THE RICE INSTITUTE

THE FAILURE OF CONCRETE UNDER TRIAXIAL STRESSES

by

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INTRODUCTION

This study was done to investigate the behavior of concrete under three-dimensional stresses with two objects in mind. The first object was to determine the effect of the lateral stresses on the longitudinal strength of a concrete specimen with empty voids. The other was to determine the effect of the interstitial pressure on the strength of the material.

To achieve these two objects cylindrical concrete specimens were subjected to triaxial compressive stresses with two lateral stresses constant and equal and the specimens brought to failure under axial compression. Some specimens were tested with empty voids and others with a liquid under pressure in the pores. To create the first of these conditions a rubber tubing was used on the specimen to protect it from the liquid pressure. In the second case the liquid was free to penetrate the specimen voids. The relative difference, between the two, in the strength of the material gives the effect of liquid under pressure in the pores.

The influence of lateral stresses on the axial strength of a concrete member has a direct application in reinforced concrete columns. Also, this influence would help us to understand the behavior of concrete under various stresses and be useful in formulating a theory of failure. The case of liquid under pressure in the voids has a direct application to structures that are subject to hydraulic pressure. This is called the effect of pore-water pressure, or uplift,and it is important to understand its effect on stability for the design of any hydraulic structure. It is suggested by the latest theories that this effect can be determined only by experimental means. There is at present no definite idea about either the exact potential area of surface or the part of it on which the pore pressure acts.

PREVIOUS INVESTIGATIONS

A material may fail in one of two ways: One way is a brittle failure in which first there is an elastic behavior when stresses are proportional to deformations. This phase is followed by fracture. The second way is called ductile and has another range between the elastic range and fracture. In this range small changes of stress are usually accompanied by large deformations.

Several theories are used to explain the failure of materials. These may be briefly summarized as follows:

Maximum-stress theory: Failure occurs when maximum normal stress on any plane exceeds a limiting value for that material.

Maximum-strain theory: Failure occurs when the strain at any point exceeds the failing strain of the material in a simple tensile test.

Maximum-distortion-energy theory: There is a limit to the amount of distortion energy that a body can absorb and remain elastic.

Besides these there is another group of failure theories which are called planes-of-least-resistance theories. According to these failure occurs along a plane where resistance to shearing stress is smallest. In this group is Coulomb's Internal Friction Theory, in which the limiting value of shearing stress, s, consists of a constant shearing strength, c, and a resistance of the nature of friction, f, which is proportional to the normal stress, , acting on the plane. Thus

$$s = c + y(f)$$

Also in this group is the maximum-shear theory. According to this theory failure is produced when the maximum shear stress reaches a limiting value. This theory was proposed by Guest.

According to Mohr's theory normal stress plays a role in failure as well as shear and their interdependence is defined by:

$$s = f\ (y)$$

This equation is determined experimentally. The value of the intermediate principal stress plays no role in this theory. A more specific study of it will be given in the analysis section.

One of the earliest works in the field is by F. D. Adams[1] who in 1901 published results of triaxial tests on rock. In his case it was impossible to measure the confining pressure because of friction as he used a steel jacket to confine the specimen.

The next work was done by Karman and Böker[2] on marble, under confining pressures, mainly to test the correctness of Mohr's theory. In these tests compressive stresses were applied in three different ways. In the first case two equal principal stresses were higher than the third principal stress, and in the second case two equal principal stresses were lower than the third principal stress. In the third case, test specimens were also subjected to tension. The first two cases indicated that the intermediate principal stress had some effect on the failure. Higher shearing stresses were present at failure in the first case than in the second. In the third case tensile stresses were produced and whenever they exceeded a limiting value failure occurred, which contradicts Mohr's theory.

Probably the most comprehensive study was done at the University of Illinois and was published in Bulletin 185.[2] In these tests three different series of tests were done. In the first group concrete specimens were subjected to two-dimensional compression. In the second and third groups specimens were subjected to triaxial compression. In the second group the two lateral stresses were lower than the axial stress; in the third group they were higher. Using these tests Brandtzaeg[3] developed a failure theory, which is explained in the analysis and also in Appendix 2.

In the biaxial tests at the University of Illinois, specimens were compressed laterally with oil pressure with no stress in the third direction. To prevent failure due to axial tensile stress specimens were covered with plaster of Paris, then by a thin sheet of annealed brass and protected from oil pressure that way. It was concluded that the strength of concrete under biaxial compression is at least as great as under uniaxial compression and in some cases 25 to 50% greater. Failure occurred suddenly as a total fracture across a plane normal to the axis of the cylindrical specimen. It was also concluded that Saint Venant's maximum-strain theory is inapplicable to concrete for the following reason: if we compute the strains due to combined compression from the equations of elasticity and stipulate that the tensile strain should not exceed a fixed limit, we find a strength in biaxial compression one-half that of uniaxial compression, which is not the case.

Series 3a presented in Bulletin 185 is much the same as the author's jacketed tests and will be referred to later. In Series 3B two lateral stresses were higher than the axial. It was concluded from Series 3a and 3b that the compressive strength of concrete increases with confining pressure, and that the amount of the increase is 4.1 times the smallest principal stress.

In 1936 Griggs[4] made important contributions to the design of high pressure equipment. His equipment is basically the same as that designed by Jones[5] and used by the author in this study.

At this point it is best to introduce some contributions on the effect of pore pressure, which, in regard to hydraulic structures, is often mentioned as uplift. Earlier theories considered the water in the pores of an hydraulic structure due to either imaginary or visible cracks. Modern views disregard these abstract views and accept the fact that water filters through the pores of masonry or concrete. It can be demonstrated that water can be made to pass through any kind of concrete by passing through the pores of the material, whether cracks are present or not.

Mr. Fillunger[6] was the first person to give a scientific approach to the modern views which later were revised by Professor Terzaghi. Professor Fillunger's approach is usually presented as three laws. He broke some specimens in free air and some subjected to confining pressure, so that water under pressure was present in the material's pores. He did not get any appreciable difference in ultimate load between the two cases, so he states that as long as the water in the pores remains at constant pressure it does not affect the resistance of the material. For his second law the author refers to Terzaghi's[6] example, which is a pier under water. See figure 1.

Let J = unit weight of the material of the pier

W = weight of the shaded portion

Then the stress at section AB will be equal to

$$\frac{W}{A} = HJ$$

Water in the pores will relieve some of this pressure. The relief in stress at section AB will be equal to the intensity of the water pressure at that level, $h\rho$, times the porosity of the material, which we

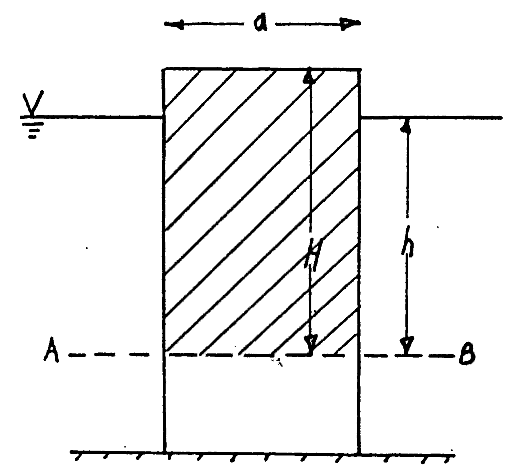

Figure 1

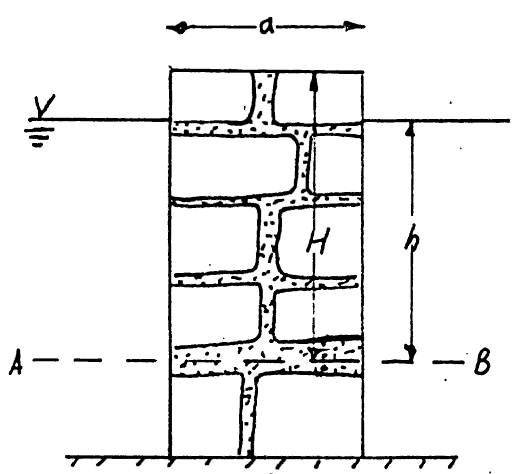

Figure 2

shall call n. Thus the relief in stress at section AB is:

$$h \rho n$$

where = unit weight of water.

But we see also that the water in the pores of the material will cause an increase in stress at section AB which would be equal to ρ times the volume of water in pores above AB per unit area of section, viz., h n. This increase in stress is thus

$$h \rho n$$

The total stress at section AB is therefore

$$HJ = h\rho n + h\rho n = HJ$$

This analysis shows that there is no difference between the cases of a pier under water and a pier completely out of water, as when there is no water the stress at section AB would still be HJ. At this point Prof. Fillunger introduced his third law by differentiating between the average porosity of the material, n, and the porosity of mortar, n_1. He reasoned that when failure occurs, the surface of rupture goes through the binding material such as mortar which binds the aggregates.

We refer to the same example of a pier under water, figure 2, which this time is formed of blocks of stone bound by more porous mortar. Using the same coefficients otherwise, pressure in the pores of section AB is: $h \rho n_1$

Weight of water absorbed at height h is:

So the final stress will be;

$$H J - h \rho (n_1 - n)$$

There is now an uplift force which is equal to:

$$P = h \rho (n_1 - n) \qquad (I)$$

and we define an uplift factor, U_f, as follows:

$$u_f = n_1 - n \qquad (2)$$

Fillunger's conclusion, expressed as Equation 2, has undergone some basic changes to which we shall refer.

Prof. K. Terzaghi[7, 8] in 1945 presented an analysis investigating the mechanical causes of failure of concrete with and without pore pressure. His analysis depends on the fact that splitting governs the failure and is due to an intergranular wedge action. He explains this action as follows:

Figure 3a is a section of a porous quasi-isotropic material which is acted on by a vertical force Y. This force will destroy the solid bonds of rounded particles by producing tension at point a. Professor Terzaghi concludes that if such a material fails by splitting, the failure in the bonds subject to tension will precede the failure in the others. Also, the average normal stress on that section is zero, but as the material is only statistically isotropic the normal stress is only statically equal to zero. If all the negative forces are divided by one-half of the section at a vertical section, negative scatter stress- y_s, is obtained. There is a compressive force per unit area on the other half. If there is an average stress, y, on the section, then one-half of the section is acted on by $y + y_s$, and the other by $y - y_s$. As soon as $-y_s$ becomes equal to the tensile strength, y_t of the material, failure is produced by the scatter stress, y_s. Prof. Terzaghi calls it splitting stress and expresses failure with equation 3 as:

$$y_s = y + y_t \qquad (3)$$

In triaxial compression, lateral pressure Y_2, is the normal stress, y, so that $y = Y_2$ in equation 3. Then failure in this case occurs when the splitting stress equals the normal stress (confining pressure in this

