballing effect as there is not sufficient relief of temperature inside the cylinder and in seconds the next combustion process is already starting. The additional heat/pressure/fuel will actually cause combustion to start occurring the moment compression is sufficient. This may be well before the designed 7° BTDC in this example! Continued operation will expose the piston crown to melting temperatures as the piston shown below details. This piston may of only been running only 300° F hotter than the ones next to it, but it was beyond the melting threshold for too long of a period of time.

The hot molten aluminum is thrown unto the cylinder head deck from the combustion explosion and attaches itself to the slightly cooler casting. In this particular case, only one of the eight cylinders was affected and was caused by a faulty fuel injector. This occurred shortly after 8 used injectors were installed on a replacement engine without determining the cause of a previous engine failure. This engine failure could have been prevented if only; the fuel 8 injectors had been sent out to a fuel injection shop for testing.