TROUBLESHOOTING REFERENCE GUIDE

Aircraft Turbochargers, Valves and Controls

HARTZELL
ENGINE TECHNOLOGIES
MONTGOMERY, ALABAMA USA

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 to detect any potential problems before they have a chance to become serious. Any abnormal or unusual operating 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 Technologies LLC components. Maintained properly, it will give you safe and reliable service for many years to come.

Sincerely,
Hartzell Engine Technologies
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Foreword

The material contained herein pertains solely to Hartzell Engine Technologies LLC (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.

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NOTE: TP20-0128, as referenced in this text, refers to the AID/Garrett "Overhaul Manual for Aircraft System Turbochargers;" and CF601000-0000 refers to the "RAJAY Overhaul Manual – Aircraft Valves and Controls." **These manuals have been superseded by HET "Overhaul Manual for Aircraft System Turbochargers" P/N 400600-0000 or for "Overhaul Manual for Valves & Controls" P/N 400999-0000.**

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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 Technologies LLC (HET) and airframe or engine manufacturer designations.

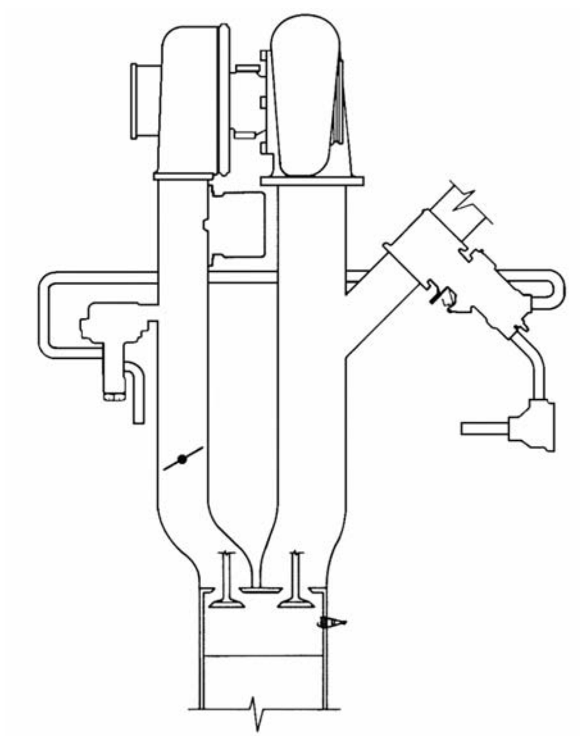
The second section provides a complete troubleshooting guide with truth tables for preliminary system diagnosis.

TURBOCHARGER SYSTEM DESCRIPTION:

The function of an aircraft turbocharger system is to maintain a desired manifold pressure at a given throttle setting, regardless of varying conditions of ambient air temperature and pressure. With few exceptions, the aircraft system comprises a turbocharger, a bypass valve, and one or more controllers. In most 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 gasses, compressed air, and pressurized engine oil can be clearly seen. Although this system features only one 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 modulated 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.

Turbo Systems Listed By Aircraft 2

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Turbo Systems Listed By Aircraft 2

Use this section to determine which type of system the aircraft has by turning to the indicated page of chapter 3.

Table 1 - Turbocharger Systems Listed by Aircraft

		VALVES				CONTROLLERS											
AIRCRAFT	ENGINE	Pressure Relief Valve	Exhaust Bypass (Butterfly)	Exhaust Bypass (Poppet)	Manual Wastegate	Fixed Abs. Press.	Variable Abs. Press.	Sloped	Press. Ratio	Density	Differential Press.	Dual Abs./Abs. Press. Ratio	Rate	Dual Abs./ Press./Rate	Sonic Venturi	Intercooler	Page No. / Table Page No.
Aero Fab Lake 250 Renegade	TIO-540-AA1AD		✓							✓	✓						35/37
Aerospatiale, Trinidad TC	TIO-540-AB1AD		✓							✓	✓						35/38
Bellanca	IO-540-G1E5, K1E5	✓															69/71
Bell Helicopter 47G3B ’61-’62	TV0-435-A1A		✓							✓							39/41
Bell Helicopter 47G3B ’63-’67	TV0-435-B1A/B,D1A/B		✓							✓							39/41
Bell Helicopter 47G3B ’68-’71	TV0-435-G1A		✓							✓							39/41
Bell Helicopter 47G3B ’72-’73	TV0-435-F1A		✓							✓							39/41
Cessna TR182 Turbo Skylane (T182)	0-540-L3C5D	✓			✓												73/75
Cessna T182T Turbo Skylane	TIO-540-AK1A	✓	✓					✓									65/67
Cessna 185 Skywagon ’66-’68	TSIO-520-C	✓	✓											✓			23/25
Cessna 185 Skywagon ’70-’76	TSIO-520-G	✓	✓			✓											15/18
Cessna T188 Ag Husky	TSIO-520-T	✓															69/71
Cessna 206 Stationair ’69-’76	TSIO-520-C	✓	✓			✓											15/18
Cessna 206 Stationair ’77-Up	TSIO-520-M	✓	✓			✓											15/18
Cessna T-206 Stationair	TIO-540-AJ1A	✓	✓					✓									65/67
Cessna T210 F-H Centurion ’66-’68	TSIO-520-C	✓	✓											✓			23/25
Cessna T210 J-L Centurion ’69-’76	TSIO-520-H	✓	✓			✓											15/18
Cessna T210 M-N Centurion ’77-’84	TSIO-520-R	✓	✓			✓											15/18
Cessna T210R Centurion ’85-Up	TSIO-520-CE	✓	✓				✓								✗	✓	43/46
Cessna T303 Crusader	L/TSIO-520-AE	✓	✓					✓									65/67
Cessna 320-1,A Skyknight ’62-’63	TSIO-470-B		✓			✓											15/18
Cessna 320B Skyknight ’64	TSIO-470-C		✓			✓											15/18
Cessna 320C Skyknight ’65	TSIO-470-D		✓			✓											15/18
Cessna 320D Skyknight ’66	TSIO-520-B	✓	✓						✓					✓			27/30

✗ Venturi Dumps Overboard

AIRCRAFT	ENGINE	VALVES				CONTROLLERS											
		Pressure Relief Valve	Exhaust Bypass (Butterfly)	Exhaust Bypass (Poppet)	Manual Wastegate	Fixed Abs. Press.	Variable Abs. Press.	Sloped	Press. Ratio	Density	Differential Press.	Dual Abs./Abs. Press. Ratio	Rate	Dual Abs./ Press./Rate	Sonic Venturi	Intercooler	Page No. / Table Page No.
Cessna 320E-F Skyknight ’67-’68	TSIO-520-B	✓	✓						✓					✓			27/30
Cessna 337 Skymaster ’67-’71	TSIO-360-A,B	✓	✓				✓						✓				57/59
Cessna P210 ’78-’81	TSIO-520-P	✓	✓			✓									✓		15/18
Cessna P210N Centurion ’82-'84	TSIO-520-AF	✓	✓					✓							✓		65/67
Cessna P210R Centurion ’85-Up	TSIO-520-CE	✓	✓				✓								✓	✓	43/46
Cessna 310 Turbo ’69	TSIO-520-B		✓			✓			✓								19/21
Cessna 310 Turbo ’70-’72	TSIO-520-B	✓	✓			✓											15/18
Cessna 310 Turbo ’73-Up	TSIO-520-B	✓	✓									✓					31/34
Cessna 335 Turbo ’80-Up	TSIO-520-E	✓	✓									✓					31/34
Cessna RT337G Reims/Skymaster	TSIO-360-D	✓	✓				✓										47/50
Cessna T337 Skymaster	TSIO-360-JB	✓	✓				✓										53/55
Cessna T337 Skymaster ’78-’80	TSIO-360-H	✓	✓				✓										53/55
Cessna T337G Skymaster ’73-’77	TSIO-360-C, F, R	✓	✓				✓								✓		47/50
Cessna 340 Turbo ’73-’75	TSIO-520-K	✓	✓									✓			✓		31/34
Cessna 340 Turbo ’76-Up	TSIO-520-NB, N	✓	✓				✓								✓		47/50
Cessna 401 Turbo ’67-’68	TSIO-520-E	✓	✓						✓					✓			27/30
Cessna 401A Turbo ’69	TSIO-520-E		✓			✓			✓								19/21
Cessna 401B Turbo ’70-’72	TSIO-520-E	✓	✓									✓					31/34
Cessna 401/402 Turbo ’67-’68	TSIO-520-E	✓	✓						✓					✓			27/30
Cessna 402A Turbo ’69	TSIO-520-E		✓			✓			✓								19/21
Cessna 402B Turbo ’70-’78	TSIO-520-E	✓	✓									✓					31/34
Cessna 402C Turbo ’79-Up	TSIO-520-VB	✓	✓				✓										47/50
Cessna 404 Titan ’77-Up	GTSIO-520-M	✓	✓				✓										47/50
Cessna 411 Turbo ’65-’66	GTSIO-520-C		✓						✓					✓			27/30
Cessna 411A Turbo ’67-’68	GTSIO-520-C		✓						✓					✓			27/30
Cessna 414 Turbo ’70-’75	TSIO-520-J	✓	✓				✓								✓	✓	47/50
Cessna 414 Turbo ’76-’77	TSIO-520-N	✓	✓				✓								✓	✓	47/51
Cessna 414A Turbo ’78-Up	TSIO-520-N	✓	✓				✓								✓	✓	47/51
Cessna 414 Riley STC	IO-720-B	✓	✓				✓										47/51
Cessna 421A Turbo ’68-’69	GTSIO-520-D	✓	✓				✓								✓	✓	47/51
Cessna 421B Turbo ’70-’75	GTSIO-520-H	✓	✓				✓								✓	✓	47/51
Cessna 421C Turbo ’76-Up	GTSIO-520-L, N	✓	✓				✓								✓	✓	47/51
Enstrom Shark	HIO-360	✓															69/71
Hiller Helicopter UH12L(4) ’65-’66	TIVO-540-A2A		✓							✓							39/41
Lake, 250 Renegade	TIO-540-AA1AD		✓						✓		✓						35/37
Lancair IV & IVP	TSIO-550-B, E	✓	✓					✓							✓	✓	65/67
Mooney 231 ’79-Up	TSIO-360-GB, LB	✓															69/71
Mooney 252 '85-Up	TSIO-360-MB	✓	✓				✓									✓	43/46
Mooney Encore	TSIO-360-SB	✓	✓				✓									✓	47/51
Mooney M-20M TLS	TIO-540-AF1A		✓							✓	✓					✓	35/37
Mooney M-20M TLS Bravo	TIO-540-AF1B		✓							✓	✓					✓	35/37
Mooney Mustang M22	TIO-541-A1A		✓				✓								✓		43/46
Page Various	R7555	✓															69/71
Piper Arrow	TSIO-360-F	✓															69/71
Piper Aztec A/B '60-64	O-540-A1,B5,D5		✓			✓											15/18
Piper Aztec C/D '66-69	IO-540-C4B5, J4A5		✓			✓											15/18
Piper Aztec E/F '70-Up	TIO-541-C1A		✓							✓	✓						35/37

AIRCRAFT	ENGINE	VALVES				CONTROLLERS											
		Pressure Relief Valve	Exhaust Bypass (Butterfly)	Exhaust Bypass (Poppet)	Manual Wastegate	Fixed Abs. Press.	Variable Abs. Press.	Sloped	Press. Ratio	Density	Differential Press.	Dual Abs./Abs. Press. Ratio	Rate	Dual Abs./ Press./Rate	Sonic Venturi	Intercooler	Page No. / Table Page No.
Piper Chieftain '73-Up	L/TIO-540-J2BD		✓							✓	✓						35/37
Piper Dakota	TSIO-360-F	✓															69/71
Piper Lance (Saratoga)	TIO-540-S1AD	✓			✓												73/75
Piper Malibu	TSIO-520-BE	✓	✓					✓							✓	✓	65/67
Piper Malibu Conversion	TSIO-550-C	✓	✓					✓							✓	✓	65/67
Piper Malibu Mirage	TIO-540-AE2A	✓	✓				✓										47/51
Piper Mojave	TIO-540-V2AD	✓	✓				✓								✓	✓	47/52
Piper Navajo 310 '67-Up	TIO-540-A1A,A1B,A2B,A2C		✓							✓	✓						35/37
Piper Navajo C/R '75-Up	L/TIO-540-F2BD		✓							✓	✓						35/38
Piper Pressurized Navajo '70-77	TIGO-541-E	✓	✓				✓								✓		47/52
Piper Saratoga TC	TIO-540-AH1A	✓	✓					✓									65/67
Piper Seneca II	L/TSIO-360-E,EB	✓															69/71
Piper Seneca III,IV	L/TSIO-360-KB	✓															69/71
Piper Seneca V	L/TSIO-360-RB	✓	✓				✓								✓		47/52
Raytheon Baron 56TC	TIO-541-E1B4		✓				✓										47/50
Raytheon Baron '76-'78	TSIO-520-L	✓		✓			✓								✗	✓	61/63
Raytheon Baron '79-Up	TSIO-520-WB	✓		✓			✓								✗	✓	61/63
Raytheon Bonanza A/B36TC	TSIO-520-U	✓	✓				✓										53/55
Raytheon Bonanza V35	TSIO-520-D		✓				✓										53/55
Raytheon Duke '69-'72	TIO-541-E1A4	✓	✓				✓								✓		47/50
Raytheon Duke '73-Up	TIO-541-E1C4	✓	✓				✓								✓		47/50
Raytheon Press. Baron '76-'78	TSIO-520-L	✓		✓			✓								✓	✓	61/63
Raytheon Press. Baron '79-Up	TSIO-520-WB	✓		✓			✓								✓	✓	61/63
Raytheon Turbo Bonanza	TSIO-520-UB	✓	✓				✓										47/50
Rockwell Commander 114 TC	TIO-540-AG1A		✓							✓	✓						35/38
Rockwell Commander 685	GTSIO-520-K	✓		✓			✓								✓	✓	61/63
Rockwell Commander 700	TIO-540-R2AD	✓	✓				✓										47/52
Socata Trinidad TC TB-21/TC	TIO-540-AB1AD		✓							✓	✓						35/38

✗ Venturi Dumps Overboard

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Turbo Systems Listed by Type 3

Turbo Systems Listed by Type . . . . Page

Turbo Systems Listed by Type 3

FIXED ABSOLUTE PRESSURE SYSTEM:

Installation Features:

1970-72 Cessna T310: Turbocharger mounted above engine oil level. Scavenged oil return.

1978-81 Cessna P210; and 1969-84 Cessna T206, T207, T210: Turbocharger below engine oil level. Check valves in inlet oil line and scavenge return line.

Cessna Skyknight: Turbocharger high-mounted with scavenge pump. Wastegate butterfly furnished by Cessna.

Piper Aztec A/B: Separate oil system with on-off switch.

Piper Aztec C/D: Low mounted turbochargers with scavenge pump, inlet check valve, and oil-out accumulator.

