Proper Leaning &
JPI EDM 730 Use

Homework???

- How many reviewed the articles?
- How many reviewed the webinars?

- Self study is a must to fully understand and come to terms with what we will talk about tonight.

Who am I?

Previous Treasurer/Instructor for the HFC
CFI/CFII
Flying 28 yrs/13,000 hrs
C205 owner

300+ hrs in the last 3 years
All using an JPI EDM 700
A “changed" instructor

I'm not the expert...but I'll be passing along what the experts have said.

- Mike Busch - Savvy Analysis
- John Deakin - Avweb, Gami, APS
- Rick Durden – Avweb

What can an engine analyzer do for you?

- CHT
- EGT
- Oil temp
- Oil pressure
- OAT
- History of engine operation
- Aids in leaning properly/efficiently
- Aids in troubleshooting mx issues

However...

Without understanding the how, why, and where of leaning and engine operations, very little of the benefit of having an analyzer will be realized.

- First, we need to talk a little about those that pioneered the research into what's happening in engines and how they should be ran.
- We also need to define some basic terms and how they relate to each other.

Proper Engine Leaning

- Gami - General Aviation Modifications
- Ada, Oklahoma
- Mid-1990s created most sophisticated test bed for aircraft engines in the world.
- Designed spark plugs with sensors
- Ran various engines for thousands of hours.
- Based on their findings, pilots should change how they operate their engines.
- Was slow to take hold but has become more mainstream as more pilots have access to engine analyzers and more historical data has been gathered.
- Still, many pilots are reluctant to try what they don't understand.
- Instructors are still passing down inaccurate techniques and practices.

"Interesting" mixtures

Stoichiometric

- Chemically perfect ratio
- Peak EGT

Best Power

- ≈ 20% excess fuel—adds ≈3% power (1.5% TAS)
- 75°F to 100°F ROP

Best Economy

- ≈ 20% less fuel—subtracts ≈10% power (5% TAS)
- 30°F to 70°F LOP (rough?)

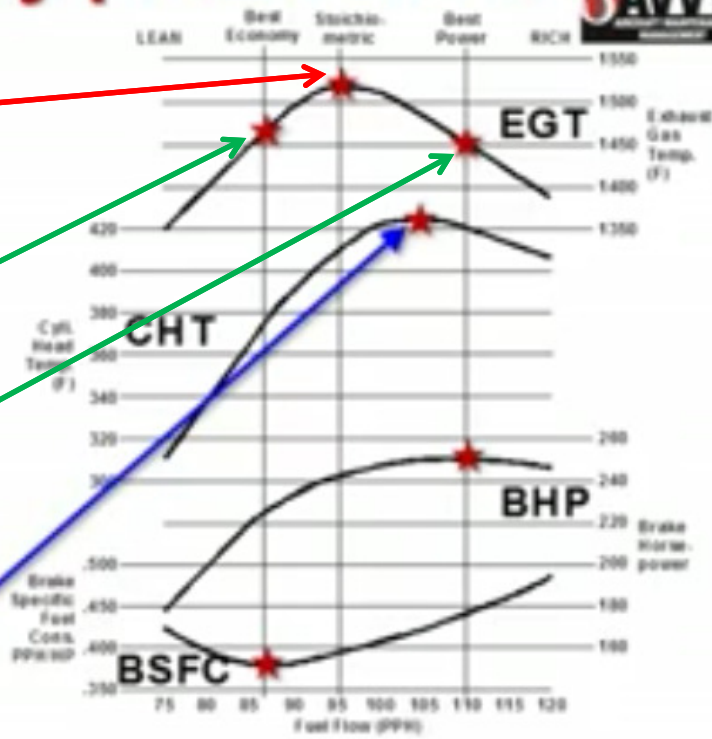
Mixture vs. key parameters

Stoichiometric
Peak EGT

Best Economy
30°F-70°F LOP

Best Power
75°F-100°F ROP

Max CHT & ICP
40°F-50°F ROP



Where does practically every POH/AFM tell the pilot to set the mixture for cruise?

50 ROP

Unfortunately, this POH guidance leaves a lot to be desired. 50°F ROP is almost precisely the worst possible mixture setting from the standpoint of engine longevity. The maximum cylinder head temperature (CHT) and peak internal cylinder pressure (ICP) occurs almost precisely at 50°F ROP. So using the "recommended lean mixture" assures that your engine operates at the hottest, most stressful corner of its operating envelope.

- Mike Busch Avweb article " CHT, EGT, & Leaning"

Why would so many aircraft manufacturers publish such bad advice in their POHs? Well for one thing, back in the 1960s and 1970s when many of the POHs were written, the relationships between EGT, CHT and ICP were not as well understood as they are today. The conventional wisdom at that time was that richer mixtures were better for the engine, and leaner mixtures were worse. A culture of fear evolved, promulgated by the flight instructors of the day: If you leaned too aggressively, you'd blow up your engine.

- Mike Busch Avweb article " CHT, EGT, & Leaning"

- Instructors today are still handing down bad information.
- Ever heard "Fuel is cheaper than cylinders"?
- Too rich can be as bad, or worse, than too lean.

