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THE CALIBRATION OF A DEUTZ F8L413 DIESEL AND DEVELOPMENT OF AN ON-BOARD BHP INDICATOR

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TEST REPORT

THE CALIBRATION OF A DEUTZ F8L413 DIESEL AND DEVELOPMENT OF AN ON-BOARD BHP INDICATOR

ESSAIS D'ETALONNAGE D'UN MOTEUR DIESEL DEUTZ F8L413 ET MISE AU POINT D'UN INDICATEUR DE PUISSANCE AU FREIN

by/par

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SUMMARY

The calibration of a Deutz F8L413 diesel engine, emphasizing characteristics pertinent to the levitation of an Air Cushion Vehicle is described, together with the development of an output indicating device to be used aboard the craft. The opportunity was also taken to install NRC developed transducers for recording cylinder and fuel injection pressure-time phenomena, with the object of subjecting them to field endurance tests.

Output and fuel consumption compared reasonably with manufacturer's data and a horsepower readout system was developed, based on fuel rack position and rotational speed.

RESUME

On y décrit des essais d'étalonnage d'un moteur diesel Deutz F8L413 qui visent principalement la mesure des caractéristiques liées à la sustentation d'un véhicule à coussin d'air. On y décrit également la mise au point d'un dispositif de mesure de la puissance de sortie destiné à être utilisé à bord du véhicule. On a également profité de l'occasion pour installer des transducteurs, mis au point au CNR, destinés à mesurer les paramètres pression/temps du cylindre et de l'injection de carburant, dans le but de soumettre ces transducteurs à des essais réels d'endurance.

La puissance de sortie et la consommation de carburant correspondent raisonnablement bien aux données du fabricant. On a mis au point un système d'affichage de la puissance basé sur le réglage de la rampe d'alimentation et la vitesse de rotation.

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THE CALIBRATION OF A DEUTZ F8L413 DIESEL AND DEVELOPMENT OF AN ON-BOARD BHP INDICATOR

1.0 INTRODUCTION

The subject engine was purchased by NRC primarily to power the levitation fans on an Air Cushion Vehicle (ACV). The main object of the calibration was to assess power availability with a suitable set of parameters, chosen during the calibration runs, which are compatible with the ACV's operation. A further requirement was the development of a system to provide brake horsepower (BHP) read-out under operating conditions. Advantage of the runs was also taken to install cylinder and injection pressure transducers to provide some field experience with these devices (Ref. 1).

2.0 TEST APPARATUS AND PROCEDURE

2.1 Engine

The test engine was a V-8 Deutz Air-Cooled Diesel F8L413, Serial 5-198-024. Its subsystems included:

Fuel Pump	Bosch No. PE8A
Injectors	Bosch KBAL 655
Air intake filters	2 Mann No. 3206675203

2.2 Fuel

The engine was operated on No. 2 Diesel fuel (see App. A).

2.3 Installation

The engine was flexibly coupled to a hydraulic dynamometer in the diesel laboratory (Fig. 1).

2.4 Data Recorded

The data were selected primarily to verify the compatibility of the engine with ACV levitation equipment characteristics.

Secondary interests in this regard were the development of a horsepower read-out device, and an endurance test for cylinder and injection pressure versus time transducers.

Data	Measured by
Rotational Speed (RPM)	Magnetic tachometer
Fuel flow	Point gauge (App. E)
Exhaust temperature	Thermocouple — Iron Constantan
Cylinder head temperature	Thermocouple — Iron Constantan
Air Inlet pressure	Manometer with Miriam 1 fluid
Exhaust pressure	Manometer with Miriam 3 fluid
Throttle (rack) position	Rheostat with balance and expander circuit (App. D)
Injection pressure) Cylinder pressure)	Resistance strain transducer (Ref. 1)
Engine torque	Heenan & Froude hydraulic dynamometer DPRX 4

2.5 Corrections

Due to the fairly wide disparity of opinions concerning the application of corrections for ambient conditions, a run was conducted at constant torque and constant rotational speed. While the induction pressure was varied between 645 mm Hg and 740 mm Hg, no variation in fuel flow was measurable, indicating no detectable change of any vital performance criterion. No attempt was therefore made to adjust data to standard conditions.

3.0 TEST RESULTS

As the ACV levitation compressors were said to require some 190 BHP at 1800 RPM, a drive ratio of 1800/2300 was assumed, as the engine output at 2300 RPM is 190 BHP, based on its continuous rating +10%. The latter is permissible for one hour. Three speeds at various BHP steps between 60 and run-out were chosen for the calibration runs (see log sheets).

