Manual No. 193, Volume 2
61-03-93
Original
February 2023

Information Manual for Experimental Aircraft

Volume 2

Integration Guide for Experimental Aircraft

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IMPORTANT MESSAGE

People who build, modify, and/or operate experimental aircraft should recognize that various types of risks are involved; and they should take all precautions to minimize them, since they cannot be eliminated entirely. The propeller is a vital component of the aircraft. A mechanical failure of the propeller could cause a forced landing or create vibrations sufficiently severe to damage the aircraft, possibly causing it to become uncontrollable.

Propellers are subject to constant vibration stresses from the engine and airstream, which are added to high bending and centrifugal stresses.

Before a propeller is certified as being safe to operate on an airplane, an adequate margin of safety must be demonstrated. Even though every precaution is taken in the design and manufacture of a propeller, history has revealed rare instances of failures, particularly of the fatigue type.

It is essential that the propeller is properly maintained according to the recommended service procedures and a close watch is exercised to detect impending problems before they become serious. Any grease or oil leakage, loss of air pressure, unusual vibration, or unusual operation should be investigated and repaired, as it could be a warning that something serious is wrong.

For operators of uncertified or experimental aircraft an even greater level of vigilance is required in the maintenance and inspection of the propeller. Experimental installations often use propeller-engine combinations that have not been tested and approved. In these cases, the stress on the propeller and, therefore, its safety margin is unknown. If a failure occurs, it could be as severe as a loss of propeller or propeller blades and cause loss of propeller control and/or loss of aircraft control.

Hartzell Propeller Inc. follows FAA regulations for propeller certification on certificated aircraft. Experimental aircraft may operate with unapproved engines or propellers or engine modifications to increase horsepower/maintain horsepower output with a reduction in fuel flow. These modifications affect the vibration output of the engine and the stress levels on the propeller. Significant propeller life reduction and failure are real possibilities.

Frequent inspections are strongly recommended if operating with a non-certificated installation; however, these inspections may not guarantee propeller reliability, as a failing device may be hidden from the view of the inspector. Propeller overhaul is strongly recommended to accomplish periodic internal inspection.

Inspect the propeller/blades in accordance with the applicable operation/maintenance documents.

RECORD OF REVISIONS

This is a record of all revisions to this manual.

ATTENTION: Always use the current revision of this manual. The current revision is available on the Hartzell website at www.hartzellprop.com.

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INTRODUCTION - CONTENTS

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1. Introduction and Applicability

   A. Introduction

   Hartzell Manual 193 consists of multiple Volumes that describe the commonly used propeller configurations and options for experimental aircraft including discussions of installation guidelines, engine/propeller compatibility, and considerations for selecting a Hartzell Propeller for an experimental aircraft. These documents provide a summary/overview, and are not intended to be a replacement for guidance from the aircraft, engine, and/or propeller manufacturers about the appropriate propeller selection. When in doubt, please consult Hartzell Propeller Owner's manuals and/or the appropriate aircraft kit manuals. Additionally, you may contact Hartzell and/or the aircraft designer directly for guidance.

   B. Applicability

   Guidance in this manual is intended to enhance the safety and efficiency surrounding the use and integration of propellers on experimental aircraft. Government regulations, specifically 14 CFR Parts 23, 33, and 35, may not have regulatory requirements applicable to the aircraft in question. However, the builder/operator/integrator of an experimental aircraft, regardless of whether it is newly built or a modified version of an existing aircraft, should consider the same governmental regulations, policy, and guidance materials when developing and testing their aircraft. These topics regularly address physical concepts that apply regardless of airworthiness category. The ultimate responsibility for determining the proper integration of the propeller and aircraft lies with the aircraft owner/operator.

2. Propeller/Blade Model Designation

   A. Model Number Designation System

   Hartzell Propeller Inc. uses a model number designation system to identify specific propeller and blade assemblies. The propeller model number and blade model number are separated by a slash (/).

   Example: *propeller model number / blade model number*
   (e.g. HC-C2YR-1BFPX/F7497X)

   Parentheses shown in the propeller/blade model number in this, or any other Hartzell publication, indicate that there are characters (letters or numbers) that, depending on the specific configuration, may or may not be present.

   For additional information about the propeller/blade model designation system, refer to the applicable Hartzell propeller owner's manual and/or the applicable Type Certificate Data Sheet (TCDS).

3. WARNINGS and CAUTIONS

WARNING 1: THIS DOCUMENT, IN CONJUNCTION WITH THE PROPELLER OWNER'S MANUAL, PROVIDES IMPORTANT INFORMATION AND WARNINGS REGARDING THE INSTALLATION, OPERATION, AND PERFORMANCE OF YOUR PROPELLER.

WARNING 2: DETERMINING THE PROPER INTEGRATION OF THE PROPELLER AND AIRCRAFT IS THE RESPONSIBILITY OF THE AIRCRAFT INTEGRATOR. HARTZELL PROPELLER INC. SUPPLIES A PROPELLER BASED ON INFORMATION PROVIDED BY THE AIRCRAFT INTEGRATOR THAT HARTZELL CANNOT AND MAY NOT BE ABLE TO VERIFY. NEW PROPELLER APPLICATIONS REQUIRE CAREFUL TESTING AND EVALUATION. TESTING OR OPERATION OF THE PROPELLER, THEREFORE, CARRIES WITH IT A RISK OF SERIOUS INJURY, DEATH, AND/OR SIGNIFICANT PROPERTY DAMAGE.

WARNING 3: THERE IS A RISK OF SERIOUS INJURY, DEATH, AND/OR SIGNIFICANT PROPERTY DAMAGE IF THE PROPELLER HAS NOT BEEN TESTED AND SHOWN TO BE COMPATIBLE WITH THE ENGINE AND AIRCRAFT INSTALLATION, OR IF IT IS OPERATED IN A MANNER THAT EXCEEDS THE ESTABLISHED LIMITS FOR THE PROPELLER. IN THESE INSTANCES, VIBRATION LOADS CAN EXCEED THE DESIGN LIMITATIONS AND CAN RESULT IN PROPELLER OR BLADE SEPARATION FROM THE AIRCRAFT.

WARNING 4: STABILIZED OPERATION WITHIN THE PROPELLER RESTRICTED RPM RANGE CAN GENERATE HIGH PROPELLER STRESSES AND RESULT IN FATIGUE DAMAGE TO THE PROPELLER. THIS DAMAGE CAN LEAD TO A REDUCED PROPELLER FATIGUE LIFE, PROPELLER FAILURE, AND LOSS OF CONTROL OF THE AIRCRAFT.

4. Trademarks and Disclaimers

A. Designers/Kit Manfacturers

This manual mentions various suppliers of aircraft kits, designs, engines, and aftermarket products. The information contained herein is not endorsed, or approved by, any of these entities.

GENERAL INFORMATION - CONTENTS

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1. Propeller Types

A. Fixed Pitch

Most of us pilots probably started flying with an airplane that used a fixed pitch propeller. A fixed pitch propeller is about as simple as it gets, the blades are fixed and cannot move, thus the propeller blade angle (pitch) is fixed. The performance of an aircraft fitted with a fixed pitch propeller is dependent on the chosen blade angle. The fixed pitch propeller limits the RPM developed by the engine at low forward velocity, such as during the take-off ground roll, and may also allow the engine RPM to exceed red-line maximum when the load on the engine is reduced, for example, in a shallow dive. Blade angle is usually chosen to produce maximum performance at a particular flight condition, either climb or cruise, or may be selected as a reasonable compromise between the regimes. A climb propeller is generally chosen when the aircraft normally operates from an airfield with a short runway or in high density altitude conditions. The climb propeller will produce maximum efficiency at full throttle around the best rate of climb airspeed and will perform fairly well at take-off. The cruise propeller will achieve maximum efficiency at cruise power at airspeeds around the design cruising speed but aircraft take-off and climb performance will not be the optimum. The cruise propeller usually has higher pitch than the climb propeller fitted to the aircraft.

NOTE: Hartzell does not currently offer fixed pitch propellers.

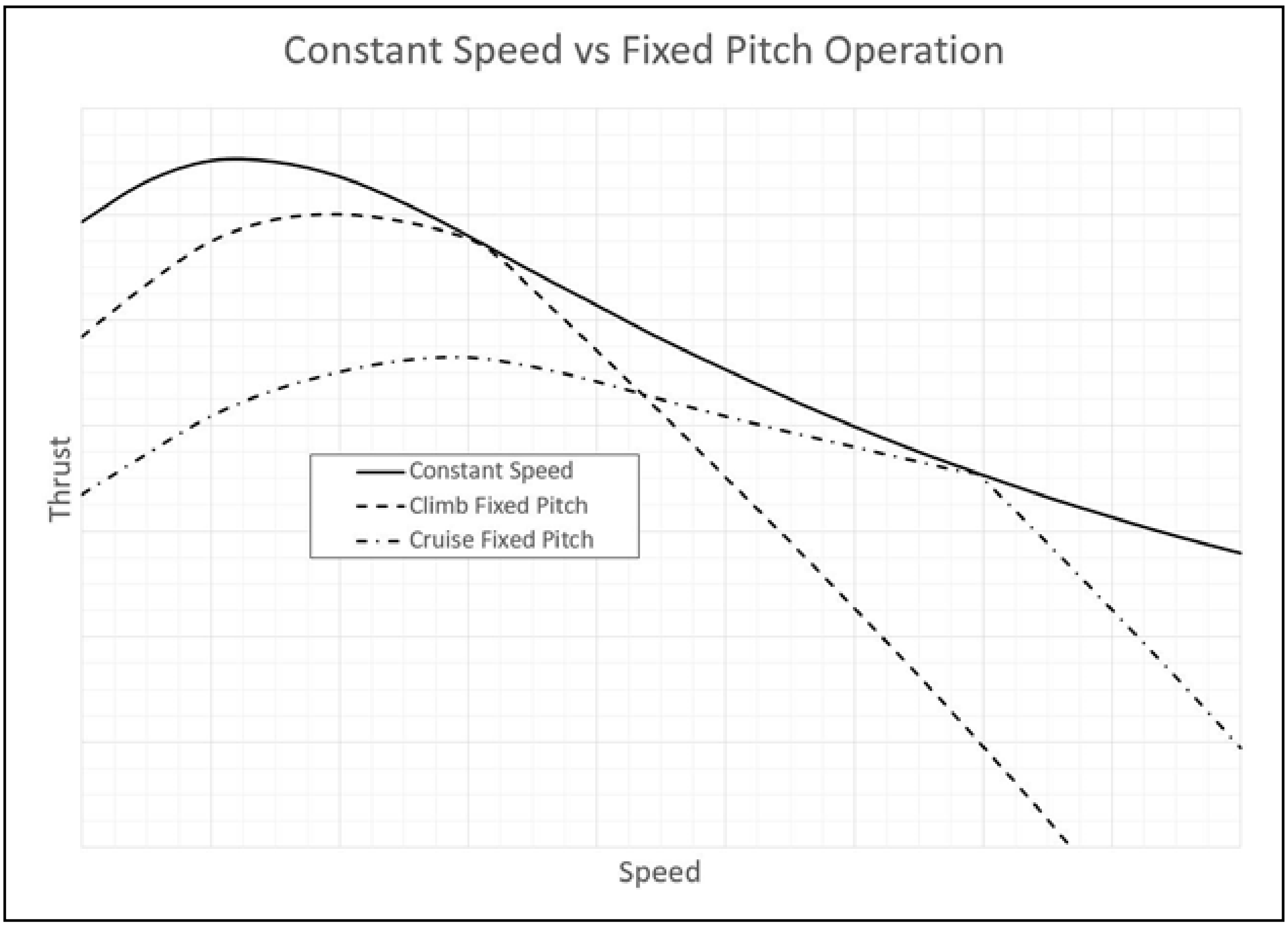
B. Ground Adjustable

A ground adjustable propeller operates in the same manner as a fixed pitch propeller, but provides a means or mechanism to adjust the pitch on the ground. Once the pitch is adjusted, it remains in that position. This allows easier adjustment to the pitch for the end user to adapt to their particular installation, and may allow for prioritization of performance depending on the mission.

