KNOWING YOUR TURBOCHARGED DIESEL ENGINE

Before entering into a discussion concerning the turbocharged diesel engine system, we should pause and review the basic characteristics of both the turbocharger and the internal combustion engine.

The internal combustion engine is classified as an air-breathing machine. This in effect means that the amount of power that can be obtained from a given displacement engine is determined by the amount of air that it breathes in a certain period of time and not by the amount of fuel that is used. This is because the fuel that is burned requires air with which it can mix to complete the combustion cycle. Once the air/fuel ratio reaches a certain point the addition of more fuel will not produce more power, only black smoke. The denser the smoke, the more the engine is being overfueled. Therefore, increasing the fuel delivery beyond the air/fuel ratio limit results only in excessive fuel consumption.

Turbochargers are installed on an engine to put more and denser air into the engine combustion chambers. Because of this increased volume and weight of compressed air more fuel can be scheduled to produce more horsepower from a given size engine. The turbocharged version of an engine will also maintain a higher level of power output than the non-turbocharged version when operated at altitudes above sea level

What is a Turbocharger?

A turbocharger very simply is an air pump designed to operate on the normally wasted energy in engine exhaust gas. These gases drive the turbine wheel (hot wheel) and shaft which is coupled to a compressor wheel (cold wheel) which when rotating provides high volume of air to the engine combustion chambers.

The turbocharger, although precision built, is basically a very simple but durable machine. It does, however, require maintenance and care as any other piece of working machinery. Mainly a positive head and flow of clean lubricating oil.

How does a Turbocharger Work?

The heat energy and pressures in the engine exhaust gas is utilized to drive the turbine wheel. The speed of the rotating assembly and output of the compressor wheel is controlled by the design and sizing of the turbine wheel and turbine housing. The housing acts as a nozzle to direct the exhaust gas flow to the turbine wheel blades, which drives the shaft wheel assembly. Since the compressor wheel is directly coupled to the shaft, it rotates at the same speed as the turbine wheel. Clean air from the air cleaner is drawn into the compressor housing and wheel where it is compressed and delivered through a crossover pipe to the engine air intake manifold. The amount of air pressure rise and air volume delivered to the engine from the compressor outlet is determined by wheel size, housing size, and performance matching of the turbocharger to a given engine. Each engine size must be properly matched.

What does a Turbocharger Do?

There are quite a number of benefits to be gained by turbocharging a diesel engine. Combustion of the fuel is more complete, cleaner, and takes place within the engine cylinders where its work is accomplished, because the turbocharger delivers an abundance of compressed air to the engine. The positive air pressure head (above atmospheric pressure) that is maintained in the engine intake manifold benefits the engine in several ways. During engine valve overlap (before intake stroke starts) clean air is pushed across the combustion chamber scavenging all remaining burned gases, cools cylinder heads, pistons, valves and the exhaust gas. The cleaner burning of the fuel plus the engine cooling which results helps to extend engine life.

Many turbochargers are used primarily for what is called normalizing or altitude compensating of a naturally aspirated engine. By this we mean that an engine and turbocharger are matched to give only a mild boost of air pressure to improve combustion, reduce smoke, and give a moderate power increase with no increase in fuel delivery. With excess air available for combustion, the engine will produce more power both at sea level and altitude.

It is possible to safely increase power output of some engines by as much as 40 to 50% with little or no change in engine components, with the correct selection and/or matching of a turbocharger. Care must be exercised to select exactly the right turbocharger and engine fuel settings, since the turbocharger has air delivery and pressure capabilities that could exceed engine tolerances. Failure to exercise proper care can result in engine overheating, excessive combustion chamber firing pressures and temperatures. Excessive pressures and temperatures could have detrimental affects on engine life by causing costly failure of engine components, such as cracked heads, scored pistons and liners, blown head gaskets, bearings, turbocharger, etc. Changing the engine fuel delivery schedule in the field on any turbocharged engine should only be made by following the manufacturer recommendations and procedures.

What Is Required to Maintain a Turbocharger?

