COMPRESSION OF FIBROUS PEAT

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ABSTRACT

PEAT IS WELL KNOWN FOR THE ENGINEERING PROBLEMS IT POSES ESPECIALLY IN THE FIELD OF SETTLEMENT ANALYSIS. THIS IS MAINLY BECAUSE THE PROCESS AND THEREFORE THE FACTORS AFFECTING SECONDARY SETTLEMENT ARE AS YET LITTLE UNDERSTOOD.

A PRELIMINARY LABORATORY INVESTIGATION WAS CARRIED OUT TO EXAMINE THE RELATIONSHIP BETWEEN SETTLEMENT AND LOAD FOR FIBROUS PEAT USING DIFFERENT LOAD INCREMENT RATIOS AND LOAD DURATIONS. THREE LOAD INCREMENT RATIOS WERE USED (3.0; 1.0; 0.33) AND TWO DURATIONS OF LOAD (15 MINS AND 24 HOURS).

THE TESTS WERE PERFORMED IN A CONSOLIDATION APPARATUS USING FIXED RINGS 2.50 INS INSIDE DIAMETER AND 0.750 INS IN HEIGHT. UNDISTURBED SPECIMENS WERE CUT FROM ONE HORIZONTAL LAYER OF A LUMP SAMPLE OF FIBROUS PEAT HAVING A WATER CONTENT OF 1100%

WITHIN THE LIMITS OF THIS PRELIMINARY INVESTIGATION THE MAIN CONCLUSIONS WERE :-

(1) ALL LOAD INCREMENT RATIOS AND LOAD DURATIONS GAVE VERY SIMILAR SETTLEMENT - LOG P OR E-LOG P CURVES PROVIDING SETTLEMENT WAS MEASURED AT THE 100% PRIMARY CONSOLIDATION POINT.

(2) THE RATE OF SECONDARY SETTLEMENT WAS INDEPENDENT OF LOAD INCREMENT RATIO AND LOAD DURATION EXCEPT FOR THE TYPE II CURVE WHICH APPEARED TO BE AFFECTED BY THE DURATION OF THE PREVIOUS LOAD INCREMENT.

(3) Only one test (#2, L.I.R. 0.33, L.D. 24 hours) gave a Type II settlement-log time curve. Curve type appeared to depend on both load increment ratio and load duration or rate of loading. This test also took about 10 times as long to reach the 100% primary consolidation point.

(4) The hypothesis of a unique settlement-log p curve at 100% primary consolidation for the load cycle regardless of previous loading history appeared to offer a aplausible general interpretation of the results of the test series.

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1.0 INTRODUCTION

1.1 General

Peat is well known for the engineering problems it poses especially in the field of settlement analysis. While much empirical information has been accumulated, the prediction of settlement, particularly the rate of settlement, is still uncertain. This is mainly because the process of secondary settlement, which frequently accounts for a large proportion of the total settlement, is little understood. Although peat consists largely or wholly of the partly decomposed remains of plants and mosses, nevertheless it does appear to be susceptible to settlement analysis based on standard one dimensional consolidation tests of representative samples.

In clay consolidation the classical Terzaghi hydrodynamic theory ignores the secondary effect and in practice it may often be neglected without serious error. However with some clays, most highly organic soils, and peat, the secondary settlement cannot be ignored either in theoretical interpretation or in practical field problems. The current position is well summarized in " Study of Deep Soil Stabilization by Vertical Sand Drains" by Moran, Proctor, Mueser and Rutledge (3).

However, no comprehensive investigation of the peat consolidation test, on the lines of Taylor's " Research on Consolidation of Clays" (2), has been reported in the literature. Of major importance in this respect is the correlation between settlements and rates of settlement obtained in

THE LABORATORY USING THE STANDARD LOAD INCREMENT RATIO OF 1.0 AND THE NORMAL LOAD DURATION OF 24 HOURS WITH THOSE OBTAINED IN THE FIELD WITH DIFFERENT LOAD INCREMENT RATIOS, LOAD DURATIONS AND TIMES TO REACH 100% PRIMARY CONSOLIDATION.

THIS INVESTIGATION REPRESENTS A LABORATORY INVESTIGATION INTO SOME ASPECTS OF THE SETTLEMENT CHARACTERISTICS OF PEAT.

1.2 PURPOSE

THE PURPOSE OF THIS INVESTIGATION WAS TO EXAMINE THE RELATIONSHIP BETWEEN SETTLEMENT AND LOAD FOR FIBROUS PEAT IN A STANDARD CONSOLIDATION APPARATUS USING DIFFERENT LOAD INCREMENT RATIOS AND LOAD DURATIONS. IT WAS ALSO INTENDED TO OBTAIN SOME INDICATION AS TO HOW THESE FACTORS AFFECTED SECONDARY SETTLEMENT IN THIS MATERIAL.

1.3 PROGRAM

THE ORIGINAL PROGRAM WAS TO USE THREE LOAD INCREMENT RATIOS I.E. 0.33; 1.0; 3.0, AND TO RUN TWO CONSOLIDATION TESTS AT EACH RATIO - ONE USING THE STANDARD 24 HOUR LOAD DURATION AND ONE USING A 15 MINUTE LOAD DURATION. THE INTENT IN THESE RAPID TESTS WAS TO RELOAD AS SOON AS PRIMARY SETTLEMENT WAS COMPLETED, WHICH WAS KNOWN TO BE IN THE ORDER OF 15 MINUTES. THIS PROVED UNSATISFACTORY FOR THE L.I.R. OF 3.0 AND A FURTHER RAPID TEST WAS RUN WITH A 25 MINUTE LOAD DURATION. IT WAS ALSO FOUND POSSIBLE TO PERFORM A CONSOLIDATION TEST ON THIS MATERIAL WITHOUT A CONSOLIDATION RING. THIS WAS DONE PRIMARILY AS A CHECK ON THE POSSIBLE EFFECTS OF SIDE FRICTION. A FINAL SHORT TEST WAS RUN USING VARYING L.I.R. AND LOAD DURATIONS DURING THE SAME TEST IN ORDER TO INVESTIGATE

WHAT EFFECT THIS WOULD HAVE. A TOTAL OF NINE CONSOLIDATION TESTS WERE RUN.

ALL SAMPLES WERE CUT FROM A SINGLE HORIZONTAL LAYER IN A BLOCK OF UNDISTURBED NATURAL FIBROUS PEAT.

AS FAR AS POSSIBLE ALL OTHER EXPERIMENTAL CONDITIONS WERE KEPT CONSTANT.

TEST NO.	LOAD INCREMENT RATIO	LOAD DURATION (NOMINAL)
#2	0.33	24 HOURS
#4	0.33	15 MINUTES
#1	1.0	24 HOURS
#5	1.0	15 MINUTES
#6	3.0	24 HOURS
#3A	3.0	15 MINUTES
#3B	3.0	25 MINUTES
#8	1.0	12 MINUTES
#7	1.0 TO 3.0	20 MINS. TO 24 HRS.

1.4 DEFINITIONS

COMPRESSION OF PEAT UNDER AN APPLIED LOAD CAN BE DIVIDED INTO THREE PARTS, DEFINED AS FOLLOWS :

INITIAL SETTLEMENT - SETTLEMENT DUE TO THE COMPRESSION OF GAS BUBBLES IN THE MATERIAL (THIS WOULD OCCUR ALMOST INSTANTANEOUSLY)

PRIMARY SETTLEMENT - HYDRODYNAMIC SETTLEMENT OCCURRING UNDER CONDITIONS OF SIGNIFICANT EXCESS PORE WATER PRESSURE (THIS IS THE SETTLEMENT PROCESS ANALYSED BY THE TERZAGHI CONSOLIDATION THEORY)

SECONDARY SETTLEMENT - REMAINING SETTLEMENT OCCURRING WITHOUT SIGNIFICANT EXCESS PORE WATER PRESSURE (TYPICALLY THIS SETTLEMENT IS THE STRAIGHT LINE PORTION OF THE SETTLEMENT-LOG TIME GRAPH COMING AFTER COMPLETION OF THE PRIMARY SETTLEMENT).

THE RATE OF PRIMARY SETTLEMENT IS GOVERNED BY THE RATE AT WHICH WATER IS EXPELLED UNDER PRESSURE FROM THE VOIDS IN THE MATERIAL AND IS THEORETICALLY DEPENDENT ON THE AVERAGE PERMEABILITY AND COMPRESSIBILITY OF THE SOIL STRUCTURE AS WELL AS THE SQUARE OF THE DRAINAGE PATH

I.E. $C_v = \dfrac{k\,(1+e)}{a_v}$ AND $C_v = \dfrac{T}{t} H^2$

THE RATE OF SECONDARY SETTLEMENT IS GOVERNED BY THE INTRINSIC RESISTANCE OF THE MATERIAL TO DEFORMATION. IT IS APPARENTLY INDEPENDENT OF THE COEFFICIENTS OF PERMEABILITY (k) AND CONSOLIDATION (C_v) BUT THE FACTORS AFFECTING THIS RATE ARE STILL BEING INVESTIGATED.

C_s = COEFFICIENT OF SECONDARY SETTLEMENT

$$= \frac{\text{INCREMENT OF SETTLEMENT PER LOG CYCLE OF TIME}}{\text{INITIAL HEIGHT OF THE SAMPLE}}$$

SEE SECTION 4 - 5

L.I.R. = LOAD INCREMENT RATIO = $\dfrac{\text{INCREMENT OF LOAD}}{\text{PREVIOUS TOTAL LOAD}} = \dfrac{\Delta p}{p}$

L.D. = LOAD DURATION I.E. PERIOD FOR WHICH LOAD IS KEPT UNCHANGED AT A GIVEN VALUE

OTHER NOMENCLATURE USED FOLLOWS STANDARD PRACTICE IN RECENT SOIL MECHANICS LITERATURE.

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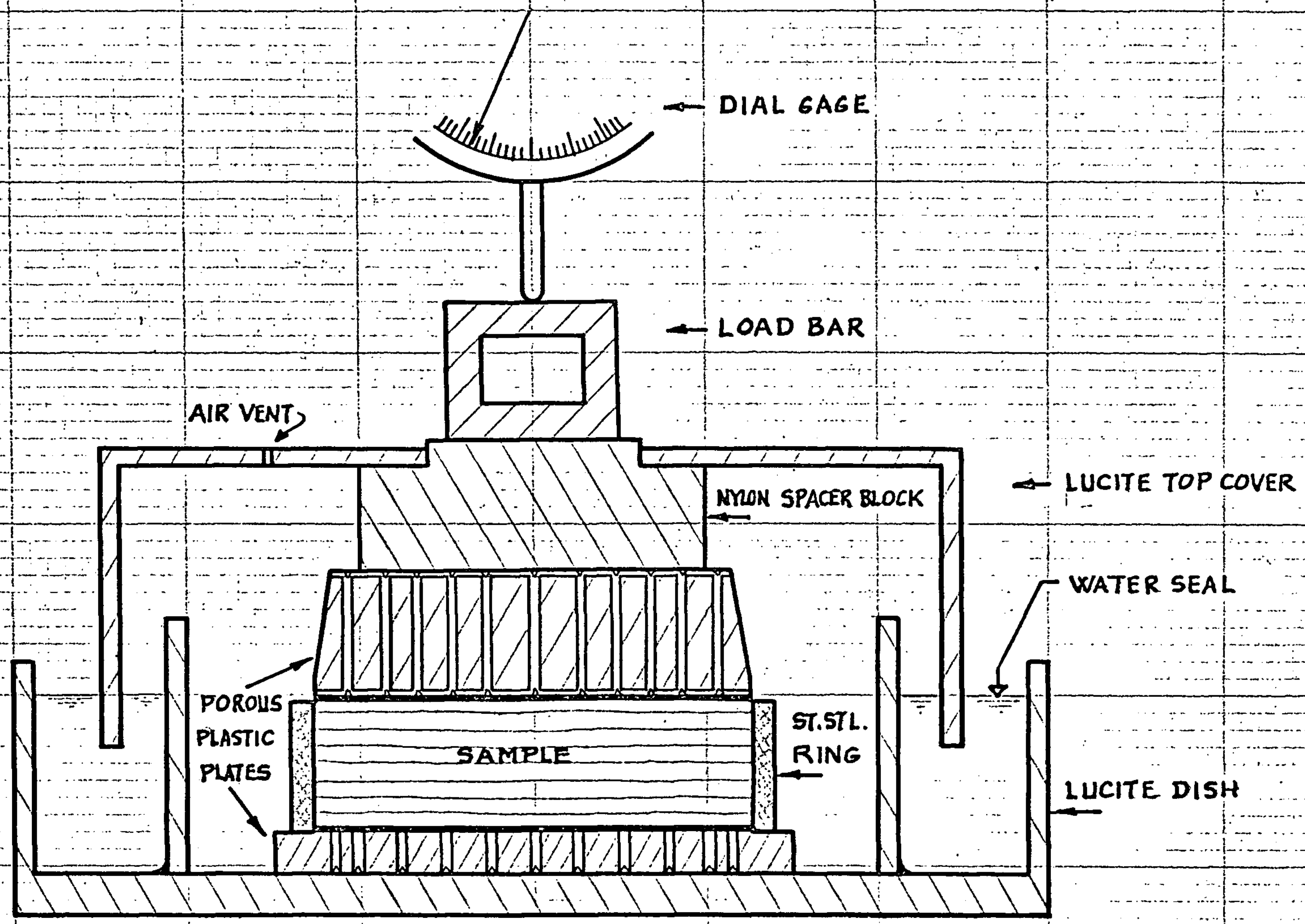

CROSS-SECTION OF CONSOLIDOMETER

NATURAL SCALE

PLATE I

2.0 EXPERIMENTAL WORK

2.1 APPARATUS

SEE PLATE I SECTION OF CONSOLIDOMETER
PLATE II PHOTOGRAPHS OF EQUIPMENT

ALL TESTS WERE CARRIED OUT ON A STANDARD TWO-SIDED CONSOLIDATION FRAME. LOAD WAS APPLIED BY WEIGHTS ACTING THROUGH A LEVER SYSTEM (LEVER ARM RATIO 7.5 TO 1). THE SYSTEM WAS BALANCED WITH COUNTERWEIGHTS AND THE LEVER ARM COULD BE LEVELLED AND ADJUSTED BY MEANS OF TURNBUCKLES.

TWO IDENTICAL FIXED RING CONSOLIDOMETERS WERE USED. EACH ONE CONSISTED OF A STAINLESS STEEL CONSOLIDATION RING BETWEEN TOP AND BOTTOM POROUS PLASTIC PLATES AND WAS CONTAINED WITHIN A LUCITE DISH AND COVER. MOISTURE LOSS FROM THE SAMPLE WAS PREVENTED BY A WATER SEAL BETWEEN THE DISH AND THE COVER. A SMALL ADJUSTABLE VENT ENSURED NO AIR PRESSURE BUILD-UP INSIDE THE COVER ESPECIALLY DURING RAPID CONSOLIDATION. BOTH TOP AND BOTTOM POROUS PLASTIC PLATES WERE MADE OF LUCITE HEAVILY DRILLED AND GROOVED AND FACED WITH FIBREGLASS SCREENING. ATTACHED INSIDE THE TOP COVER WAS A NYLON SPACER BLOCK.

THE STAINLESS STEEL CONSOLIDATION RINGS WERE 2.50 INS I.D. AND 0.750 INS HEIGHT (RATIO $\frac{I.D.}{H} = 3.33$: AREA = 31.60 SQ.CMS). THEY WERE LIGHTLY COATED BEFORE EACH TEST WITH A RING LUBRICANT COMPOSED OF LUBRIPLATE NO.1 MIXED WITH MOLYKOTE TYPE Z (CHIEF INGREDIENT MOLYBDENUM DISULPHIDE - NO GRAPHITE).

CHANGES IN SAMPLE THICKNESS WERE MEASURED WITH AN AMES DIAL GAGE EXTENSOMETER (1" TRAVEL) READING TO 0.001 INS.

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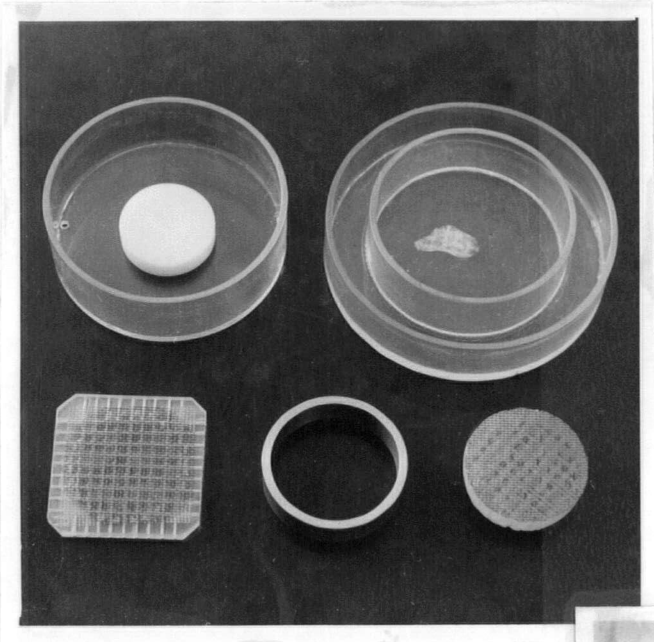

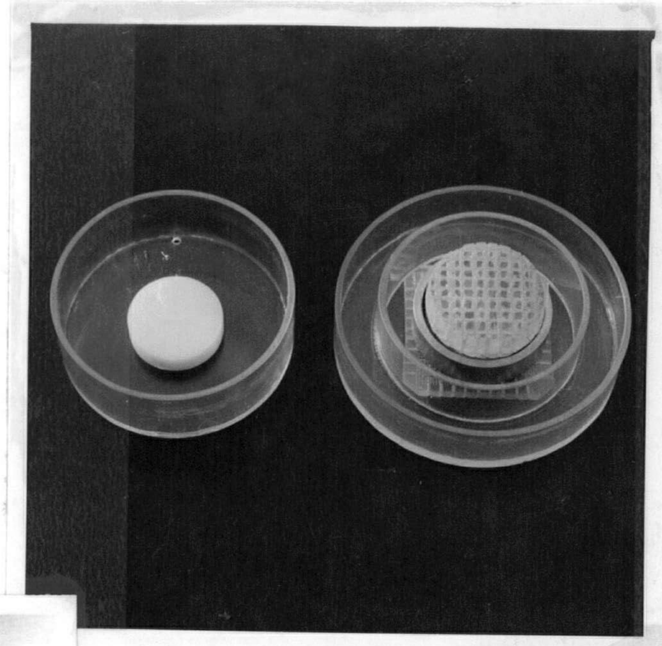

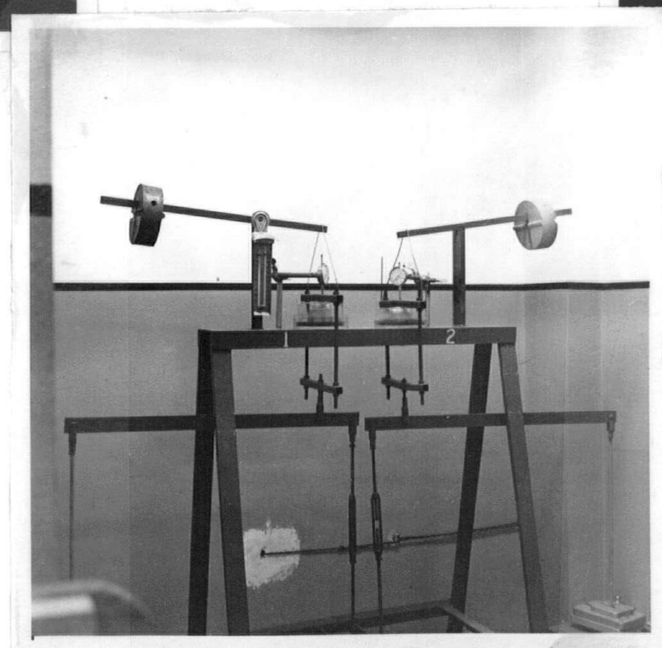

CONSOLIDATION EQUIPMENT

PLATE II

During the first hour or so readings were timed by stopwatch. For subsequent readings the laboratory clock was used.

The tests were performed in a basement room with no temperature control. However the temperature variation over a 24 hour period was found to be small. The average variation was about 3° F and the largest recorded variation 8°F. Temperatures were recorded on a maximum-minimum thermometer generally reset every 24 hours throughout the test series.

Standard soils laboratory equipment was used for weighings, water content determinations and classification tests.

2.2 Sample Preparation

For this test series all samples were cut from the top 2" of an undisturbed block of peat measuring 12" x 10" x 4". To minimize material change due to bacterial and chemical action and loss of water, the block was sprinkled with a 50% solution of carbolic acid, covered with pliofilm and kept submerged in a plastic dish in the humid room. All sample preparation was done in the humid room.

The samples were carefully cut from the block and trimmed in a clamp-type soil lathe. Trimming was done with a scalpel, any minor roots being cut with scissors. Roots larger than about 1/8" diameter were avoided. Water contents were determined on the cuttings.

In order to obtain similar material, the samples were taken as nearly as possible from the same horizontal layer in the peat.

SPECIFIC GRAVITY AND ASH CONTENT DETERMINATIONS WERE MADE ON REPRESENTATIVE PIECES AND CUTTINGS ADJACENT TO THE CONSOLIDATION SAMPLES.

TWO PROCEDURES WERE ADOPTED TO REDUCE SIDE FRICTION:

(A) THE PEAT WAS CUT TO AN EASY SLIP FIT IN THE RING

(B) THE INSIDE OF THE RING WAS LIGHTLY COATED WITH RING LUBRICANT.

AFTER THE SAMPLE HAD BEEN CUT AND TRIMMED INTO THE RING IT WAS BRIEFLY REMOVED, THE RING LIGHTLY GREASED AND THE SAMPLE THEN REPLACED FOR FINAL TRIMMING. THE CONSOLIDOMETER DISH WAS FILLED TO THE BASE OF THE RING WITH PEAT JUICE, CARE BEING TAKEN NOT TO TRAPH AIR BUBBLES IN THE BOTTOM POROUS PLASTIC PLATE. A DROP OF CARBOLIC WAS ADDED TO INHIBIT BACTERIA AND FUNGUS GROWTH DURING THE LONG TERM TESTS.

2.3 PROCEDURE

(1) A SAMPLE WAS CUT FROM THE BLOCK, TRIMMED INTO A CONSOLIDATION RING AND ASSEMBLED IN THE CONSOLIDOMETER AS PREVIOUSLY DESCRIBED. ONE WATER CONTENT WAS TAKEN FROM SAMPLE CUTTINGS.

(2) THE ASSEMBLED CONSOLIDOMETER WAS PLACED IN THE CONSOLIDATION FRAME. THE DIAL GAGE PLUNGER WAS SET ON TOP OF THE LOAD BAR DIRECTLY OVER THE CENTRE OF THE CONSOLIDOMETER AND THE MACHINE COUNTERWEIGHT WAS ADJUSTED TO BALANCE THE FORCE OF THE SPRING LOADED PLUNGER. THE ONLY INITIAL LOAD ON THE SAMPLE AT THIS POINT WAS THE WEIGHT OF THE POROUS PLASTIC PLATE AND THE PLASTIC COVER (APPROXIMATELY 200 GMS). THE LEVER ARM ON THE CONSOLIDATION FRAME WAS ADJUSTED AND LEVELLED. PERIODICALLY

DURING THE TEST, JUST BEFORE APPLYING A NEW LOAD INCREMENT, THE LEVER ARM WAS RE-LEVELLED.

(3) THE SAMPLE WAS THEN LOADED BY MEANS OF WEIGHTS ON THE END OF THE LEVER ARM ACCORDING TO THE PARTICULAR TEST SCHEDULE. FOR EACH LOADING DIAL GAGE READINGS WERE TAKEN, GENERALLY AT STANDARD TIME INTERVALS OF 6 SECS, 15 SECS, 30 SECS, 1 MIN, 2 MINS, 4 MINS, 8 MINS, 15 MINS, 30 MINS, 1 HR, 2 HRS, ETC, BUT OFTEN SUPPLEMENTED BY ADDITIONAL READINGS ESPECIALLY DURING THE RAPID TESTS.

(4) A MAXIMUM-MINIMUM THERMOMETER WAS READ AND RESET GENERALLY EVERY 24 HOURS. ADDITIONAL READINGS WERE FREQUENTLY TAKEN AT CRITICAL PERIODS AND DURING THE ONE DAY RAPID TESTS.

(5) AFTER THE FINAL LOAD WAS REACHED THE SAMPLES WERE UNLOADED IN STAGES USING A PROCEDURE SIMILAR TO THE LOADING CYCLE NOTED ABOVE.

(6) AFTER A LOAD-OFF PERIOD OF APPROXIMATELY 1 HOUR, THE SAMPLE IN ITS CONSOLIDATION RING WAS REMOVED, THE FREE WATER DRIED OFF, AND WEIGHED. THE SAMPLE WAS THEN TAKEN FROM THE RING, MEASURED, WEIGHED AND THEN CAREFULLY BROKEN IN TWO TO CHECK FOR ANY LARGE ROOTS, ETC, BEFORE BEING PLACED IN THE DRYING OVEN. THE SAMPLE WAS RE-WEIGHED AFTER OVEN DRYING FOR AT LEAST 24 HOURS AT 105°C. FINAL MEASUREMENTS WERE TAKEN OF THE DRY SAMPLE AND THE AMOUNT OF WARPING AND SHRINKAGE WAS NOTED.

(7) DIAL READINGS WERE PLOTTED ON SETTLEMENT-LOG TIME AND SETTLEMENT-LOG APPLIED PRESSURE GRAPHS AS BASIC DATA FOR FURTHER COMPUTATION.

2.4 Material Description and Classification Tests

The material used in this series of tests was a fibrous peat obtained at 2 ft depth from a test pit on Lulu Island, Vancouver, British Columbia. Seasonal ground water level varied from near surface to about 4 ft below ground level at the site. The only engineering index tests commonly used for peat are water content and ash content although specific gravity and bulk density are sometimes obtained. Water content values tend to be variable for fibrous peat. The following section gives the results of classifications, physical tests and chemical tests performed on material from the actual peat layer used in the test series.

1. Classification

(a) Description: Brown, fine, fibrous peat, occasional twigs or roots approximately ¼" diameter, noticeable horizontal layering or lamination (not sedimentary), faint odour H_2S, very compressible, considerable tensile strength in horizontal direction.

(b) Unified Soil Classification: Pt

(c) Radforth Classification:

(d) Van der Post Classification: 1 to 2 (Squeeze Test)

(e) Botanical Classification:

2. Physical Tests

(a) Natural Water Content: range 1000% to 1260% - average 1110%

(b) Specific Gravity: using peat oven dried before determination - 1.51

(c) Ash Content

(D) BULK DENSITY:

(E) CALCULATED GAS CONTENT: FROM CONSOLIDATION TESTS
AVERAGE 6% BY VOLUME (USING S.G. 1.5)

(F) CALCULATED VOID RATIO : FROM CONSOLIDATION TESTS
RANGE 16.0 TO 18.6 AVERAGE 17.3
(USING S.G. 1.5)

3. CHEMICAL TESTS

(A) p^{H}: AVERAGE VALUE FOR PORE WATER

(B) CONDUCTIVITY: AVERAGE VALUE FOR PORE WATER

(C) CATION EXCHANGE CAPACITY:

4. NOTES ON TESTS

(A) FOR ALL TESTS WHERE IT WAS REQUIRED THE WEIGHT OF DRY SOLIDS WAS DETERMINED AFTER OVEN DRYING AT 100 - 105°C FOR AT LEAST 24 HOURS.

(B) CHEMICAL TESTS (A) AND (B) WERE CARRIED OUT USING STANDARD EQUIPMENT IN THE U.B.C. SOIL SCIENCE LABORATORY.

2.5 PRECAUTIONS

SINCE THIS TEST SERIES WAS OF AN EXPERIMENTAL NATURE, PROCEDURES WERE DEVISED AND PRECAUTIONS TAKEN TO ELIMINATE OR REDUCE THE INFLUENCE OF AS MANY UNKNOWN FACTORS AS POSSIBLE. THUS SOME PRECAUTIONS MIGHT BE IN FACT UNNECESSARY AND OTHERS WOULD NOT NORMALLY BE FOLLOWED IN ROUTINE CONSOLIDATION TESTS.

OF PRIMARY CONCERN WHEN RUNNING COMPARATIVE TESTS ON UNDISTURBED SOIL, WHETHER MINERAL OR ORGANIC IN COMPOSITION, IS THE SECURING OF IDENTICAL INITIAL CONDITIONS FOR EACH TEST. THE NATURE OF THE FIBROUS PEAT USED IN THIS SERIES WAS SUCH THAT ALTHOUGH NOT EASILY " DISTURBED" OR REMOLDED, IT DID HAVE A PRONOUNCED LAYERING OR LAMINATION. DUE TO ITS HIGH WATER CONTENT (APPROXIMATELY 1100%) AND HIGH ORGANIC CONTENT (ONLY 5% ASH) IT WAS ALSO SUSCEPTIBLE TO LOSS OF MOISTURE AND TO BACTERIAL DECOMPOSITION.

THE BLOCK OF PEAT USED FOR THIS TEST SERIES WAS OBTAINED FROM A TEST PIT AT A DEPTH OF ABOUT 2 FT. IT WAS PLACED IN A PLASTIC DISH, SPRINKLED WITH CARBOLIC, COVERED WITH PLIOFILM AND KEPT IN THE HUMID ROOM, BEFORE AND DURING THE TEST SERIES. APPROXIMATELY ONE MONTH ELAPSED BETWEEN SAMPLING AND TESTING. PRECAUTIONS TAKEN DURING SAMPLE PREPARATION ARE NOTED IN SECTION 2.2. FOLLOWING THE PRACTICE RECOMMENDED BY DR. ROUSE, DEPARTMENT OF BOTANY, U.B.C., A 50% SOLUTION OF PHENOL (CARBOLIC ACID) WAS USED TO INHIBIT BACTERIAL ACTION IN THE PEAT.

SINCE THE PEAT WAS VERY CORROSIVE (p^H APPROX. 4.0), THE ONLY METAL USED WAS THE STAINLESS STEEL CONSOLIDATION RING. ALL OTHER PARTS OF THE CONSOLIDATION APPARATUS WERE PLASTIC (LUCITE, NYLON AND FIBREGLASS) TO

AVOID BOTH CORROSION AND CHEMICAL CONTAMINATION.

