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OTTAWA February 18, 1946.

REPORT

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 2002.

(Subsequent to Investigation Report)
(No. 1991, dated January 21, 1946.)

Research on Optimum Thread Form for Proposed Anglo-American-Canadian Screw Thread.

PART II. - Static Tension Calibration of 20-Ton Avery-Schenck Pulsator (Push-Pull) Fatigue Testing Machine.

==========

(This research is performed in)
(collaboration with the National)
(Bureau of Standards, Washington,)
(U. S. A., the National Physical)
(Laboratory, Teddington, England,)
(and the National Research Council,)
(Ottawa, Canada.)

(Copy No. 18.)

(Report of Investigation)
(No. 2002.)

Abstract

This report describes results obtained by calibrating in static tension the 20-ton Avery-Schenck fatigue testing machine installed in the Physical Metallurgy Research Laboratories, Ottawa. The calibration was carried up to 10 tons, the static load capacity of the springs of the machine. It was expected that the mean loads for specimens to be used for the Research on Optimum Thread Form would be less than 10 tons.

It is shown that the error introduced by hysteresis of the elastic loop is comparable to the error introduced by the difficulty of reading the microscope to within less than ±0.25 division.

The stiffness coefficient of the loop dynamometer, measured with objective of X600 magnification, was 335 pounds per division of deflection.

Bureau of Mines
Division of Metallic
Minerals
-
Physical Metallurgy
Research Laboratories

CANADA

DEPARTMENT
OF
MINES AND RESOURCES

Mines and Geology Branch

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Avery-Schenck Pulsator (Push-Pull)
Fatigue Testing Machine.

===========

Origin and Purpose of Investigation:

As the machine is to be used for a joint research of these Laboratories in conjunction with the National Physical Laboratory (England), the National Bureau of Standards (U.S.A.) and the National Research Council (Canada), for the determination of the Optimum Screw Thread Form, and because of experience of other users of this type of machine, calibration was considered necessary in order that results obtained at the different laboratories might be directly comparable.

As tension tests only are required for this research, the results of tensile calibration only are given in this report.

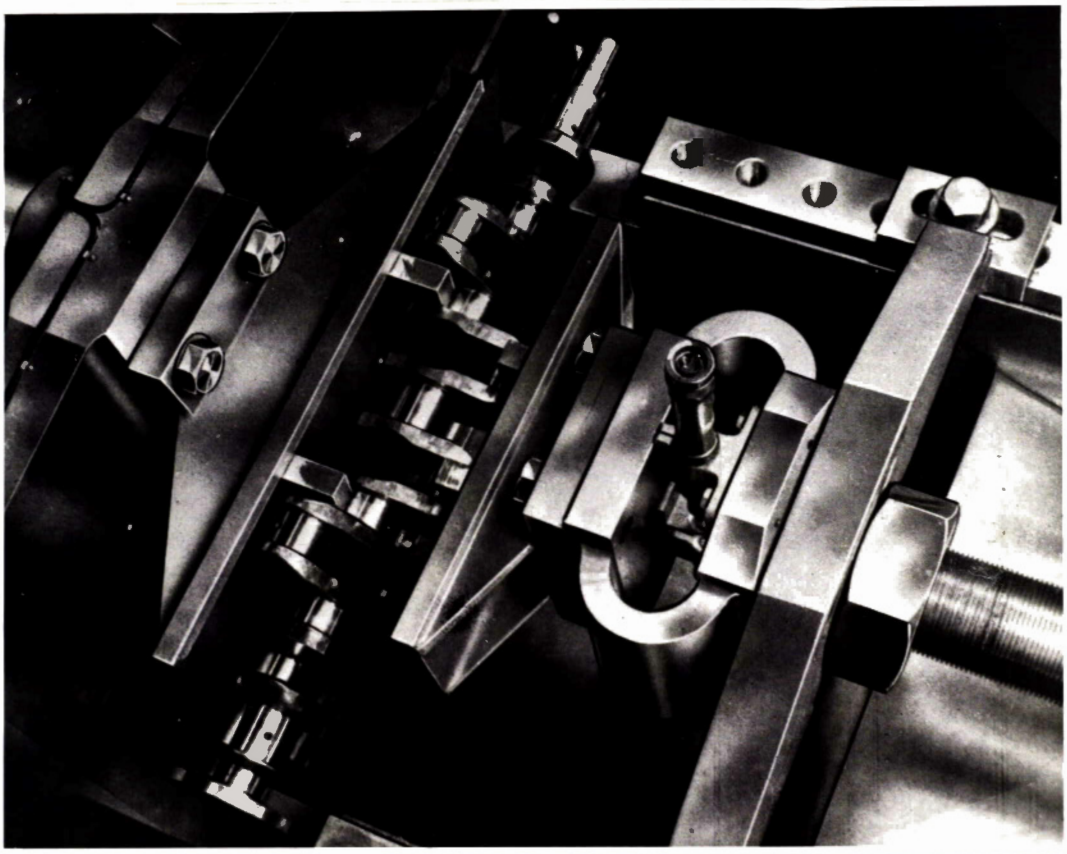
APPARATUS AND PROCEDURE

Description of the Machine:

Mean Load = 0-10 tons tension or compression.
Load Range = 20 tons maximum.

The machine is used to determine the number of cycles of load, within the above limits, which can be imposed on a sample or machine part before fracture. By means of attachments available, tensile, compressive and flexural loads can be imposed.

Figure 1.



VIEW OF 20-TON AVERY-SCHENCK PULSATOR WITH LOOP DYNAMOMETER AND CRANKSHAFT FIXED IN A SPECIAL BENDING FIXTURE.

(Continued on next page)

(Description of the Machine, cont'd) -

The Pulsator is a resonance-type machine. A steel beam, with a fundamental natural frequency in flexural vibration of about 45 C.P.S., is connected, at its mid point, to the main base of the machine by the specimen. An eccentric mass, rotating in a bearing attached to one end of the beam, excites it to flexural oscillation. The frequency of rotation of the eccentric is less than the beam's natural frequency; by varying this rotation frequency the amplitude of oscillation is controlled, smaller amplitudes being obtained as the frequency becomes farther from resonance.