Good maintenance practices should be observed, particularly with regard to air and oil filtration, to maintain service life and performance of a turbocharger. Years of experience have shown that the largest percentages of turbocharger failures are caused by oil lag, lack of oil flow and dirt in the oil. Foreign objects entering the compressor and turbine wheels cause second largest percentage.

1. Dust or sand entering the turbocharger compressor housing from a leaky air inlet system can seriously erode the compressor wheel blades and will result in the deterioration of turbocharger and engine performance. The wearing away of the blades, if uneven, can induce a shaft motion, which will pound out, and eventually fail the turbocharger shaft bearings. Ingestion of sand or dust will also cause excessive wear on engine parts, such as pistons, rings, liners, etc. Entrance of large or heavy objects; bolts, nuts, rocks, tools, etc., will completely destroy the turbocharger and in many instances cause severe damage to the engine.

2. Plugged or restricted air cleaner systems, resulting from poor maintenance procedures, will reduce air pressure and volume at the compressor air inlet and cause the turbocharger to

lose performance. Restricting the air inlet reduces airflow to the engine and overfueled condition results causing excessive engine and exhaust temperatures and black smoke. The restricted air cleaner and the resultant air pressure drop between cleaner and turbocharger can, during engine idle periods, cause oil pullover at the compressor end of the turbocharger. This would be a compressor end oil seal leak without the failure of seal parts. Proper servicing of the air cleaner system can prevent and correct the above problems.

3. Nearly all of the present day turbochargers operate at shaft speeds in excess of 60,000 rpm and utilize full floating bearings, which have correspondingly high rotational speeds. Adequate clean oil supply is required for cooling and lubrication to maintain the turbocharger bearing system.

4. Dirt or foreign material when introduced into the turbocharger bearing system by the lube oil creates wear primarily on the center housing bearing bores surfaces. Contaminants both imbed in the bearing surfaces and act as an abrasive cutting tool or cut and wear both bearings and bearing bores as it washes through. The shaft hub and either or both wheels will start to rub the housings causing the rotating assembly to turn slower when bearing and bore wear becomes excessive. Turbocharger and engine performance will rapidly deteriorate from this point and such indications as engine power loss, excessive smoke, excessive noise and the appearance of oil at either or both ends of the turbocharger could be noted. Contaminated and dirty oil is prevented when the lube oil system is properly serviced.

5. A turbocharger should never be operated under engine load conditions with less than 30-psi oil pressure. A turbocharger is much more sensitive to a limited oil supply than an engine, because of the high rotational speed of the shaft and the small area of the bearing surfaces.

   Oil pressure and flow lag during engine starting can have detrimental effects on the turbocharger bearings. During normal engine starting, this should never be a problem. There are, of course, abnormal starting conditions. Oil lag conditions will most often occur during the first engine start after engine lube oil and filter change when the lubricating oil system is empty. Similar conditions can also exist if an engine has not been operated for a prolonged period of time because some engine lube systems have tendency to bleed down. The engine should be cranked over until a steady oil pressure reading is observed, before allowing the engine to start. This will prime the lubricating system. The same starting procedure should be followed when starting an engine in cold weather as the engine oil can be congealed and it takes a longer period of time for oil to flow. Turbocharger bearing damage can occur if the oil delay is in excess of 30 seconds and much sooner if the engine is allowed to accelerate much beyond low idle rpm.

Turbocharger Failure Analysis and Corrective Procedures

The importance of determining the exact cause of a turbocharger failure cannot be overemphasized, this determination should be made at the time of failure and should in all cases be accomplished before a replacement turbocharger is installed. Even if it becomes necessary to completely disassemble the turbocharger in the field. Do it!

Often, when a failed turbocharger is replaced with little or no thought given to the cause of failure, there is a recurrence of the failure, which results in extra down time and expense. The initial and follow on failure could also be of a type that could result in costly engine damage. Also immeasurable damage is done to the reputation of the product, the dealership and the service man. The majority of turbocharger failures are found to be due to poor operating procedures, improper preventive maintenance, or incorrect repair practices. One important thing to remember is that the prevention of repeat failures will always mean more to the customer than a continuing and costly replacement of parts.

Although turbocharger durability and performance have greatly improved over the past few years, operational and environmental situations still exist that can result in turbocharger failure.

