Interoffice

National Radio Astronomy Observatory

Green Bank, West Virginia

October 1, 1976

ENGINEERING MEMO # 110

To: F. Crews

From: T. Hamed

Subject: Summary of Test Results on 140-ft Telescope Brake Springs

A total of three Goodyear original brake springs and the ten new springs recently fabricated by Sterling-Detroit were tested.

One Goodyear original and one new Sterling spring were tested extensively in test jig No. 1 which used a 50-ton hydraulic jack as the actuator.

All thirteen springs were given one full extension in test jig No. 2 using the recently rebuilt Goodyear brake cylinder as the actuator and a commercial nitrogen gas storage tank as a pressure source.

In either case, the jigs, equipment and procedures used do not insure laboratory accuracy; however, we believe the accuracy is within 10% and the tests do present a fair picture of stresses and loads involved.

The two units tested in jig No. 1 were loaded in 10,000# increments up to the point where expansion at the toggle seats matched the maximum calculated from the drawings, the load being applied along the line thru the center of the spring toggle seats. Both the original and the new unit were instrumented with strain gauges to provide stress data at identical locations on the two units.

In jig No. 1, deflection of the toggle seats versus applied load was practically identical for the old and new unit with the maximum deflection resulting in a 27.43 dimension between toggle seats compared to drawing dimension of 26.038 in the relaxed position, or a total deflection of 1.4 inches which agrees closely with the full stroke deflection at toggle seats as computed from the drawings.

Deflection or expansion between centers of the 25/32 holes in the end of each limb plotted practically identical for the old and new units, with the maximum dimension being 32.44 compared to the drawing dimension of 30.412 in the relaxed position or a total deflection of $\sim$ 2 inches. The average derived from several measurements taken on the telescope with the brakes released was 32.4

The relaxed dimension in each case above was measured before and after loading and in each case returned to the same dimensions; however, these actual relaxed dimensions were in slight variance with the drawing dimension.

Stresses as measured by the strain gages were slightly higher on the new unit but in good agreement with those on the original unit. The highest stress is in the area where previous units have broken and is apparently on the order of 95% of the material yield strength as specified on the drawings, e.g. 200 Kpsi/210 Kpsi. Under the given conditions of mean stress and alternating stress values this max. stress is approaching the fatigue endurance limit (see attached fatigue limit calculations).

Not duplicated in the test but of some concern to the writer is the possibility of a greater maximum stress due to impact loading caused by the rapid setting of the brake. Some rough figures from complicated and not very accurate formulaes indicate this value may be as much as 50% of the maximum stress determined above. However, it is nearly impossible to calculate exactly where this stress would occur and whether it would add to existing stresses to produce an instantaneous stress for greater than the previously determined maximum stress.

We propose to make some strain gauge tests on an installed brake in an attempt to answer this question.

After fabrication of jig No. 2, the two units tested in jig No. 1 were the first to be tested in the new jig. All tests in this jig consisted of installing the units individually in the jig with the Goodyear cylinder and a set of toggle plates after which sufficient nitrogen pressure ($\sim$ 240 psi) was applied to the cylinder to achieve full stroke. Measurements were then taken at the toggle seats to confirm full stroke, and at the holes in each limb for comparative purposes. Pressure was then bled off and read at first sign of contraction as indicated by a previously set pair of dial indicators. From the pressure thus read the force component of the toggle seats and acting normal to the center line of the unit was computed. This compared closely (as it should) with the maximum values of the applied force in jig No. 1 as determined from strain gage readings, but not those determined by the hydraulic gauge which was apparently approximately 10% low at its maximum reading of 100K lbs.

All 13 units thus tested yielded remarkably consistent results. The measurement across toggle seats was 27.43 inches at full stroke, exactly as computed from drawings and used as the expansion limit with jig No. 1. However, the measurement center-to-center at the holes in each limb was in all units 32.6 inches versus 32.4 in jig No. 1. This was anticipated due to the added vertical component resulting from the angle at which the toggle plates apply the load.

At present I am unable to explain why the previously mentioned 32.4 inches derived from measurements taken on the telescope agrees closely with that dimension in jig No. 1, rather than the 32.6 as measured in jig No. 2 which simulates more nearly actual conditions on the telescope.

The strain gauges on the one old and one new unit, first read on jig No. 1, were again read on jig No. 2 under full expansion and were generally slightly higher as could be expected, due again to the added vertical component of the applied force. Maximum occurred at the same point but was very near 210 Kpsi (the yield point of the material) rather than 200 Kpsi, as determined in jig No. 1. The old and new unit were in fairly close agreement.

In conclusion, it would appear that the new springs are quite similar to the old, at least in performance and stress levels but with unknown fatigue resisting capabilities which will be revealed only by time.

It also appears that in any case the springs are stressed to at least the static limit in tension in one location at minimum; and that they are working over the fatigue limit in this one location (see attached fatigue limit calculation).

The effect, if any, of rapid application of the brakes on the maximum stress or fatigue limit is yet unknown.

