TROUBLESHOOTING REFERENCE GUIDE

Aircraft Turbochargers, Valves and Controls

P/N 400888-0000, Rev A

BUILT ON HONOR
HARTZELL
ENGINE TECH

AEROFORCE™
TURBOCHARGER SYSTEMS

Warning:

Owners and Operators that fly must recognize that there are inherent risks involved in this activity, whether for business or pleasure. Every precaution in maintenance and training must be taken to minimize these risks as it is unlikely that they can be eliminated entirely. The turbocharger valves and controls listed herein are critical components of the aircraft. Any failure may result in an unplanned landing or even more severe consequences.

Turbocharger controllers, bypass valves, and pressure relief valves are subject to wear based on conditions that may make the same unit life vary from airplane to airplane and condition to condition. These components are principally used with propeller driven airplanes that subject them to constant vibration stresses from engine operation as well.

Each of the turbocharger valves and controls certified, must demonstrate adequate margins of safety before they are considered as safe to operate on an airplane or rotorcraft. Even when every precaution is taken in the design and manufacture of these components, failures may still occur.

It is essential that the controllers, bypass valves, and pressure relief valves be properly operated per the flight manual and maintained according to recommended service procedures. The overall turbocharger system must be observed closely and inspected to detect any possible problems before they have a chance to effect airworthiness. Any abnormal or unusual operating conditions or reports should be investigated and repairs effected, as it may be a warning of impending failure.

The turbocharging system provides power to your airplane for virtually all phases of flight. Without the proper care and maintenance, the effectiveness and safety cannot be assured. This Guide helps advise owners, operators and mechanics of necessary information about your turbocharging system to assure safe and long lasting operation. Please assure you give it your undivided attention.

Thank you for choosing Hartzell Engine Tech components. Maintained properly, they will give you safe and reliable service for many years to come.

Sincerely,
Hartzell Engine Tech
Product Support

Welcome

As the retired Director of Product Support for Hartzell Engine Technologies, I've been involved in the troubleshooting and maintenance of turbocharger systems for 45+ years in a manufacturing, maintenance and/or training capacity. In the early 1980's through the mid 1990's, Allied Signal/Garrett AirResearch published an Aircraft Turbocharger and Control Reference with Troubleshooting Guide which was invaluable in helping to understand the turbocharger and its related systems. When the turbocharger product line was acquired by Kelly Aerospace in the late 1990's/early 2000's, they updated the troubleshooting guide. In 2010, Hartzell Engine Technologies was formed after purchasing the turbocharging product line assets from Kelly Aerospace. We now take our turn at updating this historical document for use in the field, both by maintenance professionals, aircraft owners and pilots operating turbocharged aircraft.

In this latest Troubleshooting Guide, we have included newer turbocharged aircraft models along with adding additional detail to some existing legacy systems. In addition, we've also added additional sections covering subjects like; turbocharger cool down, storage/shelf life, TBO/ICA and basic warranty, all of which provide additional guidance for our turbocharged aircraft operators.

As Mike Rogers, from our Approved Turbo Components Recommended Service Facility (RSF) stated; "Thank you for the update on the Aircraft Turbocharger and Control Reference with

Troubleshooting Guide. Approved Turbo Components and I have been using this guide for over 40 years and have found it to be of tremendous value for mechanics in the field to understand how all the different turbo system components operate. It has been such a valuable tool in the aircraft turbocharger industry that it is required reading for any new employees at ATC. Thanks again and keep up the good work."

We thank everyone for their continued interest in this publication and in support of our HET products. We hope you will find this latest 2024 Turbocharger Troubleshooting Reference Guide even more complete and useful than ever before!

Regards,

Timothy Gauntt
Director of Product Support (Ret.)
Hartzell Engine Technologies

Foreword

The material contained herein pertains solely to Hartzell Engine Tech (HET) turbochargers, relief valves, turbocharger controllers and exhaust bypass valves (wastegates)* manufactured by HET: 2900 Selma Highway, Montgomery, Alabama, 36108 U.S.A. This material is applicable to HET products only.

The systems guide and troubleshooting information presented are for use only to aid properly qualified persons in the maintenance of the equipment covered in this publication and in no way whatsoever replaces or changes the appropriate airframe or engine manufacturer's service publications. Airframe and engine applications listed for HET products are furnished solely as a helpful reference, and are based on information available to HET at the time of publication. Actual HET products applications must conform to aircraft equipment lists published by the airframe and/or engine manufacturers under all applicable Federal Aviation Administration regulations. HET makes no representation or warranty as to the accuracy and correctness of the airframe and engine applications listed for HET products. HET reserves the right to make changes in this publication at any time, without notice.

NOTE: Within the context of this document, the terms "exhaust bypass valve," "bypass valve," and "wastegate" are used interchangeably.

NOTE: The equipment covered in this publication includes turbochargers, which are high-technology devices operating at high temperatures with their rotating parts spinning at very high speeds. Persons attempting maintenance of any sort must be qualified legally and technically to service such equipment on aircraft and must observe and satisfy the critical tolerances and necessary high standards of workmanship that are required.

For information on the products and material herein, contact:

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NOTICE OF LIMITED WARRANTY:

The limited warranty applicable to retail purchasers of products manufactured or overhauled by HET is available on the applicable HET product website.

When applicable, HET's limited warranty is in addition to any warranties provided by the manufacturer of engines, equipment or vehicles incorporating products, or distributors of products. Warranty claims must be submitted through the selling dealer* or directly to HET through the applicable product website. Unless otherwise expressly provided in writing (1) the remedy for defects in materials and workmanship under any applicable HET warranty is limited to repair or replacement of the product by HET, (2) in no event shall HET be liable for incidental or consequential damages, and (3) HET specifically disclaims any implied warranty of merchantability or fitness for a particular purpose.

TROUBLESHOOTING TURBOCHARGER SYMPTOMS:

This Guide contains lists of engine troubles and troubleshooting charts to match, as explained in the sections below. Neither the text of this Guide nor the charts should be regarded as covering every possible issue and potential cause. Rather, this information is representative of the approach to be employed in troubleshooting a turbocharged engine issue.

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Introduction 1

This publication comprises two parts. The first section is an aircraft turbocharger system guide consisting of a reference index listing turbocharger aircraft by manufacturer, engine number and the type(s) of control fitted to the engine. The page number for the proper descriptive section follows each listing. These segments describe each type of system in detail, including controller functions, then lists aircraft by manufacturer plus engine, turbocharger, wastegate and controller part numbers by Hartzell Engine Tech (HET) and airframe or engine manufacturer designations.

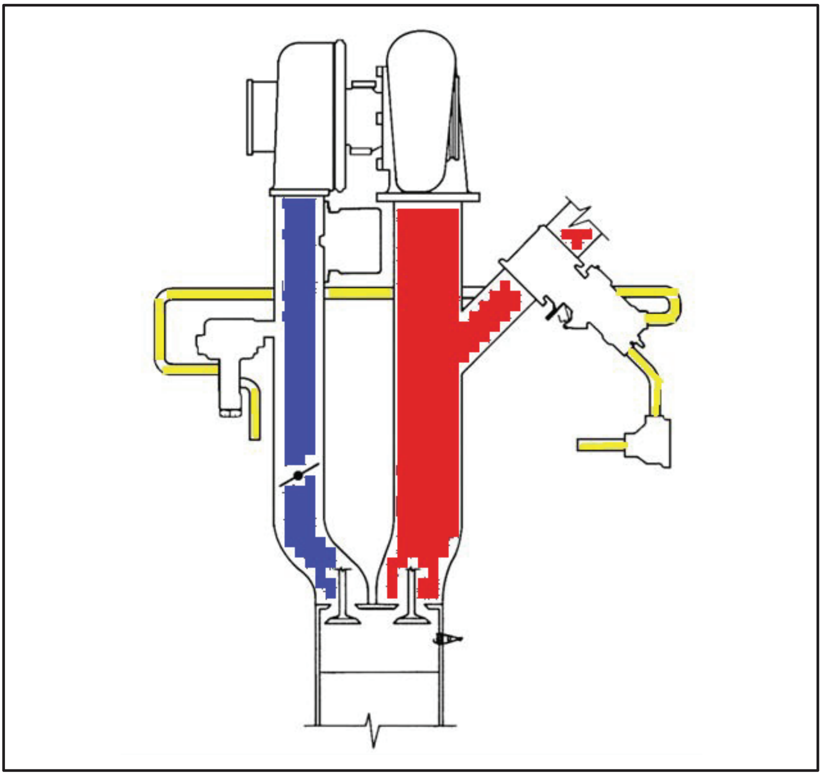
The second section provides a complete troubleshooting guide with decision trees for preliminary system diagnosis.

TURBOCHARGER SYSTEM DESCRIPTION:

The function of an aircraft turbocharger system is to provide a desired manifold pressure (MP) at a given throttle setting and, in most cases, maintaining the MP regardless of varying conditions of ambient air temperature and pressure. With few exceptions, the aircraft system comprises a turbocharger, bypass valve, and one or more controllers. In many cases, a direct-acting absolute pressure relief valve is also incorporated as a fail-safe feature in the event of total control failure or to avert any tendency towards cold-start overboost.

In the accompanying schematic diagram (Figure 1) of a simplified aircraft turbocharger system, the flow of exhaust gases (red), compressed air (blue), and pressurized engine oil (yellow) can be clearly seen. Although this system features only one turbocharger and controller, coupled with a butterfly-type exhaust bypass valve plus an absolute pressure relief valve, it is typical of common aircraft systems.

Figure 1 - Aircraft Turbochargers System Schematic



Controllers may be found in multiples, or combined in a common housing; but, as they operate in parallel (though in response to differing stimuli), their actions on the system remain the same as if only one controller were fitted.

The turbocharger compressor discharge pressure (upstream of the throttle) is regulated by controlling the flow of exhaust gases through the turbocharger turbine. The exhaust gas flow is controlled by diverting excess gas through an exhaust bypass valve of either a poppet-type, mounted directly on the turbocharger turbine housing, or a butterfly design mounted on a diversion duct that bypasses the turbine inlet. Both types are actuated by pressurized engine oil that first flows into the bypass valve actuator via a restricting orifice or capillary tube, then out of the actuator into one or more controllers. Ultimately, the now depressurized oil returns to the engine oil sump. Regardless of the type of controller used, when the controller (within its parameters) senses insufficient compressor discharge pressure, a poppet valve in the controller moves towards a closed position, thereby raising the oil pressure in the upstream, actuator side, closing the bypass valve and forcing more exhaust gas through the turbocharger turbine. This raises the turbine/compressor shaft speed, and consequently the compressor discharge pressure.

When the controller senses excessive compressor discharge pressure, the opposite action occurs. The controller poppet opens, reducing upstream oil pressure, and permitting springs in the actuator cylinder to open the bypass valve. Exhaust gases then bypass the turbine; turbine/compressor shaft speed is reduced and the compressor discharge pressure drops.

On some systems, a fixed bypass tube is placed between the exhaust turbine inlet and the turbine outlet exhaust which limits the amount of "bypass" that can occur. These systems are susceptible to over boost, especially in cold temperature, high air density operations, so the pilot much closely monitor the engine MP gauges.

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Turbo Systems Listed by Type 2

FIXED ABSOLUTE PRESSURE SYSTEM:

Installation Features:

1970-72 Textron Cessna T310
1978-81 Textron Cessna P210
1969-84 Textron Cessna T206, T207, T210
Textron Cessna Skyknight
Piper Aztec A/B
Piper Aztec C/D

Component Operation:

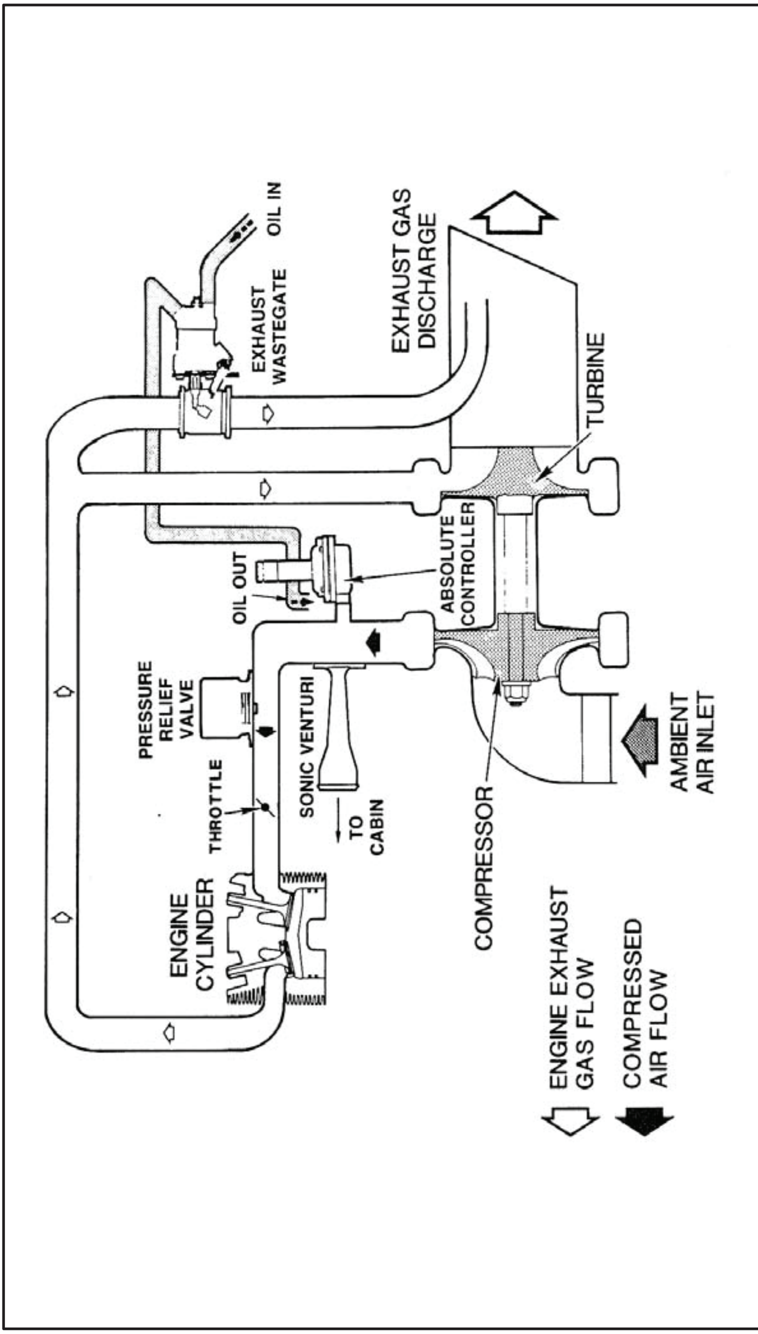
The fixed absolute pressure controller hydraulically regulates the wastegate opening for high engine power settings from sea level to altitude. The controller senses deck pressure, compares it to a reference absolute pressure, and adjusts the wastegate butterfly (controlling turbocharger speed) to maintain sea-level horsepower at varying altitudes.

If fitted, a pressure relief valve, set slightly in excess of maximum deck pressure, is provided to prevent damaging overboost in the event of a system malfunction.

A sonic venturi, if fitted, is incorporated to provide a constant source of compressed air to the cabin pressurization system.

NOTE: On Piper Aztec C models only, a transfer valve is used to allow sensing of manifold pressure rather than deck pressure at near to full-throttle settings for climb and cruise power. This permits lower turbocharger speeds, less back-pressure, more power and economy.

Figure 2 - Fixed Absolute Pressure System Schematic



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FIXED ABSOLUTE PRESSURE / PRESSURE RATIO SYSTEM:

Installation Features:

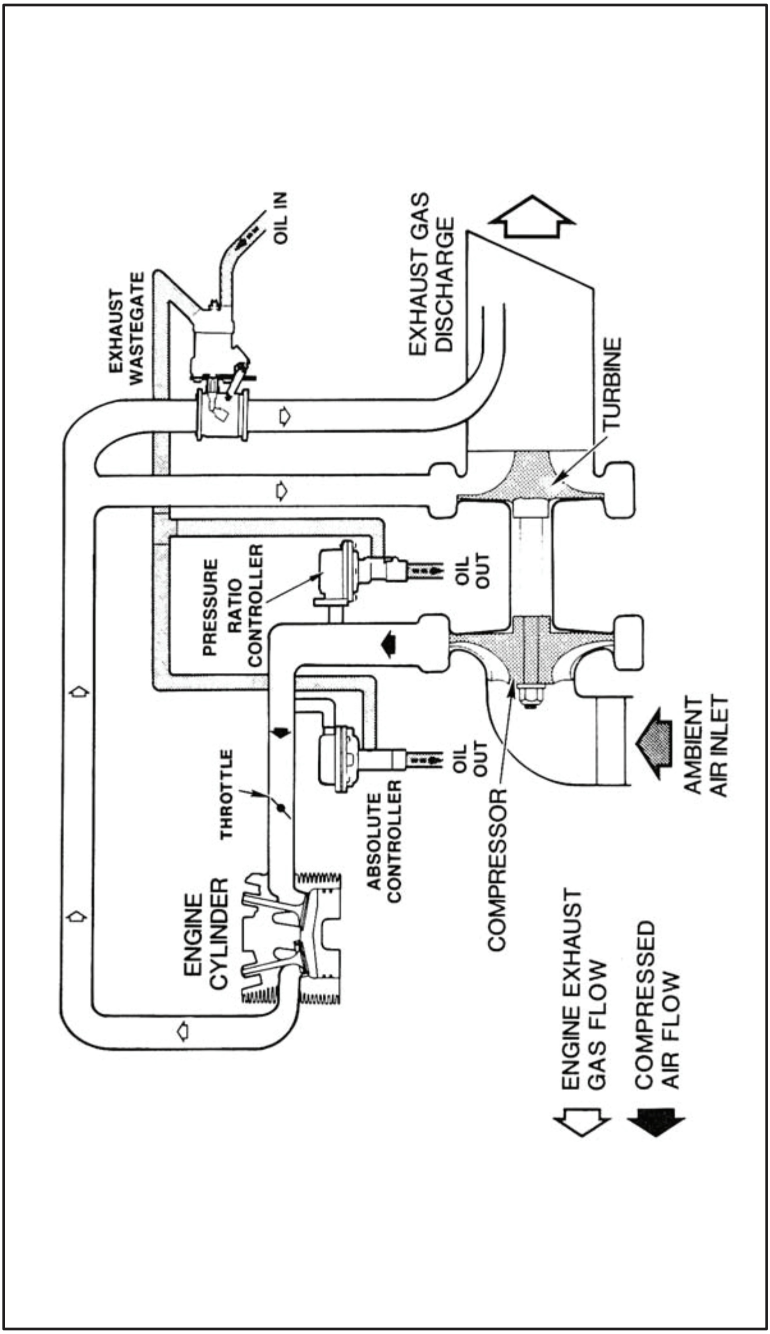
1969 Textron Cessna Turbocharged 310, 401A, 402A

Component Operation:

The fixed absolute pressure controller hydraulically regulates the wastegate opening for high engine power settings from sea-level to altitude. The controller senses deck pressure, compares it to a reference absolute pressure, and adjusts the wastegate butterfly (controlling turbocharger speed) to maintain sea-level horsepower at varying altitudes.

The pressure ratio controller is designed to override the fixed absolute pressure controller during high-altitude cruising to prevent turbocharger overspeed and lower the part-throttle critical power point of the engine. The controller senses deck and ambient pressures and compares them to a referenced absolute pressure. When the ratio of outlet to ambient pressure exceeds a preset proportion, the controller opens the wastegate and lowers turbocharger output.

Figure 3 - Fixed Absolute Pressure / Pressure Ratio System Schematic



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DUAL ABSOLUTE / RATE CONTROL SYSTEM:

Installation Features:

1966 - 68 Textron Cessna T206
1966 - 68 Textron Cessna 185
1966 - 68 Textron Cessna T210

Component Operation:

The rate/absolute dual controller performs the functions of both the rate controller and the absolute pressure controller. Components serving the separate functions are housed in a common body and capillary assembly with shared sensing and hydraulic ports.

