A REVIEW OF COMPRESSION TESTING PROCEDURE WITH REFERENCE TO A TRENTON LIMESTONE

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A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfilment of the requirements for the degree of Master of Engineering.

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The author is indebted to the Canadian Commonwealth Scholarship and Fellowship Committee for the award of a Commonwealth Scholarship with which he was able to undertake the following research. He is pleased to acknowledge the help and comments of Professor R.G.K. Morrison and other members of the staff and student body of the Department of Mining Engineering and Applied Geophysics. Finally gratitude is expressed to laboratory technicians W.J.Doig, P.Smith, A.J.Ward and M.H.Knoepfel who helped in making the equipment used in this research.

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SECTION I. INTRODUCTION

The writer set out to examine the physical properties of a Trenton limestone. In the early stages of the work he was impressed with the influence of experimental technique on results obtained in uniaxial compression tests. The study of these influences, based largely on the above rock, results in suggestions for improving techniques.

Uniaxial compression, in this context, includes measurement of the elastic moduli as well as compressive strength. There were two areas of study :-

a) Effects due to specimen preparation technique,

b) Effects due to load equalizing technique.

End preparation techniques were varied, and traces of the surfaces formed were obtained with a dial indicator. These surfaces could be divided into two groups: those that were characteristically concave, and those that were characteristically convex (figs. 3 to II).

Two load equalizing systems were employed, as well as direct loading between machine platens. The first system was that of a spherical bearing block, the usual load equalizing device in use in compression testing, and the second was a new system relying on plastic, in this case teflon, as a means of achieving the equalization.

Strain gauges were employed to assess the magnitude of the two effects on measurement of the elastic constants. Initial research was concerned with an evaluation of the use of strain gauges for for this type of work. This evaluation was based upon information obtained from gauges mounted on both limestone and steel specimens. Steel specimens proved especially useful because of the known characteristics of steel and the requirement that specimens be able to withstand, within the elastic limit, many loading cycles to high stress levels.

A series of compressive strengths was obtained for several closely controlled conditions. Lateral deformation tests proved helpful in the interpretation of the strength data.

Note: In all cases moisture was controlled to the extent that, between preparation and testing, specimens were air-dried at room temperature for a minimum of two weeks.

SECTION 2. SPECIMEN PREPARATION

The applied load should be normal to the ends of the specimen and the ends should be parallel to each other, otherwise abnormal stress patterns are developed within the specimen tending to reduce the compressive strength. However, as long as the loading system is able to apply load normal to the specimen ends it is doubtful whether a lack of parallelism of even 0.0I inches would significantly affect the compressive strength.

Specimen end preparation is in general achieved by the following methods, of which (a) is most common.

(a) Lapping, (I)*, (2),

(b) Surface grinding, (3),

(c) Lathe and tool post grinding, (4).

It is possible, providing there is no punching (4), that a high degree of polish on the specimen end may reduce frictional confinement. This could be adequately studied only when specimen ends and loading platens were perfectly flat, which is not usually the case.

2.I. LIMESTONE SPECIMENS

2.I.I. Specimen source and description

All specimens were cored from blocks of Trenton limestone, the most homogeneous rock available. These blocks were obtained from

* numbers refer to references given at the end of this thesis on page 66.

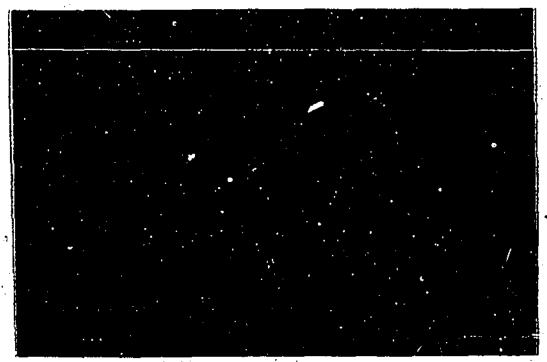
nearby building excavations, and the three most suitable, denoted A, B, and C, were selected. The limestone contained fossils and calcite stringers. Bedding planes were not conspicuous. However, as nearly as could be estimated the specimens were cored normal to the bedding. For deformation measurements care was taken to select specimens free from obvious flaws.

Thin sections (see photographs I, 2, & 3) show a relatively pure limestone, composed of approximately 95% calcite ($CaCO_3$), I.5% quartz (SiO_2), I.5% pyrite and 2% clay minerals.

About 85% of the calcite is slightly recrystallized to a homogeneous grain size of a few hundreds of a mm. in a cement of calcite. The remaining calcite exists in the form of coarse (approximately $\frac{1}{2}$ mm. diameter), well crystallized grains which are the remains of fossils. These grains are randomly spread in the fine grain matrix.

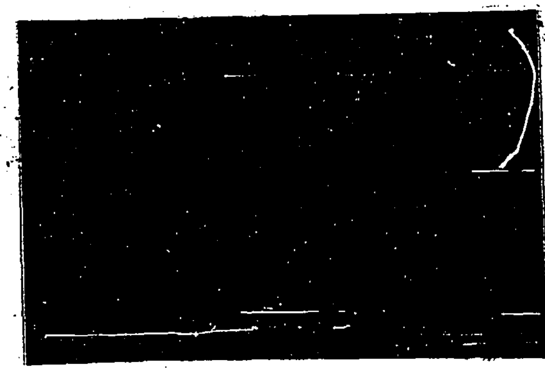
The quartz is finely grained and randomly disseminated throughout the fine grain calcite. The pyrite also is disseminated in the fine grain matrix, but occurs in concentrations around the large calcite crystals. The clay minerals are concentrated in the cement of some beds. The thin sections indicate bedding in only about 25% of the rock.

The rock would be almost homogeneous if it were not for the large calcite crystals, and occasional bedding. The latter point is the more important.



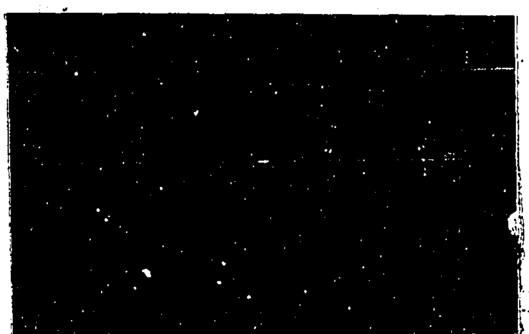
Photograph I.

Thin section parallel to bedding. Magnification x IO. Shows fossil remains.



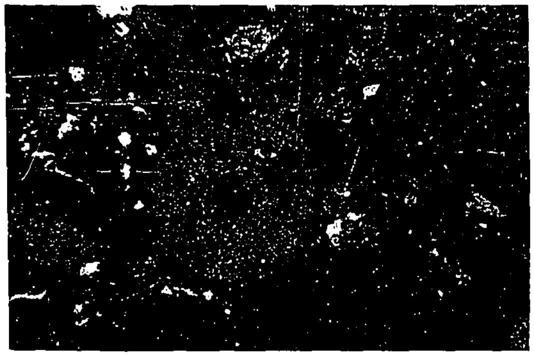
Photograph 2.

Thin section perpendicular to bedding. Shows recrystallized calcite grains. Magnification x 50.



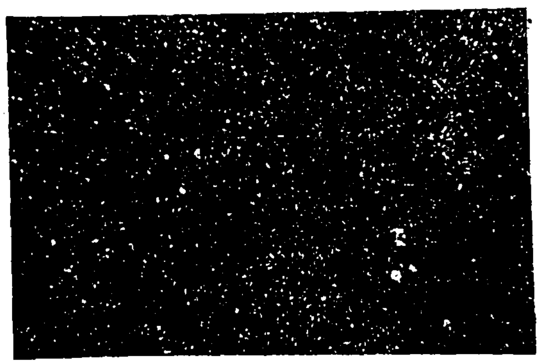
Photograph 3.

Thin section perpendicular to bedding showing recrystallized calcite grains in calcite cement. Magnification x 400.



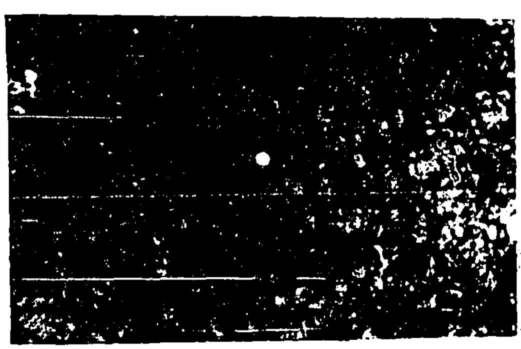
Photograph I.

Thin section parallel to bedding. Magnification x IO. Shows fossil remains.



Photograph 2.

Thin section perpendicular to bedding. Shows recrystallized calcite grains. Magnification x 50.



Photograph 3.

Thin section perpendicular to bedding showing recrystallized calcite grains in calcite cement. Magnification x 400.

2.I.2. Rough preparation

Core lengths of between IO ins. and I2 ins. were obtained using the laboratory drill. This machine is shown in photograph 4. It was fitted with a 24 inch, size AX core barrel, and in the modified form was able to drill out three core lengths in an hour. The modification referred to was a bronze bushing which eliminated the necessity for re-alignment after collaring. The core barrel exterior was well greased and kept free of dirt and as the bushing was correctly aligned no trouble was experienced.

The drilling machine was carefully positioned to ensure that all holes were parallel. Drilled core lengths were numbered and later cut with a diamond saw to give length/diameter ratios between 2.25 and 2.5.

Each specimen was labelled with respect to its former position. For example, specimen A.I.2 -

A...... identifies the limestone block,

I...... is the core length number, its position is as indicated in photograph 5.

2...... gives the elevation of the specimen as denoted in fig. I.

2.I.3. End preparation

Two techniques were used :-

(a) Hand lapping on fine, wet emery paper, the emery paper being mounted on a glass plate to ensure a flat surface. This technique was noteworthy in that it gave an extremely smooth finish to the specimen end.

(b) Using a lathe and tool post grinder, referred to as 'lathe preparation'. The equipment can be seen in photograph 6, and fig. I2.

It was found that by varying some factors of the lathe preparation technique several quite different end finishes were possible. Also each procedure could be standardized, which was not the case with hand lapping. Hand lapped specimens were utilized only for deformation measurements, so unless otherwise specified lathe grinding was the end preparation used.

Lathe preparation procedures

Early tests on the lathe indicated that the critical factors were:-

(a) The quality of the cutting edge on the grinding wheel,

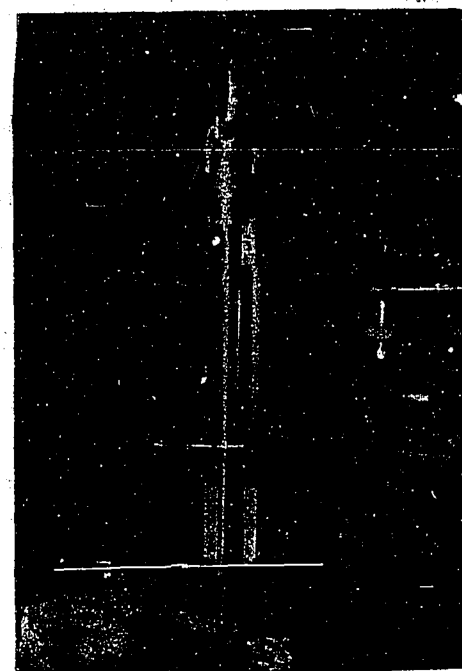
(b) The grinding wheel angle (see fig. 2),

(c) The depth of cut,

(d) The width of flat face forming the cutting edge. This factor determined the polish on the specimen end, as well as the amount of heat generated during grinding.

These factors were arranged to give four qualities of end finish. The procedures were standardized as follows.

Procedure number	Grinding wheel angle	Concluding depths of cut	Width of flat face	Finish & heating
I	$7\frac{1}{2}^{\circ}$	I0,5, thou	-	Rough,non-vitreous no heating
2	40°	I0,5,2,I,thou	-	Smooth,non-vitreous no heating
3	40°	I0,5,2,I,thou	I/I6"	Smooth,vitreous slight heating
4	40°	I0,5,2,I,thou	I/8"	Smooth,vitreous excessive heating



Photograph 4.

Drilling machine in position.

Photograph 5.

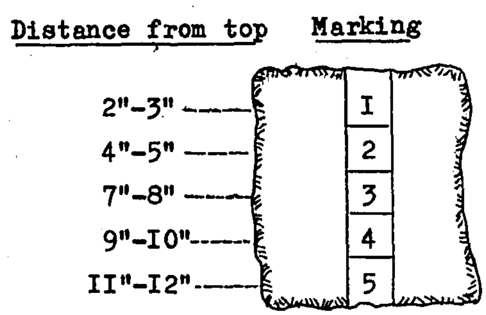
Limestone block 'C' on completion of coring.

Core numbering system.

	29	28	I3	I2
	↓	↑	↓	↑
36	35	22	2I	6

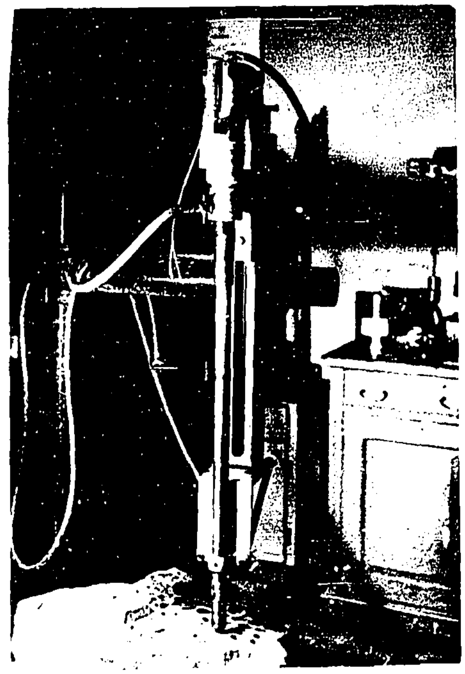
Figure I.

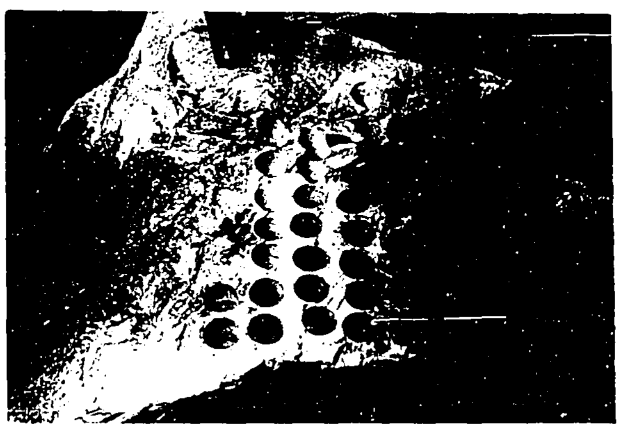
Specimen elevation markings.



Photograph 4.

Drilling machine
in position.





Photograph 5.

Limestone block 'C' on
completion of coring.

Core numbering system.

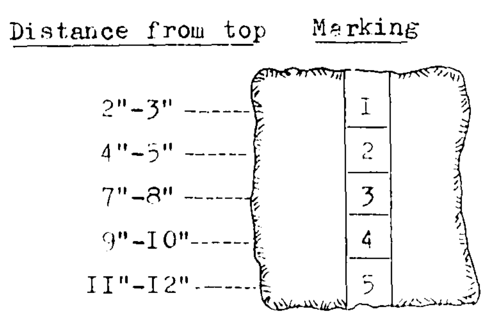
29 28 I3 I2

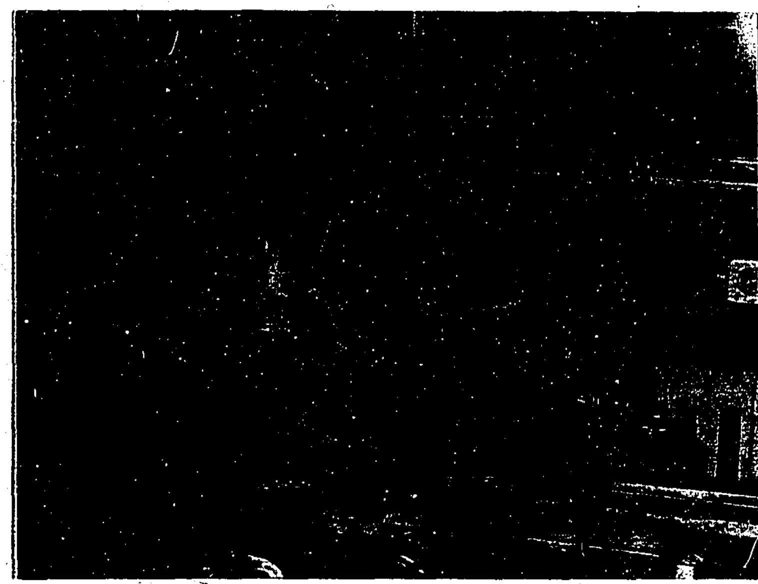
↓ ↑ ↓ ↑

36 35 22 2I 6

Figure I.

Specimen
elevation
markings.





Photograph 6. Lathe and tool post grinder.

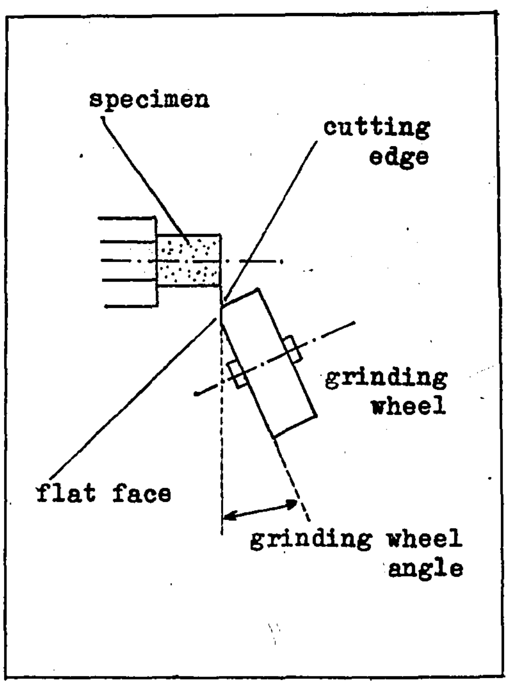
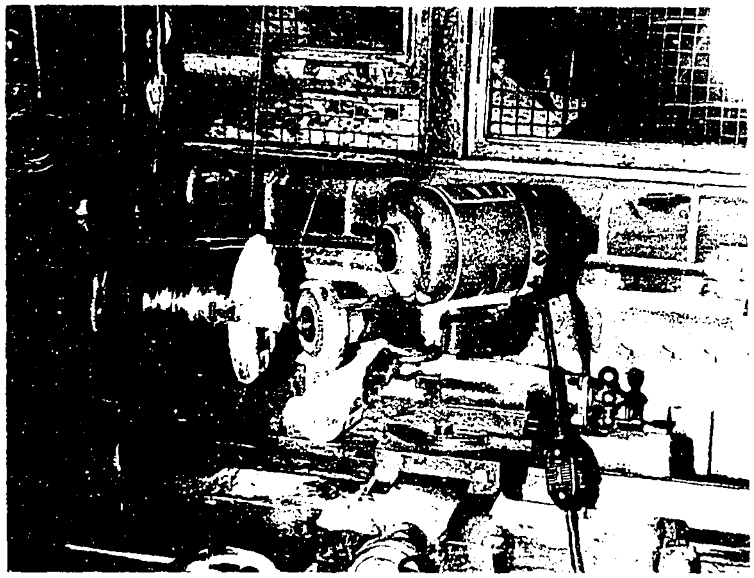


Figure 2.
Specimen grinding.



Photograph 6. Lathe and tool post grinder.

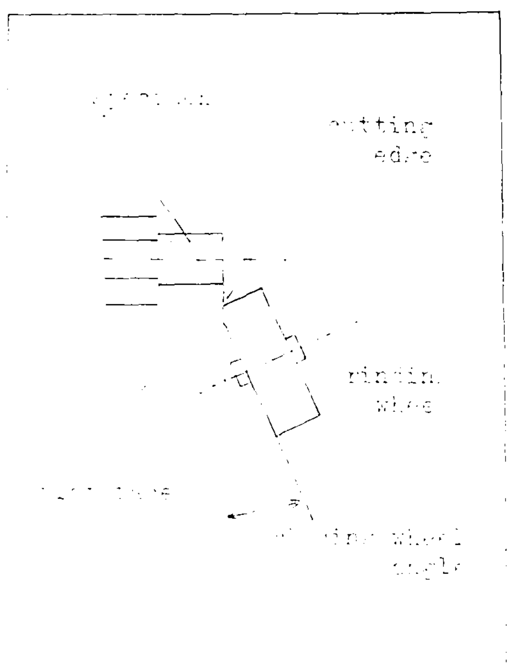
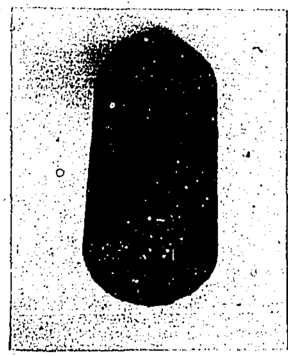
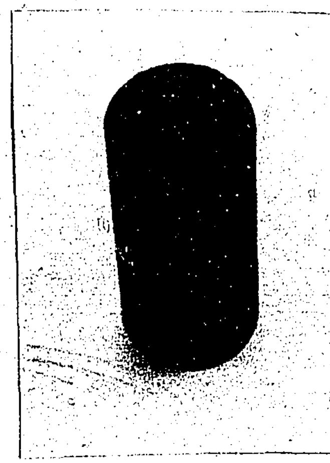


Figure 2. Specimen grinding.

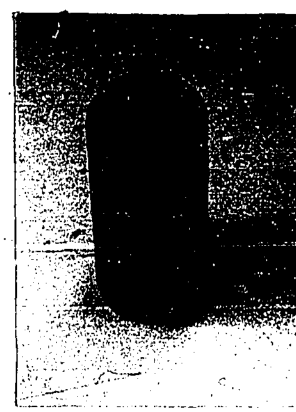


<u>Photograph 7</u>. Example of specimen prepared by lathe procedure I.



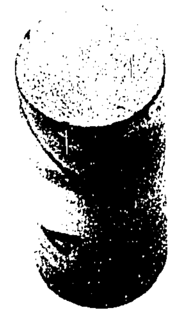
<u>Photograph 8</u>. Example of specimen prepared by lathe procedure 2.

<u>Photograph 9</u>.
Starrett dial indicator.

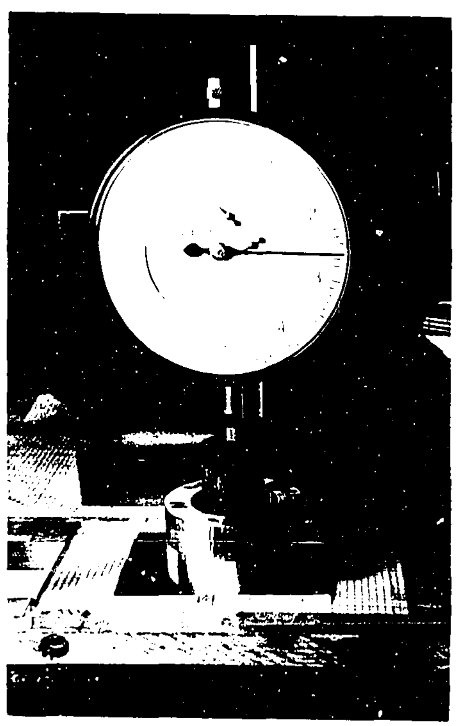


<u>Photograph IO</u>. The polished high area of a lathe prepared specimen.

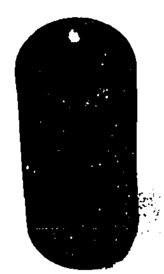
Photograph 7. Example of specimen prepared by lathe procedure I.



Photograph 8. Example of specimen prepared by lathe procedure 2.



Photograph 9.
Starrett dial indicator.



Photograph IC. The polished high area of a lathe prepared specimen.

Additional details:-

Grinding wheel type....................Simonds GC60-K8V9,

Grinding wheel speed............................6600 rpm,

Specimen speed..................................2I2 rpm,

Lateral speed of wheel................... 0.0025 ins/sec.

2.I.4. Surface irregularity measurements (see fig. 9)

A Starrett dial indicator was set vertical and rigid above a flat ground plate. The dial, graduated to 0.000I ins. had a full scale deflection of 0.20 ins. The specimen was placed in an aluminum cup of base diameter 2.0 ins. Movement of the cup was limited to a predetermined path by a rectangular wooden frame of internal dimensions 4.0 ins x 2.0 ins. Graph paper glued onto this frame provided a means of positioning the specimen, there being corresponding diametrical markings on the cup.

The specimen was rigidly clamped in the cup and then moved beneath the dial indicator in increments of 0.I ins., beginning at one side of the end face usually at a point 0.I ins. from the side. Ten traverses were completed for each surface diameter, five in either direction and a resultant mean trace determined. The traces illustrated in figs.3 to II were obtained. Points are accurate to about 0.0003 ins.

To determine the reliability of this method of surface traversing the following test was performed. A specimen was lathe prepared and one end surface traversed. The trace is given in fig. 8. This specimen end was then polished on a lapping wheel for a short time. The result was that the rim of the specimen end exhibited some polish whilst the

FIGURE 3. SURFACE TRAVERSE OF A HAND LAPPED LIMESTONE SPECIMEN.

RE. TABLES E.I.I-3

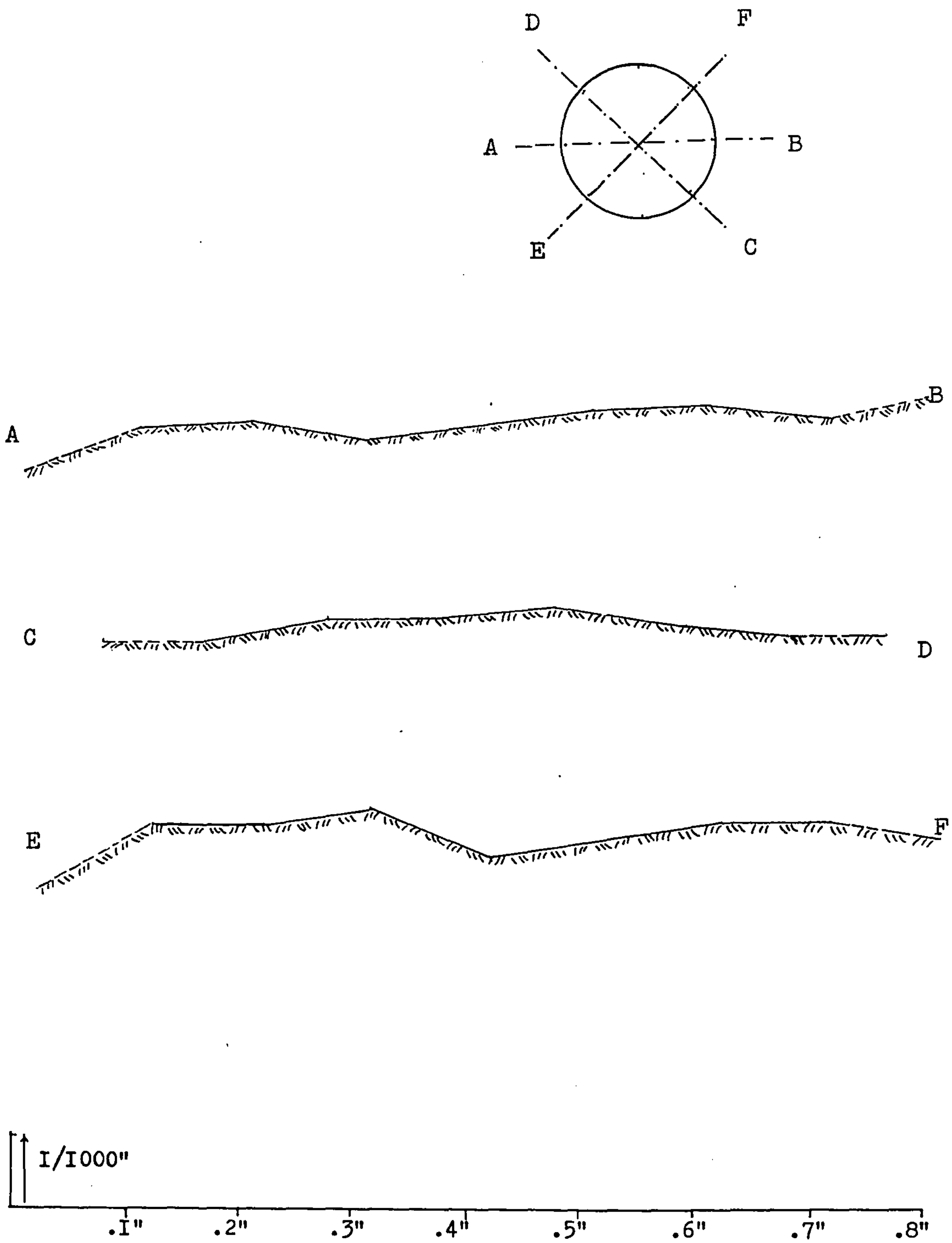
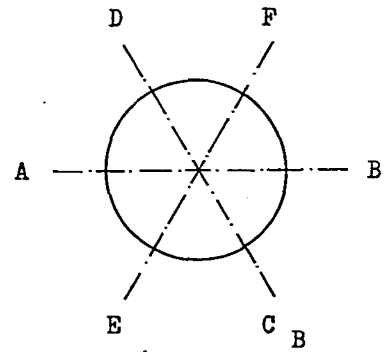


FIGURE 4. **SURFACE TRAVERSE OF A HAND LAPPED LIMESTONE SPECIMEN. RE. TABLES E.4.I.-3.**



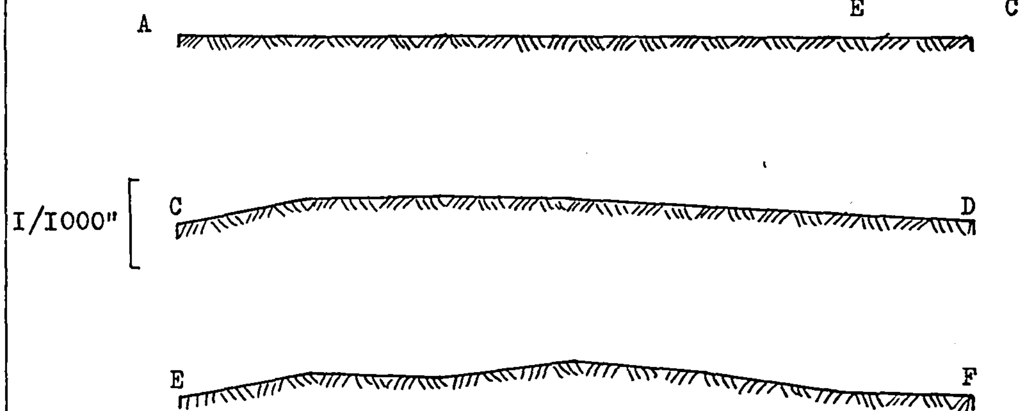
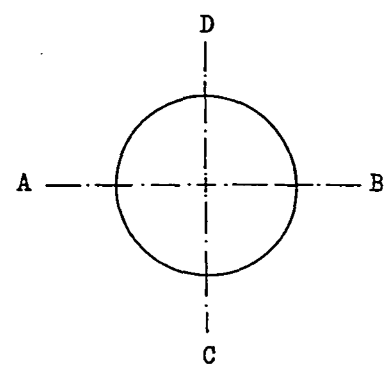
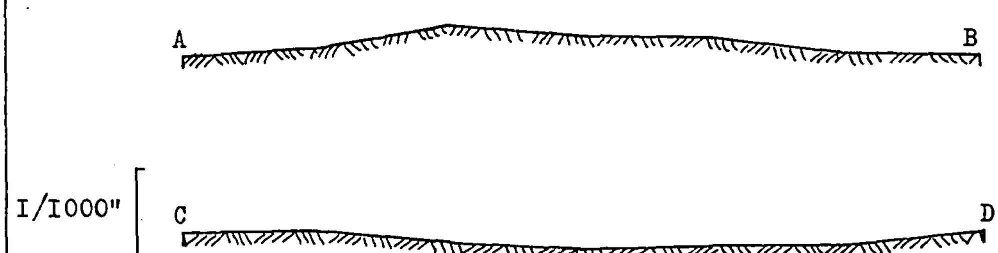


FIGURE 5. **SURFACE TRAVERSE OF A HAND LAPPED LIMESTONE SPECIMEN. RE. TABLES E.5.I..2.**





Scale.

