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OTTAWA March 16, 1946.

REPORT

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 2014.

(Subsequent to Investigation Reports)
(Nos. 1991 and 2002, Jan.-Feb., 1946.)

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

PART III. - Investigation of Axiality of Loading of a Short Threaded Specimen Loaded in Type I Adaptors of a 20-Ton Avery-Schenck Pulsator.

(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. 2014.)

Abstract

In order to determine whether the load imposed on a screw-thread specimen by Type I Adaptors (shown in Figure 2) in the Avery-Schenck fatigue testing machine is axial, four resistance wire SR-4 strain gauges, type A-7, were placed on the middle of a $\frac{5}{4}$-inch stud which was then placed in the adaptors and loaded.

During loading and unloading, readings were taken on each gauge with a Baldwin SR-4 strain indicator.

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

CANADA
DEPARTMENT
OF
MINES AND RESOURCES
Mines and Geology Branch

OTTAWA March 16, 1946.

R E P O R T

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Origin and Purpose of Investigation:

Axiality of loading has always been a problem with direct-loading fatigue machines and is important in the screw thread specimens used for the Research on Optimum Thread Form. The appearance of previously broken stud* (see Figure 3) indicates, by the portion of areas discoloured by frettage corrosion, that the specimens were subject to other than purely axial loading.

It was therefore decided to investigate, on the P. M. R. L. pulsator, how far the loading departs from axiality.

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* The threaded stud was made in accordance with N.P.L. Drwg. C103/202 (see Figure 1).

Procedure:

A stud for use as a screw thread specimen, made from high tensile steel and of thread form No. 3 (see Figure 1), was employed in this investigation together with cylindrical nuts of the same thread form. Both stud and nuts were supplied by the National Physical Laboratory.

The specimen used had a ground thread.

Four SR-4 strain gauges, type A-7, were attached to the stud. The manner of attaching terminal strips and rings to protect the gauges while placing the specimen in the machine is shown in Figure 4.

After placing the specimen in the machine, load was applied in steps of about 3,000 pounds until a load of about 15,000 pounds was reached, the loads being measured by simultaneously taken readings on two previously calibrated A-3 gauges placed on both sides of the loop dynamometer. This contributed little to accuracy but reduced time incurred in moving around to read the microscope at each observation. A SR-4 20-point switching unit was used to transfer the SR-4 strain indicator from gauge to gauge. The results obtained in this way, using Type I adaptors, are shown in Figure 5 in the form of a graph, and in Table I below:

TABLE I.

Reading No.	Load, in pounds	Strain, in micro in./in. Gauge No. 1	Gauge No. 2	Gauge No. 3	Gauge No. 4
1	310.5	27	5	21	-47
2	966.0	43	78	108	11
3	1,484	62	248	178	12
4	2,210	97	316	248	56
5	2,900	142	353	303	118
6	3,590	192	381	360	187
7	4,280	240	410	408	250
8	4,970	293	444	462	318
9	7,420	397	509	562	443
10	7,870	490	577	668	570
11	9,150	572	637	755	677
12	10,310	674	706	850	798
13	12,150	783	781	954	922
14	13,260	871	835	1035	1025
15	14,720	970	897	1115	1140

(Procedure, cont'd) -

During the discussion of preliminary results of such tests, at the time of the Conference on Unification of Engineering Standards in Ottawa in September of 1945, it was suggested that the specimen be rotated in the grips and readings be taken with the specimen in various positions. This was to take account of the fact that a screw is not a perfectly symmetrical part and that inequalities of strain distribution might arise as a result of the relative positions of the ends of the screw threads and the positions of the gauges. Briefly, the purpose was to determine if the previously obtained results are dependent on the machine, adaptors, or on the specimen.

For this purpose, zero load readings were taken on the gauges and readings at 10 tons load were taken in four different positions of the specimen rotated in Type I adaptors*. Finally, the machine was run at a load range about 25 per cent less than the safe range of a stud, to see whether the inequalities of the readings would disappear. No such effect was observed.

Discussion of Results:

Inequality of the strains measured on the gauges placed opposite each other on the stud is equivalent to the presence of a bending moment about an axis perpendicular to a horizontal plane passing through the centroids of the two gauges. This bending moment is directly proportional to the difference in strains measured on two opposite gauges. Thus

$$|M_s| = |e_s| K$$

where e_s is the inequality of strains on the surface

---

* Type I adaptors were made in accordance with National Physical Laboratory Drwg. B103 (see Figure 2, in which these adaptors are shown with cylindrical spacer applied at P.M.R.L. to keep the stud in centre position).

(Discussion of Results, cont'd) -

at two opposite points on stud diameter and K is a constant which need not be determined.

$$\left| M_{1-3} \right| = \left| e_{1-3} \right| K \qquad \left| M_{2-4} \right| = \left| e_{2-4} \right| K$$

Here e_{1-3} and e_{2-4} is the difference between the strain indicator deflections for Gauges 1 and 3 and Gauges 2 and 4 respectively.