THE HIGH WATER CONTENT AND HIGH PERMEABILITY OF THE PEAT TOGETHER WITH THE HIGH LOAD INCREMENT RATIOS (3.0) OF SOME OF THE TESTS REQUIRED TOP AND BOTTOM POROUS STONES OR PLATES OF THE HIGHEST POSSIBLE PERMEABILITY CONSISTENT WITH THE RETENTION OF FINE MATERIAL IN THE SAMPLE. DRILLED PLASTIC PLATED WERE ADOPTED IN THIS CASE FOR THE FOLLOWING REASONS:

(1) HIGH PERMEABILITY AND ABILITY TO HANDLE LARGE VOLUMES OF PORE WATER

(2) MINIMUM CONTAMINATION PLUS EASY CLEANING

(3) LIGHT WEIGHT COMBINED WITH ADEQUATE RIGIDITY.

VERY OPEN POROUS STONES COULD HAVE BEEN USED ALTHOUGH ITEM (2) ABOVE FAVOURED POROUS PLASTIC PLATES. IN ANY CASE THE VERY FIBROUS NATURE OF THE PEAT TESTED SEEMED TO PREVENT ANY SIGNIFICANT LOSS OF MATERIAL INTO THE DRILLED PLASTIC PLATES DURING THIS TEST SERIES. A DRAWBACK TO THE USE OF PLASTIC MATERIALS FOR LOAD BEARING EQUIPMENT IS ITS DEFINITE CREEP CHARACTERISTICS. ALTHOUGH THE COMPLETE CONSOLIDOMETER ASSEMBLY WAS CALIBRATED OVER THE WHOLE LOADING RANGE, FURTHER CONSIDERATION HAD TO BE GIVEN TO CREEP CORRECTIONS FOR LONG TERM TESTS.

SEE FIG. 2 - 1, CALIBRATION GRAPH FOR PLASTIC CONSOLIDOMETERS #1 AND #2.

IT WAS DECIDED NOT TO FLOOD THE DISH I.E. SUBMERGE THE CONSOLIDATION RING, DURING THIS SERIES IN ORDER TO AVOID THE POSSIBLE EFFECTS OF ANY VARIATION BETWEEN INTERNAL PORE WATER AND THE EXTERNAL DISH WATER, AS WELL AS TO GIVE MORE CHANCE FOR ESCAPE OF ANY GAS. DESSICATION WAS PREVENTED BY THE PLASTIC COVER AND WATER SEAL AS NOTED IN SECTION 2-1. ONLY ENOUGH PEAT JUICE WAS ADDED TO COVER THE BASE OF THE CONSOLIDATION

RING AT THE BEGINNING OF THE TEST THUS CONTACT WITH ALL BUT TWO POSSIBLE CONTAMINENTS WAS AVOIDED. IN THE CASE OF THE CARBOLIC AND THE RING LUBRICANT IT WAS CONSIDERED THAT THE ADVANTAGES OUTWEIGHED THE DISADVANTAGES. AT PRESENT THE EFFECTS IF ANY OF CHEMICAL OR BACTERIAL ACTION ARE UNKNOWN.

2.6 Accuracy

Basic Measurements

(1)	SETTLEMENT			
	DIAL GAGE READINGS	.001"	±	.0005"
	OCCASIONAL EXTERNAL VIBRATION, SAY		+	.002" (ROUGH ESTIMATE)
	TEMPERATURE VARIATION 68°-76°F MAX			UNKNOWN, CONSIDERED SMALL
	SETTLEMENT & CREEP OF CONSOLIDOMETER			CALIBRATED, READINGS CORR.
	SEATING ERROR - EST. MAX		+	.010" EFFECT SMALL
(2)	APPLIED PRESSURE			
	WEIGHTS		±	$5\ \text{GM} \times \frac{7.5}{31.6} = .001\ \text{KG/CM}^2$
	AT LOAD BAR (CALIBRATED) (FRICTION OF KNIFE EDGE)		±	$100\ \text{GM} \times \frac{1}{31.6} = \pm .003\ \text{KG/CM}^2$
	WEIGHT OF TOP PLATE & COVER		+	$200\ \text{GM} \times \frac{1}{31.6} = + .006\ \text{KG/CM}^2$
	SPRING-LOADED DIAL GAGE (+ 150 GM)			BALANCED AGAINST COUNTER-WEIGHT
	SIDE FRICTION			NEGLIGIBLE EXCEPT FOR SLIGHT EFFECT AT HIGHER LOADS
	LOAD APPLICATION			GENTLY BY HAND
(3)	INITIAL HEIGHT OF SAMPLE			
	HEIGHT OF RING	.750"	±	.0005": 1.905 CM ± .001
	TRIMMED HEIGHT OF SAMPLE (EST.)		±	.001" ± .002
(4)	FINAL OVEN DRY WEIGHT OF SAMPLE			
	WEIGHING READING	0.1 GM	±	.05
	TEMPERATURE VARIATION OF OVEN NOMINAL MIN 24 HRS AT 105°C			UNKNOWN VARIATION
	DISSOLVED MATERIAL IN CONSOLIDATION SAMPLE RECORDED AS DRY WT OF SOLIDS			EFFECT: APPARENT INCREASE IN DRY WEIGHT OF SOLIDS
(5)	SPECIFIC GRAVITY OF SOLID MATERIAL			
	MAX VARIATION IN TEST PROCEDURE		±	0.1
	DISSOLVED SOLIDS			UNKNOWN VARIATION

CONSIDER VARIATIONS IN INITIAL VOID RATIO.

ASSUMING AS A WORST CASE THAT THE VARIATION IN COMPUTED VALUES OF VOID RATIO WERE DUE TO EACH OF THE FOLLOWING FACTORS ACTING ALONE, THEN THE MAXIMUM INDIVIDUAL VARIATIONS BETWEEN SAMPLES SHOWN BELOW WOULD BE REQUIRED USING MEAN VALUES AS THE BASIS IN EACH CASE.

(1) VARIATION IN DETERMINATION OF OVEN DRY WEIGHT OF SOLIDS – AVE. W_s = 4.97 GM
$W_s = \pm 0.30$ GM ON 4.97 GM (± 6% VARIATION REQUIRED)

(2) VARIATION IN ACTUAL AVE. SPECIFIC GRAVITY OF SOLIDS – AVE. G_s = 1.4 TO 1.5
G_s = (1.40 TO 1.50) ± 0.07 (± 5% VARIATION REQUIRED)

(3) VARIATION IN INITIAL TRIMMED HEIGHT OF SAMPLE
$H_1 = \pm 0.055$ INS ON 0.750 INS (HEIGHT OF RING) (± 7% VARIATION REQ.)

CONSIDER POSSIBLE ERROR DUE TO VARIATION IN SEATING AND ZERO SETTING OF DIAL GAGE.

$$\text{ESTIMATED MAXIMUM VARIATION } \Delta e = \frac{\Delta \text{ DIAL}}{\text{HT. SOLIDS}} = \frac{\pm 0.010''}{0.041''} = \pm 0.25$$

EXAMPLE FROM TEST #1

AT APPLIED PRESSURE = 0.119 KG/CM^2 (APPROXIMATE PRECONSOLIDATION LOAD)

DIFFERENCE BETWEEN INITIAL e AND e AT 0.119 KG/CM^2 = 2.80

THUS Δe = 2.80 ± ERROR = 2.80 ± 0.25 (SEE ABOVE)

$$\text{HENCE VARIATION} = \frac{\pm 0.25}{2.80} \times 100 = \pm 9\%$$

IT CAN BE SEEN THAT THIS VARIATION BECOMES NEGLIGIBLE FAIRLY SOON –

E.G. AT APPLIED PRESSURE = 0.476 KG/CM^2

e INITIAL – e AT 0.476 KG/CM^2 = 8.85

THUS Δe = 8.85 ± 0.25

$$\text{HENCE VARIATION} = \frac{\pm 0.25}{8.85} \times 100 = \pm 3\%$$

SIDE FRICTION AGAINST CONSOLIDATION RING

MANY INVESTIGATORS HAVE FOUND SIDE FRICTION TO BE SIGNIFICANT IN LABORATORY CONSOLIDATION TESTS ON CLAY EVEN WHEN USING STANDARD HEIGHT TO DIAMETER RATIOS (2,5). RECENT WORK HAS INDICATED SIDE FRICTION VALUES AS HIGH AS 12% OF THE APPLIED LOAD FOR FIBROUS-AMORPHOUS PEAT IN UNGREASED RINGS (6). FOLLOWING RECOMMENDED CURRENT PRACTICE, ALL TESTS IN THIS SERIES WERE RUN IN CONSOLIDATION RINGS ($\frac{D}{H} = 3.33$) LIGHTLY COATED INSIDE WITH A MOLYBDENUM DISULPHIDE GREASE.

HOWEVER DUE TO THE VERY FIBROUS NATURE OF THE PEAT BEING TESTED AND ITS RELATIVELY HIGH LATERAL TENSILE STRENGTH, IT WAS POSSIBLE TO OBTAIN A DIRECT CHECK ON THE ACTUAL EFFECT OF SIDE FRICTION. IN TEST #8 THE PEAT WAS CUT, TRIMMED INTO THE RING AND WEIGHED. THEN THE SAMPLE WAS CAREFULLY PUSHED OUT AND THE CONSOLIDATION TEST PERFORMED WITHOUT THE RING - SEE FIG. 3-25. NO SUBSTANTIAL DIFFERENCE WAS NOTED IN THE E-LOG P OR S-LOG P GRAPHS BETWEEN THIS TEST AND THE OTHER EIGHT, EXCEPT FOR THE FINAL LOADS OF TEST #2 (L.I.R. 0.33 L.D. 24 HOURS) AFTER THIS LATTER TEST HAD BEEN RUNNING FOR ABOUT 4 WEEKS. THERE WAS A SLIGHT BULGING IN THE SAMPLE BEYOND THE PRECONSOLIDATION LOAD WHICH INCREASED ITS AVERAGE DIAMETER FROM 2.50 INS TO APPROXIMATELY 2.6 INS AT THE HIGHEST LOAD, WITHOUT HOWEVER ANY APPARENT DISTRESS IN THE SAMPLE.

HENCE IT WAS CONCLUDED THAT SIDE FRICTION WAS NOT A FACTOR DURING THE LOAD CYCLE OF THE TEST SERIES. THERE DID APPEAR TO BE SOME EFFECT ON THE UNLOAD CYCLE BUT IT WAS NOT POSSIBLE TO MAKE ANY QUANTITATIVE ESTIMATES.

THE POSSIBILITY REMAINS THAT SIDE FRICTION MAY HAVE HAD SOME EFFECT ON THE RATE VS SETTLEMENT ESPECIALLY AS BETWEEN FAST AND SLOW TESTS AND HIGH AND LOW L.I.R. IN VIEW OF THE NEGLIGIBLE EFFECT ON THE TOTAL AMOUNT OF SETTLEMENT, HOWEVER, IT APPEARED UNLIKELY THAT SIDE FRICTION WOULD HAVE HAD AN APPRECIABLE EFFECT ON RATES OF SETTLEMENT.

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TEST DATA SUMMARY

– FIG 3-1 –

[TAKING G_s = 1.5]

TEST №	L.I.R. $\frac{\Delta p}{p}$	LOAD DURATION (NOMINAL)	INITIAL WATER CONTENT (%)	INITIAL VOID RATIO e	INITIAL SATURATION (%)	COMPRESSION INDEX - C_c (0.2 TO 0.5 kg/cm²)	OVEN DRY WT. OF SOLIDS (GMS)
2	0.33	24 HRS	1,025	16.0	96.0	9.6	5.28
4	0.33	15 MINS	1,030	16.6	93.2	9.4	5.14
1	1.0	24 DRS	1,140	8.1	94.2	10.0	4.72
5	1.0	15 MINS	1,120	17.9	94.2	9.2	4.79
8 [NO RING]	1.0	12 MINS	1,000	16.3	92.7	10.4	5.24
6	3.0	24 DRS	1,035	16.8	92.7	10.0	5.07
3A	3.0	15 MINS	1,045	17.3	91.3	9.4	4.97
3B	3.0	25 MINS	1,120	17.5	95.3	9.4	4.91
7	1.0 & 3.0	15 MINS & 24 HRS + 2 STOPS	1,130	18.6	91.4	10.4	4.61
AVE. VALUES			1,110	17.3	94	9.8	4.97

3.0 EXPERIMENTAL RESULTS

3.1 Test Data Summary

Information on the type of test, sample measurements and weights and computed values of void ratio, etc, for all consolidation samples in the test series are summarized on Fig. 3 -1 Test Data Summary.

3.2 Results of Consolidation Tests

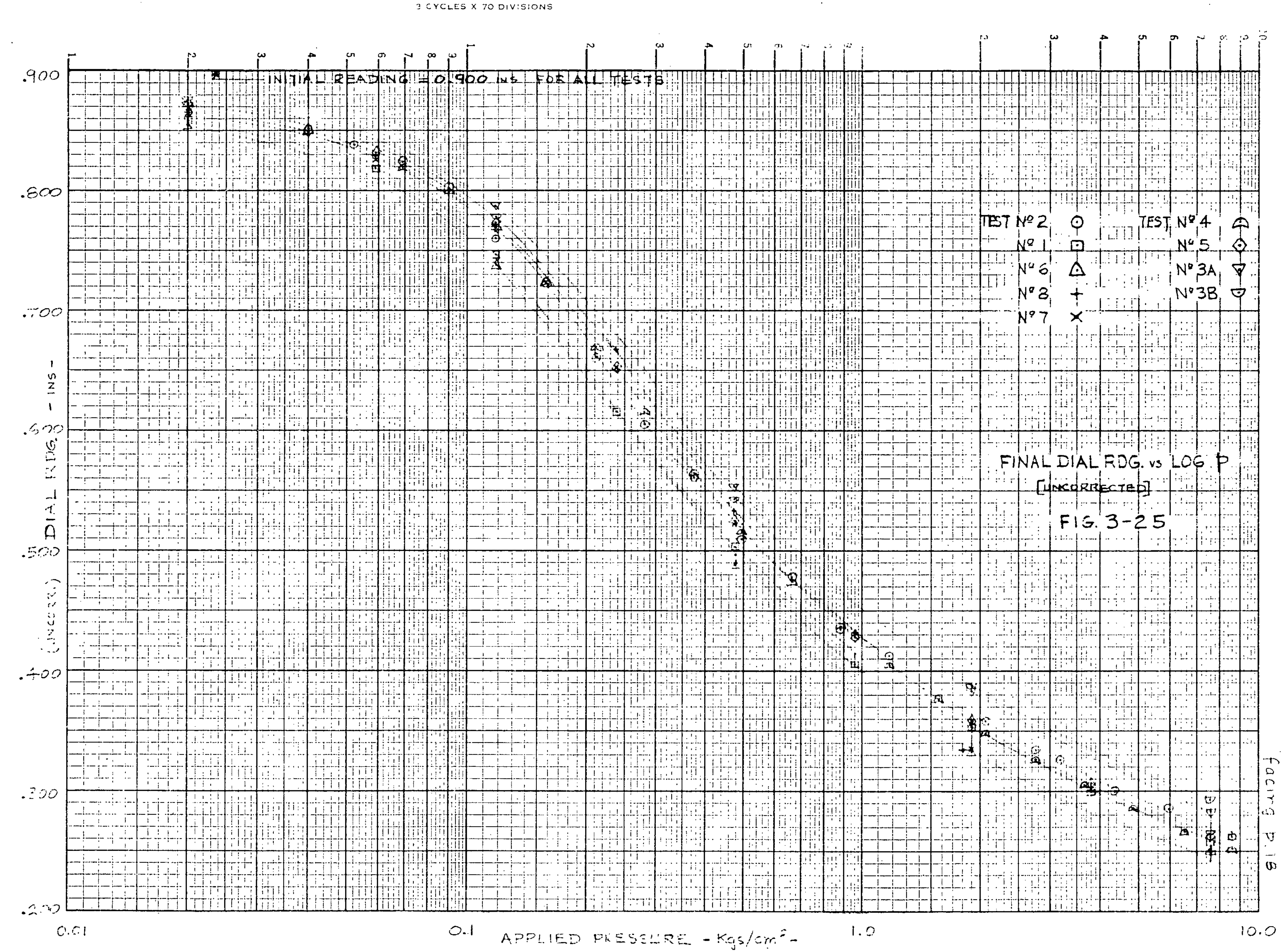
All readings taken were plotted on graphs of dial readings vs log time - as noted below.

Fig. 3 - 2 to 3 - 7 (incl) -	Tests #2 & #4	L.I.R.	0.33
Fig. 3 - 8 to 3 - 14(incl) -	Tests #1, #5 & #8	L.I.R.	1.0
Fig. 3 - 15 to 3 - 18(incl) -	Tests #3A & #3B	L.I.R.	3.0
Fig. 3 - 19 to 3 - 24(incl) -	Tests #6 & #7	L.I.R.	3.0
		L.I.R.	1.0 & 3.0

The final dial reading of settlement for each increment of load was also plotted on a graph of dial reading vs log applied pressure for all tests in this series on Fig. 3-25 - Dial Reading vs Log p.

All the graphs up to this point - Figs. 3-2 to 3-25 - used uncorrected settlement dial readings. Subsequent graphs had settlements corrected by reference to the calibration chart on Fig 2-1.

Using a common value of S.G. = 1.5 for the solids, void ratios were computed and all tests were plotted on a standard graph of (corrected) final void ratio for each increment of load against log applied pressure - see Fig. 3-26 Final e vs log p.



FINAL DIAL RDG. vs LOG P

[UNCORRECTED]

FIG. 3-25

3.3 Preconsolidation Pressure and Compression Index

The preconsolidation pressure and compression index were determined from the final e - log p curves (Fig. 3-26). The peat shows a similar preconsolidation pressure for all tests. Using the Casagrande construction the value obtained from S-log p and e-log p curves ranges from 0.120 to 0.130 Kg/cm^2 (250 p.s.f.). Since the peat sample came from approximately 2 ft below the surface in an area where seasonal ground water level varies from near surface to about 4 ft below grade, it could only have had an overburden pressure of about 2 x 65 p.c.f. = 130 p.s.f. Therefore the preconsolidation pressure reflects a certain amount of drying, assuming the peat behaves similarly to colloidal inorganic soil. Using the criterion of peak rate of secondary settlement - see Fig. 4-5 - the preconsolidation pressure would appear to be even higher around 0.20 to 0.24 Kg/cm^2.

The compression index was taken from the slope of that part of the curve between 0.15 Kg/cm^2 and 0.50 Kg/cm^2 .

Ave. C_c = 9.8 $\pm$ 0.6 - for all nine tests

3.4 Discussion

It can be seen that all the e vs log p or S vs log p curves have a very similar shape and could probably be brought into fairly close agreement by vertical adjustment. All the tests were arranged to have two common applied pressures despite varying L.I.R. These were an initial seating load = 0.024 Kg/cm^2 and a load close to the preconsolidation load - in this case 0.119 Kg/cm^2. No correlation was found between

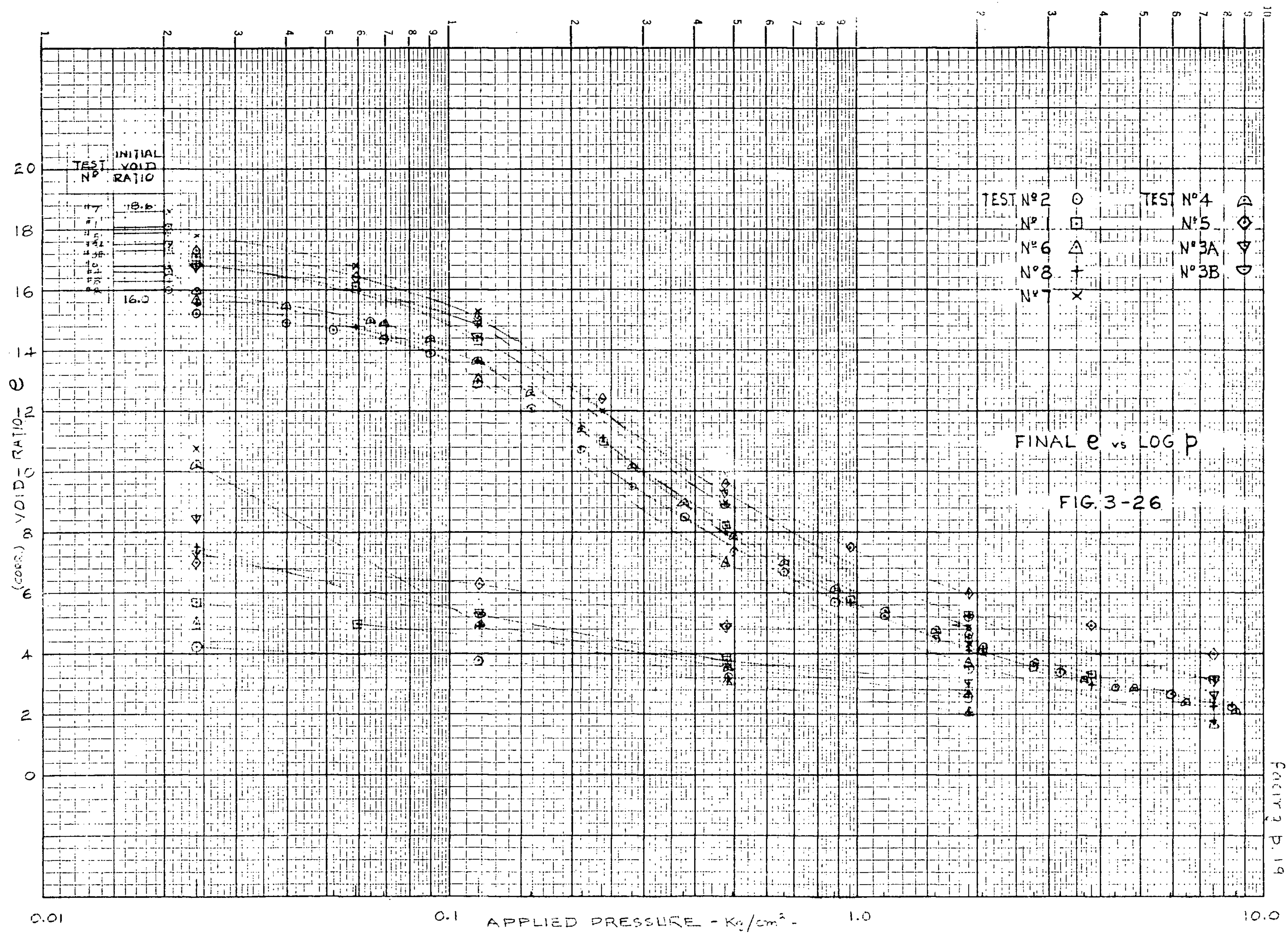


FIG. 3-26

facing p. 19

SETTLEMENTS AND VOID RATIO, DRY WEIGHT SOLIDS, INITIAL WET DENSITY OR SATURATION AT EITHER OF THE TWO COMMON APPLIED PRESSURES DESCRIBED ABOVE I.E. 0.024 Kg/cm^2 AND 0.119 Kg/cm^2.

THREE FACTORS ARE INVOLVED IN THE VARIATION BETWEEN THE CURVES AS SHOWN ON EITHER FIG. 3-25 OR FIG. 3-26.

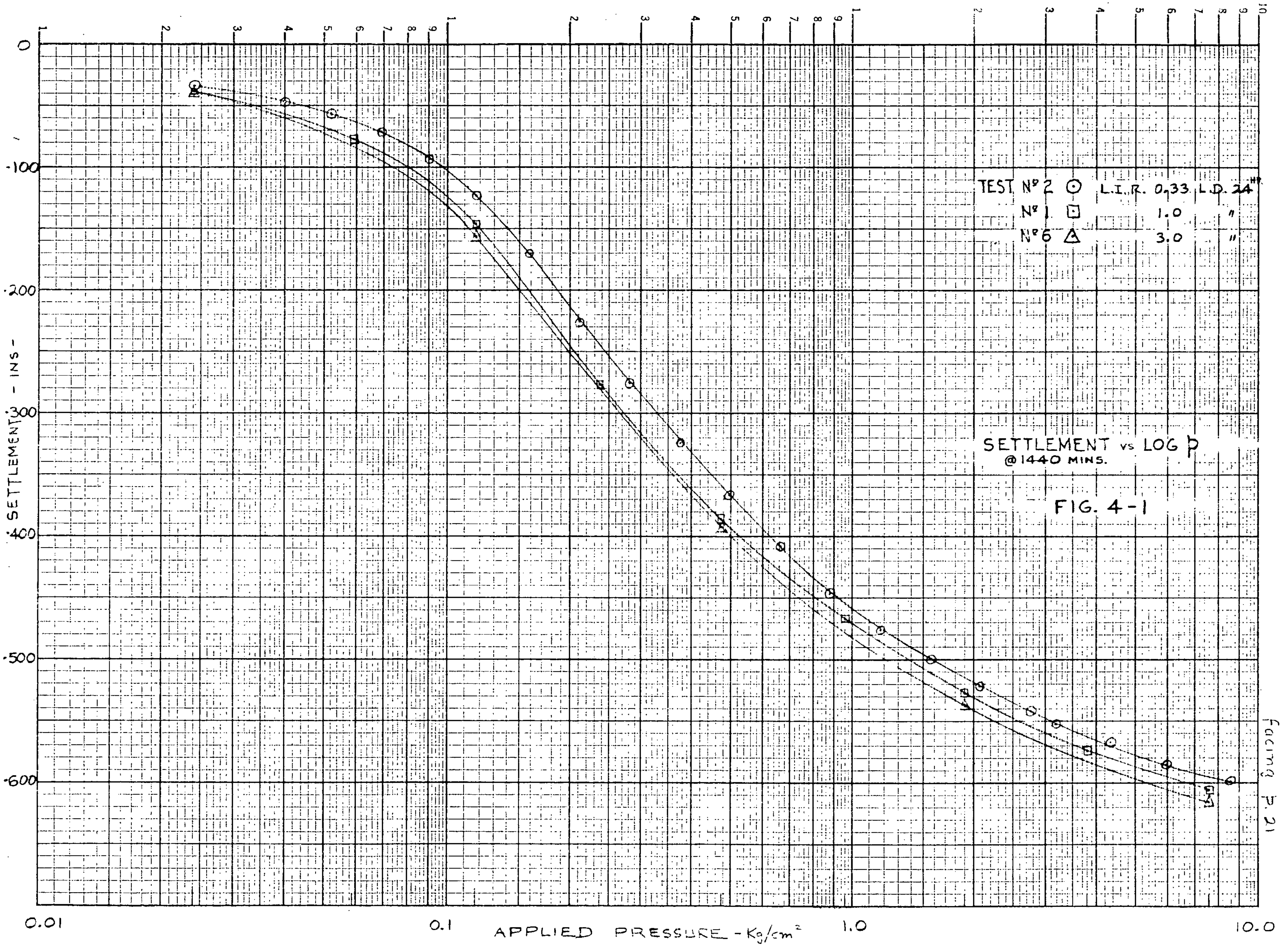
(1) UNINTENDED DIFFERENCES IN TEST CONDITIONS :- ASIDE FROM SMALL TEMPERATURE VARIATIONS (WHICH WERE MEASURED), IT WAS CONSIDERED THAT IN FACT ALL TESTS WERE PERFORMED UNDER IDENTICAL CIRCUMSTANCES.

(2) VARIATION IN MATERIAL TESTED :- THIS IS ALWAYS A PROBLEM WHEN USING NATURAL UNDISTURBED MATERIAL - MAGNIFIED IN THIS CASE SINCE THE MATERIAL IS A FIBROUS PEAT OF SUCH HIGH WATER CONTENT. IN ADDITION THE SMALL SIZE OF SAMPLES (± 5 GMS DRY WEIGHT OF SOLIDS) USED TENDED TO EXAGGERATE ANY VARIATION IN MATERIAL COMPOSITION. IT WAS CONSIDERED THAT IN GENERAL THE VARIATION BETWEEN THE CRITICAL TESTS IN THIS SERIES WAS NOT ENOUGH TO INVALIDATE COMPARISONS OF TESTS ALTHOUGH IN SOME CASES IT DID PREVENT MORE THAN GENERAL CONCLUSIONS BEING DRAWN.

(3) CONTROLLED DIFFERENCES IN TEST PROGRAM :- THE OBJECT OF THE INVESTIGATION WAS TO DETERMINE WHAT DIFFERENCES IF ANY EXISTED BETWEEN TESTS, AND, IF POSSIBLE, TO DEDUCE WHICH VARIABLE HAD CAUSED THEM. OBVIOUSLY SIGNIFICANT DIFFERENCES WOULD ONLY BE OBSERVED IF VARIATIONS IN (1) AND (2) ABOVE WERE NEGLIGIBLE IN RELATION TO THE CONTROLLED VARIABLES IN (3), OR, IF NOT NEGLIGIBLE, AT LEAST OF KNOWN EFFECT. ON THE OTHER HAND WHERE IDENTITIES WERE BEING CONSIDERED THE PROBLEM WAS TO ASSESS WHETHER THE VARIATIONS IN (1) AND (2) ABOVE WERE SUFFICIENT TO MASK AN ACTUAL SIGNIFICANT DIFFERENCE IN (3).

In ordinary consolidation theory the plotting of results on an e-log p graph is equivalent to plotting them on a %S-log p or S-log p graph, in the sense that two curves in close agreement on one plot must give close agreement on the other. In this case it was considered that little would be gained by comparing results on a void ratio basis since the variation in determination of initial void ratio would be of the same order as the apparent variation in samples. Because this test series was essentially one of comparison between samples as nearly identical as possible, it was decided to rely on measured settlements for comparative graphs and computations.

The possibility remains, however, that two samples of identical void ratio could have different settlement-load curves due to different fibre strengths within the peat. This would imply a difference in material composition or soil structure.



TEST Nº 2 ⊙ L.I.R. 0.33 L.D. 24 HR
Nº 1 ⊡ 1.0 "
Nº 6 △ 3.0 "
SETTLEMENT vs LOG P
@1440 MINS.
FIG. 4-1
SETTLEMENT - INS -
APPLIED PRESSURE - Kg/cm²
0.01
0.1
1.0
10.0
0
·100
·200
·300
·400
·500
·600
3 CYCLES X 70 DIVISIONS

facing p. 21

4.0 COMPARISONS

4.1 COMPARISON OF L.I.R. FOR 24 HOUR LOAD DURATION

CONSIDER FIG. 4-1 SHOWING SETTLEMENT AT 1440 MINS VS LOG P

TESTS #1 (L.I.R. 1.0) AND #6 (L.I.R. 3.0) SHOWED GOOD AGREEMENT BUT TEST #2 (L.I.R. 0.33) LAY SOMEWHAT ABOVE THE OTHER TWO. THE SIGNIFICANT DIFFERENCES BETWEEN THE CURVES CAN BEST BE SEEN BY NOTING THE DIFFERENCES IN THEIR SETTLEMENT AT VARIOUS APPLIED PRESSURES. THESE DIFFERENCES ARE TABULATED BELOW.

p (Kg/cm²)	·024		·119 PRECON. PRESSURE		·476		7.58	
TEST Nos	#6-#1	#6-#2	#6-#1	#6-#2	#6-#1	#6-#2	#6-#1	#6-#2
DIFF. IN S (INS)	·001	·005	·008	·033	·006	·032	·009	·018
AVE. S_2/LOG CYCLE	·004		·018		·018		·005	

IT CAN BE CONCLUDED FROM THESE FIGURES THAT TESTS #1 AND #6 HAVE COMPARABLE SETTLEMENTS FOR THE SAME APPLIED PRESSURE SINCE THEY HAVE SMALL AND NEARLY CONSTANT DIFFERENCES BEYOND THE PRECONSOLIDATION PRESSURE; BUT THAT TEST #2 IS ONLY APPROXIMATELY COMPARABLE, IF AT ALL.