FIGURE 6. **SURFACE TRAVERSE OF A SURFACE GROUND STEEL PISTON.**
RE. TABLES E.2.I.-3.

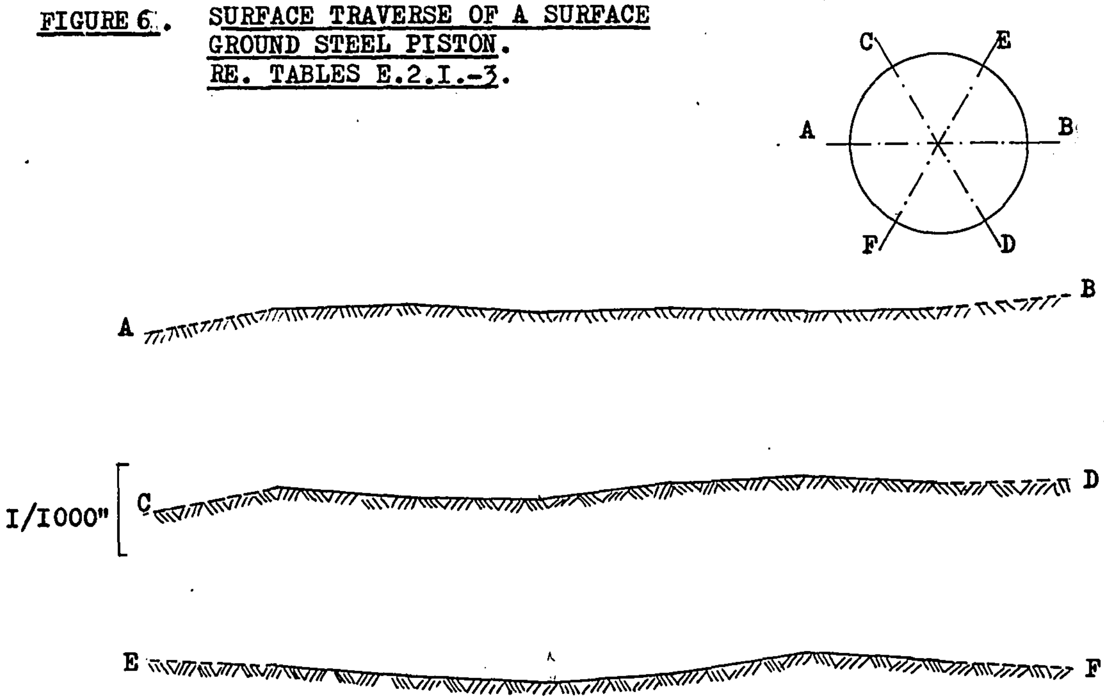


FIGURE 7. **SURFACE TRAVERSE OF A LATHE PREPARED LIMESTONE SPECIMEN PROCEDURE NO.2.**
RE. TABLES E.6.I.-3.

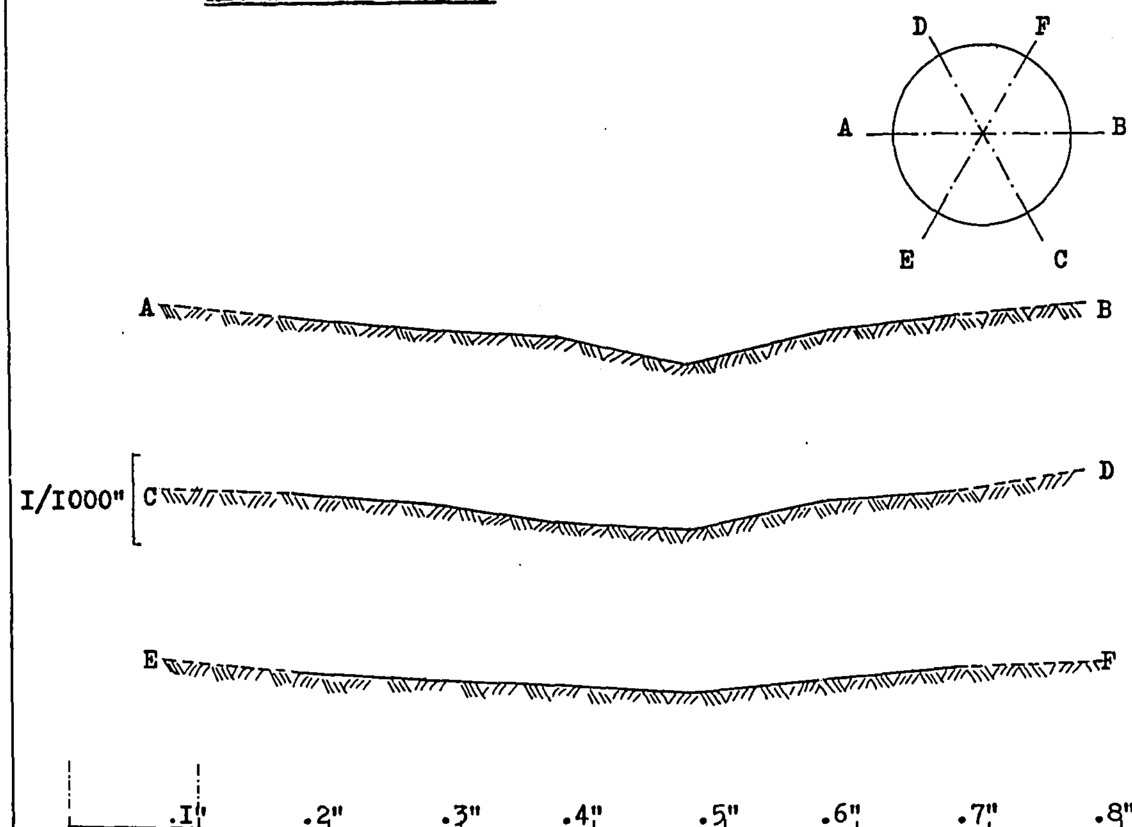


FIGURE 8. SURFACE TRAVERSE OF A LATHE PREPARED LIMESTONE SPECIMEN PROCEDURE NO.I. RE. TABLE E.3.I.

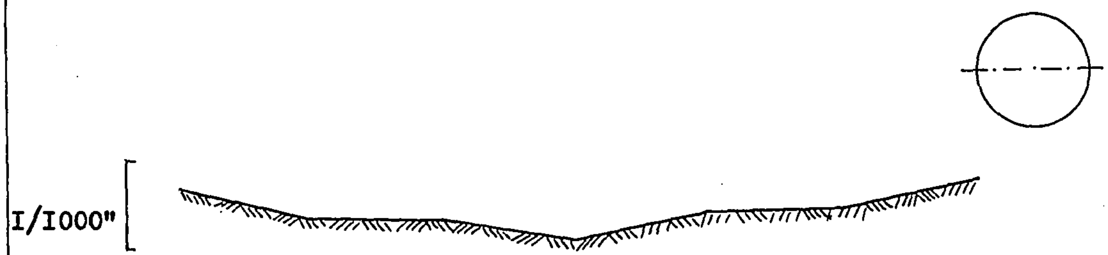


FIGURE 9. SURFACE TRAVERSE OF A LATHE PREPARED LIMESTONE SPECIMEN PROCEDURE NO.I. RE. TABLE E.8.I.

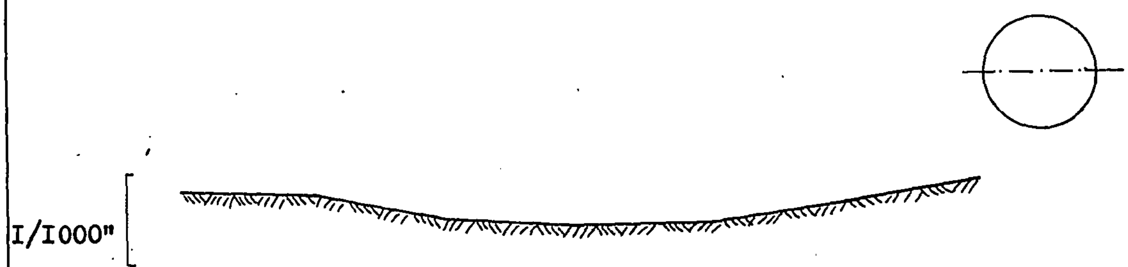


FIGURE IO. SURFACE TRAVERSE OF A LATHE PREPARED LIMESTONE SPECIMEN PROCEDURE NO.2. RE.TABLE E.7.I

FIGURE II. SURFACE TRAVERSE OF A LATHE PREPARED LIMESTONE SPECIMEN PROCEDURE NO.3. RE. TABLE E.9.I.

centre area did not, a rough indication of a concave shape. The polished end is shown in photograph IO.

The traces obtained in figs. 3 to II were as expected. Hand lapping allowed movement about a vertical axis, and so the specimen perimeter was more abraded than the centre area. This can be seen in figs. 4 and 5. The traces of the lathe ground specimens are in accordance with the observation that even after four passes of the grinding wheel in some cases the wheel was still grinding the specimen around the perimeter, though this was also dependent on the depth of cut.

2.2. STEEL SPECIMENS

As steel specimens can withstand many loading cycles to high stresses these specimens provided an excellent means of assessing the effectiveness of each load equalizing system (where nine independent loading cycles were necessary). Using a different limestone specimen for each cycle could have introduced unwanted factors into the test series.

Three steel specimens S.I., S.2. and S.3. of 2 ins. length were cut from a 0.875 ins. diameter drill rod and turned on a lathe until the ends were as flat and parallel as possible.

It was intended to use only specimen S.I. for the above mentioned tests. However this specimen was accidently destroyed part way through the test series, so then specimen S.2. was used to complete the series.

SECTION 3. COMPRESSION TESTING EQUIPMENT

If specimen ends and loading machine platens are parallel a load equalizing system is unnecessary. Rarely is this condition encountered in practice and the most commonly used compensating system is the spherical bearing block.

The author felt that spherical bearing blocks in general use were frequently too large for the specimen diameter and did not adjust to ensure that load was applied normally to the specimen face, causing abnormal stress patterns within the specimen.

3.I. LOAD EQUALIZING SYSTEMS

Specimen loading was accomplished through one of the following methods depending on the object of the test.

(a) Loading between machine platens with no equalizing system, referred to as 'direct loading',

(b) Using a spherical bearing block and top plate as the equalizing system, referred to as 'spherical block loading',

(c) Using a plastic as the equalizing agent, referred to as 'plastic loading'.

Pistons (see section 3.I.4) were used with all systems. While pistons are an integral part only of the system of plastic loading, to standardize all tests it was necessary to use them with direct loading and the spherical block.

3.I.I. Direct loading

Initial tests proved, as had been suspected, that the upper and lower compression platens of the Tinius Olsen machine (section 3.2.) were not parallel. The vertical movement of the upper platen was controlled by four screw feeds. Apparently one screw was holding most of the load. This was overcome by adjusting the retaining nuts above the top platen. Fair loading was then achieved.

3.I.2. Spherical block loading

The dimensions of the spherical block are given in fig. I4. The top plate is the same diameter and same material as the spherical block. Efficient operation of a spherical block depends on:-

(a) The condition of the spherical bearing surfaces,

(b) The size of the spherical seating with respect to the specimen diameter. The best loading is obtained when the radius of the spherical seating is equal to, or smaller than the specimen radius,

(c) Correct positioning of the specimen on the spherical block. In this case the block did not appear to be self-aligning and had to be manually aligned as the upper platen descended.

3.I.3. Plastic loading (see photographs II and I2 and fig. I6)

The operation of this device depends upon the fluidity of plastic when stressed beyond its yield point in a confined space. The plastic here, teflon, has a yield point of around I500 psi. Confinement was achieved by allowing the smallest possible tolerance between piston base and cylinder bore. Relative lateral expansion of the piston and radial expansion of the cylinder had to be taken into account to prevent jamming at high loads. Pistons were part tapered to permit the best alignment. Teflon lips were removed with a pen knife blade where necessary.

3.I.4. Pistons

Pistons were lathe turned out of special $\frac{7}{8}$ inch drill rod, heat hardened and surface ground. A surface trace of one of these ground faces is given in fig. 6. As the specimen bearing face of the piston was the same size as the specimen the possibility of punching effects was removed. Specimen and pistons were held together with Scotch tape.

3.2. LOADING MACHINE

All tests were carried out on a Tinius Olsen 50,000 lb. capacity loading machine. This machine was fitted with eight loading rates. Only the lowest of .05 ins. per minute was used. The applied load was indicated by a system of levers culminating in a graduated balance arm. A screw feed moved a balance weight (the load indicator) along this arm. The speed of the screw feed was fully adjustable and as the accuracy of measurement was dependent upon this speed great care was taken to maintain it at the correct level. Under these conditions the machine was measured accurate to within I% of the recorded load.

FIG. I2. ARRANGEMENT OF LATHE AND TOOL POST GRINDER.

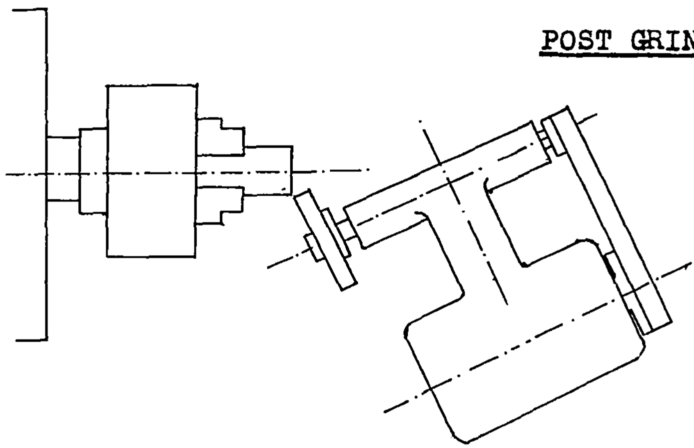


FIG. I4. SPHERICAL BEARING BLOCK

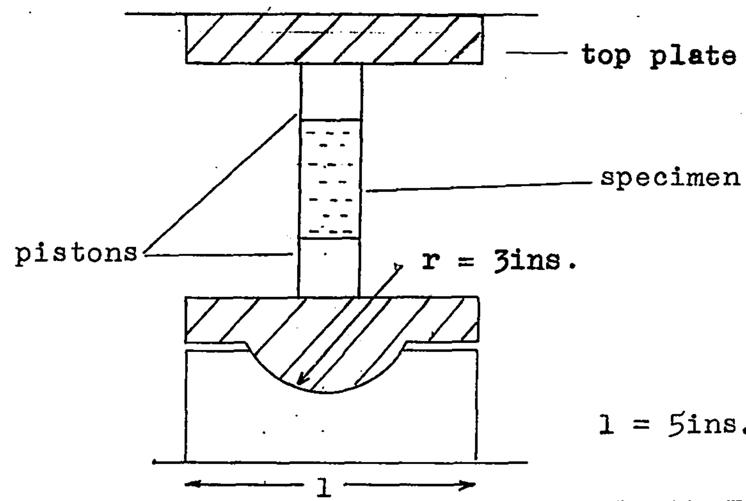


FIG. I3.

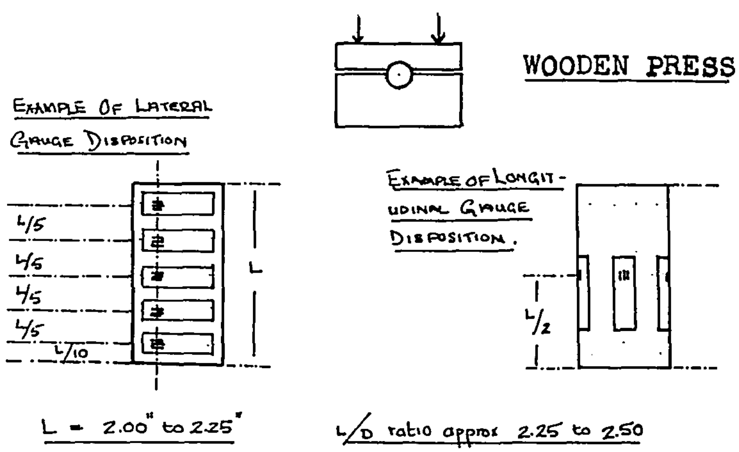


FIG. I5. ELECTRICAL CIRCUIT

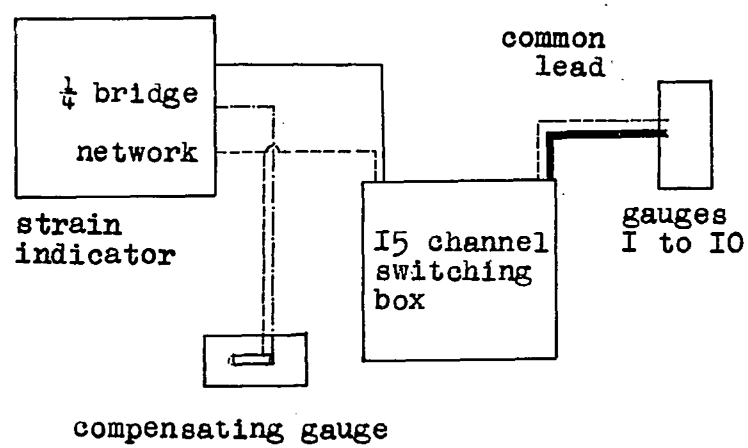
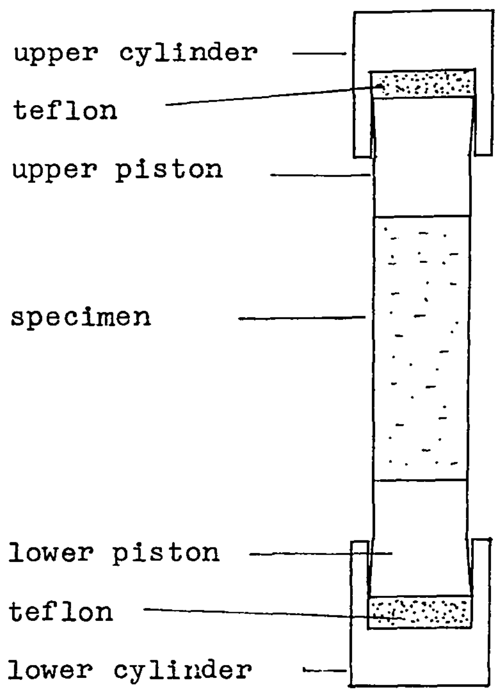
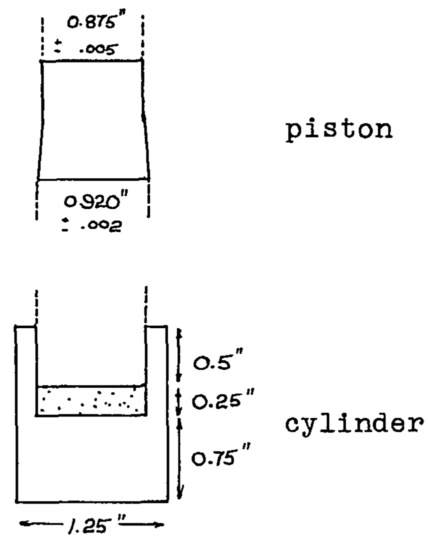
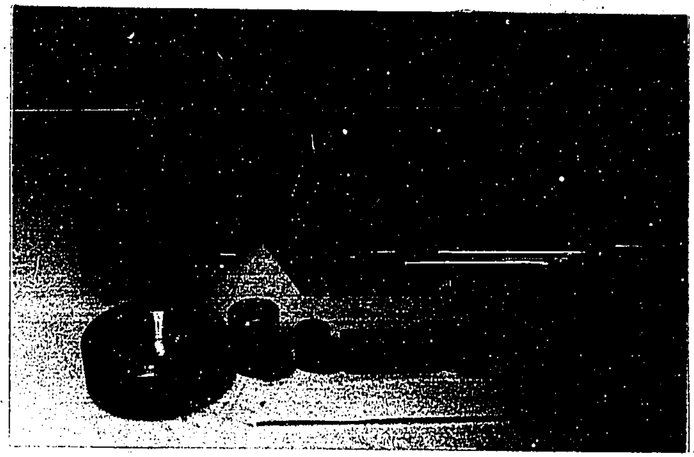


FIG.16 BASIC COMPONENTS OF SYSTEM OF PLASTIC LOADING

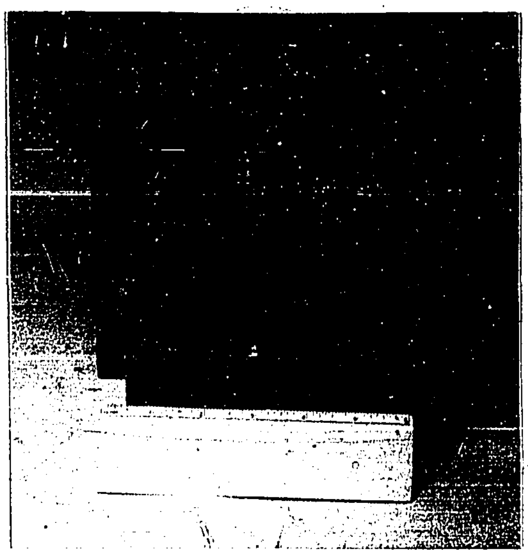


Details of cylinder and piston

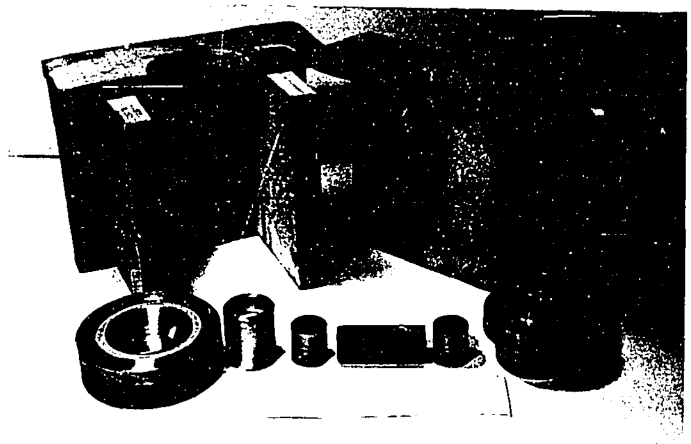




Photograph II.
Components of the'plastic loading'system.

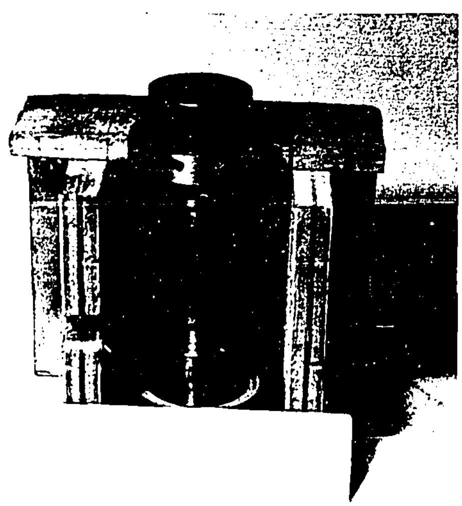


Photograph I2.
Assembled components.



Photograph II.

Components of the'plastic loading'system.



Photograph I2.

Assembled components.

SECTION 4. STRAIN GAUGES

4.I. STRAIN GAUGE FIXATION

Gauge disposition was dependent upon the object of each test. The two gauge types used were Philips PR 98I4 (gauge size 0.I5 ins. long by 0.08 ins. wide) and Budd C6-I2I (gauge size 0.I25 ins. square). The specimen surface was smoothed with emery paper to remove dirt and projections. A 'criss-cross' scratch pattern was applied to the gauge position, previousely marked with reference to pre-drawn patterns. Strain gauges were applied as instructed and allowed to set in shaped wooden presses (fig. I3). Budd gauges were used only on two occasions (tests C.I & 2).

Special attention was paid to the soldering of connections, a potential source of errors. In all cases there was one common connection between all the gauges, made possible by fixing a single strand of bare wire around the specimen and soldering one lead from each gauge to it. This reduced the number of leads to the specimen.

4.2. STRAIN READING EQUIPMENT AND EXPERIMENTAL PROCEDURE

Photograph I3 of the equipment can be seen on page 25. A diagramatic lay-out is given in fig. I5. Leads from the active gauges were taken to a I5 position switching box. The output of this box and the specimen common lead were then connected to a Budd Strain Indicator. The I/4 bridge network with compensating gauge was used. Readings were variable to 2 micro-ins./in., and accurate to 5 micro-ins./in.

Philips gauges, where possible, were stressed through 5 preliminary cycles to I0,000 psi to eliminate hysteresis effects.

All strains were computed by reference to the initial no-load reading of that particular cycle. The sign convention adopted for computations was that positive strain denoted tension and negative strain compression. The units - micro strain - are in micro inches per inch throughout the work. For convenience on graphs strains were plotted along the positive axis.

4.3. APPLICATIONS OF STRAIN GAUGES

Stress/strain curves, the modulus of elasticity and Poisson's ratio are frequently determined by strain measurements at the mid-height of a specimen.

The area covered by the gauge is important as strain readings refer only to that area, and for a given load depend upon:-

(a) The overall stress distribution, which depends on end conditions,

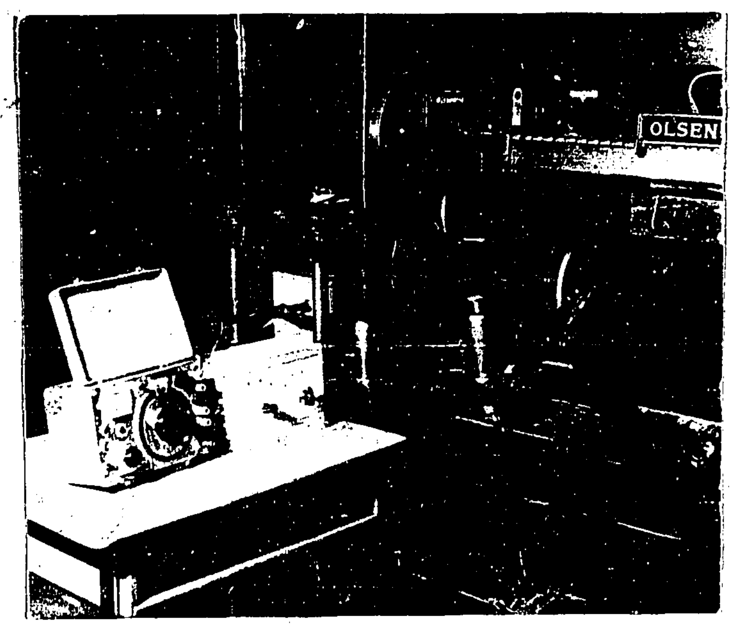
(b) Local stress concentrations depending on rock composition.

Where there is end restraint due to friction or other causes the stress distribution is not uniform through the specimen. Theoretical solutions based on the theory of elasticity are available (5) and (6). Such solutions indicate a relatively uniform longitudinal stress distribution around the circumference, over approximately the middle 5/6ths of the specimen, although the values of this stress may differ appreciably from the applied stress.

It is frequently assumed that the average reading of two diametrically opposite gauges, whether lateral or longitudinal is the strain value that would be obtained at that particular height if the specimen were evenly loaded. It is possible to check this assumption by mounting two sets of diametrically opposite gauges (designated(I & 3) and(2 & 4)in table I) at one specimen height. If the average strains recorded by the two sets are the same then the above assumption is justified. Table I sets out the results obtained based on gauge disposition and load equalizing system. Differences of upto IO micro inches/inch can be attributed to instrumental errors.

It is apparent that there are differences in the two averages but of importance mainly when the spherical block was used for loading and also when gauges were mounted near specimen ends.

It was hoped that with a rock as apparently homogeneous as this Trenton limestone local stress concentrations resulting from rock composition would not be significant.



Photograph I3.
Tinius Olsen loading machine and strain reading equipment.

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Photograph I3.

Tinius Olsen loading machine and strain reading equipment.