A steel loop is interposed between the specimen and the base of the machine. To the side of this loop remote from the specimen is attached a microscope with a scale in the focal plane of its eye-piece; to the other side, a bracket supporting a piece of silvered glass. A narrow scratch in the silver permits a band of light to be seen in the microscope. Distortion of the loop causes the position of the light-band to shift along the scale. The readings on the scale of the edges of the band are taken when the specimen is placed in the machine, before loading. From calibration charts giving the microscope deflection against the load, the microscope can be used to measure whatever mean load is applied.

The loop dynamometer and microscope are shown in Figure 1 where, between the oscillating beam and the loop dynamometer, in a special bending fixture, a crankshaft is fixed.

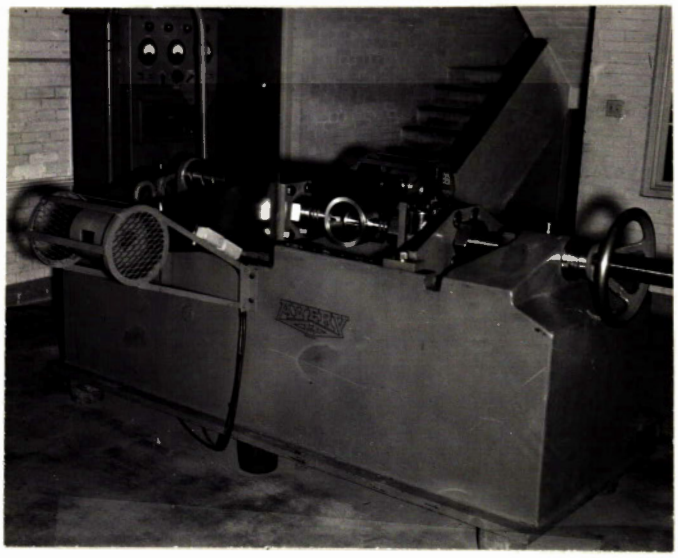
When the eccentric exciting the beam is rotating, the fluctuating load on the dynamometer causes it to distort in unison with the load. This rapidly shifts the band of light seen in the microscope back and forth and a broad band is seen. The width of this band, less the width of the light-band itself, indicates the range of load

(Description of the Machine, cont'd) -

applied to the specimen.

Two objectives are supplied, giving magnifications of X300 and X600. The scale has 200 divisions. With the X600 eyepiece each scale division represents 335 pounds of load. This objective was used during the present calibration. It was found by preliminary tests that tightening the bolts of the crosshead of the dynamometer had no effect, and they were left-loose.

Figure 2.



GENERAL VIEW OF 20-TON AVERY-SCHENCK PULSATOR WITH CALIBRATION RING.

Procedure

The calibration was done by a 50,000-pound Morehouse proving ring obtained from the N.R.C., Ottawa, and calibrated by the National Bureau of Standards in Washington. This ring was connected to the oscillating beam and to the dynamometer of the machine by attachments suited to both the N.P.L. adaptors B103/1[*] and the threaded ends of the ring. The N.P.L. adaptors mentioned are to be used for gripping thread studs under test; using them during calibration ensured that any

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[*] The N.P.L. adaptors were made in accordance with Drawing B103/1, Engineering Division of the National Physical Laboratory. This drawing is shown in Figure 7 of the present report.

clamping effects introduced by distortion of parts of the dynamometer during tightening of the grips in preparation for testing would be present. The Pulsator with the Morehouse proving ring is shown in Figure 2.

Readings were taken by an SR-4 strain indicator on a pair of strain gauges attached to either side of the dynamometer loop in the hope that these might supplant the microscope as a means of reading the load on the dynamometer. Little importance is attached to these results because they do not permit finer calculation of load than that obtainable from the microscope.

Thus it is felt that the microscope can be read with certainty to ±0.25 division at any point on its scale, while the strain indicator readings can be estimated to ±1, or even more, micro inch per inch of strain. A load which caused a microscope deflection of 71 divisions was found to deflect one strain gauge by 211 micro inches, the other by 206. As the microscope deflection can be estimated to ±0.25 division it can be read to an accuracy of 1 in 284, while the strain gauge can be read to one in 211. There is no reduction in relative error obtainable with strain gauges. SR-4, A-3 gauges, furnished by Baldwin-Southwark were used, type A being chosen for stability.

Further discussion will be confindd to results obtained with the Morehouse ring because with it the tension on the dynamometer could be estimated to about 7 pounds. As one division of the dynamometer represented, in tension, a load increment of about 335 pounds, considering that the dynamometer can be read with certainty to ±0.25 division, load measurements with the ring are about 10 times finer than those with the dynamometer.

Immediately before calibration on the machine was

(Procedure, cont'd) -

run for 1½ hours at a load-range of 15 tons in tension. The dynamometer was then five times loaded to ten tons tension and released. The microscope was read at zero load each time the load was released and only when the reading for zero load appeared to have reached an equilibrium value was the calibration started.

Previous tests had indicated that a load of ten long tons tension would change the microscope reading by about 70 divisions. Therefore, it was felt that a satisfactory curve would be obtained by taking ten readings of both microscope and ring. Load was applied until the microscope had deflected seven divisions; readings were taken and the load applied for a further seven divisions of deflection, and so on until the 70 divisions had been covered. The same procedure was followed in reducing the load. Five runs were taken in this way. The last four only are used in the calculations because it was found that after the first cycle of load the microscope reading for zero load had changed. Numerous cycles of calibration had been taken previously[*] but as the dynamometer bolts had been heavily tightened prior to the calibration described in this report, the previous results are not considered. The total shift in the zero load reading, between shut-down from running without static load and the zero-load microscope reading reaching equilibrium, was 2 divisions.

