AIRCRAFT Maintenance TECHNOLOGY

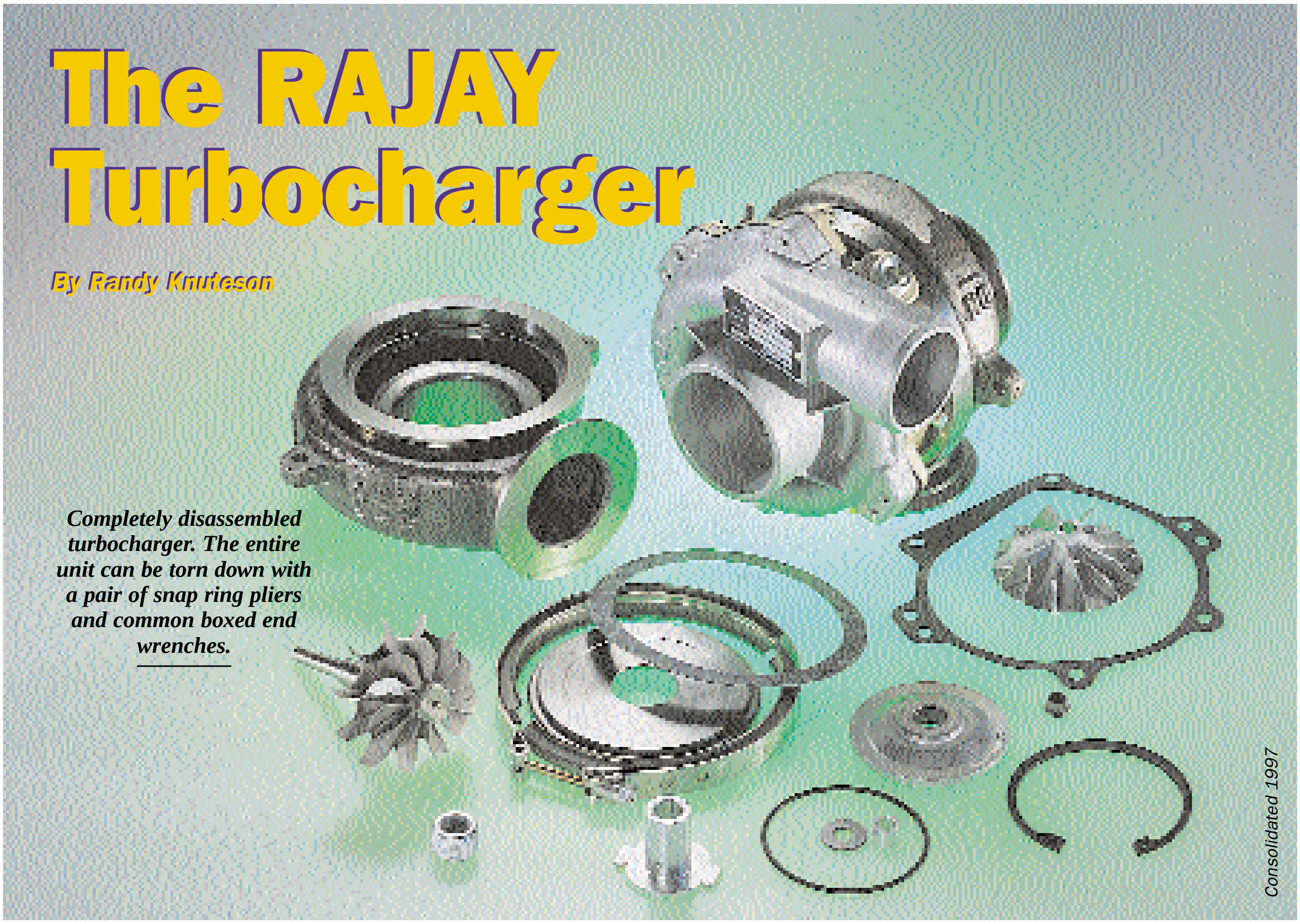
The Leading Publication For The Professional Maintenance Team

Reprinted with permission from *Aircraft Maintenance Technology*, October 1997.