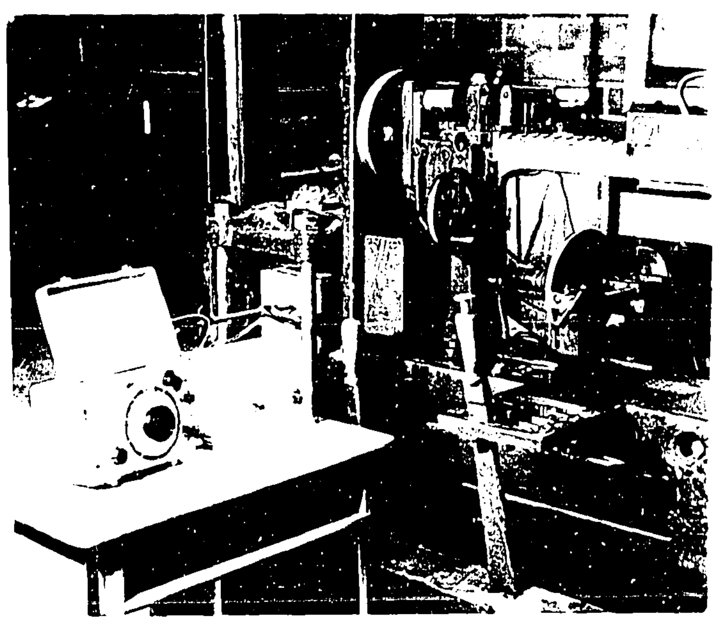
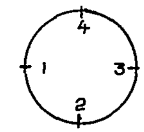


TABLE I DISCREPANCIES IN AVERAGING STRAIN GAUGE READINGS - AVERAGE STRAINS INDICATED BY TWO SETS OF DIAMETRICALLY OPPOSITE GAUGES AT THE SAME HEIGHT ON SPECIMEN



Gauge disposition		Specimen type	Loading system	Cycle no.	Stress ksi	Av.of gauges (I&3) micro-ins/in	Av.of gauges (2&4) micro-ins/in	Refer to appendix table no.
orientation	position							
Longitudinal	Mid-height	Steel	Plastic (3.I.3)	I 2 3	39.2 39.2 40.6	I342 I355 I375	I337 I360 I370	A.I.I
"	"	"	Direct (3.I.I)	I 2 3	4I.7 39.7 40.5	I405 I350 I365	I4I2 I332 I365	A.I.2
"	"	"	Spherical block (3.I.2)	I 2 3	32.7 39.3 40.0	I067 I300 I345	I082 I3I7 I357	A.I.3
Longitudinal	Mid-height	Lime-stone	Plastic	I 2 3 4	I6.3 I6.3 I6.6 36.6	I337 I352 I357 3I27	I340 I355 I357 3II5	A.2.
Longitudinal	I5/I6ths height	Lime-stone	Plastic	I 2 3	9.6 I2.7 33.0	850 II40 2790	860 II00 2745	A.3.
Lateral	Mid-height	Lime-stone	Plastic	I	7.5	I87	I85	C.I.
"	"	"	"	I 2	I7.I I4.3	545 423	540 420	C.2.

SECTION 5. RESULTS

5.I. THE EFFECT OF LOAD EQUALIZING SYSTEM ON UNIAXIAL COMPRESSIVE STRENGTH AND STRAIN MEASUREMENTS

5.I.I. Uniaxial compressive strength

A summary of the uniaxial compressive strengths obtained under three different loading conditions is given in table 2. The end preparation procedure (lathe preparation procedure no. I - see page 7) was identical for each specimen. The data can be found in full in tables D.I., D.2., and D.3. of the appendix.

Test D.I. gives the mean compressive strength and standard deviation when plastic loading was used, D.2. with the spherical block. D.3. however, the only test in which pistons were not used, gives a further set of values obtained with the spherical block, but where the specimen was in immediate contact with full sized platens.

It was noted that specimens always failed violently. Examples of fragmentation can be seen in photographs I4, I5 and I6.

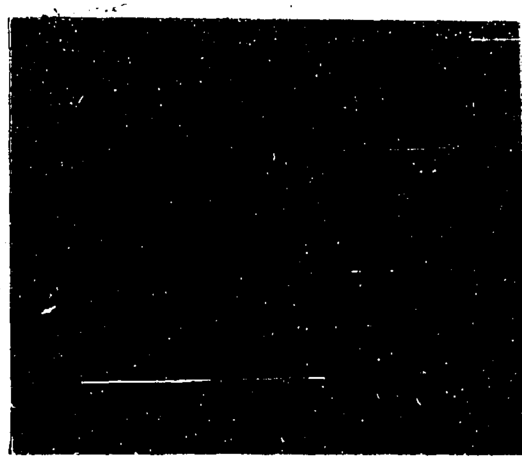
TABLE 2 EFFECT OF LOADING SYSTEM ON UNIAXIAL COMPRESSIVE STRENGTH

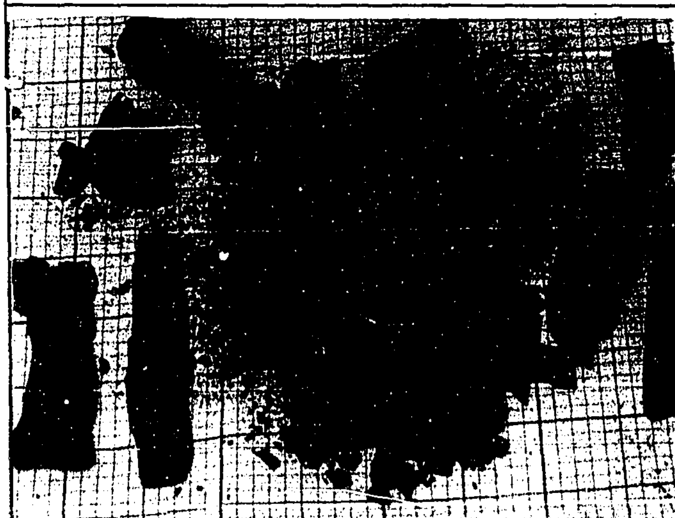
Loading system	No. of specimens tested	Mean strength psi	Standard deviation psi	Coef. of variation %	Mean L/D ratio	Appendix table no.
Plastic loading	I5	4I,300	4,000	9.7	2.47	D.I.
Spherical block with pistons	I5	35,800	5,800	I5.3	2.45	D.2.
Spherical block without pistons	I4	37,600	5,I00	I3.5	2.47	D.3.

Photograph I4.

Example of the fragmentation of a limestone specimen following failure at 25.9 Ksi

Photograph I5. Example of a specimen end after failure.





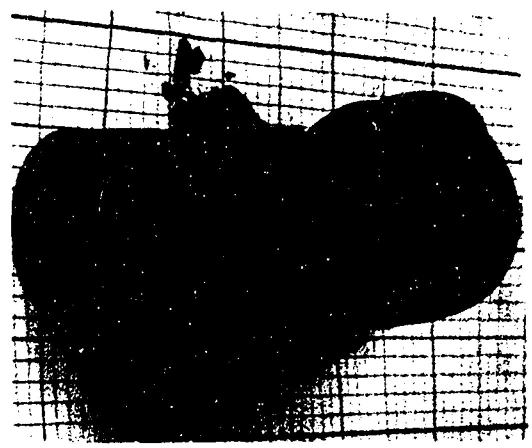
Photograph I6.

Example of the fragmentation of a limestone specimen following failure at 36.I Ksi.

Photograph I4.

Example of the fragmentation of a limestone specimen following failure at 25.9 Ksi

Photograph I5. Example of a specimen end after failure.



Photograph I6.

Example of the fragmentation of a limestone specimen following failure at 36.I Ksi.

5.I.2. Strain measurements

Strain measurements, apart from allowing a determination of the effect of load equalizing system on elastic moduli measurements, can also be used to assess the effectiveness of each equalizing system provided the gauge disposition is correct. Uniform loading of a homogeneous test specimen will result in a stress distribution symmetrical about the specimen's longitudinal axis. Strain gauges mounted at any specimen height, say the mid-height, should register the same strain for a given load.

Steel specimens (see page I6) were used for the following test. Four equally spaced, longitudinally orientated strain gauges were mounted at the specimen mid-height. Three series of tests were conducted. The means of load equalization was different for each series. Pistons were used every time to standardize tests. Each series comprised three specimen loadings to approximately 40,000 psi. Between each loading the specimen and pistons together were turned through I20°. The complete results can be found in tables A.I.I. - 3. of the appendix. From this data figs. I7 to 22 have been plotted.. Each one is a plot of stress against longitudinal strain. In some cases the longitudinal strains are those obtained from the four individual gauges (figs. I7 I8 and I9), and in the others they are the mean of the four gauges. Those diagrams where individual gauge readings have been utilized allow a comparison of the load equalization achieved with plastic loading (fig. I7), direct loading (fig. I8), and the spherical block (fig.I9). Fig. 20 sets out curves of stress against mean longitudinal strain for the three above cases. Thus it is possible to note any variation in the measurement of the modulus of elasticity caused by the load equalizing system employed. Finally figs.2I and 22 provide a comparison of the reproducability of data afforded by plastic loading and the spherical block.

FIG.17 STRESS/LONGITUDINAL STRAIN DIAGRAM - INDIVIDUAL GAUGE READINGS - STEEL SPECIMEN - LOAD EQUALIZING BY PLASTIC LOADING

RE. TABLE:A.1.1.(3).

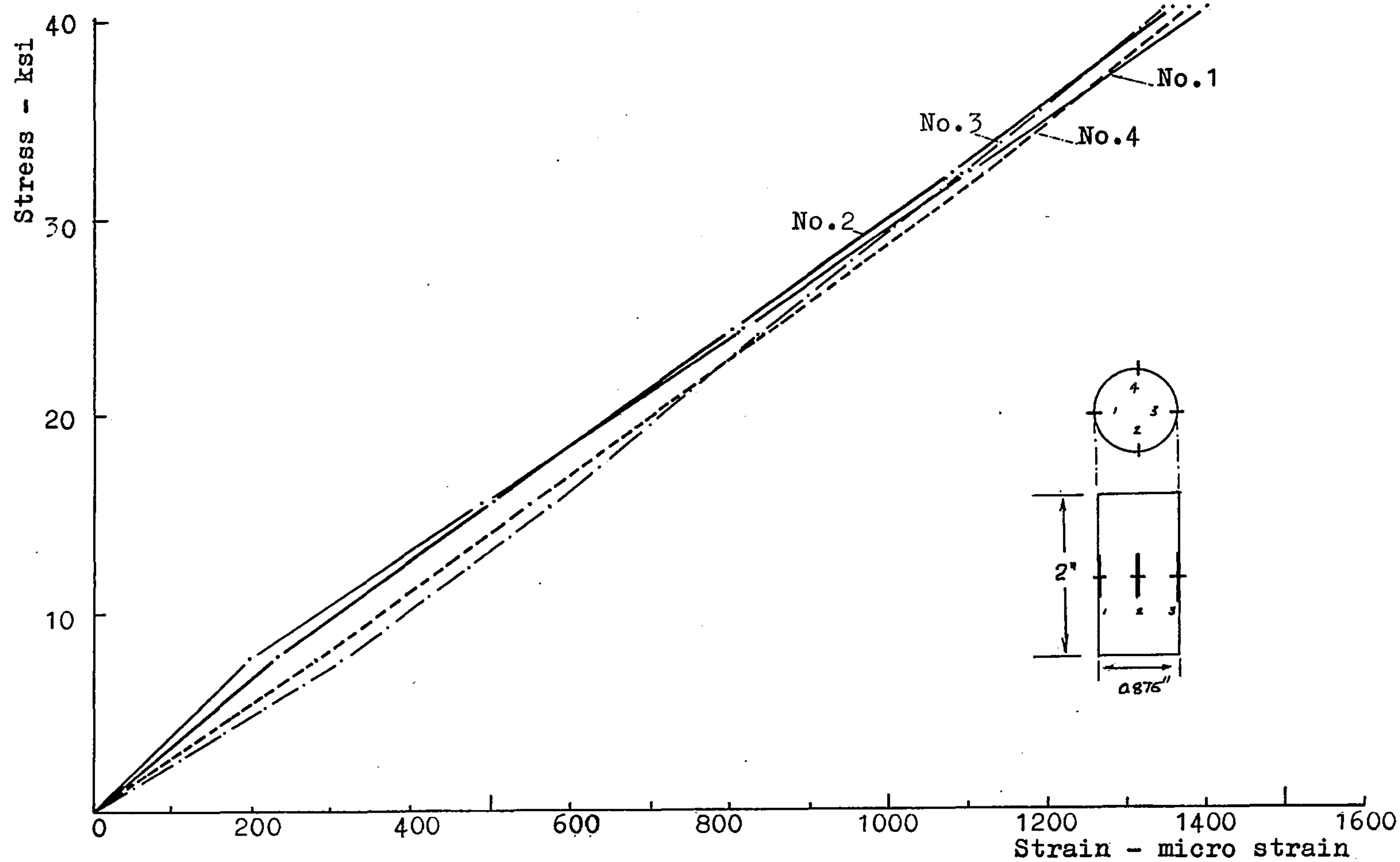


FIG.I8 STRESS/LONGITUDINAL STRAIN DIAGRAM - INDIVIDUAL GAUGE READINGS - STEEL SPECIMEN - DIRECT LOADING

RE. TABLE A.I.2.(I).

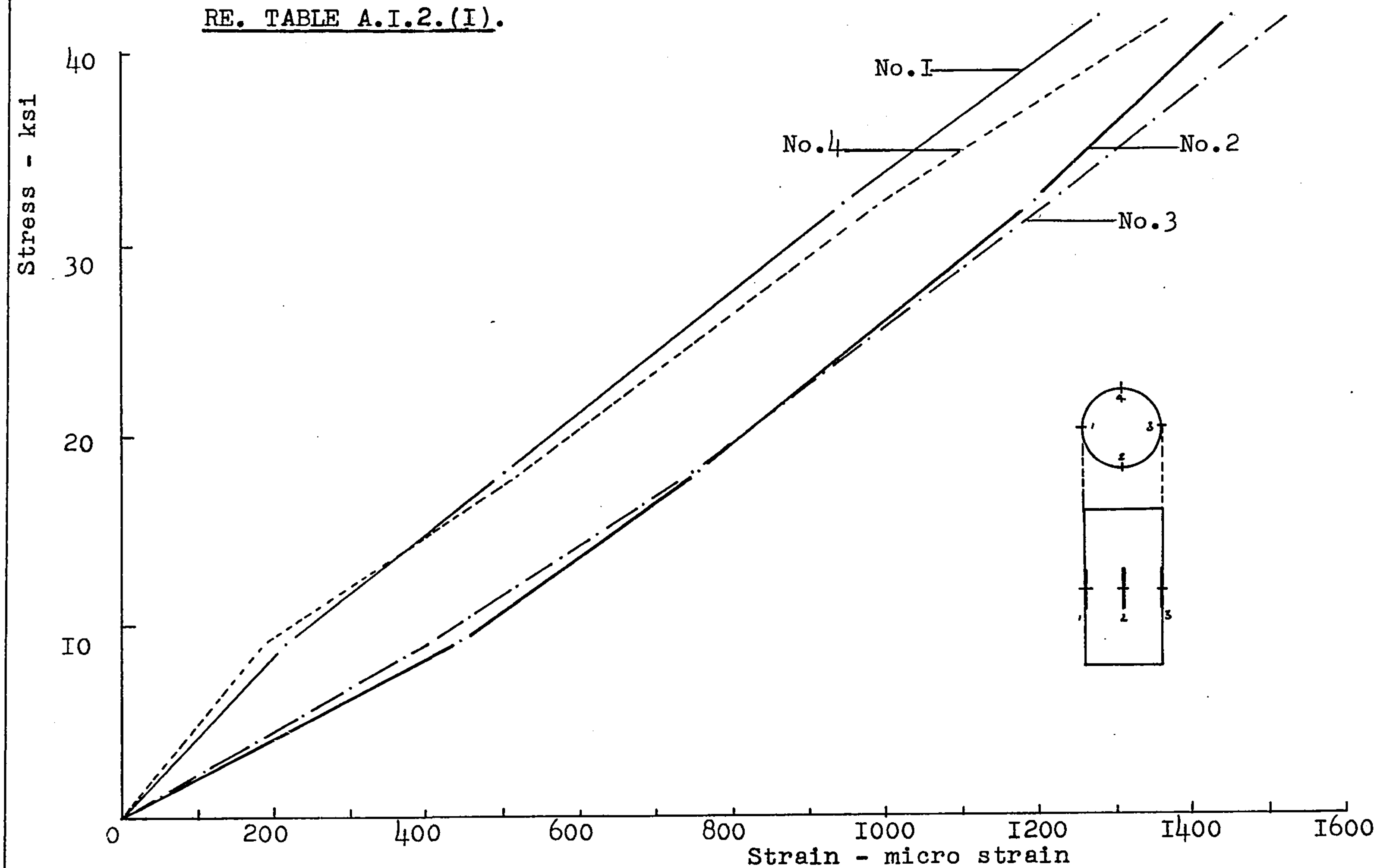


FIG. I9 STRESS/LONGITUDINAL STRAIN DIAGRAM - INDIVIDUAL GAUGE READINGS - STEEL SPECIMEN - LOAD EQUALIZING BY SPHERICAL BEARING BLOCK. RE: TABLE A.1.3.(3)

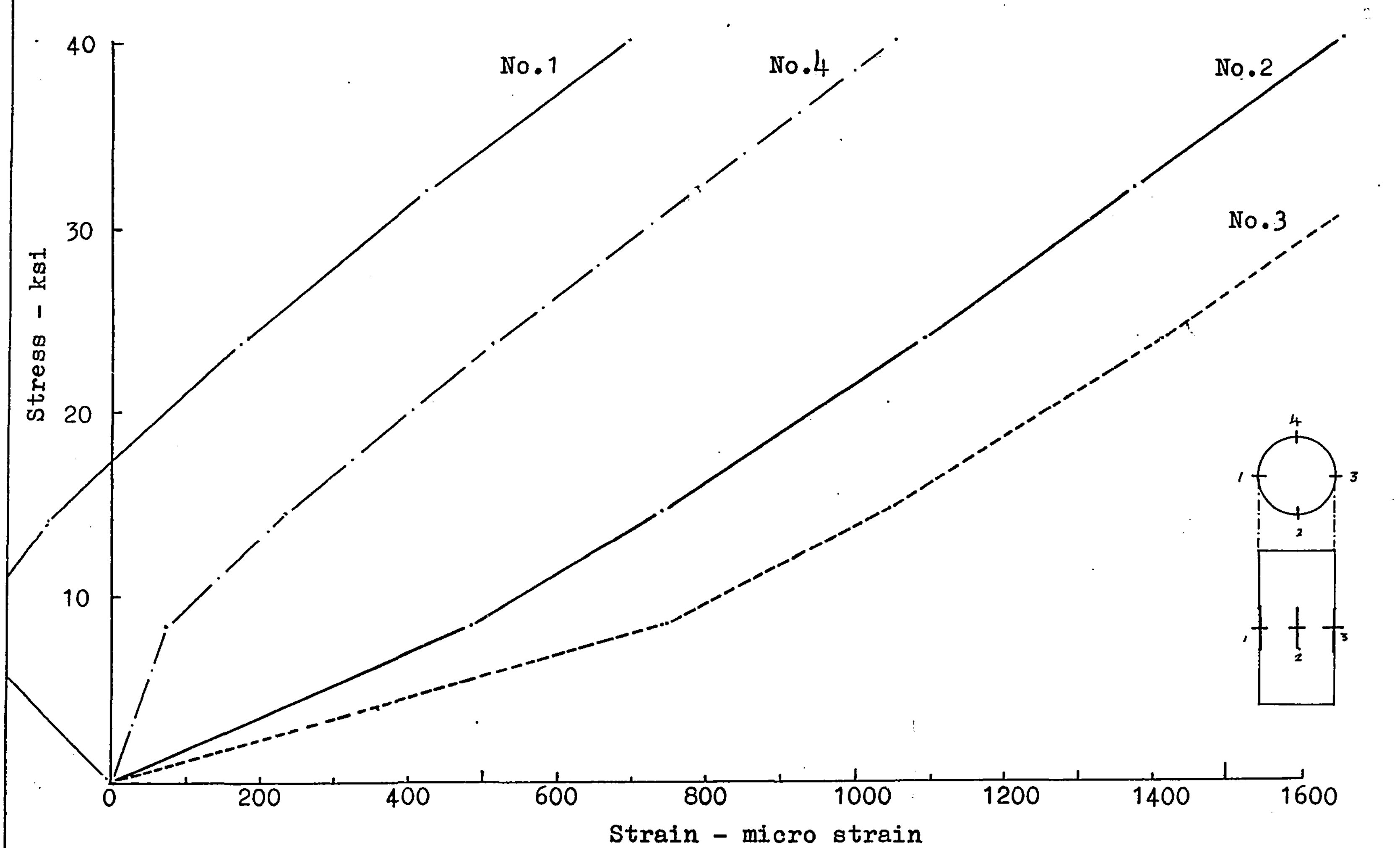


FIG.20 STRESS/LONGITUDINAL STRAIN DIAGRAM - MEAN OF FOUR GAUGE READINGS - ONE CURVE FOR EACH LOADING SYSTEM - STEEL SPECIMEN RE. TABLES A.I.I.(3).,A.I.2.(I).,A.I.3.(3).

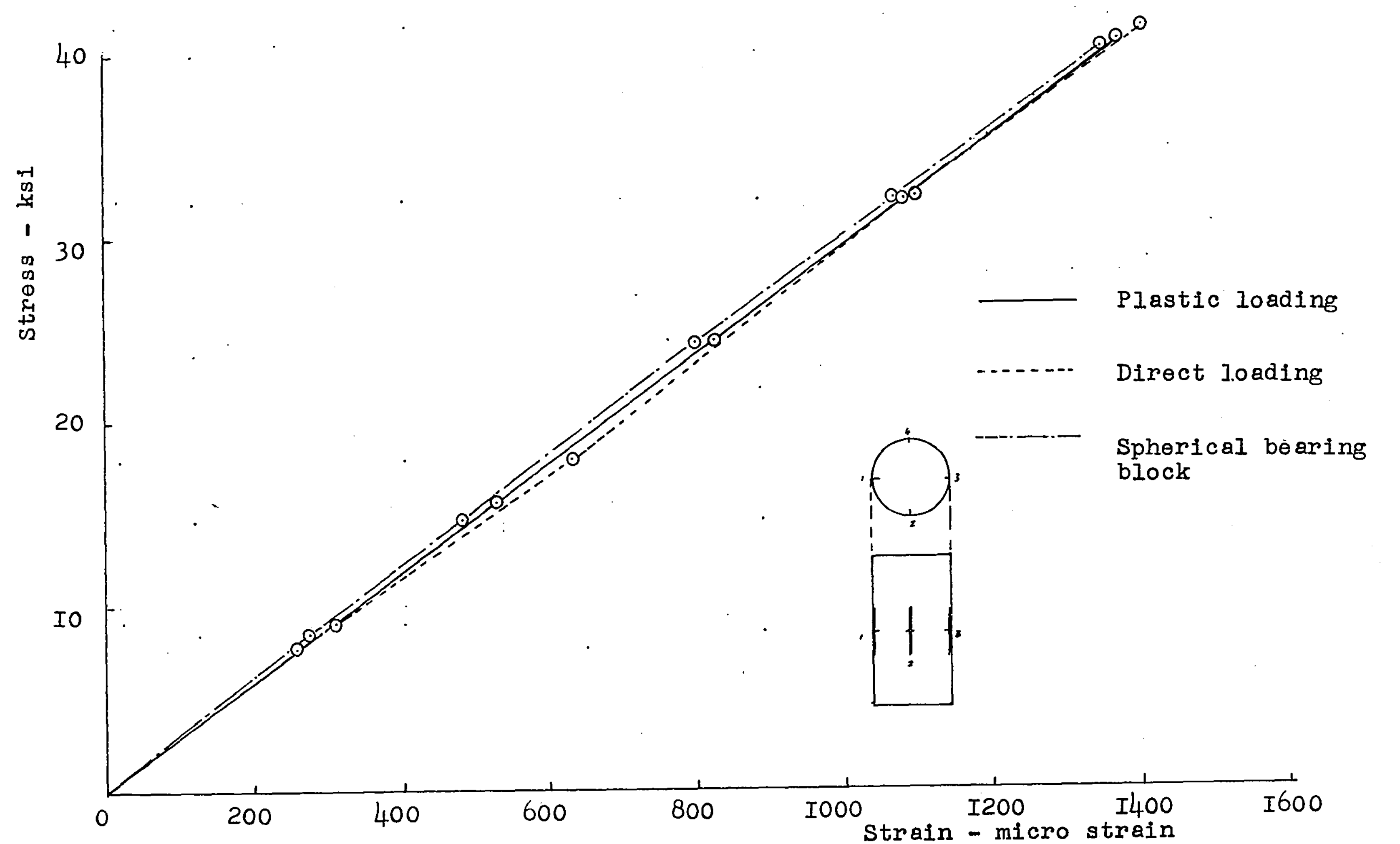


FIG.21 STRESS/LONGITUDINAL STRAIN DIAGRAM - 3 INDEPENDENT CYCLES - STEEL SPECIMEN - LOAD EQUALIZING BY PLASTIC LOADING RE: TABLE A.1.1.

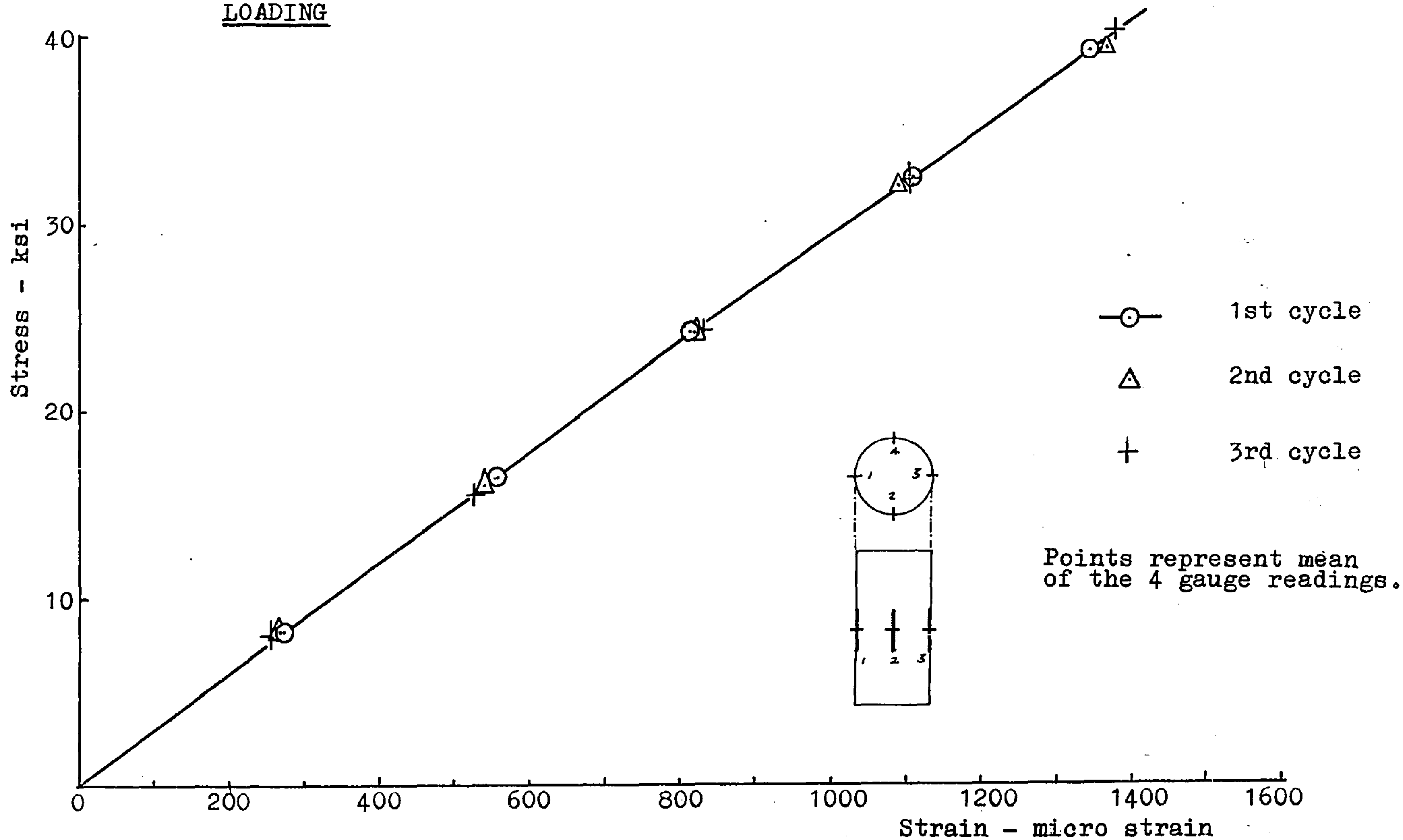
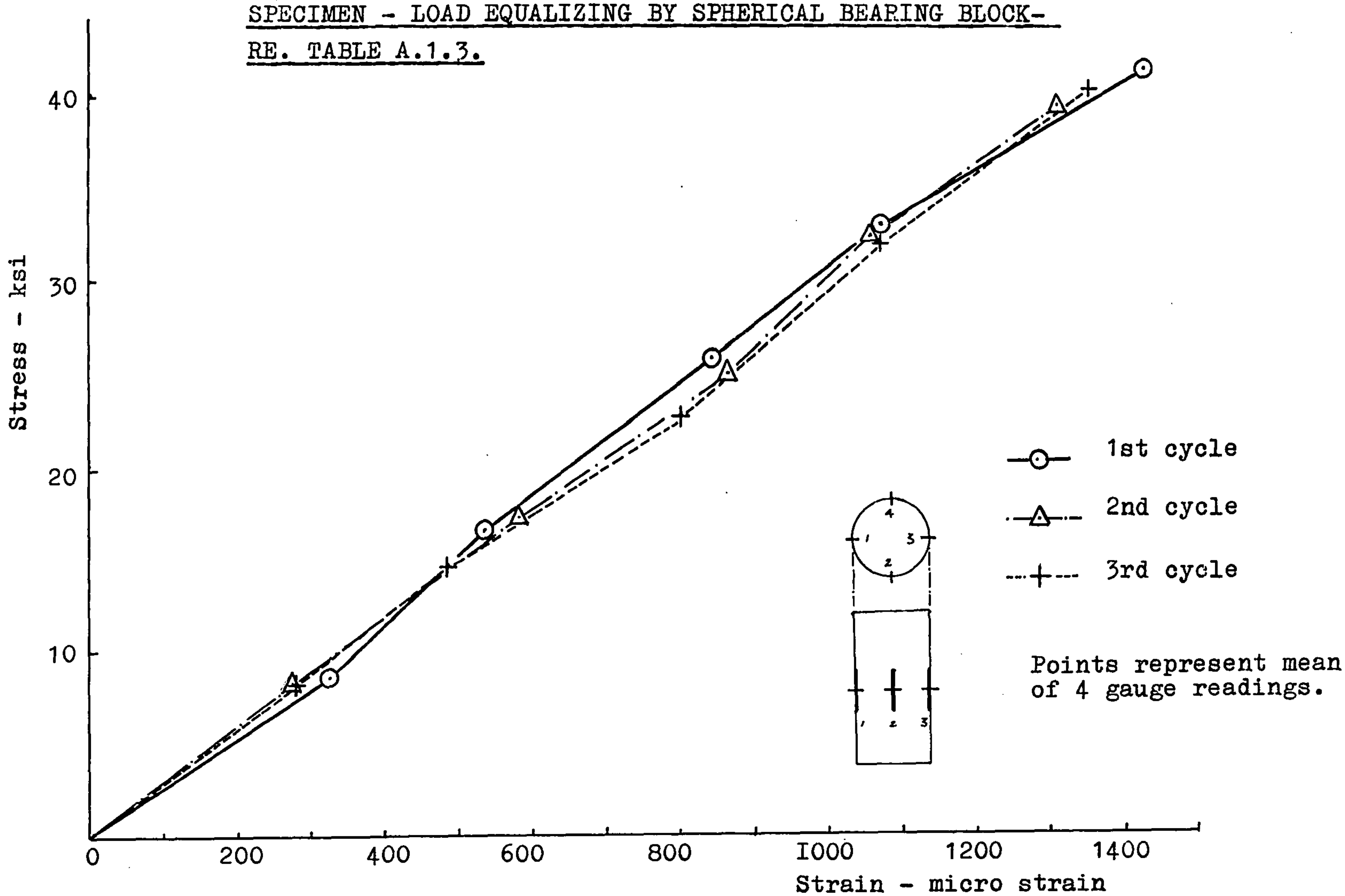


FIG. 22 STRESS/LONGITUDINAL STRAIN DIAGRAM - 3 INDEPENDENT CYCLES - STEEL SPECIMEN - LOAD EQUALIZING BY SPHERICAL BEARING BLOCK- RE. TABLE A.1.3.