Results of four calibration runs are shown diagramatically in Figure 5, a difference curve being given in Figure 6, curve B. Examination of the difference curve reveals a well-defined hysteresis loop with a maximum width of about

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[*] Numerous calibrations have been taken previously, by Mr. R. H. Field and Dr. L. G. Turnbull of the National Research Council, Ottawa; by Mr. R. C. A. Thurston, of the National Physical Laboratory, England; and by Mr. H. L. Lexier of the F. M. R. L., Bureau of Mines, Ottawa.

(Procedure, cont'd) -

0.8 microscope division along the horizontal axis and of about 240 pounds along the load axis. The manner of plotting the difference curve by taking the centroids of selected groups of points which lie fairly close together may be challenged, and a more rigourous analysis could certainly be made if care had been taken to make proving-ring readings always with the same group of readings on the dynamometer microscope. The fault is not serious because the curve, while not a straight line, displays no pronounced discontinuities except at the points corresponding to maximum and zero loads. The mean values of load as measured by Morehouse ring and deflection, as read on the microscope are given in Tables I to IV in the Appendix hereto, and in a graph in Figure 3.

Previous results had indicated that the calibration would yield a curve which would be within a small distance of a straight line passing through the origin. Further, it appeared that the curve would not depart from the straight line by more than half a division of the microscope scale, while ±0.25 division had been decided upon as the lowest limit of error one could hope to maintain. For these reasons it was anticipated that a representation of the behaviour of the dynamometer, sufficiently accurate for the task in hand, could be obtained by drawing through the origin a straight line of the correct slope. This would permit the deflection of the dynamometer for a given load to be directly calculated, and the use of a graph for this purpose would be unnecessary. It therefore remained to determine the slope of such a straight line. For a graph expressing the load in pounds on the dynamometer against the deflection in divisions of the microscope, such a slope will be expressed in pounds per division and may be regarded as a stiffness coefficient of the dynamometer.

(Procedure, cont'd) -

If the loads on the dynamometer are divided by the corresponding microscope deflections, each quotient so obtained is a possible value of the slope. Calculated values of the stiffness coefficient, found in this way, are plotted against the dynamometer deflection in Figure 5. It will be seen that there is a pronounced scatter, especially for lower values of the deflection where absolute error of the reading of the dynamometer microscope caused increasing relative errors for smaller deflections. Therefore, in determining the average value of the stiffness coefficient, only those values determined from a microscope deflection greater than 30 divisions were used. This figure was fixed because, the absolute error of the readings being ±0.25 division, if the readings are accurate to 0.5 division the deflections are known to one per cent or better. A mean of the remaining results was taken as the stiffness coefficient of the dynamometer. This was done because the dynamometer was known to have elastic hysteresis and, although no straight line can accurately represent its behaviour, it was desired to find which line would most closely do so along its entire length. This method gave a value of 335 pounds per division for the stiffness coefficient of the dynamometer. This could also be expressed in terms of the compliance, the reciprocal of the stiffness which is thus approximately 3 divisions per 1,000 pounds load.

A calibration up to 22.5 tons was performed by dismounting the dynamometer and placing it in a 50,000 Baldwin-Southwark Universal testing machine at the National Research Council laboratories, Ottawa.[*] The results obtained

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[*] The calibration of the dismounted loop dynamometer in the 50,000 lb. Southwark testing machine was performed jointly by Mr. R. H. Field and Dr. Turnbull, of the National Research Council; Mr. R. C. A. Thurston, of N.P.L.; and Mr. H. L. Lexier, of F.M.R.L.

(Procedure, cont'd) -

there are in substantial agreement with those given in this report.

Figure 3 shows the complete observations, and Figure 6 the difference curves plotted after calculating the stiffness coefficient as stated above. Figure 4 shows the end results without individual observation. It will be noted from the difference curve B that the microscope deflection can be calculated within one-half division for any given load. We feel that much more accurate readings cannot be consistently maintained. The curve A in Figure 6 shows that the error in a load calculation from a microscope reading will not be greater than ±120 pounds.

It is therefore considered that the stiffness coefficient of the Avery-Schenck machine dynamometer has been proved to be 335 pounds per division and that loads calculated on this basis from microscope deflections will not be in error by more than ±120 pounds.

Accuracy of the Calibration:

For the present purpose, the Research on Optimum A.B.C. Thread Form, it is desirable that one should be able to accurately place a given load on the dynamometer by stressing the springs. To evaluate the error incurred in using the straight line of Figures 3 and 4, the loads shown in Figure 6, were substracted from the loads which would have been calculated using the straight line. The results are plotted in Curve A, Figure 6. This curve shows that the error will not be greater than ±120 pounds at any load. To determine the relative error at different values of loading introduced by use of the straight line, this absolute error was divided by the load that would have been calculated by the straight-line basis. These relative errors, expressed as percentages, are

(Accuracy of the Calibration, cont'd) -

given in curve C, Figure 6.

CONCLUSION:

In the static calibration of the P.M.R.L.'s Avery-Schenck machine, a stiffness coefficient of 335 pounds per division deflection of the loop dynamometer has been determined.

By assuming for the dynamometer a stiffness coefficient of 335 pounds per division deflection, any desired load between zero and 24,000 pounds may be applied to a specimen, with an error range as shown in Figure 6(a,b,c).

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TWW:JW:LB.

(Figures 3 to 7 follow,)
(on Pages 11 to 15.)

(A tabulation appendix is)
(attached, comprising)
(Pages 16 to 19 inclusive.)