Major Causes of Turbocharger Failure

There are many and varied causes for turbocharger failures. They can be grouped into five major categories:

1. Lack of lubrication and/or oil lag.
2. Foreign material or dirt in the lubricating system.
3. Oil oxidation or oil breakdown.
4. Foreign material in either the exhaust or air induction systems.
5. Material and workmanship.

Causes of failure by type and corrective measures:

I. Lack of lubrication and oil lag.

1. This type of failure occurs when the oil pressure and flow is not sufficient to:

   A. Lubricate the journal and thrust bearings.

   B. Stabilize the shaft and journal bearings.

   C. Reach bearings before unit is accelerated to high speeds.

2. The turbocharger bearings need for oil increases as the turbocharger speed and engine load increases. Insufficient oil to the turbocharger bearings for periods as short as a few seconds during heavy load cycle when the shaft speed is high will cause bearing failures.

3. General precautions: When oil and filters are changed.

   A. First engine startup after oil and filter change. Crank engine, if possible, without starting until filter and oil system is filled and a steady oil pressure is shown on the gauge, or start and run engine at low idle long enough to obtain a steady oil pressure reading, otherwise, a bearing failure may result due to lack of lubrication. Priming the oil filters with clean oil will reduce engine-cranking time.

4. Engine starting procedure after installing a turbocharger:

   A. Make certain that the oil inlet and oil drain lines are clean before they are connected. If hoses are used, make certain that they have not hardened and that inner lining has not deteriorated or started to flake off. If metal tubing is used, make certain that it is not restricted or collapsed.

   B. Make certain that the lube oil is clean and at operating level. The oil filter should be filled with clean oil to minimize cranking time.

   C. Leave oil drain line disconnected at the turbocharger and crank engine over without starting until oil flows out of the center housing drain port. A steady oil flow indicates that air pockets are out of lube oil system. With drain line disconnected a funnel can be used to return oil to drain tube.

   D. Connect the oil drain line, start the engine and operate at low idle engine rpm for a few minutes before loading engine.

   NOTE: When operating an engine (at part or full load) on an incline with a low oil level or any other condition that will cause the oil pump to pick up air and drop oil pressure at or near zero for even a few seconds can cause a lack of lubrication failure.

II. Dirt or foreign material in lube oil system.

1. Operating an engine with contaminated or dirty oil and assuming that the oil filter will remove all contaminates before they reach the bearings, can be costly to both the turbocharger and the engine. There are engine-operating conditions when the oil completely bypasses the oil filter. Examples where filter will be bypassed are:

   A. Cold weather when engine oil is congealed - filter bypass can be open.
   B. When oil filter is clogged - bypass can be open.
   C. Filter bypass valve can stick in open or partly open position.
   D. Filter element can be ruptured.
   E. Filter element improperly installed.

2. Contaminated or dirty oil will wear and fail turbocharger bearings much sooner than it will fail engine bearings, because the turbocharger shaft rotates at a much higher speed than the engine. When this type failure is found in a turbocharger, the cause of oil contamination should be located and corrected before installing a replacement turbocharger. If this is not accomplished, a second turbocharger failure will soon occur along with the possibility of extensive engine damage. Also if contaminants are large enough to plug turbocharger internal oil passages, a lack of lubrication type of failure would result.

   Analysis of oil samples at oil filter change periods can help to prevent this type failure. Oil and filter change periods should never be extended beyond the engine manufacturers recommended time.

III. Oxidation or oil breakdown.

1. Sludge accumulates in engine oil when oxidation and/or oil breakdown takes place. Sludge will affect turbocharger performance, turbocharger life, and eventually engine life when the sludge condition of lubricating oil becomes severe.

   The spinning action of the turbocharger shaft throws the oil against the internal walls of the center housing where sludge particles stick and accumulate. In time, it builds up to a point that oil drainage from the turbine end journal bearing is affected. Turbine seal leakage then occurs. The deposited sludge at the turbine end becomes coked (baked) and very hard because of the high temperatures in this area. This hard coke can flake off and start wearing the turbine end journal bearing and bearing bore, but usually turbine seal leakage occurs first. Shaft rotation may or may not be affected. In many cases, the journal bearing clearances are unchanged.

