WHY TURBOCHARGE?

Ever since the introduction of diesel engines the demand has always been for small engines capable of producing maximum power. Add to this the present environmental problems of lead pollution etc., plus the economics of the diesel engine user and you have an area in which the Turbocharger can play a major part.

We have already given some reasons for Turbocharging i.e. the power of an engine is controlled by the ratio of air to fuel. Size and weight of engines have become important, no-one wants to lose a large amount of the power from the engine simply to propel the excess weight down a road, or to have huge vehicles just to carry normal loads.

Under normal circumstances the addition of a Turbocharger to a naturally aspirated engine will increase the power output by approximately 30%. Remember, this means basically the same size engine giving more power to be used by the operator. In the early days it was common practice to put a Turbocharger onto a naturally aspirated engine, now Turbocharged engines are designed to take into account the higher stress thermal and mechanical loadings placed on the engine and other ancillary equipment by the Turbocharger.

To summarize, Why Turbocharge:-
1. Power to weight ratio.
2. Environmental – lead pollution etc.
3. Improved output.

Whilst it appears very easy to assemble and fit a Turbocharger to an engine, the identification of faults and their causes presents even a highly skilled engineer with many difficulties. We will try in this paper to examine some of the major causes of Turbocharger malfunction and the manner in which we can identify these.

Under normal circumstances a supplier of Turbochargers will not give any indication of why a unit has failed unless he is specifically requested to do so; in many ways this is a great pity for, by inspecting the old unit, it is sometimes possible to advise the owner of a possible engine malfunction which with preventive maintenance will avoid expensive and unwarranted down-time and continued failure of each unit fitted.

WHAT IS A TURBOCHARGER?

Very simply, a Turbocharger is a kind of air pump taking air at ambient pressures (atmospheric pressure), compressing to a higher pressure and passing the compressed air into the engine via the inlet valves.

At the present time, Turbochargers are used basically on diesel engines, but there is now a move towards the turbo charging of production petrol engines.

As all engines are dependent on air and fuel we know that increase in either of these elements within set limits will increase power from the engine but if we increase the fuel we must be capable of burning of all of it. In order to meet our requirements for power, this requires air; putting in more air presents far more problems than putting in more fuel. Air is around us all the time and is under pressure, (at sea level this pressure is about 15 p.s.i.) It is this pressure that forces air into the cylinders. To increase the air flow, an air pump (Turbocharger) is fitted and compressed air is blown into the engine.

This air mixes with the injected fuel allowing the fuel to burn more efficiently so increasing the power output of the engine. One other side of Turbo charging, which may be of interest, is an engine, which works regularly at high altitudes, where the air is less dense, and where Turbocharging will restore most of the lost power caused by the drop in air pressure. An engine’s power at 8,000 feet is only 75% of its power at sea level.
HOW DOES A TURBOCHARGER WORK?

The waste exhaust gases of the engine are utilized to drive a turbine wheel, which is connected to a compressor wheel by a shaft. The compressor or air wheel sucks in air through the air filters and passes this into the engine. As the waste gases are expelled from the engine, they are directed to the turbine or hot wheel of the Turbocharger and so complete the cycle.

MAJOR TURBOCHARGER PROBLEMS

As we have already stated in the introduction, the main purpose of this paper is to examine service faults and to try to get some understanding of the problems, which arise.

Whilst there are many and varied problems which will cause Turbocharger malfunction, they can be split into five groups as follows:-

(1) Lack of lubricating oil or oil delay.
(2) Foreign material or dirt in the lubricating system.
(3) Oil break-down.
(4) Foreign material in exhaust or air-filtration systems.
(5) Material and workmanship.

(1) Lack of lubricating oil or oil delay

As the Turbocharger revolves at very high speeds, up to 100,000 r.p.m. the need for oil is of paramount importance. Oil is required at the correct flow rate and pressure to do the following:-

1. Lubricate the thrust and journal bearings.
2. Stabilise the rotating shaft and journal bearings.
3. Act as a coolant before high Turbocharger speeds are reached.

As the Turbocharger speed and the engine load increases, so the need for oil both as a lubricant and as a coolant increases. If there is a delay for a short period of time in the oil reaching the Turbocharger then bearing failure will occur. Oil delay can be recognised very simply by the blueing of the bearings or the shaft. The blueing is simply the colour of the shaft when it has been exposed to excessive heat.