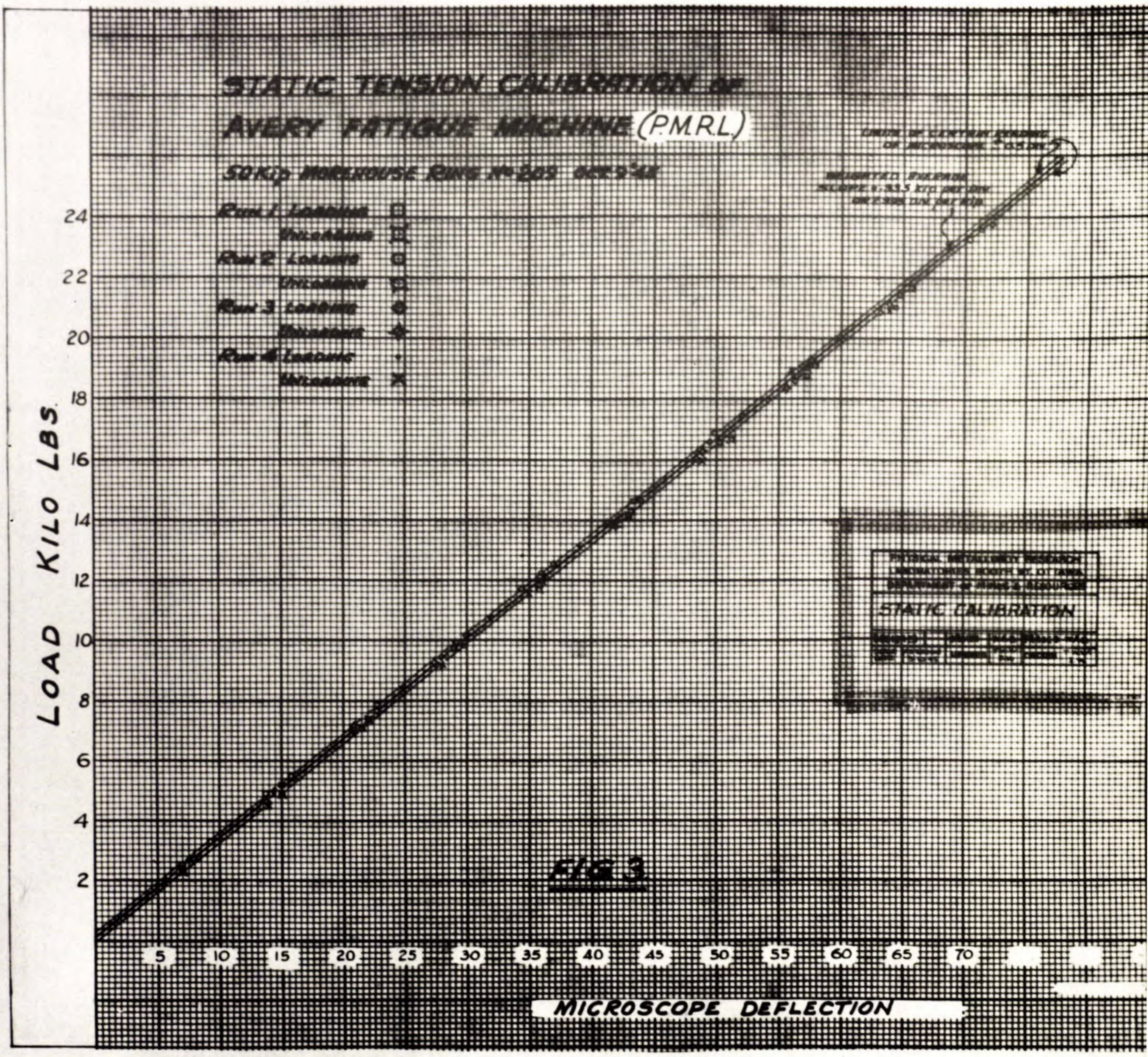

STATIC TENSION CALIBRATION OF
AVERY FATIGUE MACHINE (P.M.R.L.)
50 Kip MOREHOUSE RING No 203 OCT 9'42
Run 1 Loading □
Unloading ⊡
Run 2 Loading
Unloading
Run 3 Loading ◆
Unloading ✦
Run 4 Loading ·
Unloading ×
LOAD KILO LBS
2
4
6
8
10
12
14
16
18
20
22
24
5
10
15
20
25
30
35
40
45
50
55
60
65
70
MICROSCOPE DEFLECTION
PHYSICAL METALLURGY RESEARCH
STATIC CALIBRATION