With today's sophisticated instrumentation, we now know that this isn't true. The hottest, most stressful mixture is about 50°F ROP, and mixtures that are richer or leaner are better for the engine. At 75-percent cruise power, you want to stay well away from that worst-case mixture setting, either by operating at least 100°F ROP (preferably richer) or at least 20°F LOP (preferably leaner), take your pick.

- Mike Busch Avweb article " CHT, EGT, & Leaning"

- So how much BHP does a typical cruise setting in a 172SP generate?
- Let's look at a Standard day, 6,000 & 8,000' MSL, 2600 RPM

CRUISE PERFORMANCE

CONDITIONS:
2550 Pounds
Recommended Lean Mixture At All Altitudes (Refer to Section 4, Cruise)

PRESS ALT FT	RPM	20°C BELOW STANDARD TEMP			STANDARD TEMPERATURE			20°C ABOVE STANDARD TEMP		
		% BHP	KTAS	GPH	% BHP	KTAS	GPH	% BHP	KTAS	GPH
2000	2550	83	117	11.1	77	118	10.5	72	117	9.9
	2500	78	115	10.6	73	115	9.9	68	115	9.4
	2400	69	111	9.6	64	110	9.0	60	109	8.5
	2300	61	105	8.6	57	104	8.1	53	102	7.7
	2200	53	99	7.7	50	97	7.3	47	95	6.9
	2100	47	92	6.9	44	90	6.6	42	89	6.3
4000	2600	83	120	11.1	77	120	10.4	72	119	9.8
	2550	79	118	10.6	73	117	9.9	68	117	9.4
	2500	74	115	10.1	69	115	9.5	64	114	8.9
	2400	65	110	9.1	61	109	8.5	57	107	8.1
	2300	58	104	8.2	54	102	7.7	51	101	7.3
	2200	51	98	7.4	48	96	7.0	45	94	6.7
	2100	45	91	6.6	42	89	6.4	40	87	6.1
6000	2650	83	122	11.1	77	122	10.4	72	121	9.8
	2600	78	120	10.6	73	119	9.9	68	118	9.4
	2500	70	115	9.6	65	114	9.0	60	112	8.5
	2400	62	109	8.6	57	108	8.2	54	106	7.7
	2300	54	103	7.8	51	101	7.4	48	99	7.0
	2200	48	96	7.1	45	94	6.7	43	92	6.4

Figure 5-8. Cruise Performance (Sheet 1 of 2)

CRUISE PERFORMANCE

CONDITIONS:
2550 Pounds
Recommended Lean Mixture At All Altitudes (Refer to Section 4, Cruise)

PRESS ALT FT	RPM	20°C BELOW STANDARD TEMP			STANDARD TEMPERATURE			20°C ABOVE STANDARD TEMP		
		% BHP	KTAS	GPH	% BHP	KTAS	GPH	% BHP	KTAS	GPH
8000	2700	83	125	11.1	77	124	10.4	71	123	9.7
	2650	78	122	10.5	72	122	9.9	67	120	9.3
	2600	74	120	10.0	68	119	9.4	64	117	8.9
	2500	65	114	9.1	61	112	8.6	57	111	8.1
	2400	58	108	8.2	54	106	7.8	51	104	7.4
	2300	52	101	7.5	48	99	7.1	46	97	6.8
	2200	46	94	6.8	43	92	6.5	41	90	6.2
10,000	2700	78	124	10.5	72	123	9.8	67	122	9.3
	2650	73	122	10.0	68	120	9.4	63	119	8.9
	2600	69	119	9.5	64	117	9.0	60	115	8.5
	2500	62	113	8.7	57	111	8.2	54	109	7.8
	2400	55	106	7.9	51	104	7.5	49	102	7.1
	2300	49	100	7.2	46	97	6.8	44	95	6.5
12,000	2650	69	121	9.5	64	119	8.9	60	117	8.5
	2600	65	118	9.1	61	116	8.5	57	114	8.1
	2500	58	111	8.3	54	109	7.8	51	107	7.4
	2400	52	105	7.5	49	102	7.1	46	100	6.8
	2300	47	98	6.9	44	95	6.6	41	92	6.3

Figure 5-8. Cruise Performance (Sheet 2 of 2)

Key takeaways…

Except for low power settings, the area of maximum CHT and ICP (≈40°F ROP) should be avoided

Low power settings = < 60% BHP

Key Takeaways:

- 100-120 degrees ROP should be your target when above 60% BHP.
- POH recommended 50 degrees ROP = worst place to be.
- Fuel flow difference between 50 ROP & 100-120 ROP is well under a gallon.
- Under 60% BHP you can run about anywhere. Temps and pressure are low.
- Too rich = fouled plugs, wasted fuel, lead buildup on backside of valves and valve stem.

So now we know "where" the engine should be leaned to Rich of Peak (ROP), how do we do it using the EDM 730?

Leaning During Taxi

- Lean aggressively. Just above the point of the engine stumbling.
- Prevents fouling plugs.
- At such low power settings, no adverse affect on engine.
- Normal to see 3" or so of silver showing on the mixture control.

During run-up

- For optimal power, **always** lean for current altitude.
- During run-up, lean until first sign of RPM drop.
- Enrich back to peak RPM.
- Max RPM and full throttle for takeoff.

- EDM 730 is not used at this point!
- However, during mag check you can see the rise in EGT.

