SETTLEMENT—TIME CURVES

(FROM NORMAL 1-DIMENSIONAL CONSOLIDATION TEST.)

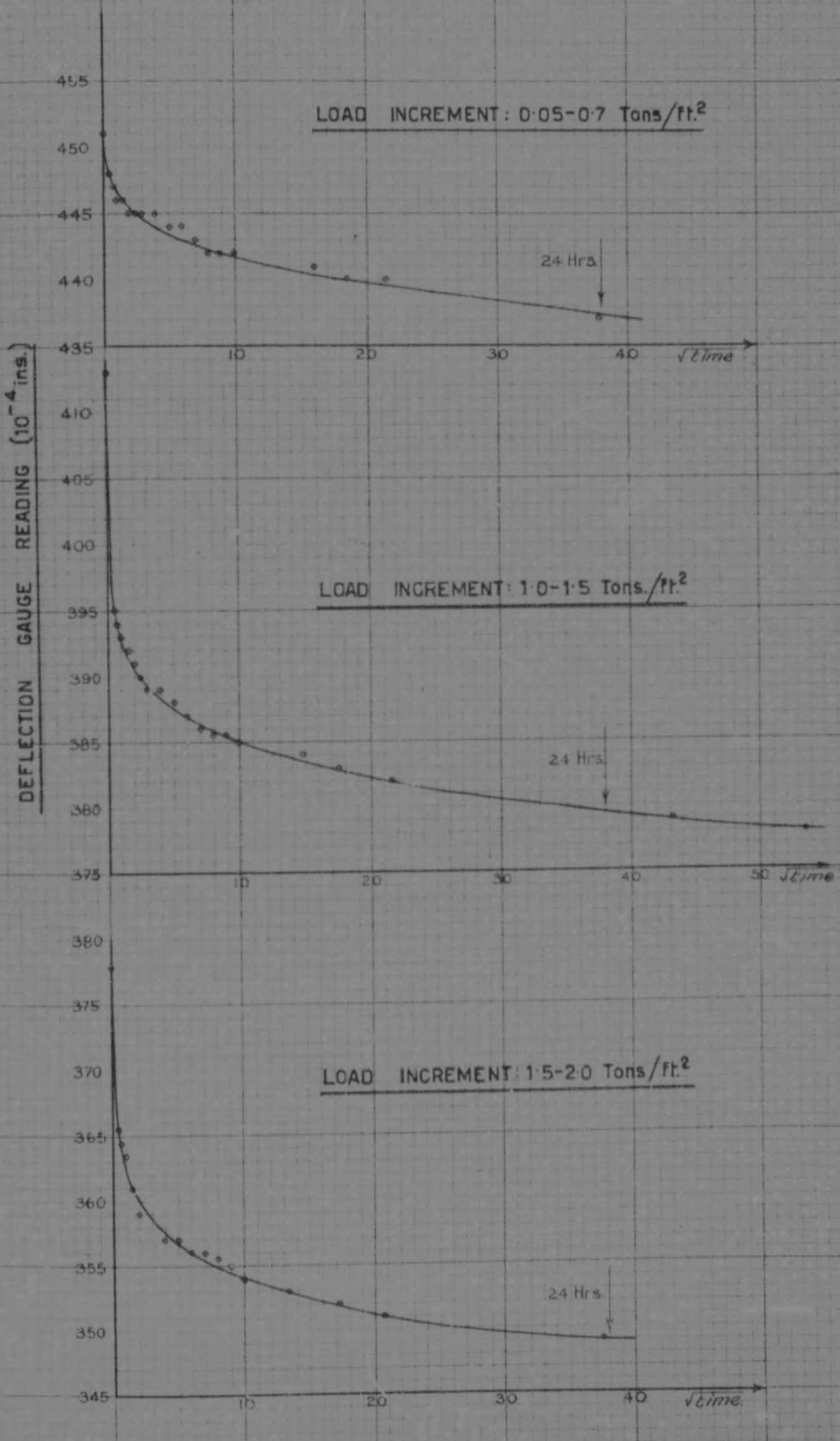


FIG. 24

This having been done, a recording of slug movement due to the combined effects of leakage and spindle entry was carried out according to the procedure described under "Test Apparatus". In addition, however, time readings were also taken in order to determine the rate of strain under these circumstances and so to ascertain the possible effect of the particular chamber pressure used on the nominal rate of strain previously established. A rate of strain was determined in this manner for each test and will hereafter be referred to as the Calibrated rate of strain.

After this combined recording, a further leakage measurement was finally made, similar to the ones previously carried out.

Then with the capillary tube circuit cut out and only the main fluid supply circuit cut in, the chamber pressure was released and the cell fluid allowed to drain back into the fluid reservoirs. The failed sample was carefully removed and a moisture content determination carried out.

According to this procedure, tests falling into each of the six type categories previously mentioned were carried out. Shear strength values for tests in the same speed category were plotted in the form of Mohr Circles and any test showing poor fit was discarded and a repeat test subsequently performed.

At the completion of the test series it was necessary to determine the cross-sectional area of the capillary tube used. This was done by obtaining the weight of mercury required to fill the tube neatly over its whole length and measuring the length of the tube accurately. From these measurements the volume of mercury required to fill the tube and hence the volume of the tube and its average cross-sectional area could be calculated. (See Item1, Appendix V).

7.6 Test Observations and Curves

On the following pages, test observations and curves are given for the results of six tests. The results of each test appear in the following sequence:

1. Tabular presentation of the following data:
   (a) Leakage measurement immediately before test.
   Denoted: "Before test".
   (b) Leakage measurement immediately after test.
   Denoted: "After test (1)".
   (c) Combined leakage + spindle entry measurement (after test).
   (d) Further leakage measurement. Denoted: "After test(2)".

2. Presentation of the curves for the above data.

3. Tabular presentation of the main test observations under suitable headings, with reduction of these observations.

4. Graphical presentation. Rate of Strain determinations:
   (a) After test: spindle entry against resistance of relevant pressure only, i.e. Calibrated Rate of Strain.
   (b) During test: spindle entry against resistance of relevant pressure as well as resistance of sample to compression, i.e. Actual Rate of Strain during test.

5. (a) Stress:Strain curve.
   (b) Young's Modulus:Strain Curve.

6. Tabular presentation: Calculation of Instantaneous values of Young's Modulus as a secant modulus over the initial range of the Stress:Strain curve.

7. Slug ..../

7. Slug movement : Deflection curve for the three combined effects during an actual test. This curve is headed: "Main slug movement : deflection curve".

Then, following on these sets of test results for each of the six tests performed, are:

8. Summary in Tabular Form of the six Triaxial Test results, i.e. the Shear Strength results required for constructing the Mohr Circles for each test.

9. Two sets of Mohr Circles, corresponding to the results of tests within the same speed categories.

The following points should, however, be especially noted:

(i) Triaxial chamber pressure values could be read on the pressure gauge provided for this purpose, but, as a check and for more accuracy, the height of a mercury column balanced by the chamber pressure was measured in each case. This pressure as a head of mercury was then converted to an equivalent pressure in lb/sq.in. The chamber pressure value read on the triaxial pressure gauge will hereafter be referred to as the "Nominal" chamber pressure and the value obtained from the measured head of mercury will be referred to as the "Actual" chamber pressure.

(ii) With regard to the deviator stress calculation in item (3) mentioned above : The initial sample area used was taken to be the cross-sectional area of the cutting cylinder, i.e. the area of a circle 1½" in diameter. This gave a figure of 1.77sq.in. The actual cross-sectional area of a sample may have been slightly less than this, thus leading to slightly greater stresses, but this is considered to be of little consequence for the purposes of these tests. However, the effect of lateral sample strain during compression, i.e., an increase in sample diameter and hence cross-sectional area, was taken into account by applying a factor:

1-(longitudinal strain), i.e. 1-ε

The "corrected stress" was thus obtained by using the initial sample area of 1.77 sq.in. divided by the appropriate value of this factor in each case.

(iii) Stress:Strain Curves (item 5(a)) and Main Slug Movement:Deflection Curves (item 7): These curves were in the first instance drawn fully according to the data observed during the tests. In most cases the presence of "bedding-in" effects at the start of tests was clearly revealed by both these curve types. In the case of Stress:Strain curves, the strain due to "bedding-in" effects was determined by producing the initial approximately linear portion of the curve backwards to intersect the strain axis. The intercept on this axis then represents the strain due to "bedding-in" effects. This information was subsequently used for constructing the Young's Modulus: Strain curves. In the case of the Main Slug Movement:Deflection curves, the unusual peak-shaped "bedding-in" effect observed in some instances, is fully discussed in Section 7 of this Chapter. With the final presentation of test results (See Chapter8,Figs. 49,50,51 and 52) "bedding-in" effects have been ignored.

(iv) Youngs' Modulus:Strain Curves (item 5(b)): These curves are based on instantaneous values of Young's Modulus calculated as a secant modulus, i.e., working from point to point along the Stress:Strain curve but always from the corrected start of the curve, i.e. as obtained after eliminating "bedding-in" effects. For this reason the start of all Young's Modulus:Strain curves is displaced to the right of the actual start of the corresponding Stress:Strain curves.

7.7 Discussion ....../

TEST No 1.

DATE PERFORMED 18/2/57

SAMPLE CONSOLIDATED FOR 22^{hrs} 15^{min} PRIOR TO TEST.

TIME START OF TEST 4/38 P.M. TEMPERATURE 27.5 °C

TIME END OF TEST 5/54 P.M. TEMPERATURE 27.25 °C

NOMINAL σ_3 CHAMBER PRESSURE 30 LB/SQ IN

HEAD OF MERCURY 58⅜ INCHES, HENCE:

ACTUAL σ_3 CHAMBER PRESSURE 28.615 LB/SQ IN

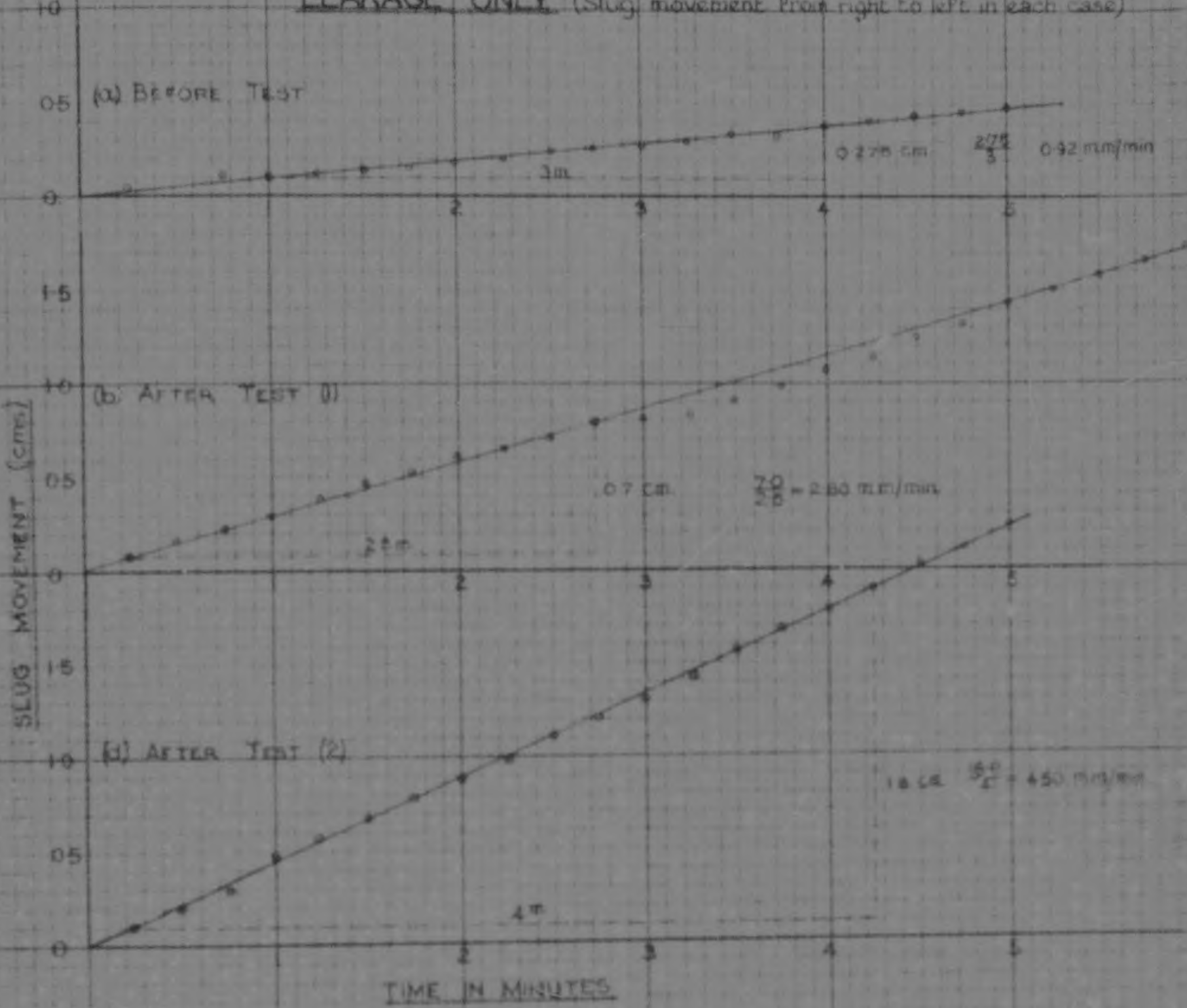
NOMINAL RATE OF STRAIN 0.00256 INCHES/MINUTE

TEST Nº 1 : LEAKAGE MEASUREMENTS.

(A) MEASUREMENT OF SLUG MOVEMENT DUE TO LEAKAGE ONLY. BEFORE TEST TEMP 27.5°C TIME 4/25 p.m.		(B) MEASUREMENT OF SLUG MOVEMENT DUE TO LEAKAGE ONLY. AFTER TEST (1) TEMP: 27.25°C TIME: 5/55 p.m.		(C) MEASUREMENT OF SLUG MOVEMENT DUE TO COMBINED EFFECTS OF LEAKAGE & SPINDLE ENTRY (AFTER TEST) TEMPERATURE 27.25°C TIME: 6/05 p.m.			(D) MEASUREMENT OF SLUG MOVEMENT DUE TO LEAKAG ONLY. AFTER TEST (2) TEMP 2[illegible].25°C TIME 6/[illegible]0 p.m.	
TIME min sec	VOLUME SCALE cm	TIME min sec	VOLUME SCALE cm	DEFLECT GAUGE 10^{-3} in	VOLUME SCALE cm	TIME min sec	TIME min sec	VOLUME SCALE cm
0 00	21.60	0 00	8.90	00 40	7.40	0 00	0 00	6.60
15	21.575	15	8.825	41	7.35		15	6.50
30	21.525	30	8.725	42	7.30		30	6.40
45	21.50	45	8.675	43	7.30		45	6.30
1 00	21.50	1 00	8.60	44	7.30		1 00	6.125
15	21.475	15	8.50	45	7.275	2 02	15	6.025
30	21.475	30	8.425	46	7.225		30	5.925
45	21.45	45	8.375	47	7.225		45	5.825
2 00	21.425	2 00	8.30	48	7.20		2 00	5.725
15	21.40	15	8.25	49	7.2[illegible]		15	5.625
30	21.375	30	8.20	50	7.175	4 00	30	5.50
45	21.35	45	8.125	51	7.175		45	5.40
3 00	21.325	3 00	8.10	52	7.15		3 00	5.30
15	21.30	15	8.075	53	7.125		15	5.175
30	21.275	30	8.00	54	7.10		30	5.05
45	21.[illegible]75	45	7,90	55	7.10	6 06	45	4.925
4 00	21.225	4 00	7.825	56	7,075		4 00	4.875
15	21.20	15	7.75	57	7.05		15	4.70
30	21.175	30	7.65	58	7.025		30	4.575
45	21.15	45	7.575	59	7.00		45	4.475
5 00	21.125	5 00	7.475	60	7.00	8 04	5 00	4.375
		15	7.40	61	6.975			
		30	7.325	62	6.975			
		45	7.25	63	6.95			
		6 00	7.175	64	6.925			
				65	6.90	10.02		
				66	6.90			
				67	6.90			
				68	6.90			
				69	6.85			
				70	6.85	11 56		
				71	6.825			
				72	6.80			
				73	6.80			
				74	6.80			
				75	6.80	13 47		
				76	6.775			
				77	6.775			
				78	6.75			
				79	6.725			
				80	6.725	15 44		
				81	6.70			

TEST No 1: LEAKAGE MEASUREMENTS

DETERMINATIONS OF RATE OF SLUG MOVEMENT DUE TO LEAKAGE ONLY (Slug movement from right to left in each case)



(c) DETERMINATION OF RATE OF SLUG MOVEMENT DUE TO COMBINED EFFECTS OF LEAKAGE & SPINDLE ENTRY

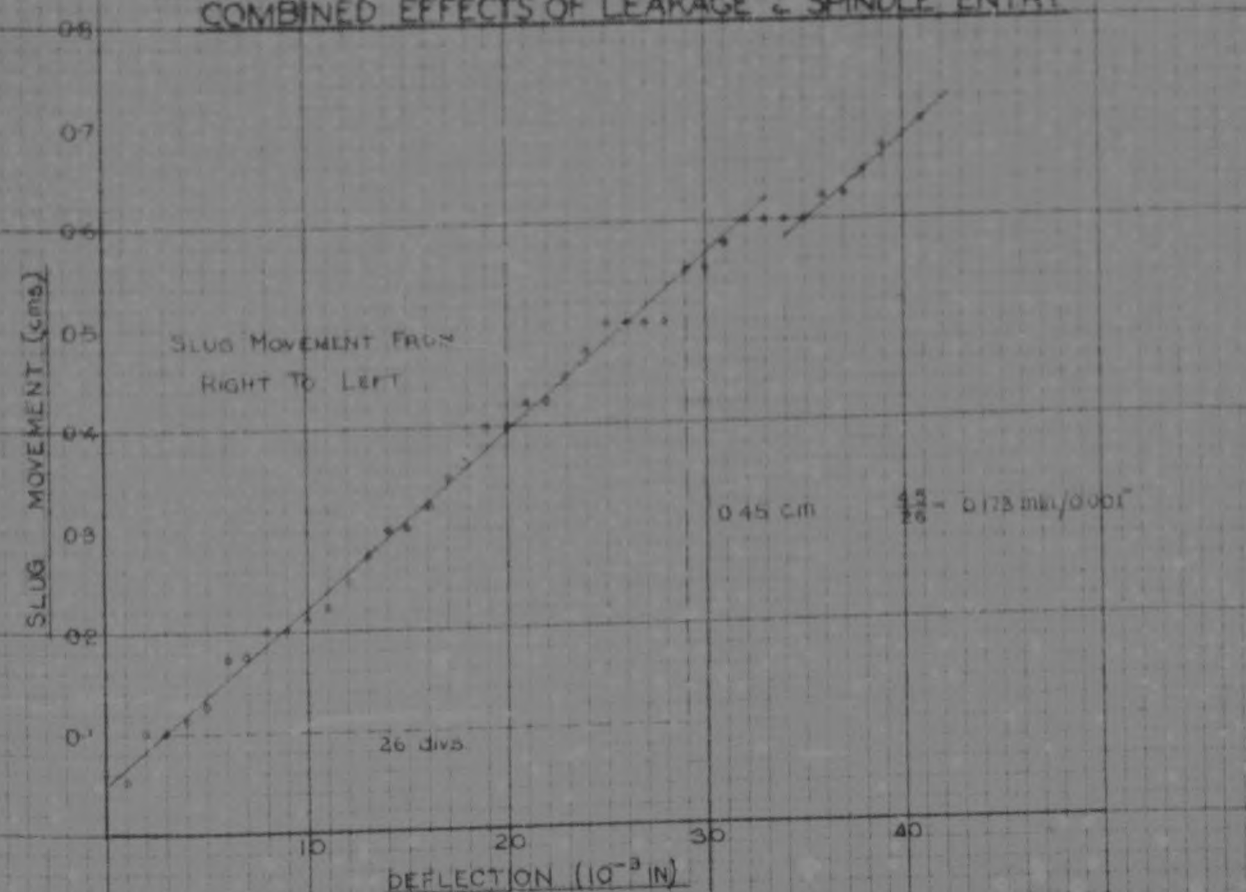


FIG. 25.

TEST No1 : MAIN TEST OBSERVATIONS.

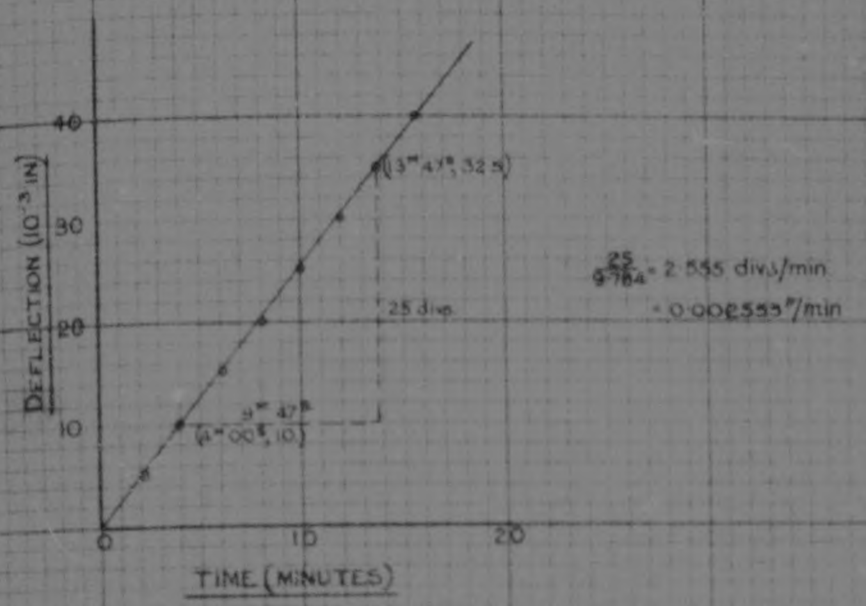
DEFLEC -TION GAUGE	LOAD GAUGE	SLUG SCALE cm.	TIME min. sec.	TEMPERA- TURE °C	CORRECTED SLUG SCAL. cm	CORRECTED LOAD lb	CORRECT DEFLECT 10^{-3} in.	STRAIN $\mathcal{E}$ percent	CORRECTED STRESS (σ)-(s)·6d lb/sq in
00 30	20	29.70	00 00	27.5	0	0	0	0	0
31	24.5	29.70	00 27		0	4.5	1	0.033	2.54
32	27.5	29.675	00 55		0.025	7.5	2	0.067	4.23
33	32	29.30	01 32		0.40	12.0	3	0.100	6.77
34	37.8	27.6	07 27		2.10	17.8	4	0.133	10.04
35	44.8	26.6	08 40		3.10	24.8	5	0.167	14.00
36	49.8	25.3	09 21		4.40	29.8	6	0.200	16.80
37	55.1	24.325	10 15		5.375	35.1	7	0.233	19.78
38	59.8	23.325	10 52		6.375	39.8	8	0.267	22.43
39	64.8	22.3	11 28		7.40	44.8	9	0.300	25.25
40	69.0	21.30	12 04		8.40	49.0	10	0.333	27.60
41	73.2	20.30	12 39		9.40	53.2	11	0.367	29.95
42	78.0	19.20	13 15		10.50	58.0	12	0.400	32.04
43	81.9	18.225	13 48		11.475	61.9	13	0.433	34.82
44	86.2	17.175	14 23		12.525	66.2	14	0.467	37.23
45	89.9	16.175	14 55		13.525	69.9	15	0.500	39.39
46	93.9	15.25	15 30		14.45	73.9	16	0.533	41.63
47	97.0	14.275	16.03		15.425	77.0	17	0.567	43.20
48	100.8	13.30	16 37		16.40	80.8	18	0.600	45.39
49	104.0	12.30	17.12		17.40	84.0	19	0.633	47.16
50	107.0	11.675	17 40		18.025	87.0	20	0.667	48.92
51	110.8	10.50	18 17		19.20	90.8	21	0.700	50.83
52	113.9	9.60	18 50		20.10	93.9	22	0.733	52.66
53	116.9	8.65	19 23		21.05	96.9	23	0.767	54.33
54	119.9	7.8	19 58		21.90	99.9	24	0.800	55.99
55	122.5	6.95	20 31		22.75	102.5	25	0.833	57.45
56	124.8	6.10	21 00		23.60	104.8	26	0.867	58.6
57	127.2	5.35	21 32		24.35	107.2	27	0.900	60.02
58	129.8	4.6	22 00		25.10	109.8	28	0.933	61.4
59	131.9	3.8	22 30		25.90	111.9	29	0.967	62.15
60	134.1	3.2	22 57		26.50	114.1	30	1.000	63.82
61	136.3	2.45	23 31		27.25	116.3	31	1.033	65.1
62	138.4	1.8	23 57		27.90	118.4	32	1.067	66.15
63	140.5	9.3			28.55	120.5	33	1.100	67.33
64	142.2	8.8	24 58		29.05	122.2	34	1.133	68.36
65	144.1	8.35	25 25		29.50	124.1	35	1.167	69.3
66	146.0	7.825	25 56		30.025	126.0	36	1.200	70.33
67	147.7	7.375	26 24		30.475	127.7	37	1.233	71.2
68	149.0	6.725	26 48		31.125	129.0	38	1.267	72.0
69	150.5	6.125	27 14		31.725	130.5	39	1.300	72.77
72	154.8	4.675	28 31		33.175	134.8	42	1.400	75.09
75	158.2	3.4	29 50		34.45	138.2	45	1.500	76.21
78	162.3	2.2	31 13		35.65	142.3	48	1.600	79.11
79	163.3	1.825	31 43		36.025	143.3	49	1.633	
80	164.5	1.5			36.35	144.5	50	1.667	
81	165.6	10.2			36.675	145.5	51	1.700	80.80
82	166.9	9.9	33 00		36.975	146.9	52	1.733	
83	167.9	9.6	33 23		37.275	147.9	53	1.767	
84	168.9	9.375	33 50		37.50	148.9	54	1.800	82.61
87	171.2	8.675	35 05		38.20	151.2	57	1.900	83.80
90	173.6	7.925	36 21		38.95	153.6	60	2.000	85.04
93	175.6	7.3	36 37	27.4	39.575	155.6	63	2.100	86.06
96	177.2	6.775	37 52		40.10	157.2	66	2.200	86.76
99	178.9	6.325			40.55	158.9	69	2.300	87.71
102	180.2	5.975	41 23		40.90	160.2	72	2.400	88.34
105	181.1	5.7	42 35		41.175	161.1	75	2.500	88.74
108	181.9	5.575	43 49		41.30	161.9	78	2.600	89.00
111	182.3	5.475	44 57		41.40	162.3	81	2.700	89.22
114	182.9	5.425	46 10		41.45	162.9	84	2.800	89.46

TEST [illegible] : MAIN TEST OBSERVATIONS. (Cont.)