ACCESSORY TECHNOLOGY

The RAJAY Turbocharger

By Randy Knuteson



Completely disassembled turbocharger. The entire unit can be torn down with a pair of snap ring pliers and common boxed end wrenches.

Consolidated 1997

Turbocharging an aircraft engine is analogous to a mountain climber making the demanding ascent of Mount Everest aided by supplemental oxygen. Without such help, each advancing step becomes slower and more ponderous. Oxygen deprivation slowly saps the strength as every breath of air becomes more labored than the last. A satisfying gulp of bottled oxygen quickly renews the energy required to gain higher ground.

It is the same with a naturally aspirated engine. As a pilot nurses his plane toward its service ceiling, performance diminishes noticeably. Like the climber, the plane is now running "short of breath." Turbocharge that same engine, and it will respond as if infused by some high altitude adrenaline. This force feeding of the oxygen required not only doubles its potential ceiling, but also allows one to climb out from sea-level to 12,000 feet in nearly half the time.

The driving force of the RAJAY turbocharger is the turbine wheel (left) and compressor impeller (right). It is capable of rotating up to 120,000 rpm.

The installation of turbochargers enables a plane to climb to new "summits" without monumental effort. Maximum cruise speed increases steadily due to reduced air resistance at these new heights. With the same given power, every 1,000 feet of altitude now yields an additional 2 kts. An increase of 30 plus miles per hour from sea level to 22,000 feet is not at all uncommon.

There are two flights that heavily underscore the value of a turbo retrofit. The first occurred some 35 years ago when Lt. Commander Marvin Smith, Jr. successfully piloted a Riley turbocharged Cessna 210A to 40,300 feet. At that time, Commander Smith's flight exceeded the altitude record held by the Japanese since 1959. The second flight that again dramatizes the increased capabilities appreciated by turbocharging a light aircraft, saw a Piper Twin Commanche fly from California to Pennsylvania on one turbocharged engine. At 18,000 feet with one prop feathered, this flight demonstrated that a single turbocharged engine is able to deliver the power necessary to hold altitude safely even over mountainous regions.

. . . force feeding of the oxygen required not only doubles its potential ceiling, but also allows one to climb out from sea-level to 12,000 feet in nearly half the time.

Few are driven by the need to set altitude records or fly twins long distances with one prop feathered. However, there remains a common denominator with all pilots/operators — the desire for an economical and safe way to squeeze the best performance out of their aircraft. To avoid turbulence, to go farther and faster for the same fuel consumption; these are basic demands that bring true satisfaction to most in the aviation community.

BASIC DESIGN

All RAJAY turbochargers are built around a 3-inch diameter rotating group. The lightweight impeller and turbine wheel design results in extremely low inertia, permitting an instant response to engine speed and load changes. The short length turbine wheel and shaft (only 4 1/2 inches) keep installation size down to a minimum (less than 7 inches from compressor inlet to turbine outlet). The average weight of the turbo is surprisingly modest with some models being only a little over 12 pounds.

Significant among the design features of the RAJAY Series turbochargers is the patented, one-piece aluminum bearing of the semi-floating design. Engine oil pressure is directed to the bearing at 30 psi with between 1 and 2 quarts per minute being supplied.

This oil pressure virtually suspends the bearing in a film of oil around the O.D., while also permitting oil to pass through radial holes to the bore.

The ends of the bearing serve as thrust surfaces in both directions. Since the oil supply to the bearing is a direct and unrestricted passage, it lends itself to rapid lubrication. If power is applied without engine warm-up, sufficient residual oil exists for initial lubrication due to the characteristics of this bearing.

This design feature has proved so durable that other turbocharger manufacturers have used it, under license, for heavy duty truck applications, where a 5,000 hour service life is quite common. Another characteristically unique feature of this turbocharger is its carbon-faced oil seal providing excellent sealing ability and also extending the life of the unit.

