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A simple thrustmeter

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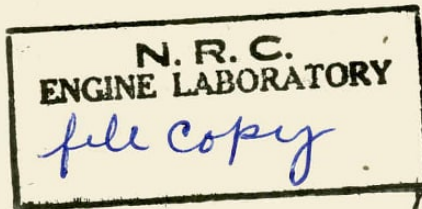
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NATIONAL RESEARCH COUNCIL
DIVISION OF MECHANICAL ENGINEERING
OTTAWA, CANADA
LABORATORY MEMORANDUM
SECTION ENGINE LABORATORY

NO. NRC-ENG-20
PAGE 1 OF 4
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DATE 12 May 1960

SECURITY CLASSIFICATION OPEN



SUBJECT A SIMPLE THRUSTMETER

PREPARED BY H. S. FOWLER

ISSUED TO

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A SIMPLE THRUSTMETER

INTRODUCTION

Measurement of the thrust of the 12" VTO Ducted Fan Test Rig in the Engine Laboratory presented a problem, since the range to be measured (50-500 lbs.) was considerably below the proper range of any thrustmeters available in the Laboratory. A thrust-cell of the circulating oil type was designed and built, and has proved satisfactory. A brief description and a calibration curve are given here.

CHOICE OF TYPE OF CELL

The first type of cell tried was the closed constant-volume oil type ("Emery Cell") shown in Figure 1.

This cell is satisfactory at its designed thrust range, but was being used here over the bottom 7% of its range. In this range, the zero-shift due to the expansion of the oil with test cell temperature changes was of the order of 30 lbs. of indicated thrust. Since the full load in this application was 250 lbs., this error was intolerable. Attempts at temperature stabilisation were not successful.

The second type of cell ("Hagan" type - see Figure 2) is supplied with 90 psi (approximately) compressed air, and blows off through a servo valve. This cell is free from temperature errors, but can suffer from instability due to the compressible nature of the working fluid (air) with resulting resonance and hunting. This resonance can be tuned out by proper adjustment of damping constrictions and chamber volumes, but it is difficult to eliminate it over the whole working range, and the required damping may seriously reduce the sensitivity of the cell.

The third type of cell was of the continuous-flow type, but used incompressible oil as the working fluid. (See Figure 3). The valve system used was reduced to the simplest possible, and consisted merely of an annular exhaust port extending right round the cylinder bore. The piston movement from minimum to maximum load was of the order of .010"-.020". The only source of trouble observed to date has been a change of calibration, apparently due to the change of viscosity of the oil due to temperature rise caused by the pump. A watercooling coil in the small tank in the oil circuit has eliminated this trouble.

The cell at present in use was designed and made in about one week, by Mr. Rimmer, the Cell Crew Chief, and no modification or development has been required in about a year's operation, except the addition of the cooling coil and an oil thermometer. A calibration was carried out with standardised 50 lb.

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weights, on 11-V-60, for the purposes of this note, using a 100" Mercury manometer instead of the usual Bourdon gauge. The results are presented in Figures 4 and 5.

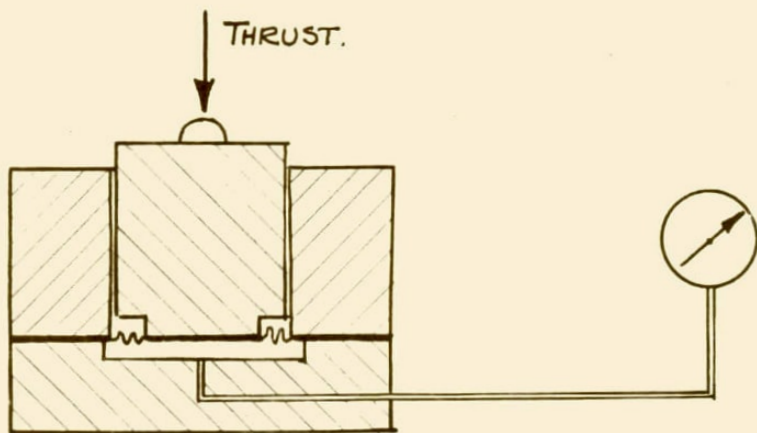
The cell is considered satisfactory in its present application, and should be capable of considerable refinement if required.