DEFLEC-TION GAUGE	LOAD GAUGE	SLUG SCALE cm.	[illegible]E [illegible] sec.	TEMPERA-TURE °C	CORRECTED SLUG SCALE cm	CORRECTED LOAD lb	CORRECT DEFLECT 10^{-3} in	STRAIN ε per cent	CORRECTED STRESS $(\sigma_1-\sigma_3)=\sigma_d$ lb/sq in
117	183.2	5.425	[illegible] 24		41.45	163.2	87	2.900	89.53
120	183.4	5.425	[illegible] 31		41.45	163.4	90	3.000	89.55
123	183.5	5.425	[illegible] 41		41.45	163.5	93	3.100	89.51
126	183.5	5.45	[illegible] 50		41.425	163.5	96	3.200	89.42
129	183.5	5.525	[illegible] 02		41.35	163.5	99	3.300	89.32
132	183.5	5.625	[illegible] 12		41.25	163.5	102	3.400	89.23
135	183.4	5.8	[illegible] 20		41.075	163.4	105	3.500	89.09
138	183.1	5.90	[illegible] 32		40.975	163.1	108	3.600	88.83
141	183.0	6.075	[illegible]		40.80	163.0	111	3.700	88.68
144	182.9	6.20	[illegible] 54		40.675	162.9	114	3.800	88.46
147	182.4	6.375	[illegible]		40.55	162.4	117	3.900	88.17
150	182.1	6.425	[illegible] 14		40.45	162.1	120	4.000	87.92
153	181.9	6.60	[illegible] 26		40.275	161.9	123	4.100	87.72
156	181.5	6.8	[illegible] 35		40.075	161.5	126	4.200	87.41
159	181.2	7.075	[illegible] 44		39.80	161.2	129	4.300	87.16
162	181.1	7.25	[illegible] 53		39.625	161.1	132	4.400	87.01
165	180.8	7.475	[illegible] 04		39.40	160.8	135	4.500	86.76
168	180.3	7.625	[illegible] 14		39.25	160.3	138	4.600	86.40
171	180.0	7.85	[illegible]		39.025	160.0	141	4.700	86.15
174	179.8	8.075	[illegible] 31		38.80	159.8	144	4.800	85.95
177	179.8	8.25	7 [illegible]		38.625	159.8	147	4.900	85.86
180	179.4	8.475	7 [illegible]		38.40	159.4	150	5.000	85.55
183	179.1	8.65	7 [illegible]7		38.225	159.1	153	5.100	85.30
186	178.9	8.8	[illegible] 25		38.075	158.9	156	5.200	85.11
189	178.7	9.00	7 11		37.875	158.7	159	5.300	84.97
190	178.7	9.025	7 [illegible]4	27.25	37.85	158.7	160	5.333	

TEST No1: RATE OF STRAIN DETERMINATIONS.

(a) CALIBRATED RATE OF STRAIN (σ_3 = 30 lb/sq. in)



(b) ACTUAL RATE OF STRAIN DURING TEST (σ_3 = 30 lb/sq. in)

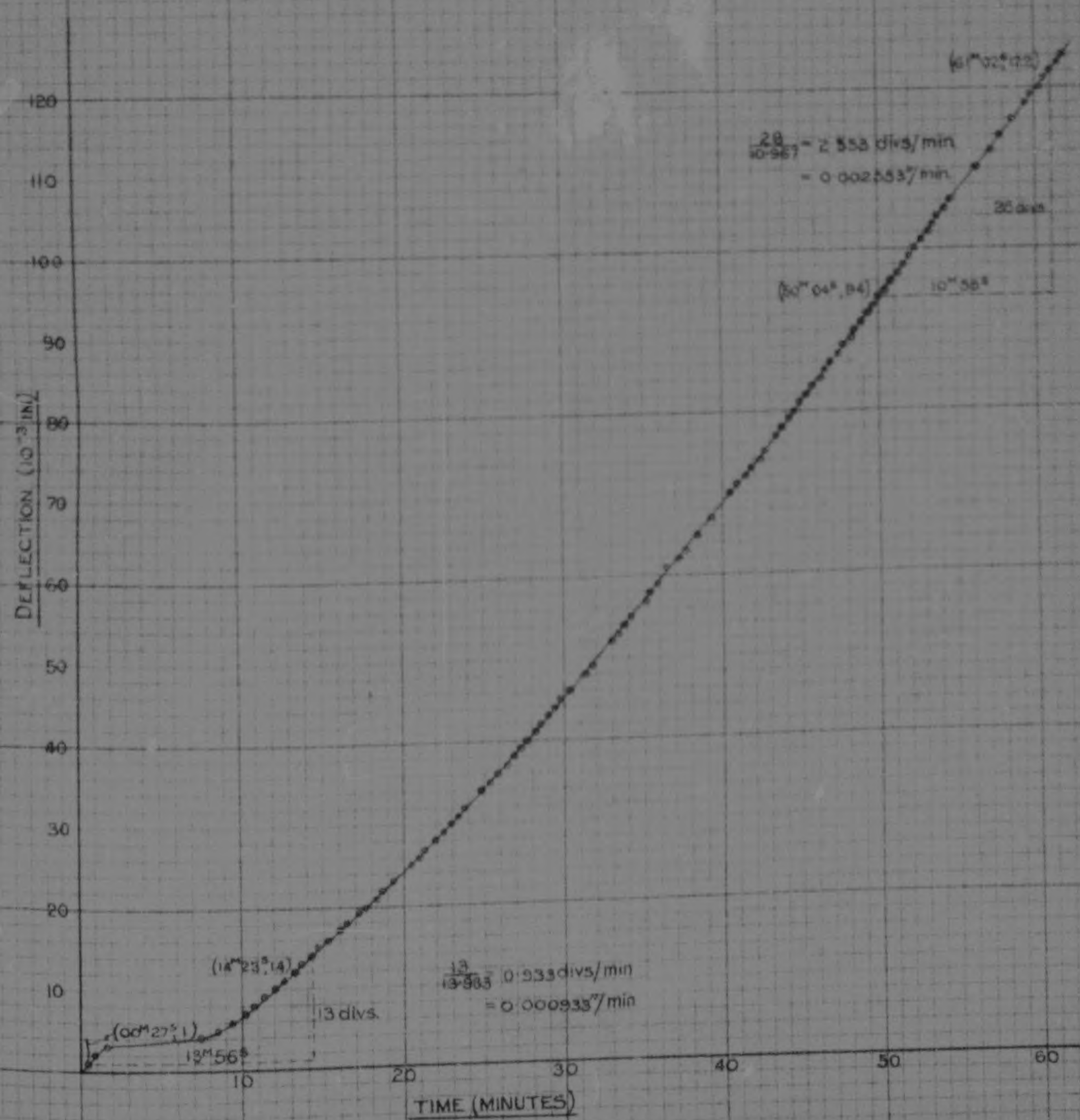


FIG. 26

TEST No 1.

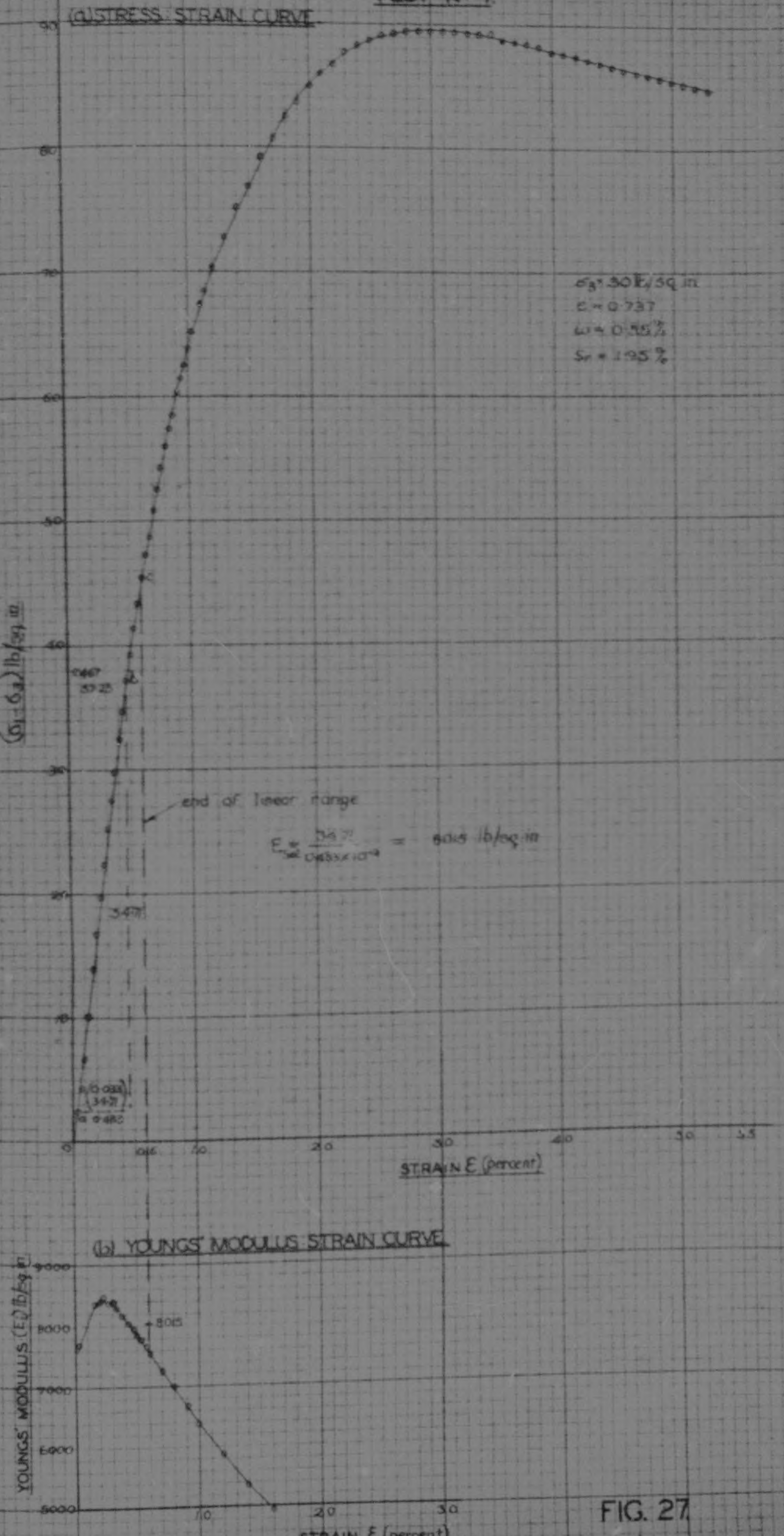


FIG. 27

TEST No 1

CALCULATION OF INSTANTANEOUS VALUES OF YOUNGS' MODULUS (E)

CORRECTED STRESS = a lb/sq in	STRAIN percent	STRAIN DUE TO BEDDING-IN EFFECTS percent	CORRECTED STRAIN = b percent	YOUNGS' MODULUS (E) = a/b lb/sq in
2.54	0.033	0	0.033	7697
4.23	0.067	0	0.067	6313
6.77	0.100	0	0.100	6770
10.04	0.133	0	0.133	7549
14.00	0.167	0	0.167	8383
16.80	0.200	0	0.200	8400
19.78	0.233	0	0.233	8489
22.43	0.267	0	0.267	8401
25.23	0.300	0	0.300	8401
27.60	0.333	0	0.333	8288
29.95	0.367	0	0.367	8161
32.64	0.400	0	0.400	8160
34.82	0.433	0	0.433	8042
37.23	0.467	0	0.467	7972
39.29	0.500	0	0.500	7858
41.53	0.533	0	0.533	7792
43.20	0.567	0	0.567	7619
45.38	0.600	0	0.600	7563
47.16	0.633	0	0.633	7450
48.82	0.667	0	0.667	7319
50.83	0.700	0	0.700	7261
52.66	0.733	0	0.733	7184
54.33	0.767	0	0.767	7083
55.99	0.800	0	0.800	6999
60.02	0.900	0	0.900	6669
63.82	1.000	0	1.000	6382
67.33	1.100	0	1.100	6121
70.33	1.200	0	1.200	5861
72.77	1.300	0	1.300	5598
75.09	1.400	0	1.400	5364
76.91	1.500	0	1.500	5127
79.11	1.600	0	1.600	4944
80.60	1.700	0	1.700	4753
82.61	1.800	0	1.800	4589
83.80	1.900	0	1.900	4410
85.04	2.000	0	2.000	4252

TEST No I.

MAIN SLUG MOVEMENT: DEFLECTION CURVE.

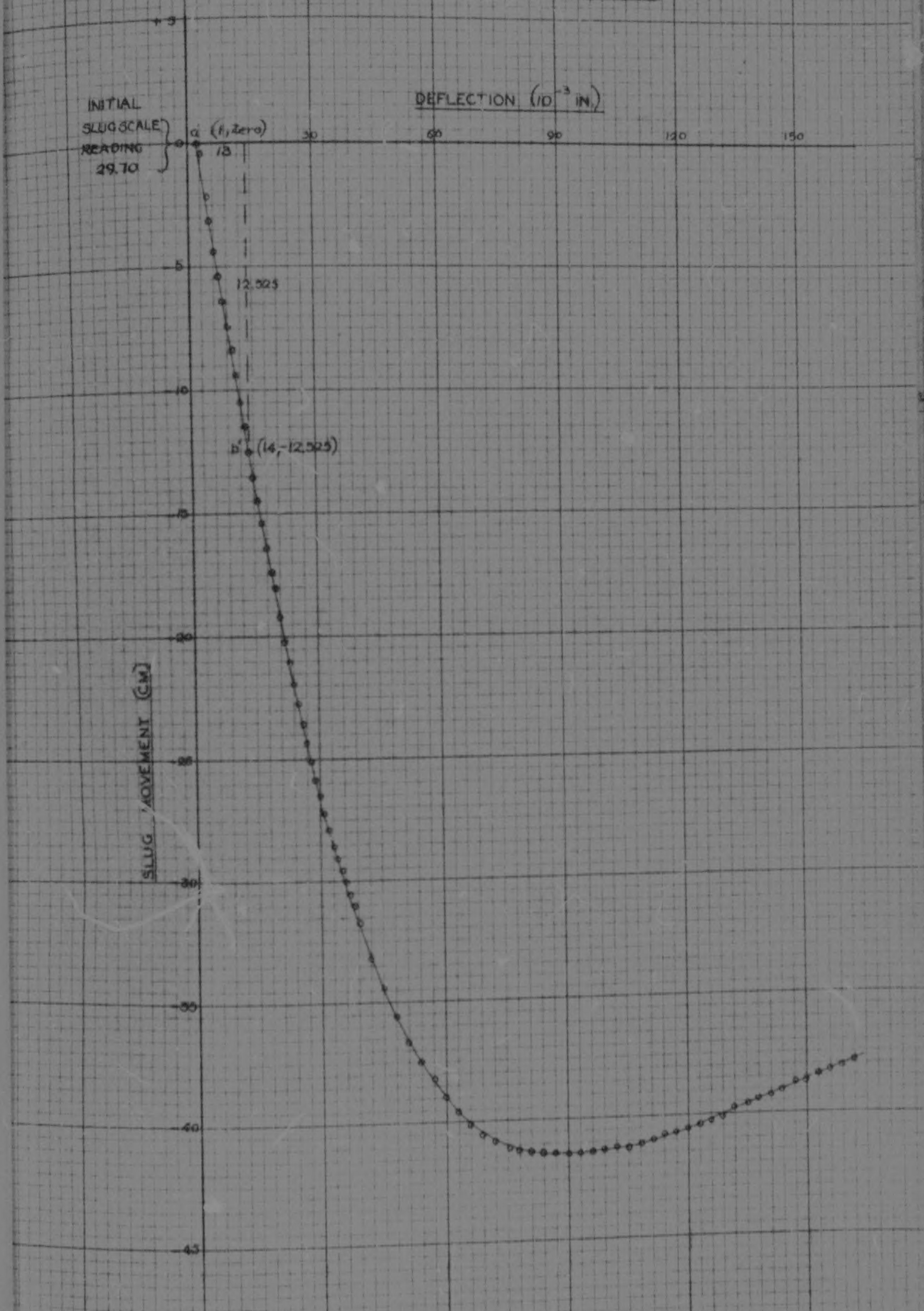


FIG. 28.

TEST No 2.

DATE PERFORMED: 22/1/57

SAMPLE CONSOLIDATED FOR 24^{HRS} 30^{MIN} PRIOR TO TEST.

TIME START OF TEST: 2/55 P.M. TEMPERATURE: 25·25°C

TIME END OF TEST: 3/10 P.M. TEMPERATURE: 25·25°C

NOMINAL σ_3 CHAMBER PRESSURE 30 LB/SQ. IN.

HEAD OF MERCURY: 58⅝ INCHES, HENCE

ACTUAL σ_3 CHAMBER PRESSURE 28·738 LB/SQ. IN.

NOMINAL RATE OF STRAIN: 0·0125 INCHES/MINUTE

TEST No 2 : LEAKAGE MEASUREMENTS.

(A) MEASUREMENT OF SLUG MOVEMENT DUE TO LEAKAGE ONLY. BEFORE TEST TEMP 25.5°C TIME 2/25p.m.		(B) MEASUREMENT OF SLUG MOVEMENT DUE TO LEAKAGE ONLY. AFTER TEST (1) TEMP 25.25°C TIME 3/15p.m.		(C) MEASUREMENT OF SLUG MOVEMENT DUE TO COMBINED EFFECTS OF LEAKAGE & SPINDLE ENTRY (AFTER TEST) TEMPERATURE: 25.5°C TIME: 3/25p.m.			(C) MEASUREMENT OF SLUG MOVEMENT DUE TO LEAKAGE ONLY. AFTER TEST (2) TEMP 25.0°C TIME 3/35p.m.	
TIME min sec	VOLUME SCALE cm	TIME min sec	VOLUME SCALE cm	DEFLECT GAUGE 10^{-3} in	VOLUME SCALE cm	TIME min. sec.	TIME min sec.	VOLUME SCALE cm
0 00	26.00	0 00	28.00	00 50	1.60		0 00	23.7
15	25.975	15	27.95	52.5	1.80		15	23.575
30	25.95	30	27.825	55	2.05		30	23.425
45	25.925	45	27.75	57.5	2.30		45	23.3
1 00	25.90	1 00	27.65	60	2.55		1 00	23.175
15	25.85	15	27.55	62.5	2.825		15	23.075
30	25.825	30	27.45	65	3.075		30	23.00
45	25.8	45	27.325	67.5	3.40		45	22.90
2 00	25.775	2.00	27.225	70	3.65		2 00	22.80
15	25.75	15	27.125	72.5	3.90		15	22.70
30	25.70	30	27.025	75	4.20		30	22.60
45	25.675	45	26.95	77.5	4.50		45	22.475
3 00	25.675	3 00	26.85	80	4.80		3 00	22.35
15	25.625	15	26.75	82.5	5.00		15	22.225
30	25.55	30	26.65	85	5.35		30	22.10
45	25.525	45	26.55	87.5	5.65		45	22.00
4 00	25.50	4 00	26.45	90	5.95		4 00	21.80
15	25.475	15	26.325	92.5	6.20		15	21.675
30	25.45	30	26.225	95	6.50		30	21.525
45	25.40	45	26.125	97.5	6.80		45	21.40
5 00	25.375	5 00	26.00	100	7.05		5 00	21.275
				102.5	7.35			
				105	7.60			
				107.	7.55			
				110	8.20			
				112.5	8.45			
				115	8.75			
				117.5	9.05			
				120	9.325			
				122.5	9.625			
				125	9.925			
				127.5	10.225			
				130	10.525			
				132.5	10.825			
				135	11.125			
				137.5	11.40			
				140	11.70			
				142.5	12.00			
				145	12.30			
				147.5	12.55			
				150	12.85			

TEST No 2: LEAKAGE MEASUREMENTS

DETERMINATION OF RATE OF SLUG MOVEMENT DUE TO LEAKAGE ONLY

(Slug movement from right to left in each case)

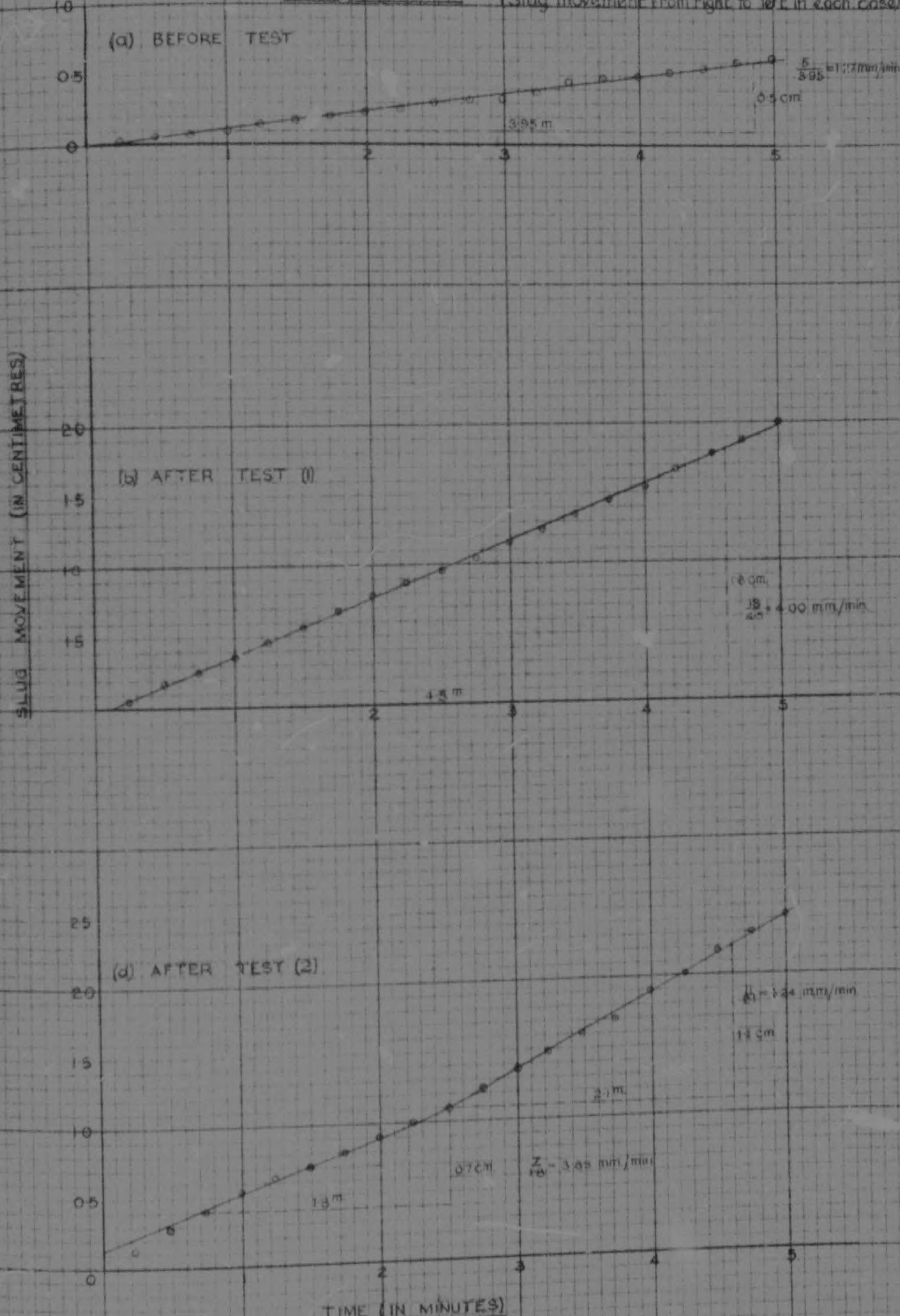


FIG. 29. (a),(b)&(d)

TEST NO.2. LEAKAGE MEASUREMENTS (CONTINUED)

