EASA DIFFERENCES TRAINING BRIEF

Variable Pitch Propellers

A study Guide by Steve Pells

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This document is, in no way, a susbstitute for good instruction from a qualified instructor.

Variable Pitch/Constant Speed Propellers

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The purpose of this document is to provide guidance and backround information for pilots who already hold as SEP (Land) rating, and wish to undertake differences training to allow them to fly aircraft with the following characteristics:

- Variable Pitch Propeller
- Retractable Undercarriage
- Turbo or Supercharged Engine
- Electronic Flight Instrument System (EFIS)
- Single Lever Power Control (SPLC)
- Tail Wheel

1: Rules & Regulations:

Differences Training should be conducted by the holder of an appropriate instructor rating who meets the following requirements:

(a) Hold a valid Flight Instructor or Class Rating Instructor qualification (SPA) for the aircraft on which the training is to be carried out.
(b) Hold a valid Type/Class Rating applicable to the particular aircraft to be flown.
(c) Have completed their own Differences Training to fly the particular aircraft on their own licence.

Upon completion of Differences Training, and when the instructor is satisfied that an acceptable level of competency has been achieved, the pilot's logbook or equivalent document should be annotated to show successful completion and be signed by the instructor who conducted the training.

The Differences Training certification is recommended to take the following format and should include the Type or Class Rating designation of the Aeroplane;

Date	Certified Differences Training In:	Signed	CAA Reference Number
	Example:- **Single Power Lever Controls** **SE Piston (Land)**	.... Name	

Date	Certified Differences Training In:	Signed	CAA Reference Number
	Example:- **Manual Engine Controls** **Turbocharged Engines** **ME Piston (Land)**	.... Name	

There is no test, as such, and, for single-engined aeroplanes, this is a one-time sign-off that never expires. For multi-engined aeroplanes it is valid for 2 years. If it has been a while since your last flight in such an aircraft, a review of procedures, or a flight with an instructor is recommended.

Variable Pitch (VP) Propellers (all propeller aeroplanes) EASA PART FCL

These systems make a significant difference to performance in all phases of flight. Mostly, the instruction in this section will be given to pilots converting from SEP aeroplanes with fixed pitch propellers to SEP or MEP aeroplanes with VP propellers and constant speed units (CSU). The system on some older types may not include a CSU and instructors must ensure that all of the system differences and handling techniques, introduced by the new type, are properly covered in the training given.

NOTE: Differences Training completed, for this section (VP Props), on an SEP aeroplane, does **NOT** provide equivalent qualification on MEP aeroplanes (due to the system differences) nor vice versa.

Theoretical Knowledge Topics: All Aeroplanes

Principle of operation and effect on performance;
System construction and function;
Propeller system limitations;
Engine limitations and instrumentation.
Operation of throttle, mixture and propeller controls, including pre-flight checks &normal handling during:

- *Start up and taxying;*
- *Take-off and climb;*
- *Cruise at various power settings and speeds;*
- *Low speed handling and stall/spin recovery;*
- *Approach and go-around;*
- *Landing and shut down.*

In-flight failures, within the propeller system, including:

- *Loss of oil pressure;*
- *Loss of governor control;*
- *Overspeed;*
- *Underspeed.*

Emergency handling, during:

- *Engine failure after take-off/go-around;*
- *Engine failure during other phases of flight, including approach and landing;*
- *Effect of engine failure on glide performance.*

Emergency Handling Considerations for Multi-Engine Aeroplanes
Engine failures after take-off including propeller feathering and effect of wind-mill drag;
Circuit and approach with one or more engines inoperative;
Go-around with one or more engines inoperative; Landing with one or more engines inoperative.

2: Introduction:

Up until now, all the single-engined piston (SEP) aircraft you have flown are likely to have had a fixed pitch propeller. That is, the blade angle of the propeller is fixed, and cannot be adjusted by the pilot. This is a compromise, because propeller efficiency varies with aircraft speed, and so the propeller cannot be operating at maximum efficiency for both take-off and cruise. Some propellers have the blade angle set to make them most efficient for take-off, but this makes them less efficient in cruise, reducing their range and increasing fuel burn. Other propellers are set to be at maximum efficiency in the cruise, but this leads to poorer take-off performance.

