TEST REPORT

The work is for convenience divided into the following series, which are reported separately.

Series 1. Shrink fit test of brass on brass, $\frac{1}{2}$ inch nominal diameter. Separated by axial force.

Series 2. Shrink fit test of aluminium on aluminium, $\frac{1}{2}$ inch nominal diameter. Separated by axial force.

Series 3. Shrink fit test of mild steel on mild steel, $\frac{1}{2}$ inch nominal diameter. Separated by axial force.

Series 4. Shrink fit test of cast iron on cast iron, $\frac{7}{16}$ inch nominal diameter. Separated by axial force.

Series 5. Shrink fit test of brass on brass, with brasso polished shaft, $\frac{1}{2}$ inch nominal diameter. Separated by axial force.

Series 6. Shrink fit test of brass on brass, with greased surface, $\frac{1}{2}$ inch nominal diameter. Separated by axial force.

Series 7. Shrink fit test aluminium on brass, $\frac{1}{2}$ inch nominal diameter. Separated by axial force.

Series 8. Shrink fit test of brass on brass, $\frac{1}{2}$ inch nominal diameter. Separated by combined axial force and constant torque of 88.3 in.-lb.

FIG 7

SPECIMEN AND SPECIMEN HOLDER

SCALE 1:1

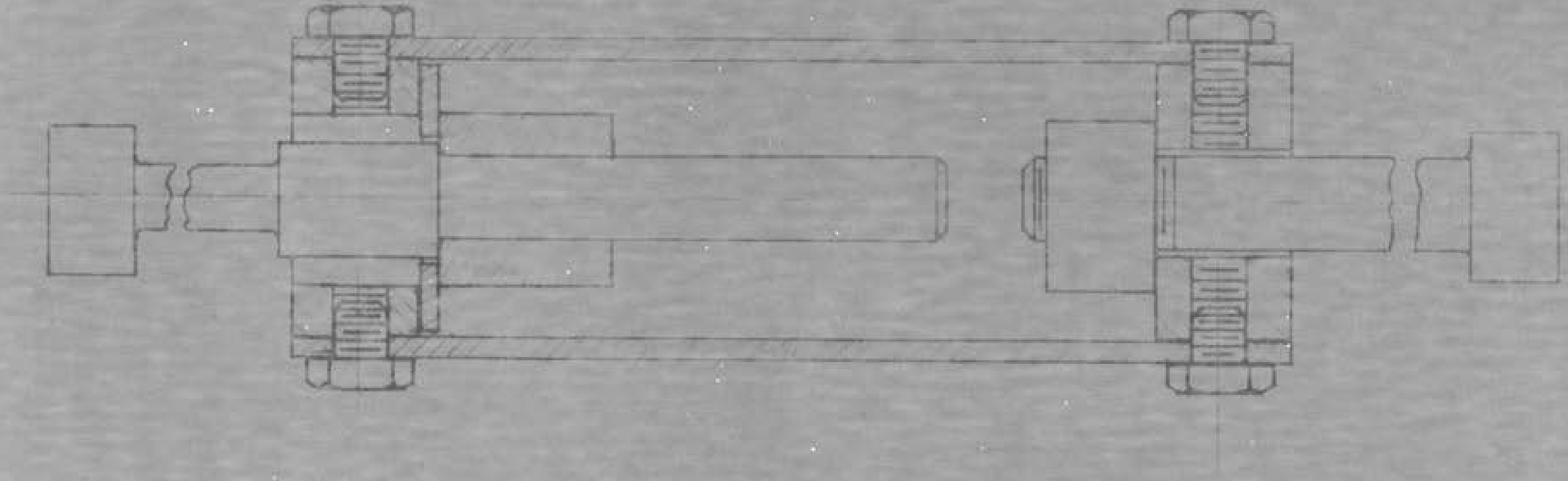
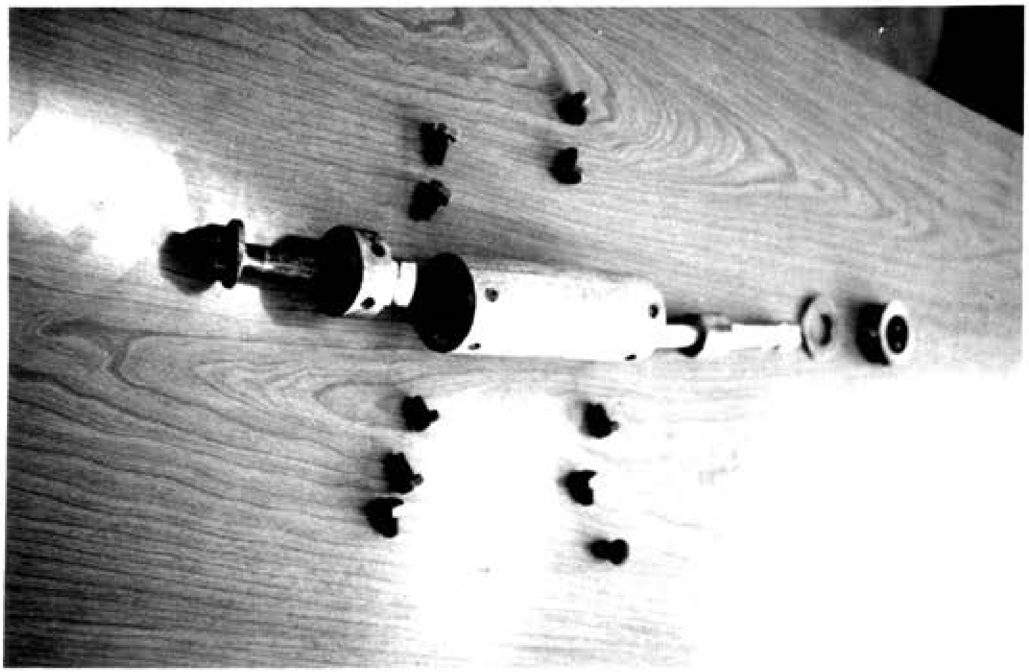
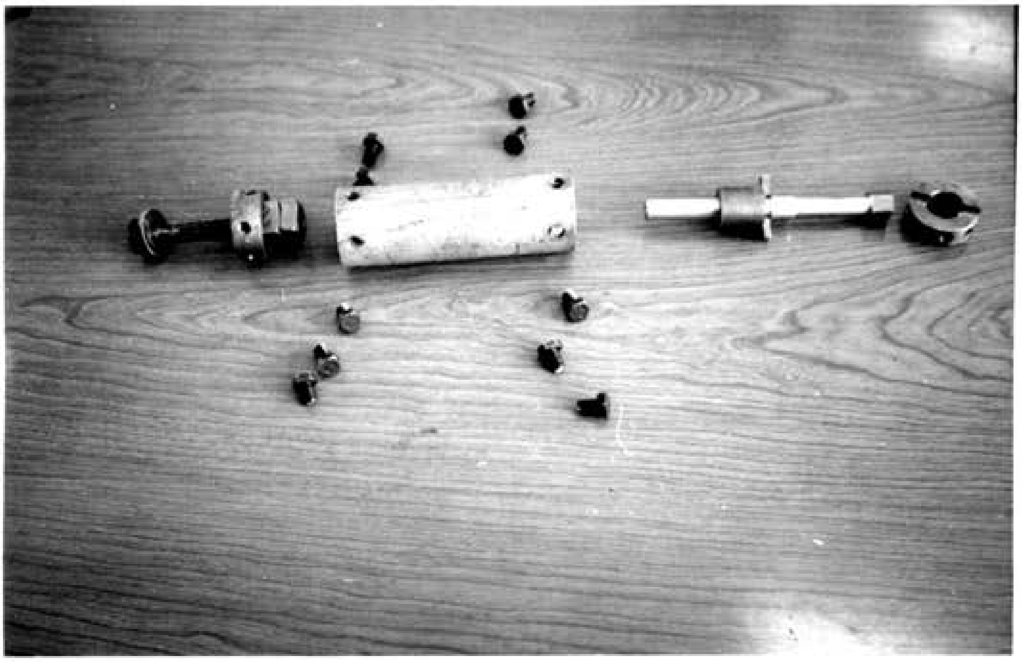


FIG. 8



SPECIMEN AND SPECIMEN HOLDER, SERIES 1-7



SPECIMEN AND SPECIMEN HOLDER, SERIES 8

SERIES I

Brass on brass, as turned surface, $\frac{1}{2}$ inch nominal diameter, as machined surface condition, $\frac{d}{D} = \frac{1}{2}$

Both shaft and hub were cleaned by an air jet. The hub was then heated by oxy-acetelene neutral flame to a high temperature as evidenced by the change in colour of the flame surrounding the hub surface. The shaft was slipped into the hub and allowed the hub to shrink on in room temperature for 3-6 hours before testing. The thin oil film that might be on the surfaces was mostly vaporized by the intense heat at the contact surfaces.

The specimens were separated by the Universal Testing Machine with a speed of approximately 15 minutes/inch. A graph drawn by the machine was obtained for each specimen. Examples of the graphs are shown in fig 11 and 12 for elastic and elasto-plastic grip respectively. At first slip, the force suddenly dropped, with a loud noise, approximately to $\frac{1}{4}$ of the maximum load. For the elastic grip, the surfaces were nearly undamaged and the load gradually decreased with the sliding of the specimens. In elasto-plastic grip, or in high pressure elastic grip as well, the surfaces were damaged. The top of the little ridges of the surfaces were crushed during shrinkage or sheared off in separation operation. Thus, for high pressure, the seizure of the point of contact was so strong that the slip caused the surface particles of each element to be pulled out of position and these were rolled and dragged during further separation so that much force was required and the mating surfaces were badly torn*.

The separating force to cause the first slip was then the most reliable data obtained. The curve of the first slip force per unit contact area with varying fits was obtained in fig 9 . The test points lie well in a straight line at early elastic grip but abruptly deviate to about 45% of maximum value.

The efficiency in the interference fit curve, being similar to the force per unit area curve except the change in ordinate scale by dividing by S_{us}, was presented on the same ordinate axis.

The test results were not in agreement with Lamé solution beyond half way of the elastic range. This phenomenon was found by Professor Thomson (6) for steel, but with less deviation. In elasto-plastic region, the results were more and more deviated. The reason will be discussed later in the discussion.

The bore tensile stress can be read off from fig 10.

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* Robert Russel, op. cit. p. 520

FIG 9

SERIES I BRASS ON BRASS

surface roughness : shaft, turned, CLA 63 Ra 1.6

hub, reamed, CLA 63 Ra 1.6

3-4 hours setting time

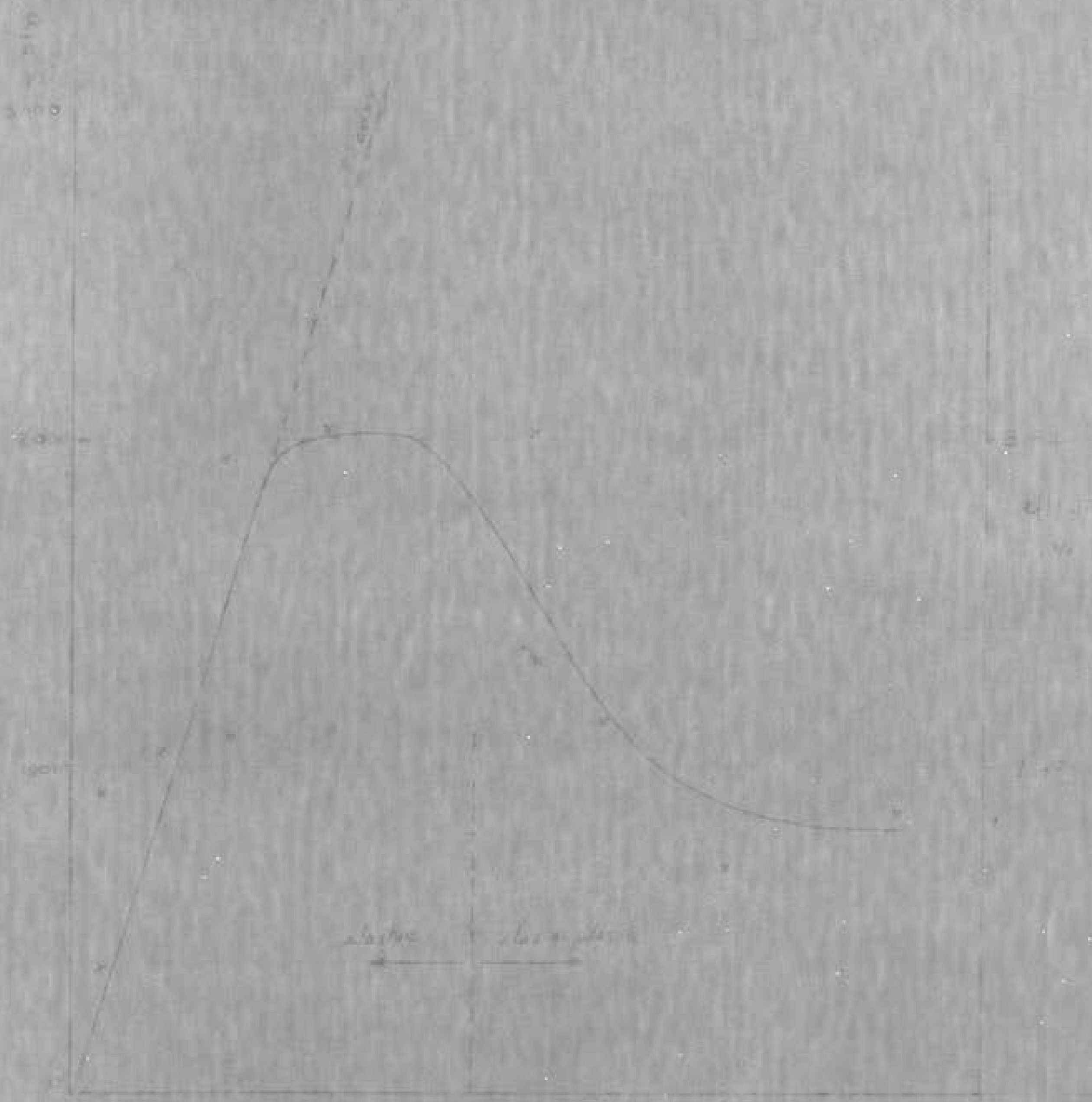
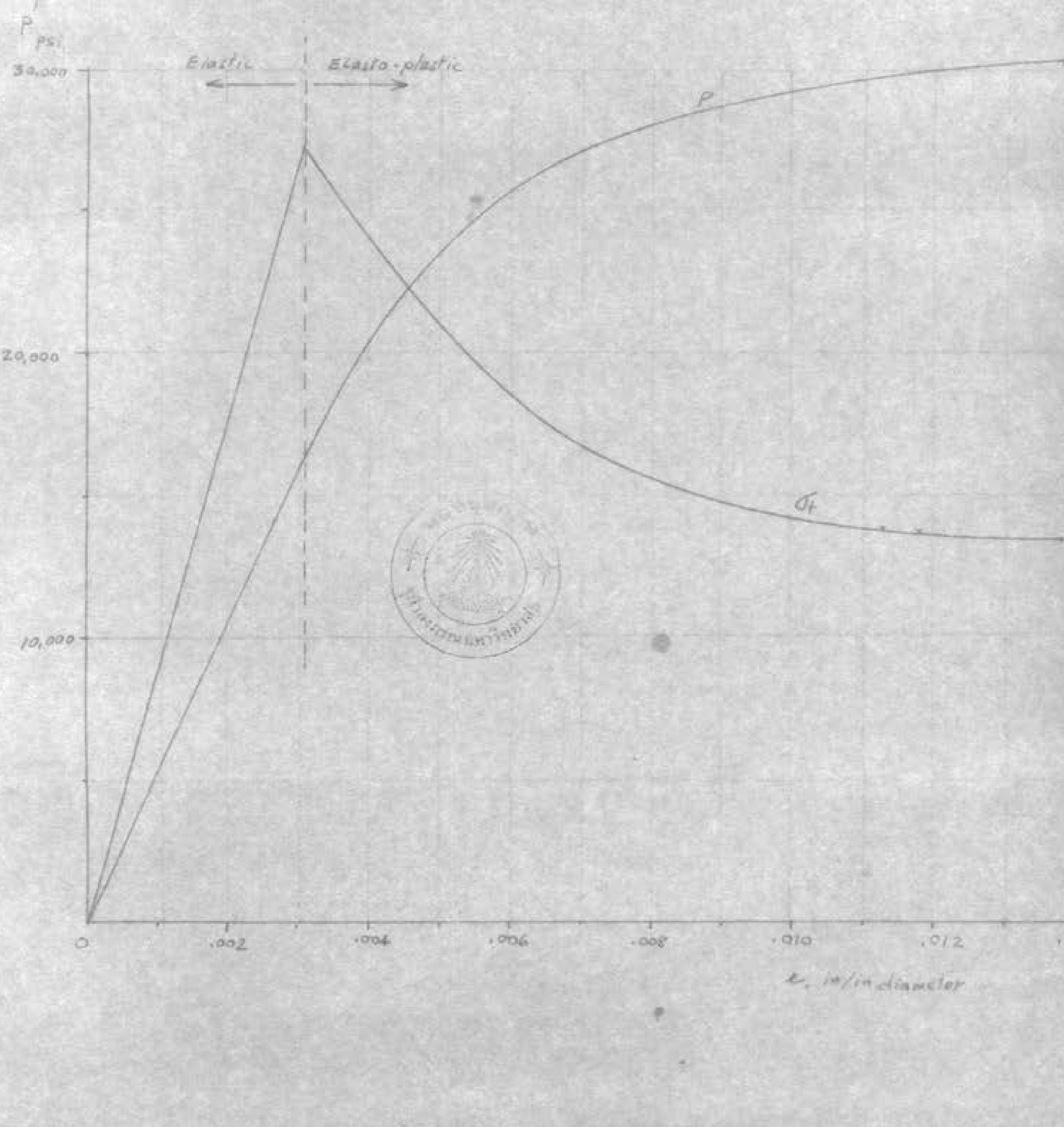