Leaning During the Climb

- We were all taught to lean while climbing. But how much and when?
- John Deakin's technique to help maintain fairly constant engine temperatures:
- At 1,000' AGL, pick one cylinder's EGT. It doesn't matter which one. (ex. #1 = 1350 degrees)
- As you climb, lean as needed to maintain that number.
- As you climb, the mixture in the engine gets richer due to less ambient air. This is why we must lean. This enrichment causes the CHTs to cool.


https://www.savvyanalysis.com/flight/1048955/e02a8984-b9c5-4229-bf9a-0966b25bf250
SavvyAnalysis - N8340Z 201...
File Edit View Favorites Tools Help
SAVVY ANALYSIS
N8340Z
2015-08-14 10:14
Duration: 1h37m, Interval: ~6s
JPI Flight #: 791
Want us to analyze this flight for you? Upgrade to SavvyAnalysis Pro...
EGT
All Odd Even EGT1 EGT2 EGT3 EGT4 EGT5 EGT6
1,400
1,200
1,000
800
EGT
00:00 00:10 00:20 00:30 00:40 00:50 01:00 01:10 01:20
400
00:50:36
CHT1: 380

So where should CHTs be maintained? What's healthy and what's bad?

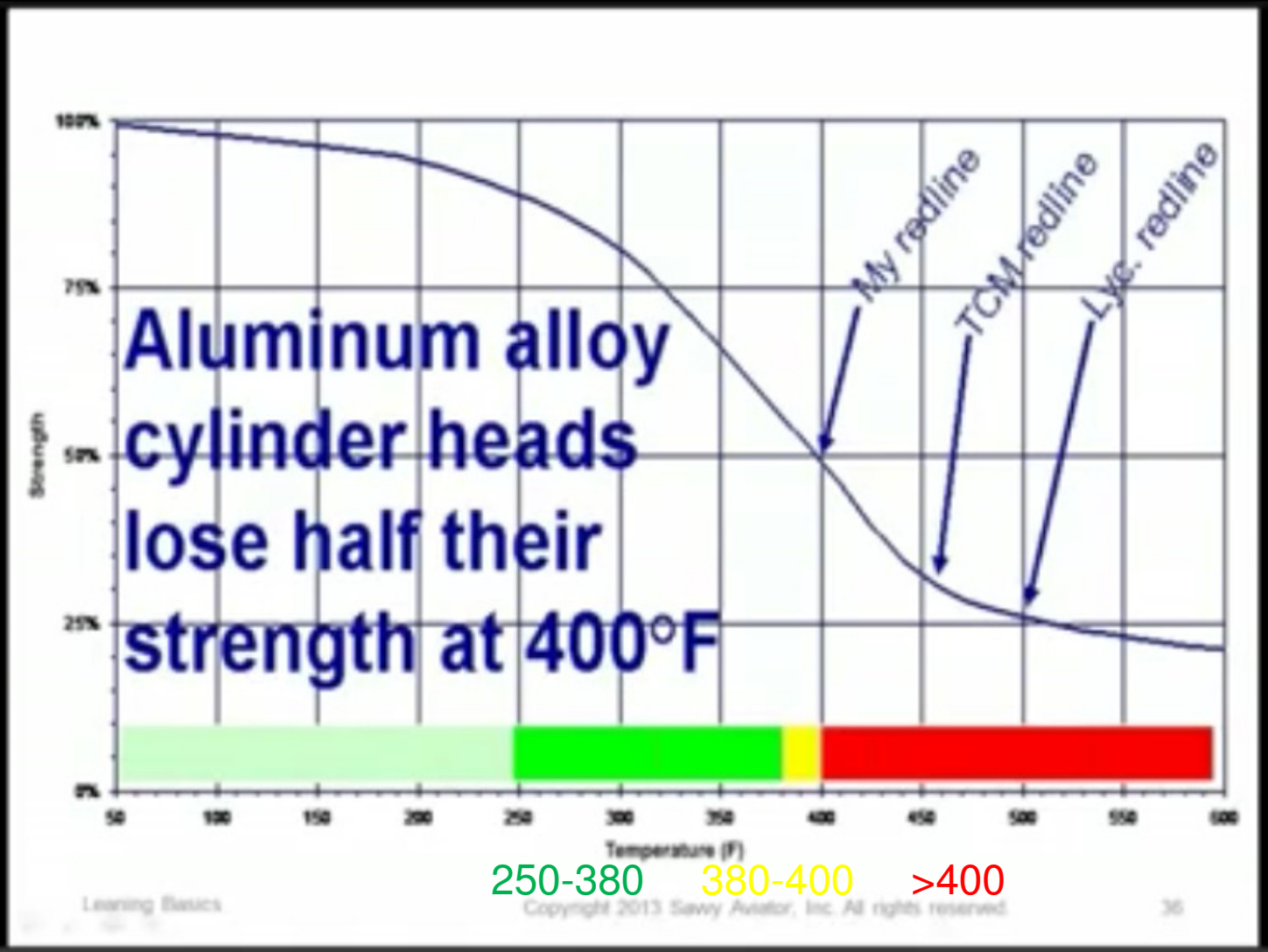
- The goal should be between 250 degrees and 380 degrees.
- Below 250-270 degrees, lead buildup occurs.
- 380 – 400 degrees is a caution area. Time to react and reverse the trend!
- > 400 degrees is bad!!!! Here's why.