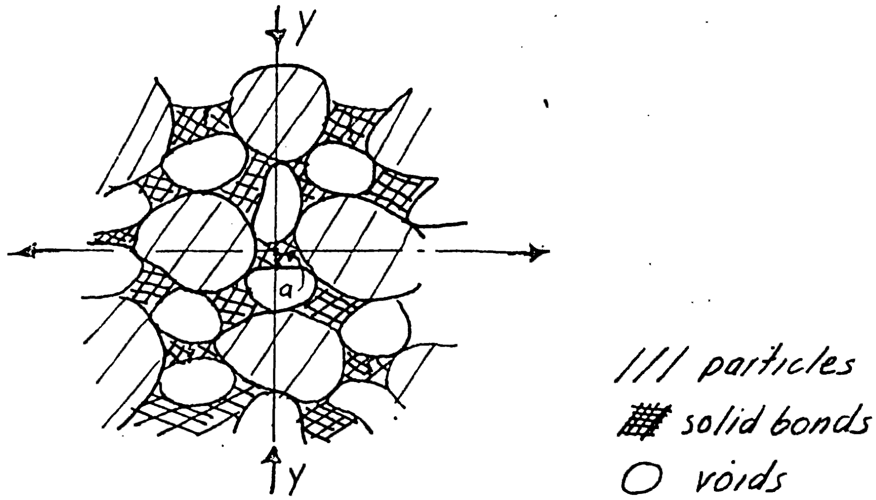

Figure 3 a

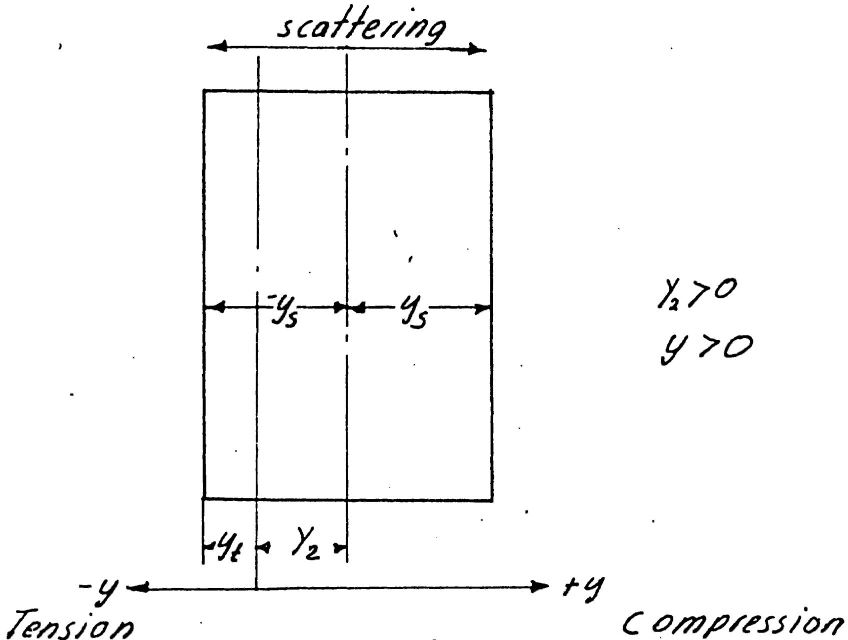

Figure 3b

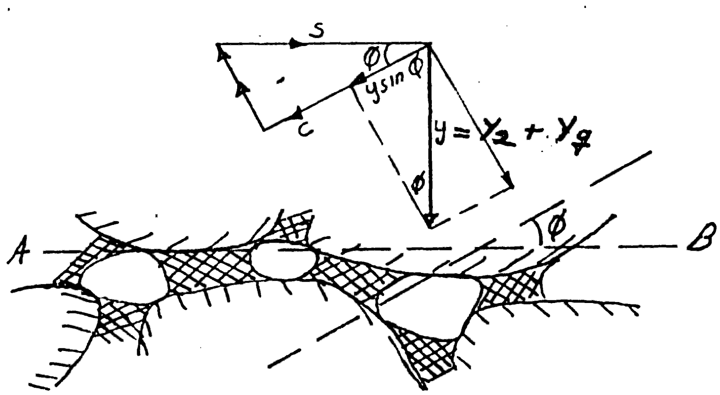

Figure 4

case) plus the tensile strength, y_t of the material. Also, since the total axial load, Y_1, produces y_s, splitting stress increases in proportion to total axial load. At $Y_2 = 0$ the failing value of Y_1 is equal to the compressive strength, y_c, of the material and:

$$y_s = y_t \frac{Y_1}{y_c}$$

Combining with equation 3, also remembering that, $y = Y_2$

$$Y_1 = y_c + Y_2 \frac{y_c}{y_t} \qquad (4)$$

Equation 4 represents the amount of total axial load we should expect in a triaxial loading.

According to this theory, failure is always intergranular, even in triaxial loading. In Figure 4, plane AB is the plane of failure of the material under triaxial loading, but at a particular point on this plane the details of the intergranular connections will cause the direction of movement associated with failure to deviate from plane AB by an angle ϕ . The total unit shearing resistance to failure, S_1, is the sum of two independent resistances, S and S_f, where

S = shearing stress required to sever the intergranular connections

S_f = frictional resistance of grains per unit area

Thus

$$S_1 = S + S_f \qquad (5)$$

From a consideration of the vector diagrams in Figure 4 we see that

$$S = \frac{c}{\cos \phi} + (Y_2 + Y_q) \tan \phi$$

and

$$S_f = (Y_2 + Y_q) \frac{f}{\cos \phi}$$

where: c = unit cohesive strength (assumed independent of stress)

f = coefficient of friction of grain on grain

y = normal stress on AB, which is actually equal to the confining pressure, Y_2, plus the excess unidimensional pressure, Y_q.

Further in his theory Professor Terzaghi considers the effect of pore water pressure and concludes that the liquid under pressure in the pores equal to lateral pressure will decrease the effect of the confining pressure as the pressure transmitted from solid to solid will no longer be Y_2, but instead will be $Y_2(1 - n_a)$, where n_a is the boundary porosity. This decrease depends on the degree of continuity of intergranular bond. It is the ratio of that area of the potential surface of failure which is in contact with the liquid in the pores and the total area of the surface. This factor should be introduced in Equations 4 and 5 when there is pore water pressure.

Professor Terzaghi's most important contribution in the uplift field is his disregarding of the plane section analysis of Professor Fillunger to find the uplift factor, as failure might be in a zig-zag way. Experimental methods are necessary to determine the uplift factor as it is not necessarily related to physical constants. As a result, equation 2 for uplift factor becomes

$$u_f = n_a - n \qquad (6)$$

Professor Terzaghi comes out with an n_a of unity in his experiments.

Mr. S. Leliavsky[9] also has made important contributions in the field of uplift. His specimens had a hole in the middle just like a small pipe with extremely thick walls. Mr. Leliavsky wanted to be sure that the pressure was the same along the entire face of rupture. First he subjected the test piece to a force, F, then he raised the outer pressure (the pressure outside the specimen) to a constant. Then he waited until the inner pressure, which he measured with a manometer, was brought to the same level. He repeated this procedure of raising the pressure by increments until failure occurred. At the moment of failure the uplift must overcome both the force, F, and the resistance, z, of the material. The total pressure in the pores is pA times a reduction factor, n_a, which is called the boundary porosity by Terzaghi. Thus the final equation will be:

$$n_a \, p \, A = z + F \tag{7}$$

Mr. Leliavsky tested several specimens at various forces, from which he determined the value of n_a to be 0.91.

Mr. Leliavsky introduced another concept in uplift theory so that Equation 6 changes into:

$$u_f = n_a - n_v \tag{8}$$

The factor n_v replaces the volumetric porosity, n, of concrete. n_v is a constant which takes into account the fact that there is always a certain amount of moisture present in concrete which reduces the amount of moisture concrete can absorb. Mr. Leliavsky finds that the water that may be added over normal moisture content is 7% of the volume of the materials in his tests. He got that result by exposing his specimens to the sun. Thus he found n_v to be 0.07 and u_f to be 0.84.

Mr. McHenry(10) has done tests on 6-inch by 12-inch specimens with both jacketed and unjacketed specimens. His testing machine was designed for a pressure of up to 125,000 psi, but the lateral pressure used in his tests were held to a maximum of 1,800 psi. He used kerosene or nitrogen gas to confine his specimens. He used the Mohr-Coulomb theory for his analysis and he reduced the normal stresses in that equation, for the case of unjacketed specimens, by the amount of the pore pressure times the boundary porosity. His equation becomes:

$$s = c + (y - Y_2\, n_a) \tan \theta$$

where θ = the angle of internal friction.

He gets an n_a value of 1.02. The effect of lateral pressure Y_2 on axial load Y_1 he found to be:

$$Y_1 = y_c + 5.848\ Y_2 \qquad \text{without pore pressure}$$

$$Y_1 = y_c + 0.772\ Y_2 \qquad \text{with pore pressure}$$

Besides the men mentioned, there are others who have made contributions in these fields. The ideas presented here cover what the author considers to be the best approaches to the problems in question.

SPECIMEN PREPARATION

Four different types of mixture were tested in this study. Test specimens for each mixture were drilled from the same concrete block by means of a diamond drill and then were cut to a standard length with a diamond saw. Specimens obtained this way had a diameter varying between 0.505 and 0.503 inches and a length varying between 1.007 and 1.0085 inches. These variations are between mixtures regardless of mixture. As far as the individual specimens were concerned these dimensions were consistent. Before cutting specimens to the required length, they were placed into an aluminum tubing with an inside diameter of 0.509 inches and a length of 2 inches. A slotted hole was cut through one side of the tube for easy entrance and for better contact during the cutting process as it could be better pressed in the vise of the saw that way. Specimens obtained that way had a very smooth surface and sharp edges.

To control the moisture content, specimens were dried at 105°C. for a period of three days, after which they did not lose any more weight. Right after drying, the specimens were vacuumed for the same length of time. Checks of the weight showed further decrease in weight during that process. After this routine, no more weight checks were made. For each mixture, moisture control of the specimens to be tested jacketed and unjacketed was done separately. Specimens tested with empty voids were placed into a plastic tubing after vacuumizing. Specimens to be tested without a jacket were saturated with oil while under vacuum. Oil used for this purpose was the one used in the test chamber, namely No. 1 motor oil.

Drilling was the most time consuming part of the specimen preparation. In order to get exact outside diameters and smooth surfaces various combinations of pressure and feeding had to be tried. The author was unsuccessful in his efforts to get mortars containing only cement and water, as all the specimens broke either during drilling or cutting. Also quite a number of specimens broke when they were removed from the aluminum tubes.

EQUIPMENT USED AND TEST PROCEDURE

Equipment used in this study is that designed by Jones[5]. It is based on the apparatus of Griggs[4]. Figures 32 and 33 show the pressure testing equipment used in this study. It is designed for a maximum of 20,000 psi oil pressure. Oil pressure is applied with an hydraulic jack, J, which is placed firmly on plate, L_3. Piston, P_2, has access to the test chamber through a cavity. Specimen, S, is placed into test chamber of the pressure vessel, V. Specimen stays on a stopper, R, which has a hole through it so that oil has an access from the cavity where the piston, P_2, moves, to the cavity where the test specimen stays. Upper piston P_1 enters the cavity through the threaded plug, T. The specimen stays between the upper piston and the stopper. It is placed into a brass sleeve which has a conical portion that fits to the conical surfaces of the stopper and piston. The rest of the brass sleeve is cylindrical and fits to a soft steel slug, used as a transition medium between specimen and piston or specimen and stopper, and extends 1/8 inch onto the specimen. This last 1/8 inch is slotted.