JH/bbs
cc: B. Peery
H. Brown

[illegible] BRAKE SPRING

COMPUTATION OF FATIGUE LIMIT

Goodman Theory ✓

Y/U = .88

yeild = 210 Kpsi
Ult = 240 Kpsi

From tests:

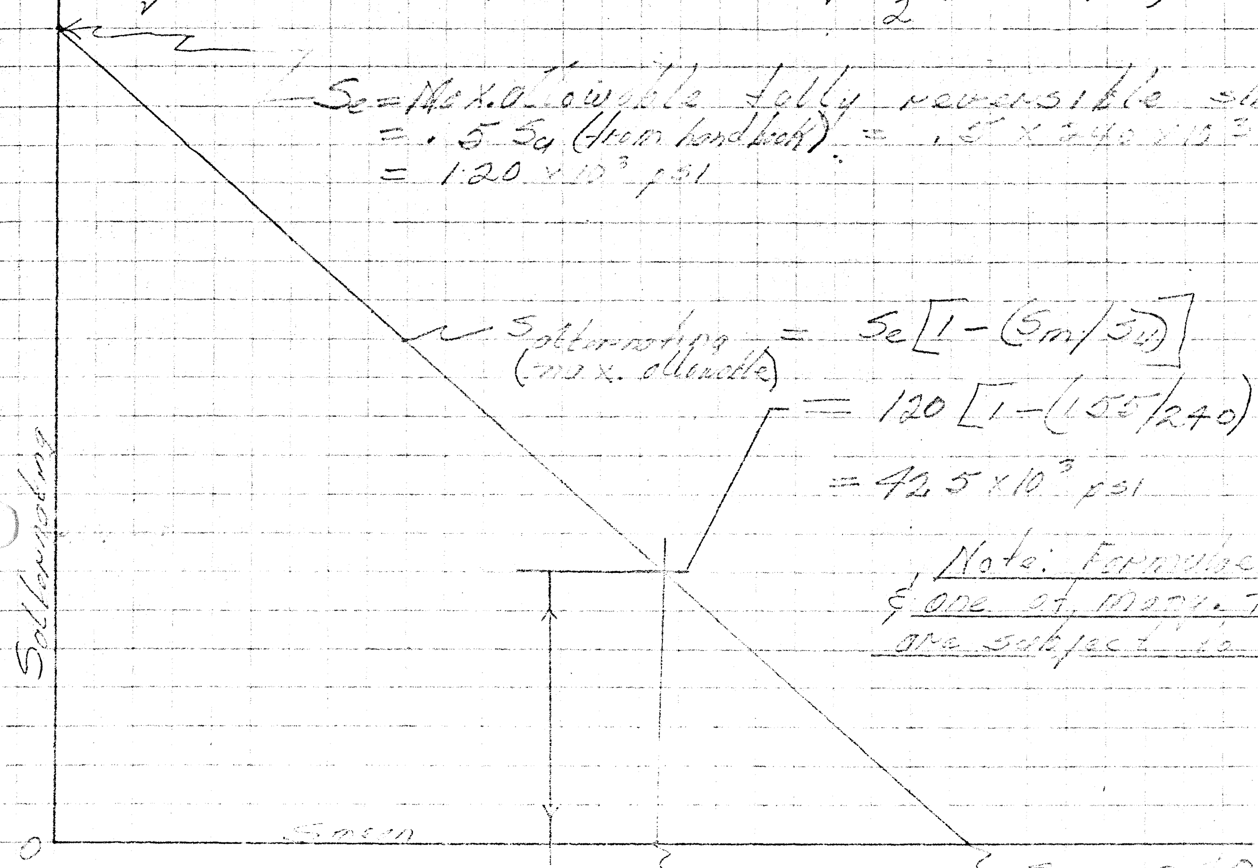
$S_{max} = +210$ Kpsi (brake released)
$S_{min} = +100$ Kpsi (brake applied)

Computation: (Goodman)

$S_{mean} = \frac{1}{2}(S_{max} + S_{min}) = \frac{210+100}{2} = 155$K

Diagram: (Goodman)

$S_{alternating} = \frac{1}{2}(S_{max} - S_{min}) = \frac{210-100}{2} = 55$K



S_e = Max. allowable fully reversible stress for 10^5 cy.
$= .5\, S_u$ (from handbook) $= .5 \times 240 \times 10^3$
$= 120 \times 10^3$ psi

$S_{alternating}$ (max. allowable) $= S_e[1 - (S_m/S_u)]$
$= 120[1 - (155/240)]$
$= 42.5 \times 10^3$ psi

Note: Formula is [illegible] & one of many. Test results are subject to [illegible]

$S_u = 240$K

Given $S_{mean} = 155 \times 10^3$ psi
Then allowable $S_{alt.} = 42.5 \times 10^3$ psi

