# My Quest for Power

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EAA Chapter 81

# Background

- RV-6A with Lycoming O-320-E2A with 150 hp
  - Would like more performance, at least +300 fpm
  - What that means - Probably 20 hp or CS Prop

| **Gross Weight 1650 lbs** | **150 hp** | **160 hp** | **180 hp** |
|---|---|---|---|
| *Top Speed* | *195 mph* | *199 mph* | *207 mph* |
| *Cruise [75% @ 8000 ft]* | *184 mph* | *188 mph* | *196 mph* |
| *Cruise [55% @ 8000 ft]* | *166 mph* | *169 mph* | *176 mph* |
| *Stall Speed* | *55 mph* | *55 mph* | *55 mph* |
| *Takeoff Distance* | *560 ft* | *535 ft* | *485 ft* |
| *Landing Distance* | *500 ft* | *500 ft* | *500 ft* |
| *Rate of Climb* | *1,305 fpm* | *1,450 fpm* | *1,740 fpm* |

# Options

- Change to a Constant Speed Prop
  - Not feasible with this engine (E2A)
- Compression ratio 7 to 8.5 (like 160 hp D2A)
  - Mods range from piston & rings only, to new cylinder and piston assemblies
- Change from Carburetor to Fuel Injection
  - Mechanical or Electrical, supports improved lean operation at altitude
- Change from Magneto to Electronic Ignition
  - Enables variable timing advance at altitude
- Supercharging or Turbocharging
- Bigger Engine
  - All it takes is money!

# Compression Ratio Mod

- Reviewing online discussions of this mod, there is much said about how easy and about how not-so-easy it is.
- I researched Lycoming's engine history and compared parts lists, and the sweet spot for my 150hp E2A is to convert it to a 160hp D2A, where the only internal difference is the piston.  The starter and flywheel tooth count is different, suggesting a higher ratio to improve starting torque for the higher compression engine.
- If I started with a different 150hp O-320, the changes required could include rods, wrist pins, and more.
- Cost - $1,000 with serviceable parts up to $5,000 for complete cylinder assemblies (Millenium)

# Engine Lineage

- First Produced in 1953
  - 150HP E2A

| | | | | | |
|---|---|---|---|---|---|
| O-320-E2A | 150/140 | 2700/2450 | 80 | 7.00:1 | Same as –E1A but with fixed pitch prop. and uses 3/8 in. attaching bolts and has alternate rating of 140 HP at 2450 RPM |
| O-320-E1A | 150 | 2700 | 80 | 7.00:1 | Same as –A3B but with Type 1 dynafocal mounts |
| O-320-A3B | 150 | 2700 | 80 | 7.00:1 | Same as –A3A except for straight riser in oil sump and -32 carburetor |
| O-320-A3A | 150 | 2700 | 80 | 7.00:1 | Same as –A1A but uses 7/16 in. dia. prop. bolts |
| O-320-A1A | 150 | 2700 | 80 | 7.00:1 | Controllable prop., 25° spark advance, Bendix S4LN-20 and S4LN-21 Magnetos |

  - 160HP D2A

| | | | | | | |
|---|---|---|---|---|---|---|
| O-320-D2A | 160 | 2700 | 100/100LL | 8.50:1 | Same as –D1A but with fixed pitch prop. and 3/8 in. attaching bolts | -39 |
| O-320-D1A | 160 | 2700 | 100/100LL | 8.50:1 | Same as –B1B but with Type 1 dynafocal mounts | -39 |
| O-320-B1B | 160 | 2700 | 100/100LL | 8.50:1 | Same as –B1A except for straight riser in oil sump and -32 carburetor | -39 |
| O-320-B1A | 160 | 2700 | 100/100LL | 8.50:1 | Same as –A1A but high comp. ratio | -39 |

| FIG. REF. 17 | PART NUMBER | DESCRIPTION | | QUANTITY PER ASSEMBLY A2B | A2C | A2D | A3B | E1A | E1F | E2A | E2B | E2C | E2D | E2F | E2G | E2H | E3D | E3H |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 78030 | ROD ASSY., Connecting | 4 | | | | | | | | | | | | | | | |
| 2 | LW-13923 | BUSHING, Connecting rod, upper | 4 | | | | | | | | | | | | | | | |
| 3 | 78027 | BOLT, Connecting rod | 8 | | | | | | | | | | | | | | | |
| 4 | LW-17198 | NUT, Connecting rod | 8 | | | | | | | | | | | | | | | |
| 5 | 69373 | BEARING, Connecting rod | 8 | | | | | | | | | | | | | | | |
| 6 | 75413 | PISTON, Compression ratio 7.00:1 | 4 | | | | | | | | | | | | | | | |
| | 75089 | PISTON, Compression ratio 8.50:1 | | | 4 | | | | | | | | | | | | | |
| 7 | LW-14068 | PIN, Piston (49/64" I.D.) See Note | 4 | | | | | | | | | | | | | | | |
| | LW-14077 | PIN, Piston (5/16" I.D.) See Note | | | | | | | | 4 | | | | | | | | |
| | LW-14078 | PIN, Piston (37/64" I.D.) See Note | | | 4 | | | | | | | | | | | | | |
| 8 | 60828 | PLUG, Piston pin | 8 | | | | | | | | | | | | | | | |
| | LW-11775 | PLUG, Piston pin (piloted in piston pin) | | 8 | | | 8 | | | 8 | 8 | | | | | | | |
| 9 | 74989* | RING, Piston, compression | 8 | | | | | | | | | | | | | | | |
| | 74241** | RING, Piston, compression | | 8 | 8 | | 8 | | | 8 | 8 | 8 | | | | | | |
| 10 | 73857 | RING, Piston, oil regulating (expander type) | 4 | | | | | | | | | | | | | | | |