The fixed absolute pressure controller portion of the dual controller hydraulically regulates the wastegate opening for high engine power settings from sea-level to altitude. The controller senses deck pressure, compares it to a reference absolute pressure, and adjusts the wastegate butterfly (controlling turbocharger speed) to maintain sea-level horsepower at varying altitudes.

The rate controller portion of the dual controller senses deck pressure and acts to prevent excessive increase in the turbocharger discharge air pressure. Thus, when a too rapid throttle advance causes an excessive rate of change in deck pressure, the controller overrides the absolute pressure controls and opens the wastegate butterfly and slows the compressor, lowering deck pressure and preventing overboost.

If fitted, a pressure relief valve, set slightly in excess of maximum deck pressure, is provided to prevent damaging overboost in the event of a system malfunction.

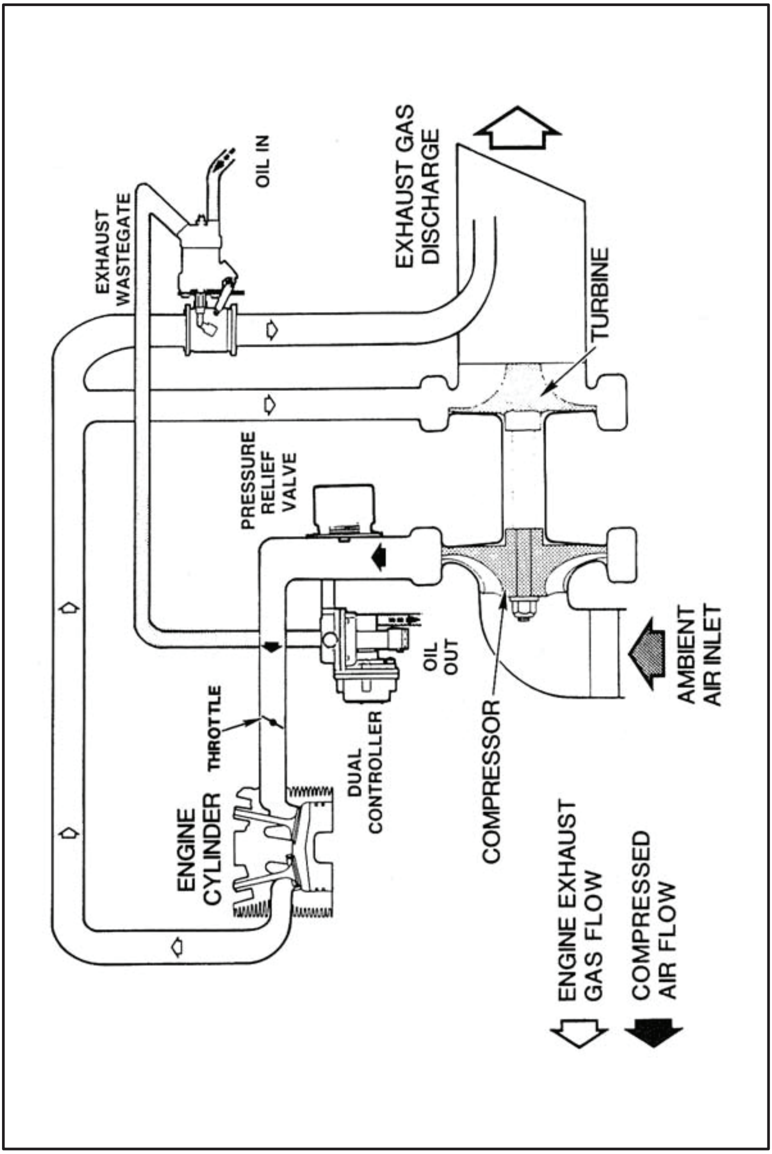

Figure 4 - Dual Absolute / Rate Control System Schematic

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DUAL ABSOLUTE/RATE CONTROL SYSTEM WITH PRESSURE RATIO CONTROL:

Installation Features:

1965-66 Textron Cessna 411
1967-68 Textron Cessna 401, 402, 411A
1966-68 Textron Cessna 320

Component Operation:

The rate/absolute dual controller performs the functions of both the rate controller and the absolute pressure controller. Components serving the separate functions are housed in a common body and capillary assembly with shared sensing and hydraulic ports.

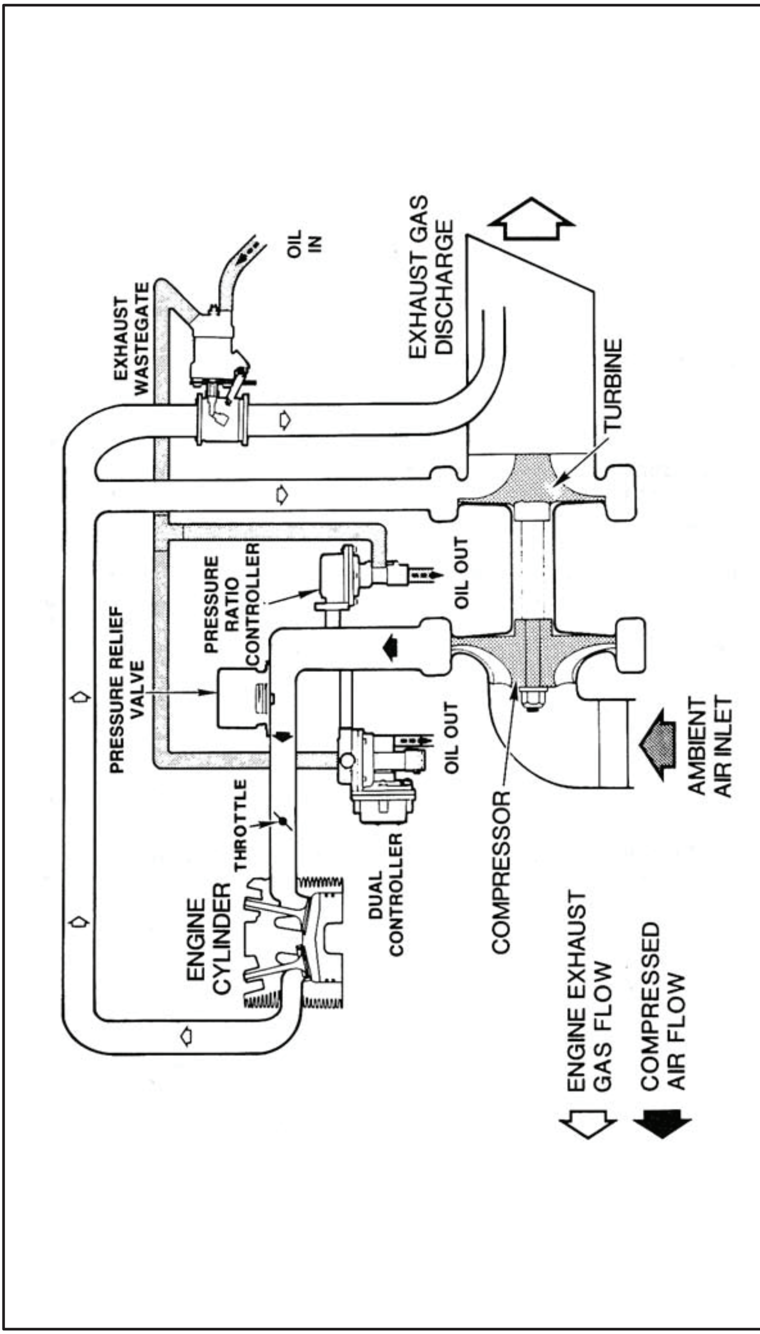
The fixed absolute pressure controller portion of the dual controller hydraulically regulates the wastegate opening for high engine power settings from sea-level to altitude. The controller senses deck pressure, compares it to a reference absolute pressure and adjusts the wastegate butterfly (controlling turbocharger speed) to maintain sea-level horsepower at varying altitudes.

The rate controller portion of the dual controller senses deck pressure and acts to prevent excessive increase in the turbocharger discharge air pressure. Thus, when a too rapid throttle advance causes an extreme rate of change in deck pressure, the controller overrides the fixed absolute pressure controller and opens the wastegate butterfly and slows the compressor, lowering deck pressure and preventing overboost.

The pressure ratio controller is designed to override the fixed absolute pressure controller during high-altitude cruising to prevent turbocharger overspeed and lower the part throttle critical point of the engine. The controller senses deck and ambient pressures and compares them to a referenced absolute pressure. When the ratio of outlet to ambient pressures exceeds a pre-set proportion, the controller opens the wastegate and lowers turbocharger output.

If fitted, a pressure relief valve, set slightly in excess of maximum deck pressure, is provided to prevent damaging overboost in the event of a system malfunction.

Figure 5 - Dual Absolute / Rate Control System with Pressure Ratio Control Schematic



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DUAL ABSOLUTE/PRESSURE RATIO CONTROL SYSTEM:

Installation Features:

1973-'75 Textron Cessna T310
1980-Up Textron Cessna 335
1973-75* Textron *Cessna Turbo 340
1970-72 Textron Cessna 401B
1970-78 Textron Cessna 402B

Component Operation:

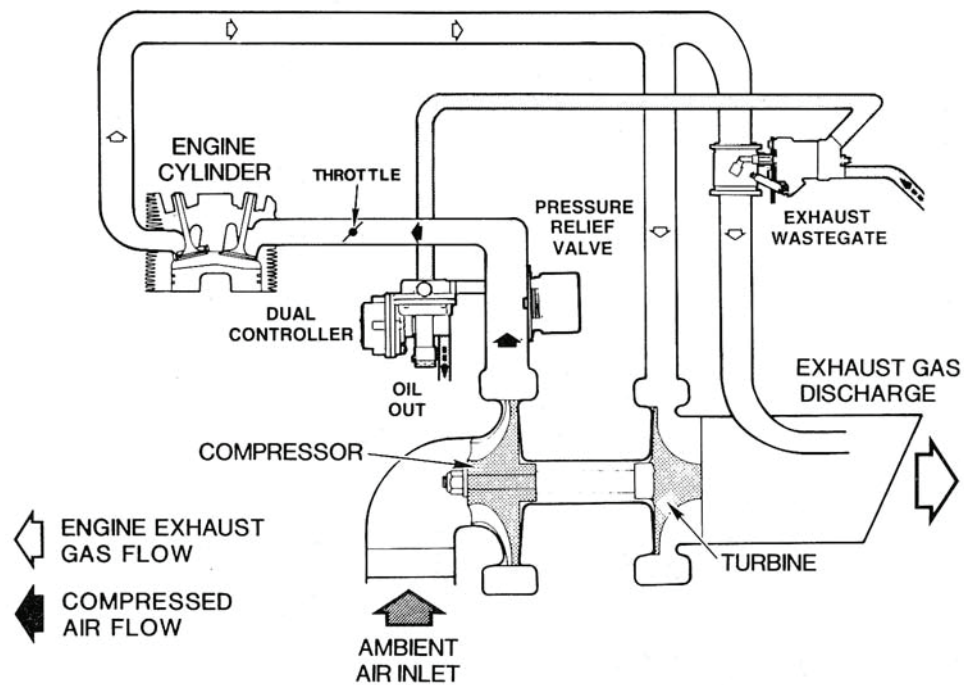
The ratio/absolute dual controller performs the functions of both the pressure ratio controller and the absolute pressure controller. Components serving the separate functions are housed in a common body assembly, with shared pressure sensing and hydraulic ports.

The fixed absolute pressure controller portion of the dual controller hydraulically regulates the wastegate opening for high engine power settings from sea-level to altitude. The controller senses deck pressure, compares it to a reference absolute pressure and adjusts the wastegate butterfly (controlling turbocharger speed) to maintain sea-level horsepower at varying altitudes.

The pressure ratio controller portion of the dual controller is designed to override the fixed absolute pressure controller during high altitude cruising to prevent turbocharger overspeed and lower the part throttle critical point of the engine. The controller senses the deck and ambient pressures and compares them to a referenced absolute pressure. When the ratio of outlet to ambient pressure exceeds a preset proportion, the controller opens the wastegate and lowers turbocharger output.

If fitted, a pressure relief valve, set slightly in excess of maximum deck pressure, is provided to prevent damaging overboost in the event of a system malfunction.

Figure 6 - Dual Absolute / Pressure Ratio Control System Schematic



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DENSITY CONTROL SYSTEM (FIXED WING):

Installation Features:

Piper Aztec
Aerospatiale Trinidad TC
Lake 250 Renegade
Piper PA31 Navajo and Chieftain

Component Operation:

The density controller senses both the temperature and pressure (therefore density) of the compressor discharge. When density of the air reaches a pre-set level, the density controller modulates the wastegate, raising or lowering the compressor output pressure to the proper level for wide-open throttle operation.

The differential controller is designed to keep deck pressure from exceeding manifold pressure by more than a specified amount during part throttle operation. When deck pressure exceeds manifold pressure by more than a pre-determined value, the controller opens the wastegate, reducing turbocharger output.

If fitted, a pressure-relief valve, set slightly in excess of maximum deck pressure, is provided to prevent damaging overboost in the event of a system malfunction.

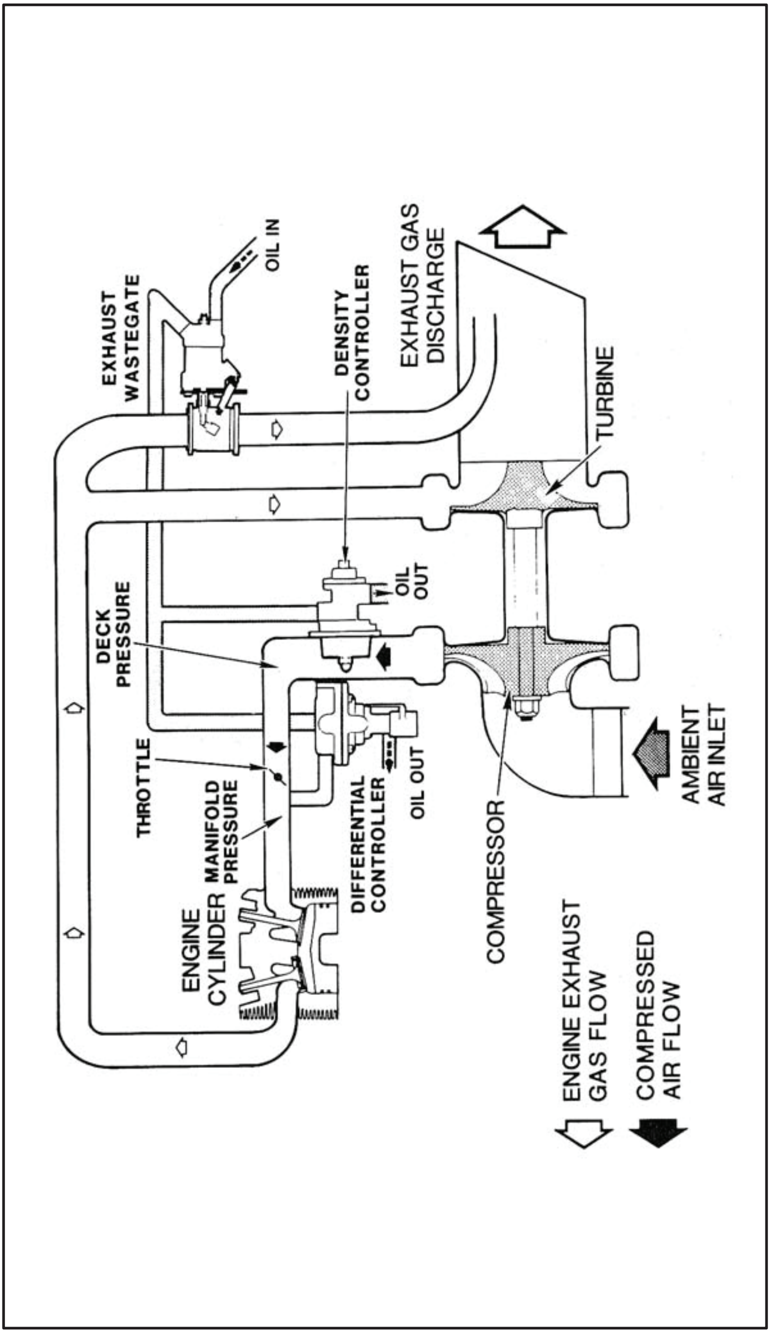

Figure 7 - Density Control System (Fixed Wing) Schematic

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DENSITY CONTROL SYSTEM (ROTARY WING):

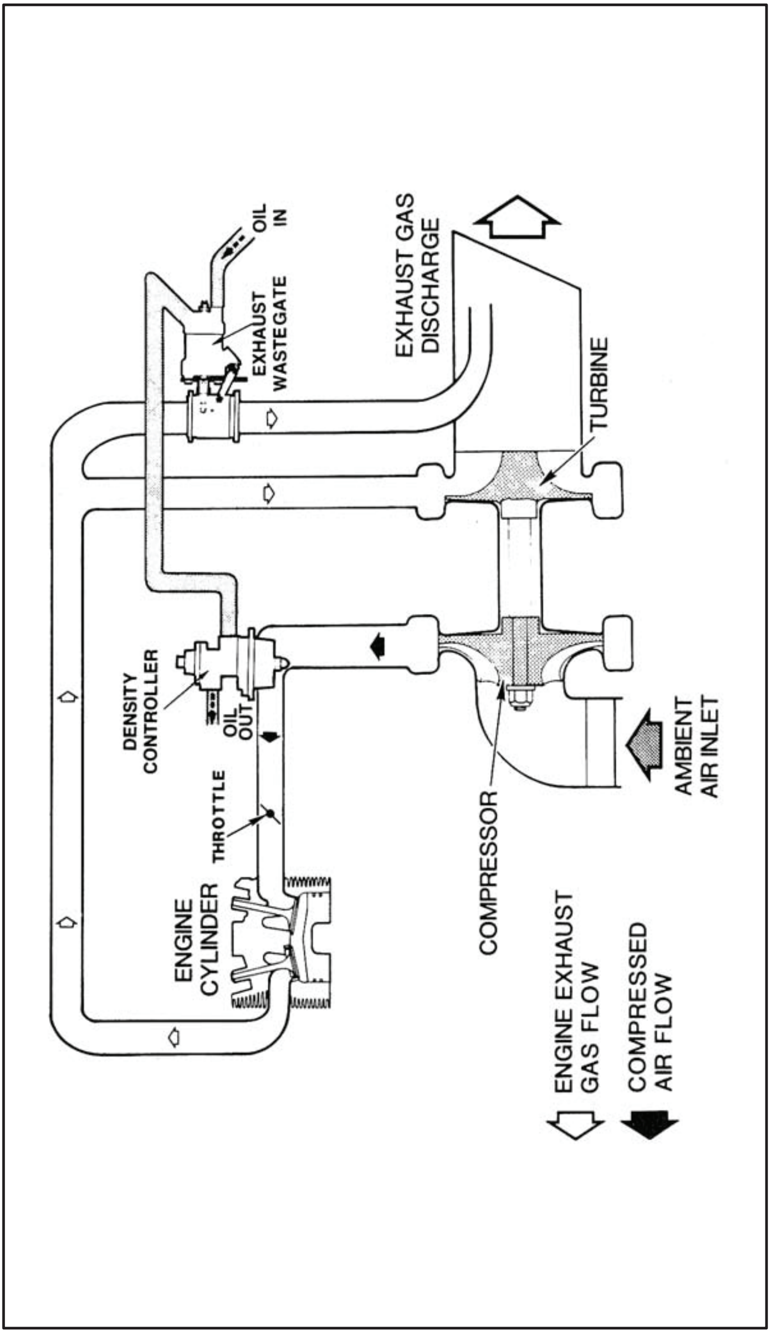
Installation Features:

1961-75 Bell 47G3B Helicopter
Siam Hiller SL-4 Helicopter

Component Operation:

The density controller senses both the temperature and pressure (therefore density) of the compressor discharge. When density of the air reaches a pre-set level, the density controller modulates the wastegate, raising or lowering the compressor output pressure to the proper level for wide-open throttle operation.