NOTE: Hartzell does not currently offer ground adjustable propellers.

C. Constant Speed

Rather than providing a single, fixed pitch, the constant speed propeller allows an infinite number of in flight adjustable pitches between the pitch stops, which allows improved performance as shown in Figure 1-1. A constant speed propeller accomplishes this because it provides a mechanism for the blade angle to be actuated in flight in conjunction with a system to regulate the blade angle in order to maintain a constant RPM. The regulation of blade angle is performed by the governor even as power setting, airspeed, or atmospheric conditions change. In most aircraft, the pilot can vary the speed of the propeller using the propeller RPM control lever or knob, which controls the governor RPM set point. This allows the full power of the engine to be utilized by maintaining RPM at the engine's peak power RPM irrespective of airspeed as opposed to a fixed pitch propeller which will load the engine down several hundred RPM during takeoff, reducing the engine power. It also allows for efficient cruise flight by allowing wide open throttle, with reduced RPM settings whereas a fixed pitch propeller will require partial throttle settings to limit engine RPM. Refer to the section, "Governors" for information on governor operation. Refer to the section, "Actuation" for more information on the propeller actuation mechanism.



Fixed Pitch vs. Constant Speed Operation
Figure 1-1

2. Hartzell Constant Speed Propellers

A. General

There are two different series of Hartzell constant speed propellers that are typically used on experimental aircraft: the Compact-series and the Raptor-series. This section describes the attributes of each propeller series and explains the differences between them.

B. Compact Propellers

(1) Compact propellers mount to General Aviation (GA) reciprocating engines and are available in Standard and Lightweight configurations.

(a) Lightweight Compact propellers are variants of the Standard Compact 3-blade propeller. These propellers use a lighter hub assembly with fewer clamping bolts.

(b) Lightweight Compact propeller model numbers include a "1" after the shank designation "Y" (ex. HC-C3Y**1**R-1N).

(2) Standard Compact propellers can be configured with either aluminum or composite blades.

(3) Lightweight Compact propellers can only be configured with composite blades.

(4) Blades designated for use in Compact-series propellers cannot be used in Raptor-series propellers.

C. Raptor Propellers

NOTE: Hartzell manufactures Raptor propeller models for reciprocating engines and models for turbine engines. This manual is only applicable for propeller models designed for reciprocating engines.

(1) Raptor propellers mount to General Aviation (GA) reciprocating engines.

(2) Raptor propellers are designed to be lighter than Compact-series propellers.

(a) Weight reduction is achieved by using a redesigned blade preload/retention system and composite blades.

(3) Raptor propellers can only be configured with composite blades.

(4) Blades designated for use in Raptor propellers cannot be used in Compact propellers.

3. <u>Buying a Propeller</u>

A. Kit Manufacturer

Hartzell has worked directly with most kit manufactures to offer the best pricing available to builders when purchased directly through the kit manufacturer. Though ordered through the kit manufacturer, in many instances these propellers are shipped directly to you from the Hartzell factory. Hartzell allows this competitive pricing for the first propeller for newly built aircraft, and upgraded propellers for that aircraft.

B. Used

Propellers are frequently available on the used market; these propellers may have significant calendar and operating time on them and could have significant internal corrosion. A propeller will carry any damage or fatigue from its previous use and maintenance, or lack thereof. Hartzell recommends sending any used propeller to an appropriately rated service facility for inspection and potentially overhaul prior to installing on your aircraft.

(1) Previously Installed on Experimental Aircraft

(a) Refer to the section, "Engine/Propeller Compatibility" in this manual when choosing a used propeller from another experimental aircraft and consider the following: Was the propeller operated in accordance with the applicable operating restrictions? Are there modifications to the previous installation that may have subjected the propeller to unknown or increased loads? Are the risks associated with that installation risks you would be willing to assume yourself?

(2) "OK for Experimental"

(a) Some used propellers came from certified aircraft, or assembled from parts from certified propellers, but are advertised as “OK for Experimental.” This is a reason to be concerned, and you should ask what about that propeller makes it not ok for a certified installation.

Was the propeller operated in accordance with the applicable operating restrictions? Are there modifications to the previous installation that may have subjected the propeller to unknown or increased loads? Has the propeller itself been modified? Are the risks associated with that installation risks you would be willing to assume yourself?

PROPELLER CONFIGURATIONS - CONTENTS

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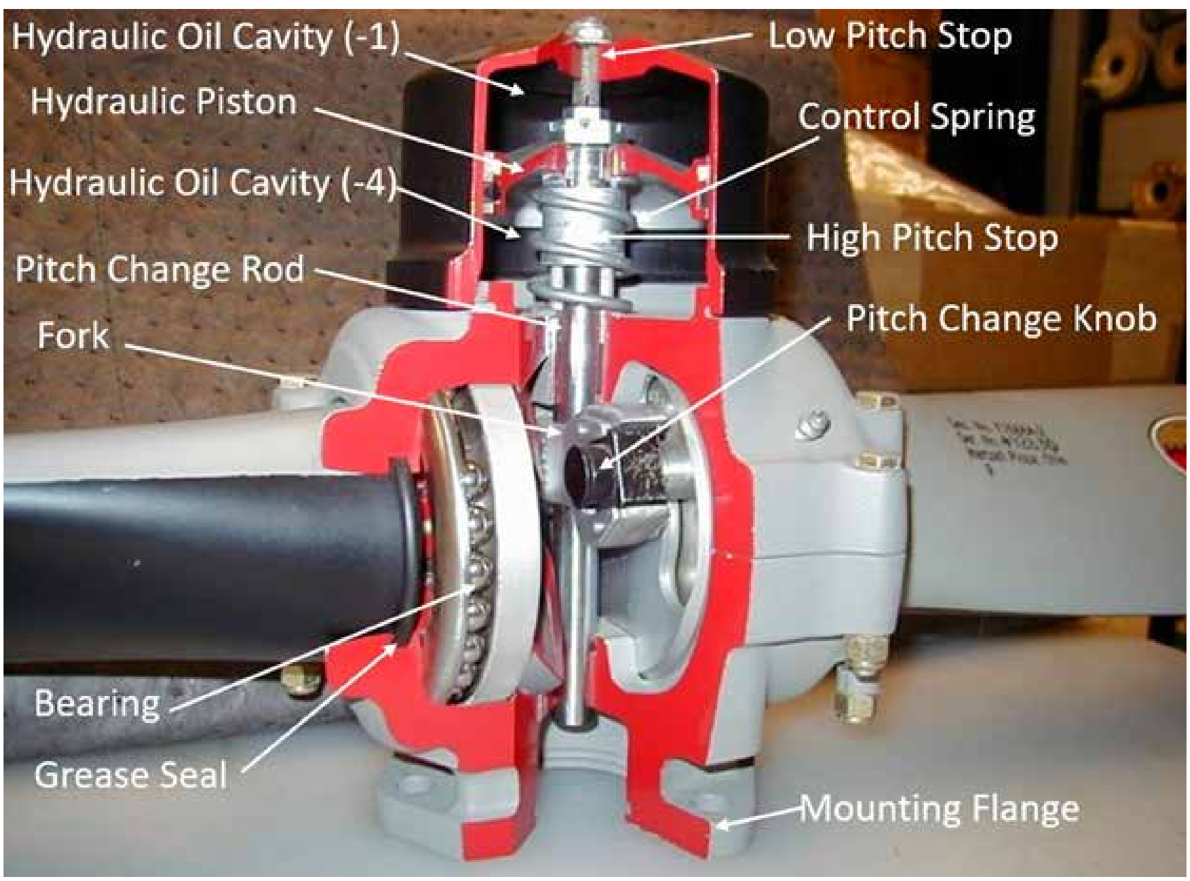
1. Propeller Actuation

   A. Constant Speed Propellers

NOTE: The actuation type is indicated in the propeller model number as shown.
Compact-series Type "1": ( )HC-C2YR-**1**( )
Raptor-series Type "1": 3C**1**-R430A1( )

Most constant speed propellers recommended for experimental aircraft models use what Hartzell refers to as a Type "1" or "-1" actuation style. This style uses hydraulic oil pressure to increase pitch and a spring (along with aerodynamic and centrifugal forces) to return to low pitch; the propeller will move towards low pitch if oil pressure is lost or decreased. This system is referred to as single acting; so named because the oil pressure works in a single direction. The propeller includes an externally adjustable low pitch stop. High pitch is internally limited with a fixed stop and is not adjustable without propeller disassembly. See Figure 2-1 for a cutaway of the internals of a compact propeller.

Some users may choose to use a Type "4" or "-4" actuation style, which is intended for aerobatics. The Type "4" system uses hydraulic oil pressure to decrease pitch and blade counterweights to return to high pitch; the propeller will move towards high pitch if oil pressure is lost. This requires a different governor.



Compact Propeller: Internal Components
Figure 2-1

2. Propeller Mounting Flange

NOTE: The flange type is indicated in the propeller model number as shown.
Compact-series ("R" flange): ( )HC-C2Y**R**-1( )
Raptor-series ("R" flange): 3C1-**R**430A1( )

A. "F" Flange

(1) Most Continental 6-cylinder engines use an "F" flange

(a) 4.000" bolt circle using two 1/2" drive dowels and 1/2"-20 studs

(b) A modification of the SAE ARP 502 flange specification

B. "L" Flange

NOTE: When installing an "L" flange propeller on a Lycoming or similar engine, a starter ring gear (flywheel) must be installed between the engine and the propeller flange for proper bushing and thread engagement.

(1) 320 Lycoming (and "Lycoming-type") engines may use an "L" flange, but not all 320's have bushing configurations compatible with this flange.

(a) 4.750" bolt circle using bushings and 7/16"-20 captured bolts

(b) Two flush bushings

(c) Two "loose" tolerance bushings

(d) Two "tight" tolerance bushings

(e) A modification of the SAE AS127D, #5 flange specification

(2) There are several variations to the flanges used on 320 engines. Check the applicable engine manufacturer's documentation for the specific engine.

C. "R" Flange

NOTE: When installing an "R" flange propeller on a Lycoming or "Lycoming-type" engine, a starter ring gear (flywheel) must be installed between the engine and the propeller flange for proper bushing and thread engagement.

(1) 360/390/540/580 Lycoming (and "Lycoming-type") engines use an "R" flange.

(a) 4.750" bolt circle using bushings and 1/2"-20 captured bolts

(b) A modification of the SAE AS127D, #6 flange specification

3. Propeller Extension Length

A. Compact Hubs

CAUTION: HARTZELL PROPELLER INC. DOES NOT ENDORSE THE USE OF BOLT-ON, AFTERMARKET PROPELLER HUB EXTENSIONS. HARTZELL MANUFACTURES PROPELLERS WITH APPROVED, EXTENDED HUBS IN A VARIETY OF LENGTHS.

The propeller extension length is the distance between the propeller/engine mounting flange interface and the blade centerline (disc).

For Compact propellers, the hub design and the mounting flange type determine the propeller extension length. "C" hubs are the shortest and most commonly used hub design.

The hub design type is indicated by a letter in the Compact-series propeller model number. Example: Compact ("C" hub): ( )HC-**C**2YR-1( )

The table below lists the propeller extension lengths for 2-blade and 3-blade hubs by Hub Design/Flange type.