5.2. THE EFFECT OF END PREPARATION TECHNIQUE ON UNIAXIAL COMPRESSIVE STRENGTH AND STRAIN MEASUREMENTS

5.2.I. Uniaxial compressive strength

Table 3 summarises the data given in tables D.I. and D.4. - 6. of the appendix. Each group of specimens was given a different lathe preparation procedure (four in all - see page 7). Only the system of plastic loading was used.

TABLE 3 EFFECT OF LATHE PREPARATION PROCEDURE ON UNIAXIAL COMPRESSIVE STRENGTH

Preparation procedure (finish)	No. of specimens tested	Mean strength psi	Standard deviation psi	Coef. of variation %	Mean L/D ratio	Appendix table no.
No.I (rough, non-vitreous no heating)	I5	4I,300	4,000	9.7	2.47	D.I.
No.2 (smooth, non-vitreous no heating)	I5	42,300	4,700	II.I	2.46	D.4.
No.3 (smooth, vitreous, slight heating)	I5	42,600	4,500	I0.5	2.43	D.5.
No.4 (smooth, vitreous, excessive heating)	I3	36,300	6,300	I7.4	2.45	D.6.

5.2.2. Strain measurements

One difficulty in studying the influence that end preparation technique has on specimen response to load is that of ensuring standardized end conditions of both the specimen and loading platens, in this case the pistons (particularly after several specimen loadings), so that results are reproducible.

To determine whether the strain pattern exhibited by a lathe prepared specimen under load was different to that of a hand lapped specimen strain gauges were mounted along the lengths of several specimens prepared by the two procedures. The results where longitudinal gauges were employed can be seen in figs.23 to 25 where the strains for three specimen heights are plotted. Examples of lateral strain distributions are given in figs. 26 to 28 and 3I to 33.

The effect of preparation procedure on strain pattern is interesting, but of greater importance is the effect on experimental values of the elastic moduli. To this end, strain readings were obtained for a specimen originally lathe prepared and then hand lapped. The relevant lateral strain distributions are given in fig. 26. Removing the specimen for lapping meant different relative positions of the specimen and pistons on reassembly, the effect of which had also to be considered, as can be appreciated from fig.26d.

Only the one loading system, plastic loading, was used in the above tests.

FIG.23 STRESS/LONGITUDINAL STRAIN - AVERAGE GAUGE READINGS-LIMESTONE SPECIMEN - LATHE PREPN. PROC. I - PLASTIC LOADING RE. TABLE A.5.(5)

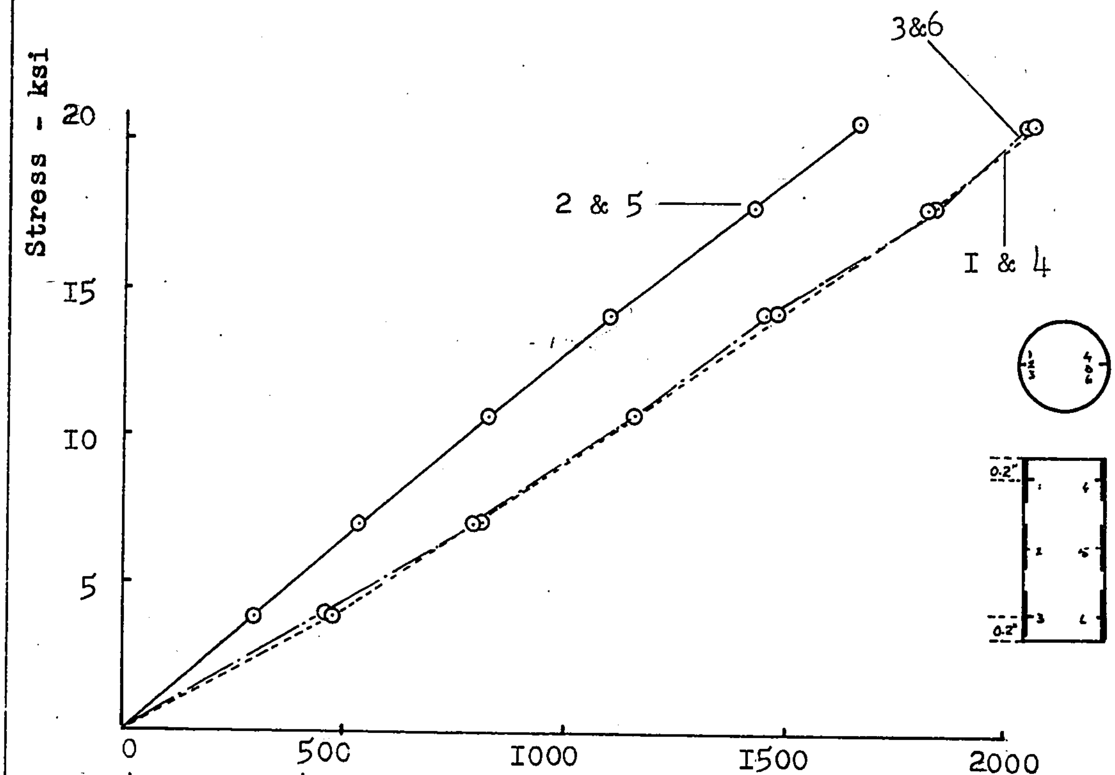


FIG.24 STRESS/LONGITUDINAL STRAIN - AVERAGE GAUGE READINGS-LIMESTONE SPECIMEN - HAND LAPPED - PLASTIC LOADING RE. TABLE A.6.(2)

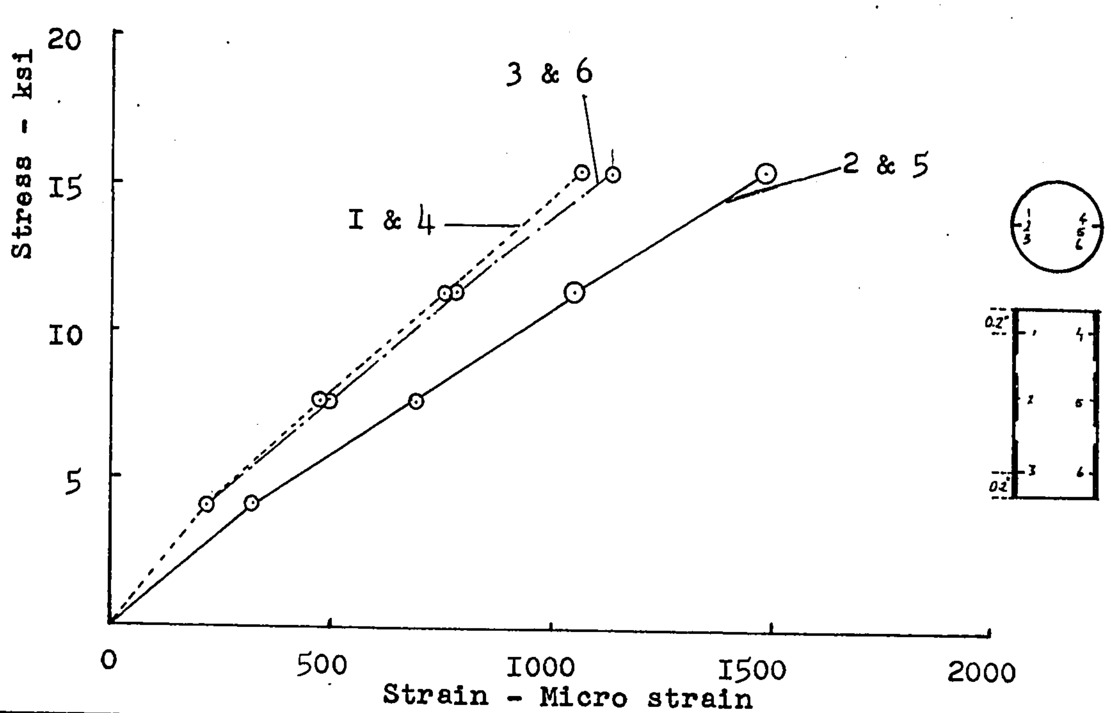
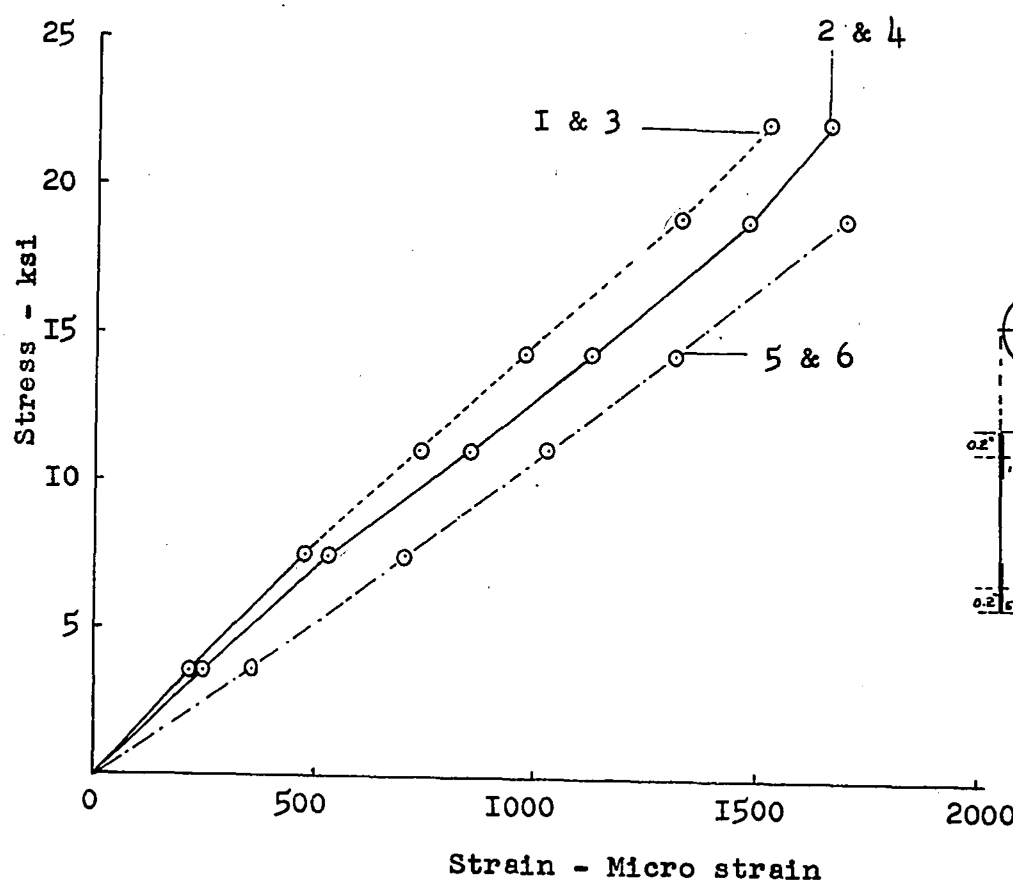


FIG.25 STRESS/LONGITUDINAL STRAIN - AVERAGE GAUGE READINGS - LIMESTONE SPECIMEN - LATHE PREPN. PROC. I - PLASTIC LOADING RE. TABLE A.4.(3)



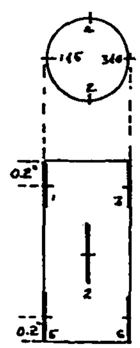


FIG.26 LATERAL STRAIN DISTRIBUTION - INDIVIDUAL AND AVERAGE GAUGE READINGS - PLASTIC LOADING - SPECIMEN ORIGINALLY LATHE PREPN. PROC. I , THEN HAND LAPPED

RE. TABLES C.3.(I) & (5)

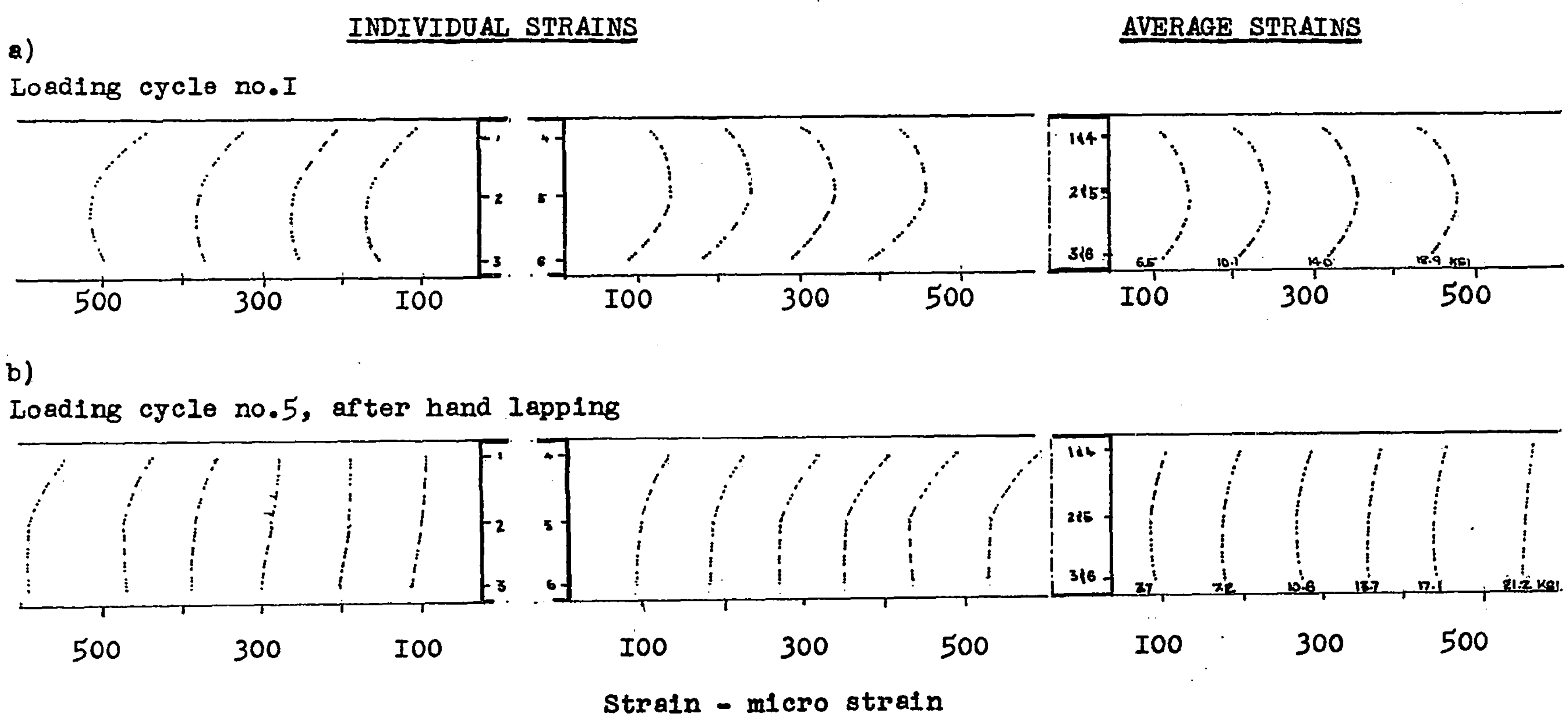
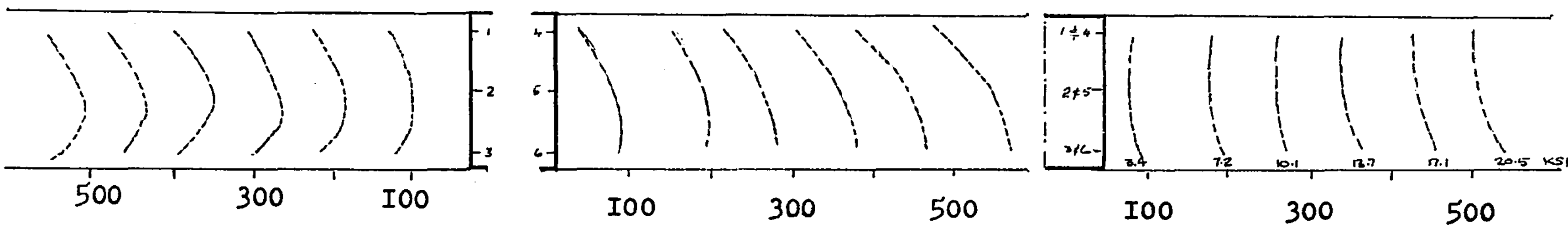


FIG.26 (CONT.)

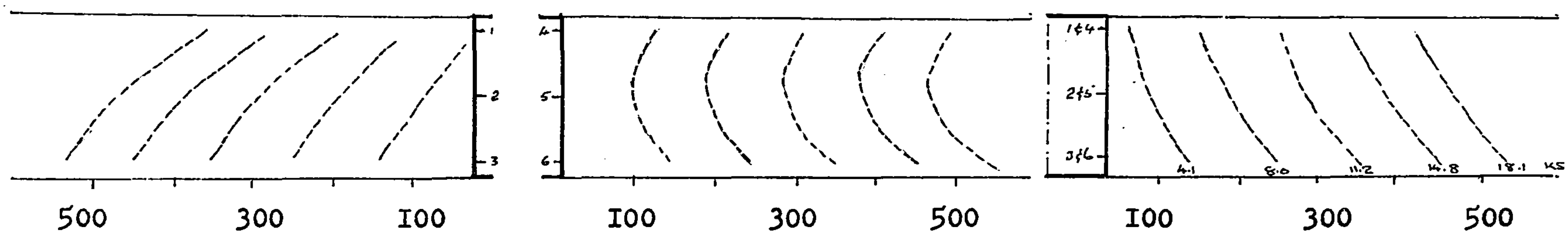
INDIVIDUAL STRAINS

AVERAGE STRAINS

c)
Loading cycle no.9 - specimen and pistons rotated together



d)
Loading cycle no.IO - pistons rotated relative to specimen



Strain - micro strain

FIG.27 LATERAL STRAIN DISTRIBUTION - INDIVIDUAL AND AVERAGE GAUGE READINGS - PLASTIC LOADING - LATHE PREPN. PROC. I - LIMESTONE SPECIMEN RE. TABLE C.4.(I)

INDIVIDUAL STRAINS

AVERAGE STRAINS

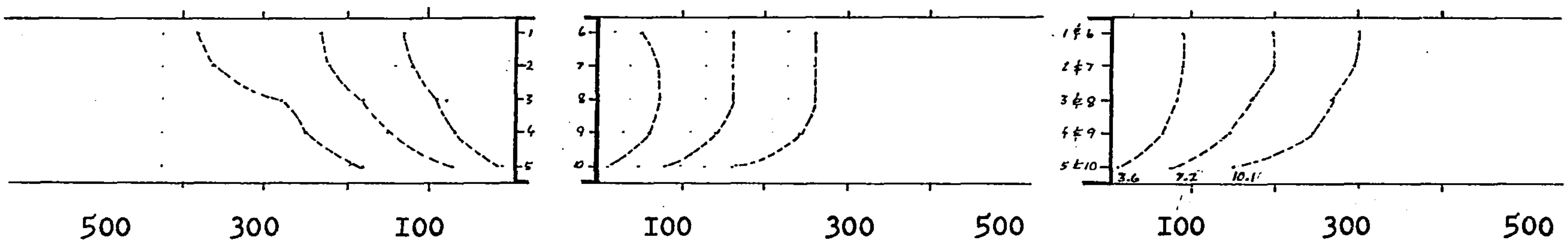
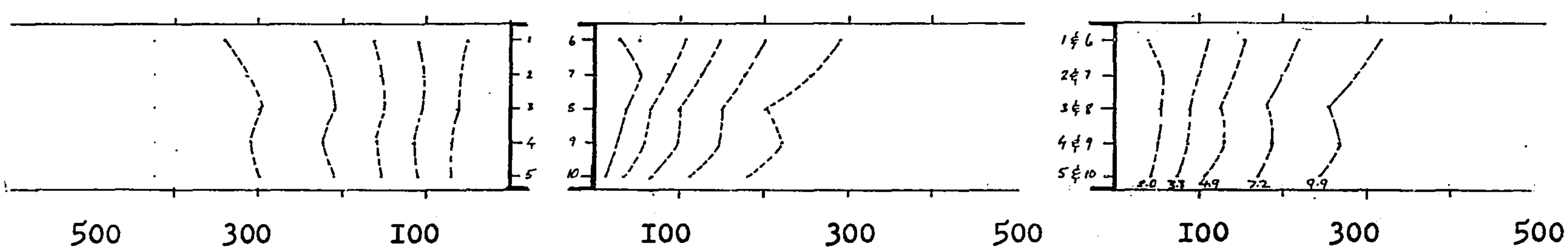


FIG.28 LATERAL STRAIN DISTRIBUTION - INDIVIDUAL AND AVERAGE GAUGE READINGS - PLASTIC LOADING - HAND LAPPED - LIMESTONE SPECIMEN RE. TABLE C.5.(I)

INDIVIDUAL STRAINS

AVERAGE STRAINS



Strain - micro strain

5.3. STRESS / STRAIN AND LATERAL DEFORMATION DIAGRAMS FOR TRENTON LIMESTONE SPECIMENS LOADED TO FAILURE

It was felt that several stress / strain and lateral deformation diagrams for this rock type would be of interest and also prove useful in assessing the potential of the limestone for further experimental work.

All specimens were loaded with the plastic loading system. In each case the specimen was loaded to failure.

Included is one stress / longitudinal strain diagram (fig. 29), one figure of stress against strain and Poisson's ratio (fig. 30), and three lateral strain distribution curves (figs. 3I, 32 and 33).

FIG.29 STRESS/LONGITUDINAL STRAIN - MEAN OF 4 GAUGE READINGS - LIMESTONE SPECIMEN

L/D = 2.5 - LATHE PREPN. PROC. I - PLASTIC LOADING RE. TABLE A.2.(4)

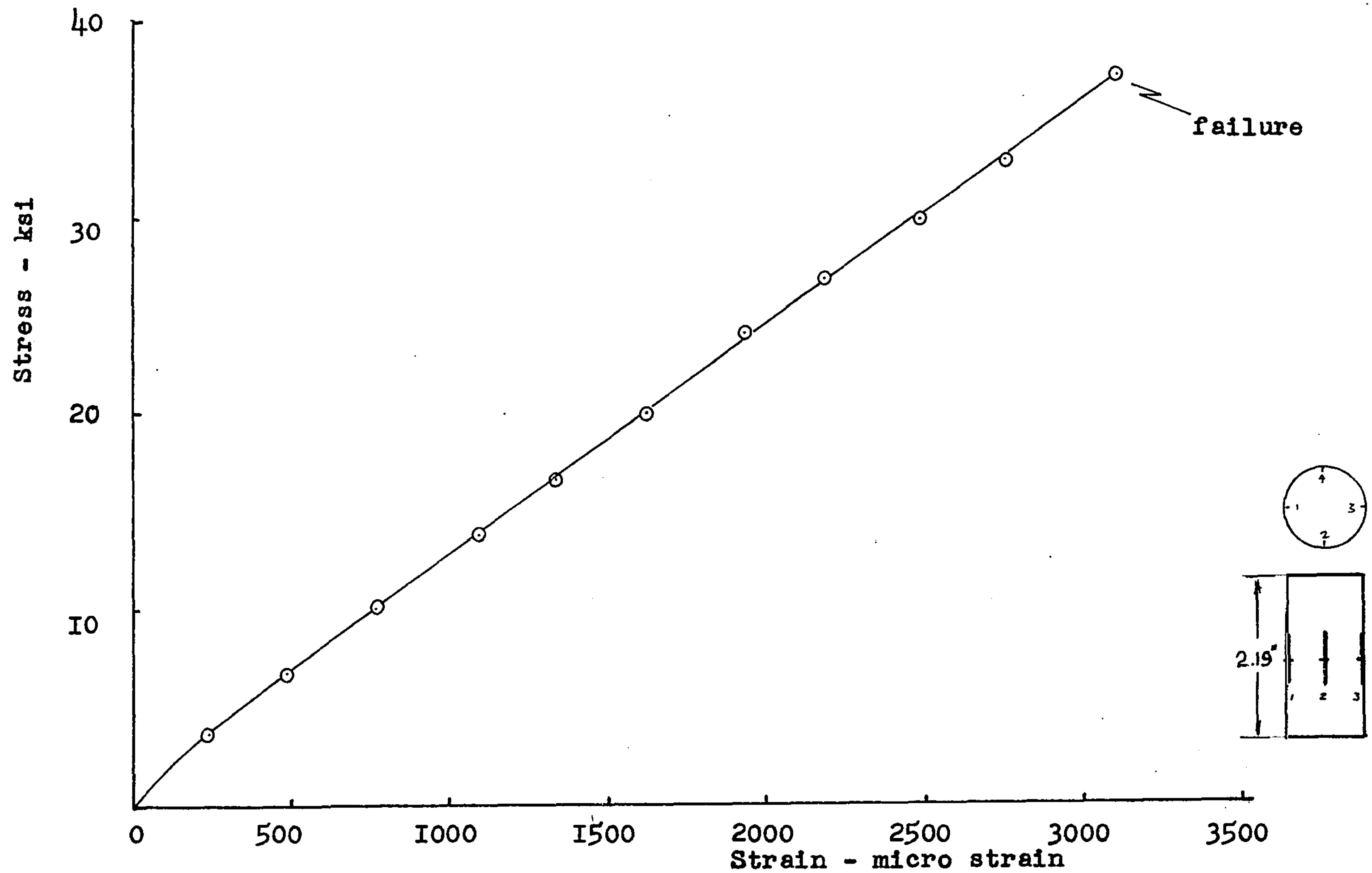


FIG.30 STRESS/STRAIN & POISSONS RATIO - MEAN OF 2 GAUGE READINGS - LIMESTONE SPECIMEN - L/D = 2.4 - HAND LAPPED - PLASTIC LOADING RE. TABLE B.2.(2)

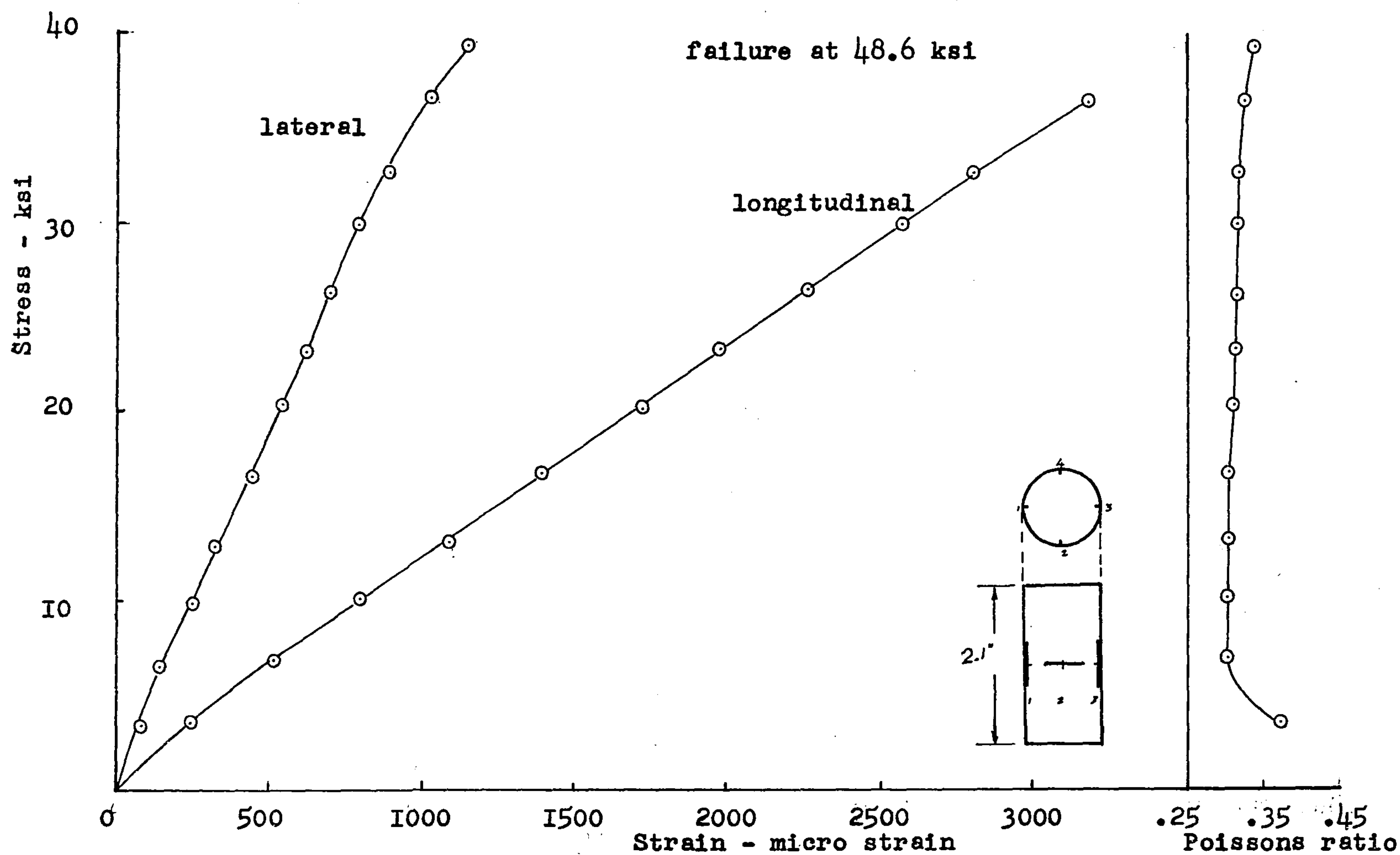


FIG.3I LATERAL STRAIN DISTRIBUTION TO FAILURE OF A LIMESTONE SPECIMEN, L/D = 2.5 - INDIVIDUAL AND AVERAGE GAUGE READINGS - HAND LAPPED - PLASTIC LOADING RE. TABLE C.6.