FIG 3

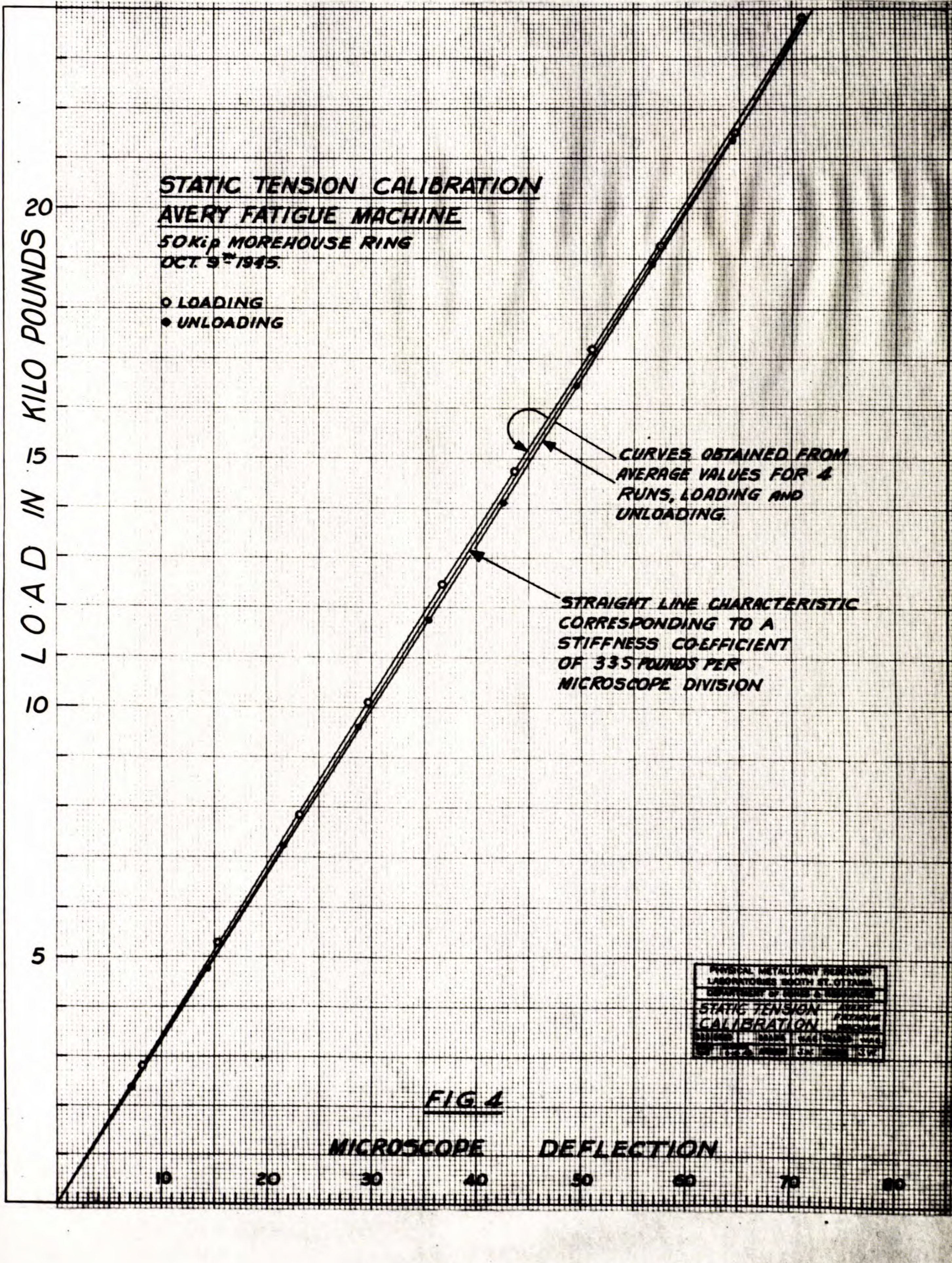

STATIC TENSION CALIBRATION
AVERY FATIGUE MACHINE
50Kip MOREHOUSE RING
OCT. 9th 1945.
○ LOADING
● UNLOADING
CURVES OBTAINED FROM AVERAGE VALUES FOR 4 RUNS, LOADING AND UNLOADING.
STRAIGHT LINE CHARACTERISTIC CORRESPONDING TO A STIFFNESS CO-EFFICIENT OF 335 POUNDS PER MICROSCOPE DIVISION
LOAD IN KILO POUNDS
5
10
15
20
MICROSCOPE DEFLECTION
10
20
30
40
50
60
70
80
PHYSICAL METALLURGY RESEARCH LABORATORIES BOOTH ST. OTTAWA
STATIC TENSION CALIBRATION