TURBO NORMALIZING

RAJAY turbochargers have become original equipment on a variety of piston engine aircraft, such as the Piper Seneca, Turbo Arrow, Enstrom Helicopter, and Aerostars, as well as over 1,200 aftermarket Turbo Normalizing STC installations on normally aspirated engines.

Turbo Normalizing is an effort to restore lost power suffered while gaining altitude since power produced by a naturally aspirated engine is directly proportionate to the density of air entering its intake. For instance, the density of air at sea level is 0.0765 pounds per cubic feet. But at 10,000 feet, air density drops to 0.0565 pounds per cubic feet. So, an engine that develops 100 hp at sea level is limited to roughly 73.9 hp at 10,000 feet.

Turbo Normalizing an engine enables it to gain altitude with no appreciable loss of power. Wasted energy from exhaust gases is harnessed by rerouting those gases to a turbine wheel placed in their path. These escaping gases cause the turbine to spool up to as much as 120,000 rpm. Since the compressor impeller is attached to the turbine by means of a common shaft, the impeller rotates at the same rpm, compressing the induction air being ingested by the engine.

An automatic wastegate device is used to expel exhaust gases at sea level. The wastegate gradually inches its way toward the closed position as the plane gains altitude. As the wastegate closes, it progressively diverts more and more exhaust energy to the turbo and consequently feeds additional boost pressure to the engine.

A pressure controller positions the wastegate by means of an actuator, constantly maintaining air density to the engine and assuring no loss of horsepower. Once the aircraft reaches the altitude at which the wastegate completely closes, all exhaust gases now pass through the turbine. This is the plane's critical altitude. Above this altitude, the plane will begin to lose power because it does not possess sufficient boost to maintain sea level performance.

MANUAL AND "FIXED" SYSTEMS

It would be appropriate to mention that other wastegate configurations are also used. The Rockwell 112TC and Enstrom Helicopter use a wastegate that is directly linked to the throttle so that as the throttle advances, the wastegate moves toward closure. Takeoff is performed at part throttle and a pressure relief valve prevents overboost.

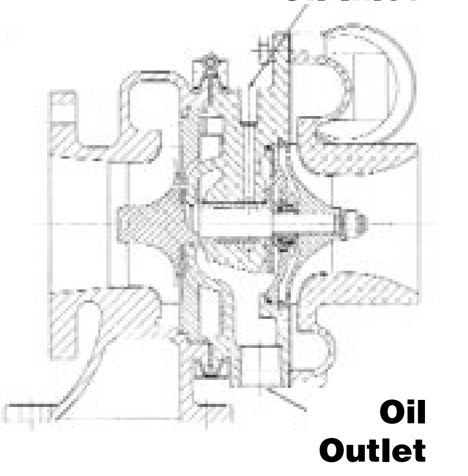
Early wastegates were introduced as manually operated devices. In climb, as manifold pressure begins to drop, the pilot simply makes vernier adjustments manually to the wastegate to compensate for altitude changes. These systems remain both in production and use.

Another form of wastegate is the orificed or "fixed" wastegate used on some Pipers. This style of wastegate continuously allows some of the exhaust to flow through the turbo but never diverts the entire flow. As a result, it experiences a lower critical altitude. Together, these systems require little to no maintenance and will generally perform trouble free well past TBO.

TROUBLESHOOTING

Troubleshooting is usually limited to determining the source of an oil leak. Often, the assumption is made that the turbo is at fault. This assumption can lead to both unnecessary maintenance and additional expenses. In most cases, an oil leak is not a turbo problem — rather it is caused by either improper turbo installation or poor engine maintenance. Most often, turbocharger damage is caused by contaminated lubricating oil or insufficient lubrication of the center housing assembly. Another source of turbocharger failure is caused by foreign objects entering either the compressor or turbine.