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

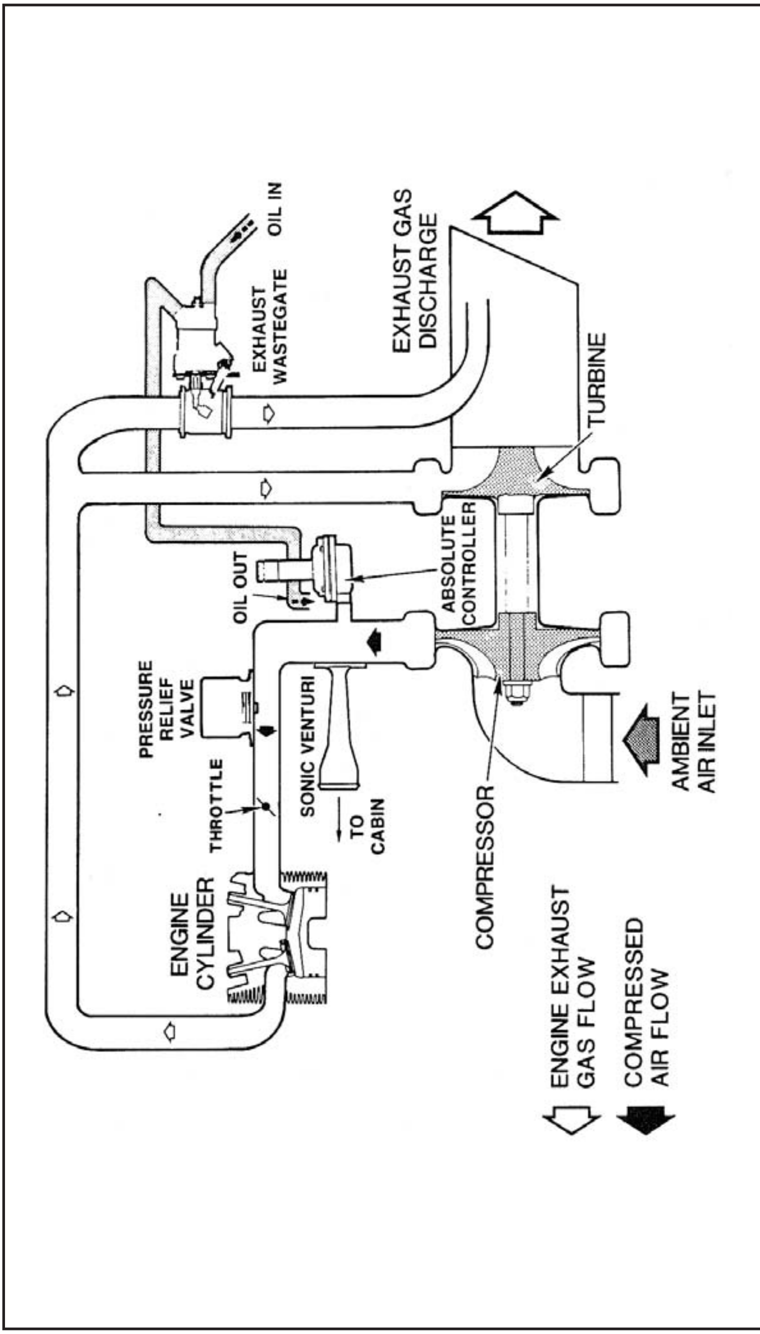

Table 2 - Fixed Absolute Pressure System Applications

System Specifics:

Aircraft	Engine	Turbocharger	L-Wastegate	R-Wastegate	Controller	PRV	Venturi
Cessna '78-'81 Press. P210	TSIO-520-P	465680-4 C295001-0202	470908-20 C165006-0114	Not Used	470688-8 C165004-0503	470944-3 C482002-0107	Customer Supplied
Cessna '69-'76 T210	TSIO-520-H	406610-5 C295001-0101	470908-11 C165006-0105	Not Used	470688-5 C165004-0501	470930-1 C482002-0101	Not Used
Cessna '77-Up T210	TSIO-520-R	406610-5 C295001-0101	470908-11 C165006-0105	Not Used	470688-7 C165004-0502	470944-12 C482002-0108	Not Used
Cessna '70-'76 T207	TSIO-520-G	406610-5 C295001-0101	470908-11 C165006-0105	Not Used	470688-5 C165004-0501	470930-4 C482002-0103	Not Used
Cessna '69-'76 T206	TSIO-520-C	406610-5 C295001-0101	470908-11 C165006-0105	Not Used	470688-5 C165004-0501	470930-1 C482002-0101	Not Used
Cessna '77-Up T206, T207	TSIO-520-M	406610-5 C295001-0101	470908-11 C165006-0105	Not Used	470688-7 C165004-0502	470944-12 C482002-0108	Not Used
Cessna '70-'72 Turbo. 310	TSIO-520-B	406610-9025 632729-11	470780-14 5050154-14	470780-13 5050154-13	470688-5 C165004-0501	470930-1 C482002-0101	Not Used
Cessna '62-'65 320 Skyknight	TSIO-470-B, C, D	404350-1 629844-1	470618 0851598-2	Same As Left Engine	470616 0851597-2	None	None
Piper '60-'64 Aztec A, B	0-540-A, B5, D5	406330-1	470656-4	Same As Left Engine	470688-3	None	None
Piper '66-'69 Aztec C, D	IO-540-C4B5, JA45	406610-3	470656-1	Same As Left Engine	470688-4	None	None

FIXED ABSOLUTE PRESSURE / PRESSURE RATIO SYSTEM:

Installation Features:

1969 Cessna Turbocharger 310, 401A, 402A: Turbocharger mounted above crankcase oil level. Scavenged oil return.

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

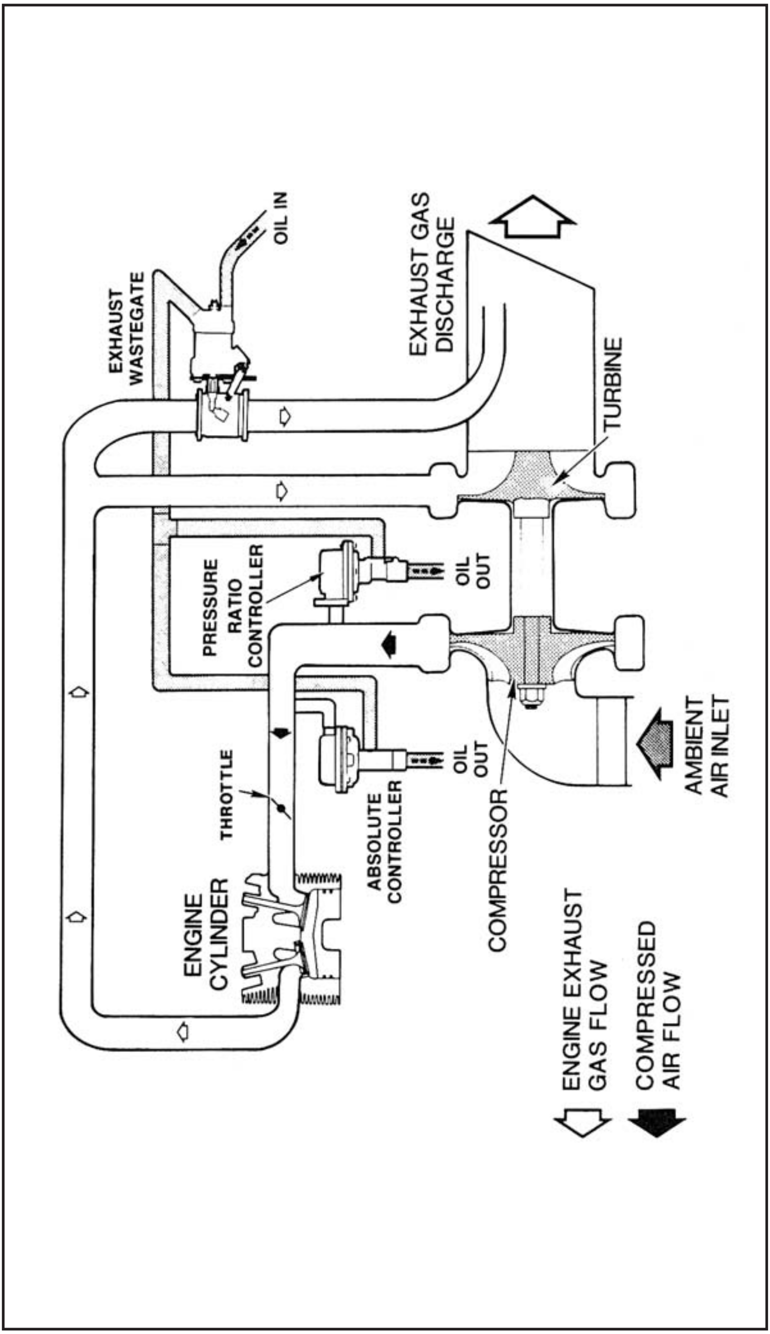

Table 3 - Fixed Absolute Pressure / Pressure Ratio System Applications

System Specifics:

Aircraft	Engine	Turbocharger	L-Wastegate	R-Wastegate	Controller	2nd Controller
Cessna '69 Turbo. 310	TSIO-520-B	406610-9025 632729-11	470780-14 5050154-14	470780-13 5050154-13	470688-5 C165004-0501	470822-1 C165004-0401
Cessna '69 401A/402A	TSIO-520-E	406610-9025 632729-11	470780-15 5050154-15	470780-16 5050154-16	470688-5 C165004-0501	470822-1 C165004-0401

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DUAL ABSOLUTE / RATE CONTROL SYSTEM:

Installation Features:

1966-68 Cessna T206, T210: Low mounted turbochargers. Scavenged oil system with check valves on inlet and scavenge return lines.

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.

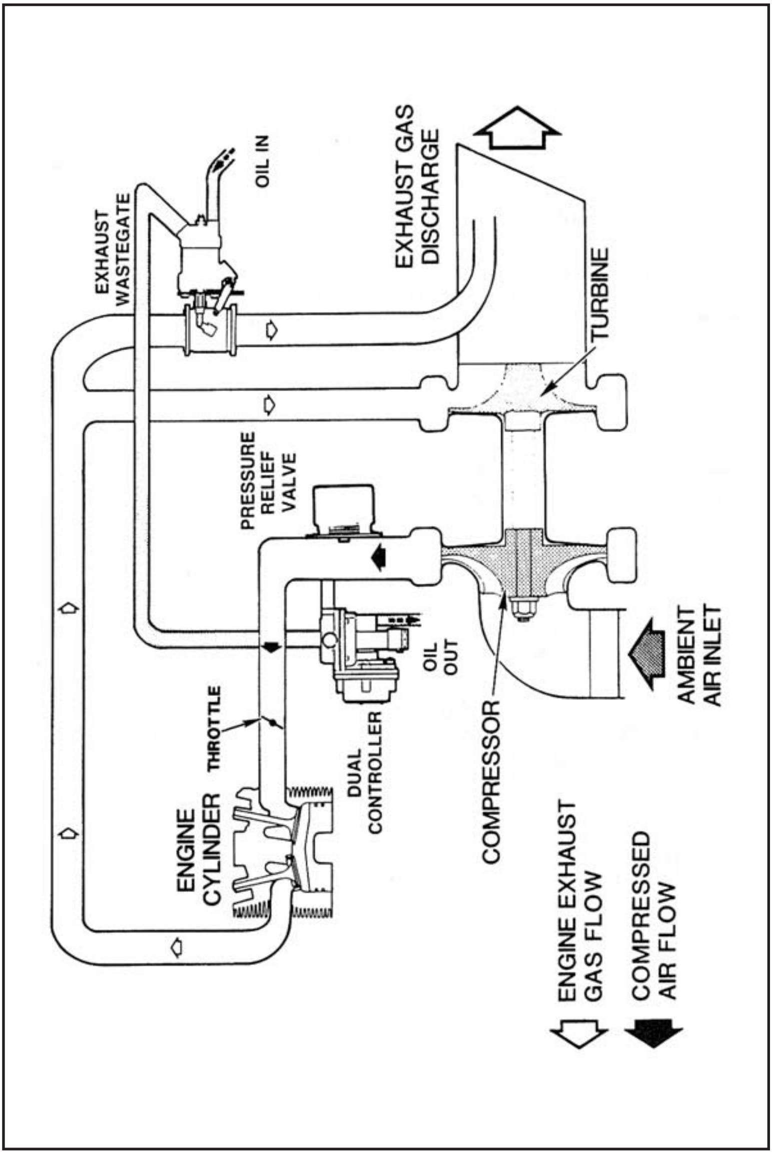

Figure 4 - Dual Absolute / Rate Control System Schematic

Table 4 - Dual Absolute / Rate Control System Applications

System Specifics:

Aircraft	Engine	Turbocharger	Wastegate	Controller	PRV
Cessna ’66-’68 T206 A-C	TSIO-520-C	406610-5 C295001-0101	470908-11 C165006-0105	470782-3 C165004-0101	470930-1 C482002-0101
Cessna ’66-’68 T210	TSIO-520-C	406610-5 C295001-0101	470908-11 C165006-0105	470782-3 C165004-0101	470930-1 C482002-0101

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DUAL ABSOLUTE / RATE CONTROL SYSTEM WITH PRESSURE RATIO CONTROL:

Installation Features:

1965-66 Cessna 411; 1967-68 Cessna 401, 402, 411A; and 1966-68 Cessna 320: High mounted turbochargers with scavenged oil system.

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

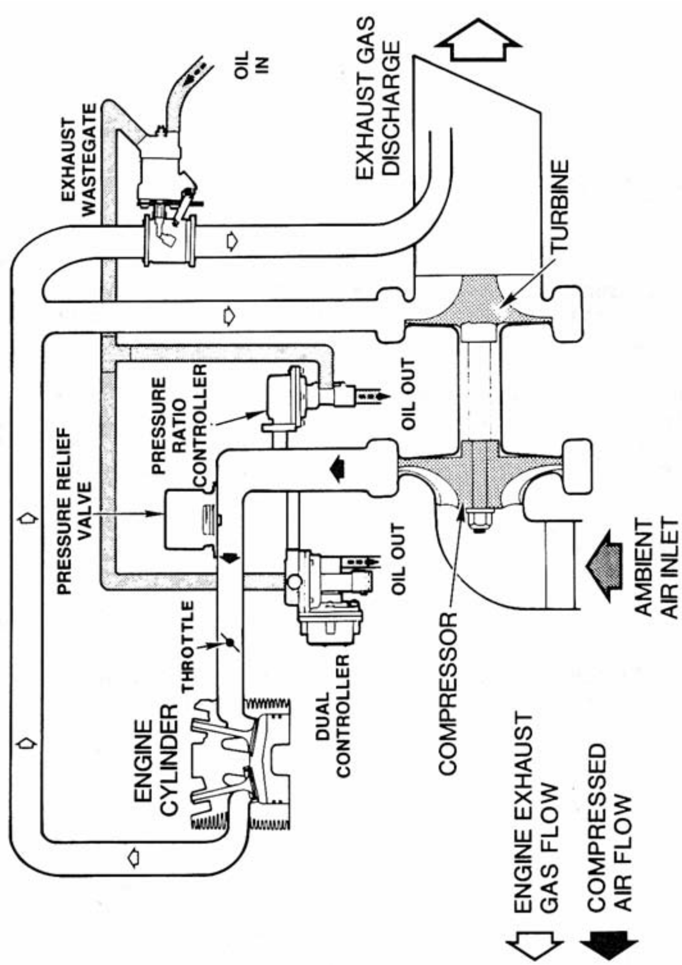

Table 5 - Dual Absolute / Rate Control System With Pressure Ratio Control Applications

System Specifics:

Aircraft	Engine	Turbocharger	L-Wastegate	R-Wastegate	Controller	2nd Controller	PRV
Cessna 411/411A ’65-’68	GTSIO-520-C	404360-4 630374-4	470780-13 5050154-13	470780-14 5050154-14	470782-3 C165004-0101	470822-1 C165004-0401	None
Cessna ’66-’68 320 D-F Skyknight	TSIO-520-B	406610-9025 632729-11	470780-14 5050154-14	470780-13 5050152-13	470782-3 C165004-0101	470822-1 C165004-0401	470930-1 C482002-0101
Cessna 401/402 ’67-’68	TSIO-520-E	406610-9025 632729-11	470780-15 5050154-15	470780-16 5050152-16	470782-3 C165004-0101	470822-1 C165004-0401	470930-4 C482002-0103

DUAL ABSOLUTE / PRESSURE RATIO CONTROL SYSTEM:

Installation Features:

1973-'75 Cessna T310; 1980-Up Cessna 335; 1973-75 Cessna Turbo 340; 1970-72 Cessna 401B; and 1970-78 Cessna 402B: Turbochargers mounted above engine oil level. Scavenged oil system.