Figure 8 - Density Control System (Rotary Wing) Schematic



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VARIABLE ABSOLUTE PRESSURE SYSTEM (SINGLE ENGINE, WITHOUT COVER):

Installation Features:

1967-70 Mooney Mustang

1985-Up Textron Cessna T210R

Textron Cessna P210R

Mooney 252

Component Operation:

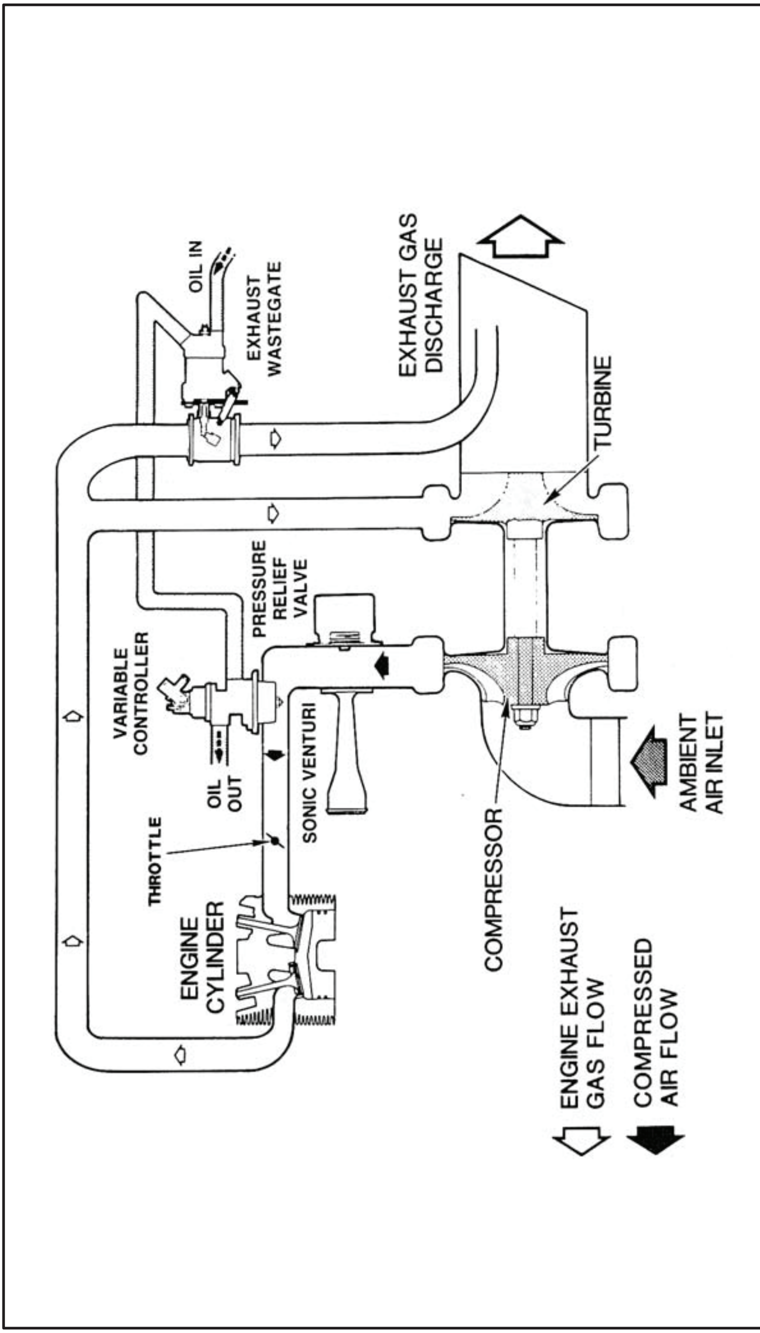
The variable absolute pressure controller (direct-sensing, without cover) works much like the non-variable absolute pressure controller in that it senses deck pressure, compares it to a reference absolute pressure, and adjusts the wastegate butterfly (controlling turbocharger speed) to maintain sea-level horsepower at varying altitudes. It differs from the non-variable version, however, in that it is directly linked to the engine throttle, and through a system of cams and followers, adjusts itself to varying power settings, achieving the optimum deck pressure for a given throttle movement.

A pressure relief valve, set slightly in excess of maximum deck pressure, is provided to prevent damaging overboost in the event of a system malfunction.

A sonic venturi, if installed, is incorporated to provide a constant source of compressed air to the cabin pressurization system. In the Cessna T210R, this air is bled overboard.

An intercooler is incorporated in the Cessna T210R, P210R and Mooney 252 to cool compressor discharge air and increase cylinder charge density.

Figure 9 - Variable Absolute Pressure System (Single Engine, Without Cover) Schematic



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VARIABLE ABSOLUTE PRESSURE SYSTEM (TWIN ENGINE, WITHOUT COVER):

Installation Features:

All Lycoming Engine Systems (Except Piper Mojave)
All Continental Engine Systems (Except Textron Cessna Skymaster)
Textron Cessna Skymaster
Piper Mojave
Rockwell Commander 700

Component Operation:

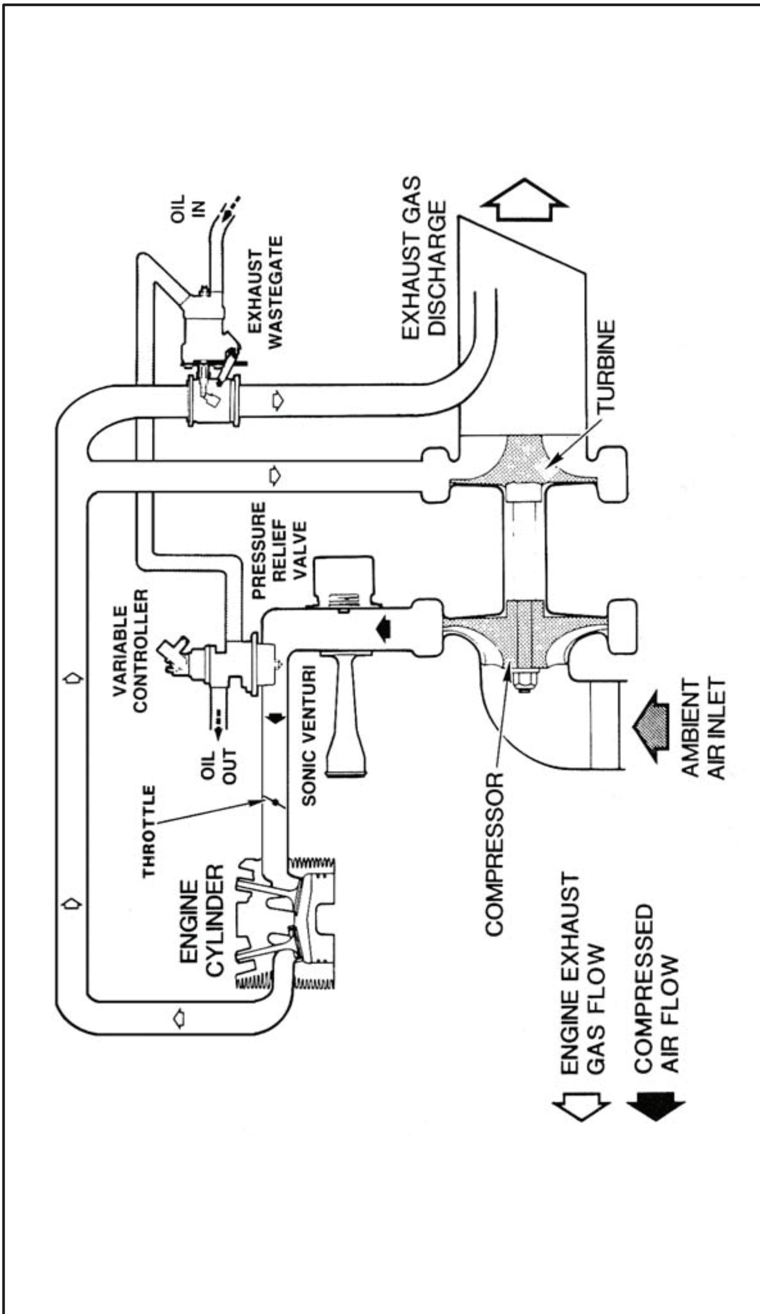
The variable absolute pressure controller (direct-sensing, without cover) works much like the non-variable absolute pressure controller in that it senses deck pressure, compares it to a reference absolute pressure, and adjusts the wastegate butterfly (controlling turbocharger speed) to maintain sea-level horsepower at varying altitudes. It differs from the non-variable version, however, in that it is directly linked to the engine throttle, and through a system of cams and followers, adjusts itself to varying power settings, achieving the optimum deck pressure for a given throttle movement.

A pressure relief valve, set slightly in excess of maximum deck pressure, is provided to prevent damaging overboost in the event of a system malfunction.

A sonic venturi, if installed, is incorporated to provide a constant source of compressed air to the cabin pressurization system.

An intercooler, if fitted, is added to cool the compressor outflow and increase cylinder charge air density.

Figure 10 - Variable Absolute Pressure System (Twin Engine, Without Cover) Schematic



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VARIABLE ABSOLUTE PRESSURE SYSTEM (WITH COVER):

Installation Features:

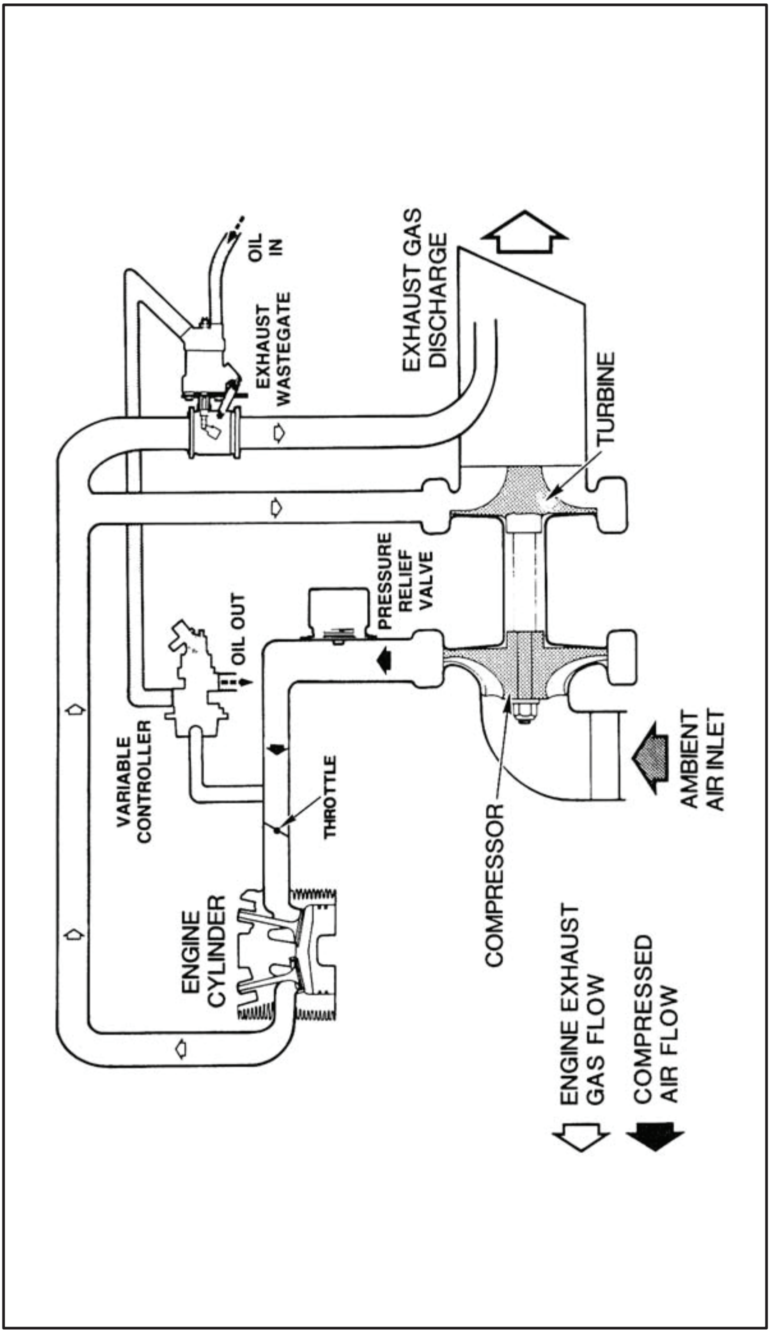
Textron Beechcraft Bonanza
Textron Cessna Skymaster

Component Operation:

The variable absolute pressure controller (remote sensing with cover) works much like the non-variable pressure controller in that it senses deck pressure, compares it to a reference absolute pressure, and adjusts the wastegate butterfly (controlling turbocharger speed) to maintain sea-level horsepower at varying altitudes. It differs from the non-variable version, however, in that it is directly linked to the engine throttle, and through a system of cams and followers, adjusts itself to varying power settings, achieving the optimum deck pressure for a given throttle movement.

A pressure relief valve (when used), set slightly in excess of maximum deck pressure, is provided to prevent damaging overboost in the event of a system malfunction.

Figure 11 - Variable Absolute Pressure System (With Cover) Schematic



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VARIABLE ABSOLUTE CONTROL SYSTEM WITH RATE CONTROL:

Installation Features:

Textron Cessna 337

Component Operation:

The variable absolute pressure controller (direct sensing, without cover) works much like the non-variable absolute pressure controller in that it senses deck pressure, compares it to a reference absolute pressure, and adjusts the wastegate butterfly (controlling turbocharger speed) to maintain sea-level horsepower at varying altitudes. It differs from the non-variable version, however, in that it is directly linked to the engine throttle, and through a system of cams and followers, adjusts itself to varying power settings, achieving the optimum deck pressure for a given throttle movement.

The rate controller senses deck pressure and acts to prevent excessive increase in the turbocharger discharge air pressure. Thus, when a too-rapid throttle advance causes an extreme rate of change in deck pressure, the controller overrides the fixed absolute pressure controller and opens the wastegate butterfly and slows the compressor, lowering deck pressure and preventing overboost.

A pressure relief valve, set slightly in excess of maximum deck pressure, is provided to prevent damaging overboost in the event of a system malfunction.

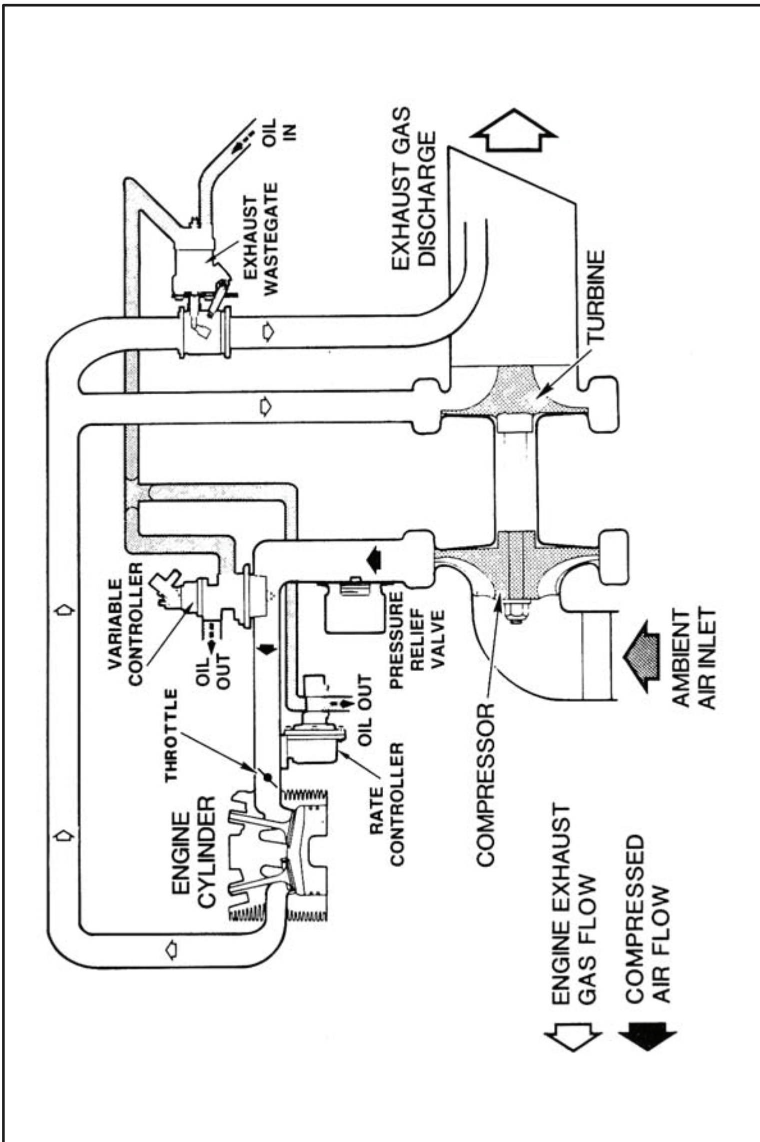

Figure 12 - Variable Absolute Pressure System with Rate Control Schematic

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VARIABLE ABSOLUTE PRESSURE SYSTEM WITH POPPET-TYPE WASTEGATE:

Installation Features:

1976-Up Textron Beechcraft Baron
Rockwell Commander 685

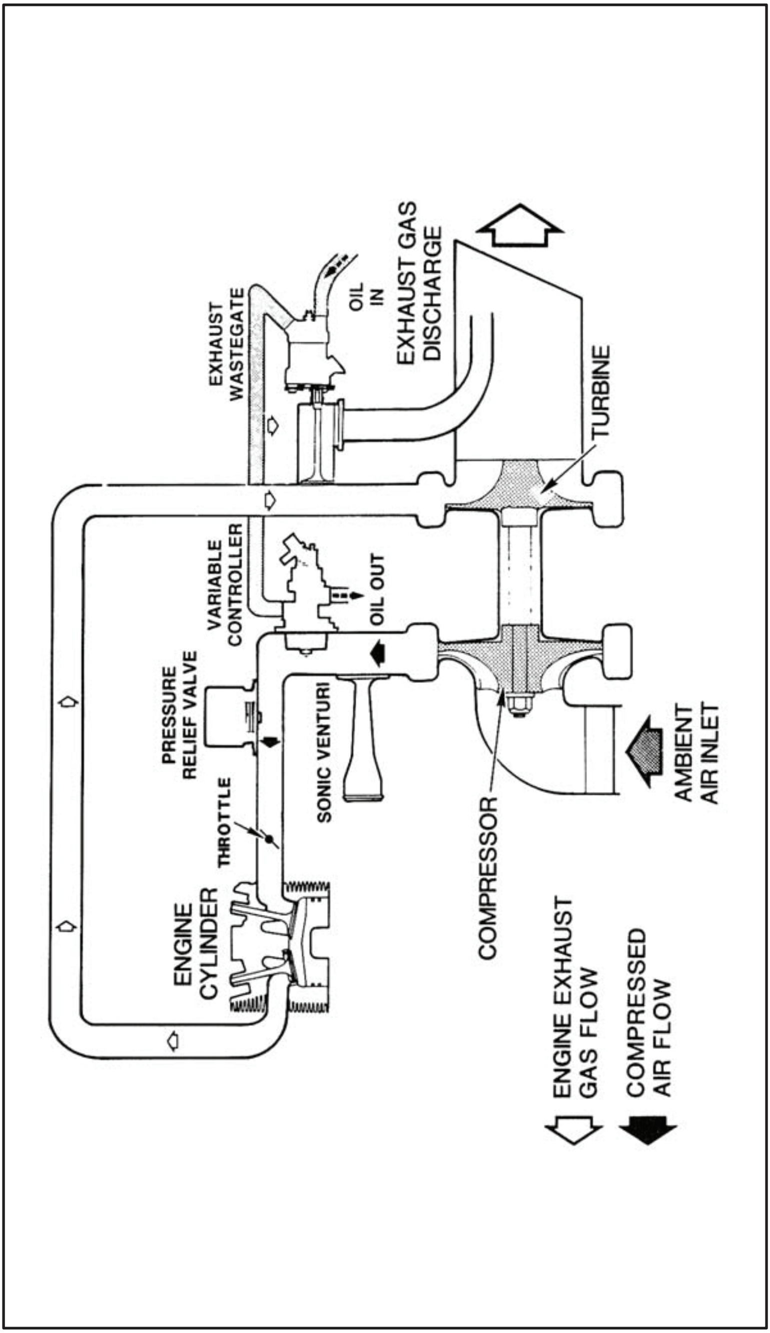
Component Operation:

The variable absolute pressure controller (direct sensing, without cover) works much like the non-variable pressure controller in that it senses deck pressure, compares it to a reference absolute pressure, and adjusts the wastegate butterfly (controlling turbocharger speed) to maintain sea-level horsepower at varying altitudes. It differs from the non-variable version, however, in that it is directly linked to the engine throttle, and through a system of cams and followers, adjusts itself to varying power settings, achieving the optimum deck pressure for a given throttle movement.