| FIG. REF. 17 | PART NUMBER | DESCRIPTION | ON ALL | QUANTITY PER ASSEMBLY B2B | B2C | B3B | D1A | D1D | D1F | D2A | D2B | D2C | D2G | D2J | D3G | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 78030 | ROD ASSY., Connecting | 4 | | | | | | | | | | | | | | |
| 2 | LW-13923 | BUSHING, Connecting rod, upper | 4 | | | | | | | | | | | | | | |
| 3 | 78027 | BOLT, Connecting rod | 8 | | | | | | | | | | | | | | |
| 4 | LW-17198 | NUT, Connecting rod | 8 | | | | | | | | | | | | | | |
| 5 | 69373 | BEARING, Connecting rod | 8 | | | | | | | | | | | | | | |
| 6 | 75089 | PISTON, Compression ratio 8.50:1 | 4 | | | | | | | | | | | | | | |
| 7 | LW-14078 | PIN, Piston | 4 | | | | | | | | | | | | | | |
| | LW-14077 | PIN, Piston | | | | | | | 4 | 4 | | | | | | | |
| 8 | 60828 | PLUG, Piston pin | 8 | | | | | | | | | | | | | | |
| | 72198* | PLUG, Piston pin | | 8 | 8 | | | | | | | | | | | | |
| | LW-11775 | PLUG, Piston pin (piloted in piston pin) | | | | | | | 8 | 8 | | | | | | | |
| 9 | 74241** | RING, Piston, compression | 8 | | | | | | | | | | | | | | |
| | 74873● | RING, Piston, compression | | 8 | 8 | | | | | | | | | | | | |
| 10 | 73857● | RING, Piston, oil regulating (expander type) | 4 | | | | | | | | | | | | | | |
| | 73908‡ | RING, Piston, oil regulating (expander type) | | 4 | 4 | | | | | | | | | | | | |

# Fuel Injection

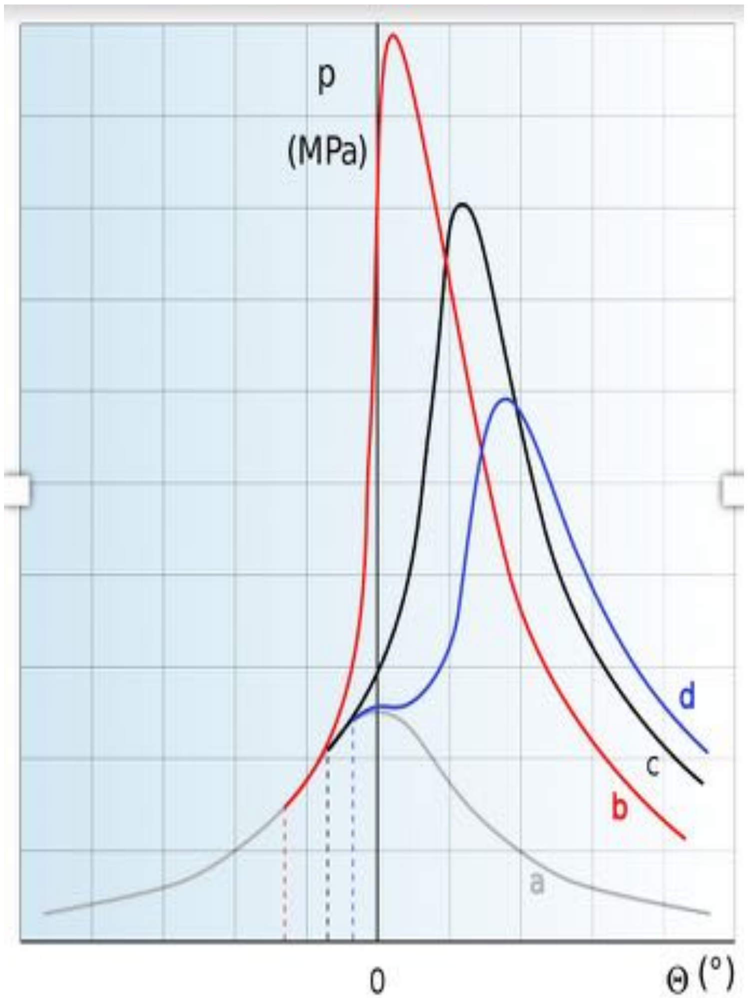
- While there is no “direct quoted” improvement from injection over carburation, it is a “facilitator”
  - Better mixture control at high density altitudes enables leaner operation and higher % of available power
  - Elimination of carburetor ice risk, could enhance inlet geometry for another inch of MP (4% more hp)
  - Electronic fuel injection can provide “tuning” of fuel delivery to each cylinder from the cockpit
  - Cost - $1500 (serviceable mechanical parts) up to $6,500 as part of an electronic Fuel and Ignition system