In order to eliminate as far as possible the effect of viscosity in the oil tube from the cell to the manometer as a source of error, a second calibration was run. In this case, the length of $3/16$ " d. bore copper tube from thrust cell to manometer was reduced from 40' to 2'. As is seen from Figure 6, the error was reduced, although piston stickiness still produced roughly a $\pm 1\%$ error.

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TABLE 1
THRUSTMETER CALIBRATIONS - NO. 1 CELL, 12" VTO FAN RIG

Applied Load	<u>"Hg. Indicated</u>								
	Run	1	2	3	4	5	6	7	8
	<u>CALIBRATION NO. 1 - LONG TUBE</u>								
0 lbs.	24.50	24.80 =	24.80	24.60 =	24.60	24.60	-	-	
50 lbs.	↓ 40.75	↑ 41.50	↓ 41.10	↑ 41.70	↓ 41.20	↑ 41.50	-	-	
100 lbs.	↓ 57.90	58.10	↓ 58.80	↑ 58.75	↓ 58.65	↑ 58.45	-	-	
150 lbs.	↓ 75.65	75.30	↓ 75.90	↑ 75.80	↓ 75.80	↑ 75.30	-	-	
200 lbs.	92.40 =	92.40	93.45 =	93.45	92.90 =	92.90	-	-	
	<u>CALIBRATION NO. 2 - SHORT TUBE</u>								
0 lbs.	↓ 22.25	↑ 22.50 =	22.50	↑ 22.55 =	22.55	↑ 22.65 =	22.65	↑ 22.60	
50 lbs.	↓ 39.65	-	↓ 39.35	↑ 39.80	↓ 39.65	↑ 39.90	↓ 39.95	↑ 40.00	
100 lbs.	↓ 57.70	57.30	↓ 57.00	↑ 57.30	↓ 57.20	↑ 57.20	↓ 57.50	↑ 57.45	
150 lbs.	↓ 74.00	74.45	↓ 74.60	↑ 74.55	↓ 74.50	↑ 74.55	↓ 74.90	↑ 74.80	
200 lbs.	92.60 =	92.60	91.95 =	91.95	91.80 =	91.80	92.50 =	92.50	
	Loading	Unloading	Loading	Unloading	Loading	Unloading	Loading	Unloading	



CLOSED CONSTANT VOLUME THRUST CELL. ["EMERY" TYPE]