FIG. 10

INTERFERENCE FIT PRESSURE AND BORE TENSILE STRESS

OF BRASS

$d = \frac{1}{2}''$ $D = 1''$



(O.)

Br x Br.

shaft OD hub ID

1770 #

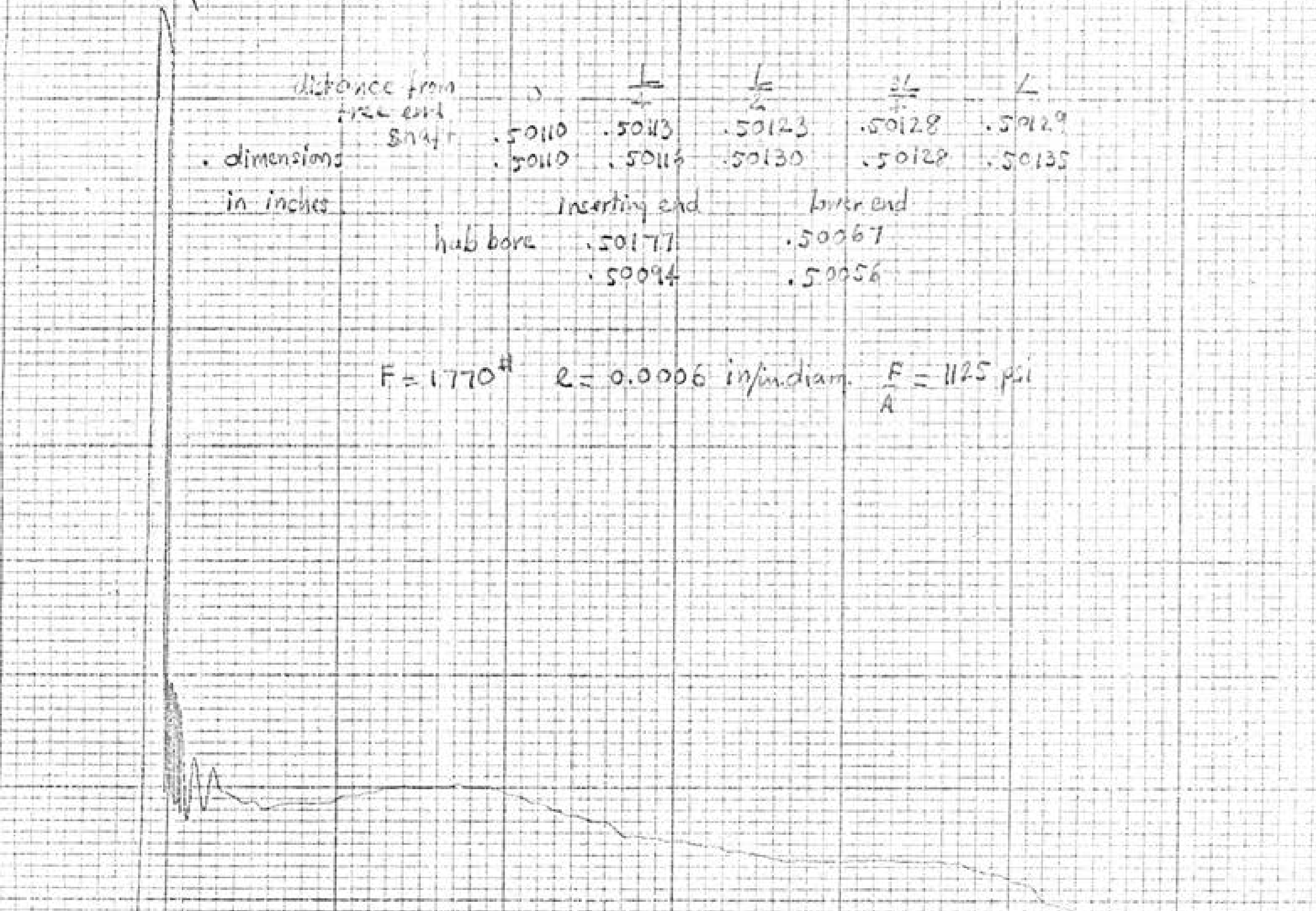
FIG. 11

SERIES I BRASS

	distance from free end	0	$\frac{L}{4}$	$\frac{L}{2}$	$\frac{3L}{4}$	L
dimensions in inches	shaft	.5010	.50113	.50123	.50128	.50129
		.5010	.50116	.50130	.50128	.50135

	inserting end	lower end
hub bore	.50177	.50067
	.50094	.50056

$F = 1770^{\#}$ $e = 0.0006$ in/in.diam. $\frac{F}{A} = 1125$ psi



Both.

Shaft PG hub HR
CLA 63
Ra 1.6.

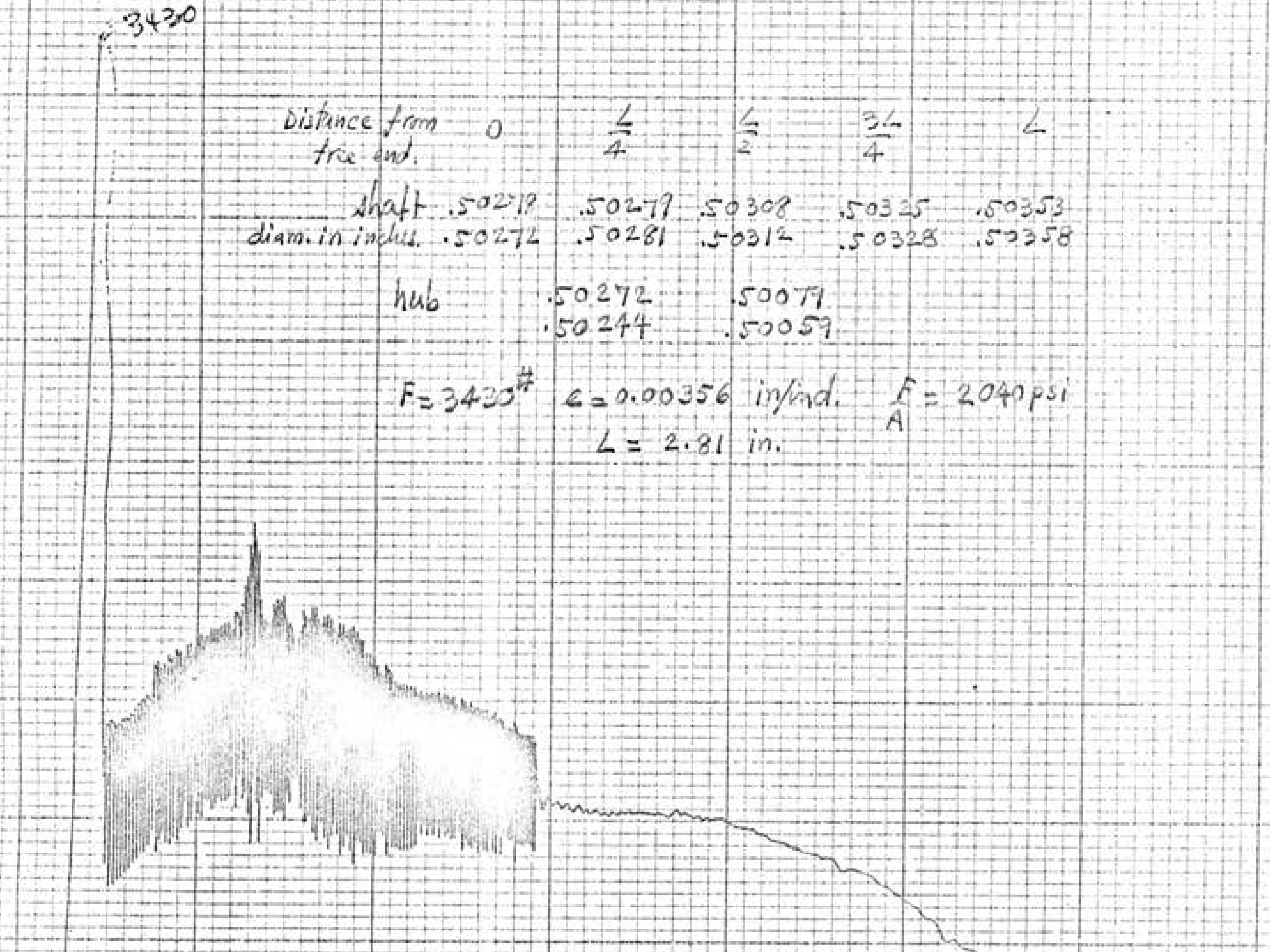
FIG. 12

SERIES I BRASS

Distance from free end.	0	$\frac{L}{4}$	$\frac{L}{2}$	$\frac{3L}{4}$	L
shaft diam. in inches.	.50279 .50272	.50279 .50281	.50308 .50312	.50325 .50328	.50353 .50358
hub		.50272 .50244	.50079 .50059		

$F = 3430^{\#}$ $\epsilon = 0.00356$ in/ind. $\frac{F}{A} = 2040$ psi

$L = 2.81$ in.



SERIES 2

Aluminium on aluminium, as turned surface, $\frac{1}{2}$ inch nominal diameter as machined surface condition, $\frac{d}{D} = \frac{1}{2}$

Aluminium surfaces were softer and can easily be machined with lower surface roughness. The measurement could be made more accurately and the out-of roundness effect was smaller. As a reason, the test points were not much scattered. The assembly and disassembly method were the same as for Series 1. Because of the soft surface, the movement of the separating specimens were sliding rather than slipping. The test curves are shown in fig 15 and fig 16 for elastic and elasto-plastic grip respectively. The axial load per unit area curve was much similar to that of Series 1 in elastic range, but continued with constant maximum load in elasto-plastic range.