FIG 4

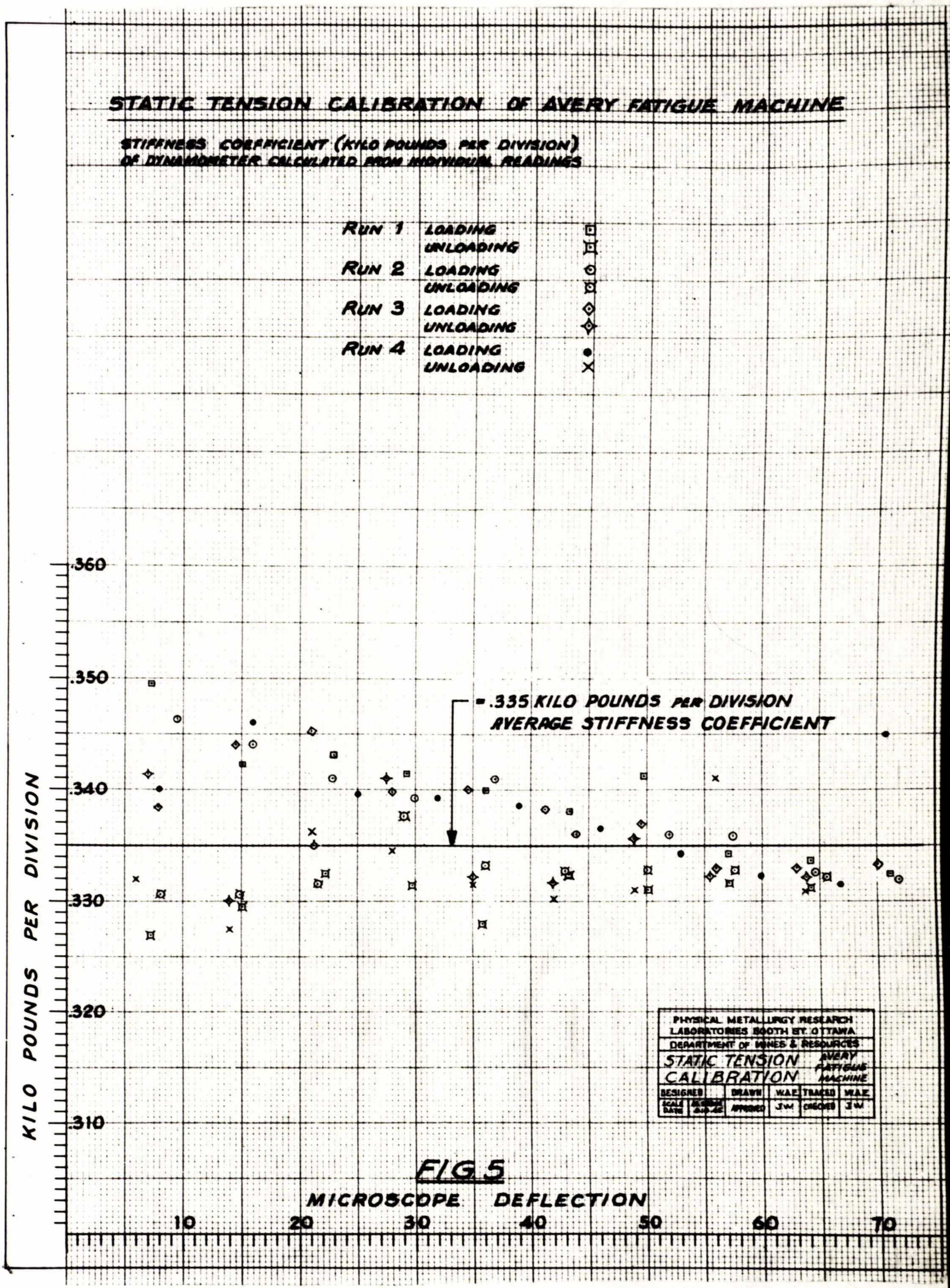

STATIC TENSION CALIBRATION OF AVERY FATIGUE MACHINE
STIFFNESS COEFFICIENT (KILO POUNDS PER DIVISION) OF DYNAMOMETER CALCULATED FROM INDIVIDUAL READINGS
RUN 1 LOADING ⊡
UNLOADING
RUN 2 LOADING ⊙
UNLOADING
RUN 3 LOADING ◇
UNLOADING
RUN 4 LOADING ●
UNLOADING ×
= .335 KILO POUNDS PER DIVISION AVERAGE STIFFNESS COEFFICIENT
.360
.350
.340
.330
.320
.310
KILO POUNDS PER DIVISION
10
20
30
40
50
60
70
MICROSCOPE DEFLECTION
PHYSICAL METALLURGY RESEARCH LABORATORIES BOOTH ST. OTTAWA
DEPARTMENT OF MINES & RESOURCES
STATIC TENSION CALIBRATION
AVERY FATIGUE MACHINE
DESIGNED
DRAWN
W.A.F.
TRACED
W.A.F.
SCALE DATE
APPROVED
J.W.
CHECKED
J.W.

FIG 5

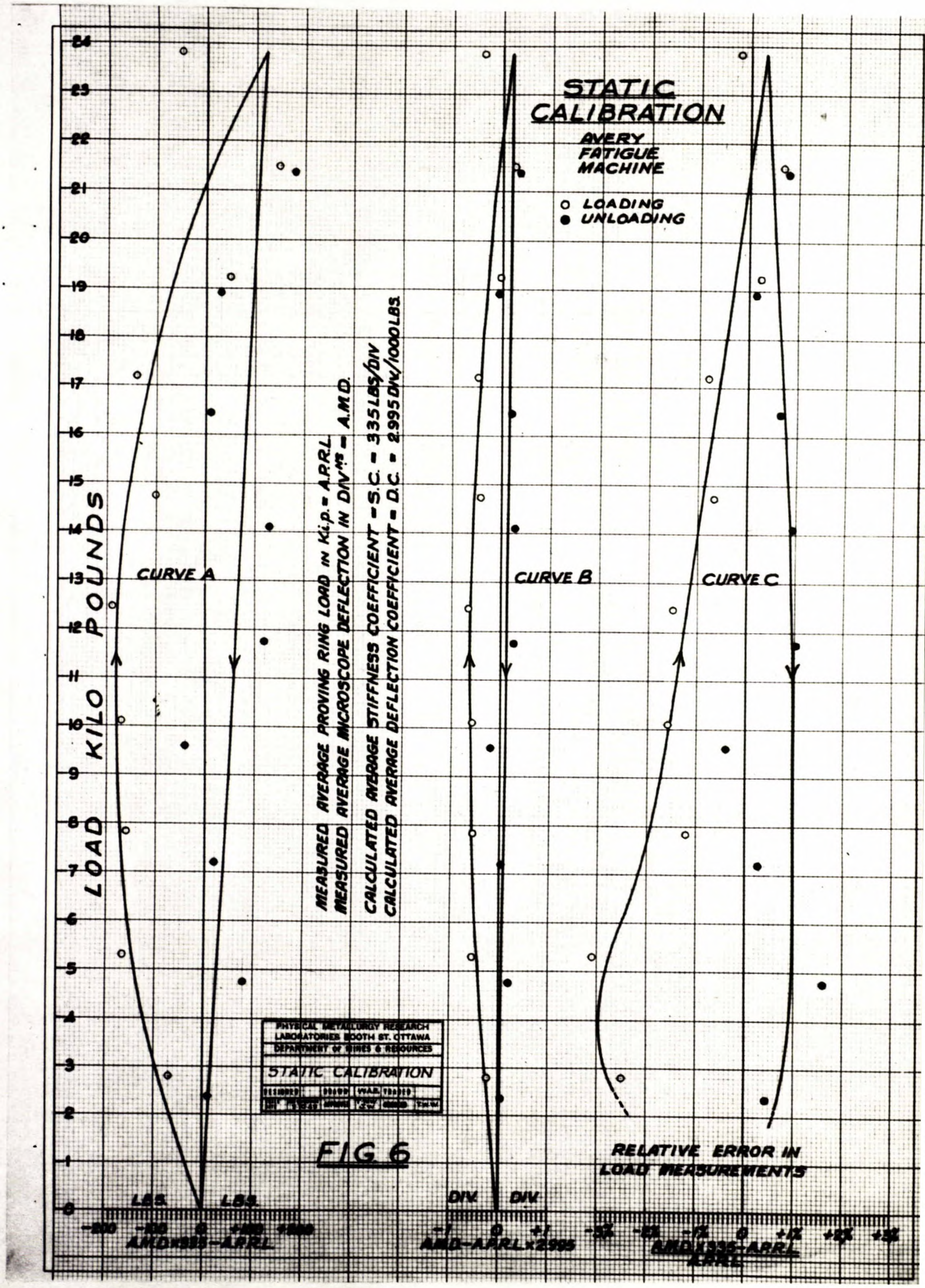
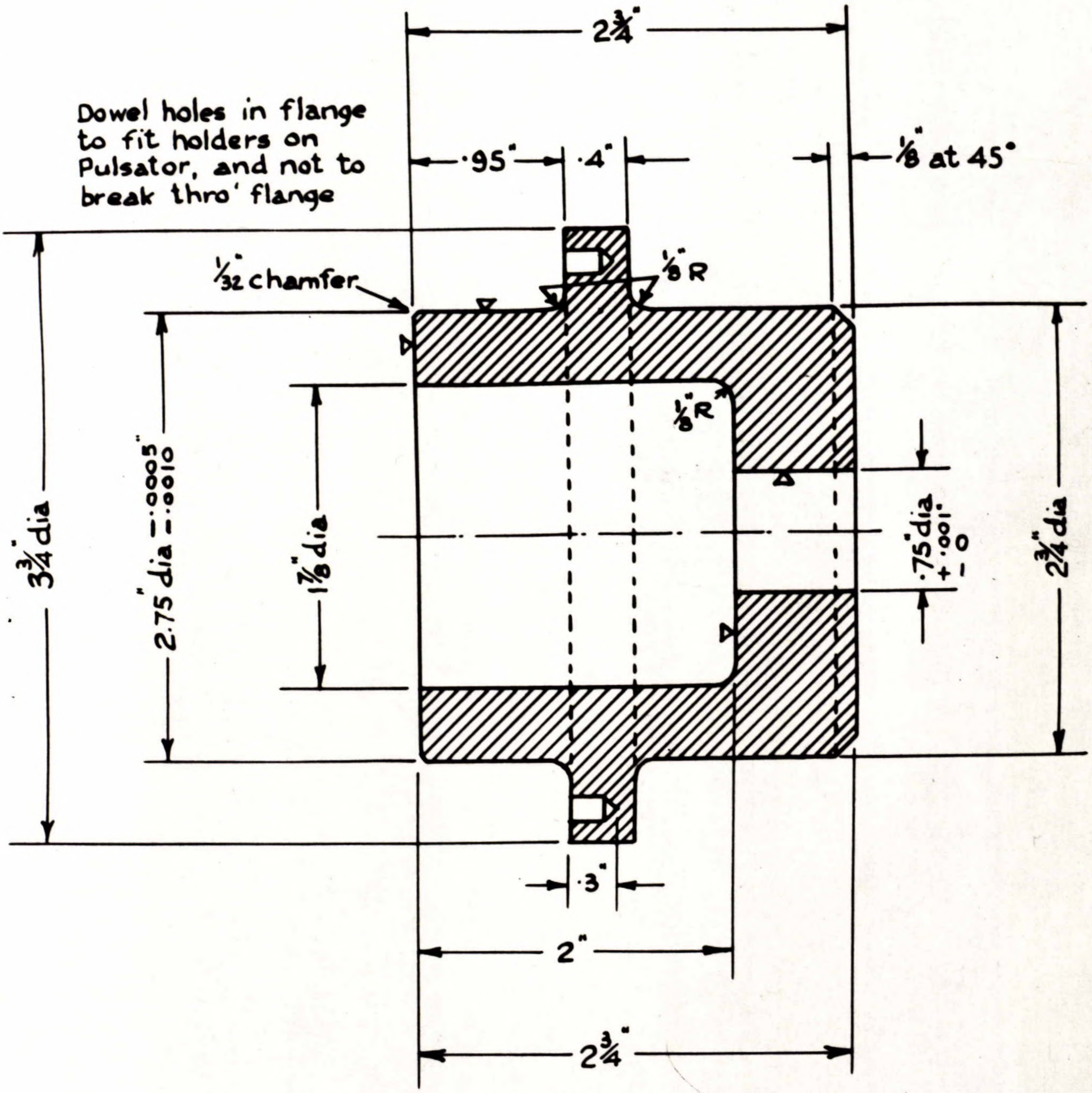