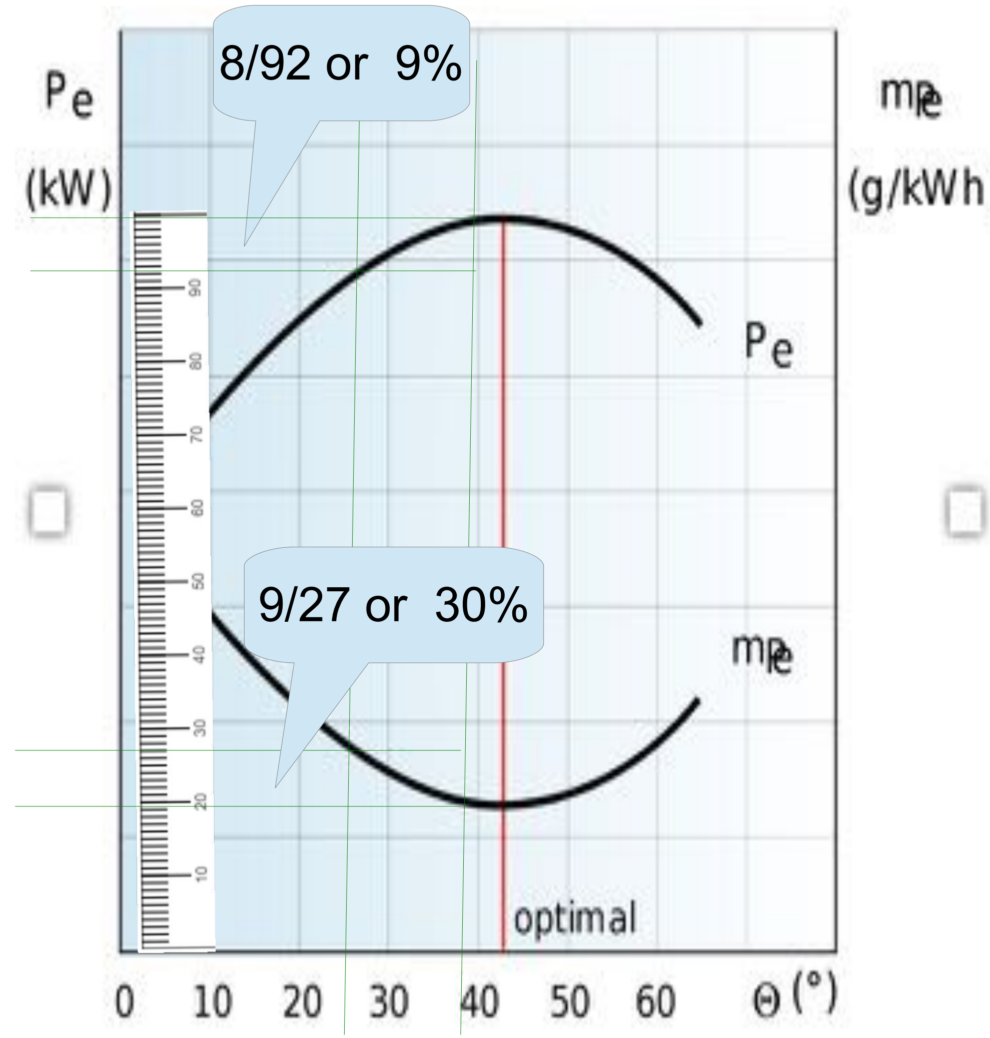
# Electronic Ignition

- Magnetos are reliable but....
  - Can contribute to hard starting
  - Do not efficiently ignite a real lean mixture
  - Do not provide optimum ignition advance
    - Conservatively set to avoid detonation under all altitude, RPM, and throttle settings
  - Require periodic maintenance and overhaul
- Electronic Ignition addresses these issues
  - Provides high energy at low cranking speeds
  - Provides high energy with a larger spark gap for improved lean operation
  - Can include a "map" to increase timing advance under appropriate conditions of RPM and MP for 10% hp at altitude

# Effects of Ignition Advance

- Too much will detonate, too little wastes energy



# Mechanical Fuel Injection

- Bendix System from Twin Comanche IO-320
  - RSA-5AD1 Servo
  - Fuel Inector Nozzles
  - Fuel Flow Divider
  - Fuel Distribution Lines
  - 30 psi Fuel Pump
  - $750 on Ebay
  - Must add 30 psi Fuel Boost Pump, fuel filters, and high pressure gascolator

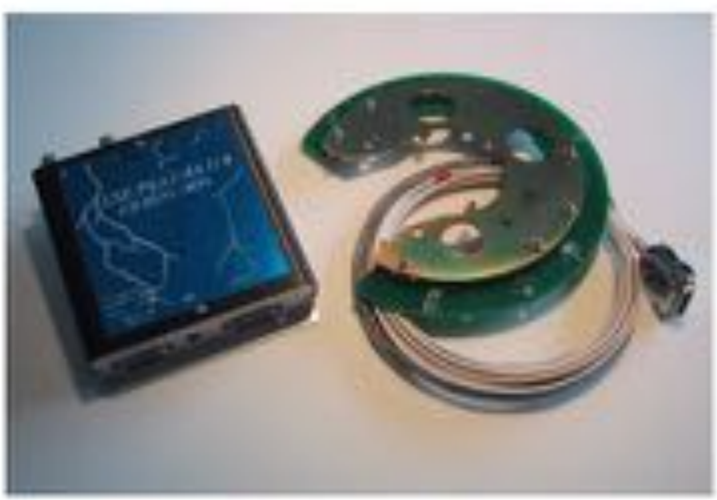
# Electronic Fuel Injection and Ignition

- FLY EFII system- fully redundant turnkey
  - $6,500, but Requires a redundant electrical system
  - Requires a fuel return to the tank

# Standalone Electronic Ignition

- Light Speed Engineering
  - Systems for single or dual operation, $1,200 to $3,500

**PLASMA II PLUS**
**CAPACITIVE DISCHARGE IGNITION SYSTEM**



Plasma II+ CDI with Direct Crank Sensor

Plasma II+ CDI with Hall Effect Module

# Standalone Electronic Ignition

- E-Mag replaces one or both magnetos
  - Includes internal alternator, no power required when running. (Power needed for starting)
  - With needed accessories, $1,700 each