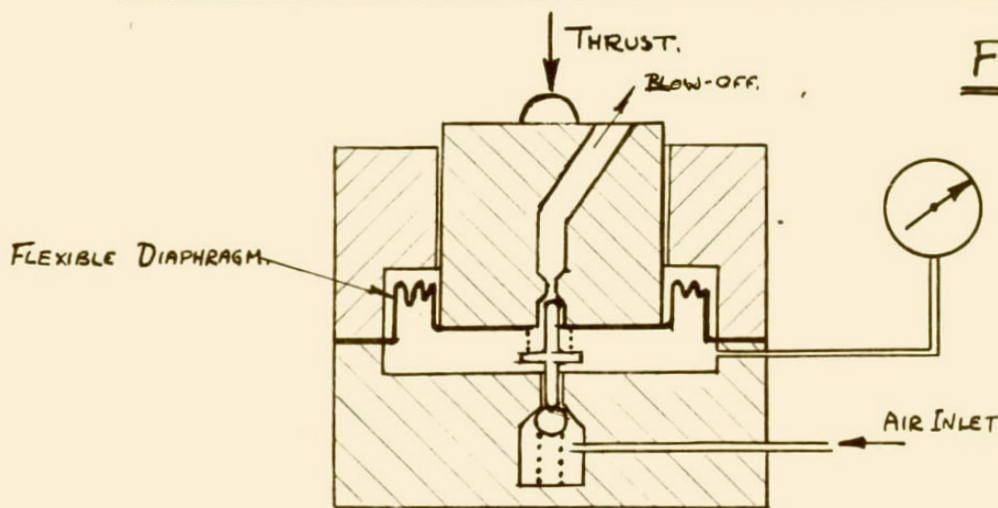
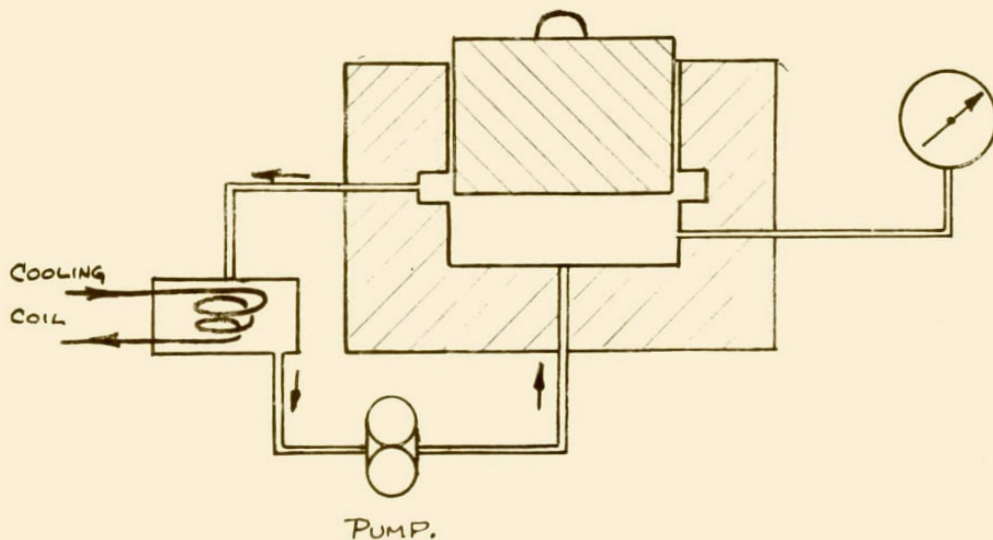


FIG. 1.

CONTINUOUS FLOW THRUST CELL [AIR] — ["HAGAN" TYPE]

FIG. 2.