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

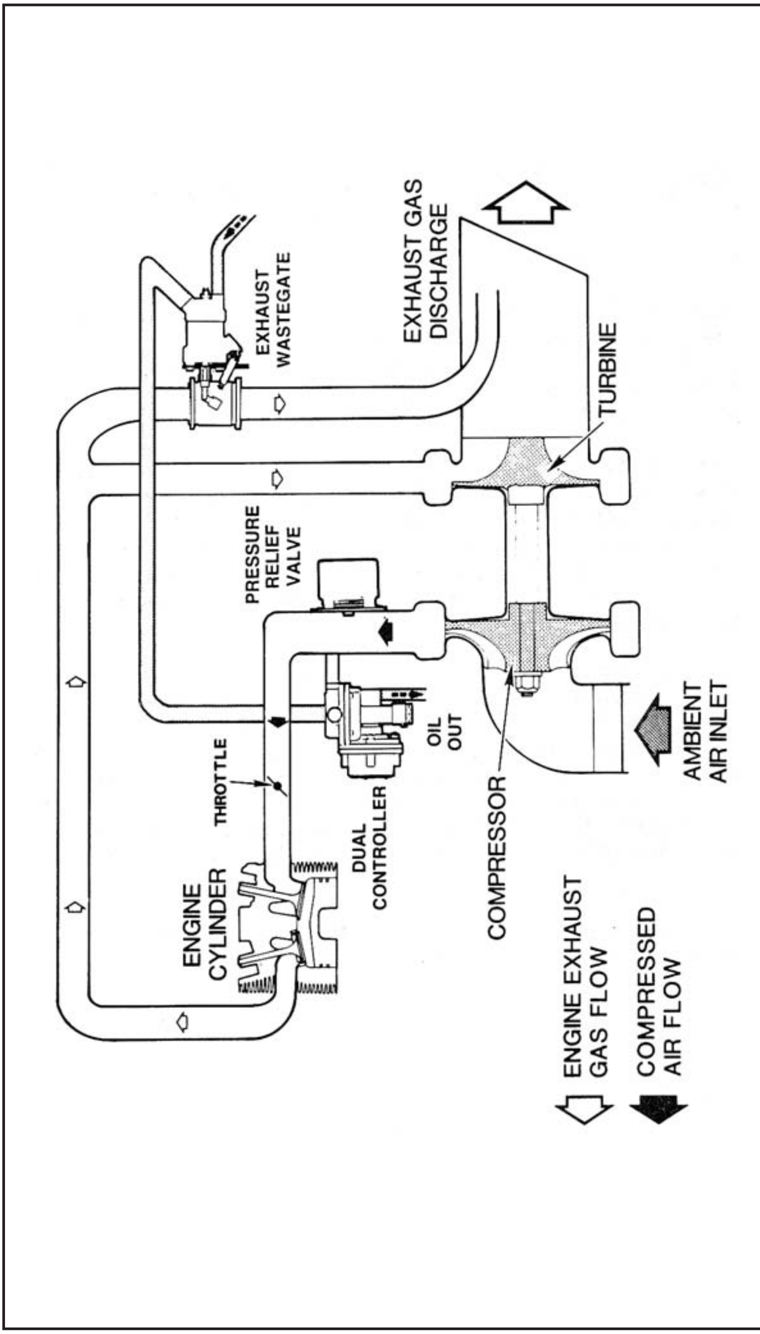

Table 6 - Dual Absolute / Pressure Ratio Control System Applications

System Specifics:

Aircraft	Engine	Turbocharger	L-Wastegate	R-Wastegate	Controller	PRV
Cessna ’73-75 Turbo. 310 P-Q	TSIO-520-B	406610-9025 632729-11	470780-14 5050154-14	470780-13 5050154-13	470948-1 C165002-0102	470930-1 C482002-9010
Cessna ’80-Up 335	TSIO-520-E	406610-9025 632729-11	470780-15 5050154-15	470780-16 5050154-16	470948-1 C165002-0102	470930-4 C482002-0103
Cessna ’73-’75 340	TSIO-520-K	470810-1 635630	470908-6 C165006-0104	470908-6 C165006-0104	470934-1 C165002-0101	470930-17 637583-17
Cessna ’70-'78 401B/402B	TSIO-520-E	406610-9025 632729-11	470780-15 5050154-15	470780-16 5050154-16	470948-1 C165002-0102	470930-4 C482002-0103

DENSITY CONTROL SYSTEM (FIXED WING):

Installation Features:

Piper Aztec; Aerospatiale Trinidad TC; Lake 250 Renegade: Turbocharger mounted below engine oil level. Scavenged oil system with oil inlet check valve and oil out accumulator.

Piper Navajo and Chieftain: High mounted turbochargers with gravity drain oil system.

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

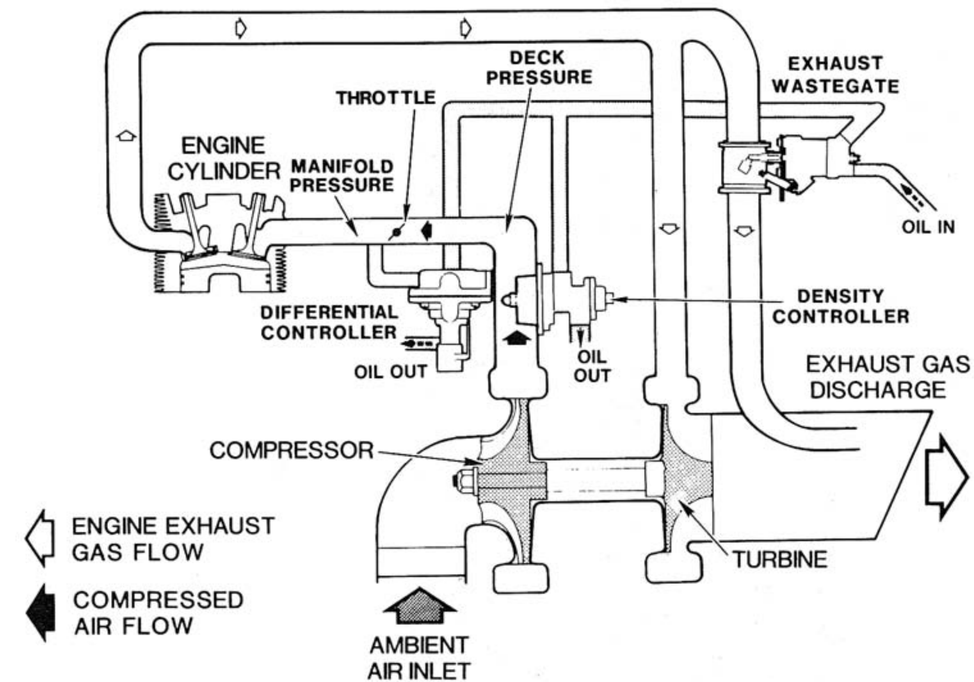

Table 7 - Density Control System (Fixed Wing) Applications

System Specifics:

Aircraft	Engine	Turbocharger	Wastegate	Controller	2nd Controller	Intercooler
Aerospatiale Trinidad TC	TIO-540-AB1AD	406610-31 LW-19330	470954-5 LW-18861	470884-4 LW-10682	470912-3 LW-19193	
Aztec E-F ‘70-Up	TIO-540-C1A	406610-21 LW-12950	470818-3 LW-12778	470884-4 LW-10682	470886-2 LW-10098	
Chieftain ‘73-Up	TIO-540-J2BD	409170-1 LW-12463	470818-3 LW-12778	470884-10 LW-16840	470886-2 LW-10098	
Lake 250 Renegade	TIO-540-AA1AD	406610-32 LW-19174	470954-5 LW-18861	470884-4 LW-10682	470886-2 LW-10098	
Mooney M-20M TLS	TIO-540-AF1A	466011-2 46C19836	470954-5 LW-18661	470884-4 LW-10682	470886-2 LW-10098	42K19837
Mooney M-20M TLS Bravo	TIO-540-AF1B	466011-2 46C19836	470954-5 LW-18661	470884-4 LW-10682	470886-2 LW-10098	42K19837
Navajo ‘67-’71	TIO-540-A1A, A2A	406610-20 LW-12689	470818-3 LW-12778	470654-1 75992	470912-1 LW-10644	
Navajo ‘67-’71	TIO-540-A1B, A2B	406610-20 LW-12689	470818-3 LW-12778	470884-2 78451	470912-1 LW-10644	

Table 7 - Density Control System (Fixed Wing) Applications (Cont.)

System Specifics:

Aircraft	Engine	Turbocharger	Wastegate	Controller	2nd Controller	Intercooler
Navajo ‘71-Up	TIO-540-A2C	406610-20 LW-12689	470818-3 LW-12778	470884-5 LW-12067	470912-1 LW-10644	
Navajo C/R ‘75-Up	TIO-540-F2BD	406610-20 LW-12689	470818-10 LW-14283	470884-8 LW-11801	470912-1 LW-10644	
Rockwell Commander 114TC	TIO-540-AG1A	466011-2 46C19836	470954-5 LW-18661	470884-4 LW-10682	470886-4 48B21935	
Socata Trinidad TC TB-21 TC	TIO-540-AB1AD	406610-31 LW-19330	470954-5 LW-18661	470884-4 LW-10682	470912-3 LW-19193	

DENSITY CONTROL SYSTEM (ROTARY WING):

Installation Features:

1961-75 Bell 47G3B Helicopter; Hiller SL-4 Helicopter: Dry-sump, vertical-mount engine. Scavenged oil system with check valves in oil inlet and outlet lines. Controllers use hydraulic system oil rather than engine oil.

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

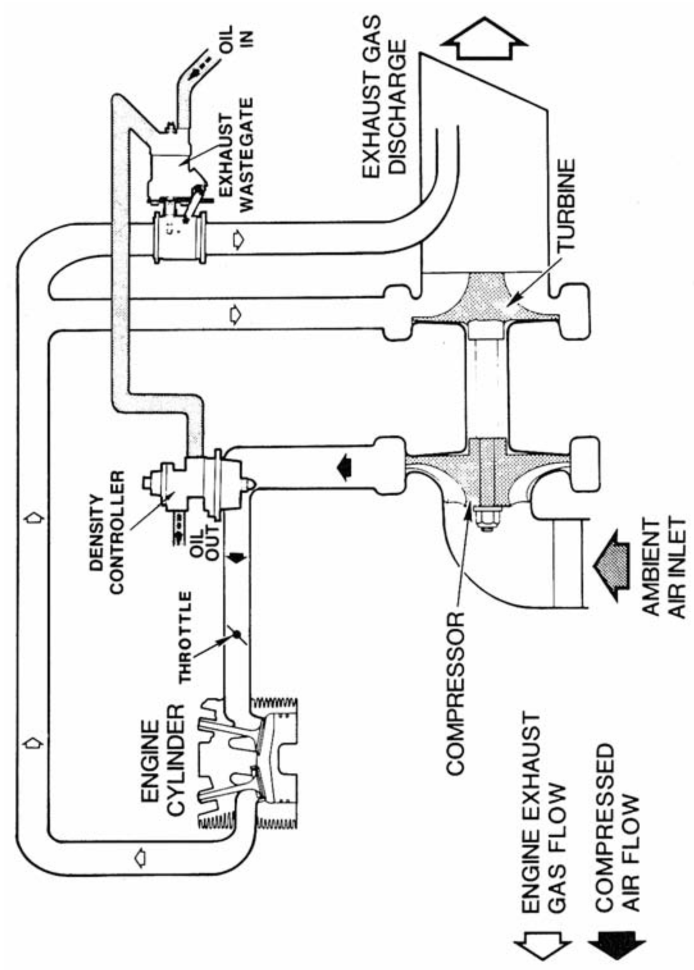

Table 8 - Density Control System (Rotary Wing) Applications

System Specifics:

Aircraft	Engine	Turbocharger	Wastegate	Controller
Bell 47G3B ’61-’62	TVO435A1A	404460-2 77692	470622 73785	470620 73784
Bell 47G3B ’63-’67	TVO435B1A/B1B	404460-2 77692	470622-1 74422	470620-1 74423-1
Bell 47G3B ’63-’67	TVO435D1A/D1B	406610-15 LW13112	470818-1 76649-1	470620-2 74423-2
Bell 47G3B ’68-’71	TVO435G1A	406610-15 LW13112	470818-1 LW12778	470620-3 74423-3
Bell 47G3B ’72-’73	TVO435F1A	406610-15 LW13112	470818-1 76649-1	470620-3 74423-3
Hiller UH12L(4)	TIVO540A2A	404830-1 73895	470656 73897	470654 73898

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

Installation Features:

1967-70 Mooney Mustang: Turbocharge mounted above engine oil level. Return oil gravity drained.

1985-Up Cessna T210R; P210R; and Mooney 252: Low-mounted turbocharger. Scavenge oil system with check valve in oil return line.

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

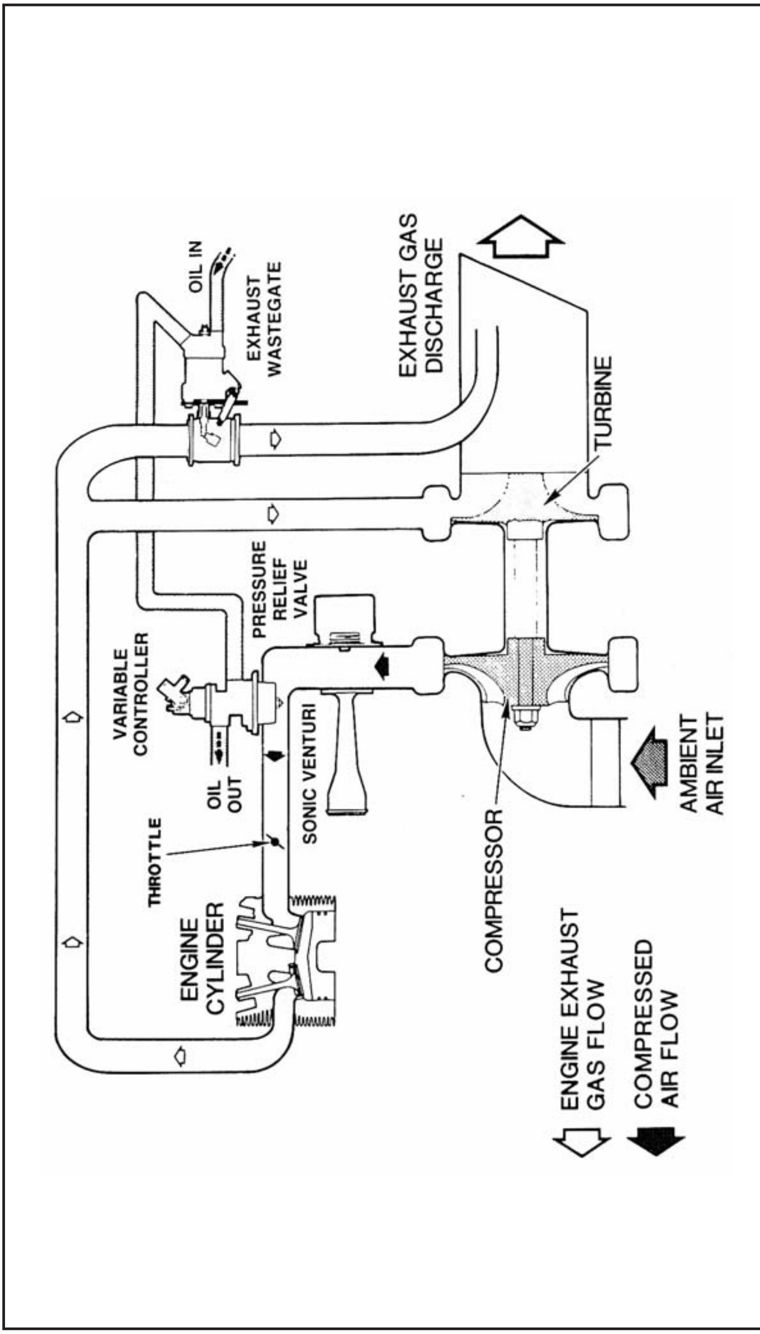

Table 9 - Variable Absolute Pressure System (Single Engine, Without Cover) Applications

System Specifics:

Aircraft	Engine	Turbocharger	Wastegate	Controller	PRV	Venturi	Intercooler
Cessna '85-Up P210R/T210R	TSIO520CE	465448-4 C295001-0203	481064-4 C165006-0115	481008-26 C165004-0605	470944-15 C482003-0110	Customer Supplied	491910-2 (Same)
Mooney '67-70 Mustang M22	TIO541A1A	406110-5 LW11968	470872-1 77676	481008-9 LW14299	Not Used	470824 75994	Not Used
Mooney '85-Up 252	TSIO360MB	466642-1 649151-1	470842-7 649006-7	481008-28 640655-28	481066-3 643511-3	Not Used	492110-2 649012

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

Installation Features:

All Lycoming Engine Systems (Except Piper Mojave): High-mounted turbochargers with gravity drain oil systems.
All Continental Engine Systems (Except Cessna Skymaster): High-mounted turbochargers with scavenge oil systems.
Cessna Skymaster: Low-mounted turbochargers with scavenged oil systems and oil inlet and outlet check valves.
Piper Mojave: High-mounted turbochargers with intercooler. Scavenged oil system.
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

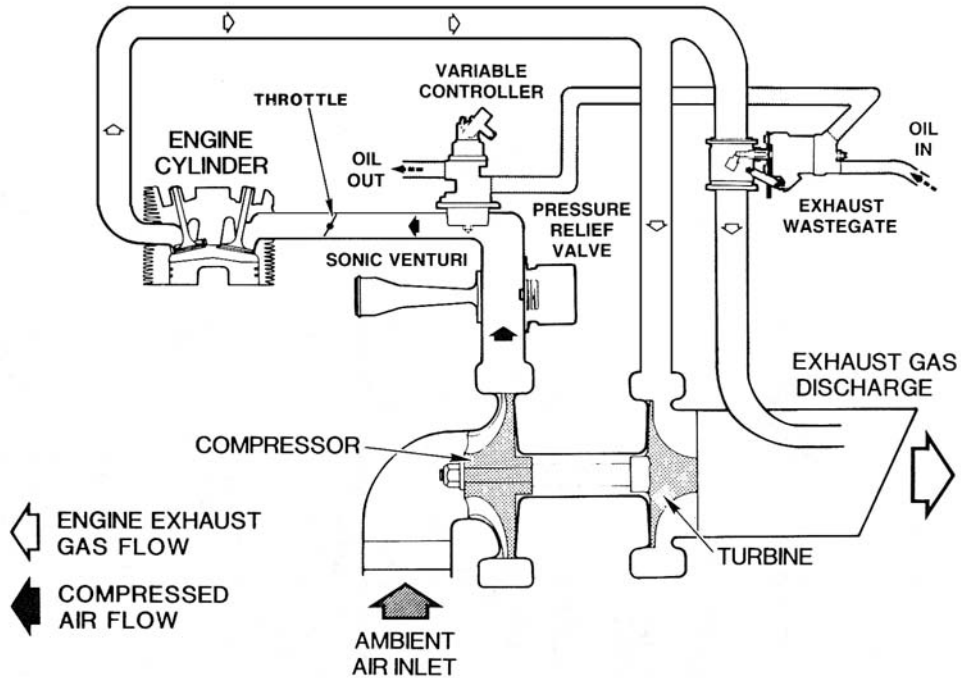

Table 10 - Variable absolute Pressure System (Twin Engine, Without Cover) Applications

System Specifics: * Left or Front Engine. ** Right or Rear Engine.

Aircraft	Engine	Turbocharger	WG (L / F)*	WG (R / R)**	Controller	PRV	Venturi	Intercooler
Beech ’69-’72 Duke	TIO-541-E1A4	406110-7 LW-13309	470864-1 77551	470864-1 77551	481008-8 LW-14297	470944-7 LW-14445-2	470868-1 77796	Not Used
Beech ’73-Up Duke	TIO-541-E1C4	470540-3 LW-13310	470818-5 LW-10759	470818-5 LW-10759	481008-8 LW-14297	470944-7 LW-14445-2	470868-1 77796	Not Used
Beech Baron 56TC	TIO-541-E1B4	406110-7 LW-13309	470864-1 77551	470864-1 77551	481008-8 LW-14297	None	None	Not Used
Cessna RT337G Reims Skymaster	TSIO-360-D	406970-1 C295001-0102	470842-3 C165006-0303	470842-4 C165006-0304	481008-17 C165004-0603	470944-12 C482002-0108	Not Used	Not Used
Cessna ’73-’80 Skymstr., Press. T337G	TSIO-360-C/F/R	406610-18/22 C295001-0103 C295001-0108	470842-3 C165006-0303	470842-4 C165006-0304	481008-17 C165004-0603	470944-3 C482002-0107	Customer Supplied	Not Used
Cessna ’77-Up Titan (404)	GTSIO-520-M	465930-2 641672-2	470908-15 C165006-0109	470908-15 C165006-0109	470836-19 633388-11	470930-5 C482002-0104	Not Used	Not Used
Cessna ’76-Up 340A	TSIO-520-NB, N	407810-1 635630	470908-12 C165006-0106	470908-13 C165006-0107	470836-18 633388-10	470944-15 C482002-0110	Customer Supplied	Not Used
Cessna ’79-Up 402C	TSIO-520-VB	406610-28 632729-12	470908-13 C165006-0107	470908-13 C165006-0107	470836-21 C165004-0604	470944-15 C482002-0110	Not Used	Not Used
Cessna ’70-’75 414	TSIO-520-J	407810-1 635630	470908-12 C165006-0106	470908-13 C165006-0107	470836-1 633388-3	470930-6 C482002-0105	Customer Supplied	Customer Supplied

Table 10 - Variable absolute Pressure System (Twin Engine, Without Cover) Applications (Cont’)

System Specifics: * Left or Front Engine. ** Right or Rear Engine.

Aircraft	Engine	Turbocharger	WG (L / F)*	WG (R / R)**	Controller	PRV	Venturi	Intercooler
Cessna ’76-Up 414	TSIO-520-N	407810-1 635630	470908-12 C165006-0106	470908-13 C165006-0107	470836-18 633388-10	470944-15 C482002-0110	Customer Supplied	Customer Supplied
Cessna ’78-Up 414A	TSIO-520-N	407810-1 635630	470908-12 C165006-0106	470908-13 C165006-0107	470836-20 642247	470944-15 C482002-0110	Customer Supplied	Customer Supplied
Cessna Riley 414 STC	IO-720-B	406610-27	470908-18	470908-18	470794-1	470860-3	Customer Supplied	Customer Supplied
Cessna ’68-’69 421A	GTSIO-520-D	406990-4 633274-4	470830-10 C165006-0401	470830-20 C165006-0402	470836-3 633388-9	470930-5 C482002-0104	Customer Supplied	Customer Supplied
Cessna ’70-’75 421B	GTSIO-520-H	408610-1 637374-1	470830-10 C165006-0401	470830-20 C165006-0402	470836-3 633388-9	470930-5 C482002-0104	Customer Supplied	Customer Supplied
Cessna ’76-Up 421C	GTSIO-520-L, N	C465930-3 641672-3	481064-1 C165006-0113	481064-1 C165006-0113	470836-3 633388-9	481040-1 C482002-0111	Customer Supplied	Customer Supplied
Mooney Encore	TSIO-360-SB	466642-1 649151-1	470842-7 649006-7		481008-28 649362-1	481066-3 643511-3	Not Used	Not Used
Piper Malibu Mirage	TIO-540-AE2A	466642-5 (2) 46C19839	470954-7 47E21296		481008-33 48E21383	470944-7 LW-14445-2	Customer Supplied	Customer Supplied

Table 10 - Variable absolute Pressure System (Twin Engine, Without Cover) Applications (Cont')

System Specifics: * Left or Front Engine. ** Right or Rear Engine.

Aircraft	Engine	Turbocharger	WG (L / F)*	WG (R / R)**	Controller	PRV	Venturi	Intercooler
Piper Mojave	TIO-540-V2AD	465680-5 LW-18470	470954-5 LW-18861	470954-5 LW-18861	481008-25 LW-18518	470944-10 LW-14445-4	Customer Supplied	491670-2 LW-18822
Piper '70-'77 PR Navajo	TIGO-541-E	407800-3 LW-13234	470818-5 LW-10759	470818-5 LW-10759	481008-10 LW-14298	470944-11 LW-14445-3	Customer Supplied	Not Used
Piper Seneca V	L/TSIO-360-RB	466642-2 649151-2	470842-8 649006-8	470842-8 649006-8	470836-19 649362-3	481066-3 643511-3	Not Used	Not Used
Rockwell 700 Commander	TIO-540-R2AD	465680-1 LW-13897	470954-1 LW-12960	470954-1 LW-12960	481008-20 LW-16060	470944-22 LW-14445-6	Not Used	Not Used

VARIABLE ABSOLUTE PRESSURE SYSTEM (WITH COVER):

Installation Features:

Beechcraft (Raytheon) Bonanza; Cessna Skymaster: Turbochargers mounted below engine oil level. Scavenged oil system with oil inlet and outlet check valves.

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

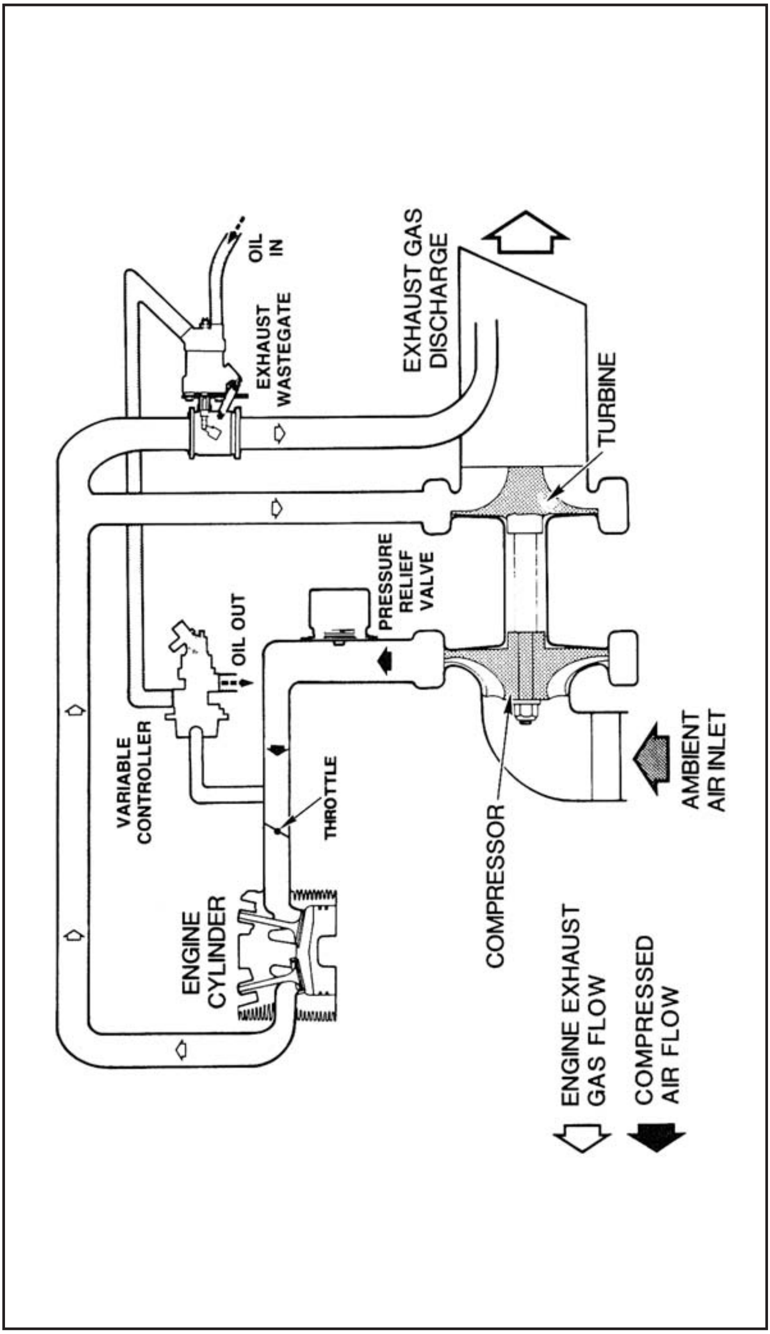

Table 11 - Variable Absolute Pressure System (With Cover) Applications

System Specifics: * Left or Front Engine. ** Right or Rear Engine.

Aircraft	Engine	Turbocharger	WG (L / F*)	WG (R / R**)	Controller	PRV
Beech Bonanza A36TC, B36TC	TSIO-520-U	406610-29 632729-13	470908-17 636188-17	Not Used	481012-6 642628-6	470944-26 639319-26
Beech V35 Bonanza	TSIO-520-D	406610-1 632729-1	470818-2	Not Used	481012-2	Not Used
Beech Turbo Bonanza	TSIO-520-UB	406610-29 632729-13	470908-17 636188-17	Not Used	481012-6 642722-1	470944-26 639319-26
Cessna T337 Skymaster	TSIO-360-JB	465292-5 C295001-0305	470842-3 C165006-0303	470842-4 C165006-0304	481012-5 C165004-0204	470944-3 C482002-0107
Cessna ’78-’80 Skymaster	TSIO-360-H	465292-1 C295001-0301	470842-3 C165006-0303	470842-4 C165006-0304	481012-3 C165004-0202	470944-19 C482002-0112

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VARIABLE ABSOLUTE CONTROL SYSTEM WITH RATE CONTROL:

Installation Features:

Cessna 337: Low-mounted turbochargers with scavenged oil system. Oil inlet and outlet check valves.

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.

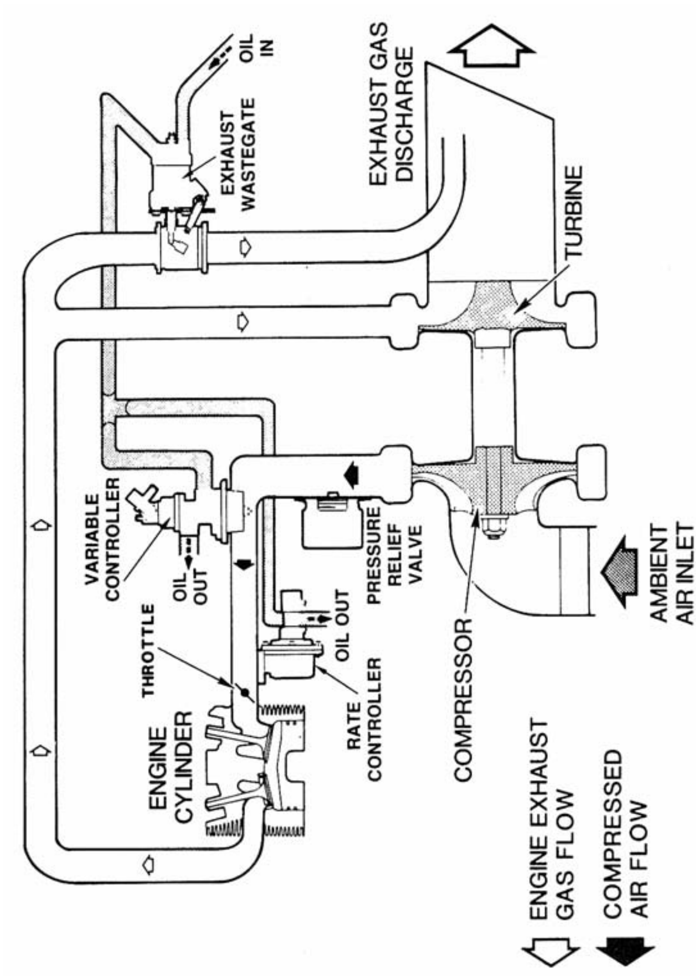

Figure 12 - Variable Absolute Pressure System With Rate Control Schematic

Table 12 - Variable Absolute Pressure System with Rate Control Application

System Specifics: * Left or Front Engine. ** Right or Rear Engine.