(2) Foreign material or dirt in the lubricating system

Many operators assume, quite wrongly, that if they operate the engines with dirty or contaminated oil, the oil filters will remove any foreign matter before the oil reaches the engine and, in our case, the Turbocharger bearings. IT CAN BE A VERY COSTLY MISTAKE. All of these materials can cause damage to the bearings when the amount is sufficient to cause bearing wear and bearing-housing bore wear or if the particles of dirt are large enough to block the internal oil passages of the Turbocharger so causing the unit to become starved of oil. The Turbocharger bearings are most likely to fail before the main engine bearings, simply because the Turbocharger rotates at much higher speeds than the engine. A unit with 80,000 r.p.m. will have a blade tip speed on the compressor wheel of 700 miles per hour. New designs of Turbochargers have blade speeds of over 1,000 miles per hour.

(3) Oil break-down

Diesel lubrication is a very important part of the engine and although modern oil technology has gone a long way in providing good oils, we still have two basic problems to contend with:-

(a) Oil deterioration.
(b) Outside contamination.

(a) Oil deterioration

The high temperatures that are present in modern diesel engines can cause oils to crack or break-down. This action produces carbonaceous (tarry) materials, which stick to the engine rings and cause other troubles. Oxidisation is caused by the hydrocarbons in the oil mixing with the oxygen; this produces organic acids of which there are two main types: those with low boiling points and those with highly corrosive. These products are responsible for several of the problems on diesel engines and Turbochargers. If the acids are allowed to become concentrated, they will attack the bearings etc., causing pitting and subsequent failure. Also they react to the remaining oil to form sludge, this is then deposited throughout the engine, particularly in the filters aggravating the Turbocharger oil supply. Heavier oxidation causes hard varnish to appear. Where sludge is allowed to accumulate in the oil systems, as this passes through the Turbocharger it is thrown by centrifugal force from the rotating shaft against the walls and internal surfaces of the bearing housing where it can stick and impede the free oil flow. In time the build-up will cause problems with oil drainage, resulting in oil leaking from the
turbine end of the unit. If this matter is allowed to accumulate on the turbine side, the heat will cause a baking to take place and the result is usually unbalance in the Turbocharger system.

(b) Outside contamination
So far we have briefly looked at oil break-down caused by changes in the oil, usually caused by its exposure to heat and air. However, we must also consider other agents.

Amongst these are the products of fuel combustion, such as ash, soot, the un-burnt heavy ends of the fuel and water. All these elements cause oil contamination. The engine itself contributes to oil break-down in that tiny metal particles produced by wear and tear will either pass through the oil ways into the Turbocharger or oxidise and hasten deterioration.

Finally, foreign matter from outside the engine, such as dust and dirt, enters the cylinders through the air intake system.

(3) Foreign material in exhaust or air-filtration systems
Any material, which enters these systems is, without doubt, going to damage the Turbocharger and could damage the engine. As a Turbocharger is a precision instrument its vulnerability will become instantly apparent the first time any particles go into the casings; damage will be to the wheels which could cause pieces of aluminium to go into the engine, resulting in engine piston, valve, liner and, possibly, crank shaft damage.

This type of material will vary tremendously from dust in the air system to engine valve fragments in the exhaust system. It should also be noted that if any foreign body stays in these systems, the Turbocharger will react with possible loss of power, black smoke, excessive oil usage and leakage and damaged wheels.

(4) Material and workmanship
Only quality assured materials are used and constant quality checks are made on both material and workmanship to meet the stringent O.E. specifications.

The Turbocharger is probably the most misunderstood component on the engine, and it is this lack of knowledge by the owner that makes Turbocharger service a very difficult area to work in. As we have seen, a Turbocharger will increase a given engine power by about 30%; it will not change any operating characteristics of the engine, it will only do what the engine tells it to do. The source of power for the Turbocharger is exhaust gases produced by the engine and this power is controlled by flow, pressure and temperature. If there is an engine malfunction or an abnormal working condition in the engine, the Turbocharger will not overcome this, it is more likely to emphasize the problem. From this it follows that replacing a faulty unit with a new one will not always solve the problem. If we are in any doubt at all, we should consult the original equipment engine manual.