IN ANTICIPATION OF LATER DISCUSSION OF RATES OF SECONDARY SETTLEMENT, THE AVERAGE AMOUNTS OF SECONDARY SETTLEMENT PER LOG CYCLE EXHIBITED BY THE THREE TESTS ARE INCLUDED IN THE ABOVE TABLE.

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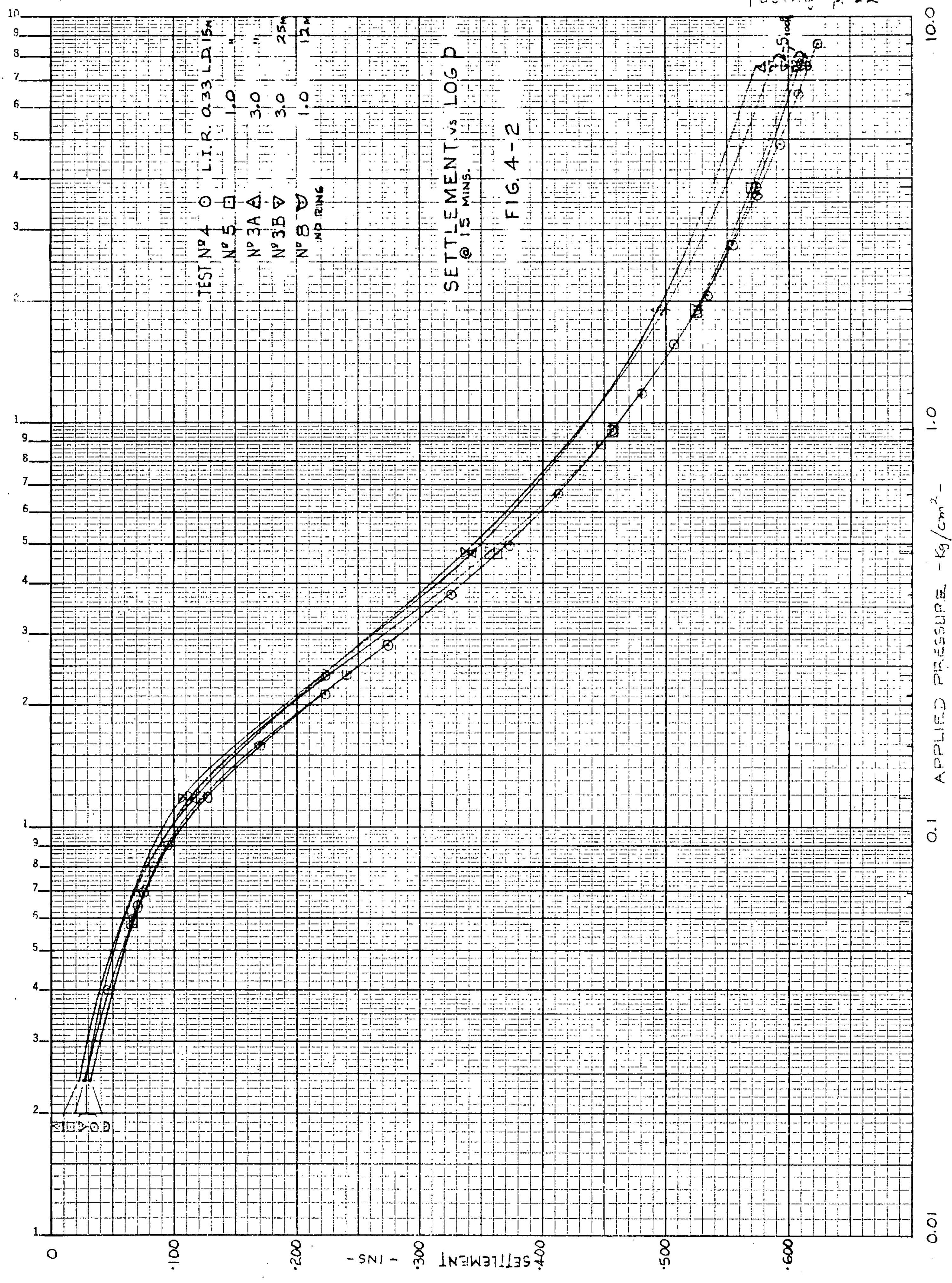

TEST Nº 4 ⊙ L.I.R. 0.33 L.D. 15M
Nº 5 □ 1.0
Nº 3A △ 3.0
Nº 3B ▽ 3.0 25M
Nº 8 ND RING 1.0 12M
SETTLEMENT vs LOG D
@ 15 MINS.
FIG. 4-2
APPLIED PRESSURE -Kg/cm²-
SETTLEMENT - INS -
0.01
0.1
1.0
10.0
0
·100
·200
·300
·400
·500
·600
3 CYCLES X 70 DIVISIONS

4.2 Comparison of L.I.R. for 15 min Load Duration

Consider Fig. 4-2 showing Settlement at 15 mins vs Log p.

Five tests were plotted on this graph -

Three having a load duration of	15 minutes	(#4, #5 and #3A)
one " " " " "	25 "	(#3B)
one " " " " "	12 "	(#8 - no ring)

since all were in the category of rapid tests.

It can be seen that there was close agreement throughout between Test #4 (L.I.R. 0.33) and $5 (L.I.R. 1.0) while Test #8 (L.I.R. 1.0 - no ring) showed some variation between applied pressures of 0.1 and 0.5 Kg/cm^2 only. Both tests #3A and #3B (L.I.R. 3.0) plot considerably above the other curves. The settlement-log time graphs of these rapid tests show that approximately 100% primary consolidation had taken place under the previous load increment before the next load increment was applied in the case of tests #4, #5 and #8, except for the last few increments for #5 and #8, but not in the case of tests #3A and 3B. Hence the reason for the variation in the latter tests was that they were reloaded before primary settlement had been completed. This explanation is supported in test #3A by the settlement under the final applied pressure of 7.58 Kg/cm^2 which was allowed to remain for 2 days, well past the 100% primary consolidation point. The 100% primary settlement point for test #3A then plots in good agreement with test #5. The last two load increments for tests #5 and #8 did not quite reach 100% primary consolidation either, except for the last load on test #8 which then plots in close agreement with test #4.

COMPARING THE CURVES FOR TESTS #4, #5 AND #8 :-

p (Kg/cm²)	.024		.119 PRECON. PRESSURE			.476		7.58		
TEST No's	#4-#5	#4-#8	#4-#5	#4-#8	#4-#3B	#4-#5	#4-#8	#4-#5	#4-#8	#4-#3B
DIFF. IN S (in)	.001	-.005	.004	.012	.019	.001	.008	.007 TO .002	.005 TO .000	.030 TO .019 ±
								AT 100% PRIMARY		
AVE. S_2/LOG CYCLE	.003 ±		.010 ±			.018 ±		.005		

THIS TABLE SHOWS THE GOOD AGREEMENT BETWEEN TESTS #4 AND #5 AND THE GENERALLY GOOD AGREEMENT OF TEST #8. ALTHOUGH TESTS #3A AND #3B (L.I.R. 3.0) ARE NOT VERY COMPARABLE, THE INDICATIONS ARE THAT THEY WOULD ALSO BE IN GENERALLY GOOD AGREEMENT IF THEIR LOAD DURATIONS WERE EXTENDED TO PERMIT 100% PRIMARY CONSOLIDATION TO BE COMPLETED. HOWEVER IT SHOULD BE NOTED THAT THE CURVES FOR TESTS #3A AND #3B AGREE FAIRLY WELL WITH EACH OTHER (EXCEPT FOR THE LAST LOAD) DESPITE THE DIFFERENT LOAD DURATIONS OF 15 MINUTES AND 25 MINUTES RESPECTIVELY.

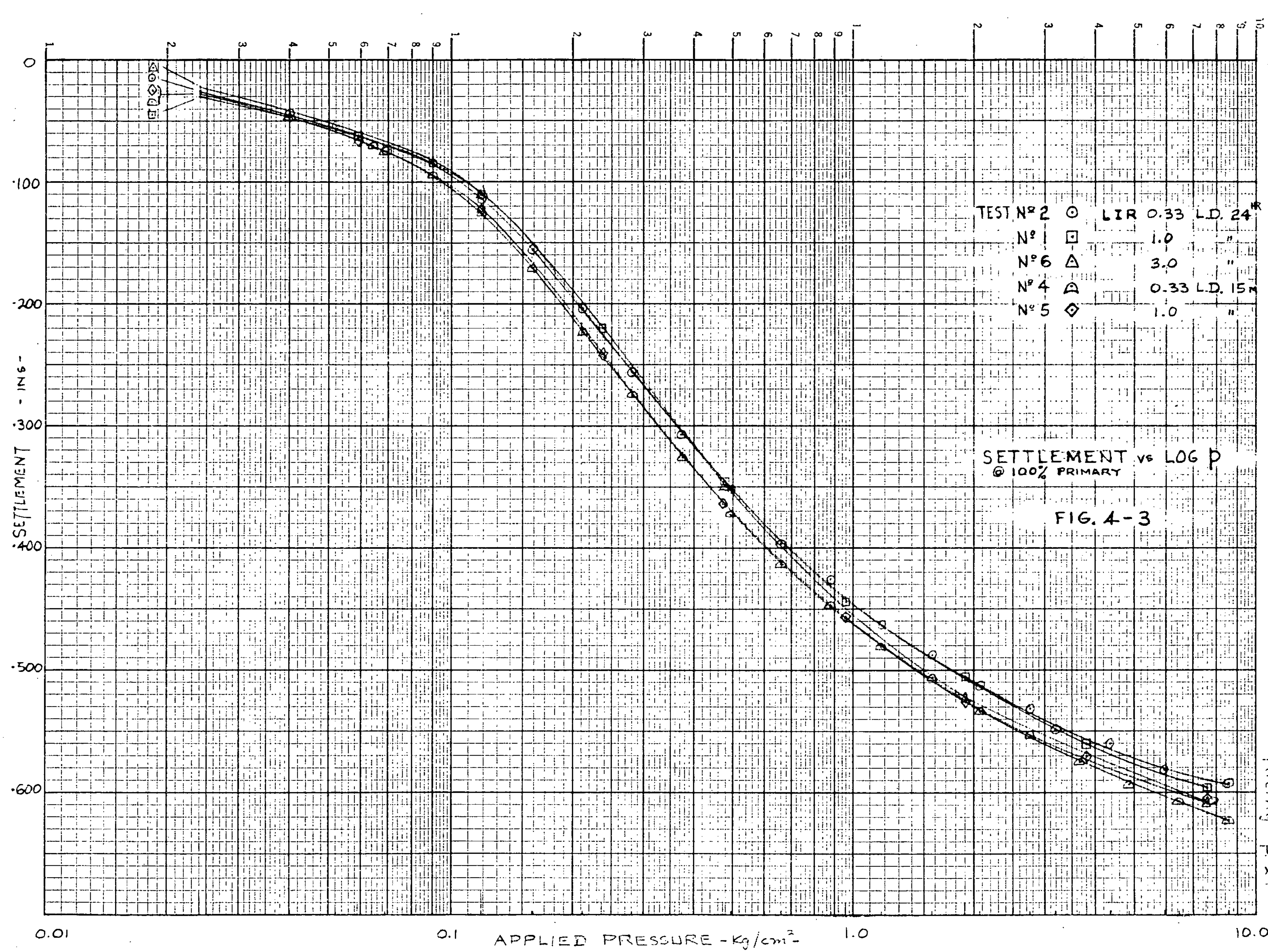

3 CYCLES X 70 DIVISIONS
TEST Nº 2 ⊙ LIR 0.33 L.D. 24 HR
Nº 1 ⊡ 1.0 "
Nº 6 △ 3.0 "
Nº 4 ◬ 0.33 L.D. 15 M
Nº 5 ◇ 1.0 "
SETTLEMENT vs LOG P
@ 100% PRIMARY
SETTLEMENT - INS -
APPLIED PRESSURE - Kg/cm²
0
·100
·200
·300
·400
·500
·600
0.01
0.1
1.0
10.0

FIG. 4-3

4.3 Comparison of 24 hour and 15 min tests for different L.I.R.

Consider Fig. 4-3 showing Settlement at 100% primary vs Log p

Three tests run with nominal load durations of 24 hours have been plotted (#2, #1 and #6 with respective L.I.R. of 0.33, 1.0 and 3.0) together with two tests with load durations of 15 minutes (#4 and #5 with respective L.I.R. of 0.33 and 1.0). Tesys #3A and #3B were omitted since they did not reach 100% primary consolidation - see discussion in section 4-2.

The 100% primary consolidation point was determined from the dial reading-log time graphs as follows :

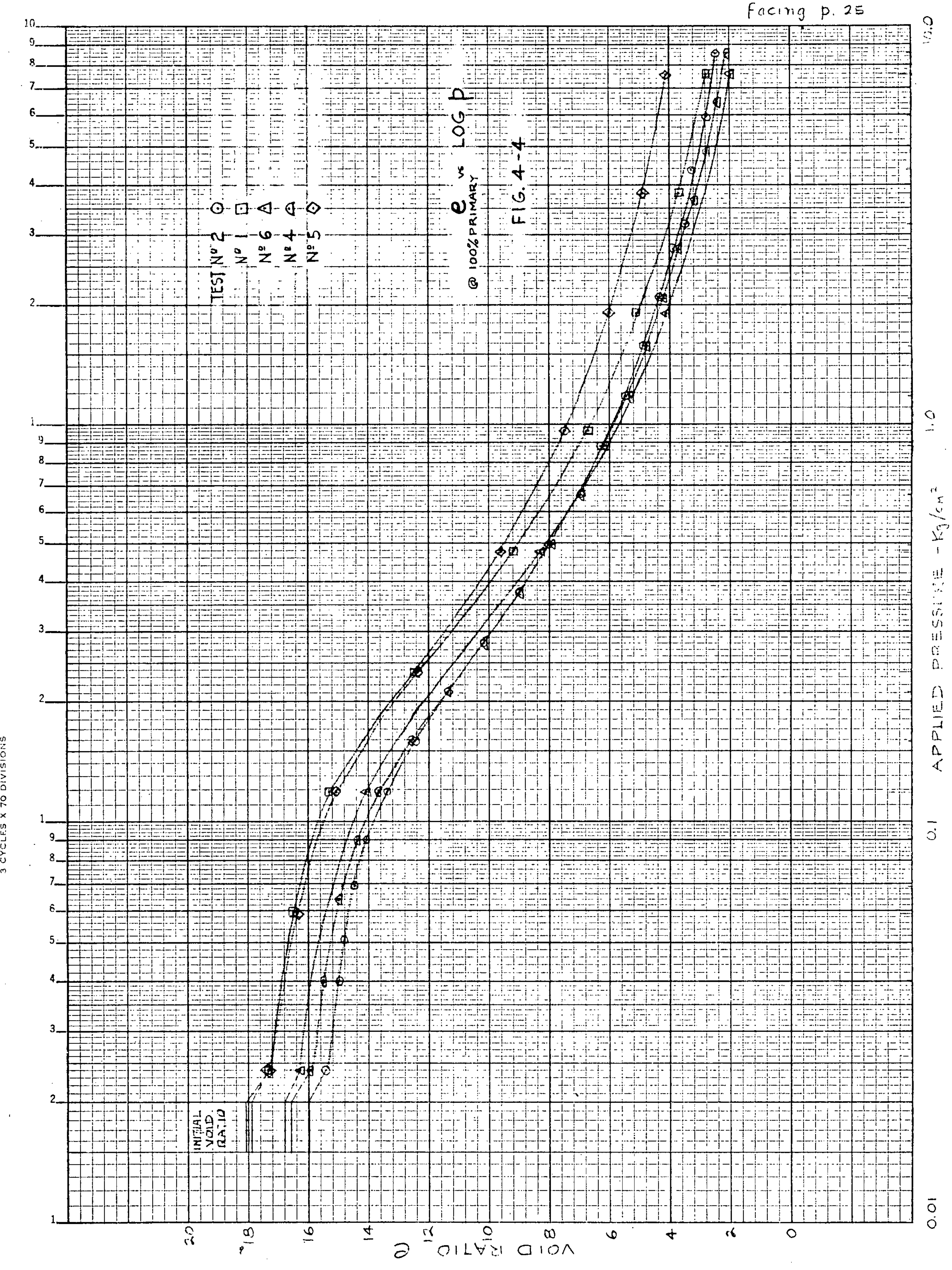
(i) For curves concave upwards in the 100% primary consolidation region the standard tangent intercept method was used. (A. Casagrande construction, Ref.1, p.241)

(ii) For curves convex upwards in the 100% primary consolidation region the tangent point method was used. According to Leonards & Girault (5) this point is approximately the point where pore pressure readings became essentially zero.

Method (ii) was mainly applicable to test #2 with a L.I.R. of 0.33 and a nominal load duration of 24 hours. The 100% primary points used are marked on the curves in the Dial Reading vs log time graphs. The two curve shapes involved are shown in sketches in section 4.4.

As in the previous graphs on Fig. 4-2, tests #4 and #5 can be represented quite closely by a single line except for the last few load increments. However when plotted together the 15 minute tests fall consistently below the 24 hour tests - the difference in settlement

Facing p. 25


e vs LOG p
@ 100% PRIMARY
FIG. 4-4
TEST No 2
No 1
No 6
No 4
No 5
INITIAL VOID RATIO
APPLIED PRESSURE - Kg/cm²
VOID RATIO e
0.01
0.1
1.0
10.0
20
18
16
14
12
10
8
6
4
2
0
3 CYCLES X 70 DIVISIONS

BEING APPROXIMATELY 0.015 INS TO .020 INS. THIS IS EXACTLY OPPOSITE TO THE TREND THAT MIGHT BE EXPECTED IF THE 15 MINUTE TESTS WERE BEING RELOADED BEFORE REACHING 100% PRIMARY CONSOLIDATION.

AS A CHECK ON THE RAPID TESTS #4 AND #5, THE 100% PRIMARY POINT WAS ESTIMATED FOR THESE TWO TESTS USING THE PREVIOUS TWO METHODS (I) AND (II) ASSISTED WHERE POSSIBLE BY THE SQUARE ROOT FITTING METHOD. ALTHOUGH THESE WERE ONLY APPROXIMATE DETERMINATIONS THEY DID INDICATE THAT TEST #5 (L.I.R. 1.0) HAD COMPLETED ITS PRIMARY SETTLEMENT BY 15 MINUTES WHEREAS TEST #4 (L.I.R. 0.33) ONLY COMPLETED ITS PRIMARY SETTLEMENT WITHIN THE 15 MINUTE LOAD DURATION UP TO AN APPLIED PRESSURE OF ABOUT 0.5 KG/CM^2. IN NEITHER CASE DID THESE CONSIDERATIONS MAKE ANY SIGNIFICANT IMPROVEMENT IN AGREEMENT BETWEEN TESTS #4 AND #5 AND TESTS #1, #2 AND #6. THE RANGE OF TIMES TAKEN TO REACH 100% PRIMARY CONSOLIDATION FOR THE LATTER TESTS IS SHOWN IN SECTION 4.4.

A FURTHER COMPARISON WAS MADE BY PLOTTING THE SAME TESTS ON A VOID RATIO BASIS. FROM THE GRAPH OF e AT 100% PRIMARY VS LOG P - FIG. 4-4 - IT CAN BE SEEN THAT THERE WAS NO BETTER AGREEMENT THAN PREVIOUSLY.

TWO DIFFERENT CONCLUSIONS COULD BE DRAWN FROM THESE RESULTS.

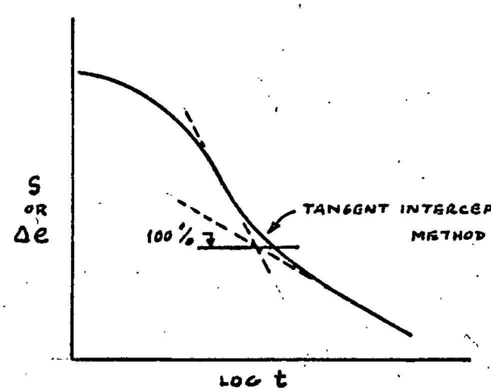
(A) SINCE THE CURVES ARE VERY SIMILAR WITH A FAIRLY CONSISTENT SETTLEMENT DIFFERENCE BETWEEN THE 24 HOUR AND 15 MINUTE TESTS, IT MAY BE ASSUMED THAT THEIR DIFFERENCES ARE NOT DUE TO RANDOM CAUSES, THUS IMPLYING A VARIATION IN THE SAMPLES OR THE TESTS.

(B) ASSUMING SIMILAR MATERIAL, THEN THERE APPEARED TO BE A DEFINITE TREND TO INCREASED SETTLEMENT WHERE TESTS WERE RUN WITH SHORT LOAD

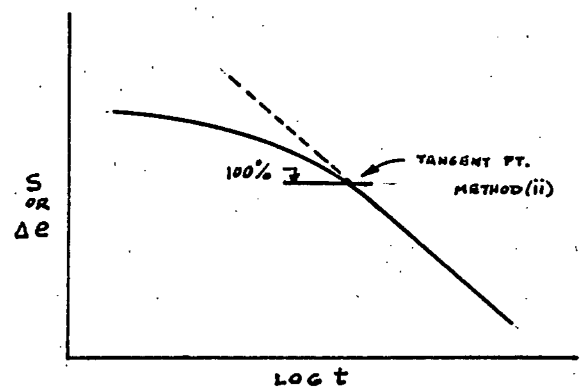
DURATIONS I.E. RELOADED AT OR CLOSE TO THE 100% PRIMARY CONSOLIDATION POINT - THIS TREND SHOWED FOR AT LEAST TWO LOAD INCREMENT RATIOS - 0.33 AND 1.0.

4.4 Comparison of Curve Shapes and Time Required to Reach 100% Primary Consolidation

The shape of a compression curve when plotted on a graph of settlement vs log time generally falls into one of two distinct categories. They have been so classified by several investigators (4, 5, 7) into Type I and Type II curves as shown in the sketch below. In some cases a transition curve between these two types has been recognised.



TYPE I



TYPE II

Since these curve types have been observed for both laboratory and field consolidation settlements in peat as well as in clay, they afford a convenient classification system. Generally a shallow form of either Type I or Type II or possibly a transition type curve could be considered to prevail below the preconsolidation pressure for all L.I.R!s and load durations used in this test series.

Due to the high initial water content and relatively high initial permeability of the peat, approximately 50% of the primary settlement had occurred by the time the first reading could be obtained (at 6 secs), so the first part of the Type I curve was never really observed. A general comparison of curve types and time to 100% primary consolidation (determined as described in section 4.3) for applied pressures beyond the preconsolidation load is shown in following table.

Test #	L.I.R.	Load Duration	Curve Type	Range of times to reach 100% primary (mins)
2	0.33	24 hrs nominal	II	150 - 300 - 90
1	1.0	"	I	3 - 35
6	3.0	"	I	5 - 40
4	0.33	15 mins	I	5 - 20 +
5	1.0	"	I	2 - 20
3A	3.0	"	I	-
3B	3.0	25 mins	I	4 and 40
8	1.0	12 mins	I	2 - 35 (no ring)
7	1.0 3.0	15 mins 24 hrs	I I	2 - 4 10

Several considerations arise from the above comparison as well as from the settlement-log time graphs Figs. 3-2 to 3-24.

(a) All the tests except #2 had the same curve type and approximately the same range of time to reach 100% primary consolidation. In other words varying the L.I.R. and the Load Duration did not make a pronounced difference to the 100% primary time provided the curve type did not change (as discussed earlier tests #3A and 3B did not

PROPERLY REACH 100% PRIMARY SETTLEMENT).

(B) IN TEST #2 THE TIMES TO 100% PRIMARY SHOWED A DEFINITE TREND TO SHORTER VALUES AT HIGHER APPLIED PRESSURES I.E. AT LOWER VOID RATIOS, WHEREAS ALL THE OTHER TESTS SHOWED A SLOW TREND TO LONGER TIMES AT HIGHER APPLIED PRESSURES.

(C) VARIATIONS OF THE L.I.R. DURING TEST #2 CAUSED SIGNIFICANT VARIATIONS IN THE TIME TO 100% PRIMARY SETTLEMENT ALTHOUGH APPARENTLY NOT IN OTHER TESTS WITH TYPE I CURVES. CONSIDER THE FOLLOWING EXAMPLES FROM TESTS #2 AND #7:-

TEST #	LOAD INCREMENT (KG.CM2)	CHANGE IN L.I.R.	CHANGE IN TIME TO 100% PRIMARY (MINS)
2	2.76 TO 3.19	DECREASED FROM 0.33 TO 0.16	INCREASED FROM 90 TO 300
	5.98 TO 8.58	INCREASED FROM 0.37 TO 0.44	DECREASED FROM 150 TO 90
7	0.476 TO 1.90	INCREASED FROM 1.0 TO 3.0	INCREASED FROM 4 TO 10 (EXPECTED NORMAL INCR.)

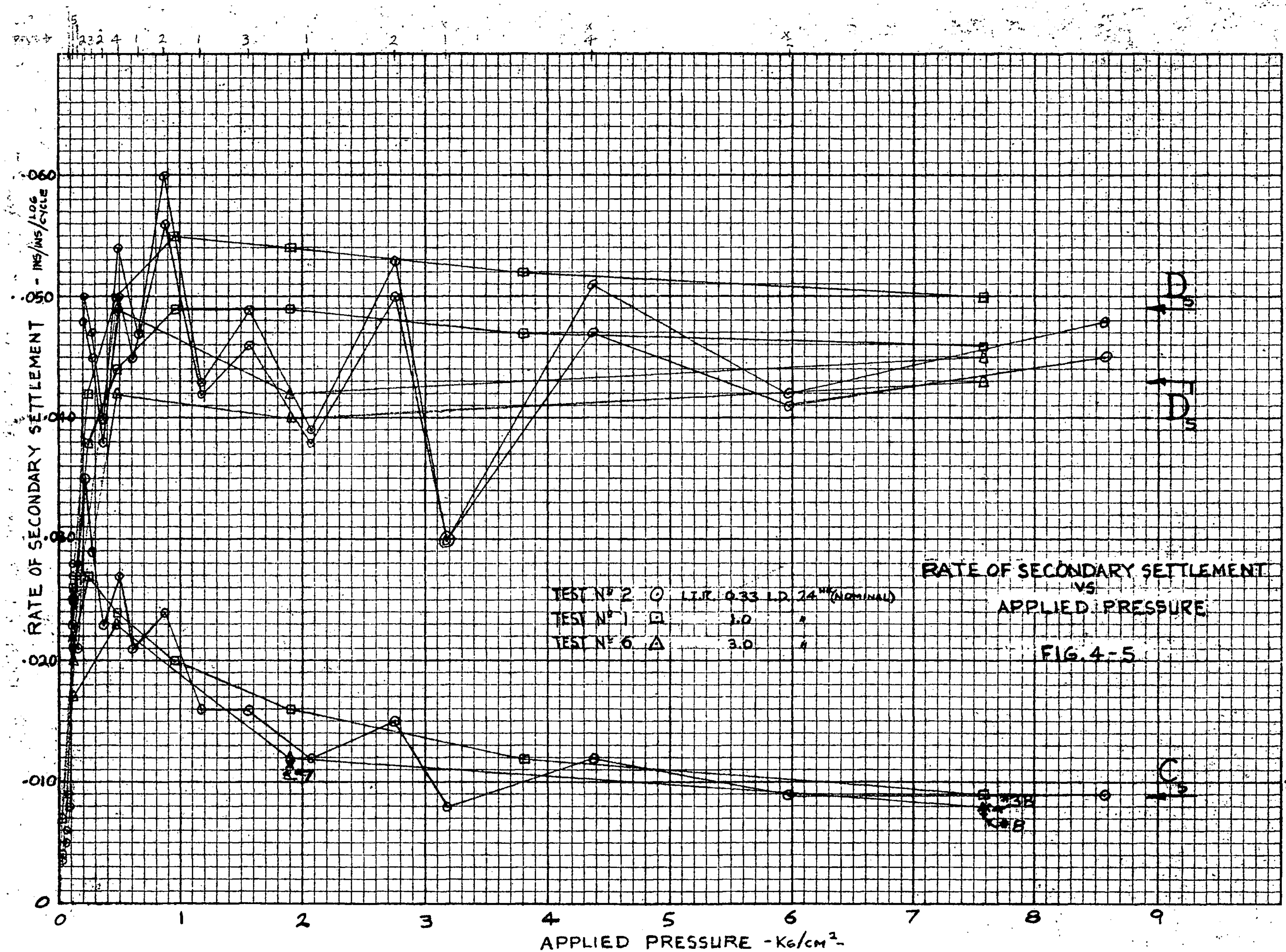
(D) FOR TESTS AT L.I.R. OF 1.0 AND 3.0 THERE APPEARED TO BE A SLIGHT TENDENCY FOR THE 100% PRIMARY TIME TO BE LONGER FOR THE RAPID 15 MINUTE L.D. TESTS THAN FOR THE 24 HOUR TESTS AT THE SAME L.I.R. ESPECIALLY AT HIGHER APPLIED PRESSURES (I.E. LOWER VOID RATIOS). THE REVERSE WAS THE CASE FOR TESTS AT THE L.I.R. OF 0.33.

(E) THE TIME TAKEN TO REACH 100% PRIMARY SETTLEMENT IN TEST #2 (L.I.R. 0.33) WAS ROUGHLY ONE LOG CYCLE OF TIME IN MINUTES LONGER THAN IN THE OTHER TESTS.

IT WAS CONCLUDED THAT THE CURVE TYPE WAS DEPENDENT ON BOTH LOAD INCREMENT RATIO AND LOAD DURATION OR RATE OF LOADING.

Support for this conclusion is given by a very similar consolidation test carried out recently by the writer in the laboratory of R.A.Spence Ltd., Vancouver. The test was performed under nearly identical conditions on fibrous peat approximately 6 ins deeper from an adjacent test pit at the same site. In this case a L.I.R. of 0.30 and a very consistent load duration of 24 hours also gave a Type II curve.

Settlement vs log time graphs (Figs. A-1 to A-5 inclusive) for this test No.P1 are included in the appendix.