FIG 13

[illegible] 2. ALUMINUM ON ALUMINUM

Surface roughness: [illegible] ca 15 [illegible]
hub, [illegible] ca 16 ca 14
5-6 hours setting time

FIG. 14

INTERFERENCE FIT PRESSURE AND BORE TENSILE STRESS

OF ALUMINIUM

$d = \frac{1}{2}''$ $D = 1''$

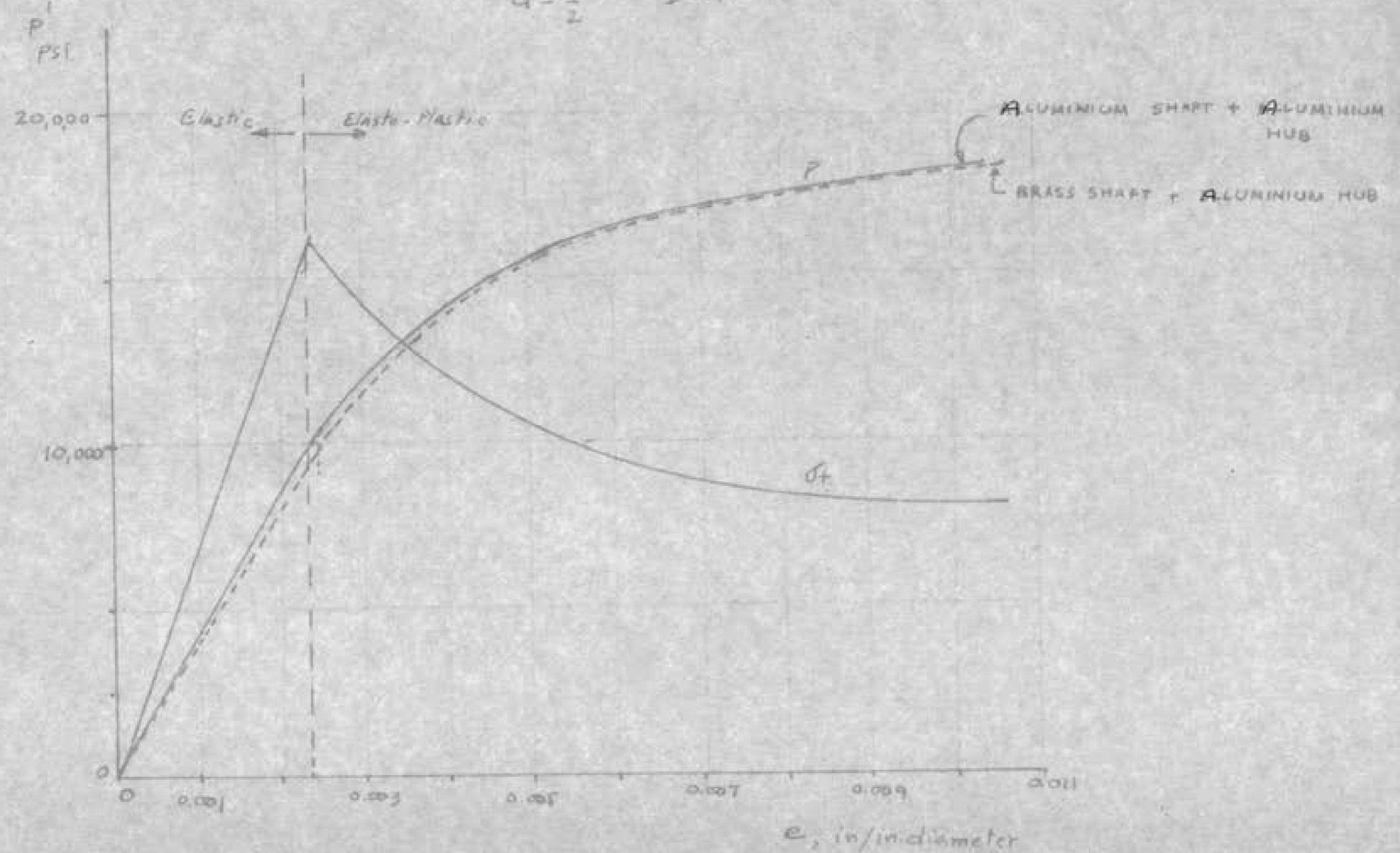


FIG. 15

SERIES 2 . ALUMINIUM

	0	$\frac{L}{4}$	$\frac{L}{2}$	$\frac{3L}{4}$	L
shaft dimensions inches.	.50062 .50064	.50072 .50085	.5011 .50114	.50145 .50147	.50142 .50147
hub	.50110 .50092	.50106 .50098			

$F = 951^{\#}$

$\varepsilon = 0.00064$ in/in. $\frac{F}{A} = 578$ psi.

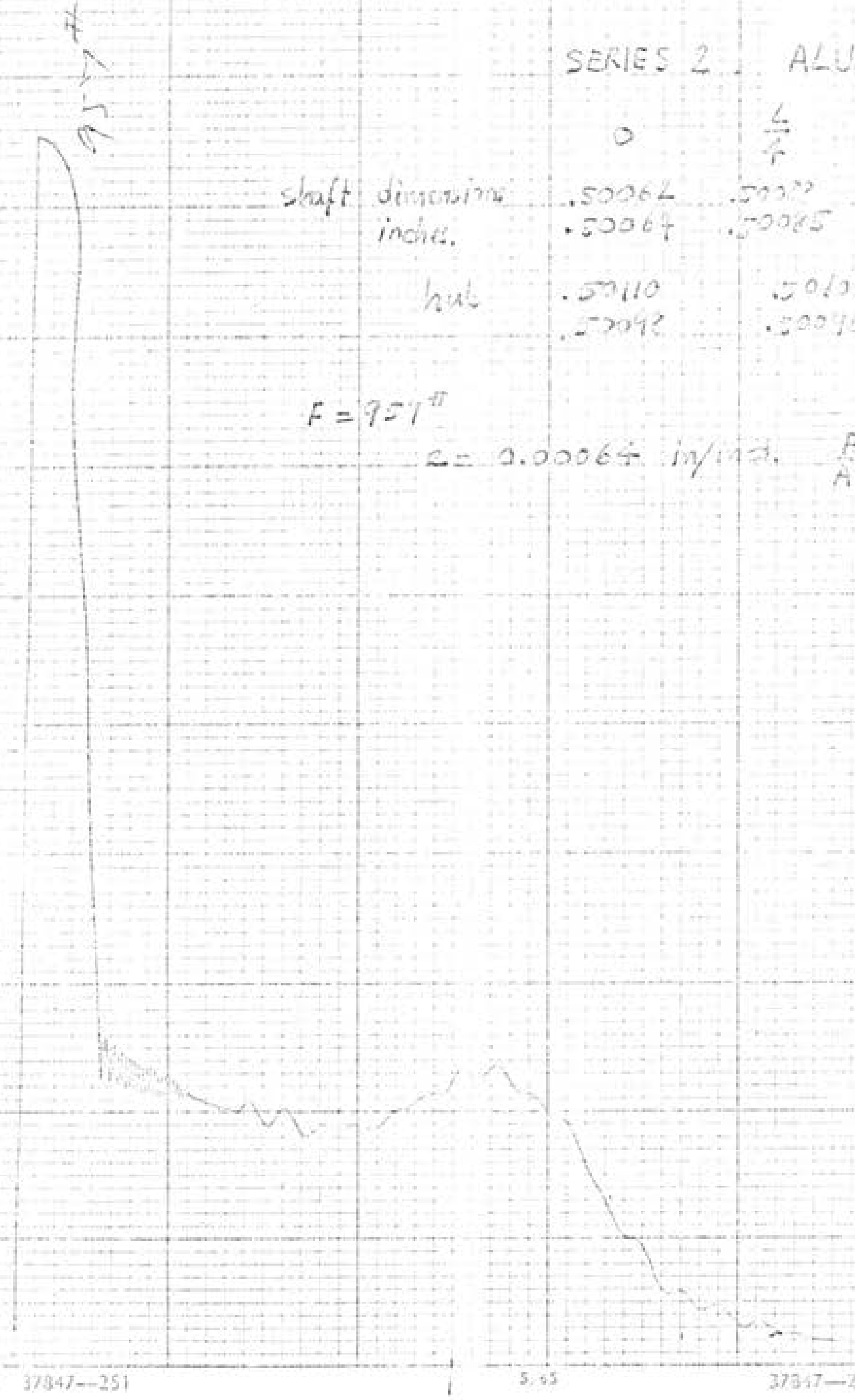
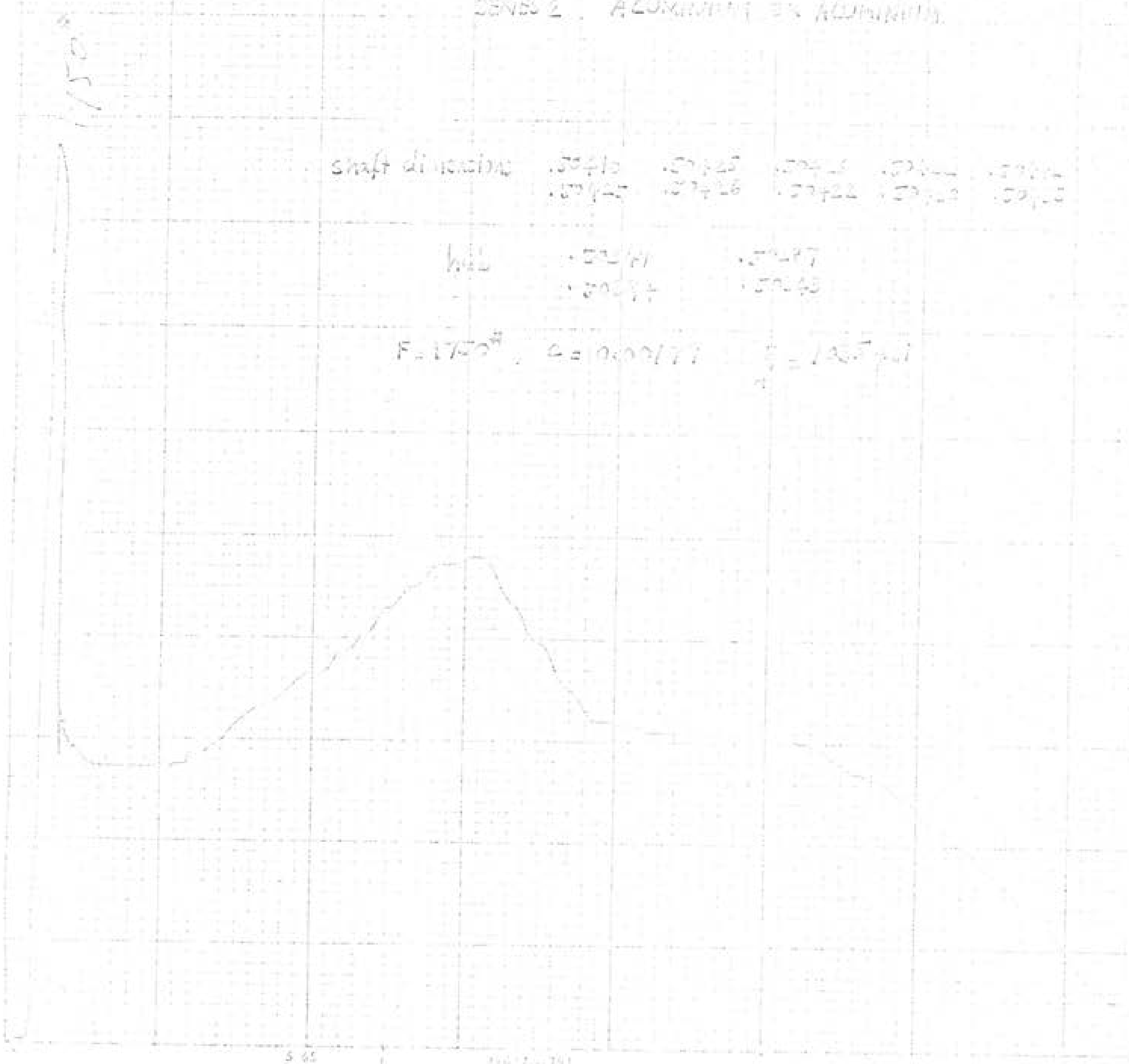


FIG. 16



SERIES 2 . ALUMINUM ON ALUMINUM

shaft dimension .50415 .50425 .50415 .50444 .50416
.50425 .50426 .50422 .50423 .50423

hole .50441 .50487
.50044 .50443

F = 1750#, G = 10,000/77 [illegible] = 1455 psi

SERIES 3

MILD STEEL ON MILD STEEL

As turned, chemically dry surface, $\frac{1}{2}$ inch nominal diameter, $\frac{d}{D} = \frac{1}{2}$ The shaft and hub were soaked with carbon tetra chloride for 5 minutes. The hub was then heated and the shaft was slipped in. The specimens were left in open air for 2 days.

The surface of mild steel was hard and tough. The surfaces were badly damaged for both elastic and elasto-plastic grip test. In elasto-plastic grip test, the surfaces wereso damaged that the separating force increased rapidly and tends to increase without dropping as in fig 20 . The separating force per unit contact area curve were in good agreement with theory within elastic range. The test results obtained were similar to that of Prof. Thomson (6). The test points at small interferences were rather scattered mainly because of the out-of-straighness and out-of-roundness effect which became dominent at small interferences. The curve is shown in fig 17 .

FIG 17

SERIES 3, MILD STEEL ON MILD STEEL

surface roughness shaft, as turned CLA 125 Ra 3.4
nut, reamed CLA 85 Ra 2.2
chemically dry 2 days setting time