STATIC CALIBRATION
AVERY FATIGUE MACHINE
○ LOADING
● UNLOADING
LOAD KILO POUNDS
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
CURVE A
CURVE B
CURVE C
MEASURED AVERAGE PROVING RING LOAD IN Ki.p. = A.P.R.L.
MEASURED AVERAGE MICROSCOPE DEFLECTION IN DIV'S = A.M.D.
CALCULATED AVERAGE STIFFNESS COEFFICIENT = S.C. = 335 LBS/DIV
CALCULATED AVERAGE DEFLECTION COEFFICIENT = D.C. = 2.995 DIV/1000 LBS.
PHYSICAL METALLURGY RESEARCH LABORATORIES BOOTH ST. OTTAWA
DEPARTMENT OF MINES & RESOURCES
STATIC CALIBRATION
DESIGNED
DRAWN
W.A.F.
TRACED
RELATIVE ERROR IN LOAD MEASUREMENTS
LBS.
LBS.
-200
-100
0
+100
+200
AMD×335−APRL
DIV.
DIV.
-1
0
+1
AMD−APRL×2995
-3%
-2%
-1%
0
+1%
+2%
+3%
AMD×335−APRL / APRL

FIG 6



Dowel holes in flange to fit holders on Pulsator, and not to break thro' flange

Faces marked △ must be square and concentric

Two Off – Ni. Cr Steel

FIG. 7.