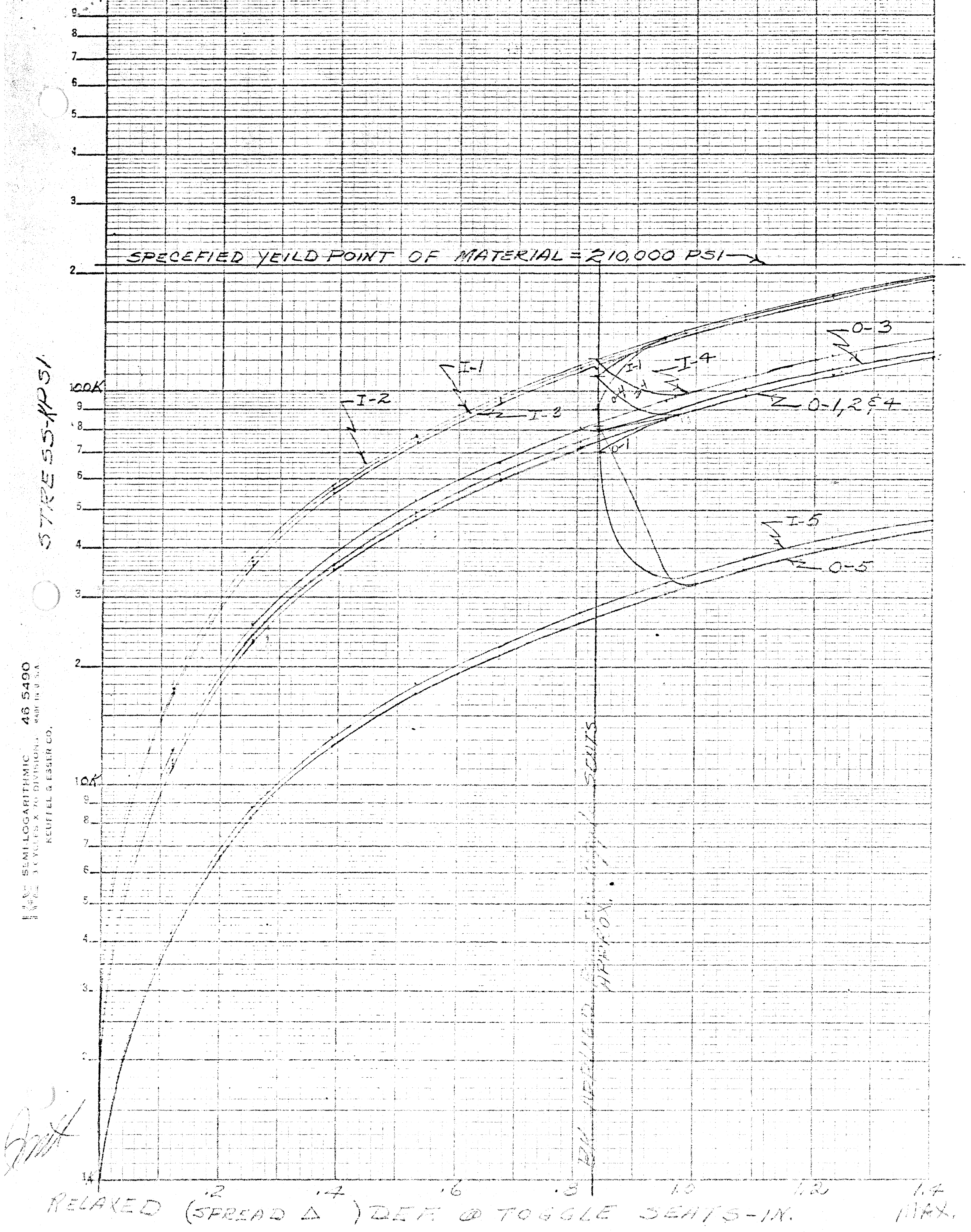
Actual $S_{alt} = 55 \times 10^3$ psi

∴ S_{alt} (actual) > S_{alt} (allowable) (for 10^5 cycles)