Why do you recommend keeping CHTs at or below 380°F, while TCM sets its CHT red line at 460°F and Lycoming sets it at 500°F? Aren't you being excessively conservative?

- Both TCM and Lycoming specify CHT limits (460°F and 500°F, respectively) that should be considered emergency limits, not operational limits. Allowing your CHT to get anywhere close to those values for significant periods of time will most likely result in premature exhaust-valve problems and increased incidence of cylinder-head fatigue cracking. I do not like to see CHT above about 400°F, which is the temperature at which the aluminum alloy from which your cylinder head is made loses one-half its tensile strength. (The strength decreases rapidly as the temperature rises above 400°F.) For legacy aircraft, I recommend a maximum target CHT of about 380°F just to provide a little extra cushion, and consider any CHT above 400°F to be grounds for "doing something right now" to get it down.

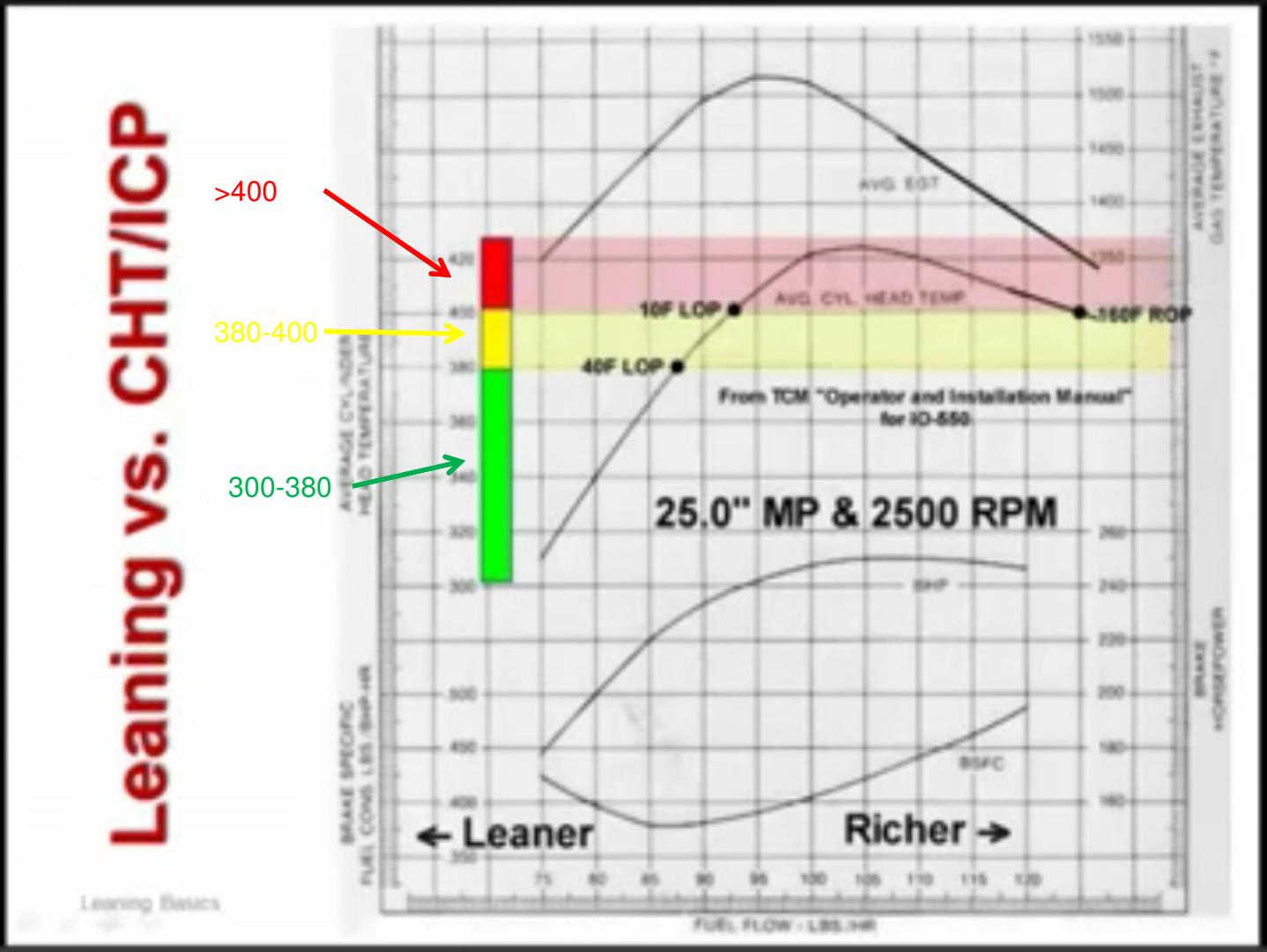
- Use mixture, cowl flaps, & pitch as needed to maintain CHTs below 400 degrees. Goal should be mid 300s.
- Too low is also bad. Water and lead build up. CHT > 250-270. Oil temp > 170 to boil off water in oil.