The pressure testing equipment is placed between the platens of the testing machine, which applied the axial load. Axial load is transferred to the specimen by means of upper piston, P_1, whose spherical head fits to a bore at the center of plate, L_1. Plates L_1 and L_3 are yoked together by three equally spaced columns, Y, and as the specimen deflects they are free to move. Three columns, C, connect the pressure vessel to plate L_2. One bar equipped with a slotted hole is fitted to each one of the pistons. The other edges contact the plunger of a dial indicator, D_1 for upper piston and D_2 for lower piston, which are mounted to the sides of the pressure vessel.

An 1/8 inch "O" ring is placed in the groove in the bore of the plug T. A 3/16 inch "O" ring is placed in a groove in the pressure vessel where it contacts the plug T. Lower piston has a groove for a 1/8 inch "O" ring.

A specimen is placed into the test cavity with sleeves and steel slugs as explained. A specimen to be tested jacketed is fitted into plastic tubing which covers the specimen, sleeves and part of the upper piston (Figure 34a). After placing the specimen into the test chamber, oil is added to the level of the "O" ring and then nut T is threaded into place. There are small grooves in the nut threads through which air in the test cavity escapes. When the test equipment is all assembled there is a small hydrostatic pressure. Then the pressure equipment is placed in the testing machine and an initial end load of a little more than 68 pounds is added. Jones found out that the part of the equipment which the upper piston supports is 32 pounds, but there are also the friction forces due to "O" rings of 100 pounds. Then the oil pressure is applied. As oil has access to the pressure chamber through the stopper R, a condition of equal hydrostatic pressure is created all over the specimen. The head of the testing machine is lowered to keep the excess pressure. The procedure is repeated until the desired oil pressure is reached and from then on the axial load is applied with increments of 200 pounds. At higher axial loads the increment is increased. After a few readings it was possible to record readings without stopping the testing machine.

At each increment dial indicator readings are recorded. As the two pistons are yoked together, the lower piston P_2 withdraws as much as upper piston P_1 advances into the chamber. This helps to keep the hydrostatic pressure constant in the test vessel. If the volume of the specimen changes, remembering that the lower piston could move independently from the upper piston, though it repeats all the movements of the upper piston, (See Figure 32), we get a difference between piston movements. Multiplying this difference by the piston area will give the volume change in the chamber.

For the upper piston a 0.0001-inch dial indicator with a travel of 0.3 inches was used, and for the lower piston a 0.001-inch dial with a travel of one inch was used.

In order to get the exact volume changes and deflections we must correct the readings obtained during the experiment as those readings include deflection of upper piston steel slugs, pressure vessel and so on. For this purpose a steel specimen, with known modulus of elasticity and the same shape and dimensions as the concrete specimens, was tested under exactly the same conditions as concrete specimens. Axial load was kept below the yield stress of the steel specimen. From this data, we will get the apparatus deflection which is the correction to be applied to the piston readings. In these calibration tests the difference of piston readings did not show any significant amount, which points out a zero volume change and also could be taken as a proof about the correctness of future volume change readings of concrete specimens.

The correction to be applied is 1×10^{-4} inches for every 100 pounds of excess load up to 3000 pounds, 8×10^{-5} inches from 3000 to 5000 pounds, 6×10^{-5} from 5000 up to 7500 pounds, and from then on 2×10^{-5} pounds for every 100 pounds excess load. Decrease in those values is due to decrease in apparatus deflections. Also corrections are rounded up to 10^{-4} of an inch. There is no definite difference for different oil pressures so that the above corrections are used for all oil pressures. Only at zero oil pressure the deflection from 0 to 100 pounds excess load is 7×10^{-4} and from then on goes the same as the others. So these are the values applied for correction.

RESULTS OF TESTS

In this study four different concrete mixtures were tested in three dimensional loading. For each mixture both jacketed and unjacketed specimens were tested at eight different oil pressures: 0, 2,500; 5,000; 7,500; 10,000; 12,500; 15,000 and 17,500 pounds per square inch. A series of 2 by 4 inch cylinders in compression and standard tensile briquets were tested for each mixture. Concrete blocks, 2 by 4 inch cylinders and tensile briquets for each mixture were kept in a moist closet for 28 days. All mixtures were hand mixed.

Each mixture is separated into two groups which are differentiated with alphabetic letters C, D, E, F, G, H, I, J. C is for the first mixture unjacketed and D for its jacketed specimens; E is for the second mixture unjacketed and so on. Table 1 shows characteristics of the 2 by 4 inch cylinders.

TABLE 1

Mixture	*Group	w/c	**Compressive strength (psi)	Tensile strength(psi)
0.75: 0.92: 0.25	C & D	0.98	4,210	420
1:2 Mortar	E & F	0.60	4,960	430
1:3 Mortar	G & H	0.88	2,910	260
1: 1: 0.64	I & J	1.00	2,320	185

* C, E, G, I, groups tested unjacketed

D, F, H, J groups tested jacketed

** Compressive strengths of ½ by 1 inch cylinders is higher than these. See tables 10 and 11.

For all the mixtures the same kind of cement and sand were used, which are: ASTM Type 1 Portland Cement with a specific gravity of 2.63; sand which has a sieve analysis of 100% passing 40 mesh sieve and 100% retained on 60 mesh sieve.

For groups C and D (mixture 0.75: 0.92: 0.25) a pozmix cement blend of 75-25 was used. Pozallan used in this blend is called pozmix A (fly ash), which is a reactive silicate that reduces the free lime in portland cement and renders it more resistant to sea water's corrosion. Pozmix A has a specific gravity of 2.46. For groups I and J (mixtures 1: 1: 0.64) an expanded clay aggregate is used. Expanded clay has a specific gravity of 2.63.

Most of the data and computations are presented in Appendix II. Columns 1, 2, 3, and 6 show the applied oil pressure, applied excess load, and dial indicator readings for the lower and upper pistons respectively. These are the readings taken during the experiment. The other columns of figures are computed quantities. Column 4 is the difference between two successive lines of Column 3 with a correction applied. (The amount and need for correction is explained in the section "Equipment Used and Test Procedure".). Column 5 gives corrected lower piston deflection readings found for each load by adding Column 3 readings up to that point. Column 7 is the amount of correction needed at each load increment in the upper piston readings. Column 8 gives corrected upper piston readings (Column 6 - Column 7) or Unit Deformation of the Specimen in inches per inch. Column 9 (Column 8 - Column 5) times the piston area (both pistons have the same area, viz., 0.37 square inch) gives the volume change of the specimen, Column 10.

* For unjacketed specimens and zero oil pressure we cannot get the volume changes with this equipment. At zero oil pressure specimens tested are without oil, as the only way to check that the chamber is full of oil is to have some hydrostatic pressure in it due to excess oil. We cannot do this for simple compression tests, for if we do, it will affect the results. And, as long as the chamber is not full, we cannot get volume changes. For the unjacketed specimens as the oil is free to move into or out of the pores we cannot measure volume changes in the specimen with this apparatus. Attention is called to the data in Appendix II where some of the volume changes for unjacketed specimens are computed. These data show a variation around a straight vertical line which proves the above hypothesis. Jacketed specimens did not have any contact with the oil so that we get results directly.

Tables 2 to 5 are for jacketed specimens and 6 to 9 are for unjacketed specimens. All the specimens tested are presented with their confining pressure and their excess load over confining pressure. Also, when possible, permanent unit deformations are given in axial and lateral directions, which are a decrease and increase in dimension respectively. This is done only for jacketed specimens which deflect beyond the scope of dial indicators and they always stay solid so that it is possible to get permanent deformations. Lateral deformations are measured at the approximate center of the specimen.

Considering the graphs, Figures 9-16, for jacketed specimens, we see that there is a plastic yielding even at the lowest lateral pressure. In unjacketed specimens all the failures are brittle. For jacketed specimens all groups deflected in a similar way except group J which

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* Refer to the section "Equipment Used and Test Procedure" to see the way volume changes are computed.

showed larger deflections. Deviations from average strength are mostly independent of oil pressure.

Volume changes for jacketed specimens are also plotted (Figs. 21-28) and show a decrease in volume.

Initial slopes of load-deformation curves are presented in Tables 2 through 9. Those lines are drawn as tangents to the straight bottom part of the load-deformation curves (Figures 9-20). These are the slopes after excess load over confining pressure is applied and often do not include the very first one which is usually way off with respect to the others.

Tables 10 and 11 are the summaries of Tables 2 to 5 and 6 to 9 respectively. They contain the average of the initial slopes and maximum axial loads at constant oil pressure. Average compressive strengths at zero oil pressure of all mixtures came out more than their corresponding 2 by 4 inch cylinder strengths, Table 1. The differences for Groups D, F, H and J are 13.5%, 12%, 8% and 6% respectively. Strengths of unjacketed specimens are more or less similar to corresponding jacketed ones, with no fixed pattern.

Average maximum unit loads in Tables 10 and 11 are plotted in Figure 8 against confining oil pressure, for both jacketed and unjacketed specimens. In group F (jacketed) the ultimate strength of the specimen at lower oil pressures increases 4.8 times the applied oil pressure; at higher oil pressures the increase in ultimate strength is 3.8 times the applied oil pressure. For group D the same increase factor for low and high oil pressures is 3.8 and 3.3 respectively; for group H it is 4.5 and 3.5; for group J it is 4.6 and 3.5. That is to say, for jacketed specimens the increase in axial load with increasing oil pressure is not a straight-line relationship. A smooth curve through the data would show a greater slope at low pressures than at high pressures. For jacketed specimens the average increase of strength is about 3.9 times the oil pressure applied and straight lines representing that relation are drawn in Figure 8. For unjacketed specimens an average increase in strength of 1.2 times the oil pressure is accepted, and straight lines representing this relation are drawn. For them, the increase in axial load with increasing oil pressure first follows a curve of increasing strength and after low pressures a straight line.

Actual angles of failure are measured for unjacketed specimens and presented in Appendix II with the compiled data. All jacketed specimens showed a ductile behavior. If the experiment was continued long enough, the jacketed specimens broke into pieces. The surface of failure usually made an approximate angle of about 30° with the longitudinal axis of the specimen. Angles that lines on the barrel-shaped specimens made with the longitudinal axis kept increasing as long as the experiment was carried on. Whenever an experiment was carried until the specimen shortened more than approximately 20% of its length, the brass sleeves were destroyed, so usually the author stopped the experiment before then.

Also sometimes it was not possible to measure the angles of unjacketed specimens due to breaking into pieces from the brass sleeves or during removal from the test chamber. For such cases the author only wrote that the piece was damaged.

In general the failures for group E happened as two pieces with an angle of failure of around 33° with the longitudinal axis. For this group usually one of the two pieces was larger than the other.

For group C failure consisted of two pieces with some longitudinal splitting and possibly with an average failure plane of 30°. For group G failure planes were around 28° with two major pieces and a few small pieces. For group I failure planes were around 23° with two major and several small pieces. For these last three groups the failure plane usually started from one corner and continued approximately diagonally across to the opposite corner.

There was usually a slight increase of strength, but not always, with increasing lateral pressures. There was considerable variation in failure angle within each group.