(c) DETERMINATION OF RATE OF SLUG MOVEMENT DUE TO COMBINENED EFFECTS OF LEAKAGE & SPINDLE ENTRY

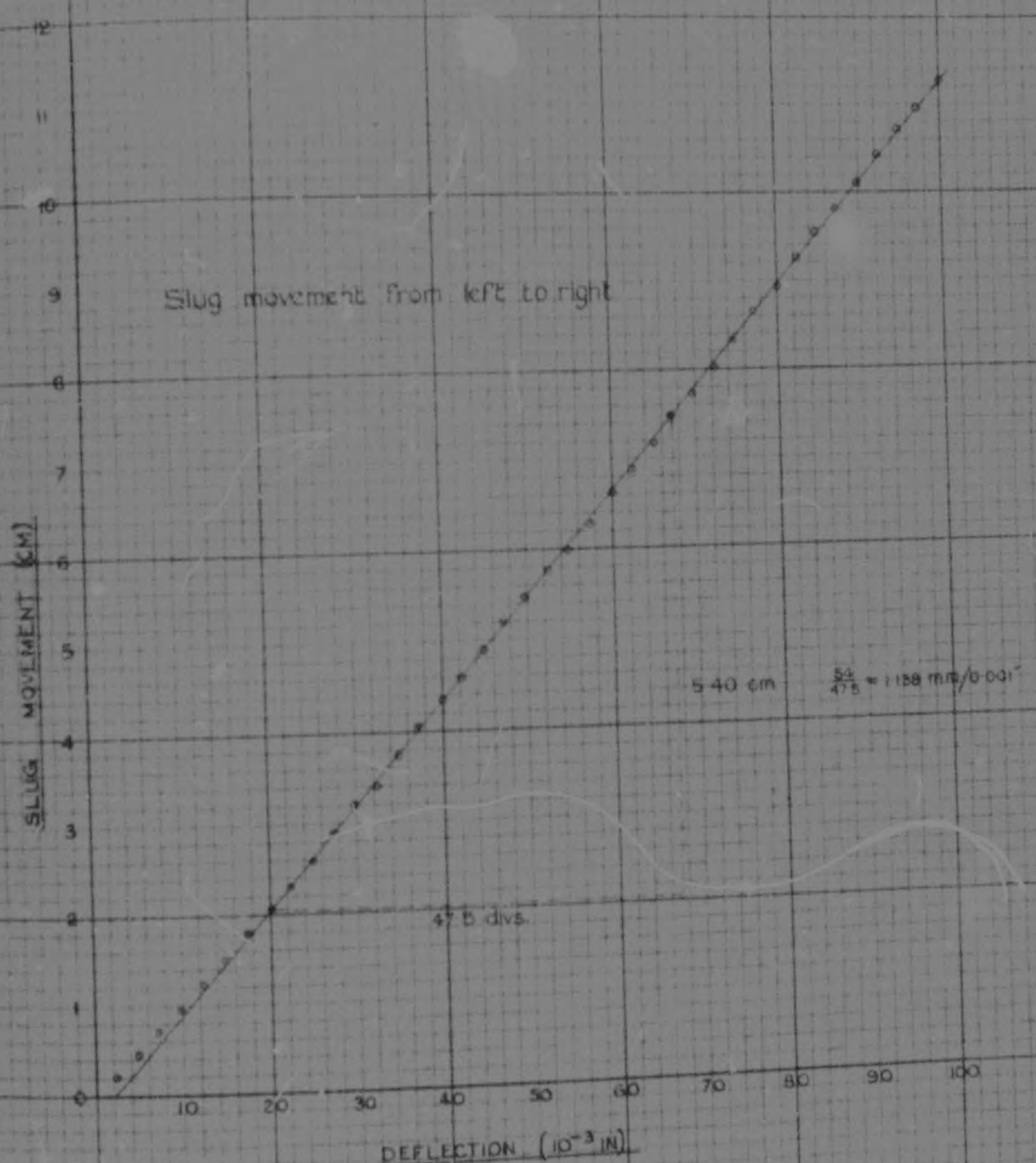
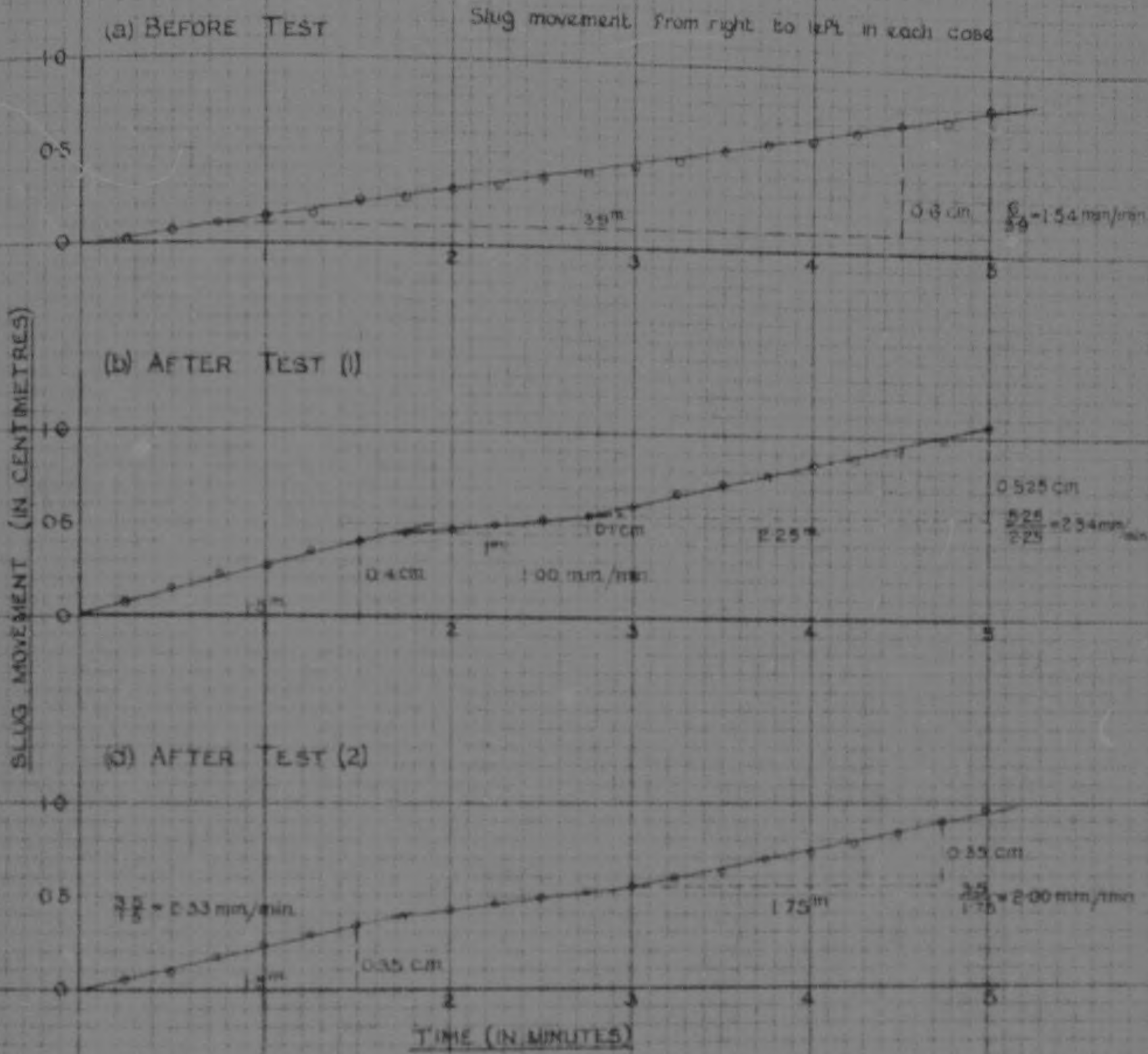


FIG. 29(C)

TEST No3: LEAKAGE MEASUREMENTS.

DETERMINATION OF RATE OF SLUG MOVEMENT DUE TO LEAKAGE ONLY.



(c) DETERMINATION OF RATE OF SLUG MOVEMENT DUE TO COMBINED EFFECTS OF LEAKAGE & SPINDLE ENTRY

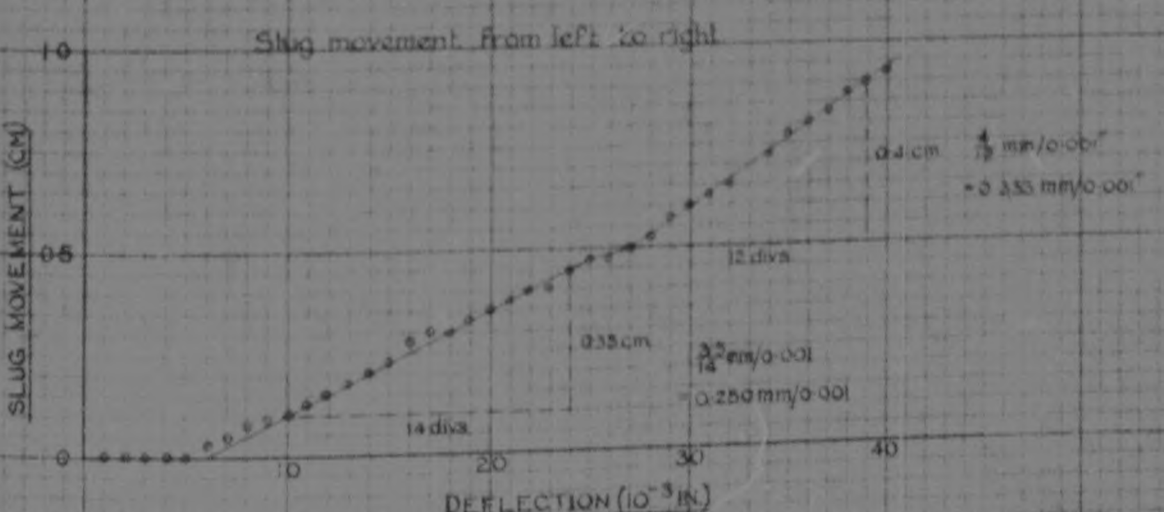


FIG 32

TEST Nº 6 : LEAKAGE MEASUREMENTS.

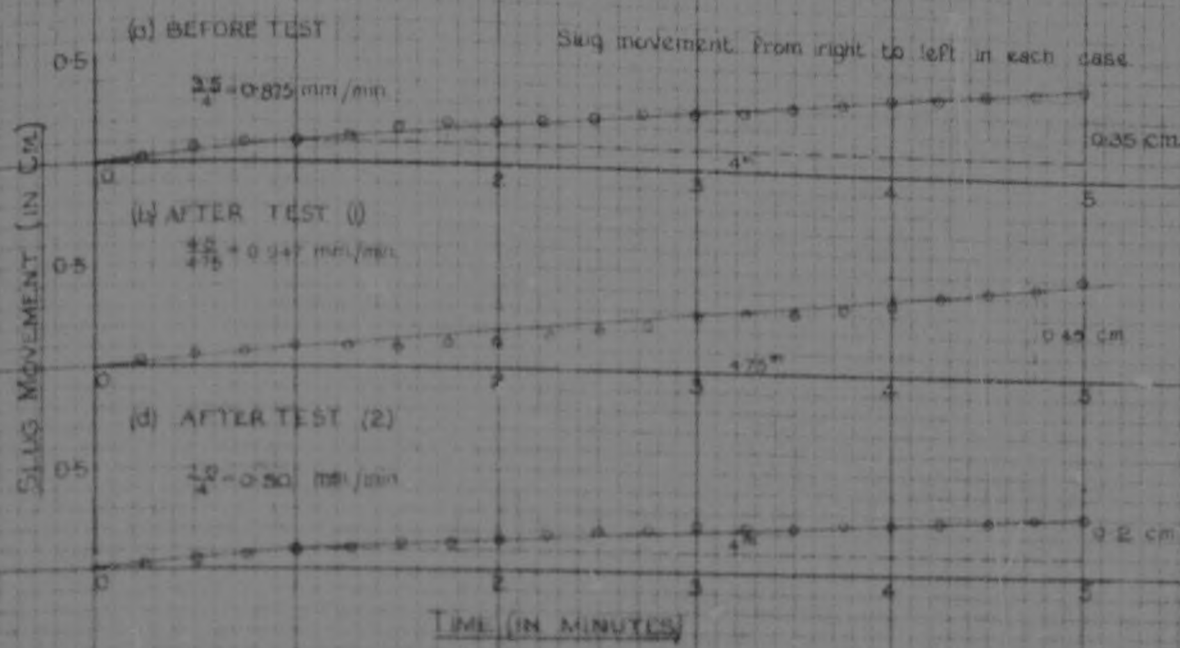
(A) MEASUREMENT OF SLUG MOVEMENT DUE TO LEAKAGE ONLY. BEFORE TEST TEMP 2025°C TIME: 11.10a.m.		(B) MEASUREMENT OF SLUG MOVEMENT DUE TO LEAKAGE ONLY. AFTER TEST (1) TEMP: 20.75°C TIME: 12/10p.m.		(C) MEASUREMENT OF SLUG MOVEMENT DUE TO COMBINED EFFECTS OF LEAKAGE & SPINDLE ENTRY (AFTER TEST) TEMPERATURE: 20.75°C TIME. 12/18p.m.			(D) MEASUREMENT OF SLUG MOVEMENT DUE TO LEAKAGE ONLY. AFTER TEST (2) TEMP: 21.[illegible]°C TIME 12/35p.m.	
TIME min sec	VOLUME SCALE cm.	TIME min sec	VOLUME SCALE cm.	DEFLECT GAUGE 10^{-3}	VOLUME SCALE cm.	TIME min sec	TIME min sec	VOLUME SCALE cm.
0 00	22.00	0 00	19.60	00 40	18.80	0 00	0 00	19.10
15	21.975	15	19.575	41	18.90		15	19.075
30	21.925	30	19.55	42	19.00		30	19.05
45	21.90	45	19.525	43	19.10		45	19.025
1 00	21.90	1 00	19.50	44	19.20		1 00	19.00
15	21.875	15	19.50	45	19.275	1 58	15	19.[illegible]
30	21.825	30	19.50	46	19.375		30	18.975
45	21.80	45	19.475	47	19.475		45	18.975
2 00	21.80	2 00	19.475	48	19.55		2 00	18.95
15	21.775	15	19.425	49	19.625		15	18.925
30	21.75	30	19.40	50	19.725	3 58	30	18.90
45	21.725	45	19.375	51	19.85		45	18.90
3 00	21.725	3 00	19.325	52	20.00		3 00	18.875
15	21.70	15	19.30	53	20.15		15	18.875
30	21.675	30	19.30	54	20.20		30	18.875
45	21.65	45	19.275	55	20.325	5 58	45	18.85
4 00	21.625	4 00	19.25	56	20.475		4 00	18.85
15	21.60	15	19.20	57	20.60		15	18.825
30	21.60	30	19.175	58	20.725		30	18.825
45	21.575	45	19.15	59	20.825		45	18.80
5 00	21.55	5 00	19.10	60	21.00	8 02	5 00	18.80
				61	21.10			
				62	21.20			
				63	21.275			
				64	21.40			
				65	21.50	10 00		
				66	21.60			
				67	21.675			
				68	21.775			
				69	21.875			
				70	21.925	11 56		
				71	22.00			

TEST Nº 3 : MAIN TEST OBSERVATIONS.

DEFLEC-TION GAUGE	LOAD GAUGE	SLUG SCALE cm	TIME min sec	TEMPERA-TURE °C	CORRECTED SLUG SCALE cm	CORRECTED LOAD lb	CORRECT DEFLECT 10^{-3}in	STRAIN ε percent	CORRECTED STRESS $(\sigma_1-\sigma_3)=\sigma_d$ lb/sq in
00 35	15	23.30	00 00	23.25	0	0	0	0	0
36	17.25	23.35			-0.05	2.25	1	0.033	
37	19.8	23.325			-0.025	4.8	2	0.067	
38	20.8	23.30			0	5.8	3	0.100	3.3
39	24.0	23.10			+0.20	9.0	4	0.133	5.1
40	26.7	22.80	02 35		0.50	11.7	5	0.167	6.6
41	28.0	22.10	03 15		1.20	13.0	6	0.200	7.34
42	33.25	20.75	08 07		2.55	18.25	7	0.233	10.29
43	37.8	20.2			3.10	22.5	8	0.267	12.68
44	42.8	19.2			4.10	27.8	9	0.300	15.66
45	48.2	17.85			5.45	33.2	10	0.333	18.70
46	52.3	16.9	11 19		6.40	37.3	11	0.367	21.00
47	56.9	15.7	11 57		7.50	41.9	12	0.400	23.58
48	60.6	14.7			8.60	45.6	13	0.433	25.65
49	64.6	13.65	13 08		9.65	49.[illegible]	14	0.467	27.99
50	68.2	12.7	13 41		10.60	53.[illegible]	15	0.500	29.91
51							16	0.533	
52	75.2	10.8	14 46		12.50.	60.2	17	0.567	33.82
53	78.2	9.95			13.35	63.2	18	0.600	35.49
54	81.5	9.2			14.10	66.5	19	0.633	37.35
55	84.6	8.3			15.00	69.6	20	0.667	39.06
56	87.4	7.5	16 55		15.80	72.4	21	0.700	40.62
57	90.5	6.7			16.60	75.5	22	0.733	42.34
58	93.2	5.95			17.35	78.2	23	0.767	43.84
59	95.8	5.2			18.10	80.8	24	0.800	45.28
60	98.0	4.55	19 00		18.75	83.0	25	0.833	46.50
61	100.7	3.775			19.525	85.7	26	0.867	48.00
62	102.7	3.3			20.00	87.7	27	0.900	49.10
63	104.2	2.775			20.525	89.2	28	0.933	49.92
64	106.0	2.275			21.025	91.0	29	0.967	50.21
65	107.8	1.775	21 24		21.525	92.8	30	1.000	51.90
68	112.0	27.8			22.75	97.0	33	1.100	54.20
69	113.4	27.45			23.10	98.4	34	1.133	54.96
70	114.7	27.15	23 41		23.40	99.7	35	1.167	55.67
71	115.5	26.9			23.75	100.5	36	1.200	56.10
72	116.5	26.55			24.00	101.5	37	1.233	56.64
73	117.5	26.25			24.30	102.5	38	1.267	57.18
74	118.2	26.025			24.525	103.2	39	1.300	57.55
75	119.0	25.775	25 51		24.775	104.0	40	1.333	57.97
80	121.8	24.9	27 51		25.65	106.8	45	1.500	59.43
85	124.2	24.575	29 57		26.175	109.2	50	1.667	60.66
90	125.8	24.125	31 53		26.425	110.8	55	1.833	61.4
95	126.8	24.00	33.53		26.55	111.8	60	2.000	61.9
100	127.3	24.00	35 53		26.55	112.3	65	2.167	62.1
105	128.1	24.10	37 52		26.45	113.1	70	2.333	62.5
110	129.2	24.25			26.30	114.2	75	2.500	63.0
115	130.4	24.475	41 51		26.075	115.4	80	2.667	63.5
120	131.2	24.725	43 49		25.825	116.2	85	2.833	63.9
125	131.7	24.875	45 49		25.675	116.7	90	3.000	63.9
130	132.1	25.175	47 45		25.40	117.1	95	3.167	64.0
135	132.2	25.45	49 45		25.125	117.2	100	3.333	64.1
140	132.7	25.875	51 41		24.70	117.7	105	3.500	64.1
145	133.0	26.425	53 41		24.15	118.0	110	3.667	64.2
150	133.5	27.05	55 40		23.525	118.5	115	3.833	64.4
155	134.1	27.6	57 39		22.975	119.1	120	4.000	64.6
160	134.8	28.2	59 39		22.375	119.8	125	4.167	64.6
165	135.1	28.8	61 38		21.775	120.1	130	4.333	64.91
168	135.2	29.10			21.475	120.2	133	4.433	
170	135.7	3.60			21.275	120.7	135	4.500	65.10
171	135.8	3.70			21.175	120.8	136	4.533	

TEST Nº6: LEAKAGE MEASUREMENTS.

DETERMINATIONS OF RATE OF SLUG MOVEMENT DUE TO LEAKAGE ONLY.



(c) DETERMINATION OF RATE OF SLUG MOVEMENT DUE TO COMBINED EFFECTS OF LEAKAGE & SPINDLE ENTRY

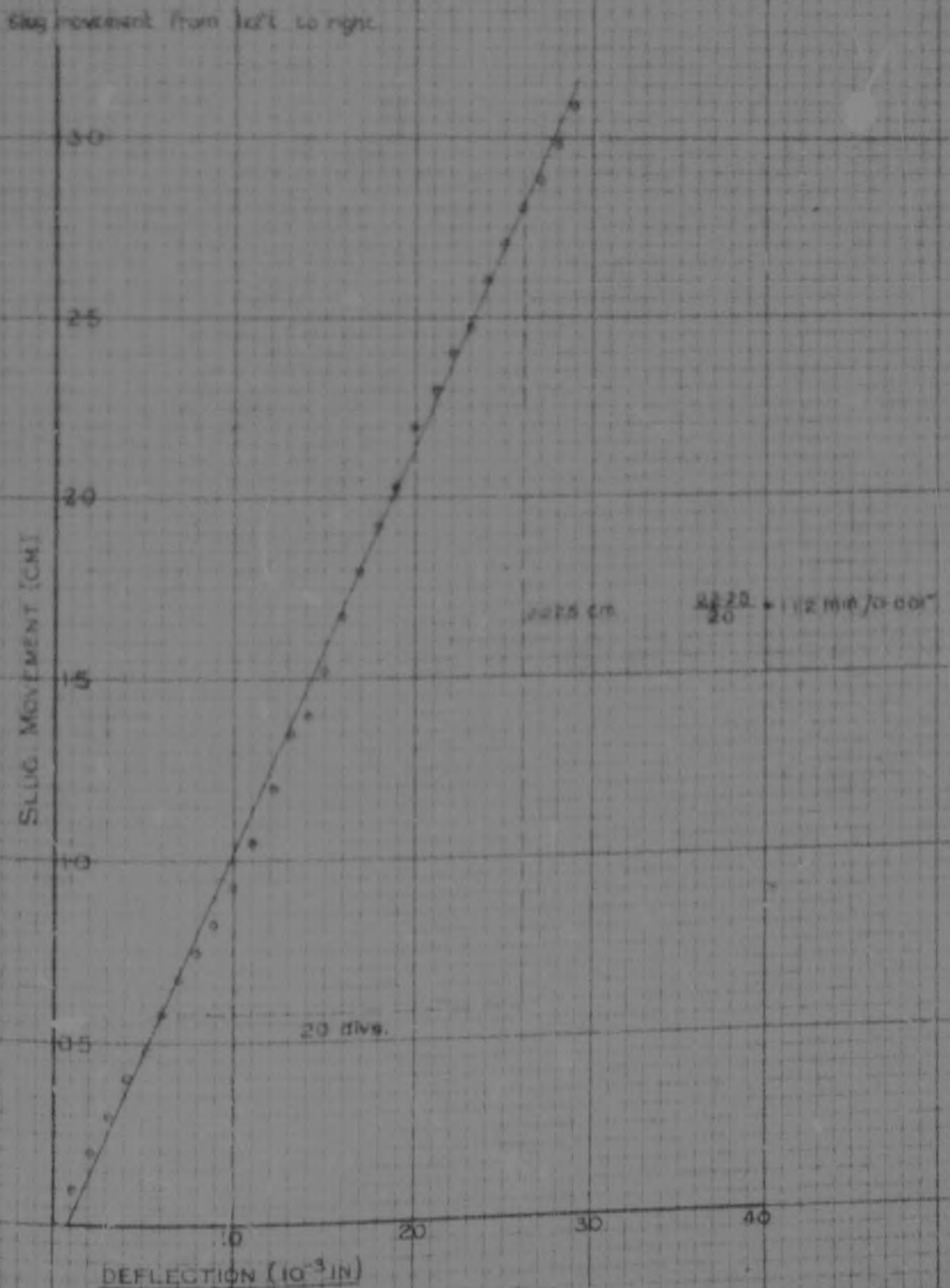


FIG 44

TEST No 3 MAIN TEST OBSERVATIONS. (Cont.)

DEFLECTION GAUGE	LOAD GAUGE	SLUG SCALE cm	TIME min	TIME sec	TEMPERATURE °C	CORRECTED SLUG SCALE cm	CORRECTED LOAD lb	CORRECT DEFLECT 10^{-3} in	STRAIN ε percent	CORRECTED STRESS $(\sigma_1-\sigma_3)$ σ_d lb/sq in
172	135.9	3.80				21.075	120.9	137	4.567	
173	135.9	3.90				20.975	120.9	138	4.600	
174	136.0	4.00				20.875	121.0	139	4.633	
175	136.0	4.10	65	34		20.775	121.0	140	4.667	65.16
180	136.2	4.60	67	26		20.275	121.2	145	4.833	65.16
185	136.7	5.20	69	22		19.675	121.7	150	5.000	65.30
190	136.9	5.75	71	17	24.0	19.125	121.9	155	5.167	65.28
195	137.1	6.325	73	17		18.550	122.1	160	5.333	65.30
200	137.2	6.90	75	13		17.975	122.2	165	5.500	65.24
205	137.2	7.50	77	11		17.375	122.2	170	5.667	65.12
210	137.2	8.20	79	11		16.675	122.2	175	5.833	65.01
215	137.2	8.90	81	04		16.075	122.2	180	6.000	64.89
220	137.2	9.475	83	00		15.40	122.2	185	6.167	64.77
225	137.2	10.075	84	56		14.80	122.2	190	6.333	64.68
230	137.2	10.7	86	51		14.175	122.2	195	6.500	64.55
235	137.2	11.35	88	48		13.525	122.2	200	6.667	64.43
240	137.2	11.90	90	43		12.975	122.2	205	6.833	64.31
245	137.2	12.50	92	38	24.0	12.375	122.2	210	7.000	64.21

TEST Nº 6 MAIN TEST OBSERVATIONS.

DEFLECTION GAUGE	LOAD GAUGE	SLUG SCALE cm	TIME min sec	TEMPERATURE °C	CORRECTED SLUG SCALE cm	CORRECTED LOAD lb	CORRECT DEFLECT 10^{-3} in	STRAIN ε percent	CORRECTED STRESS [illegible] lb/sq.in
00 35	15	27.10	00 00	20.25	0	0	0	0	0
36	15.9	27.025	01 09		0.075	0.9	1	0.033	0.5
37	16.4	27.025	01 34		0.075	1.4	2	0.067	0.8
38	17.3	27.075	01 59		0.025	2.3	3	0.100	1.3
39	18.0	27.075	02 22		0.025	3.0	4	0.133	1.7
40	19.9	27.05	02 49		0.05	4.9	5	0.167	2.76
41	23.6	26.725	03 20		0.375	8.6	6	0.200	4.81
42	27.0	25.9	04 06		1.20	12.0	7	0.233	6.76
43	30.9	24.5	09 15		2.60	15.9	8	0.267	8.96
44	36.2	23.6	10 40		3.50	21.2	9	0.300	11.93
45	41.0	22.675	11 29		4.425	26.0	10	0.333	14.64
46	46.0	21.6	12 26		5.50	31.0	11	0.367	17.45
47	51.2	20.4	13 05		6.70	36.2	12	0.400	20.39
48	55.9	19.4	13 42		7.70	40.9	13	0.433	23.04
49	60.9	18.35	14 19		8.75	45.9	14	0.467	25.81
50	65.9	17.6	14 55		9.50	50.9	15	0.500	28.65
51	71.0	16.75	15 34		10.35	56.0	16	0.533	31.48
52	76.0	15.825	16 12		11.275	61.0	17	0.567	34.25
53	80.7	15.2	16 49		11.90	65.7	18	0.600	36.90
54	84.9	14.5	17 22		12.60	69.9	19	0.633	39.25
55	89.0	14.0	17 58		13.10	74.0	20	0.667	41.53
56	93.7	13.55	18 34		13.55	78.7	21	0.700	44.12
57	97.3	13.05	19 09		14.05	82.3	22	0.733	46.16
58	101.6	12.925	19 47		14.175	86.6	23	0.767	48.55
59	104.9	12.3	20 21		14.80	89.9	24	0.800	50.33
60	107.9	12.1	20 51		15.00	92.9	25	0.833	51.99
61	110.8	11.95	21 25		15.15	95.8	26	0.867	53.65
62	113.1	11.90	21 56		15.20	98.1	27	0.900	54.90
63	115.2	11.875	22 25		15.225	100.2	28	0.933	56.00
64	117.1	11.875	22 52		15.225	102.1	29	0.967	57.15
65	118.9	11.80	23 21		15.30	103.9	30	1.000	58.11
66	120.2	12.125	23 49		14.975	105.2	31	1.033	58.82
67	121.3	12.4	24 15		14.70	106.3	32	1.067	59.42
68	122.1	12.8	24 41		14.30	107.1	33	1.100	59.84
69	123.0	13.00	25 07		14.00	108.0	34	1.133	60.3
70	123.6	13.90	25 34		13.20	108.6	35	1.167	60.6
71	123.8	14.6	25 54		12.50	108.8	36	1.200	60.6
72	123.9	15.8	26 18		11.30	108.9	37	1.233	60.65
73	123.9	16.7	26 40		10.40	108.9	38	1.267	60.65
74	123.9	17.7	27 04		9.40	108.9	39	1.300	60.6
75	123.6	18.8	27 29		8.30	108.6	40	1.333	60.5
76	123.2	19.8	27 52		7.30	108.2	41	1.367	60.4
77	122.5	21.3	28 12		5.80	107.5	42	1.400	59.9
78	121.9	22.6	28 34		4.50	106.9	43	1.433	59.5
79	121.1	23.8	28 54		3.30	106.1	44	1.467	59.1
80	120.4	24.9	29 14		2.20	105.4	45	1.500	58.7
81	119.1	26.1	29 36		+ 1.00	104.1	46	1.533	57.9
82	118.1	27.5	29 57		− 0.40	103.1	47	1.567	57.4
83	117.0	28.5	30 19		− 1.40	102.0	48	1.600	56.4
84	116.0	29.5	30 40		− 2.40	101.0	49	1.633	56.1
85	115.0	30.5	31 02		− 3.40	100.0	50	1.667	55.5
86	114.3	31.4	31 23		− 4.30	99.3	51	1.700	55.1
87	113.4		31 44	20.75		98.4	52	1.733	54.55

TEST No 3: RATE OF STRAIN DETERMINATIONS.