100%

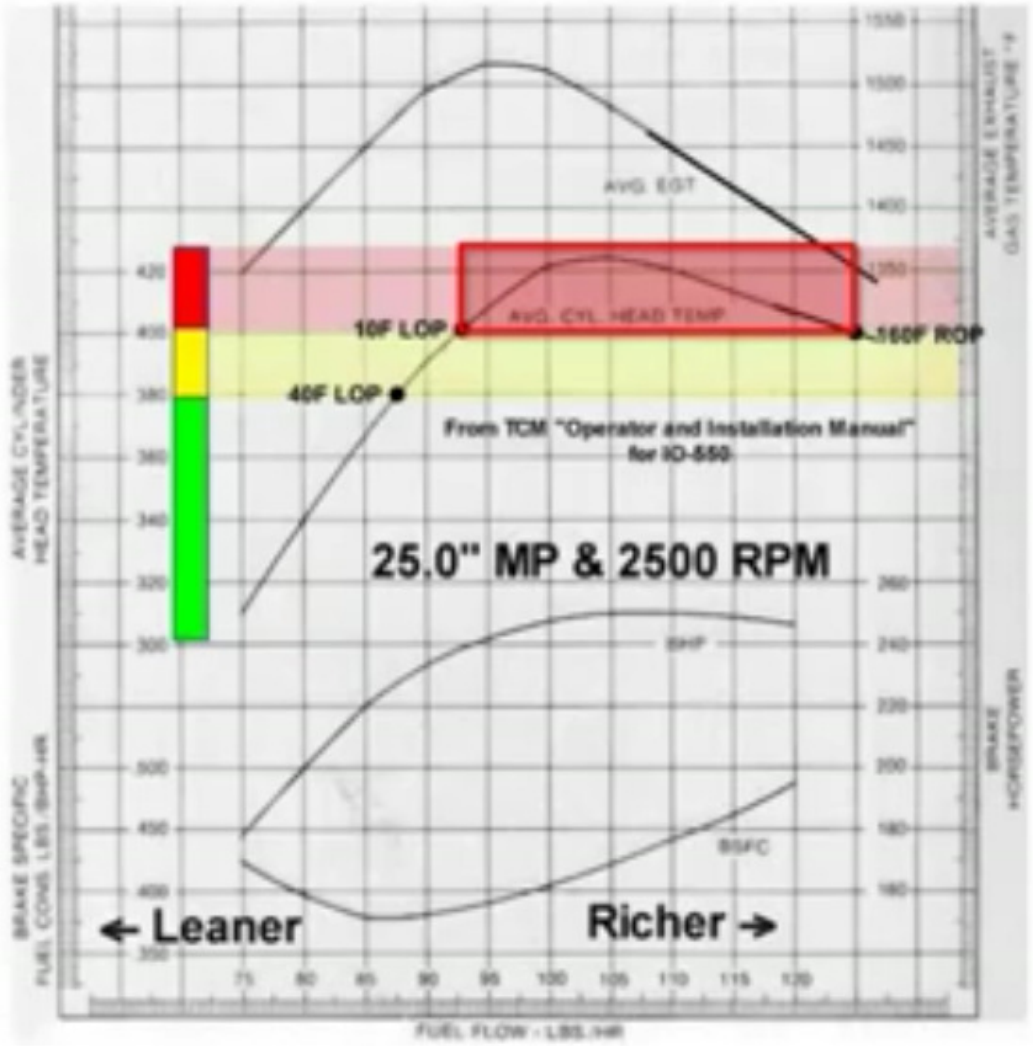

Aluminum alloy cylinder heads lose half their strength at 400°F
My redline
TCM redline
Lyc. redline
Strength
Temperature (F)
100%
75%
50%
25%
0%
50
100
150
200
250
300
350
400
450
500
550
600
250-380
380-400
>400
Leaning Basics
Copyright 2013 Savvy Aviator, Inc. All rights reserved.
36

0%

Leaning vs. CHT/ICP



The Red Box


AVG. EGT
AVG. CYL. HEAD TEMP
10F LOP
-150F ROP
40F LOP
From TCM "Operator and Installation Manual" for IO-550
25.0" MP & 2500 RPM
BHP
BSFC
← Leaner
Richer →
AVERAGE CYLINDER HEAD TEMPERATURE
BRAKE SPECIFIC FUEL CONS. LBS./BHP-HR
AVERAGE EXHAUST GAS TEMPERATURE - F
BRAKE HORSEPOWER
FUEL FLOW - LBS./HR

Leaning for Cruise

- Established at cruise, allow 2-3 minutes for engine temps to stabilize.
- Reference POH/AFM. What will your power setting be? > or < than 60% BHP?
- > 60% BHP = 100-120 degrees ROP.
- < 60% BHP = dealer's choice.