   Center housing inspection can be made by looking through the oil drain opening, if turbine end oil leakage is encountered and it is suspected that sludge has built up at the turbine end of the center housing. Heavy sludge build up will be seen on the shaft between the bearing journals and in the center housing from oil drain opening back to the turbine end when sludge and coked condition exists. In many cases, disassembling, cleaning and replacement of kit parts can repair turbocharger

   NOTE: When oil leakage is noted at the turbine end of the turbocharger, always check the turbocharger oil drain tube and the engine breathers for restricted condition. Correct as necessary before working on the turbocharger. When sludged engine oil condition is found it is mandatory that the engine oil and oil filters are changed using the factory recommended lubricating oil.

Sludge accumulation results from oxidation and/or breakdown of the engine oil. Primary causes are engine overheating, excessive products of combustion from piston blowby, mixing non-compatible oils, engine coolant leaking into oil, wrong grade or quality of oil and the non-observance of proper oil change intervals.

IV. Foreign material in either exhaust or air induction systems.

1. Foreign material, which enters the exhaust or inlet air system, will damage the wheels because of the extremely high speed of the turbine and compressor wheels. Small particles such as sand erode the leading edges of the blades. Large hard particles tend to rip or tear the blades. Soft material, such as shop towels or rubber, roll the blades back opposite the direction of the wheel rotation.

   A thorough cleaning of the exhaust manifold and inlet air system is essential, if there has been a turbocharger failure caused by foreign material damage the wheels. In many cases, compressor wheel damage can throw and imbed pieces of metal into the air filter element. If element is not changed, metal pieces can shake out and fail another turbocharger.

   It is extremely important to carefully service the turbocharger air inlet system. Be sure that no foreign objects are in the piping and that all air connections are in place and are secure.

V. Material or workmanship.

This failure type is in most cases self-explanatory - faulty material – not assembled properly - part omitted.

Troubleshooting a Turbocharged Engine System

First it should be emphasized that a turbocharger does not basically change the operating characteristics of an engine. The turbocharger's only function is to supply a greater volume of compressed air to the engine so that more fuel can be burned to produce more power. A turbocharger is not a power source within itself. It can function only as dictated by the flow, pressure and temperature in the engine exhaust gas.

A turbocharger cannot correct or overcome such things as, malfunctions or deficiencies in the engine fuel system, timing, plugged air cleaners, loose intake air or exhaust connections, valve problems, scored pistons and liners, etc. Therefore, if a turbocharged engine system has malfunctioned and the turbocharger has been examined and determined to be operational proceed with trouble shooting as though the engine was non-turbocharged. Replacing a good turbocharger with another will not correct engine deficiencies.

All too frequently; serviceable turbochargers are removed from engines before cause of malfunction has been determined. Always inspect and assess a turbocharger's condition before removing it from the engine.

Recommended inspection procedure:

1. Remove inlet and exhaust tubing from turbocharger.

2. Inspect both wheels for blade damage caused by foreign material. The compressor wheel is easily inspected by looking through the compressor housing air inlet opening. A light is necessary when examining the turbine wheel blade tips, as they are positioned inside the turbine housing and you have to look between the turbine wheel blades from the exhaust outlet end of the turbine housing.

3. Examine outer blade tip edges, both wheels, adjacent to their respective housing bores and check for wheel rub.

4. Rotate the shaft wheel assembly by hand and feel for smooth turning, drag or binding conditions. Push shaft to 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 journal bearing clearance. If clearance is normal, very little shaft movement will be detected. If the shaft is rocked up and down from one end only, in a unit having normal bearing clearances .003 to .006 the movement at end of shaft could be dial indicated at .015 to .020. Actual shaft endplay is easily dial indicated without removing the turbocharger from the engine.

6. If the shaft assembly rotates freely, no wheel damage, binding or rubs have been

noted it can be assumed that the turbocharger is serviceable.

Troubleshooting Procedures

NOTE: To acquire confidence, ability and feel for accomplishing a turbocharger inspection examine a new turbocharger as outlined. Compare inspection results between the new and used turbocharger.