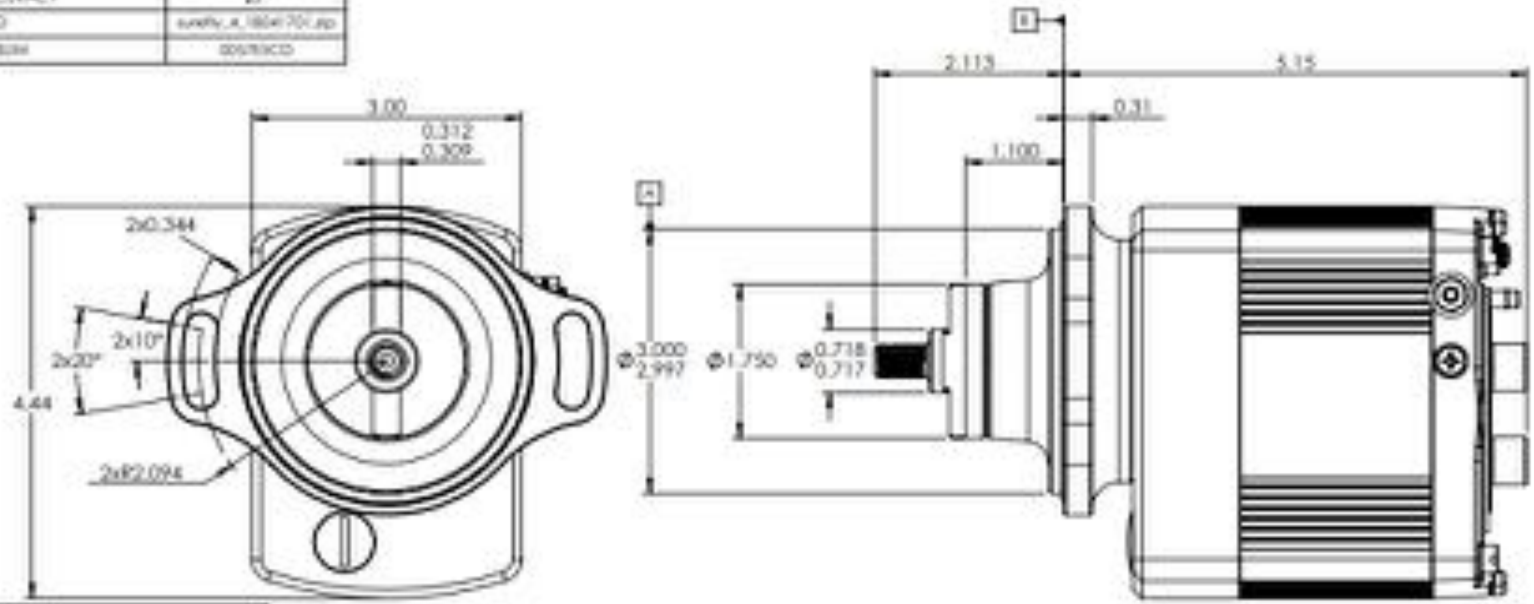
# Standalone Electronic Ignition

- “Surefly” replaces one (STC) or both magnetos (Experimental with alternate power available
- FAA Certified, can be used on most Lycoming or Continental engines in most certified aircraft as a single mag replacement
- STC prohibits auto fuel and turbo or supercharging, and requires CHT monitoring of all cylinders
- Utilizes existing Slick wiring harness
- $1,250 each

| GENERAL SPECIFICATIONS | |
|---|---|
| IGNITION TYPE | WASTED SPARK |
| MAX. INPUT RPM | 3500 RPM |
| OPERATING TEMPERATURE RANGE | -38°C TO +105°C |
| VOLTAGE INPUT RANGE | 8.5 - 30 Vdc |
| OPERATING POWER REQUIREMENTS @ 2700 RPM | 0.70±0.2 A @ 14 Vdc<br>0.35±0.2 A @ 28 Vdc |
| MANIFOLD PRESSURE INPUT RANGE | 3 - 40 inHg |
| TIMING ACCURACY | ±2° |
| BUILD | surefly_A_[illegible].zip |
| CHECKSUM | [illegible] |

## REVISIONS

| ZONE | REV | DESCRIPTION | DATE | APPROVED |
|---|---|---|---|---|
| ALL | PT-1 | PROTOTYPE 1 | 04/14/2017 | RVC |
| ALL | PT-2 | PROTOTYPE 2 | 06/01/2017 | RVC |
| ALL | IR | INITIAL RELEASE FOR PRODUCTION | 05/21/2018 | RVC |




| DIP SWITCH SETTINGS | | | | | | | |
|---|---|---|---|---|---|---|---|
| ENGINE TIMING | TIMING OPTION | DIP SWITCH 1 | DIP SWITCH 2 | DIP SWITCH 3 | DIP SWITCH 4 | LED CODE | TIMING SCHEDULE |
| 30° | ADVANCED | OFF | ON | ON | ON | [illegible] | A-30 |
| | FIXED | ON | ON | ON | ON | [illegible] | F-30 |
| 28° | ADVANCED | OFF | ON | ON | OFF | [illegible] | A-28 |
| | FIXED | ON | ON | ON | OFF | [illegible] | F-28 |
| 26° | ADVANCED | OFF | ON | OFF | ON | [illegible] | A-26 |
| | FIXED | ON | ON | OFF | ON | [illegible] | F-26 |
| 25° | ADVANCED | [illegible] | ON | OFF | OFF | [illegible] | A-25 |
| | FIXED | ON | ON | OFF | OFF | [illegible] | F-25 |
| 24° | ADVANCED | OFF | OFF | ON | ON | [illegible] | A-24 |
| | FIXED | ON | OFF | ON | ON | [illegible] | F-24 |
| 22° | ADVANCED | OFF | OFF | ON | OFF | [illegible] | A-22 |
| | FIXED | ON | OFF | ON | OFF | [illegible] | F-22 |
| 20° | ADVANCED | OFF | OFF | OFF | ON | [illegible] | A-20 |
| | FIXED | ON | OFF | OFF | ON | [illegible] | F-20 |
| 18° | ADVANCED | OFF | OFF | OFF | OFF | [illegible] | A-18 |
| | FIXED | ON | OFF | OFF | OFF | [illegible] | F-18 |