RATE OF SECONDARY SETTLEMENT VS APPLIED PRESSURE

FIG. 4-5

4.5 COMPARISON OF RATE OF SECONDARY SETTLEMENT

CONSIDER FIG. 4-5 SHOWING RATE OF SECONDARY SETTLEMENT VS APPLIED PRESSURE

CONSIDER FIG. 4-6 " " " " " VS LOG P

PLOTTED ON THE ABOVE GRAPHS ARE THE RATES OF SECONDARY SETTLEMENT AT EACH LOAD FOR THE 24 HOUR TESTS #6, #1 AND #2 PLUS SINGLE DETERMINATIONS FROM TESTS #8, #7 AND #3A WHERE THE LOAD INCREMENT REMAINED ON FOR AT LEAST 24 HOURS.

FOUR METHODS OF COMPUTING THIS RATE WERE ATTEMPTED SINCE THERE APPEARS TO BE NO GENERAL AGREEMENT ON THE MOST SIGNIFICANT MANNER OF PRESENTATION.

(I) $C_S = \dfrac{\Delta \text{ DIAL RDG. PER LOG CYCLE OF TIME}}{H_1 \text{ (INITIAL HEIGHT OF SAMPLE)}}$

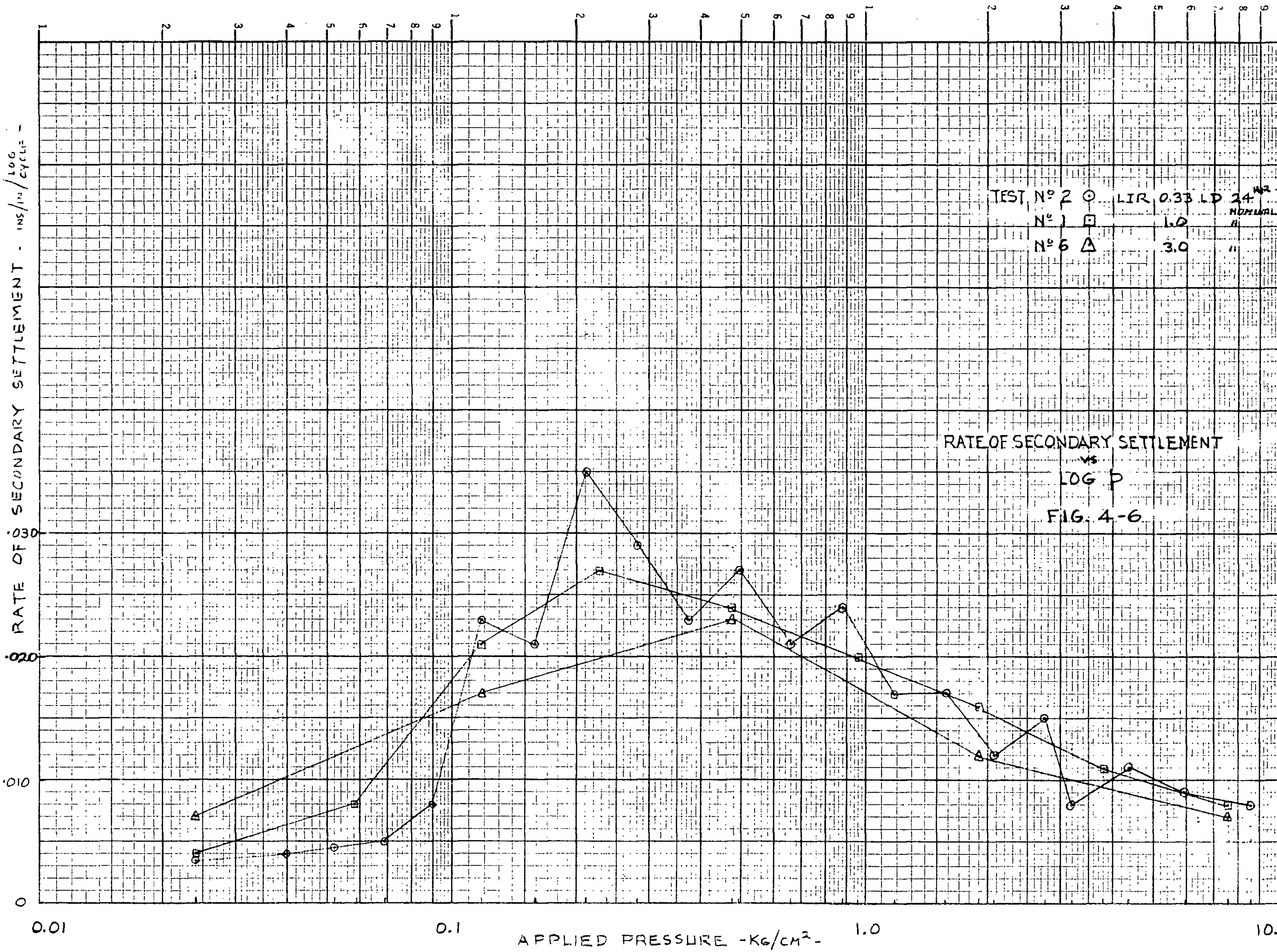
(II) $C'_S = \dfrac{\Delta \text{ DIAL RDG. PER LOG CYCLE}}{H_p \text{ (HT. OF SAMPLE AT PRECONSOLIDATION PRESSURE - 100\% PRIMARY POINT)}}$

(III) $D_S = \dfrac{\Delta \text{ DIAL RDG. PER LOG CYCLE}}{H_F \text{ (PREVIOUS FINAL HT. OF SAMPLE)}}$

(IV) $D'_S = \dfrac{\Delta \text{ DIAL RDG. PER LOG CYCLE}}{H_{100\%} \text{ (PREVIOUS HT. OF SAMPLE AT 100\% PRIMARY POINT)}}$

IN THIS TEST SERIES $H_1 = 0.750''$ AND $H_p = 0.630'' \pm 0.010''$ FOR ALL TESTS, CONSEQUENTLY C'_S WAS NOT GRAPHED SINCE IT WAS SIMILAR TO C_S. BOTH D_S AND D'_S WERE PLOTTED SO AS TO INDICATE ANY POSSIBLE TRENDS BETWEEN THE VARIOUS L.I.R.

THE CURVES OF C_S SHOWED THE TYPICAL SHAPE OF PEAT SECONDARY RATES WITH A PEAK VALUE AT THE PRECONSOLIDATION PRESSURE THEN DECREASING WITH INCREASED PRESSURE (E.G. PLATE 41 IN REFERENCE 3).



RATE OF SECONDARY SETTLEMENT vs LOG P

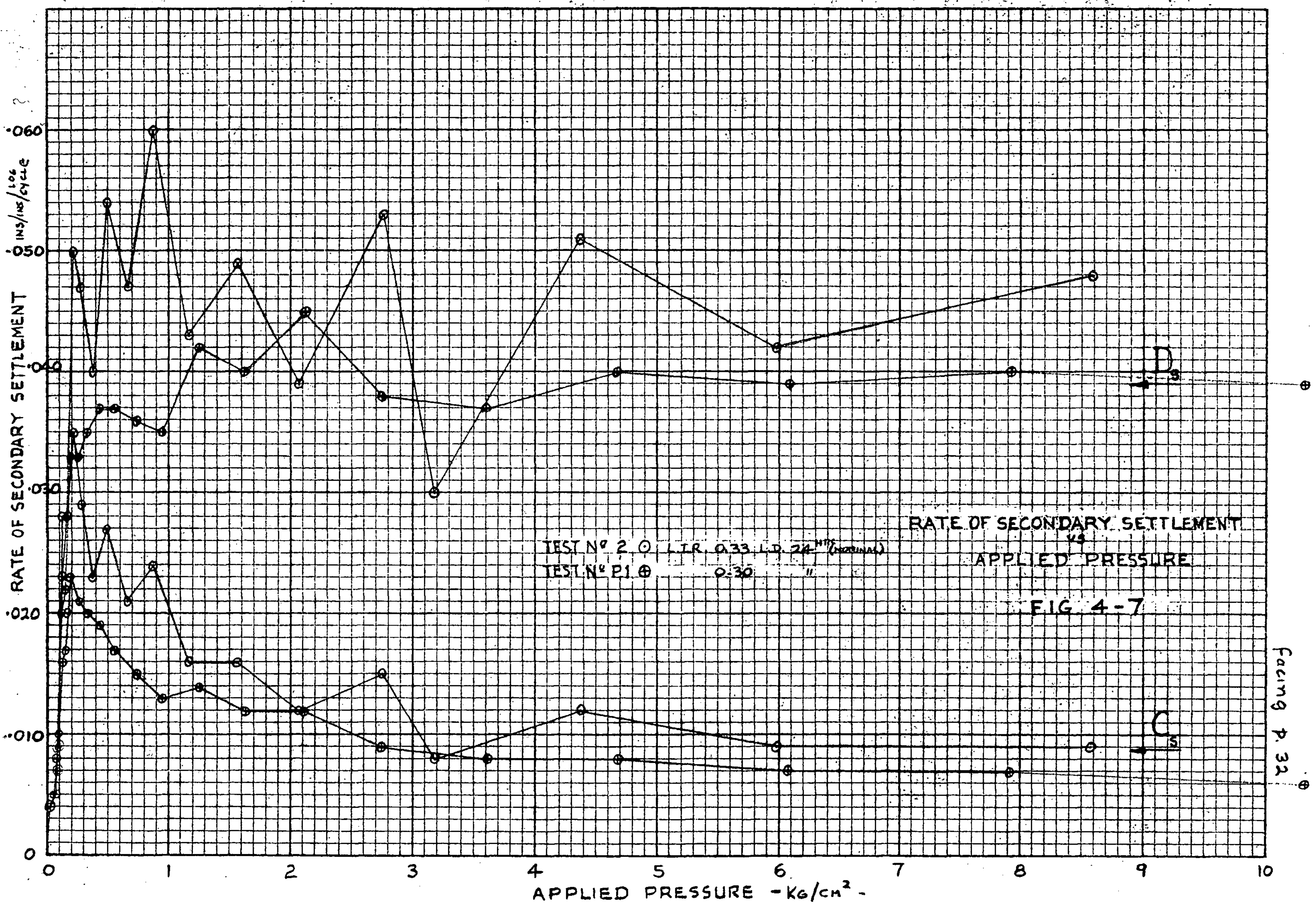
FIG. 4-6

facing p. 31

Tests #1 and #6 (L.I.R. 1.0 and 3.0) give reasonably smooth and consistent curves but test #2 (L.I.R. 0.33 Curve Type II) is very erratic especially when plotted on curves of D_S and D'_S. Other work has demonstrated that temperature does have an appreciable effect on the rate of secondary settlement but in the case of test #2 there did not appear to be any temperature correlation.

The significant factor in test #2 appeared to be the duration of the previous load increment, since the rate of secondary settlement decreased appreciably after a longer than usual previous load duration e.g. two or three day L.D. during a nominal 24 hour L.D. test. It might be thought that the duration of the previous load increment would influence the rate of secondary settlement by its effect on the void ratio. Indeed the definitions of D_S and D'_S are used for the very purpose of eliminating the void ratio at the start of a given load increment as a variable. In this case however, the curves of D_S and D'_S serve to show that this variation was not related to decreased void ratio.

On the other hand test #1 (L.I.R. 1.0 - 24 hour L.D.) also had several longer than usual load durations but these had no apparent effect on the rate of secondary settlement - see Fig. 4-5 between 0.476 Kg/cm^2 and 7.58 Kg/cm^2. The rate of secondary settlement for the 1.90 Kg/cm^2 loading in test #6 did appear to be a low value, again possibly due to the three day load duration under the previous load increment. However this may have been a temperature effect since at that particular load increment test #6 was at an average temperature of 72°F compared



RATE OF SECONDARY SETTLEMENT vs APPLIED PRESSURE

FIG. 4-7

facing p. 32

WITH TEST #1 WHICH WAS AT AN AVERAGE TEMPERATURE OF 74°F.

A SUPERFICIAL COMPARISON OF THE PEAK VALUES OF C_S AND C'_S IN THE REGION OF THE PRECONSOLIDATION PRESSURE FOR TESTS #6, #1 AND #2 WOULD INDICATE THAT TEST #2 HAD MUCH HIGHER VALUES THAN #1 AND #6.

MAX. C'_S = .041 : MAX. C_S = .035 : TEST #2 (L.I.R. 0.33 - 24 HR L.D.)
MAX. C'_S = .032 : MAX. C_S = .027 : TEST #1 & #6 (L.I.R. 1.0 & 3.0 - 24 HR L.D.)

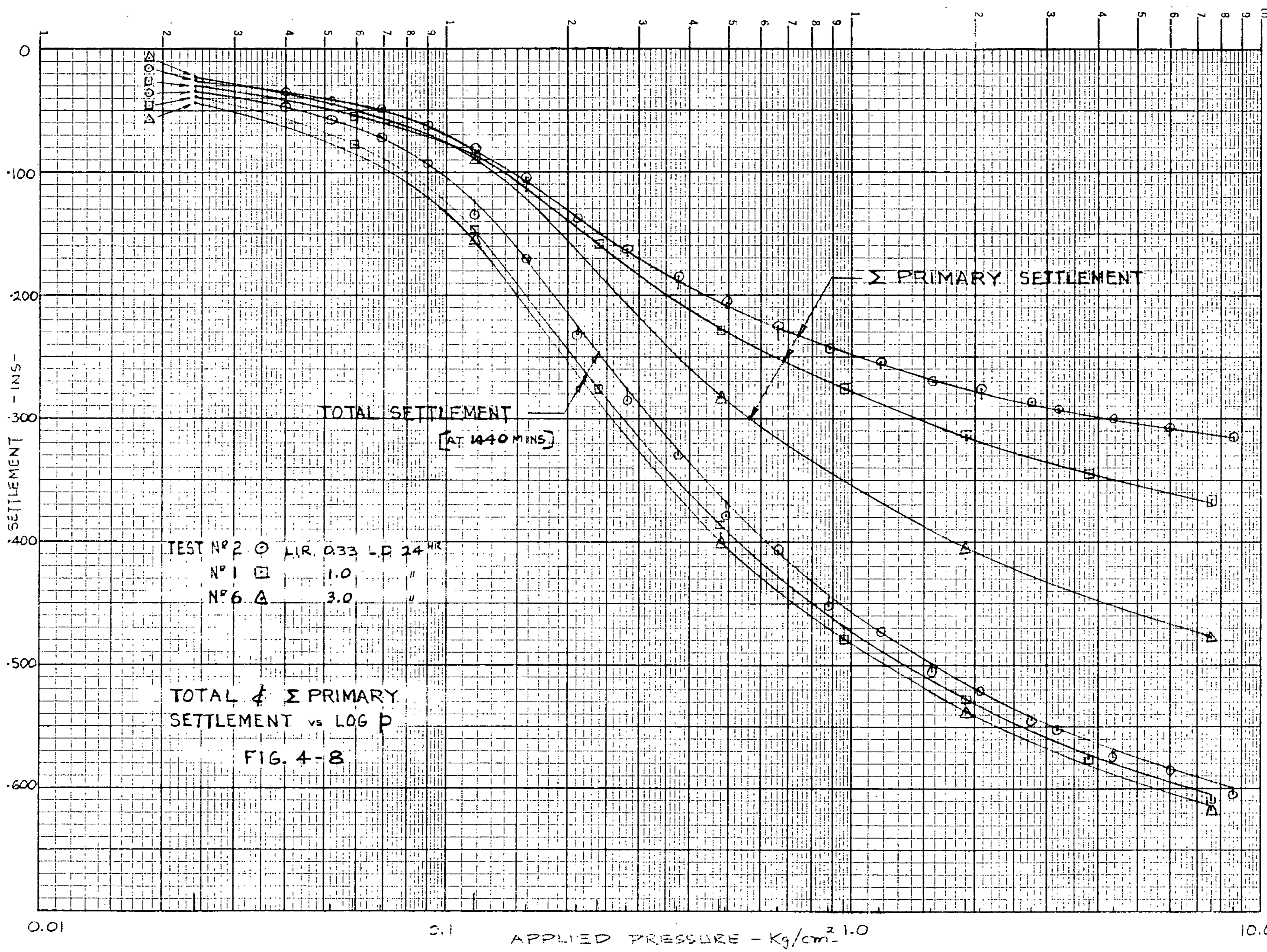
BUT IF, BEYOND THE MAXIMUM PAST PRESSURE, C_S IS INVERSELY PROPORTIONAL TO THE APPLIED PRESSURE THEN POSSIBLY TESTS #1 AND #6 WOULD ALSO GIVE A MAXIMUM VALUE OF C_S = .035 IF THEIR LOAD INCREMENTS WERE ARRANGED TO LAND ON THE CRITICAL VALUE OF APPLIED PRESSURE. ALTERNATIVELY THE VARIATION OF MAXIMUM C_S MAY BE SENSITIVE TO THE L.I.R. (MAGNITUDE OF LOAD INCREMENT), OR RATE OF LOAD APPLICATION, ANALOGOUS TO THE CONDITION OF A SENSITIVE CLAY WHERE THE PRECONSOLIDATION PRESSURE IS DETERMINED BY THE USE OF SMALL LOAD INCREMENTS.

OF PARTICULAR INTEREST WERE THE SINGLE DETERMINATIONS FROM TESTS #8 (L.I.R. 1.0 - 12 MINS L.D. - NO RING), #3B (L.I.R. 3.0 - 25 MIN L.D.) AND #7 (L.I.R. 1.0 TO 3.0 - 20 MIN LOAD DURATION). DESPITE THEIR VARIED LOADING HISTORY THEY PLOT IN CLOSE AGREEMENT WITH THE C_S CURVE FOR TESTS #1, #2 AND #6.

IT WAS CONCLUDED THAT THE RATE OF SECONDARY SETTLEMENT FOR ALL TESTS IN THIS SERIES WAS INVERSELY RELATED TO THE APPLIED PRESSURE. THIS RATE WAS NOT A FUNCTION OF THE L.I.R. OR OF THE HEIGHT OF SAMPLE (I.E. VOID RATIO) AT THE TIME THE LOAD INCREMENT WAS APPLIED. THE DURATION OF THE PREVIOUS LOAD PERIOD APPEARED TO AFFECT ONLY TEST #2 WHICH WAS THE ONLY

TEST WITH A TYPE II SETTLEMENT-TIME CURVE.

IN COMPARISONS OF RATES OF SETTLEMENT PERHAPS MORE THAN IN OTHER COMPARISONS, IT IS FELT THAT DUPLICATE SAMPLES ARE PARTICULARLY NECESSARY IN ORDER TO ESTIMATE HOW MUCH SCATTER DUE TO EXPERIMENTAL PROCEDURE, TEMPERATURE DIFFERENCES, AND SAMPLE VARIABILITY CAN BE EXPECTED ESPECIALLY WHERE TYPE II CURVES ARE INVOLVED. THE ONLY MITIGATING FACTOR APPEARS TO BE THAT SMALL VARIATIONS IN INITIAL TRIMMED SAMPLE HEIGHT (OR PRESUMABLY VOID RATIO) SHOULD HAVE NEGLIGIBLE EFFECT ON THE COMPUTED VALUES OF C_S AND D_S . FOR GENERAL COMPARISON PURPOSES A GRAPH SHOWING RATE OF SECONDARY SETTLEMENT VS APPLIED PRESSURE FOR TEST #2 AND TEST #P1 (SEE SECTION 4.4 AND APPENDIX) WAS PLOTTED - FIG.4-7. IT CAN BE SEEN THAT THERE WAS FAR LESS SCATTER OF VALUES FOR WHAT WERE IN FACT NEARLY IDENTICAL TESTS. THE ONLY APPARENT REASON FOR THE DIFFERENCE WAS THE MUCH MORE CONSISTENT ACTUAL LOAD DURATIONS IN THE CASE OF TEST #P1.



TOTAL & Σ PRIMARY SETTLEMENT vs LOG p

FIG. 4-8

facing p. 34

4.6 Comparison of Amounts of Primary and Secondary Settlement

Consider Fig. 4-8 showing Total and Σ Primary Settlement vs Log p

Tests #6, #1 and #2 were plotted on the above graph; first the total settlement for 24 hours then the corresponding cumulative primary settlement in the same period for each test.

The main purpose of this graph was to investigate whether primary and secondary settlement as defined in section 1.4 could be regarded as separate processes or whether any relationship could be discerned.

It can be seen quite conclusively that primary and secondary settlement are inter-related and cannot be separated. In other words although the final settlements are nearly identical the proportions of primary and secondary are very different for different load increment ratios.

A further aspect of this inter-relation was shown by the total settlement under 0.119 Kg/cm^2 in test #2 and under 0.96 Kg/cm^2 in test #1. In both cases the load duration was five days instead of the nominal one day so that the final settlement plotted well below the best-fitting settlement-log p curve. More important was the fact that this additional settlement did not appear to affect the 24 hour settlement reading of the next load increment.

4.7 Summary of Observed Results

4.1 S_{1440} vs log p for 24 hour L.D. - Fig.4-1

L.I.R. 1.0 = L.I.R. 3.0 but L.I.R. 0.33 high.

4.2 S_{15} vs log p for 15 min. L.D. - Fig. 4-2

(I) L.I.R. 1.0 = L.I.R. 0.33 but L.I.R. 3.0 had not reached 100% primary consolidation.

(II) Test #8 no ring (L.I.R. 1.0) in good agreement.

4.3 $S_{100\%}$ vs log p for all L.I.R. and L.D. - Fig.4-3

(I) 15 min L.D. tests settled more than 24 hour tests.

(II) All L.I.R. agreed up to load of 1.0 Kg/cm^2 when plotted 100% primary consolidation.

4.4 Curve shapes and time to 100% primary consolidation

(I) All tests except #2 had Type I curve and a longer time to 100% primary as void ratio decreased.

(II) Test #2 (L.I.R. 0.33, L.D. 24 hours) had Type II curve and shorter times to 100% primary as void ratio decreased.

(III) Variations in L.D. during test caused variations in time to 100% primary in test #2 only.

(IV) Test #2 (Type II curve) took ten times as long to reach 100% primary as other tests.

4.5 Rate of secondary settlement vs p Fig. 4-5, 4-6, 4-7

(I) Rate of Secondary independent of L.I.R. and L.D. except test #2.

(II) Test #2 Type II curve was affected by duration of previous load.

4.6 Total and cumulative primary settlement Fig. 4-8

Total settlement not a function of loading procedure but ratio of primary to secondary was.

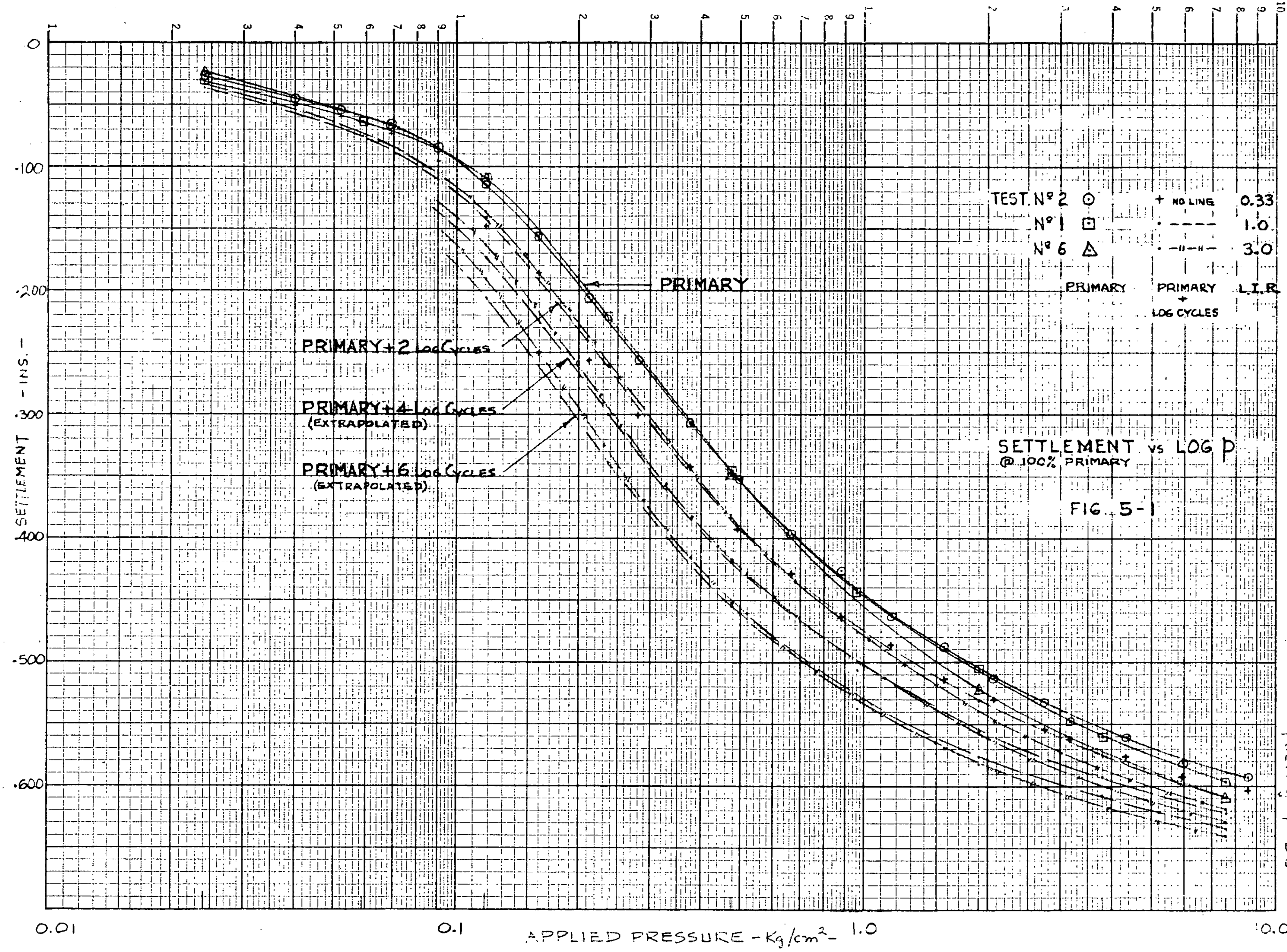


FIG. 5-1

Facing P. 36

5.0 ANALYSIS

5.1 INTERPRETATION OF RESULTS BASED ON A UNIQUE RELATIONSHIP BETWEEN APPLIED PRESSURE AND SETTLEMENT AT 100% PRIMARY CONSOLIDATION

CONSIDER FIG. 5-1 SHOWING SETTLEMENT AT 100% PRIMARY VS. LOG P.

THE "PRIMARY" LINE ON THE ABOVE GRAPH WAS PLOTTED USING THE 100% PRIMARY SETTLEMENTS OF TESTS #6, #1 AND #2 (L.I.R. 3.0, 1.0, 0.33, L.D. 24 HOURS), THE 100% POINT BEING DETERMINED FROM THE DIAL READING - LOG TIME GRAPHS BY THE METHODS DISCUSSED IN SECTION 4.3. THE ONE DAY, 100 DAY, 10,000 DAY LINES WERE DRAWN BY EXTRAPOLATING FROM THE OBSERVED VALUES OF THE AMOUNT OF SECONDARY SETTLEMENT PER TWO LOG CYCLES OF TIME FOR EACH INDIVIDUAL TEST. THUS SMALL DIFFERENCES IN VALUES OF C_S WERE MAGNIFIED FOR EACH SUCCESSIVE CURVE.

THIS GRAPH DEMONSTRATES FIRST OF ALL A REMARKABLE AGREEMENT BETWEEN THE THREE TESTS FOR THE PRIMARY CURVE. REFERRING BACK TO SECTION 4.1 IT WAS NOTED THERE THAT TEST #2 WAS NOT IN GOOD AGREEMENT WHEN COMPARED FOR 24 HOUR LOAD DURATIONS. HENCE IT WOULD APPEAR PROBABLE THAT THE TRUE BASIS OF COMPARISON SHOULD BE THE 100% PRIMARY SETTLEMENT TIME. SECONDLY IT CAN BE SEEN THAT EACH SET OF CURVES ESSENTIALLY PARALLELS THE PRIMARY CURVE IN THE RANGE 0.1 TO 2.0 KG/CM^2 BEFORE STARTING TO BECOME ERRATIC. THE AGREEMENT BETWEEN EACH SET OF CURVES (ONE DAY, 100 DAY, ETC) INDICATES THAT ALL THREE TESTS HAD ESSENTIALLY THE SAME RATES OF SECONDARY SETTLEMENT AT THE SAME APPLIED PRESSURE, AS NOTED IN SECTION 4.5, DESPITE THEIR VARYING LOAD INCREMENT RATIOS. THE SCATTER OF VALUES BEYOND ABOUT 2.0 KG/CM^2 REFLECTS MAINLY THE SCATTER IN THE PRIMARY SETTLEMENT CURVES,

SINCE THE VALUES OF C_S BECOME MORE CONSISTENT AT HIGHER APPLIED LOADS - SEE FIG. 4-5.

THE HYPOTHESIS FOR THIS INTERPRETATION MAY BE STATED AS FOLLOWS :- NO MATTER WHAT THE PREVIOUS LOADING HISTORY, THERE IS ONLY ONE VALUE OF SETTLEMENT (OR VOID RATIO) AT 100% PRIMARY CONSOLIDATION CORRESPONDING TO A PARTICULAR APPLIED PRESSURE. THUS IDEALLY THERE IS A UNIQUE S-LOG P OR e-LOG P LAW RELATING TOTAL SETTLEMENT OR VOID RATIO TO APPLIED PRESSURE AT THE MOMENT WHEN THE PORE PRESSURE IS EFFECTIVELY DISSIPATED. THIS HYPOTHESIS HAS BEEN DEVELOPED RECENTLY FOR REMOLDED ORGANIC SILT BY H.E.WAHLS (4) BUT IT WAS ALSO IMPLIED IN TAYLOR'S WORK ON REMOLDED SILTY CLAY (2). PROBABLY THERE WOULD BE A GRADUAL TRANSITION BETWEEN PRIMARY AND SECONDARY MECHANISMS OF SETTLEMENT, BUT THIS DOES NOT SERIOUSLY AFFECT THE CONCEPT SINCE THE AMOUNT OF SECONDARY SETTLEMENT OCCURRING BEFORE THE END OF PRIMARY SETTLEMENT WOULD BE SMALL.

TWO QUALIFICATIONS WOULD APPEAR TO BE NECESSARY - THERE SHOULD BE NO UNLOAD - RELOAD CYCLE INVOLVED AND ONLY APPLIED PRESSURES GREATER THAN THE PRECONSOLIDATION PRESSURE SHOULD BE CONSIDERED. INSPECTION OF THE GRAPH ON FIG. 5-1 INDICATES ANOTHER QUALIFICATION THAT WOULD PROBABLY BE REQUIRED - AFTER SEVERAL CYCLES OF SECONDARY SETTLEMENT (SAY TO REACH THE 100 DAY CURVE) THE ADDITION OF A SMALL LOAD INCREMENT WOULD REQUIRE THE SAMPLE TO SWELL TO ARRIVE BACK ON THE UNIQUE S-LOG P CURVE. HOWEVER THIS SUGGESTS THAT A BETTER BASIS MIGHT BE " FINAL SETTLEMENT " AT SAY 3000 YEARS OR PRIMARY PLUS 8 LOG CYCLES OF TIME.

