AIRCRAFT PISTON ENGINE WATER INJECTION SYSTEMS BY PETER LAW



Pete Law at Reno



Piston Engine Water Injection – Why it is Used and How it Works

- BACKGROUND
 - AT HIGH POWER, COMBUSTION CHAMBERS APPROACH 4,500 °F
 - AT THESE CONDITIONS FUEL CAN BURN WITH EXLOSIVE VIOLENCE AT THE WRONG TIME IN THE CYCLE, MELTING PISTONS
 - THIS IS KNOWN AS "DETONATION", WHICH CANNOT BE TOLLERATED
 - INSIPIENT DETONATION IN ENGINES IS AN AUDIBLE "KNOCK"
 - SEVERAL METHODS ARE USED TO INHIBIT DETONATION
 - ANTIKNOCK ADDITIVES OF FUEL SUCH AS AROMATICS (TOLUENE), TETRAETHYL LEAD (2,2,3-Trimethylbutane), TRIPTANE, MMT/Cl2 (Methylcyclopentadienal Manganese Tricarbolyl; 24.4% Mn by weight), AND OTHERS THAT STABALIZE AND CONTROL REACTION RATE
 - WATER-ALCOHOL INJECTION IS A VERY POWERFUL AND SIMPLE WAY TO:
 - LOWER CHARGE AND COMBUSTION TEMPERATURES
 - SLOW FLAME FRONT SPEED AND LOWER RATE OF PRESSURE INCREASE
 - EXTEND TIME OF BURNING AND REACTION RATE
 - ALLOW ENGINES TO GO TO HIGHER POWER BEFORE ONSET OF DETONATION
 - WATER-ALCOHOL MIXTURE (ADI) IS INJECTED ALONG WITH FUEL INTO SUPERCHARGER INLET
 - THOROUGHLY MIXES IN COMPRESSOR
 - HOPEFULLY ENTERS EACH CYLINDER AS UNIFORM MIXTURE

EFFECT OF FUEL ADDITIVES AND WATER INJECTION ON KNOCK LIMITED IMEP (IMEP IS "INDICATED MEAN EFFECTIVE PRESSURE", MEASURE OF ABSOLUTE POWER)

EFFECT OF WATER-ALCOHOL INJECTION ON DETONATION - LIMITED IMEP IN A SUPERCHARGED CFR ENGINE



KNOCK - LIMITED IMEP DATA FOR TETRAETHYL LEAD IN ISO-OCTANE

AND TRIPTANE





WATER-ALCOHOL "ADI" MIXTURES USED FOR CHARGE COOLING

- ADI (ANTI-DETONATION INJECTION) FLUID IS A'MIXTURE OF METHANOL AND WATER; TWO MIXTURE RATIOS ARE USED:
 - . MOST USED IS 50% METHANOL-50% WATER BY VOLUME
 - ALSO USED IS 607 METHANOL -40 % WATER BY VOLUME

· COMPARISON CHART FOR VARIOUS FLUIDS (BY VOLUME)

ELUID .	ALTITUDE	H2.0 70	метн. %	Batling Temp. 95	SPECIFIC GRAVITY D60°F	реизітч #/ft ³	DEUSITY #/GAL	HEAT OF VAPORIZATION BTU / #	
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	10,000'	0	100	132	•	•	•	4 <i>B</i> (EFFECT

GENERAL WATER INJECTION SYSTEM ISSUES

- AT WHAT POWER SETTINGS IS WATER INJECTION USED ON ENGINES?
 - AS POWER INCREASES, A FUEL ENRICHMENT CIRCUIT OPENS IN THE CARBURETOR (AT 50% OF NORMAL POWER) TO SUPPRESS DETONATION. (THIS IS CALLED "POWER ENRICHMENT.")
 - AT ABOUT 75% POWER, THE WATER INJECTION SYSTEM IS ACTIVATED. FOR MOST ENGINES, THIS IS AT 40-45. "HgA, MANIFOLD PRESSURE.



ADI (AND OIL COOLING SYSTEM) FOR CONQUEST

VENT

RACING F8F BEARCAT - CONQUEST

(ADI SYSTEM SIMILAR TO OTHER R-2800 AND R-4360 RACERS)



TYPICAL WATER BOILER SYSTEM FOR RADIAL ENGINE APPLICATIONS



GENERAL WATER INJECTION SYSTEM ISSUES (Con't)

- WHAT HAPPENS WHEN THE SYSTEM IS ACTIVATED?
 - "ADI" FLUID PUMP IN ADI TANK COMES ON, PUMPS TO REGULATOR
 - "ADI" FLUID PRESSURE IN REGULATOR SENDS PRESSURE SIGNAL TO VALVE IN CARBURETOR THAT REDUCES FUEL FLOW (DERICHMENT), APPROACHES "BEST POWER" F/A RATIO (0.08:1)
 - "ADI" FLUID METERED THROUGH WATER REGULATOR INTO SUPER-CHARGER, REMOVES SOME OF THE HEAT OF COMPRESSION
 - DETONATION TENDENCY IS SUPPRESSED
 - P&W ENGINES MIX ADI WITH FUEL, INJECT THROUGH SINGLE NOZZLE
 - OTHER ENGINES USE SEPARATE FUEL AND ADI NOZZLES
 - AMOUNT OF "ADI" IS CONTROLLED BY PRESSURE FROM CARBURETOR "D" CHAMBER ACTING ON REGULATOR METERING VALVE
 - "D" CHAMBER PRESSURE INCREASES WITH HIGHER POWER SETTINGS, INCREASING FUEL FLOW AND THEREBY ADI FLOW