Define bending moment as M.

$$\left| M \right| = \sqrt{M^2_{1-3} + M^2_{2-4}}$$

also

when θ is the angle measured from the horizontal plane of Gauges 1 and 3.

$$\sin \theta = \frac{M_{1-3}}{\sqrt{M_{1-3}^2 + M_{2-4}^2}} = \frac{e_{1-3}}{\sqrt{e_{1-3} + e_{2-4}}}$$

$$e = \sqrt{e^2_{1-3} + e^2_{2-4}}$$

Let e be the maximum difference in strain on opposite sides of the specimen. In Figure 6 the values of e_{1-3} and e_{2-4} may be read directly. The curve for Gauges 1 and 3 gives e_{1-3} (deflection of Gauge 1 - deflection of Gauge 2) and the curve for Gauges 2 and 4 gives e_{2-4} (deflection of Gauge 2 - deflection of Gauge 4). See also Table II, on Page 10.

Considering Figure 7, it can be seen that for a load of about about 15,000 (e.g., 14,720) pounds on a $\frac{3}{4}$ threaded stud specimen, the maximum difference of unit strain between two points on opposite ends of a diameter was 282 micro inches per inch. Assuming an elastic modulus of 30×10^6 pounds per square inch, this corresponds to a variation of unit load of 8,500 p.s.i. The area of the specimen is 0.442 square inch. At 15,000 pounds load, the average unit tension was 34,000 p.s.i. The magnitude of stress over the specimen varied $\pm \frac{.8500}{34000} \times 100$, (Discussion of Results, and Conclusions, cont'd) -

or

or 25.0 per cent, from the average.

Loading the specimen in various positions shows no systematic variation that can be attributed solely to assymmetry of the screw thread specimen.

The question as to the cause of the asymmetrical loading when using the Type I adaptors must be considered. Such asymmetry could arise from either of the following: misalignment of the beam and dynamometer of the machine, or non-parallelism of the bearing surfaces of the nuts. The Type I adaptors were inspected by the metrology section of the National Research Council, Ottawa, for parallelism of the three plane faces marked A, B and C in Figure 2. The results of this inspection are as follows:

Faces Checked	Error in Parallelism	Adaptor
A - C	3.5'	M
B - C	0.3'	M
A - C	2.3'	B
B - C	0.4'	B

The adaptors were inspected by placing face C on a surface plate and running a dial indicator mounted on a suitable block around the other faces. With both adaptors it was found that minimum readings on face A corresponded with minima for face B, so that the error between these two faces is the difference between the other errors. Thus, if the machine is adjusted by placing shims where needed till the faces C when the adaptors are placed in the machine are parallel, the faces B will be out of parallel by not more than 5.1 minutes.

The specimen used in these tests was similarly inspected. This was not done before attaching the strain gauges, and the latter made it impossible to use an inside

(Discussion of Results, and Conclusions, cont'd) -

micrometer. Therefore the nuts were placed a suitable distance apart, and the distance between their bearing surfaces was measured as near as possible to the four gauges by use of an internal caliper and an outside micrometer. These readings indicate that these faces were out of parallel by not more than 1 minute, although it must be recognized that the precision possible by this method is not all one could wish.

The parallelism of the machine was checked as previously described by placing the adaptors in the grips, tightening them in with the nuts provided, and measuring the distance between the faces at four equal-spaced points on the edges of the faces C with an internal micrometer. Such readings taken between the tests with Type I adaptors were out of parallel by not more than 20 seconds of arc. Similarly, the working plane surfaces of the nuts on the strain gauge specimen unstressed were not out of parallel by more than 20 seconds. It may, therefore, be assumed that when the specimen was tensed, the bearing surfaces of the nuts would not be rotated more than 40 seconds of arc from their direction when the machine was unstressed. The maximum fibre stress on a $\frac{3}{4}$-inch cylinder bent uniformly 40 seconds of arc over a length of $2\frac{1}{2}$ inches will be about 1,740 pounds. The observed values are much higher than this. Such values might be explained by asymmetrical yielding of parts of the machine when it is loaded. However, this has not been checked, because the adaptors are too close together to admit an inside micrometer when the specimen is in place.

Conclusion:

The tests described herein show that it was not possible to secure purely axial loading, or an acceptable approximation of it, in the 20-ton Avery-Schenck push-pull fatigue testing machine of the Physical Metallurgy Research Laboratories, Ottawa, when using Type I adaptors.

The resultant bending effect as obtained on the fatigue machine used for this investigation is shown in Figure 7. It varied in magnitude and position through the whole range of loading, reaching the maximum at 2,210 pounds of load in a plane placed about 29 degrees as measured from the horizontal position in the direction marked in Figure 7.