3.1 Fuel Consumption and Thermal Efficiency

Figure 2 shows the result of the fuel flow runs in terms of specific fuel consumption (BSFC) versus BHP and RPM, in solid line; the dotted line in Figure 2(A) provides a comparator based on Deutz's published claims at 2000 RPM. It will be noted that this curve interpolates the solid 2300 and 1800 RPM curves such that it is evident that the manufacturer's claims compare well with the tests. The curve at Figure 2(B) confirms an expected reasonably flat SFC through the speed range, .365 to .385 (lb/BHP hr) at an approximately constant BMEP of some 83 PSI i.e., 80% of the rated value. Anticipating the ACV's demand to be 186 BHP at 2300 RPM fully loaded (Fig. 3), an SFC of some .365 (lb/BHP hr) may be expected (Fig. 2(A)). This represents some 67.9 lb of fuel per hour, or approximately 8 gallons per hour. Thermal efficiency is derived in Appendix A to facilitate comparison on that basis.

3.2 Horsepower Indicator

The output of a given diesel engine conforms approximately to:

$$BHP = CFR$$

where C = a variable with load and RPM
F = fuel delivered/stroke/cylinder
R = number of firing strokes/time

On this basis instrumentation was arranged as described at 2.4, from which Figure 3 was compiled (App. D). The irregularities repeat fairly consistently and are considered characteristic of the hardware, etc. The broken line anticipates fan power requirements at each RPM, and passes through the most stable area of the chart, providing an expected accuracy of horsepower readout of some ±2%. (For chart application see App. F).

4.0 INJECTION PRESSURE/TIME RECORDING

Four resistance transducers were installed on the fuel injector lines at cylinders 1, 2, 3 and 4 (Fig. 4). Two points are worthy of note:

(A) The low amplitude of the reflected wave, indicating large volumetric compensation.

(B) The extremely slow decay, indicating low damping. The transducers are to be checked for endurance after field operation (see Ref. 1).

5.0 CYLINDER PRESSURE/TIME RECORDING

Five transducers were installed in this case, on cylinders 5, 6, 7 and 8 (Fig. 5). Cylinder 6 in addition to having a single-element standard fatigue life transducer as fitted to the others, bears a double high fatigue life transducer at its front, or inner surface (App. C). Some instrumentation trouble was encountered during the runs, rendering signature amplitudes unreliable. The signatures are, however, of some value for endurance proving as at 4.0 above (see Ref. 1).

6.0 CONCLUSIONS

1. The calibration has demonstrated that the engine meets the manufacturer's power and fuel consumption claims.

2. The engine appears compatible with the power demands of its ACV fan load.

3. A horsepower correlation with speed and indicated rack position has been developed.

4. Transducers to measure injection signatures and cylinder strain signatures have been fitted for field endurance testing.

7.0 REFERENCE

1. Heggie, W.S. *The Use of Component Strain to Plot Pressure vs Time Histories on Reciprocating Engines.*
PART I Diesel Fuel Injection Phenomena.
PART II Cylinder Strain Phenomena.
Submitted to ASME for publication 26 November 1974.

DEUTZ F8L413 DIESEL
CALIBRATION LOG

DATE: Sept. 9/74
RUN NO. 27

RPM		Load	Fuel Cons.			Exh. Temp.		Amb.		Inlet P.				Exh. P.				Lub.		Cyl. T.	Fuel Rack Pos.
										L		R		L		R					
Tach.	Cntr	Lbs	Temp.	Lbs	Secs.	L	R	T	P	S	T	S	T	S	T	S	T	T	P		
1500		96	23	1	145	267	262	21	29.82	6.1	6	6.0		2.7	5.6	3.5	5.4	73	60	50	120
1500		120	25	2	245	303	301	21	29.82	6.0		5.9		2.7	5.8	3.7	5.6	81	58	55	135
1500		144	28	2	217	343	339	21	29.83	5.9		5.8		4.3	6.1	3.9	5.9	90	55	65	150
1500		168	30	3	291	389	384	21	29.83	5.8		5.7		4.4	6.3	4.1	6.1	94	54	70	165
1500		192	32	3	244	455	451	22	29.83	5.7		5.6		4.8	6.9	4.3	6.6	98	52	80	185

°F °F °C ← M1 ✳ M3 →

DEUTZ F8L413 DIESEL
CALIBRATION LOG

DATE: Sept. 9/74
RUN NO. 28

RPM		Load	Fuel Cons.			Exh. Temp.		Amb.		Inlet P.				Exh. P.				Lub.		Cyl. T.	Fuel Rack Pos.
										L		R		L		R					
Tach.	Cntr	Lbs	Temp.	Lbs	Secs.	L	R	T	P	S	T	S	T	S	T	S	T	T	P		
1800		80	29	1	131	259	259	26	29.81	7.7		7.5		5.3	7.5	4.8	7.2	77	64	55	95
1800		100	31	2	231	298	297	26	29.81	7.5		7.4		5.6	7.9	5.0	7.4	84	61	55	115
1800		120	32	2	205	339	333	27	29.81	7.5		7.4		5.9	8.4	5.3	7.9	92	58	65	135
1800		140	35	3	274	368	366	27	29.81	7.4		7.3		6.1	8.6	5.1	8.2	96	57	70	145
1800		160	36	3	245	419	407	28	29.80	7.2		7.1		6.3	9.0	5.7	8.4	100	56	75	160
1800		180	37	4	295	463	457	29	29.80	7.1		6.9		6.5	9.3	6.0	8.8	105	54	80	175
1800		200	39	4	264	513	509	29	29.80	6.9		6.7		6.8	9.6	6.3	9.2	111	52	90	195