Group	Specimen Number	Oil Pressure 16.per sq. in.	Differential Load 16	Initial Slope by load Deformation Curve 1000 lb. per sq. in.	Permanent Deformation Axial in	Permanent Deformation Lateral in.
	1		1000	4100		
F	2	0	1150	3400		
	3		1000	2900		
	4		1000	4100		
	5		1300	3700		
	1		2880	1250	.094	.040
F	2	2500	2980	1300	.082	.054
	3		3080	1460	.243	.150
	1		4300	1460	.064	.037
F	2		4280	930		
	3	5000	4400	780	.135	.060
	4		4500	1700		
	1		+5200	780		
F	2	7500	5420	1250	.114	.051
	3		5700	1280	.285	.159
	1		6400	1700	.127	.067
F	2	10000	6240	850	.218	.073
	3		7000	1130	.191	.087
	1	12500	7800	1020	.199	.051
F	2		8220	1340	.151	.074
	3		+8600	1460		
	4		+7380	1020		
	1		9280	1460		
F	2	15000	9640	1250	.154	.080
	3		+9300	925		
	4		9000	1300	.092	.041

All Specimens Tested Jacketed, Cont'd.

F	1	17500	12000	1700	.126	.047
	2		9400	1600	.107	.072
	3		9900	1020	.122	.058
	4		11740	700		

* During test oil penetrated rubber tubing + specimen broken

Table 3

All Specimens tested Jacketed

Group	Specimen Number	Oil Pressure 16.per sq.in.	Differential Load 16	Initial Slope of Load Deformation Curve 1000 lb. per sq. in.	Permanent Deformation Axial in.	Permanent Deformation Lateral in.
D	1	0	800	3400		
	2		1120	1140		
	3		1000	5300		
	4		1100	3960		
	5		780	2900		
D	1	2500	2170	1140	.073	.026
	2		3020	1020		
	3		+1840	1160		
D	1	5000	*1800	1000		
	2		4220	1620	.179	.053
	3		*2000	1500	.151	.074
D	1	7500	+4200	1620		
	2		4400	900	.181	.051
	3		4500	1280	.159	.083
D	1	10000	6600	1460	.304	.130
	2		*2800	1460		
	3		6400	1400	.164	.071

Cont'd. on Next Page.

Table 3 - Cont'd.

All Specimens Tested Tacketed

D	1	10000	6600	1460	.304	.130
	2		*2800	1460		
	3		6400	1400	.164	.071
D	1	12500	7650	1130	.091	.032
	2		8400	1400	.474	.263
	3		+7620	700		
D	1	15000	9300	1130	.240	.014
	2		+9000	1020		
	3		*2420	1050		
D	1	17500	*9560	1020	.256	.090
	2		*3600	830		
	3		9500	1320	.191	.062
	4		+9900	1020		

* During test oil penetrated rubber tubing
\+ Specimen broken

All specimens tested Jacketed

Group	Specimen Number	Oil Pressure 16 per sq in	Differential Load 16	Initial Slope of Load Deformation Curve 1000 lb. per sq. in.	Permanent Deformation Axial in.	Permanent Deformation Lateral in.
	1		800	4100		
	2		520	1460		
H	3	0	600	1610		
	4		650	3400		
	5		430	1200		
	1		2820	1140	.064	.036
H	2	2500	*1740	1460		
	3		2400	1400	.120	.041
	1		4000	625	.213	.092
H	2	5000	3800	930		
	3		3900	1020		
	1		5280	900	.181	.053
H	2	7500	5040	850	.12	.086
	3		+5200	850		
	1		6620	900		
H	2	10000	*3800	900	.246	.081
	3		5980	950		
	4		6300	950		
	1		7830	930	.252	.081
H	2	12500	7220	785	.243	.092
	3		+7580	1280		
	1		7970	850	.032	.047
H	2	15000	8600	1020	.153	.055
	3		9040	730		
	1		9600	930	.171	.036
H	2	17500	+9650	1020		
	3		+8600	1020		

* During test oil penetrated rubber tubing
\+ Specimen broken

All Specimens Tested Jacketed

Group	Specimen Number	Oil Pressure 16 per sq in	Differential Load 16	Initial Slope of Load Deformation Curve 1000 lb per sq in	Permanent Deformation Axial in	Permanent Deformation Lateral in
	1		400	- 730		
	2		500	1460		
J	3	0	620	850		
	4		430	1200		
	1		2000	640	.181	.087
J	2	2500	2460	780	.106	.057
	3		+2200	780		
	1		3200	400	.238	.104
J	2	5000	3460	680	.171	.061
	3		+2000	781	.644	.378
				850		
	1		4820	550	.259	.081
J	2	7500	4640	550	.257	.090
	1		6400	300	.476	.200
J	2	10000	6200	600	.249	.078
	3		6000	400	.193	.054
	1		7400	400	.260	.079
J	2	12500	7600	500	.253	.090
	3		*2420	500		
	1		8600	500	.258	.059
J	2	15000	8300	790	.263	.084
	3		8450	500	.304	.093
	4		8400	850		
	1		8600	400	.219	.047
J	2	17500	9200	520	.253	.078
	3		9200	405	.223	.041

* During test oil penetrated rubber tubing
\+ Specimen broken

Table 6
All Specimens Tested Unpacketed

Group	Specimen Number	Oil Pressure 16 per sq.in.	Differential Load 16	Initial Slope of Load Deformation Curve 1000 lb per sq. in
C	1	0	1240	4500
	2		800	1500
	3		860	3050
C	1	2500	1450	1020
	2		1020	1700
	3		1410	2400
C	1	5000	1760	1020
	2		1340	1220
	3		1200	1530
C	1	7500	1600	1330
	2		1680	1530
	3		1470	1200
C	1	10000	1520	1140
	2		1050	1180
	3		1420	1910
C	1	12500	1220	1140
	2		1400	1180
	3		1600	990
C	1	15000	1350	1180
	2		1800	1330
	3		1600	1400
C	1	17500	1300	1460
	2		1800	1400
	3		1910	1400

Table 7
All Specimens Tested Unjacketed

Group	Specimen Number	Oil Pressure 16 per sq.in.	Differential Load 16	Initial Slope of Load Deformation Curve 1000 lb persq. in.
E	1	0	950	2300
	2		1300	4100
	3		1160	4500
E	1	2500	1040	1460
	2		1600	1460
	3		1600	1390
E	1	5000	1800	1460
	2		1400	1390
	3		1220	1100
E	1	7500	1600	1850
	2		1400	710
	3		1460	1850
E	1	10000	1580	1840
	2		1400	1450
E	1	12500	1610	1860
	2		1600	1860
	3		1800	1100
E	1	15000	1500	1300
	2		2000	1600
	3		1600	1600
	4		1700	1250
E	1	17500	1600	1390
	2		1840	1800
	3		1810	1920
			1700	1800

All Specimens Tested Unjacketed

Group	Specimen Number	Oil Pressure 16 per sq. in.	Differential Load 16	Initial Slope of load Deformation Curve 1000 lb. per sq. in.
G	1		920	3050
	2	0	400	2550
	3		570	2300
G	1		920	1020
	2	2500	1120	1140
	3		1000	980
G	1		900	980
	2	5000	1330	1400
	3		1100	1000
G	1		1200	1930
	2	7500	1040	930
G	1		1150	1020
	2	10000	1400	1460
	3		1300	1000
G	1		1090	1000
	2	12500	1300	1400
	3		1600	1180
G	1		1100	780
	2	15000	1700	1280
	3		1350	1000
G	1		1450	1280
	2	17500	1160	1280
	3		1300	830

Table 9
All Specimens Tested Unjacketed

Group	Specimen Number	Oil Pressure 16 per sq. in.	Differential Load 16	Initial Slope of Load Deformation Curve 1000 lb. per sq. in.
I	1	0	400	1140
	2		500	1280
	3		300	1000
I	1	2500	1240	850
	2		620	930
	3		1140	785
I	1	5000	1200	875
	2		900	875
	3		920	825
I	1	7500	1440	970
	2		1260	875
	3		1220	1020
I	1	10000	1050	570
	2		1250	930
	3		1270	550
I	1	12500	1220	640
	2		1360	1180
	3		1280	550
I	1	15000	1280	730
	2		1400	1280
I	1	17500	1300	680
	2		1500	1330
	3		1480	1400

Group	Lateral Oil Pressure 16 per sq. in.	Number of Specimens Tested	Differential Load 16 per sq. in.	Maxiumn Axial Load 16per sq.in.	Average Initial Slope of Load Deformation Curves 1000 lb per sq. in.
	0	3	5740	5740	3300
	2500	3	7190	9690	1440
	5000	3	7500	12500	1320
	7500	3	7850	15350	1140
E	10000	2	7600	17600	1650
	12500	3	8500	21000	1600
	15000	3	8600	23600	1440
	17500	3	8900	26400	1480
	0	3	4800	4800	3000
	2500	3	6590	9090	1700
	5000	3	7300	12300	1250
C	7500	3	7200	14700	1680
	10000	3	6800	16800	1410
	12500	3	7200	19700	1110
	15000	3	8000	23000	1310
	17500	3	8500	26000	1440
	0	3	3200	3200	2550
	2500	3	5200	7700	1050
	5000	3	5890	10890	1120
	7500	2	5710	13210	1430
G	10000	3	6390	16390	1150
	12500	3	6800	19300	1170
	15000	3	6390	21390	1020
	17500	3	6700	24200	1130
	0	3	2350	2350	1140
	2500	3	5100	7600	770
	5000	3	5250	10250	870
I	7500	3	5620	13120	660
	10000	3	6100	16100	685
	12500	3	6530	19030	790
	15000	2	6850	21850	1000
	17500	3	7250	24750	1140

Table 11
Summary of all Groups Tested Jacketed

Group	Lateral Oil Pressure 16 per sq. in.	Number of Specimens Tested	Differential Load 16 per sq. in.	Maxiumn Axial Load 16 per sq. in.	Average Initial Slope of Load Deformation Curves 1000 16 per sq. in.
F	0	5	5620	5620	4000
	2500	3	15200	17700	1340
	5000	4	22200	27200	1210
	7500	3	27600	35100	1100
	10000	3	34500	44500	1230
	12500	4	41000	53500	1210
	15000	4	46100	61100	1240
	17500	4	51800	69300	1260
D	0	5	4870	4870	3240
	2500	3	11800	14300	1110
	5000	3	21500	26500	1370
	7500	3	27500	35000	1260
	10000	3	33000	43000	1440
	12500	3	40000	52500	1070
	15000	3	46000	61600	1060
	17500	4	49000	66500	1040
H	0	5	3160	3160	2400
	2500	3	11800	14300	1330
	5000	3	19800	24800	860
	7500	3	26100	33600	870
	10000	4	32000	42000	700
	12500	3	38400	50900	1000
	15000	3	43500	58500	865
	17500	3	41000	64500	980
J	0	4	2480	2480	1100
	2500	3	11300	13800	735
	5000	3	16900	21900	680
	7500	2	24100	31600	550
	10000	3	31600	41600	435
	12500	3	38100	50600	465
	15000	4	43000	58000	655
	17500	3	45900	63400	449

COMPARISON AND ANALYSIS OF RESULTS

Maximum stress and strain theories fail to explain the behavior of materials under hydrostatic pressure. In the first case the high normal stresses which are present without failure as a result of lateral pressures and in the latter case the occurrence of large strains without failure contradicts these theories.