Aircraft	Engine	Turbocharger	WG (L / F)*	WG (R / R)**	Controller	2nd Controller	PRV
Cessna '67-'71 337	TSIO360A/360B	406970-1 C295001-0102	470842-3 C165006-0303	470842-4 C165006-0304	481012-1 C165004-0203	470838-1 C165004-0301	470930-2 C482002-0102

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VARIABLE ABSOLUTE PRESSURE SYSTEM WITH POPPET-TYPE WASTEGATE:

Installation Features:

1976-Up Beechcraft (Raytheon) Baron: High-mounted turbochargers with scavenged oil system.
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

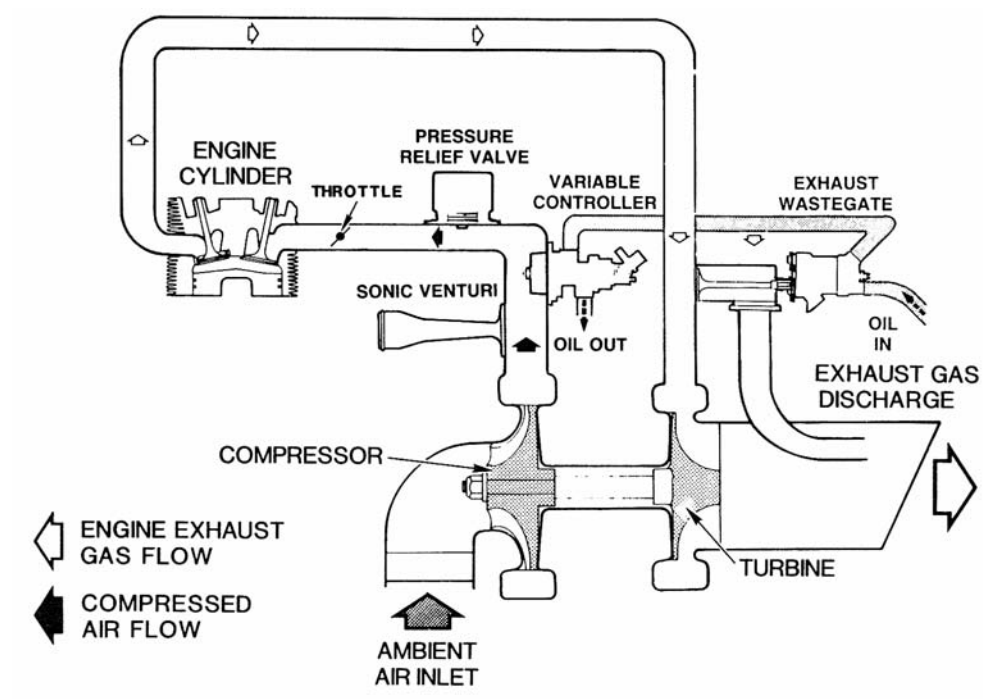

Table 13 - Variable Absolute Pressure System With Poppet-Type Wastegate Applications

System Specifics: * Venturi Dumps Overboard.

Aircraft	Engine	Turbocharger	Wastegate	Controller	Turbo W/O WG	PRV	Venturi
Beech '76-'78 Baron	TSIO-520-L	409680-1 640327-1	470892-2 635381-2	481008-2 640655-2	409680-11 640327-11	470944-9 639319-9	Customer Supplied*
Beech '76-'78 Press. Baron	TSIO-520-L	409680-1 640327-1	470892-2 635381-2	481008-2 640655-2	409680-11 640327-11	470944-9 639319-9	Customer Supplied
Beech '79-Up Baron	TSIO-520-WB	409680-1 640327-1	470892-2 635381-2	481008-22 640655-22	409680-11 640327-11	470944-34 639319-34	Customer Supplied*
Beech '79-Up Press. Baron	TSIO-520-WB	409680-1 640327-1	470892-2 635381-2	481008-22 640655-22	409680-11 640327-11	470944-34 639319-34	Customer Supplied
Rockwell Commander 685	GTSIO-520-F, K	408590-2 635034-2	470892-1 635381-1	481008-4 640655-4	408590-12 635034-12	470944-1 639319-1	Not Used

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SLOPED CONTROL SYSTEM:

Installation Features:

Cessna T182T, T206, T303 and 1982-'84 Cessna P210: Low-mounted turbochargers with scavenged oil system.
Lancair IV & IVP: Twin Turbocharger
Piper Malibu & Malibu Conversion: Twin low-mounted turbochargers with scavenged oil system.
Piper Saratoga TC

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 pre-determined 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

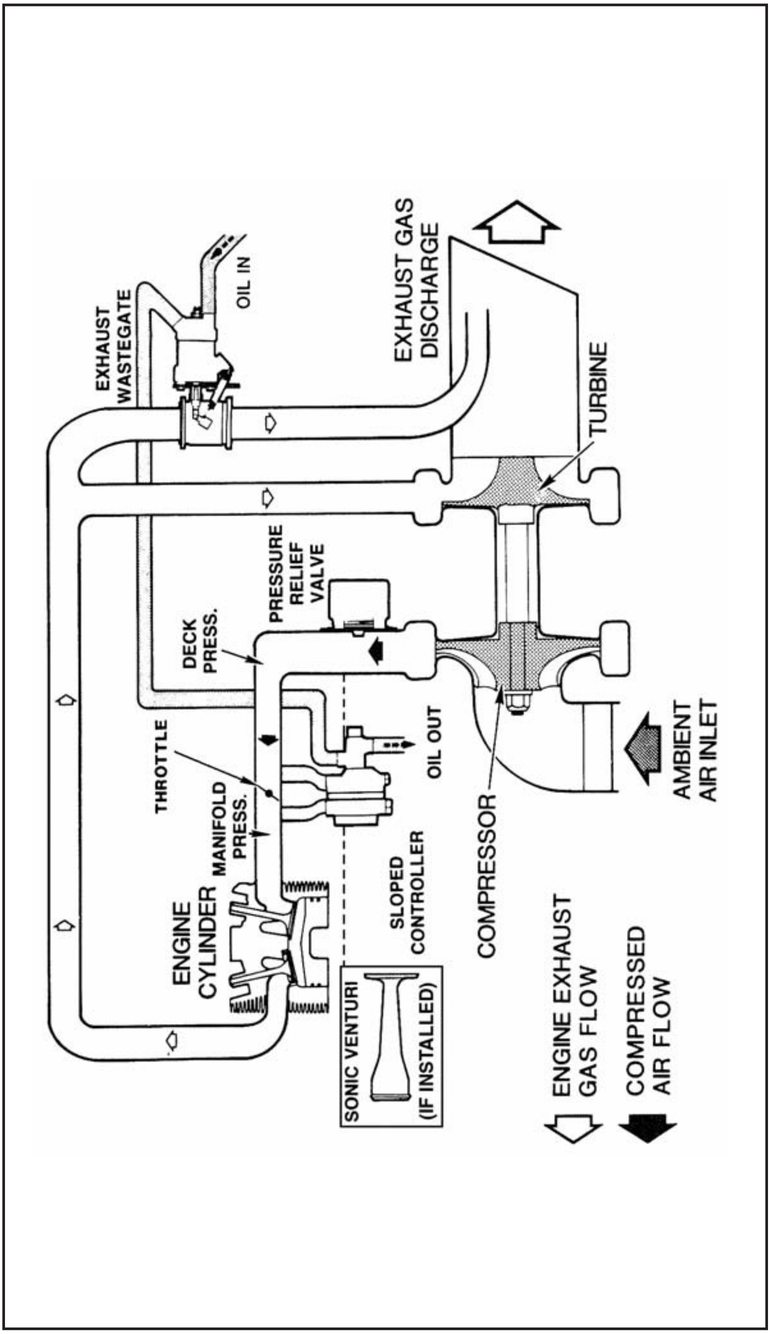

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Table 14 - Sloped Control System Applications

System Specifics: *** R & L refers to turbocharger location on Piper Malibu engine.**

Aircraft	Engine	L-Turbo*	R-Turb*	Wastegate	Controller	PRV	Sonic Venturi	Intercooler
Cessna Crusader	L/TSIO-520-AE	406610-30 C295001-0501	N/A	470954-3 C165006-0601	481058-1 C165004-0701	470944-20 C482002-0113		
Cessna ’82-’84 Centurion P210	TSIO-520-AF	465680-4 C295001-0202	N/A	470908-20 C165006-0114	481058-2 C165004-0702	470944-12 C482002-0108		
Cessna T-206 Stationair	TIO-540-AJ1A	466881-1 46P22250	N/A	470954-5 LW-18661	481058-5 48B22314	470944-30 LW-14445-11		
Lancair IV & IVP	TSIO-550-B	(2) 466304-3 646667	N/A	470908-17 636188-17	481058-4 646318-4	470944-34 639319-34	Customer Supplied	(2) 646462
Lancair IV & IVP	TSIO-550-E	(2) 466304-3 646667	N/A	481064-1 646317	481058-4 646318-4	470944-26 639319-26	Customer Supplied	(2) 646462
Piper Malibu	TSIO-520-BE	466304-2 646316	466304-1 646315	481064-2 646317	481058-3 646318	470944-9 639319-9	Customer Supplied	Customer Supplied
Piper Malibu Conversion	TSIO-550-C	(2) 466304-3 646677	N/A	481064-1 646317	481058-4 646318-4	470944-26 639319-26	Customer Supplied	(2) 646462
Piper Saratoga TC PA-32-301T	TIO-540-AH1A	466011-2 46C19836	N/A	470954-9 47J22459	481058-7 48B22488	470944-40 LW-14445-12		
Cessna Turbo. Skylane	TIO-540-AK1A	466642-6 46C22924	N/A	470954-1 LW-12960	48B22970	LW-14445-10	N/A	

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PRESSURE RELIEF VALVE CONTROL SYSTEM:

Installation Features:

Enstrom; Mooney 231; Piper Arrow, Dakota and Seneca: Engine fitted with Hartzell Engine Technologies (HET) turbocharger and HET pressure relief valve only.
Cessna Ag Husky; Page: Engine fitted with Hartzell Engine Technologies turbocharger and HET pressure relief valve only.

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

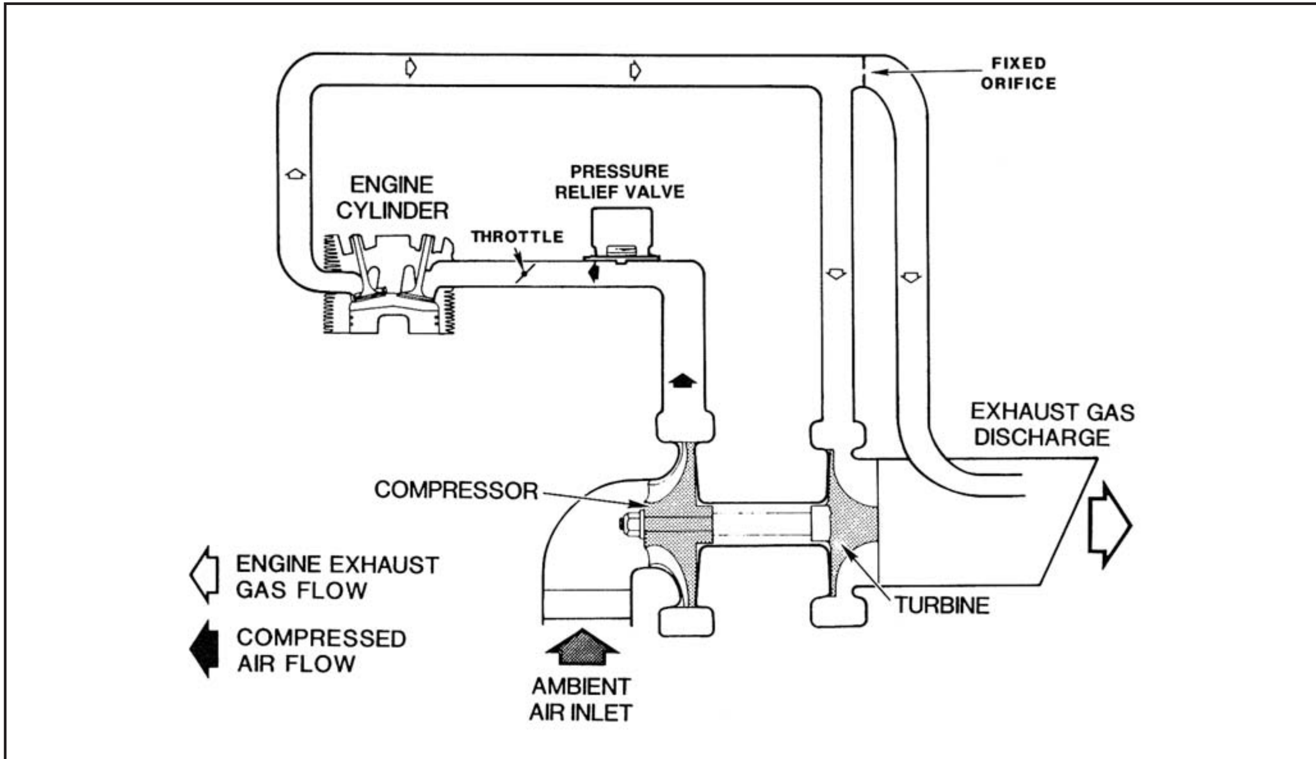

Table 15 - Pressure Relief Valve Control System Applications

System Specifics:

Aircraft	Engine	Turbocharger	PRV
Bellanca	IO-540-G1E5, K1E5	CF600572 3DT5FF10J2	470930-16 7110067
Cessna AG Husky	TSIO-520-T	465292-4 642518-4	70944-24 639319-24
Enstrom Shark	HIO-360	600700 3BT5EE10J2	470944-18
Mooney 201	IO-360-A3B6D	CF600573	470944-25
Mooney 231	TSIO-360-GB	CF600573 646396	481028-2 641404-2
Mooney 231	TSIO-360-LB	CF600573 646396	481066-3 643511-3
Page	R755S/(M)	480250-4 4885-1	470944-2 4884-1
Piper Arrow / Dakota	TSIO-360-F	CF600573 646396	481028-1 641404-1
Piper Seneca II	L/TSIO-360-E/EB	CF600573 646396	481028-1 641404-1
Piper Seneca III	L/TSIO-360-KB	CF600573 646396	481066-1 643511-1

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MANUAL WASTEGATE CONTROL SYSTEM WITH PRESSURE RELIEF VALVE:

Installation Features:

Cessna Turbo Skylane: Low-mounted turbocharger with scavenged oil system. Manual, throttle-linked wastegate.
Piper Lance and Saratoga: Low-mounted turbocharger with scavenged oil system. Manual, throttle-linked wastegate.