GENERAL WATER INJECTION SYSTEM ISSUES (Con't)

- WHAT HAPPENS WHEN THE SYSTEM IS ACTIVATED (Con't)?
 - JET IN REGULATOR (2 IN R-2800 UNIT) METER ADI FLOW
 SIMILAR TO WAY CARBURETOR JETS METER FUEL TO ENGINE.
 - ADI PRESSURE GAUGE IN COCKPIT, NEED 22 28 psig FOR PROPER ATOMIZATION AND OPERATION
 - COCKPIT INDUCTION TEMPERATURE GAUGE (CHARGE TEMPERATURE) SHOULD BE 80 – 90°C (176 – 194°F) TO INSURE NO DETONATION. REGULATOR JETS ARE EASILY SIZED TO PROVIDE PROPER RANGE
 - SIGNIFICANT POWER INCREASES CAN BE OBTAINED WITH WATER INJECTION WHEN HIGH PERFORMANCE FUEL IS USED.
 - 115/145 FUEL SHOULD BE ADEQUATE FOR RACING AT TAKEOFF OR "WAR EMERGENCY POWER", BUT HIGHER "RACE" POWER REQUIRES SPECIAL ADDITATIVES TO GIVE PERFORMANCE NUMBER OF 170



LMSW PORM 79208-4





FUEL AND ADI FLOWRATES FOR VARIOUS LARGE ENGINES

NOTE: FUEL USED IS 115/145 OR V.P. RACING FUEL: S.G. = 0.690, 8=5.75 4/44, LHV=18,900 Bru #

ENGINE TYPE	DISP	BRAKE POWER	ALFLOW	FUEL	DEPCHART	RUEL/ALL	#1800	FLOW	APT IR	ADI FLOW	a di Flow	$\frac{\lambda_{11} \Delta}{t_{212}} = \frac{1}{2}$
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PR-SBES												
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R-2800 CARBURETOR FLOW BENCH TEST DATA

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Metering Suction	Test Point	No.] -							•					:	Ī	
Inches of Water Date Issued: $10-2-56$ Corresponding Density: 0.0235 Mixiture Control Density: 0.0743 0.0511 0.0408 0.0235 Lever Position Density: 0.0743 0.0511 0.0408 0.0235 Burette Volume Density: 0.0743 0.0511 0.05116 $0.05166666666666666666666666666666666666$	Metering S	uction] F	low Me	thod:	B-L									2330	260,841	3.005
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Alr Flow L	<u>.b./Hr. '</u>					· .	5600	5800	7400	9000	10500	10500	12000	14020	16000	19000	19000	21500	27000	27000		27000	l
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Limits	Max.			· ·	,	NF	33.6	41.0	0 31.5	28.2	37.8	30.4	33.4	28.6	30.9	28.9	x	26.0	19.4	x		24.0	1
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Burette	Volume					_																·	l
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Inches of	!						•																46
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1.1161	[Obs.					•																	9



WATER REGULATOR FLOW BENCH TEST SHEET

FOR USE WITH ANY CARBURETOR GENERAL FLOW CHECK CUSTOMER: WATER INLET PRESSURE: 25 LBS/IN2 ENGINE MODEL DISCHARGE NOZZLE PRESSURE: 5 LBS/IN2 REGULATOR MODEL CA TYPE MAIN METERING JET: #20 (2270 cc) SERIAL NO -WATER ENRICHMENT JET: ___NONE PO. NUMBER: SP GR. OF NAPHTHA AT 70"-80"Ft _____ DATE TESTED: CHECK VALVE OPENING: NONE IN NAPHTHA (MHD) TESTED BY: _____ ZERO HEAD LEAKAGE :_____LBS/HR.

TEST POINT	NQ,	1	2	3	4.	5	6	7	8	9	10	11	12
METERING H Inches o (Nches o	EAD (MHD) F FUEL F Hg.	20	30	40	50	60	70		6"	7"	A"	رم» ا	17"
FLOW	MIN.	160	230	280	320	360	390	430	480	520	550	620	680
LBS/HR.	MAX.	200	250	300	340	380	410	450	500	540	570	640	700
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	OBS.			· · · · ·					·················				
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WATER REGULATOR FLOW BENCH TEST SHEET

FOR USE WITH PR-10084 CARBURETOR (P/L 391467-11)

CUSTOMER:_____ ENGINE MODEL: <u>B-9360-63A</u> REGULATOR MODEL: <u>352 8/4</u>* SERIAL NO.: PO. NUMBER:_____ DATE TESTED: _____ TESTED BY: _____ WATER INLET PRESSURE: 25±1 LBS/IN² DISCHARGE NOZZLE PRESSURE: 10±1 LBS/IN² MAIN METERING JET: No. 221301 (3610 ft) WATER ENRICHMENT JET: BLANK SP. GR. OF NAPHTHA AT 70°-80°F1 CHECK VALVE OPENING: (22**2*) IN. NAPHTHA (MHD) ZERO HEAD LEAKAGE: _____LBS/HR.

* EARLY SETTING WAS 224300

TEST POINT	NQ	J	2	3	4	5	6	7	8	9	10	11	12
METERING HI	EAD (MHD) FUEL	:40	50	60	70	80	90						
INCHES OF	Hg.	2.30	2.88	3.44	4.00	4.60	5.16	1		•			
FLOW	MIN.	. 1 57	514	542	604	649	686			-			
LBS/HR.	MAX.	475	536	586	628	676	714						
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