Dimensions are in accordance with Dwg. Nº B 103/1, National Physical Laboratories, Eng. Divⁿ

PHYSICAL METALLURGY RESEARCH LABORATORIES BOOTH ST. OTTAWA
DEPARTMENT OF MINES & RESOURCES
ADAPTOR FOR STUDS
AVERY PULSATOR FATIGUE M/C
DESIGNED M.J.C DRAWN M.J.C TRACED W.A.E.
SCALE FULL SIZE
DATE 18·12·45 APPROVED CHECKED

TABULATION APPENDIX

TABLE I. - Results of Calibration

Load, in pounds	Microscope deflection, divisions	Stiffness Coeff., kips per division	Load, in pounds	Microscope deflection, divisions	Stiffness Coeff., kips per division
CALIBRATION RUN NO. 1 -			CALIBRATION RUN NO. 2 -		
2,800	7.3	0.34931	2,800	9.5	0.34631
5,290	15.1	.34238	5,290	15.9	.34402
7,830	22.85	.34310	7,830	22.85	.34091
10,110	29.2	.34143	10,110	30.0	.33966
12.460	36.15	.34000	12,460	36.95	.34073
14,720	43.45	.33808	14,720	43.95	.33606
17,190	49.75	.34130	17,190	51.95	.33589
19,240	57.1	.33432	19,240	57.5	.33547
21,500	64.2	.33367	21,500	64.55	.33292
23,830	71.15	.33253	23,830	71.95	.33148
21,370	64.25	.33136	21,370	65.55	.33211
18,910	57.1	.33169	18,910	57.7	.33275
16,450	50.15	.33100	16,450	50.1	.33233
14,100	43.2	.33240	14,100	43.0	.33279
11,750	35.8	.32793	11,750	36.15	.33333
9,600	29.75	.33142	9,600	29.0	.33758
7,190	22.25	.33258	7,190	21.6	.33148
4,760	15.05	.32956	4,760	14.85	.33063
2,360	7.25	.32689	2,360	8.15	.33128
Average Stiffness Coefficient, kips per division:					
The whole range -		0.33531			0.33567
Range over 30 divisions microscope deflection -		.33439			.33485
CALIBRATION RUN NO. 3 -			CALIBRATION RUN NO. 4 -		
2,800	7.8	0.33846	2,800	8.0	0.34000
5,290	14.5	.34413	5,290	16.0	.34625
7,830	21.0	.34523	7,830	24.9	.33935
10,110	27.9	.33978	10,110	31.85	.33908
12,460	34.55	.34066	12,460	39.0	.33846
14,720	41.3	.33874	14,720	45.9	.33660
17,190	49.5	.33656	17,190	52.9	.33421
19,240	56.1	.33297	19,240	59.9	.33238
21,500	63.0	.33285	21,500	66.85	.33103
23,830	70.15	.33328	23,830	70.8	.34533
21,370	63.8	.33228	21,370	63.85	.33124
18,910	55.5	.33243	18,910	55.9	.34078
16,450	48.8	.33586	16,450	48.9	.33087
14,100	41.85	.33166	14,100	42.0	.33023
11,750	35.0	.33228	11,750	35.0	.33142
9,600	27.5	.34109	9,600	28.0	.33464
7,190	21.25	.33505	7,190	21.15	.33617
4,760	13.9	.33093	4,760	14.0	.32714
2,360	7.0	.34146	2,360	6.0	.33200
Average Stiffness Coefficient, kips per division:					
The whole range -		0.33661			0.33564
Range over 30 divisions microscope deflection -		.33541			.33509

TABLE II. (Figure 6A)

Average Microscope Deflection (A.M.D.) for Runs 1 to 4, in divisions	A.M.D. x 335, pounds	Average Proving Ring Load (A.P.R.L.), pounds	A.M.D. x 335 minus A.P.R.L., pounds
8.15	2,730	2,800	-70
15.30	5,125	5,290	-165
22.90	7,670	7,830	-160
29.70	9,940	10,110	-170
36.65	12,275	12,460	-190
43.65	14,620	14,720	-100
51.00	17,050	17,190	-140
57.60	19,290	19,240	+50
64.65	21,650	21,500	+150
71.00	23,780	23,830	-50
64.35	21,550	21,370	+180
56.55	18,940	18,910	+30
49.45	16,560	16,450	+110
42.50	14,230	14,100	+130
35.45	11,870	11,750	+120
28.55	9,560	9,600	-40
21.55	7,210	7,190	+20
14.45	4,840	4,760	+80
7.10	2,370	2,360	+10

-

TABLE III. (Figure 6B)

Average Proving Ring Load (A.P.R.L.), pounds	A.P.R.L. x 2.995, divisions	Average Microscope Deflection (A.M.D.), divisions	A.M.D. minus A.P.R.L. x 2.995, in divisions
2,800	8.38	8.15	-0.23
5,290	15.84	15.30	-0.54
7,830	23.44	22.90	-0.54
10,110	30.27	29.70	-0.57
12,460	37.31	36.65	-0.66
14,720	44.08	43.65	-0.43
17,190	51.48	51.00	-0.48
19,240	57.62	57.60	-0.02
21,500	64.39	64.65	+0.26
23,830	71.37	71.00	-0.37
21,370	64.00	64.35	+0.35
18,910	56.63	56.55	-0.08
16,450	49.26	49.45	+0.19
14,100	42.22	42.50	+0.28
11,750	35.19	35.45	+0.26
9,600	28.75	28.55	-0.20
7,190	21.53	21.55	+0.02
4,760	14.25	14.45	+0.20
2,360	7.06	7.10	+0.04

TABLE IV. (Figure 6C)

Average Microscope Deflection (A.M.D.) for Runs 1 to 4, in divisions	A.M.D. x 335, pounds	Average Proving Ring Load (A.P.R.L.), in pounds	$\frac{\text{A.M.D. x 335} - \text{A.P.R.L.}}{\text{A.P.R.L.}} \times 100$, (Per cent)
8.15	2,730	2,800	-2.5
15.30	5,125	5,290	-3.1
22.90	7,670	7,830	-1.2
29.70	9,940	10,110	-1.6
36.65	12,270	12,460	-1.5
43.65	14,620	14,720	-0.67
51.00	17,050	17,190	-0.81
57.60	19,290	19,240	+0.25
64.65	21,650	21,500	+0.69
71.00	23,780	23,830	-0.20
64.35	21,550	21,370	+0.81
56.55	18,940	18,910	+0.15
49.45	16,560	16.450	+0.66
42.50	14,230	14,100	+0.92
35.45	11,870	11,750	+1.0
28.55	9,560	9,600	-0.41
21.55	7,210	7,190	+0.27
14.45	4,840	4,760	+1.6
7.10	2,370	2,360	+0.42

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Ottawa, Canada,
February, 1946.
TWW:JW:PES.