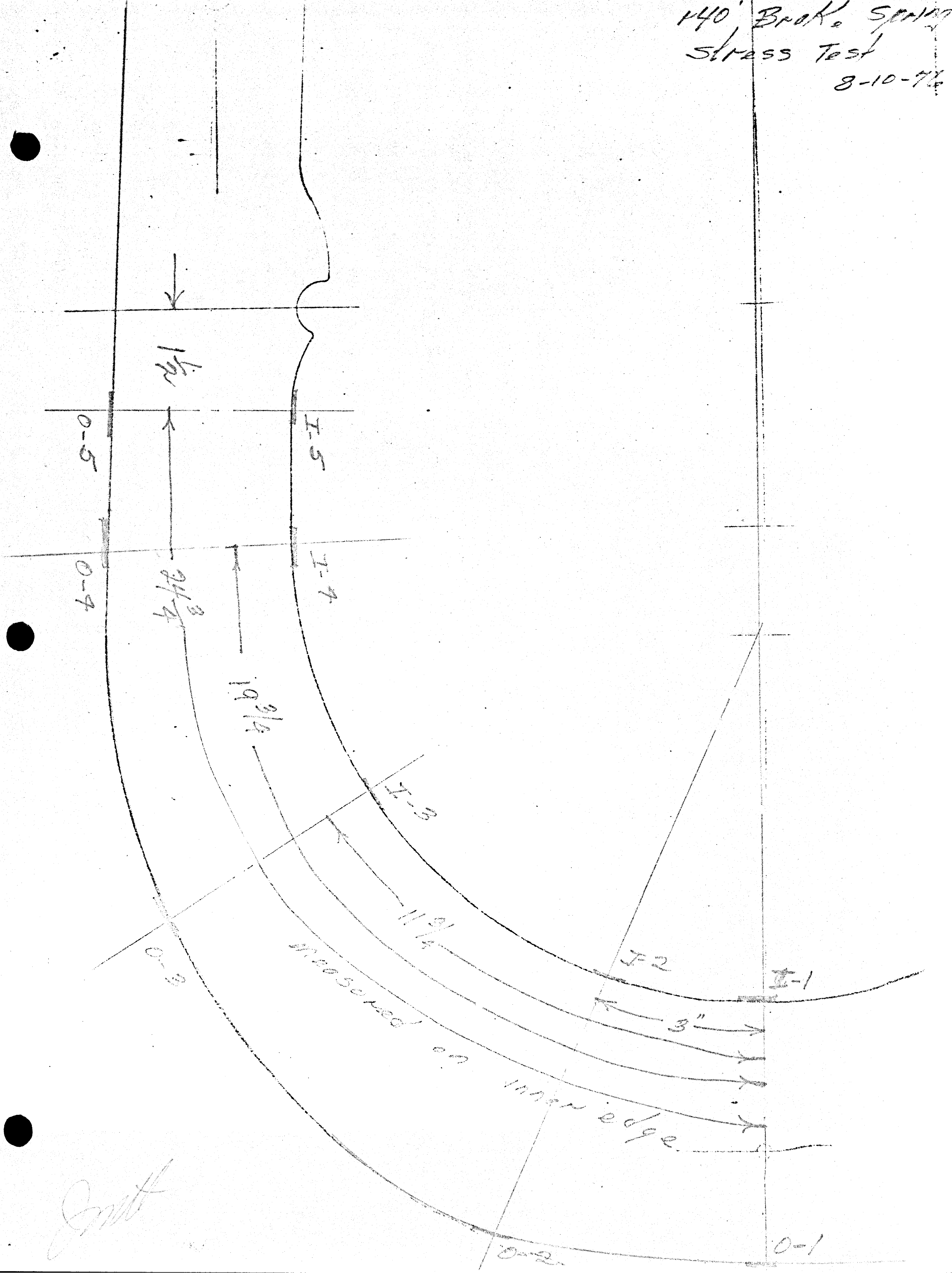
[illegible]

Note: above does not include possibility of change in Smax, or Smin on cyclic rate due to rapid [illegible] of brake.

140 BRAE SPRING-STRESS TEST 8-10-76



140' Brake Spring
Stress Test
8-10-7?



140 Drone Spring-Stress Test 8-10

INNER

Load-K	I-1 #1	I-2 #2	I-3 #3	I-4 #4	I-5 #5	
→	590	590	530	406	140	Stress =
10 .119						
20 .254	1232	1236	1213	852	293	micro strain x 30
30 .389	1874	1880	1835	1293	443	
40 .529	2550	2560	2500	1760	603	
50 .672	3196	3204	3128	2204	755	
60 .805	3864	3875	3784	2670	918	
70 .95	4575	4586	4480	3168	1092	
80 1.083	5707	5221	5100	3516	1247	
90 1.232	failed	5915	5780	4104	1419	
95						
100 1.4	—	6555	6411	4537	1577	
			6510	[illegible]	1620	Retake 8-11
Applied	3406	3430	3669	3327	2937	@ 31,81
	2570	3530	2790	4030	3100	[illegible]
	4260	4670	4060	3230	1120	Load released

OUTER

	O-1 6	O-2 7	O-3 8	O-4 9	O-5 10
5					
10	-371	-377	-386	-371	-134
20	-769	-777	-804	-775	-278
30	-1168	-1130	-1218	-1175	-419
40	-1588	-1604	-1655	-1507	-570
50	-1981	-2090	-2066	-1996	-715
60	-2402	-2421	-2500	-2418	-865
70	[illegible]	[illegible]	[illegible]	[illegible]	-1030
80	[illegible]	[illegible]	3364	3260	-1179
90	[illegible]	[illegible]	[illegible]	[illegible]	-1342
95					
100				[illegible]	-1493
					1540
Applied	-2195	[illegible]	-2530	[illegible]	-2750
					-2725
					[illegible]

Retake 8-11 @ [illegible]

@ [illegible]

[illegible] = 33,173 ([illegible] 3.137)

$-16,516^{4} = 16,912$ 3.137

[illegible] Dev. - 100

.25 coeff. of friction assumed

33,110 [illegible]

[illegible]

140' Brake Spring-Load Test → Δ=1.37

8-3-76

Design Dim.: Relaxed: out-to-out @ toggle = 26.038 } c-c @ Pins = 30.412 } Δ=[illegible]
Max.: " " = 27.408 } " " = 32.412 }