A pressure relief valve, set slightly in excess of maximum deck pressure, is provided to prevent damaging overboost in the event of a system malfunction.

A sonic venturi, if fitted, is incorporated to provide a constant source of compressed air to the cabin pressurization system.

Figure 13 - Variable Absolute Pressure System with Poppet-Type Wastegate Schematic



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SLOPED CONTROL SYSTEM:

Installation Features:

Textron Cessna T182T, T206, T303 and 1982-'84
Textron Cessna P210 Lancair IV & IVP
Piper Malibu & Malibu Conversion
Piper Saratoga TC
Cirrus Design SR22T
Cirrus Design SR22 with TAT Conversion

Component Operation:

The sloped controller is designed to maintain the rated deck pressure at wide open throttle, and to maintain a reduced deck pressure at part-throttle settings. The controller senses both deck and manifold pressure and monitors the differential between them. If either the deck pressure or differential pressure rises above predetermined values for a given throttle setting, the controller opens the exhaust bypass valve, thus lowering compressor speed and output.

A pressure relief valve, set slightly in excess of maximum deck pressure, is installed to prevent damaging overboost in the event of a system malfunction.

A sonic venturi, if installed, is incorporated to provide a constant source of compressed air to the cabin pressurization system.

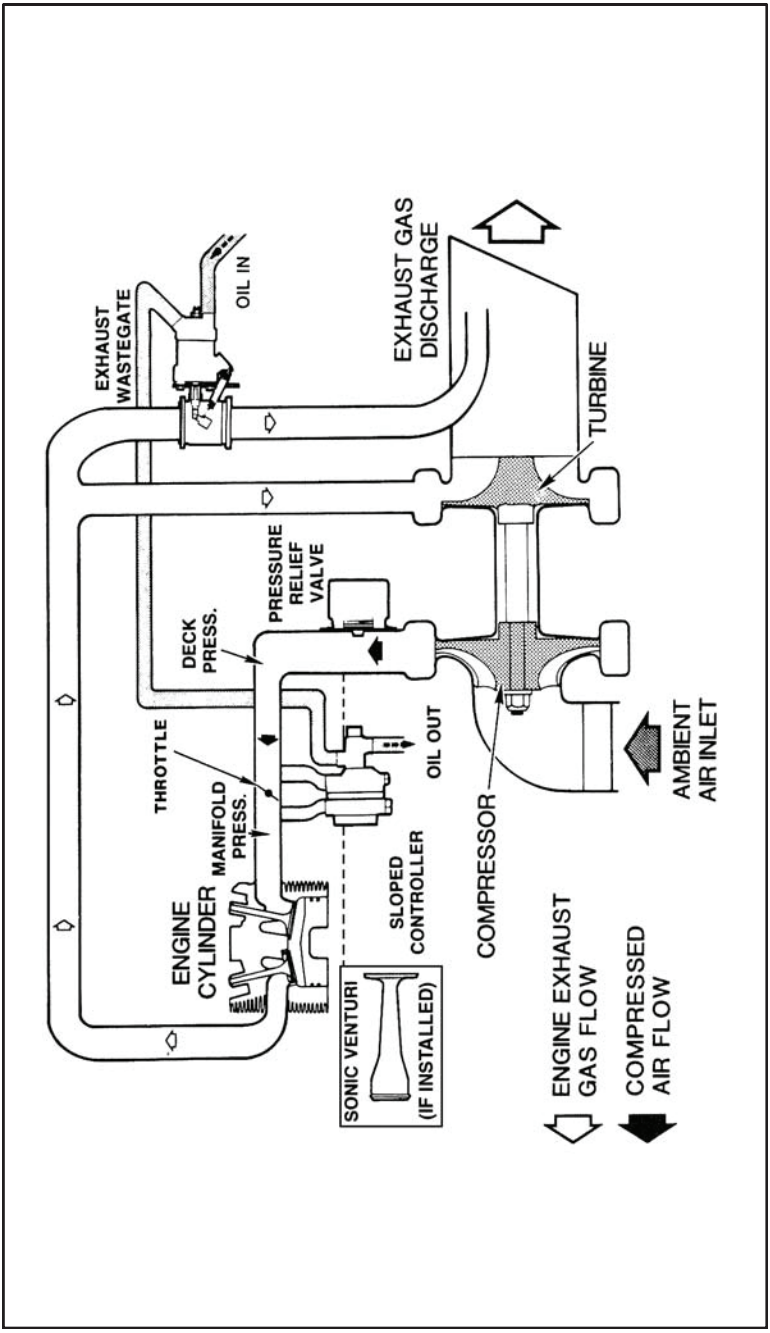

Figure 14 - Sloped Control System Schematic

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PRESSURE RELIEF VALVE CONTROL SYSTEM:

Installation Features:

Enstrom
Mooney 231
Piper Arrow, Dakota and Seneca
Textron Cessna Ag Husky
Alexander Aircraft (Bellanca)

Component Operation:

Continuous management of throttle required to maintain manifold pressure during climb and descent.

Pressure relief valve, set slightly in excess of maximum manifold pressure, is provided to prevent damaging overboost in event of pilot error.

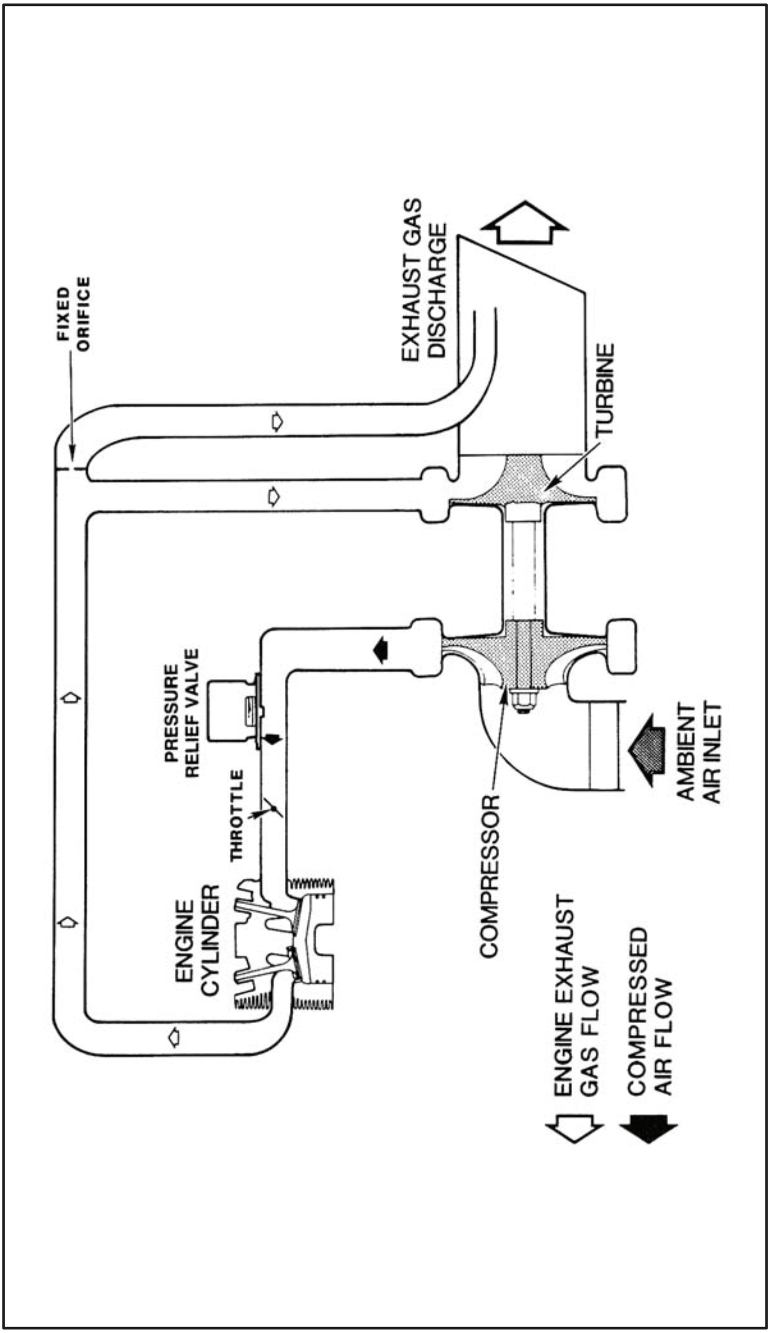

Figure 15 - Pressure Relief Valve Control System Schematic

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MANUAL WASTEGATE CONTROL SYSTEM WITH PRESSURE RELIEF VALVE:

Installation Features:

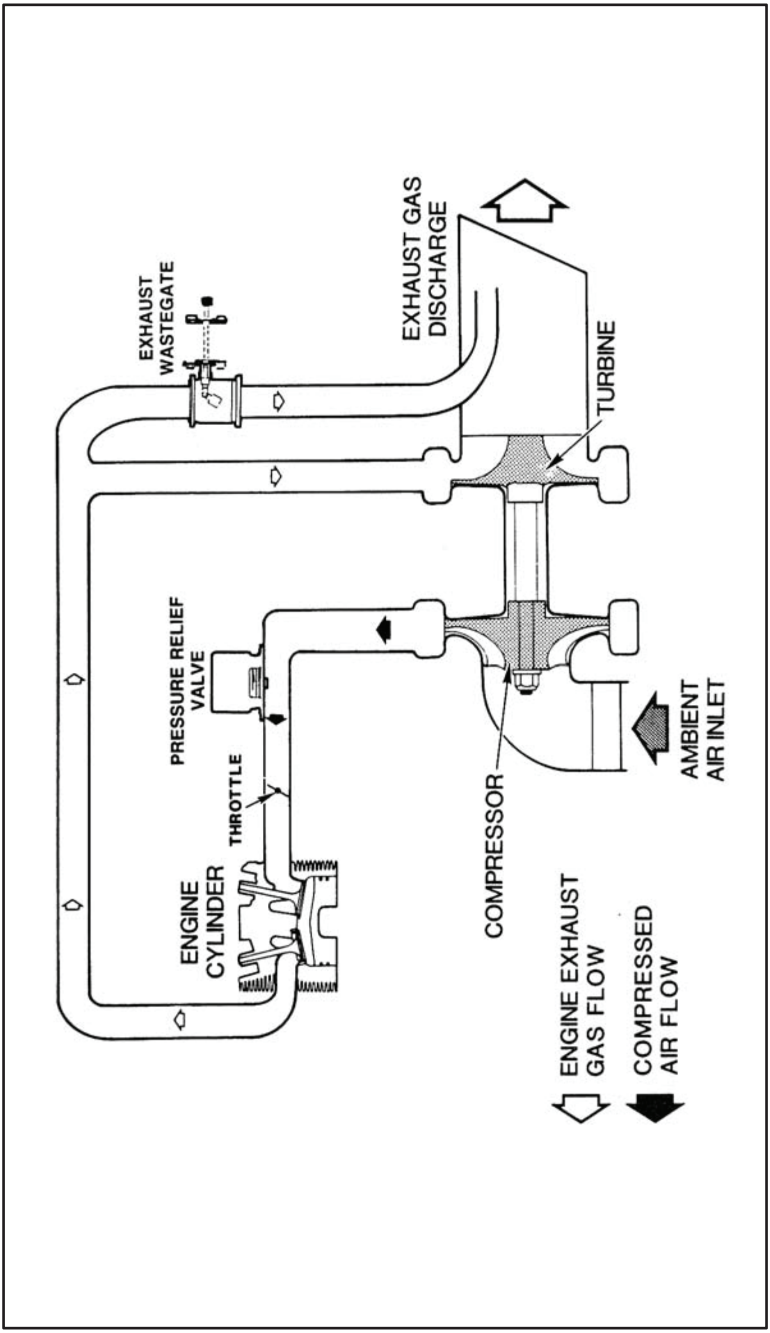
Textron Cessna Turbo Skylane
Piper Lance and Saratoga

Component Operation:

In this installation, the wastegate is directly and/or proportionally linked to the throttle. It requires continued throttle management to maintain the desired manifold pressure during climb and descent.

A pressure relief valve, set slightly in excess of maximum manifold pressure, is installed to prevent damaging overboost in the event of system malfunction.

Figure 16 - Manual Wastegate Control System with Pressure Relief Valve Schematic



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Introduction to Troubleshooting 3

Too often, in the event of malfunction of a turbocharged engine, the turbocharger is immediately assumed to be at fault, and is replaced. At times, the replacement unit soon fails, prompting an investigation into the real cause of the initial failure. Such a sequence of events is both frustrating and expensive.

Hartzell Engine Techs' (HET) stringent quality controls make it unlikely that a turbocharger leaves the factory incorrectly assembled or not up to specifications. A "faulty" turbocharger would operate badly almost from the moment of installation. But a turbocharger which has operated successfully for a period of time and then fails, almost invariably fails due to a deficiency in the operation of the associated engine systems. Years of actual experience with service failures demonstrate the major cause of turbocharger failures to be faulty lubrication systems. Abnormal wear in the bearings or seals results from abrasives in the oil, or an insufficient supply of oil. Other systems, such as fuel and ignition, can also play a part in causing engine performance issues in which turbocharger system malfunction is originally suspected.

The overall objective of troubleshooting is to find the root cause of trouble and take corrective action to prevent a recurrence.

To enable effective repairs, this objective must be kept in mind while determining if anything is actually wrong with the turbocharger system components. Even perfectly operational turbocharger system components cannot compensate for incorrect engine operating procedures, deficiencies in the engine oil supply, oil drain, ignition, air induction, fuel, exhaust systems or for damaged engine internal components.

CAUTION: Turbochargers operate at high speed and high temperatures. Caution should be used at all times when operating turbochargers to avoid injury and damage by keeping fingers and foreign objects away from openings and avoiding contact with its hot surfaces and other hot connecting parts.

TROUBLESHOOTING PROCEDURES:

An important rule of turbocharger system troubleshooting is to find the root cause of engine malfunctions before removing or disassembling the turbocharger system components: i.e., to leave all turbocharger system components intact. For instance, if there are loose connections affecting system output, this can only be discovered if the connections are checked for looseness or leakage before they are removed.

SEQUENCE OF OPERATIONS:

The sequence of operations for troubleshooting, prescribed in this manual, can be summarized as follows:

a. List the engine symptom which seems to be related to turbocharger-supplied air and if applicable, the specific flight conditions in which the issue occurs; such as altitude, engine rpm, manifold pressure, and fuel flow.

b. Carry out the systematic “Pre-Troubleshooting Inspection” below which may correct the issue without further troubleshooting.

c. If the trouble persists, consult the text and/or the troubleshooting chart for the specific engine trouble, narrow down the possible causes and apply the specified remedy or remedies.

d. If the “remedy” of the chart in step "c" above is to consult the troubleshooting chart for a specific turbocharger system component condition, proceed to that chart and continue to trace the cause(s) and apply the remedy or remedies. For instance, troubleshooting the “Manifold Pressure Low” trouble may eliminate other possible causes except “Turbocharger Output Low or Operates Sluggishly.” Following the troubleshooting procedure for this trouble may acquit the turbocharger itself of any deficiency but lead to the conclusion that the “Exhaust Bypass Valve Fails to Close or Operates Sluggishly,” and lead the troubleshooting mechanic to the troubleshooting chart for that component malfunction. The troubleshooting chart for bypass valve failure to close may lead to the discovery of a clogged inlet port orifice or it may conclude that the command to close never reaches the bypass valve from the controller. In this hypothetical case, the

"Controller Fails to Close Oil Flow" troubleshooting chart may help discover a leak in a sensing line to the controller or foreign particles in the oil in the controller, holding open an internal poppet valve. Simple flushing of the controller may be the only remedy required except for finding the source of the foreign particles.

LISTING ENGINE TROUBLES:

The following is a list of engine troubles or symptoms of malfunctions, related to the supplying of air to the engine by the turbocharger. For each symptom there is a troubleshooting chart and a written troubleshooting procedure. For example:

a. Manifold pressure low or fluctuating or the aircraft cannot reach critical altitude.

b. Oil leakage into engine intake air or exhaust.

c. Engine overboost.

d. Cabin loses pressure at altitude and partial power.

PRE-TROUBLESHOOTING INSPECTION:

The pre-troubleshooting inspection described below, and summarized in Table 17, constitutes a thorough visual inspection capable of detecting and eliminating many possible causes of performance issues. Examine each disconnected, removed or replacement part prior to reinstallation for cleanliness and to prevent the entry of damaging foreign matter into the system.

NOTE: Consult engine manufacturer maintenance publications for procedures which use an outside source of air pressure and soap solution to detect leaks in the air induction system and exhaust system.

a. With the engine shut down, externally inspect all components of the air induction system for loose connections, cuts, cracks, punctures and corrosion or other evidence of deterioration that could permit air leakage and the ingestion of damaging foreign matter. The components include the engine air cleaner, ducting and alternate air valve from the air cleaner to the turbocharger compressor inlet, ducting from the compressor outlet to the engine intake manifold, and the intake manifold. Tighten loose connections and repair or replace parts, as needed, per engine manufacturer maintenance publications.

b. Inspect the air cleaner for a clogged element and service per manufacturer instructions.

c. Check the engine crankcase breather for restrictions to air flow and remove any restriction.

d. Inspect the exhaust system for leakage, especially at the exhaust manifold connection to the turbocharger turbine inlet and at the engine exhaust manifold gasket. Tighten connections as needed, and replace damaged components in accordance with the engine manufacturer maintenance publications.

Table 2 - Summary of Pre-Troubleshooting Inspection

System / Location:	Problem to be Found & Corrected:
Air induction system	Air leaks, loose connections, damage, deterioration.
Engine air cleaner	Clogging.
Crankcase breather	Restriction.
Exhaust system	Leaks, especially at exhaust manifold connections to turbocharger and to engine (gasket).
Turbocharger oil	Oil leaks, loose connections, bad gaskets, fittings, check valves.
Bypass valve and controller oil lines, sensing lines, and their brackets	Leaks, vibrations.
Bypass valve actuator	Oil leakage due to twisted or damaged piston packing due to cylinder scoring or dirt.
Controller	a. Oil leakage past seal of internal poppet. b. Air leaks at any place in signal lines. c. Oil pressure variations.
Exterior of bypass valve or controller	Accumulated debris on cooling fins of poppet-type bypass valve, or on linkage of butterfly-type, or on any external controller linkage.
Turbocharger	With engine running, shrill whine above normal whine - shut engine down and check turbocharger bearing clearance.
Compressor wheel or turbine wheel	Indication of seal leakage, wheel damage or rubbing, binding or dragging. (For any of these defects, check turbocharger bearing clearance and troubleshoot as applicable. For foreign object damage, also clean and repair air system or exhaust system.)