°F °F °C ← M1 ✳ M3 →

DEUTZ F8L413 DIESEL
CALIBRATION LOG

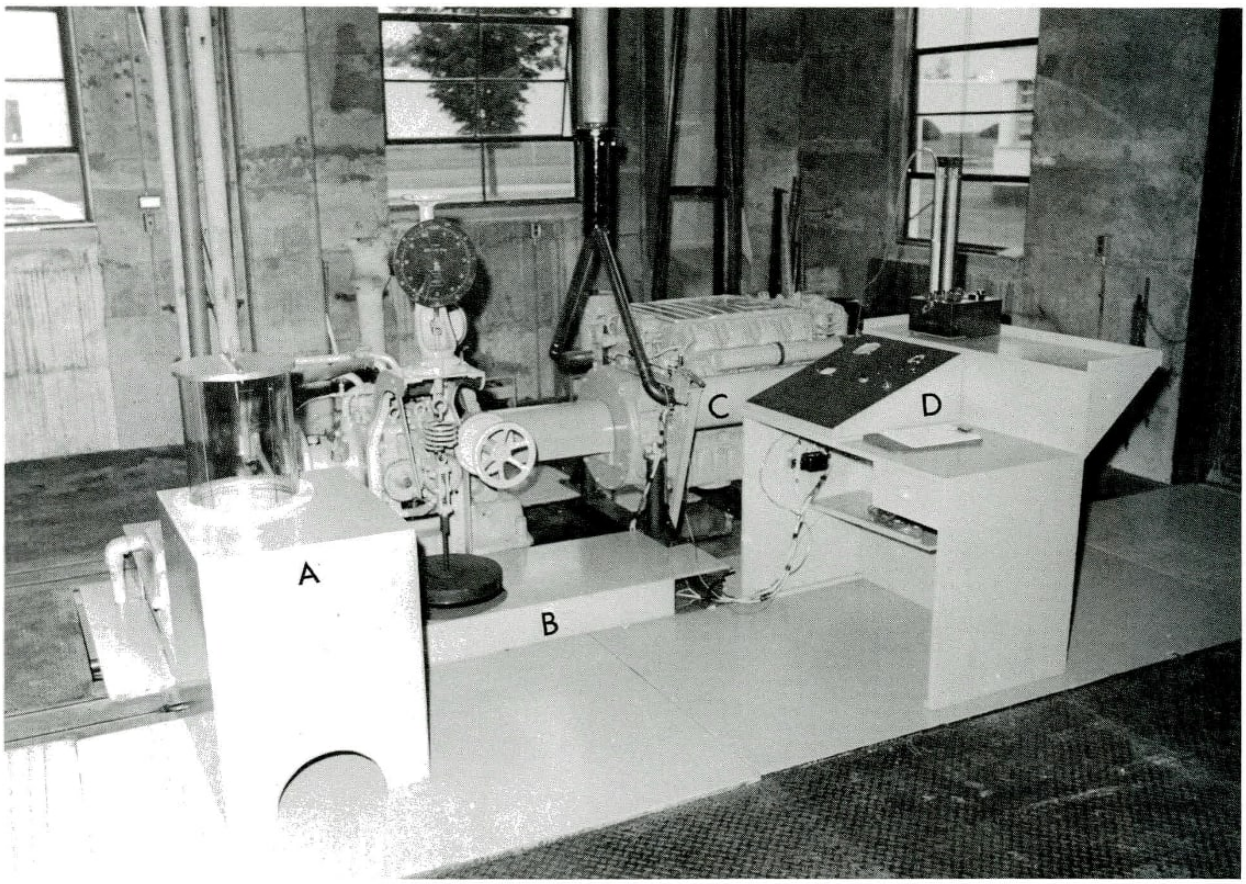
DATE: Sept. 10/74
RUN NO. 29

RPM		Load	Fuel Cons.			Exh. Temp.		Amb.		Inlet P.				Exh. P.				Lub.		Cyl. T.	Fuel Rack Pos.
						L	R			L		R		L		R		T	P		
Tach.	Cntr	Lbs	Temp.	Lbs	Secs.			T	P	S	T	S	T	S	T	S	T				
2300		61.1	25	2	227	253	248	21	29.93	11.1		10.9		8.5	11.6	7.7	11.1	81	68	45	85
2300		76.4	27	2	206	277	273	21	29.93	11.0		10.8		8.9	12.1	8.0	11.6	89	66	55	95
2300		91.7	29	3	274	299	302	22	29.93	10.9		10.7		9.2	12.6	8.3	11.9	91	65	60	100
2300		106.9	31	3	250	324	330	22	29.91	10.7		10.7		9.5	13.0	8.5	12.4	93	64	62	105
2300		122.2	32	4	304	368	366	22	29.91	10.5		10.4		9.9	13.7	8.9	12.9	95	63	70	125
2300		137.5	33	4	279	401	387	22	29.90	10.3		10.3		10.3	14.1	9.1	13.3	98	62	70	138
2300		152.8	33	4	260	437	425	23	29.90	10.3		10.2		10.6	14.7	9.5	13.8	101	61	70	150
2300		168	35	5	298	473	261	25	29.90	10.3		10.1		11.0	15.1	9.8	14.2	106	60	75	165
2300		183.3	36	5	271	511	505	25	29.90	10.3		9.5		11.4	15.8	10.4	14.9	110	58	85	180
2300		198.6	36	5	250	528	517	23	29.90	10.2		10.1		12.2	16.9	11.1	16.0	107	60	75	192