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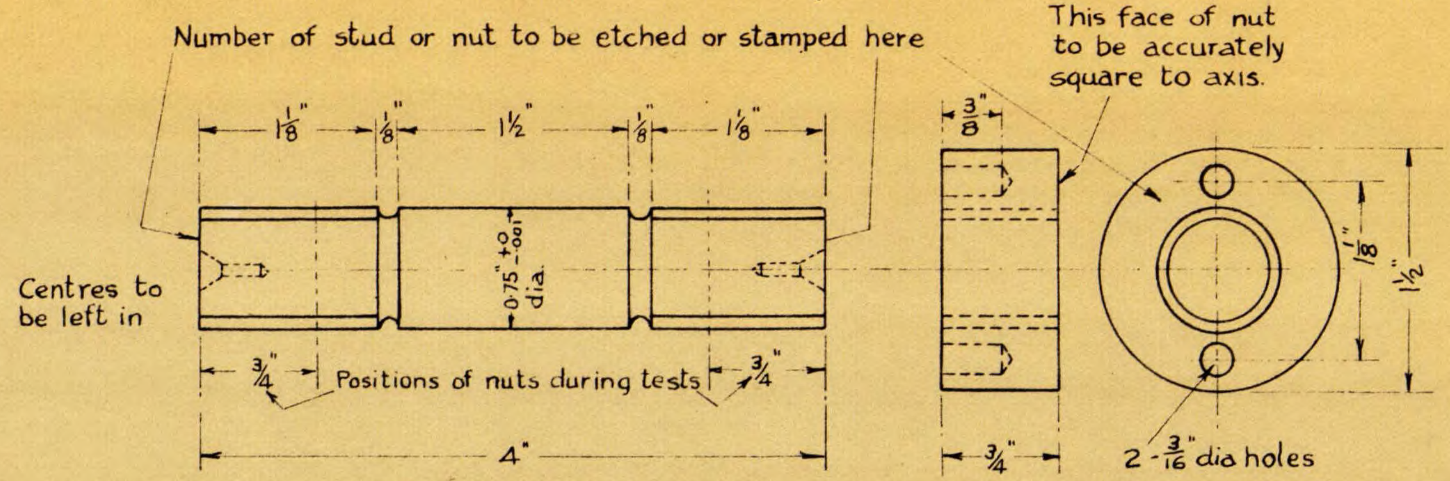
oooo
oo

TWW:JW:PES.

(Figures 1 to 7 follow,)
(on Pages 8 to 13.)

(Table II appears on)
(Page 10.)