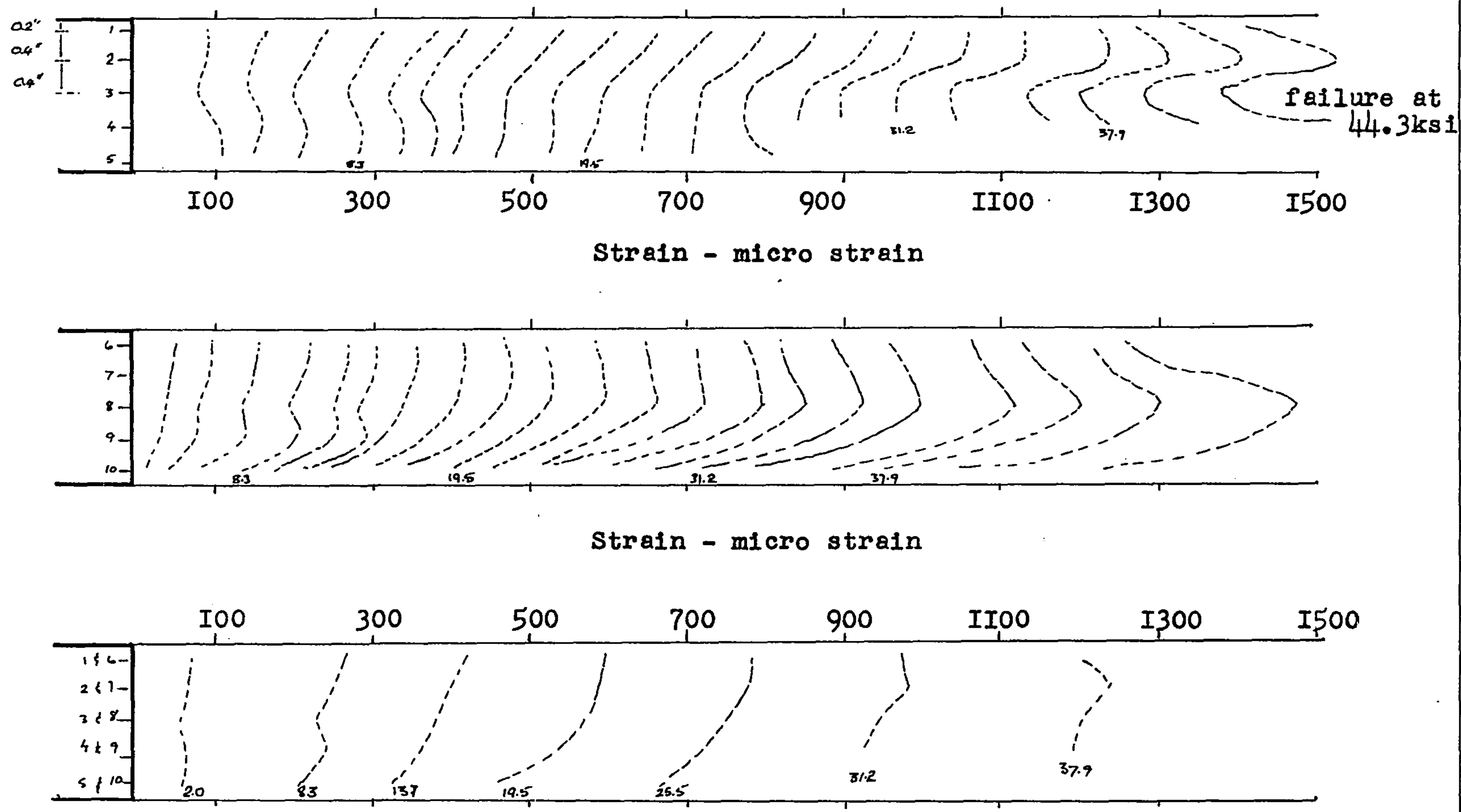


FIG.32 LATERAL STRAIN DISTRIBUTION TO FAILURE OF A LIMESTONE SPECIMEN, L/D = 2.4 - INDIVIDUAL AND AVERAGE GAUGE READINGS - HAND LAPPED - PLASTIC LOADING RE. TABLE C.7.

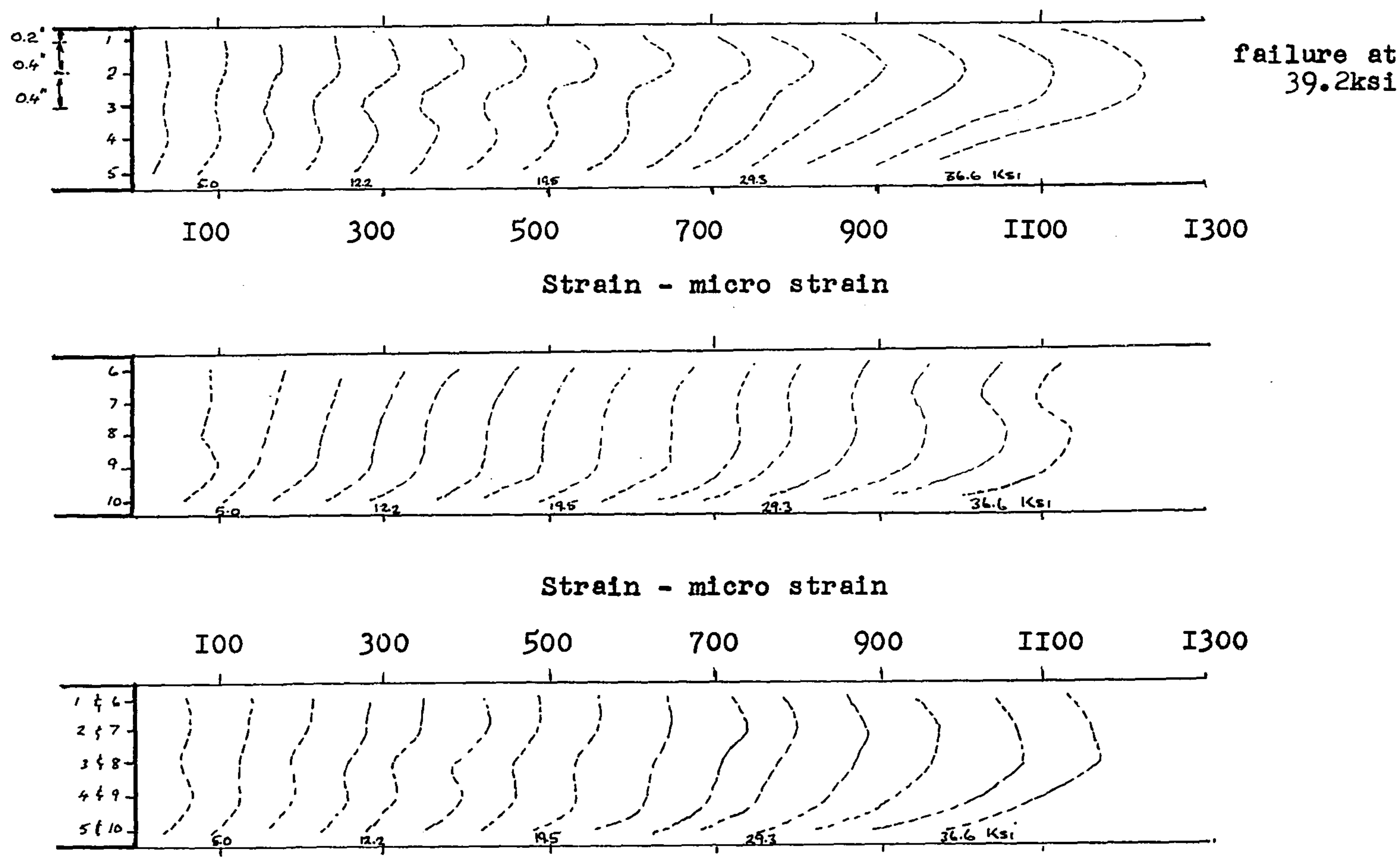


FIG.32 LATERAL STRAIN DISTRIBUTION TO FAILURE OF A LIMESTONE SPECIMEN, L/D = 2.4 - INDIVIDUAL AND AVERAGE GAUGE READINGS - HAND LAPPED - PLASTIC LOADING RE. TABLE C.7.

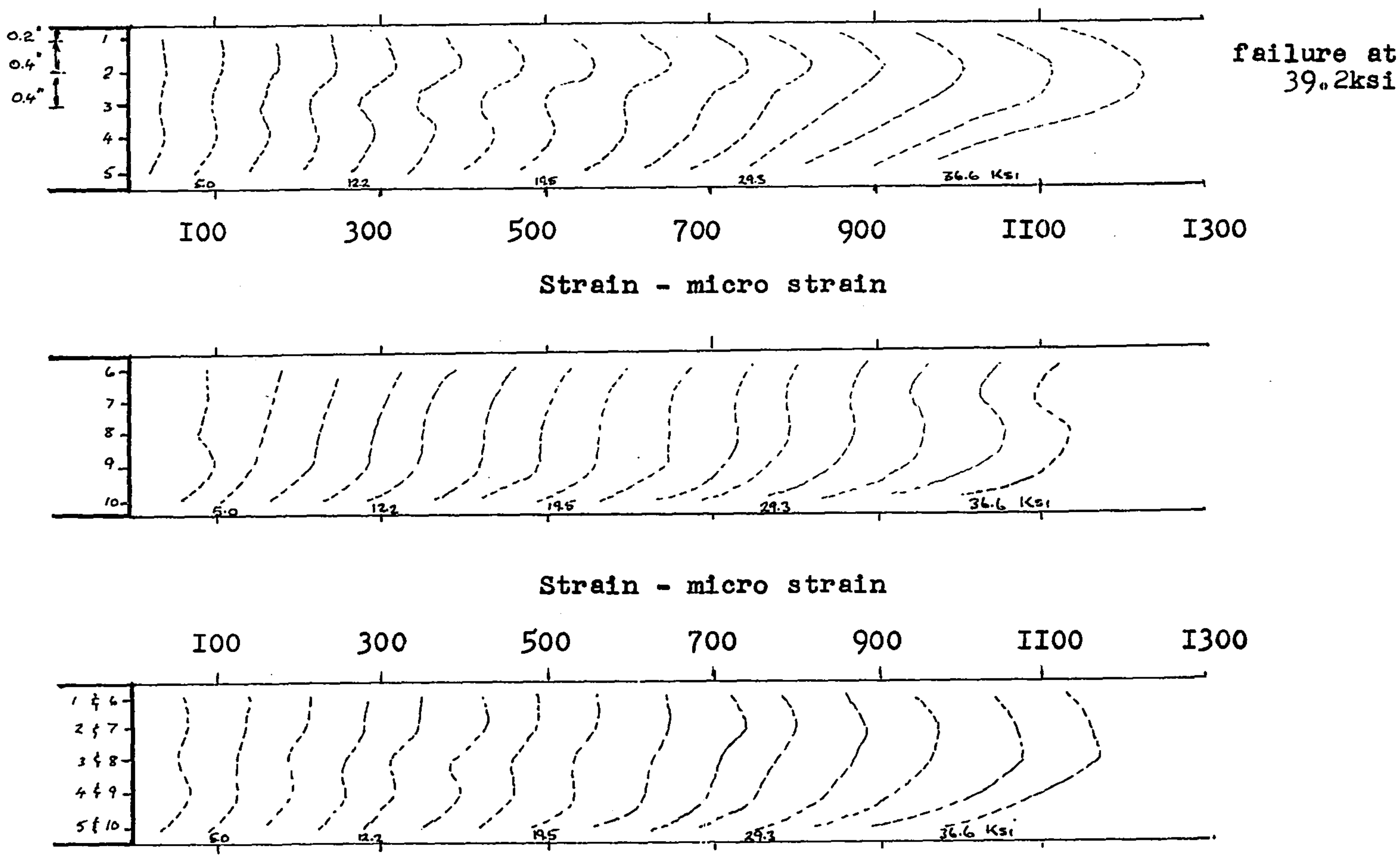
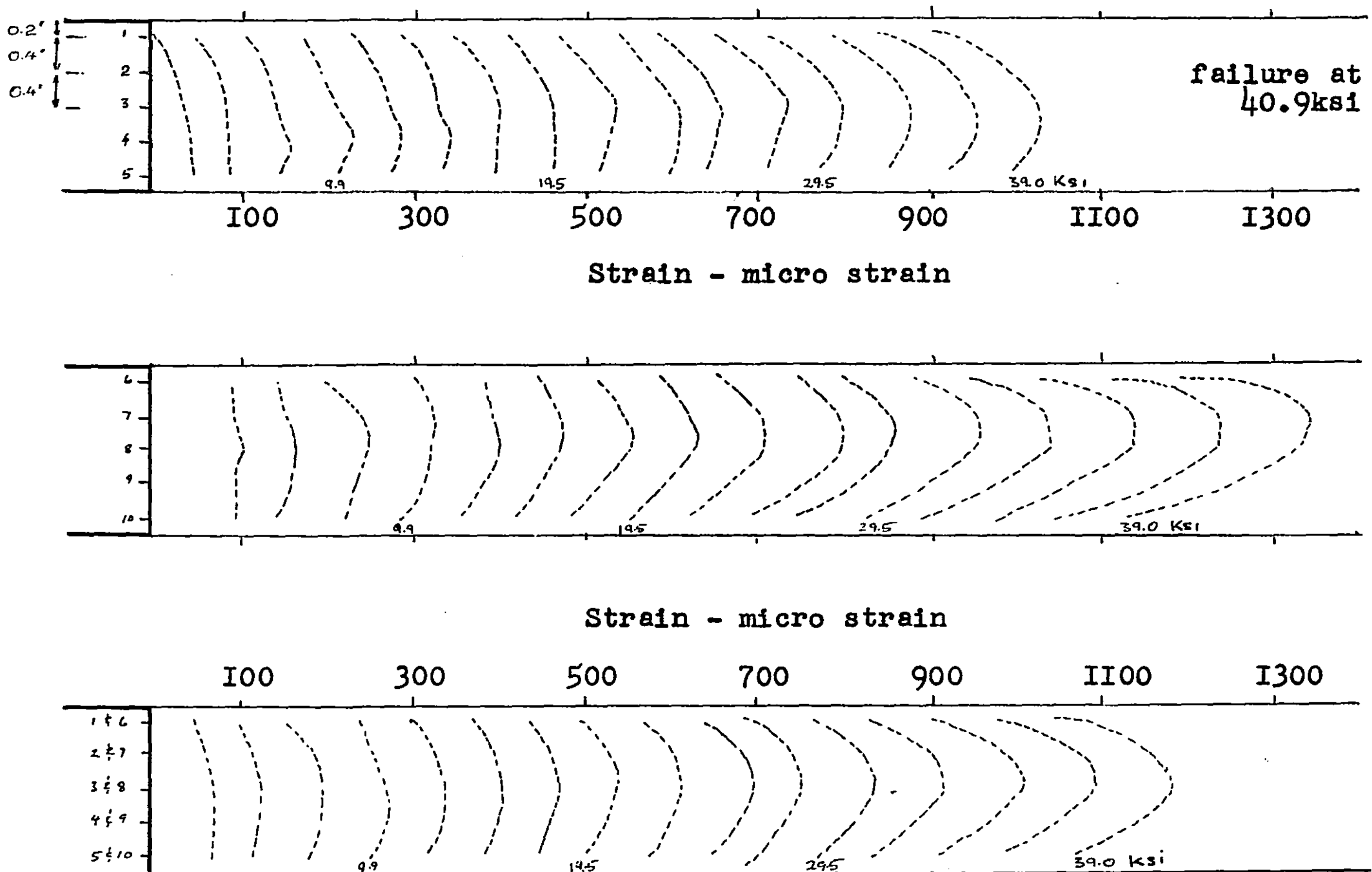


FIG. 33 LATERAL STRAIN DISTRIBUTION TO FAILURE OF A LIMESTONE SPECIMEN, L/D = 2.4 - INDIVIDUAL AND AVERAGE GAUGE READINGS - LATHE PREPN. PROC. 3 - PLASTIC LOADING RE. TABLE C.8.



SECTION 6. DISCUSSION OF RESULTS

Efficient specimen end preparation should provide flat, and if possible, parallel ends. These specimen ends may diverge by 5 - I0 thou. over the specimen diameter depending on the type and condition of the preparation device employed. However this divergence may be well within the divergence of the loading machine platens. The load equalizing system, usually a spherical bearing block is intended to compensate for these divergences.

For any load equalizing system to function correctly the system platens must be correctly seated on the specimen. This can be impeded in two ways. The first, and likely most important way, is that the load equalizing system does not function correctly, and the second that the contacting surfaces of the specimen and loading platen are not flat. The importance of this latter point will depend on the response of the contacting points of the two surfaces to the extra load they carry.

It can be seen in fig. 6 that a surface ground steel piston end is not perfectly flat, there being differences of upto 3/I0,000ths of an inch between high and low points. This is in general not much less than the size of irregularities of the limestone specimen ends. It is noteworthy that a lathe prepared limestone specimen end tends to be symmetrically concave (figs. 7 - II), while a lapped specimen end trends to an irregular convex shape (figs. 3 - 5). Thus we can expect a flat platen to seat itself much better on a specimen which has been lathe prepared.

When investigating the influence of load equalizing system on uniaxial compressive strength only one preparation procedure was used for all the specimens and when investigating the effect of preparation procedure on specimen performance only one loading system, plastic loading, was used.

Since the shape of specimen end can affect the performance of the load equalizing system it will be best to consider this aspect first.

6.I. THE EFFECT OF END PREPARATION TECHNIQUE ON UNIAXIAL COMPRESSIVE STRENGTH AND STRAIN MEASUREMENTS

6.I.I. Uniaxial compressive strength

Uniaxial compressive strength tests were restricted in scope to determine the influence of several factors of the lathe preparation technique. These factors (page 7), the angle of the grinding wheel, depth of cut, and width of grinding wheel face, determine the finish on the specimen end and the amount of heat generated during preparation.

Results obtained, given on page 39, prove that only one factor, the width of grinding wheel face, had an appreciable effect on the strength and standard deviation of the specimens tested, no doubt because of the excessive heating at specimen ends during preparation. This accounted for a reduced strength of nearly I5% (36.3 Ksi compared to 42.6 Ksi) and an increased standard deviation of some 40% (6.3 Ksi compared to 4.5 Ksi).

The remaining three procedures, where heating was not evident, resulted in compressive strengths of 41.3, 42.3 and 42.6 Ksi, with standard deviations of 4.0, 4.7 and 4.5 Ksi respectively. End traverses of specimens prepared in these ways (figs. 7 to 11) show similarly shaped non-flat ends, which would account for the lack of variation in strength results.

6.1.2. Strain measurements

Not much conclusive information on the extent to which a particular preparation technique can affect the overall pattern can be obtained from figs. 23 to 25 of stress against longitudinal strain and figs. 26 to 28 and 31 to 33 of lateral strain distributions. Specimens were prepared as indicated - either hand lapped or lathe procedure no. 1. It is noticeable in several specimens that the strain distributions lack symmetry, about the longitudinal axis (compare individual gauge readings on opposite sides of the specimen), and about a horizontal axis through the specimen mid-height (compare average strains above and below the mid-height). This is common to both preparation techniques and it must be assumed that around the specimen circumference and near the specimen ends the strain pattern produced is very sensitive to any irregularities on either specimen or pistons (see in particular fig. 26d.), and to a smaller extent the loading system (fig. 26c.)

Considering only those cases where the average strains are symmetrical about the mid-height the maximum longitudinal strains (average) are found at the specimen ends (fig.23) and maximum lateral strains at the mid-height (figs 26a and 33) where the specimen was lathe prepared. A hand lapped specimen gave the opposite effect (figs.24 and 26b).

Elastic moduli

The elastic moduli are usually determined from strain measurements at the specimen mid-height. Many gauge lengths are used. Preparation technique seems to have a bearing on the overall strain distribution, at least at lower stress levels, but this does not necessarily mean an equivalent effect on the elastic moduli values obtained. Gauge length is obviousely an important consideration. In this case there was only one test, and the results are only pertinent to this gauge length. After obtaining the necessary strain readings for a lathe prepared specimen (fig. 26a) the specimen ends were hand lapped and further sets of strains recorded for the new condition (fig. 26b). Although there was an obvious change in the overall strain distribution the mid-height average strain was little affected (strain in first case was 360 micro-ins/in at I4.0 Ksi, and in the second 365 micro-ins/in. at I3.7 Ksi). It must be noted that to allow hand lapping the pistons were removed from the specimen. This means that these components were differently orientated on reassembly. This resulted in a new overall distribution as illustrated in fig. 26d. However there was little change in the mid-height strain (estimated to be 362 micro-ins/in. at I4.0 Ksi).

6.2. THE EFFECT OF LOAD EQUALIZING SYSTEM ON UNIAXIAL COMPRESSIVE STRENGTH AND STRAIN MEASUREMENTS

6.2.I. Uniaxial compressive strength

There is no doubt that the load equalizing system can have a considerable effect on compressive strength if that system is not functioning correctly. In this case (see page 28) the spherical block gave a strength some I3.3% lower than the value obtained with plastic loading (35.8 Ksi compared to 4I.3 Ksi) and increased the standard deviation from 4.0 Ksi to 5.8 Ksi, an increase of 45%. A further test designed to prove or disprove any punching effect by the use and lack of use of pistons, resulted in an indication that without pistons rock strength is increased, but this increase was only I,800 psi and hardly significant (standard deviation 5,I00 psi).

6.2.2. Strain measurements

All data in this section was obtained from gauges mounted on steel specimens (see page I6). It was intended that only one specimen be used, thus there would be one variable only - the load equalizing system. Unfortunately specimen S.I. was accidently destroyed after the first two test series (results given in tables A.I.I. and A.I.2. of the appendix). However as specimen S.2. was identical to S.I. it is felt that the third series of tests (table A.I.3) is fully compatible with the first two.

It is possible to use the data to two ends:-

(a) to explain the variation in compressive strengths given above,

(b) to determine whether there is an equivalent effect on values of the elastic moduli.

It has been established in section 6.I.2. that strain readings at the specimen mid-height with this particular size of gauge are little, if at all, influenced by the flatness of the specimen and piston ends, Assuming that equal readings from gauges at this specimen height would represent the condition of perfect loading figs. I7, I8 and I9 allow an immediate comparison of the equalization possible with each system. Figs. I7,I8 and I9 represent only one loading cycle of the three recorded for each system. Analysing the complete data in terms of standard deviation and coefficient of variation (table 4 and figs.34 and 35) the following points emerge.

(I) Load distribution is greatly improved with plastic loading when compared to direct loading. At 40 Ksi the strain variation* at the mid-height is less than 2%.

(2) Load distribution undergoes a deterioration on using the spherical block. At 40 Ksi the strain variation at the mid-height can be as much as 25%.

(3) Over the recorded loading range there is a slight improvement in load distribution with increasing load in the case of plastic loading, but none in the case of the two other systems.

Also worth noting is the reproducability of strain data as afforded by each load equalizing system. In figs. 2I and 22 the plots of stress against mean longitudinal strain for the two systems, each for three independent loading cycles, show that while using plastic loading nearly all the points lay on one line this was not the case with the spherical block. However even here a best fit line to the three sets of points would be similar to the plastic case.

*coefficient of variation

TABLE 4 STANDARD DEVIATION AND COEFFICIENT OF VARIATION OF STRAIN READINGS AT SPECIMEN MID-HEIGHT FOR EACH LOADING SYSTEM

RE. TABLES A.I.I.- 3 OF THE APPENDIX

STRESS RANGE psi	STANDARD DEVIATION micro-ins/in			COEFFICIENT OF VARIATION %		
	Plastic loading	Direct loading	Spherical block	Plastic loading	Direct loading	Spherical block
8,000	36	I00	3I6	I3.5	36.2	88.0
I6,000	32	II3	335	5.9	I9.5	62.0
24,000	25	II8	336	3.0	I3.7	42.0
32,000	26	II3	34I	2.3	I0.0	33.0
40,000	23	I02	3I9	I.7	7.5	25.0

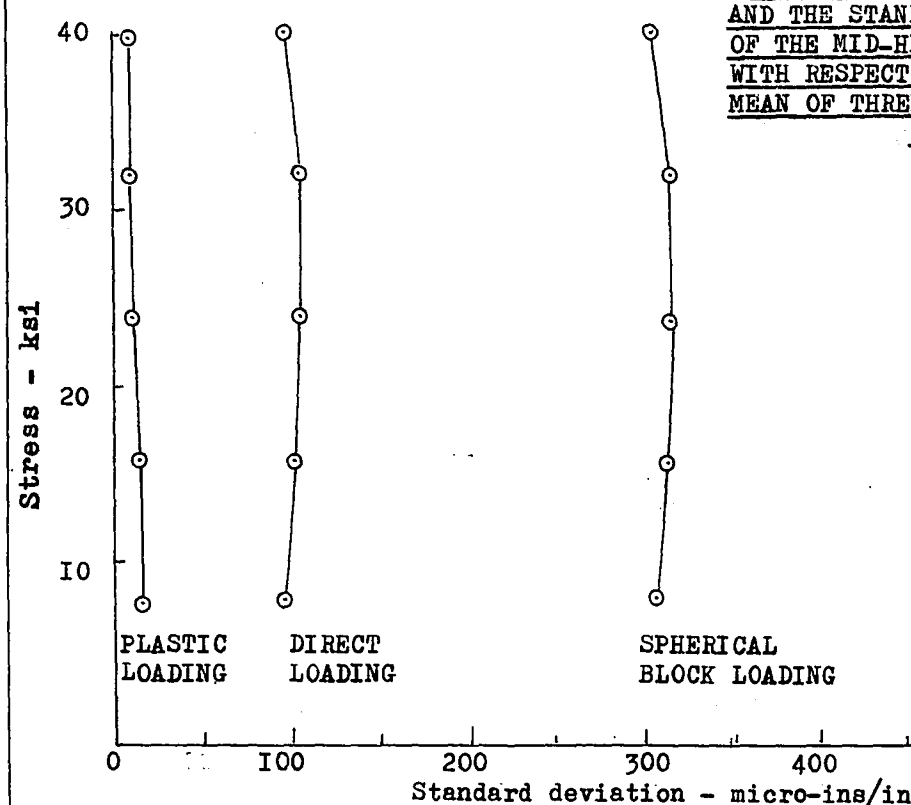


FIG.34 LOADING SYSTEMS AND THE STANDARD DEVIA- OF THE MID-HEIGHT GAUGES WITH RESPECT TO LOAD. MEAN OF THREE POSITIONS RE. TABLE 4

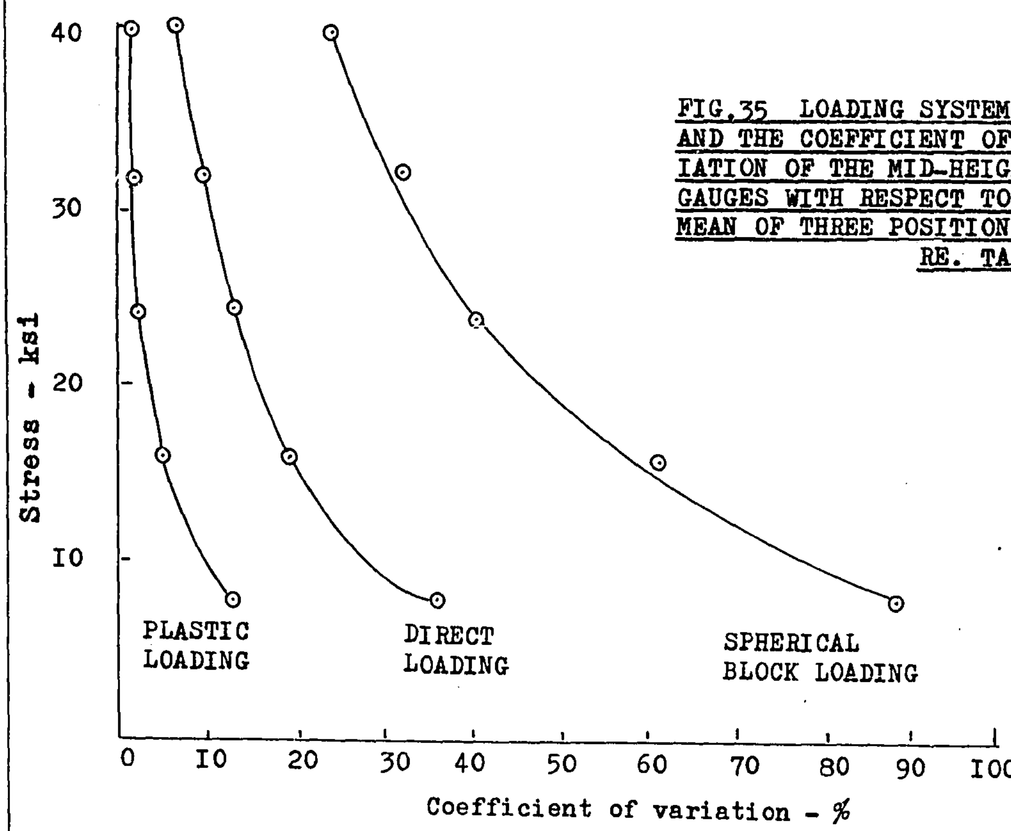


FIG.35 LOADING SYSTEM AND AND THE COEFFICIENT OF VAR- IATION OF THE MID-HEIGHT GAUGES WITH RESPECT TO LOAD. MEAN OF THREE POSITIONS RE. TABLE 4

Elastic moduli

So far there has been no reference to the slopes of the stress / longitudinal strain curves of the steel specimens. It is interesting to note that at stresses greater than 8 Ksi the plots of the individual gauges are all similarly sloped (see figs. I7, I8 and I9) irrespective of the load equalizing system employed. If the tangent modulus of elasticity is required then provided the requisite data is obtained from the upper part of the curve the error involved in taking the slope of an individual gauge plot (rather than the slope of the plot of the mean of four gauges) is much less than may have been expected. In fig. I9 the error is within 4%. The error is nearer I0% where plastic loading was employed (fig.I7). This is because load equalization was still taking place and the individual plots were tending to converge.

The usual practice in obtaining the modulus of elasticity is to plot the curve of the mean reading of two diametrically opposite gauges. Such curves, one for each loading system, are given in fig.20 These plots are for the particular cycles illustrated in figs. I7, I8 and I9. Once again plastic loading gave a more uniform plot, but the tangent and secant moduli for the specimen under any of these loading conditions at any stress would be much the same. Presumably similar comments apply to lateral readings at the mid-height position. It has been possible to derive a figure for Young's modulus for this steel, which is 29.0 x $I0^6$ psi. This is the AISC recommended value.

6.3. SOME PHYSICAL PROPERTIES OF A TRENTON LIMESTONE

6.3.I. Uniaxial compressive strength

In all 87 limestone specimens were uniaxially compressed to failure. The maximum recorded strength was 49.3 Ksi, and the minimum 24.2 Ksi. The maximum strength for any test series was 42.6 Ksi with a standard deviation of 4.5 Ksi (table D.5. of the appendix). The I5 specimens tested had a mean L/D ratio of 2.43. Specimen ends were lathe prepared (procedure no. 3) with final cuts of 5, 2, and I thou. Plastic loading was used. This value of compressive strength is higher than many of the hard rock types tested in the laboratory and the standard deviation much lower than usually obtained. This is no doubt partly due to the improved testing technique.