If the maximum shear theory were correct the enveloping curve on the Mohr circles of failure should be a horizontal straight line and the fact that this is not so could be seen from Figures 29-31. We can get such a case if the compressive and tensile stress at failure are equal.

The maximum-distortion-energy theory is more applicable to elastic failure as the ability of materials to withstand hydrostatic stresses without yielding contradicts it.

Coulomb's internal friction theory is the most applicable one so far. As could be seen from Figures 29-31, the relationship between maximum load and lateral load is more or less a linear one. Coulomb's theory has all the disadvantages of Mohr's theory, which will be discussed.

In this study Mohr's theory is used for analysis. Naturally the causes of failure are more complex than assumed by this theory but nevertheless it gives the relationships of stresses at failure quite accurately in a simple and pictorial way. According to it normal stress plays a role in failure as well as the shearing stress. This interdependence could be expressed by this equation

$$s = f(y)$$

This relationship is determined experimentally by drawing stress circles for different failing stresses and drawing a common envelope to them called the envelope of rupture, Figures 29-31. From these curves the angle of the plane of sliding could be determined so that ϕ is the angle between the longitudinal axis and the direction of weakness of elements which first fail by sliding. All points of every stress circle should be below that envelope of rupture. For every circle there is a point on the circle which gives the stresses on the plane of failure. Referring below we find those stresses to be

$$y = Y_2 \sin^2 \phi + Y_2 \cos^2 \phi$$

$$s = \frac{Y_1 - Y_2}{2} \sin 2\phi$$

These could be directly measured from the Mohr diagram too.

As for the case of the specimens tested with pore pressure, there is no point, as McCutchen[11] suggested, in drawing Mohr circles with pore pressure as a parameter. Instead effective pressure should be used. That is, only 31% of the confining pressure should be included in the computations instead of 100%. Due to pore pressure the strength that the bonds get from the lateral pressure is reduced, which directly depends on the degree to which pore pressure is effective. This point and the way 0.31 is found will be explained later in the analysis. The Mohr diagrams in Figures 31 are drawn according to that principle and they definitely have the interdependence equation as mentioned. This point corresponds to University of Illinois experiments too.

According to Mohr's theory materials are homogeneous and isotropic so that there is nothing in the material that would cause failure to happen in any particular direction. He assumes that there is a relation between the normal stress and the shearing stress in any plane which governs the resistance to failure along that plane.

Another assumption of this theory completely disregards the effect of intermediate stress on the failure of materials. It reaches this conclusion since for any stress there are many planes that might have that stress (a vertical line at that stress on the Mohr circle represents all of those points) but only one plane at the same time has maximum shearing stress and failure will take place on that plane if it ever does with that stress. The intersection of the enveloping curve on the negative side of the normal stress axis shows there is a limit to the amount of tension the material can take. In this case ϕ would equal to zero degrees.

Failure angle ϕ is equal to $\frac{\pi}{4} - \frac{\theta}{2}$ where θ is the angle of internal friction so that this theory predicts a shear failure at a stress equal to the shearing strength plus the normal stress times the tangent of θ. In Coulomb's theory θ is constant.

To prove that intermediate stress has no influence we have to make tests by using small axial stress and larger lateral pressure. In this case we should get exactly the same limiting curves. The author has not done any tests of this kind. Bulletin 185 of the University of Illinois Engineering Experiment Station presents results of some tests of this kind. These tests indicated lower failing values when axial stress was less than lateral pressure than occurred when axial stress was greater than lateral pressure. This is the opposite result of Kármán and Böker's tests on marble. It was concluded in the Illinois bulletin that the tests were not sufficient to prove or disprove the point in question.

The greatest advantage of Mohr's theory is that we can obtain the angle of sliding from it as mentioned before. By comparing it with the actual surfaces of failure deviation from a pure shear could be seen. Considering Figure 25 we see that the angle of failure changes from 42° in group E (richest mixture) to 37° for group I (poorest mixture). And there is an average of 7° difference between tests of highest lateral pressure and no lateral pressure. We can conclude by using Professor Terzaghi's term that failure for unjacketed specimens are pseudo-shear type or a failure between a splitting and a shear type, as actual angles of failure are lower than these values.

As for the jacketed specimens the failure angle on Mohr diagrams changes between 33° and 29° and there is not considerable difference between individual mixtures. This fact is consistent with the University of Illinois results. We can conclude that jacketed specimens usually failed close to a shear type failure.

Comparing Mr. Brandtzaeg's theory we see that he based his analysis on an ideal material of non-isotropic elements. Its difference from Mohr's theory is that instead of the material itself its elements yield plastically through intragranular sliding along planes of one direction fixed for one element but varying from one element to the other. Mr. Brandtzaeg introduces the well-known Coulomb equation for elements, not for the whole material, which defines the plastic equilibrium of the elements. Mr. Brandtzaeg also assumes that plastic elements deform proportionally to the stresses they carry plus a plastic sliding so that their total deformation is equal to that of elastic elements which results in all elements deforming alike. An element will not be free to deform in its own direction of weakness unless it breaks off.

A point against this theory is that most of the constants still had to be determined experimentally. Also, Mr. Brandtzaeg disregards the pores which play the dominant part with materials that have pore pressure. If the voids are empty still there is a compacting of the material. In Mr. Brandtzaeg's equations unit volumetric deformation of the material is the same as in individual elements. The effect of voids on failure is obviously seen in the author's experiments. As different elements will reach plastic stages at different times this theory shows the passage of the material from the elastic to the plastic stage.

In simple compression plastic elements can carry stresses only if they are supported laterally by elastic elements, which produces a lateral tension in elastic elements. The same condition occurs in specimens subjected to lateral compression where this action is retarded and a general sliding and disorganizing occurs. Mr. Brandtzaeg concludes that the eventual failure still will be due to a limiting tension. His analysis does not apply after splitting starts.

Professor Terzaghi(7) considers failures in simple compression as a splitting type but he does not account for it definitely as he says failure by splitting is not strictly comparable to failure by pure tension because the mutual displacement of the individual constituents which precedes these two types of failure is somewhat different. But nevertheless he says the material fails by splitting as soon as the negative scatter stress equals the tensile strength of the material. For the case of triaxial failure his analysis in basic principles corresponds to the author's. As seen from Fig. 3, with increasing confining pressure failure will depend more and more on the average stress, which is the lateral stress, though still the tensile strength will govern the failure but with substantially more normal stress. The equation Professor Terzaghi derives (4) gives an increase in strength ten times the lateral pressure. Compared to author's 3.9 and University of Illinois' 4.1 that is too high. In finding stresses by Equation (5) Professor Terzaghi uses cohesive strength and includes the fact that most of the failures are intergranular though intragranular for high lateral pressures.

The author's way of relating the effect of pore pressure is basically the same as that used by Professor Terzaghi. A reduction formula is introduced to all of the formulas (see section on Previous Work).

Mr. McHenry(10) approached the problem with the Mohr-Coulomb theory, so that there is no disagreement with the author in that respect, but his results about the effect of pore pressure does not agree with the author's. Reference to this will be made later. Also his increase in strength of material is 5.8 times the lateral pressure which does not agree with the author's 3.9.

Initial slope averages in tables 10 and 11 show a definite decrease with respect to their values in zero oil pressure. This is due to the effect of the oil pressure. Those are the initial slopes after oil pressure and some excess load was applied but before then the specimens also deflect due to an inelastic compacting in all directions. This point and the general appearance of the curves correspond to the University of Illinois results.

Volume changes for jacketed specimens show a definite decrease of volume due to inelastic compacting which is almost the same at the same lateral pressure for all groups except group J. It seems that added strength due to lateral pressure is the same for all groups except group J. This could be seen by the similarity of both load-deflection curves and volume change curves. Group J shows larger decreases in volume and increase in deformation than all the rest. This is due to its having a higher porosity than the others (Fig. 5). This proves that pores affect the failure of material even when the voids are empty and should be considered.

In Figure 6 load deformation for group H are plotted, where deflections during the application of oil pressure are also included. This figure will clearly show the increase in strength in axial direction with increasing oil pressure. This is done by applying a correction of 5×10^{-4} inches per 2500 psi oil pressure (same as early stages of loading) to Column 6 readings of data.* Final deflection, when we reach constant oil pressure, is added to each Column 8 reading to get deformations at various axial loads.

The effect of lateral pressure on the strength of the specimen is represented by a polynomial of the form:

$$Y_1 = y_c + b\, Y_2 + c\, Y_2^2$$

where Y_1 is the maximum axial load, Y_2 is the lateral pressure, and y_c is the standard compressive strength of the concrete. An equation of this type could be written for each experiment, from which coefficients b and c could be determined. These equations for jacketed and unjacketed specimens should be written separately as they are tested under different conditions. As we have more equations than unknowns, the author used the method of least squares to solve them. This method is explained on the following page.** The resulting equation for the jacketed specimens:

$$Y_1 = y_c + 4.5\, Y_2 - 0.56 \times 10^{-4}\, Y_2^2 \qquad (9)$$

* See Appendix II.

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Group	Change in Volume	
	* grams	** porosity in per cent
D	0.5	15.4
F	0.68	21.1
H	0.6	18.8
J	1.0	31

* These are the averages of weight decreases, for each group, after moisture control.

** A sample calculation for group J is presented below.

Change in Volume = 1 gr = 2.2×10^{-3} lb

$$V = \frac{2.2 \times 10^{-3}\ \text{lb}}{62.4\ \text{lb/ft}^3} = 0.352 \times 10^{-3}\ \text{ft}^3 \text{ or } 0.352 \times 10^{-3} \times 1728\ \text{in}^3$$

$= 0.061\ \text{in}^3$ This is the amount of water removed from the specimen.

Volume of a 1/2 by 1 inch specimen is $\frac{\pi (\frac{1}{2})^2}{4} = 0.196\ \text{in}^3$

per cent change in volume:

$$\frac{.061}{.196} \times 100 = 31\%$$

This is the porosity in percent for Group J.