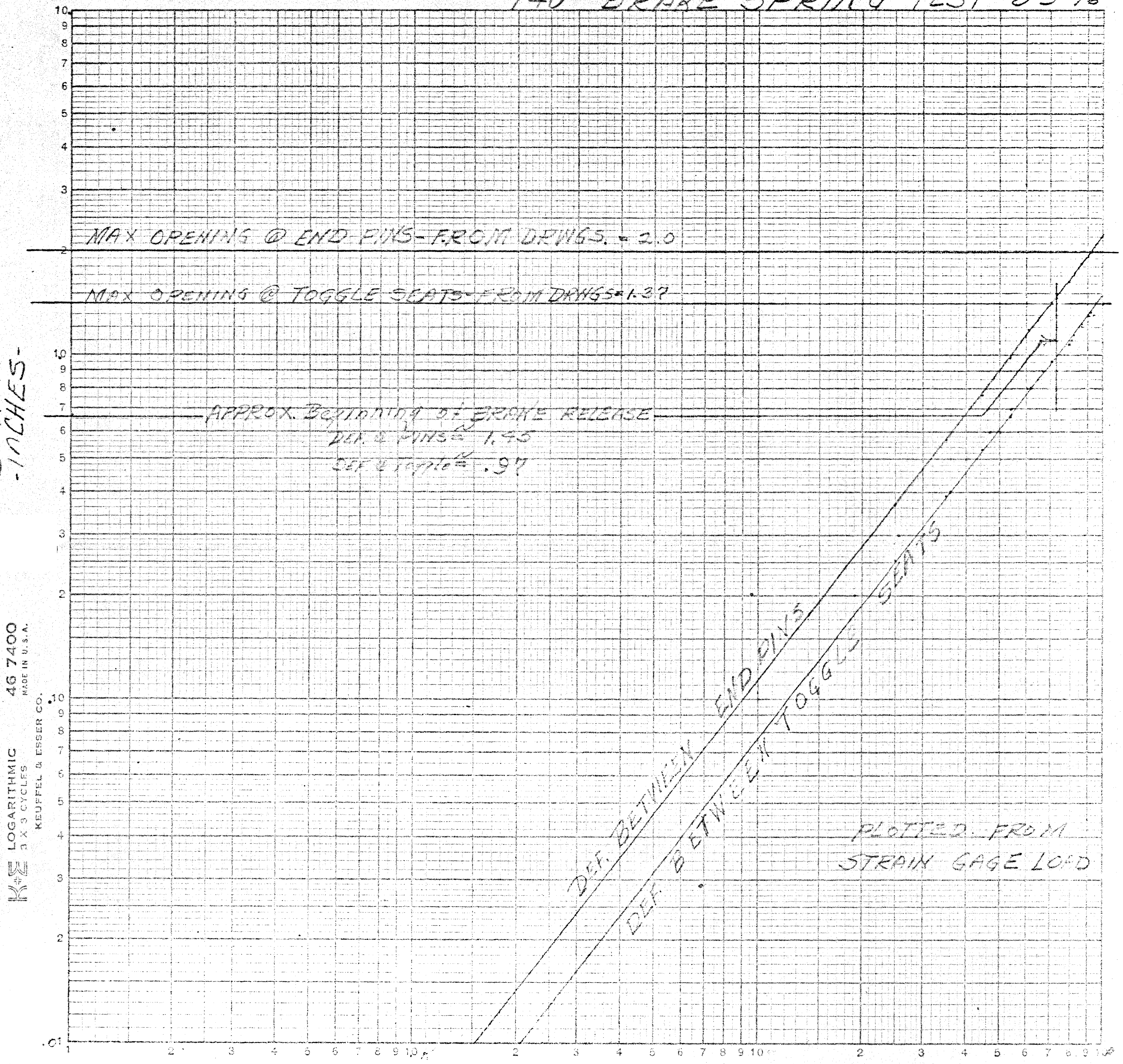
① Strain Gage-Rdg.	② LOAD ① x 35.0	③ Hyd. Gage	④ Pin-to-Pin @ Toggle	⑤ out-to-out ④+3.0 @ toggle	⑥ Pin-to-Pin @ End	⑦ c-c Pins ⑥+0.781	⑧ Δ @ toggle	⑨ Δ @ Pins
-0-	-0-	-0-	23.075	26.075	29.686	30.467	—	—
400	14,000	10 K	23.194	26.194	29.860	30.641	.119	.174
710	24,850	20 K	23.329	26.329	30.058	30.839	.254	.372
1000	35,000	30 "	23.464	26.464	30.258	31.039	.389	.572
1267	44,345	40 "	23.604	26.604	30.460	31.241	.529	.774
1534	53,690	50 "	23.747	26.747	30.679	31.460	.672	.993
1769	61,915	60 "	23.880	26.880	30.880	31.661	.805	1.194
* 2011	70,385	69 "	24.023	27.023	31.095	31.876	.948	1.409
2255	78925	80 "	24.158	27.158	31.308	32.089	1.083	1.622
2354	82390	85 "	24.219	27.219	31.399	32.180	1.144	1.713
2486	87010	90 "	24.307	27.307	31.512	32.293	1.232	1.826
2575	90125	94 "	24.353	27.353	31.606	32.382	1.278	1.920
2646	92610	98 "	24.392	27.392	31.662	32.443	1.31[illegible]	1.976
Do Not Exceed	Limit →		24.408	27.408	31.63	32.412	1.37	2.0[illegible] '053