IN SUMMARY THE HYPOTHESIS OF A UNIQUE SETTLEMENT-LOG P CURVE AT 100% PRIMARY CONSOLIDATION APPEARS TO OFFER A PLAUSIBLE GENERAL INTERPRETATION OF THE RESULTS OF THIS TEST SERIES. HOWEVER THE PROBLEM OF THE MECHANISM AND FACTORS AFFECTING SECONDARY SETTLEMENT STILL REMAINS.

5.2 Difference in Curve Types between Test #2 and Test #4

Consider Figs. 3-2 to 3-7 (incl) showing Dial Reading vs Log Time for Tests #2 and #4

The reason for the difference in curve type and difference in rate of settlement cannot easily be seen from these two tests. Putting the problem anthropomorphologically - how did sample #4 know that it had only 15 minutes to reach 100% primary consolidation while sample #2 could take at least 200 minutes? All tests conditions were essentially the same including the L.I.R. (both 0.33), the only difference being the load duration: 15 minutes vs 24 hours. Hence the different behaviour could only be due to the duration of the previous load, the difference in stress conditions or the difference in flow conditions just before reloading.

Possibly some sort of "bonding" or " thixotropic" action takes place during the secondary settlement analogous to the concept of a flocculated clay soil over a period of time developing more interparticle contacts under a given effective stress (8). Alternatively it may be a question of reduced permeability or increased viscosity in the micropores of the material. Certainly it seems worth further investigation.

6.0 CONCLUSIONS

6.1 PRACTICAL

(1) THE RESULTS OF STANDARD LABORATORY CONSOLIDATION TESTS ON FIBROUS PEAT SHOULD BE PLOTTED ON A GRAPH OF S – LOG P OR e – LOG P WHERE THE SETTLEMENT USED IS THAT OCCURRING AT 100% PRIMARY CONSOLIDATION.

(2) IN GENERAL THE LOAD INCREMENT RATIO CAN BE VARIED BETWEEN 0.35 AND 3.0 AND THE LOAD DURATION, OR TIME OF RELOADING, VARIED BETWEEN THE END OF THE PRIMARY CONSOLIDATION AND ABOUT FIVE DAYS WITHOUT SERIOUSLY AFFECTING THE "PRIMARY" $S_{100\%}$ – LOG P OR $e_{100\%}$ – LOG P CURVE FOR FIBROUS PEAT. THUS ACCELERATED TESTS OF ONE DAY (OR MUCH LESS IF HIGHER LOAD INCREMENT RATIOS ARE USED) WILL GIVE ALL THE INFORMATION USUALLY OBTAINED WITH THE STANDARD LABORATORY CONSOLIDATION USING L.I.R. OF 1.0 AND 24 HOUR LOAD DURATIONS.

(3) SIDE FRICTION WAS NEGLIGIBLE DURING THE LOAD CYCLE IN THIS TEST SERIES FOR FIBROUS PEAT OF HIGH WATER CONTENT EXCEPT POSSIBLY AT HIGHER LOADS FOR TEST #2 (L.I.R. 0.33 – L.D. 24 HOURS) AFTER IT HAD BEEN ABOUT FOUR WEEKS IN THE CONSOLIDOMETER. STAINLESS STEEL CONSOLIDATION RINGS ($\frac{\text{DIAM.}}{\text{HEIGHT}} = \frac{2.500}{0.750} = 3.33$) LIGHTLY COATED WITH A MOLYBDENUM DISULPHIDE GREASE WERE USED, THE SAMPLE WAS TRIMMED TO AN EASY FIT IN THE RING AND THE TESTS WERE RUN IN FIXED RING CONSOLIDOMETERS WITH TOP AND BOTTOM DRAINAGE.

6.2 Theoretical

Within the bounds of this test series, the following relations were established for the consolidation of peat :-

(1) Primary and Secondary Settlement are inter-related and cannot be separated as to amount.

(2) Curve type depends not only on the load increment ratio but also on the load duration or rate of loading.

(3) Decreasing the load increment ratio during a test significantly increased the time required to reach 100% primary consolidation for test #2 which had a Type II curve.

Further conclusions were more tentative since they depended in varying degree upon similarity of samples and procedure.

(4) Tests with 24 hour load durations and rapid tests reloaded at about the 100% primary consolidation point gave reasonably good agreement when plotted on a graph of Settlement at 100% primary vs log applied pressure.

(5) The rate of secondary settlement ($C_s = \frac{S_2 \text{ (log cycle)}}{H_1 \text{ (initial ht.)}}$)

was dependent on the applied pressure or effective pressure during the load cycle.

It did <u>not</u> depend on the load increment ratio, the previous height of sample i.e. magnitude of load increment, or the duration of the previous load period up to at least 5 days, except for test #2 with a Type II curve.

(6) Based on the above conclusions, there appears to be a unique S-log p or e-log p relation for the load cycle based on the settlement at 100% consolidation regardless of previous loading history.

(7) THERE WAS A POSSIBILITY THAT 24 HOUR TESTS UNDERWENT SLIGHTLY LESS SETTLEMENT THAN RAPID 15 MINUTE TESTS AT ALL L.I.R.

(8) FOR TEST #2 - CURVE TYPE II - THERE APPEARED TO BE A TREND TO SHORTER TIME TO REACH 100% PRIMARY CONSOLIDATION WITH INCREASING LOADS; WHICH WAS OPPOSITE TO THE USUAL TREND SHOWN BY THE OTHER TESTS.

SINCE $t = \frac{TH^2}{C_v}$: AS LOADS INCREASE k AND SO C_v GETS SMALLER (LONGER t)
H GETS SMALLER (SHORTER t)
HENCE EITHER EFFECT MAY DOMINATE.

6.3 GENERAL

IT IS APPRECIATED THAT MANY OF THE CONCLUSIONS DRAWN FROM A LIMITED TEST PROGRAM OF THIS KIND CAN ONLY BE TENTATIVE SINCE THEY ARE BASED ON SINGLE LABORATORY TESTS ON A NATURAL UNDISTURBED MATERIAL OF CONSIDERABLE VARIABILITY. HOWEVER SOME OF THE CONCLUSIONS ARE IN ACCORDANCE WITH PREVIOUS EXPERIENCE , WITH OTHER WORK ON PEAT AND WITH SIMILAR INVESTIGATIONS INTO CLAY CONSOLIDATION. THIS IS PARTICULARLY SO WITH THE CONCLUSION IN SECTION 5.1 THAT THERE APPEARS TO BE A UNIQUE S-LOG P OR e-LOG P RELATIONSHIP FOR FIBROUS PEAT BASED ON THE SETTLEMENT AT 100% PRIMARY CONSOLIDATION. A SIMILAR RELATIONSHIP FOR CLAY CONSOLIDATION HAS BEEN SUGGESTED BY TAYLOR (2) AND OTHERS (4).

BEING OF AN EXPLORATORY NATURE, THESE TESTS HAVE RAISED SEVERAL QUESTIONS ON WHICH FURTHER WORK COULD BE DONE. ASIDE FROM CONFIRMING OR REJECTING SOME OF THE PREVIOUS CONCLUSIONS, SPECIFIC ATTENTION COULD BE GIVEN TO THE INVESTIGATION OF THE UNLOAD CYCLE AND TO THE FACTORS INVOLVED IN TYPE II CURVES.

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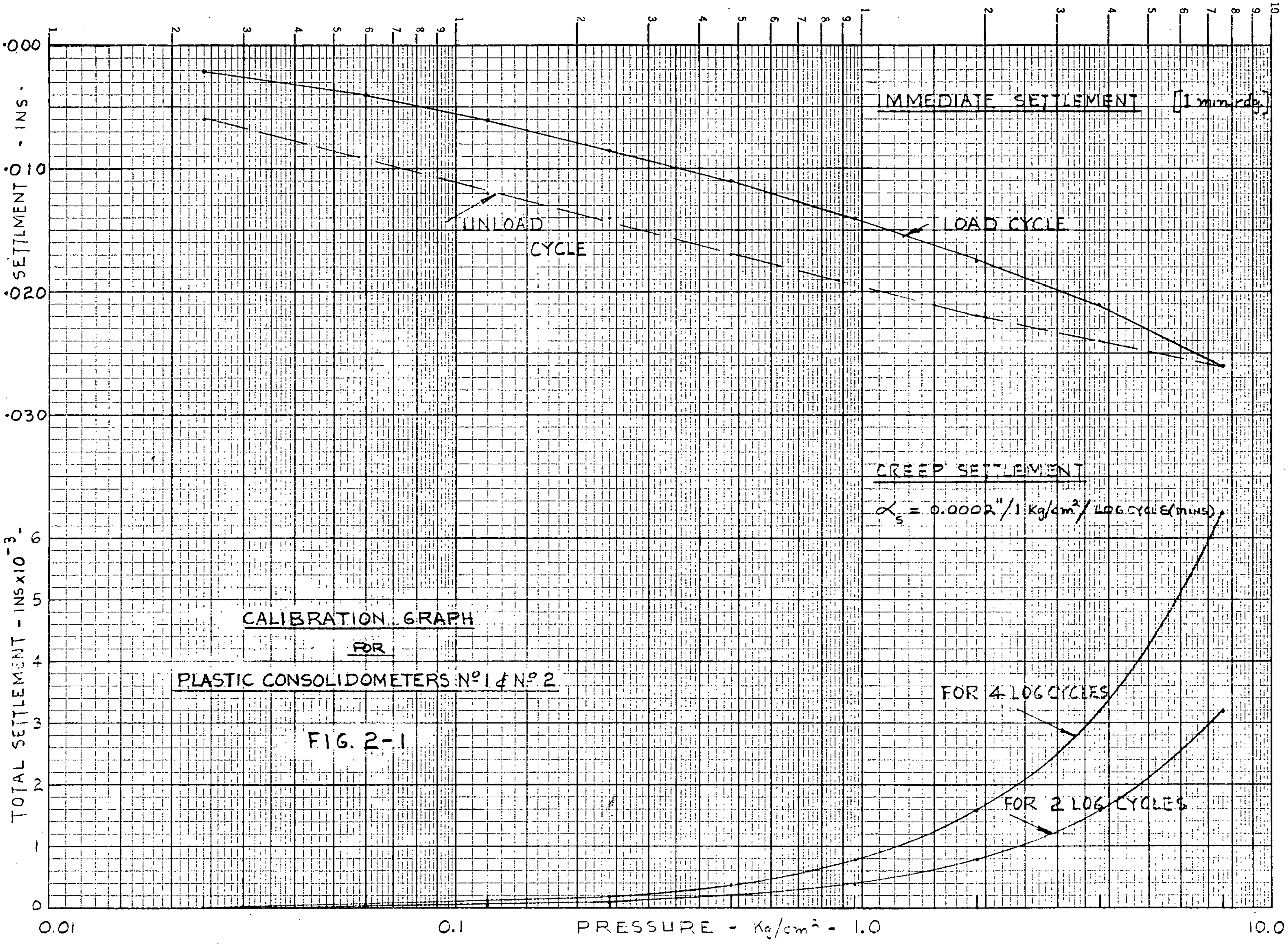
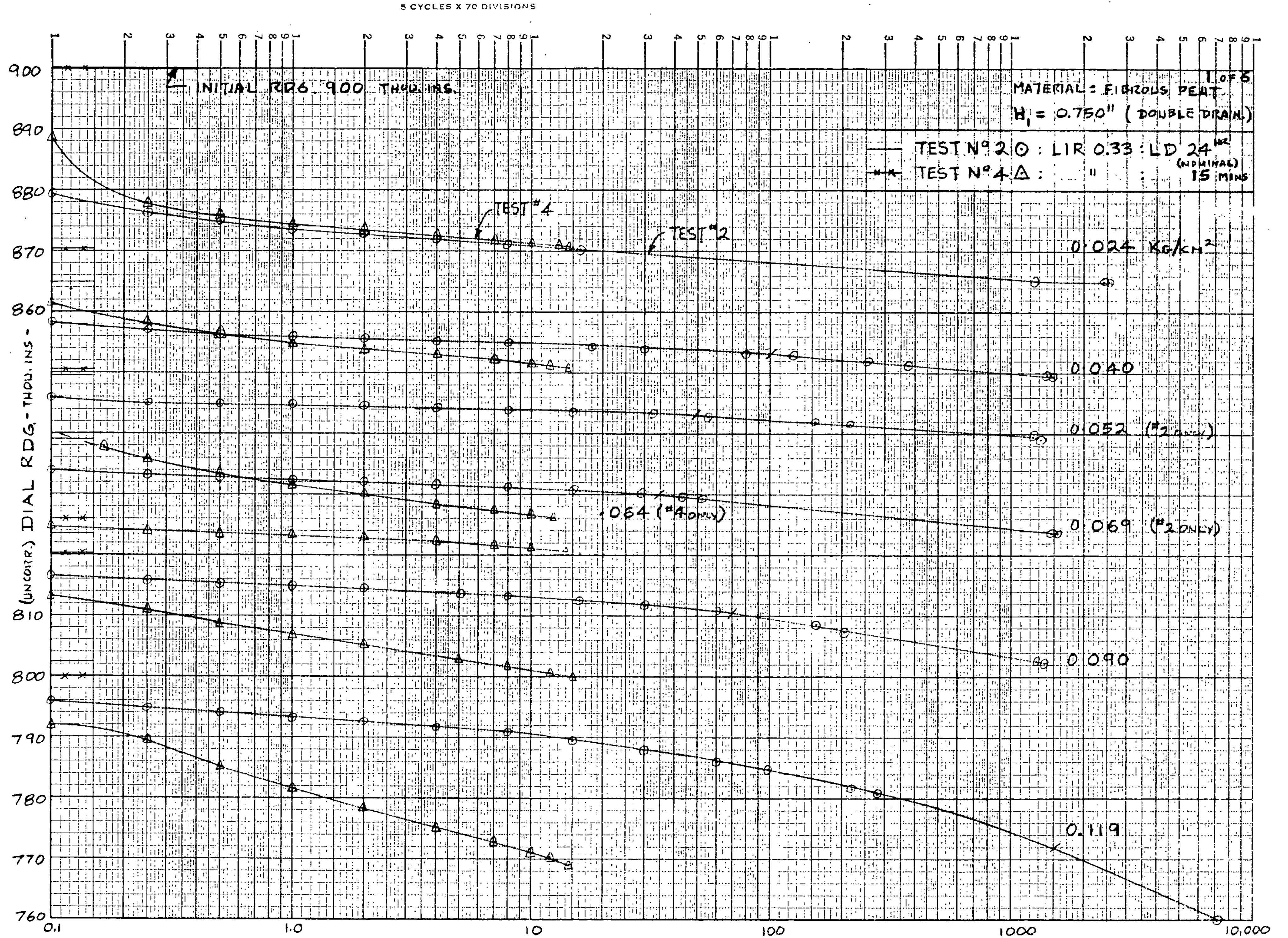

·000
·010
·020
·030
SETTLMENT - INS -
IMMEDIATE SETTLEMENT [1 min rdg]
UNLOAD CYCLE
LOAD CYCLE
CREEP SETTLEMENT
α_s = 0.0002"/1 Kg/cm²/ LOG CYCLE (mins)
FOR 4 LOG CYCLES
FOR 2 LOG CYCLES
TOTAL SETTLEMENT - INS x 10⁻³ -
0
1
2
3
4
5
6
0.01
0.1
1.0
10.0
PRESSURE - Kg/cm² -
CALIBRATION GRAPH FOR PLASTIC CONSOLIDOMETERS Nº 1 & Nº 2

FIG. 2-1



5 CYCLES X 70 DIVISIONS
INITIAL RDG. 900 THOU. INS.
1 OF 5
MATERIAL: FIBROUS PEAT
H_1 = 0.750" (DOUBLE DRAIN)
TEST Nº 2 ⊙ : LIR 0.33 : LD 24 HR
TEST Nº 4 △ : " : (NOMINAL) 15 MINS
TEST #4
TEST #2
0.024 KG/CM²
0.040
0.052 (#2 ONLY)
.064 (#4 ONLY)
0.069 (#2 ONLY)
0.090
0.119
(UNCORR.) DIAL RDG. - THOU. INS. -
900
890
880
870
860
810
800
790
780
770
760
0.1
1.0
10
100
1000
10,000
ELAPSED TIME - MINS -

FIG. 3-2

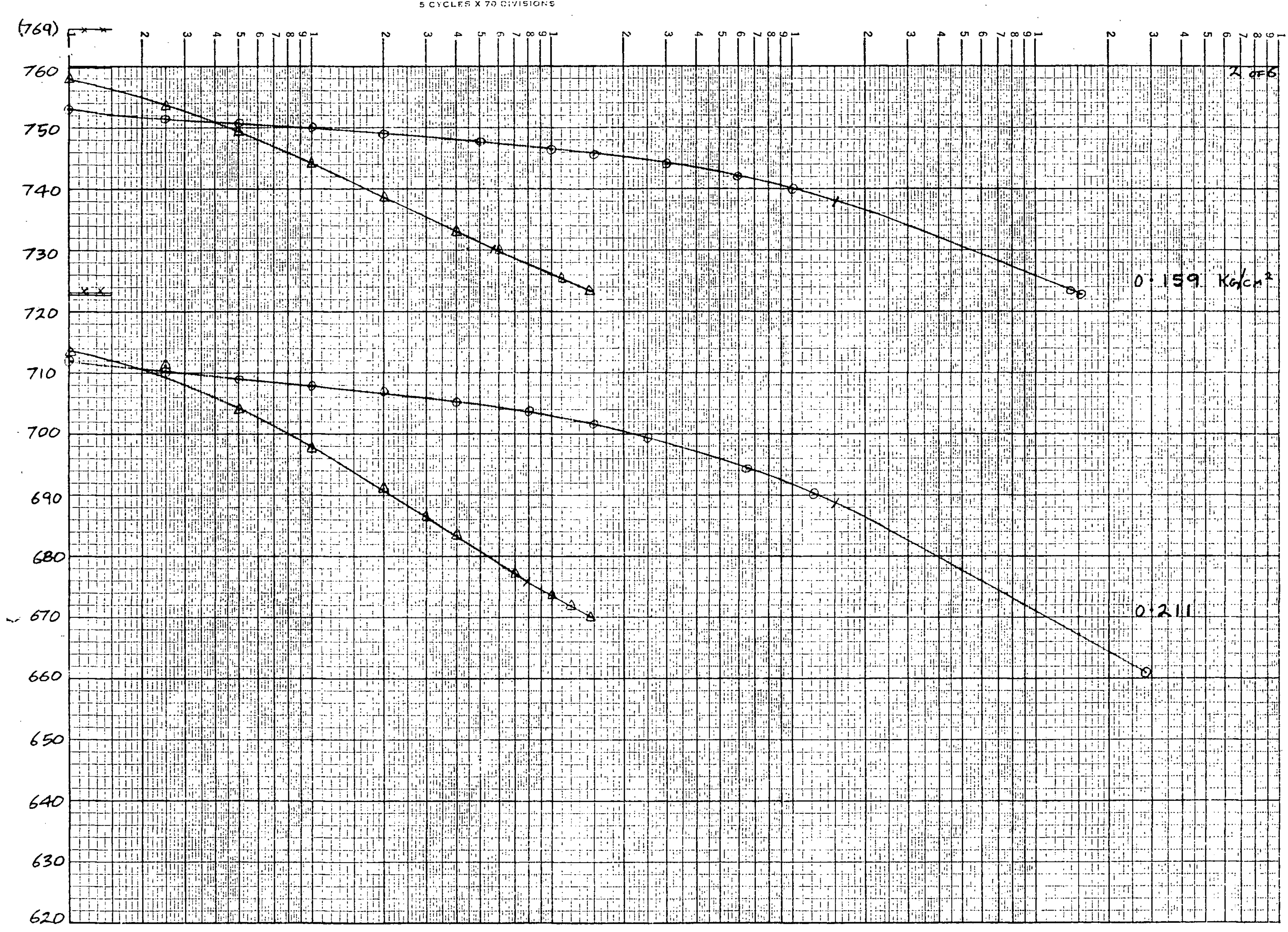

5 CYCLES X 70 DIVISIONS
(769)
760
750
740
730
720
710
700
690
680
670
660
650
640
630
620
2 of 6
0·159 KG/CM²
0·211

FIG. 3-3

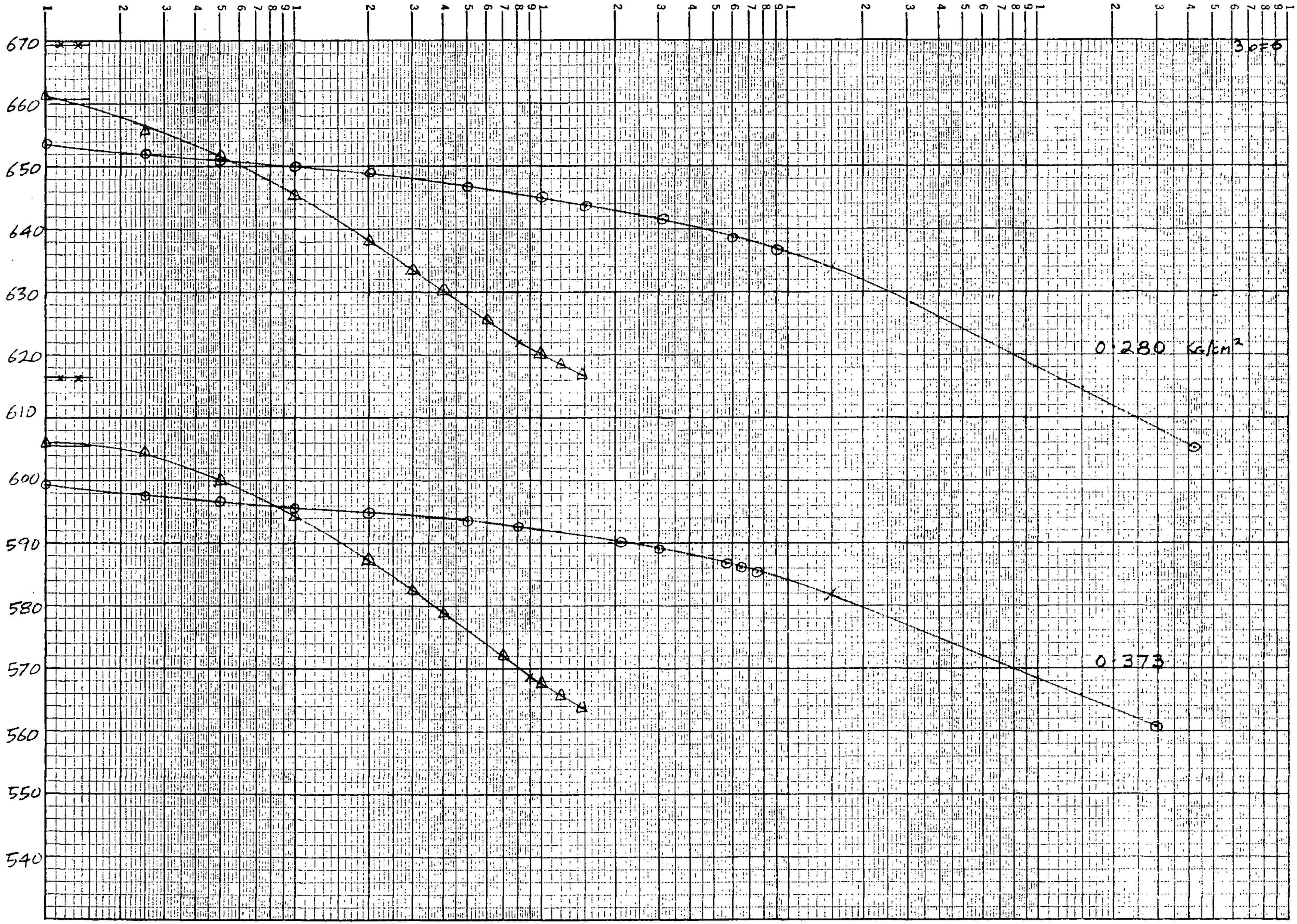

3 of 6
0·280 Kg/cm²
0·373
670
660
650
640
630
620
610
600
590
580
570
560
550
540

FIG. 3-4

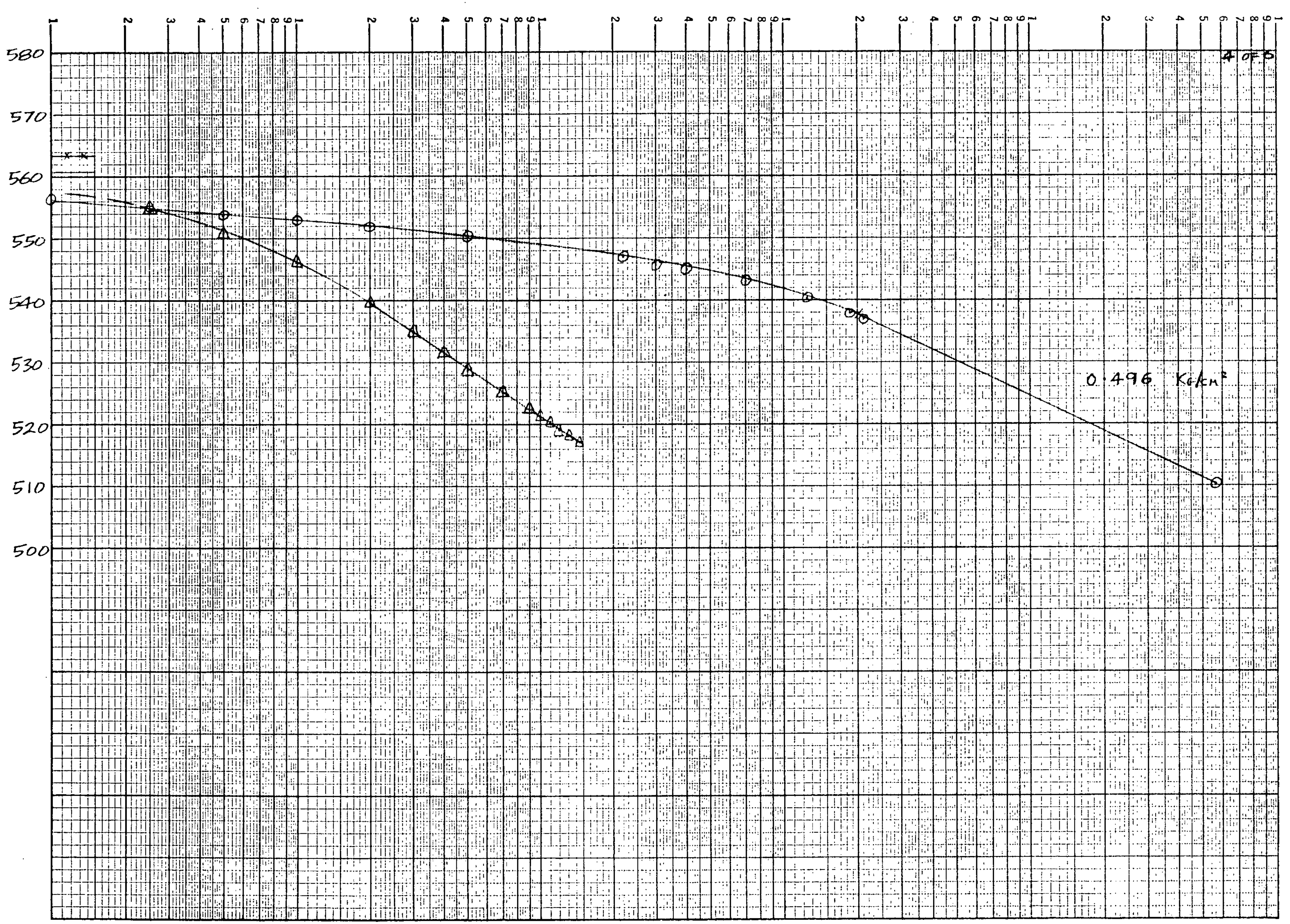
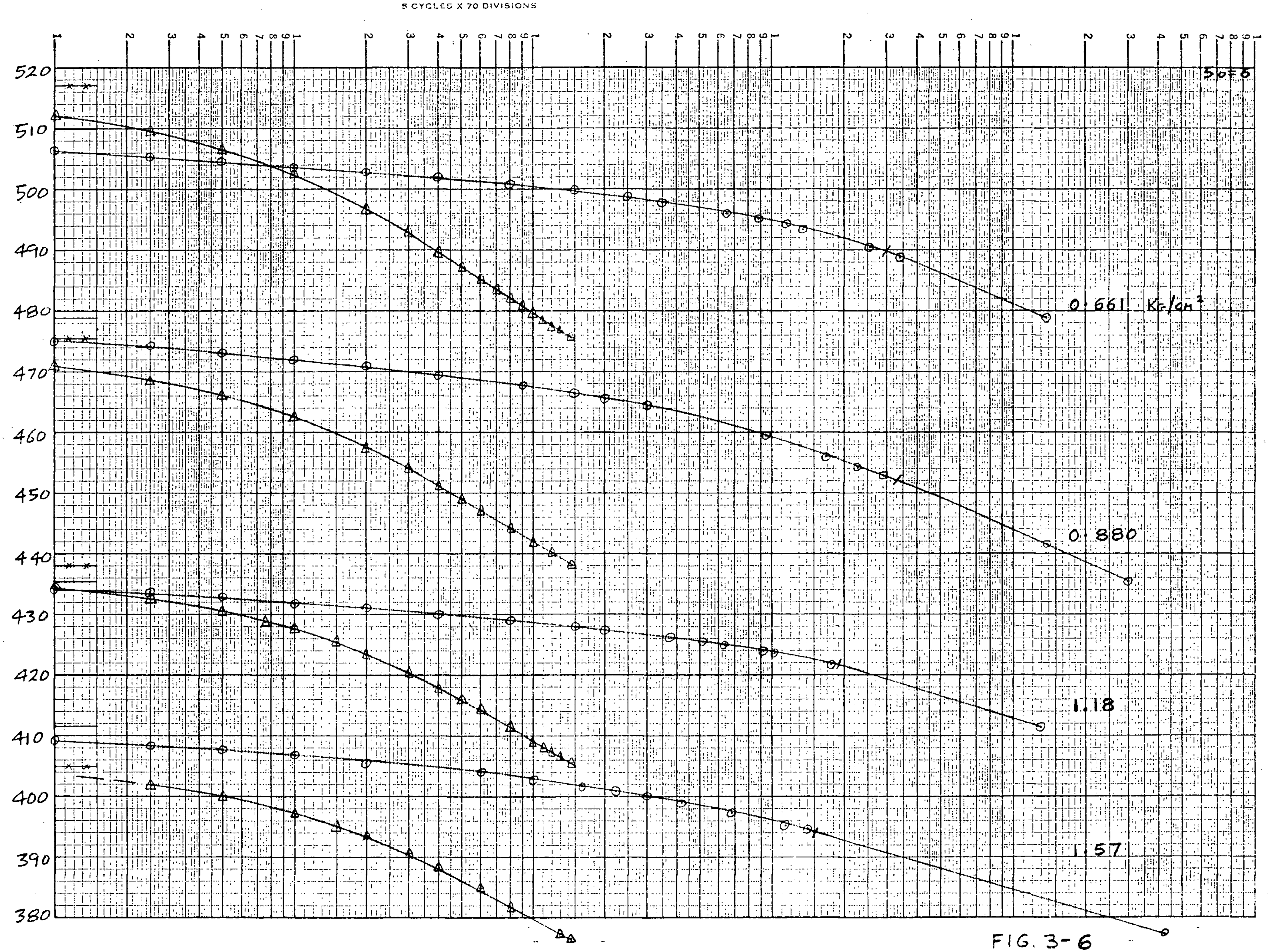