Hub Design	Propeller Extension Length		
	"F" Flange	**"L" Flange**	**"R" Flange**
C	3.250 in.	4.187 in.	4.187 in.
L	3.750 in.	n/a	n/a
G	4.250 in.	n/a	5.187 in.
I	5.250 in.	n/a	6.187 in.
J	6.500 in.	n/a	n/a
H	7.500 in.	n/a	n/a
M	n/a	n/a	6.750 in.
F	n/a	7.187 in.	7.187 in.
E	7.750 in. *(2-blade only)*	9.187 in.	9.187 in.

HC-**C**2YR-( ) HC-**M**2YR-( )

Integral Hub Extensions: Compact-series Hubs
Figure 2-2

B. Raptor Hubs

<u>CAUTION</u>: HARTZELL PROPELLER INC. DOES NOT ENDORSE THE USE OF BOLT-ON, AFTERMARKET PROPELLER HUB EXTENSIONS. HARTZELL MANUFACTURES PROPELLERS WITH APPROVED, EXTENDED HUBS IN A VARIETY OF LENGTHS.

The propeller extension length is the distance between the propeller/engine mounting flange interface and the blade centerline (disc).

The propeller extension length is indicated by a numeral in the Raptor propeller model number, and is represented in hundredths of inches (may be rounded). Example: 3C1-R**<u>430</u>**A1( ), "**<u>430</u>**" = 4.287 inches

The table below lists the propeller extension lengths and the available flange types.

Propeller Extension Numeral (in the propeller model number)	Propeller Extension Length	
	"L" Flange	"R" Flange
430	4.287 in.	4.287 in.
619	6.187 in.	6.187 in.
675	6.750 in.	6.750 in.
919	n/a	9.187 in.

3C1-R**<u>430</u>**( ) 3C1-L**<u>675</u>**( )

Integral Hub Extensions: Raptor-series Hubs
Figure 2-3

4. Propeller Diameter

A. General

The assembled diameter of the propeller is dependant on two factors: blade length and the number of blades in the hub.

2-blade Compact propellers with N7605( ) blades will have a smaller diameter than 3-blade Compact propellers with the same blades. As the number of blades in a hub increases, the room required for the bearings also increases. This forces the blades further outboard, therefore increasing the propeller diameter.

Hartzell uses a blade model designation system that incorporates the "basic diameter" into the blade model number. The first two/three numeric digits in the blade model number indicate the propeller diameter (in inches) when that blade is installed in the "basic hub" for that propeller series - this is refered to as the "basic diameter".

NOTE: The "basic diameter" is indicated in the blade model number as shown.
Example #1: N**76**05C (basic diameter = 76")
Example #2: **76**C03 (basic diameter = 76")

Some blades may have diameter modifications specified at the end of the blade model number. A modification that reduces the diameter will appear with a minus sign "-", followed by a number. The number following the minus sign "-", indicates the reduction to the basic diameter (in inches). A modification that increases the diameter will appear with a plus sign "+", followed by a number. The number following the plus sign "+", indicates the increase to the basic diameter (in inches).

NOTE: Example #1: N**76**05C**-2** (propeller diameter = 74")
Example #2: **76**C03**+2** (propeller diameter = 78")

B. Compact Hubs

The "basic hub" for the Compact-series is the 2-blade hub. In the Compact series, the difference in diameter between the 2-blade hub and 3-blade hub is two inches. For example: 2-blade Compact propellers with N7605( ) blades will have a propeller diameter of 76 inches. 3-blade Compact propellers with the same N7605( ) blades will have a diameter of 78 inches.

Diameter modifications at the end of the blade apply to the propeller diameter regardless of the hub.

C. Raptor Hubs

The "basic hub" for the Raptor-series is the 3-blade hub.

5. Blades

A. Aluminum Blades

Aluminum became the prevalent material for propeller blades much in the same way as it became the prevalent material for airframes; it's relatively inexpensive, lightweight, and simple to manufacture. Aluminum blades are also simple to repair and maintain due to familiarity; most A&P mechanics are familiar with the need and procedures to grind and polish out nicks and dings, and most pilots know to look for these. However, material can only ever be removed, which in many instances limits the useful life of the propeller blade.

B. Composite Blades

The primary advantage of composite blades for the homebuilder is weight; composite blades save a considerable amount of weight compared to aluminum blades. Composite bladed props also have lower polar moment of inertia, and are generally reported by pilots to feel smoother in flight. Hartzell composite blades incorporate a nickel-cobalt leading edge, which offers substantial impact and erosion resistance as compared to an aluminum blade. Composite blades may also be restored to the original dimensions during overhaul, as compared to aluminum blades which must have material removed; as such the life cycle of a composite blade can be much longer.

(1) Hartzell Composite Blade Technologies

(a) Hartzell has been producing composite propeller blades since the 1970s; as of this writing some Hartzell composite propeller blades have accumulated as much as 50,000 hours in service. The current generation of Hartzell composite manufacturing technology is referred to as ASC-II (Advanced Structural Composite, Generation II); introduced in 2006, ASC-II is our designation for the process that forms the blade. In general, an ASC-II blade is a semi-monocoque structure utilizing a composite skin and spar around a foam core internal structure and retained with a metallic shank; this foam is an engineered material, and contributes to the structure. An example cross section is shown in Figure 2-4. Hartzell composite blade designs are stringently tested for fatigue, bird strike, and lightning strike.

ASC-II Composite Blade Cross-section
Figure 2-4

(2) Composite Blade Repairs

(a) A major concern of aircraft owners is how to maintain their composite propeller blades and how susceptible to damage they may be. In a lot of instances, composite blades are more durable and repairable than their aluminum counterparts, and damage that would otherwise ground a metal blade qualifies as airworthy minor damage to be addressed at a later date; see Figure 2-5 for an example of damage that is still airworthy on a Hartzell composite blade. Just as with metal blades, minor repairs may be performed by a certificated A&P mechanic and Hartzell offers a Composite Field Repair kit, part number 106561, for completing minor repairs in the field. Hartzell Composite Propeller Blade Field Maintenance and Minor Repair Manual 170 is available on the Hartzell website, and covers the types of damage and procedures necessary to address them. There are also videos on the Hartzell YouTube channel illustrating minor composite blade repairs, and preflight inspections.

C. Blended Airfoil Design

Older propeller blade designs used a constant airfoil section, e.g. a Clark Y, along the entire length of the propeller blade. Hartzell's aerodynamic process allows the engineer to design different airfoil sections at specific locations along the blade to optimize performance; locations in between are the blended shape between the designs.

While most modern Hartzell designs can be considered to be a blended airfoil design one design in particular, the F7497 has become synonymous with the term as it pertains to experimental aircraft.

Example of Airworthy Damage to a Composite Blade
Figure 2-5

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ACCESSORIES - CONTENTS

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1. Spinners and Spinner Mounting Kits

A. Kit Spinners

Some aircraft kits include spinner components as part of the kit, consult the kit manufacturer for compatibility with Hartzell propellers. Hartzell can provide general geometry for mounting to Hartzell hubs upon request.

B. Hartzell Spinners

Hartzell offers a variety of aluminum and hybrid (aluminum bulkhead, composite dome) spinners. Please see application specific guidance on our website via Manual 159, or in the applicable volume of Manual 193 for information on applicable Hartzell spinners for your installation.

C. Spinner Mounting Kits

Most Hartzell propellers for reciprocating engine installations are configured with a spinner mounting kit of some sort; this kit defines the outer bolts, washers, spacers (if included), and nuts used to clamp the hub together which are also used to mount the spinner bulkhead. Spinner mounting kits are preconfigured based on information from the manufacturer and end users; changes in mounting kit are possible but are not configured to order. A different kit is required for metal bulkheads vs composite bulkheads; the difference is that kits configured for composite bulkheads incorporate wave washers and specific hat bushings to prevent excessive clamping loads on the bulkhead itself while ensuring proper clamping torque on the hub. Refer to Figure 3-1. The torque of these bolts is critical to flight safety, consult the appropriate propeller owner's manual for detailed instructions. A minimum of 0.125” spacing, either with washers or spacers, is required between the bulkhead and the hub in order to properly clear the hub. See Hartzell Application Guide, Manual 159, for a detailed description of spinner mounting kits.

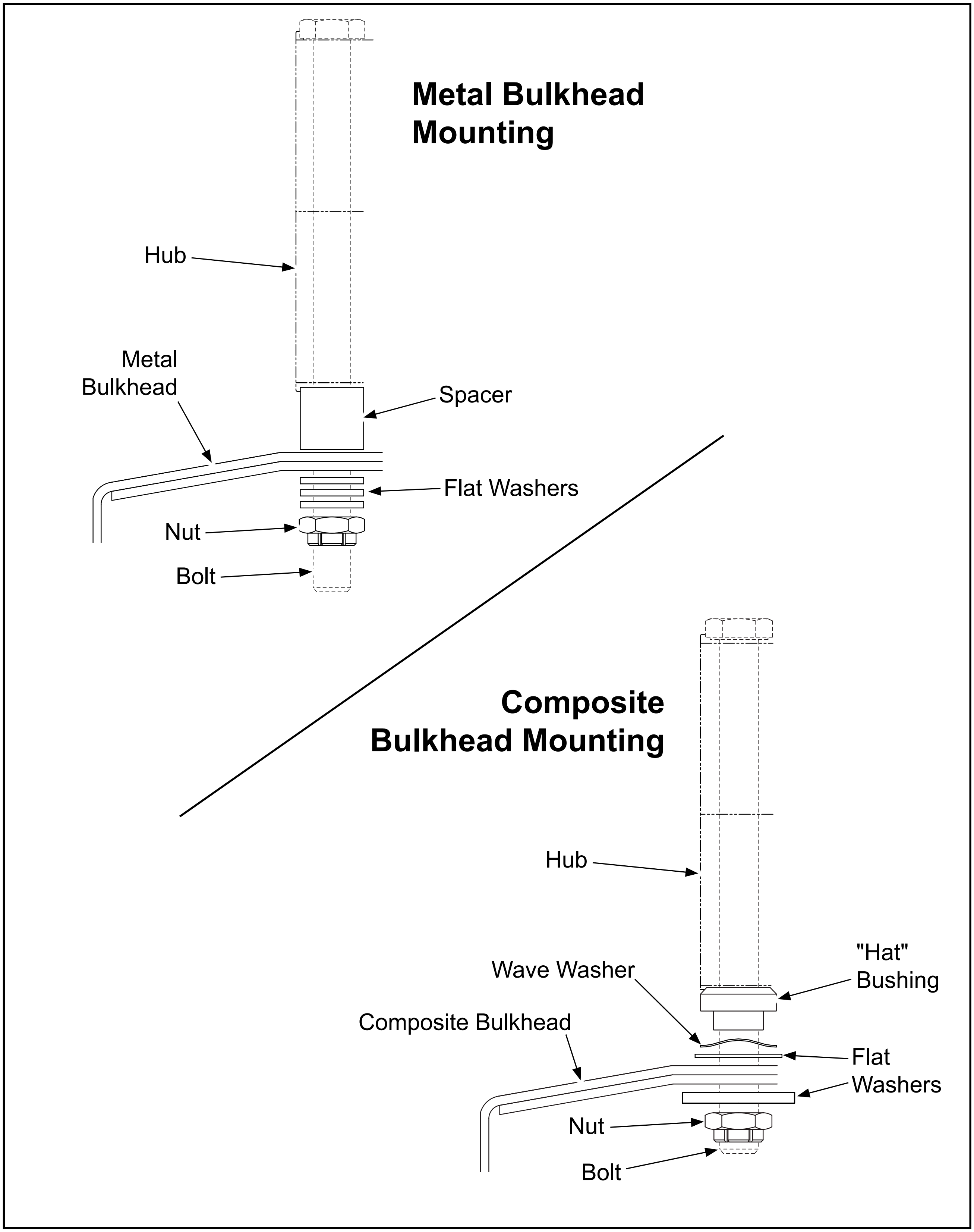
(1) Mounting Bolts

(a) Bolts are available in a few different lengths, configured based on the spinner mounting kit. Use of non- Hartzell bolts is strictly prohibited.