The extreme violence of failure was also interesting. Generally, the greater the breaking strength the greater the sound energy released at failure, and the greater the amount of small fragments and dust. It was hoped that the lateral strain distribution diagrams, figs. 3I to 33 would give some picture of the failure pattern. In all cases at failure the maximum strains were recorded near the mid-height of the specimen (which was not the case at lower stresses). Also specimens tended to be irregularly barrel shaped at the higher stresses, suggesting end friction was still a factor.

6.3.2. Modulus of elasticity

It has been possible to obtain several values of the modulus of elasticity. In each case the measurements of longitudinal strain were obtained from diametrically opposite gauges at the specimen mid-height. These values and their sources are given in table 5 below.

Table 5 Modulus of elasticity of a Trenton limestone

Figure	Stress	Modulus of elasticity psi
30	20	11.1×10^6
29	20	11.5×10^6
23	15	12.0×10^6
24	15	10.0×10^6
25	15	12.2×10^6

The average value is 11.4×10^6 psi with a standard deviation of 0.8×10^6 psi which gives a coefficient of variation of 7%.

6.3.3. Poisson's ratio

A measurement of Poisson's ratio was obtained from only one specimen (see fig. 30). This gave a value (at 20 Ksi) of 0.3. There is a tendency for this value to increase with increasing stress, but it should be remembered that measurements were made with different gauge lengths in the two directions and the above tendency may be solely due to experimental technique.

SECTION 7. CONCLUSIONS

Experimental determination of uniaxial compressive strength

I. The load equalizing system employed is very important. Values of uniaxial compressive strength of limestone specimens with a spherical bearing block providing equalization were some I3% lower than the values obtained with plastic loading (table 2) and the standard deviation was increased by 45%. This is because the spherical block did not give the same uniformity of loading as plastic loading. Strain measurements at four points at the mid-height of a steel specimen showed that with the spherical block, on average, at 40 ksi, one gauge was registering 3I% more strain than the average of the four (table A.I.3). The equivalent value with plastic loading was 2.5% (table A.I.I.).

2. Punching did not seem to have much influence on compressive strength. Test D.3. (table 2) showed a 5% change in strength which was not significant. With plastic loading, as pistons are the same diameter as the specimen end, punching is not a factor requiring attention.

3. Specimens seemed to be considerably weakened when tool post grinding produced excessive heating during preparation. Specimens prepared in this way gave strengths with plastic loading I5% lower and standard deviation 40% higher than specimens having a similar preparation, but without heating.

4. Effects due to smoothness and flatness of prepared specimen ends are difficult to study, requiring very refined techniques, but at least as far as limestone specimens are concerned do not appear to have much influence on compressive strength. The values with plastic loading with ends by tool post grinding to varying degrees of smoothness differed by only 3% (table 3). As to the effect of flatness on specimen strength it is noted that at failure maximum lateral strain was recorded at or near the mid-height, irrespective of preparation technique (figs. 3I to 33).

Measurement of the elastic moduli

I. Gauge length would appear to be a very important factor here and the following comments are pertinent only to the gauge size used here.

2. The practice of using two diametrically opposite gauges at the specimen mid-height is sound. Small errors were introduced when the spherical block was used (table I). Even one gauge will give a satisfactory value providing the tangent modulus is taken at a sufficiently high stress level (fig. I9). On the basis of the modulus of elasticity derived for steel using diametrically opposite gauges (29×10^6 psi - fig. 2I) the modulus for rock specimens should be very near the true modulus.

3. End preparation procedure has little effect at the specimen mid-height (fig. 26) and hence little effect on measurements of the modulus of elasticity and Poisson's ratio.

Trenton limestone

I. This has proved a fairly homogeneous rock, as illustrated by the relatively low standard deviations obtained, highly suitable for investigations into physical property testing.

2. Tests D.I., D.4. and D.5. suggest a compressive strength of approximately 42,000 psi and standard deviation of 4,300 psi with careful lathe and tool post grinder preparation. The modulus of elasticity is $II.4 \times I0^6$ psi, standard deviation $0.8 \times I0^6$ psi (table 5) and Poisson's ratio 0.3 (fig. 30).

It is obvious that many values can be assigned to the compressive strength and elastic moduli of rocks depending on experimental technique employed, emphasizing the need for commonly followed standard procedures.

This work strongly suggests that the plastic loading system and careful lathe and tool post grinding of the ends will result in the best values for uniaxial compressive strength and for elastic deformations.

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SECTION 8. APPENDIX

8.I. DEFINITIONS

Mean, standard deviation, coefficient of variation and % maximum deviation

If X_I, X_2, X_3 and X_4 are four comparable experimental values then:-

Mean value $$X_m = \frac{X_I + X_2 + X_3 + X_4}{4}$$

Standard deviation $$X_s = \sqrt{\frac{(X_I-X_m)^2+(X_2-X_m)^2 \ldots +(X_n-X_m)^2}{n}}$$

Coefficient of variation - % $$= \frac{X_s}{X_m} \times 100$$

$$\% \text{ maximum deviation} = \frac{\text{maximum deviation between the four values}}{X_I + X_2 + X_3 + X_4} \times 100$$

% maximum deviation was an easily calculated quantity used as a quick indication of the uniformity of loading being achieved. The values X_I, X_2, X_3 and X_4 were the readings obtained from strain gauges equally spaced around the specimen.

8.2. INDEX OF RESULTS

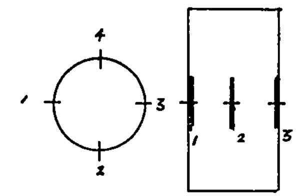
Results have been classified in the following way.

The use of brackets with a table number, for example A.2.(3) denotes the particular loading cycle in question (here it is the third cycle).

LONGITUDINAL STRAIN DATA.

Table: A.1.1 **Specimen:** S.1

Loading: Load equalizing by plastic loading.



Stress K.S.I.	Gauge Readings 1	2	3	4	Computed Strains 1	2	3	4	Mean Strain	(1+3) -(2+4)	%Maxm Devn	Std Devn	Coef Varn
0	115	90	- 205	-1245	–	–	–	–					
8.1	- 150	- 140	- 480	-1550	- 265	- 230	- 275	- 305	- 269	5	7.0	28	10.4%
16.3	- 435	- 425	- 755	-1835	- 550	- 515	- 550	- 590	- 552	5	3.4	26	4.9%
24.1	- 720	- 690	-1000	-2090	- 835	- 780	- 795	- 845	- 814	5	2.0	33	4.1%
32.4	-1025	- 985	-1275	-2375	-1140	-1075	-1070	-1130	-1104	5	1.6	35	3.2%
39.2	-1275	-1235	-1500	-2595	-1390	-1325	-1295	-1350	-1340	10	1.8	35	2.6%
CHK 0	115	95	- 200	-1240	0	5	5	5					
Specimen and pistons together, turned through 120°													
0	110	90	- 205	-1245	–	–	–	–	–	–	–	–	–
8.1	- 150	- 130	- 475	-1555	- 260	- 220	- 270	- 310	- 265	0	8.5	33	12.4%
15.9	- 425	- 410	- 750	-1825	- 535	- 500	- 545	- 580	- 540	0	3.7	28	5.2%
24.1	- 705	- 695	-1025	-2100	- 815	- 785	- 820	- 855	- 819	5	2.2	20	2.4%
32.0	- 980	- 970	-1290	-2365	-1090	-1060	-1085	-1120	-1089	5	1.4	26	2.4%
39.2	-1255	-1255	-1550	-2620	-1365	-1345	-1345	-1375	-1358	10	0.6	12	0.9%
CHK 0	115	95	- 205	-1245	5	5	0	0	–	–	–	–	–
Specimen and pistons together, turned through 120°													
0	115	95	- 200	-1245	–	–	–	–	–	0	–	–	–
7.7	- 85	- 140	- 515	-1525	200	235	315	280	258	0	11.0	46	17.8%
15.6	- 375	- 410	- 775	-1795	490	505	575	550	530	10	4.0	41	7.7%
24.3	- 700	- 710	-1040	-2090	815	805	840	845	825	5	1.2	22	2.6%
32.0	- 990	- 985	-1290	-2365	1105	1080	1090	1120	1099	5	0.9	16	1.4%
40.6	-1290	-1265	-1545	-2625	1405	1360	1345	1380	1373	10	1.1	22	1.6%

LONGITUDINAL STRAIN DATA

Table: A.1.2 Specimen: S.1

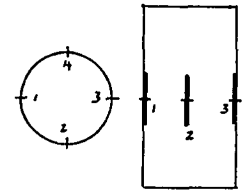
Loading: Directly, between machine platens, pistons.

Stress K.S.I.	Gauge Reading 1	2	3	4	Computed Strains 1	2	3	4	Mean Strain	(1+3) −(2+4)	%Maxm Devn	Std Devn	Coef Varn
0	115	90	- 205	-1290	-	-	-	-	-	-	-	-	-
9.1	- 95	- 335	- 610	-1475	- 210	- 445	- 405	- 185	- 311	15	17.7	113	36.5%
17.9	- 390	- 670	- 955	-1805	- 505	- 760	- 750	- 515	- 633	20	10.0	123	19.4%
31.9	- 820	-1100	-1425	-2275	- 935	-1200	-1220	- 985	-1085	30	6.6	129	11.9%
41.7	-1165	-1365	-1735	-2660	-1280	-1455	-1530	-1370	-1409	15	4.5	93	6.6%
CHK 0	120	95	200	-1315	5	5	5	-25	-	-	-	-	-
Specimen and pistons together, turned through 120°													
0	120	95	- 200	-1280	-	-	-	-	-	-	-	-	-
7.8	- 25	- 220	- 280	-1485	- 145	- 315	- 380	- 170	- 253	40	23.3	98	39.0%
17.4	- 355	- 560	- 915	-1810	- 475	- 655	- 715	- 495	- 585	40	10.7	98	17.0%
26.7	- 675	- 870	-1215	-2120	- 795	- 965	-1015	- 805	- 873	40	6.7	98	11.1%
36.5	-1015	-1180	-1540	-2475	-1135	-1275	-1340	-1160	-1228	40	4.2	86	7.0%
39.7	-1130	-1285	-1650	-2600	-1250	-1380	-1450	-1285	-1341	35	3.7	74	5.6%
CHK 0	120	100	- 200	-1295	0	5	0	-15	-	-	-	-	-
Specimen and pistons together, turned through 120°													
0	120	95	- 200	-1285	-	-	-	-	-	-	-	-	-
8.0	- 40	- 230	- 580	-1495	- 160	- 330	- 380	- 210	- 270	0	20.3	89	33.0%
16.3	- 300	- 550	- 880	-1730	- 420	- 645	- 680	- 445	- 548	10	11.8	118	22.0%
25.1	- 585	- 885	-1205	-2015	- 705	- 980	-1005	- 730	- 855	0	8.8	138	16.2%
37.4	- 840	-1150	-1475	-2275	- 960	-1245	-1275	- 990	-1118	0	7.0	124	11.1%
40.5	-1110	-1350	-1700	-2570	-1230	-1445	-1500	-1285	-1365	0	4.9	141	10.3%

LONGITUDINAL STRAIN DATA.

Table: A.1.3 Specimen: S.2

Loading: Spherical block, pistons

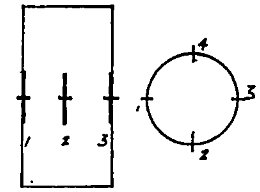


Stress K.S.I.	Gauge Readings 1	2	3	4	Computed Strains 1	2	3	4	Mean Strain	(1+3) -(2+4)	%Maxm Devn	Std Devn	Coef Varn
0	-1690	4600	4610	1435	-	-	-	-	-	-	-	-	
8.5	-1620	4015	4000	1465	70	- 585	- 610	30	- 324	15	44.7	273	85%
16.3	-1825	3700	3680	1255	- 135	- 900	- 930	- 180	- 536	15	37.0	380	71%
25.7	-2100	3380	3355	965	- 410	-1220	-1255	- 470	- 844	25	25.2	398	47%
32.7	-2320	3135	3105	735	- 630	-1465	-1505	- 700	-1075	30	20.3	412	38%
40.8	-2875	2860	2815	460	-1185	-1740	-1795	- 975	-1424	265	14.4	352	25%
CHK 0	-1650	4605	4635	1475	40	5	25	40	-	-	-	-	
Specimen and pistons together, turned through 120°													
0	-1680	4570	4595	1445	-	-	-	-	-	-	-	-	
8.3	-1780	4310	4145	1145	- 100	- 260	- 450	- 300	- 278	10	31.5	131	47%
17.2	-2030	3995	3810	860	- 350	- 575	- 785	- 585	- 574	25	18.9	156	27%
24.9	-2310	3695	3500	565	- 630	- 875	-1095	- 880	- 870	30	13.3	168	19%
32.2	-2495	3500	3305	375	- 815	-1070	-1290	-1070	-1061	35	11.2	166	16%
39.3	-2735	3255	3050	125	-1055	-1315	-1545	-1320	-1311	45	9.3	174	13%
CHK 0	-1655	4595	4615	1465	25	25	20	20	-	-	-	-	
Specimen and pistons together, turned through 120°													
0	-1695	4560	4580	1430	-	-	-	-	-	-	-	-	
8.5	-1495	4075	3835	1355	200	- 485	- 745	- 75	- 276	15	85.5	361	131%
14.6	-1610	3820	3535	1195	85	- 740	-1045	- 235	- 484	15	63.6	435	89%
23.6	-1870	3470	3170	910	- 175	-1090	-1410	- 520	- 799	25	38.7	478	60%
31.9	-2120	3185	2880	650	- 425	-1375	-1700	- 780	-1070	30	29.8	499	47%
40.0	-2385	2900	2580	375	- 690	-1660	-2000	-1055	-1351	25	24.2	512	38%
CHK 0	-1675	4640	4590	1445	20	80	10	15	-	-	-	-	

LONGITUDINAL STRAIN DATA.

Table: A.2 Specimen: A.10.1 Preparation: Lathe, final cut 5 thou. (procedure no.I)

Loading: Load equalizing by plastic loading - 4 continuous cycles.



Stress K.S.I.	Gauge Readings 1	2	3	4	Computed Strain 1	2	3	4	Mean Strains 1&3	2&4	% Maxm. Devn.
0	6840	7905	9105	8150	-	-	-	-	-	-	
2.8	6610	7725	8920	7900	- 230	- 180	- 185	- 250	- 208	- 215	8.3
6.7	6330	7470	8610	7580	- 510	- 435	- 495	- 570	- 503	- 503	6.7
9.9	6065	7205	8315	7280	- 775	- 700	- 790	- 870	- 782	- 785	5.4
12.8	5800	6940	8025	6990	-1040	- 965	-1080	-1160	-1060	-1063	4.6
16.3	5535	6665	7735	6710	-1305	-1240	-1370	-1440	-1338	-1340	3.7
0	6855	7925	9130	8165	-	-	-	-	-	-	
2.9	6605	7720	8925	7915	- 250	- 205	- 205	- 250	- 228	- 228	5.0
6.3	6350	7475	8630	7610	- 505	- 450	- 500	- 555	- 503	- 503	5.0
9.9	6045	7170	8300	7280	- 810	- 755	- 830	- 885	- 820	- 820	4.6
13.0	5780	6905	8020	7000	-1075	-1020	-1110	-1165	-1092	-1092	3.3
16.3	5530	6645	7750	6735	-1325	-1280	-1380	-1430	-1353	-1355	2.8
0	6870	7935	9145	8180	-	-	-	-	-	-	
3.4	6610	7730	8930	7915	- 260	- 205	- 215	- 265	- 238	- 235	6.3
7.0	6330	7450	8600	7580	- 540	- 485	- 545	- 600	- 543	- 543	5.3
9.9	6065	7185	8315	7295	- 805	- 740	- 830	- 885	- 818	- 813	4.4
13.3	5825	6940	8055	7040	-1045	- 995	-1090	-1140	-1068	-1068	3.5
16.6	5545	6655	7755	6745	-1325	-1280	-1390	-1435	-1358	-1357	2.8

Table: A.2 (Cont'd.)

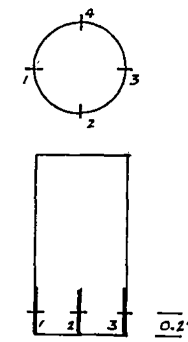
Stress K.S.I.	Gauge Readings 1	2	3	4	Computed Strains 1	2	3	4	Mean Strains 1&3	2&4	% Maxm. Devn.
0	6870	7935	9145	8180	-	-	-	-	-	-	-
3.3	6625	7735	8940	7930	- 245	- 200	- 205	- 250	- 225	- 225	5.6
6.7	6375	7495	8645	7625	- 495	- 440	- 500	- 555	- 498	- 498	5.8
9.8	6100	7215	8350	7330	- 770	- 720	- 795	- 850	- 783	- 785	4.2
13.3	5795	6910	8020	7000	-1075	-1025	-1125	-1180	-1100	-1103	3.4
16.3	5565	6675	7775	6765	-1305	-1260	-1370	-1415	-1337	-1337	2.9
19.7	5285	6390	7475	6480	-1585	-1545	-1670	-1700	-1628	-1623	2.3
23.6	4990	6085	7155	6165	-1880	-1850	-1990	-2015	-1935	-1933	2.1
26.5	4745	5830	6880	5910	-2125	-2105	-2265	-2270	-2195	-2188	1.9
29.6	4450	5525	6560	5600	-2420	-2410	-2585	-2580	-2503	-2495	1.7
32.7	4190	5265	6285	5310	-2680	-2670	-2860	-2870	-2770	-2770	1.8
36.6	3840	4925	5920	4960	-3030	-3010	-3225	-3220	-3128	-3115	1.7
	Failure										

LONGITUDINAL STRAIN DATA.

Table: A.3 Specimen: C.30.3 Preparation: Lathe, Wheel angle 40°, Final cuts 5, 2, 1 thou. (procedure no.2)

Loading: (1) Spherical block, pistons, (2) Load equalizing by plastic loading.
(3) " " " "

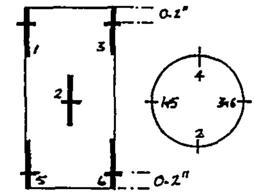
	Stress K.S.I.	Gauge Readings 1	2	3	4	Strains 1	2	3	4	(1+3) -(2+4)	Mean Strain
(1)	0	1095	495	1625	1750						
	3.4	735	135	1350	1440	- 360	- 360	- 275	- 310	35	- 326
	6.3	450	- 90	1110	1120	- 645	- 605	- 515	- 630	75	- 599
	9.6	165	- 345	855	890	- 930	- 860	- 770	- 860	20	- 855
(2)	0	1070	460	1600	1725	-	-	-	-	-	-
	3.3	775	135	1285	1465	- 295	- 325	- 315	- 260	25	- 299
	6.5	445	- 205	990	1235	- 625	- 685	- 610	- 490	60	- 602
	9.8	175	- 520	725	1030	- 895	-1000	- 875	- 695	75	- 866
	12.7	- 70	- 825	480	830	-1160	-1305	-1120	- 895	80	-1120
	CHK 0	1100	485	1620	1745	30	25	20	20	-	-
(3)	0	1065	460	1595	1720	-	-	-	-	-	-
	3.1	750	165	1300	1435	- 315	- 295	- 295	- 285	30	- 298
	6.5	430	- 125	1030	1180	- 635	- 605	- 565	- 540	55	- 586
	10.2	105	- 450	735	895	- 960	- 930	- 860	- 825	65	- 894
	13.8	- 200	- 770	440	600	-1285	-1250	-1155	-1120	70	1952
	16.3	- 405	- 975	255	410	-1490	-1455	-1340	-1310	65	1399
	19.8	- 730	-1295	- 10	115	-1815	-1775	-1625	-1605	60	1705
	22.8	- 975	-1530	- 230	- 90	-2060	-2010	-1845	-1830	65	1936
	26.7	-1290	-1840	- 525	- 385	-2375	-2320	-2140	-2125	70	2240
	30.0	-1575	-2120	- 800	- 660	-2660	-2600	-2415	-2400	75	2514
	33.0	-1840	-2380	-1040	- 890	-2925	-2860	-2655	-2630	90	2768
	36.3	-2140	-2685	CM	-1135	-3225	-3165	CM	-2875	-	-
	39.5	-2415	CM	CM	-1380	-3500	CM		-3120	-	-
	CHK 0	1030	190	1510	1700	35	270	85	20	-	-



LONGITUDINAL STRAIN DATA.

Table: A.4 Specimen: A.13.2 Preparation: Lathe, Final cut 5 thou. (procedure no.I)

Loading: Load equalizing by plastic loading.

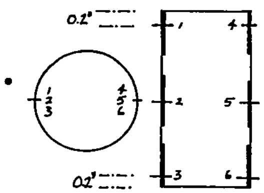


Stress K.S.I.	1	2	3	4	5	6	1	2	3	4	5	6	Means 1&3	Means 2&4	Means 5&6
0	945	2870	1700	2905	3835	2515	-	-	-	-	-	-	-	-	-
4.1	685	2515	975	2635	3595	2145	- 260	- 355	?	- 270	- 240	- 480	-	- 313	- 360
7.7	450	2230	1010	2275	3325	1730	- 495	- 640	- 690	- 630	- 510	- 785	-	- 635	- 648
10.9	205	1960	1035	1955	3050	1380	- 740	- 910	- 665	- 950	- 785	-1135	-	- 930	- 960
14.5	- 55	1660	1020	1640	2740	1055	-1000	-1210	?	-1265	-1095	-1460	-	-1238	-1278
17.4	- 270	1415	1000	1385	2485	810	-1215	-1455	?	-1520	-1350	-1705	-	-1488	-1528
0	945	2885	1670	2890	3835	2500	-	-	-	-	-	-	-	-	-
4.1	710	2540	1485	2605	3590	2135	- 235	- 345	- 185	- 285	- 245	- 365	-	- 315	- 305
7.7	470	2255	1375	2260	3325	1745	- 475	- 630	- 295	- 630	- 510	- 755	-	- 630	- 633
-	190	1946	1220	1910	3020	1360	- 755	- 945	?	- 980	- 815	-1140	-	- 963	- 978
14.6	- 45	1665	1070	1630	2745	1070	- 990	-1220	?	-1260	-1090	-1430	-	-1240	-1260
17.7	- 280	1415	1955	1375	2475	820	-1225	-1470	?	-1515	-1360	-1680	-	-1493	-1520
Pistons turned relative to specimen															
0	925	2865	2990	2870	3815	2480	-	-	-	-	-	-	-	-	-
3.7	660	2625	2815	2710	3510	2005	- 265	- 240	- 175	- 260	- 305	- 415	- 220	- 250	- 360
7.5	360	2310	2610	2350	3230	1650	- 565	- 555	- 380	- 520	- 585	- 830	- 473	- 538	- 708
11.0	70	2020	2360	2015	2945	1290	- 855	- 845	- 630	- 855	- 870	-1190	- 743	- 850	-1030
14.3	- 175	1750	2145	1740	2665	1000	-1100	-1115	- 845	-1130	-1150	-1480	- 973	-1123	-1315
18.9	- 515	1385	1780	1395	2285	625	-1440	-1480	-1210	-1475	-1530	-1855	-1325	-1478	-1693
22.2	- 735 Failure	1205	1600	1220	-	275	-1660	-1660	-1390	-1650	-	-2205	-1525	-1655	-

LONGITUDINAL STRAIN DATA.

Table: A.5 Specimen: A.11.1 Preparation: Lathe, Final cuts 5 thou. (procedure no.I)

Loading: Load equalizing by plastic loading.



Stress K.S.I.	Gauge Readings 1	2	3	4	5	6	Computed Strains 1	2	3	4	5	6	Mean Strain 1&4	2&5	3&6	Mean 1,3,4,6
0	3570	1825	2970	3755	3315	3410	-	-	-	-	-	-	-	-	-	-
3.7	3295	1465	2510	3430	3115	3200	- 275	- 360	- 460	- 325	- 200	- 210	- 300	- 280	- 335	- 317
7.2	2675	1145	2140	2965	2865	2905	- 895	- 680	- 830	- 790	- 450	- 505	- 843	- 565	- 668	- 756
10.6	2200	830	1645	2565	2585	2530	-1370	- 995	-1325	-1190	- 730	- 880	-1230	- 863	-1103	-1167
13.8	1885	555	1315	2230	2330	2215	-1685	-1270	-1655	-1525	- 985	-1195	-1605	-1128	-1425	-1515
17.6	1535	220	945	1885	2020	1865	-2035	-1605	-2025	-1870	-1295	-1545	-1953	-1450	-1780	-1867
CHK 0	3585	1825	2910	3765	3325	3375	15	0	-60	10	10	-35	-	-	-	
0	3590	1825	2910	3675	3325	3375	-	-	-	-	-	-	-	-	-	
3.6	2960	1460	2455	3290	3110	3100	- 630	- 365	- 455	- 385	- 215	- 275	- 508	- 290	- 365	- 437
7.2	2560	1175	2090	2960	2900	2815	-1030	- 650	- 820	- 695	- 425	- 560	- 912	- 538	- 690	- 803
10.2	2120	820	1655	2575	2600	2450	-1470	-1005	-1255	-1100	- 725	-1025	-1235	- 865	-1140	-1188
17.1	1500	240	1005	1970	2070	1825	-2090	-1565	-1905	-1705	-1255	-1550	-1898	-1410	-1728	-1813
CHK 0	3565	1820	2905	3680	3320	3345	-25	-5	-5	5	-5	-30	-	-	-	
0	3575	1820	2900	3675	3320	3440	-	-	-	-	-	-				
3.6	3020	1500	2465	3205	3065	3050	- 555	- 320	- 445	- 470	- 255	- 290	- 513	- 288	- 368	- 440
7.0	2025	1215	2085	2815	2810	2720	- 950	- 605	- 815	- 860	- 510	- 620	- 905	- 558	- 718	- 812
10.6	2220	885	1675	2405	2495	2335	-1355	- 935	-1225	-1270	- 825	-1005	-1313	- 880	-1115	-1214
14.5	1870	565	1300	2055	2195	1990	-1705	-1255	-1600	-1620	-1125	-1450	-1663	-1190	-1475	-1569
18.7	1485	185	895	1665	1845	1600	-2090	-1635	-2005	-2010	-1475	-1740	-2050	-1555	-1873	-1912

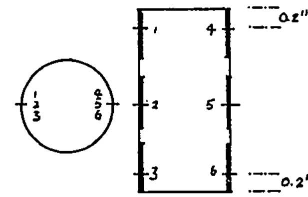
Table: A.5 (Cont'd.)

Stress K.S.I.	Gauge Readings 1	2	3	4	5	6	Computed Strains 1	2	3	4	5	6	Mean Strain 1&4	2&5	3&6	Mean 1,3,4,6
0	3500	1815	2900	3660	3315	3320	-	-	-	-	-	-	-	-	-	-
3.4	3090	1535	2480	3125	3020	3000	- 470	- 280	- 420	- 535	- 295	- 320	- 503	- 287	- 390	- 447
7.2	2645	1210	2045	2695	2735	2630	- 915	- 605	- 855	- 965	- 580	- 690	- 940	- 593	- 773	- 857
10.4	2255	885	1630	2325	2455	2290	-1305	- 930	-1270	-1335	- 860	-1030	-1320	- 895	-1150	-1235
14.5	1890	540	1235	1965	2150	1935	-1670	-1275	-1665	-1695	-1165	-1385	-1632	-1220	-1525	-1579
18.7	1525	180	840	1610	1825	1565	-2035	-1635	-2060	-2050	-1490	-1755	-2045	-1733	-1908	-1982
23.1	1135	-245	425	1185	1455	1165	-2425	-2060	-2475	-2475	-1860	-2155	-2450	-1960	-2315	-2383
Pistons changed.																
0	3545	1785	2870	3625	3295	3250	-	-	-	-	-	-	-	-	-	-
3.9	3040	1445	2320	3150	3015	2860	- 505	- 340	- 550	- 465	- 280	- 390	- 485	- 310	- 470	- 478
7.0	2710	1180	1930	2840	2800	2555	- 835	- 605	- 940	- 785	- 495	- 695	- 810	- 550	- 818	- 814
10.6	2360	870	1540	2480	2520	2250	-1185	- 915	-1330	-1145	- 775	-1000	-1165	- 845	-1165	-1165
14.0	2045	580	1220	2140	2250	1935	-1500	-1205	-1650	-1485	-1045	-1315	-1493	-1125	-1483	-1488
17.6	1720	250	870	1780	1930	1570	-1825	-1530	-2000	-1845	-1365	-1680	-1835	-1448	-1840	-1838
20.5	1490	0	650	1520	1705	1340	-2055	-1785	-2220	-2105	-1590	-1910	-2080	-1688	-2065	-2073
28.7	Failure															

LONGITUDINAL STRAIN DATA.

Table: A.6   Specimen: A.15.4   Preparation: Hand lapped.

Loading: Load equalizing by plastic loading.

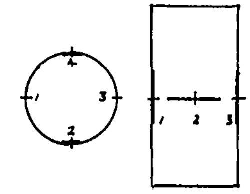


Stress K.S.I.	Gauge Readings 1	2	3	4	5	6	Actual Strains 1	2	3	4	5	6	Means 1&4	2&5	3&6
0	3605	3500	3155	5515	8420	7580	-	-	-	-	-	-			
3.8	3385	3180	2955	5310	8110	7360	- 220	- 320	- 200	- 215	- 310	- 220	- 217	- 315	- 210
7.3	3095	2810	2695	5095	7785	7100	- 510	- 690	- 460	- 420	- 635	- 480	- 465	- 662	- 470
10.9	2850	2475	2445	4870	7455	6805	- 755	-1025	- 710	- 645	- 965	- 775	- 697	- 995	- 742
15.1	2495	2015	2085	4545	6995	6385	-1110	-1485	-1070	- 970	-1425	-1195	-1040	-1455	- 938
	3610	3495	3150	5525	8415	7575	-	-	-	-	-	-			
4.1	3405	3170	2930	5285	8075	7350	- 205	- 325	- 220	- 240	- 340	- 225	- 222	- 332	- 222
7.6	3125	2790	2650	5050	7740	7100	- 485	- 705	- 500	- 475	- 675	- 475	- 480	- 690	- 488
11.3	2810	2400	2350	4810	7405	6825	- 800	-1095	- 800	- 715	-1010	- 750	- 758	-1052	- 775
15.4	2465	1925	1955	4530	7025	6500	-1145	-1570	-1195	- 995	-1390	-1075	-1070	-1480	-1135
* 0	3610	3495	3140	5520	8415	7570	-	-	-	-	-	-			
4.0	3335	3115	2885	5365	8165	7395	- 275	- 380	- 255	- 155	- 250	- 175	- 215	- 315	- 215
7.6	3060	2725	2585	5145	7840	7150	- 550	- 770	- 555	- 375	- 675	- 420	- 462	- 722	- 488
11.3	2775	2355	2290	4905	7510	6830	- 835	-1140	- 850	- 615	- 905	- 740	- 725	-1022	- 795
14.5	2530	2030	2015	4665	7195	6545	-1080	-1465	-1125	- 855	-1220	-1025	- 967	-1342	-1075

* Sellotaped specimen ends.