| FIRING ORDER | |
|---|---|
| LEFT ROTATION (CCW) | RIGHT ROTATION (CW) |
| A-B-C-D | A-D-C-B |



**SureFly**
Granbury, Texas

**4 CYLINDER IMPULSE COUPLER IGNITION**

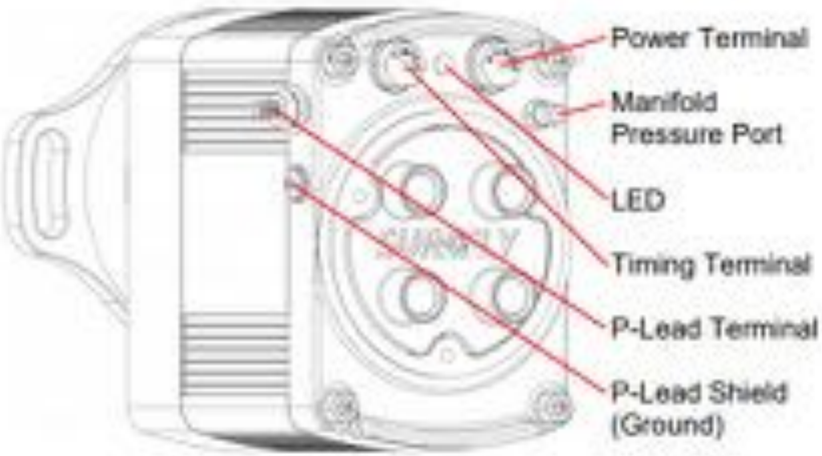
| SCALE | MATERIAL | FINISH |
|---|---|---|
| 1:2 | N/A | N/A |

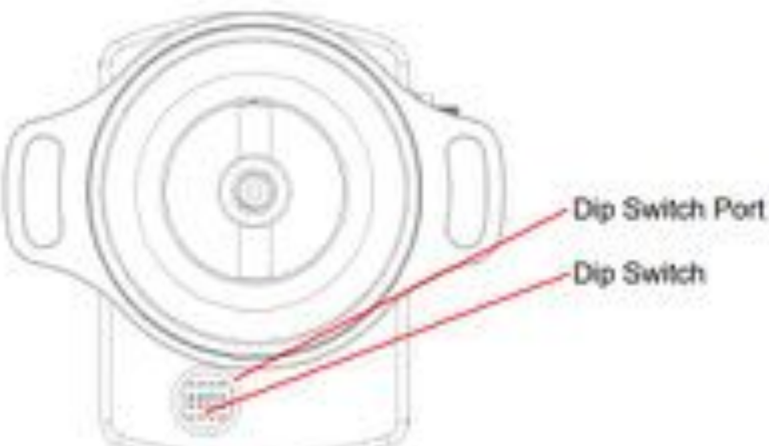
| DIMENSIONS IN INCHES UNLESS OTHERWISE SPECIFIED | DRAWN BY | DATE |
|---|---|---|
| | R. CONDY | 05/21/2018 |

| TOLERANCES: ANGLES | X.X | X.XX | X.XXX | SHEET | PART NO. | REV |
|---|---|---|---|---|---|---|
| ±1° | ±0.050 | ±0.030 | ±0.010 | 1/1 | SIM4P | IR |

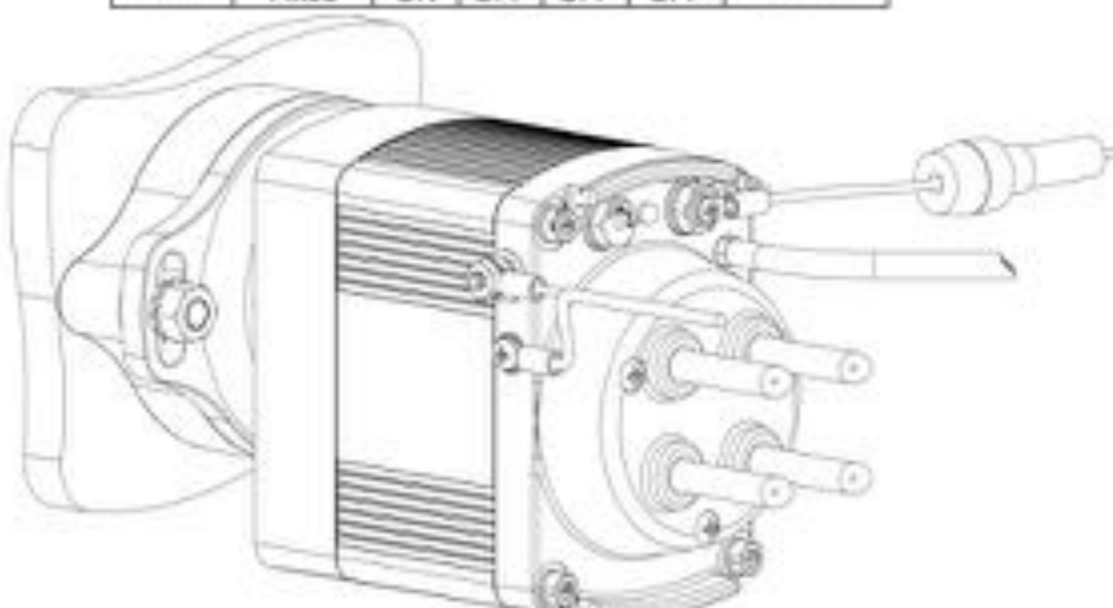
# Surefly Ignition

| Engine Timing | Timing Mode | Dip Switch 1 | Dip Switch 2 | Dip Switch 3 | Dip Switch 4 | LED Code |
|---|---|---|---|---|---|---|
| 30° | Advance | OFF | ON | ON | ON | — · · · |
| | Fixed | ON | ON | ON | ON | · · · · |
| 28° | Advance | OFF | ON | ON | OFF | — · · — |
| | Fixed | ON | ON | ON | OFF | · · · — |
| 26° | Advance | OFF | ON | OFF | ON | — · — · |
| | Fixed | ON | ON | OFF | ON | · · — · |
| 25° | Advance | OFF | ON | OFF | OFF | — · — — |
| | Fixed | ON | ON | OFF | OFF | · · — — |
| 24° | Advance | OFF | OFF | ON | ON | — — · · |
| | Fixed | ON | OFF | ON | ON | · — · · |
| 22° | Advance | OFF | OFF | ON | OFF | — — · — |
| | Fixed | ON | OFF | ON | OFF | · — · — |
| 20° | Advance | OFF | OFF | OFF | ON | — — — · |
| | Fixed | ON | OFF | OFF | ON | · — — · |
| 18° | Advance | OFF | OFF | OFF | OFF | — — — — |
| | Fixed | ON | OFF | OFF | OFF | · — — — |