An early solution to this problem was to have a 2-position lever in the cockpit which manually changed the blade angle of the propeller between take-off and cruise settings. As propeller and engine design improved, this has changed to a continuously variable propeller angle, controlled by a new lever in the cockpit.

Here, on the left, is the throttle quadrant for a Piper Arrow, showing the new Propeller Control Lever or RPM lever.

On most aircraft it is the middle of the 3 levers, and usually coloured blue.


In a twin enginned aircraft, this leads to a lot of levers to be managed!


The similar arrangement of levers in Cessna aircraft

The operation of the Mixture control is unchanged.

3: Constant Speed Unit (CSU) or Propeller Governor:

Rather than changing the blade angle of the propeller directly, the Propeller Control Lever (RPM lever) is used to select a desired RPM within the operating range (usually around 1500-2600 rpm). The blade angle then changes automatically to keep the RPM constant as speed changes. This is done by setting the desired RPM on the RPM gauge using the RPM lever to make changes. The propeller governor then uses a combination of springs and engine oil pressure to alter the blade angle to keep the RPM at the desired value.

When in the typical operation range for in-flight use (typically 2000-2600 RPM), the RPM lever is used to set a desired RPM value. This lever is quite sensitive, and so only small movements are needed. Once set, the RPM value should not change with speed or altitude (hence constant speed). The throttle (which used to be used to set engine RPM in fixed pitch aircraft), in now used to set a new parameter – Manifold Pressure (MP). Generally, this lever is much less sensitive and much larger movements are needed to produce the desired changes.

Below the usual flight operating range (say 2000-2600 RPM), the RPM Lever is mostly ineffective, and in these low power situations, such as taxying, the throttle controls engine RPM as before.
With the RPM lever fully forward, we say the prop is at MAX RPM or in FINE pitch. With the RPM lever fully rearward, we say the prop is at MIN RPM or in COARSE pitch.

3a: Order of Operation of Levers:

We now understand which levers control RPM and MP. However, when we want to make a change to either or both of these values, there is a specific order which MUST be adhered to, to prevent engine stress and possible damage.

When increasing power, the **BLUE (RPM)** lever must be advanced before the **BLACK (Throttle)**
When decreasing power, the **BLACK (Throttle)** lever must be retarded before the **BLUE (RPM)**

There are various ways to try to remember this:

Increase power – levers Right to Left Decease power – levers Left to Right	Blue UP, Black Down	REV UP – POWER DOWN

However you remember, it is important to get the order right, so every time you touch the levers, stop, think and make sure you know what you are going to do.

4: Typical Operation:

We will now go through a typical flight profile, taking the Piper Arrow as our example, although very similar figures will apply for other aircraft.

4a: Pre Flight:

On the ground, with the engine shut down, the RPM will be reading zero, fairly obviously, and the Manifold Pressure gauge will be reading atmospheric pressure in inches of mercury (Usually about 29-31” at sea level but decreases by 1” per 1000’ as you gain altitude or elevation).

The RPM lever should be in the fully forward/Fine/Max RPM position when you enter the aircraft.

After engine start, the RPM should be kept at around 1000-1200 RPM (see PoH) using the throttle alone. The RPM lever will remain at MAX throughout the taxy phase.

RPM lever should be fully forward when you enter the aircraft.

4b: Power Checks:

Power checks are carried out as shown in the checklist or PoH. The power is increased to 2000 RPM (1700 for Cessna 182) using the throttle alone. RPM lever remains at MAX. When the check of the propeller governor is reached, the Blue RPM lever is cycled to MIN RPM and back to MAX 3 times, accompanied by a change in engine note. It should take about 3-5 seconds to cycle the lever there and back, and each time we do this, we are looking at a different gauge for verification.

1: RPM decreases and returns to initial value of 2000/1700 RPM. Try not to let the RPM reduce by more than 500 RPM during the check.
2: MP increases and returns.
3: The oil pressure (which moves the propeller blade) shows a change in pressure.

After the power checks, the RPM lever should be returned to MAX for take-Off.