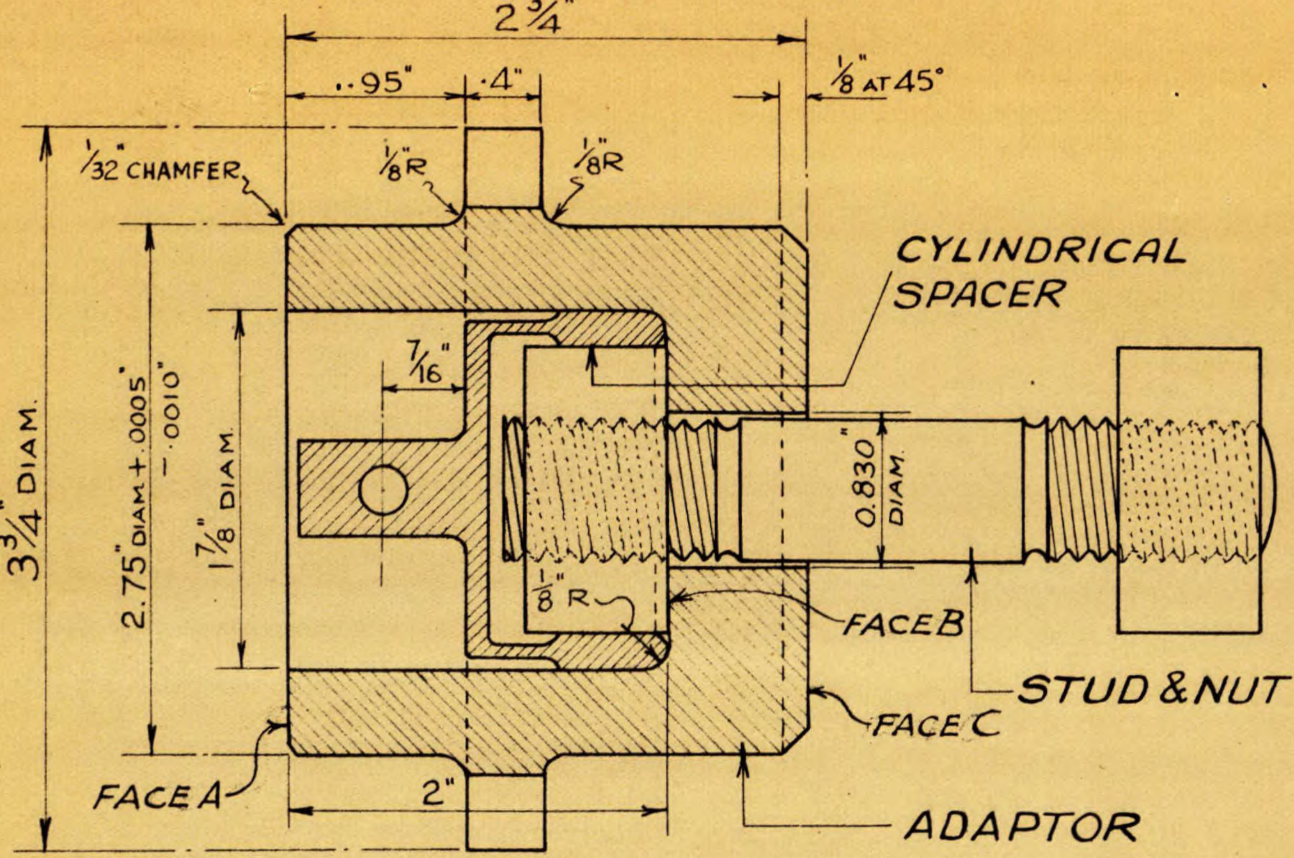


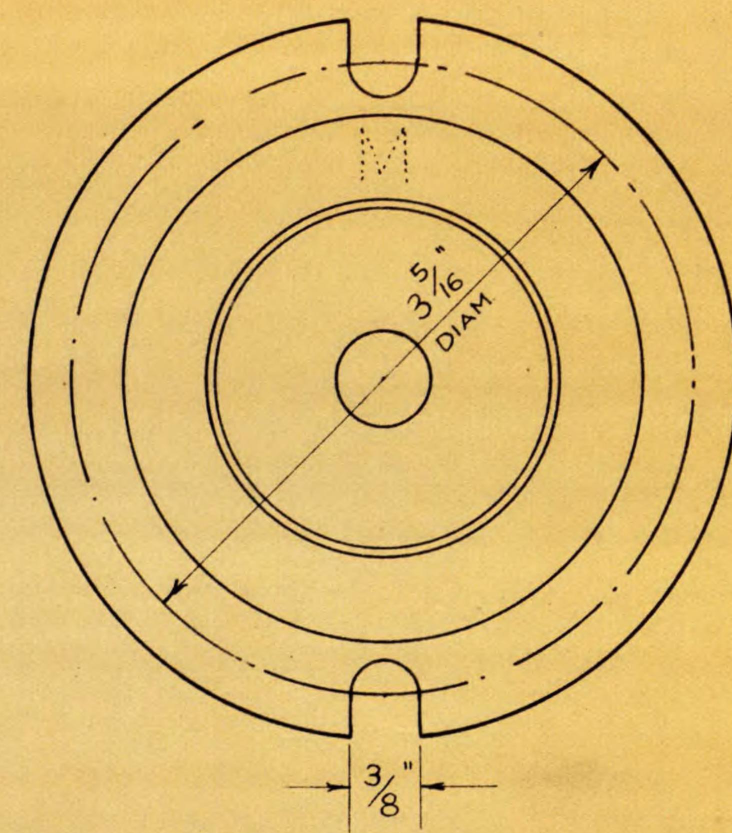
NUMBER OF THREAD FORM		1	2	3	4	5
INCLUDED ANGLE	DEG.	45	50	55	60	65
PITCH	IN.	0.1000	0.1000	0.1000	0.1000	0.1000
ROOT RADIUS	IN.	0.0163	0.0152	0.0141	0.0129	0.0115
STUD MAJOR DIAMETER	IN	0.7411	0.7386	0.7362	0.7339	0.7317
STUD EFFECTIVE DIAMETER	IN	0.6931	0.6906	0.6882	0.6859	0.6837
STUD MINOR DIAMETER	IN	0.6250	0.6250	0.6250	0.6250	0.6250
NUT MAJOR DIAMETER	IN	0.7612	0.7562	0.7514	0.7468	0.7424
NUT EFFECTIVE DIAMETER	IN	0.6931	0.6906	0.6882	0.6859	0.6837
NUT MINOR DIAMETER	IN	0.6451	0.6426	0.6402	0.6379	0.6357

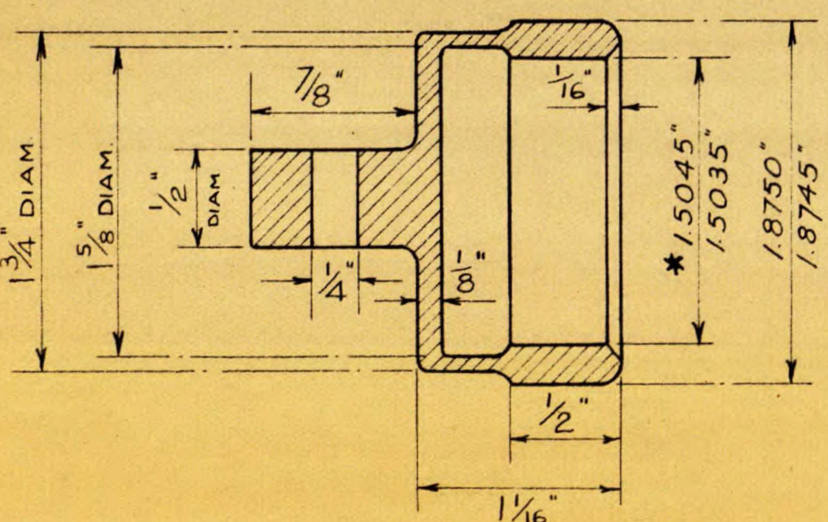
THESE PARTICULARS ARE IN ACCORDANCE WITH DWG. # C103/202. NATIONAL PHYSICAL LABORATORIES ENG. DIVISION. (GREAT BRITAIN).