Component Operation:

Wastegate directly and/or proportionately linked to throttle. Requires continuous throttle management to maintain 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

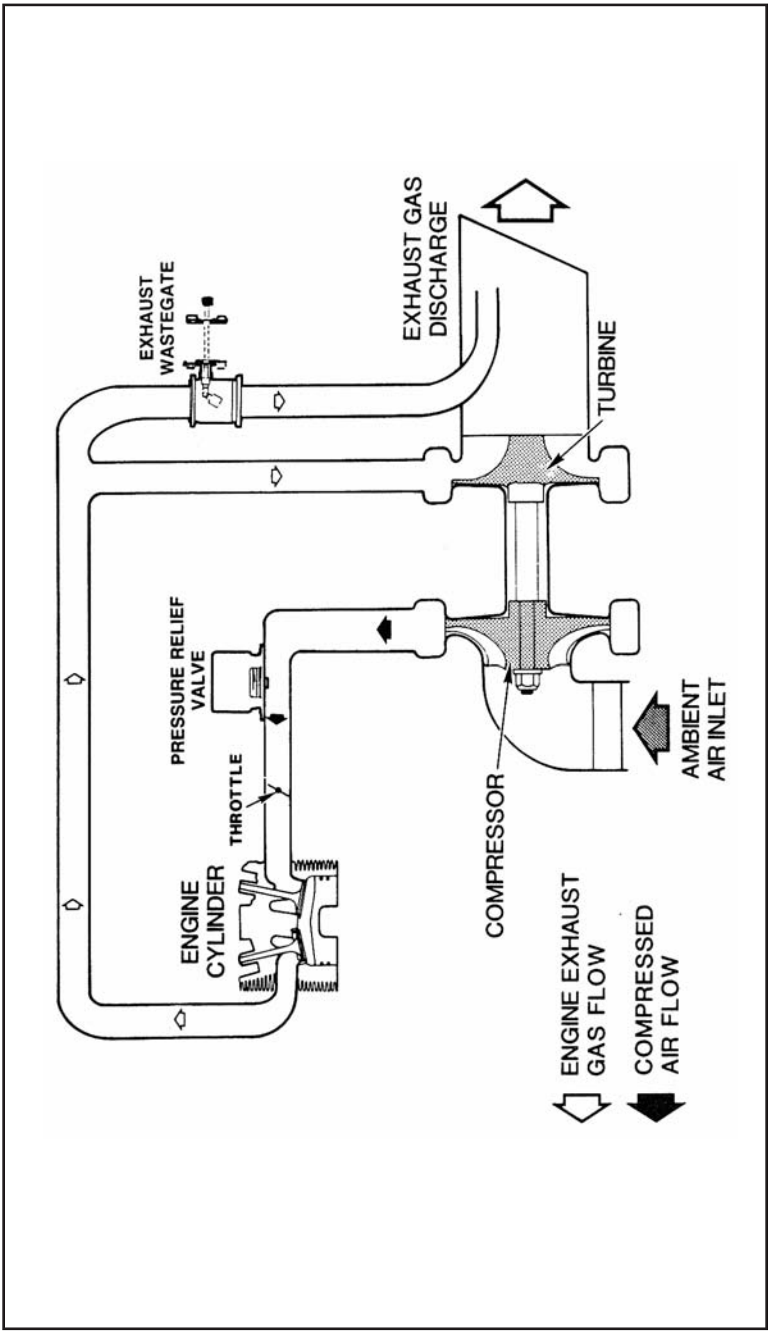

Table 16 - Manual Wastegate Control System With Pressure Relief Valve Applications

System Specifics:

Aircraft	Engine	Turbocharger	Wastegate	PRV
Cessna Turbo. Skylane	0-540-L3C5D	465292-2 C295001-0304	481044-2 C165006-0502	470944-20 C482002-0113
Piper Lance; Saratoga	TIO-540-SIAD	406610-26 LW15749	Textron Lycoming	470944-29 LW14445-10

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Introduction To Troubleshooting 4

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Introduction To Troubleshooting 4

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

Hartzell Engine Technologies' (HET) stringent quality controls make it highly unlikely that a turbocharger could leave the factory incorrectly assembled, or not up to specifications. A "bad" 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 troubles in which turbocharger system malfunction is originally suspected.

The overall objective of troubleshooting is to find the cause of trouble and take corrective action to prevent a recurrence. This objective must be kept in mind even while determining whether anything is actually wrong with the turbocharger system components, and just what is wrong, to enable repairs. Even perfectly operational turbocharger system components cannot compensate for incorrect engine operating procedures, for deficiencies in the engine oil supply, oil drain, ignition, air induction, fuel, or 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 try to find the cause of engine malfunctions before removing or disassembling the turbocharger system components: i.e., to leave the evidence intact. For instance, if there are loose connections permitting leakage from the compressor, this can be discovered only if the connections are checked for looseness 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 trouble which seems to be related to turbocharger-supplied air, and if applicable, the specific flight conditions in which the malfunctions occurred, such as altitude, engine rpm, manifold pressure, and fuel flow.

b. Carry out the systematic “Pre-Troubleshooting Inspection,” below, which may correct the trouble 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 aircraft cannot reach critical altitude.

b. Oil leakage into engine intake air or exhaust.

c. Engine overboosts.

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 malfunctions for which troubleshooting would otherwise be necessary. 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 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 17 - 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 inside scorching of 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 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, or constant leakage. Temporarily disconnect the line if necessary. If there is such leakage, disassemble the actuator and check for cylinder wall scoring. If there is no scoring, replace the actuator piston packing in accordance with the engine 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 noncaustic 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.

j. Use a noncaustic 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, but 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 non-operative period.

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, below, for the condition, "Turbocharger Shaft Bearings, Journals or Bearing Bores Worn," and 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 shaft end, rotate the wheel by hand while pressing the rotating assembly toward the turbine end of the turbocharger. Rock 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 shaft end, rotate the wheel by hand while pressing the rotating assembly toward the compressor end of the turbocharger; also rock shaft up and down. Look for oil in the turbine wheel and its housing indicative of seal leakage, and 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, as applicable, 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, and 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, trouble-shooting 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, however, 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, for the most part, until all in-place inspections have been performed. Table 18 is a list of troubleshooting procedure notes which are referred to in the troubleshooting charts as supplementary information.

Table 18 - 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; at other air-sensing lines or ports; or, for a duct-mounted controller without a cover, by removing the controller and inspecting the bellows area. Repair or replace.

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 refer to KAPS SB 023 "Turbocharger System Operatinal Tests" latest revision.

D. Inspect the interior of the turbocharger center housing by removing the oil drain and looking in through the oil drain opening. When a sludged or coked condition exists, sludge builds 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.

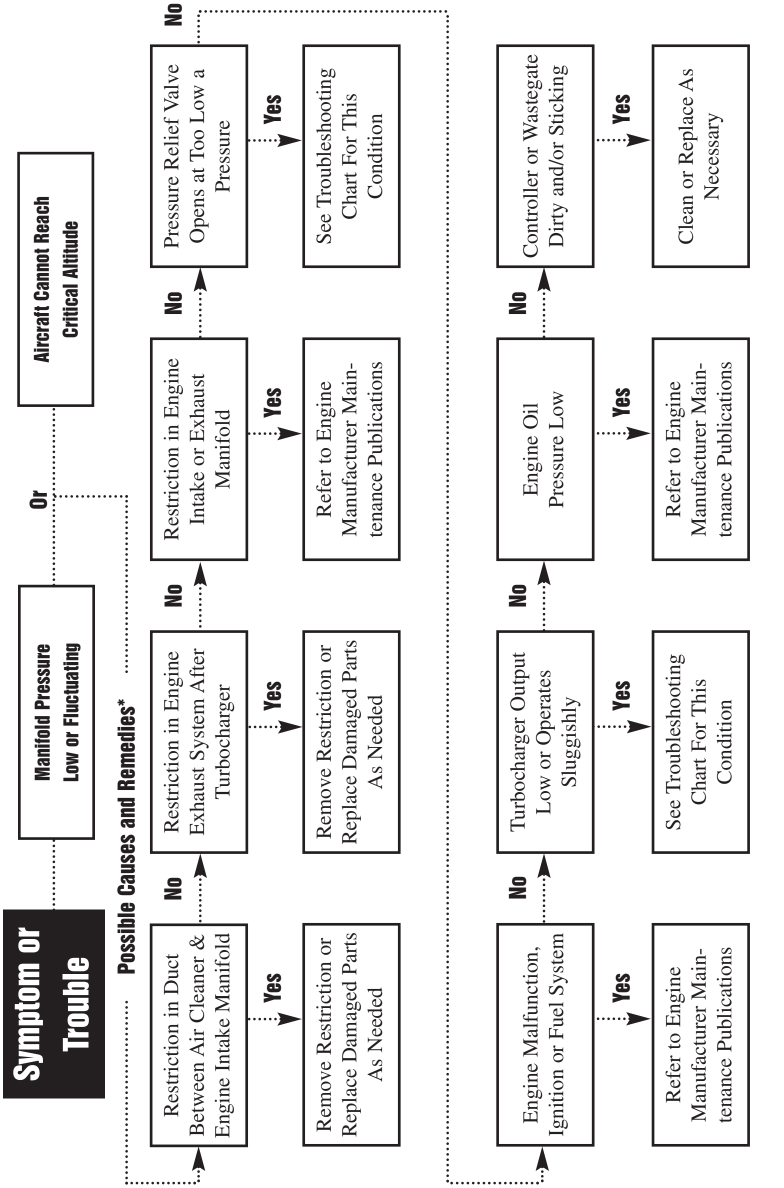
E. Detect abnormal wear in the turbocharger shaft bearings, journals, or bearing bores by performing the "Bearing Clearance Inspection" found in Chapter 2 of the latest revision of the HET Aircraft Turbocharger Overhaul Manual P/N 400600-0000.

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, using a light to see the turbine wheel blade tips from the housing outlet. Exserting uniform pressure, rotate the wheels by hand while pressing the rotating assembly toward each end. There should be no binding, rubbing, or other interference with free rotation.

G. Thoroughly clean the air induction and exhaust system following compressor wheel damage by foreign object impact. Change the air cleaner element so that any metal pieces embedded in the air cleaner element are not drawn into the replacement turbocharger.

H. Whenever oil contamination is indicated or suspected, Hartzell Engine Technologies 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 together 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, obviously must 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.

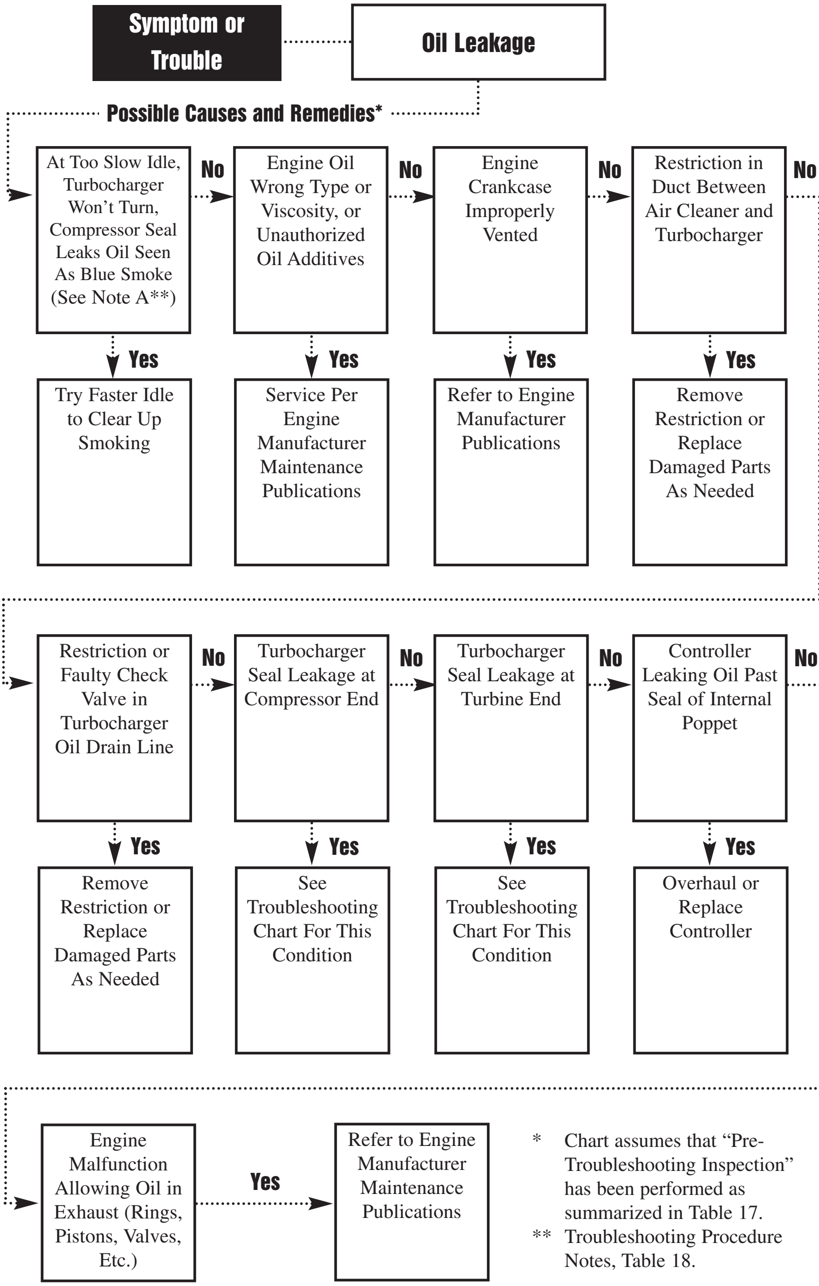
d. Malfunctions in the engine ignition for fuel system can, of course, also affect the efficiency of the air-fuel combustion. Correct them per the engine manufacturer maintenance publication.

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

Oil Leakage (See Figure 18):

The Turbocharger system is a possible source of oil leaks because it is connected to the engine lubricating oil system for lubricant/coolant in the turbocharger directly, and for power fluid in the exhaust bypass valve and controller(s). "Pre-Troubleshooting Inspection" includes checks for oil leakage at oil supply and drain lines and connections, and eliminates several possible defects which can help to cause oil leakage from the

Figure 18 - Troubleshooting - Oil Leakage



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

** Troubleshooting Procedure Notes, Table 18.

turbocharger system components: a clogged air cleaner, loose connections on the duct from the compressor to the intake manifold, and leakage at the intake manifold. 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 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. Also 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 a restriction 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 Overboosts (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 engine is known to have overboosts, consult engine manufacturer's instructions for inspection(s) required before engine may be operated again.

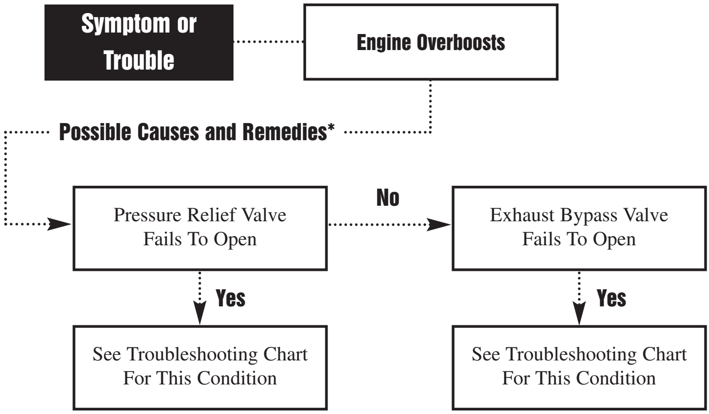
a. Some engines include a pressure relief valve in the turbocharger system, preset to crack open when compressor discharge pressure reaches a value slightly above the rated manifold pressure. If this relief valve fails to open, overboost can occur. See the troubleshooting chart for “Pressure Relief Valve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

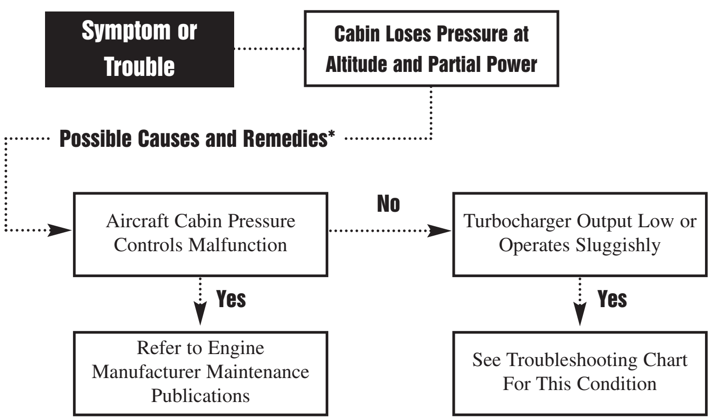
If the aircraft cabin loses pressure at altitude but manifold pressure is adequate, then the aircraft controls for cabin pressure may have malfunctioned, and may require repair per the manufacturer’s instructions. Insufficient cabin pressure at partial power, however, can indicate that the turbocharger 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," below, can save much troubleshooting time and effort.