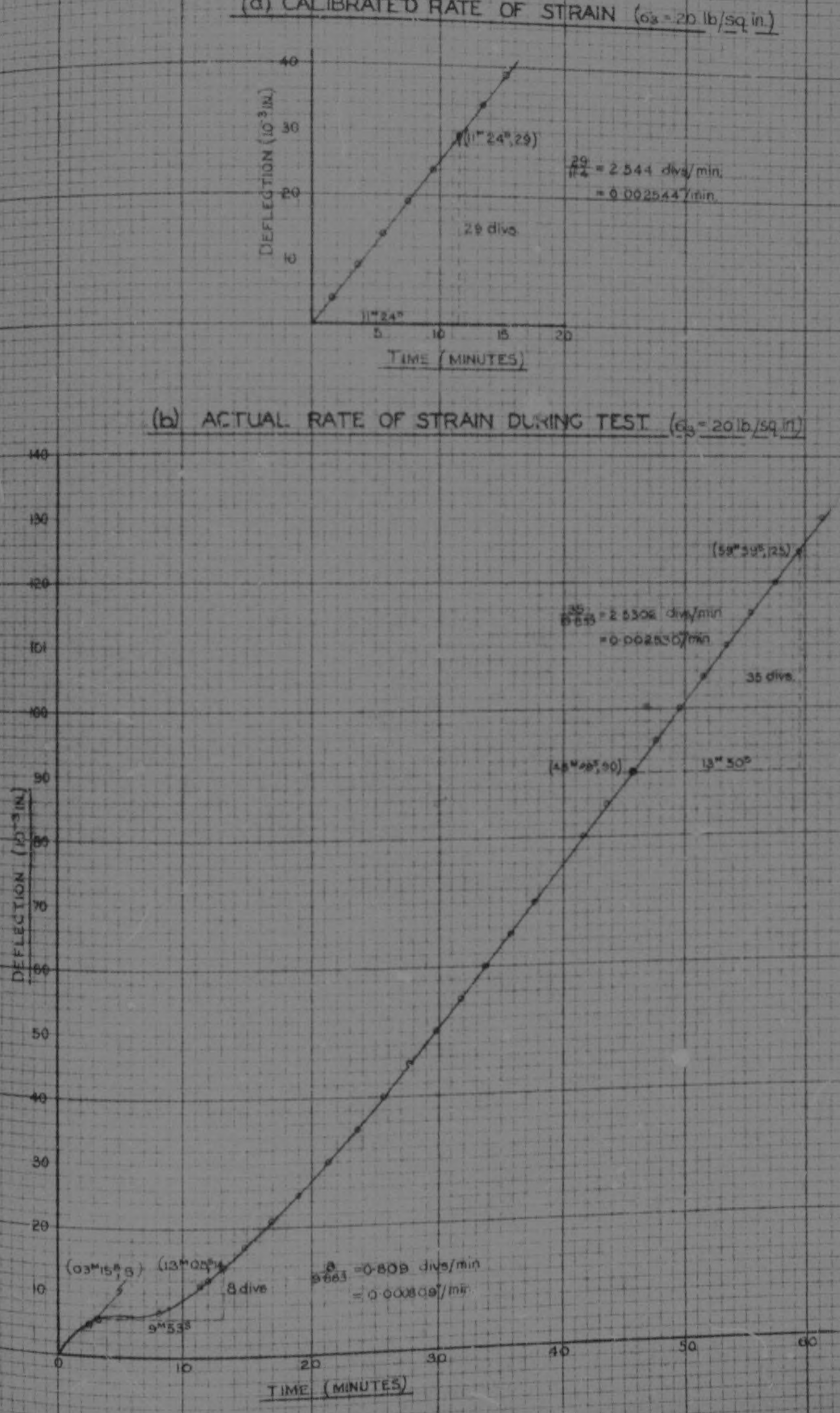
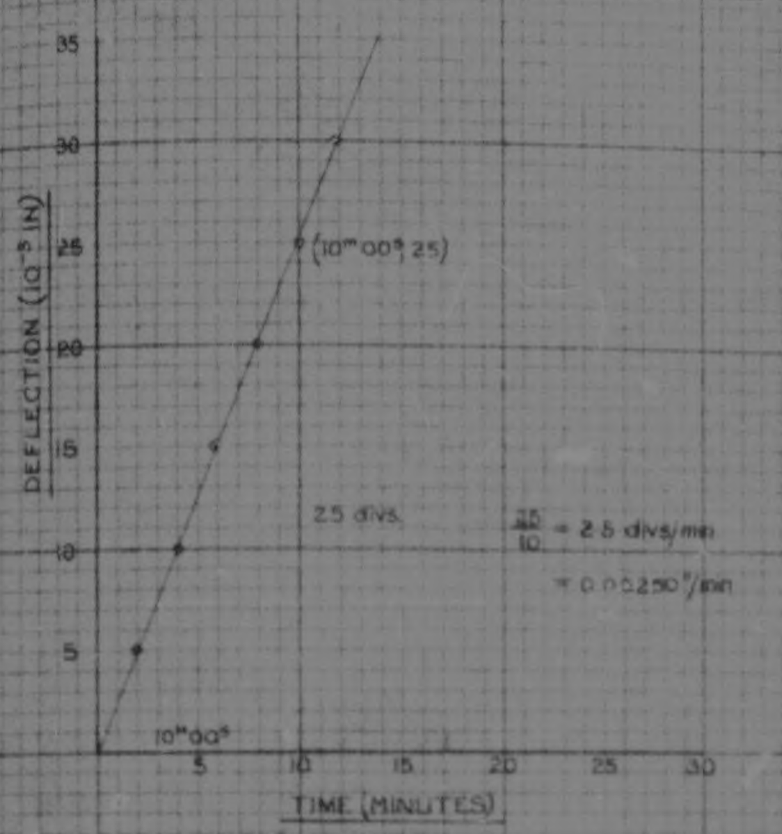


FIG. 33.

TEST No6 RATE OF STRAIN DETERMINATIONS

(a) CALIBRATED RATE OF STRAIN (σ_3=10 lb/sq.in)



(b) ACTUAL RATE OF STRAIN DURING TEST (σ_3=10 lb/sq.in)

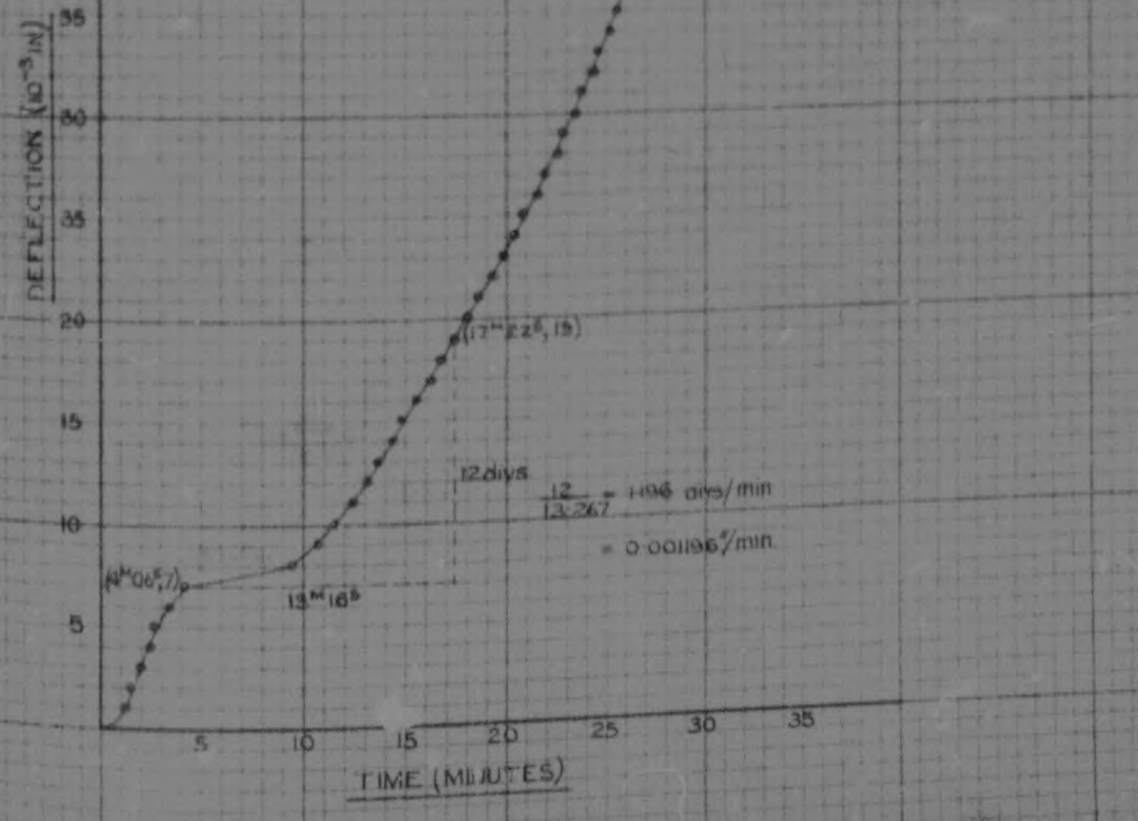


FIG. 45

TEST No 3.

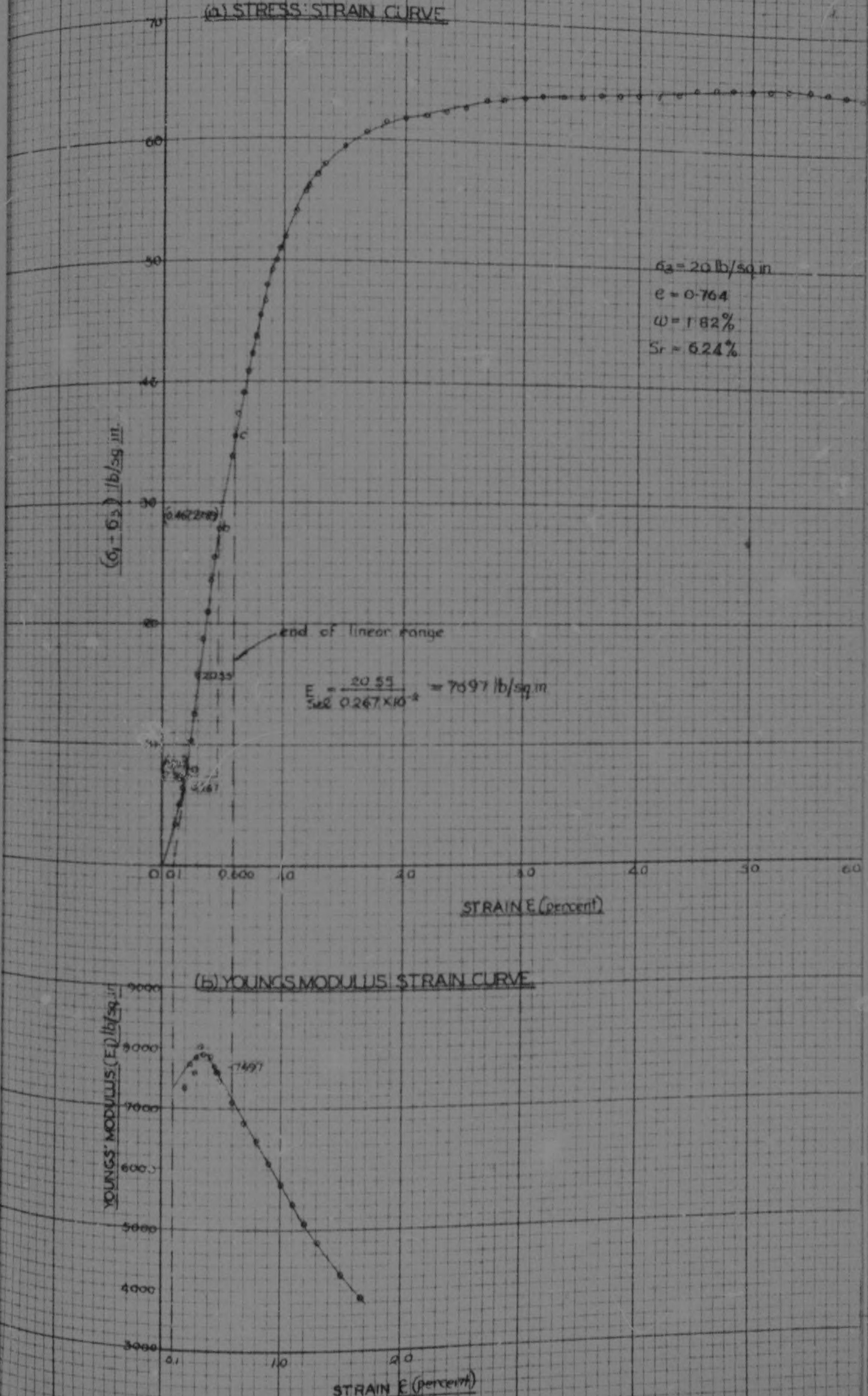


FIG. 34.

TEST No 6.

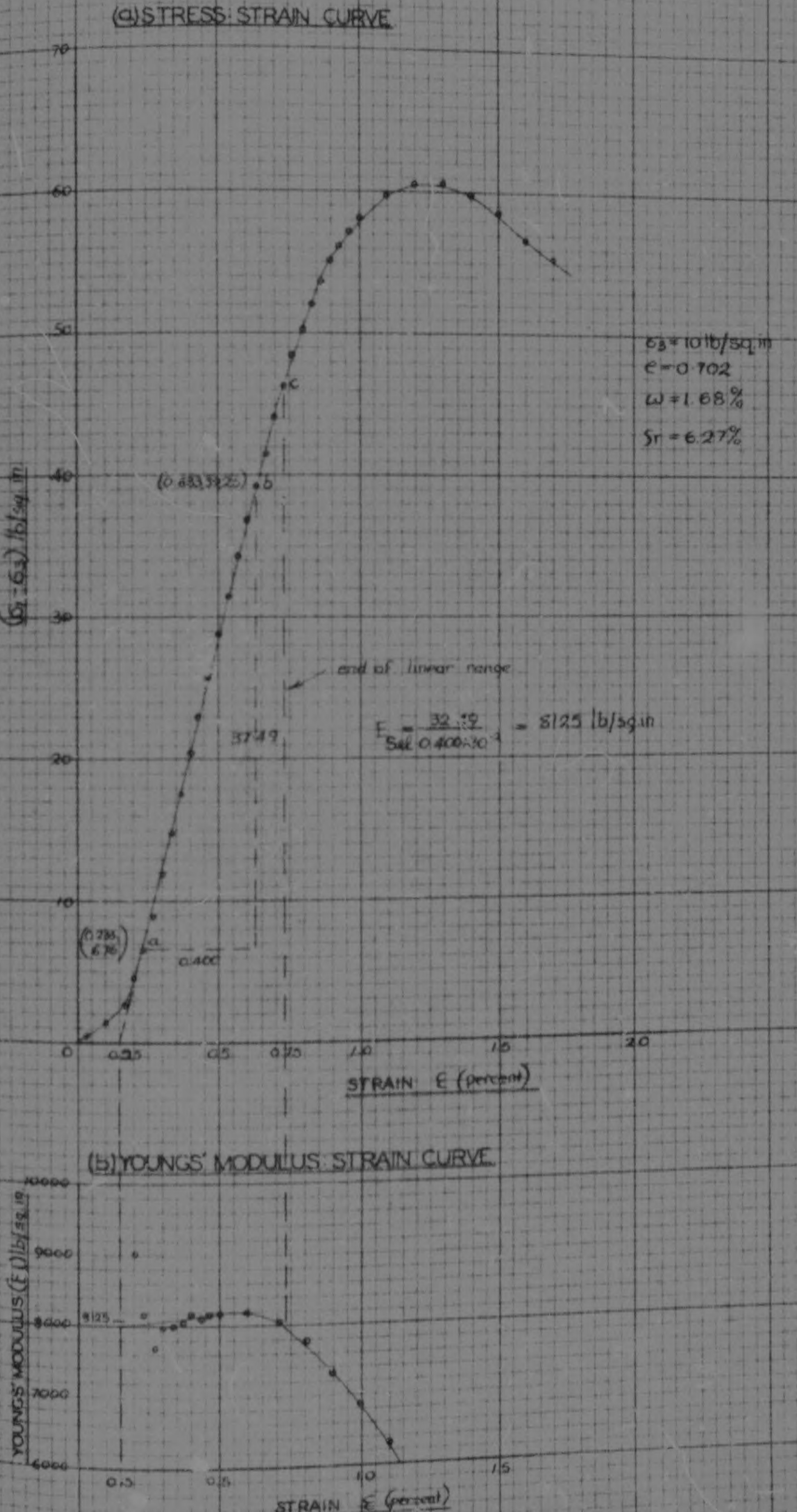


FIG 46

TEST Nº 3

CALCULATION OF INSTANTANEOUS VALUES OF YOUNGS' MODULUS (E)

CORRECTED STRESS = a lb/sq in	STRAIN percent	STRAIN DUE TO BEDDING - IN EFFECTS percent	CORRECTED STRAIN = b percent	YOUNGS' MODULUS (E) = a/b lb/sq in
7.34	0.200	0.100	0.100	7340
10.29	0.233	"	0.133	7737
12.68	0.267	"	0.167	7593
15.66	0.300	"	0.200	7830
18.70	0.333	"	0.233	8026
21.00	0.367	"	0.267	7585
23.58	0.400	"	0.400	7860
25.65	0.433	"	0.333	7703
27.89	0.467	"	0.367	7599
29.91	0.500	"	0.400	7478
33.82	0.567	"	0.467	7242
35.49	0.600	"	0.500	7098
37.33	0.633	"	0.533	7004
39.06	0.667	"	0.567	6889
40.62	0.700	"	0.600	6770
42.34	0.733	"	0.633	6689
43.94	0.767	"	0.667	6573
45.28	0.800	"	0.700	6468
46.50	0.833	"	0.733	6344
48.00	0.867	"	0.767	6258
49.10	0.900	"	0.800	6138
49.92	0.933	"	0.833	5993
50.91	0.967	"	0.867	5872
51.90	1.000	"	0.900	5767
54.20	1.100	"	1.000	5420
54.96	1.133	"	1.033	5320
55.67	1.167	"	1.067	5217
56.10	1.200	"	1.100	5100
56.64	1.233	"	1.133	4999
57.18	1.267	"	1.167	4900
57.55	1.300	"	1.200	4796
57.97	1.333	"	1.233	4702
59.43	1.500	"	1.400	4245
60.66	1.667	"	1.567	3871

TEST Nº 6

CALCULATION OF INSTANTANEOUS VALUES OF YOUNGS' MODULUS (E)

CORRECTED STRESS = a lb/sq in	STRAIN percent	STRAIN DUE TO BEDDING-IN EFFECTS percent	CORRECTED STRAIN = b percent	YOUNGS MODULUS (E) = a/b lb/sq in
4.51	0.200	0.150	0.050	9020
6.76	0.233	"	0.083	8144
8.96	0.267	"	0.117	7658
11.93	0.300	"	0.150	7953
14.63	0.333	"	0.183	7994
17.45	0.367	"	0.217	8041
20.38	0.400	"	0.250	8152
23.04	0.433	"	0.283	8141
25.81	0.467	"	0.317	8142
28.65	0.500	"	0.350	8186
31.46	0.533	"	0.383	8214
34.25	0.567	"	0.417	8213
36.93	0.600	"	0.450	8200
39.25	0.633	"	0.483	8126
41.53	0.667	"	0.517	8033
44.15	0.700	"	0.550	8027
46.16	0.733	"	0.583	7918
48.55	0.767	"	0.617	7869
50.33	0.800	"	0.650	7743
51.99	0.833	"	0.683	7612
53.65	0.867	"	0.717	7482
54.92	0.900	"	0.750	7323
56.08	0.933	"	0.783	7163
57.12	0.967	"	0.817	6991
58.11	1.000	"	0.850	6836
58.[illegible]	1.033	"	0.883	6661
59.42	1.067	"	0.917	6489
59.04	1.100	"	0.950	6299

TEST Nº 2 : MAIN TEST OBSERVATIONS.

DEFLEC-TION GAUGE	LOAD GAUGE	SLUG SCALE cm	TIME min. sec.	TEMPERA-TURE °C	CORRECTED SLUG SCALE cm	CORRECTED LOAD lb	CORRECT DEFLECT 10^{-3} in.	STRAIN ε percent	CORRECTED STRESS $(\sigma_1-\sigma_3)=\sigma$ lb/sq in
00 50	12.7	25.5		25.25	0	0	0	0	0
52.5	17.0	25.65			- 0.15	4.3	2.5	0.083	2.43
55	17.9	25.75			- 0.25	7.2	5	0.167	4.05
57.5	23.8	25.7			- 0.20	11.1	7.5	0.250	6.25
59 pronounced time-lag sets in.									
60	39.0	23.7			+ 1.8	26.3	10	0.333	14.81
62.5	53.0	21.2			4.3	40.3	12.5	0.417	22.67
65	64	18.8			6.7	51.3	15	0.500	28.84
67.5	75	16.45			9.05	62.3	17.5	0.583	34.99
70	84.5	14.55			10.95	71.6	20	0.667	40.29
72.5	94.5	12.40			13.10	81.8	22.5	0.750	45.87
75	103	10.55			14.95	90.3	25	0.833	50.59
77.5	112	8.75			16.75	99.3	27.5	0.917	55.59
80	119	7.20			18.30	106.3	30	1.000	59.45
82.5	126.5	5.55			19.95	113.8	32.5	1.083	63.62
85	133.5	4.05			21.45	120.8	35	1.167	67.45
87.5	140	2.60			22.90	127.3	37.5	1.250	71.1
90	145					132.3	40	1.333	73.2
92.5	150.3					137.6	42.5	1.417	76.7
95	155.8	28.9			27.15	143.1	45	1.500	79.6
97.5	160	28.5			27.55	147.3	47.5	1.583	81.9
100	164.5	27.7			28.35	151.6	50	1.667	84.2
102.5	168.1	26.95			29.1	155.4	52.5	1.750	86.3
105	171.7	26.15			29.9	159.0	55	1.833	88.1
107.5	175	25.45		25.5	30.6	162.3	57.5	1.917	90.0
110	178	25.00			31.05	165.3	60	2.000	91.6
112.5	180.4	24.55			31.50	167.7	62.5	2.083	92.6
115	183	24.20			31.85	170.3	65	2.167	94.1
117.5	185	23.275			32.15	172.3	67.5	2.250	95.1
120	187.3	23.55			32.4	174.6	70	2.333	96.4
122.5	189.0	23.40			32.65	176.3	72.5	2.417	97.1
125	190.8	23.325			32.725	178.1	75	2.500	98.1
127.5	192.0	23.275			32.825	179.3	77.5	2.533	98.2
130	193.5	23.275			32.825	180.8	80	2.667	99.4
132.5	194.6	23.275			32.825	181.9	82.5	2.750	99.9
135	195.6	23.30			32.80	182.9	85	2.833	100.4
137.5	196.6	23.45			32.65	183.9	87.5	2.917	100.9
140	197.3	23.65			32.45	184.6	90	3.000	101.2
142.5	198.0	23.85			32.25	185.3	92.5	3.083	101.5
145	198.5	24.05			32.05	185.8	95	3.167	101.6
147.5	199.0	24.30			31.80	186.3	97.5	3.250	101.8
150	199.1	24.65			31.45	186.4	100	3.333	101.9
152.5	199.5	25.15			30.95	186.8	102.5	3.417	102.0
155	199.7	25.70			30.40	187.0	105	3.500	102.0
157.5	199.8	26.20			29.90	187.1	107.5	3.583	101.9
160	199.8	26.80			29.30	187.1	110	3.667	101.8
162.5	199.9	27.40			28.70	187.1	112.5	3.750	101.7
165	199.8	28.00			28.10	187.1	115	3.833	101.6
167.5	199.7	28.65			27.45	187.0	117.5	3.917	101.5
170	199.3	29.30			26.80	186.6	120	4.000	101.2
175	198.7	30.75			25.35	186.0	125	4.167	100.7
177.5	198.2	31.40			24.70	185.5	127.5	4.250	100.3
180	197.5					184.8	130	4.333	99.9
185	196.5					183.8	135	4.500	99.2
192.5	195.0					182.3	142.5	4.750	98.1
200	192.8			25.25		180.1	150	5.000	96.7

TEST Nº 5 MAIN TEST OBSERVATIONS

DEFLECTION GAUGE	LOAD GAUGE	SLUG SCALE cm	TIME min sec	TEMPERATURE °C	CORRECTED SLUG SCALE cm	CORRECTED LOAD lb	CORRECT DEFLECT 10^{-3} in	STRAIN ε percent	CORRECTED STRESS (10^3) lb/sq in
00 30	15	22.7		24.0	0	0	0	0	0
32.5	16.0	22.9			- 0.20	1.0	2.5	0.083	0.56
35	16.8	23.2			- 0.50	1.8	5	0.167	1.02
37.5	19.0	23.5			- 0.80	4.0	7.5	0.250	2.25
40	21.3	23.8			- 1.10	6.3	10	0.333	3.55
41 pronounced time-lag sets in.									
42.5	34.5	22.45			+ 0.25	19.5	12.5	0.417	10.97
45	46.0	19.65			3.05	31	15	0.500	17.43
47.5	56.0	17.30			5.40	41	17.5	0.583	23.03
50	64.0	15.50			7.20	49	20	0.667	27.5
52.5	73.0	14.00			8.70	58.0	22.5	0.750	32.52
55	80.4	12.80			9.90	65.4	25	0.833	36.54
57.5	87.5	11.70		24.0	11.00	72.5	27.5	0.917	40.58
60	93.0	11.35			11.35	78.0	30	1.000	43.63
62.5	97.0	11.15			11.55	82.0	32.5	1.083	45.83
65	101.0	11.10			11.60	86.0	35	1.167	48.02
67.5	104.0	11.25			11.45	89.0	37.5	1.250	49.6
70	106.5	11.80			10.90	91.5	40	1.333	51.0
72.5	108.5	12.40			10.30	93.5	42.5	1.417	52.1
75	109.6	14.10			8.60	94.6	45	1.500	52.8
77.5	110.1	16.35			6.35	95.1	47.5	1.583	52.9
80	110.5	18.70			4.00	95.6	50	1.667	53.0
82.5		21.1			+ 1.60		52.5	1.750	
85	110.3	23.60			- 0.90	95.3	55	1.833	52.9
87.5	110.3	26.10			- 3.40	95.3	57.5	1.917	52.8
90	110.0	29.20			- 6.50	95.0	60	2.000	52.6
92.5	109.8	32.00			- 9.30	94.8	62.5	2.083	52.4
95							65	2.167	
97.5	108.1					93.1	67.5	2.250	51.4
100	107.5					92.5	70	2.333	51.1
102.5	106.8					91.8	72.5	2.417	50.6
105	105.9					90.9	75	2.500	50.0
107.5	105.3					90.3	77.5	2.583	49.6
110	104.8					89.8	80	2.667	49.4
112.5	104.0					89.0	82.5	2.750	48.9
115	103.2					88.2	85	2.833	48.4
117.5	102.4					87.4	87.5	2.917	48.0
120	100.9					85.9	90	3.000	47.1
122.5	99.0					84.0	92.5	3.083	46.0
125	97.2					82.2	95	3.167	45.0
127.5	95.5					80.5	97.5	3.250	44.0
130	93.9			24.0		78.9	100	3.333	43.1

TEST No 2.