FIG. I.

PHYSICAL METALLURGY RESEARCH LABORATORIES BOOTH ST OTTAWA		
DEPARTMENT OF MINES & RESOURCES		
STUD & NUT FOR FATIGUE TEST		
DESIGNED N.P.L.	DRAWN W.A.E.	TRACED W.A.E.
SCALE: NONE DATE: 3·11·45	APPROVED	CHECKED







ADAPTOR - TYPE I. (N.P.L. DWG. No B103/1)
MADE FROM STEEL S.A.E. 4340.
QUENCHED 1500°F IN OIL. DRAWN 700°F
ROCKWELL C50. 2 REQUIRED, 1 MARKED
B (BEAM SIDE) & 1 MARKED M (MICROSCOPE SIDE)
CYLINDRICAL SPACER IS MADE FROM
STEEL S.A.E. 1060 OR EQUIVALENT.

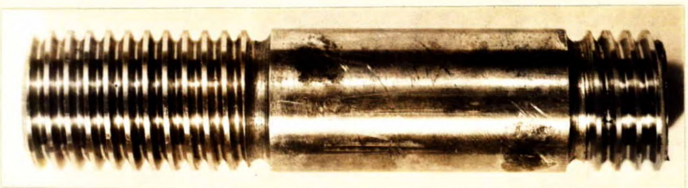
* TO SUIT DIMENSIONS OF NUT

FIG. 2

PHYSICAL METALLURGY RESEARCH LABORATORIES BOOTH ST OTTAWA
DEPARTMENT OF MINES & RESOURCES
ASSEMBLY OF ADAPTOR ETC. AVERY PULSATOR

DESIGNED T.W.W. J.W.	DRAWN W.A.E.	TRACED W.A.E.
SCALE FULL DATE 5.11.45	APPROVED	CHECKED T.W.W.

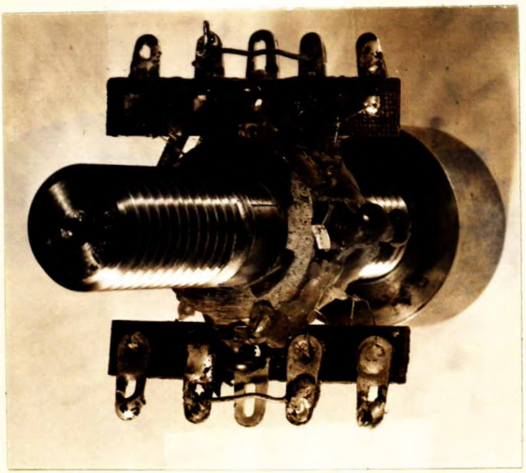
Figure 3.



BROKEN STUD WITH AREAS DISCOLOURED BY FRETTAGE CORROSION.

-

Figure 4.



STUD WITH SR-4 GAUGES AND TERMINALS AS USED TO MEASURE THE AXIALITY OF LOADING.

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TABLE II.

Reading No.	Load, in pounds	Strain, in micro inches per inch: e_{1-3} Gauge 1, active; Gauge 3, compensating	Strain, in micro inches per inch: e_{2-4} Gauge 2, active; Gauge 4, compensating	$e = \sqrt{e^2_{1-3} + e^2_{2-4}}$	Approx. value of θ, in degrees, measured from 1-3 plane
1	310.5	-10	138	138	94
2	966.0	-57	166	175.6	19
3	1,484	-110	241	265	24.5
4	2,210	-144	256	294	29
5	2,900	-152	228	276	33
6	3,590	-160	188	247	40
7	4,280	-160	156	223	45
8	4,970	-161	120	200	54
9	7,420	-164	63	176	69
10	7,870	-164	6	164	90
11	9,150	-174	-44	179	346
12	10,310	-170	-92	193	332
13	12,150	-160	-147	217	317.5
14	13,260	-154	-191	265	303.5
15	14,720	-145	-243	283	301