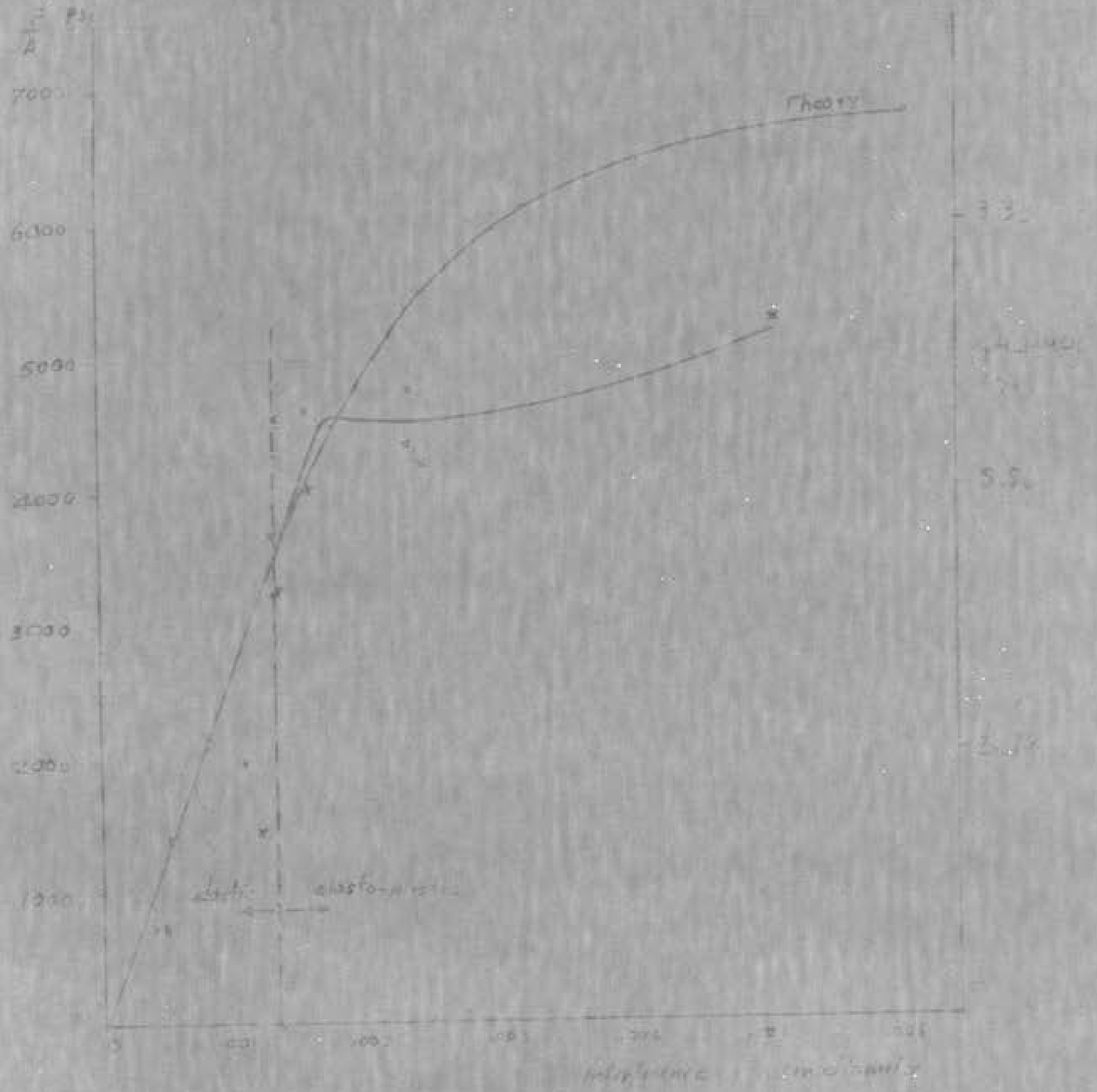


FIG. 18

INTERFERENCE FIT PRESSURE AND BORE TENSILE STRESS OF MILE STEEL

$d = \frac{1}{2}''$ $D = 1''$

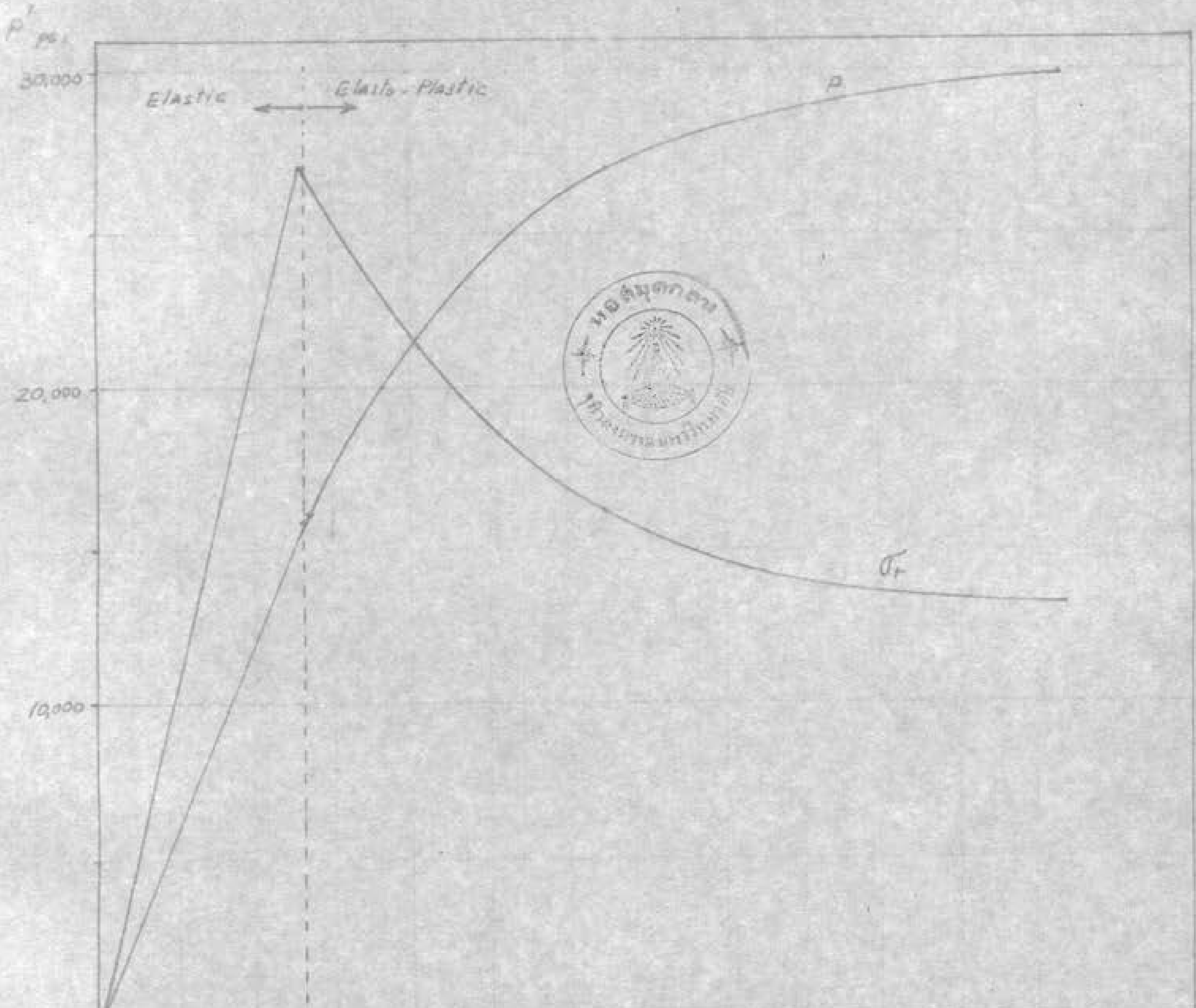
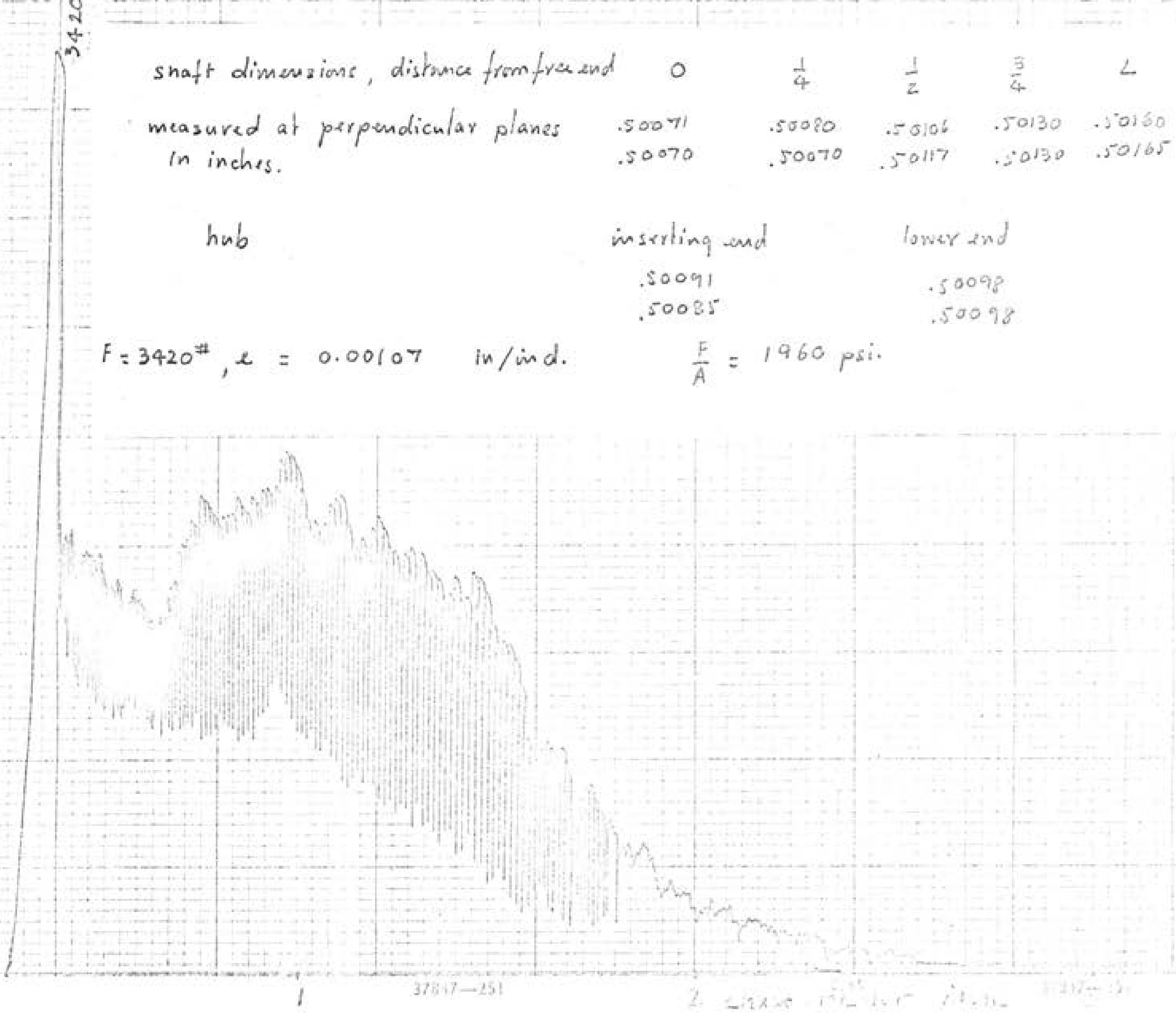


FIG. 19

SERIES 3 _ MILD STEEL



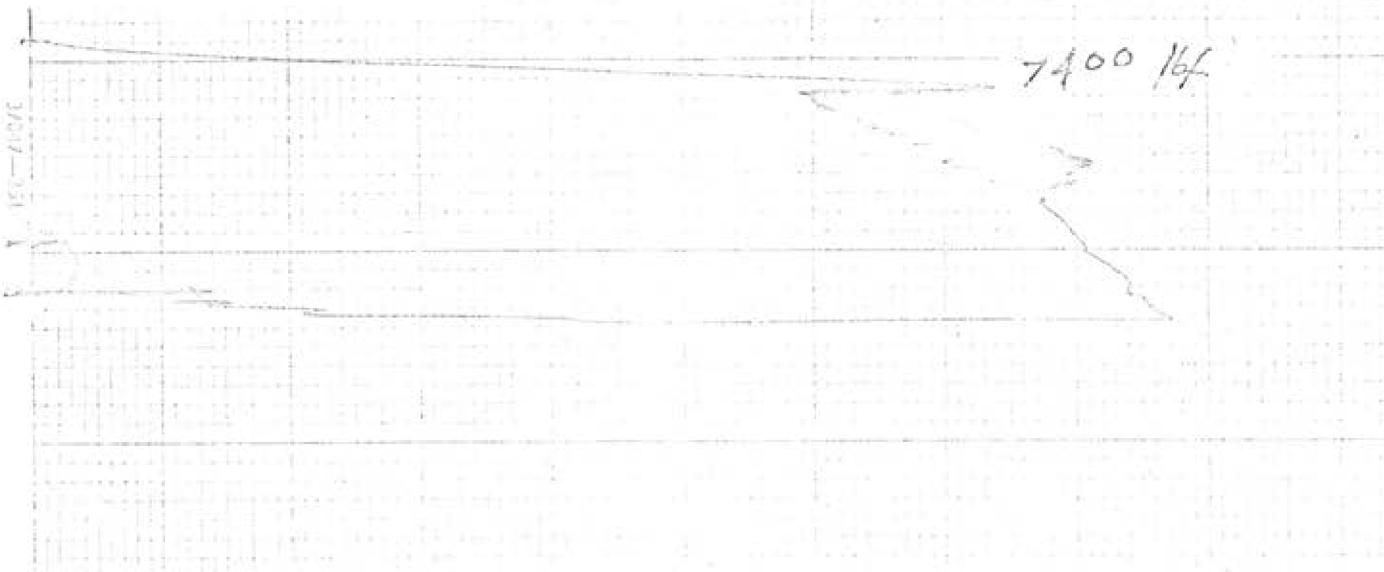
shaft dimensions, distance from free end	0	$\frac{1}{4}$	$\frac{1}{2}$	$\frac{3}{4}$	L
measured at perpendicular planes in inches.	.50071 .50070	.50080 .50070	.50106 .50117	.50130 .50130	.50160 .50165

hub	inserting end	lower end
	.50091 .50085	.50098 .50098

F = 3420#, e = 0.00107 in/in d. $\frac{F}{A}$ = 1960 psi.

FIG. 20

SERIES-3
MILD STEEL



shaft dimensions	.50107	.50122	.50130	.50147	.50150
	.50105	.50127	.50135	.50147	.50155
hub dimension	.50047	.50118			
	.50102	.50071			

F = 7400# ϵ = .00132 in/in d. $\frac{F}{A}$ = 4570 psi.

SERIES 4

Cast iron on cast iron, as turned, chemically dry surface, $\frac{7}{16}$ inch nominal diameter, 0.96 inch external diameter of hub.

Because of the brittleness property, cast iron could be machined with less out-of straightness and out-of-roundness effect. The surface roughness could not be measured because of the porous surfaces. The specimens were dried the same way as in Series 3.

The results were in good agreement with theory. Unfortunately, the interferences could not be made more than 0.002 in./in. diameter because the grip strength was more than tensile strength of shaft and the shafts failed by tension near the shrinked portion.

According to the great amount of graphite grains in cast iron, the co-efficient of friction after first slip reduced considerably and the specimens slided after the first slip. Investigation of hub bore after test revealed a very smooth surface of hub bore caused by compressed graphite dust.