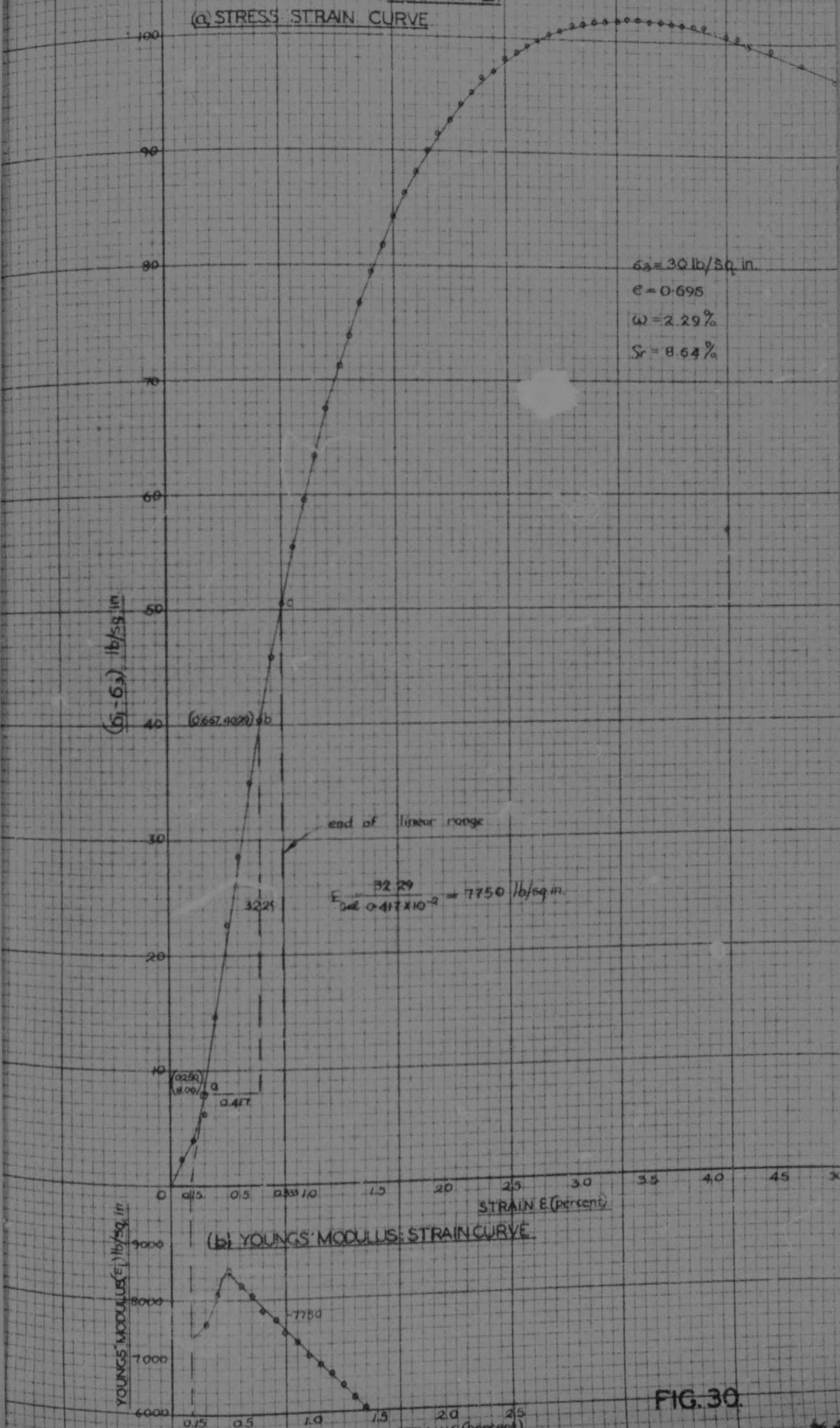
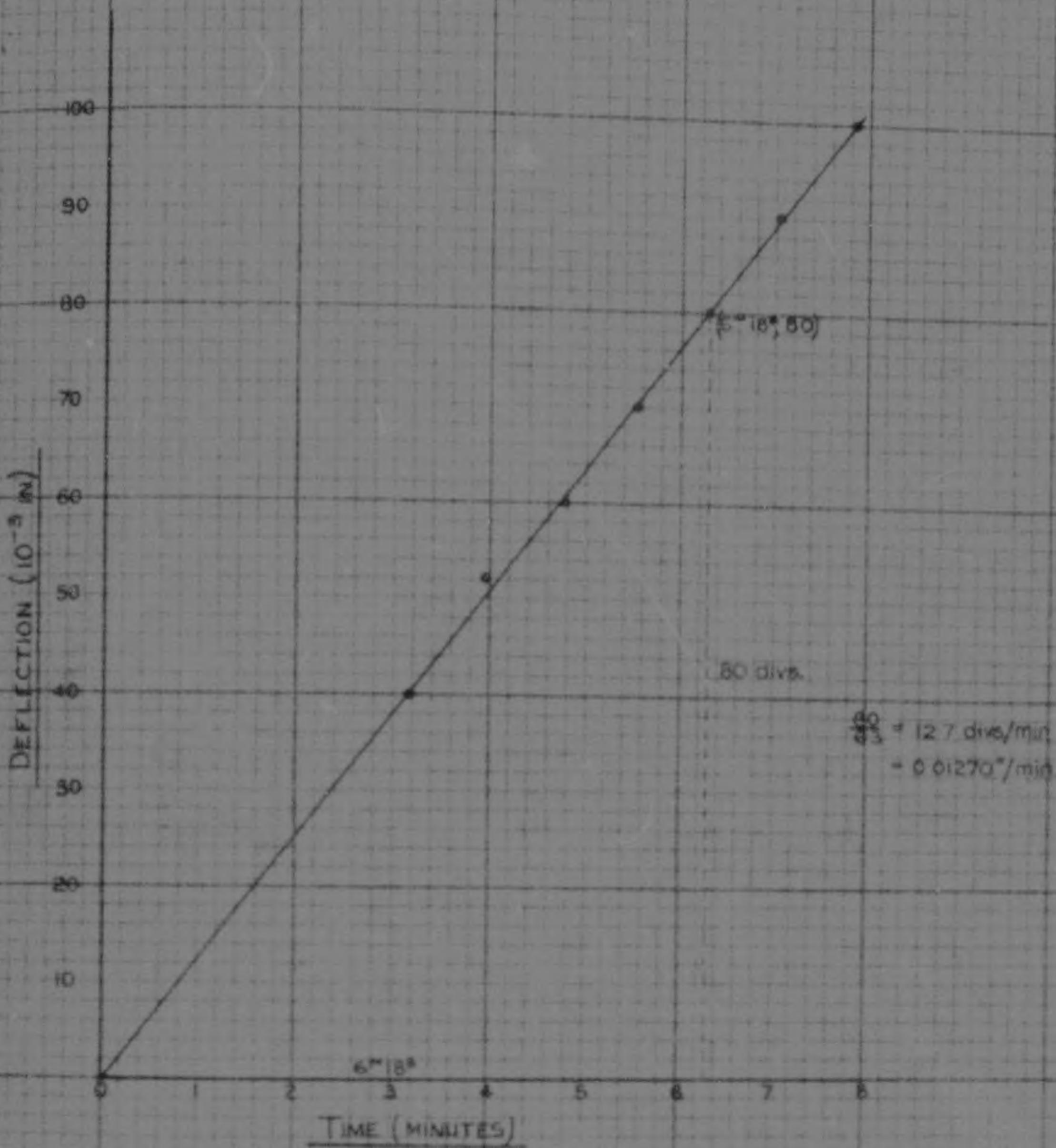


FIG. 30.

TEST No 5. RATE OF STRAIN DETERMINATION

FIG. 41 CALIBRATED RATE OF STAIN. ($\sigma_3 = 10$ lb/sq.in)



NOTE: No curve for determination of actual rate of strain during test, due to continuous time measurements not having been taken.

TEST Nº 2

CALCULATION OF INSTANTANEOUS VALUES OF YOUNGS' MODULUS (E)

CORRECTED STRESS = a lb/sq. in	STRAIN percent	STRAIN DUE TO BEDDING-IN EFFECTS percent	CORRECTED STRAIN = b percent	YOUNGS' MODULUS (E) = a/b lb/sq. in.
5.00	0.216	0.150	0.066	7575
14.81	0.333	"	0.183	8092
22.67	0.417	"	0.267	8492
28.84	0.500	"	0.350	8240
34.99	0.583	"	0.433	8081
40.29	0.667	"	0.517	7793
45.87	0.750	"	0.600	7645
50.59	0.833	"	0.683	7407
55.59	0.917	"	0.767	7248
59.45	1.000	"	0.850	6994
63.62	1.083	"	0.933	6819
67.45	1.167	"	1.017	6632
71.02	1.250	"	1.100	6456
73.75	1.333	"	1.183	6234
76.64	1.417	"	1.267	6049
79.63	1.500	"	1.350	5898

TEST No 5

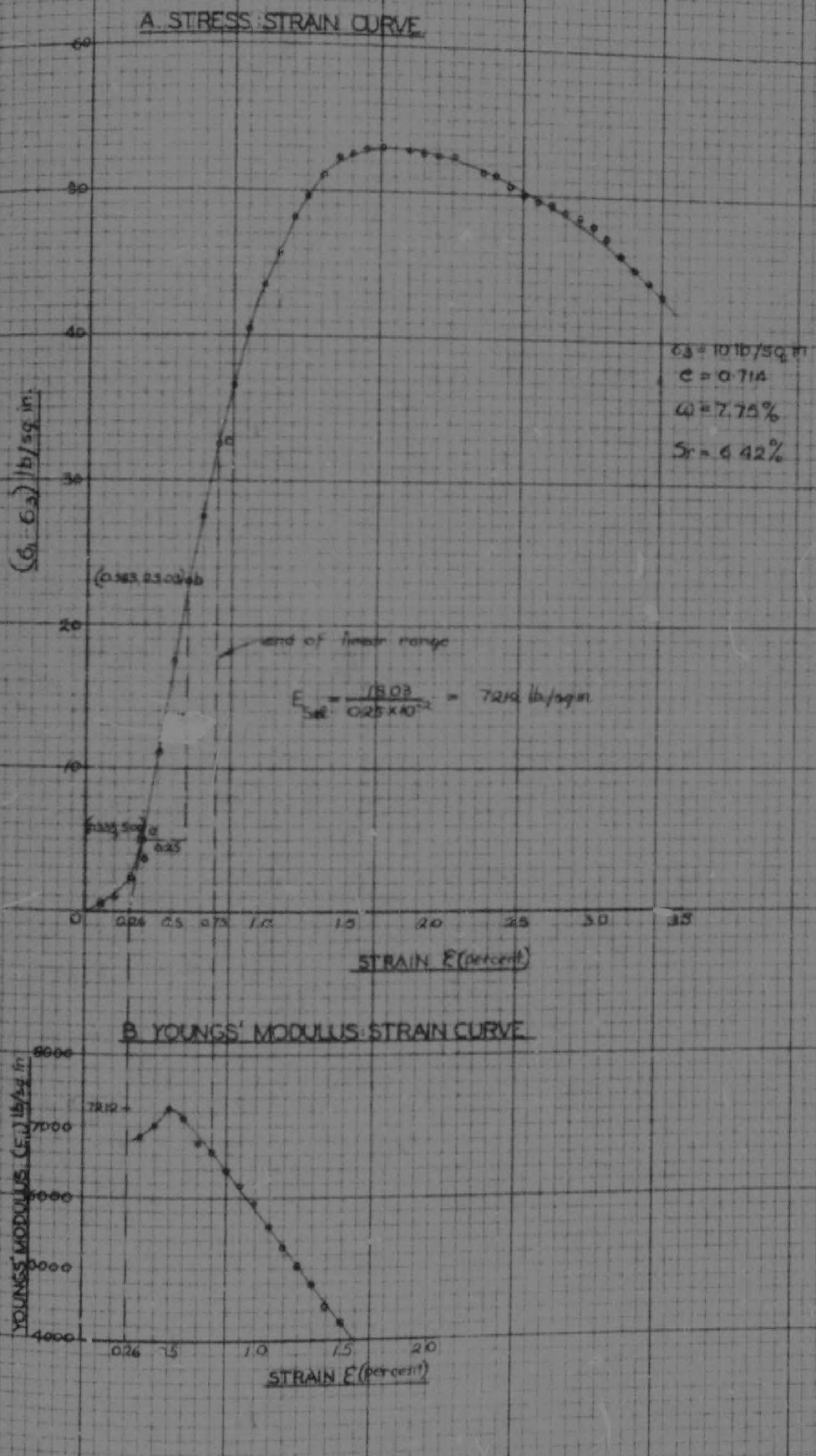


FIG 42

TEST No 2.

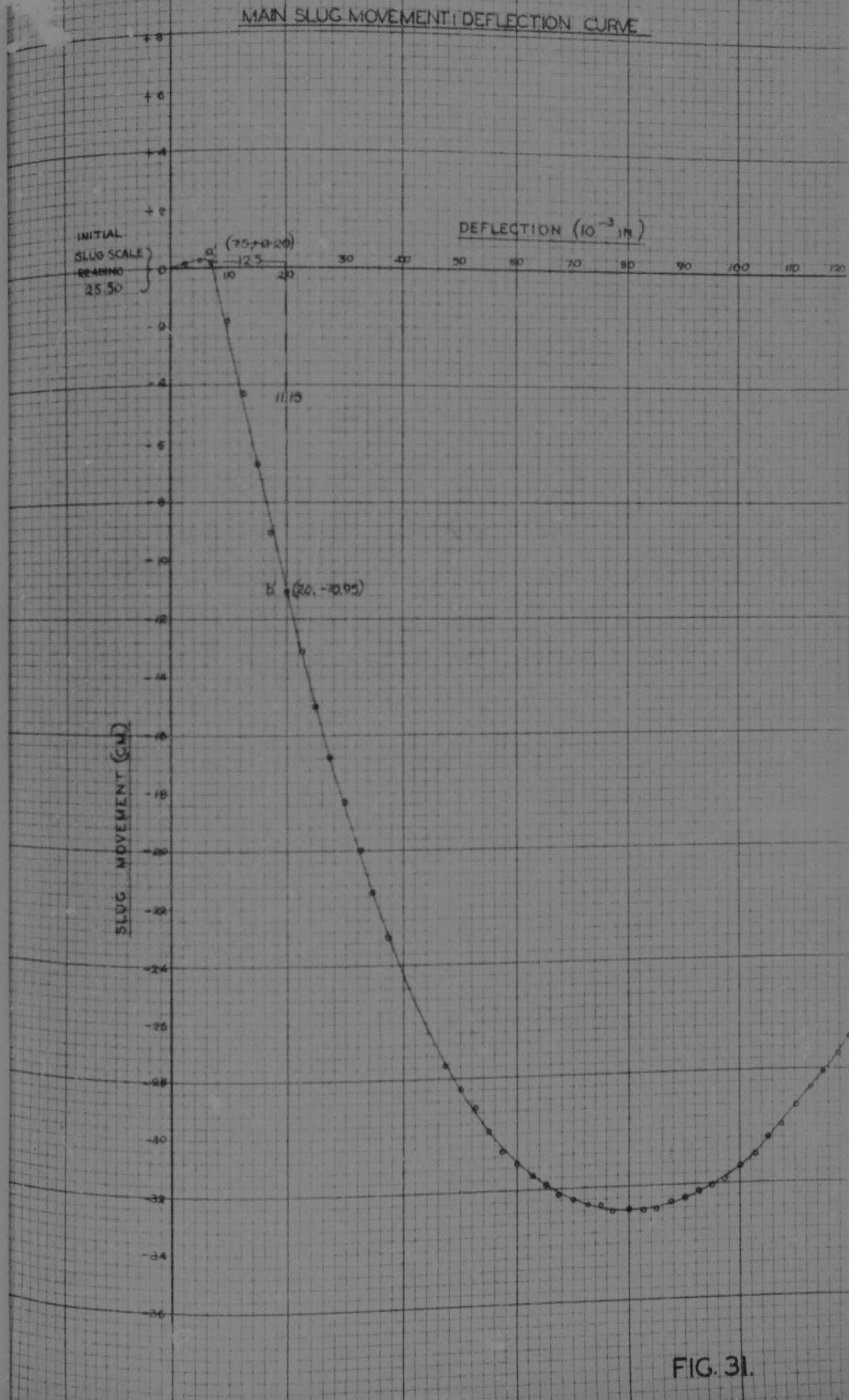


FIG. 31.

TEST No5

CALCULATION OF INSTANTANEOUS VALUES OF YOUNGS' MODULUS (E)

CORRECTED STRESS = a lb/sq in	STRAIN percent	STRAIN DUE TO BEDDING - IN EFFECTS percent	CORRECTED STRAIN = b percent	YOUNGS' MODULUS (E) = a/b lb/sq in
5.000	0.333	0.260	0.073	6849
10.97	0.417	"	0.157	6987
17.43	0.500	"	0.240	7262
23.03	0.583	"	0.323	7130
27.50	0.667	"	0.407	6757
32.52	0.750	"	0.490	6637
36.64	0.833	"	0.573	6394
40.58	0.917	"	0.657	6177
43.63	1.000	"	0.740	5896
45.83	1.003	"	0.823	5569
48.02	1.167	"	0.907	5294
49.65	1.250	"	0.990	5015
51.01	1.333	"	1.073	4754
52.08	1.417	"	1.157	4501
52.64	1.500	"	1.240	4245

TEST No5.

MAIN SLUG MOVEMENT DEFLECTION CURVE

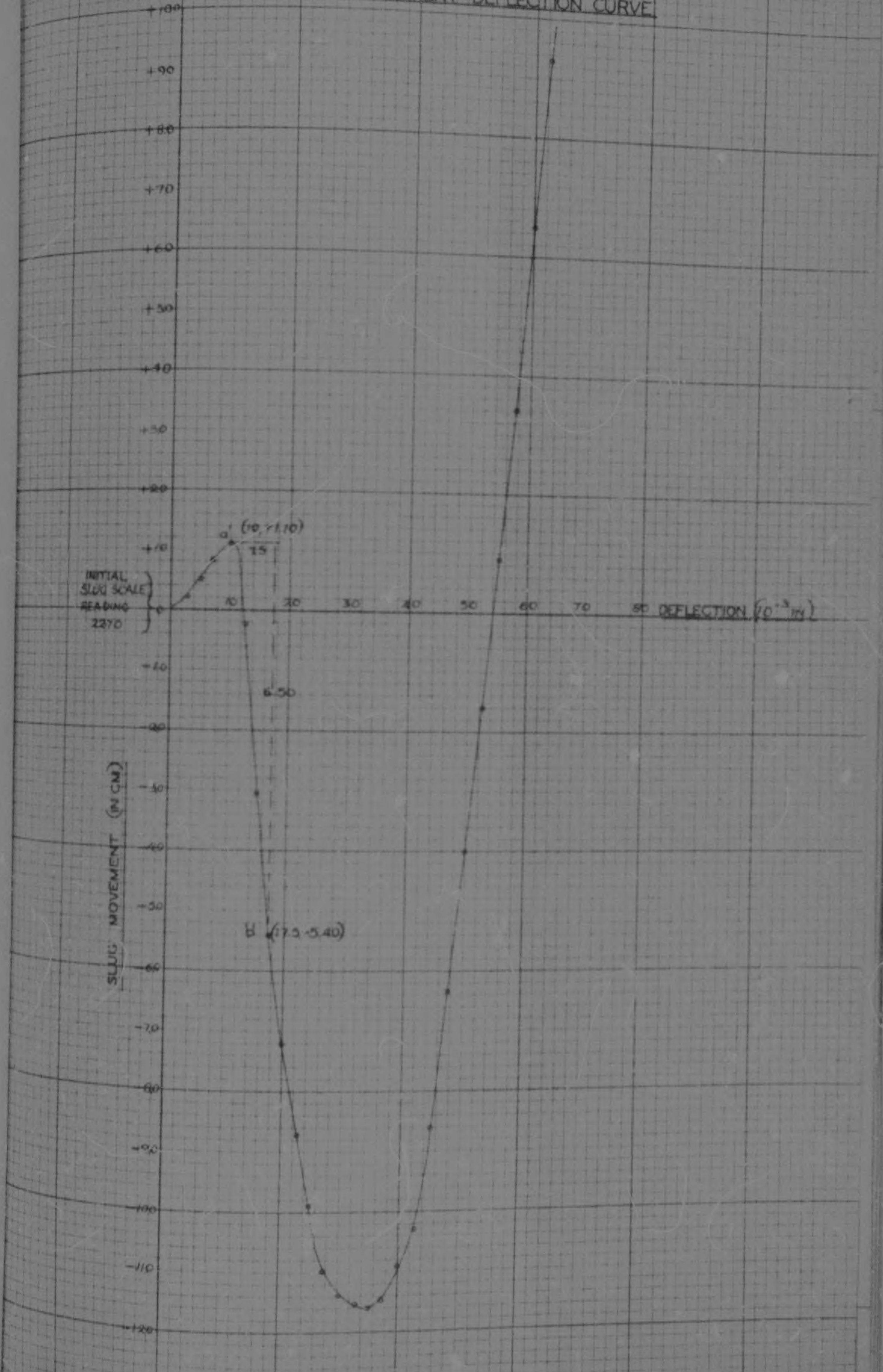


FIG. 43

TEST No 3.

DATE PERFORMED: 29/1/57

SAMPLE CONSOLIDATED FOR 24 00 PRIOR TO TEST.

TIME START OF TEST: 12/32 P.M. TEMPERATURE: 23·25°C

TIME END OF TEST: 2/05 P.M. TEMPERATURE: 24·0°C

NOMINAL σ_3 CHAMBER PRESSURE: 20 LB/SQ.IN.

HEAD OF MERCURY: 38⅛ INCHES. HENCE:

ACTUAL σ_3 CHAMBER PRESSURE: 18·889 LB/SQ.IN.

NOMINAL RATE OF STRAIN: 0·00256 INCHES/MINUTE

TEST No 3 : LEAKAGE MEASUREMENTS.

(A) MEASUREMENT OF SLUG MOVEMENT DUE TO LEAKAGE ONLY. BEFORE TEST. TEMP 23.25°C. TIME 12/15p.m.		(B) MEASUREMENT OF SLUG MOVEMENT DUE TO LEAKAGE ONLY. AFTER TEST (1). TEMP 24.0°C. TIME 2/05p.m.		(C) MEASUREMENT OF SLUG MOVEMENT DUE TO COMBINED EFFECTS OF LEAKAGE & SPINDLE ENTRY (AFTER TEST). TEMPERATURE 24.0°C. TIME 2/15p.m.			(D) MEASUREMENT OF SLUG MOVEMENT DUE TO LEAKAGE ONLY. AFTER TEST (2). TEMP 24.0°C. TIME 2/35p.m.	
TIME min sec	VOLUME SCALE cm	TIME min sec	VOLUME SCALE cm.	DEFLECT GAUGE 10^{-3} in	VOLUME SCALE cm	TIME min sec	TIME min sec	VOLUME SCALE cm
0 00	20.70	0 00	11.90	00 51	10.70	00 00	0 00	11.50
15	20.675	15	11.825	52	10.70		15	11.45
30	20.625	30	11.75	53	10.70		30	11.40
45	20.60	45	11.675	54	10.70		45	11.325
1 00	20.55	1 00	11.625	55	10.70	01 34	1 00	11.275
15	20.525	15	11.55	56	10.725		15	11.20
30	20.475	30	11.50	57	10.75		30	11.15
45	20.45	45	11.45	58	10.775		45	11.10
2 00	20.40	2 00	11.425	59	10.775		2 00	11.075
15	20.375	15	11.40	60	10.80	03 38	15	11.025
30	20.325	30	11.375	61	10.825		30	11.00
45	20.30	45	11.35	62	10.85		45	10.975
3 00	20.25	3 00	11.30	63	10.875		3 00	10.95
15	20.225	15	11.225	64	10.90		15	10.90
30	20.175	30	11.175	65	10.925	05 35	30	10.875
45	20.125	45	11.125	66	10.975		45	10.80
4 00	20.10	4 00	11.075	67	11.00		4 00	10.775
15	20.05	15	11.025	68	11.00		15	10.725
30	20.00	30	10.975	69	11.025		30	10.675
45	19.975	45	10.90	70	11.05	07 32	45	10.60
5 00	19.90	5 00	10.825	71	11.075		5 00	10.525
				72	11.10			
				73	11.10			
				74	11.15			
				75	11.175	09 28		
				76	11.175			
				77	11.20			
				78	11.225			
				79	11.275			
				80	11.30	11 24		
				81	11.325			
				82	11.35			
				83				
				84	11.425			
				85	11.475	13 20		
				86	11.50			
				87	11.525			
				88	11.575			
				89	11.60			
				90	11.625	15 14		

TEST No 6.