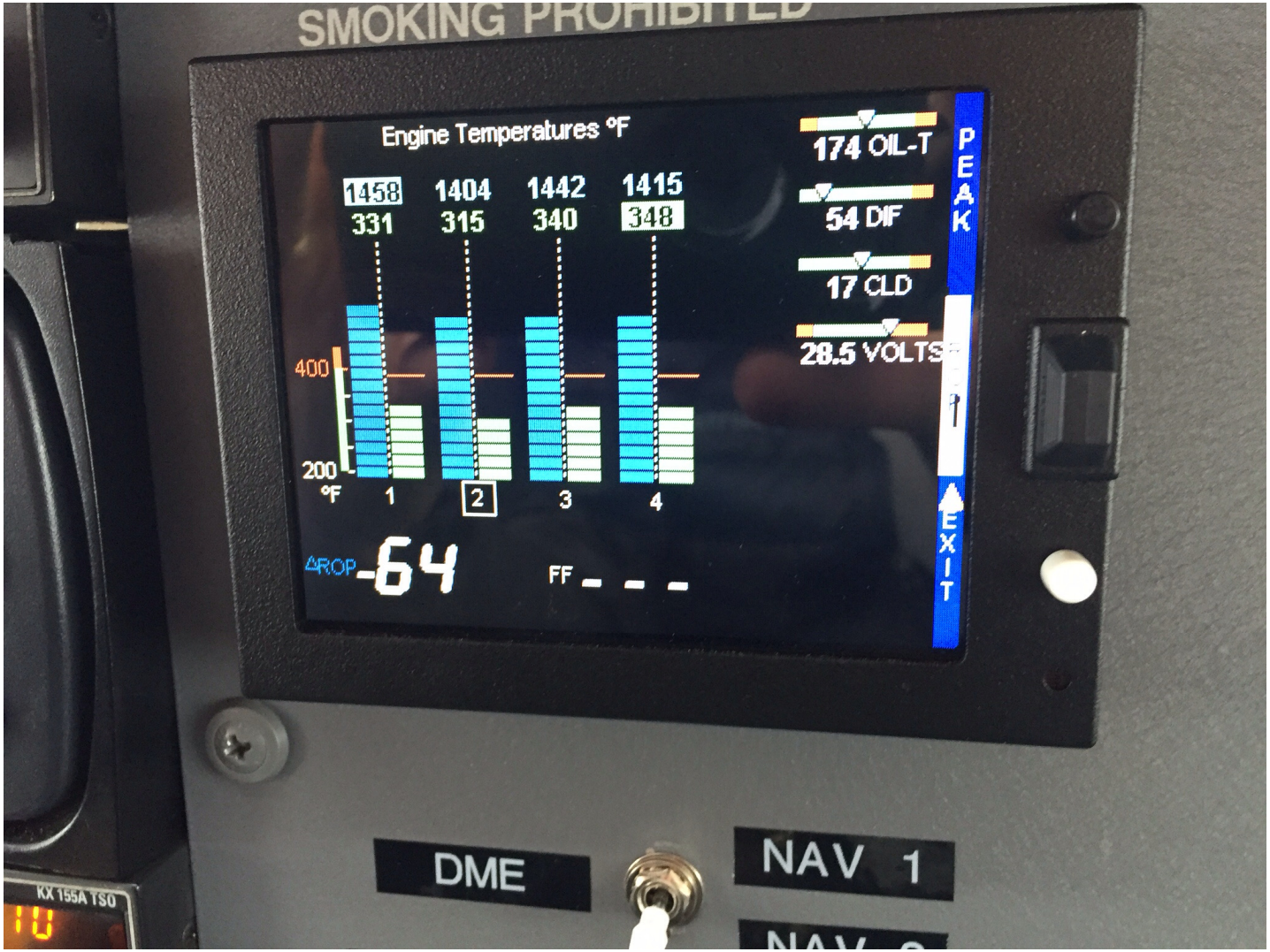
EDM 730: Leaning ROP

- **<u>Step 1</u>** - Press LF button. Verify ROP mode.

- **<u>Step 2</u>** - Lean continuously at 10 degrees / sec without stopping. Leanest cylinder boxed. EDM armed to find first peaked cylinder.