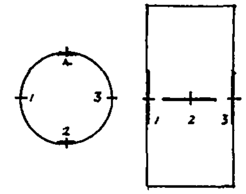
Table: B.1 Specimen: B.02.2 Preparation: Hand lapped.

Loading: Load equalizing by plastic loading.



Stress K.S.I.	Gauge Readings 1	2	3	4	Computed Strains 1	2	3	4	Mean Strains 1&3	2&4	Poisson's Ratio
0	2240	3595	1200	1205	-	-	-	-			
1.8	2090	3650	1045	1255	- 150	55	- 155	50	- 153	53	.34
3.6	1950	3695	925	1290	- 290	100	- 275	85	- 283	93	.33
4.9	1825	3735	800	1325	- 415	140	- 400	120	- 408	130	.32
7.2	1630	3790	610	1385	- 610	195	- 590	180	- 600	188	.31
9.8	1410	3865	355	1455	- 830	270	- 845	250	- 838	260	.31
11.9	1215	3950	165	1510	-1025	335	-1035	305	-1030	320	.31
14.0	1040	3990	-0000	1565	-1200	395	-1220	360	-1210	378	.31
16.4	825	4060	- 225	1630	-1415	465	-1445	425	-1430	445	.31
CHK 0	2240	3625	-1195	1235	0	30	5	30	-	-	-
0	2225	3605	1180	1215	-	-	-	-			
3.3	2105	3670	995	1245	- 120	65	- 185	30	- 153	48	.31
6.0	1965	3720	840	1285	- 260	105	- 340	70	- 300	88	.29
9.0	1815	3765	690	1325	- 410	160	- 490	110	- 450	135	.30
11.0	1705	3800	565	1360	- 520	195	- 615	145	- 568	170	.30
14.0	1555	3850	400	1405	- 670	245	- 780	190	- 725	218	.30
16.9	1380	3910	210	1460	- 845	305	- 970	245	- 908	275	.30
21.7	1140	3985	- 5	1530	-1085	380	-1220	315	-1153	348	.30
26.2	865	4065	- 265	1605	-1360	460	-1480	390	-1420	423	.30
CHK 0	2240	3620	1190	1230	15	15	10	15	-	-	-
0	2240	3620	1190	1230	-	-	-	-			
3.3	2010	3655	1085	1290	- 230	35	- 105	60	- 168	43	.25
6.2	1860	3700	940	1335	- 380	80	- 250	105	- 315	92	.29
8.5	1740	3740	805	1375	- 500	120	- 385	145	- 443	133	.30
13.2	1510	3840	560	1470	- 730	220	- 630	190	- 680	205	.30
17.7	1265	3920	305	1545	- 975	300	- 885	315	- 930	308	.33
22.3	1035	4000	60	1615	-1205	380	-1130	385	-1168	383	.33
27.1	755	4085	- 200	1695	-1485	465	-1425	465	-1455	465	.32

Table: B.1 Specimen: B.02.2 Preparation: Hand lapped.

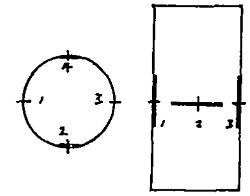


Loading: Load equalizing by plastic loading.

Stress K.S.I.	Gauge Readings				Computed Strains				Mean Strains		Poisson's Ratio
	1	2	3	4	1	2	3	4	1&3	2&4	
0	2240	3595	1200	1205	-	-	-	-			
1.8	2090	3650	1045	1255	- 150	55	- 155	50	- 153	53	.34
3.6	1950	3695	925	1290	- 290	100	- 275	85	- 283	93	.33
4.9	1825	3735	800	1325	- 415	140	- 400	120	- 408	130	.32
7.2	1630	3790	610	1385	- 610	195	- 590	180	- 600	188	.31
9.8	1410	3865	355	1455	- 830	270	- 845	250	- 838	260	.31
11.9	1215	3950	165	1510	-1025	335	-1035	305	-1030	320	.31
14.0	1040	3990	-0000	1565	-1200	395	-1220	360	-1210	378	.31
16.4	825	4060	- 225	1630	-1415	465	-1445	425	-1430	445	.31
CHK 0	2240	3625	-1195	1235	0	30	5	30	-	-	-
0	2225	3605	1180	1215	-	-	-	-			
3.3	2105	3670	995	1245	- 120	65	- 185	30	- 153	48	.31
6.0	1965	3720	840	1285	- 260	105	- 340	70	- 300	88	.29
9.0	1815	3765	690	1325	- 410	160	- 490	110	- 450	135	.30
11.0	1705	3800	565	1360	- 520	195	- 615	145	- 568	170	.30
14.0	1555	3850	400	1405	- 670	245	- 780	190	- 725	218	.30
16.9	1380	3910	210	1460	- 845	305	- 970	245	- 908	275	.30
21.7	1140	3985	- 5	1530	-1085	380	-1220	315	-1153	348	.30
26.2	865	4065	- 265	1605	-1360	460	-1480	390	-1420	423	.30
CHK 0	2240	3620	1190	1230	15	15	10	15	-	-	-
0	2240	3620	1190	1230	-	-	-	-			
3.3	2010	3655	1085	1290	- 230	35	- 105	60	- 168	43	.25
6.2	1860	3700	940	1335	- 380	80	- 250	105	- 315	92	.29
8.5	1740	3740	805	1375	- 500	120	- 385	145	- 443	133	.30
13.2	1510	3840	560	1470	- 730	220	- 630	190	- 680	205	.30
17.7	1265	3920	305	1545	- 975	300	- 885	315	- 930	308	.33
22.3	1035	4000	60	1615	-1205	380	-1130	385	-1168	383	.33
27.1	755	4085	- 200	1695	-1485	465	-1425	465	-1455	465	.32

Table: B.2 Specimen: B.02.2 Preparation: Hand lapped.

Loading: Spherical block, pistons

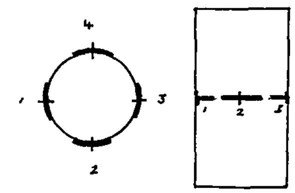


Stress K.S.I.	Gauge Readings 1	2	3	4	Computed Strains 1	2	3	4	Mean Strains 1&3	2&4	Poisson's Ratio
0	3730	5210	3150	2820							
4.1	3510	5165	2700	3100	- 220	- 45	- 450	280	- 335	118	.35
6.5	3350	5180	2460	3205	- 380	- 30	- 690	415	- 535	193	.36
9.8	3065	5235	2135	3330	- 665	25	-1015	510	- 840	268	.32
13.5	2745	5315	1810	3450	- 985	105	-1340	630	-1163	368	.32
16.1	2535	5360	1600	3510	-1195	150	-1550	690	-1373	420	.31
Loading: Load equalizing by plastic loading.											
0	3650	5150	3075	2750							
3.4	3390	5225	2865	2850	- 260	75	- 210	100	- 235	88	.37
6.7	3105	5290	2600	2915	- 545	140	- 475	165	- 510	153	.30
9.9	2790	5385	2275	3015	- 860	235	- 800	265	- 830	250	.30
12.8	2535	5465	2030	3090	-1115	315	-1045	340	-1080	328	.30
16.4	2230	5560	1755	3185	-1420	410	-1320	435	-1370	428	.31
20.0	1895	5660	1430	3285	-1755	510	-1645	535	-1700	528	.31
23.0	1635	5730	1190	3365	-2015	580	-1885	615	-1950	598	.31
26.2	1345	5815	910	3450	-2305	665	-2165	700	-2235	683	.31
29.6	1020	5910	610	3560	-2630	760	-2465	810	-2548	785	.31
32.5	750	5980	350	3670	-2900	830	-2725	920	-2813	875	.31
36.3	400	6090	20	3830	-3250	940	-3055	1080	-3153	1010	.32
39.0	105	6185	- 230	3970	-3545	1035	-3325	1220	-3435	1128	.33
42.8	- 265	6315	- 590	-	-3935	1165	-3685	-	-3810	-	-
46.0	- 680	6420	-1995	-	-4350	1270	-	-	-	-	-
48.6	Failure										

LATERAL STRAIN DATA.

Table: C.1 Specimen: A.15.1 Preparation: Lathe, Final cut of 5 thou. (procedure no.I)

Loading: Load equalizing by plastic loading.



Stress P.S.I.	Gauge Readings 1	2	3	4	Computed Strains 1	2	3	4	Mean Strains 1&3	2&4	(1+3)-(2+4)
0	2080	2675	2325	2225	-	-	-	-			
4,000	2175	2800	2435	2305	95	125	110	80	103	103	0
7,500	2255	2885	2525	2385	175	210	200	160	188	185	3
11,100	2255	2930	2565	-	175	255	240	-	-	-	-
11,100	Failure										

Table: C.2 Specimen: B.01.1 Preparation: Hand lapped Gauge arrangement as above.

Stress P.S.I.	Gauge Readings 1	2	3	4	Computed Strains 1	2	3	4	Mean Strains 1&3	2&4	(1+3)-(2+4)
0	4705	4455	4105	4545	-	-	-	-	-	-	
4,300	4815	4555	4210	4740	110	100	105	195	108	148	0
7,800	4920	4650	4320	4780	215	195	215	235	215	215	0
10,500	4990	4725	4400	4850	285	270	295	305	290	288	2
13,300	5090	4825	4515	4960	385	370	410	415	398	393	5
17,100	5225	4975	4675	5105	520	520	570	560	545	540	5
CHK 0	4760	4515	4165	4630	55	40	60	85	-	-	-
0	4760	4510	4165	4630	-	-	-	-			
4,700	4890	4625	4285	4765	130	115	120	135	125	125	0
7,900	4980	4715	4385	4870	220	205	220	240	220	223	3
11,200	5080	4820	4495	4970	320	310	330	340	325	325	0
14,300	5175	4915	4595	5065	415	405	430	435	423	420	3
17,600	Failure										

LATERAL DEFORMATION DATA

Table. C.3. Specimen. A.09.3 Preparation. Lathe, final cut 5 thou. (procedure no.I)

Loading. Load equalizing by plastic loading.

Stress K.S.I.	Gauge readings						Computed strains						Mean strains		
	I	2	3	4	5	6	I	2	3	4	5	6	(I&4)	(2&5)	(3&6)
0	3745	3330	3245	3345	4160	3215	-	-	-	-	-	-	-	-	-
6.5	3850	3490	3390	3465	4315	3310	I05	I60	I45	I20	I45	95	II2	I53	I20
I0.I	3945	3580	3490	3555	4405	3400	200	250	245	2I0	245	I85	205	248	2I5
I4.0	4060	3700	36I0	3655	45I0	35I0	3I5	370	365	3I0	350	295	3I2	360	330
I8.9	4I80	3835	3735	3775	4625	36I0	435	505	490	430	465	395	433	485	443
Specimen ends hand lapped.															
0	3750	3335	3255	3350	4I65	3220	-	-	-	-	-	-	-	-	-
4.4	3795	34I5	3335	3450	4295	3290	45	80	80	I00	I30	70	72	I05	75
7.7	3880	3500	3425	3530	4380	3375	I30	I65	I70	I80	2I5	I55	I55	I90	I62
I0.7	3970	3595	3520	36I0	4465	3460	220	260	265	260	300	240	240	280	252
I3.8	4050	3685	3605	3690	4550	3545	300	350	350	340	385	325	320	367	337
I6.4	4II5	3755	3675	3755	46I5	3605	365	420	420	405	450	385	385	435	402
0	3740	3340	3245	3345	4I65	3220	-	-	-	-	-	-	-	-	-
4.4	3825	3455	3375	3430	4260	3260	85	II5	I30	85	95	40	85	I05	85
-	3890	3530	3450	3485	43I5	3320	I50	I90	205	I40	I50	I00	I45	I70	I52
9.9	4000	3645	3570	3575	44I0	34I5	260	305	325	230	245	I95	245	275	260
I5.9	4I30	3790	3705	3700	4540	3540	390	450	460	355	375	320	372	4I2	390

Table. C.3.Continuation   Cycles 3-5.

Stress K.S.I.	Gauge readings I	2	3	4	5	6	Computed strains I	2	3	4	5	6	Mean strains (I&4)	(2&5)	(3&6)
Specimen ends hand lapped.															
0	3745	3340	3250	3350	4I65	3220	-	-	-	-	-	-	-	-	-
3.7	3790	34I5	33I0	3420	4275	3305	45	75	60	70	II0	85	58	92	72
7.7	3880	35I0	3405	3500	4360	3395	I35	I70	I55	I50	I95	I75	I42	I82	I65
II.2	3985	3620	35I5	3595	4460	3495	240	280	265	245	295	275	242	287	270
I5.I	4085	3725	36I5	3685	4545	3585	340	385	365	335	380	365	337	382	365
I7.9	4I70	3820	3700	3755	4620	3660	425	480	450	405	455	440	4I5	468	455
Specimenends hand lapped.															
0	3770	3365	3270	3370	4435	3235	-	-	-	-	-	-	-	-	-
3.9	3840	3470	3370	3455	4525	3305	70	I05	I00	85	90	70	77	97	85
7.2	39I5	3550	3455	3545	4605	3385	I45	I85	I85	I75	I70	I50	I60	I77	I67
I0.6	4000	3645	3550	3645	4695	3480	235	280	280	275	260	245	255	270	263
I4.9	4II0	3755	3655	3770	48I0	3590	340	390	385	400	375	355	370	382	370
I8.7	4I95	3850	3740	3870	4900	3680	425	485	470	500	465	445	462	475	457
Specimen ends hand lapped.															
0	3745	3355	3225	3355	4420	3205	-	-	-	-	-	-	-	-	-
3.7	3835	3450	3335	3480	45I5	3290	90	95	II0	I25	95	85	I08	95	98
7.2	3925	3540	3425	3575	4600	3380	I80	I85	200	220	I80	I75	200	I82	I87
I0.6	40I5	3640	3520	3670	3685	3470	270	285	295	3I5	265	265	292	275	280
I3.7	4I00	3735	36I0	3755	4770	3550	355	380	385	400	350	345	380	365	365
I7.I	4I85	3825	3695	3840	4850	3635	440	470	470	485	430	430	482	450	450
2I.2	4290	3945	38I0	3950	4950	3735	545	590	585	595	530	530	570	560	558

Table. C.3.Continuation Cycles 6&7

Specimen ends hand lapped.

Stress K.S.I.	Gauge readings						Computed strains						Mean strains		
	1	2	3	4	5	6	1	2	3	4	5	6	(1&4)	(2&5)	(3&6)
0	3750	3375	3270	3355	4220	3220	-	-	-	-	-	-	-	-	-
4.4	3860	3475	3420	3445	4315	3315	110	100	150	90	95	95	100	98	123
8.0	3970	3560	3510	3540	4400	3400	220	185	240	185	180	180	203	183	210
11.5	4070	3650	3615	3620	4500	3505	320	275	345	265	280	285	293	277	315
14.8	4160	3735	3705	3715	4595	3600	410	360	435	360	375	380	385	367	408
17.2	4220	3800	3770	3790	4670	3675	470	425	500	435	450	455	452	437	477
20.2	4280	3860	3840	3860	4740	3750	530	485	570	505	520	530	518	503	550
Specimen and pistons together turned through 90°															
0	3785	3380	3290	3375	4225	3235	-	-	-	-	-	-	-	-	-
3.7	3905	3475	3430	3460	4315	3825	120	95	140	85	90	90	102	92	115
7.7	4000	3565	3520	3540	4410	3425	215	185	230	165	185	190	190	185	210
9.8	4090	3655	3620	3630	4505	3525	305	275	330	255	280	280	280	277	310
13.0	4155	3715	3685	3695	4570	3590	370	335	395	325	345	355	347	340	375
16.3	4220	3780	3750	3765	4645	3665	435	400	460	390	420	430	412	410	445
19.5	4290	3865	3830	3850	4735	3750	505	485	540	475	510	515	490	497	527

Table. C.3.Continuation Cycles 8-IO

Stress K.S.I.	Gauge readings I	2	3	4	5	6	Computed strains I	2	3	4	5	6	Mean strains (I&4)	(2&5)	(3&6)
Specimen and pistons together turned through 90°															
0	3795	3395	3300	3390	4235	3245	-	-	-	-	-	-	-	-	-
3.4	3890	3455	3395		4330	3360	95	60	95	-	95	II5	-	78	I05
7.2	3980	3540	3500	3560	4425	3450	I85	I45	200	I70	I90	205	II7	I67	202
I0.7	4070	3625	3590	3650	4520	3550	275	230	290	260	285	305	267	257	297
I4.I	4I65	37I5	3685	3750	4625	3655	370	320	385	360	390	4I0	365	355	397
I7.9	4245	3805	3775	3840	4720	3750	450	4I0	475	450	485	505	450	447	490
2I.5	4325	3890	3855	3935	4825	3850	530	495	555	545	590	6I5	538	543	585
Specimen and pistons together turned through 90°															
0	3795	3390	3300	3390	4200	3250	-	-	-	-	-	-	-	-	-
3.4	3920	3480	34I0	3445	4290	3345	I25	90	II0	55	90	95	90	90	I02
7.2	4020	3565	35I0	3540	4395	3455	225	I75	2I0	I50	195	205	I87	I85	207
I0.I	4I00	3645	3590	36I0	4470	3540	305	255	290	220	270	290	262	262	290
I3.7	4I95	3730	3680	3695	4565	3640	400	340	380	305	365	390	352	353	385
I7.I	4275	38I0	3755	3775	4650	3730	480	420	455	385	450	480	437	445	467
20.5	4355	3890	3835	3860	4750	3825	560	500	535	470	550	575	5I5	525	555
Pistons turned relative to specimen.															
0	3780	3375	3290	3375	4200	3245	-	-	-	-	-	-	-	-	-
4.I	3805	3470	3425	3495	4295	3380	25	95	I45	I20	95	I35	72	95	I40
8.0	3885	3565	3540	3585	4390	3485	I05	I90	250	2I0	I90	240	I57	I90	245
II,2	3975	3665	3645	3685	4490	3590	I95	290	355	3I0	290	345	252	290	350
I4.8	4065	3760	3745	3780	4580	3685	285	385	455	405	380	440	345	382	447
I8.I	4I45	3850	3825	3860	4665	3770	365	475	535	485	465	525	425	470	530
2I.9	3860	3950	3930	3955	4760	3860	485	575	640	580	560	6I5	532	567	627

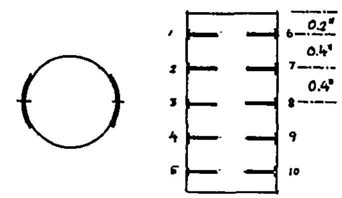
Table. C.3.Continuation Cycles 8-I0

Stress K.S.I.	Gauge readings I	2	3	4	5	6	Computed strains I	2	3	4	5	6	Mean strains (I&4)	(2&5)	(3&6)
Specimen and pistons together turned through 90°															
0	3795	3395	3300	3390	4235	3245	-	-	-	-	-	-	-	-	-
3.4	3890	3455	3395		4330	3360	95	60	95	-	95	II5	-	78	I05
7.2	3980	3540	3500	3560	4425	3450	I85	I45	200	I70	I90	205	II7	I67	202
I0.7	4070	3625	3590	3650	4520	3550	275	230	290	260	285	305	267	257	297
I4.I	4I65	37I5	3685	3750	4625	3655	370	320	385	360	390	4I0	365	355	397
I7.9	4245	3805	3775	3840	4720	3750	450	4I0	475	450	485	505	450	447	490
2I.5	4325	3890	3855	3935	4825	3850	530	495	555	545	590	6I5	538	543	585
Specimen and pistons together turned through 90°															
0	3795	3390	3300	3390	4200	3250	-	-	-	-	-	-	-	-	-
3.4	3920	3480	34I0	3445	4290	3345	I25	90	II0	55	90	95	90	90	I02
7.2	4020	3565	35I0	3540	4395	3455	225	I75	2I0	I50	I95	205	I87	I85	207
I0.I	4I00	3645	3590	36I0	4470	3540	305	255	290	220	270	290	262	262	290
I3.7	4I95	3730	3680	3695	4565	3640	400	340	380	305	365	390	352	353	385
I7.I	4275	38I0	3755	3775	4650	3730	480	420	455	385	450	480	437	445	467
20.5	4355	3890	3835	3860	4750	3825	560	500	535	470	550	575	5I5	525	555
Pistons turned relative to specimen.															
0	3780	3375	3290	3375	4200	3245	-	-	-	-	-	-	-	-	-
4.I	3805	3470	3425	3495	4295	3380	25	95	I45	I20	95	I35	72	95	I40
8.0	3885	3565	3540	3585	4390	3485	I05	I90	250	2I0	I90	240	I57	I90	245
II,2	3975	3665	3645	3685	4490	3590	I95	290	355	3I0	290	345	252	290	350
I4.8	4065	3760	3745	3780	4580	3685	285	385	455	405	380	440	345	382	447
I8.I	4I45	3850	3825	3860	4665	3770	365	475	535	485	465	525	425	470	530
2I.9	3860	3950	3930	3955	4760	3860	485	575	640	580	560	6I5	532	567	627

LATERAL STRAIN DATA.

TABLE: C.4. Specimen: C.04.1 Preparation: Lathe Final Cut 5 thou. (procedure no.I)

Loading: Load equalizing by plastic loading.



Stress K.S.I.	Gauge Readings 1	2	3	4	5	6	7	8	9	10
0	2860	3080	2810	3530	3280	2350	3640	3820	3440	2730
3.6	2990	3200	2900	3600	3290	2400	3710	3890	3550	2740
7.2	3090	3300	2990	3680	3350	2510	3800	3980	3580	2810
10.1	3200	3410	3090	3180	3420	2610	3900	4080	3680	2890
Pistons inverted.										
0	2870	3090	2810	3520	3280	2350	3630	3810	3430	2720
3.9	2980	3180	2900	3600	3290	2450	3740	3930	3510	2740
7.2	3070	3280	2980	3690	3350	2570	3840	4010	3600	2800
9.9	3150	3350	3050	3750	3400	2660	3920	4090	3670	2860
Specimen and pistons together inverted.										
0	2870	3090	2820	3520	3280	2860	3640	3820	3440	2730
3.7	2980	3190	2900	3590	3280	2480	3740	3920	3520	2740
7.7	3080	3290	3000	3700	3350	2610	3860	4030	3620	2820
10.4	3160	3370	3060	3770	3400	2690	3940	4110	3690	2880

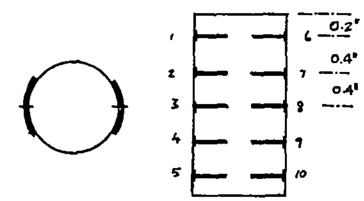
Table: Continuation of Table No. C.4.

Stress K.S.I.	Computed Strains 1	2	3	4	5	6	7	8	9	10	Mean Strains (1&6)	(2&7)	(3&8)	(4&9)	(5&10)
0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
3.6	130	120	90	70	10	50	70	70	60	10	90	95	80	65	10
7.2	230	220	180	150	70	160	160	160	140	80	195	200	170	145	75
10.1	340	330	280	250	140	260	260	260	240	160	300	295	270	245	150
Pistons inverted.															
0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
3.9	110	90	90	80	10	100	110	120	80	20	105	100	105	80	15
7.2	200	190	170	170	70	220	210	200	170	80	210	200	185	170	75
9.9	280	260	240	230	120	310	290	280	240	140	295	275	260	235	130
Specimens and pistons together inverted.															
0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
3.7	110	100	80	70	0	120	100	100	80	10	115	100	90	75	5
7.7	210	200	180	180	70	250	220	210	180	90	230	210	195	180	80
10.4	290	280	240	250	120	330	300	290	250	150	310	290	265	250	135

LATERAL DEFORMATION DATA

Table: C.5. Specimen: C.03.4 Preparation: Hand lapped.

Loading: Load equalizing by plastic loading.



Stress K.S.I.	Gauge Readings 1	2	3	4	5	6	7	8	9	10
0	2290	2695	4000	3155	3545	3140	2365	0025	3800	135
2.0	2340	2755	4065	3225	3615	4155	2415	0060	3825	145
3.3	2400	2800	4105	3270	3655	4235	2445	0090	3655	165
4.9	2455	2850	4150	3315	3695	4275	2490	0125	3895	200
7.2	2525	2910	4210	3380	3755	4330	2540	175	3945	245
9.9	2630	3010	4300	3465	3845	4420	2620	255	4020	315
CHK 0	2300	2700	4005	3165	3555	4135	2365	0030	3805	135
Pistons turned relative to specimens.										
0	2275	2680	3975	3135	3535	4115	2350	0010	3790	0110
3.1	2355	2750	4045	3205	3590	4275	2460	110	3875	165
6.5	2485	2870	4155	3315	3695	4375	2570	210	3975	265
10.1	2585	2965	4240	3410	3780	4485	2670	300	4065	340
13.7	2690	3060	4330	3510	3880	4590	2775	400	4170	430
Pistons inverted.										
0	2305	2720	3995	3145	3595	4155	2380	0035	3810	0135
2.4	2350	2780	4050	3200	3655	4255	2450	0100	3865	0170
5.0	2430	2850	4105	3275	3715	4330	2530	0170	3935	0235
8.6	2540	2945	4205	3375	3815	4440	2635	0270	4035	0330
10.9	2620	3030	4280	3450	3895	4520	2720	350	4120	410

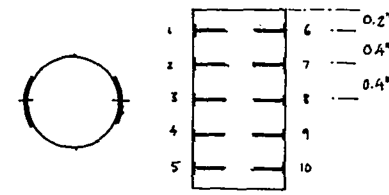
Table: Continuation of Table C.5.

Stress K.S.I.	Computed Strains 1	2	3	4	5	6	7	8	9	10	Mean Strains (1&6)	(2&7)	(3&8)	(4&9)	(5&10)
0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.0	50	60	65	70	70	25	50	35	25	10	38	55	50	48	40
3.3	110	105	105	115	110	105	85	65	55	30	108	95	85	85	70
4.9	165	155	150	160	155	145	125	100	95	65	155	140	125	128	105
7.2	235	215	210	225	210	200	175	150	145	110	218	195	180	185	170
9.9	340	315	300	310	300	290	255	200	220	180	315	285	250	265	240
CHK 0	10	5	5	10	10	5	0	5	5	0					
Pistons turned relative to specimen.															
0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3.1	80	70	70	70	55	160	110	100	85	55	120	90	85	78	55
6.5	210	210	180	180	160	260	220	200	185	155	235	215	190	183	158
10.1	310	315	265	275	245	370	320	290	275	230	340	318	278	275	238
13.7	415	420	355	375	345	475	425	390	380	320	445	423	373	378	333
Pistons inverted.															
0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.4	45	60	55	55	60	100	70	65	55	35	73	65	60	55	48
5.0	125	130	110	130	120	175	150	135	120	100	150	140	123	125	110
8.6	235	225	210	230	220	285	255	235	225	195	260	240	223	228	268
10.9	315	310	285	305	300	365	340	315	310	275	340	325	300	308	288

LATERAL DEFORMATION DATA.

Table: C.6. Specimen: C.03.4 Preparation: Hand lapped.

Loading: Load equalizing by plastic loading.



Stress K.S.I.	Gauge Readings					Gauge Readings				
	1	2	3	4	5	6	7	8	9	10
0	2315	2745	4020	3285	3680	4245	2385	125	3865	155
2.0	2405	2835	4100	3385	3790	4300	2435	165	3900	175
3.9	2480	2895	4160	3445	3835	4350	2485	210	3945	200
5.9	2555	2965	4220	3505	3895	4405	2540	265	4005	245
8.3	2630	3035	4290	3510	3965	4470	2605	325	4070	290
10.2	2695	3095	4345	3625	4015	4520	2660	380	4125	335
11.5	2735	3130	4385	3665	4055	4555	2695	415	4165	365
13.7	2795	3190	4435	3700	4080	4600	2745	475	4180	410
15.8	2860	3255	4495	3755	4140	4660	2805	540	4240	460
17.7	2925	3320	4555	3815	4205	4715	2865	595	4295	505
19.5	2985	3355	4615	3870	4250	4770	2915	655	4350	555
21.5	3050	3450	4675	3930	3525	4835	2980	725	4410	610
23.7	3115	3520	4740	3995	4385	4895	3040	790	4470	675
25.5	3180	3590	4805	4060	4485	4955	3105	855	4540	680
27.5	3255	3665	4870	4130	4790	5020	3175	925	4615	753
29.3	3305	3720	4915	4180	4915	5070	3220	1980	4665	800
31.2	3375	3795	4985	4256	5085	5135	3295	1055	4745	876
33.3	3440	3870	3050	4330	5225	5205	3365	1130	4820	935
36.0	3535	3985	5155	4450	5470	5305	3470	1250	4935	1035
37.9	3585	4065	5270	4525	5550	5370	3540	1330	5010	1105
40.0	3645	4166	5705	4640	5750	5455	3620	1435	5125	1205
42.3	3725	4280	5400	4810	6055	5505	3725	1605	5295	1380
44.3	Failure									

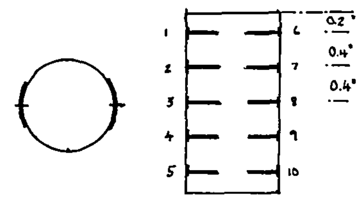
Table: Continuation of table No.C. 6.

Stress K.S.I.	Computed Strains 1	2	3	4	5	6	7	8	9	10	Mean Strains (1&6)	(2&7)	(3&8)	(4&9)	(5&10)
0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.0	90	90	80	100	110	55	50	40	35	20	72	70	60	68	68
3.9	165	150	140	160	155	105	100	85	80	45					
5.9	240	220	200	220	215	160	155	140	140	90					
8.3	315	290	270	285	285	225	220	200	205	135	270	255	235	245	210
10.2	380	350	325	340	335	275	375	255	260	180					
11.5	420	385	365	380	375	310	310	290	300	210					
13.7	480	445	415	415	400	355	360	350	315	255	417	400	382	365	327
15.8	545	510	475	470	460	415	420	415	375	305					
17.7	610	575	535	530	525	470	480	470	430	350					
19.5	670	640	595	585	570	525	530	530	485	400	600	585	562	535	455
21.5	735	705	656	645	645	590	595	600	545	455					
23.7	800	775	720	710	705	650	655	665	605	520					
25.5	865	845	785	775	805	710	720	730	675	525	787	782	755	725	665
27.5	940	920	850	845	1110	775	790	800	750	600					
29.3	990	975	895	895	1235	825	835	855	800	645					
31.2	1060	1050	965	965	1405	890	910	930	880	715	975	980	945	922	-
33.3	1125	1125	1030	1045	1545	960	980	1005	935	780					
36.0	1220	1240	1135	1165	1790	1060	1085	1125	1070	880					
37.9	1270	1320	1200	1240	1870	1125	1155	1205	1145	950	1200	1237	1200	1192	-
40.0	1330	1415	1285	1355	2070	1210	1235	1310	1260	1050					
42.3	1410	1535	1380	1525	2315	1260	1340	1480	1430	1225					
44.3	Failure														

LATERAL DEFORMATION DATA

Table: C.7. Specimen: C.06.2 Preparation: Hand lapped.