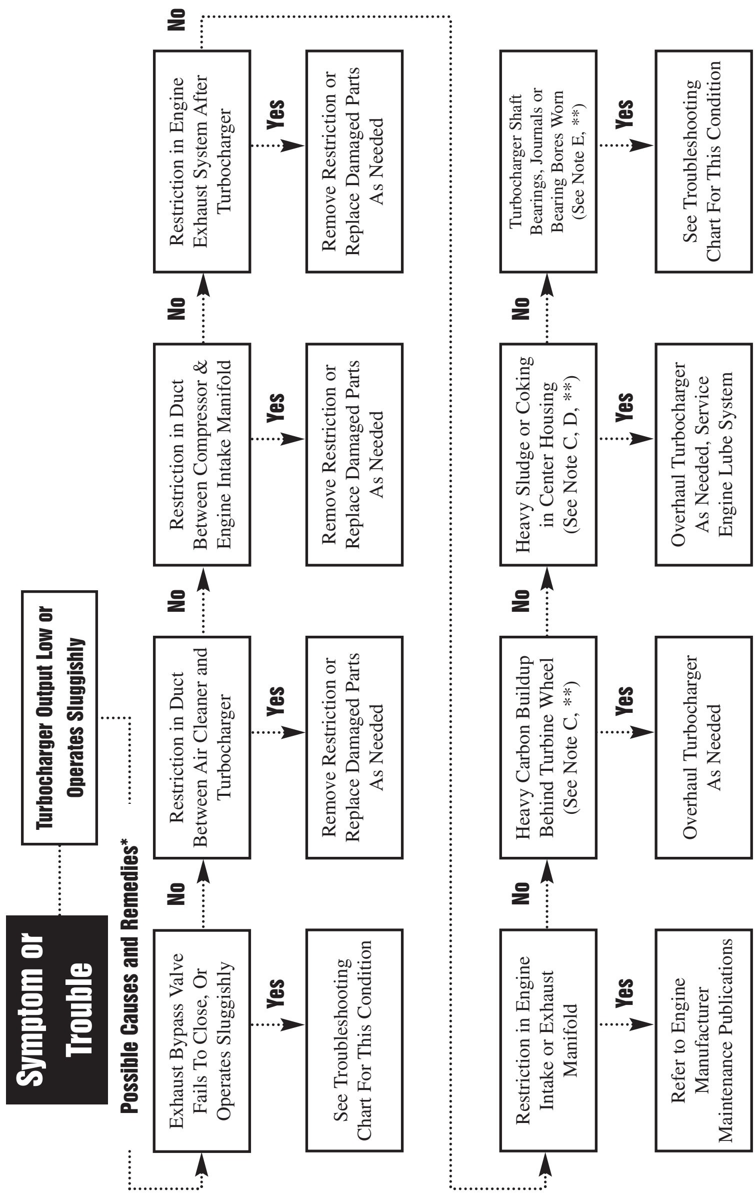
b. Restrictions in the air ducting between the air cleaner and the turbocharger would reduce the volume of air entering the compressor, and restrictions in the duct between the compressor and the engine intake manifold would hinder the delivery of compressed air to the engine. Also, any restriction in 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 of the 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 carbon 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 result 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 heavy sludging or coking in the turbocharger center housing, with hindrance of rotation and added wear on bearings among its negative effects. Inspect the interior of the center housing by removing the oil drain and looking in through the oil drain opening, removing the turbocharger if necessary. When a sludged or coked condition exists, sludge builds up heavily 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 as needed and a complete servicing of the engine lubricating oil system components supplying and draining the turbocharger center bearing housing assembly.

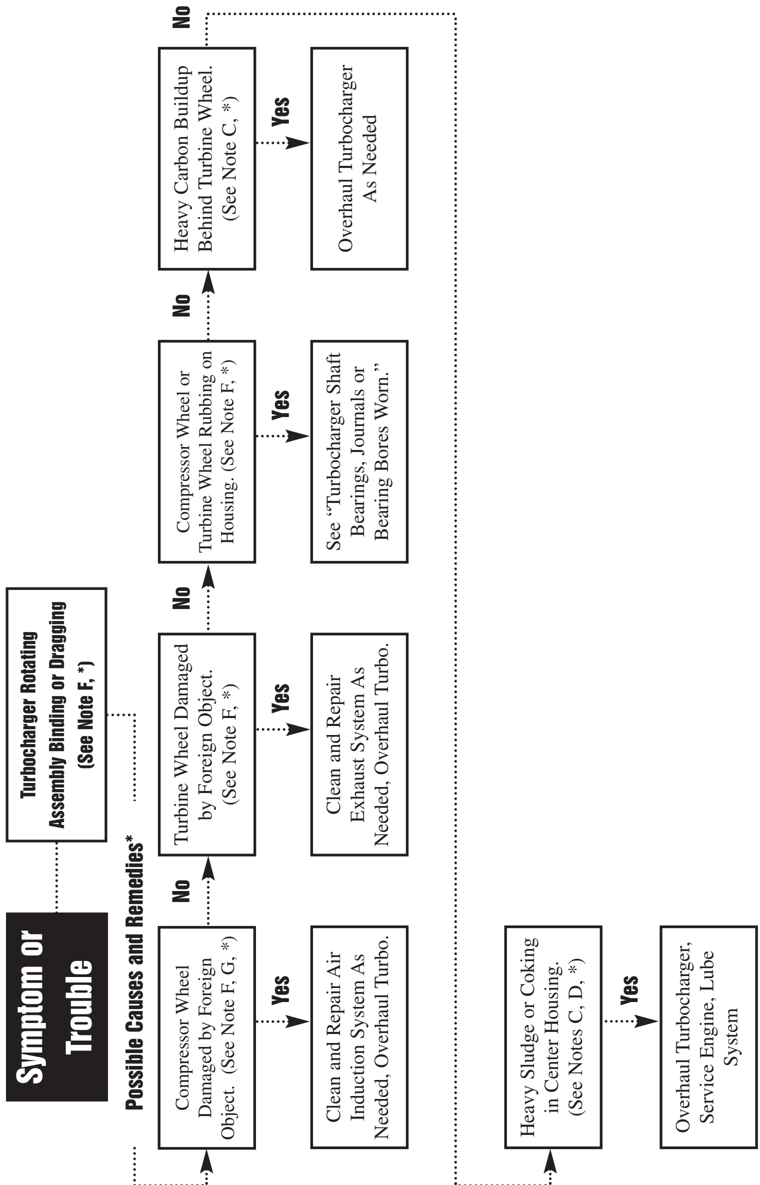
f. If there is suspicion of abnormal wear in the turbocharger bearings, perform the "Bearing Clearance Inspection" found in Chapter 2 of the latest revision of the HET Aircraft Turbocharger Overhaul Manual P/N 400600-0000. Failure to pass this inspection calls for overhaul or replacement of the turbocharger after seeking causes of wear in 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 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:

a. To detect hindrances to rotation in the 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, and proceed 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, as needed, and try to 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 heavy carbon buildup behind the turbine wheel, overhaul the turbocharger as needed, and examine the engine operation and maintenance procedures for departures from accepted practices and standards.

b. To detect heavy sludge or coking 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 sludged or coked condition exists, sludge builds up heavily 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 completely 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):

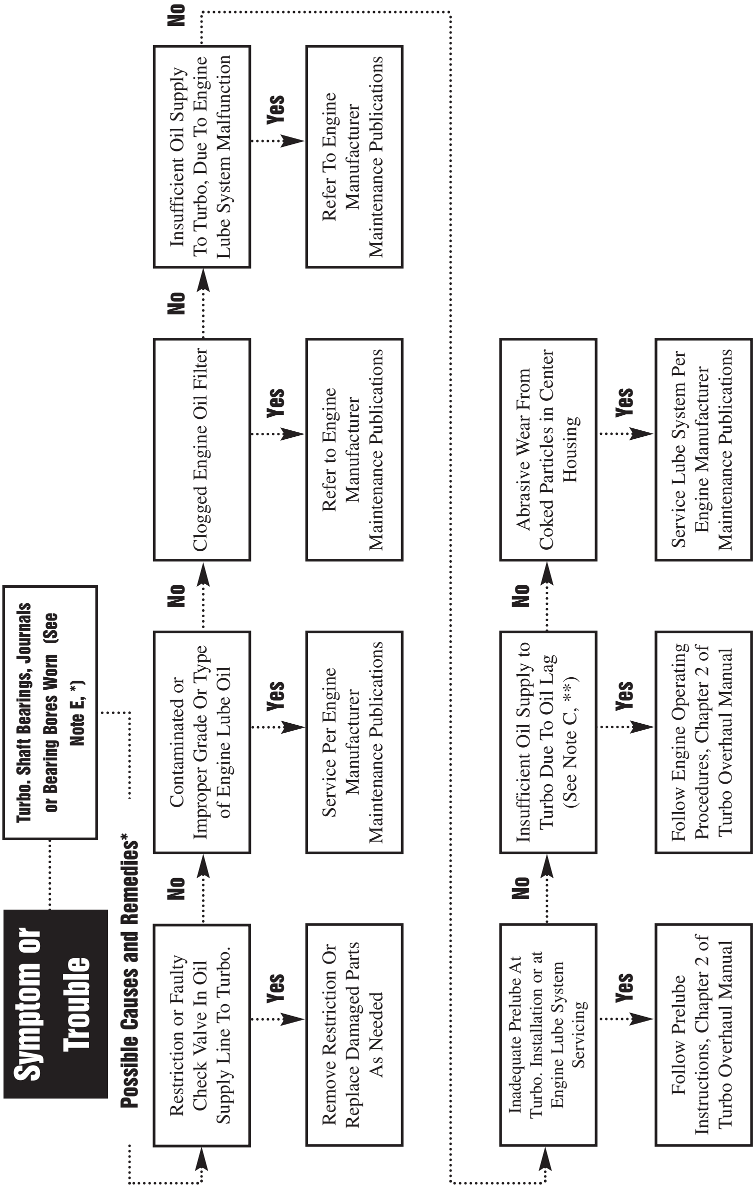
Suspected abnormal wear in the turbocharger shaft bearings, journals, or bearing bores can be readily confirmed by performing the “Bearing Clearance Inspection” found in Chapter 2 of the latest revision of the HET Aircraft Turbocharger Overhaul Manual P/N 400600-0000. It is imperative to detect and eliminate 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, as needed.

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.

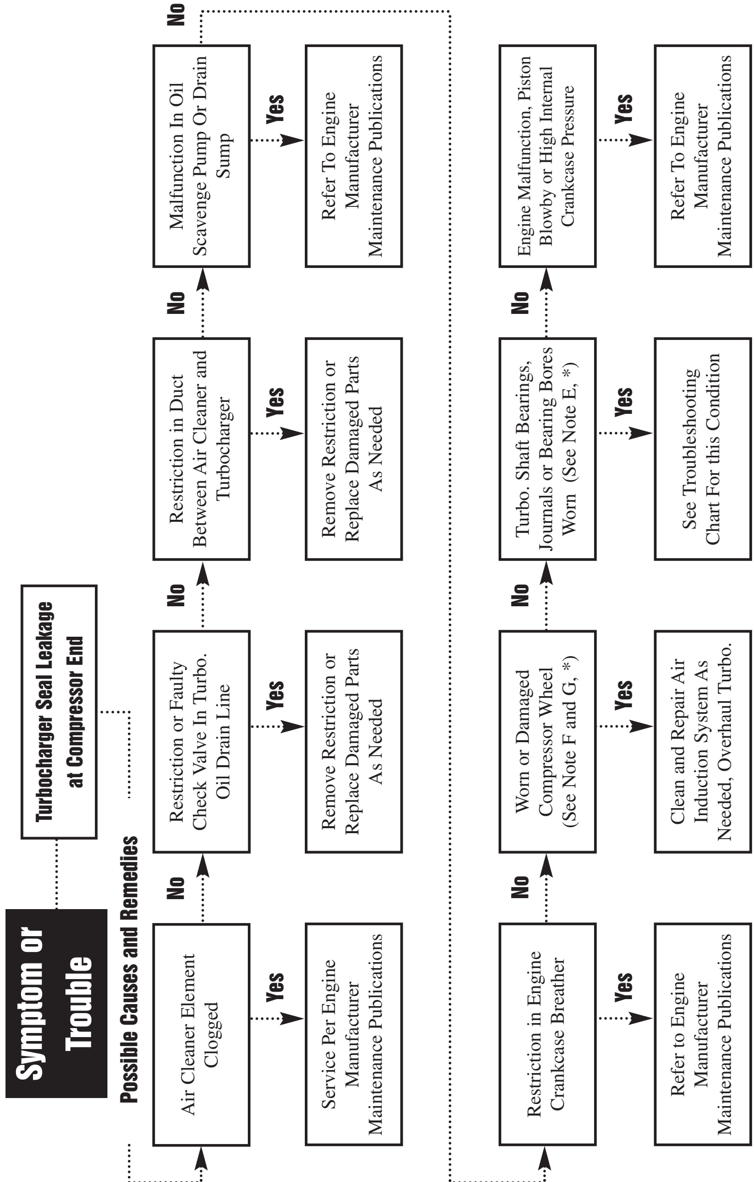
b. If there is a restriction or faulty check valve in the turbocharger oil drain line, remove the restriction or replace damaged parts as needed.

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. 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 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 to contribute to seal leakage, clean and repair the air induction system, as needed, and 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 blowby 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 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.

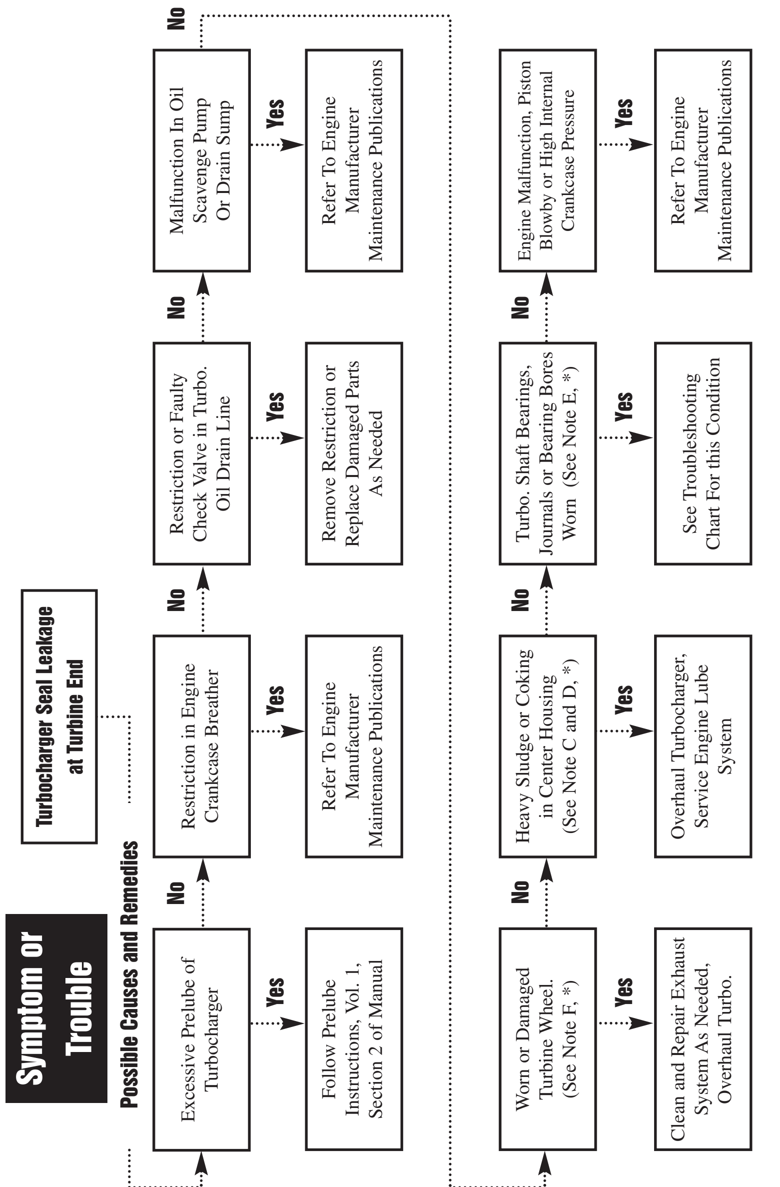
c. If there is a restriction or faulty check valve in the turbocharger oil drain line, remove the restriction or replace damaged parts as needed.