FIG 21

SERIES 4 CAST ALUM ON CAST IRON
CHEMICALLY DRY SURFACES [illegible]

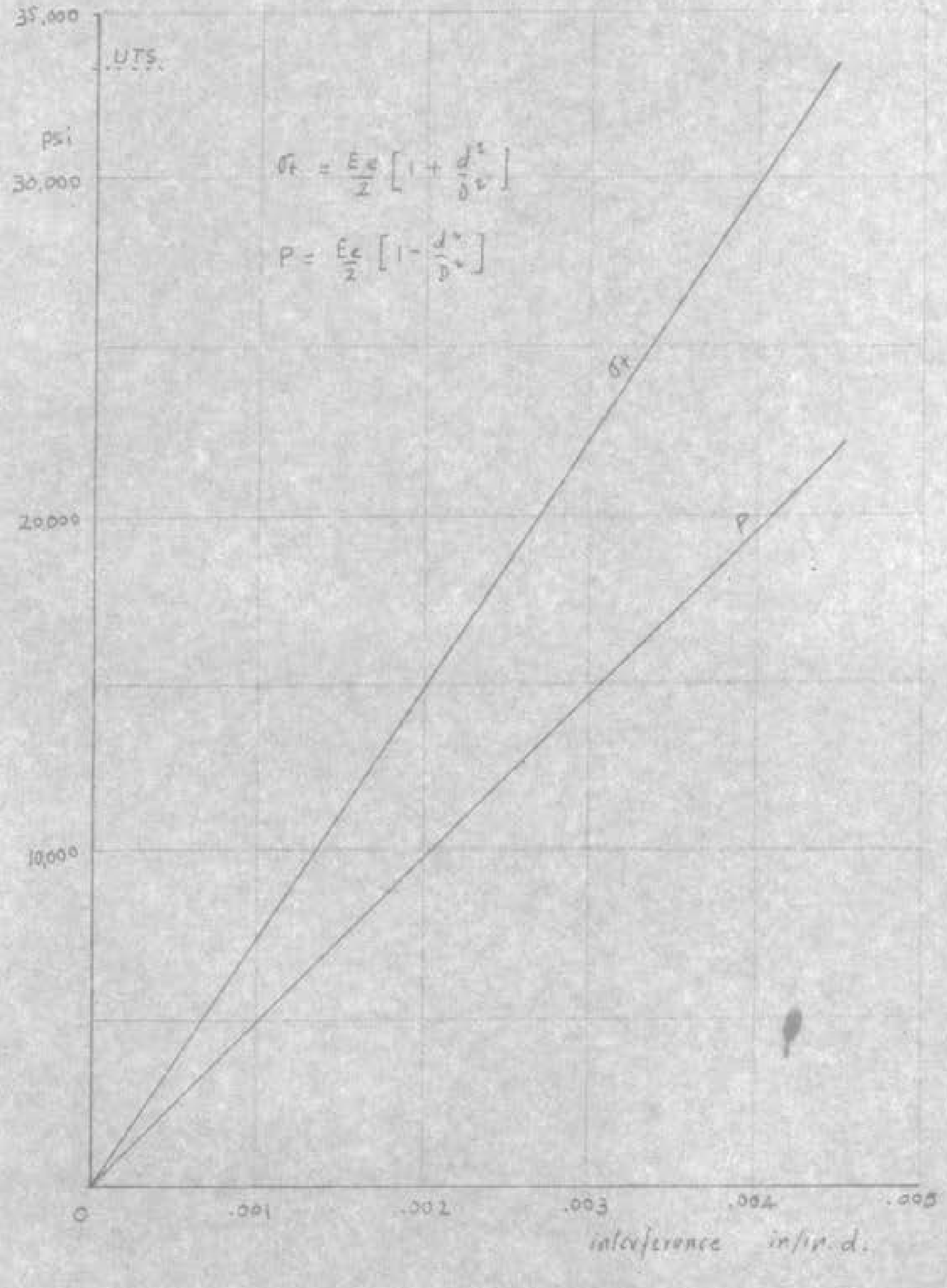
FIG. 22

INTERFERENCE FIT PRESSURE

AND BORE TENSILE STRESS

OF CAST IRON

$d = \frac{7}{16}''$ $D = 0.96''$



$$\sigma_t = \frac{Ee}{2}\left[1 + \frac{d^2}{D^2}\right]$$

$$P = \frac{Ee}{2}\left[1 - \frac{d^2}{D^2}\right]$$

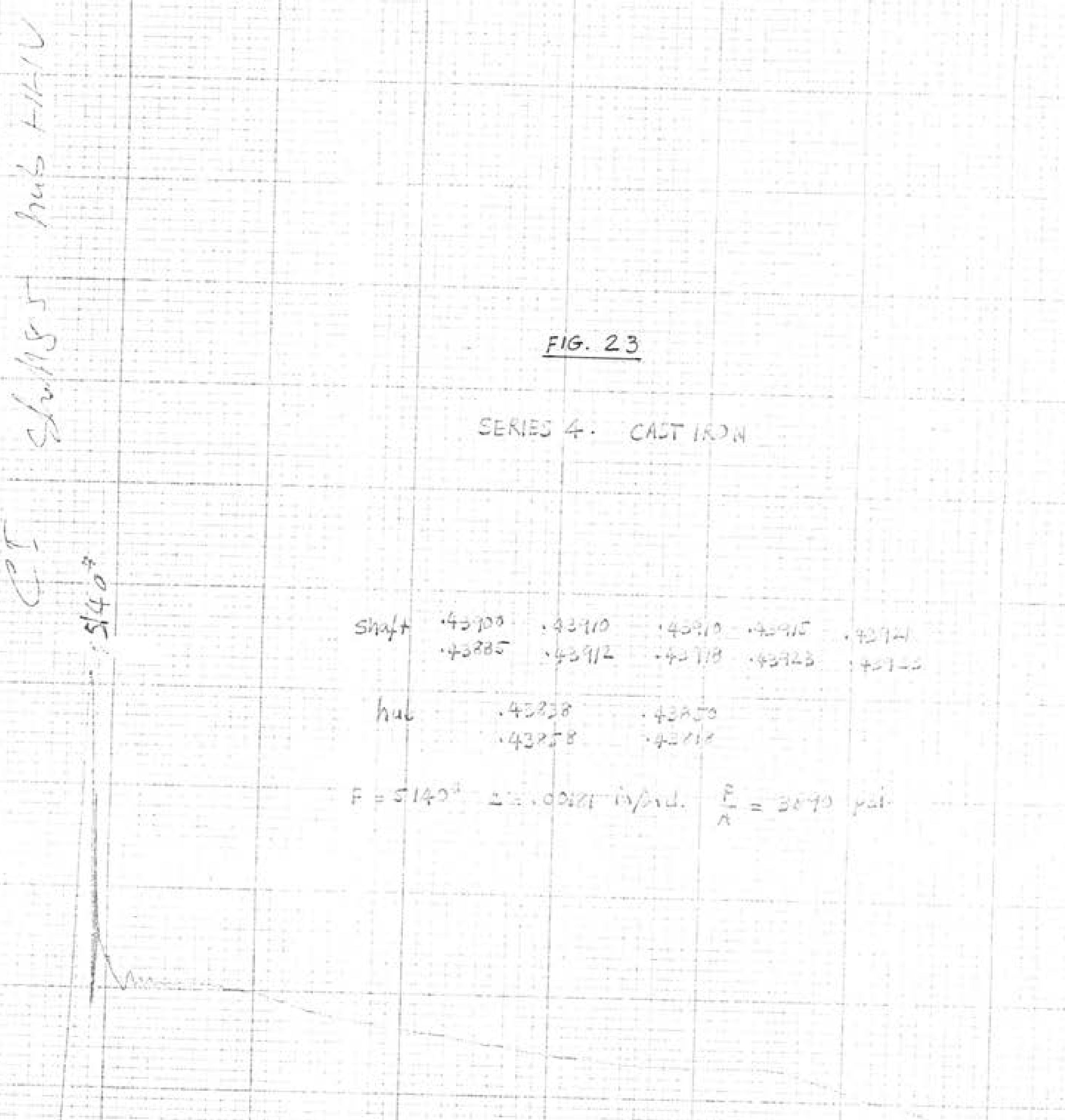


FIG. 23

SERIES 4. CAST IRON

Shaft .43900 .43910 .43910 .43915 .43921
.43885 .43912 .43918 .43923 .439[illegible]

hub .43838 .43850
.43858 .43818

F = 5140# Δ = .00121 in/dia. $\frac{F}{A}$ = 3890 psi

SERIES 5

Brass on brass, with polished shaft, ½ inch nominal diameter, $\frac{d}{D} = \frac{1}{2}$

The shaft surface was sand papered longitudinally by No. 320 silicon paper until no scratches can be seen by naked eye. It was then brasso polished with clean cloth. The hub could not be polished because of the limiting measurement condition of the engineering microscope.

This series was conducted to see the difference in results caused by surface finish as compared with Series 1. The results shows a marked decrease in maximum efficiency at elastic range and a small increase in co-efficient of friction. The efficiency in elasto-plastic range increases instead of falling down as in Series 1. Investigation of the surfaces of specimens after test reveals line surface contacts rather than area contact. This out-of-roundness effect was caused by the sand-papering process. The effect of the polished surface over as turned surface was a decrease in efficiency at elastic range and increase at elasto-plastic range.

FIG 24

SERIES 5 BRASS ON BRASS

with polished shaft.
surface roughness : shaft - brasso polished
hub - reamed, CLA 63 Ra1,6.
3-6 hours setting time.

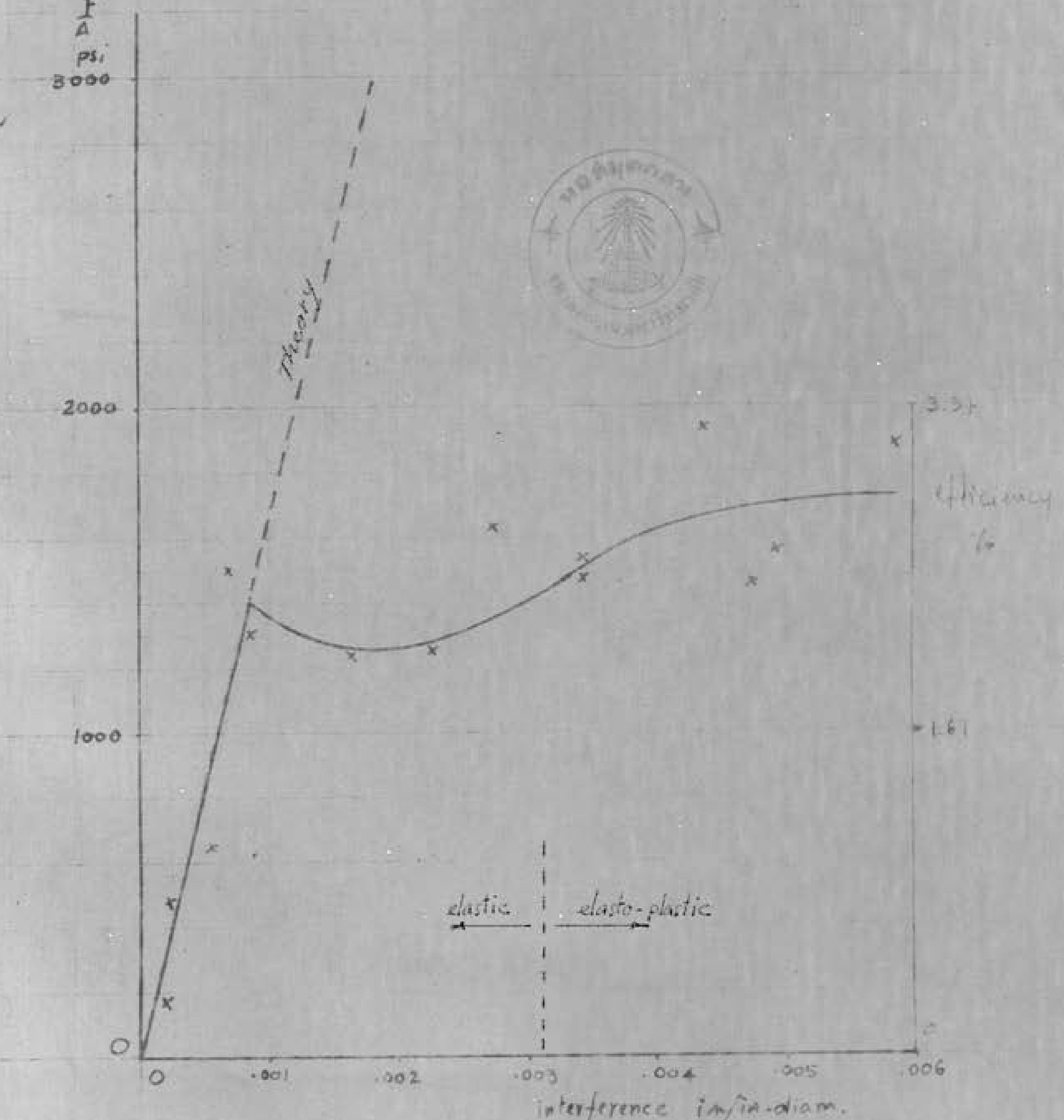


FIG. 25

SERIES 5 BRASS – Polished shaft.

Shaft .49965 .49982 .49968 .50007 .50060
.49975 .49970 .49982 .50010 .50065

Hub .50036 .50021
.49982 .50038

$F = 690^{\#}$ $e = 0.00051$ in/ind. $L = 2.84$ in.