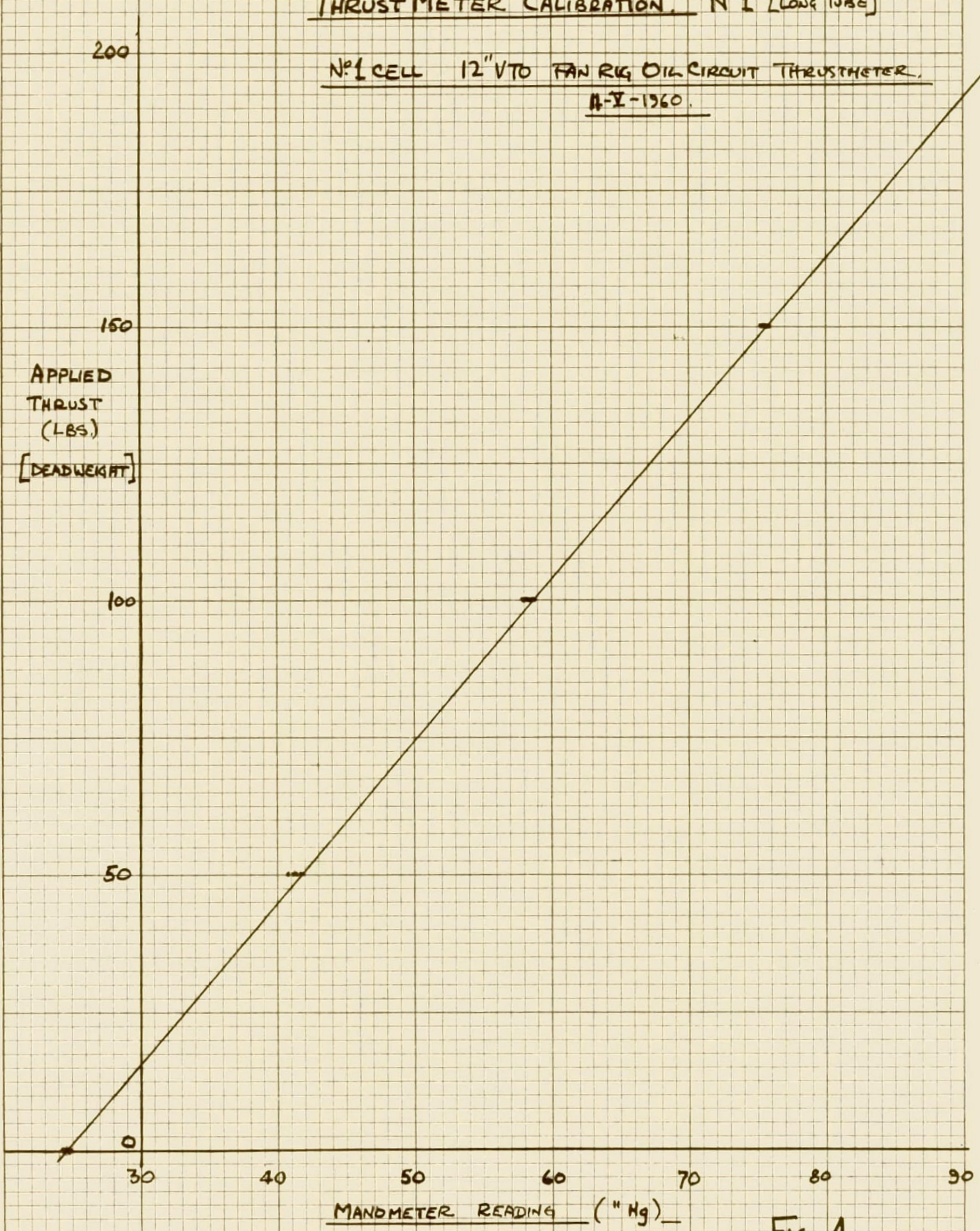


CONTINUOUS FLOW THRUST CELL [OIL]

FIG. 3.

THRUST METER CALIBRATION, N°1 [LONG TUBE]

N°1 CELL 12" VTO FAN RIG OIL CIRCUIT THRUSTMETER.
A-X-1960.