(2) Mounting Spacers

CAUTION: USE OF NON-HARTZELL SPACERS HAS NOT BEEN EVALUATED. IMPROPER SPACER MATERIAL SELECTION AND/OR DESIGN COULD RESULT IN A LOSS OF HUB CLAMPING PRESSURE, WHICH COULD RESULT IN BLADE SEPARATION.

(a) Aluminum spacers, A-2246-( ), are available in various lengths, configured by the -( ).



Hub Mounted Bulkheads
Figure 3-1

2. Governors

A. Governor Operation

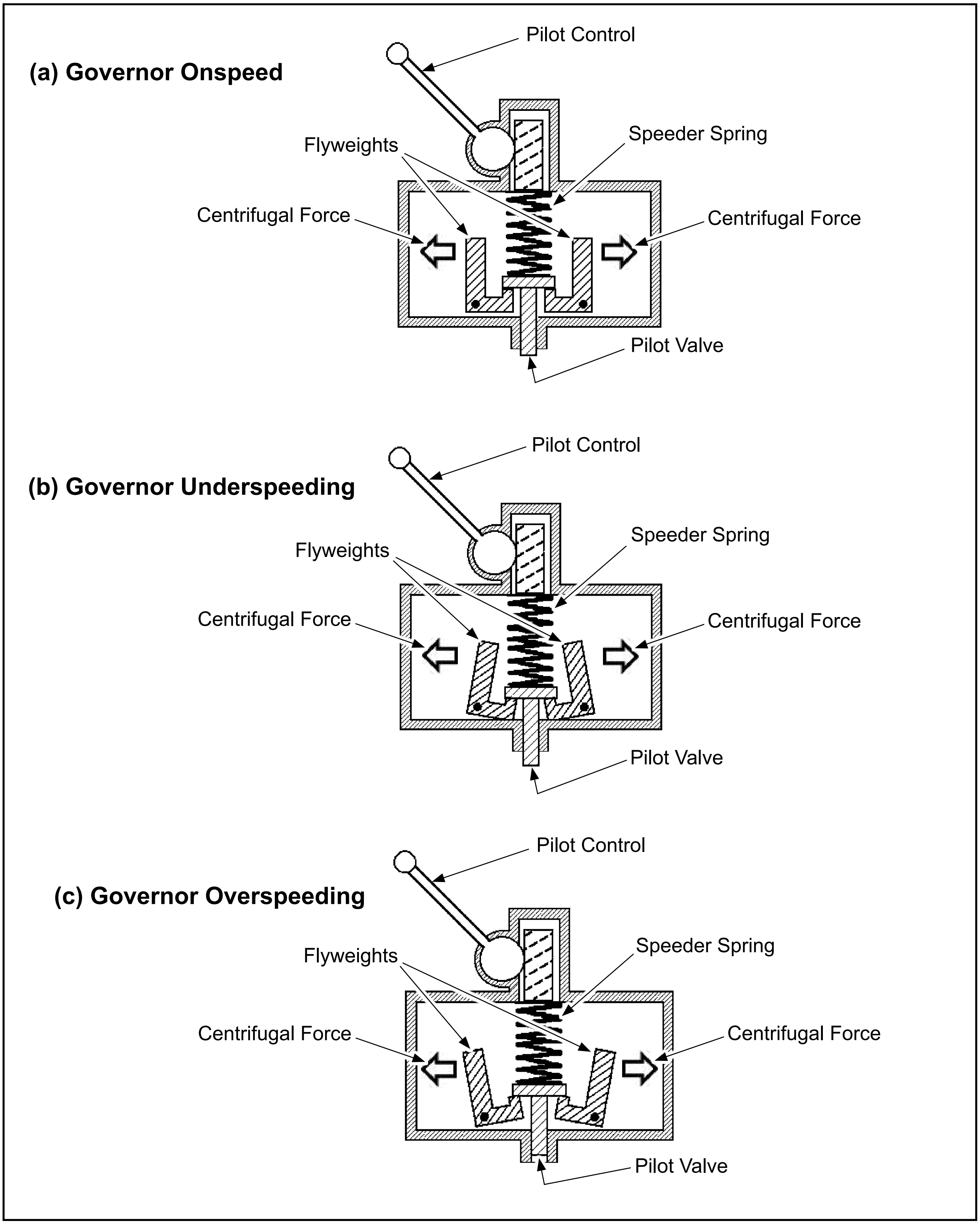
A governor is an engine/propeller RPM sensing device that incorporates a high pressure oil pump. In a constant speed propeller system, the governor responds to a change in engine/propeller RPM by directing oil under pressure to the propeller hydraulic cylinder, or by releasing oil from the hydraulic cylinder to the drain. The change in oil volume in the hydraulic cylinder changes the propeller blade angle and returns the engine/propeller system RPM to the pilot selected RPM set value. The governor is set to a specific RPM setting which compresses or releases the governor speeder spring.

When the engine is operating at the requested RPM setting, the governor is operating onspeed - refer to Figure 3-2 (a). In an onspeed condition, the centrifugal force acting on the spinning flyweights is balanced by the speeder spring, and the pilot valve is not sending oil to or from the propeller hydraulic cylinder.

During normal operation, the governor is almost always rapidly adjusting between underspeeding and overspeeding, towards onspeed, as the system reacts to changes (in atmosphere, engine, flight condition, etc).

When the engine is operating below the requested RPM setting, the governor is operating underspeed - refer to Figure 3-2 (b). In an underspeed condition, the flyweights tilt inward because there is not enough centrifugal force on the spinning flyweights to overcome the force of the speeder spring. The pilot valve, forced down by the speeder spring and flyweights, meters oil flow to decrease propeller pitch and raise engine RPM.

When the engine is operating above the requested RPM setting, the governor is operating overspeed - refer to Figure 3-2 (c). In an overspeed condition, the centrifugal force acting on the spinning flyweights is greater than the speeder spring force. The flyweights tilt outward, and raise the pilot valve. The pilot valve then meters oil flow to increase propeller pitch and lower engine RPM.

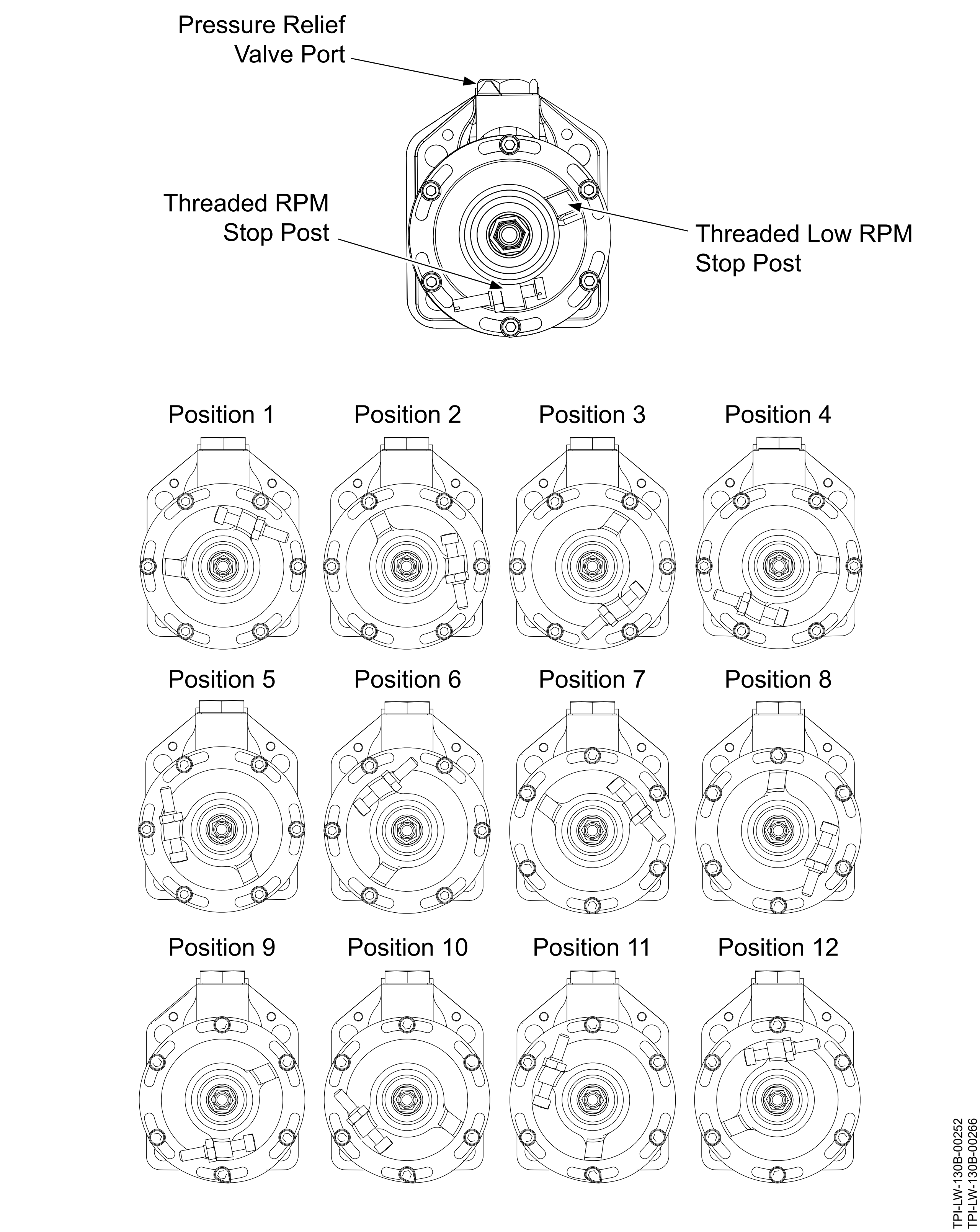


Governor Operation Examples
Figure 3-2

B. Governor Models

There are numerous models of governor typically supplied by Hartzell for experimental installations. Hartzell S-series governors are the latest design for the typical reciprocating engine used for these aircraft. The governors are typically -1 governors, to match with the -1 actuation of the propeller (refer to the "Propeller Actuation" section in this manual) . Following the selection of the actuation method, the major selection factor for the model of governor is the drive ratio; different engine models have different governor drive ratios. You can find the drive ratio on the engine TCDS, or query the engine builder. Different governor models have different head orientations to allow alignment with aircraft side governor control cables and brackets. Hartzell is also introducing newer models with a lower minimum governing speed, none are currently configured as drop-in replacements for what we typically supply; configuration in this manner may be available on request. See Hartzell Service Letter HC-SL-61-277 for detailed instructions regarding governor installation.