°F °F °C ← M1 ✳ M3 →

DEUTZ F8L413 DIESEL
CALIBRATION LOG
(Fuel Rack Position Runs)

RPM		Load	Fuel Cons.			Exh. Temp.		Amb.		Inlet P.				Exh. P.				Lub.		Cyl. T.	Fuel Rack Pos.	BHP
										L		R		L		R						
Tach.	Cntr	Lbs	Temp.	Lbs	Secs.	L	R	T	P	S	T	S	T	S	T	S	T	T	P			
1600								21													137	83.5
1600								—													152	100
1600								—													170	115
1600								—													190	131
2000								—													145	120
2000								—													164	140
2000								—													185	155
								—													198	170



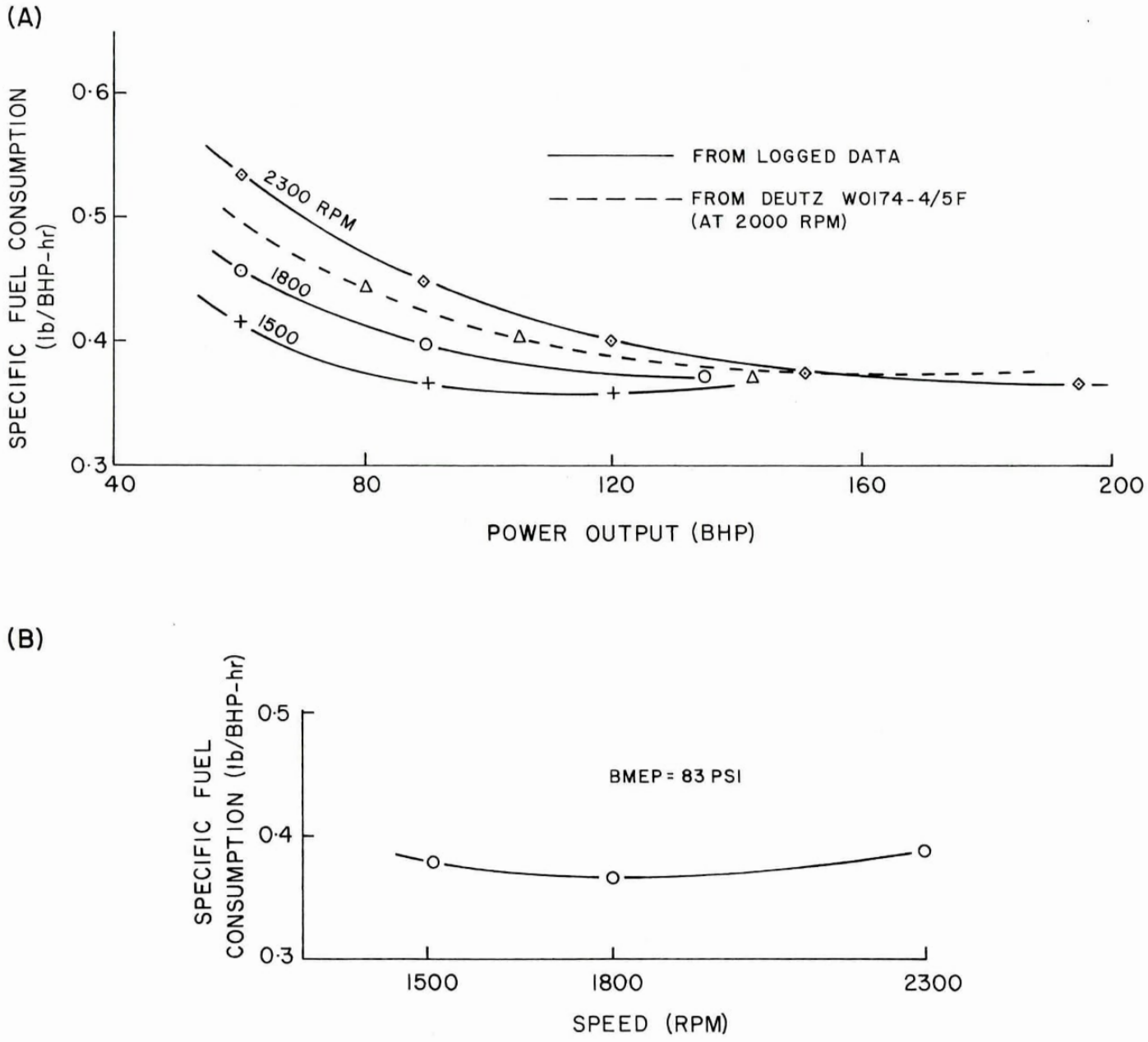
A POINT GAUGE FOR FUEL CONSUMPTION

B HYDRAULIC DYNAMOMETER

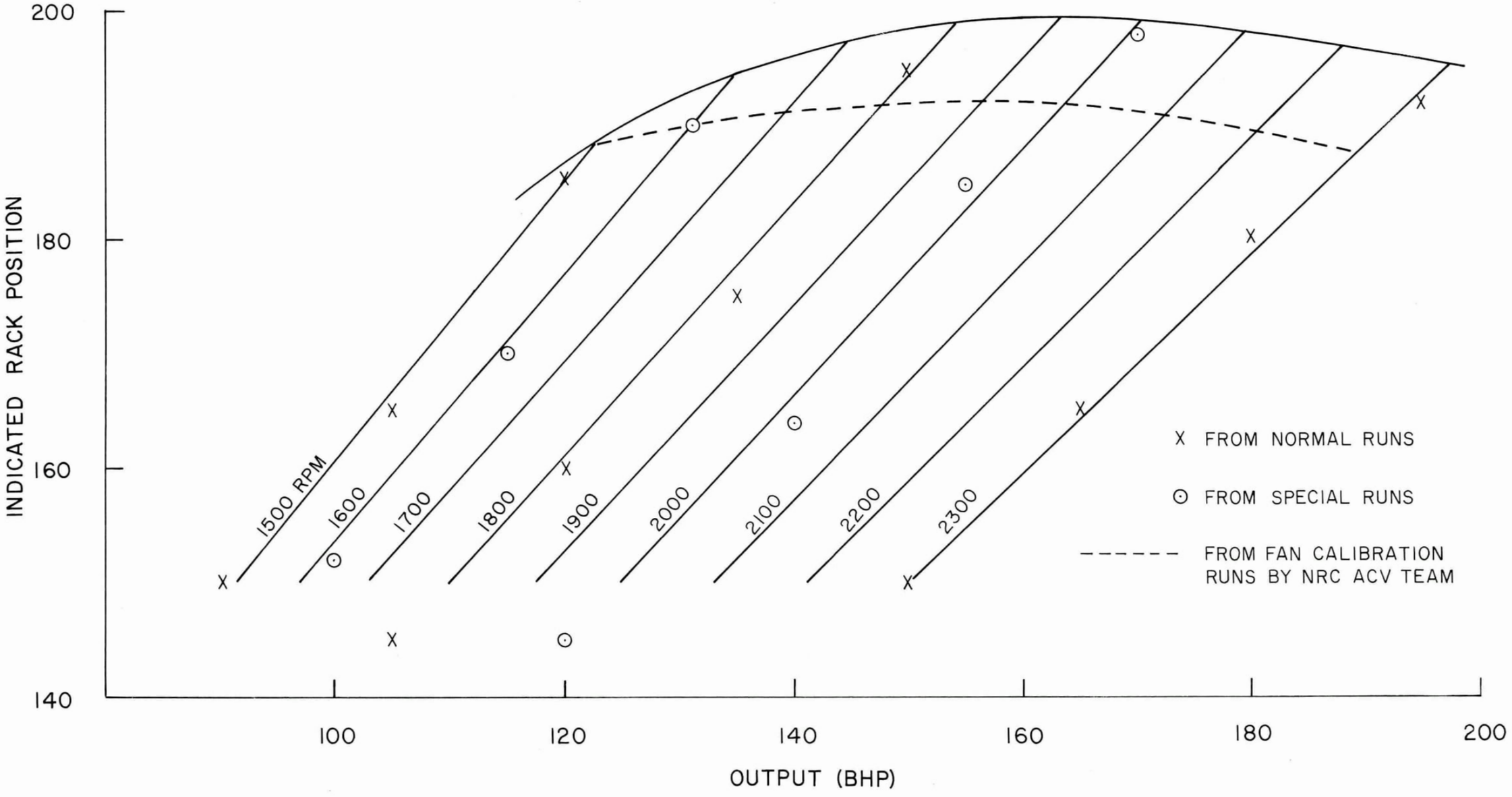
C DIESEL ENGINE

D INSTRUMENT CONSOLE

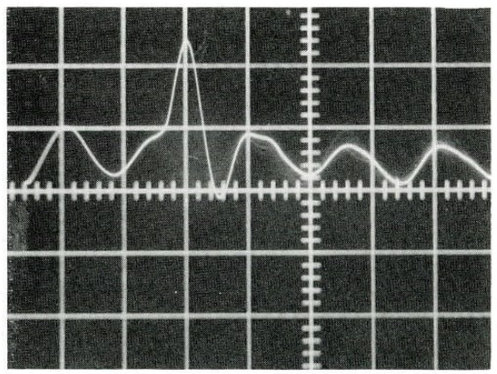
FIG. 1: GENERAL VIEW OF TEST RIG



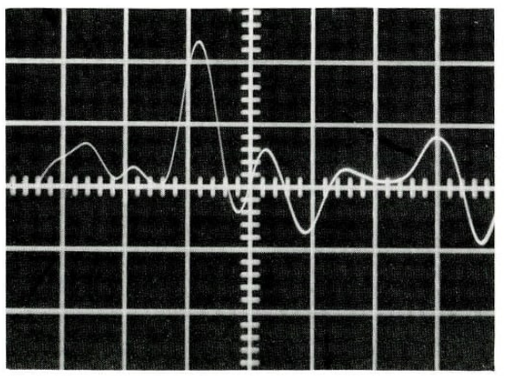
FIG· 2: ENGINE FUEL CONSUMPTION



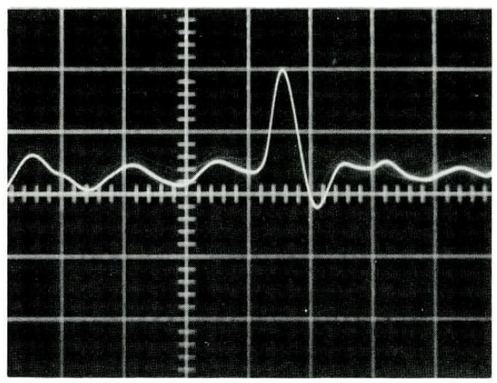
FIG·3: CORRELATION OF RACK POSITION WITH OUTPUT POWER