-

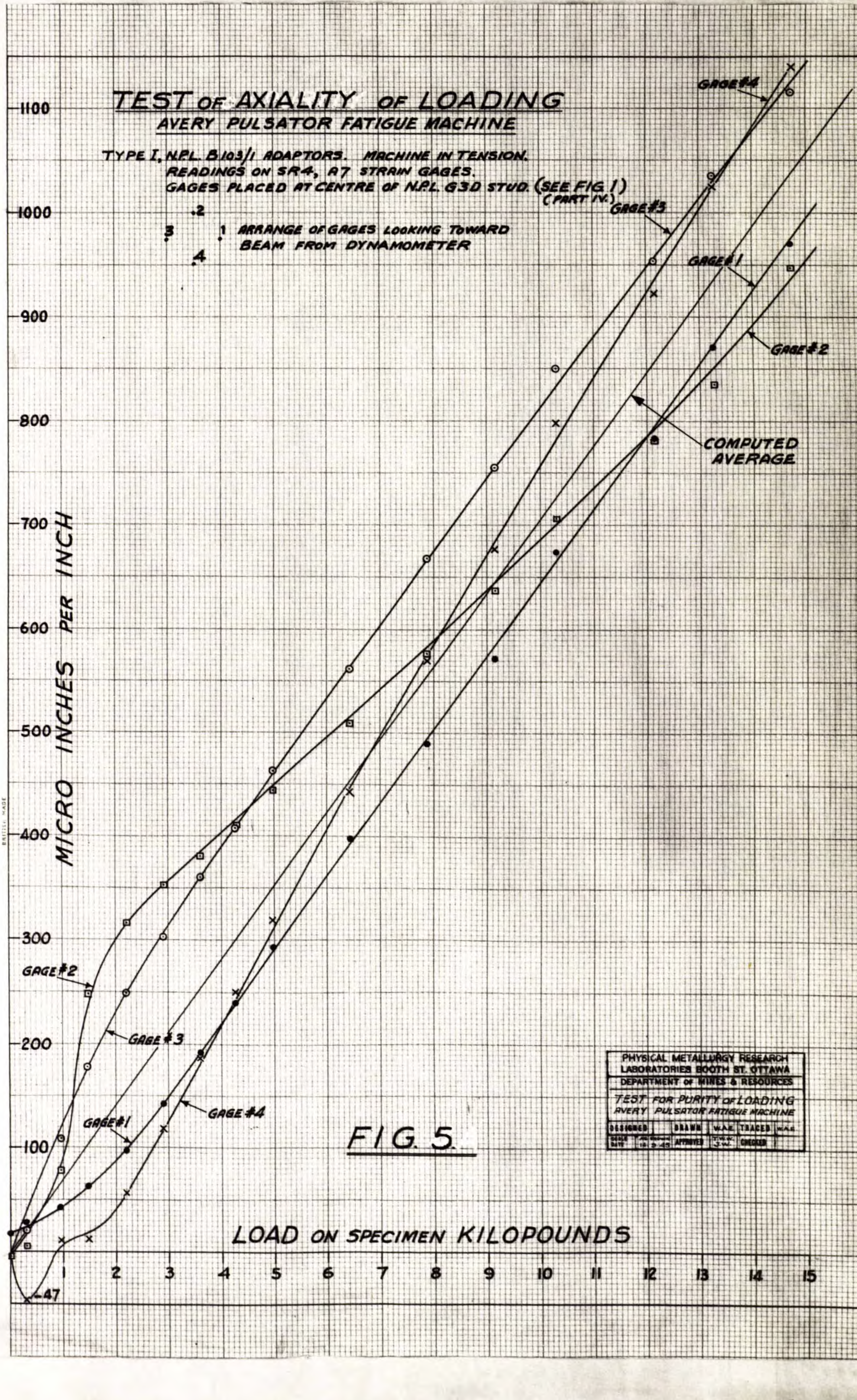
TEST OF AXIALITY OF LOADING
AVERY PULSATOR FATIGUE MACHINE
TYPE I, N.P.L. B103/1 ADAPTORS. MACHINE IN TENSION.
READINGS ON SR4, A7 STRAIN GAGES.
GAGES PLACED AT CENTRE OF N.P.L. G3D STUD. (SEE FIG. 1) (PART IV.)
1 ARRANGE OF GAGES LOOKING TOWARD BEAM FROM DYNAMOMETER
2
3
4
GAGE #4
GAGE #3
GAGE #1
GAGE #2
COMPUTED AVERAGE
MICRO INCHES PER INCH
LOAD ON SPECIMEN KILOPOUNDS
-47
PHYSICAL METALLURGY RESEARCH LABORATORIES BOOTH ST. OTTAWA
DEPARTMENT OF MINES & RESOURCES
TEST FOR PURITY OF LOADING AVERY PULSATOR FATIGUE MACHINE