Common Hartzell Governor Models					
Governor Model	**Drive Ratio**	**Typical Engine**	**Design Governing Propeller RPM**	**Head Position** *(see Figure 3-3)*	**Minimum Governing RPM**
S-1-10	0.866:1	(I)O-360	2700	#9	~1600
S-1-26	0.895:1	(I)O-540	2575	#4	~1500
S-1-32	0.947:1	(I)O-540	2700	#4	~1600
S-1-79	0.895:1	IO-390	2700	#4	~1600
S-1-86	1:1	IO-550	2700	#5	~500
S-1-87	0.947:1	IO-540	2700	#5	~500
S-1-88	0.895:1	N/A	2700	#5	~500
S-1-89	0.866:1	N/A	2700	#5	~500



Governor Head Orientations
Figure 3-3

ENGINE/PROPELLER COMPATIBILITY - CONTENTS

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1. Engine/Propeller Compatibility

A. General

Engine and propeller vibration compatibility is probably the most important topic of consideration when selecting a propeller and engine. To be clear, this discussion of vibration is not the vibration you may feel in the cabin of the aircraft. The propeller may be experiencing damaging vibration, even if there is no perceptible vibration in the cabin. Conversely, experiencing vibration in the cabin doesn't necessarily mean that the the propeller is experiencing significant loads. Cabin vibration and propeller vibration are different phenomena. Propellers are rotating systems subject to high frequency alternating loads (vibration) imparted from the air and the powerplant, and this is what drives the stresses the propeller is subjected to. Propellers are highly stressed components and small changes to engine configurations can significantly alter the loads on the propeller; the engine and propeller together are a system, and must be determined to be compatibile as a combination. Improper engine and propeller combination can cause catastrophic failure and fatalities. Modifications to the engine, such as increasing the compression ratio, may create an improper engine/propeller combination; these modifications are discussed in more detail in the following sections and in Volume 1 of Manual 193.

B. Certified/Certificated Propellers

A propeller is considered a certificated (or certified) propeller in the U.S. if it meets the standards of 14 CFR Part 35, has a type certificate, and has been appropriately manufactured and marked. However, just because the propeller is certified, does not mean it may be used on any engine (even if the engine is certified as well) or airplane; the combination of engine and propeller must be determined to be compatible and compliant with regulations for specific certificated aircraft.

C. Known vs. Unknown Vibration Compatibility

(1) Compatibile Installations

A compatible installation is an installation that meets the requirements of 14 CFR 23.2400 or 14 CFR §23.907 (up to amendment 23-59) which is more descriptive, Propeller Fatigue and Vibration, which states:

> *The applicant must determine the magnitude of the propeller vibration stresses or loads, including any stress peaks and resonant conditions, throughout the operational envelope of the airplane by either:*
>
> > *Measurement of stresses or loads through direct testing or analysis based on direct testing of the propeller on the airplane and engine installation for which approval is sought; or*
> >
> > *Comparison of the propeller to similar propellers installed on similar airplane installations for which these measurements have been made.*
>
> *The applicant must demonstrate by tests, analysis based on tests, or previous experience on similar designs that the propeller does not experience harmful effects of flutter throughout the operational envelope of the airplane.*
>
> *The applicant must perform an evaluation of the propeller to show that failure due to fatigue will be avoided throughout the operational life of the propeller using the fatigue and structural data obtained in accordance with Part 35 of this chapter and the vibration data obtained from compliance with paragraph (a) of this section. For the purpose of this paragraph, the propeller includes the hub, blades, blade retention component and any other propeller component whose failure due to fatigue could be catastrophic to the airplane. This evaluation must include:*
>
> > *The intended loading spectra including all reasonably foreseeable propeller vibration and cyclic load patterns, identified emergency conditions, allowable overspeeds and overtorques, and the effects of temperatures and humidity expected in service.*
> >
> > *The effects of airplane and propeller operating and airworthiness limitations.*

Hartzell follows FAA standards and regulations for propeller certification and determining compatibility, both of which are required for certificated installations. Neither vibrational compatibility nor propeller certification are required by regulation for experimental installations but it is highly recommended; physics does not care about your airworthiness category. Changes to a compatible combination may increase stresses; untested and unapproved installations have unknown stresses and therefore, unknown margins of safety. Hartzell can only determine compatibility for installations for which we have adequate data. Fortunately, the experimental market is vibrant and innovative; unfortunately this means that new combinations and modifications are created faster than we can test them. Often, the most truthful insight we can provide regarding a particular propeller and engine combination is "We don't know." The combination may be safe, it may be unsafe, it may be safe if used with an operating restriction, but without the data we don't know and can't determine compatibility.

Hartzell's general policy is to list or specify the combinations that are compatible; all others can be assumed to be incompatible or at least unknown. If there is any doubt or question, please contact Hartzell directly.

(2) Use with Unknown Compatibility

(a) As an experimental aircraft manufacturer/integrator in the Experimental category, the FAA allows you to experiment as you wish and approval from Hartzell is not required. Our goal is to educate and promote the safety of flight whenever possible, not to prohibit aviation and innovation. By making or using modifications and combinations with unknown compatibility, you are assuming the associated risks, and expose anyone who flies with you, or whom you fly over, to those same risks. Please make an effort to educate yourself before assuming those risks.

WARNING: THERE IS A RISK OF SERIOUS INJURY, DEATH, AND/OR SIGNIFICANT PROPERTY DAMAGE IF THE PROPELLER IS NOT VIBRATIONALLY COMPATIBLE WITH THE ENGINE AND AIRCRAFT INSTALLATION. VIBRATION CAN RESULT IN PROPELLER OR BLADE SEPARATION FROM THE AIRCRAFT.

(b) Type Certificated propellers used on experimental aircraft should be marked or indicated in such a way as to prevent subsequent reuse on a certificated aircraft; this is typically accomplished by stamping X suffixes on all propeller and blade model numbers. These propellers have may have been subjected to unknown loads and as such are no longer appropriate for use on a certificated installation.

D. How to Know if a Combination is Compatible

There are several different ways to know if a propeller/engine combination is compatible, as detailed in the following sections. If there is any doubt, please contact Hartzell directly.

(1) Hartzell Propeller Inc.

(a) There is information available, specific to the homebuilder, in Hartzell Manual 193, Vol. 1 which is available on our website. When in doubt, please contact Hartzell directly.

(2) Certificated Aircraft

(a) If the engine and propeller are legally installed on a certificated aircraft, and haven't been modified, that combination has been approved. The aircraft TCDS will show the engine model and propeller model.

(3) Note 9

(a) Note 9 on a propeller TCDS lists approved and vibrationally compatible engine and propeller combinations that may be applied generally. These approvals only apply to single engine, tractor, non-aerobatic installations with "stock" or unmodified components. Note that not every approved combination is necessarily included in Note 9.

(4) Kit Manufacturer

(a) Hartzell works directly with kit manufacturers to provide information on the most commonly used Hartzell products for those airplanes.

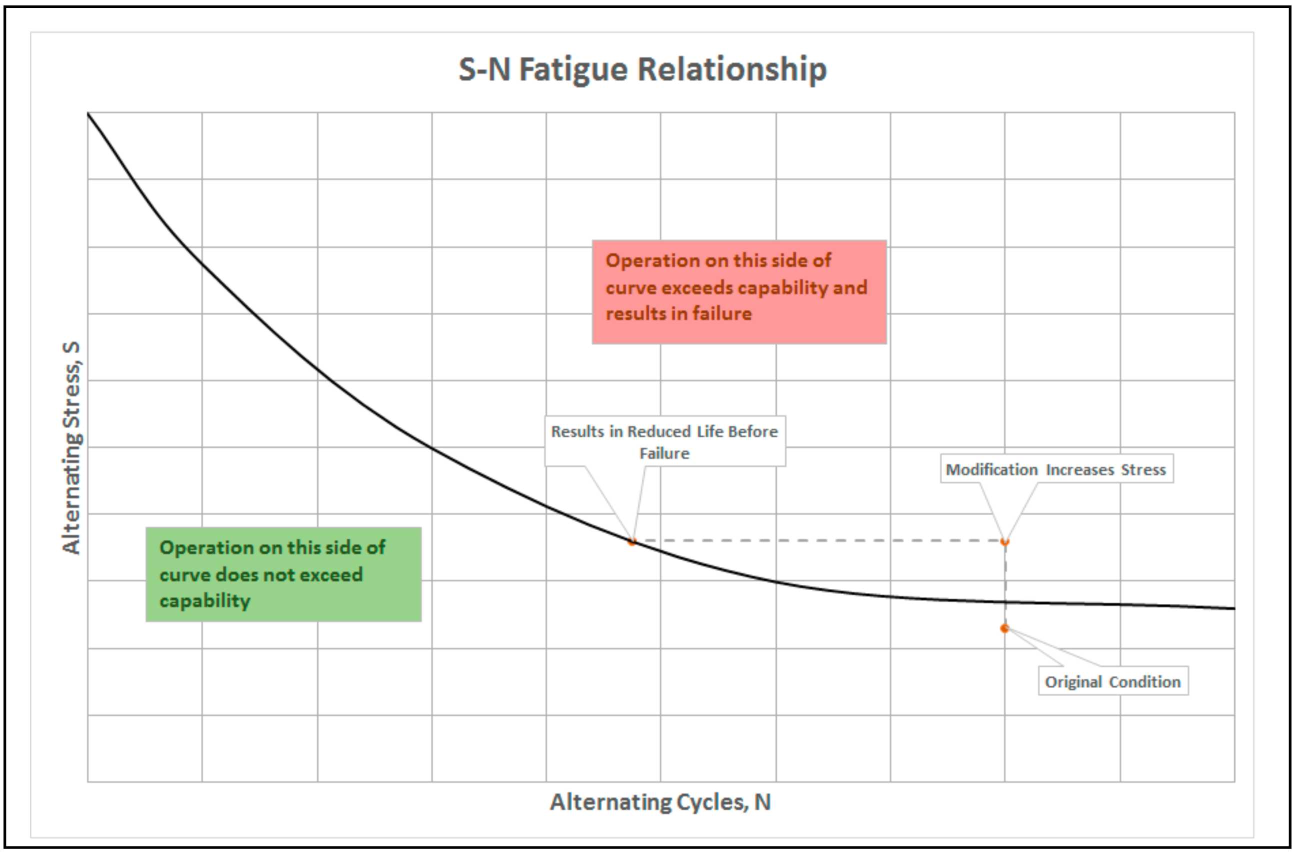
E. Resonant Conditions and Operating Restrictions

It is often impossible or impracticable to design a propeller that does not experience some sort of vibratory interaction with a reciprocating engine; such a propeller may be too heavy and/or too expensive and/or perform too poorly to be viable. Further, there is substantial variety to the engines available to the general aviation market; a propeller free from vibratory interaction with one engine model may experience it on a slightly different engine model. The magnitude and frequency of these loads is a function of the total vibratory system, with each component contributing to the overall response. For this reason, when Hartzell engineers test engine and propeller combinations to determine vibrational compatibility and find these conditions with unacceptable loads, an operating restriction is often the most practical solution.

Operating restrictions must be marked on the tachometer, and may also require a text placard nearby in order to fully describe the operating restriction. These restrictions are typically indicated with yellow arcs and red lines; if you have questions about how to indicate this, please contact Hartzell Propeller directly. Operating restrictions should also be specified in the aircraft flight manual.

F. Fatigue

Propeller/engine compatibility issues can create fatigue failures. It is critical to understand that fatigue accumulates at a far more rapid pace in propellers than in other airframe components, and as such the real time between damage initiation and failure can be very brief. It is not uncommon to measure alternating loads on reciprocating engines that occur 2, 4, 6, 8, and 10 times per revolution. For an hour in cruise at 2300 RPM, a 2x vibratory condition will accumulate 276,000 fatigue stress cycles in that hour. The ability of the propeller to withstand fatigue is based on the S-N relationship, which is the relationship between the amplitude of the fatigue cycles and the number of cycles at that amplitude that can be withstood. (Refer to Figure 4-1). Small increases in stress can result in substantial reduction in life, as shown below. Frequent inspections are strongly recommended if operating with a non-certificated installation; however, these inspections may not guarantee propeller reliability, as a failing device may be hidden from the view of the inspector. There are generally no outward signs of fatigue, and fatigue can not be assessed via inspection, either visual or NDT, until a crack initiates; it typically requires trained personnel with specialized equipment to identify small initial cracks. With the high stresses and high cyclic loading frequency of propellers, a small crack initiation can propagate into a full failure very quickly; in some cases within a single flight.