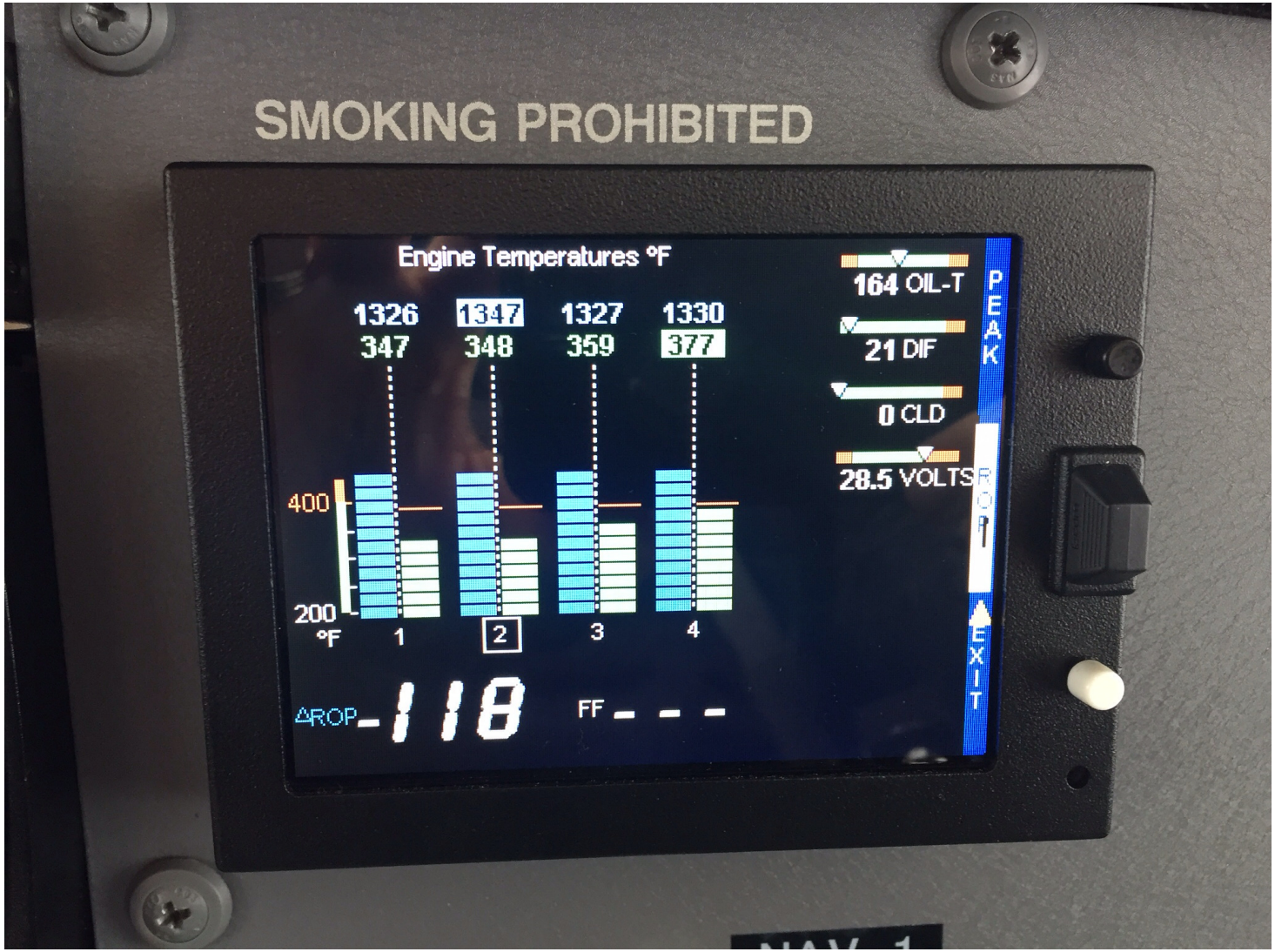
- **<u>Step 3</u>** - When first EGT column begins to flash, STOP!!! This is the leanest cylinder and first to reach peak.
- Even though you stopped leaning at the first indication of a peaking cylinder, you are LOP due to a lag called thermal inertia.

- **<u>Step 4</u>** - Press and hold the LF button to show the peak EGT value of that cylinder.
- This is your reference number for setting 100-120 degrees ROP.