FIG. 3-5


5 CYCLES X 70 DIVISIONS
5 of 6
0.661 Kg/cm²
0.880
1.18
1.57
520
510
500
490
480
470
460
450
440
430
420
410
400
390
380
FIG. 3-6

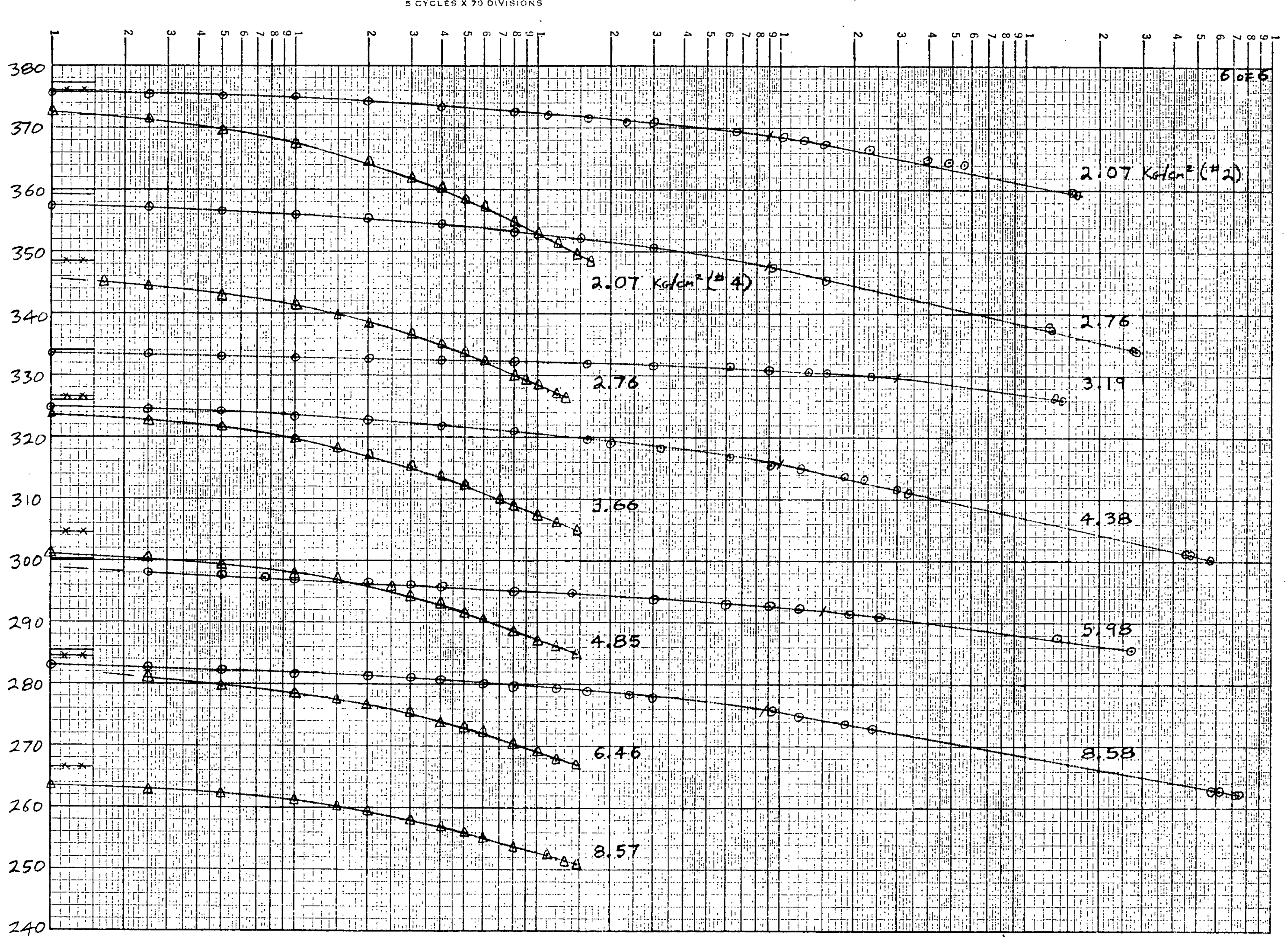

5 CYCLES X 70 DIVISIONS
6 of 6
2.07 Kg/cm² (#2)
2.07 Kg/cm² (#4)
2.76
3.19
2.76
3.66
4.38
4.85
5.98
6.46
8.58
8.57

FIG. 3-7

5 CYCLES X 70 DIVISIONS

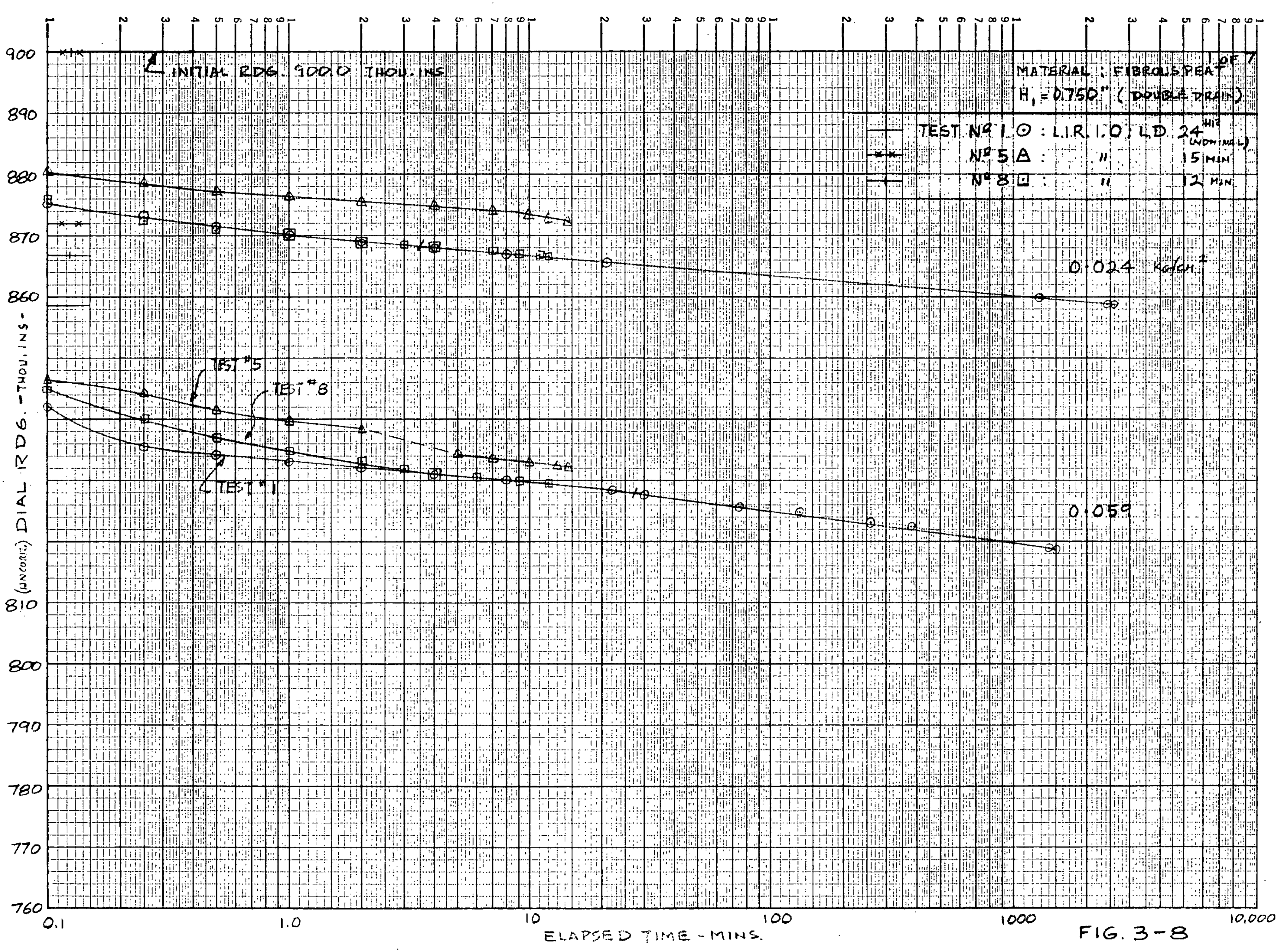


FIG. 3-8

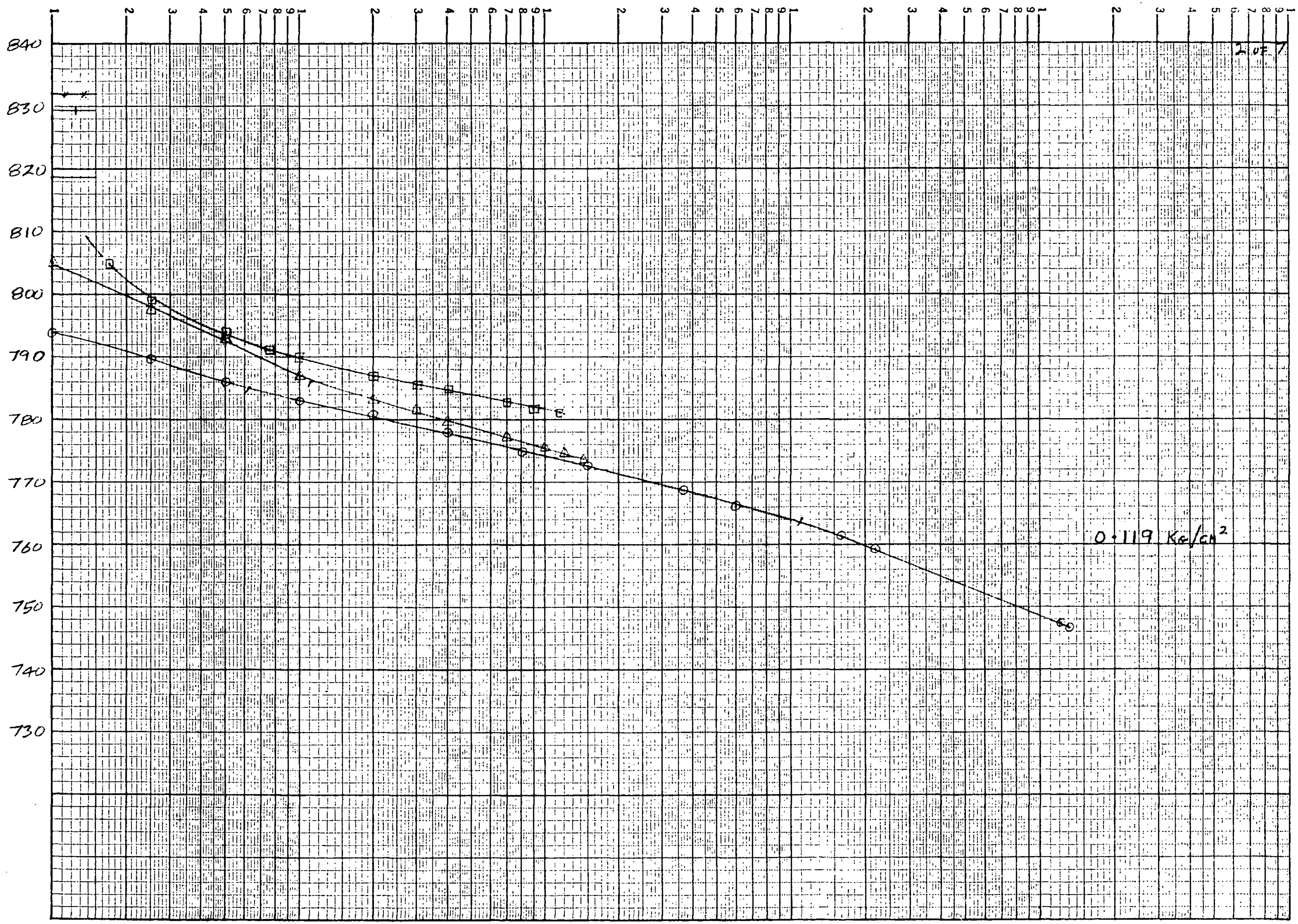


FIG. 3-9

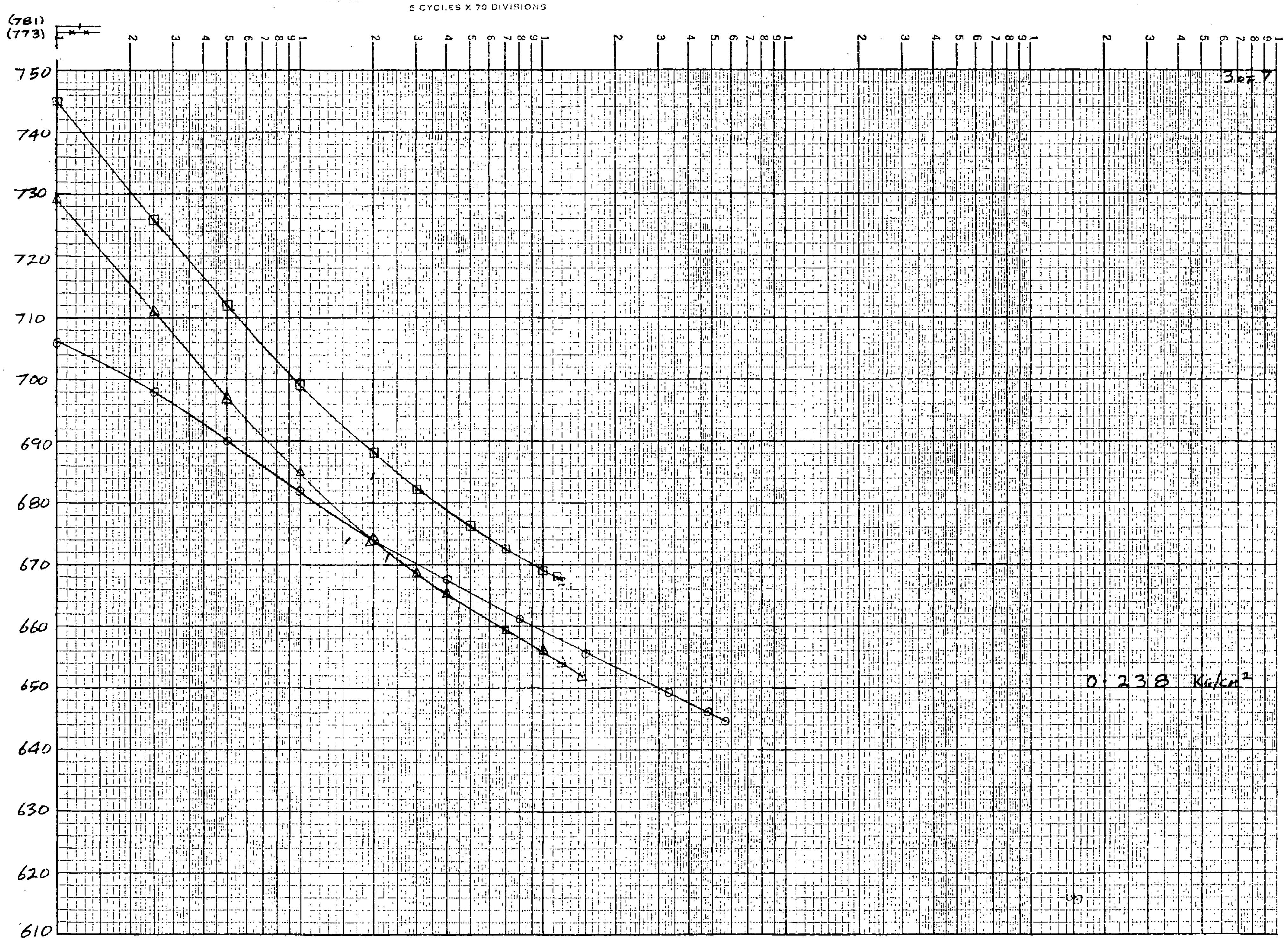
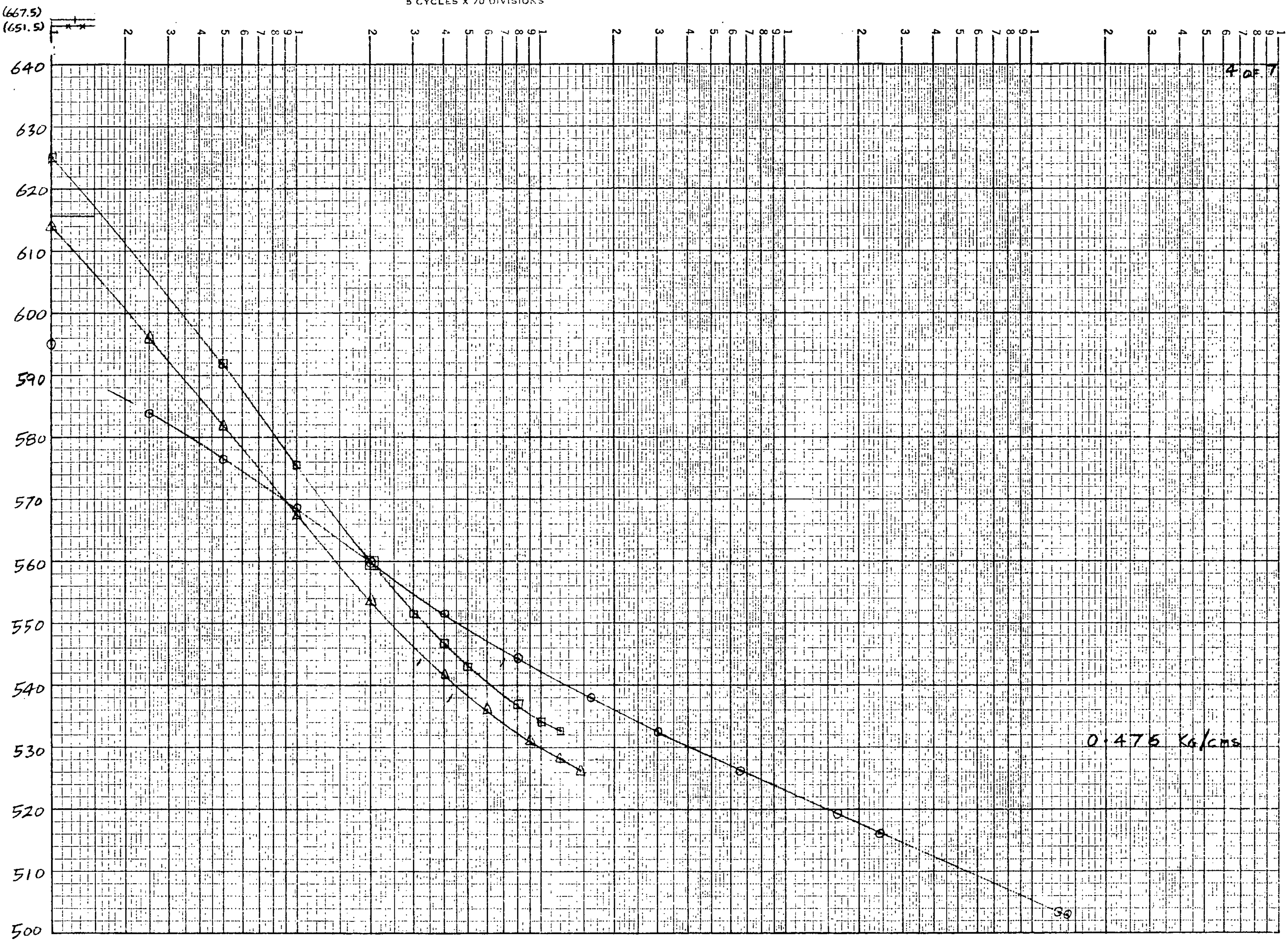

5 CYCLES X 70 DIVISIONS
(781)
(773)
750
740
730
720
710
700
690
680
670
660
650
640
630
620
610
3 of 7
0.238 Kg/cm²

FIG 3-10



5 CYCLES X 70 DIVISIONS
(667.5)
(651.5)
640
630
620
610
600
590
580
570
560
550
540
530
520
510
500
4 of 7
0.476 Kg/cms

FIG. 3-11

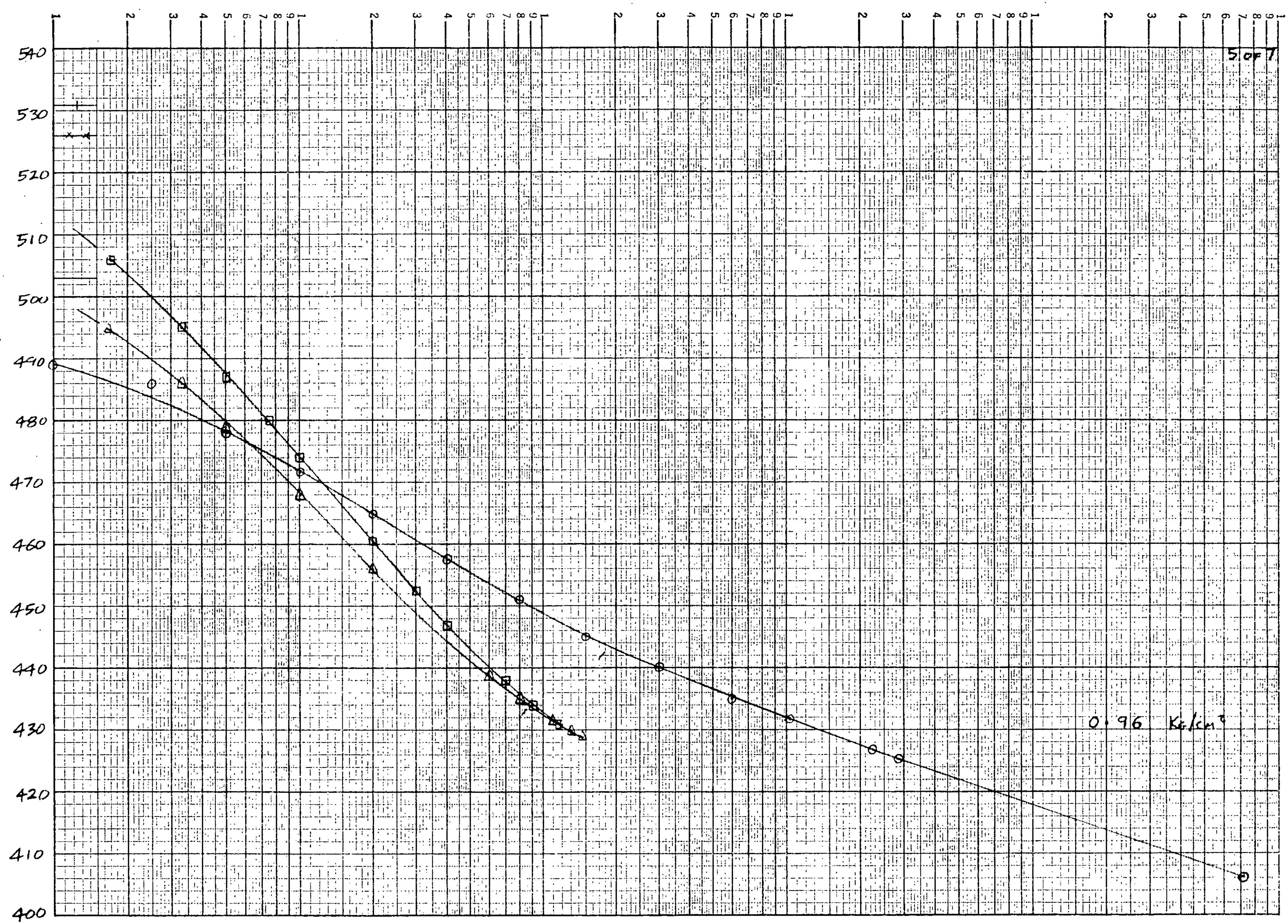

5 of 7
0.96 Kg/cm²
540
530
520
510
500
490
480
470
460
450
440
430
420
410
400

FIG. 3-12

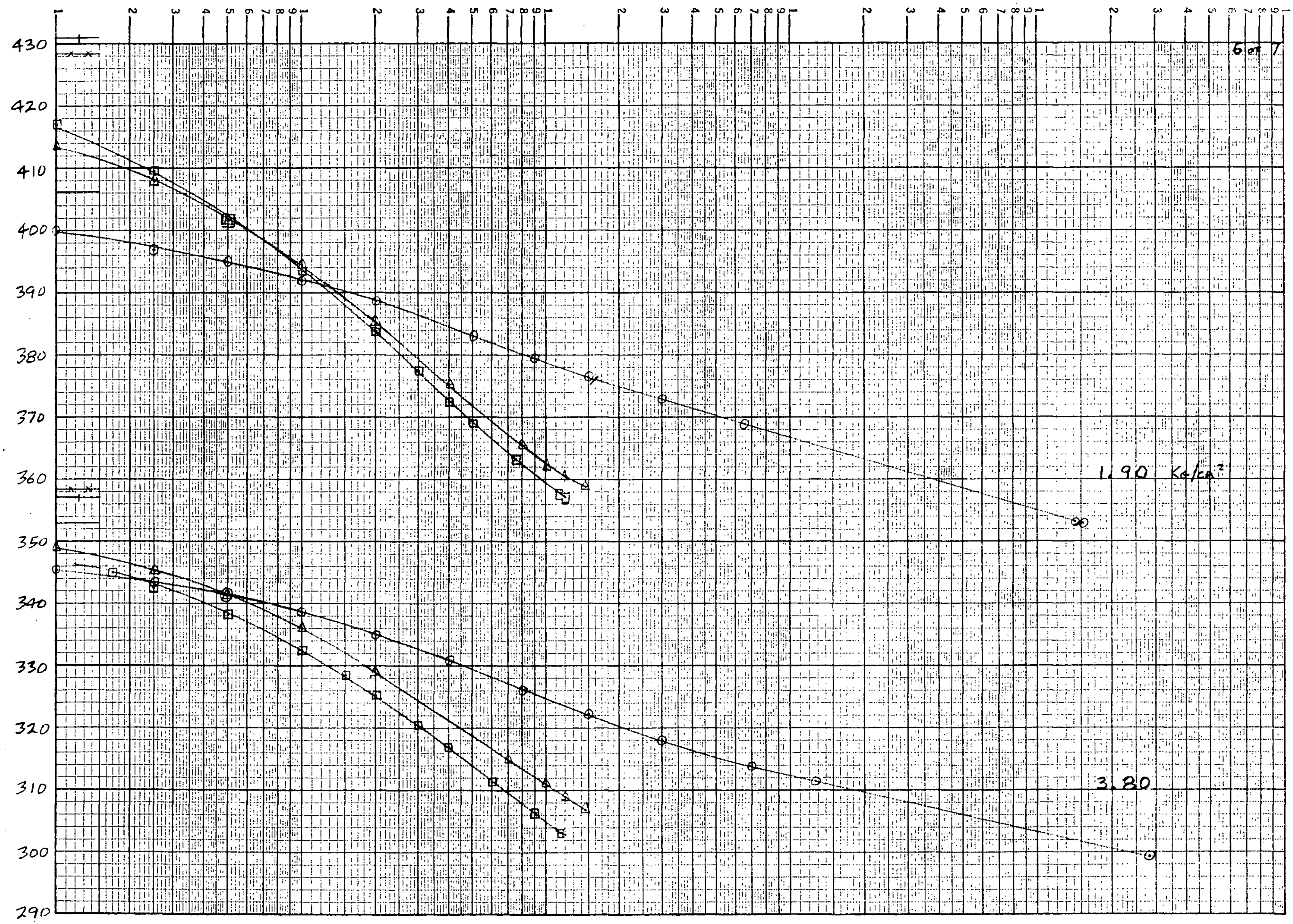

6 of 7
1.90 Kg/cm²
3.80
430
420
410
400
390
380
370
360
350
340
330
320
310
300
290