SN Relationship Example
Figure 4-1

G. Propeller Diameter

The length of the propeller blade affects how it responds to the engine, and therefore the resultant stresses. As a result, Hartzell may only list determined vibrational compatibility for specific diameters, or ranges of diameters for propeller/engine combinations. Use of a propeller of a different diameter voids the approval. Aluminum blades wear in service due to erosion and repair, so the approvals typically list the maximum and minimum diameter approved and diameters in between are implicitly approved as well; eventually a blade will fall below the minimum allowable diameter and must be retired from service. Composite blade approvals typically list specific diameters; these blades incorporate formed erosion shields at the correct diameter, which can be replaced, and the composite material can be repaired, so composite blades spend their lives at a nearly constant diameter.

H. Propeller Modifications

Modifications to the propeller itself are not endorsed or supported by Hartzell Propeller. By modifying your propeller outside of approved maintenance procedures, you are assuming responsibility for any effects which may invalidate vibrational compatibility, decrease safety, and lead to failure. The following are some modifications we’ve seen and the pitfalls.

(1) Diameter

(a) Shortening a blade, particularly an aluminum blade, beyond its approved limits changes the mass and vibrational response of the blade to something that hasn’t been tested or analyzed. This can, and has, lead to propeller failure. Note that the same blade design may have different approved diameter limits depending on the specific engine onto which it is installed; be sure that the diameter limits are applicable to your installation.

(2) Thinned, Narrowed, or Re-profiled Blades

(a) Altering the basic geometry of the propeller outside of approved repair limits is creating a completely different propeller. These modifications change the mass and the fundamental frequencies of the blades, which could lead to radically different loads with untested and unknown margins of safety.

(3) Twisted Blades

(a) Cold working blades can create damage that only later becomes apparent. Not only can damage occur in the areas that are being modified, but damage can also occur in areas used to restrain the blade when trying to twist it. Never try to twist blades when assembled in a hub. Some Hartzell blades have special, alternate twist designs, typically indicated by a D or J suffix in the blade; these twists are machined in from the factory and are not cold worked.

(4) Polished Blades

(a) Hartzell aluminum blades are coated and painted to protect them from corrosion. Corrosion provides an opportunity for crack initiation. Removing these protections increases the likelihood of corrosion, and will require more frequent maintenance. This practice is not endorsed or recommended.

(5) Blade Tape

(a) Hartzell discourages the use of blade erosion tape on aluminum blades. This tape creates areas for moisture to be trapped, and may yellow or craze over time which hides areas of concern from visual inspection.

(6) Hardware

(a) Replacement or incorrect usage of Hartzell hardware with that of a different type, such as usage of incorrect spacers with composite bulkheads, could compromise hub clamping and lead to failure.

I. Engine Modifications

Propeller loads on reciprocating aircraft engines are predominately driven by the engine and its characteristics. Every time the crankshaft accelerates, or decelerates, the propeller must as well; the propeller responds to these impulses based on its characteristics and is stressed as a result. Don’t be fooled by the steady tach signal, the crankshaft speed is not constant and varies as the engine completes each cycle (intake, compression, combustion, exhaust) of each cylinder. Anything that alters this relationship may alter the impulses forced into the propeller, either in terms of phasing, amplitude, duration, or all three. Such modifications include, but are not limited to, the addition of a turbocharger or turbonormalizer, increased boost pressure, increased compression ratio, increased RPM, altered ignition timing, electronic ignition, full authority digital engine controls (FADEC), or tuned induction or exhaust. Any modification that claims to increase power, or maintain power while reducing fuel flow (which is the same as getting more power from a given amount of fuel), or changes the mass and/or stiffness of the crankshaft and/or counterweights should be cause to consider the impact on the propeller. The most popular of these modifications, electronic ignition and compression ratio increases, are discussed in the following sections.

J. Electronic Ignition and Ignition Timing

Changing the ignition system characteristics can significantly alter the vibratory characteristics of the system. By altering when the mixture ignites, how completely/quickly it ignites, and as a result how long it burns, electronic ignitions with and without variable timing advance can increase propeller stresses. In the same way, altered magneto timing can also alter stresses. Hartzell is in the process of testing multiple electronic system designs and parameters to try to characterize the resultant effects on propeller loads. Preliminary data has shown that certain electronic ignition systems produce increased vibrational loads for certain propellers. However, there is not currently enough substantiating data to determine compatibility of propeller/engine combinations with the many electronic ignition systems available to the market in general, and more testing is necessary; it would not be sufficient to publish a range of timing settings independent of the ignition system specifics. Unless the specific propeller and engine combination is tested and determined to be compatible with the specific electronic ignition system and settings, use of electronic ignition systems are not endorsed. Use of ignition systems or configurations other than those listed as compatible is done at the user’s own risk.

K. Compression Ratio Increases

Increasing the compression ratio increases the amplitude of the compression and power impulses (bigger bang) driven into the propeller. This increases propeller stresses which may have a significant effect on propeller fatigue life and flight safety. This may result in a harmful condition, and propellers that didn’t have an operating restriction with a lower compression ratio may need one with an increased compression ratio and propellers with an operating restriction may need an extended operating restriction; without testing and data, the specifics of the restriction cannot be determined. Unless explicitly stated, the approved compression ratio is the “stock” compression ratio for that engine model. Use of engines with a compression ratio higher than Hartzell specifies as compatible is done at the user’s own risk.

L. Crankshaft Counterweights/Dampers

Some engines incorporate crankshaft counterweights, also referred to as (pendulum) dampers. Engines incorporating these may be commonly referred to as “counterweighted” or “damped” whereas engines not incorporating these may be commonly referred to as “non-counterweighted” or “undamped” configurations. Counterweights are dynamic engine parts which are attached to the engine crankshaft and are different from the offset mass balances of the crankshaft. Their purpose is to smooth out the vibration imparted into the crankshaft by the piston cycles of the engine. This helps to reduce the stresses in the engine and propeller. Counterweights are only capable of absorbing vibrations at certain frequencies, therefore they are tuned to help absorb the worst vibratory frequencies produced by the engine rotating system. Counterweights are typically described in terms of their quantity and “order”, ex: 1x 5th order. The term “order” refers to the number of vibration beats per crankshaft revolution that the counterweight absorbs. In addition to the frequency of the counterweight being tuned, the mass of the counterweight can be adjusted to change how much of the vibration is absorbed. The configuration of these components is critical. Engines which do and do not feature crankshaft counterweights, but are otherwise identical, produce entirely different vibrational characteristics and loads. In general, propellers installed on engines with crankshaft counterweights (dampers) experience lower loads than when installed on engines without crankshaft counterweights. Hartzell recommends, if able, to select or configure an engine with crankshaft counterweights. Not all counterweight configurations are identical between different engine models. Use of engines with a crankshaft counterweight configuration different from that determined to be compatible is done at the user’s own risk.

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ENGINE SPECIFIC INFORMATION - CONTENTS

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1. Information for Specific Engine Series

A. 4-cylinder 360 Series by Lycoming/Continental (Titan)/ECI/Superior Air Parts

The 4-cylinder 360 series has three basic crankshaft configurations; “Thick Wall”, “Thin Wall”, and Counterweighted. The “Thick Wall” crankshaft is typically used on “Angle Valve” certified engines with 8.7:1 compression ratio producing 200 HP at 2700 RPM. The “Thin Wall” crankshaft is typically used on “Parallel Valve” certified engines with 8.5:1 compression ratio producing 180 HP at 2700 RPM. For Lycoming 360 series engines, the fourth digit of the engine suffix provides information about the crankshaft counterweight configuration. Engines featuring a “6” in the fourth digit, ex: IO-360-B1G6, feature 1x 6.3 and 1x 8th order crankshaft counterweights. Engines not featuring a fourth digit, ex: O-360-A1C, do not have crankshaft counterweights. Superior Air Parts 360 series engines are all parallel valve engines. These engines are offered with 2 types of constant speed crankshafts, “Thin-Wall” and “Heavy-Wall”. For Superior engines with Heavy-Wall crankshafts, use propellers listed for Angle Valve Engines. For Superior engines with Thin-Wall crankshafts, use propellers listed for Parallel Valve Engines.

B. 4-cylinder 370 Series by Continental (Titan) and 375 Series by AeroSport Power

The 370 or 375 series engines use the same components for the engine rotating system, which is critical for propeller vibratory characteristics. These engines are offered with or without crankshaft counterweights. When possible, the best option to choose for propeller compatibility is the version with crankshaft counterweights. The engines are offered with two compression ratio options, 8.1:1 and 9.6:1. The 9.6:1 pistons should only be used on engines featuring crankshaft counterweights. Use of compression ratios higher than 8.5:1 in 370/375 series engines without crankshaft counterweights can produce hazardous propeller loads.

C. 4-cylinder 390 Series by Lycoming

For Lycoming 390 series engines the second digit in the engine suffix determines the propeller flange indexing. Engines featuring a “1” in the second digit, ex: IO-390-A1A6, get BHC- hubs. Engines featuring a “3” in the second digit, ex: IO-390-C3B6, get HC- hubs. For Lycoming 390 series engines, the fourth digit of the engine suffix provides information about the crankshaft counterweight configuration. Engines featuring a “6” in the fourth digit, ex: IO-390-A1A6 feature 1x 6.3 and 1x 8th order crankshaft counterweights. Hartzell propellers are currently only vibrationally compatible with 390 series engines with crankshaft counterweights.

D. 6-cylinder 540 Series by Lycoming

Lycoming 540 series engines have several counterweight order configurations. Hartzell propellers are only compatible with engines that feature 1x 5th and 1x 6th order crankshaft counterweights. These engines are denoted with a “5” in the 4th digit of the engine suffix, ex: O-540-E4A5. Lycoming 540 series engines with 1x 5th and 1x 6th order crankshaft counterweights come in several mass configurations. Lycoming Service Instruction 1012 has a comprehensive list of crankshaft counterweight configurations cross-referenced with engine model numbers.

E. 6-cylinder 470 Series by Continental

The Continental 470 series engines have a diverse set of configurations which affect propeller vibratory loads. There are 3 different available compression ratios, carbureted or fuel injected configurations, many different power and rotational speed ratings, and many different crankshaft counterweight configurations. Careful attention must be paid, particularly for power and rotational speed ratings, compression ratio, and crankshaft counterweight configurations, when determining propeller suitability from a propeller vibration perspective. Due to the complexity of determining propeller/engine compatibility for the Continental 470 series, it is strongly recommended to only install propellers which have been approved via Note 9 on the applicable propeller TCDS, are approved for use on a certified aircraft installation, or are summarized in Manual 193, Vol. 1 available on Hartzell’s website. If vibration suitability cannot be verified by these means, please contact Hartzell for further guidance on the vibration suitability of the combination.