4c: Take Off:

For take-off in a non turbo charged engine, all levers – Throttle, RPM & Mixture should be fully forward. In a turbo charged engine, a maximum MP will be stated (and must be observed).
Monitor oil temperatures, pressures and MP (in a turbo-charged) engine during take-off.

Above we see the levers and MP/RPM readings during take-off in an Arrow III. Note the Fuel Flow

And here at Climb power

4d: Climb Power:

Although it is permissible to climb at full take-off power, on most variable pitch propeller aircraft, a reduced power is often set after take-off. This is known as climb power. Climb power is usually set at a safe height, when initial obstacles have been cleared, often 500 - 1000’ agl.

On the Piper Arrow, climb power is 2500 rpm & 25” MP. This is usually abbreviated to 25/25 or 25 squared. Remember, when setting climb power, that there is an order of levers. As we are reducing power, we move the throttle first (large lever movement) then RPM (very small lever movement).

On the Cessna 182, climb can be at full power or at 2400 RPM/23” MP (24/23).

4e: Climb:

During the climb, the RPM will stay at whatever value you set with the RPM lever (it is a constant speed prop). However, as atmospheric pressure drops by 1” for every 1000’ altitude gained, the MP will fall by 1” for each 1000’ climbed. So, it is important to continually move the throttle forward in the climb to maintain the MP, otherwise the power output of the engine will decrease. Eventually, full throttle will be needed to maintain climb power. This is known as ‘full throttle height’. It is typically around 5-6000’. Further climb will result in the loss of climb performance. In a turbo charged aircraft, the full throttle height will be much higher than for a normally aspirated engine.

4f: Cruise:

In the cruise, you must select a suitable cruise setting. A typical setting for the Piper arrow is 2300/23” (23 squared). The PoH will recommend a selection of different cruise settings depending on speed and range requirements.
Again, when we come to set cruise power after levelling off after a climb, this will involve a reduction in power, so the throttle is retarded before the RPM lever.

Power Setting Table for Lycoming Model IO-360-C1C6 Engine as Installed in PA-28R-201 Arrow   Best Economy Mixture

POWER SETTING TABLE (Best Economy)

Pressure Altitude	ISA Temperature		55% Power 110 BHP @ Propeller Mixture Peak EGT Manifold Pressure - In. Hg		65% Power 130 BHP @ Propeller Mixture Peak EGT Manifold Pressure - In. Hg		Pressure Altitude
Feet	°F	°C	2200 RPM	2500 RPM	2200 RPM	2500 RPM	Feet
S.L.	59	15	24.8	22.2	27.5	24.5	S.L.
1000	55	13	24.4	22.0	27.1	24.3	1000
2000	52	11	24.0	21.8	26.7	24.1	2000
3000	48	9	23.7	21.5	26.3	23.8	3000
4000	45	7	23.3	21.3	26.0	23.6	4000
5000	41	5	22.9	21.1	25.8	23.3	5000
5250	40	4	22.8	21.0	F.T.	23.2	5250
6000	38	3	22.5	20.8		23.1	6000
7000	34	1	22.1	20.6		22.8	7000
8000	30	-1	21.8	20.4		22.6	8000
8750	28	-2	21.5	20.2		F.T.	8750
9000	27	-3	F.T.	20.1			9000
10000	23	-5		19.9			10000
11000	19	-7		19.7			11000
12000	16	-9		F.T.			12000

← Some suggested cruise settings for the Piper Arrow.

CRUISE PERFORMANCE
PRESSURE ALTITUDE 4000 FEET

CONDITIONS:
2950 Pounds
Recommended Lean Mixture
Cowl Flaps Closed

NOTE
For best fuel economy at 65% power or less, operate at the leanest mixture that results in smooth engine operation or at peak EGT if an EGT indicator is installed.