DATE PERFORMED 31 / 1 / 57

SAMPLE CONSOLIDATED FOR 24^{HRS} 00^{MIN} PRIOR TO TEST

TIME START OF TEST 11 · 28 A M TEMPERATURE 20·75°C

TIME END OF TEST 12.00 NOON TEMPERATURE 20·75°C

NOMINAL σ_3 CHAMBER PRESSURE 10 LB / SQ IN

HEAD OF MERCURY 18 INCHES HENCE

ACTUAL σ_3 CHAMBER PRESSURE 8·825 LB / SQ IN

NOMINAL RATE OF STRAIN 0·00256 INCHES / MINUTE

TEST No3

MAIN SLUG MOVEMENT; DEFLECTION CURVE

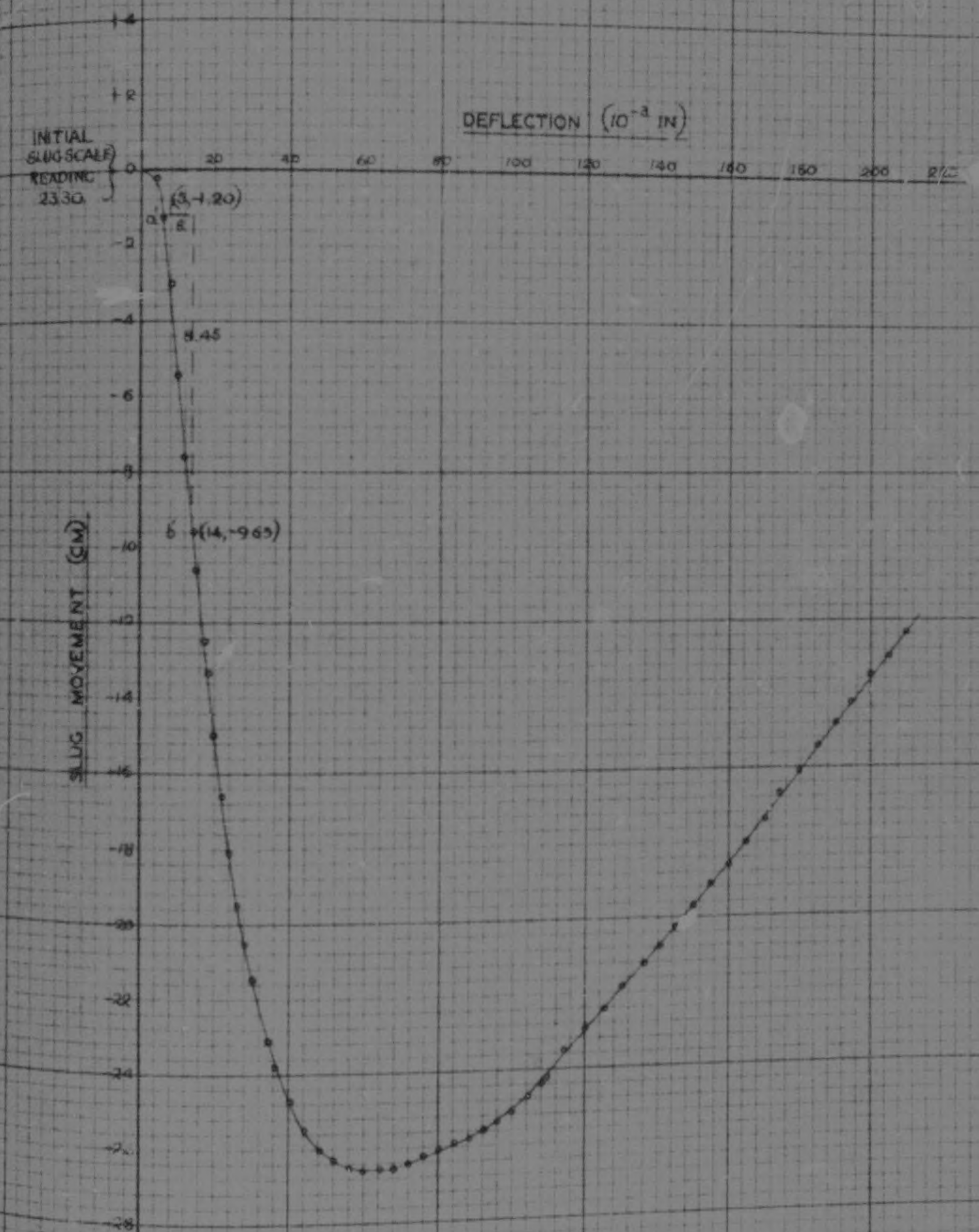


FIG. 35

TEST No. 4.

DATE PERFORMED: 15 / 2 / 57

SAMPLE CONSOLIDATED FOR 23 HRS 40 MIN PRIOR TO TEST.

TIME START OF TEST: 8.46 A.M. TEMPERATURE: 24.0°C

TIME END OF TEST: 8.56 A.M. TEMPERATURE: 24.25°C

NOMINAL σ_3 CHAMBER PRESSURE: 20 LB/SQ. IN.

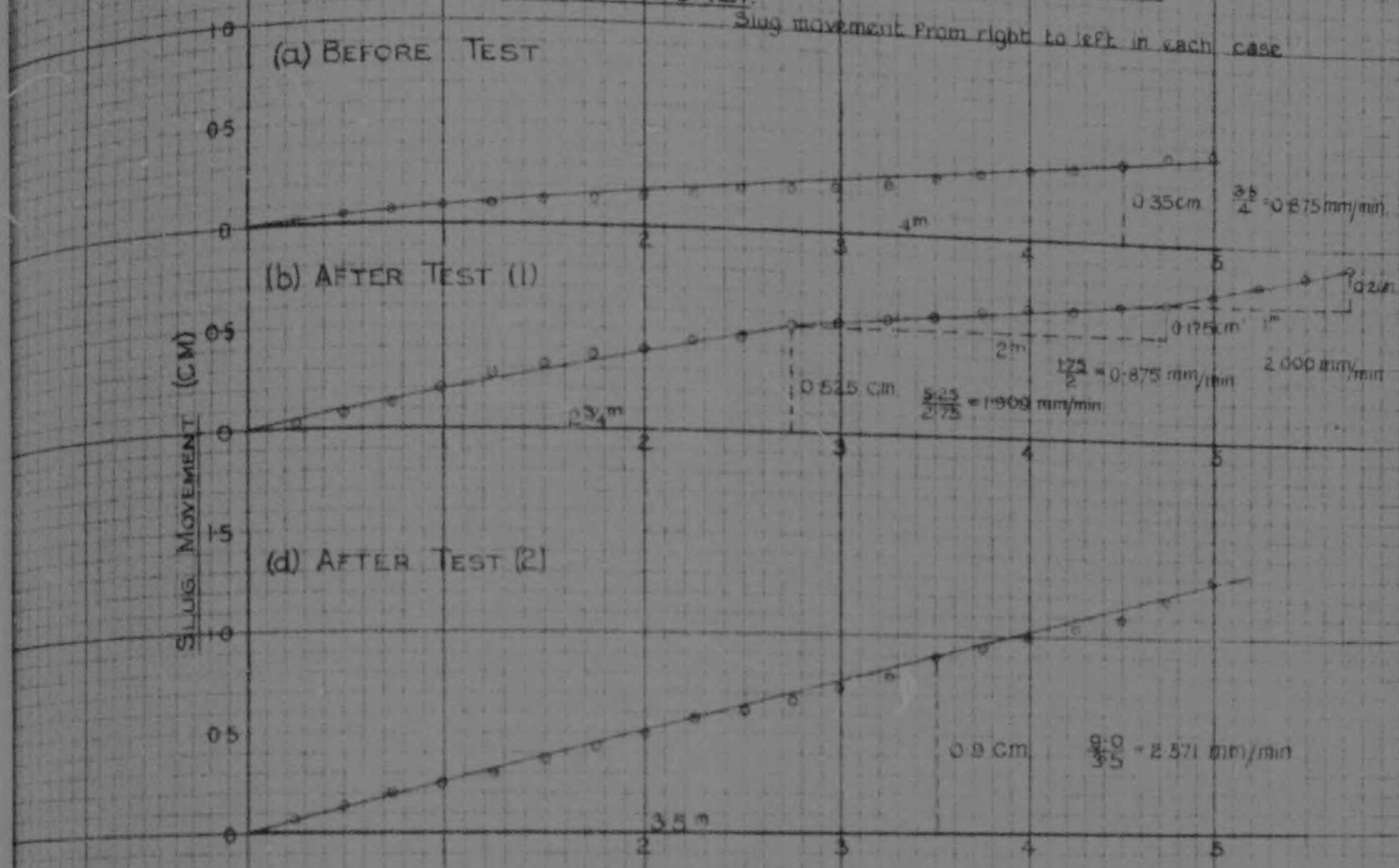
HEAD OF MERCURY: 38¼ INCHES, HENCE:

ACTUAL σ_3 CHAMBER PRESSURE: 18.750 LB/SQ. IN.

NOMINAL RATE OF STRAIN 0.0125 INCHES/MINUTE

TEST No 4: LEAKAGE MEASUREMENTS

DETERMINATION OF RATE OF SLUG MOVEMENT DUE TO LEAKAGE ONLY



(c) DETERMINATION OF RATE OF SLUG MOVEMENT DUE TO COMBINED EFFECTS OF LEAKAGE AND SPINDLE ENTRY

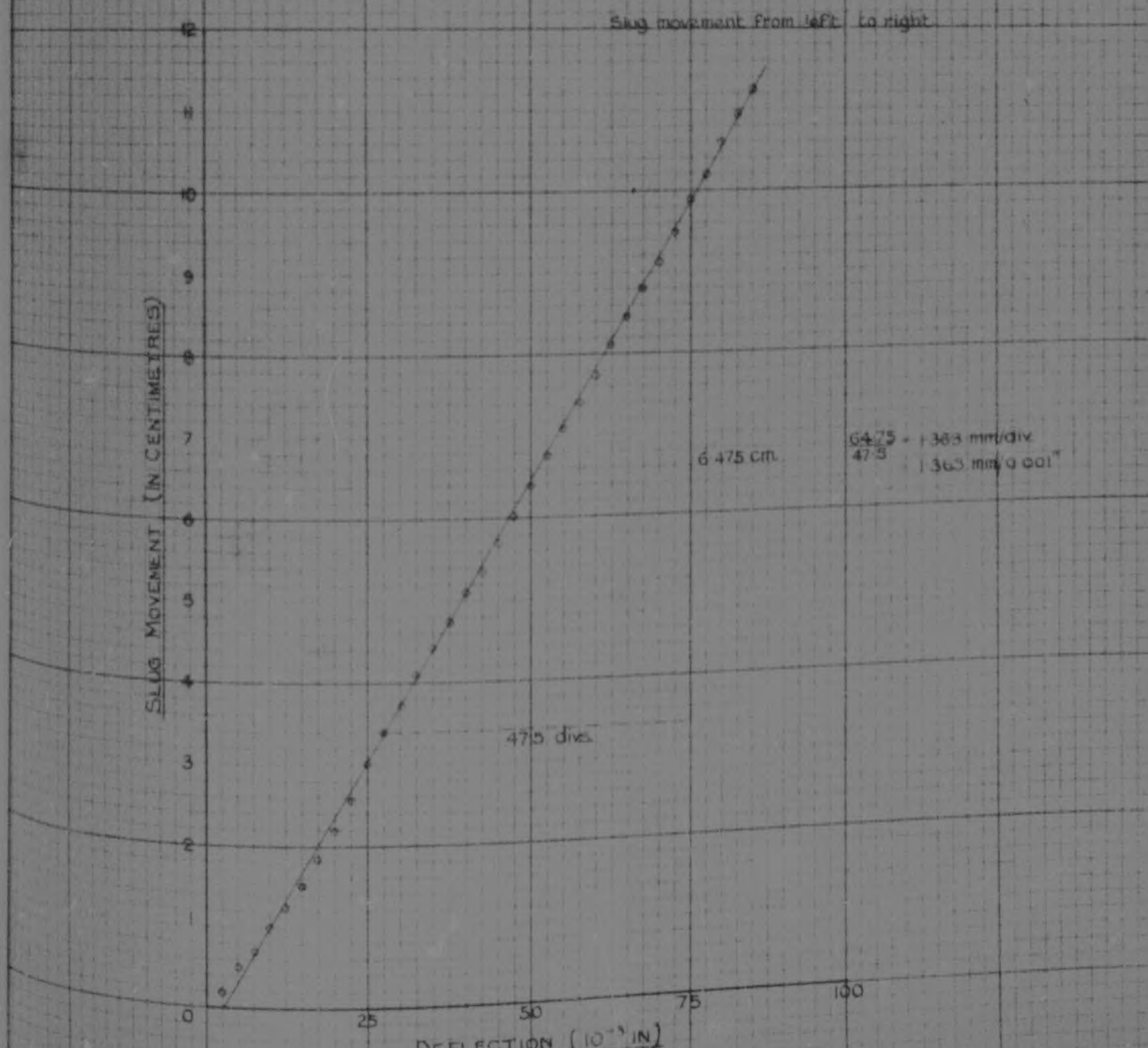
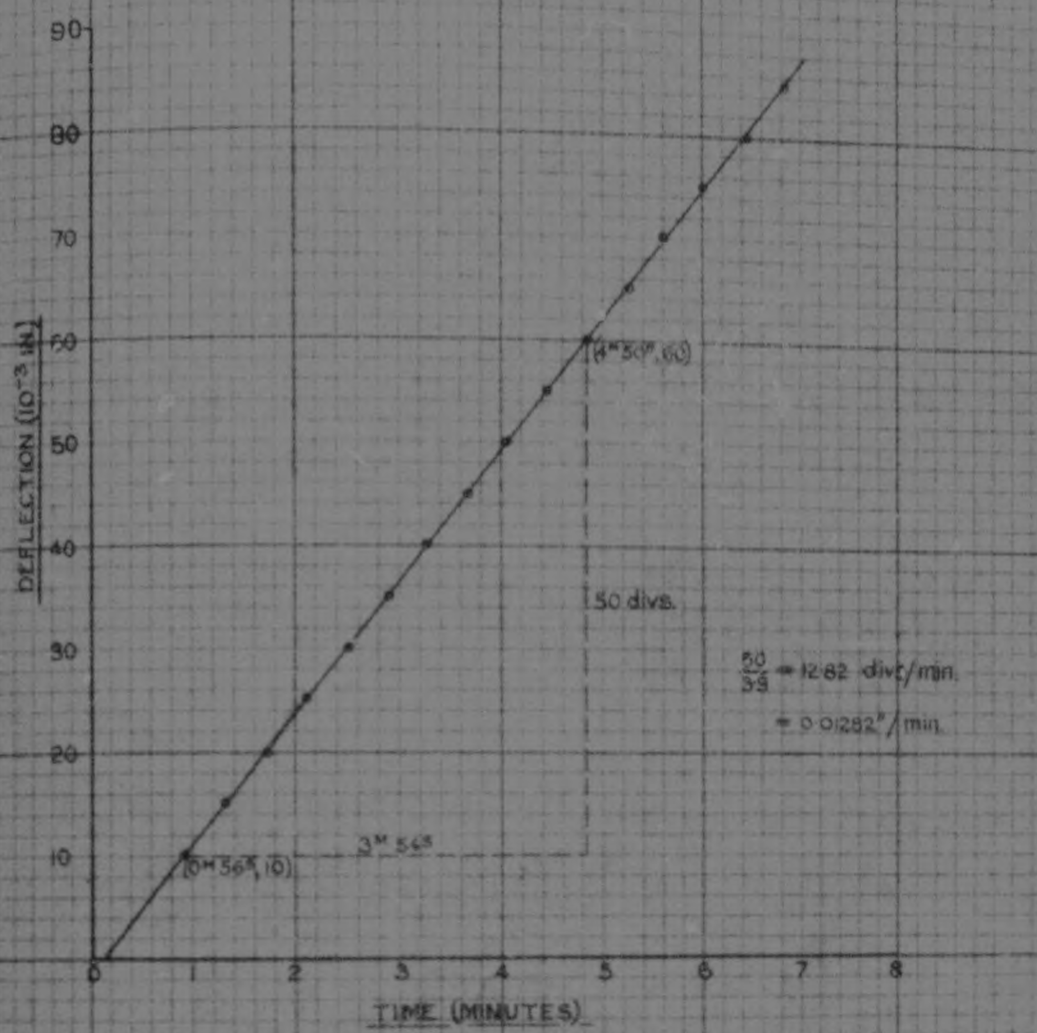


FIG. 36.

TEST No 4: RATE OF STRAIN DETERMINATIONS

(a) CALIBRATED RATE OF STRAIN ($\sigma_3 = 20$ lb/Sq.in)



(b) ACTUAL RATE OF STRAIN DURING TEST ($\sigma_3 = 20$ lb/Sq.in)

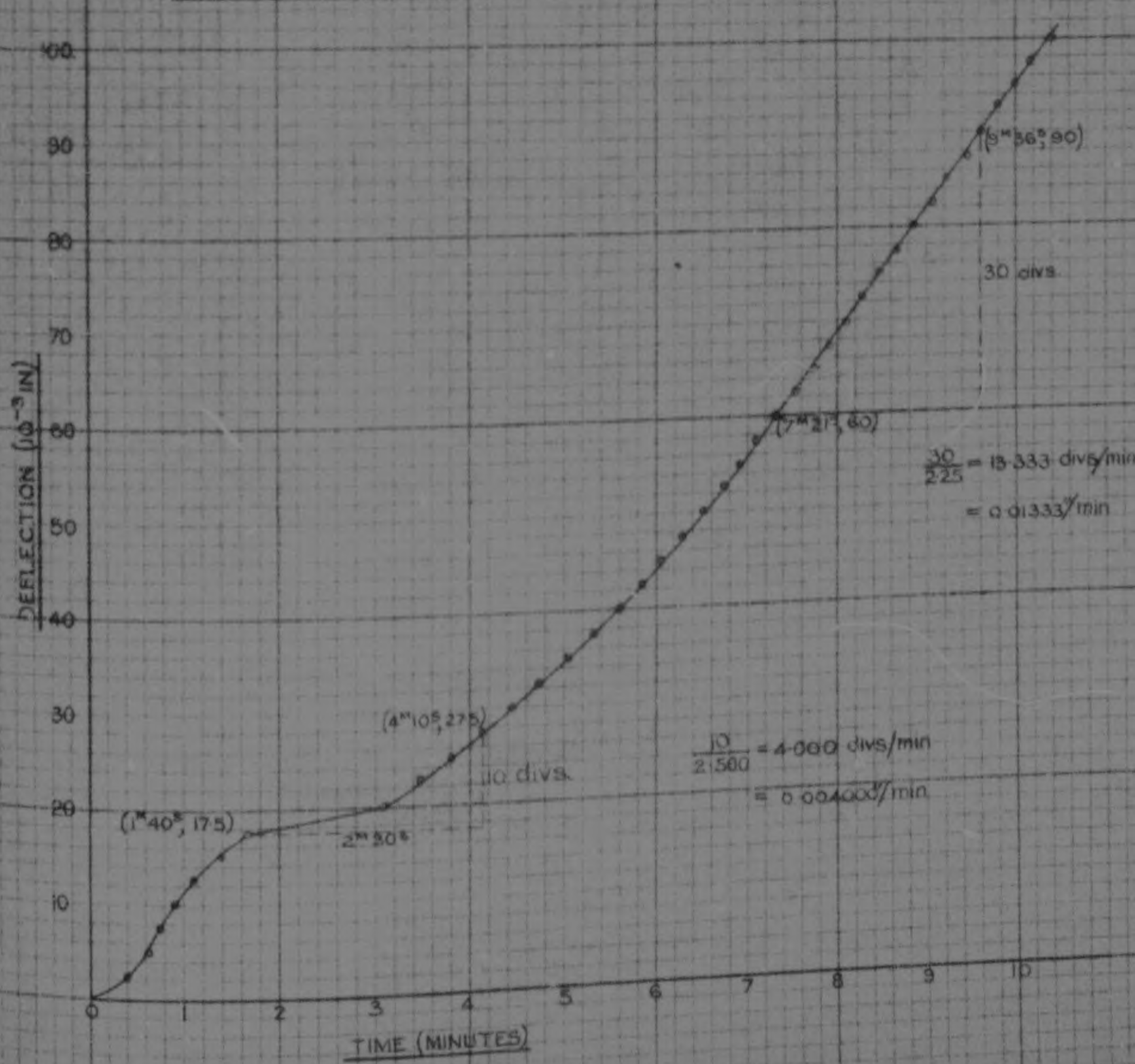


FIG. 37.

TEST No4

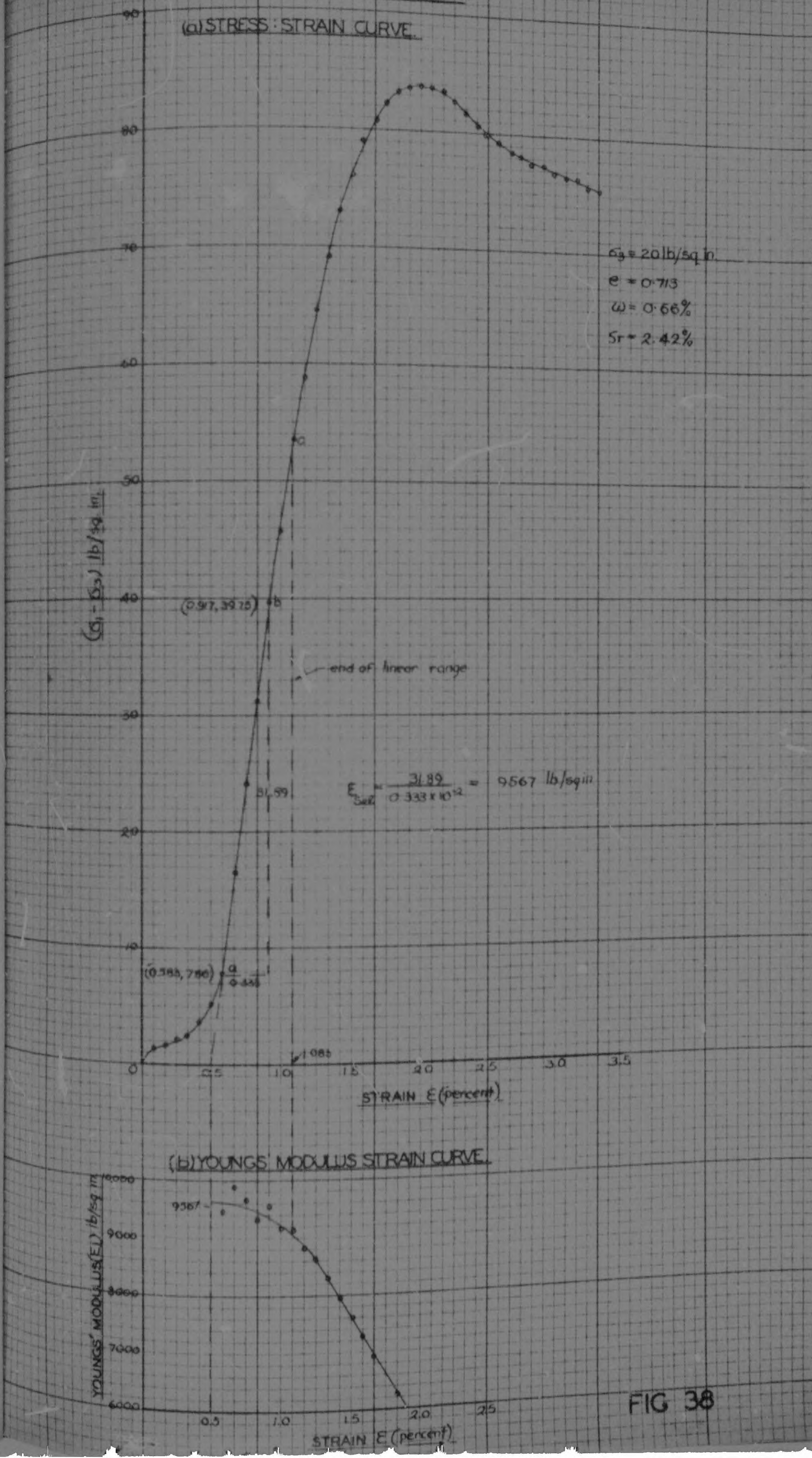


FIG 38

TEST No 4

CALCULATION OF INSTANTANEOUS VALUES OF YOUNGS' MODULUS (E)

CORRECTED STRESS = a lb/sq in	STRAIN percent	STRAIN DUE TO BEDDING-IN EFFECTS percent	CORRECTED STRAIN = b percent	YOUNGS' MODULUS (E) = a/b lb/sq in
7.86	0.583	0.500	0.083	9470
16.56	0.667	"	0.167	9916
24.12	0.750	"	0.250	9648
31.10	0.833	"	0.333	9339
39.75	0.917	"	0.417	9532
45.87	1.000	"	0.500	9174
53.37	1.083	"	0.583	9154
58.85	1.167	"	0.667	8823
64.72	1.250	"	0.750	8629
69.12	1.333	"	0.833	8296
72.96	1.417	"	0.917	7956
75.96	1.500	"	1.000	7596
78.96	1.583	"	1.083	7291
80.83	1.667	"	1.167	6926
82.15	1.750	"	1.250	6572
83.19	1.833	"	1.333	6241
83.67	1.917	"	1.417	5905
83.88	2.000	"	1.500	5592

TEST Nº 4.

MAIN SLUG MOVEMENT DEFLECTION CURVE.

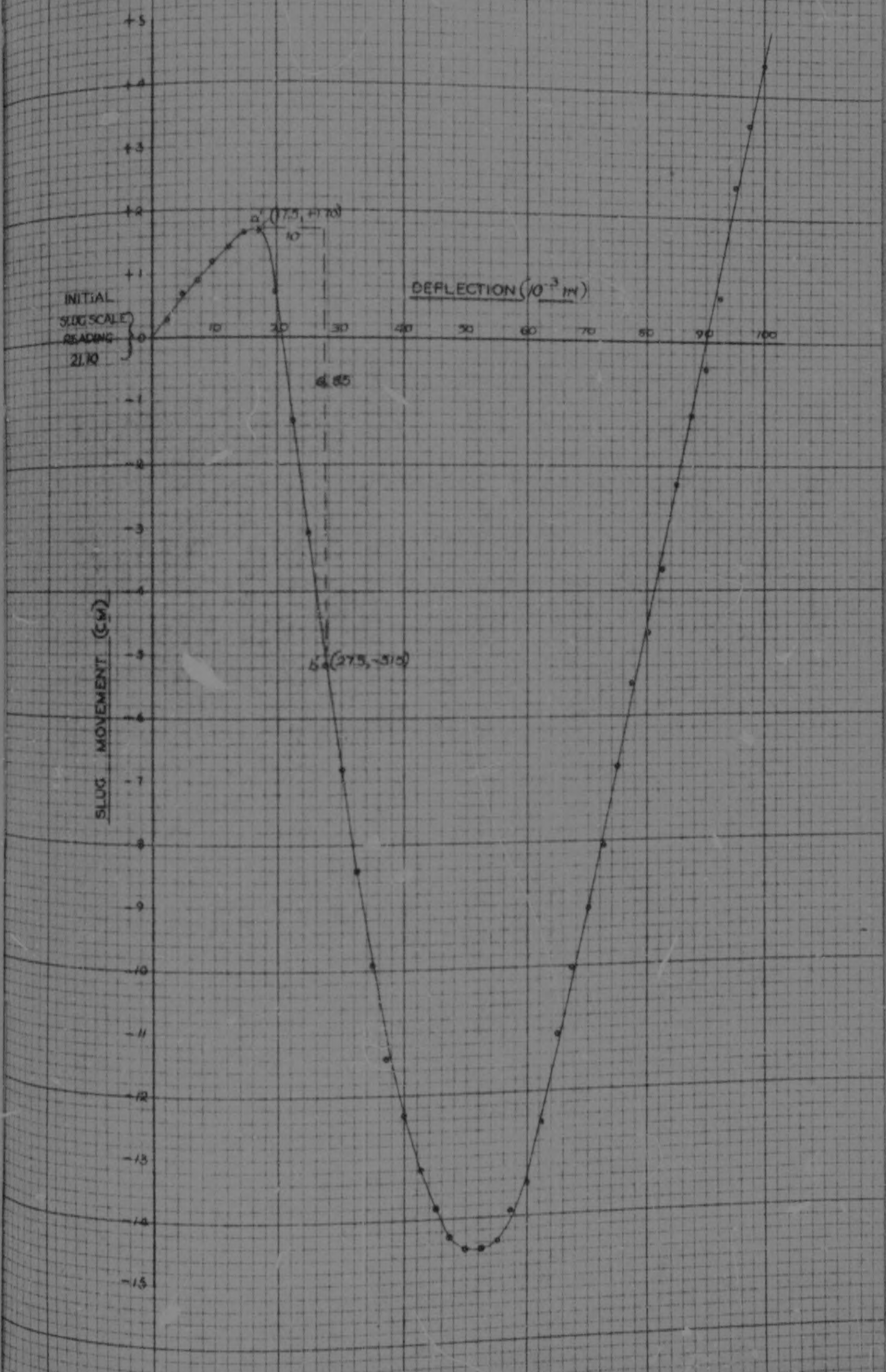


FIG. 39.