FIG. 3-13

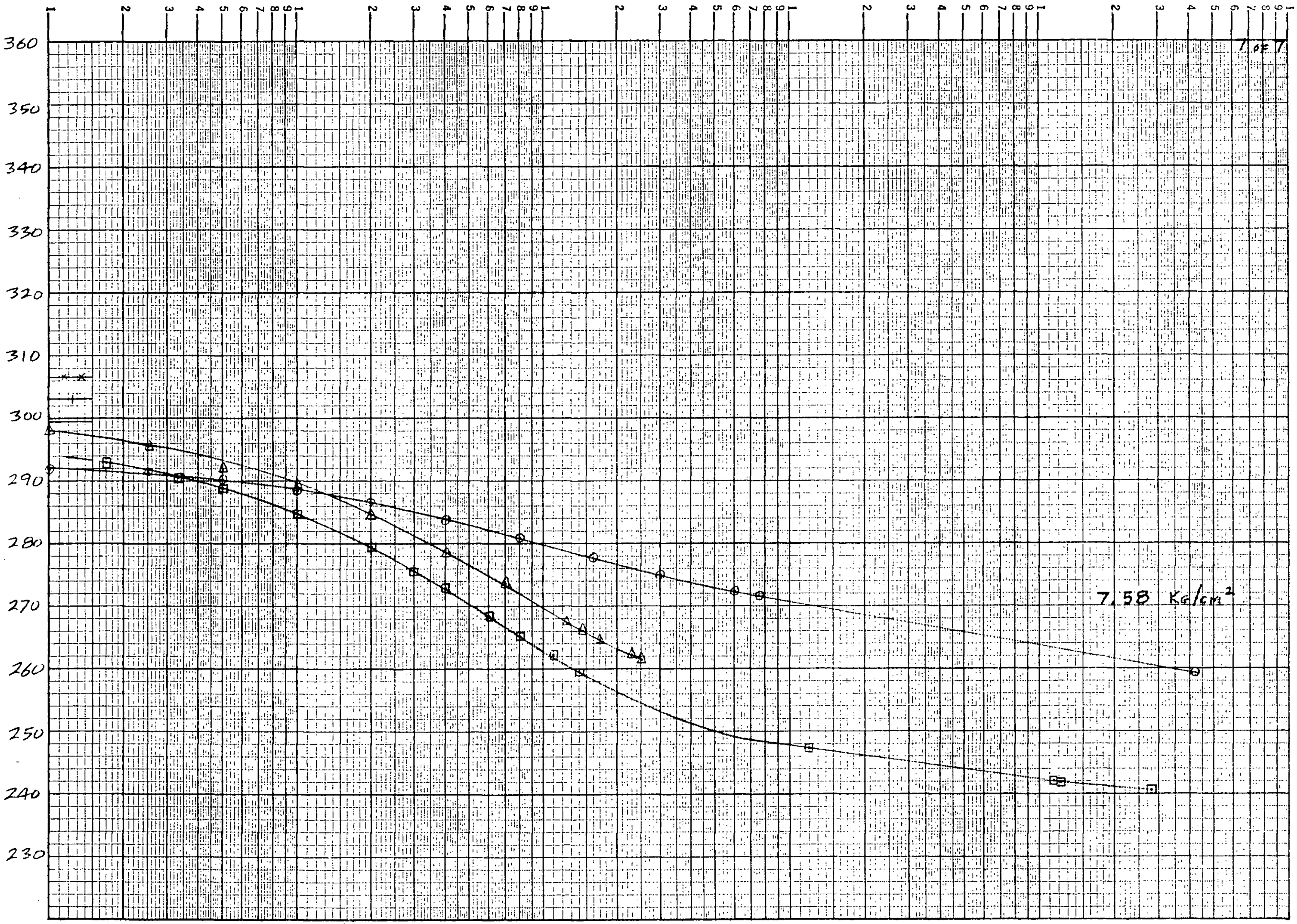

7 of 7
7.58 Kg/cm²
360
350
340
330
320
310
300
290
280
270
260
250
240
230

FIG. 3-14

5 CYCLES X 70 DIVISIONS

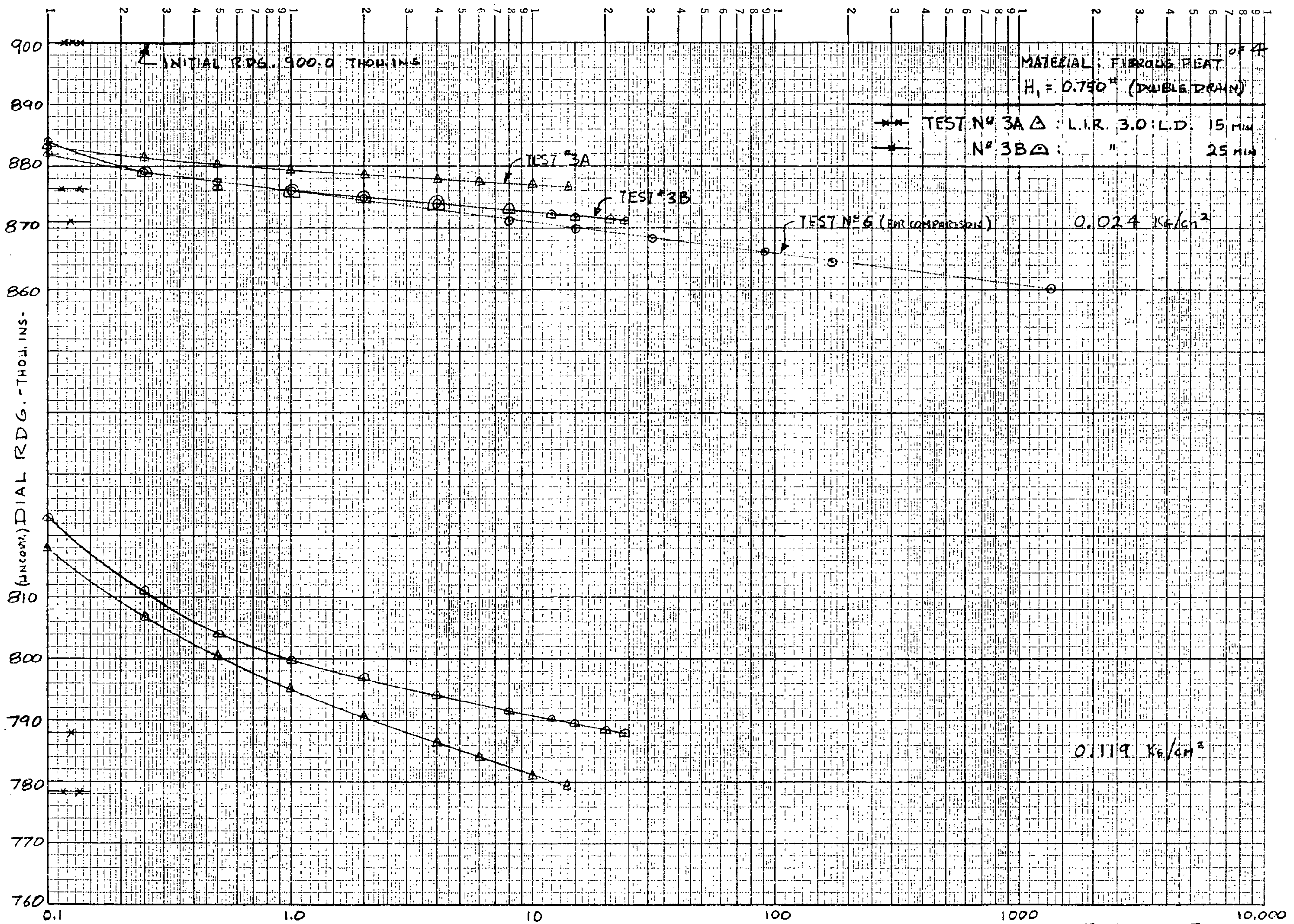


FIG. 3-15

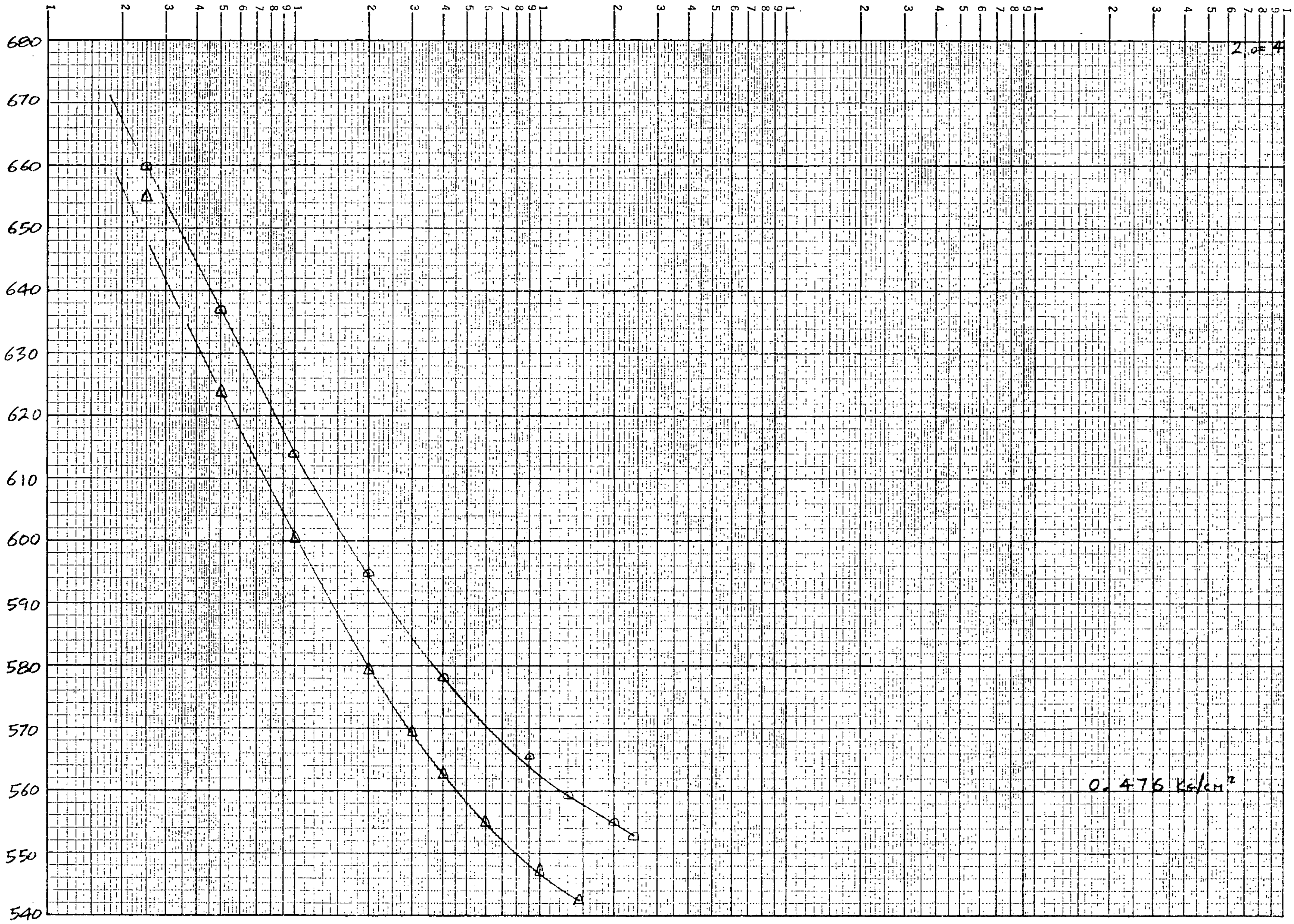

2 of 4
0.476 Kg/cm²
680
670
660
650
640
630
620
610
600
590
580
570
560
550
540

FIG. 3-16

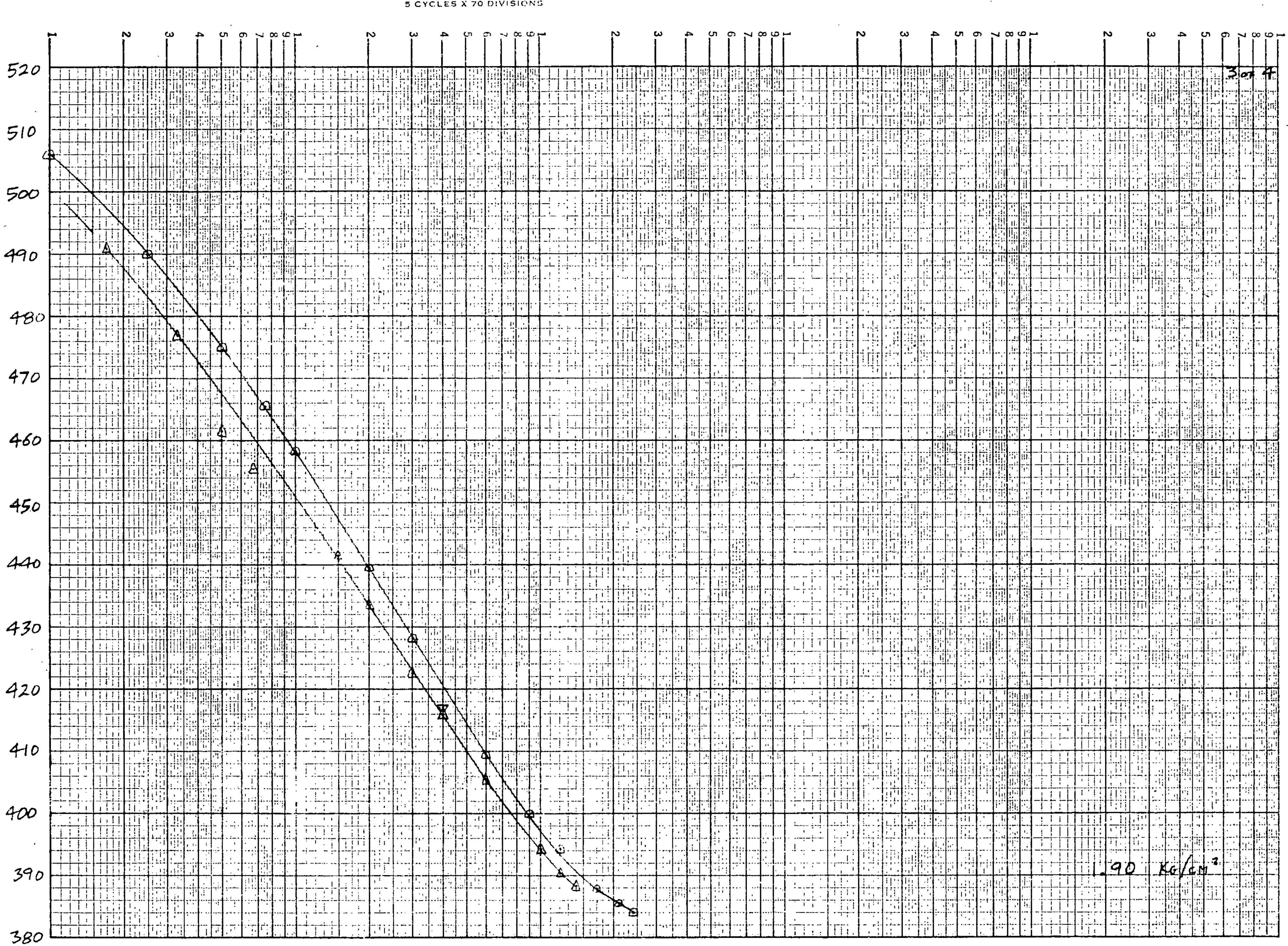
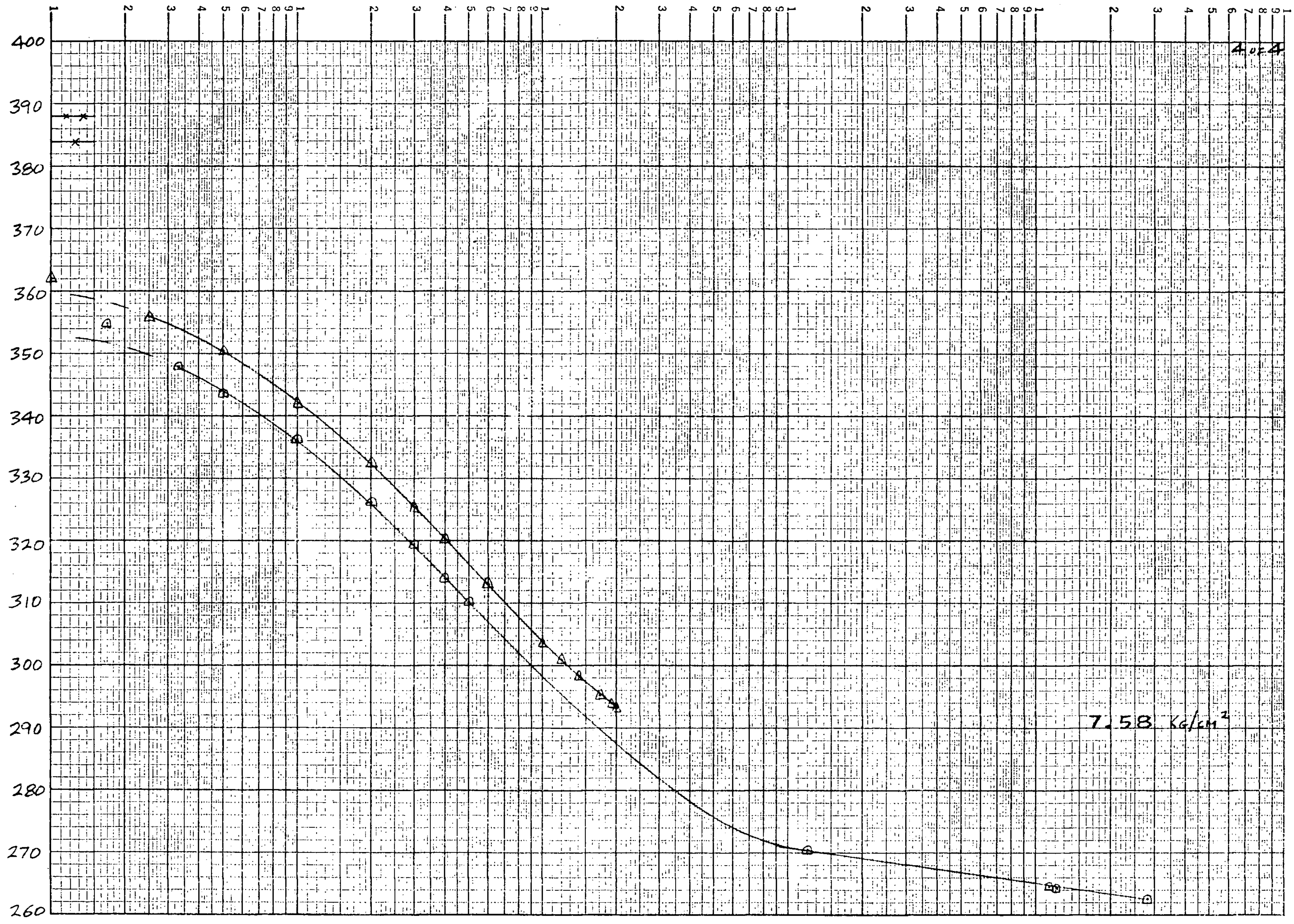
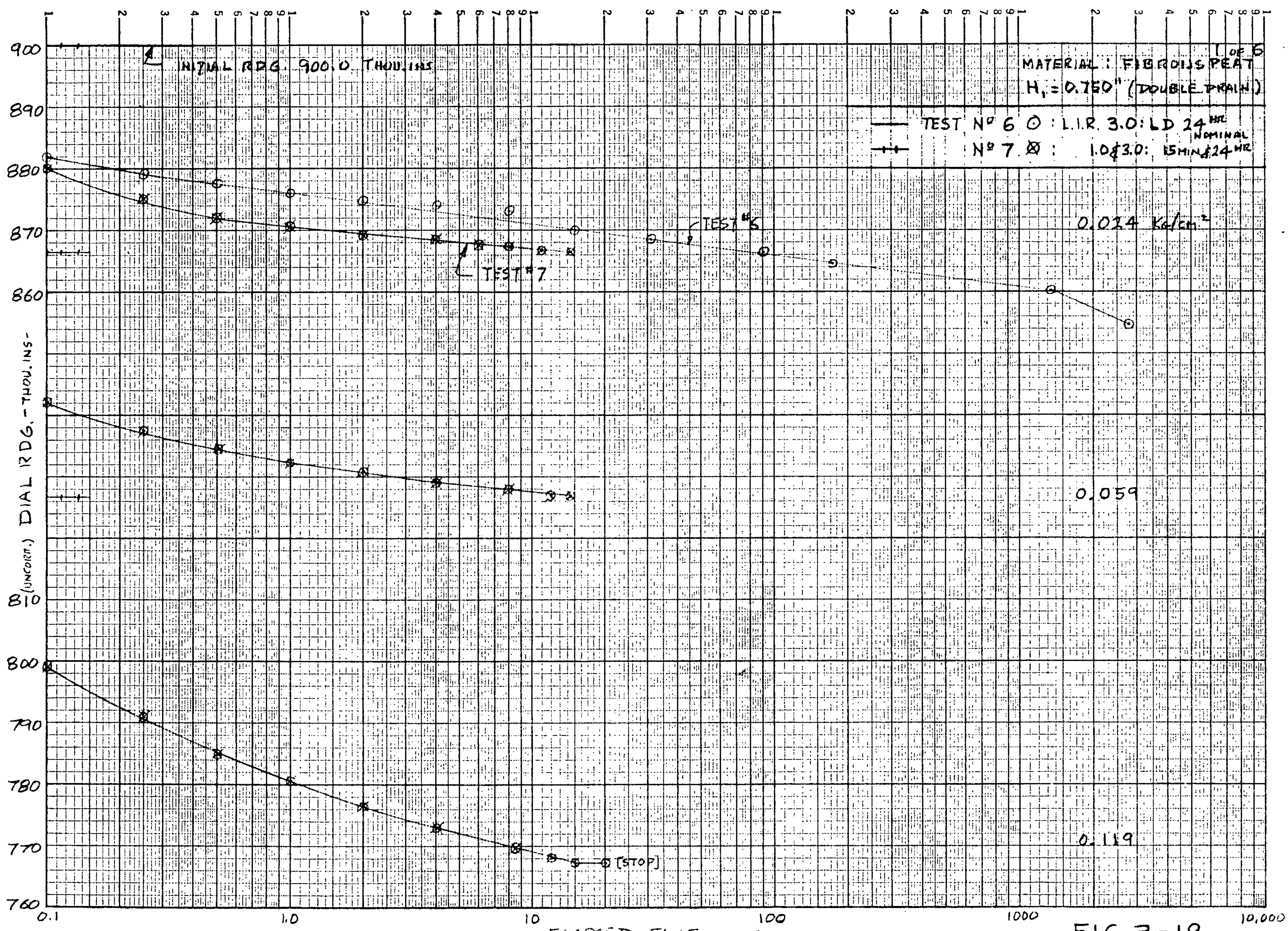

5 CYCLES X 70 DIVISIONS
3 of 4
1.90 Kg/cm²
520
510
500
490
480
470
460
450
440
430
420
410
400
390
380

FIG 3-17


4 of 4
7.58 KG/CM²
400
390
380
370
360
350
340
330
320
310
300
290
280
270
260
FIG. 3-18



1 of 6
INITIAL RDG. 900.0 THOU.INS.
MATERIAL: FIBROUS PEAT
H₁ = 0.750" (DOUBLE DRAIN)
TEST Nº 6 ⊙ : L.I.R. 3.0 : LD 24 HR NOMINAL
Nº 7 ⊗ : 1.0 & 3.0 : 15 MIN & 24 HR
TEST #6
TEST #7
0.024 Kg/cm²
0.059
0.119
[STOP]
(UNCORR.) DIAL RDG. - THOU. INS -
900
890
880
870
860
810
800
790
780
770
760
0.1
1.0
10
100
1000
10,000
ELAPSED TIME - MINS. -

FIG. 3-19

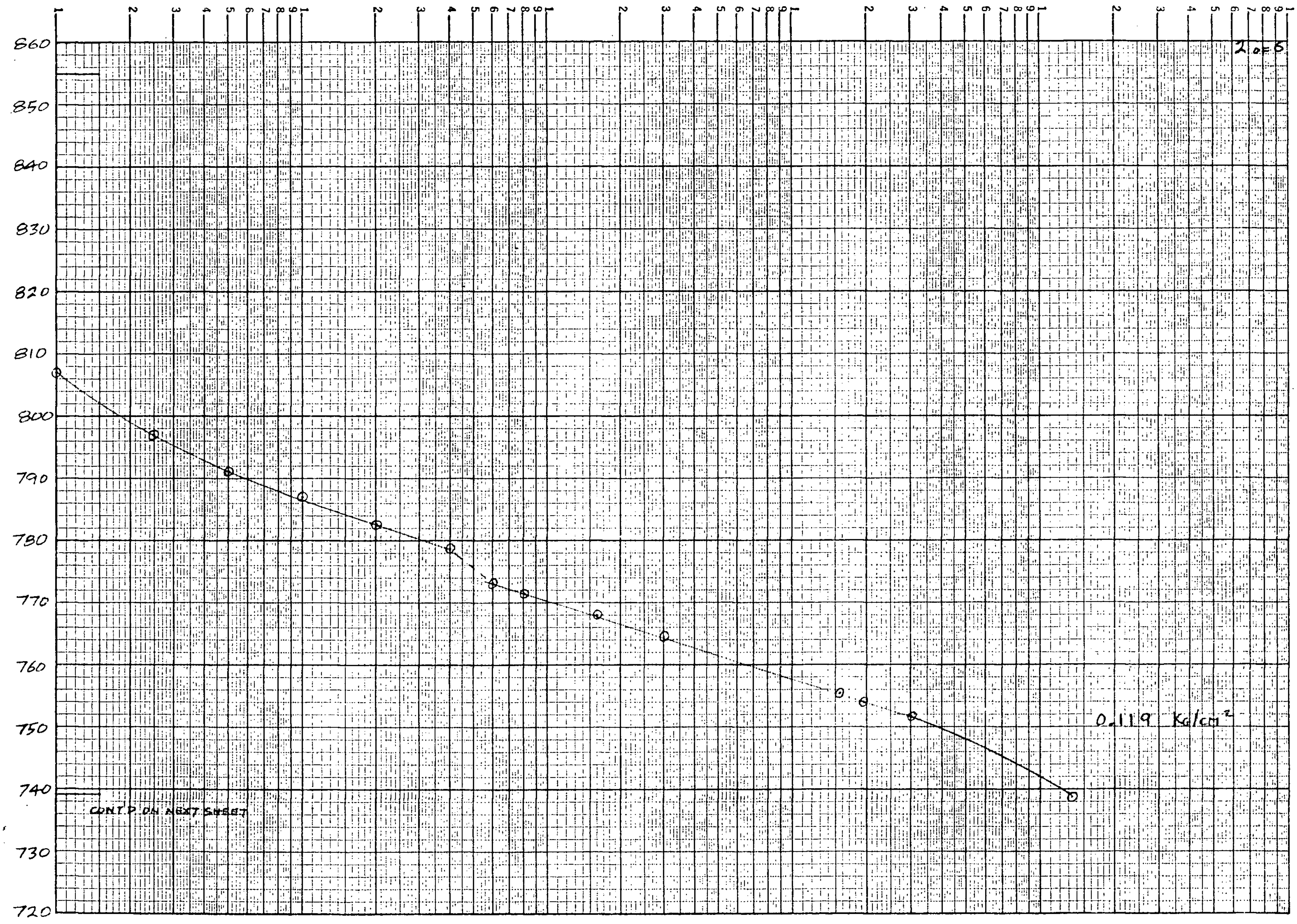

2 of 6
0.119 Kg/cm⁻²
CONT'D ON NEXT SHEET
860
850
840
830
820
810
800
790
780
770
760
750
740
730
720

FIG. 3-20

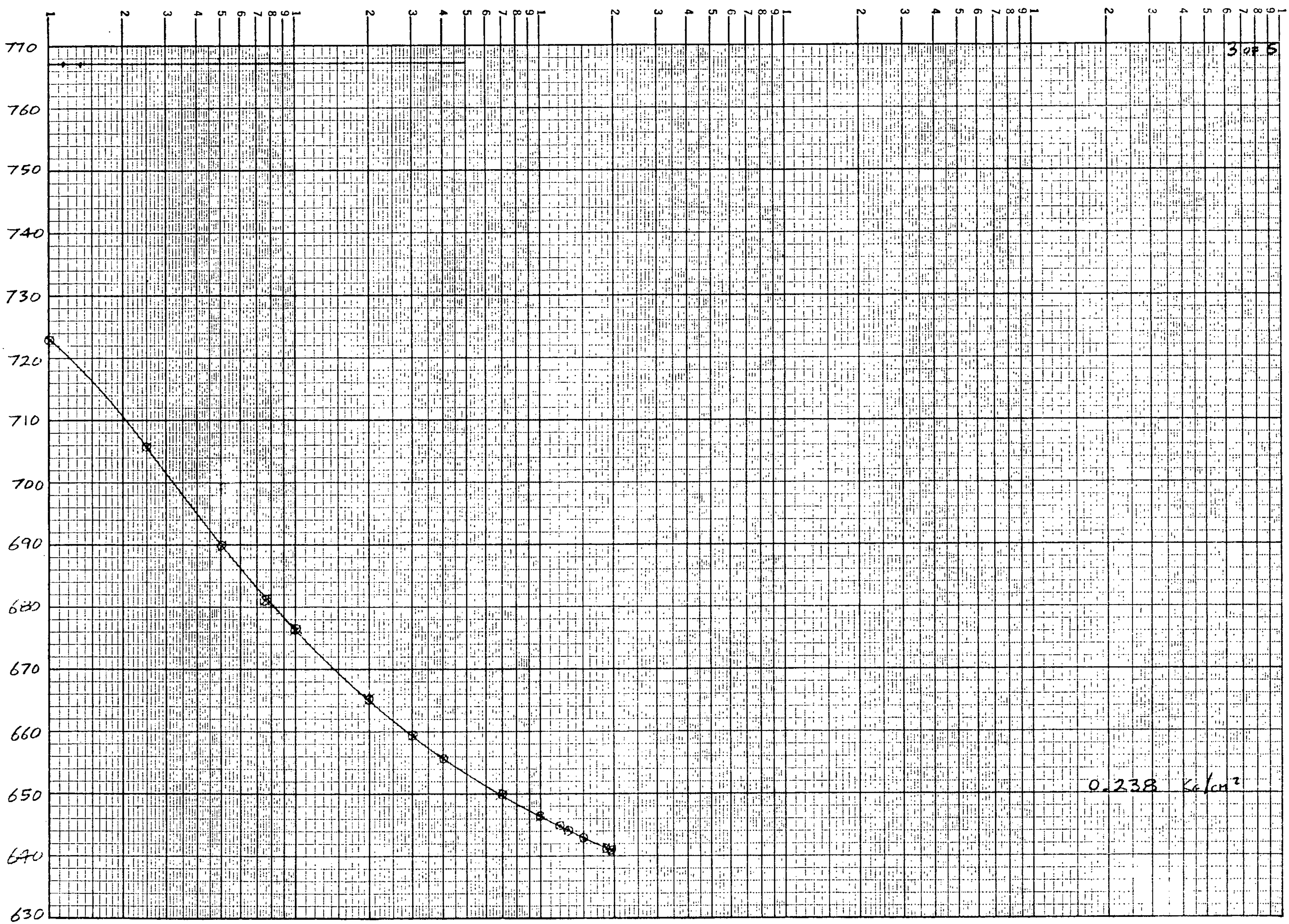

3 of 5
0.238 Kg/cm²
770
760
750
740
730
720
710
700
690
680
670
660
650
640
630

FIG 3-21

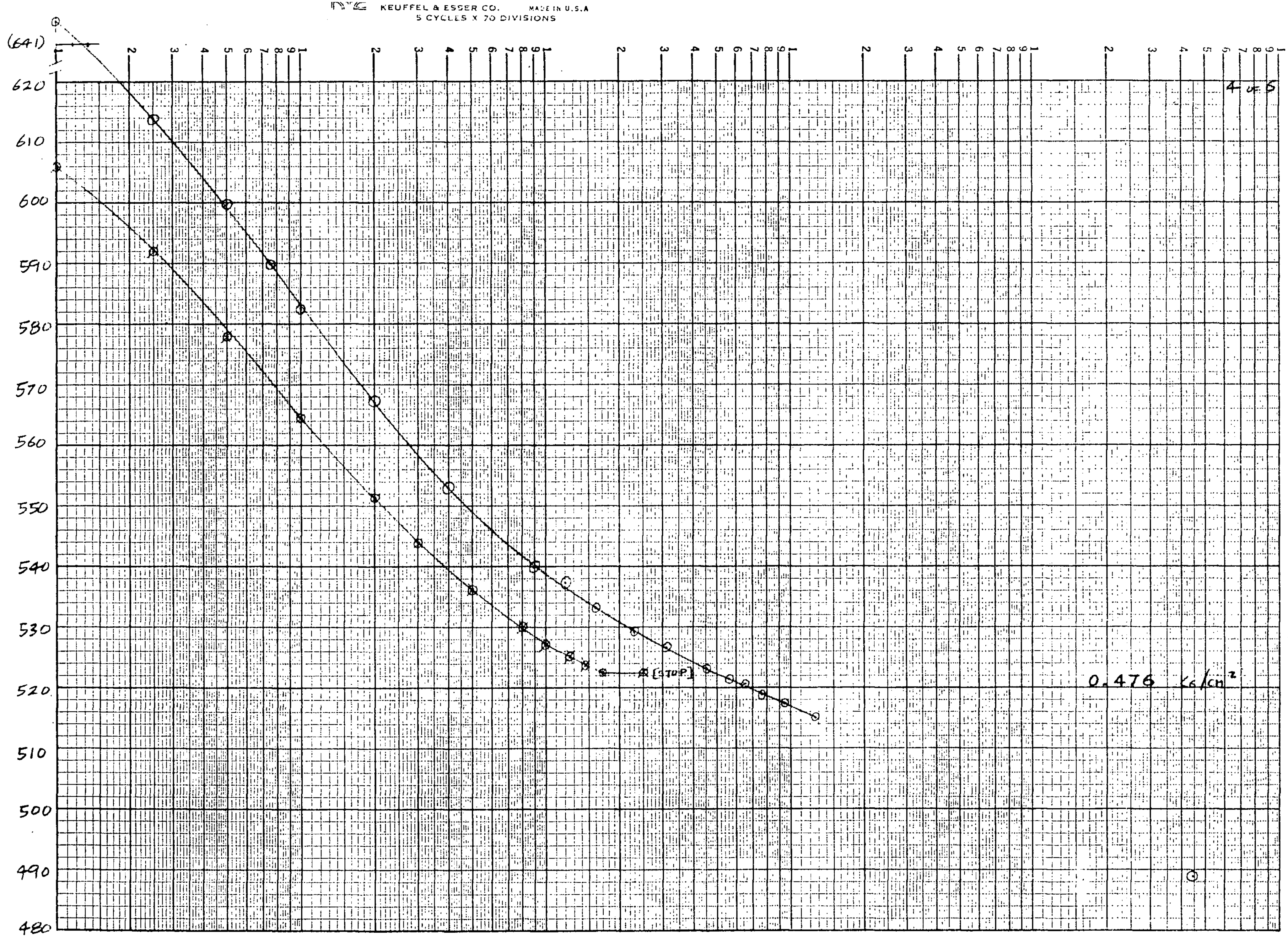

KEUFFEL & ESSER CO. MADE IN U.S.A
5 CYCLES X 70 DIVISIONS
4 of 5
(641)
620
610
600
590
580
570
560
550
540
530
520
510
500
490
480
[STOP]
0.476 Kg/cm²