Although this scenario could be catastrophic to the health of the turbo, the airplane would merely revert to its naturally aspirated condition. However, in a ground boosted system with low compression pistons, a roughness generally accompanies this change. This roughness is due in large part to the loss of deck pressure to the fuel pump and at the injection nozzles. A seizure of the turbocharger causes the MAP to fall 2 inches below naturally aspirated conditions because of the backpressure at the turbo. At takeoff or climb, the richness caused by low atomization of the fuel through the injection nozzles can only be corrected by a leaning of the mixture.



Cross sectional view of RAJAY Series turbocharger.
Note the direct unrestricted passage for oil supply to the semi-floating bearing.

Allowing a cooling down period for the turbo is a maintenance procedure that should be universally practiced. When taxiing in, allow the engine an additional two minutes of idle time before going to ICO. This simple practice will prevent any oil residue from coking in the hot turbine housing and will prolong the life of the turbo.

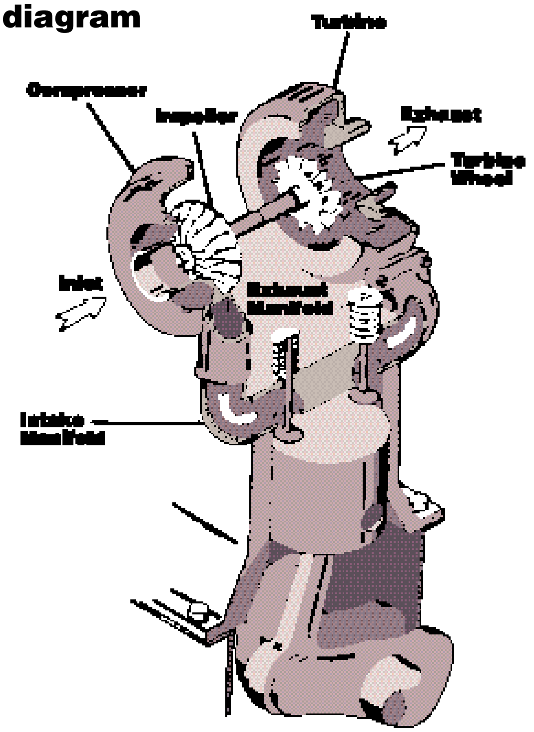
If a scavenge pump is installed, periodically inspect hoses for integrity and check hose routing to assure there are no kinks. Any collapsing or kinking of a scavenge pump hose causes a backpressure to the turbo resulting in oil seepage past the seals of the bearing housing. Faulty, or improperly positioned check valves can also contribute to oil leakage from the bearing housing. Oil residue found in the exhaust or telltale plumes of black smoke at run-up may be indicative of oil seepage past the piston ring of the turbine wheel.

Another preventative maintenance tip that is often overlooked is related to cylinder repair work performed on the engine. Any time valve or cylinder damage has occurred, it is wise to check the condition of the turbine and housing. It is not unusual to find fragments of valve faces or stems lodged in the turbine. In the event of any potential FOD, always remove the turbine exhaust and, using a suitable light, visually inspect the turbine assembly for nicked, bent , broken, or missing blades.

Remove the turbocharger if any damage is evident. A careful troubleshooting procedure should be accomplished prior to automatically removing the turbo from the aircraft. Typical early warning signs are low manifold pressures at altitude or oil leakage evident in the air induction system or turbine outlet exhaust stack. If manifold pressure is the problem, check for turbine or impeller damage and for air leaks in the compressor discharge, the intake manifold, and the air throttle body ducting. If oil leakage is evident, remove the ducting to the compressor inlet and again examine the compressor wheel for blade damage or rubbing on the housing. Also check the radial play and if found to be excessive, remove the turbocharger for overhaul.

A RAJAY turbocharger is basically very simple in its design and function. This simplicity coupled with its rugged features assures a long and satisfying operating life. With consistent care and maintenance, these turbochargers will often outlast the engine.

Turbocharger operation diagram



Randy Knuteson is director of operations for Consolidated Fuel Systems Inc. in Montgomery, AL.