Figure 5

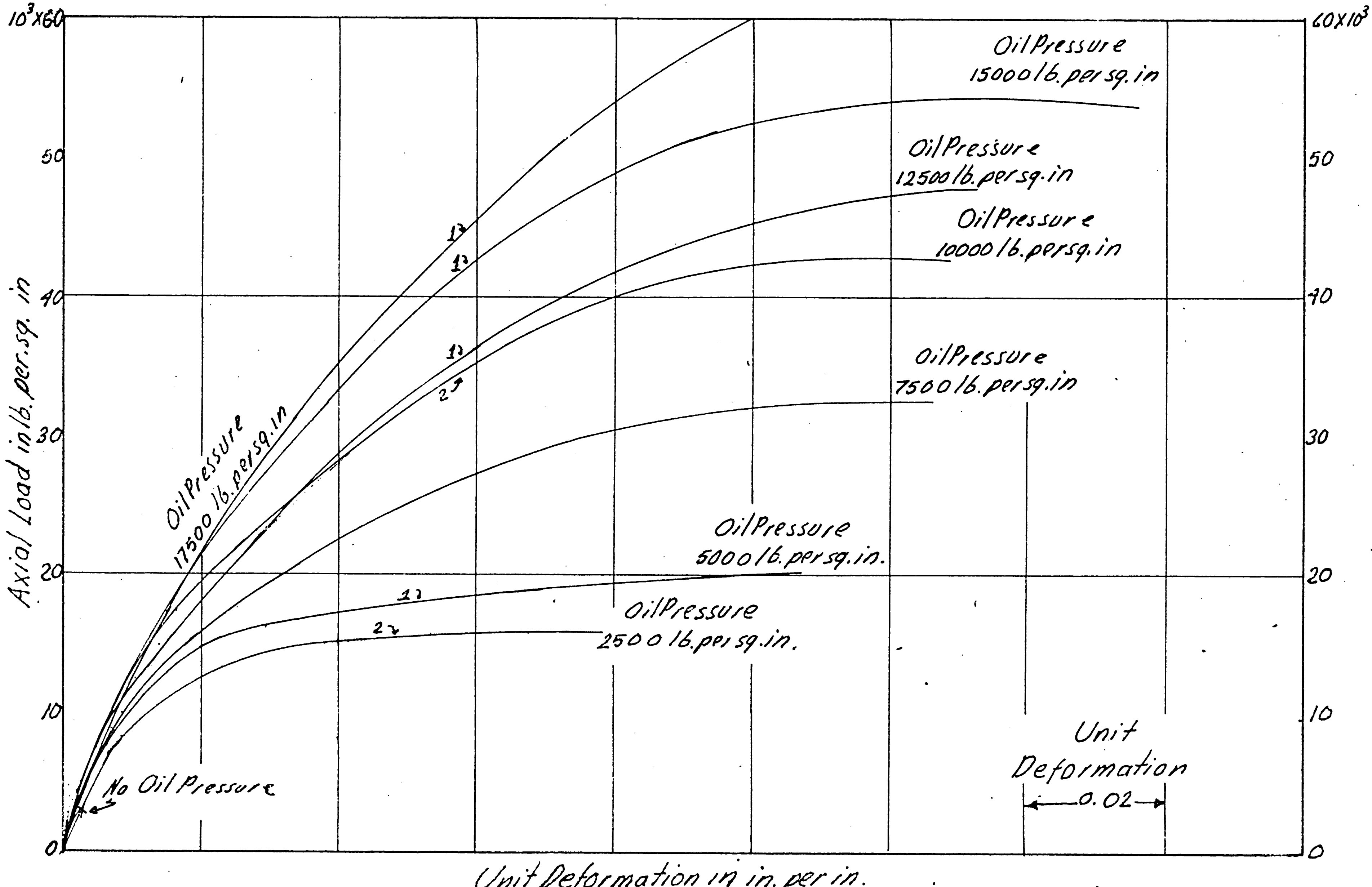


Fig 6 Load Deformation Curves for Specimens with empty voids in triaxial Compression
Group H

This equation represents the effect of the lateral pressure on strength in the axial direction. It is plotted in Figure 7 Experimental results are also shown on the same figure. As explained in the presentation of the results, increase in axial load with increasing lateral pressure follows a curve whose slope decreases with increasing lateral pressure. This fact is consistent with University of Illinois results. Equation (9) follows a similar pattern. The author has also drawn a straight-line relation in Fig. 8 which gives the following approximate equation for jacketed specimen:

$$Y_1 = y_c + 3.9\, Y_2 \tag{10}$$

The 3.9 in this equation compares with a coefficient of Y_2 of 4.1 in the Illinois tests. As the author's tests were carried to higher lateral pressures than the Illinois tests a lower coefficient, i.e., a lower average slope of the line, would be expected in the author's results. The advantage of Equation 9 over 10 is that we get higher maximum axial loads at lower pressures as the effect of $0.56 \times 10^{-4}\, Y_2^2$ is very little at low lateral pressures. Equation 9 also represents experimental results better.

The resulting equations for the unjacketed specimens are as follows:

The quadratic equation:

$$Y_1 = y_c + 1.41\, Y_2 - 0.11 \times 10^{-4}\, Y_2^2 \tag{11}$$

The straight-line equation:

$$Y_1 = y_c + 1.2\, Y_2 \tag{12}$$

As mentioned in the results the same y_c is used for the jacketed and unjacketed specimens of each mixture as there is no obvious difference between the two. Equations 9 and 11 could be reduced into one equation which would represent the effect of lateral pressure at different

Given equations are:

$$Y_{11} - y_c = (b)Y_{21} + (c)Y_{21}^2$$
$$Y_{12} - y_c = (b)Y_{22} + (c)Y_{22}^2$$
$$\cdot \quad \cdot \quad \cdot$$
$$Y_{1n} - y_c = (b)Y_{2n} + (c)Y_{2n}^2$$

Where, b and c are the unknowns. The, n, given equations arranged in the following form:

$$[Y_2 Y_2]b + [Y_2 Y_2^2]c = [Y_2(Y_1 - y_c)]$$
$$[Y_2 Y_2^2]b + [Y_2^2 Y_2^2]c = [Y_2^2(Y_1 - y_c)]$$

These equations are solved to get best values of a and b.

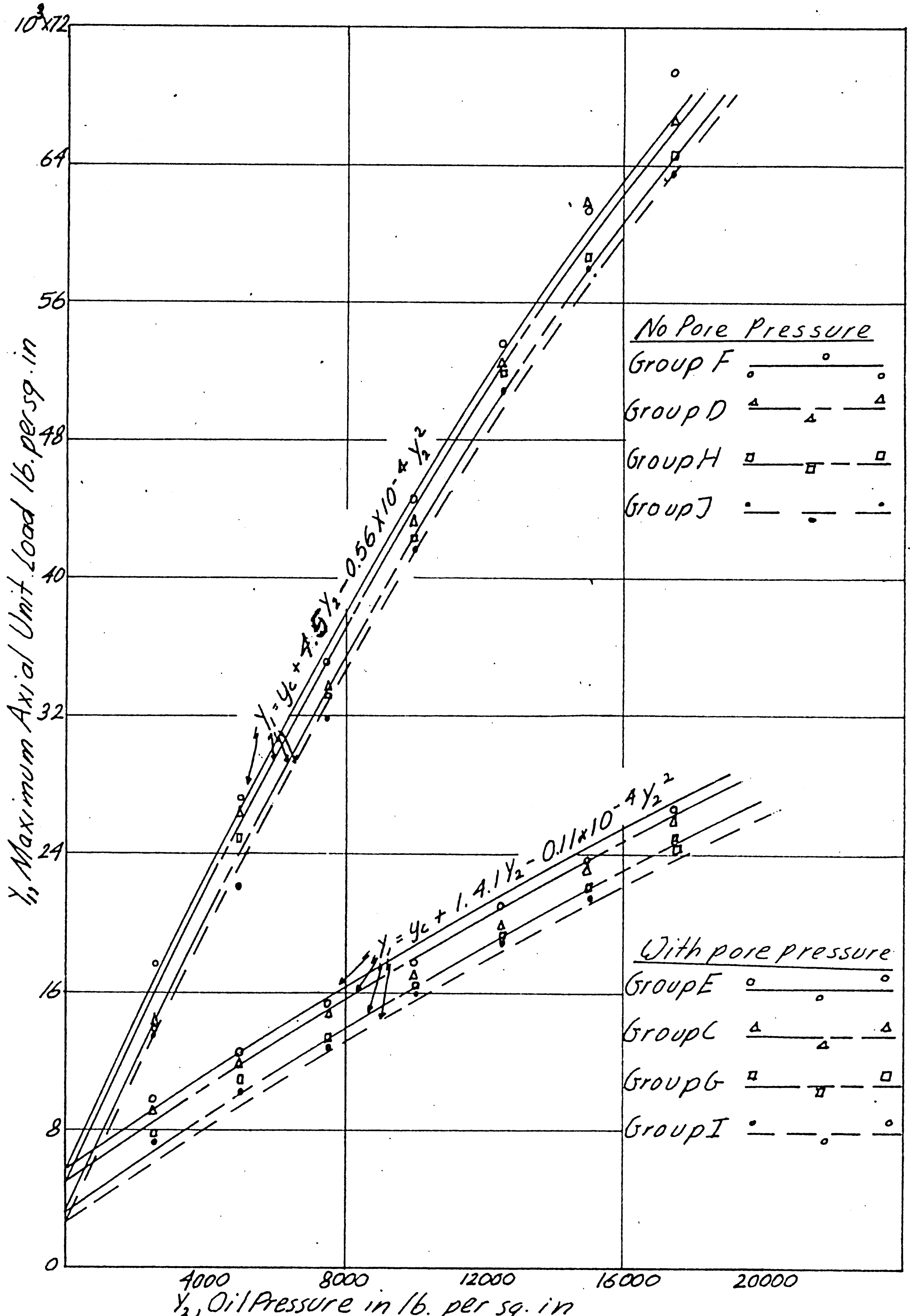
Notations: $[Y_2 Y_2] = Y_{21}^2 + Y_{22}^2 + Y_{23}^2 \cdots\cdots Y_{2n}^2$

$$[Y_2 Y_2^2] = Y_{21}^3 + Y_{22}^3 + Y_{23}^3 \cdots\cdots Y_{2n}^3$$
$$[Y_2^2 Y_2^2] = Y_{21}^4 + Y_{22}^4 + Y_{23}^4 \cdots\cdots Y_{2n}^3$$
$$[Y_2(Y_1 - y_c)] = Y_{21}(Y_{11} - y_c) + Y_{22}(Y_{12} - y_c) \cdots\cdots Y_{2n}(Y_{1n} - y_c)$$

Sample Calculation for jacketed specimens:

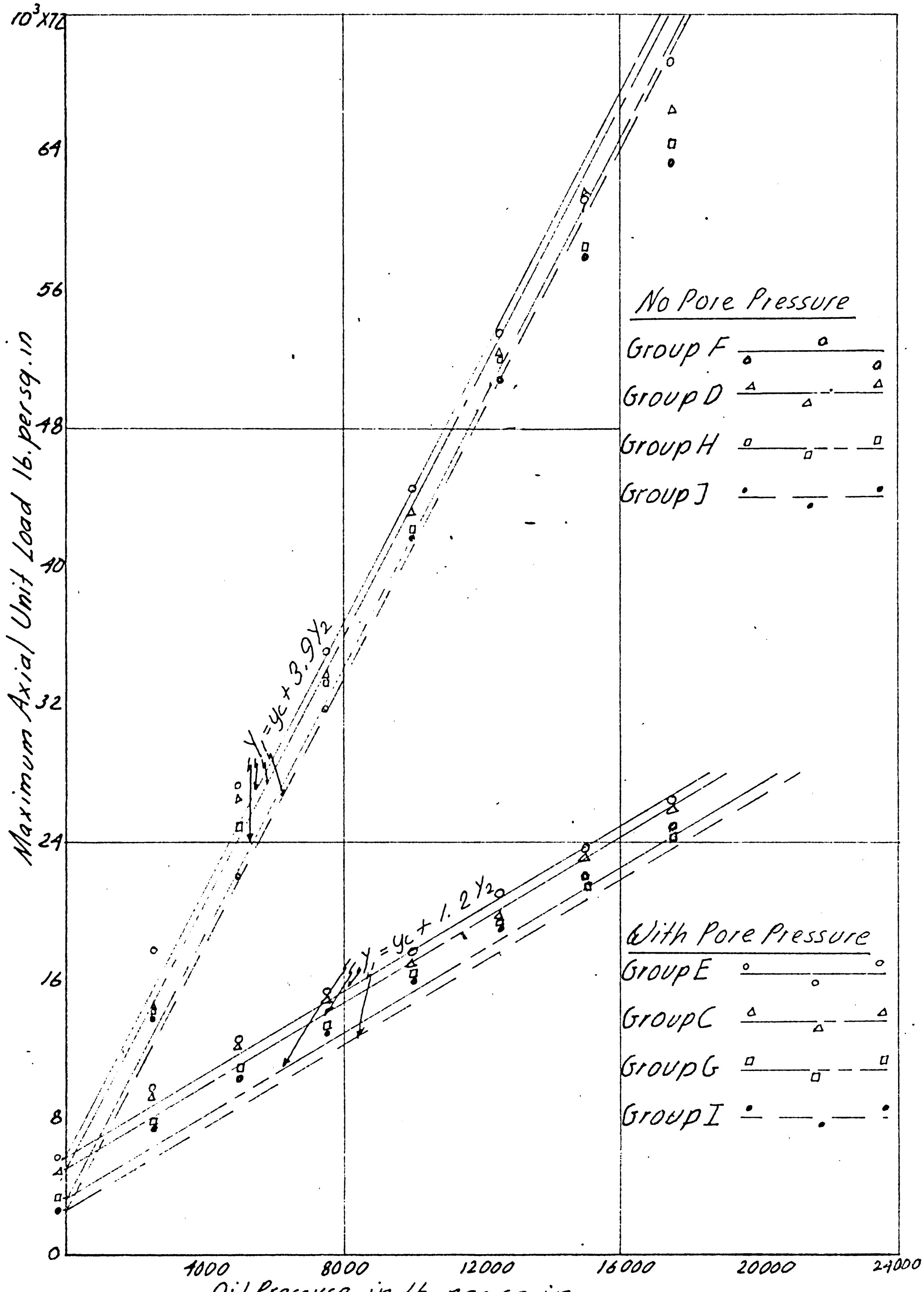
$[Y_2(Y_1 - y_c)]$ = 2500(17700 − 5620) + 5000 (27200 − 5620) + 7500(35100 − 5620) + 10000(44500 − 5620) + 12500 (53500 − 5620) + 15000 (61100 − 5620) + 17500(69300 − 5620) + 2500 (14300 − 4870) + 5000(26500 − 4870) + 7500 (35000 − 4870) + 10000 (43000 − 4870) + 12500(52500 − 4870) + 15000(61600 − 4870) + 17500(66500 − 4870) + 2500 (14300 − 3160) + 5000(24800 − 3160) + 7500 (33600 − 3160) + 10000(42000 − 3160) + 12500 (50900 − 3160) + 15000 (58500 − 3160) + 17500 (64500 − 3160) + 2500 (13800 − 2480) + 5000 (21900 − 2480) + 7500 (31600 − 2480) + 10000 (41600 − 2480) + 12500 (50600 − 2480) + 15000 (58000 − 2480) + 17500 (63400 − 2480) = $\underline{1{,}303{,}700 \times 10^4}$

Average maximum axial load Y_1 is used at each oil pressure for each mixture. (Tables 9 and 10)



$10^3 \times 72$
64
56
48
40
32
24
16
8
0
4000
8000
12000
16000
20000
Y_1, Maximum Axial Unit Load lb. per sq. in
Y_2, Oil Pressure in lb. per sq. in
$Y_1 = y_c + 4.5Y_2 - 0.56 \times 10^{-4} Y_2^2$
$Y_1 = y_c + 1.41Y_2 - 0.11 \times 10^{-4} Y_2^2$
No Pore Pressure
Group F
Group D
Group H
Group J
With pore pressure
Group E
Group C
Group G
Group I

Figure 7



10³X72
64
56
48
40
32
24
16
8
0
4000
8000
12000
16000
20000
24000
Maximum Axial Unit Load lb. per sq. in
Oil Pressure in lb. per sq. in.
Y = yc + 3.9Y2
Y = yc + 1.2Y2
No Pore Pressure
Group F
Group D
Group H
Group J
With Pore Pressure
Group E
Group C
Group G
Group I

Figure 8

pore pressures P:

$$Y_I = y_c + 1.41\ P - 0.11 \times 10^{-4}\ P^2 + 4.5(Y_2 - P) - 0.56 \times 10^{-4}(Y_2^2 - P_2^2) \tag{13}$$

The second part of the experiments, the unjacketed tests, was done to find the effect of the pore-water pressure on the strength of the specimens. This effect will be a reduction in the lateral support of the material. As pore pressure will counteract the lateral stresses, there will be a decrease in the strength of the material in the axial direction depending on the effectiveness of pore pressure P. Accordingly Equation 9 should reduce into Equation 11 if we deduct effective pore pressure from lateral stresses.

$$Y_1 = y_c + 4.5\ (Y_2 - P\ n_a) - 0.56 \times 10^{-4}(Y_2^2 - P^2\ n_a^2) \tag{14}$$

or remembering that $Y_2 = P$

$$Y_1 = y_c + 4.5\ Y_2\ (1 - n_a) - 0.56 \times 10^{-4}\ Y_2^2\ (1 - n_a^2) \tag{15}$$

where n_a is the reduction factor that will reduce equation 15 into 11. An $n_a = 0.69$ will reduce 4.5 into 1.41 and an $n_a = 0.90$ will reduce 0.56×10^{-4} into 0.11×10^{-4}. This way we get two different reduction factors where actually there should be one. As the author arrived at those two equations independently and also remembering the size of the specimens this discrepancy would seem justified. Since at low oil pressures the effect of the second degree term is negligible, it would be best to use 0.69 for n_a. The author suggests Equation 14 with an n_a factor of 0.69 for all cases, i.e., full pore pressure, no pore pressure, or various degrees of pore pressure.

This way we get the reduction factor which is part of the uplift factor or the effect of the pore-water pressure on the strength of the material. In this analysis the author got the reduction factor in a purely experimental way, which should be the case as concluded in all the latest theories, contrary to the earlier ones. It is determined as a purely physical problem. It is an empirical constant that we should know, since in design of hydraulic structures it would be foolish either to disregard it or to consider a 100% effect which would make the design uneconomical.

When the voids are empty a lateral pressure provides an additional support to the bonds between particles, but when there is pore pressure the strength is reduced as the supporting pressure applied to the bonding material is reduced. Professor Terzaghi calls the reduction factor boundary porosity which he defines as the ratio of the part of the area of the potential surface of failure which is in contact with the interstitial liquid to the total area of this surface. This term of potential surface of failure is important as failure never occurs in a plane section contrary to Professor Fillunger's approach. Failure usually occurs in the binding material but as it is not a plane section it could be best determined experimentally by tests of failure,as we really do not know either the actual shape of the pores or the shape of the potential shape of failure.

In our experiments, specimens being small compared to the amount of hydraulic pressure applied, either the effect of additional weight due to water in the pores or the increase in hydraulic pressure due to its own weight with increasing depth is completely insignificant. But in hydraulic structures the weight of the water in the pores increases the specimen's own weight and thus reduces the uplift factor. This is related to the quantity called effective volumetric porosity, n_v , of the material. It could be best determined experimentally. It is the amount of water that the material could absorb over the permanently present water content. A value of 7% is found by Mr. Leliavsky as an average value of permanently present water for the specimens he exposed to the sun in order to determine it. Now the final formula for uplift is

$$u_f = n_a - n_v$$

By multiplying this by the area of the pressure diagram we get the amount of uplift.

All the earlier theories considered the uplift factor equal to the average porosity of the material

$$u_f = n$$

That would give a value of 22%, taking the average porosity from Figure 5. They thought of it as a result of imaginary cracks. This is the average porosity of the material and does not agree either with the author's approach or coefficient.

Fillunger, who introduced the modern theory, made the plane section a basis. But we cannot do this as the material is not homogeneous and the failure most probably would not happen that way as explained before. His formula gives an uplift factor:

$$u_f = n_1 - n$$

where n_1 is the porosity of the mortar that binds the aggregates.

*Professor Terzaghi's approach gives a value of 0.78.

$$u_f = n_a - n$$

As seen from the above equation his reduction factor is 1.00 which is far from agreement with the author's but also his experimental values of 0.83 up to 1.20 are debatable too. Another difference is his using volumetric

*Refer to section on Previous Work

porosity instead of effective volumetric porosity. Effective volumetric porosity better expresses the true conditions as the material has always some amount of water present in its pores.

Mr. Leliavsky's formula for the uplift factor forms the last link in the modern theories which is:

$$u_f = n_a - n_v$$

His values for this equation were

$$u_f = 0.91 - 0.07 = 0.84$$

Mr. Serafim[(12)] obtained values for uplift factor between 0.40 and 0.80.

Mr. McHenry found uplift factors ranging from 0.78 to 1.18 with an average of 1.02. Those values seem too high. His using gas for confining pressure probably influenced the results as it has a lower viscosity than water.

The author's reduction factor of 0.69 is less than the values obtained by others as explained. That might be partly due to his using oil as a medium for lateral pressure which has a higher viscosity than water which would make it harder for its penetration into finer voids. Also, in the unjacketed specimens some values of ultimate load deviated as much as 20% from average values. In the University of Illinois tests the maximum deviation was 11.8%, but a greater deviation might be expected in the author's results because of the small size of specimen. These factors suggest that possibly the value of reduction factor should be higher than 0.69, but perhaps not as high as Professor Terzaghi's and Mr. McHenry's values. The author also got a second n_a of 0.90. This too suggests a value higher than 0.69. In all the experiments on the effect of pore pressure, the author believes that Mr. Leliavsky did the best one. He created the actual failure conditions that might happen in an hydraulic structure, viz., a constant weight producing compression, and a tension due to hydraulic pressure in the pores that might cause the failure.

CONCLUSIONS

Concrete may fail in one of two ways, brittle or ductile. In a brittle failure stresses are proportional to deformations almost up to fracture. In a ductile failure small changes of stress may be accompanied by large deformations; this happens between the elastic range and fracture.

The tests of jacketed specimens definitely prove that concrete subject to lateral compression shows a ductile behavior under axial compression, and it resists high stresses and shows large amounts of deflections, sometimes even up to 3/4th of its length. The relationships of stresses are given accurately by Mohr's theory. The comparison of angles suggests that shear plays a dominant part in failure. There is probably some splitting but mostly disorganizing of material and an intragranular type of failure due to sliding at an inclined direction. As suggested by Brandtzaeg the plastic elements are supported by elastic ones and that causes a tension in them, but under triaxial loading that action is retarded and its effect is much less important.

For specimens subject to pore pressure the condition of failure could only be expressed by Mohr circles using effective pore pressure.