BK. Release - calculated from Drwg's & Measuring. - 31.08 31.86

*. Nearest to brake release

Released after last Reading → 23.077

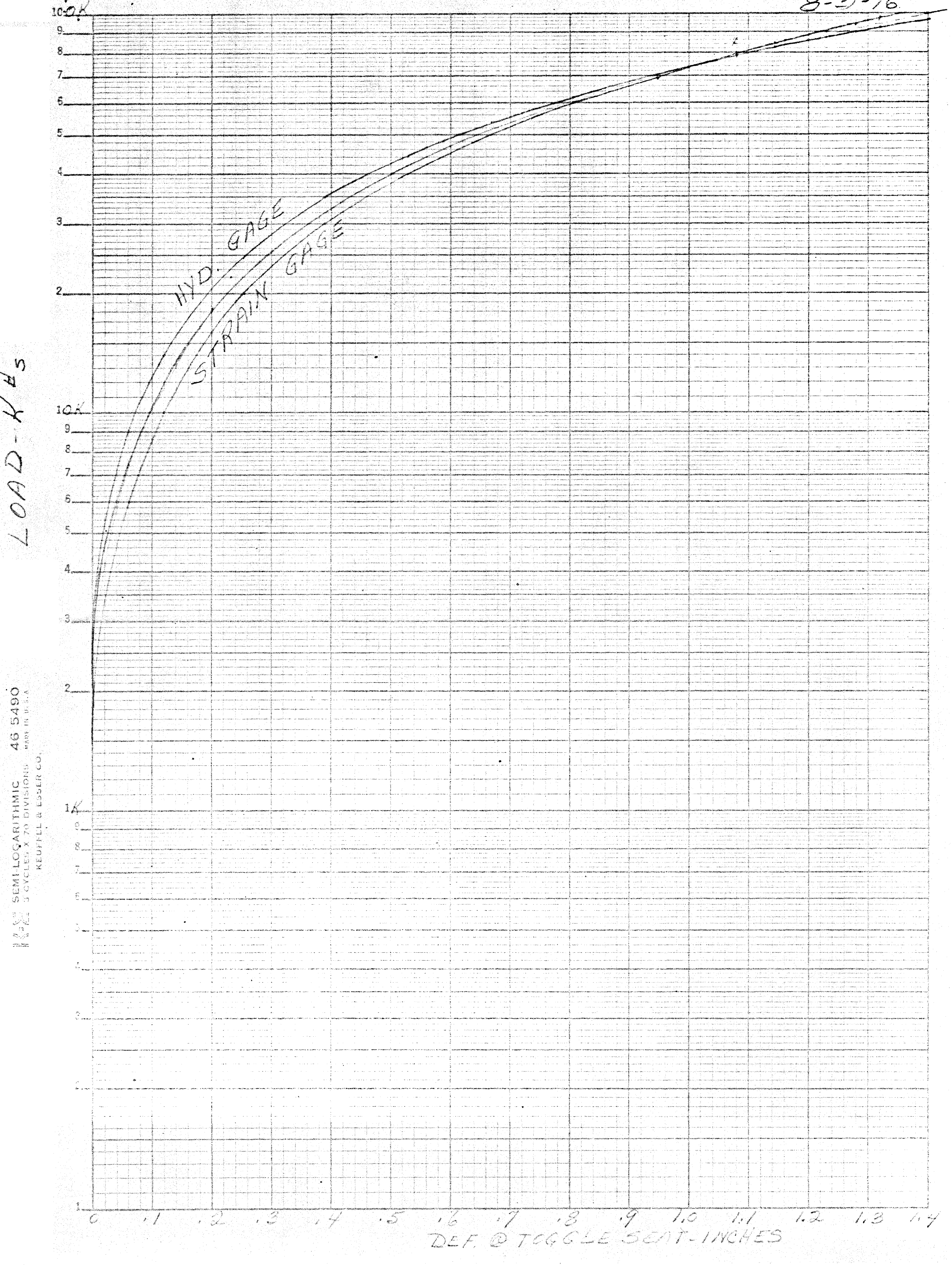
140 BRAKE SPRING TEST 8-3-76



LOAD APPLIED ON LINE OF TOGGLES

K-#s

8-3-76



LOAD - K #s
HYD. GAGE
STRAIN GAGE
100K
10K
1K
DEF. @ TOGGLE SEAT - INCHES
0
.1
.2
.3
.4
.5
.6
.7
.8
.9
1.0
1.1
1.2
1.3
1.4
SEMI-LOGARITHMIC 46 5490
3 CYCLES X 70 DIVISIONS MADE IN U.S.A.
KEUFFEL & ESSER CO.