Loading: Load equalizing by plastic loading.

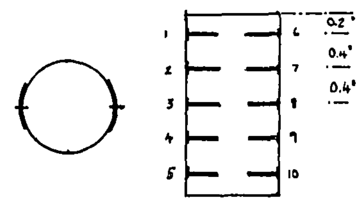


Stress K.S.I.	Gauge Readings 1	2	3	4	5	6	7	8	9	10
0	495	180	300	670	1380	2115	1735	2610	500	305
2.4	500	1105	335	710	1425	2210	1635	2715	600	405
5.0	545	1155	385	760	1470	2260	1580	2780	660	450
7.3	605	1215	445	820	1530	2345	1495	2855	735	525
9.9	670	1280	515	890	1595	2420	1415	2935	815	595
12.2	725	1340	575	950	1655	2495	1340	3010	885	665
14.6	785	1400	635	1010	1715	2560	1265	3080	950	725
17.1	845	1465	700	1070	1780	2635	1190	3160	1020	790
19.5	905	1525	765	1135	1845	2700	1110	3235	1090	855
22.3	965	1590	835	1200	1905	2775	1030	3315	1165	925
24.9	1035	1665	905	1280	1980	2855	940	3405	1255	1000
26.8	1080	1715	955	1325	2025	2910	880	3465	1310	1045
29.3	1145	1785	1030	1400	2095	2990	785	3560	1395	1125
31.7	1205	1855	1100	1470	2160	3060	700	3645	1475	1145
34.1	1275	1930	1175	1545	2230	3140	600	3745	1565	1270
36.6	1335	2000	1250	1625	2300	3220	505	3840	1655	1350
39.2	1400	2070	1325	1700	2375	3300	400	3940	1755	1430
	Failure									

LATERAL DEFORMATION DATA

Table: C.7. Specimen: C.06.2 Preparation: Hand lapped.

Loading: Load equalizing by plastic loading.



Stress K.S.I.	Gauge Readings 1	2	3	4	5	6	7	8	9	10
0	495	180	300	670	1380	2115	1735	2610	500	305
2.4	500	1105	335	710	1425	2210	1635	2715	600	405
5.0	545	1155	385	760	1470	2260	1580	2780	660	450
7.3	605	1215	445	820	1530	2345	1495	2855	735	525
9.9	670	1280	515	890	1595	2420	1415	2935	815	595
12.2	725	1340	575	950	1655	2495	1340	3010	885	665
14.6	785	1400	635	1010	1715	2560	1265	3080	950	725
17.1	845	1465	700	1070	1780	2635	1190	3160	1020	790
19.5	905	1525	765	1135	1845	2700	1110	3235	1090	855
22.3	965	1590	835	1200	1905	2775	1030	3315	1165	925
24.9	1035	1665	905	1280	1980	2855	940	3405	1255	1000
26.8	1080	1715	955	1325	2025	2910	880	3465	1310	1045
29.3	1145	1785	1030	1400	2095	2990	785	3560	1395	1125
31.7	1205	1855	1100	1470	2160	3060	700	3645	1475	1145
34.1	1275	1930	1175	1545	2230	3140	600	3745	1565	1270
36.6	1335	2000	1250	1625	2300	3220	505	3840	1655	1350
39.2	1400	2070	1325	1700	2375	3300	400	3940	1755	1430
	Failure									

Table: Continuation of Table C.7.

Stress K.S.I.	Computed Strains										Mean Strains				
	1	2	3	4	5	6	7	8	9	10	(1&6)	(2&7)	(3&8)	(4&9)	(5&10)
0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.4	35	45	35	40	25	90	95	85	100	50	63	70	60	70	38
5.0	110	110	95	100	75	180	170	160	155	110	145	140	128	128	93
7.3	170	175	155	165	140	250	240	225	220	170	210	208	190	193	155
9.9	240	250	215	230	205	325	305	290	285	235	283	277	253	258	220
12.2	305	320	275	290	265	390	365	350	345	290	348	343	313	318	278
14.6	380	400	345	365	335	460	435	425	420	360	420	418	385	393	348
17.1	450	475	420	435	400	530	505	495	490	425	490	490	458	463	413
19.5	525	560	500	510	470	600	570	570	500	490	563	565	535	535	480
22.3	615	655	595	595	545	675	650	650	640	565	645	652	628	620	555
24.9	700	750	695	675	620	750	730	730	720	635	725	740	713	698	628
26.8	765	820	770	745	675	805	790	795	775	690	785	805	783	760	683
29.3	845	910	865	810	745	885	870	875	855	760	865	890	870	838	753
31.7	935	1010	975	895	815	960	940	960	940	835	947	975	968	918	825
34.1	1030	1115	1100	990	900	1050	1025	1055	1035	915	1040	1070	1078	1013	908
36.6	1125	1220	1215	1075	970	1125	1090	1135	1115	990	1125	1155	1175	1100	980
39.2	-	1395	1510	1205	1140	-	1020	1160	1245	1080					

LATERAL DEFORMATION DATA

Table: C.8. Specimen: C.05.1 Preparation: Lathe, final cuts,5 ,2, I thou. Face 1/16". (procedure no.3)

Loading: Load equalizing by plastic loading.

Stress K.S.I.	Gauge Readings 1	2	3	4	5	6	7	8	9	10
0	1645	1965	1640	2325	2175	1305	2505	2720	2355	1680
2.6	1680	2010	1675	2365	2200	1395	2600	2805	2435	1730
4.7	1755	2075	1735	2425	2250	1485	2675	2880	2510	1790
7.3	1815	2140	1795	2490	2315	1555	2745	2945	2575	1850
9.9	1885	2215	1855	2555	2380	1630	2810	3010	2640	1915
12.2	1950	2285	1915	2615	2440	1695	2870	3070	2700	1970
14.6	2025	2365	1985	2690	2510	1765	2940	3145	2775	2040
17.1	2095	2440	2060	2760	2575	1835	3010	3215	2845	2105
19.5	2170	2525	2140	2835	2645	1905	3075	3290	2915	2170
22.0	2260	2620	2735	2920	2720	1980	3155	3370	2995	2245
24.9	2345	2715	2335	3000	2795	2055	3235	3450	3015	2315
26.7	2410	2785	2410	3060	2850	2110	3295	3515	3130	2370
29.3	2490	2875	2505	3135	2920	2190	3370	3595	3210	2440
31.7	2580	2975	2615	3220	2990	2265	3445	3680	3295	2515
34.3	2675	3080	2740	3315	3075	2355	3530	3775	3390	2595
36.8	2770	3185	2855	3400	3145	2430	3595	3855	3470	2670
39.0	-	3310	3150	3530	3215	-	3525	3880	3600	2760
40.9	Failure									

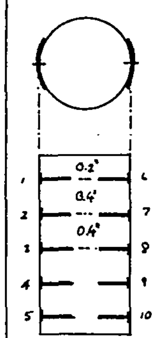


Table: Continuation of Table C.8.

Stress K.S.I.	Computed Strains 1	2	3	4	5	6	7	8	9	10	Mean Strains (1&6)	(2&7)	(3&8)	(4&9)	(5&10)
0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.6	5	25	35	40	45	95	100	105	100	100	50	63	70	70	73
4.7	50	75	85	90	90	145	155	170	160	145	98	115	128	125	118
7.3	110	135	145	160	150	200	240	245	235	220	155	190	195	198	185
9.9	175	200	215	230	215	305	320	325	315	290	240	260	270	273	253
12.2	230	260	275	290	275	380	395	400	385	360	305	328	338	338	318
14.6	290	320	335	350	335	445	470	470	455	420	373	395	403	400	378
17.1	350	385	400	400	400	520	545	550	525	485	435	465	475	460	443
19.5	410	445	465	465	465	585	625	625	590	550	498	535	545	528	508
22.0	470	510	535	530	525	660	705	705	665	620	568	608	620	598	573
24.9	540	585	605	610	600	740	795	795	755	695	640	690	700	683	648
26.7	585	635	655	655	645	795	855	855	810	740	690	745	755	732	693
29.3	650	705	730	730	715	875	950	950	895	820	763	828	840	813	768
31.7	710	775	800	800	780	945	1035	1035	975	890	828	905	918	888	835
34.3	780	850	875	875	850	1025	1135	1135	1065	965	903	993	1005	970	908
36.8	840	920	950	955	920	1105	1230	1230	1155	1045	3974	1075	1090	1055	983
39.0	905	990	1025	1030	995	1185	1335	1330	1255	1125	1045	1163	1178	1143	1060
40.9	Failure														

Table: D.1 UNIAXIAL COMPRESSIVE STRENGTHS.

Preparation: Wheel angle $7\frac{1}{2}^{o}$, Final cut 5 thou. (procedure no.I)

Loading: Load equalizing by plastic loading.

Specimen No.	Original No.	Length Ins.	Failure Load, Lbs.	Strength p.s.i.
1.01	C.09.3	2.14	21,300	34,600
1.02	C.10.4	2.13	28,300	46,000
1.03	C.13.1	2.18	27,600	44,900
1.04	C.15.2	2.26	26,700	43,400
1.05	C.16.3	2.21	26,800	43,600
1.06	C.17.3	2.21	26,400	43,000
1.07	C.18.3	2.20	21,500	34,900
1.08	C.19.3	2.25	25,300	41,100
1.09	C.20.3	2.18	20,900	34,000
1.10	C.22.2	2.22	24,900	40,500
1.11	C.23.3	2.10	22,900	37,300
1.12	C.24.3	2.11	23,800	38,700
1.13	C.25.3	2.21	27,000	43,900
1.14	C.26.3	2.22	24,700	40,100
1.15	C.27.4	2.24	21,700	35,200

Mean Strength 41,300 p.s.i.

Standard deviation 4,000 p.s.i.

Coefficient of variation 9.7%

Mean L/D 2.47

Table: D.2 UNIAXIAL COMPRESSIVE STRENGTHS.

Preparation: Wheel angle $7\frac{1}{2}^{o}$, Final cut 5 thou., (procedure no.I)

Loading: Spherical block, pistons.

Specimen No.	Original No.	Length Ins.	Failure Load, lbs.	Strength p.s.i.
2.01	C.09.4	2.15	25,400	41,300
2.02	C.11.2	2.17	18,400	29,900
2.03	C.14.1	2.24	24,800	40,300
2.04	C.15.3	2.15	19,500	31,700
3.05	C.16.4	2.22	22,800	37,100
2.06	C.17.4	2.16	24,400	39,700
2.07	C.18.4	2.14	22,700	36,900
2.08	C.19.4	2.14	17,900	29,100
2.10	C.22.3	2.13	17,000	27,600
2.11	C.23.4	2.19	18,200	29,600
2.12	C.24.4	2.17	26,600	43,300
2.13	C.25.4	2.17	24,900	40,500
2.14	C.26.4	2.16	20,100	32,700
2.15	C.28.1	2.19	18,400	29,900
2.16	C.29.1	2.20	28,700	46,700

Mean Strength 35,800 p.s.i.

Standard Deviation 5,800 p.s.i.

Coefficient of variation 15.3%

Mean L/D 2.45

Table: D.3 UNIAXIAL COMPRESSIVE STRENGTHS.

Preparation: Wheel angle $7\frac{1}{2}^{o}$, Final cut 5 thou.(procedure no.I)

Loading: Spherical block, no pistons.

Specimen No.	Original No.	Length Ins.	Failure Load,lbs.	Strength p.s.i.
3.01	C.10.1	2.12	22,600	36,700
3.02	C.11.3	2.26	24,400	39,700
3.04	C.15.4	2.20	21,200*	-
3.05	C.16.5	2.21	27,500	44,700
3.06	C.17.5	2.26	22,500	36,600
3.07	C.18.5	2.19	26,000	42,300
3.08	C.19.5	2.25	21,900	35,600
3.09	C.21.1	2.17	21,700	35,300
3.10	C.22.4	2.24	18,200	29,600
3.11	C.23.5	2.19	16,100	26,200
3.12	C.24.5	2.13	28,500	46,300
3.13	C.25.5	2.12	24,000	39,000
3.14	C.26.5	2.19	23,300	37,900
3.15	C.28.2	2.17	23,400	38,000
3.16	C.29.2	2.16	23,500	38,200

Mean strength 37,600 p.s.i.

Standard deviation 5,100 p.s.i.

Coefficient of variation 13.5%

Mean L/D 2.47

*excluded, may be incorrect

Table: D.4 UNIAXIAL COMPRESSIVE STRENGTHS.

Preparation: Wheel angle 40°, Final cuts 5, 2, 1 thou. (procedure no.2)

Loading: Load equalizing by plastic loading.

Specimen No.	Original No.	Length Ins.	Failure Load, Lbs.	Strength p.s.i.
4.01	C.10.2	2.18	29,100	47,300
4.02	C.12.1	2.22	24,000	39,000
4.03	C.14.3	2.16	27,000	43,900
4.04	C.16.1	2.24	28,200	45,900
4.05	C.17.1	2.19	24,900	40,500
4.06	C.18.1	2.17	24,400	39,700
4.07	C.19.1	2.20	27,100	44,100
4.08	C.20.1	2.17	21,700	35,300
4.09	C.21.2	2.23	27,200	44,200
4.11	C.24.1	2.21	30,300	49,300
4.12	C.25.1	2.19	22,200	36,100
4.13	C.26.1	2.19	28,500	46,300
4.14	C.27.2	2.11	28,700	46,700
4.15	C.28.3	2.10	20,200	32,800
4.16	C.29.3	2.17	27,100	44,100

Mean strength 42,300 p.s.i.

Standard deviation 4,700 p.s.i.

Coefficient of variation 11.1%

Mean L/D 2.46

Table: D.5 UNIAXIAL COMPRESSIVE STRENGTHS.

Preparation: Wheel angle 40°, Face 1/16",Final cuts 5,2,1 thou. (procedure no.3)

Loading: Load equalizing by plastic loading.

Specimen No.	Original No.	Length Ins.	Failure Load,lbs.	Strength p.s.i.
5.01	C.10.3	2.12	25,600	41,600
5.02	C.12.2	2.18	27,100	44,100
5.03	C.14.4	2.18	30,100	48,900
5.04	C.16.2	2.12	28,600	46,500
5.05	C.17.2	2.15	22,100	35,900
5.06	C.18.2	2.18	27,700	45,000
5.07	C.19.2	2.15	26,000	42,300
5.08	C.20.3	2.17	26,500	43.100
5.09	C.22.1	2.18	25,200	41,000
5.10	C.23.2	2.17	26,600	43,300
5.11	C.24.2	2.12	29,600	48,100
5.12	C.25.2	2.07	27,000	43,900
5.13	C.26.2	2.09	19,100	31,100
5.14	C.27.3	2.19	28,100	45,500
5.15	C.28.4	2.18	23,500	38,200

Mean strength 42,600 p.s.i.

Standard deviation 4,500 p.s.i.

Coefficient of variation 10.5%

Mean L/D 2.43

Table: D.6 UNIAXIAL COMPRESSIVE STRENGTHS.

Preparation: Wheel angle 40°, face 1/8", Final cuts 5,2,1 thou. (procedure no.4)

Loading: Load equalizing by plastic loading

Specimen No.	Original No.	Length Ins.	Failure Load, Lbs.	Strength p.s.i.
6.01	C.29.4	2.12	14,900	24,200
6.02	C.30.2	2.19	25,600	41,600
6.03	C.30.4	2.11	25,000	40,700
6.04	C.31.2	2.12	24,200	39,300
6.05	C.32.3	2.18	16,500	26,800
6.06	C.32.5	2.17	23,400	38,000
6.07	C.33.2	2.25	19,000	30,900
6.08	C.34.1	2.19	21,200	34,500
6.09	C.34.3	2.19	22,200	36,100
6.10	C.35.1	2.31	18,500	30,100
6.11	C.35.3	2.12	26,400	42,900
6.12	C.36.2	2.14	26,500	43,100
6.13	C.37.2	2.14	27,000	43,900

Mean Strength 36,300 p.s.i.

Standard deviation 6,300 p.s.i.

Coefficient variation 17.4%

Mean L/D 2.45

SURFACE TRAVERSES

Table: E.1.1 Surface: Specimen C.05.2, End No. 2

Preparation: Hand lapped.

Positions of Readings, at 0.1" Intervals.

Traverse	1	2	3	4	5	6	7	8	9
1	.03575	.03783	.04105	.04310	.04510	.05167	.05035	.05263	.05478
2	590	898	157	358	595	850	106	350	470
3	635	790	89	310	508	736	20	280	485
4	642	884	152	400	605	858	100	352	482
5	640	802	85	325	517	740	12	265	480
6	648	917	147	386	602	850	120	350	470
7	636	800	82	315	550	775	18	304	486
8	615	892	150	380	597	865	120	345	480
9	645	804	90	310	510	772	50	280	484
10	636	900	133	378	514	842	127	355	489
Sum	6262	8470	1190	3472	5568	8055	708	3144	4804
Mean	626	847	119	347	557	806	71	314	480

SURFACE TRAVERSES

Table: E.1.2 Surface: Specimen C.05.2, End No. 2

Preparation: Hand lapped.

Positions of Readings, at 0.1" Intervals.

Traverse	1	2	3	4	5	6	7	8
1	.04623	.04736	.04925	.05160	.05332	.05528	.05691	.05890
2	628	824	37	217	405	590	770	975
3	570	721	940	157	335	515	695	870
4	625	840	7	222	400	568	750	970
5	560	714	930	174	322	503	698	865
6	620	840	37	222	409	595	756	954
7	562	718	940	160	310	510	695	865
8	615	835	33	235	402	590	770	965
9	555	720	915	160	310	500	692	860
10	630	832	40	230	405	596	770	974
Sum	5988	7780	9804	1937	3630	5555	7287	9198
Mean	599	778	980	194	363	556	729	920

SURFACE TRAVERSES

Table: E.1.3 Specimen: C.05.2, End No. 2

Preparation: Hand lapped.

Positions of Readings, at 0.1" Intervals.

Traverse	1	2	3	4	5	6	7	8	9
1	.18335	.18496	.18670	.18870	.19020	.19283	.19480	.19650	.19762
2	210	518	685	892	68	292	515	710	768
3	280	512	682	895	90	312	485	610	800
4	300	525	660	880	25	262	482	660	760
5	300	472	655	815	10	222	417	690	755
6	315	512	720	817	70	308	457	672	155
7	315	495	770	825	968	305	415	600	732
8	270	520	680	912	20	280	485	640	738
9	310	490	710	868	25	275	415	595	740
10	205	538	175	850	75	282	480	685	762
Sum	2900	5078	6857	8624	401	2821	4631	6518	7512
Mean	290	508	686	862	40	282	463	652	757

SURFACE TRAVERSES

Table: E.2.1 Surface: Piston No. 1.

Preparation: Surface ground.

Positions of Readings, at 0.1" Intervals.

Traverse	1	2	3	4	5	6	7	8
1	.07790	.07802	.07860	.07905	.07942	.08020	.08082	.08119
2	880	930	962	25	55	102	150	170
3	850	852	900	930	975	03	80	100
4	882	930	961	24	58	97	152	142
5	815	820	860	908	968	104	88	110
6	875	930	967	25	57	105	152	172
7	852	855	898	938	977	5	80	108
8	857	930	965	25	58	107	142	143
9	812	840	895	930	975	104	68	108
10	872	930	970	27	60	93	150	160
Sum	8485	8819	9238	9737	10125	10740	1144	1332
Mean	849	882	924	974	12	74	114	133

SURFACE TRAVERSES

Table: E.2.2 Surface: Piston No. 1.

Preparation: Surface ground.

Positions of Readings, at 0.1" Intervals.

Traverse	1	2	3	4	5	6	7	8
1	.08532	.08360	.08197	.08060	.07880	.07722	.07564	.07446
2	475	315	150	990	784	644	505	398
3	490	302	208	50	878	720	570	450
4	472	302	134	974	787	640	503	386
5	519	364	237	58	882	720	554	424
6	462	297	162	978	785	640	500	390
7	507	364	241	58	892	720	515	438
8	470	296	169	960	788	645	512	394
9	520	365	197	60	881	730	516	428
10	475	307	152	973	785	645	502	389
Sum	4922	3332	1847	10161	8342	6824	5361	4143
Mean	492	333	185	16	834	682	536	414

SURFACE TRAVERSES

Table: E.2.3 — Surface: Piston No. 1

Preparation: Surface Ground.

Positions of Readings, at 0.1" Intervals.

Traverse	1	2	3	4	5	6	7	8
1	.08640	.08438	.08233	.08038	.07820	.07625	.07441	.07242
2	552	370	187	970	732	538	384	198
3	618	440	240	42	798	625	443	237
4	544	362	180	945	734	548	368	195
5	630	431	238	40	825	625	430	242
6	545	375	194	940	710	545	386	198
7	625	434	248	30	827	622	460	246
8	552	372	190	930	727	556	382	200
9	632	448	250	35	820	628	460	255
10	547	380	190	943	737	555	380	210
Sum	5885	4050	2150	9913	7730	5867	4134	2223
Mean	589	405	215	991	773	587	413	222

SURFACE TRAVERSES

Table: E.3.1. Surface: X.1.

Preparation: Lathe, final cuts 10, 5thou.(procedure no.I)

Positions of Readings, at 0.1" Intervals.

Traverse	1	2	3	4	5	6	7
1	.04299	.04299	.04322	.04353	.04422	.04482	.04580
2	319	319	392	417	505	570	670
3	312	312	327	353	422	484	574
4	320	320	392	420	508	570	658
5	297	297	323	355	422	482	580
6	318	320	398	420	510	575	692
7	302	302	323	357	438	482	575
8	320	320	392	422	508	570	672
9	320	317	330	357	442	483	575
10	317	320	392	424	512	575	682
Sum	2924	3126	3672	3879	4689	5273	6198
Mean	292	313	367	388	469	527	620

SURFACE TRAVERSES

Table: E.4.1 Surface: C.06.2, End No. 1

Preparation: Hand lapped.

Positions of Readings, at 0.1" Intervals.

Traverse	1	2	3	4	5	6	7	8
1	.11212	.11212	.11212	.11212	.11212	.11212	.11212	.11212
2	210	210	210	210	210	210	210	210
3	210	210	210	210	210	210	210	210
4								
5								
6					No change			
7								
8								
9								
10								
Sum								
Mean	210	210	210	210	210	210	210	210

SURFACE TRAVERSES

Table: E.4.2 Surface: C.06.2, End No. 1

Preparation: Hand lapped.

Positions of Readings, at 0.1" Intervals.

Traverse	1	2	3	4	5	6	7
1	.10862	.10995	.11100	.11205	.11293	.11383	.11480
2	982	86	190	280	378	465	523
3	897	998	97	200	288	370	432
4	982	90	190	274	382	462	522
5	942	0	100	200	300	376	472
6	990	100	180	288	380	467	520
7	960	0	115	205	290	392	445
8	990	83	177	280	370	463	520
9	915	0	100	203	297	380	440
10	983	90	197	275	375	465	520
Sum	9503	442	1446	2410	3353	4223	4874
Mean	950	44	144	241	335	422	487

SURFACE TRAVERSES

Table: E.4.3 Surface: C.06.2, End No. 1

Preparation: Hand lapped.

Positions of Readings, at 0.1" Intervals.

Traverse	1	2	3	4	5	6	7
1	.10915	.11023	.11152	.11256	.11327	.11422	.11515
2	28	152	260	355	440	532	560
3	922	27	158	265	325	443	520
4	39	153	255	358	445	520	570
5	925	27	173	265	325	422	520
6	40	157	255	360	457	530	560
7	915	30	172	261	325	442	522
8	40	153	257	360	455	533	567
9	910	27	180	265	325	467	516
10	50	155	260	360	454	538	558
Sum	9964	904	2116	3105	3872	4849	5408
Mean	996	90	212	311	387	485	541

SURFACE TRAVERSES

Table: E.5.1 Surface: C.06.2, End No. 2

Preparation: Hand lapped.

Positions of Readings, at 0.1" Intervals.

Traverse	1	2	3	4	5	6	7
1	.12646	.12675	.12700	.12722	.12782	.12800	.12815
2	745	767	818	832	832	832	833
3	678	700	712	730	790	798	823
4	740	765	815	855	860	860	860
5	668	694	713	729	790	802	824
6	680	748	777	830	832	832	832
7	678	694	717	735	786	805	825
8	750	770	837	862	862	802	862
9	678	697	716	730	790	802	825
10	740	767	818	863	870	870	870
Sum	7063	7227	7623	7888	8194	8203	8369
Mean	706	723	762	789	819	820	837

SURFACE TRAVERSES

Table: E.5.2 Surface: C.06.2, End No. 2

Preparation: Hand lapped.

Positions of Readings, at 0.1" Intervals.

Traverse	1	2	3	4	5	6	7
1	.12662	.12723	.12788	.12875	.12964	.13032	.13146
2	762	860	953	18	90	152	205
3	762	762	802	872	980	35	132
4	767	862	960	20	83	166	205
5	767	780	800	870	980	25	118
6	762	865	928	15	72	165	202
7	762	762	800	882	930	68	135
8	770	862	957	17	87	168	210
9	770	770	800	898	930	59	119
10	770	860	952	995	75	56	205
Sum	7554	8106	8740	9462	191	1021	1677
Mean	755	811	874	946	19	102	168

SURFACE TRAVERSES

Table: E.6.1 Surface: D.4.01, End No. 1

Preparation: Lathe, Final cuts 5, 2, 1 thou. Wheel angle 40° (procedure no.2)

Positions of Readings, at 0.1" Intervals.

Traverse	1	2	3	4	5	6	7	8
1	.03402	.03440	.03494	.03515	.03601	.03672	.03742	.03800
2	454	530	560	596	692	755	852	860
3	430	460	498	518	603	677	735	805
4	458	530	575	597	690	752	852	902
5	417	456	500	517	607	684	740	804
6	455	530	562	590	685	753	850	874
7	428	459	495	520	610	680	740	805
8	471	533	565	600	682	753	845	847
9	437	458	496	520	602	670	742	808
10	473	527	568	597	680	752	852	882
Sum	4425	4923	5313	5570	6472	7148	7950	8387
Mean	443	492	531	557	647	715	795	839

SURFACE TRAVERSES

Table: E.6.2 Surface: D.4.01, End No. 1

Preparation: Lathe, Final cuts 5, 2, 1 thou. Wheel angle 40^0 (procedure no.2)

Positions of Readings, at 0.1" Intervals.

Traverse	1	2	3	4	5	6	7	8
1	.03526	.03526	.03530	.03539	.03595	.03636	.03701	.03767
2	540	564	602	617	660	732	783	790
3	520	520	522	537	588	645	700	773
4	548	562	600	606	658	738	785	800
5	508	510	522	534	596	629	695	763
6	538	565	598	614	657	748	782	790
7	510	510	522	533	587	626	703	772
8	540	565	593	610	660	747	780	785
9	502	505	521	576	588	625	694	764
10	538	562	590	608	666	743	770	772
Sum	5270	5389	5600	5774	6255	6868	7393	7776
Mean	527	539	560	577	626	687	739	778

SURFACE TRAVERSES

Table: E.6.3 Surface: D.4.01, End No. 1

Preparation: Lathe, Final cuts 5,2,1 thou. Wheel angle 40° (procedure no.2)

Positions of Readings, at 0.1" Intervals.

Traverse	1	2	3	4	5	6	7	8
1	.03692	.03692	.03669	.03642	.03623	.03622	.03622	.03610
2	634	618	608	607	607	607	607	607
3	704	700	670	635	625	625	625	610
4	645	610	585	560	560	560	560	560
5	688	687	658	640	615	613	613	605
6	642	615	600	594	594	594	594	594
7	706	703	677	638	612	612	612	608
8	647	618	610	600	600	600	600	600
9	700	698	668	630	618	615	615	610
10	632	615	609	607	607	607	607	607
Sum	6690	6556	6354	6153	6061	6055	6055	6011
Mean	669	656	635	615	606	606	606	601

SURFACE TRAVERSES

Table: E.7.1 Surface: D.4.01, End No. 2

Finish: Lathe, Final cuts 5, 2, 1 thou Wheel angle 40° (procedure no.2)

Positions of Readings, at 0.1" Intervals.

Traverse	1	2	3	4	5	6	7
1	.03466	.03467	.03467	.03463	.03463	.03473	.03488
2	472	474	474	474	483	499	499
3	479	479	475	472	472	480	489
4	472	472	473	475	482	490	490
5	480	480	467	466	466	480	490
6	472	472	472	473	487	500	500
7	477	477	470	470	470	482	490
8	472	472	473	474	485	495	495
9	478	478	477	472	472	480	492
10	472	472	472	474	482	492	492
Sum	4740	4743	4720	4713	4762	4871	4925
Mean	474	474	472	471	476	487	493

SURFACE TRAVERSES

Table: E.8.1 Surface: C.3.01, End No. 1

Preparation: Lathe, Final cut 5 thou. Wheel angle $7\frac{1}{2}^{o}$ (procedure no.I)

Positions of Readings at 0.1" Intervals.

Traverse	1	2	3	4	5	6	7
1	.00890	.00890	.00895	.00915	.00990	.01070	.01125
2	915	955	986	48	78	150	195
3	898	900	903	928	995	62	120
4	921	956	993	50	80	158	169
5	882	885	898	920	0	63	117
6	913	955	992	50	87	165	204
7	892	895	901	925	992	63	130
8	922	955	990	47	85	160	165
9	882	886	892	920	0	67	117
10	920	956	995	50	72	157	188
Sum	9035	9233	9445	9853	10379	11115	11530
Mean	904	923	945	985	38	112	153

SURFACE TRAVERSES

Table: E.9.1 Surface: D.5.01, End No. 1

Preparation: Lathe, Final cuts 5,2,1 thou. Wheel angle 40^{o}, Face 1/16" (procedure no.3)

Positions of Readings, at 0.1" Intervals.

Traverse	1	2	3	4	5	6	7
1	.07420	.07420	.07408	.07347	.07310	.07256	.07255
2	368	311	283	220	220	218	218
3	412	412	400	333	309	263	262
4	375	318	288	223	222	220	220
5	410	410	390	332	310	268	253
6	374	314	290	230	230	230	230
7	420	418	398	342	310	265	254
8	382	318	290	228	228	228	228
9	412	412	401	340	310	260	253
10	383	324	298	248	248	248	250
Sum	3956	3657	3446	2843	2697	2456	2423
Mean	396	366	345	284	270	246	242