Cruise table for the Cessna 182Q →

RPM	MP	20°C BELOW STANDARD TEMP -13°C % BHP	KTAS	GPH	STANDARD TEMPERATURE 7°C % BHP	KTAS	GPH	20°C ABOVE STANDARD TEMP 27°C % BHP	KTAS	GPH
2400	22	---	---	---	76	139	13.0	73	140	12.5
	21	74	135	12.6	71	136	12.1	69	136	11.7
	20	69	131	11.8	66	132	11.3	64	133	11.0
	19	64	127	10.9	62	128	10.6	60	128	10.2
2300	23	---	---	---	76	140	13.1	74	141	12.6
	22	75	135	12.8	72	136	12.3	70	137	11.9
	21	70	132	12.0	68	133	11.5	65	134	11.2
	20	66	128	11.2	63	129	10.8	61	130	10.4
2200	23	75	135	12.8	72	136	12.3	70	137	11.9
	22	70	132	12.0	68	133	11.6	66	134	11.2
	21	66	129	11.3	64	129	10.9	61	130	10.5
	20	62	125	10.5	59	126	10.2	57	126	9.8
	19	57	121	9.8	55	121	9.5	53	121	9.2
2100	23	70	132	11.9	67	133	11.5	65	133	11.1
	22	66	128	11.2	63	129	10.8	61	130	10.4
	21	62	125	10.5	59	126	10.1	57	126	9.8
	20	57	121	9.8	55	121	9.5	53	122	9.3
	19	53	117	9.2	51	117	8.9	50	117	8.7
	18	49	112	8.6	47	112	8.3	46	112	8.1
	17	45	107	8.0	43	107	7.8	42	106	7.6

← A twin engined aeroplane set at 22 squared in the cruise

4g: Descent:

During the descent, the RPM lever is often left at the cruise setting. Indeed, it can remain there until shortly before landing. However, the MP will need to be reduced continually. Remember, in the climb, how the MP reduced by 1" for every 1000' climbed? Well the reverse happens during descent, so every 1000' or so, inch the throttle back to keep the desired MP.

In larger engines, say over 200 HP, such as the Cessna 182, care should be taken to avoid shock cooling of the cylinders. This is best achieved by only reducing the MP slightly. A typical minimum of 20" will help, and an absolute minimum of 15” if needed. Cylinder Heat Temperature (CHT) can be monitored in descent to check that cooling is not too rapid.

4h: Landing:

The propeller will perform quite happily during landing at most RPM settings, however in case of a go-around, maximum RPM will be needed. For this reason, prior to every landing, the RPM lever should be moved fully forward. This can either be done as part of the Pre-Landing checklist (typically downwind), or on base leg or on finals. The best time to do this is when the throttle is at a low setting, as this reduces the unwanted noise change associated with the increasing engine RPM. For this reason, I recommend advancing the RPM lever to MAX once descent has begun on the base leg.
Once established on short finals, we should always ensure that the RPM lever is set to MAX by doing our **Red, Blue, Green Checks**:

- REDS Mixture(s) Fully Rich
- BLUES Propeller(s) Max RPM
- GREENS Gear Down, 3 Greens

4i: Go Around:

Since we moved the RPM lever to MAX on finals (or before), should a go-around be necessary, the lever is already in the correct position. Just advancing the throttle is needed to achieve go-around power.

4j: After Landing:

The RPM lever should be left at MAX until and after shutdown.

5: Abnormal Operations

There are 2 main things that could go wrong with the constant speed propeller:

- **Loss of oil pressure:** How a loss of oil pressure affects the constant speed prop, generally depends on whether you are in a single or multi engined aeroplane. In singles, a loss of oil pressure usually drives the propeller to high RPM (low pitch) to allow the engine to supply maximum power in the event of a failure. In a twin, the propeller will normally feather – drive to low RPM (high pitch) to reduce drag.
- **Propeller Overspeed:** Normally a matter of trying to control the prop as best you can. Often a checklist in the manual.

PA28R-201 Arrow III: PROPELLER OVERSPEED

1.	Throttle	**RETARD**
2.	Oil Pressure	**CHECK**
3.	Propeller Control	**FULL DECREASE RPM**. Then set if any control available.
4.	Airspeed	**REDUCE**
5.	Throttle	**AS REQD TO KEEP BELOW 2700 rpm**

6: Suggested Flight Profile for Training

A typical training flight will involve:

- External Checks to include propeller and engine
- Familiarisation of the cockpit controls and indicators.
- Power Checks including propeller RPM check
- Selection of climb power after take-off
- Cruise power settings
- Descent management
- Propeller overspeed considerations
- Return to the airfield for touch and go training.

8: Suggested Circuit Profile for PA28R-201 Arrow 3