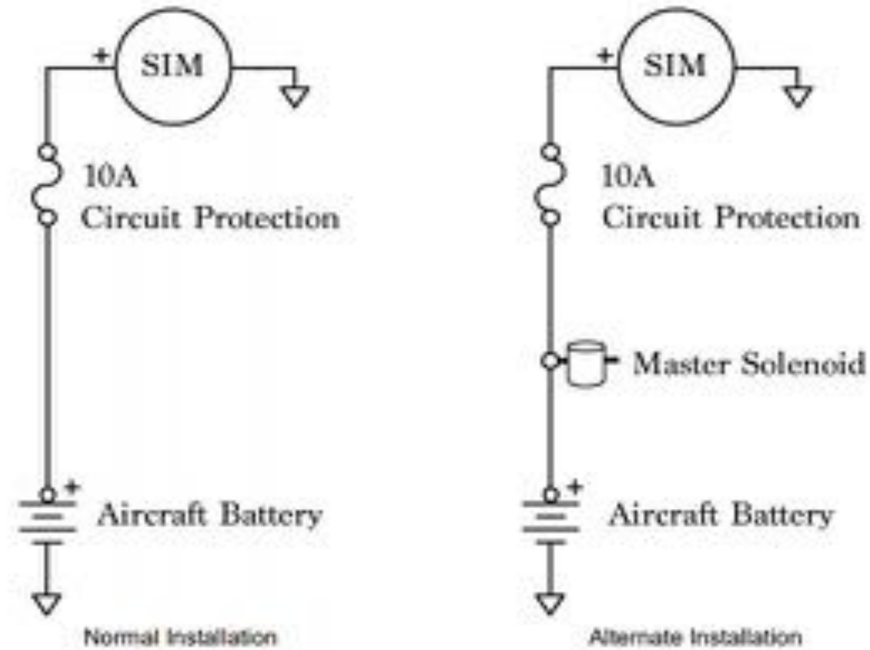

SIM Terminals and Ports



Typical SIM4P Installation

# Surefly Power Requirements

- STC requires direct & continuous power connection
- STC requires 1 conventional magneto to be retained
- Standby power is less than 1 ma.




The SIM requires a constant, external supply of 8.5 – 30VDC power to operate.

Operating power requirements @ 2700RPM:

| Model: | @ 14VDC | @ 28VDC |
|---|---|---|
| SIM4P | 0.7±0.2A | 0.35±0.2A |
| SIM4N | 0.7±0.2A | 0.35±0.2A |
| SIM6C | 1.0±0.2A | 0.5±0.2A |
| SIM6L | 1.0±0.2A | 0.5±0.2A |

The SIM grounds through the engine.

When turned off (SIM p-lead grounded), a SIM goes into standby and will continuously draw less than 1milliamp in this mode.

SureFly recommends keeping the aircraft battery on a maintenance charger when not in use for extended periods of time (1 month or more).

# Big Motor

- To “go big”, one can purchase O-360 or O-390 engines with prop combinations that provide 180 to 210 hp.
- Lowest cost option – about $8,000 for a useable O-360 fixed pitch, either good as-is but high time, or a prop-strike unit after being lucky with the inspection.
- Practical high cost option – about $38,000 for new XO-360-A1A with constant speed prop, new from VANS as part of kit (about 45% off)
- Anywhere in between!

# Supercharging

- Various options, starting at about $8,000
- Not very “turnkey”

# Turbocharging

- Available kits for “turbo normalizing”
- Complex air and exhaust plumbing
- Critical thermal management under the cowl

# Turbocharger sizing

- 150 hp target at 10,000 ft, 40F inlet temp
- Only 2.55 psi (about 5”) needed for 149 hp per online sizing tool, a modest airflow for a very small turbocharger. Will pursue an example paper design for future consideration.

| | Mid Range RPM | Max Power RPM |
|---|---|---|
| Power at crankshaft (HP) | 111 | 149 |
| Boost gauge pressure (PSI) | -0.30 | 2.55 |
| Pressure ratio | 1.07 | 1.34 |
| Intake manifold temp (°F) | 44 | 58 |
| Airflow, corrected (Lb/Min) | 14.28 | 19.15 |
| Torque at crankshaft (Lb-Ft) | 234 | 290 |

# The Decision

- I wanted to minimize complexity, cost, impact to existing systems and reliability
- Turbo & Supercharging were ruled out, too developmental with cost and reliability issues
- Big Motor “partially ruled out”. New motor too expensive, but will be on the lookout for a “deal” on a used motor – a long term solution.
- Electronic Ignition and Compression Ratio appear to be feasible, relatively cheap, with almost no impact on systems and reliability.