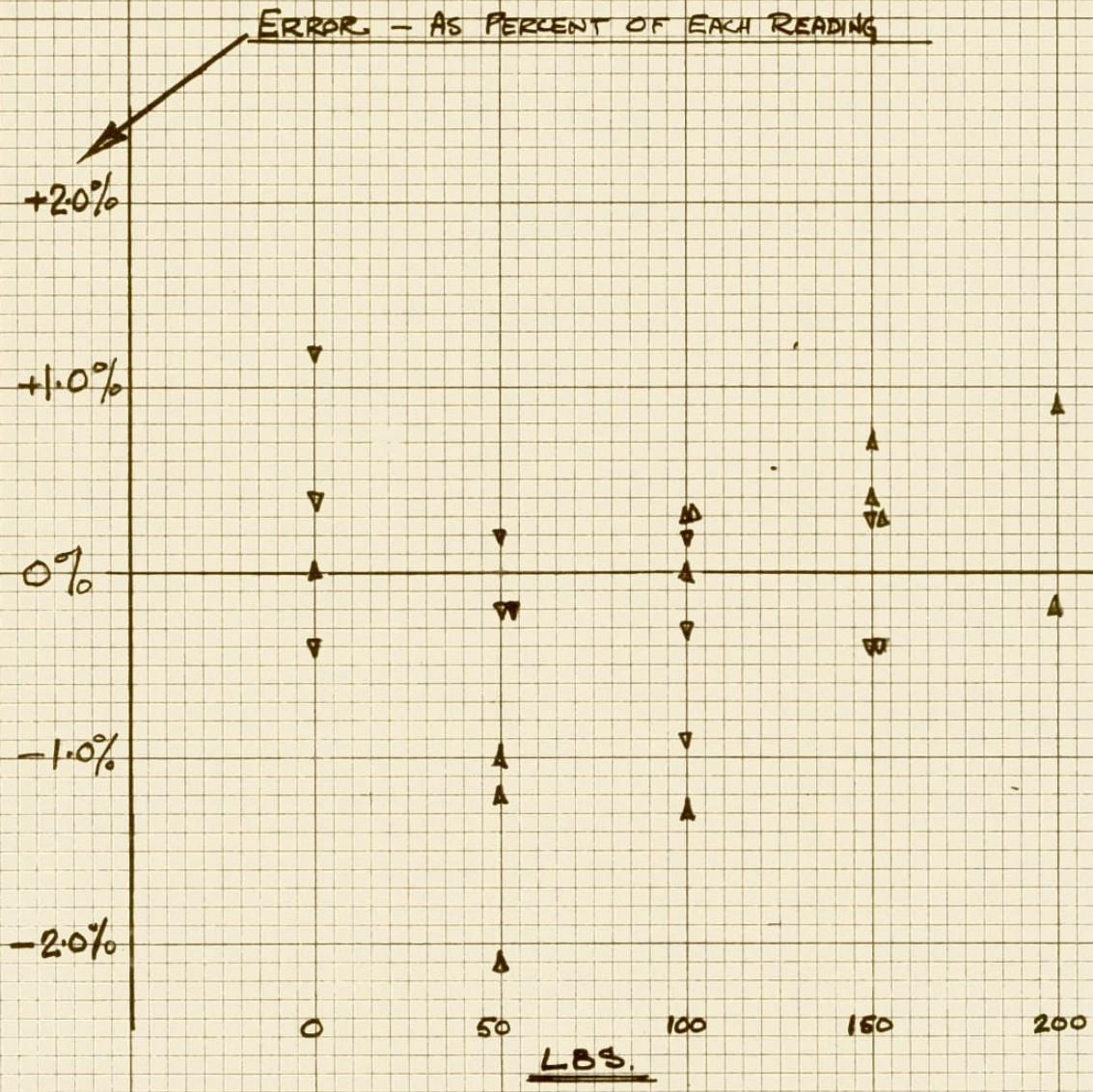


APPLIED
THRUST
(LBS)
[DEADWEIGHT]

MANDMETER READING ("Hg)

FIG. 4.

THRUST METER CALIBRATION N°1 [LONG TUBE]
N°1 CELL 12" VTO FAN RIG OIL CIRCUIT THRUSTMETER.
11-~~X~~-1960.



▲ POINTS ON LOADING RUNS
 ▼ POINTS ON UNLOADING RUNS.