F. 6-cylinder 520/550 Series by Continental

The Continental 520 and 550 series engines share much in common in their rotating system. Generally, the Continental 520 and 550 series produce similar propeller vibratory loads and characteristics. Care must still be given to the specific engine configuration for which vibration suitability is being determined. The most critical factors when determining the compatibility are compression ratio, crankshaft counterweight configuration, and power and rotational speed ratings. In general, if the propeller has been approved on a naturally aspirated Continental 520 or 550 engine, it can be deemed acceptable vibrationwise on other 520 and 550 series with the same compression ratio, crankshaft counterweight configuration, and the same or lower power and rotational speed ratings. Approved propeller/engine combinations are listed in Note 9 on the propeller TCDS, approved for use on a certified aircraft installation, or are summarized in Manual 193, Vol. 1 available on Hartzell’s website. If there is any doubt about the vibration compatibility of a propeller/engine combination, please do not hesitate to contact Hartzell Propeller for further guidance on the vibration suitability of the combination.

G. Polar Moment Limitations for Continental 6-cylinder Engines

Most Continental 6 cylinder engines, as part of the installation manual, specify a minimum polar moment of inertia for the propeller. Hartzell is aware of these limits, and as a matter of course, does not recommend using propellers that exceed these limitations. This precludes the use of small diameter, composite propellers on most Continental six-cylinder engines. Continental engineering has advised that this can cause premature wear of the crankshaft counterweights, spalled gear teeth, bearing distress, and broken magneto shafts. Contact Continental before selecting a low polar moment of inertia propeller for your installation. If you make your own determination of suitability, Hartzell is not responsible for the effects that may arise out of this use.

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INTEGRATION - CONTENTS

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1. Pitch Settings

NOTE: A typical Hartzell constant speed propeller has two pitch settings that must be selected and determined to be appropriate to the aircraft installation.

A. Low Pitch

The low pitch setting in a -1 and -4 system sets the minimum blade angle the propeller can achieve. It is a physical stop which is externally adjustable; consult the appropriate propeller owners manual for adjustment procedure. Determination of an appropriate low pitch setting is the responsibility of the aircraft manufacturer or modifier; in this case, the homebuilder. Experimental propellers shipped from Hartzell will have a preliminary setting which, at a minimum, must be verified to be acceptable; refer to the section, "Flight Test" for low pitch testing. The propeller will operate at the low pitch setting whenever it is underspeeding. The low pitch setting will affect the following key behaviors:

(1) Ground Idle

(a) The low pitch setting will affect the load on the engine at idle and how much thrust is produced. For a fixed idle speed, an increased low pitch angle will result in more thrust and a faster idle taxi speed.

(b) Adjustments to the low pitch setting may require adjustments to engine settings.

(2) Takeoff

(a) The low pitch setting will affect the behavior during takeoff by adjusting the point (power/airspeed) at which the propeller begins to govern.

(b) Too high of a low pitch setting will prevent reaching rated RPM and increase takeoff distance

1 This may be a deliberate trade off.

(c) Too low of a pitch setting may result in:

1 Transient overshoots as the governor attempts to control with rapid throttle application

2 Masking of engine health issues

(d) Hartzell recommends selecting a setting for naturally aspirated engines wherein the static RPM is at least 25-50 RPM less than the maximum rated RPM of the engine.

1 Ensure that this is not being masked by the governor setting. Refer to the appropriate governor manual and the "Governor" section in the Accessories chapter of this manual.

(3) Stall

(a) The low pitch setting will affect the idle power stall behavior due to changes in thrust/drag and flow field around the tail.

(b) A low pitch setting that produces significant residual thrust at idle power will reduce the stall speed.

1 In the event of an engine failure, the power off stall speed may then be higher than documented.

(4) Approach/Landing

(a) The low pitch setting will affect the residual thrust or drag present during idle and/or low power approaches and influence the descent rate and float during flare.

(5) Emergency

(a) In the event of a seal, supply, governor, or other failure that prevents an otherwise operative propeller from controlling, the low pitch blade angle becomes the fixed pitch angle for the propeller.

(b) This angle may result in an aircraft that may not maintain level flight without propeller overspeed. The amount of overspeed will be a function of airspeed and applied power.

1 Depending on the situation, flight may be possible at a speed lower than best glide as the propeller will be able to absorb more power and create more thrust at lower airspeeds.

2 Depending on the situation, continued flight may require overspeed.

(c) The low pitch angle also affects the amount of drag present during glide. Generally, a higher low pitch angle decreases the descent rate while a lower low pitch angle increases the descent rate.

B. High Pitch

The high pitch setting in a -1 and -4 system sets the maximum blade angle the propeller can achieve. This is set via a physical stop inside the propeller cylinder and is not adjustable. If adjustment is necessary, please send the propeller to an appropriately rated propeller repair station for replacement of the stop with a different one; there is a minimum stop length, and therefore maximum high pitch angle that can be achieved for any given propeller system and blade combination. High pitch is not infinitely adjustable, and the total operation range of the propeller is limited.

2. Performance

A. General

Most people want to know how well a new or different propeller will perform on their airplane, though you may be surprised at how often the selection is driven by other factors. There are two main ways of answering the question of how well a propeller will perform.

B. Analytical

Hartzell uses analytical methods to predict performance as well as to design and recommend propellers for specific applications. These analytical methods are only a model of reality; as George E.P. Box said, “All models are wrong, but some of them are useful.” Not all factors that influence the performance may be accounted for, or may not be known for a particular aircraft. The ultimate answer of performance differences comes via testing.

(1) How Fast Will My Airplane Be With (Propeller)?

(a) This is difficult to answer. How much drag, as a function of flight condition, does your airplane have? How much power, as a function of flight condition, can your engine deliver?

C. Flight Test

The best way to know how well a propeller performs on an airplane is to put it on that airplane and flight test it. It is important to do the testing well; there are a myriad of factors that can influence the test results, and without accounting for those factors, the data acquired could be useless or misleading.

(1) Propeller Performance Flight Test Technique

(a) Performance flight testing to measure differences between propellers requires great care as the differences between two well suited propellers can be small. Drag racing two “identical” airplanes is not a complete answer; no two airplanes are truly identical and those two airplanes may have differences that obscure the result. Testing must be done in manner that tightly controls the variables that can be controlled, and accounts for those that can’t; this means testing must be done on the same airframe with the same engine, as close as possible to the same weight and CG locations, and as close as possible to the same atmospheric conditions. This only gets the raw data, and any data collected inevitably has scatter around the “true” answer; sufficient data must be collected to satisfy the desired (or required) level of precision for the test effort. The raw data must then be corrected using flight test engineering principles to account for differences in temperature, power, weight, etc. between test points. Hartzell employs these techniques whenever conducting performance flight test, and encourages others to do the same.

3. Flight Test and Integration

In additional to excellent resources like FAA AC 90-89B and the EAA flight test manual, here are some considerations for flight testing and integrating your experimental aircraft and Hartzell propeller. All flight testing, including propeller testing, carries risk and must be approached and conducted with due caution, planning, and rigor.

A. Propeller Specific Tests

(1) Weight and Balance

(a) The weight and balance of your aircraft can be substantially altered by the propeller you choose; it’s a decent amount of weight at the end of the aircraft and so it’s moment contribution can be significant. The choice of propeller could be the difference between useful load and required ballast, or drive the decision about where to put your battery or other systems. An extended hub may allow you to have a lighter propeller by increasing the moment arm, but may require more cowling work. Make sure to consider the effect of the propeller weight and CG on your aircraft center of gravity (CG) and mission before selecting and/or when changing propellers.

(2) Propeller CG

(a) Generally, a good approximation is to assume that the CG of the propeller is located at the center of the disc. Refer to the "Propeller Extension Length" section in this manual for distances between the center of the hub (disc) and the propeller mounting flange for the various propeller extensions offered.

(3) Low Pitch

(a) Setting the low pitch angle is accomplished by positioning the aircraft perpendicular to the prevailing wind and running up the engine at full throttle with the brakes applied and noting the resultant RPM, then repeating the measurement on the reciprocal heading; the two measurements are then averaged. This procedure is repeated for several adjustments of low pitch as necessary; adjustment is available on wing by removing the spinner dome (which need not be installed for this testing) and the adjustment procedure is detailed in the owner’s manual. To ensure the governor is not in play, it may be adjusted higher for this testing and then returned to the original setting. The low pitch angle may also be tracked and measured during this procedure with a protractor at a defined blade location; however in some applications the shape of the blade will make it difficult to achieve a consistent measurement without a template. If tracking via a protractor, ensure that the protractor is reliably zeroed before each measurement; the front of the cylinder provides a convenient flat plane oriented with the propeller disc.

(4) High Pitch

(a) If the propeller high pitch setting is too low, the propeller pitch will become fixed at the high pitch angle and the governor won’t be able to control RPM; this will become evident by an increase in RPM above governing RPM with an increase in airspeed. This attribute should be checked as part of any new constant speed propeller testing program, and caution must be exercised when doing so. To that end, we recommend testing at two conditions to determine the acceptability of the high pitch stop setting:

1 A normal, wide open throttle, reduced RPM cruise setting as appropriate for the aircraft. Make note of minimum achievable governing RPM; this may be limited by the governor or by the high pitch stop. Initiate a normal descent from this condition with the RPM set at least 100 RPM higher than the minimum governing speed, up to a typical descent speed for the aircraft, and note if the RPM remains stable. If the RPM begins to increase above the set governing RPM, knock off the test point and recover the aircraft.

2 A full throttle and full RPM, dive up to, but not beyond, aircraft V_{NE}, starting from a safe altitude with enough altitude to ensure a safe recovery. This may require build ups to approach the limit progressively. If the RPM begins to increase above the set governing RPM, knock off the test point and recover the aircraft. Refer to the paragraph on "Flutter/Dive/V_{NE}" later in this section for more information regarding V_{NE} testing. Ensure that aircraft attitude does not starve the engine of oil.

(b) In both instances, the airspeed should be increased slowly to ensure that that, in the event that the propeller high pitch stop is reached, the increase in RPM over governing that will result will be small and noticed before exceeding propeller and/or engine limits. Recovery from this overspeed should be a reduction in power and/or in airspeed. A small amount of overspeed, up to 10%, for a short period of time (<20 seconds) is typically allowable per the appropriate Hartzell Propeller Owners Manual, so priority is on a smooth, controlled recovery of the aircraft. Ensure that aircraft attitude does not starve the engine of oil.

(c) High pitch is not infinitely adjustable, and the total operation range of the propeller is limited.