NOTE: Exhaust gas leakage may be indicated by streaks of exhaust deposits at joints, and by heat damage or scorching of the nacelle.

e. Check for oil leakage at the connections to the turbocharger oil inlet and drain ports and tighten connections or replace gaskets, fittings, etc., as needed. Inspect for faulty check valves which can allow oil to drain into the turbocharger center housing after shutdown, leading to turbocharger seal leakage.

f. Check the oil supply and drain lines to and from the exhaust bypass valve and controller(s) and any air pressure sensing lines for leakage or vibration. Tighten connections and mounting bracket attachments as needed. Also look for line damage which might cause restriction, and repair or replace as needed.

g. Check the oil drain line from the actuator drain port of the exhaust bypass valve for more than slight leakage. Temporarily disconnect the line if necessary. If there is more than residual oil, the actuator should be disassembled and checked for cylinder wall scoring. If there is no scoring, replace the actuator piston packing in accordance with the manufacturer's instructions for the specific valve. If there is scoring, overhaul or replace the exhaust bypass valve.

h. Check for oil leakage from the controller(s) past the seal of the controller internal poppet. Significant leakage is cause for overhaul or replacement of a controller. Such leakage may be detected at a compressor outlet sensing line to the controller, at a low-pressure sensing port or for a duct-mounted controller without a cover, by removing the controller and inspecting the bellows area.

i. If the turbocharger system includes an absolute pressure relief valve, use a non-caustic cleaning solvent and compressed air to remove any accumulation of debris which may tend to restrict bellows or valve motion. Check the bolts and o-ring on the mounting flange and tighten or replace as needed.

ii. Use an industry standard, non-caustic cleaning solvent and compressed air to remove any accumulated debris from the cooling fins of a poppet-type exhaust bypass valve or from the linkage of a butterfly-type exhaust bypass valve. Clean the debris from any controller external linkage, without solvent, to avoid loss of lubricant from self-lubricating bearings.

WARNING: Operation of the turbocharger without all normally installed inlet ducts and filters connected can result in injury to personnel and damage to equipment from foreign objects entering the turbocharger.

CAUTION: Operation of the engine at any speed faster than idle immediately after start-up can result in "oil lag" failure of turbocharger bearings, especially in cold weather or after a prolonged inoperative periods of time.

k. If feasible, operate the engine at a low partial-power setting and listen for unusual turbocharger noises. If a shrill whine is heard above the normal turbine whine, indicating imminent turbocharger bearing failure, shut down immediately. For such a turbocharger, perform the "Bearing Clearance Inspection" found in Chapter 2 of the latest revision of the HET Aircraft Turbocharger Overhaul Manual P/N 400600-0000. If the turbocharger fails to pass this inspection, determine the cause of wear by performing the troubleshooting procedure for the condition, "Turbocharger Shaft Bearings, Journals or Bearing Bores Worn". Overhaul or replace the turbocharger.

l. Remove the air duct from the turbocharger compressor inlet and inspect the compressor wheel and compressor housing for damage to wheel blades indicating rubbing on the compressor housing, erosion by ingestion of dirt and sand or impact with foreign objects. Also look for a heavy buildup of oil and dirt, indicating seal leakage. Remove any foreign matter. Grasping the shaft ends, rotate the wheel by hand while pressing the rotating assembly toward the turbine end of the turbocharger. Rock the shaft up and down. There should be no binding, rubbing or other interference with free rotation. If none of the above defects is found, securely reconnect the air duct to the compressor inlet.

m. Disconnect the exhaust ducting from the turbine outlet and examine the turbine wheel blades for damage. Grasping the shaft end, rotate the wheel by hand while pressing the rotating assembly toward the compressor end of the turbocharger while rocking the shaft up and down. Look for oil around the turbine wheel and its housing indicative of seal leakage. Check for evidence of the wheel rubbing on the housing. Remove any foreign matter. If none of the above defects is found, securely reconnect the exhaust duct to the turbine outlet.

n. If any listed conditions were found in steps (l) and (m) above, see the troubleshooting procedures for the conditions of "Turbocharger Seal Leakage at Compressor End," or "Turbocharger Seal Leakage at Turbine End," or "Turbocharger Rotating Assembly Binding or Dragging." Also perform the "Bearing Clearance Inspection" found in Chapter 2 of the latest revision of the HET Aircraft Turbocharger Overhaul Manual P/N 400600-0000. If the bearings do not pass this inspection, determine the cause of wear by performing the troubleshooting procedure "Turbocharger Shaft Bearings, Journals or Bearing Bores Worn," as described below. Overhaul or replace the turbocharger.

o. If the compressor wheel or turbine wheel has suffered foreign object damage, clean or repair the air induction system or engine exhaust system as needed before installing a replacement or overhauled turbocharger.

p. If there was turbocharger seal leakage, troubleshoot the condition "Turbocharger Seal Leakage at Compressor End," or "Turbocharger Seal Leakage at Turbine End," as applicable.

TROUBLESHOOTING ENGINE SYMPTOMS:

Each of the engine troubles named under “Listing Engine Troubles” above has a troubleshooting chart to match, and is further explained below. Neither the text nor the charts should be regarded as covering every possible cause. Rather, this information is primarily representative of the approach to be employed in troubleshooting a turbocharged engine malfunction. Those troubleshooting operations which can be performed most quickly and easily should be accomplish first. Removal or disassembly should be postponed until all in-place inspections have been performed. Table 18 is a summary of troubleshooting procedure notes which are referred to in the troubleshooting charts as supplementary information.

Table 3 - Troubleshooting Procedure Notes

A. A new turbocharger may smoke for a short period of perhaps 30 minutes, until factory oil coatings are consumed.

B. Check for oil leakage past the seal of the controller internal poppet at a compressor outlet air sensing line to the controller, other air- sensing lines or ports or, for a duct-mounted controller without a cover, by removing the controller and inspecting the bellows area.

C. Examine engine operating and maintenance procedures to detect departures from accepted practices and standards. Review the applicable portions of the airframe/engine manufacturer maintenance publications, AFM/POH and the latest revision of KAPS SB 023 "Turbocharger System Operational Tests".

D. Inspect the interior of the turbocharger center housing by removing the oil drain and looking in through the oil drain opening. When a soft contamination (sludge) or hard contamination (coking, rust) condition exists, these contaminants build up heavily on the shaft between the bearing journals, on the walls of the housing from the oil drain opening back to the turbine end and on the turbine-end piston ring seal.

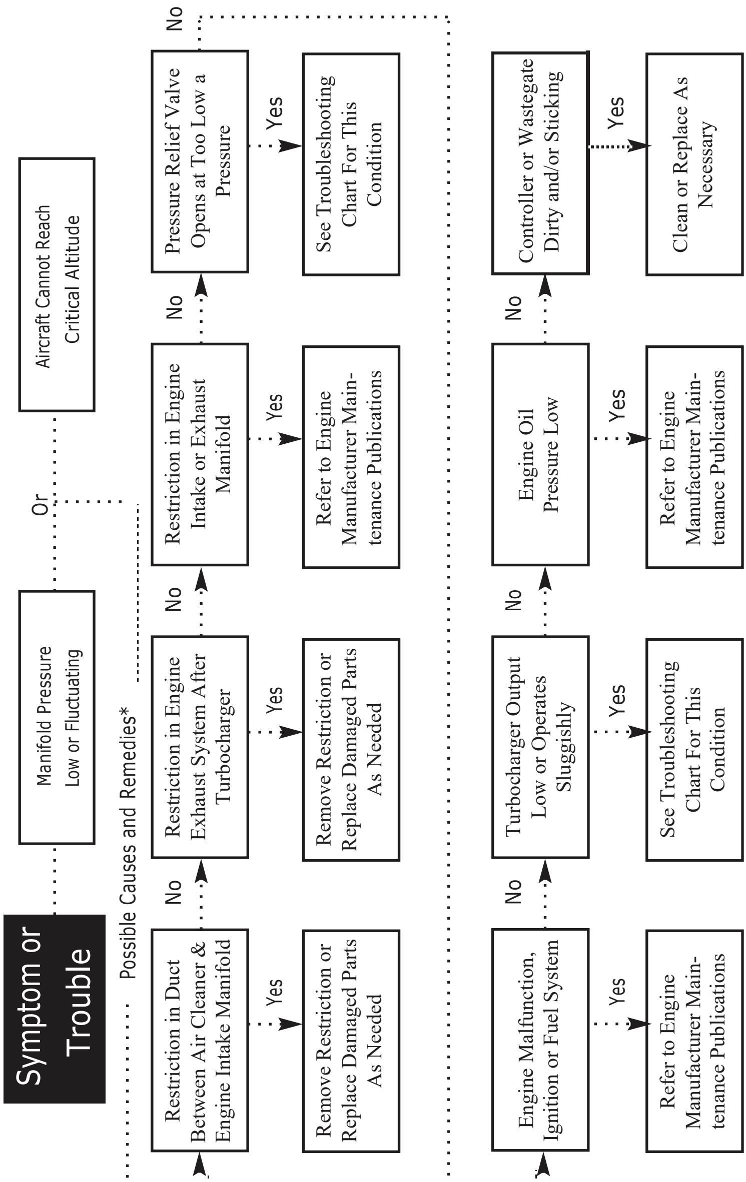
E. Detect abnormal wear in the turbocharger shaft bearings, journals, or bearing bores by performing the "Bearing Clearance Inspection" found in Chapter 2 of the latest revision of the HET Aircraft Turbocharger Overhaul Manual P/N 400600-0000.

F. With the air inlet and exhaust outlet ducting separated from the turbocharger, look for blade damage to the compressor wheel or turbine wheel. Examine the outer blade tip edges for evidence of rubbing on adjacent housing surfaces. Use a light to see the turbine wheel blade tips from the housing outlet. Exerting uniform pressure on each wheel, rotate the wheels by hand while pressing the rotating assembly axially toward each end and radially up and down. There should be no binding, rubbing, or other interference with free rotation.

G. Thoroughly clean and inspect the air induction and intake system following compressor wheel damage by foreign object impact. If wheel pieces are missing, boroscope the engine cylinders. Verify no residual FOD can be drawn into the replacement turbocharger or engine.

H. Whenever oil contamination is indicated or suspected, Hartzell Engine Tech recommends a thorough flushing of the oil system per the engine manufacturer's maintenance publications.

Figure 17 - Troubleshooting - Manifold Pressure Low or Fluctuating or Aircraft Cannot Reach Critical Altitude



* Chart assumes that “Pre-Troubleshooting Inspection” has been performed as summarized in Table 17.

Manifold Pressure Low or Fluctuating or Aircraft Cannot Reach Critical Altitude (See Figure 17):

Any of the symptoms listed here can indicate that not enough compressed air is consistently reaching the engine from the turbocharger to maintain required manifold pressure. Some of the possible causes and remedies are as follows:

a. Loose connections or other leakage in the exhaust system would reduce the energy available to drive the turbine which turns the compressor wheel. Leakage in the air induction system downstream of the compressor would reduce the mass of air actually getting to the combustion chamber. Either of these types of leakage should have been detected in carrying out the "Pre-Troubleshooting Inspection" procedure.

b. Restrictions in the air ducting or in the exhaust system, either upstream or downstream of the turbocharger, would affect the compression and flow of air to the engine. The "Pre-Troubleshooting Inspection" procedure includes a check of the air cleaner for restriction. As the troubleshooting chart indicates, the air ducts between the air cleaner and the compressor and between the compressor and the engine intake manifold as well as the exhaust system downstream of the turbocharger must be examined for restrictions. Remove any restrictions and repair or replace damaged parts as needed. Correct any restrictions in the engine intake or exhaust manifold per the engine manufacturer maintenance publications.

c. Manifold pressure will not reach required levels if the system includes a pressure relief valve which opens at too low a pressure. See the troubleshooting procedure for this condition.

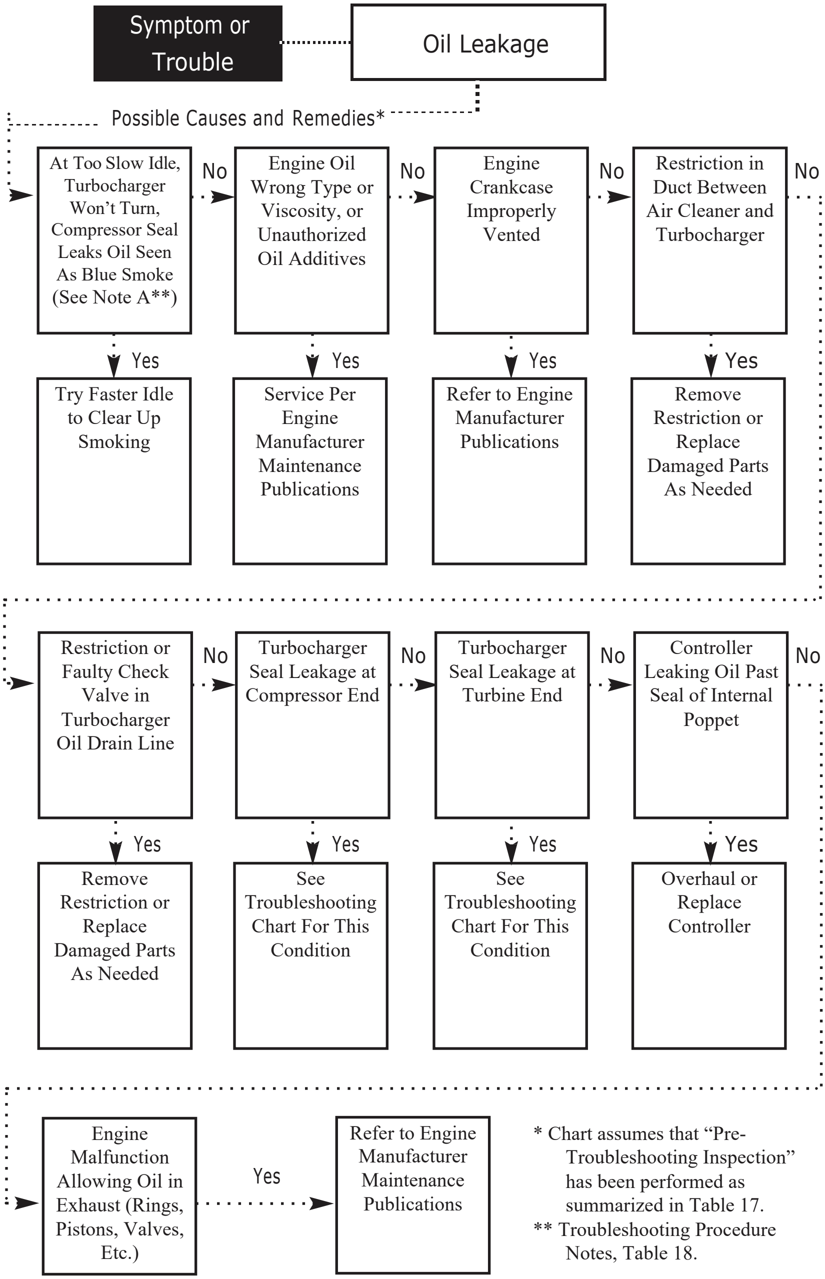
d. Malfunctions in the engine ignition or fuel system can also affect the efficiency of the air-fuel combustion. Correct them per the engine manufacturer maintenance publication.

e. If the troubleshooting procedure eliminates the other possible causes, it may be that the turbocharger is not supplying a sufficient mass of air for some reason other than from the causes already eliminated. See the troubleshooting procedure for "Turbocharger Output Low or Operates Sluggishly" which examines causes which include possible issues in the turbocharger system as well as other sources of trouble.

Oil Leakage (See Figure 18):

The Turbocharger system may be a possible source of oil leaks because it is part of and connected to the engine lubricating system. Oil lubricates and cools the turbocharger directly and provides for actuation and control of the exhaust bypass valve and controller(s). "Pre-Troubleshooting Inspection" includes checks for oil leakage at oil supply and drain line connections, a clogged air cleaner, loose connections on the duct from the compressor to the intake manifold and leakage at the intake manifold.

Figure 18 - Troubleshooting - Oil Leakage



* Chart assumes that "Pre-Troubleshooting Inspection" has been performed as summarized in Table 17.

** Troubleshooting Procedure Notes, Table 18.

This helps eliminate several possible issues which can contribute to oil leakage from turbocharger system components. Some other possible causes and remedies are as follows:

a. If the engine idles too slowly, the turbocharger may not turn, allowing oil to leak past the compressor seal during low MP pressure at idle and appear as blue smoke in the exhaust. Increase idle speed slightly to stop smoking. A new turbocharger may smoke for perhaps 30 minutes until factory oil coatings are consumed.

b. If the wrong type or viscosity of oil or unauthorized oil additives are being used in the engine lubrication system, service the system per the engine manufacturer maintenance publications.

c. If the engine crankcase is improperly vented, correct per engine manufacturer maintenance publications.

d. The “Pre-Troubleshooting Inspection” procedure checks for air cleaner restriction which can cause oil to be drawn past the turbocharger seal at the compressor end. Remove any restriction in the duct between the air cleaner and the turbocharger and replace damaged parts as needed.

e. Restrictions in oil drainage may raise the oil level in the turbocharger center housing and cause seal leakage. As the troubleshooting chart suggests, check for a restriction or a faulty check valve in the turbocharger oil drain line. Remove such restrictions or replace damaged parts as needed.

f. If there is turbocharger seal leakage at either the turbine end or compressor end even after other possible causes mentioned in steps a, b, and c have been eliminated, see the troubleshooting chart for the seal leakage condition.

g. If a controller is discovered to be constantly leaking oil past the seal of the internal poppet, overhaul or replace the controller. Detect such leakage at a compressor outlet sensing line to the controller, at a low-pressure sensing port or, for a duct-mounted controller without a cover, by removing the controller and inspecting the bellows area.

h. Oil in the exhaust system upstream of the turbocharger indicates an engine malfunction such as problems with rings, pistons, or valves. Correct these conditions per the engine manufacturer maintenance publications.

Engine Overboost (See Figure 19):

Overboost or excessive manifold pressure can result if the control system malfunctions and continues until the pilot takes corrective action or the malfunction is overcome.

WARNING: If the engine is known to have experienced an overboost condition, consult engine manufacturer's instructions for inspection(s) required before engine may be operated again.

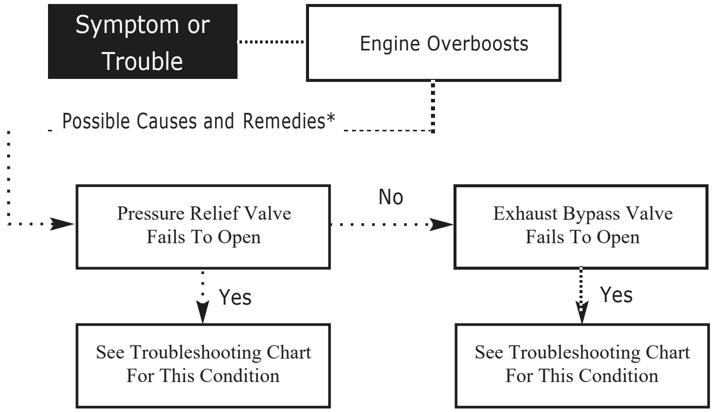
a. Some engines include a pressure relief valve in the turbocharger system, preset to crack open when compressor discharge pressure reaches a value slightly above the rated manifold pressure. If this relief valve fails to open, overboost can occur. See the troubleshooting chart for “Pressure Relief Valve Fails to Open.”

b. In some systems, a safeguard against overboost is the rate controller or the rate section of a rate/absolute dual controller, which opens the exhaust bypass valve when there is an excessive rate of increase in compressor discharge pressure as during a too-rapid throttle advance. If the exhaust bypass valve has failed to open, the troubleshooting chart “Exhaust Bypass Valve Fails to Open” may possibly point the way to a malfunctioning rate controller.