Turbocharger actual shaft end play and journal bearing radial clearances can be checked as per instructions in the applicable turbocharger service manual.

CAUTION: Do not place hands or fingers near the turbocharger air inlet bore while engine is running. Air pressure drop at this location can draw fingers into the compressor wheel blades and cause injury.

Each turbocharged engine system, when operating, has its own distinctive sound or noise level. In many cases, malfunctions can be detected when this noise level changes. If noise level changes to a higher pitch it can indicate an air leak between air cleaner and engine or a gas leak in the exhaust system between turbocharger and engine. Noise level cycling from one noise level to another can indicate plugged air cleaner or restriction in front of the turbocharger air inlet or heavy dirt build up in the compressor housing and on compressor wheel. Sudden reduction in noise level with resultant, black or blue smoke, and excessive oil leakage indicates a complete failure.

Noise and Air Leak Check

With engine running, check turbocharger for uneven noise and vibration. This can indicate malfunction in the shaft wheel assembly. If suspicious conditions are noted shut down engine immediately to protect turbocharger and engine from further damage.

Examine the turbocharger as per recommended inspection procedure. If any damage is evident, the turbocharger will have to be removed, cleaned, repaired or replaced as necessary.

If turbocharger is assumed to be functional, proceed check of air system as follows:

Engine not running:

1. Check air cleaner for restricted condition.
2. Check all hose clamps for tightness.
3. Check intake manifold gaskets.
4. Check hoses for cracks or deterioration.

With engine running at idle:

1. Air tube and connections between air cleaner and turbocharger can be checked by lightly spraying with starting fluid. Leaks would be indicated by increase in engine speed. This is because of the air pressure drop in this part of the air system and the starting fluid would be pulled into and through the compressor wheel into the engine.

2. Air leaks between turbocharger and engine can be checked by feel and by application of a lightweight oil or soap suds on crossover tube, connections and hoses.

Exhaust gas leakage between engine block and inlet to turbocharger will also create a noise level change and reduce turbocharger performance. Check exhaust system as follows:

1. Check manifold gaskets for leakage.

2. Check manifold retaining bolts for tightness.

3. Check manifold for cracks or porosity.

4. Check turbocharger inlet gasket for leaks.

5. Check turbocharger inlet flange bolts for tightness.

Exhaust gas leakage is detected by heat discoloration in the area of the leak.

Trouble and Symptoms	Probable Causes
Engine Lacks Power	1, 4, 5, 6, 7, 8, 9, 10, 11, 18, 20, 21, 22, 25, 26, 27, 28, 29, 30 A-1, 3, 5
Black Smoke	1, 4, 5, 6, 7, 8, 9, 10, 11, 18, 20, 21, 22, 25, 26, 27, 28, 29, 30 A-1, 3, 5
Blue Smoke	1, 4, 8, 9, 19, 21, 22, 32, 33, 34 A-1, 2, 3, 4
Excessive Oil Consumption	2, 8, 17, 19, 20, 33, 34 A-1, 3, 5
Excessive Oil Turbine End	2, 7, 8, 17, 19, 20, 22, 32, 33, 34
Excessive Oil Compressor End	1, 2, 4, 5, 6, 8, 9, 19, 20, 21, 33 A-1, 2, 3, 4, 5
Insufficient Lubrication	12, 15, 16, 23, 24, 29, 31, 35, 37
Oil in Exhaust Manifold	2, 7, 19, 20, 22, 28, 29, 33, 34
Damaged Compressor Wheel	3, 6, 8, 20, 21
Damaged Turbine Wheel	7, 8, 18, 20, 22, 34, 38
Drag or Bind in Rotating Assy.	3, 6, 7, 8, 13, 14, 15, 16, 18, 20, 21, 22, 31, 34, 37, 39
Worn Bearings, Journals, Bearing Bores	6, 7, 8, 12, 13, 15, 16, 20, 23, 24, 31, 35, 36, 37, 39
Noisy	1, 3, 4, 5, 6, 7, 8, 9, 10, 11, 18, 20, 21, 22 A-1
Sludged or Coked Center Housing	2, 15, 17, 37, 38, 39