$\frac{F}{A} = 645$ psi

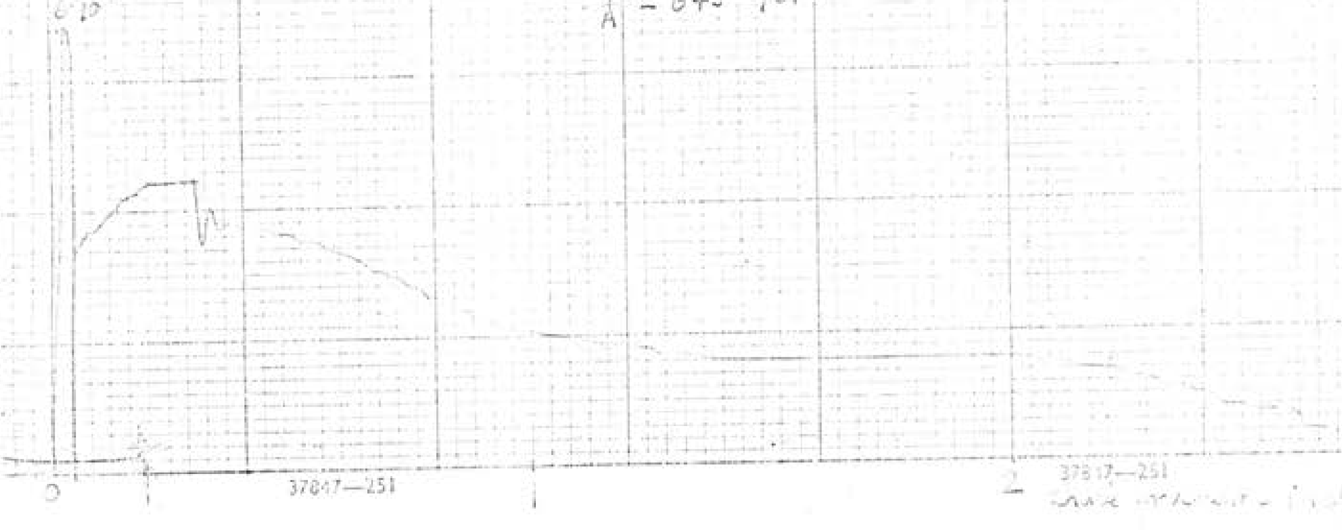


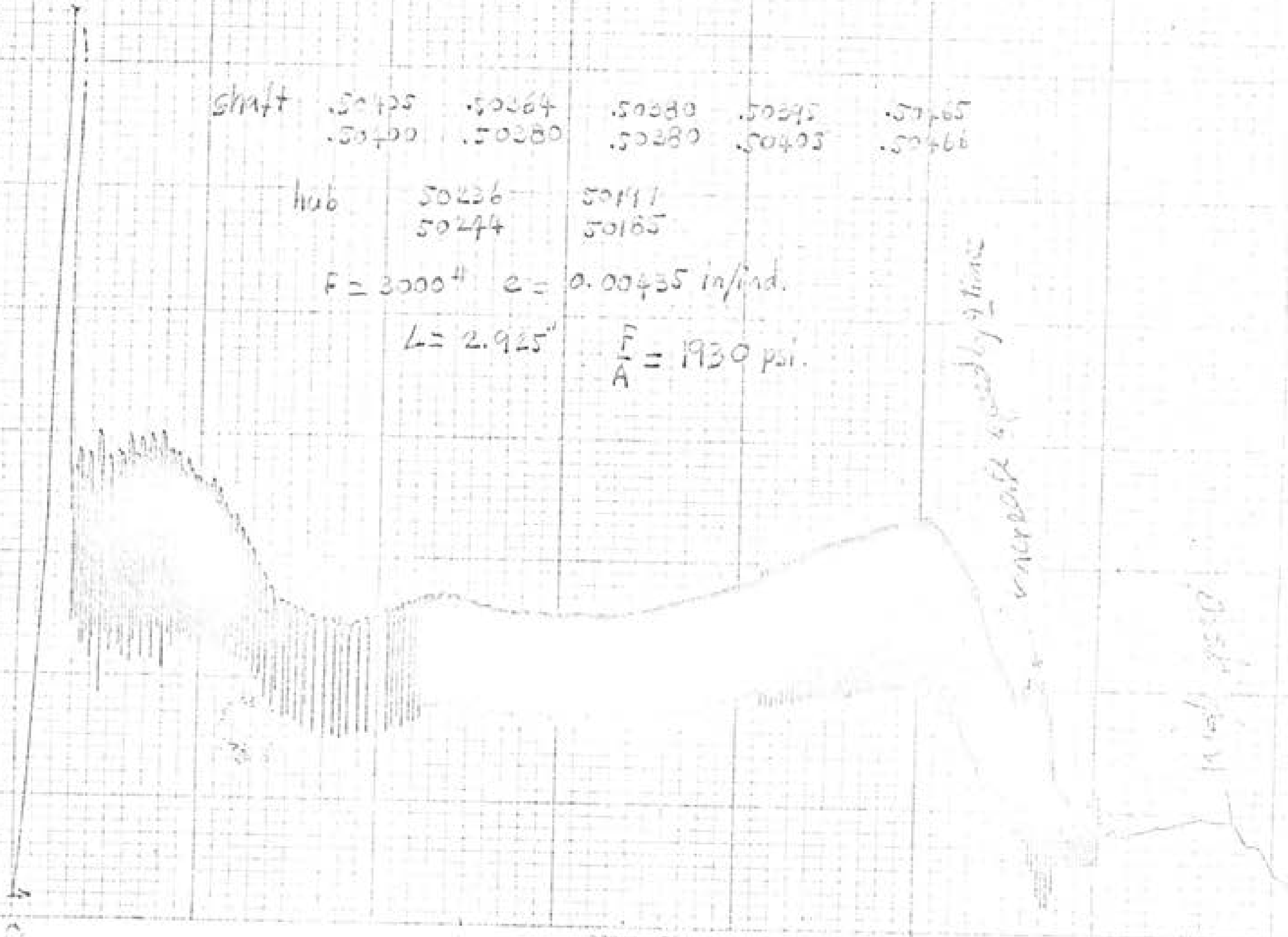
FIG. 26

SERIES 5 BRASS - polished shaft.

shaft	.50425 .50400	.50264 .50280	.50280 .50280	.50295 .50405	.50465 .50466
hub	50236 50244	50111 50165			

F = 3000# e = 0.00435 in/in.

L = 2.925" $\frac{F}{A}$ = 1930 psi.



SERIES 6

Brass on brass, with greased surfaces, $\frac{1}{2}$ inch nominal diameter, $\frac{d}{D} = \frac{1}{2}$, as turned surface.

The shaft was pastered with grease before slipping into the expanded hub*. The results were much scattered because of the unequal amount of grease film locked between the mating surfaces. Graphs on fig 28 and fig 29 shows that the specimens slides easily after first slip and grease film can be sensed on surfaces after test.

The results of this series were in good agreement with theory within elastic limit. The effect over Series 1 are to decrease efficiency for both elastic and elasto-plastic range and a considerable decrease in co-efficient of friction. The test curve was similar to that of series 1.

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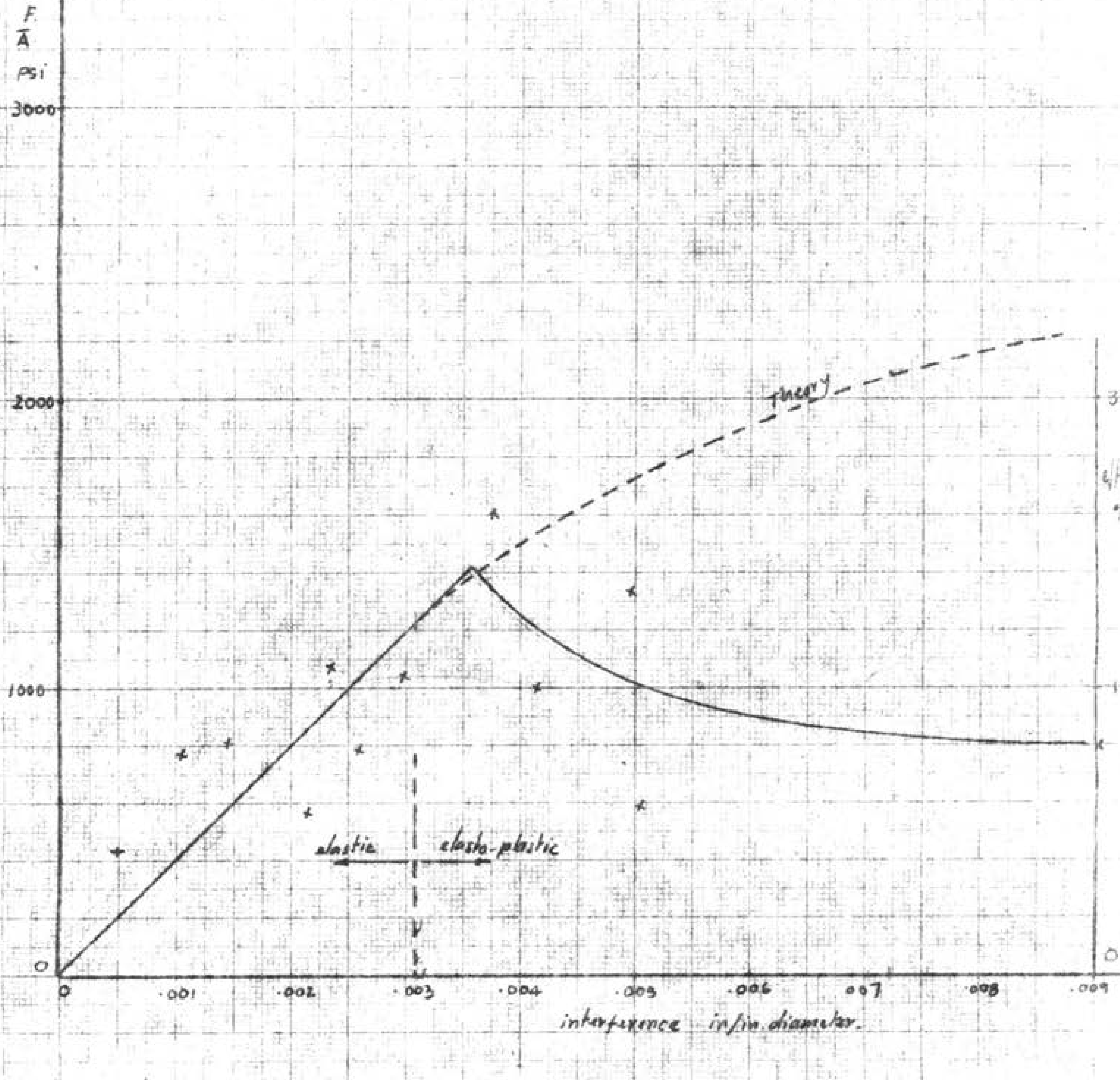
* Ref. 7 p. 799

FIG 27

SERIES 6. BRASS ON BRASS

with greased surfaces
surface roughness : shaft, turned, CLA 63 Ra 1.6
hub, reamed, CLA 63 Ra 1.6
3-6 hours setting time.



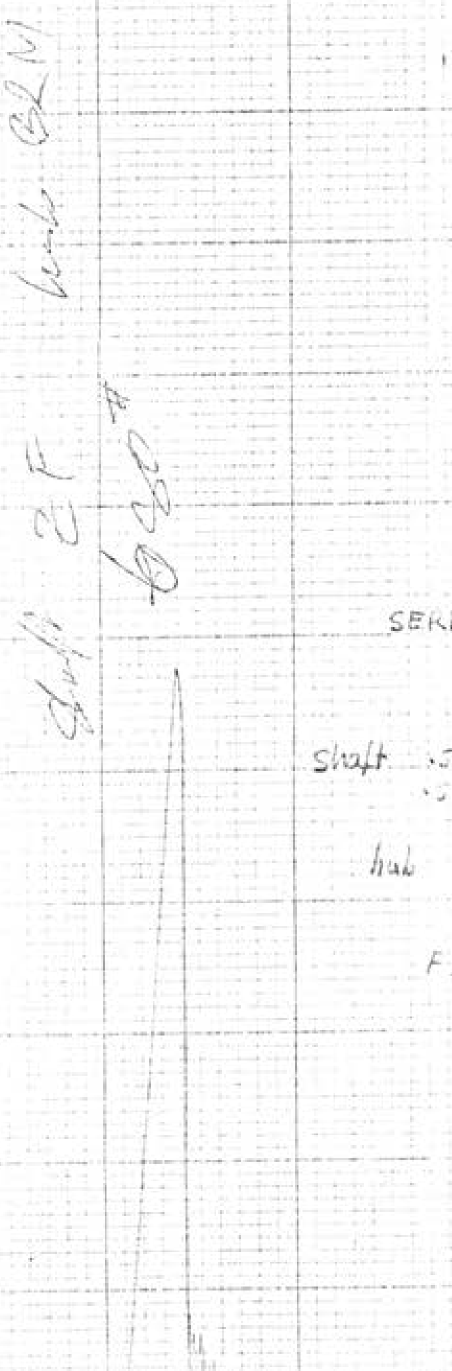


FIG. 28

SERIES 6 BRASS - with greased surface.

Shaft .50016 .50040 .50020 .50120 .50125
.50017 .50043 .50075 .50121 .50135

hub .50106 .50079
.50091 .50078

$F = 680^{\#}$ $e = 0.00049$ in/in. $L = 2.85$ in

$\frac{F}{A} = 435$ psi.

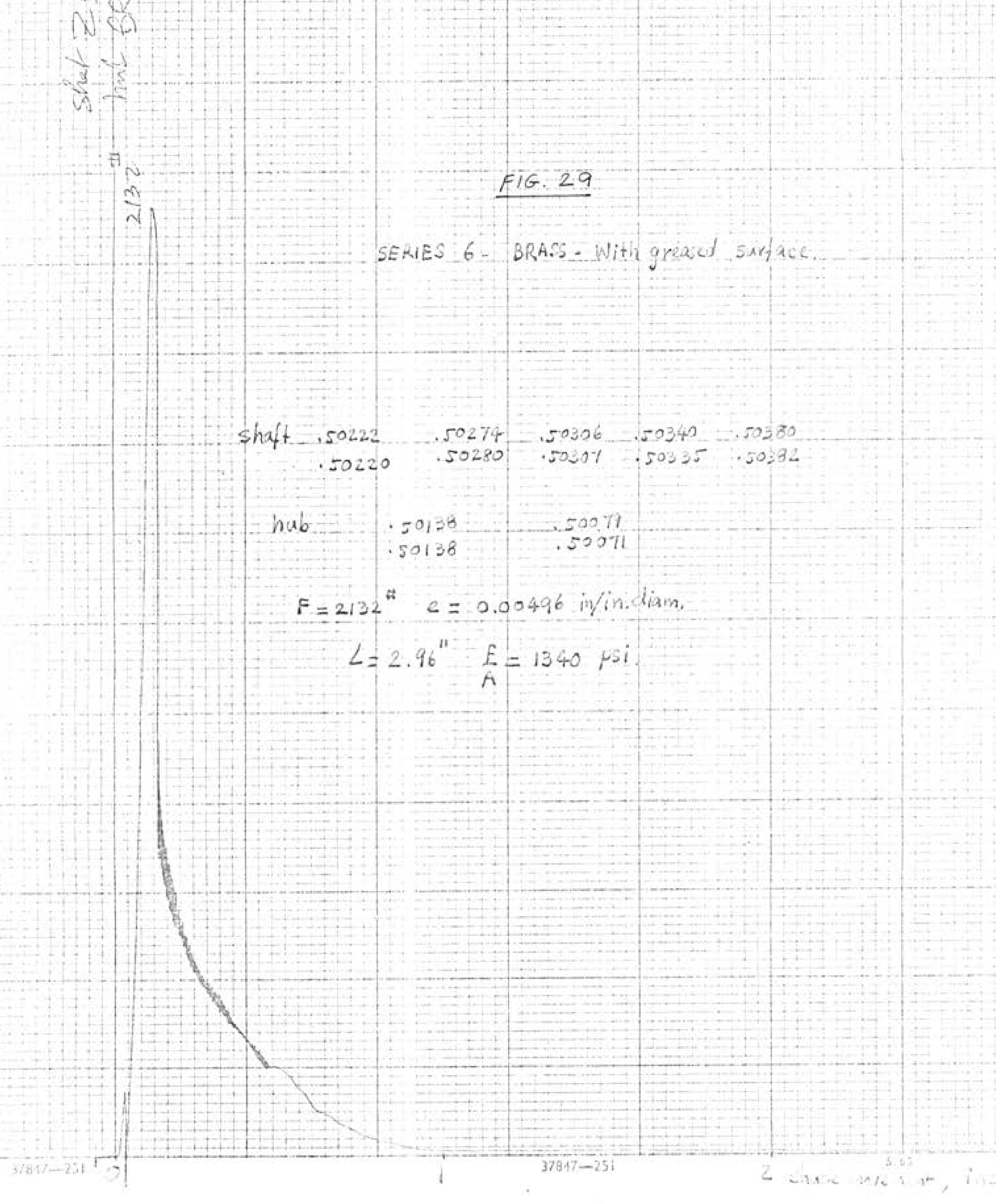


FIG. 29

SERIES 6 - BRASS - With greased surface.

shaft .50222 .50274 .50306 .50340 .50380
.50220 .50280 .50307 .50335 .50382

hub .50138 .50071
.50138 .50071

F = 2132# e = 0.00496 in/in. diam.

$L = 2.96''$ $\frac{F}{A} = 1340$ psi.