Cabin Loses Pressure at Altitude and Partial Power (See Figure 20):

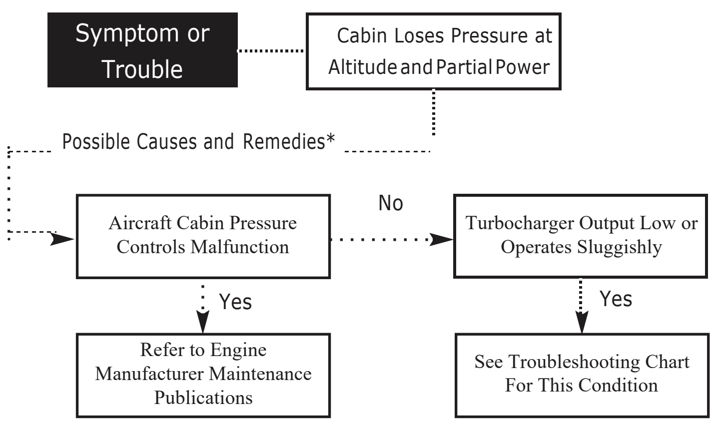
If the aircraft cabin loses pressure at altitude but manifold pressure is adequate, then the aircraft controls for cabin pressure may have malfunctioned and may require repair per the manufacturer’s instructions. Insufficient cabin pressure at partial power, however, can indicate that the turbocharger may not be supplying air at sufficient pressure for the cabin pressure system. The troubleshooting chart “Turbocharger Output Low or Operates Sluggishly” helps to pinpoint possible causes and remedies for this condition. One such cause may be an exhaust bypass valve which fails to close properly because its controller is out of adjustment.

Figure 19 - Troubleshooting - Engine Overboost



* Chart assumes that "Pre-Troubleshooting Inspection" has been performed as summarized in Table 17.

Figure 20 - Troubleshooting - Cabin Loses Pressure at Altitude and Partial Power



* Chart assumes that "Pre-Troubleshooting Inspection" has been performed as summarized in Table 17.

TROUBLESHOOTING TURBOCHARGER SYMPTOMS:

Turbocharger Output Low or Operates Sluggishly (See Figure 21):

The condition of "Turbocharger Output Low or Operates Sluggishly" is listed as a possible cause in two engine troubleshooting procedures, each of which includes "Pre-Troubleshooting Inspections" so that a number of possible causes of turbocharger insufficiency may be investigated and eliminated. These causes include: loose connections or other leaks in the air induction or engine exhaust systems; restriction in the air cleaner; observable damage to, or foreign material lodged in, the compressor wheel or turbine wheel; and discernible binding or dragging of the turbocharger rotating assembly. Other possible causes and remedies are as follows:

a. Turbocharger output may be low because the exhaust bypass valve fails to close and instead allows too much of the exhaust gas to bypass the turbine. Early detection of this condition and troubleshooting under "Exhaust Bypass Valve Fails to Close or Operates Sluggishly" can save much troubleshooting time and effort.

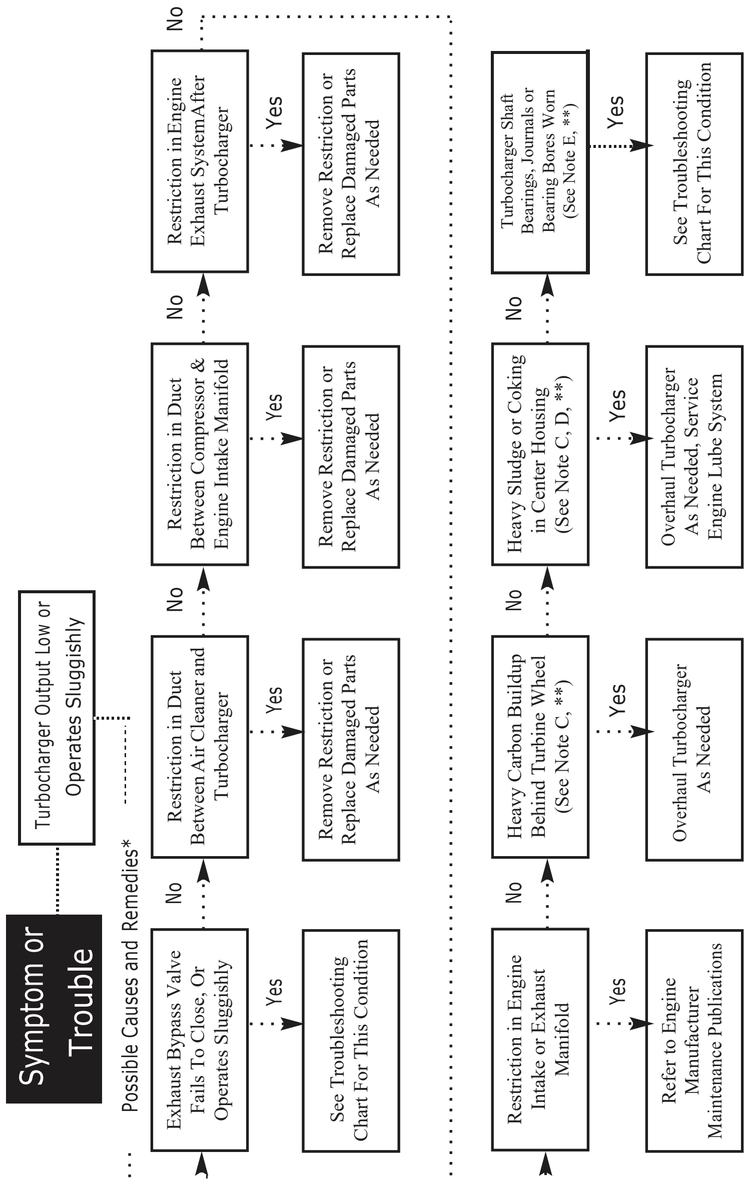
b. Restrictions in the air ducting between the air cleaner and the turbocharger would reduce the volume of air entering the compressor and restrictions in the duct between the compressor and the engine intake manifold would hinder the delivery of compressed air to the engine. Any restriction in the engine exhaust system downstream of the turbocharger turbine would affect the flow of exhaust gas through the turbine to drive the compressor. For any restrictions listed in this step, remove the restriction and replace damaged parts as needed.

c. In the case of restrictions in the engine intake or exhaust manifolds, correct the condition per the engine manufacturer maintenance publications.

d. A heavy buildup of hard carbon or rust deposits behind the turbine wheel can be a hindrance to rotation and requires disassembly and overhaul or replacement of the turbocharger. The condition is also a good reason to review engine operation and maintenance procedures if they resulted in excessive unburned hydrocarbons in the exhaust or oil in the turbine housing.

e. Faulty operation or poor maintenance of the engine can also cause soft contamination (sludge) or hard contamination (coking or rust) in the turbocharger center housing, with hindrance of rotation and added bearing wear among its negative effects. Remove the turbocharger if necessary and inspect the interior of the center housing by removing the oil drain and looking in through the oil drain opening. When a soft or hard contamination exists, contaminants build up on the shaft between the bearing journals, on the wall of the housing from the oil drain opening back to the

Figure 21 - Troubleshooting - Turbocharger Output Low or Operates Sluggishly



* Chart assumes that "Pre-Troubleshooting Inspection" has been performed as summarized in Table 17 (page 84).

** Troubleshooting Procedure Notes, Table 18 (page 90).

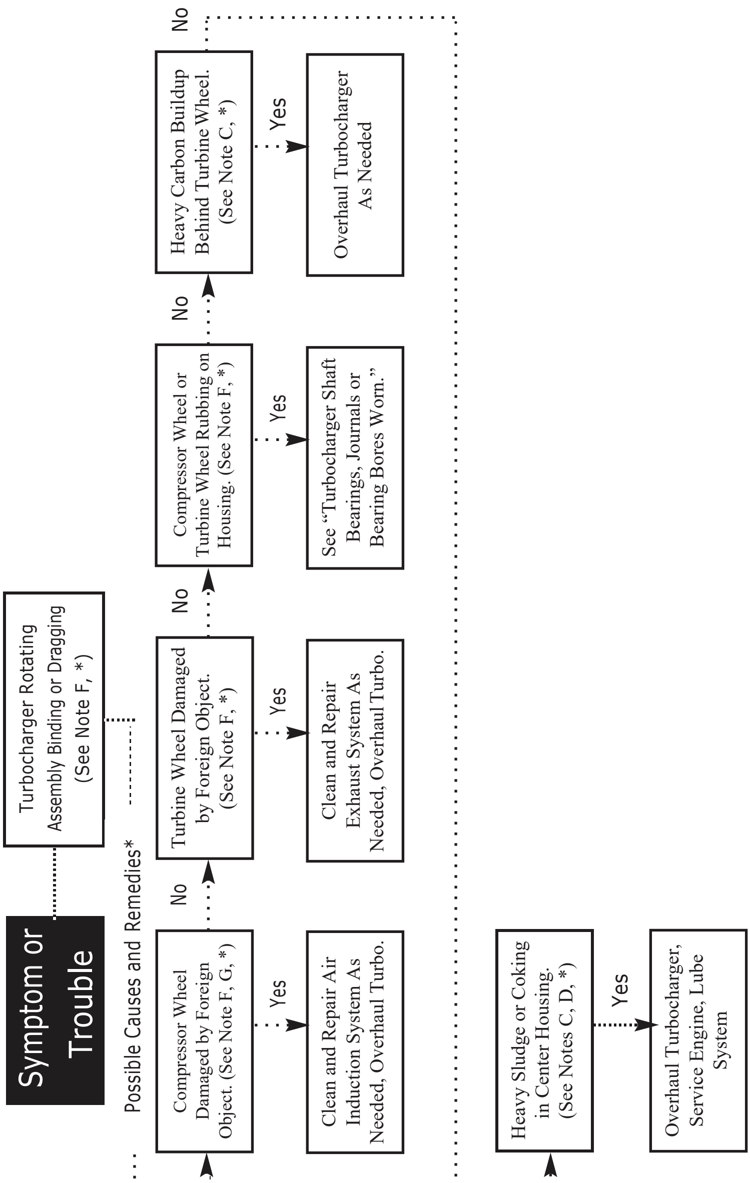
turbine end, and on the turbine-end piston ring seal. This condition requires overhaul of the turbocharger and a complete servicing of the engine lubricating oil system components supplying and draining the turbocharger center bearing housing assembly.

f. If there is suspicion of abnormal wear in the turbocharger bearings, perform the “Bearing Clearance Inspection” found in Chapter 2 of the latest revision of the HET Aircraft Turbocharger Overhaul Manual P/N 400600-0000. Failure to pass this inspection calls for overhaul or replacement of the turbocharger after determining the root causes of wear per the troubleshooting procedure, “Turbocharger Shaft Bearings, Journals or Bearing Bores Worn.”

Turbocharger Rotating Assembly Binding or Dragging (See Figure 22):

Binding or dragging of the turbocharger rotating assembly may be detected visually by removing the air duct from the compressor inlet and/or the exhaust duct from the turbine outlet and looking for wheel damage or rubbing. This symptom may also be detected by hearing the sound or by feeling the drag while manually turning the rotating assembly. Possible causes and remedies are as follows to detect rotational interference of compressor or turbine housings. Remove the air duct from the turbocharger compressor inlet and the exhaust duct from the turbine outlet and inspect the compressor wheel and turbine wheel, and their housings as follows:

Figure 22 - Troubleshooting - Turbocharger Rotating Assembly Binding or Dragging



* Chart assumes that "Pre-Troubleshooting Inspection" has been performed as summarized in Table 17 (page 84).

** Troubleshooting Procedure Notes, Table 18 (page 90).

1. If there is compressor wheel or turbine wheel damage from a foreign object, clean and repair the air induction system or engine exhaust system respectively and determine the source of the foreign object to prevent a recurrence. Overhaul or replace the turbocharger.

2. If there is evidence of the compressor wheel or turbine wheel rubbing on the housing, perform the “Bearing Clearance Inspection” found in Chapter 2 of the latest revision of the HET Aircraft Turbocharger Overhaul Manual P/N 400600-0000. If the bearings do not pass this inspection, determine the cause of wear by troubleshooting the condition, “Turbocharger Shaft Bearings, Journals or Bearings Bores Worn” and overhaul or replace the turbocharger.

3. If there is hard contamination (carbon or rust) buildup behind the turbine wheel, overhaul the turbocharger and examine the engine operation and maintenance procedures for departures from accepted practices and standards.

b. To detect soft or hard contamination (sludge, coke or rust) in the turbocharger, remove the oil drain from the center housing and look in through the oil drain opening, removing the turbocharger if necessary. When a soft or hard contamination (sludge, coke or rust) condition exists, contamination builds up on the shaft between the bearing journals, on the wall of the housing from the oil drain opening back to the turbine end, and on the turbine- end piston ring seal. For this condition, overhaul or replace the turbocharger and service the engine lubricating oil system. Also examine the engine operation and maintenance procedures for departures from accepted practices and standards.

Turbocharger Shaft Bearings, Journals or Bearing Bores Worn (See Figure 23):

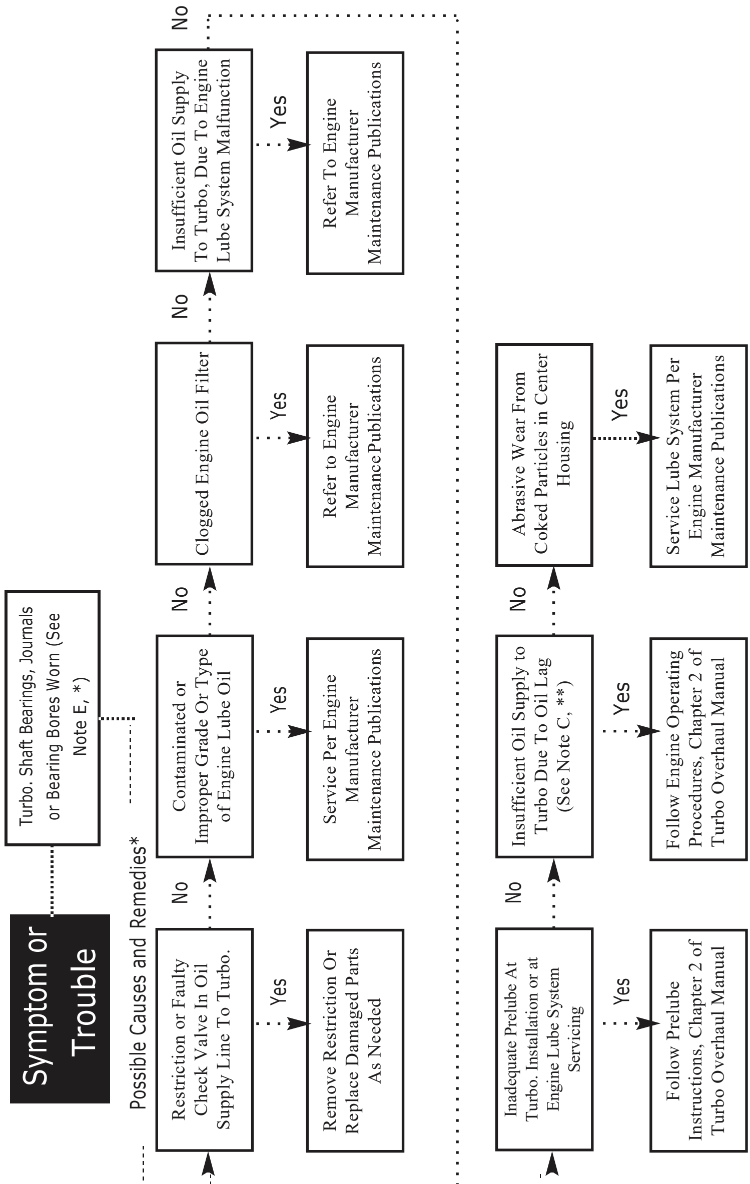
Suspected abnormal wear in the turbocharger shaft bearings, journals, or bearing bores can be readily confirmed by performing the “Bearing Clearance Inspection” found in Chapter 2 of the latest revision of the HET Aircraft Turbocharger Overhaul Manual P/N 400600-0000. It is imperative to detect and eliminate the cause of such failure before a replacement turbocharger is installed. Abnormal wear in the bearings results from abrasives in the oil or from an insufficient supply of oil. Examine engine operation and maintenance procedures for departures from accepted practices and standards. These are some of the possible causes of bearing wear, and their remedies:

a. If there is a restriction or faulty check valve in the oil supply line to the turbocharger, remove the restriction or replace damaged parts.

b. If the engine oil is contaminated or of improper grade or type, or if the engine oil filter is clogged, provide service for the engine lubricating oil system in accordance with the manufacturer maintenance publications.

c. If a malfunction of the engine lubricating oil system causes an insufficient oil supply to the turbocharger, correct the condition per engine manufacturer maintenance publications.

Figure 23 - Troubleshooting - Turbocharger Shaft Bearings, Journals or Bearing Bores Worn



* Chart assumes that "Pre-Troubleshooting Inspection" has been performed as summarized in Table 17 (page 84).

** Troubleshooting Procedure Notes, Table 18 (page 90).

d. Check whether the turbocharger was properly prelubricated at installation, or at the most recent servicing of the engine lubricating system. See Chapter 2 of the latest revision of the HET Aircraft Turbocharger Overhaul Manual P/N 400600-0000 for the procedure, "Prelubricating Turbocharger on Engine."

e. If engine speed and load is increased above idle before oil pressure has built up to at least the minimum level prescribed by the engine manufacturer, the "oil lag" may damage the turbocharger. See the engine operating precautions under "Special Operating Procedures" found in Chapter 2 of the latest revision of the HET Aircraft Turbocharger Overhaul Manual P/N 400600-0000.

f. Improper operation, especially overheating, may produce carbonized or "coked" particles in the oil, abrasive enough to cause direct wear of the turbocharger bearing surfaces. The lubricating system must be serviced per engine manufacturer maintenance publications before installing a replacement turbocharger.

Turbocharger Seal Leakage at Compressor End (See Figure 24):

Several conditions can cause turbocharger seal leakage at the compressor end of the rotating assembly by drawing or forcing oil past this seal. Higher-than-normal pressure outside the housing or an increase in the level of oil within the housing will contribute to oil loss past the seal. A worn or damaged compressor wheel and/or worn turbocharger shaft bearings may also cause motion and wear at the seal. These are some possible causes and remedies:

a. If the engine air cleaner element is clogged, inspect and service the air cleaner per the engine manufacturer maintenance publications.