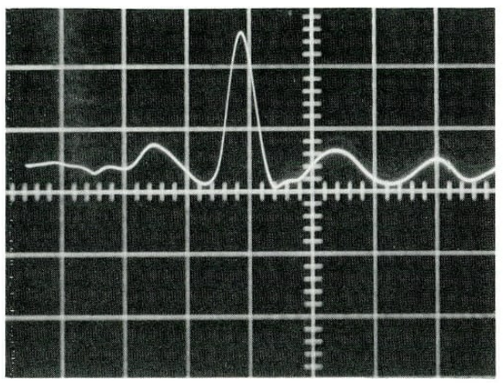
CYL· 1



CYL· 2

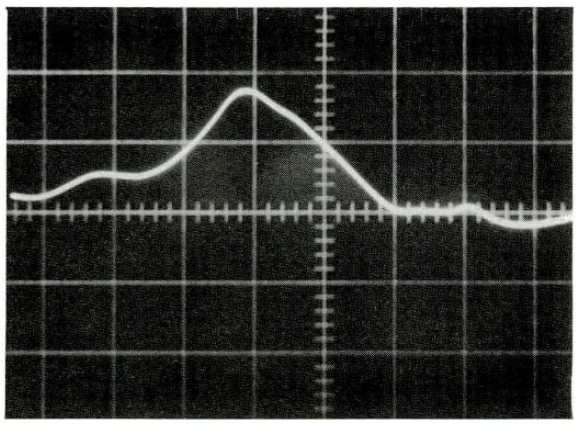


CYL· 3

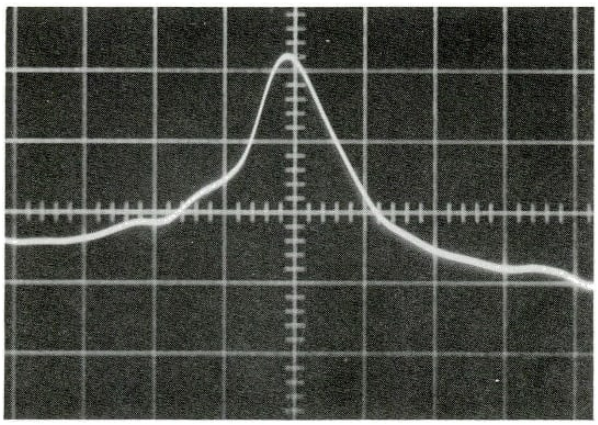


CYL· 4

FIG· 4: INJECTION PRESSURE/TIME TRACES TAKEN AT 1100 RPM, NO LOAD (0·05 V/CM AND 5 MS/CM)



IDLE 700 RPM



60 HP 1000 RPM

FIG. 5: CYLINDER PRESSURE/TIME TRACES TAKEN ON CYLINDER 6

(0.2 V/CM AND 5 MS/CM)

APPENDIX A

FUEL AND THERMAL EFFICIENCY

The following formula was considered appropriate for the purpose of this paper.