IDENTIFICATION OF FAULTS

(1) Lack of lubrication oil
Lack of lubricating oil shows itself in excessive shaft movement in the bearings. It can be identified by the presence of the following defects:-

(a) Wear on the inside and outside diameters of the bearings.
(b) Heat discolouration near the outside diameters of the piston ring carrier at the compressor end.
(c) The back face and intake section (inducer) of the compressor wheel shows signs of rubbing. The face of the wheel will show signs of rubbing 180° from the area of contact on the back of the wheel.
(d) The turbine wheel will show similar signs as the compressor wheel.
(e) One section of the turbine end seals (piston rings) will show heavy rubbing.
(f) Heat discolouration and rubbing on one area of the face of the thrust ring.
(g) Wear pattern on the thrust bearing.

All these symptoms will vary in degree dependent upon the length of time that the Turbocharger has been run without adequate lubrication.

(2) Foreign material in the lubrication system
As we have already stated, the fault will result in excessive bearing wear and a possible blocking of the oil inlet channels in the Turbocharger causing oil starvation. This fault should show itself in the form of scratches, either light or extreme on the outside diameter of the bearings or on the bearing housing bore. The extent of damage depends upon the amount and size of foreign bodies present in the lubrication system.
(3) Oil oxidisation
A hard deposit of baked oil builds up at the turbine end. Turbine seal leakage can occur; if the hard carbon flakes away, damage can be caused to the bearings. Sludge will be apparent in the Turbocharger, particularly round the bearing housing outlet bore.

(4) Foreign material in either the exhaust or air induction systems
This is fairly obvious to detect, the turbine or compressor wheel could have sections of a blade of blades broken off there may be indentations at the entrance to the compressor cover. Rubbing of the compressor wheel, due to the unbalance of the rotating assembly caused by any broken blades. At the turbine end, damage can be caused by broken valves, pistons or fuel injector tips. Small particles, such as sand, erode the leading edges of the blades. Large hard particles tend to rip or tear the blades. Soft materials, such as shop towels or rubber, roll the blades back in the opposite direction of the wheel rotation.

TROUBLE-SHOOTING PROCEDURES – CAUTION!

Do not place hands or fingers near the Turbocharger air inlet bore while the engine is running. Air pressure drop at this location can draw fingers onto the compressor wheel blades and cause injury. Every Turbocharged engine system when operating has its own distinctive sound or noise level. In many cases malfunction can be detected when the noise level changes. If the noise level changes to a higher pitch, it can indicate an air leak between the air cylinder and the engine or a gas leak in the exhaust system between the Turbocharger and the engine.

Noise level cycling from one level to another can indicate a blocked air cleaner or restriction in front of the Turbocharger air inlet or heavy dirt built-up on the compressor housing or on the compressor wheel. Sudden reduction in a noise level, with a resultant black or blue smoke and excessive oil leakage, indicate a complete failure.

NOISE AND AIR LEACK CHECK

With the engine running, check the Turbocharger for uneven noise and vibrations (this can indicate a malfunction in the shaft and wheel assembly). If suspicious conditions are apparent, shut down immediately to protect the Turbocharger and engine from further damage. Examine the Turbocharger as per the recommended inspection procedures. If any damage is evident, the Turbocharger will have to be removed. If the Turbocharger is assumed to be functional, check the air system as follows:-

With the engine not running, check the air cleaner for restricted condition. Check all the hose clamps for tightness. Check that the intake manifold gasket is fitted and is in good condition. Check the air hoses for cracks or deterioration. A pin hole in the air hoses can lose 10% of the Turbocharger’s power.

WITH THE ENGINE RUNNING AT IDLE:-

1. Where starting fluid is used on the engine, spray lightly the air tubes and connections between the air cleaner and Turbocharger. Leaks will be indicated by an increase in engine speed, this is caused by the air pressure drop in this part of the air system causing the starting fluid to be drawn through the compressor wheel into the engine.

2. Air leaks between the Turbocharger and the engine can be checked by feel and by application of a light-weight oil or soap suds on the cross-over tubes connections or hoses. Exhaust gas leakage between the engine block and turbine inlet flange will also create a change in the noise level and reduce Turbocharger performance. Check the exhaust system as follows:-

2.1. Check the manifold gaskets for leakage.
2.2. Check manifold bolts for tightness.
2.3. Check the manifold for cracks or porosity.
2.4. Check the manifold Turbocharger inlet gasket for leaks.
2.5. Check the manifold Turbocharger inlet flange for contamination.
2.6. Check the manifold flange (Turbocharger) for contamination.
2.7. Check the Turbocharger inlet flange bolts for tightness.
2.8. An obvious sign of exhaust gas leakage is heat discolouration around the leaking part.
RECOMMENDED INSPECTION PROCEDURE (FIELD SERVICE)