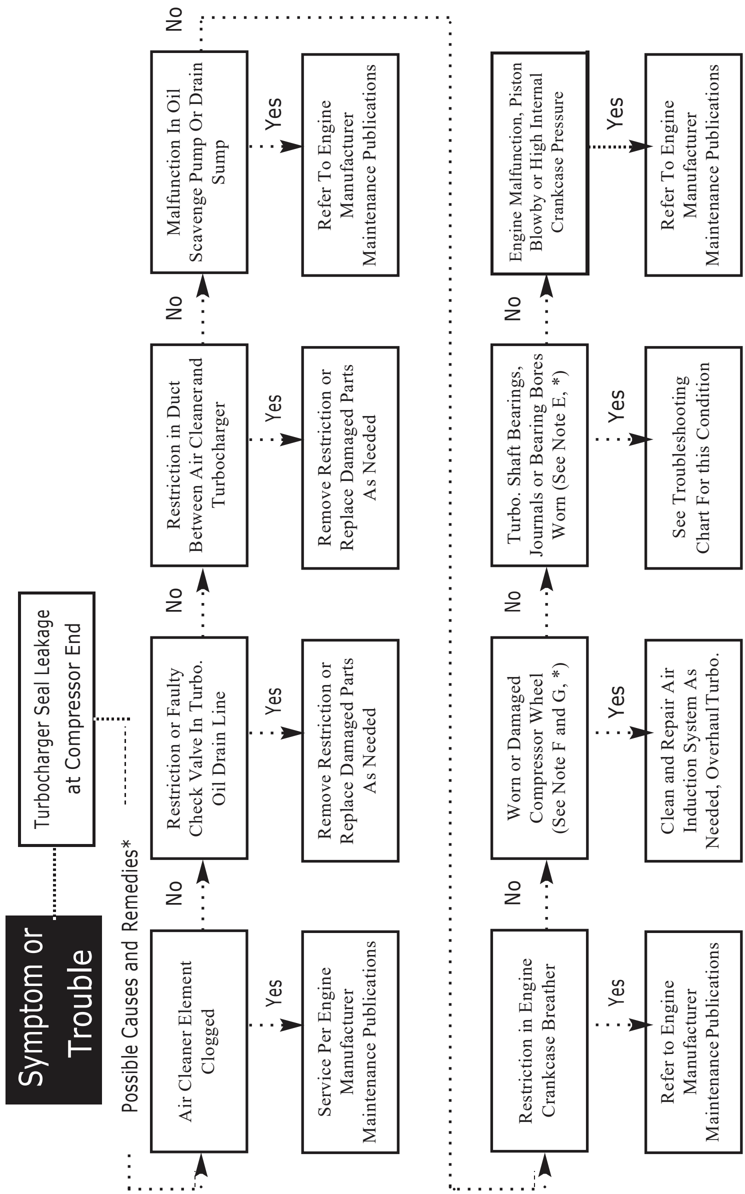
b. If there is a restriction or faulty check valve in the turbocharger oil drain line, remove the restriction or replace damaged parts as needed.

c. If there is a restriction in the duct between the air cleaner and the turbocharger compressor intake, remove the restriction or replace damaged parts as needed.

d. Any issue in the oil scavenge pump or the drain sump may cause oil backup in the turbocharger center housing. Correct such conditions per the engine manufacturer maintenance publications.

e. If there is a restriction in the engine crankcase breather, detect and eliminate the condition per the engine manufacturer maintenance publications.

Figure 24 - Troubleshooting - Turbocharger Seal Leakage, Leakage at Compressor End



* Troubleshooting Procedure Notes, Table 18 (page 90).

f. If compressor wheel damage or wear is present and contributes to seal leakage, clean and repair the air induction system. Overhaul or replace the turbocharger.

g. If the turbocharger shaft bearings, journals, or bearing bores are worn to the extent of not passing the "Bearing Clearance Inspection" found in Chapter 2 of the latest revision of the HET Aircraft Turbocharger Overhaul Manual P/N 400600-0000, determine the cause of wear by troubleshooting this condition before overhauling or replacing the turbocharger.

h. If there is an engine malfunction such as piston blow by or too high internal crankcase pressure, correct the condition per the engine manufacturer maintenance publications.

Turbocharger Seal Leakage at Turbine End (See Figure 25):

Most of the possible causes considered here for turbocharger seal leakage at the turbine end of the rotating assembly tend to raise the level of the oil within the turbocharger center housing or to affect the relative pressures on the internal and external sides of the seal. There is also the possibility of seal damage or wear if the turbine wheel is worn or damaged or if the shaft bearings have worn abnormally. These are some possible causes and remedies:

a. Check whether the turbocharger was prelubricated excessively, and follow the instructions for "Prelubricating Turbocharger on Engine" found in

Chapter 2 of the latest revision of the HET Aircraft Turbocharger Overhaul Manual P/N 400600-0000.

b. If there is a restriction in the engine crankcase breather, detect and eliminate the condition per the engine manufacturer maintenance publications.

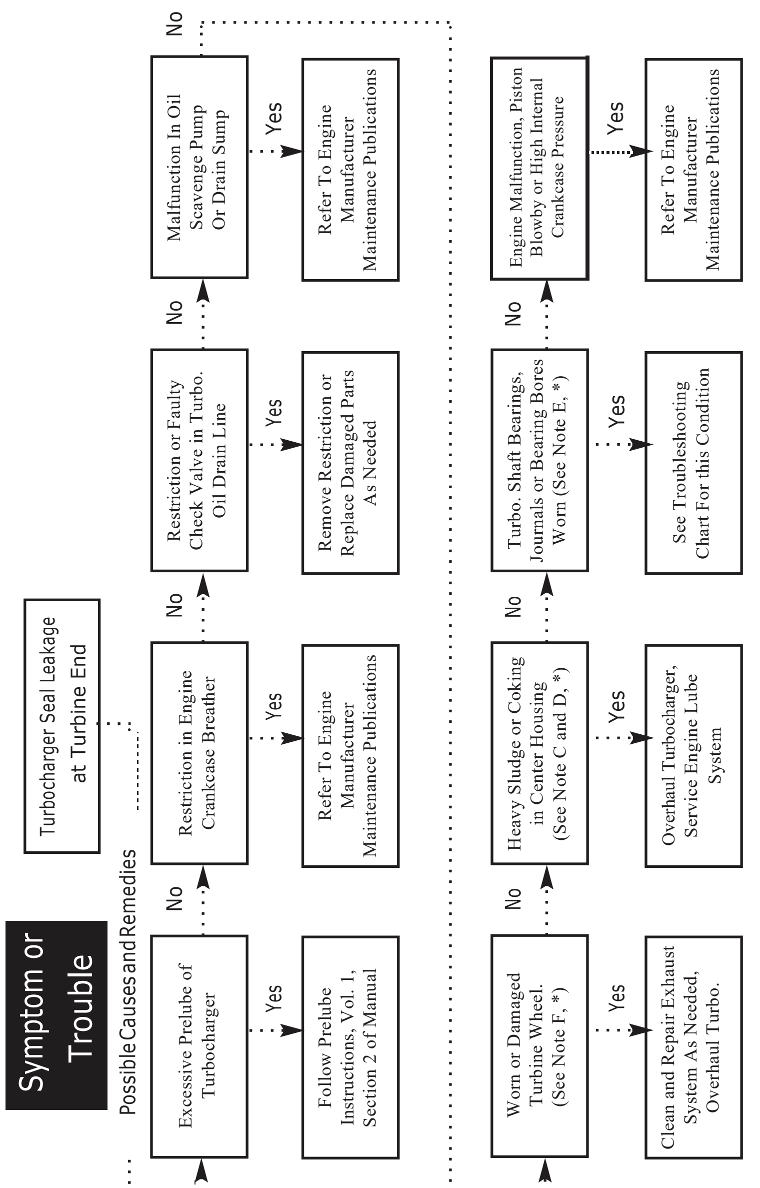
c. If there is a restriction or faulty check valve in the turbocharger oil drain line, remove the restriction or replace damaged parts as needed.

d. A malfunction in the oil scavenge pump or the drain sump may cause oil backup in the turbocharger center housing; correct such conditions per the engine manufacturer maintenance publications.

e. If turbine wheel damage or wear is present to contribute to seal leakage, clean and repair the exhaust system, as needed, and overhaul or replace the turbocharger.

f. To detect soft or hard contamination (sludge, carbon or rust) in the turbocharger, remove the oil drain from the center housing and look in through the oil drain opening. Remove the turbocharger if necessary. When a soft or hard contamination condition exists, contamination builds up on the shaft, between the bearing journals, on the walls of the housing from the oil drain opening back to the turbine end, and on the turbine- end piston ring seal. For this condition, overhaul the turbocharger and completely service the engine lubricating oil system. Also review engine operation and maintenance procedures for departures from accepted practices and standards.

Figure 25 - Turbocharger Seal Leakage at Turbine End



* Troubleshooting Procedure Notes, Table 18.

g. If the turbocharger shaft bearings, journals, or bearings bores are worn (to the extent of the not passing the “Bearing Clearance Inspection” found in Chapter 2 of the latest revision of the HET Aircraft Turbocharger Overhaul Manual P/N 400600-0000, determine the cause of wear by troubleshooting this condition before overhauling or replacing the turbocharger.

h. If there is an engine malfunction such as piston blow by or too high internal crankcase pressure, correct the condition per the engine manufacturer maintenance publications.

TROUBLESHOOTING VALVE AND CONTROLLER:

Pressure Relief Valve Does Not Open (See Figure 26):

If the absolute pressure relief valve in a turbocharger system does not open to prevent overboost, it must be removed and disassembled. If testing of the valve (Chapter 2 of the latest revision of HET Aircraft Valves and Controls Overhaul Manual P/N 400999-0000) indicates a malfunctioning aneroid bellows, overhaul or replace the valve. If testing shows that the valve is out of calibration, recalibrate or replace the valve.

Figure 26 - Troubleshooting - Pressure Relief Valve Does Not Open

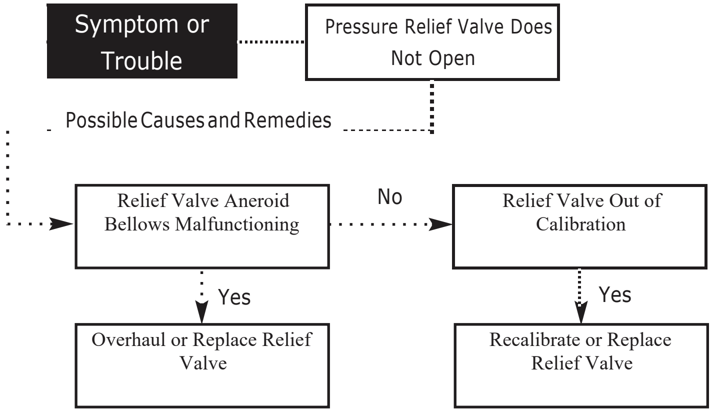
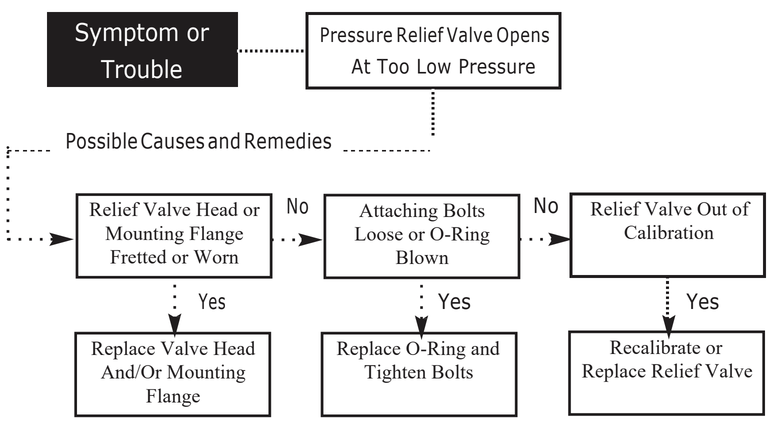


Figure 27 - Troubleshooting - Pressure Relief Valve Opens at Too Low a Pressure



Pressure Relieve Valve Opens at Too Low a Pressure (See Figure 27):

The absolute pressure relief valve in a turbocharger system may open at too low a pressure. Here are some possible causes and remedies for this malfunction:

a. If the spring (if accessible), valve head and/or the mounting flange are fretted, broken or worn, replace the part(s) as needed.

b. If the attaching bolts for the valve are loose, tighten them. If the O-Ring at the attaching surface has blown, replace it.

c. If the testing shows that the relief valve is out of calibration, recalibrate or replace the valve.

Exhaust Bypass Valve Does Not Close or Operates Sluggishly (See Figure 28):

An exhaust bypass valve normally stays open until oil pressure builds up in its hydraulic cylinder to actuate its closing. Not closing must be traced to a hydraulic problem in building up oil pressure or to a mechanical problem in closing the poppet-type or butterfly-type valve. Some of the possible causes and remedies are as follows:

a. The engine oil system may be operating at a pressure too low to actuate the exhaust bypass valve. Check and correct for such a condition per the engine manufacturer maintenance publications.

b. If there is a restriction in the oil supply line to the exhaust bypass valve actuator, remove the restriction or replace the line, as needed.

c. If the wrong poppet-type exhaust bypass valve has been installed, with a poppet size not matching the seat to which it must mate, replace with the correct unit as listed in the engine/aircraft manufacturer's publications.

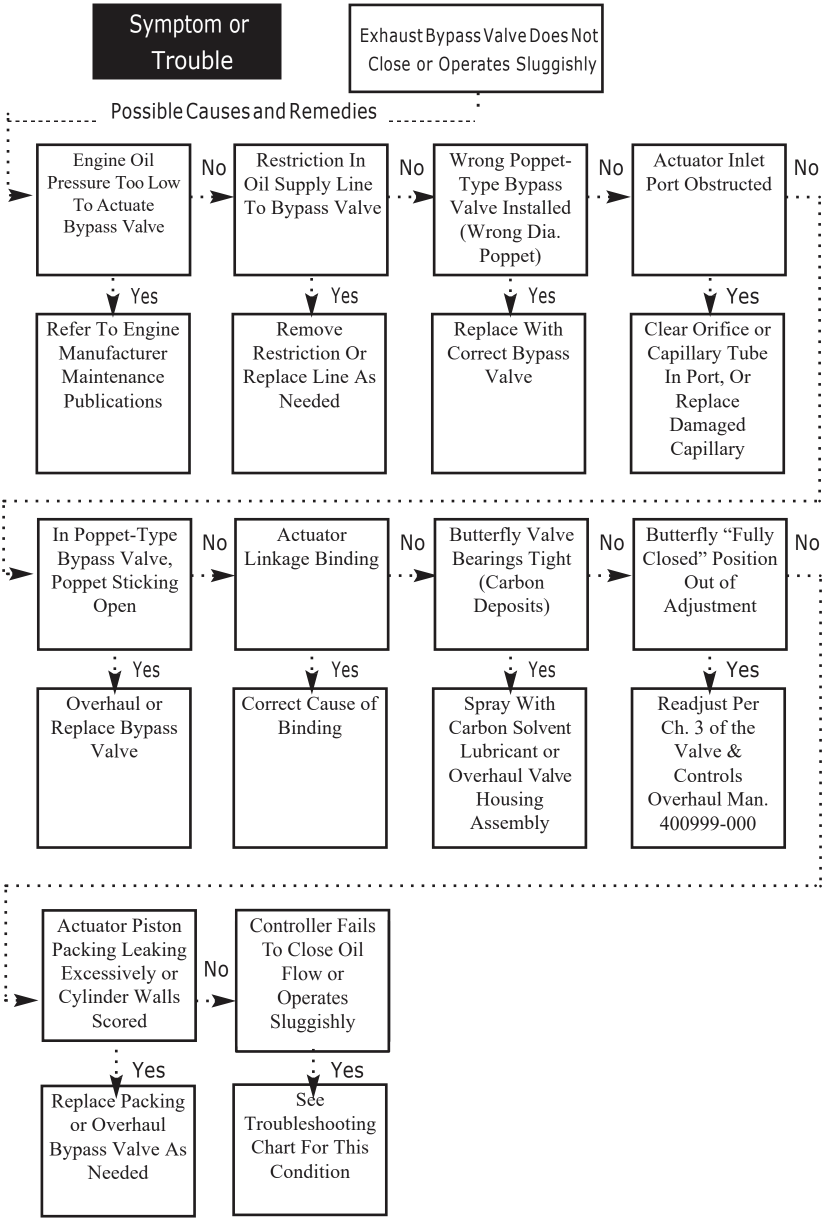
d. If the inlet port of the actuator is obstructed, clear the orifice or capillary tube in the port or replace the capillary tube if damaged.

e. If the poppet is stuck in the open position in a poppet-type exhaust bypass valve, overhaul or replace the valve.

f. On a butterfly-type exhaust bypass valve, if the external linkage from the actuator to the butterfly valve is binding, correct the cause of the binding. If the butterfly itself cannot move because the bearings are tight, perhaps from exhaust by-products, try freeing the shaft by spraying with a carbon solvent lubricant (Mouse Milk). Otherwise, overhaul or replace the valve housing assembly.

g. Check butterfly clearance in the "fully closed" position against the valve in the "Reassembly" procedure for the specific exhaust bypass valve in Chapter 2 of the latest revision of the HET

Figure 28 - Troubleshooting - Exhaust Bypass Valve Does Not Close or Operates Sluggishly



Aircraft Valves and Controls Overhaul Manual P/N 400999-0000. If necessary, adjust to the correct clearance.

h. If disassembly and inspection of the actuator shows that the piston packing has worn, fretted, or cracked to allow excessive oil leakage, replace the packing. If the actuator cylinder walls are scored, overhaul or replace the exhaust bypass valve.

i. Oil pressure cannot build up if a controller located between the actuator outlet and the engine crankcase fails to close off the oil flow. See the troubleshooting procedure, “Controller Fails to Close Oil Flow,” Figure 30.

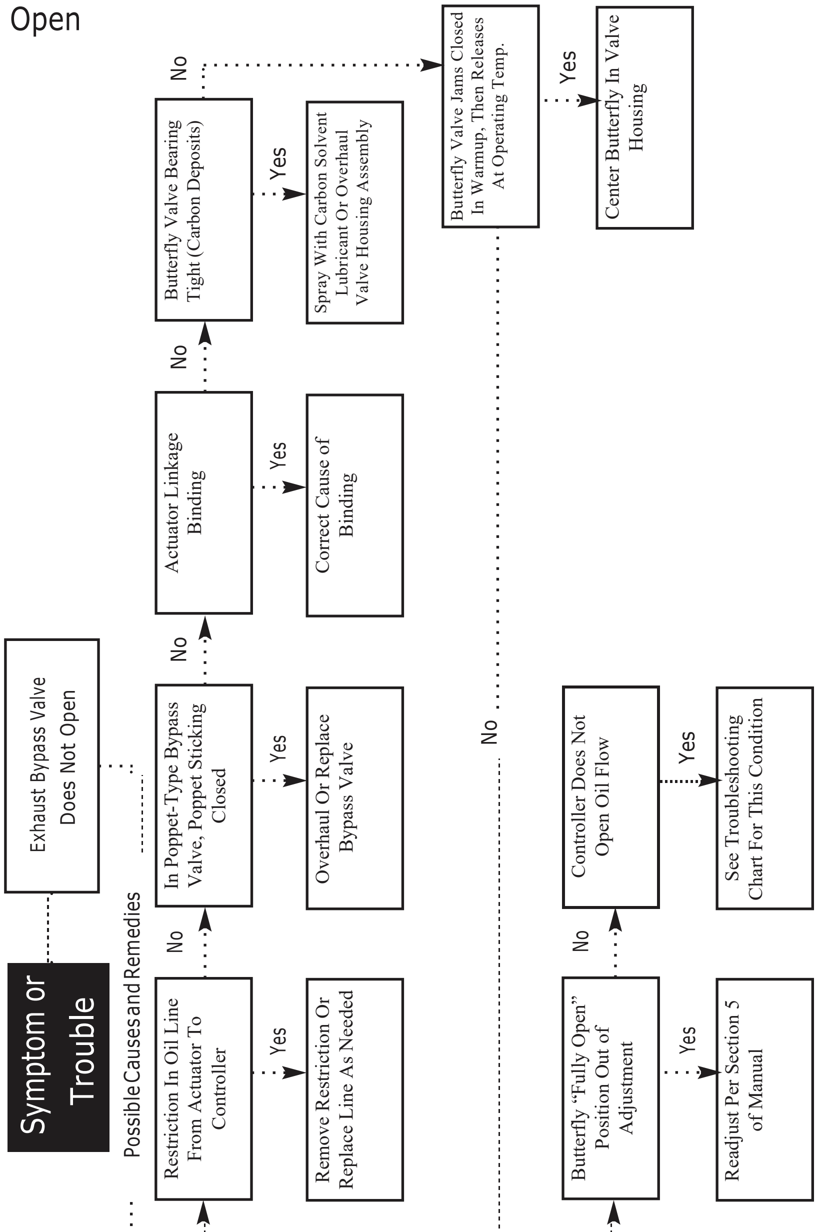
Exhaust Bypass Valve Does Not Open (See Figure 29):

If an exhaust valve which is normally open does not open, this is due to either a hydraulic problem which prevents relief of the oil pressure which actuates the valve to close or a mechanical problem which interferes with opening. Some of the possible causes and remedies are as follows:

a. If there is a restriction in the oil line from the exhaust bypass valve actuator to the controller(s), remove the restriction or replace the line, as needed.

b. If the poppet is stuck in the closed position in a poppet type exhaust bypass valve, overhaul or replace the bypass valve.