# What Ignition?

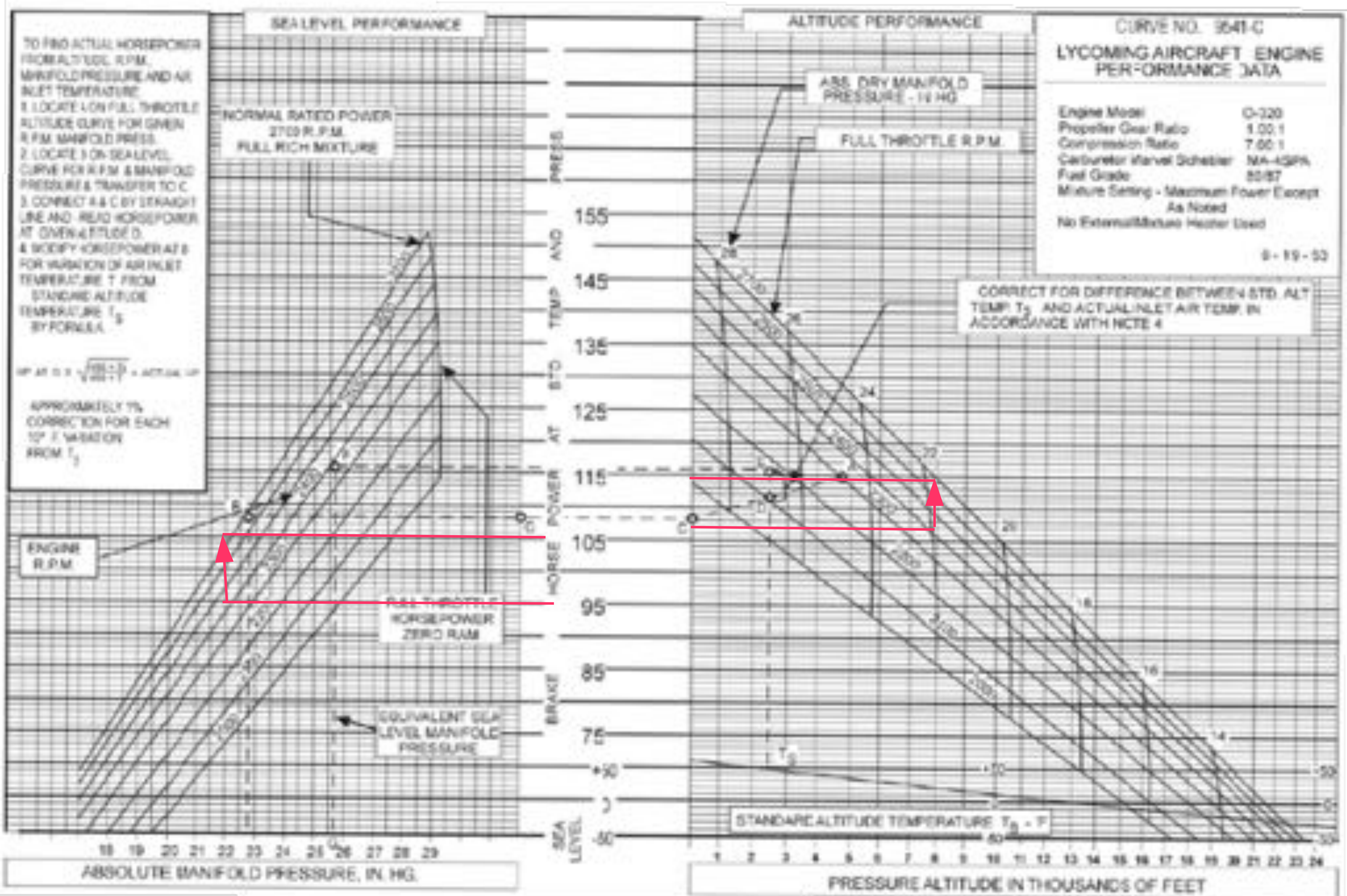
- The Emag and Surefly magneto replacements have almost zero system impact.
- Surefly has benefit of cost, using existing Slick mag harness, and reduced maintenance (Emag requires periodic bearing inspections necessitating removal).
- I secured a Surefly "impulse mag" replacement as an "experimental" unit for $1,175 delivered.

# Compression Ratio Mod

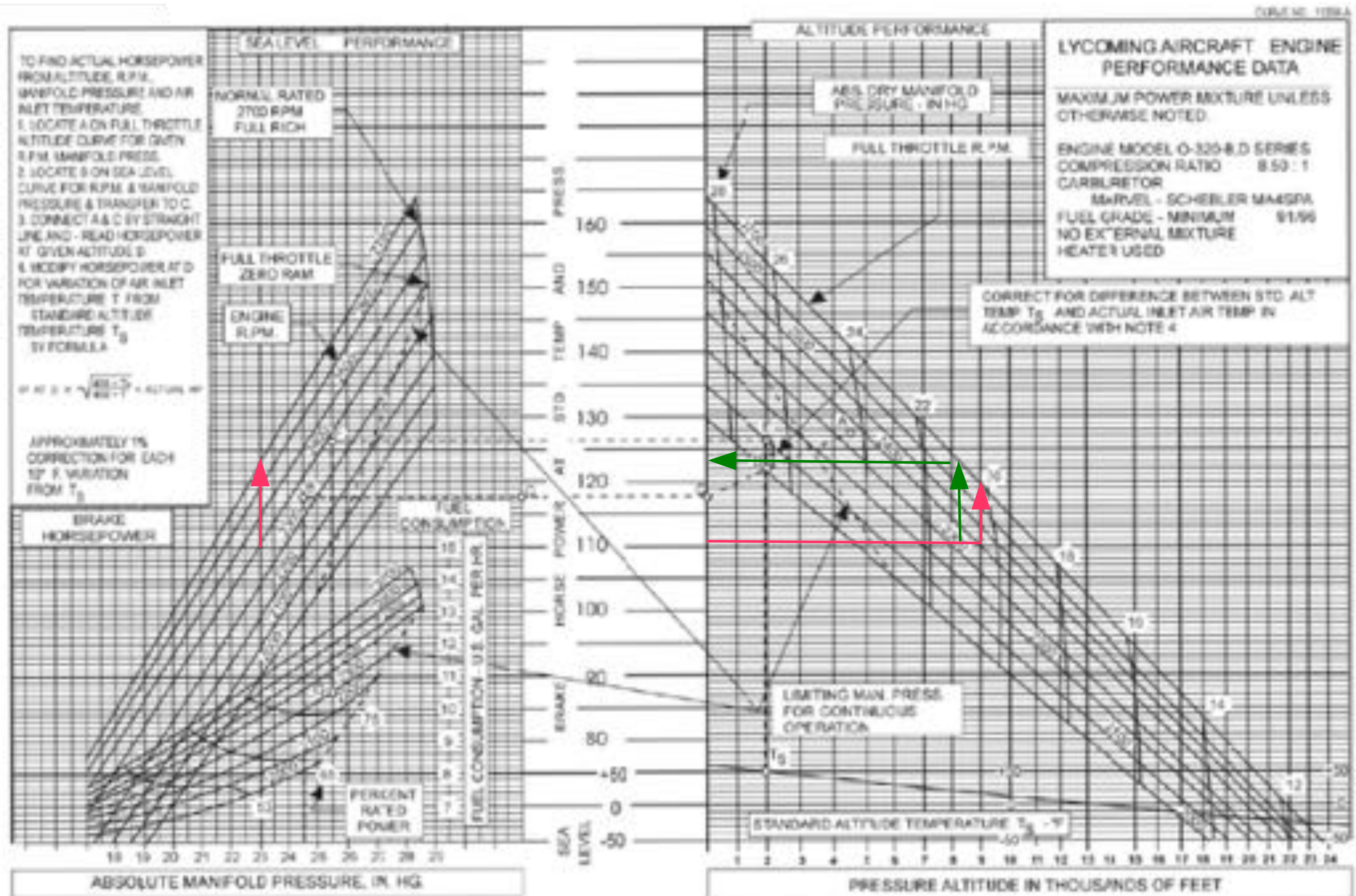
- My O-320 is running well, but is high time. Resale (eventually) will be impacted. (3750 total, 1750 since field overhaul)
- At my condition inspection (this month) my plan was to inspect and if there is a reason to “top”, then do the cheap piston-only upgrade. If when pulling the cylinders there appears to be cam corrosion, then do a field overhaul with new cylinder assemblies. Cost range $1,000 to $8,000
- However, as luck would have it, compressions were 74 minimum, borescope was good, oil analysis was good, no metal in the filter. No convenient excuse to tear it apart.
- Therefore... I will do the ignition mod and kick the compression mod down the road.