Probable Causes

1. Dirty air cleaner element
2. Plugged crankcase breathers
3. Air cleaner element missing, leaking not sealing correctly loose connections to turbocharger
4. Collapsed or restricted air tube before turbocharger
5. Restricted – damaged crossover pipe turbocharger to inlet manifold
6. Foreign object between air cleaner and turbocharger
7. Foreign object in exhaust system (from engine) check engine
8. Turbocharger flanges, clamps or bolts loose
9. Inlet manifold cracked gaskets loose or missing – connections loose
10. Exhaust manifold cracked, burned, gaskets loose blown or missing
11. Restricted exhaust system
12. Oil lag (oil delay to turbocharger at start up)
13. Insufficient lubrication
14. Lubricating oil contaminated with dirt or other material
15. Improper type lubricating oil used
16. Restricted oil feed line
17. Restricted oil drain line
18. Turbine housing damaged or restricted
19. Turbocharger seal leakage
20. Worn journal bearings
21. Excessive dirt build up in compressor housing
22. Excessive carbon build up behind turbine wheel
23. Too fast acceleration at initial start (oil lag)
24. Too little warm-up time
25. Fuel pump malfunction
26. Worn damaged injectors
27. Valve timing
28. Burned valves
29. Worn piston rings
30. Burned pistons
31. Leaking oil feed line
32. Excessive engine pre-oil
33. Excessive engine idle
34. Coked or sludged center housing
35. Oil pump malfunction
36. Oil filter plugged
37. Coolant leakage to crankcase
38. Excessive exhaust temperature engine overfueled
39. Time between oil change too long

A. Oil bath air cleaner
1. Air inlet screen restricted
2. Oil pull over
3. Dirty air cleaner
4. Oil viscosity low
5. Oil viscosity high

Turbocharger Life and Causes of Failures

Preventive maintenance must be practiced to achieve maximum performance and a full service from a turbocharger. A turbocharger is in a very vulnerable position and many kinds of engine failures will also damage a turbocharger. Most turbocharger failures are secondary failures following primary failures of the engine and its accessories and not the result of normal wear.

The things, which can cause a turbocharger, to fail, are many and vary, but they can all be grouped into four general categories:

1. Lack of lubricating oil.

2. Foreign material or dirt in the lubrication system.

3. Foreign material in either the exhaust or air induction systems.

4. Defective material or workmanship.

Lack of Lubricating Oil

This type of failure can occur where the amount and pressure of oil being supplied to the turbocharger is not sufficient to:

a. Lubricate the thrust and journal bearings adequately.

b. Stabilize the journal bearings and shaft to maintain adequate oil film for load carrying capacity.

c. Provide the necessary cooling for the bearings and journal surfaces. Insufficient oil (pressure & volume) to the turbocharger for periods as short as five seconds can cause a failure. The operating temperature and the pressure differentials across the turbine and compressor wheels affects the volume and pressure of oil required. As the turbochargers speed or the engine load increases, the turbochargers need for oil increases.

Foreign Material or Dirt in the Lubricating System

Contaminated oil can damage the internal parts of a turbocharger.
Dirt and sludge will effect the amount of cooling and flow of the oil to the unit.

Operating the engine with contaminated oil under the assumption that the oil filters will remove any contaminants before they reach the bearings can be quite costly. Actually, there are certain conditions under which the oil is bypassed and if this occurs then turbocharger damage can result. This bypassing of oil can occur when the oil filter is clogged and the bypass valve is open or if the bypass valve malfunctions.

Contaminated oil will actually cause damage to the turbocharger bearings when this oil is permitted to enter in an amount sufficient to wear the bearings. This bearing wear will result in a clearance change and will normally affect the stability of the rotating assembly. Also, when the contaminating particles are large enough to plug the internal oil passages and starve the turbocharger for oil.

Foreign Material in Either the Exhaust or Air Induction Systems

The turbocharger is dependent on the intake system. The turbocharger needs plenty of clean air to give a long, trouble free life and supply the correct amount of air to the engine.