TEST No 5.

DATE PERFORMED: 30/1/57

SAMPLE CONSOLIDATED FOR: 23 HRS 15 MIN PRIOR TO TEST

TIME START OF TEST: 4/33 P.M. TEMPERATURE: 24·0°C

TIME END OF TEST: 4/43 P.M. TEMPERATURE: 24·0°C

NOMINAL σ_3 CHAMBER PRESSURE: 10 LB/SQ IN

HEAD OF MERCURY: 18 INCHES, HENCE:

ACTUAL σ_3 CHAMBER PRESSURE: 8·825 LB/SQ IN

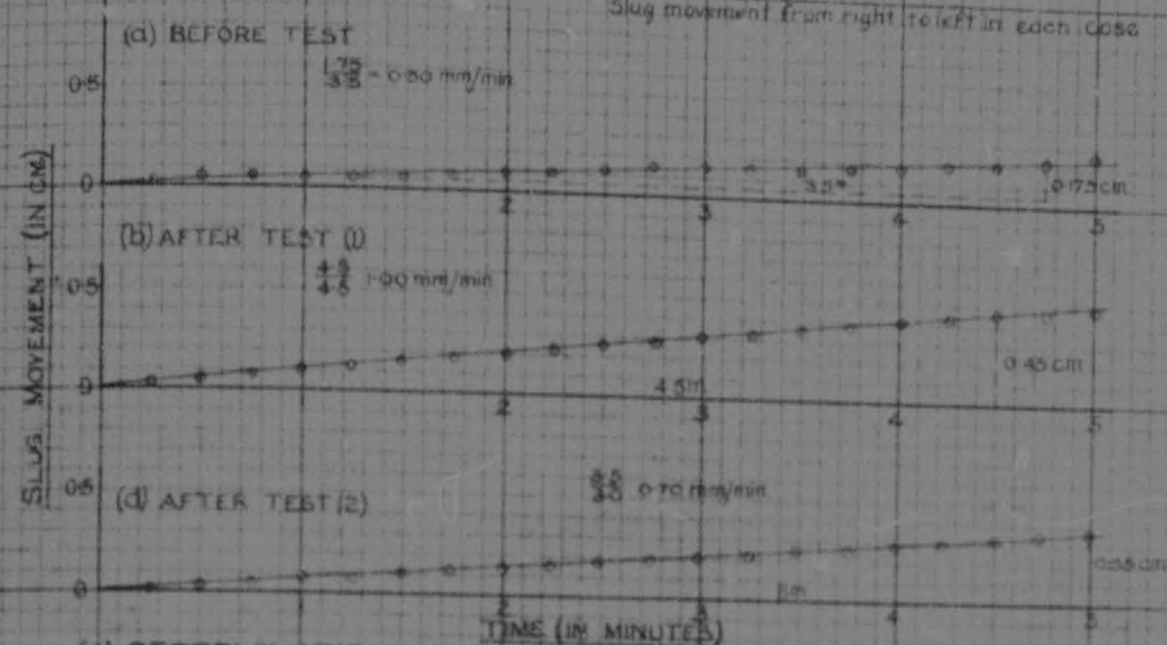
NOMINAL RATE OF STRAIN: 0·0125 INCHES/MINUTE

TEST Nº 5 : LEAKAGE MEASUREMENTS.

(A) MEASUREMENT OF SLUG MOVEMENT DUE TO LEAKAGE ONLY. BEFORE TEST TEMP 23.75°C TIME 4/20p.m.		(B) MEASUREMENT OF SLUG MOVEMENT DUE TO LEAKAGE ONLY. AFTER TEST (1) TEMP 24.0°C TIME 4/45p.m.		(C) MEASUREMENT OF SLUG MOVEMENT DUE TO COMBINED EFFECTS OF LEAKAGE & SPINDLE ENTRY (AFTER TEST) TEMPERATURE 24.0°C TIME 4/55p.m.			(D) MEASUREMENT OF SLUG MOVEMENT DUE TO LEAKAGE ONLY. AFTER TEST (2) TEMP 24.25°C TIME 5/10p.m.	
TIME min. sec.	VOLUME SCALE cm	TIME min. sec.	VOLUME SCALE c.m.	DEFLECT GAUGE 10^{-3} in	VOLUME SCALE cm.	TIME min. sec.	TIME min. sec.	VOLUME SCALE cm
0 00	22.75	0 00	18.00	00 10	2.30	0 00	0 00	15.70
15	22.725	15	17.975	12.5	2.65		15	15.675
30	22.70	30	17.95	15	3.00		30	15.675
45	22.70	45	17.925	17.5	3.30		45	15.65
1 00	22.70	1 00	17.90	20	3.625		1 00	15.625
15	22.70	15	17.875	22.5	3.90		15	15.625
30	22.675	30	17.85	25	4.25		30	15.60
45	22.675	45	17.825	27.5	4.60		45	15.575
2 00	22.65	2 00	17.80	30	4.925		2 00	15.575
15	22.65	15	17.775	32.5	5.30		15	15.55
30	22.625	30	17.75	35	5.60		30	15.525
45	22.60	45	17.725	37.5	5.975		45	15.50
3 00	22.60	3 00	17.70	40	6.30		3 00	15.50
15	22.60	15	17.675	42.5	6.70		15	15.475
30	22.60	30	17.65	45	7.025		30	15.45
45	22.575	45	17.625	47.5	7.50		45	15.45
4 00	22.575	4 00	17.60	50	7.90	3 10	4 00	15.425
15	22.55	15	17.575	52.5	8.25		15	15.40
30	22.55	30	17.55	55	8.70		30	15.375
45	22.525	45	17.55	57.5	9.20		45	15.375
5 00	22.50	5 00	17.525	60	9.60	3 58	5 00	15.35
		15	17.50	62.5	9.85			
				65	10.25			
				67.5	10.675			
				70	11.10	4 46		
				72.5	11.425			
				75	11.70			
				77.5	12.275			
				80	12.625	5 32		
				82.5	12.95			
				85	13.30			
				87.5	13.60			
				90	14.05	6 18		
				92.5	14.40			
				95	14.80			
				97.5	15.20			
				100	15.475	7 03		
				102.5	16.00			
				105	16.40			
				107.5	16.775			
				110	17.15	7 51		

TEST No 5: LEAKAGE MEASUREMENTS.

DETERMINATIONS OF RATE OF SLUG MOVEMENT DUE TO LEAKAGE ONLY



(c) DETERMINATION OF RATE OF SLUG MOVEMENT DUE TO COMBINED EFFECTS OF LEAKAGE & SPINDLE ENTRY

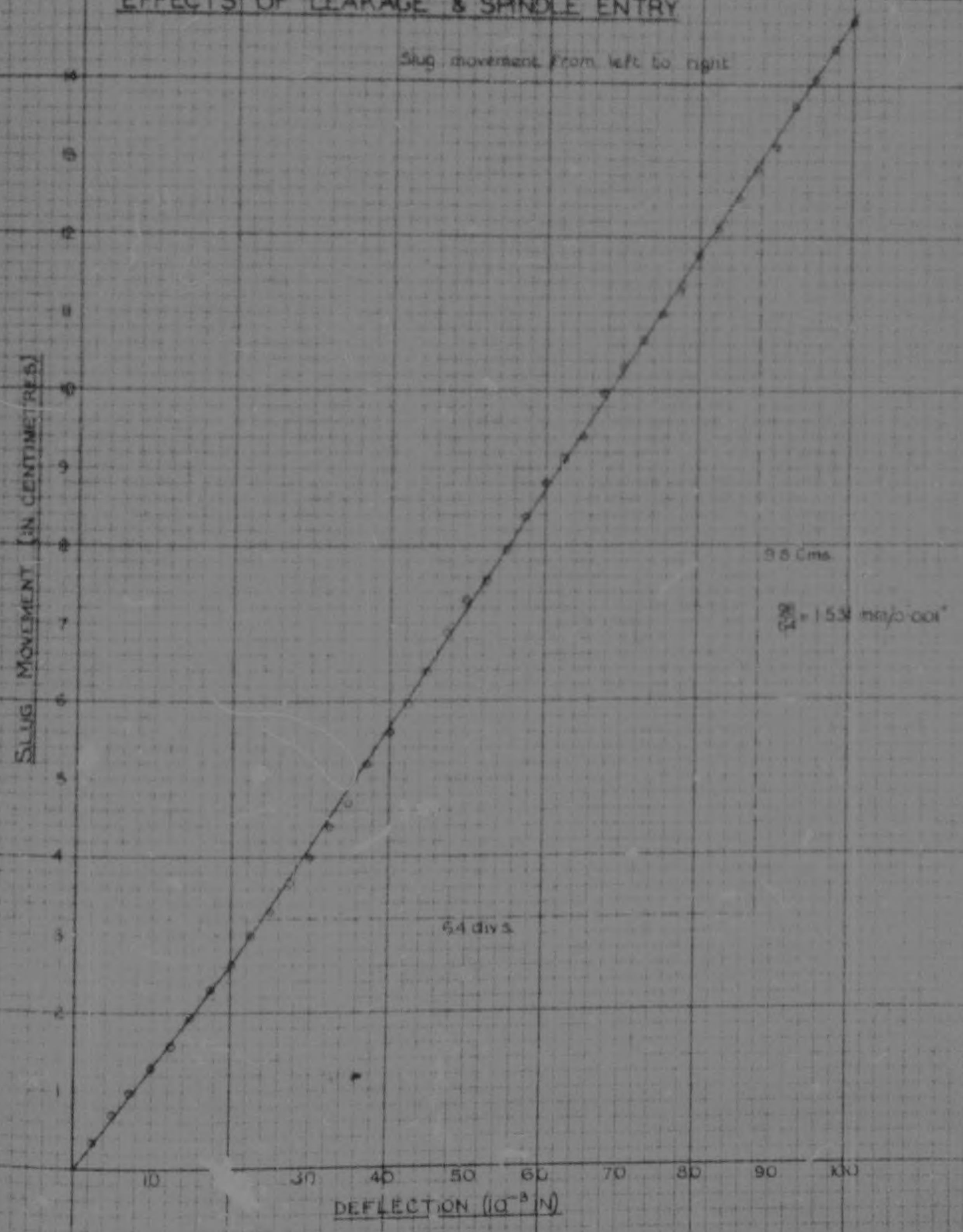


FIG. 40.

TEST Nº 4 : LEAKAGE MEASUREMENTS.

(A) MEASUREMENT OF SLUG MOVEMENT DUE TO LEAKAGE ONLY. BEFORE TEST TEMP 24.0°C TIME 8.25 a.m.		(B) MEASUREMENT OF SLUG MOVEMENT DUE TO LEAKAGE ONLY. AFTER TEST (1). TEMP 24.25°C TIME 8.59 a.m.		(C) MEASUREMENT OF SLUG MOVEMENT DUE TO COMBINED EFFECTS OF LEAKAGE & SPINDLE ENTRY (AFTER TEST) TEMPERATURE 24.25°C TIME 9.07 a.m.			(D) MEASUREMENT OF SLUG MOVEMENT DUE TO LEAKAGE ONLY. AFTER TEST (2). TEMP 24.25°C TIME 9.10a.m.	
TIME min sec	VOLUME SCALE cm	TIME min sec	VOLUME SCALE cm	DEFLECT GAUGE 10^{-3} in	VOLUME SCALE cm	TIME min sec	TIME min sec	VOLUME SCALE cm
0 00	21.70	0 00	24.70	00 30	8.40	00 00	0 00	16.10
15	21.675	15	24.675	32.5	8.60		15	16.025
30	21.65	30	24.60	35	8.90		30	15.975
45	21.625	45	24.575	37.5	9.125		45	15.90
1 00	21.60	1 00	24.50	40	9.40	00 56	1 00	15.85
15	21.60	15	24.425	42.5	9.65		15	15.80
30	21.60	30	24.40	45	9.925	01 20	30	15.725
45	21.575	45	24.325	47.5	10.25		45	15.675
2 00	21.55	2 00	24.30	50	10.60	01 44	2 00	15.60
15	21.525	15	24.25	52.5	10.975		15	15.525
30	21.50	30	24.225	55	11.40	02 08	30	15.50
45	21.50	45	24.175	57.5	11.80		45	15.425
3 00	21.475	3 00	24.15	60	12.125	02 32	3 00	15.375
15	21.45	15	24.125	62.5	12.50		15	15.30
30	21.40	30	24.10	65	12.825	02 55	30	15.20
45	21.375	45	24.075	67.5	13.15		45	15.15
4 00	21.35	4 00	24.05	70	13.50	03 19	4 00	15.10
15	21.325	15	24.05	72.5	13.775		15	15.05
30	21.30	30	24.025	75	14.125	03 42	30	15.00
45	21.25	45	24.00	77.5	14.425		45	14.90
5 00	21.225	5 00	23.95	80	14.80	04 04	5 00	14.80
		15	23.90	82.5	15.15			
		30	23.85	85	15.50	04 28		
		45	23.80	87.5	15.80			
		6 00	23.775	90	16.15	04 50		
		15	23.725	92.5	16.50			
		30	23.70	95	16.85	05 14		
				97.5	17.20			
				100	17.575	05 37		
				102.5	17.875			
				105	18.275	06 01		
				107.5	18.60			
				110	19.00	06 26		
				112.5	19.35			
				115	19.65	06 50		

TEST Nº 4 : MAIN TEST OBSERVATIONS.

DEFLEC-TION GAUGE	LOAD GAUGE	SLUG SCALE cm	TIME min sec	TEMPERA-TURE °C	CORRECTED SLUG SCALE cm	CORRECTED LOAD lb	CORRECT DEFLECT 10^{-3} in.	STRAIN ε percent	CORRECTED STRESS $(\sigma)-(\sigma_s)\cdot\sigma_d$ lb/sq.in
00 30	15	21.10	00 00	24.25	0	0	0	0	0
32.5	17.5	21.375	00 24		- 0.275	2.5	2.5	0.083	1.4
35	18	21.60	00 37		- 0.70	3.0	5	0.167	1.7
37.5	18.7	22.00	00 45		- 0.90	3.7	7.5	0.250	2.1
40	19.2	22.30	00 56		- 1.20	4.2	10	0.333	2.4
42.5	21.5	22.525	01 07		- 1.425	6.5	12.5	0.417	3.7
45	24.1	22.75	01 24		- 1.65	9.1	15	0.500	5.1
47.5	29.0	22.80	01 40		- 1.70	14.0	17.5	0.583	7.86
50	44.5	21.85	03 07		- 0.75	29.5	20	0.667	16.56
52.5	58	19.80	03 30		+ 1.30	43.0	22.5	0.750	24.12
55	70.5	18.05	03 48		3.05	55.5	25	0.833	31.10
57.5	86	15.95	04 10		5.15	71.0	27.5	0.917	39.75
60	97	14.30	04 26		6.80	82.0	30	1.000	45.67
62.5	110.5	12.70	04 46		8.40	95.5	32.5	1.083	53.37
65	120.4	11.20	05 03		9.90	105.4	35	1.167	58.85
67.5	131.0	9.70	05 21		11.40	116.0	37.5	1.250	64.72
70	139.0	8.775	05 35		12.325	124.0	40	1.333	69.12
72.5	146.0	7.90	05 50		13.20	131.0	42.5	1.417	72.96
75	151.5	7.30	06 04		13.80	136.5	45	1.500	75.96
77.5	157.0	6.825	06 19		14.275	142.0	47.5	1.583	78.96
80	160.5	6.625	06 33		14.475	145.5	50	1.667	80.83
82.5	163.0	6.625	06 45		14.475	148.0	52.5	1.750	82.15
85	165.0	6.70	06 56		14.40	150.0	55	1.833	83.19
87.5	166.0	7.20	07 08		13.90	151.0	57.5	1.917	83.67
90	166.5	7.625	07 21		13.475	151.5	60	2.000	83.88
92.5	166.5	8.575	07 33		12.525	151.5	62.5	2.083	83.9
95	165.8	10.00	07 45		11.10	150.8	65	2.167	83.3
97.5	164.7	11.05	07 56		10.05	149.7	67.5	2.250	82.7
100	163.4	12.025	08 06		9.075	148.4	70	2.333	81.9
102.5	161.5	13.025	08 16		8.075	146.5	72.5	2.417	80.8
105	160.2	14.275	08 27		6.825	145.2	75	2.500	80.0
107.5	158.8	15.625	08 40		5.475	143.8	77.5	2.583	79.1
110	158.0	16.40	08 51		4.70	143.0	80	2.667	78.6
112.5	157.0	17.45	09 04		3.65	142.0	82.5	2.750	78.1
115	156.2	18.75	09 13		2.35	141.2	85	2.833	77.5
117.5	156.0	19.90	09 27		1.20	141.0	87.5	2.917	77.4
120	155.3	20.65	09 36		+ 0.45	140.3	90	3.000	76.9
122.5	154.8	21.00	09 47		- 0.70	139.8	92.5	3.083	76.5
125	154.2	22.70	09 59		- 2.50	139.2	95	3.167	76.3
127.5	153.5	23.60	10 10		- 3.50	138.5	97.5	3.250	75.6
130	153.2	24.60	10 24	24.25	- 4.50	138.2	100	3.333	75.5

TEST No 6.

MAIN SLUG MOVEMENT: DEFLECTION CURVE

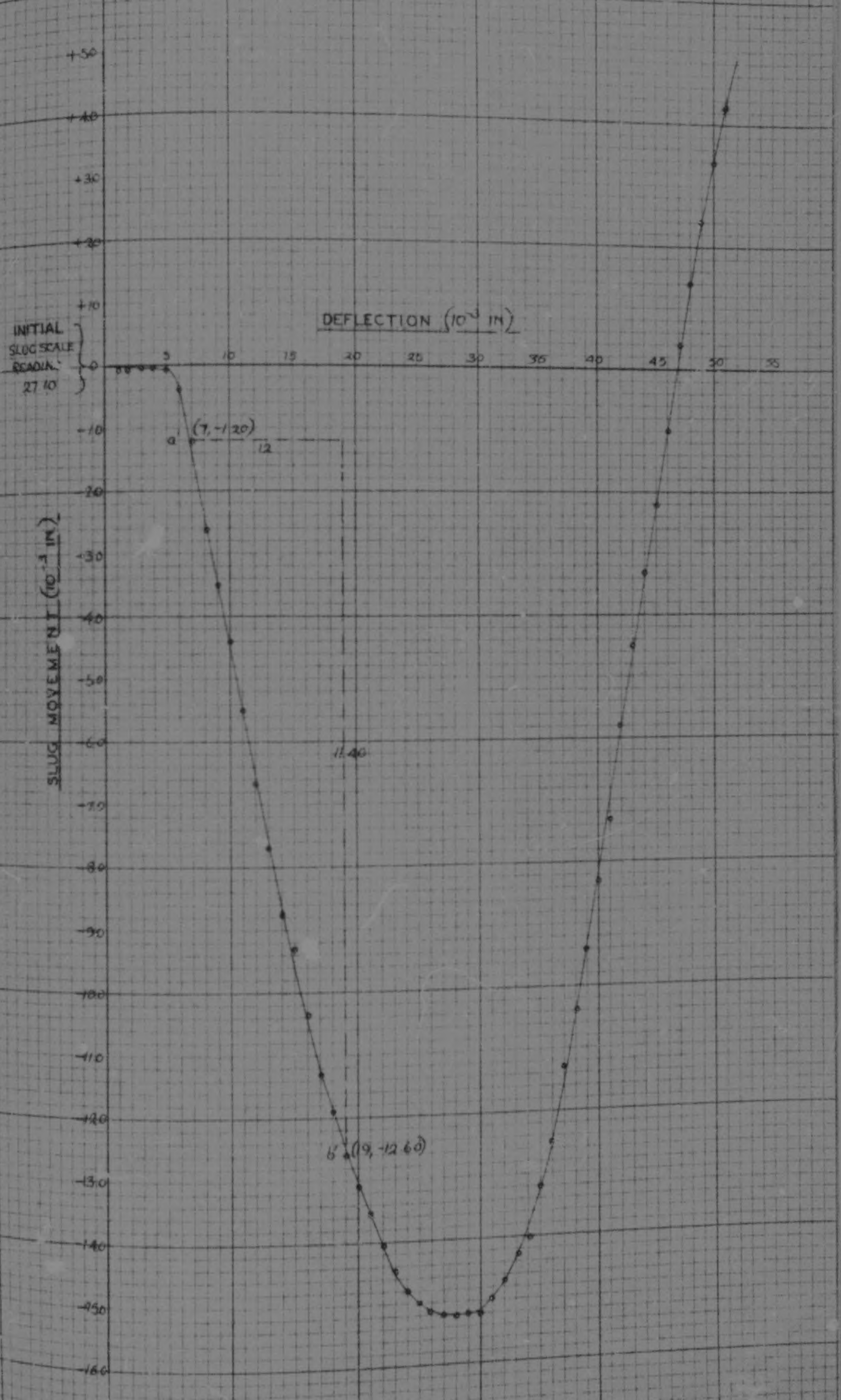


FIG: 47.

SUMMARY OF TRIAXIAL TEST RESULTS.

TABLE VIII

TEST NUMBER	NOMINAL RATE OF STRAIN INCHES/MINUTE	ACTUAL CHAMBER PRESSURE (σ_3) LB/SQ. IN.	DEVIATOR STRESS AT FAILURE $(\sigma_1 - \sigma_3)_f$ LB/SQ. IN.	HENCE: NORMAL STRESS AT FAILURE $(\sigma_1)_f$ LB/SQ. IN.
1.	0·00256	28·6	89·6	118·2
3.	0·00256	18·7	65·3	84·0
6.	0·00256	8·8	60·6	69·4
2.	0·0125	28·7	102·0	130·7
4.	0·0125	18·8	83·9	102·7
5.	0·0125	8·8	53·0	61·8

MOHR CIRCLES FOR TRIAXIAL TESTS

Fig. 48 (a)

NOMINAL RATE OF STRAIN 0·00256 inches/min.

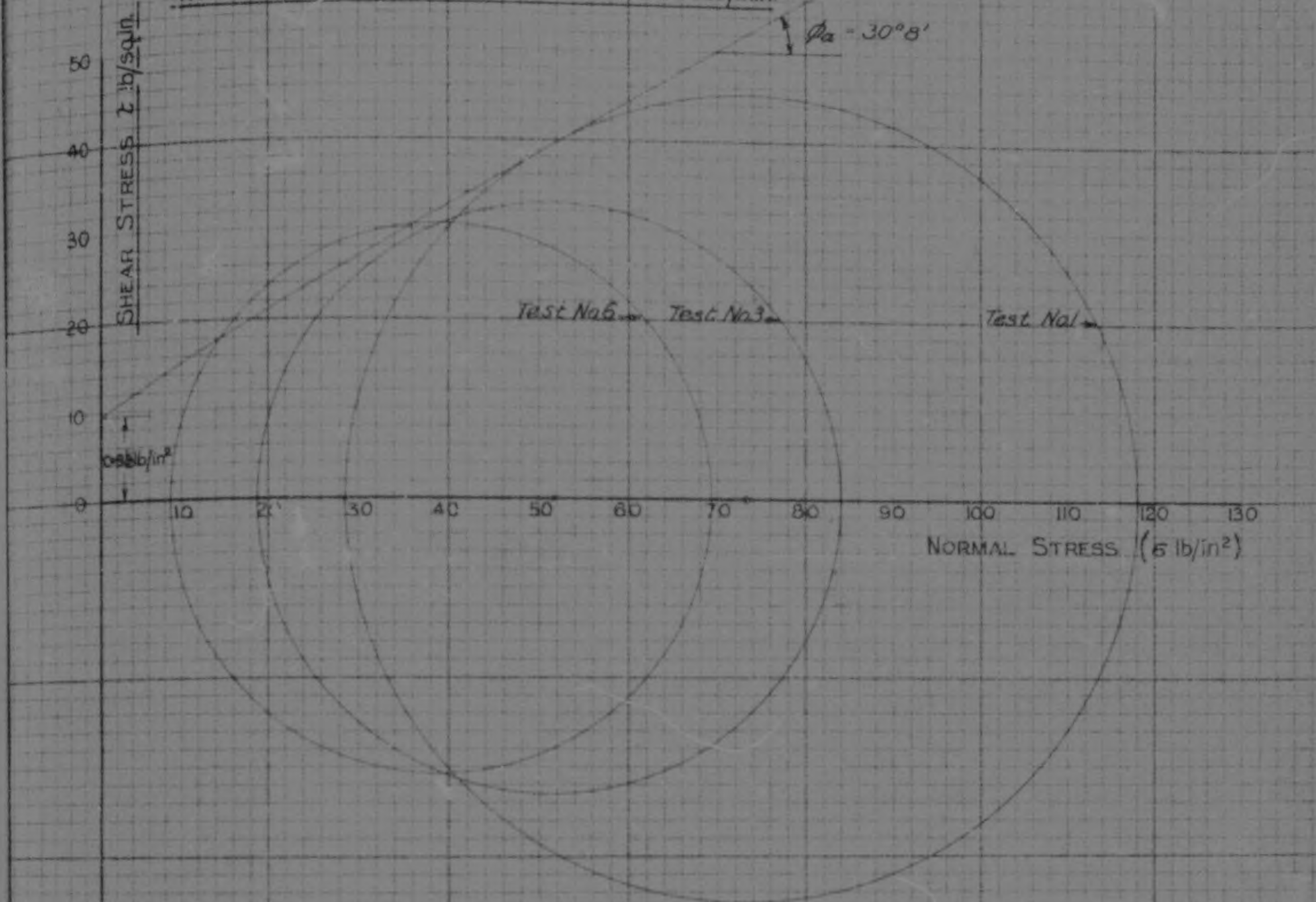


Fig.48 (b)

NOMINAL RATE OF STRAIN 0·0125 inches/min.