(5) Ground Clearance

(a) Proper ground clearance is important to safe operations, and to avoiding damage. See 14 CFR 23.925 for guidance on specific recommendations; in summary:

1 In the most critical of takeoff or taxi attitude: 7” of clearance for tricycle gear aircraft, 9” for tailwheel aircraft

2 Positive clearance in the landing condition with the gear deflected and tire(s) deflated

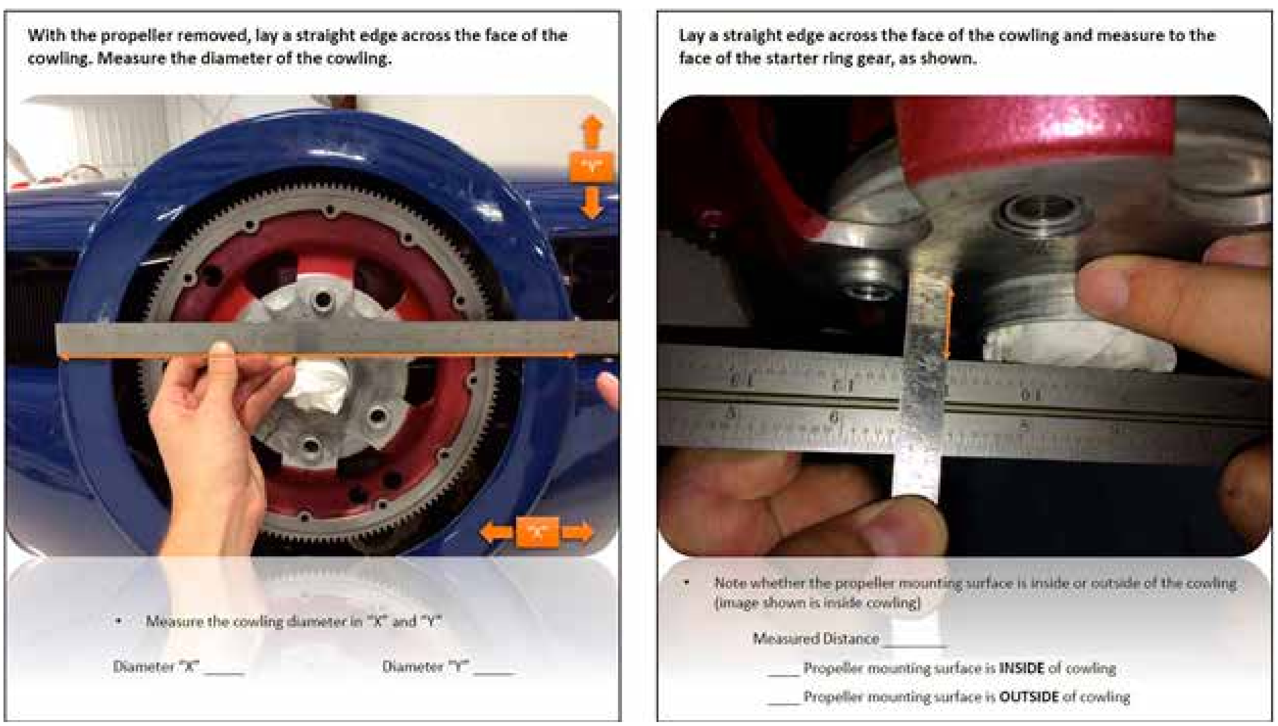
(b) Please contact the kit or aircraft manufacturer for recommended diameters.

(6) Cowling Clearance

(a) The propeller and spinner need appropriate clearance between the rest of the airframe. 14 CFR 23.925 recommends a minimum of 0.5” clearance between the blades and any stationary portion of the airframe. It also recommends a minimum of positive clearance between the spinner and the cowling; keep in mind the engine isolators allow the engine to move, the cowling is not perfectly stiff, and the isolators will typically sag with age. Check the cowling, spinner, and propeller for witness marks and signs of contact as you expand the aircraft flight envelope.

(b) The use of blade paddles to manually rotate the blades to check clearance is not recommended and is to be avoided, especially for composite blades. To check clearance at high pitch, measure at low pitch and use trigonometry to calculate the change in clearance as the propeller moves to high pitch. The high and low pitch angles of the propeller as built, for new propellers, are detailed on a build slip included with the Propeller Owner’s Manual. These are absolute angles measured at a specific location and are relative to the propeller disc, the delta between the two angles is consistent regardless of blade station used.

(c) To aid in selecting the appropriate combination, refer to the section, "Propeller Extension Length" in this manual for available hub extensions as appropriate, along with the information in the applicable volume of Manual 193 for specific spinners to calculate the location of the aft edge of the spinner. Use the methods illustrated in Figure 6-1 to measure your installation.



Cowling Measurement
Figure 6-1

(7) Spinner Clearance

(a) The propeller blades must have positive clearance to the spinner, again per 14 CFR 23.925. Check the blades and spinner for witness marks and signs of contact as you expand the aircraft flight envelope.

(8) Propeller Control

(a) The governor must be able to appropriately control the propeller. If the governor appears to have difficultly controlling the propeller, particularly at high speed, the relief pressure of the governor may be too low. Consult the "Testing and Troubleshooting" chapter of the applicable Propeller Owner's Manual.

B. Other Tests

The following tests are not specific to the propeller, but may be influenced by, or have effects on the propeller.

(1) Flutter/Dive/V_{NE}

(a) Exercise caution while expanding the aircraft speed envelope, in particular pay attention to the deck angle of the aircraft. It is possible to unport the engine oil pick up tube with substantial nose down angles; at these conditions the propeller may overspeed rapidly if deprived of oil and may result in propeller and/or engine damage or worse. Refer to the paragraph on "High Pitch" in this section for more information.

(2) Pitot Static Calibration

(a) The propeller affects the flow field around the airframe and as such, a change in propeller may change the pitot-static calibration; typically by altering the pressure at the static port.

(3) Engine Out Glide or Idle Descent

(a) The propeller low pitch angle influences the drag at idle or windmilling; changing the pitch setting or the propeller will change the drag and the aircraft performance. Refer to the "Low Pitch" section in this manual for more information.

(4) Takeoff

(a) The propeller low pitch angle influences the takeoff performance; changing the pitch setting or the propeller will change the aircraft takeoff performance. Refer to the "Low Pitch" section in this manual for more information.

(5) Stall

(a) The propeller low pitch angle influences the drag at idle or windmilling; changing the pitch setting or the propeller will change the aircraft stall speeds. Refer to the "Low Pitch" section in this manual for more information.

(6) Cooling

(a) The propeller and spinner have an effect on the flow field entering the cooling inlets. Propeller blades are generally not optimized for cooling; trying to use the propeller to force air into the inlets is generally a reduction in overall system efficiency and the propeller is there to move the aircraft, not cool the engine. Changes to the propeller and, to a lesser extent, spinner warrant checking cooling characteristics. In general, locating cooling and intake inlets further outboard, away from the center of the propeller, is beneficial.

4. Maintenance and Overhaul

A. Maintenance

Information on maintenance practices and requirements, servicing and inspections, personnel requirements for performing maintenance, and propeller critical parts is contained in the applicable propeller owner's manual, available on our website. It is essential that the propeller is properly maintained according to the recommended service procedures and a close watch is exercised to detect potential problems before they become serious. Any grease or oil leakage, loss of air pressure, unusual vibration, or unusual operation should be investigated and repaired, as it could be a warning that something serious is wrong.

B. Overhaul

"I'm Part 91, I don't have to overhaul." This is true, the regulations do not require that you overhaul your propeller - but you should. Consider your aircraft's annual or condition inspection, and talk to some mechanics that do annual or condition inspections on multiple airframes, and ask the following "How often do you conduct an inspection and find nothing wrong?" And these aircraft are inspected every year; propeller TBO is on a much longer interval. Propeller overhaul is an opportunity, through visual and NDT inspection, to find (some) things that could be about to go wrong before they before do. Your propeller may be in pristine condition, or it may be internally corroded. You won't know unless you have it inspected. Frequent inspections are strongly recommended if operating with a non-certificated installation; however, these inspections may not guarantee propeller reliability, as a failing device may be hidden from the view of the inspector.

Hartzell specifies two different limiting times for TBO, a flight time and a calendar time. Flight time is specified to address wear and fatigue. Calendar time is specified to address corrosion and sealing. TBO is specified in Hartzell Service Letter HC-SL-61-61Y, available at the Hartzell website. TBO periods are based on certified installations; modifications to the installation warrant more frequent inspections and are strongly recommended.

(1) Blade Angles

(a) As the integrator of the propeller, engine, airframe combination, you are responsible for determining the appropriate blade angle settings for the installation. In order to maintain these angles, instruct the service facility to measure the blade angles of the propeller prior to disassembly to create a specification to assemble it to; otherwise the reassembled propeller may not have the appropriate angles. Refer to the sections, "Pitch Settings" and "Flight Test and Integration" in this manual for more information.

C. Damage

Inspection for damage, especially on metal blades, and particularly on metal blades used in installations with unknown vibration compatibility, is critical. Fatigue failures can be rapid, and surface damage provides an initiating site for cracks to begin. Consult the applicable propeller owner’s manual, contact Hartzell Product Support, or an appropriately rated propeller repair station if you have any questions regarding damage to your propeller.

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SPECIAL CASES - CONTENTS

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1. Aerobatics

A. Integration

(1) Of critical importance is to consider the operating characteristics of the propeller; for a -1 propeller, if the oil supply is interrupted for any reason the propeller will move towards low pitch. This can lead to rapid and significant overspeed events which, depending the flight condition, can become catastrophic faster than the pilot can react. For this reason, Hartzell recommends a -4 system for any significant aerobatic activity that may interrupt oil supply. Propellers with a -4 control system require a compatible governor. These propellers incorporate blade counterweights, and as such may weigh more, cost more, and require a larger spinner. Blade counterweights are selected specific to the installation and alter the operating pressures and characteristics.

(2) Aerobatic Counterweight Warning

WARNING: THERE IS RISK OF SERIOUS INJURY, DEATH, AND/OR SIGNIFICANT PROPERTY DAMAGE IF THE PROPELLER COUNTERWEIGHTS ARE INSUFFICIENTLY SIZED. A HAZARDOUS OVER- SPEED OF THE PROPELLER AND ENGINE MAY OCCUR, LEADING TO PROPELLER AND/ OR ENGINE SEPARATION AND/OR DAMAGE, LOSS OF THRUST AND POSSIBLE LOSS OF AIRCRAFT CONTROL.

B. Loads

It is Hartzell's position that “light” aerobatics (loops, rolls, lazy-eights, wingovers) do not significantly impact propeller acceptability with regards to installation stresses. Installations where “heavy” aerobatics are intended (snap-rolls, spins, lomcevaks, etc.) need to be evaluated on a case by case basis for vibrational compatibility and loads.

2. Racing

A. Integration

Of critical importance is to consider the operating characteristics of the propeller; for a -1 propeller, if the oil supply is interrupted for any reason the propeller will move towards low pitch. This can lead to rapid and significant overspeed events which, depending the flight condition, can become catastrophic faster than the pilot can react. For this reason, Hartzell recommends a -2 (feathering) system for single engine installations more likely to experience failure (e.g. highly tuned racing installations). Propellers with a -2 control system require a compatible governor. Feathering propellers incorporate counterweights and a longer cylinder for increased range of motion; as such they weigh more, cost more and require a larger spinner.

B. Loads

Racers frequently increase the operating RPM above the typical rated RPM of the engine. Increased RPM increases the centrifugal loads experienced by the retention components and may shorten propeller component life significantly. These areas may be untested for vibratory modes and loads. Racing engines may also be modified with a variety of mechanisms to increase power such as increased compression ratios, cylinder shape/size modifications, turbochargers, superchargers, and nitrous oxide; all of these modifications alter the impulses and loads imposed on the propeller; these modifications may shorten propeller component life significantly and lead to catastrophic failure. Operation in untested regimes and/or use of untested equipment is done at the risk and judgment of the operator.

3. Pusher Installations

Since propellers on pusher installations operate in the aerodynamic wake from the aircraft ahead of the propeller, a pusher propeller will experience additional aerodynamically induced loads compared to those on a conventional tractor-type aircraft. Pusher installations must therefore be individually evaluated, and require a specific vibration approval. In general, placing the propeller plane of rotation as far away as possible from the wing trailing edges and exhaust exit will minimize propeller stresses, temperatures, and noise level. Many pusher installations eject high temperature exhaust gas into the propeller, which causes elevated temperatures of the propeller hub and blade shanks; therefore, thermal surveys are required on most pusher applications to identify the operating temperatures to which the propeller will be subjected. These temperature effects can influence the strength and fatigue life of the propeller and must be evaluated by Hartzell Propeller Inc. Operation without a spinner dome installed may produce different thermal conditions on the propeller, as compared to operation with a spinner dome. Both conditions should be evaluated. Pusher installations are more susceptible to foreign object damage (FOD) and to the corrosive combustion products from the engine exhaust that are deposited on the propeller; therefore, additional maintenance requirements for pusher installations may be specified by Hartzell Propeller Inc.

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