# What to Expect?

- Rumours (supplier claims) (and some analyses) suggest 10% power improvement at low manifold pressures due to ignition advance and hotter spark.
- With a fixed pitch prop, power improvements compound. Higher hp means higher RPM, higher RPM means higher power.
- I expect almost 15 hp equivalent at 8000 ft.
  - See charts next two pages
  - Eventual compression ratio boost to yield another 15 hp equivalent at 8000 ft
- Flight test next week!



SEA LEVEL PERFORMANCE
ALTITUDE PERFORMANCE
CURVE NO. 9641-C
LYCOMING AIRCRAFT ENGINE PERFORMANCE DATA
Engine Model O-320
Propeller Gear Ratio 1.00:1
Compression Ratio 7.00:1
Fuel Grade 80/87
Mixture Setting - Maximum Power Except As Noted
8 - 19 - 53
TO FIND ACTUAL HORSEPOWER FROM ALTITUDE, R.P.M., MANIFOLD PRESSURE AND AIR INLET TEMPERATURE
NORMAL RATED POWER
FULL RICH MIXTURE
ABS. DRY MANIFOLD PRESSURE - IN HG
FULL THROTTLE R.P.M.
CORRECT FOR DIFFERENCE BETWEEN STD. ALT TEMP. $T_s$ AND ACTUAL INLET AIR TEMP. IN ACCORDANCE WITH NOTE 4
APPROXIMATELY 1% CORRECTION FOR EACH 10° F VARIATION FROM $T_s$
ENGINE R.P.M.
FULL THROTTLE HORSEPOWER ZERO RAM
EQUIVALENT SEA LEVEL MANIFOLD PRESSURE
BRAKE HORSE POWER AT STD TEMP. AND PRESS.
155
145
135
125
115
105
95
85
75
SEA LEVEL
STANDARD ALTITUDE TEMPERATURE $T_s$ - °F
18 19 20 21 22 23 24 25 26 27 28 29
ABSOLUTE MANIFOLD PRESSURE, IN. HG.
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
PRESSURE ALTITUDE IN THOUSANDS OF FEET


LYCOMING AIRCRAFT ENGINE PERFORMANCE DATA
MAXIMUM POWER MIXTURE UNLESS OTHERWISE NOTED
ENGINE MODEL O-320-B,D SERIES
COMPRESSION RATIO 8.50 : 1
CARBURETOR
MARVEL - SCHEBLER MA4SPA
FUEL GRADE - MINIMUM 91/96
NO EXTERNAL MIXTURE HEATER USED
SEA LEVEL PERFORMANCE
ALTITUDE PERFORMANCE
TO FIND ACTUAL HORSEPOWER FROM ALTITUDE, R.P.M., MANIFOLD PRESSURE AND AIR INLET TEMPERATURE
1. LOCATE A ON FULL THROTTLE ALTITUDE CURVE FOR GIVEN R.P.M. MANIFOLD PRESS.
2. LOCATE B ON SEA LEVEL CURVE FOR R.P.M. & MANIFOLD PRESSURE & TRANSFER TO C.
3. CONNECT A & C BY STRAIGHT LINE AND - READ HORSEPOWER AT GIVEN ALTITUDE D
4. MODIFY HORSEPOWER AT D FOR VARIATION OF AIR INLET TEMPERATURE T FROM STANDARD ALTITUDE TEMPERATURE $T_S$ BY FORMULA
APPROXIMATELY 1% CORRECTION FOR EACH 10° F. VARIATION FROM $T_S$
NORMAL RATED 2700 R.P.M. FULL RICH
FULL THROTTLE ZERO RAM
ENGINE R.P.M.
BRAKE HORSEPOWER
FUEL CONSUMPTION
FUEL CONSUMPTION - U.S. GAL. PER HR.
PERCENT RATED POWER
ABS. DRY MANIFOLD PRESSURE - IN HG.
FULL THROTTLE R.P.M.
CORRECT FOR DIFFERENCE BETWEEN STD. ALT. TEMP. $T_S$ AND ACTUAL INLET AIR TEMP. IN ACCORDANCE WITH NOTE 4
LIMITING MAN. PRESS. FOR CONTINUOUS OPERATION
BRAKE HORSE POWER AT STD. TEMP. AND PRESS.
STANDARD ALTITUDE TEMPERATURE $T_S$ - °F
SEA LEVEL
ABSOLUTE MANIFOLD PRESSURE, IN. HG.
PRESSURE ALTITUDE IN THOUSANDS OF FEET