1. Remove inlet and exhaust tubing from the Turbocharger.
2. Inspect both wheels for blade damage caused by foreign material. The compressor wheel is easily examined by looking through the compressor air inlet opening. A light is necessary when examining turbine wheel blade tips, as they are positioned inside the turbine housing and you must look between the turbine wheel blades from the exhaust outlet end of the turbine housing.
3. Examine the outer blade tip edges, both wheels adjacent to their respective housing bores and check for wheel rub.
4. Rotate the shaft and wheel by hand and feel for smooth turning drag or binding conditions; push the shaft to one side and rotate to feel for rub.
5. Lift up and down both ends of the shaft at the same time and feel for excessive bearing clearance. If clearance is normal, very little shaft movement will be detected. If the shaft is rocked up and down at one end only in a unit having bearing clearances of .003 to .006 inches, the movement at the opposite end of the shaft could be .015 inches to .020 inches.
6. If the shaft and wheel rotates freely, no wheel damage, binding or rubs have been noticed, it can be assumed that the Turbocharger is serviceable.

GENERAL FACTORS AFFECTING TURBOCHARGERS - SERVICE LIFE

An analysis of Turbochargers removed from service indicates that approximately 40% of the troubles are due to foreign material going through either the turbine or the compressor. An additional 40% are due to lubrication failures. The remaining 20% are of a miscellaneous nature.

Some of the foreign material damage is the result of pieces of burned or broken valves and combustion cups passing through the exhaust system into the turbine. Other turbine damage is due to casting fins that may break out of the manifolds and ports.

Occasionally improperly installed gaskets will permit pieces of the gasket to overhang a port and break off into the exhaust system.

Damage due to nuts and washers that have dropped into the exhaust system is also altogether too frequent.

Occasionally engines suffer from scuffed and broken pistons, pieces of these pistons will damage turbine wheels.

Compressor wheel breakage also occurs due to foreign material, although not as frequently as turbine wheel damage. Sometimes pieces of the air cleaner will break loose and go through the compressor. There have also been instances where hose connections fail and pieces of rubber or wire reinforcing from the hose get into the compressor wheel.

Again, carelessness in allowing nuts, bolts and washers to get into the intake system, sometimes cause compressor wheel failures.

Lubrication failure may be any one of a number of types; undersized or plugged oil lines are quite common. It is essential to have an adequate supply of oil at full engine oil pressure for the Turbocharger bearings; the Turbocharger runs at very high speeds and will very quickly overheat with even a momentary failure of the oil supply.

The oil supply to the Turbocharger should first pass through a good filter of adequate size so that there is always full oil pressure at the Turbocharged bearings. With an adequate supply of clean oil, Turbocharge bearings will run for thousands of hours with no measurable wear. Failures may occur due to extreme exhaust temperatures encountered in excessive altitude operation. Inlet restrictions due to plugged air cleaners, collapse in hose connections or undersized air pipes, have the effect of reducing the air supply to the engine and result in excessive exhaust temperatures.

Both inlet restriction and the excessive altitude operation can cause turbine housing cracking or even turbine wheel failures due to excess temperature.

With any Turbocharger it is possible to accumulate enough dirt in the compressor housing to reduce the air flow capacity and efficiency of the compressor, if the air cleaning system is not properly maintained. Reduced air flow will cause the engine to run hotter and may result in burnt valves and pistons which in turn will cause Turbocharger failure.

Leaking gaskets or connections on either the intake or exhaust system of the engine will cause a reduction in the air supply to the engine and will result in high exhaust temperatures.
Sometimes air connections and exhaust connections are made in such a manner that the thermal expansion of the exhaust manifold and other parts connected to the Turbocharger will produce very high loads on the Turbocharger. These high loads result in housing distortions that cause the compressor and turbine wheels to rub.

Excessively heavy piping that is supported only by the Turbocharger may cause housing distortion.

Turbocharger mountings that are not sufficiently rigid to prevent excessive vibrations in the Turbocharger can also cause distortions and failures.

In conclusion, it can be stated that very few Turbocharger failures would occur if no foreign material were permitted to enter the turbine or compressor; if precautions were taken to prevent excessive exhaust temperatures and if the Turbocharger was always supplied with an adequate amount of clean oil.