FIG. 3-22

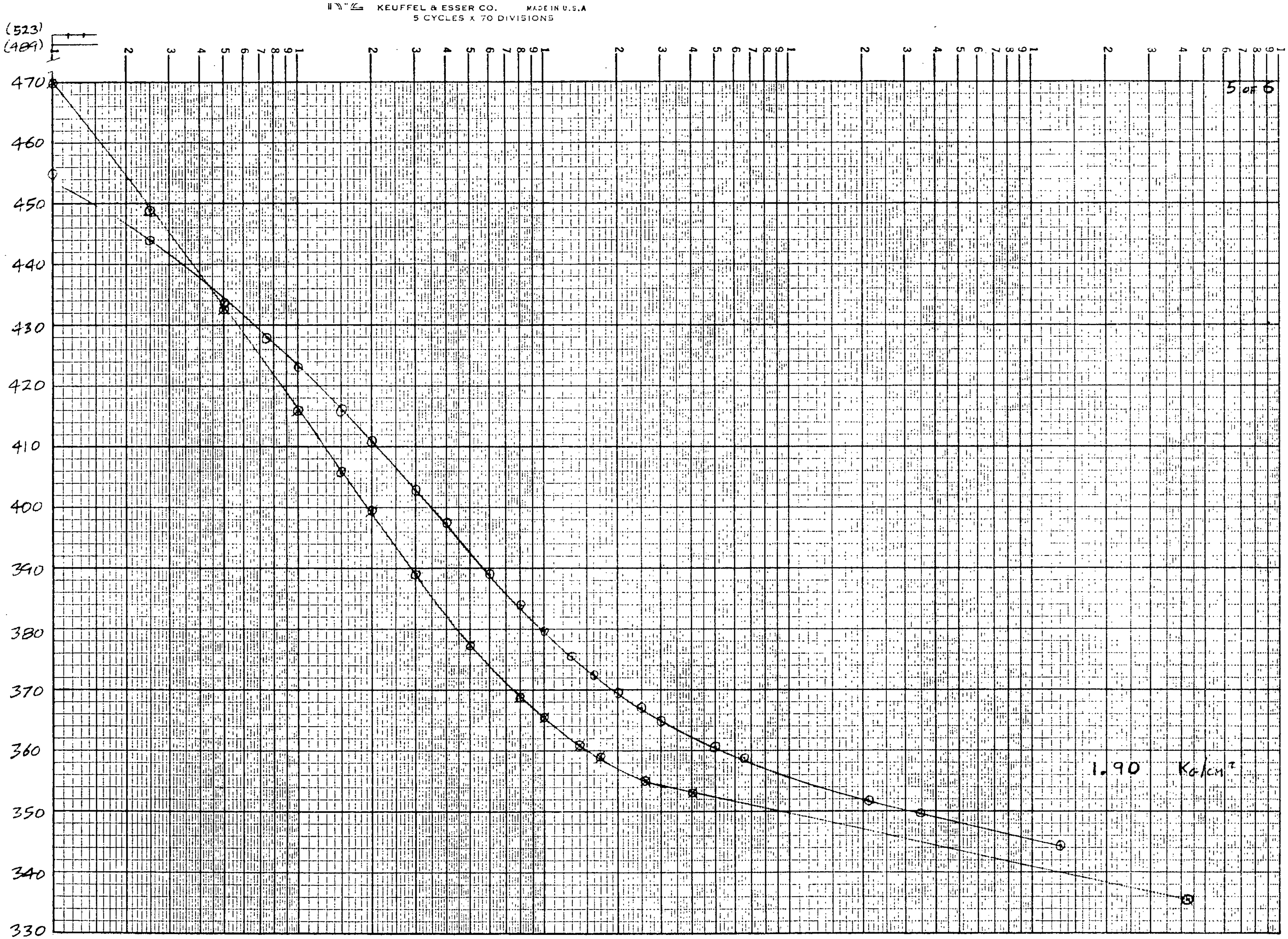

KEUFFEL & ESSER CO. MADE IN U.S.A.
5 CYCLES X 70 DIVISIONS
5 of 6
1.90 Kg/cm²
(523)
(489)
470
460
450
440
430
420
410
400
390
380
370
360
350
340
330

FIG. 3-23

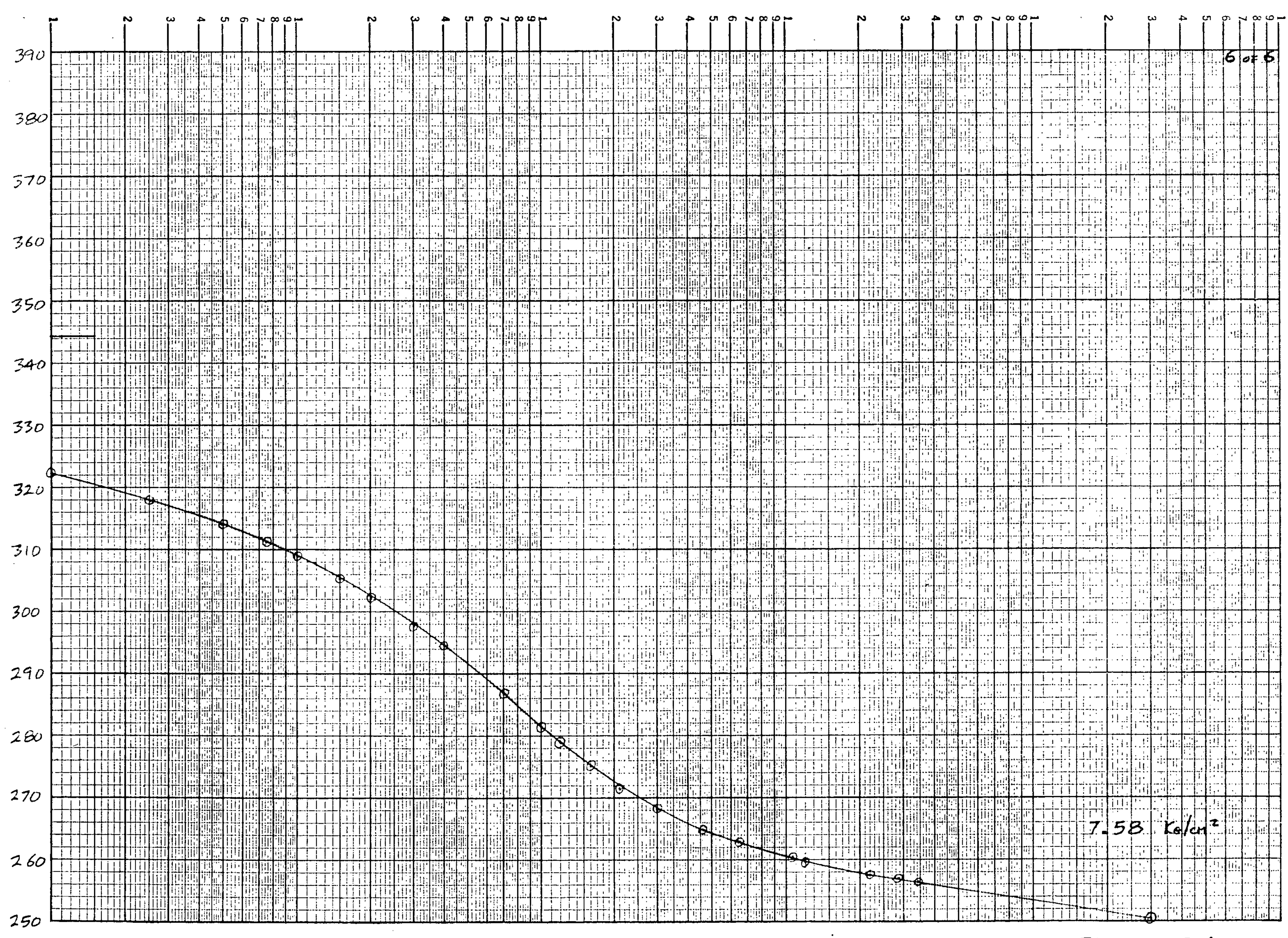
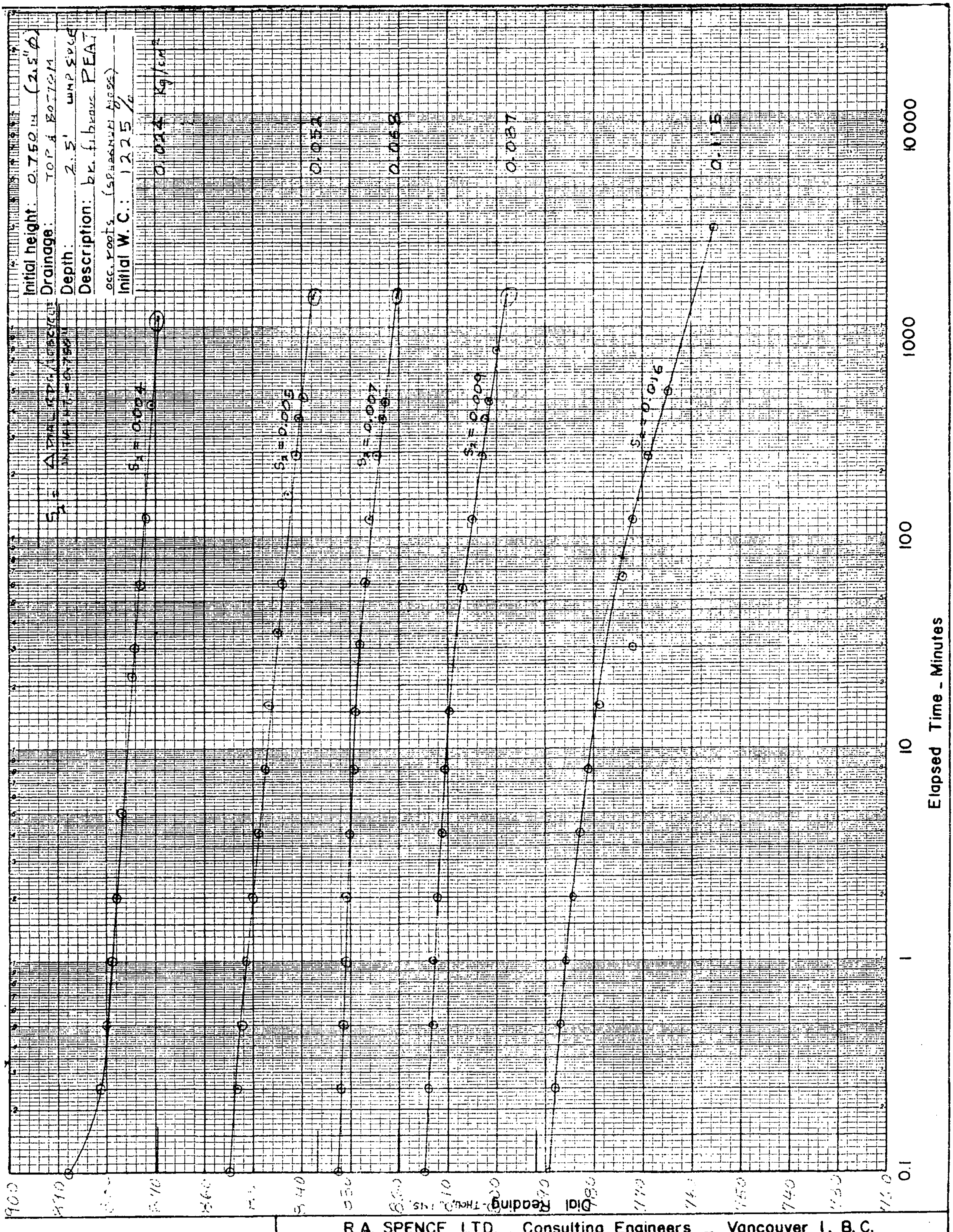

6 of 6
7.58 Kg/cm²
390
380
370
360
350
340
330
320
310
300
290
280
270
260
250

FIG. 3-24



PEAT CONSOLIDATION #P1
LOAD INCREMENT RATIO - 0.30

R.A. SPENCE LTD. _ Consulting Engineers _ Vancouver 1, B.C.

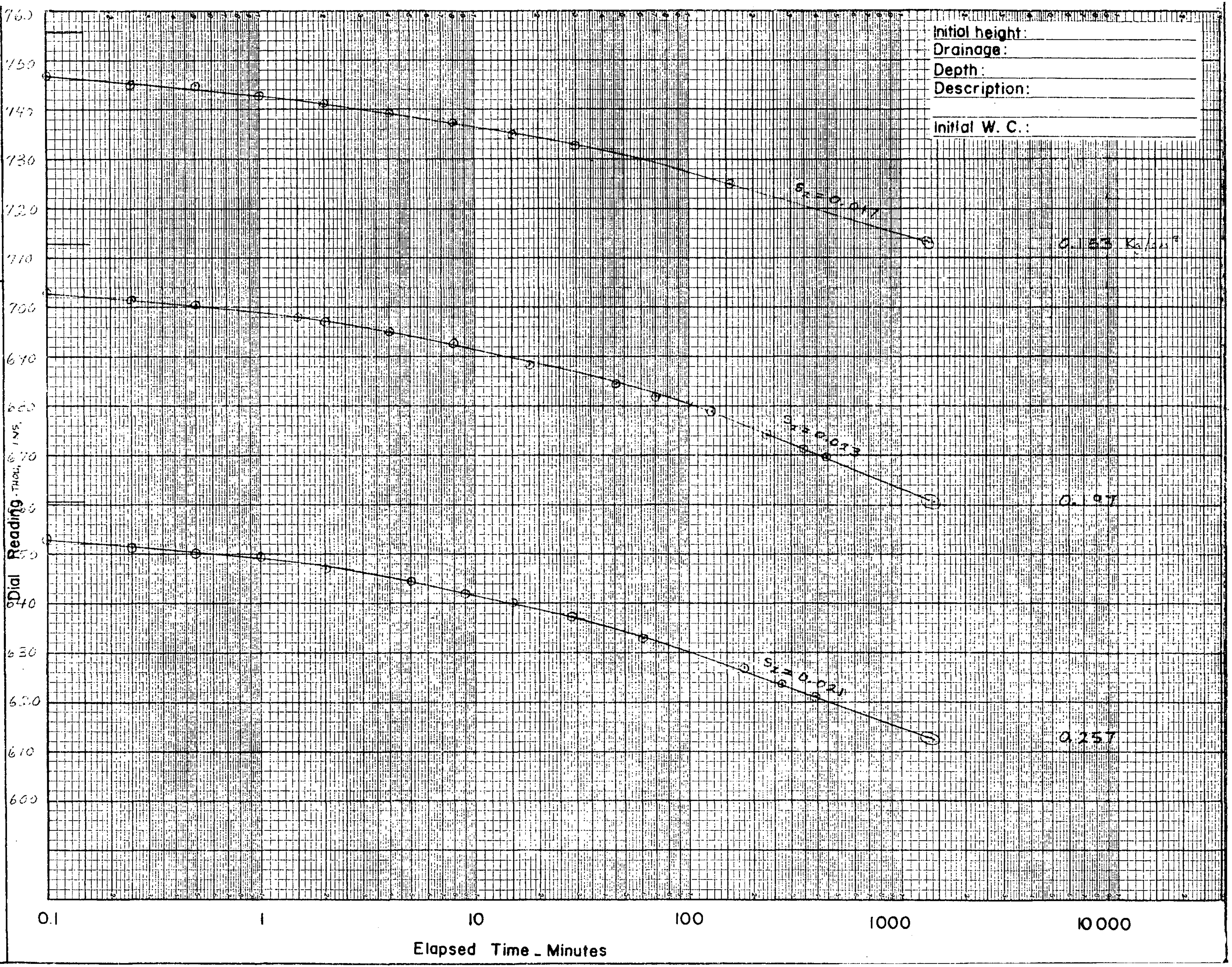
CONSOLIDATION TEST	Hole: T.P. 1	Job: P.P.I.	Date: MAR. '62	Dwg: A1
	Sample: B1	Sheet: A1 of 5	By: GM & DC	

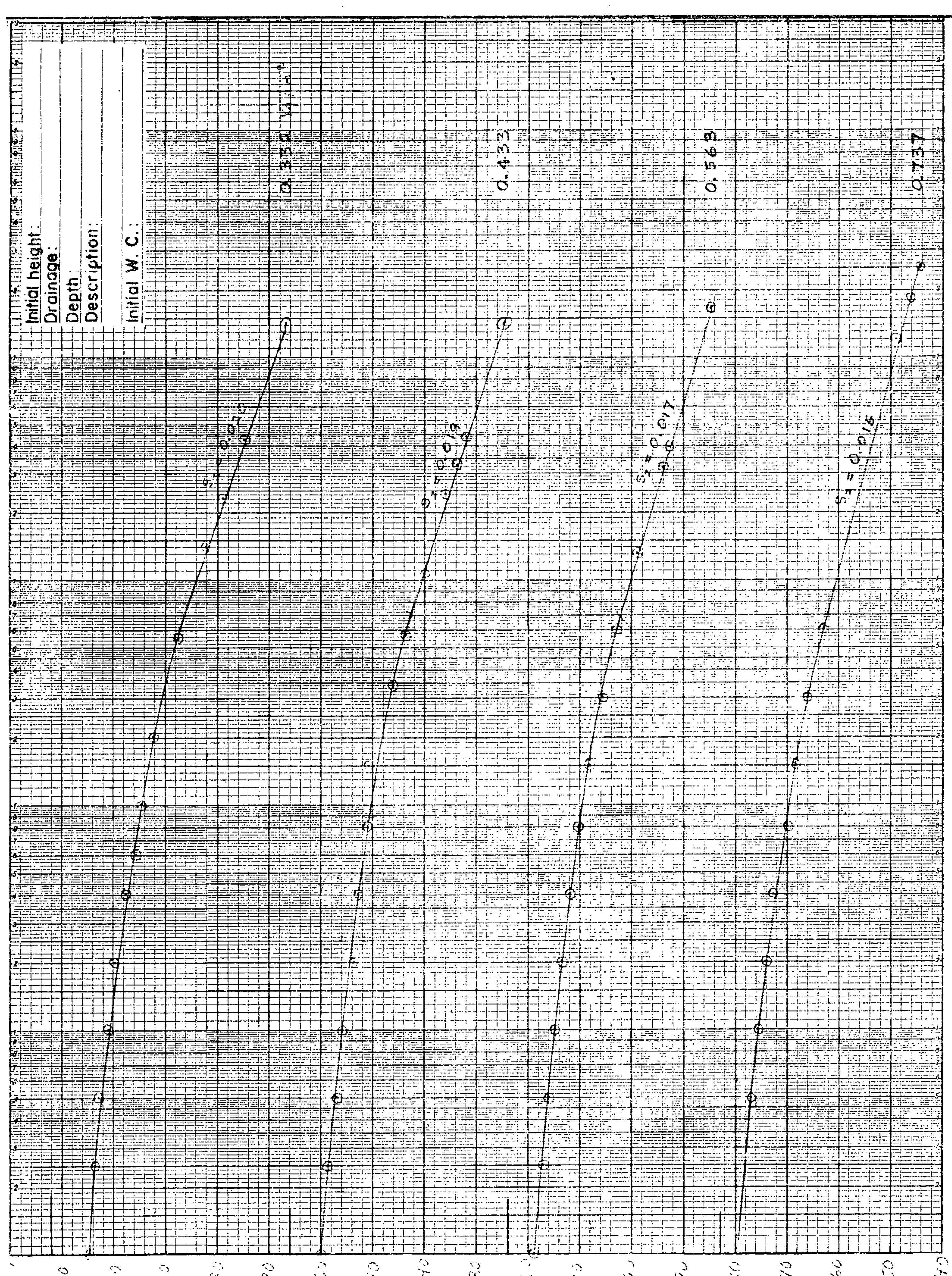
CONSOLIDATION TEST

R.A. SPENCE LTD. – Consulting Engineers – Vancouver 1, B.C.

Hole: TP1	Job: PP1	Date:
Sample: B1	Sheet: A2 of 5	By:

Dwg: A2





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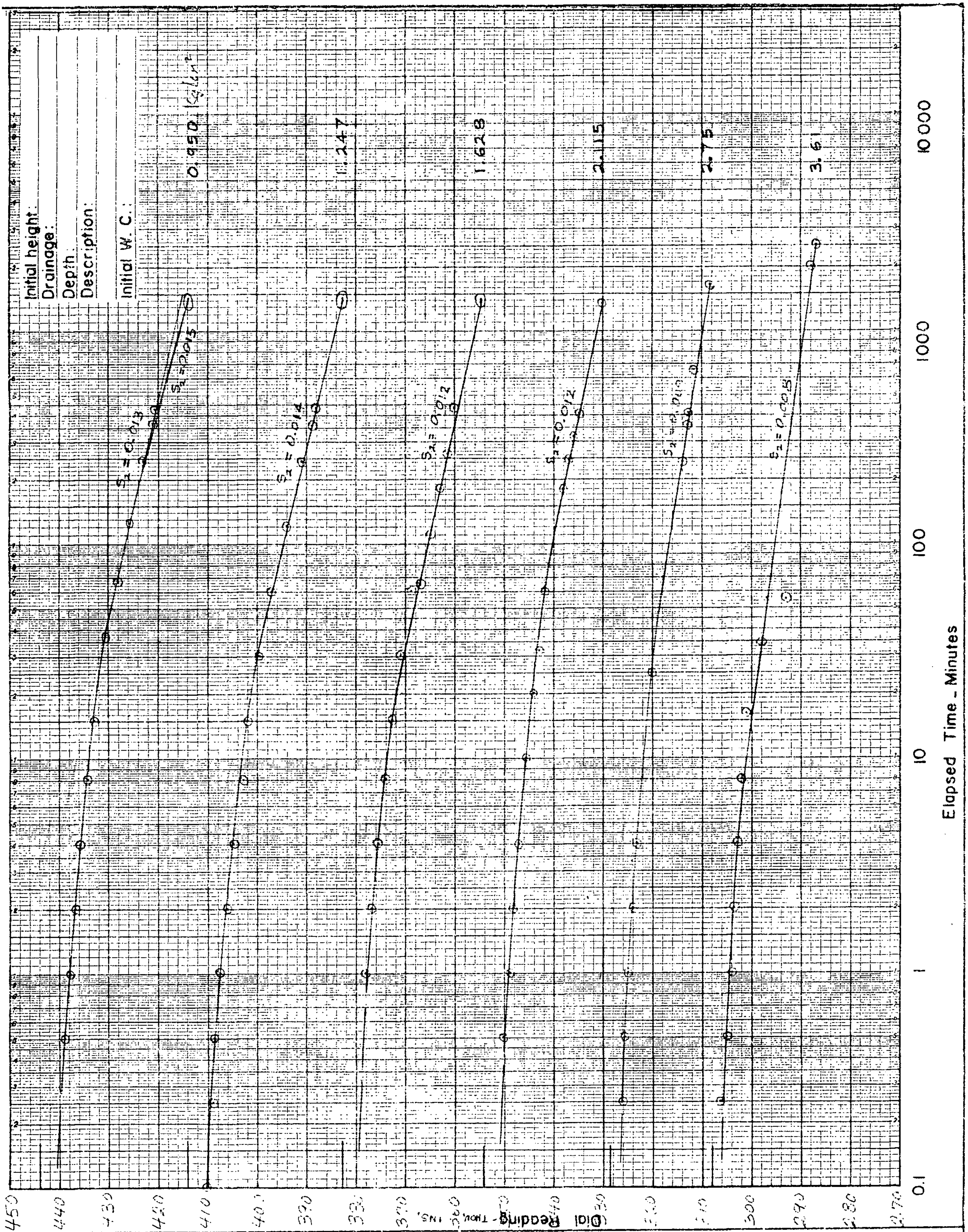
# PI CONSOLIDATION TEST	Hole: TPI	Job: PPI	Date:	Dwg: A3
	Sample: BI	Sheet: A3 of 5	By:	



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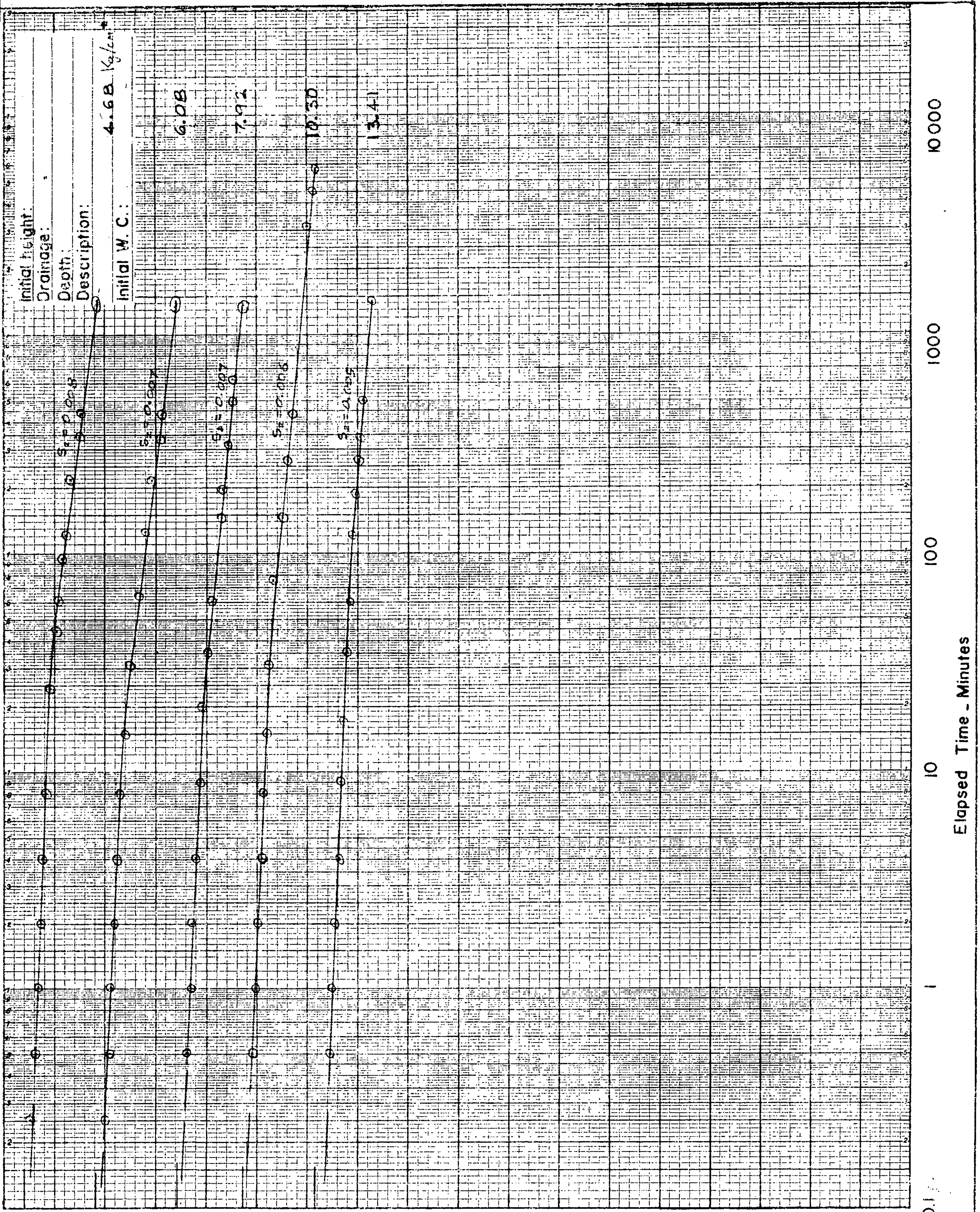
H P1 CONSOLIDATION TEST	Hole: TP1	Job: PF1	Date:	Dwg: A4
	Sample: B1	Sheet: A4 of 5	By:	



R.A. SPENCE LTD. _ Consulting Engineers _ Vancouver I, B. C.				
CONSOLIDATION TEST	Hole: TP1	Job: PP1	Date:	Dwg: A5
	Sample: B1	Sheet: A5 of 5	By:	