A brief history of the five manufacturers who have owned the RAJAY turbocharger line:

1958 — TRW (Thompson-Ramo-Wooldrige of Cleveland, OH) develops the 300 Series Turbocharger.

1969 — RAJAY Industries (Long Beach, CA.), a unit of the Texstar Corp. in Grand Prairie, TX, acquires the entire TRW Turbocharger line. Texstar later became a unit of the Hillman Co. of Pittsburgh, PA.

1982 — Roto-Master Inc. (North Hollywood, CA), later a unit of Echlin Corp. (Branford, CT) acquires the entire RAJAY Industries operation from Hillman Co., including the RAJAY STC's for aircraft kits.

1986 — AiResearch Industrial Division of the Garrett Corporation, now AlliedSignal Automotive, acquires the entire operation of Roto-Master from Echlin Corporation and relocates it to the Garrett turbocharger facilities in Torrance, CA.

1995 — RAJAY turbocharger STCs were divested of to Consolidated Fuel Systems in Montgomery, AL.

1997 — Consolidated Fuel Systems (Montgomery, AL.), a division of Kelly Aerospace, announces in August its purchase of the RAJAY turbocharger line from AlliedSignal. This purchase includes manufacturing, engineering, and design rights to both aircraft and automotive turbochargers.

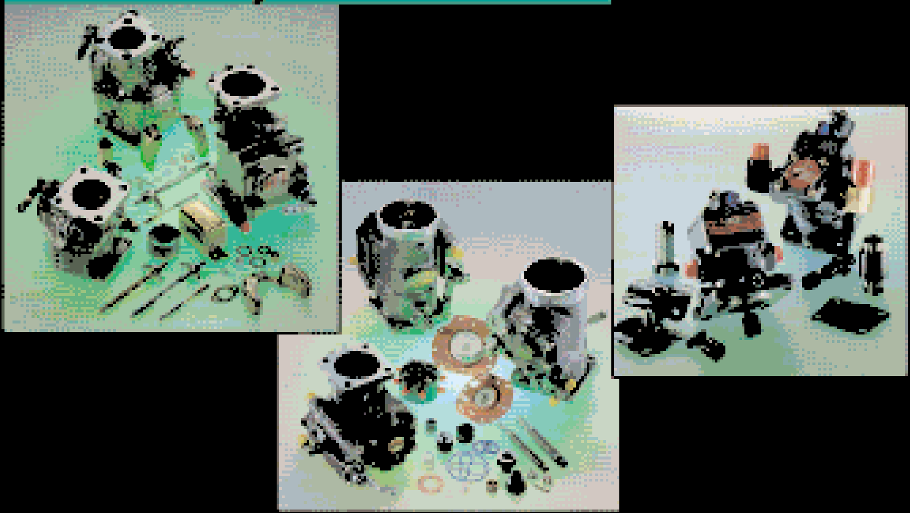
Actions

Speak Louder Than Words

Alabama's Best Kept Secret.

CONSOLIDATED

Quality Products



- **Overhaul:**
  - Carburetors
  - Fuel Servos
  - Fuel Pumps
  - TCM Fuel Systems
- **FAA Approved Replacement Parts.**
- **OEM Approved**

Guaranteed Reliability.

- One Year, "No Hassle" Warranty.
- Highly Skilled / Trained Technicians.
- Over 75 Years Combined Experience.
- Mass Airflow Testing on 100% of Carburetors.
- 100% Calibration of Fuel Pumps and Servos.
- Largest Exchange Pool in the Industry.
- Distributed "Worldwide" Through the Leading Aviation Wholesale Distributors.

Certified Repair Station #FUXR511K

For more information please give us a call or contact your favorite Aviation wholesale distributor today.

And We're Not Just Whistling Dixie.

CONSOLIDATED

Consolidated Fuel Systems, Inc.
1400 East South Blvd. • Montgomery, AL 36116
334-286-8551 • Fax: 334-286-8018

A KELLY AEROSPACE Company