Because of the extremely high tip speeds of the turbine and compressor wheels (up to 1,000 miles per hour) any foreign material, which gains entrance through the inlet, or exhaust systems can mechanically damage the rotating parts of the turbocharger. This is one of the reasons why proper maintenance of the air cleaner is extremely important and also why thorough cleaning of the inlet and exhaust systems is essential if there has been a previous turbocharger failure, valve failure or any other type of failure which could leave foreign particles in the engine.

Material or Workmanship

This type of failure is self-explanatory. Either some component of the turbocharger was faulty or the parts were not assembled property.

Due to the nature of most turbocharger failures, the cause of failure must be determined and corrected if necessary before a new turbocharger is installed. Once it is determined the turbocharger has failed, an organized system of trouble shooting should be followed to determine the cause of failure.

Turbochargers have been in use for many years, and their usage has become rather commonplace on today's diesel engines. In spite of this, there still seems to be an aura of mystery about them.

When a problem develops on a turbocharged engine, there is a tendency to fault the turbo with no consideration for a number of other factors, which could also be the cause of the problem. It is only after the turbocharger has been replaced, and the symptoms still exist, that further checking is performed.

The removed turbocharger is seldom reinstalled and is subsequently needlessly exchanged, repaired, or sent to the manufacturer for warranty, which will be denied.

There are methods of determining the condition of a turbocharger on an engine by visual inspection and by the use of simple instruments to measure a few key pressures and temperatures.

A visual inspection should be performed initially to rule out the obvious. This inspection would include:

1. A check for loose ducting connections from the air cleaner to the turbo. A loose duct could mean a dusted engine.

2. Checking the crossover duct from the turbocharger to the engine intake system. A loose duct can cause low power, noise, and oil loss through the compressor seals.

3. Check the wheels of the turbo for impact damage from foreign objects from engine or ducting.

4. Check for evidence of wheel contact against the housing walls. This would indicate internal bearing failure from loss of oil, contaminated oil, or imbalance.

5. Check the shaft for free rotation. Stiffness could indicate the presence of sludged oil or coking from over heating.

6. Check the exhaust manifold for loose connections and cracks. This could cause noise and low power.

7. Check oil drain line for restriction. Any restriction can cause severe oil loss through the turbo seals. There may also be traces of burned oil on the turbine housing exterior.

If the visual inspection fails to reveal any obvious discrepancies, then instrumentation could be applied as a means of pin-pointing the cause of the problem.

AiResearch has developed an instrument kit, which is used to measure key parameters of the engine and turbocharger to determine relative system condition and pin-point the problem source. This kit is quite practical and its operation can be easily performed by shop mechanics.

Most complaints on turbocharged engines are reported to be low power, oil consumption, noisy operation, smoke emission, or combinations of these symptoms.

This engine has been instrumented to include measurement of the air cleaner restriction, crankcase pressure, boost pressure, exhaust gas temperature, and turbo oil pressure.

The engine should be operated at rated power on an engine or chassis dynamometer and the readings observed and recorded after they have stabilized for 5 or 10 minutes.

The air cleaner restriction should not exceed 24 inches of water vacuum. A normal reading for a clean air cleaner is from 6 to 10 inches of water vacuum. Excessive vacuum results in low power, low boost pressures, excessive exhaust temperatures, and quite possibly oil leakage from the compressor seals, particularly at high engine RPM and no load. There would probably be black smoke emitted at load condition and white smoke emitted at no load condition.

Internal engine crankcase pressure measured through the dip stick tube should not exceed 3 to 5 inches of water pressure. Excess pressure here causes oil carry over past the turbine seal and into the stack. Over a prolonged time, this condition can cause turbine seal wear and formation of hard carbon behind the turbine wheel, as well as engine seal malfunction.

Boost pressures vary for each engine make; however, these values are known and should be compared to the actual readings taken. Low boost and low turbine pyrometer readings with normal air intake readings indicate insufficient fuel supply and point to pump and injector problems. There would be general low power indication and possibly black exhaust smoke at low engine RPM.