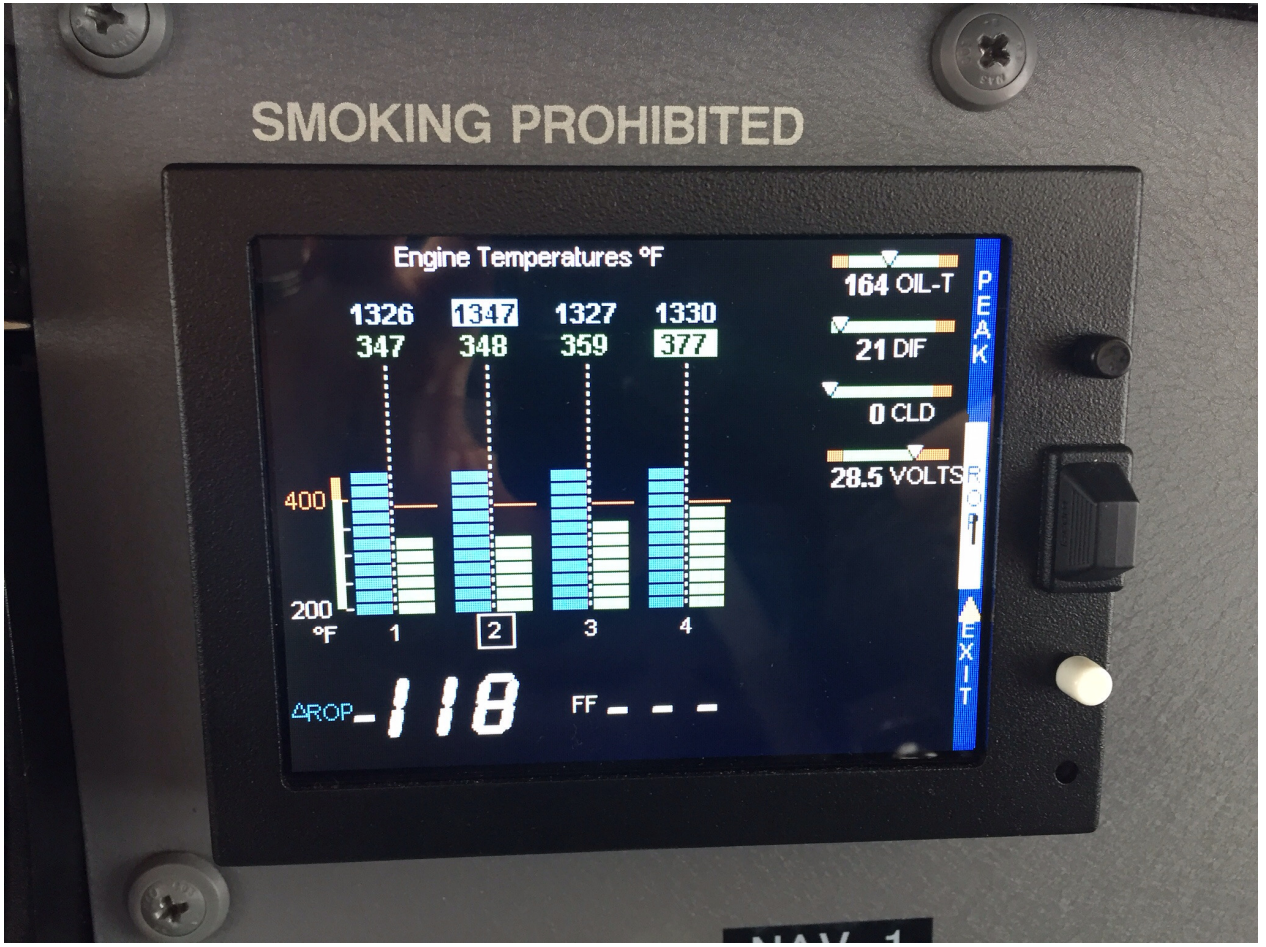


- Tapping the LF button will give you delta peak (ex. - 15 LOP).
- By slowly enrichening the mixture, that number will decrease until at peak.

- When Delta ROP = 0, you've arrived at peak.
- You can also use the absolute value of peak to reach peak EGT.



- **<u>Step 5</u>** - Continuing to enrichen and the number will increase to show the degrees ROP. The 100-120 degrees ROP can be set this way. Adjust <u>slowly</u>! There is some lag.



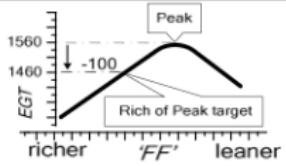
- You can also just enrichen until the EGT for the leanest cylinder is 100-120 degrees cooler than the peak value that was observed when LF was pressed and held.
- Either one will result in the mixture set to where it should be.
- * Note: Delta ROP is shown as a negative when both ROP & LOP.

- That's it! Repeat with any altitude change.

Normal Cruise Indications

Rich of Peak leaning is as simple as:

A. Pre-lean your mixture.
B. Tap the LF button (verify *ROP* appears).
C. Lean mixture until *LEANEST* flashes *(*peak found).
D. Enrichen to the desired value 'Rich Of Peak'.

R	Procedure	Scanner Example	Comments
1	Establish cruise at 65 to 75% power.		
2	Pre-lean the mixture to 50°F estimated rich of peak on any EGT: _____°F.	EGT *1490* CHT *370*	* See 'Pre-leaning'
3	Wait one minute		Let engine stabilize.
4	Tap the LF button	*ROP*	Start LeanFind (if *LOP* appears hold STEP & LF until *ROP appears*)
5	Lean the mixture at approx. 10°/second *without* pausing. (cylinder I.D. box flashes when a EGT rises 15°F)	EGT *1520 LF* (Without FF) - or - EGT *1520* FF *13.8* (With FF)	Flashing cylinder I.D. box identifies the hottest EGT and that an EGT has increased at least 15°F which arms the EDM to now look for first EGT to peak.
6	Stop leaning when a column begins flashing. You will see *LEANEST* for one second, followed by:	EGT *1545 SET* (Without FF) - or - EGT *1545* FF *12.4* (With FF)	Flashing cylinder I.D. box *AND* its column indicates leanest cylinder. (SET means Set the mixture.) Due to thermal inertia this will usually be about -15°F down the lean side of peak.
7	If you hold LF, peak EGT will be displayed while the LF button is held down.	EGT *1560 PK* (Without FF) - or - EGT *1560* FF *12.9* (With FF)	Captured peak EGT value (plus peak FF, if FF equipped) is displayed.
8	If you tap LF, the difference from peak EGT is shown. Tap again to return to the peaked EGT value.	EGT *-90 SET* (Without FF) - or - EGT *-90* FF *13.4* (With FF)	A useful mode for enrichening the mixture to desired degrees below peak. Just set to desired value - no math required! NOTE: Unit remembers view last used.
9	Slowly enrich mixture noting that EGT is returns to peak then drops. Stop enriching at the desired EGT. 'Peak': best Econ. 'ROP' target: best power.	EGT *1560 SET* (PEAK) EGT *1460 SET* (100° RICH OF PEAK)	

Leaning During Descent

- Enrichen only as needed to maintain a smooth engine.
- This minimizes cooling the engine.
- No later than downwind, adjust mixture to go-around setting for altitude (not full mixture unless at seal level).
- For our area it's roughly 1" or one knuckle out.

- Another technique is to maintain a constant EGT. Similar to how the engine was leaned during the climb.

Takeaways

- CHTs are a trend. EGTs are more instantaneous.
- We don't care about absolute EGT numbers, only relative numbers to peak.
- CHTs = health of the engine.
- CHTs over 400 degrees is bad!
- CHTs of mid 300s should be the goal. (Above 250-270)
- EGTs don't measure anything good or bad. Simply a reference number to the amount of energy lost.
- Lean to 100-120 degrees ROP - Best power - to avoid Red Box if above 60% BHP.
- Invest the time to study and understand these principles.

Questions???