FIG. 5

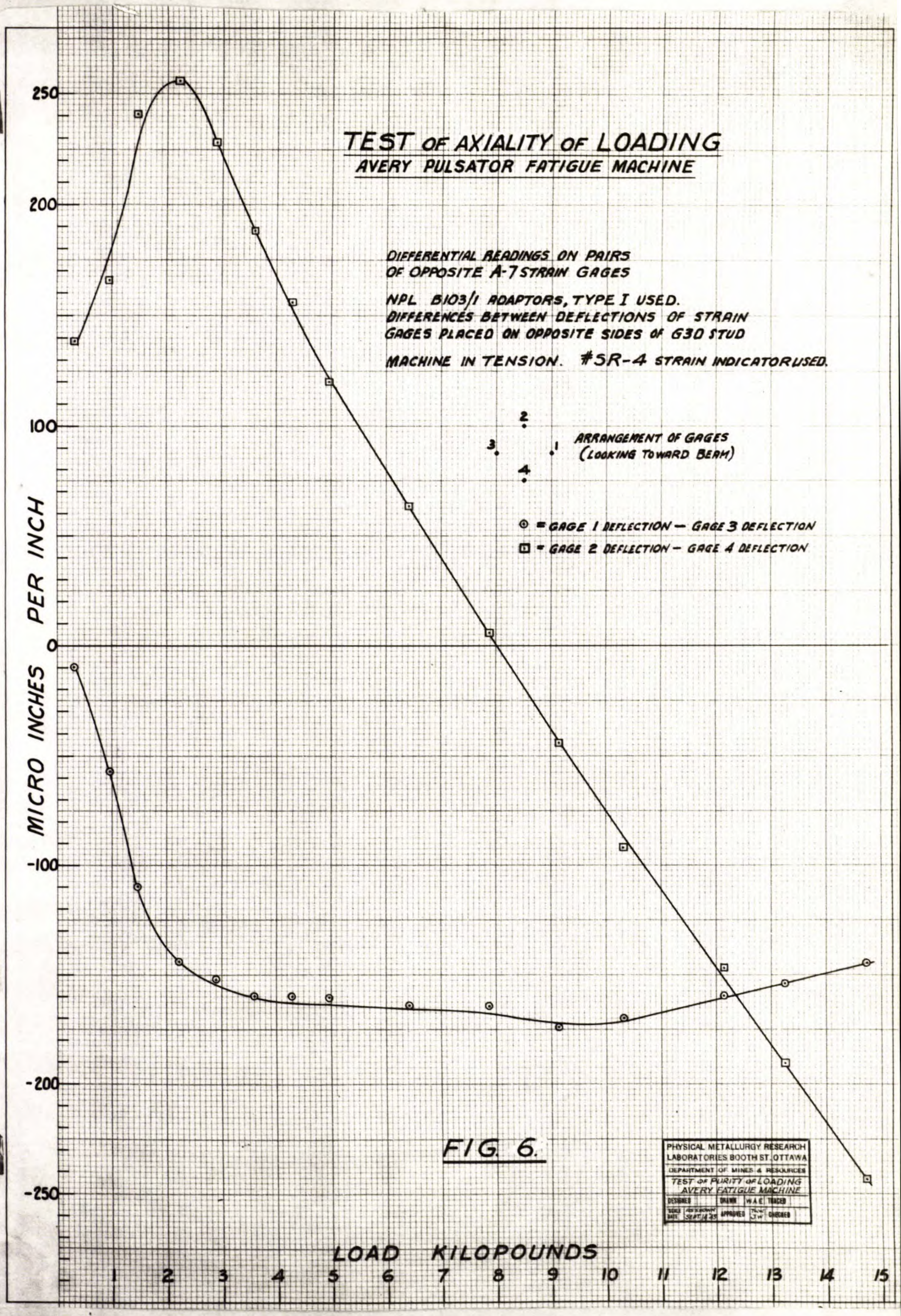
TEST OF AXIALITY OF LOADING
AVERY PULSATOR FATIGUE MACHINE
DIFFERENTIAL READINGS ON PAIRS
OF OPPOSITE A-7 STRAIN GAGES
NPL B103/I ADAPTORS, TYPE I USED.
DIFFERENCES BETWEEN DEFLECTIONS OF STRAIN
GAGES PLACED ON OPPOSITE SIDES OF G30 STUD
MACHINE IN TENSION. #SR-4 STRAIN INDICATOR USED.
ARRANGEMENT OF GAGES
(LOOKING TOWARD BEAM)
2
3
1
4
⊙ = GAGE 1 DEFLECTION — GAGE 3 DEFLECTION
⊡ = GAGE 2 DEFLECTION — GAGE 4 DEFLECTION
MICRO INCHES PER INCH
250
200
100
0
-100
-200
-250
LOAD KILOPOUNDS
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
PHYSICAL METALLURGY RESEARCH
LABORATORIES BOOTH ST. OTTAWA
DEPARTMENT OF MINES & RESOURCES
TEST OF PURITY OF LOADING
AVERY FATIGUE MACHINE
DESIGNED
DRAWN
W.A.E.
TRACED
APPROVED
CHECKED

FIG. 6.