Figure 29 - Troubleshooting - Exhaust Bypass Valve Does Not Open



c. On a butterfly-type exhaust valve, if the external linkage from the actuator to the butterfly valve is binding, correct the cause of binding. If the butterfly itself is stuck in the closed position or cannot move because the bearings are tight, perhaps from exhaust by-product deposits, try freeing the shaft by spraying with a carbon solvent lubricant (Mouse Milk). Otherwise, overhaul or replace the valve housing assembly.

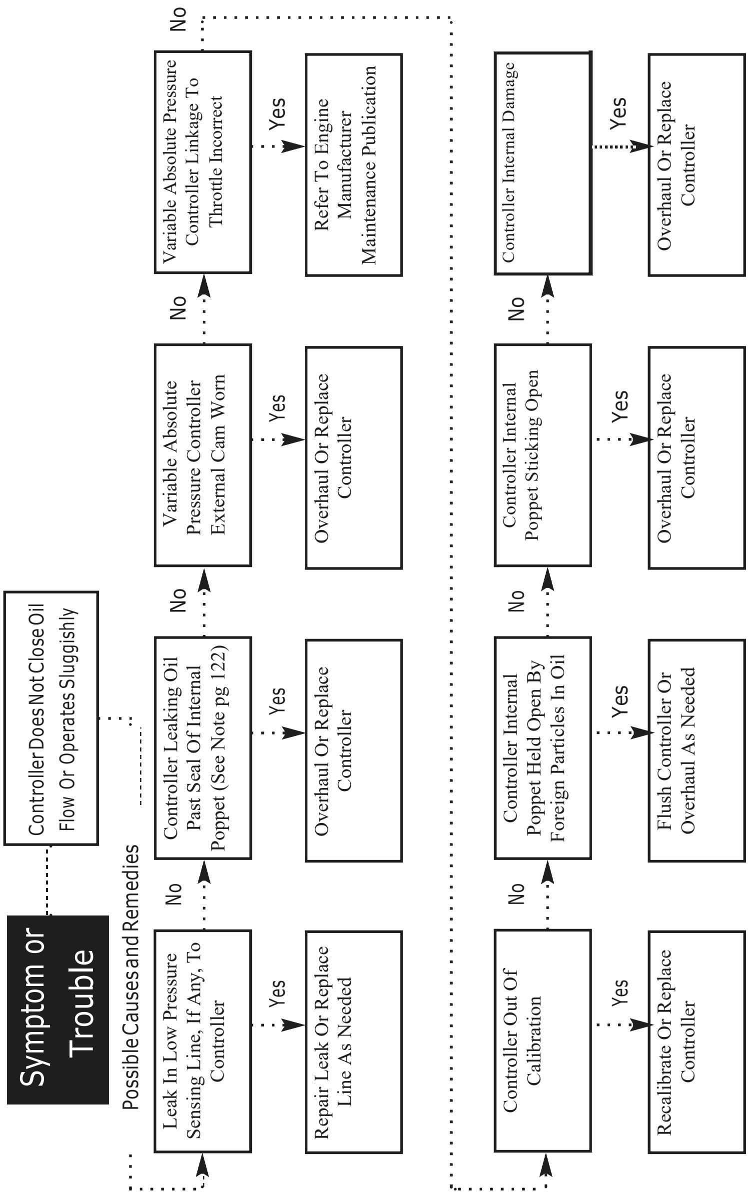
d. Check butterfly clearance in the "fully open" position against the valve given in the "Reassembly procedure for the specific exhaust bypass valve in Chapter 2 of the latest revision of the HET Aircraft Valves and Controls Overhaul Manual P/N 400999-0000. If necessary, adjust to the correct clearance.

e. If the controller located between the actuator outlet and the engine crankcase which is supposed to relieve oil pressure to open the bypass does not do so, see the troubleshooting procedure, "Controller Fails to Open Oil Flow."

Controller Does Not Close Oil Flow or Operates Sluggishly (See Figure 30):

Each controller is designed so that its internal poppet valve is nearly closed within what it senses as "normal" conditions. This partially closes off oil flow through the controller from the exhaust bypass valve to the engine crankcase. Some of the possible causes of controller not closing off oil flow consistently are as follows:

Figure 30 - Troubleshooting - Controller Does Not Close Oil Flow or Operates Sluggishly



a. If there are air pressure sensing lines to the controller, inspect the lines for leaks or restrictions and repair or replace the line as needed.

b. Check for significant oil leakage past the seal of the controller internal poppet. Look for this leakage at the compressor outlet air sensing line to the controller, at the other air sensing lines or ports or, for a duct-mounted controller without a cover, remove the controller and inspect the bellows area. If there is leakage, overhaul or replace the controller.

c. If the controller is a variable absolute pressure type which has been in service for some time, it is possible that some of the external mechanisms have become worn, especially the cam. If so, overhaul or replace the controller.

d. On a variable absolute pressure controller, the linkage to the engine throttle may be incorrectly assembled, loose or out of adjustment. If so, reassemble, tighten or readjust per the engine manufacturer maintenance publications.

e. If testing (in Chapter 2 of the latest revision of the HET Aircraft Valves and Controls Overhaul Manual P/N 400999-0000) shows that the controller is out of calibration, recalibrate or replace the controller.

f. If inspection shows that the controller internal poppet is held open by foreign particles in the oil, flush the controller with clean engine oil. If flushing alone does not cure the trouble, overhaul or replace the controller.

g. If there is other internal damage to the controller, such as a torn diaphragm or broken spring, overhaul or replace the controller.

Controller Does Not Open Oil Flow (See Figure 31):

Each controller is designed so that its internal poppet valve is normally closed until it senses those conditions in which it is to open and permit oil flow from the exhaust bypass valve to the engine crankcase, permitting the exhaust bypass valve to open. Some possible causes of the controller not permitting oil flow are as follows:

a. If the engine oil is too cold for the controller to operate properly, allow time for the oil to warm up.

b. If there is a restriction in the oil line from the controller back to the engine crankcase or oil sump, remove the restriction or replace the line as needed.

c. If there is an air pressure sensing line to the controller, inspect the line for leaks or restrictions and repair or replace the line as needed. If present, check for tears or holes in the diaphragm. If found, repair or replace the controller.

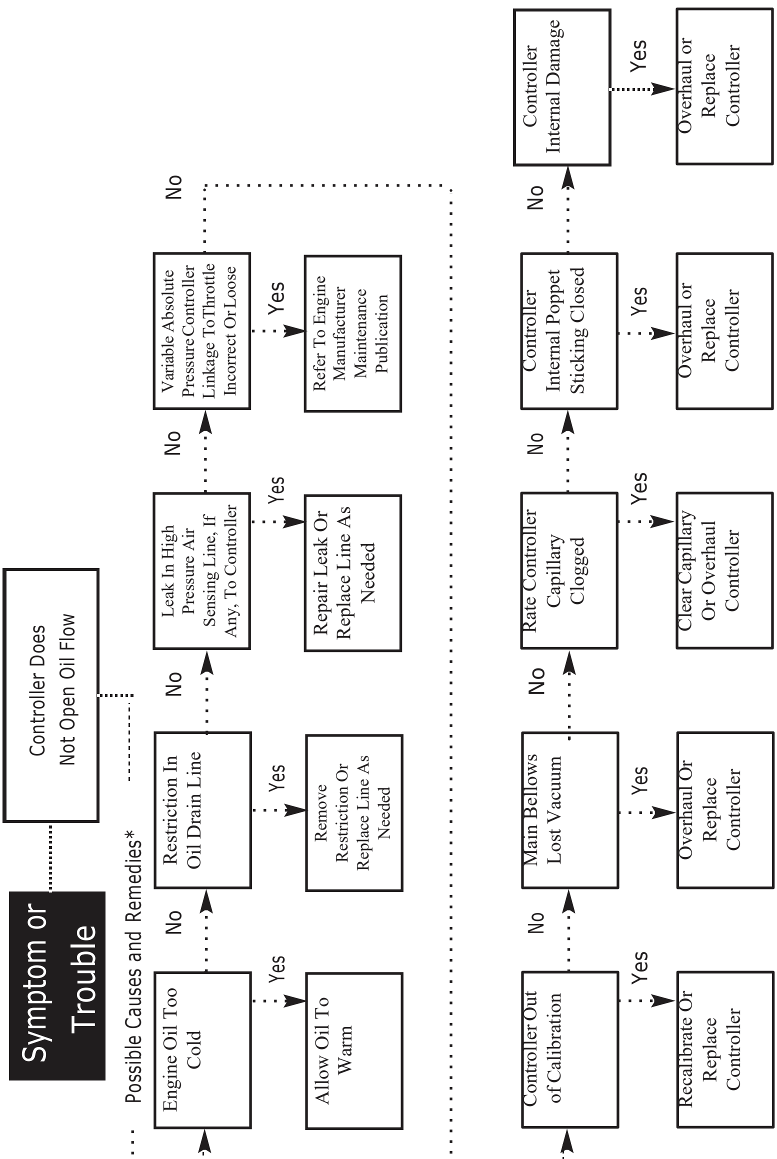
d. On a variable absolute pressure controller, the linkage to the engine throttle may be incorrectly assembled or out of adjustment. If so, reassemble or readjust per the engine manufacturer maintenance publications.

e. If testing (in Chapter 2 of the latest revision of the HET Aircraft Valves and Controls Overhaul Manual P/N 400999-0000 shows that the controller is out of calibration, recalibrate or replace the controller.

f. If the capillary is clogged in a rate controller, clear the capillary or overhaul the controller.

g. If inspection of the controller shows that the internal poppet is stuck closed or the controller is otherwise damaged, overhaul or replace the controller.

Figure 31 - Troubleshooting - Controller Does Not Open Oil Flow



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Turbocharger Cool-Down 4

General

The time required for "cooling down" a turbocharger is directly related to the internal turbocharger heat generated. On a "normal" flight, any turbocharger would be at its coolest point at aircraft touchdown unless engine power was carried to that touchdown point. If the engine is shutdown prior to the turbocharger temperature stabilizing, coking of the oil internally may occur which will be detrimental to future turbocharger operation and longevity.

Due to operational and product differences, review recommended guidelines for operation. Those guidelines come from the applicable aircraft, engine or turbocharger manufacturer's documents, with lower level documents always superseded by upper level documents.

Cool-down Recommendations

1. What does the POH or Engine Operating manual recommend? Any recommendations provided would be the guideline to follow.
2. Other Considerations
    a. What series turbocharger
        i. HET 600 Series turbochargers require no cool-down period as they are constructed with an aluminum center housing which dissipates heat rapidly.
        ii. HET 400 Series may require a cool-down period of "several" minutes to make sure temperatures have stabilized prior to engine shutdown.

b. Boosted or normalized system

   i. Boosted engines - greater than sea level manifold pressure at rated power. This system is constantly flowing exhaust gases over the turbocharger turbine wheel assembly which keeps the internal temperatures elevated. Boosted engines require close monitoring of temperatures prior to engine shutdown.
   ii. Normalized engines - not greater than sea level manifold pressure at rated power. These systems are typically not "boosting" with standard day conditions. Normalized engines are not generating turbocharger output at standard day conditions so temperatures are not as critical.

c. Operator variables

   i. Pilots - good flight planning with vigilant monitoring of engine temperatures can decrease the amount of cooling time required prior to engine shut-down.
   ii. Mechanics - when performing required operational checks following inspections, make sure the engines are cowled and after running to verify static power output, ensure enough time is allowed for proper engine cool-down prior to shutting down the engine(s) for final adjustments.

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Miscellaneous Information 5

Turbochargers - TBO and ICA
The Published Time Between Overhaul “TBO” is predicated on operation of the component or engine within the normal recommended conditions per the applicable engine/airframe type certificate holder. The recommended “TBO” in no way constitutes an expressed or implied guarantee or warranty.

Aside from required inspections, periodic maintenance in the usual sense is not required on a HET turbocharger because no in- service calibration or adjustment procedures are possible.

The time between overhaul (TBO) for any HET turbocharger shall coincide with but not exceed the TBO (in hours’ time in service) published by the engine manufacturer for the specific engine using the turbocharger. Further, component TBO shall commence at any engine overhaul and / or upon reaching 12 (twelve) years. TBO shall be the first of these to occur per the HET 400600-0000 Turbocharger Overhaul Manual.

Turbochargers - Storage
Per the HET 400600-0000 Turbocharger Overhaul Manual, when storing a new or overhauled turbocharger there are two categories to consider. Will it be a short term storage or a long term storage on or off the aircraft? Short term storage will be considered as storage up to but not exceeding twenty-four (24) calendar months. Long term storage will be considered as storage up to but not exceeding twelve (12) calendar years. There is a different method for each type of storage.

Short term, if on the shelf, requires only that the unit be kept in its original packaging. If the unit is on the aircraft (or unmounted engine) rotating the engine to achieve 5 - 8 psi oil pressure at an interval of sixty (60) days is required.

Long term, if on the shelf, requires that the turbocharger be removed from the box and from the corrosion inhibitive plastic bag as originally packaged. Discard the bag if any condensation is found. Remove the shipping caps and fill center housing with multi-vis AD aircraft engine oil. Do not drain and cap the oil ports. Wipe or lightly spray outside and all openings with preservative oil. Recap all openings and wrap tightly with a waxed type paper.

Place back into original shipping container and store in a cool dry environment.

If it is anticipated or determined that the aircraft (or unmounted engine) will be in a long term storage situation, as soon as practicable, remove the compressor inlet/ outlet ducts and remove exhaust inlet/outlet pipes and liberally spray with preservative oil. Return the inlet and exhaust to airworthy condition. Rotate the engine (do not start) to achieve 5 - 8 psi oil pressure. Wipe and spray the outside of the unit with preservative oil. Rotate the engine (do not start) to achieve 5 - 8 psi oil pressure at an interval of sixty (60) days is required.

Turbocharger - Shelf Life

All HET turbochargers have a shelf life up to, but not to exceed, twelve (12) calendar years at which time the unit must be overhauled.

Wastegate/Bypass Valves - TBO and ICA

The time between overhaul (TBO) is established at 2000 (two thousand) hours' time in service or upon reaching 12 (twelve) years and at any engine overhaul, the first to occur per the HET 4400999-0000 Valves and Controls Overhaul Manual.

Wastegate/Bypass Valves - Storage

When storing a new or overhauled turbocharger exhaust bypass valve (wastegate) there are two categories to consider. Will it be a short term storage or a long term storage on or off the aircraft? Short term storage will be considered as storage up to but not exceeding twenty-four (24) calendar months. Long term storage will be considered as storage up to but not exceeding twelve (12) calendar years. There is a different method for each type of storage.

Short term, if on the shelf, requires only that the unit be kept in its original packaging. If the unit is on the aircraft (or unmounted engine), no additional action other than that required for the turbocharger is needed.

Long term, if on the shelf, requires that the wastegate be removed from the box and the corrosion inhibitive plastic bag as originally packaged. Remove the shipping caps and fill the cylinder with multi-vis AD aircraft engine oil. Do not drain and cap the oil ports. Lubricate the butterfly valve shaft with a small amount of "mouse milk" or equivalent. Wipe or lightly spray outside and all openings with preservative oil. Recap all openings and wrap tightly with a waxed type paper. If condensation is found in the plastic bag discard the bag. Place back into original shipping container and store in a cool dry environment.

If it is anticipated or determined that the aircraft (or unmounted engine) will be in a long term storage situation, as soon as practicable, remove the exhaust inlet/ outlet pipes and lubricate the butterfly valve shaft with "mouse milk" or equivalent inside and outside while working the valve. Liberally wipe or spray wastegate body with preservative oil. Return the exhaust to airworthy condition. No additional action other than that required for the turbocharger is needed.

Wastegate/Bypass Valves – Shelf Life

All HET controllers have a shelf life of up to, but not to exceed, twelve (12) calendar years at which time the unit must be overhauled. Shelf life time does not preclude storage requirements.

Controllers – TBO and ICA

The time between overhaul (TBO) is established at 2000 (two thousand) hours' time in service or upon reaching 12 (twelve) years and at any engine overhaul, the first to occur per the HET 4400999-0000 Valves and Controls Overhaul Manual.

Controllers - Storage

When storing a new or overhauled turbocharger system controller, there are two categories to consider. Will it be a short term storage or a long term storage on or off the aircraft? Short term storage will be considered as storage up to but not exceeding twenty-four (24) calendar months. Long term storage will be considered as storage up to but not exceeding twelve (12) calendar years. There is a different method for each type of storage.

Short term, if on the shelf, requires only that the unit be kept in its original packaging. If unit is on the aircraft (or unmounted engine), no additional action other than that required for the turbocharger is needed.

Long term, if on the shelf, requires that the controller be removed from the box and the corrosion inhibitive plastic bag as originally packaged. Wipe or lightly spray outside and all openings with preservative oil. Recap all openings and wrap tightly with a waxed type paper. If condensation is found in the plastic bag, discard the bag. Place back into original shipping container and store in a cool dry environment. If it is anticipated or determined that the aircraft (or unmounted engine) will be in a long term storage situation, as soon as practicable, liberally wipe or spray controller assembly with preservative oil. No additional action other than that required for the turbocharger is needed.

Controllers - Shelf Life

All HET controllers have a shelf life of up to, but not to exceed, twelve (12) calendar years at which time the unit must be overhauled. Shelf life time does not preclude storage requirements.

Application Guides
Application guides are NOT the FAA-approved Applicable Models List (AML). Matters of certification eligibility can be found at: **www.hartzell.aero/pma**.

Application guides are simply intended as a reference guide for fitting most aircraft by type. However, due to variances between aircraft due to manufacturing changes, modifications, cumulative years of maintenance, and/or conversion, it can be difficult to recommend a turbocharger system component based on make/model alone. So please only use this document or any Application Guide published AS A GUIDE ONLY. When in doubt, contact Hartzell Engine Tech for confirmation. Installation of the wrong turbocharger system component will void the factory warranty. Hartzell Engine Tech will not warranty a turbocharger system component when it is installed incorrectly or is used in an inappropriate application.

There may be a turbocharger system component that will fit an aircraft even when the Application Guide indicates no fit. Many older aircraft have been converted and upgraded. Confirm the aircraft/engine make/model before determining whether an Aeroforce solution is or is not applicable.

DO NOT ORDER THE PRODUCT unless you are sure of fit and function. If in doubt, contact Hartzell Engine Tech. Recommendations are based on Original Equipment (OE) manufacturer installations as factory standard equipment. Factory or after-market installed options may affect the applicability of the primary recommendation. It is imperative that the installer CONFIRM the proper product is being installed.

If you are unsure whether the turbocharger system component received is correct, PLEASE DO NOT MOUNT IT! Contact Hartzell Engine Tech first. Mounting the turbocharger system component will change the component status to “used” even if it is a zero-time classification. Installing the component will leave “witness” marks evident of installation.

Finally, our application and troubleshooting guides are for reference, are not comprehensive and there may be omissions and variances. We’ve done our best to include the majority of general aviation aircraft models. If you cannot find what you are looking for (or what you are looking for is not where you expect it), we encourage you to contact Hartzell Engine Tech to find the turbo system component for your particular application.

For application information, please go to:
https://aeroforce.aero/aircraft-turbochargers-support/application-information/

NOTES

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