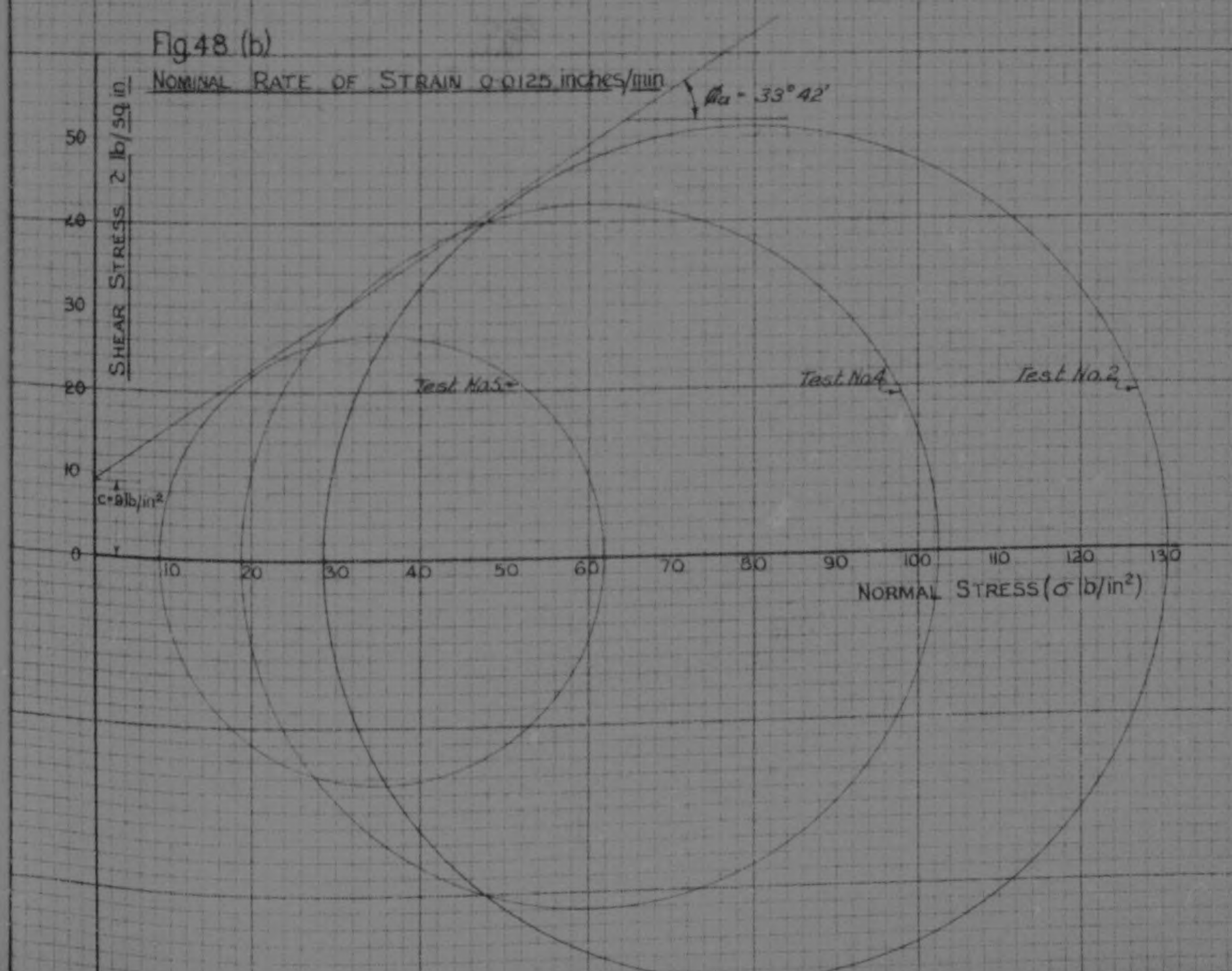


Fig. 48

7.7 Discussion

A study of the recorded data for each test shows that the variation in temperature inside the enclosing wooden box was insignificant during test in all cases, the greatest variation being 0.75°C in the case of Test No.3 which lasted for 92 min. 38 sec. It also appears that the test series as a whole was conducted within a temperature range of 20.75°C-27.5°C, ie., a maximum variation in test temperature between any two tests of 6.75°C (Tests No.1 and No.6.)

The actual time allowed for consolidation in the triaxial test cell was in each case very close to 24 hours if not exactly so, except in the case of Test No.1 in which consolidation was allowed for only 22hrs.15min. However, this probably had very little bearing (if any) on the results of the tests. The test samples were apparently so dry in each case, that no moisture was ever found in the bowl below the open drainage cock after the completion of consolidation.

From the moisture content measurements taken, it appears that:

(a) over the duration of the test series, (which lasted for about 4 weeks excluding the time taken for trial tests), the initial moisture content of test samples decreased in value from about 2.5% to 0.5%, thus indicating that drying out had been taking place in the laboratory while handling the block sample. The various values of initial moisture content:time have been plotted (Fig.53, Appendix IV) and seem to indicate that the rate of decrease in moisture content was approximately uniform during this period.

(b) the final (after test) moisture content of test samples was always slightly greater than the corresponding initial moisture content. In each case this was probably mainly due to leakage through the walls of the rubber membrane enclosing the test sample, as no special provisions were made to prevent this from happening. An additional cause may have been that some of the moisture adhering to the surface of the rubber membrane after test was imparted to the sample on removal of the membrane. It is rarely possible to prevent this from happening. Table XX, Appendix IV is a summary in tabular form of the moisture content before and after test of each test sample.

Regarding the Void Ratio and Degree of Saturation figures shown alongside the various stress:strain curves, it needs to be mentioned that they were obtained (See Table XXI, Appendix IV) by using the oven-dry weight of each test sample after test and a sample volume of 85.0cc, which is slightly less than the volume of the cutting cylinder used. A full discussion giving reasons for this procedure is given later in Section 8.4. The moisture content figure shown is in each case the initial moisture content of the particular test sample. With some tests no initial moisture content determination was made (see Table XX, Appendix IV). In such cases an estimated figure was used which was obtained by reading off the initial moisture content value corresponding to the date of the test on Fig. 53, Appendix IV.

The curves of slug movement due to leakage only as well as the curves of slug movement due to the combined effects of leakage and spindle entry only, show in some instances that leakage from the test cell could be erratic at times. In such cases more than one value of the rate of leakage was determined as shown. The results of all leakage determinations are presented

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in summarised form in Table IX, Section 8.2. In the same Section these results as well as the factors effecting the rate of leakage from the test cell are discussed in more detail.

The <u>stress:strain curves</u> generally show a well defined linear range which commences at or close to the start of the curve depending on the magnitude of the bedding-in effects. Some mention about "bedding-in" effects was already made in section 7.6. It was mentioned that the corrected start of the stress:strain curve was obtained by producing the approximately linear portion of the curve backwards to intersect the strain axis. In order to determine the point at which proportionality between stress and strain ceases, i.e., the end of the linear range, the curve of Young's Modulus versus strain was prepared. This curve is considered to serve as a very useful guide to the selection of the point mentioned, since, while stress and strain are proportional, Young's Modulus has a constant value (independent of strain), and therefore, under these conditions, the curve of Young's Modulus versus strain is a horizontal straight line. Hence, in the ideal case, the strain at which the Young's Modulus:strain curve starts to slope downward after the initial horizontal straight line portion, demarcates the point at which proportionality between stress and strain ceases, i.e., demarcates the end of the linear range. The actual plotted curves, however, show that this horizontal straight line portion of the ideal Young's Modulus:strain curve was seldom perfectly realised. Nevertheless, these curves were of considerable assistance in judging by careful inspection where the linear range ceased in each case. The point eventually decided on, is shown marked by the letter <u>c</u> .

Having determined the end of the linear range of the stress:strain curve for each test in the manner just described the "best" portion of this range in the sense of being the closest representation of truly linear conditions, was selected, and the terminal points of this <u>selected range</u> marked by the letters <u>a</u> and <u>b</u>. Hereafter, this range will be referred to <u>only</u> as the "<u>Selected Range</u>". The value of Young's Modulus was <u>then</u> determined for each selected range and denoted by the symbols Esel.

The <u>Main Slug Movement:Deflection curves</u> generally show a well defined linear range, usually falling closely within the same range of strain as the linear range of the relevent stress:strain curve. The points corresponding to the limits of the Selected Range are in each case shown marked <u>a</u>' and <u>b</u>'. This information is later used in the evaluation of Poisson's Ratio (Section 8.5). These linear ranges in all cases terminate in the development of trough-shaped turning points in the curves, which demarcate the commencement of the phenomenon of sample expansion on approaching failure conditions.

The curves again reveal the presence of "bedding-in" effects, generally by an initially flat portion immediately before the main steep linear portion of the curve commences. but in some instances, (see Figs. 39 and 43), by a pronounced peak-shaped portion before the main curve commences. The phenomenon in this case can be explained as follows: During the "bedding-in" period, only portion of the applied loading is taken up by the test sample, the remainder being used up in causing the bedding-in movements in the test set-up. Hence, during the bedding-in period at the start of a test, sample compression is small and therefore the tendency for fluid flow <u>into</u> the test cell due to this cause is small. In contrast, the loading spindle during the same period has a partially unrestrained and hence comparatively rapid advance into the test cell with a tendency to cause fluid flow <u>out</u> of the test cell. It appears that during

the ..../

the bedding-in period, this latter effect outweighs the combined effects of an initial small sample compression and leakage from the test cell (which both tend to cause fluid flow into the test cell), and results in a nett fluid flow out of the test cell i.e. increasing slug scale readings and hence the initial upward trend of the curve.

Subsequently, however, when the test set-up is firmly bedded down, all the applied loading is taken by the test sample causing it to compress considerably and at the same time severely restraining the advance of the loading spindle into the test cell. As soon as this happens, the combined effects of sample compression and leakage from the test cell start to outweigh the effect of spindle entry into the test cell, and thus, result in a nett inflow of fluid into the test cell, i.e., decreasing slug scale readings and hence the commencement of a downward trend in the curve and the formation of the peak observed.

The argument presented above is strengthened by the actual calculation of Sample Dilation ($\delta V/V$) during test (Section 8.5). These calculations show that over the bedding-in range, sample compression is small compared with subsequent sample compression when bedding-in is complete. (See, for example, the calculation of Sample Dilation for Test No.4.) The pronounced peak-shaped bedding-in effect would thus occur in cases where the effect of the initial advance of the loading spindle into the test cell considerably exceeds the opposite effects caused by sample compression and leakage. This is probably only possible in the case of an initially very loosely bedded sample.

Mention was previously made about the possible effect of chamber pressure on the Calibrated Rate of Strain, i.e. the rate of strain obtained from the calibration of loading spindle entering the test cell against the resistance of the relevant chamber pressure only. (See end of Section 7.5) Table IX Section 8.2, shows the values of calibrated rate of strain, obtained at the various chamber pressures for the same nominal rates of strain. The values apparently show that the calibrated rate of strain decreases as the chamber pressure decreases. This is contrary to expectation and is possibly due to insufficient values being available. This suspicion is based on the fact that in the case of Test No. 6B (not included in the test series being reported on herein), a calibrated rate of strain of 0.002590 inches/min. for a chamber pressure of 10lb./sq.in. was obtained. It is considered that the calibrated rate of strain would possibly increase with decreasing chamber pressure.

Where detailed time measurements were taken, the resulting deflection:time curves show clearly that the actual rate of strain during test is very uneven, especially during the initial stages of the test. A very pronounced time lag is obtained at a point corresponding approximately to the start of the linear range of the stress:strain curve. The phenomenon is revealed by the nearly horizontal portion of the curve soon after its commencement, indicating a negligible increase in deflection during this period. In contrast, there is a rapid increase in loading during the same period. In most cases, it will also be noted (from the curves of Young's Modulus versus Strain), that Young's Modulus has a maximum value just about at the point where the time lag occurs. Subsequently the actual rate of strain steadily increases until, when sample failure is approached, it tends to take on the value of the calibrated rate of strain.

Careful investigation seems to show that the pronounced time lag occurs at the completion of the bedding-in period. It

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is possibly due to a back-lash in the loading system once the bedding down is complete and the applied loading is directed in full at overcoming the resistance of the sample to deformation, which, at this point happens to be a maximum. The subsequent steady increase in the actual rate of strain is due to a steady decrease in the value of Young's Modulus (See Young's Modulus: Strain curves). This continues until, at sample failure, the rate of strain is approximately the same as the calibrated rate of strain, which, notably, was determined for the condition of loading spindle advancing into the test cell against the resistance of the relevant chamber pressure only. The disturbing thought is that the tests were intended to have been conducted as tests subject to strain control.

Finally, it is necessary to consider reasons for the peaks in the Young's Modulus:Strain curves which occur in most cases. The basic cause of this phenomenon is the shape of the stress : strain curve. Careful inspection shows that within the accepted extent of the linear range of the stress:strain curve, the curve usually makes a slight S-shaped bend, i.e., according to actual points plotted. (See, for instance, Test No.1, Fig. 27.) The curve of Young's Modulus : Strain was prepared by calculating instantaneous values of Young's Modulus as a secant modulus, i.e. working from point to point along the curve but always from the start of the curve, which in this case, is the 'corrected' start as obtained after eliminating bedding-in effects. With an S-shaped curve and this secant modulus method of calculation, the result is clearly a peak-shaped variation of Young's Modulus.

It is considered that the slight S-shape of the curve is at its lower end probably due to the inclusion of bedding-in effects, and, at the upper end, due to a natural slight curving over to the right of the actual stress:strain curve (this being the case even within the extent of the linear range). In the absence of bedding-in effects the portion of the Young's Modulus: Strain curve to the left of its peak would probably have been much nearer horizontal and thereby would have conformed closer to the requirements of the ideal Young's Modulus:Strain curve as previously discussed in this Section. The fact that the respective values of Esel (Young's Modulus for the Selected Range) are in all cases lower than the corresponding peak values of Young's Modulus as indicated by the Young's Modulus:Strain curves, is due to the fact that in each case the Selected Range is in effect the straight line joining the ends of a slightly S-shaped curve. This clearly leads to a lower value of Young's Modulus than the maximum value obtainable by the other method.

In the following Chapter, Poisson's Ratio (μ) has for each test been calculated using both instantaneous values of Young's Modulus (yielding instantaneous values of μ, denoted μ_i) and the value of Young's Modulus obtained from the Selected Range (the corresponding μ value being denoted μsel).

CHAPTER 8

REDUCTION OF TEST RESULTS AND THE DETERMINATION OF POISSON'S RATIO

8.1 Introduction

Before the evaluation of Poisson's Ratio for each test can finally be commenced, it is necessary to discuss in more detail some important factors relating to the evaluation, some of which have already been briefly discussed. These discussions follow in Sections 8.2, 8.3 and 8.4 hereafter.

8.2 Rate of Slug Movement due to Leakage only during Actual Test

For the evaluation of Poisson's Ratio, the rate of slug movement due to leakage from the test cell during actual test needs to be known. As previously discussed (Section 7.4), this measurement cannot be made directly, since it is not possible to isolate the effects of slug movement due to entry of the loading spindle into the test cell and change in volume of the test sample during test.

To enable some idea of the rate of leakage during actual test, the only circumstances under which slug movement due to leakage only can be measured directly, viz., under the steady cell conditions existing immediately before and after test, were resorted to. As the rate of leakage measured under these circumstances was likely to be different to the rate of leakage occurring under the disturbed cell conditions of an actual test, a further indirect measurement of the rate of leakage was made from a test which it was hoped simulated the disturbed cell conditions of an actual test.

Thus, having observed values of the rate of leakage under the steady cell conditions existing before and again after test, as well as having determined the rate of leakage under disturbed cell conditions similar to those of an actual test although possibly not identical, it is necessary to consider in some detail the possible value of the rate of leakage occurring under the disturbed cell conditions of an actual test.

For this purpose, it is in the first instance necessary to study carefully the results of all the various leakage measurements made during the test series. These are presented in summarised form in Table IX on the next page. Table X on the same page, shows the determination of slug movement due to leakage only under the disturbed cell conditions of the test simulating the conditions of an actual test. The basis of this determination was discussed in Section 7.4 (pages 59 and 60). Table X also shows a comparison of these results with the maximum observed slug movement due to leakage only measured under the steady cell conditions existing before and again after test. In Table IX, where more than one value appears under the same heading in some instances, this happens as a result of a definite change in value having been observed during test due to a change in the rate of leakage from the test cell. The determination of the rate of slug movement due to entry of the loading spindle into the test cell, is given in Appendix V ,item 2.

From the data shown in the Tables, it is evident that:

(i) The rate of slug movement due to leakage measured immediately after any triaxial test is generally higher than

that ..../

TABULAR SUMMARY OF ALL LEAKAGE MEASUREMENTS

NOTE: AN ARROW THUS ← ABOVE A FIGURE DENOTES SLUG MOVEMENT FROM RIGHT TO LEFT.
AN ARROW THUS → ABOVE A FIGURE DENOTES SLUG MOVEMENT FROM LEFT TO RIGHT.

TABLE IX

TEST NUMBER	NOMINAL σ_3 CHAMBER PRESSURE LB./SQ. IN.	NOMINAL RATE OF STRAIN. Inches/minute	OBSERVED SLUG MOVEMENT DUE TO LEAKAGE ONLY UNDER STEADY CELL CONDITIONS.			CALCULATED SLUG MOVEMENT DUE TO SPINDLE ENTRY ONLY = N	OBSERVED SLUG MOVEMENT DUE TO COMBINED EFFECTS OF LEAKAGE & SPINDLE ENTRY = M	CALIBRATED RATE OF STRAIN = S
			BEFORE TRIAXIAL TEST. mm/minute	AFTER TRIAXIAL TEST. 1. mm/minute	AFTER TRIAXIAL TEST. 2. mm/minute	mm/div. deflect	mm/div. deflect	Inches/minute
1.	30	0.00256	← 0.92	← 2.80	← 4.500	→ 1.614	← 0.173	0.002555
3	20	0.00256	← 1.54	← 2.667 1.00 2.34	← 2.00 2.33	→ 1.614	→ 0.250 0.333	0.002544
6	10	0.00256	← 0.875	← 0.947	← 0.50	→ 1.614	→ 1.112	0.002500
2	30	0.0125	← 1.27	← 4.00	← 3.89 5.238	→ 1.614	→ 1.138	—
4	20	0.0125	← 0.875	← 1.909 0.875 2.000	← 2.571	→ 1.614	→ 1.363	0.01282
5	10	0.0125	← 0.500	← 1.000	← 0.700	→ 1.614	→ 1.531	0.01270

NOTE: THE MAXIMUM VALUES OF SLUG MOVEMENT DUE TO LEAKAGE FOR EACH TEST, ARE SHOWN UNDERLINED IN RED.

DETERMINATION OF SLUG MOVEMENT DUE TO LEAKAGE ONLY UNDER DISTURBED CELL CONDITIONS, AND COMPARISON WITH MAXIMUM OBSERVED SLUG MOVEMENT DUE TO LEAKAGE UNDER STEADY CELL CONDITIONS

TABLE X

TEST NUMBER	M = OBSERVED SLUG MOVEMENT DUE TO COMBINED EFFECTS OF LEAKAGE & SPINDLE ENTRY mm/div. deflect	S = CALIBRATED RATE OF STRAIN div. deflect/min	HENCE: SLUG MOVEMENT DUE TO COMBINED EFFECTS OF LEAKAGE & SPINDLE ENTRY = M × S = a mm/minute	N = CALCULATED SLUG MOVEMENT DUE TO SPINDLE ENTRY ONLY. mm/div. deflect	HENCE: CALCULATED SLUG MOVEMENT DUE TO SPINDLE ENTRY ONLY. = N × S = b mm/minute	HENCE: RESULTANT SLUG MOVEMENT DUE TO LEAKAGE ONLY UNDER DISTURBED CELL CONDITIONS. = a-b = c mm/minute	MAXIMUM OBSERVED SLUG MOVEMENT DUE TO LEAKAGE UNDER STEADY CELL CONDITIONS = d mm/minute	DIFFERENCE c−d mm/minute
1	← 0.173	2.555	← 0.442	→ 1.614	→ 4.124	← 4.586	← 4.500	0.086
3	→ 0.333	2.544	→ 0.847	→ 1.614	→ 4.108	← 3.259	← 2.667	0.592
6	→ 1.112	2.500	→ 2.780	→ 1.614	→ 4.035	← 1.255	← 0.947	0.308
2	→ 1.138	12.50 *	→ 14.225	→ 1.614	→ 20.175	← 5.950	← 5.238	0.712
4	→ 1.363	12.82	→ 17.474	1.614	→ 20.691	← 3.217	← 2.571	0.646
5	→ 1.531	12.70	→ 19.444	→ 1.614	→ 20.498	← 1.054	← 1.000	0.054

* NOMINAL RATE OF STRAIN USED HERE, AS CALIBRATED RATE OF STRAIN WAS NOT DETERMINED FOR THIS TEST.

TABULAR SUMMARY OF ALL LEAKAGE MEASUREMENTS:

NOTE: AN ARROW THUS: ←— ABOVE A FIGURE DENOTES SLUG MOVEMENT FROM RIGHT TO LEFT.
AN ARROW THUS —→ ABOVE A FIGURE DENOTES SLUG MOVEMENT FROM LEFT TO RIGHT.

TABLE IX

TEST NUMBER	NOMINAL σ_3 CHAMBER PRESSURE LB./SQ. IN.	NOMINAL RATE OF STRAIN. inches/minute	OBSERVED SLUG MOVEMENT DUE TO LEAKAGE ONLY UNDER STEADY CELL CONDITIONS.			CALCULATED SLUG MOVEMENT DUE TO SPINDLE ENTRY ONLY = N mm/div deflect	OBSERVED SLUG MOVEMENT DUE TO COMBINED EFFECTS OF LEAKAGE & SPINDLE ENTRY = M mm/div deflect	CALIBRATED RATE OF STRAIN = S inches/minute
			BEFORE TRIAXIAL TEST. mm/minute	AFTER TRIAXIAL TEST 1. mm/minute	AFTER TRIAXIAL TEST 2. mm/minute			
1.	30	0.00256	$\overleftarrow{0.92}$	$\overleftarrow{2.80}$	$\overleftarrow{4.500}$	$\overrightarrow{1.614}$	$\overleftarrow{0.173}$	0.002555
3	20	0.00256	$\overleftarrow{1.54}$	$\overleftarrow{\left\{\begin{matrix}2.667\\1.00\\2.34\end{matrix}\right.}$	$\overleftarrow{\left\{\begin{matrix}2.00\\2.33\end{matrix}\right.}$	$\overrightarrow{1.614}$	$\overrightarrow{\left\{\begin{matrix}0.250\\0.333\end{matrix}\right.}$	0.002544
6	10	0.00256	$\overleftarrow{0.875}$	$\overleftarrow{0.947}$	$\overleftarrow{0.50}$	$\overrightarrow{1.614}$	$\overrightarrow{1.112}$	0.002500
2	30	0.0125	$\overleftarrow{1.27}$	$\overleftarrow{4.00}$	$\overleftarrow{\left\{\begin{matrix}3.89\\5.238\end{matrix}\right.}$	$\overrightarrow{1.614}$	$\overrightarrow{1.138}$	—
4	20	0.0125	$\overleftarrow{0.875}$	$\overleftarrow{1.909}$ 0.875 2.000	$\overleftarrow{2.571}$	$\overrightarrow{1.614}$	$\overrightarrow{1.363}$	0.01282
5	10	0.0125	$\overleftarrow{0.500}$	$\overleftarrow{1.000}$	$\overleftarrow{0.700}$	$\overrightarrow{1.614}$	$\overrightarrow{1.531}$	0.01270

NOTE: THE MAXIMUM VALUES OF SLUG MOVEMENT DUE TO LEAKAGE FOR EACH TEST, ARE SHOWN UNDERLINED IN RED.

DETERMINATION OF SLUG MOVEMENT DUE TO LEAKAGE ONLY UNDER DISTURBED CELL CONDITIONS, AND COMPARISON WITH MAXIMUM OBSERVED SLUG MOVEMENT DUE TO LEAKAGE UNDER STEADY CELL CONDITIONS

TABLE X

TEST NUMBER	M = OBSERVED SLUG MOVEMENT DUE TO COMBINED EFFECTS OF LEAKAGE & SPINDLE ENTRY mm/div deflect	S = CALIBRATED RATE OF STRAIN divs deflect/min	HENCE SLUG MOVEMENT DUE TO COMBINED EFFECTS OF LEAKAGE & SPINDLE ENTRY = M X S = a mm/minute	N = CALCULATED SLUG MOVEMENT DUE TO SPINDLE ENTRY ONLY. mm/div deflect	HENCE CALCULATED SLUG MOVEMENT DUE TO SPINDLE ENTRY ONLY. = N X S = b mm/minute	HENCE RESULTANT SLUG MOVEMENT DUE TO LEAKAGE ONLY UNDER DISTURBED CELL CONDITIONS = a - b = c mm/minute	MAXIMUM OBSERVED SLUG MOVEMENT DUE TO LEAKAGE UNDER STEADY CELL CONDITIONS = d mm/minute	DIFFERENCE c - d mm/minute
1	$\overleftarrow{0.173}$	2.555	$\overleftarrow{0.442}$	$\overrightarrow{1.614}$	$\overrightarrow{4.124}$	$\overleftarrow{4.586}$	$\overleftarrow{4.500}$	0.066
3	$\overrightarrow{0.333}$	2.544	$\overrightarrow{0.847}$	$\overrightarrow{1.614}$	$\overrightarrow{4.106}$	$\overleftarrow{3.259}$	$\overleftarrow{2.667}$	0.592
6	$\overrightarrow{1.112}$	2.500	$\overrightarrow{2.780}$	$\overrightarrow{1.614}$	$\overrightarrow{4.035}$	$\overleftarrow{1.255}$	$\overleftarrow{0.947}$	0.308
2	$\overrightarrow{1.138}$	12.50*	$\overrightarrow{14.225}$	$\overrightarrow{1.614}$	$\overrightarrow{20.175}$	$\overleftarrow{5.950}$	$\overleftarrow{5.238}$	0.712
4	$\overrightarrow{1.363}$	12.82	$\overrightarrow{17.474}$	1.614	$\overrightarrow{20.691}$	$\overleftarrow{3.217}$	$\overleftarrow{2.571}$	0.646
5	$\overrightarrow{1.531}$	12.70	$\overrightarrow{19.444}$	$\overrightarrow{1.614}$	$\overrightarrow{20.498}$	$\overleftarrow{1.054}$	$\overleftarrow{1.000}$	0.054

* NOMINAL RATE OF STRAIN USED HERE, AS CALIBRATED RATE OF STRAIN WAS NOT DETERMINED FOR THIS TEST.