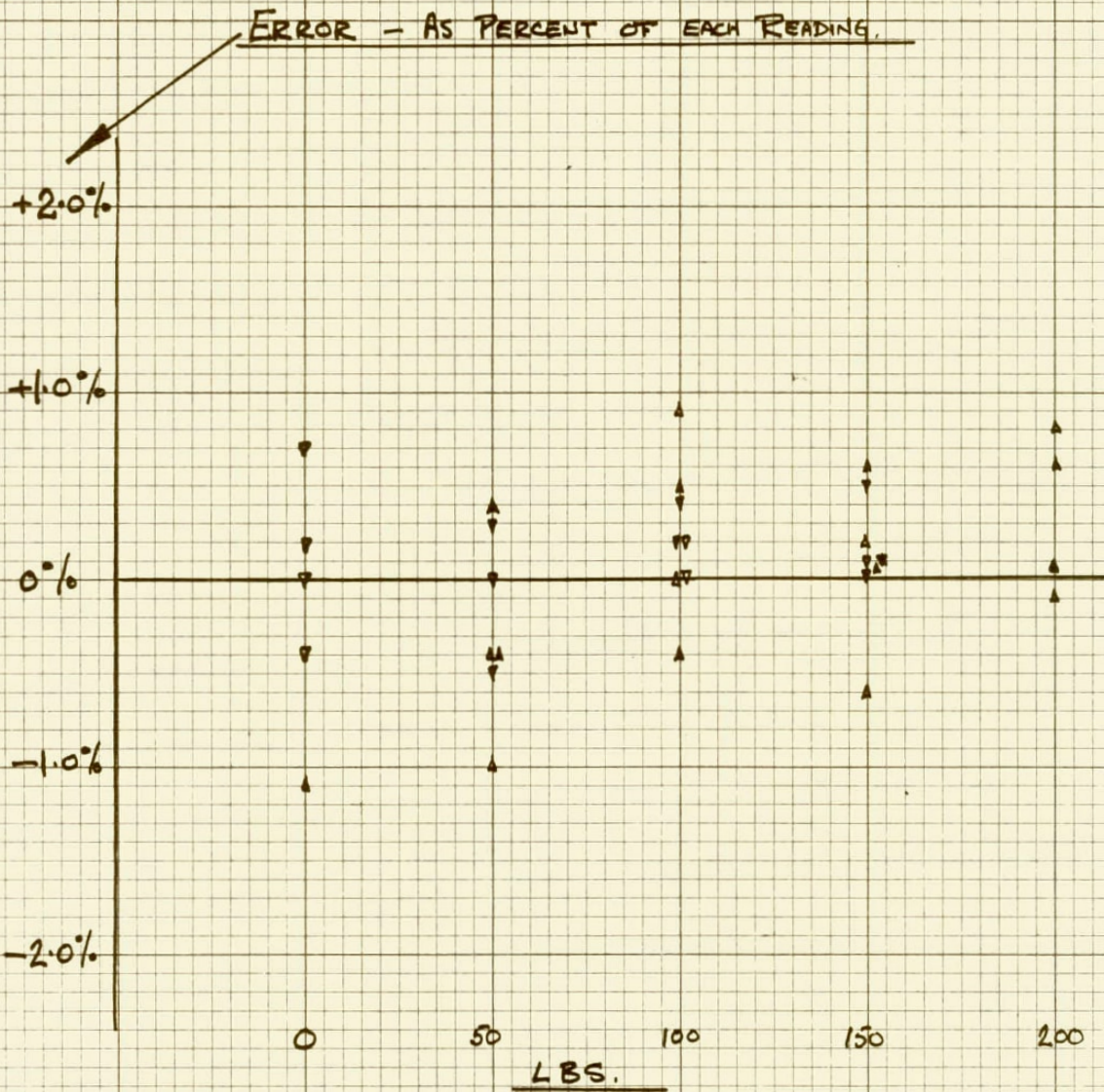
Fig. 5

THE POINTS FALL ON A GAUSSIAN CURVE OF RANDOM ERROR.

THRUST METER CALIBRATION N° 2 [SHORT TUBE]

N° 1 CELL 12" VTO FAN RIG OIL CIRCUIT THRUSTMETER.

17-1-1960.



▲ POINTS ON LOADING RUNS.

▼ POINTS ON UNLOADING RUNS.

Fig. 6.

THE POINTS FALL ON A GAUSSIAN CURVE OF RANDOM ERROR.