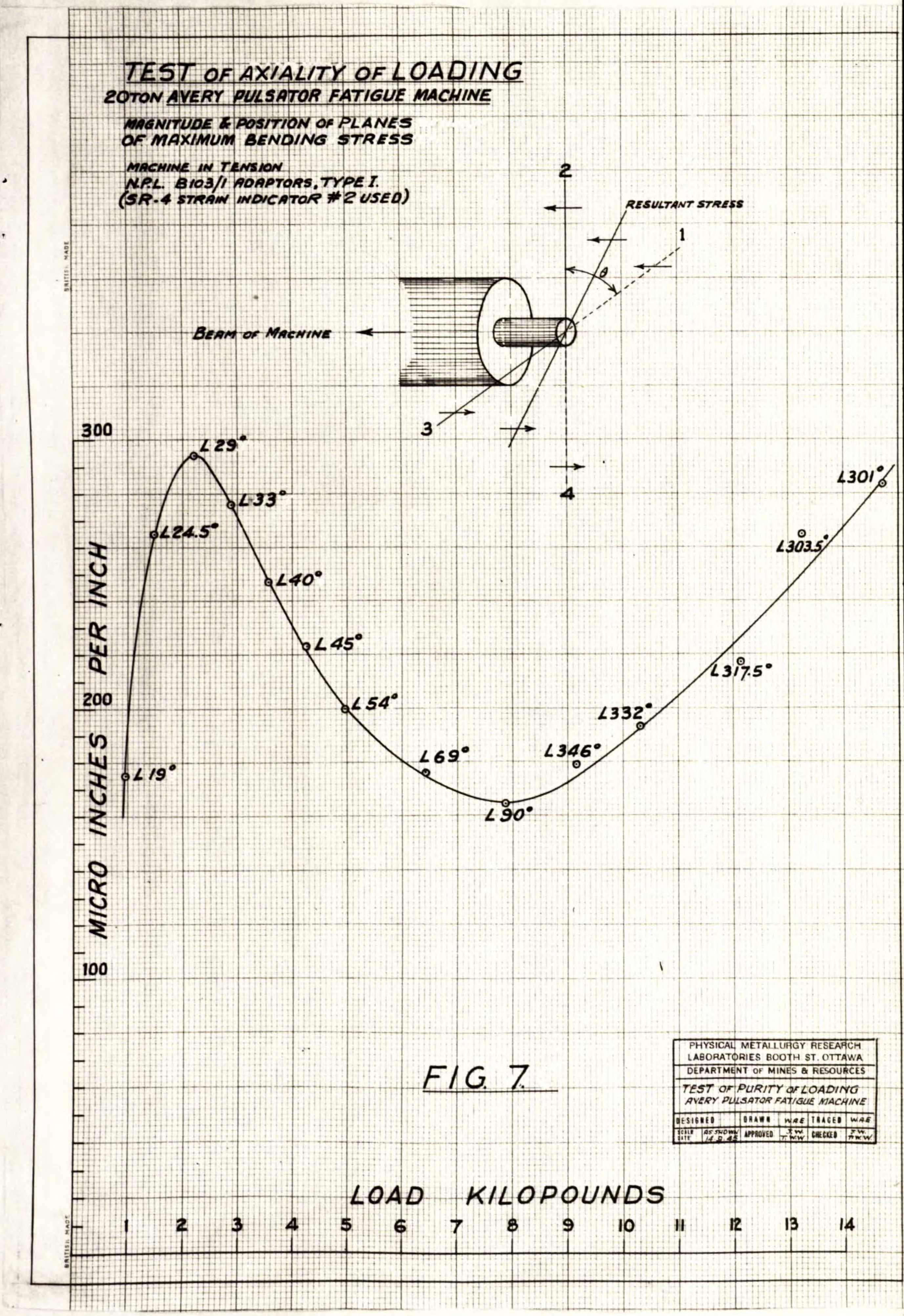
TEST OF AXIALITY OF LOADING
20 TON AVERY PULSATOR FATIGUE MACHINE
MAGNITUDE & POSITION OF PLANES
OF MAXIMUM BENDING STRESS
MACHINE IN TENSION
N.P.L. B103/1 ADAPTORS, TYPE I.
(SR-4 STRAIN INDICATOR #2 USED)
RESULTANT STRESS
BEAM OF MACHINE
1
2
3
4
θ
MICRO INCHES PER INCH
300
200
100
∠19°
∠24.5°
∠29°
∠33°
∠40°
∠45°
∠54°
∠69°
∠90°
∠346°
∠332°
∠317.5°
∠303.5°
∠301°
LOAD KILOPOUNDS
1
2
3
4
5
6
7
8
9
10
11
12
13
14
PHYSICAL METALLURGY RESEARCH
LABORATORIES BOOTH ST. OTTAWA
DEPARTMENT OF MINES & RESOURCES
TEST OF PURITY OF LOADING
AVERY PULSATOR FATIGUE MACHINE
DESIGNED
DRAWN
WAE
TRACED
WAE
SCALE
AS SHOWN
DATE
14.9.45
APPROVED
J.W.
T.W.W.
CHECKED
J.W.
T.W.W.

FIG. 7