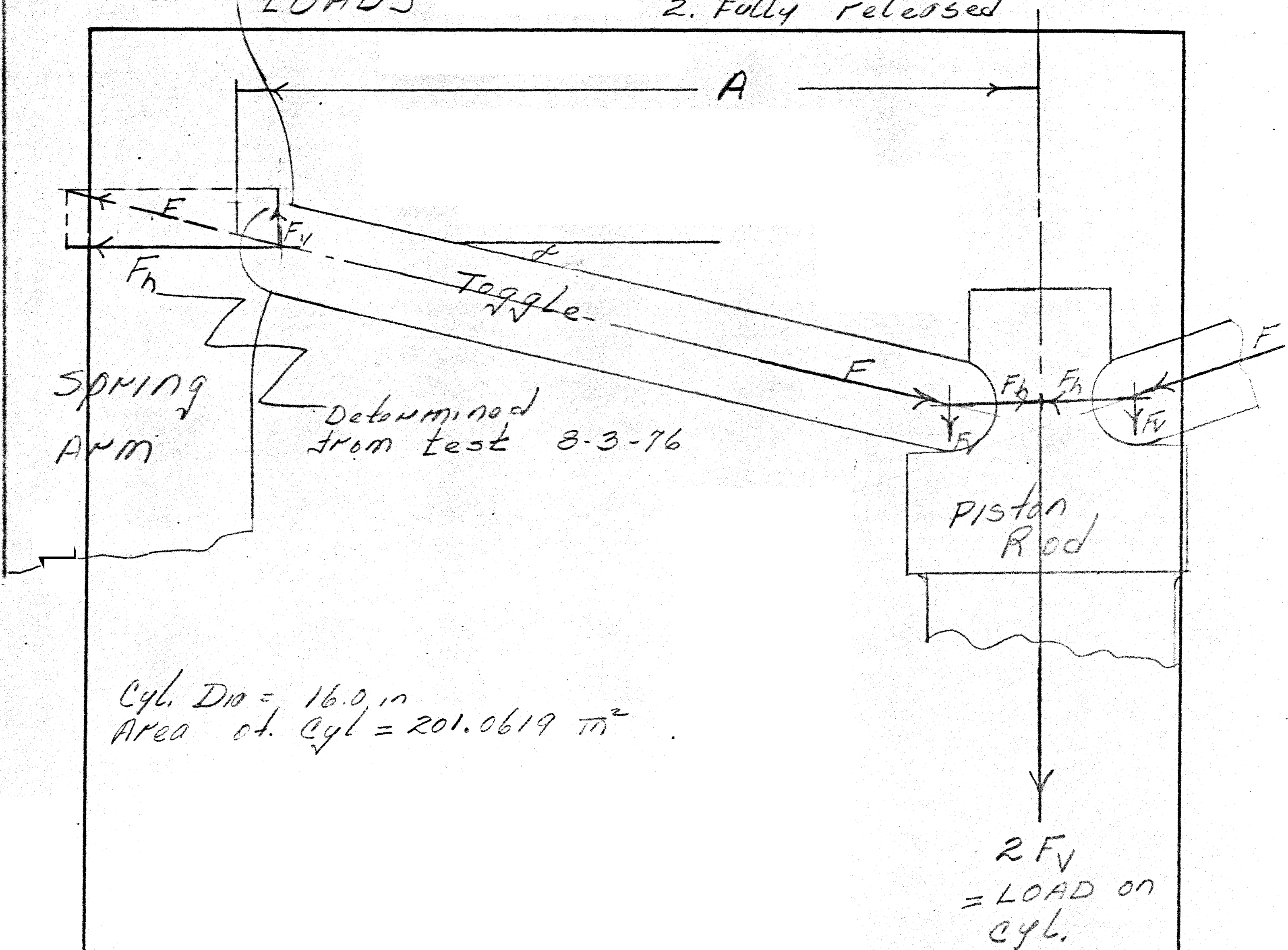
NATIONAL RADIO ASTRONOMY OBSERVATORY
POST OFFICE BOX 2
GREEN BANK, WEST VIRGINIA 24944
TELEPHONE ARBOVALE 456-2011

REPORT NO. ________
CONTRACT NO. ________
PAGE ____ OF ____
DATE ________

PROJECT: 140' Brake Spring

SUBJECT: LOADS

1. @ beginning of release
2. Fully released



Cyl. Dia = 16.0 in
Area of Cyl = 201.0619 in²

PREPARED BY ________ APPROVED BY ________ SUBMITTED BY ________

1. Load @ beginning of release. – From 1 spring

From test 8-3-76: $2A = 26.038 + .97 = 27.008$

$A = 13.504$

From data sheet:

$$\cos\alpha = \frac{A - 1.55 - .75}{11.58} = \frac{11.204}{11.58} = .9675$$

$\alpha = 14.6406°$

From test:

$F_h \cong 73K^{\#}$ $F = \frac{F_h}{\cos\alpha} = 75.45K$

$F_v = F_h \tan\alpha = 19.07K$

Tot. Ld. on Cyl - 1 spring = $2F_v = 38.14K$

For 10 springs Load = 381,400#

Pressure reqd to hol = L/Pis Area = 381.4K/201.0619

$\cong 1897$ psi

---

2. Load @ Full release:

$2A = 27.408$
$A = 13.704$

From data sheet: $\alpha \cong 10°$

From test: $F_h \cong 95K$

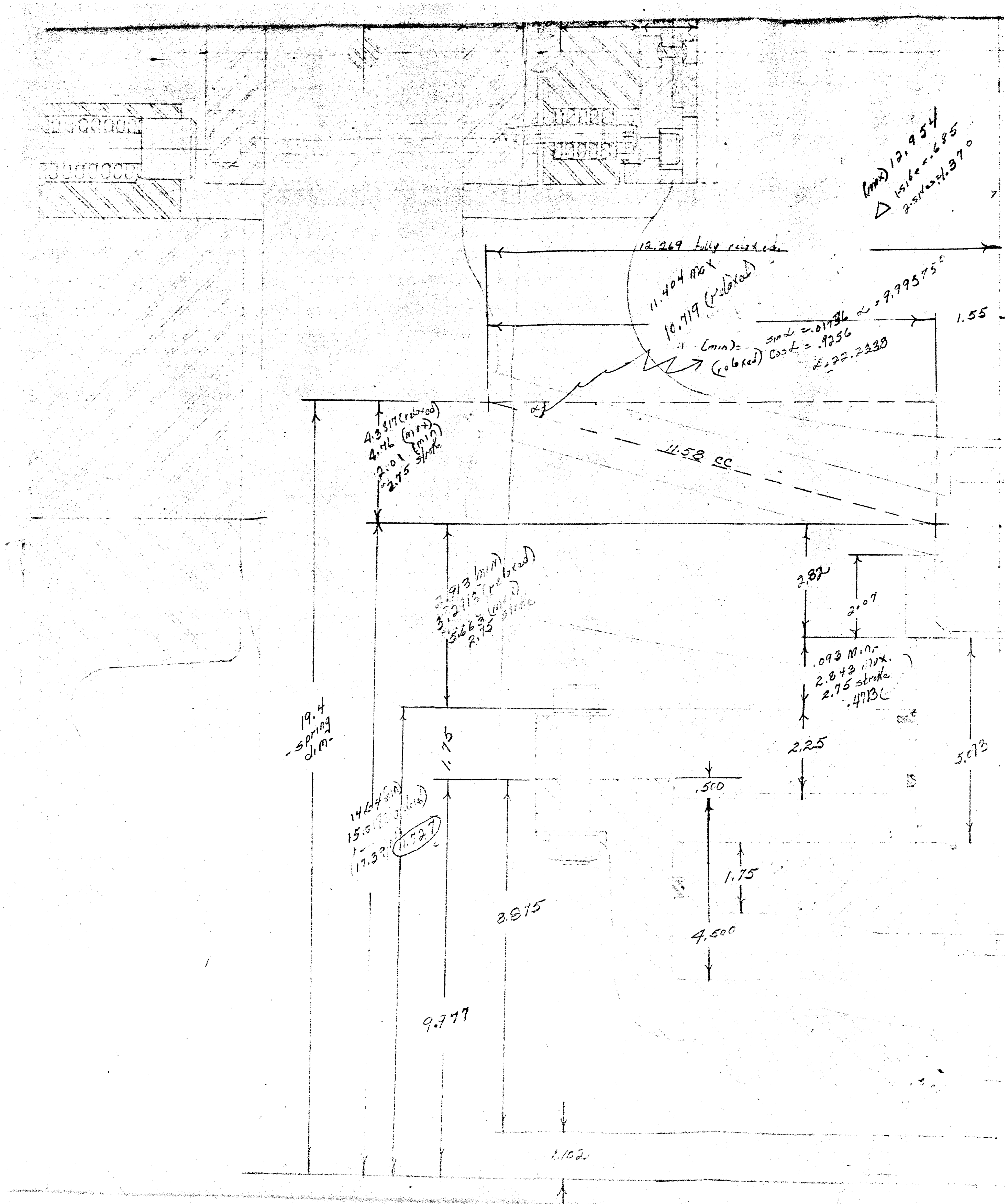
$F = F_h/\cos\alpha = 96.466K$

$F_v = F_h \tan\alpha = 16.75K$ $2F_v = 33.5K$

Load on Cyl - 1 spring = 33.5K

10 " = 335,000

Press reqd to hol = L/A $\cong$ 1666. psi



12.269 fully relaxed
11.404 max
10.719 (relaxed)
(max) 12.954
1.55
11.58 cc
19.4
spring dim.
2.82
2.07
.093 Min.
2.75 stroke
2.25
5.073
1.75
.500
1.75
4.500
8.875
9.777
1.102

9/22/76
G.M.P.