The fuel used was No. 2 Diesel which weighed 8.523 lb/imp. gal. at 60° F, giving a lower heat of combustion of 18372 BTU/lb at an API gravity of 34.4 (Esso Technical Fuel Manual 1960, 3rd Ed. Table 1).

$$E = \frac{Bh\ 100}{CH}$$

$$= \frac{2544 \times 100}{.38 \times 18372}$$

$$= 36.4\%$$

where

E = Brake Thermal Eff. (%)

Bh = Dimensional Constant (BTU/HP hr)

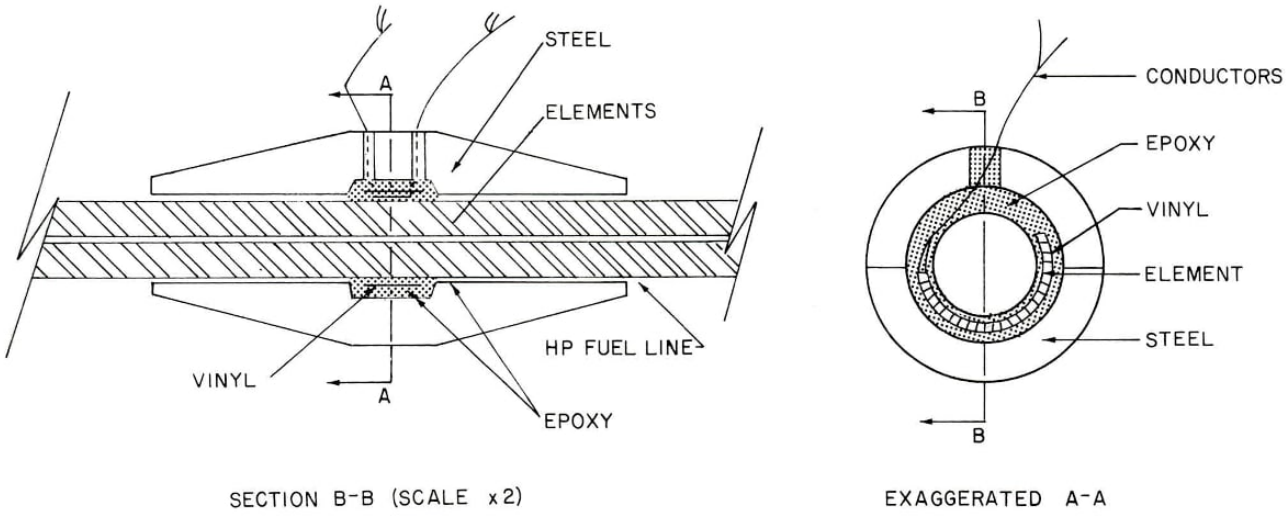
C = Brake specific fuel consumption (lbs/BHP-hr)

H = BTU/lb of fuel

APPENDIX B

INJECTION PRESSURE TRANSDUCER SKETCH AND LOCATION

Fuel injection pressure transducers as shown in the sketch were fitted to the high pressure lines to numbers 1, 2, 3 and 4 cylinders.



SECTION B-B (SCALE x2)

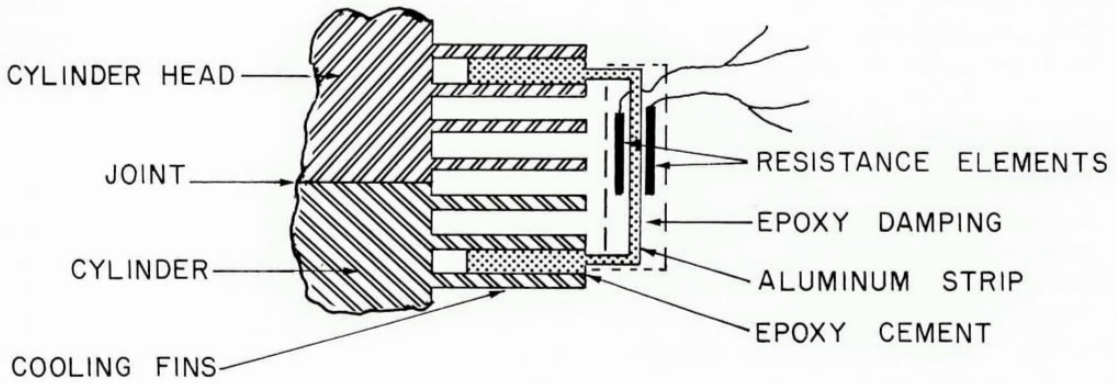
EXAGGERATED A-A

RESISTANCE INJECTION PRESSURE TRANSDUCER

APPENDIX C

CYLINDER PRESSURE TRANSDUCER SKETCH AND LOCATION

Cylinder pressure transducers were fitted across the cylinder head joints in accordance with the sketch.