SERIES 7

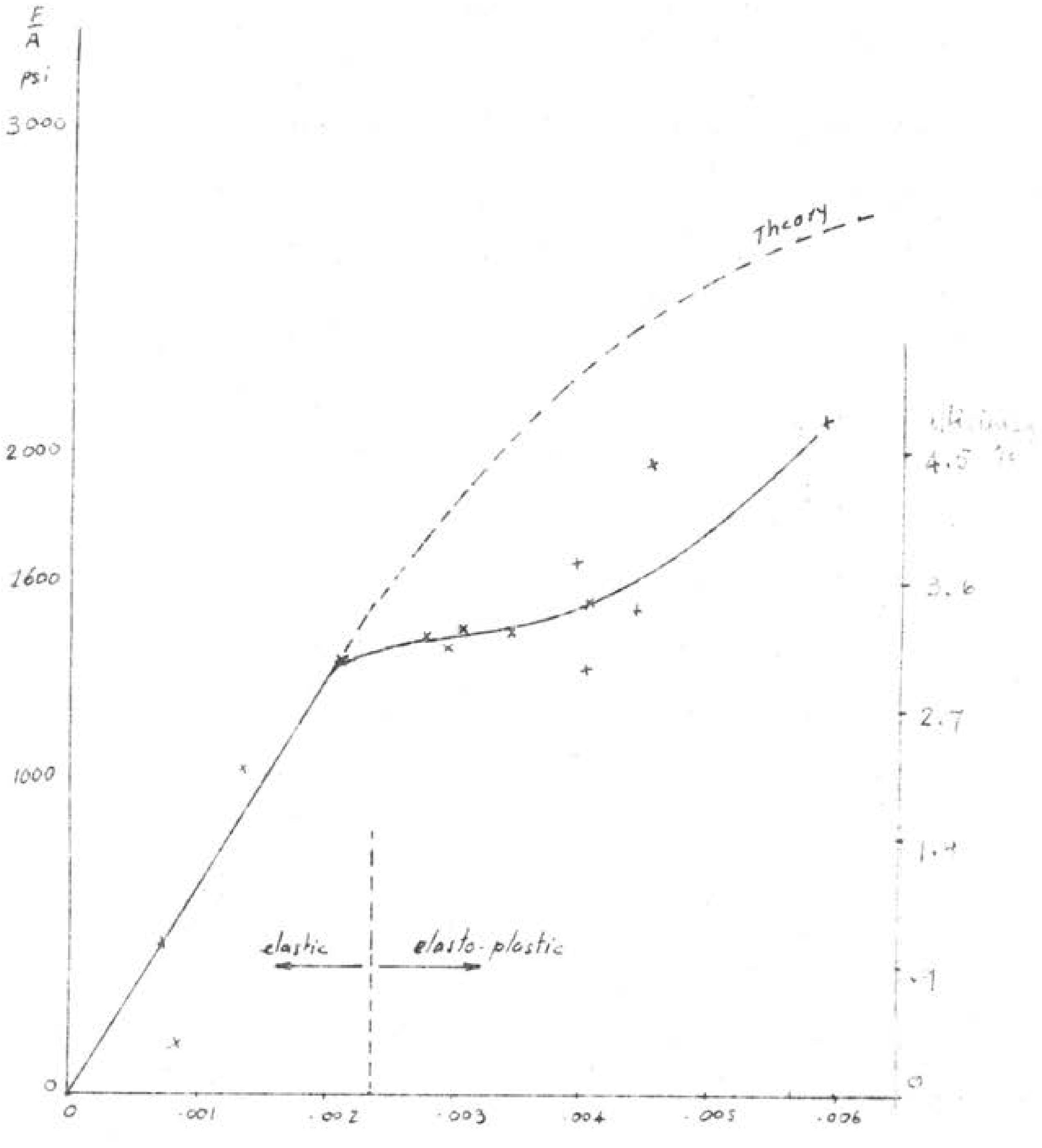
Aluminium on brass, $\frac{1}{2}$ inch nominal diameter, $\frac{d}{D} = \frac{1}{2}$, as turned surfaces.

The grip strength of this test was higher than Series 2 because of the hardness effect. Since the hardness of aluminium is smaller, its surface will contract firmly into brass surface. When separating force was applied, the ridges of the brass surface will tear off the aluminium surface, thus, the efficiency would not depend only on co-efficient of friction and pressure, but on direct shear strength of aluminium surface. This effect increases with increasing interferences. The curve then have much deviation from that of Series 2 although, theoretically, it should be nearly the same. The co-efficient of friction decreases.

FIG 30

Series 7 ALUMINIUM ON BRASS

surface roughness : BRASS shaft , CLA 63 Ra 1,6 , turned.
ALUMINIUM HUB. CLA 16 Ra 0.4 , reamed.
3 - 6 Hours setting time.



For Al hub (E)

[illegible]/PS

FIG. 31

SERIES 7 ALUMINIUM ON BRASS

Brass shaft .50082 .50110 .50135 .50152 .50190
.50082 .50105 .50130 .50150 .50190

Aluminium hub .50098 .50098
.50079 .50138

$F = 1700^{\#}$ $e = 0.00134$ in/ind.

$L = 2.810$ in. $\frac{F}{A} = 1020$ psi

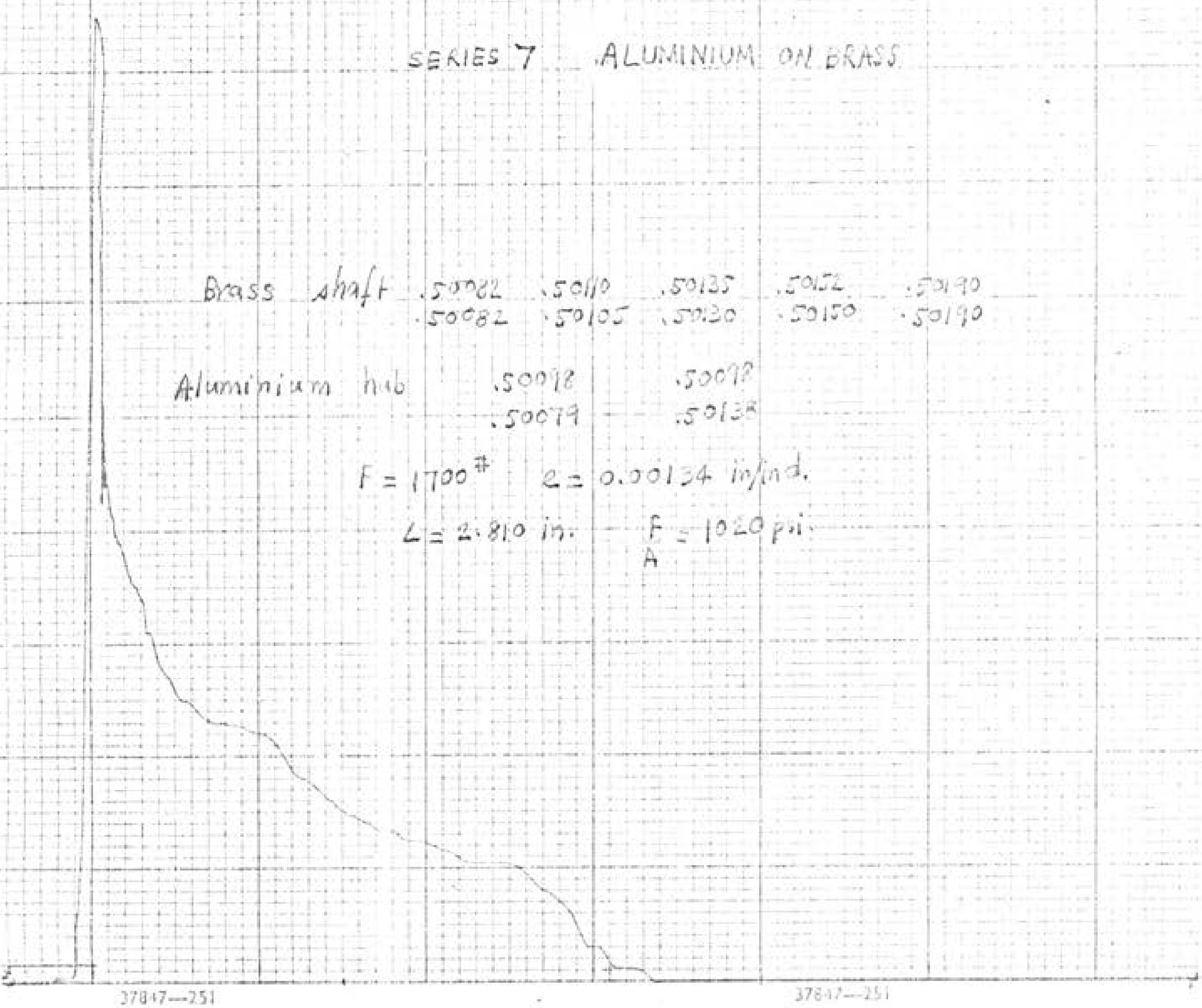
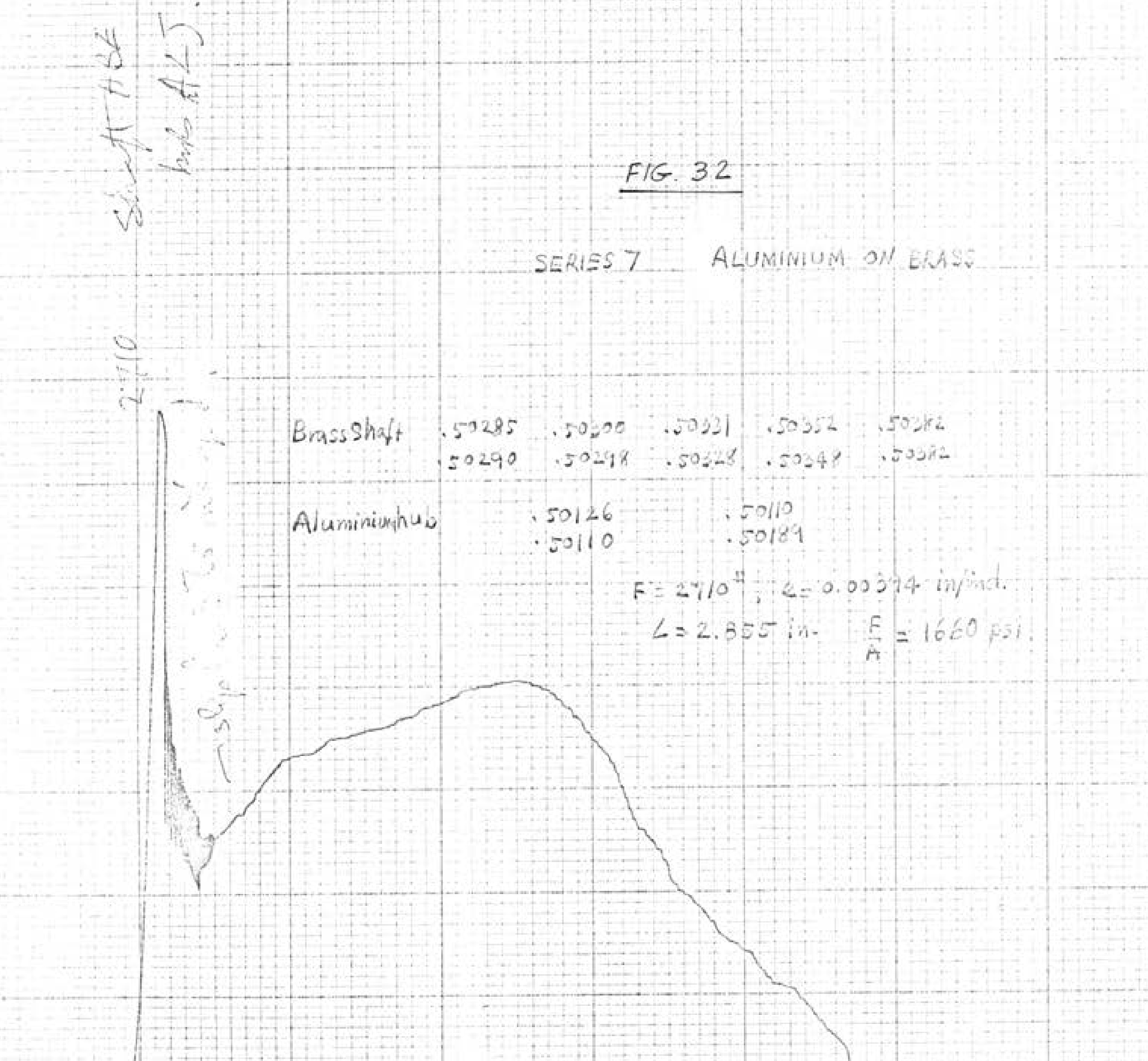


FIG. 32

SERIES 7 ALUMINIUM ON BRASS



Brass Shaft .50285 .50300 .50331 .50352 .50382
.50290 .50298 .50328 .50348 .50382

Aluminium hub .50126 .50110
.50110 .50189

F = 2710#; e = 0.00374 in/in.
L = 2.855 in. $\frac{F}{A}$ = 1660 psi.

SERIES 8

Brass on brass, with constant torque of 88.3 lb-in. $\frac{1}{2}$ inch nominal diameter, $\frac{d}{D} = \frac{1}{2}$, as turned surface.

By applying a constant torque of 88.3 lb.in. in accordance with the axial separation, it was found that the grip strength decreased considerably over Series 1. in elastic range and nearly constant at elasto-plastic range. The slip happened with both axially and circumferential movements. This caused the surface to be rubbed with each other and decrease the co-efficient of friction and so the decrease in grip strength. At a short distance of separation, the grip strength decreased so that the grip failed only by torsion as can be seen from graph in fig 35 and fig 36. After the removal of torque, the members catch again and continued sliding.

FIG. 33

COMBINED PULLING AND TORSION SPECIMEN (SERIES 8) UNDER TEST.