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 heavy sludge or coking 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 sludge or coked condition exists, sludge builds 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. 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 blowby 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

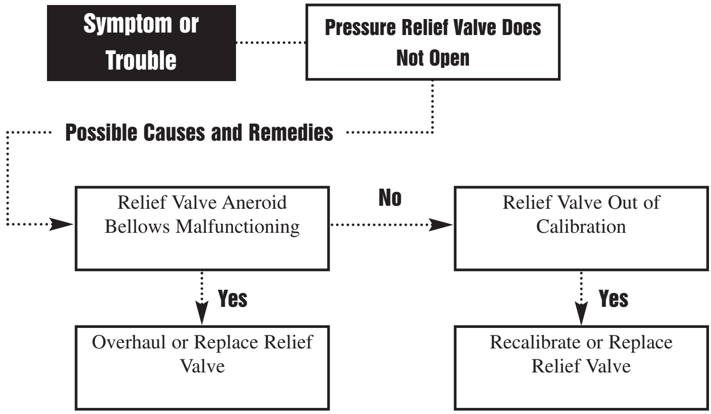
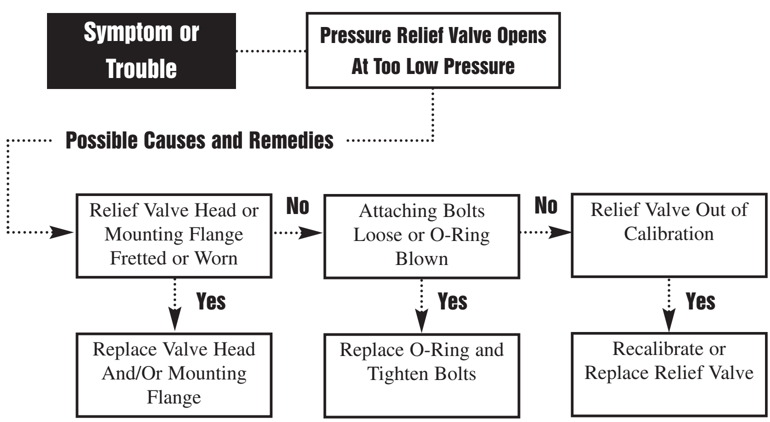


Figure 27 - Troubleshooting - Pressure Relief Valve Opens at Too Low a Pressure



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 manufacturer's publications.

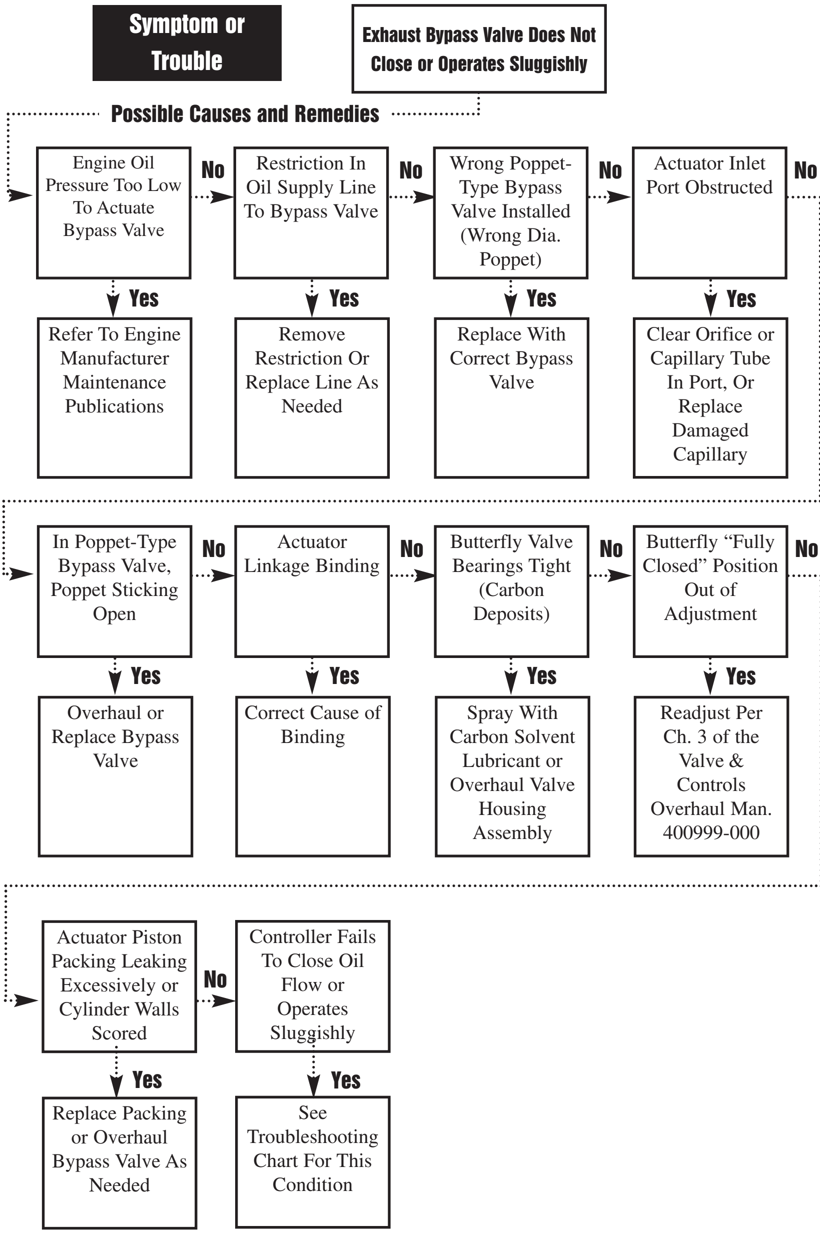
d. If the inlet port of the actuator is obstructed, clear the orifice or capillary tube in the port, or replace the capillary tube if damaged.

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

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 carbon deposits, try freeing the shaft by spraying with carbon solvent lubricant. 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.

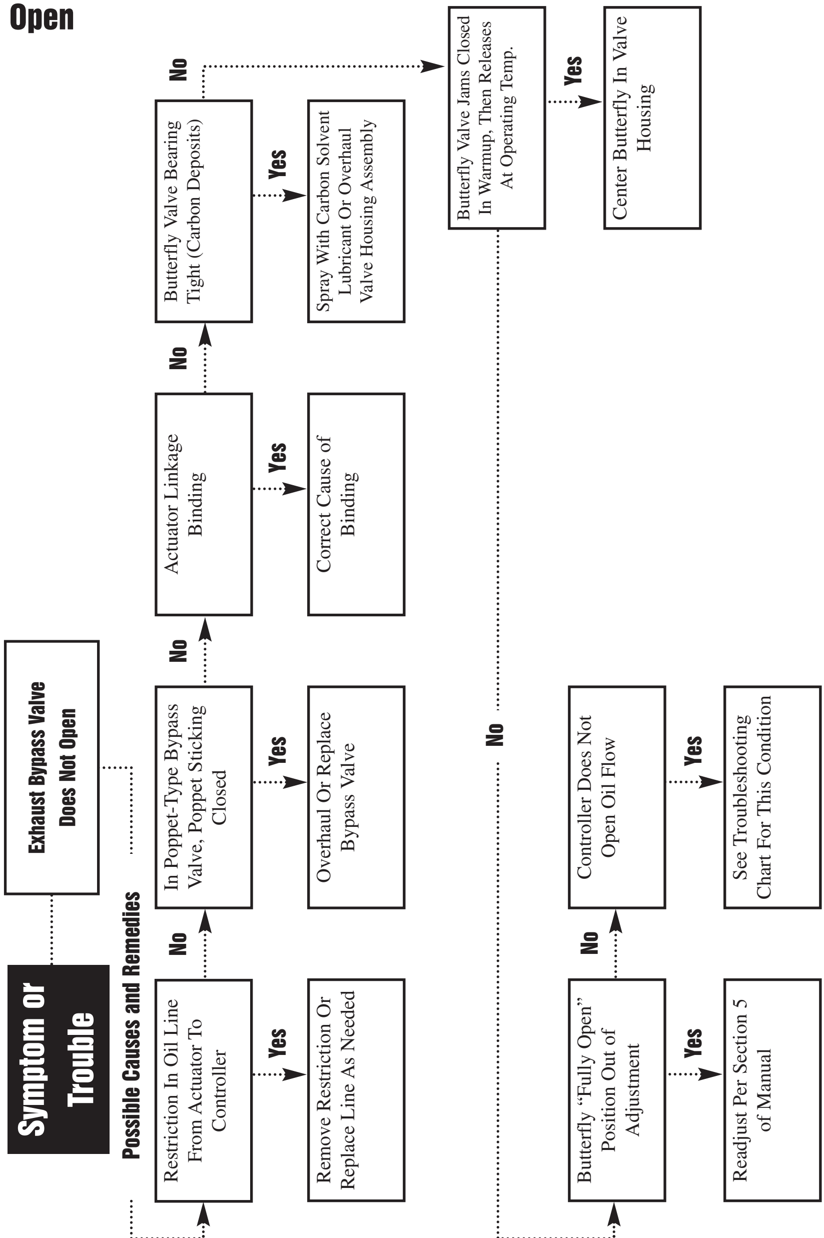
Exhaust Bypass Valve Does Not Open (See Figure 29):

If an exhaust valve, which is normally open, does not open, this must be 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. In a poppet-type exhaust bypass valve, if the poppet is stuck in the closed position, 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 if stuck in the closed position, or cannot move because the bearings are tight, perhaps from carbon deposits, try freeing the shaft by spraying with carbon solvent lubricant. Otherwise, overhaul or replace the valve housing assembly.

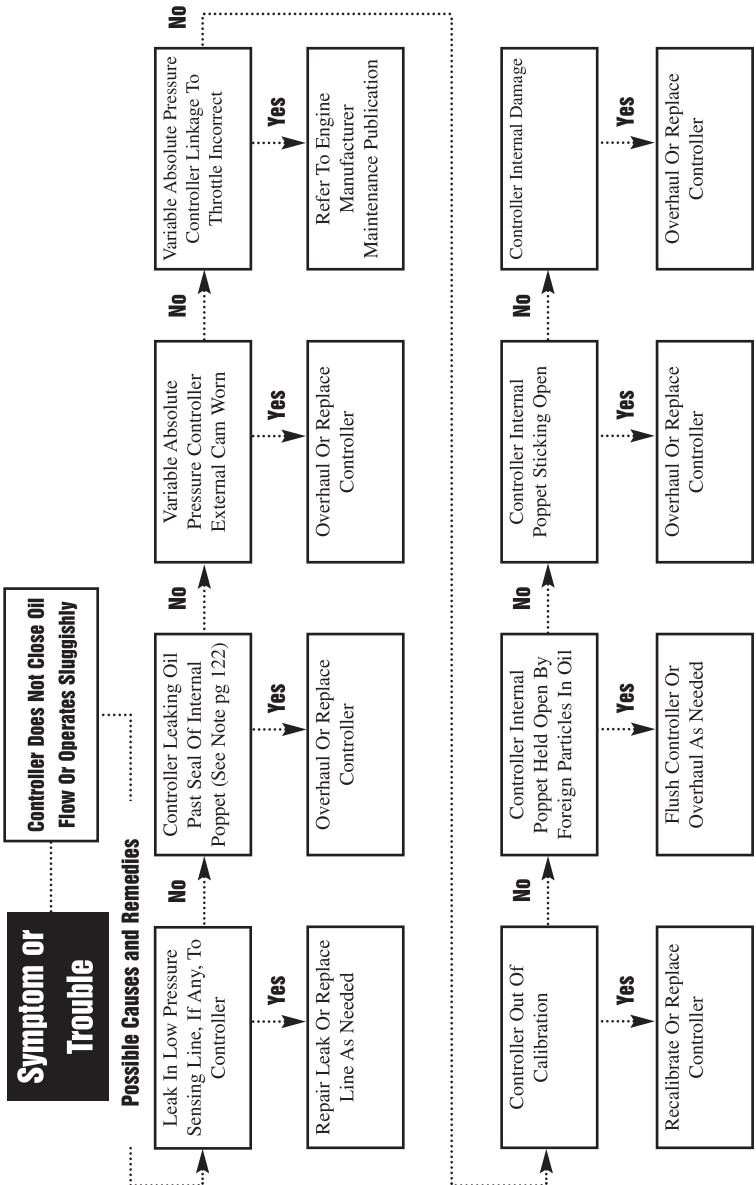
d. Check butterfly clearance in the "fully open" position against the valve given in the "Reassembly procedure for the specific exhaust bypass valve in Chapter 2 of the latest revision of the HET Aircraft Valves and Controls Overhaul Manual P/N 400999-0000. If necessary, adjust to the correct clearance.

e. If the controller located between the actuator outlet and the engine crankcase which is supported 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 is 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, and their remedies, 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 such 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 controller not permitting oil flow, and their remedies, 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 so, replace diaphragm.

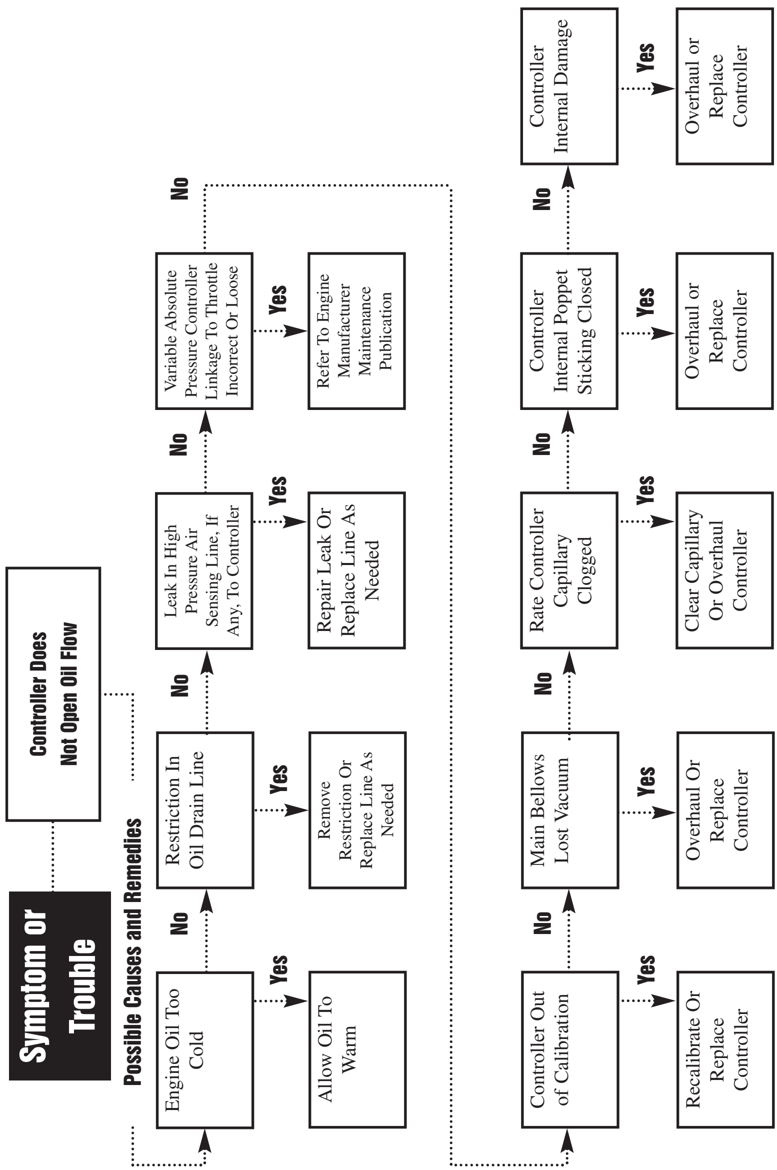
d. On a variable absolute pressure controller, the linkage to the engine throttle may be incorrectly assembled or out of adjustment. If so, reassemble or readjust per the engine manufacturer maintenance publications.

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. In a rate controller, if the capillary is clogged, 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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