High boost and excessive pyrometer readings indicate over-fueling. If this condition exists for an extended time, cracks could develop in the turbine housing and exhaust manifold. Also affected would be the engine pistons and valves.

Normal pyrometer readings for most four-cycle diesel engines should indicate 1250°F maximum in the manifold ahead of the turbocharger. These figures are also published for each engine and should not be exceeded, since it is detrimental to both engine and turbocharger.

The oil pressure reading should be no less than 20 psig at engine idle and at least 30 to 35 psig at full load condition. It should compare within 5 pounds of indicated engine oil pressure. High differentials indicate dirty oil filters or oil line restrictions.

Low oil quantities create bearing failures from over heating.

Generally, if the pressures are correct, the flow quantities will be correct. The average amount of oil flowing through a turbocharger at maximum load is from one to one-and-one half gallons per minute.

FAILURE ANALYSIS

Turbocharger malfunctions generally are caused by lack of lubrication, contaminated oil, or foreign object damage from failed engine parts. It is advisable to disassemble and inspect a failed turbocharger prior to installing a replacement unit in order to determine the cause of failure and to prevent premature failure of the replacement for the same reason by correcting the cause.

A failed turbocharger will invariably show heavy rubbing contact of the wheels against the housing walls. Note blade material displacement on this compressor wheel.

Lack of Lube

If failure was from lack of oil, the shaft will show severe heat discoloration. This heat can exceed 1000°F. Lack of lube failures are caused by lube pump failures, broken or blocked oil lines, and in some instances, oil lag after oil and filter service due to improper oil priming.

Bearing material will also transfer to the shaft journals. This only happens in the absence of oil.

The bearings will extrude and the oil holes will start to close. The bearings also expand and become fixed in the bearing bores. These bearings are called floating bearings and fit loosely on the shaft and in the center housing bearing bores.

Heavy seal contact will occur and the seal spacer and piston ring will deteriorate rapidly. The thread on the spacer is reverse to rotation and pumps oil inboard. The piston ring is primarily an air seal.

The thrust collar also wears heavily and may expose the oil slinger holes. Heavy oil leakage then occurs through the seals into the compressor and engine.

There will be corresponding wear in the outboard thrust washer. The aluminum thrust washer here has practically disappeared from heavy contact against the thrust collar due to loss of protective oil film.

The inboard thrust washer also wears heavily. There is little load on this bearing normally.

Foreign objects

The turbine blade tips will be battered severely from loose material from the engine. Note that each blade has the same appearance. Damage is fairly uniform. Loose material is generally from failed valves, piston rings, or pieces of the piston.

Hard material through the compressor wheel severely damages the blades. The blade particles enter the engine and may or may not create other damage. Often carelessness when servicing air cleaners is responsible for this type damage.

Soft material, such as shop towels or rubber booting, bends the blades. These blades cannot be straightened. Quite often the material will jam the wheel and stop shaft rotation.

Loose air cleaner ducts cause severe sand or dirt erosion to compressor blades. The result is low power and noise, as well as ruined engine, in a very short period of time.

The bearings will also be damaged from heavy loads caused by severe imbalance. The seals will also receive wear damage. In some instances, the center housing bearing struts will fracture.

Contaminated Lube

Dirt or metals in the oil causes heavy wear on the shaft journals, bearing surfaces, and thrust bearings. Note the heavy impregnation of dirt in the bearing surfaces. This debris enters the turbo oil system when the filter by-pass opens or filter element malfunctions.

Thrust bearings wear out. Three of the four pads of this thrust bearing are gone completely, indicating high abrasive content in the oil supply.

The thrust collar also will be heavily scored and worn on both surfaces.

Bearing surfaces will be worn and scored. Note the tin plating is worn away. The bearing bores of the center housing will also show scoring and wear. Severe shaft motion results in seal destruction and eventual heavy wheel rub.

Heavy concentrations of oil contamination can channel the bearing surfaces. A good bearing is also shown on the right for comparison.

For the most part, most turbocharger failures can be prevented by proper maintenance procedures. The only wear that occurs in a turbocharger is introduced by way of the lubricating system or air system. Conceivably, the turbocharger could last indefinitely if provided with adequate supplies of clean air and clean oil.