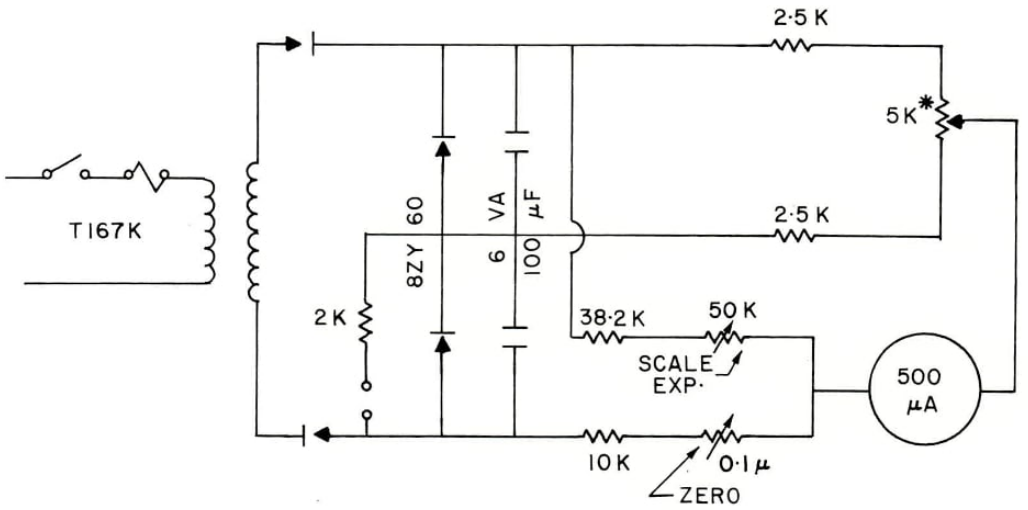
RESISTANCE CYLINDER PRESSURE TRANSDUCER

Cylinders five to eight inclusive have single standard resistance element transducers (strain gauge element No. MM CEA-06-500UW-350) fitted to surfaces facing away from the engine. Cylinder number six has an additional transducer fitted to its inward-facing surface. The latter bears two high fatigue life elements (No. MM-ED-DY-250BG-350).

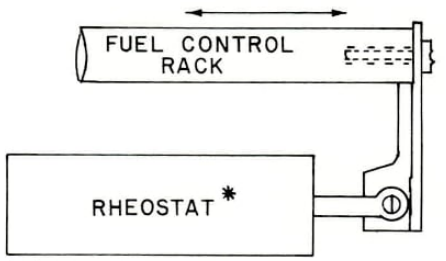
APPENDIX D

SKETCHES AND DESCRIPTION OF THE FUEL RACK POSITION INDICATOR

These data are intended to provide sufficient information upon which a rack position indicator may be designed.



SKETCH A



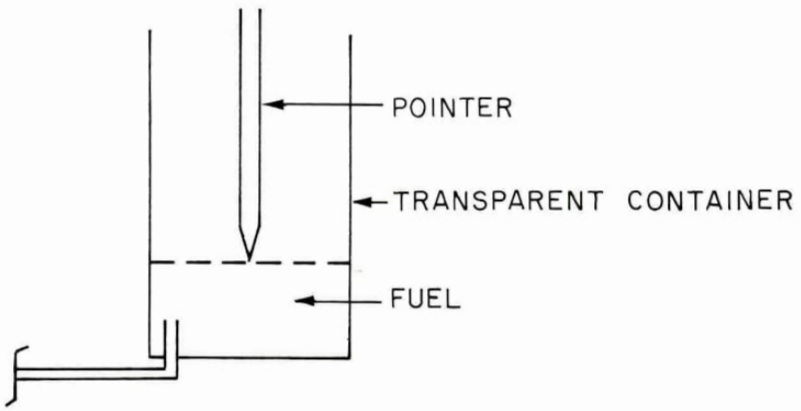
SKETCH B

Sketch B shows the main rheostat connected to the fuel rack by a solid link. Alignment is simplified by a single ball joint at the rheostat end while a rigid connection is used at the rack. Sketch A shows the electrical circuitry. The Zero Adjuster is set at commencement of injection registering 64 on the Adjuster scale, and the expander is set st 12.5, giving a 0-500 µA deflection for Zero to full throttle

APPENDIX E

POINT GAUGE FOR FUEL CONSUMPTION MEASUREMENT

The instrument illustrated in this sketch, while simple, is one of the most accurate devices for measuring fuel flow during a test run.



POINT GAUGE FOR FUEL CONSUMPTION MEASUREMENTS

The test is started with fuel slightly above the tip of the pointer and a stop-watch is started when the fuel adhering to the tip by surface tension is broken. A quantity of fuel measured, preferably by weight, is poured into the container and when fuel breaks at the tip for the second time, the stop-watch indicates the time taken to consume the measured quantity of fuel.

APPENDIX F

USE OF THE BHP CHART

It will be noted that the chart (Fig. 3) shows rack number versus BHP plotted at various RPM. The rack number and RPM are taken directly from the instruments provided and atmospheric temperature and pressure, representing the engine's operating environment, may also be recorded.

Example:

Rack No. = 180, RPM = 2300, Temperature = 30°C
Pressure = 740 mm Hg. From 180 Rack No. on the chart, one follows the horizontal line until the 2300 RPM line is intersected, at which point the vertical line is followed downwards indicating 181 BHP.