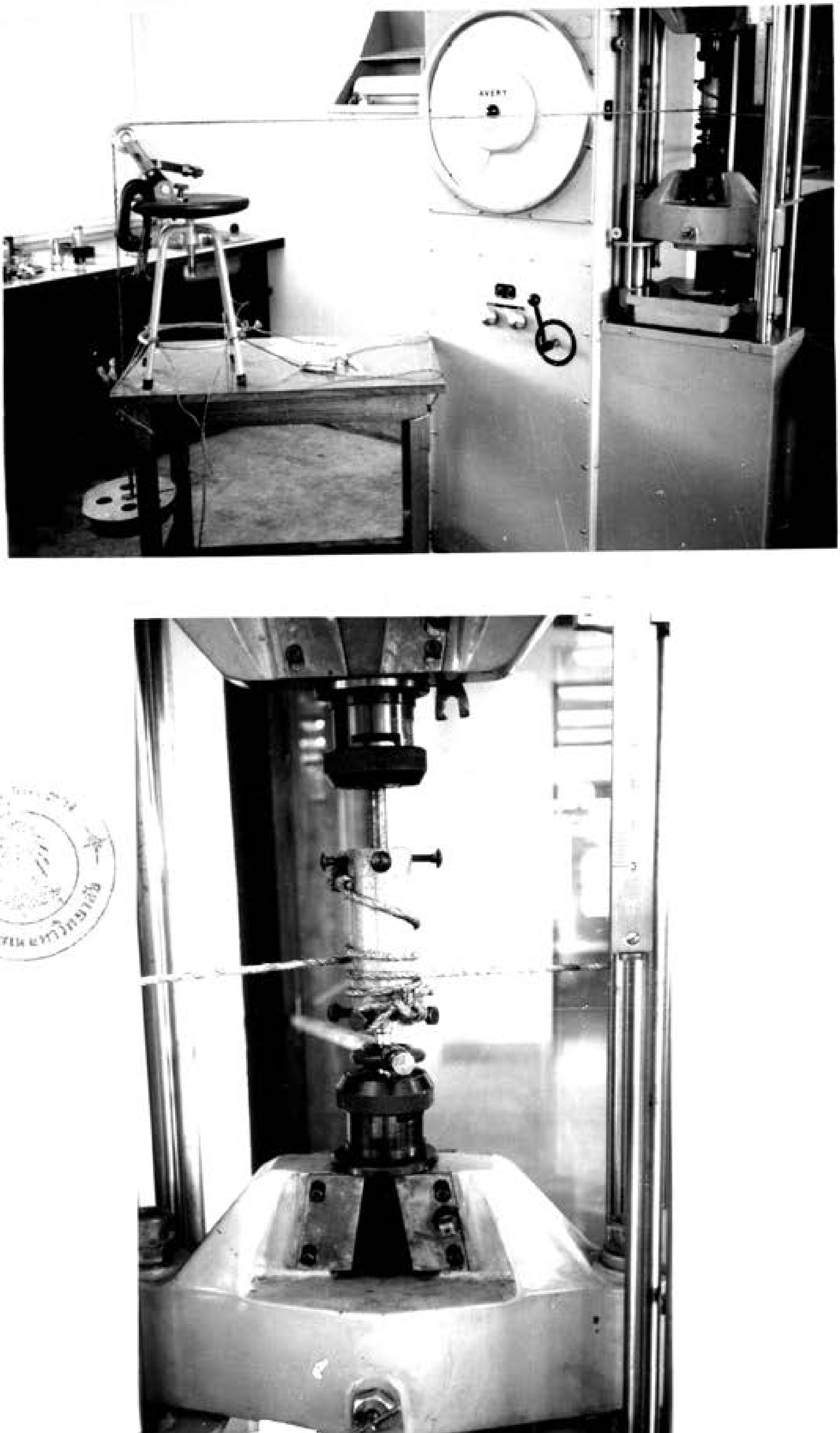


FIG 34

SERIES 8 BRASS ON BRASS
with 88.3 in-lb. torque
Surface roughness : shaft, turned, CLA 63 Ra 1,6
hub, reamed, CLA 63 Ra 1,6
3-6 hours setting time.

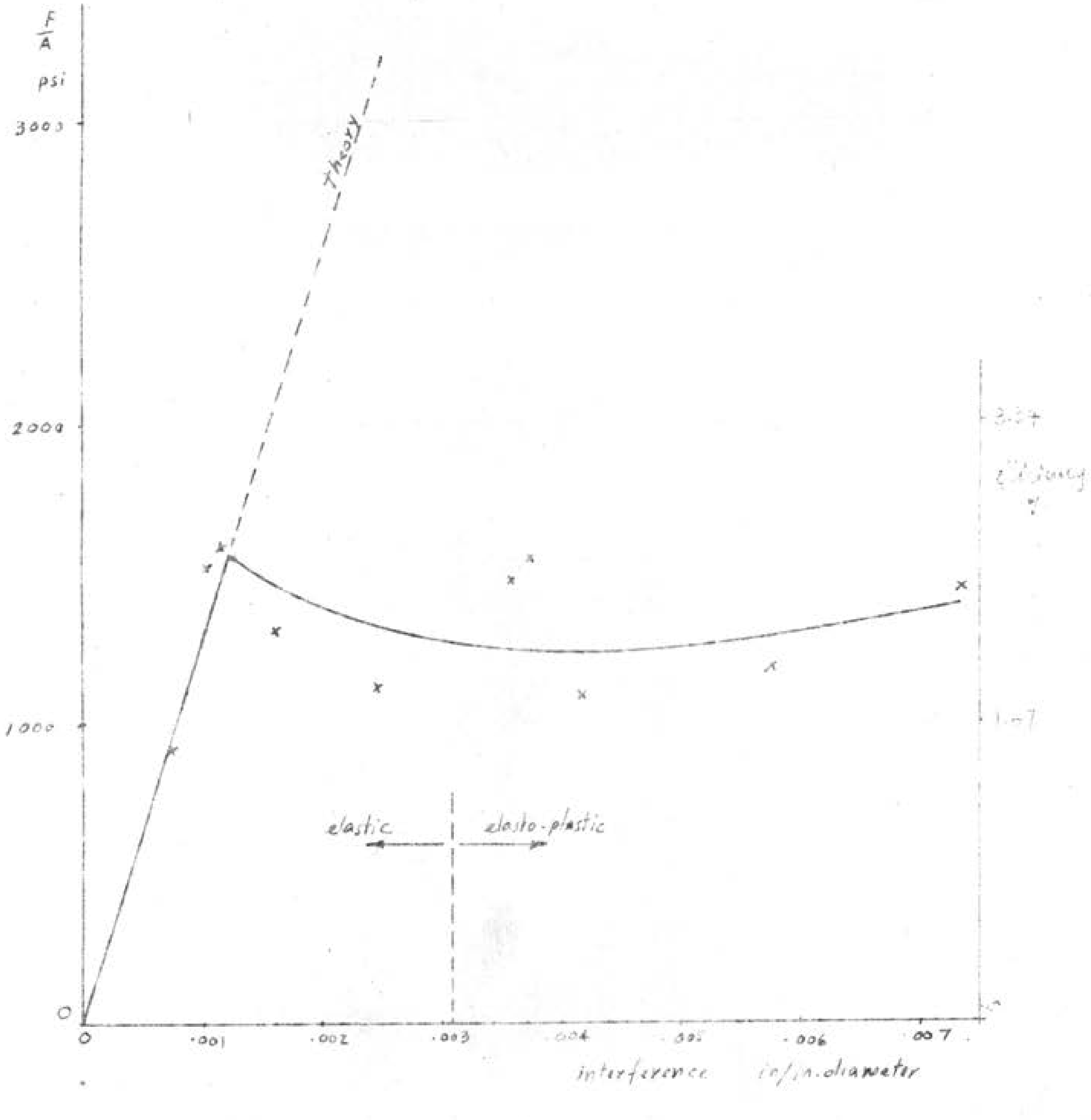
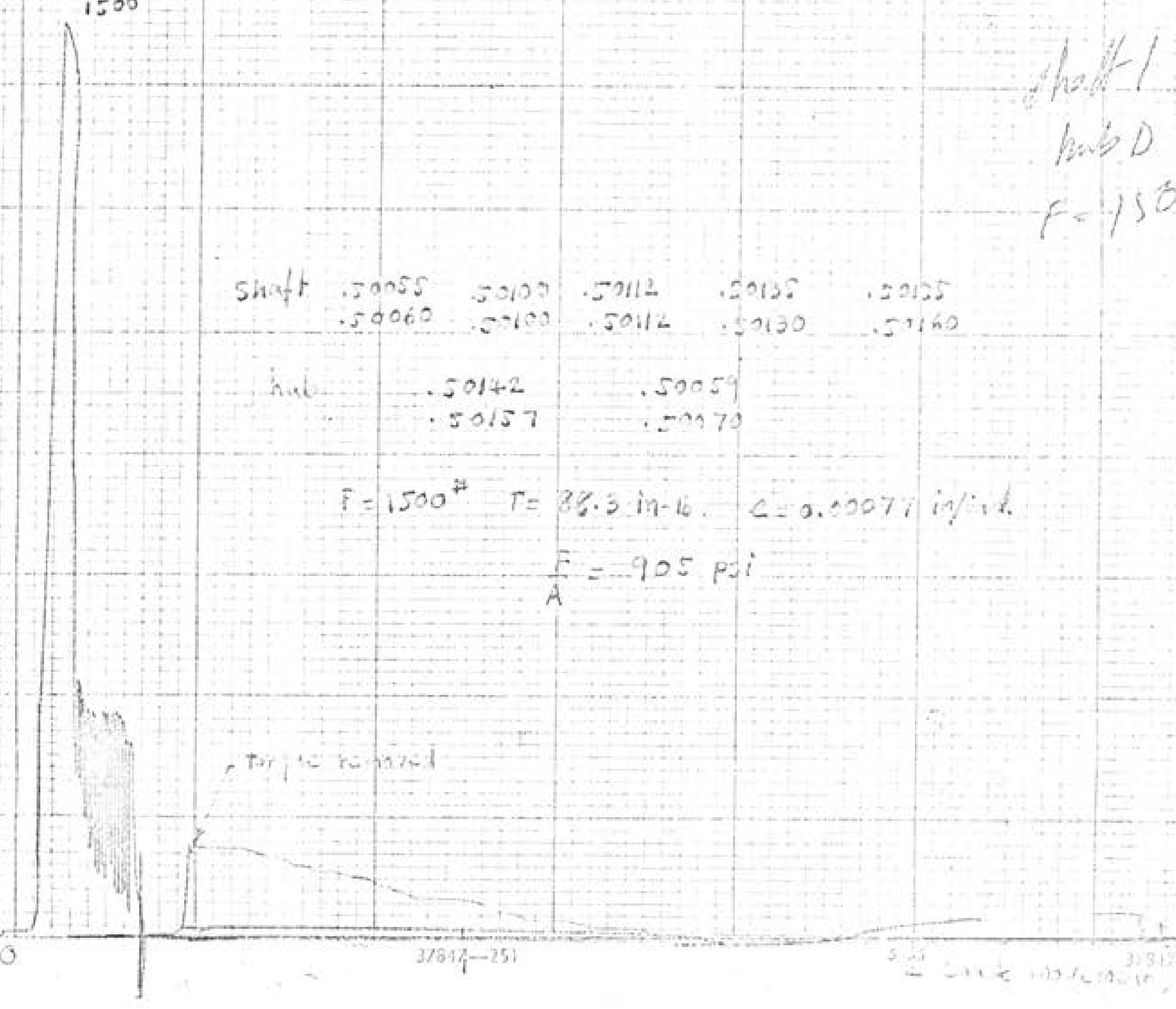


FIG. 35

SERIES 8 – BRASS – with torque.



shaft 1
hub D
F = 150

shaft .50055 .50100 .50112 .50135 .50155
.50060 .50100 .50112 .50130 .50160

hub .50142 .50059
.50157 .50070

F = 1500# T = 88.5 in-lb. e = 0.00077 in/in.

$\frac{F}{A}$ = 905 psi

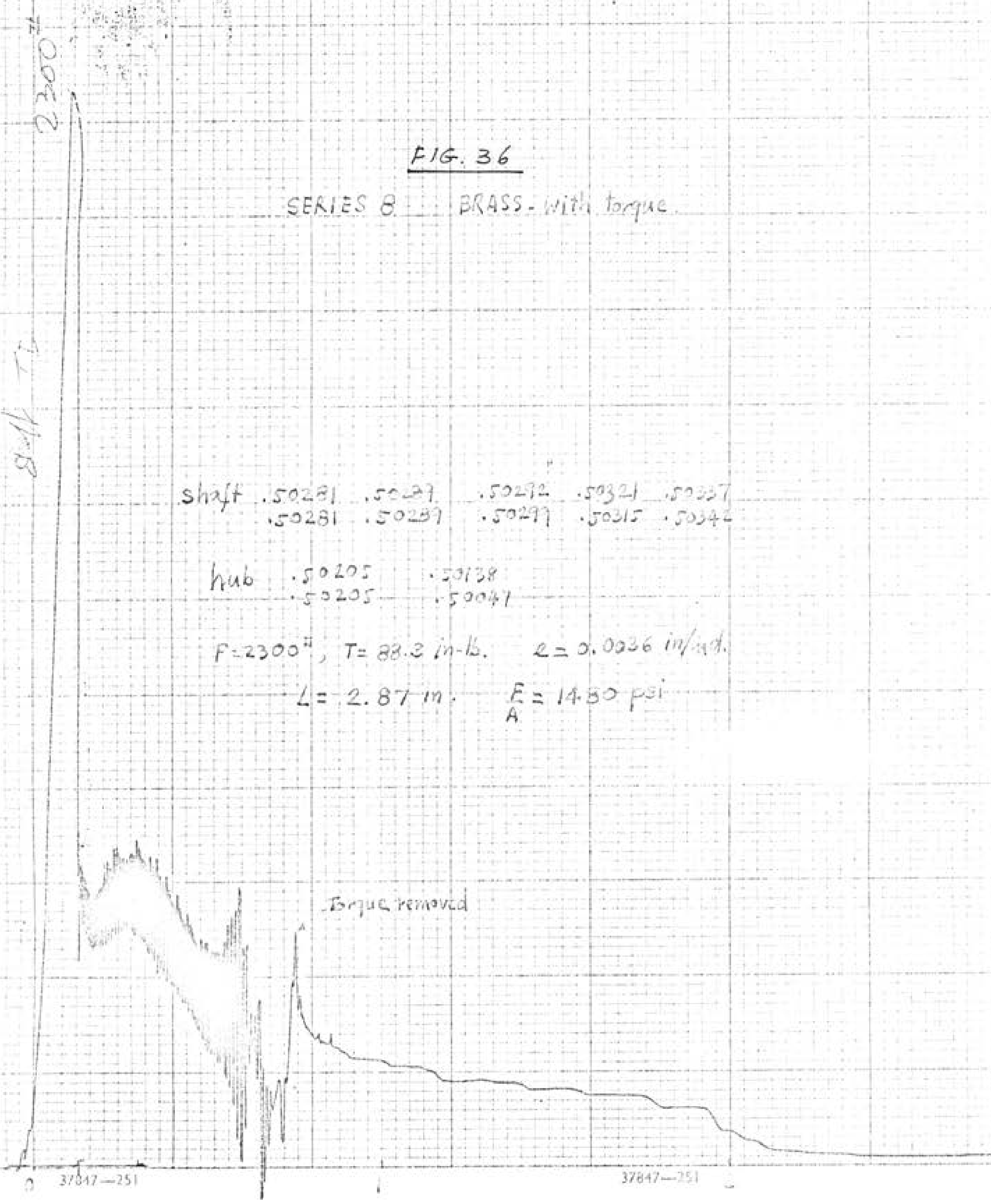


FIG. 36

SERIES 8 BRASS - with torque

shaft .50281 .50287 .50292 .50321 .50337
.50281 .50287 .50297 .50315 .50342

hub .50205 .50138
.50205 .50041

F=2300#, T= 88.2 in-lb. e = 0.0026 in/in.

L = 2.87 in. $\frac{F}{A}$ = 1450 psi