There is an inelastic reduction in volume of concrete specimens with empty voids. The load-deflection curves and volume change curves are similar for all mixtures except one which has a much higher porosity than the rest. This proves the influence of voids on strength of a material whether the voids are empty or not. Group J with a greater porosity than any other mixture showed a larger decrease in volume and greater deformation than the rest of the mixtures.

The specimens with pore pressure in the voids failed in a brittle manner. Splitting due to lateral tension played some role in this as sliding occurred on one plane eventually.

There is no question that uplift force may exist in hydraulic structures and may cause their failure in tension if enough attention is not given to it. This force depends on the potential surface of failure, which is not a plane section, and also upon the ratio of the part of that failure area with which the liquid under pressure is in contact to the total of it. Due to these reasons it may be studied best by experimental means, such as was done in this study.

The relationship between stresses in triaxial compression, with or without pore pressure, could be defined by the following empirical equation:

$$Y_1 = y_c + 4.5(Y_2 - Pn_a) - 0.56 \times 10^{-4}(Y_2^2 - P^2n_a^2) \qquad (14)$$

Y_1 = axial load at failure

Y_2 = the equal and smaller stresses, i.e., the confining lateral pressure

P = pore pressure

y_c = standard compressive strength of concrete

When there is no pore pressure this equation reduces to:

$$Y_1 = y_c + 4.5\tfrac{1}{2} - 0.56 \times 10^{-4}\ Y_2^2 \qquad (9)$$

When pore pressure is equal to lateral pressure this equation reduces to:

$$Y_1 = y_c + 1.41\tfrac{1}{2} - 0.29 \times 10^{-4}Y_2^2 \qquad (16)$$

The effect of pore-water pressure or boundary porosity could be expressed by the reduction factor, n_a, which has a value of 0.69.

This might be higher, as mentioned in the analysis. As can be seen, this ratio will reduce Equation 14 into 16. In hydraulic structures the effect of pore-water pressure is called uplift, where n_a represents only part of the pore pressure effect. The uplift factor is equal to:

$$u_f = n_a - n_v \tag{17}$$

Where n_v is the effective volumetric porosity of the material Equation 17 is the factor that needs to be multiplied by the area of the pressure diagram in order to find the uplift force in hydraulic structures. N_v is the effective volumetric porosity which again needs to be found experimentally. It takes the permanently present water in the pores into consideration.

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APPENDIX I

LIST OF FIGURES IN ORDER

Figure 34a:	Specimen Assembly Showing Upper Piston, Lower Support, Brass Sleeves, and Plastic Tubing
Figure 34b:	1: 2 Concrete, Tested Unjacketed at 10,000 psi Confining Pressure
Figure 34c:	1: 2 Concrete, Tested Unjacketed at zero Oil Pressure
Figure 34d, g:	1: 2 Concrete, Untested Length = 1 inch; Diameter = ½ inch
Figure 34e:	1: 1: 0.64 Concrete, Tested Jacketed at 5000 psi Confining Pressure, Length = 0.35 inches; Diameter = 0.864 inches
Figure 34f:	1: 2 Concrete, Tested Jacketed at 7500 psi Confining Pressure; Length = 0.502 inches; Diameter = 0.762 inches
Figure 34h:	1: 3 Concrete, Tested Jacketed at 12,500 psi Confining Pressure; Length = .270 inches; Diameter = 0.8.25

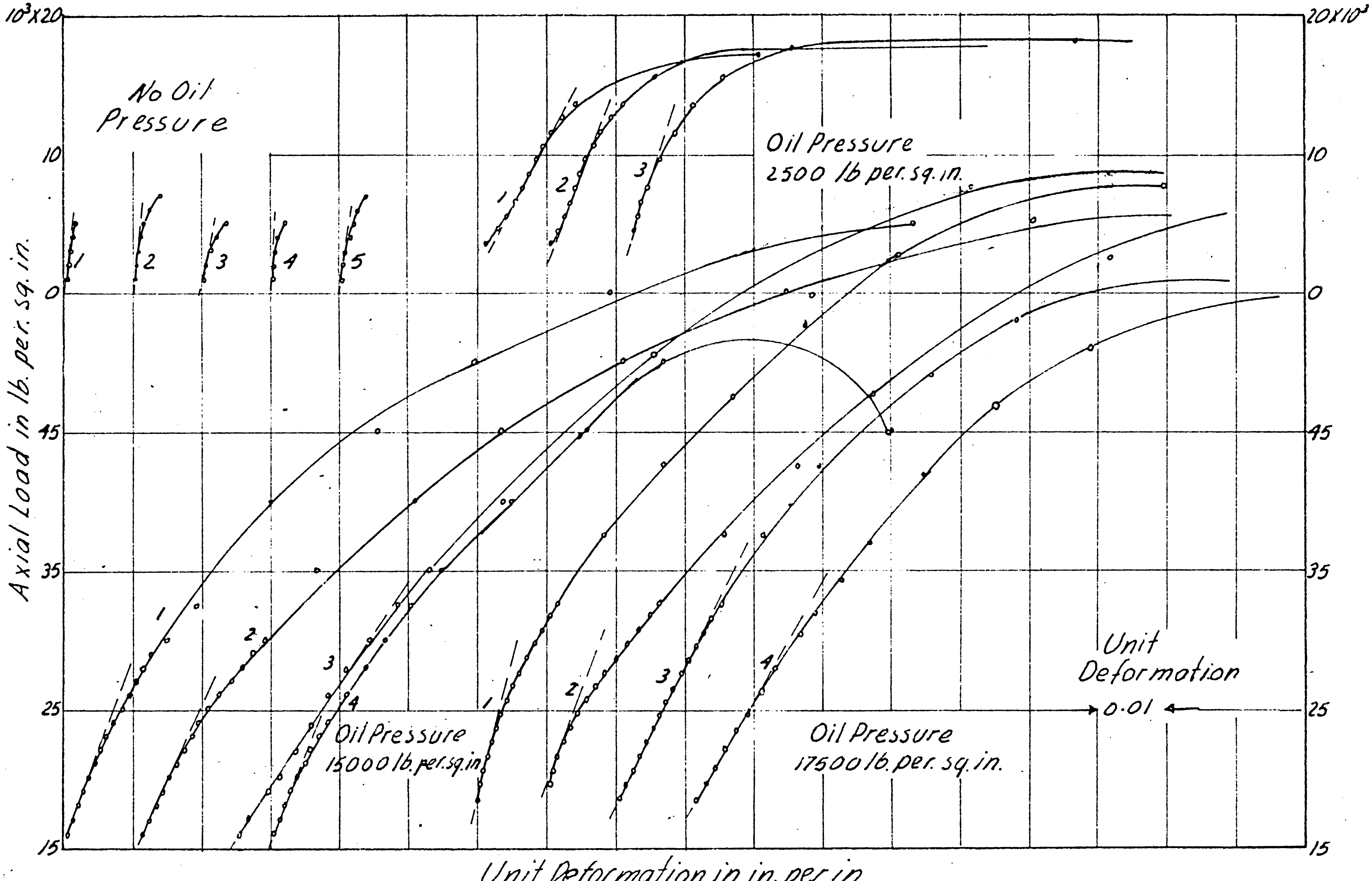


Fig. 9 Load Deformation Curves for Specimens with empty voids in Triaxial Compression
Group F

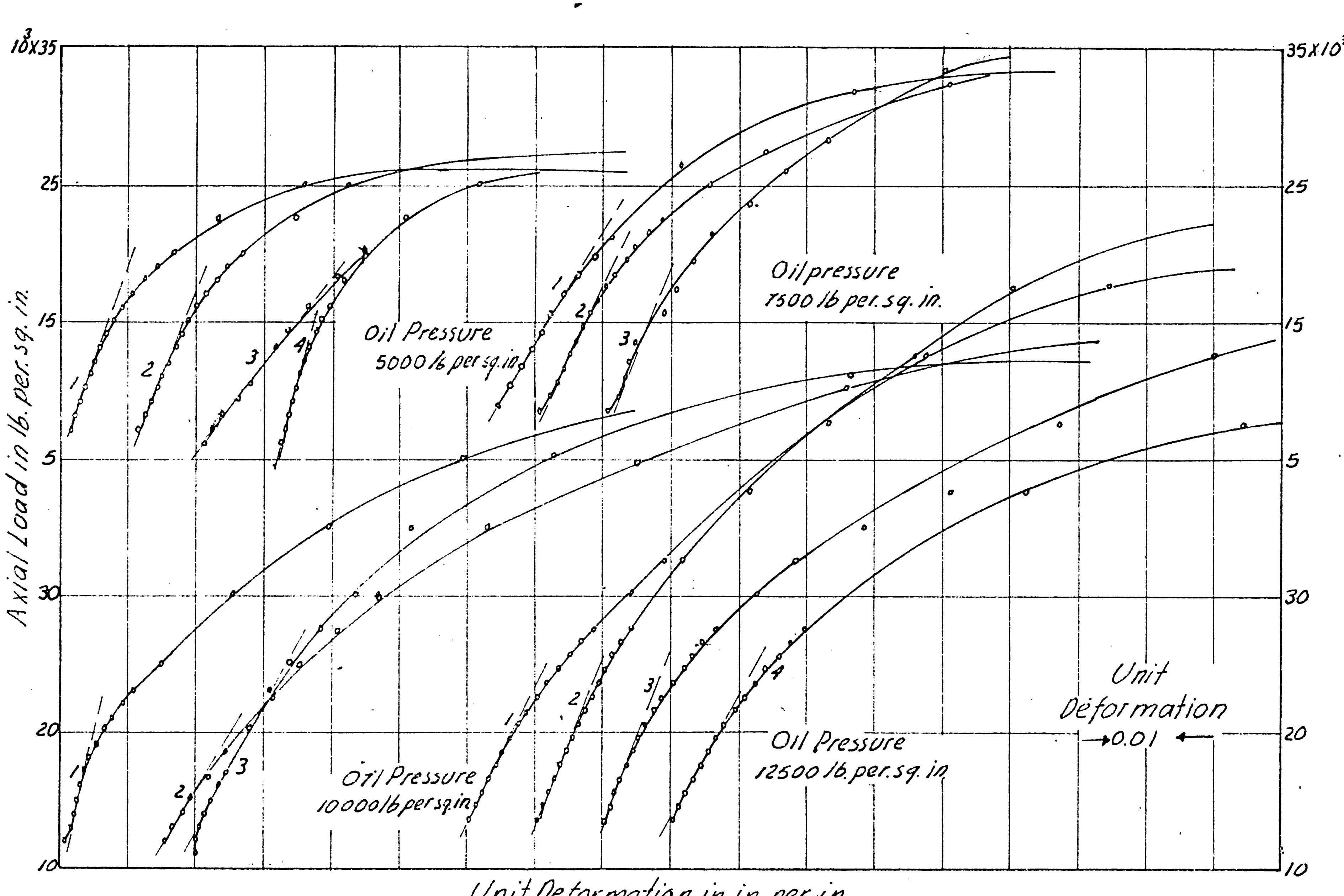


Fig. 10 Load Deformation Curves for Specimens with empty voids in Triaxial Compression
Group F

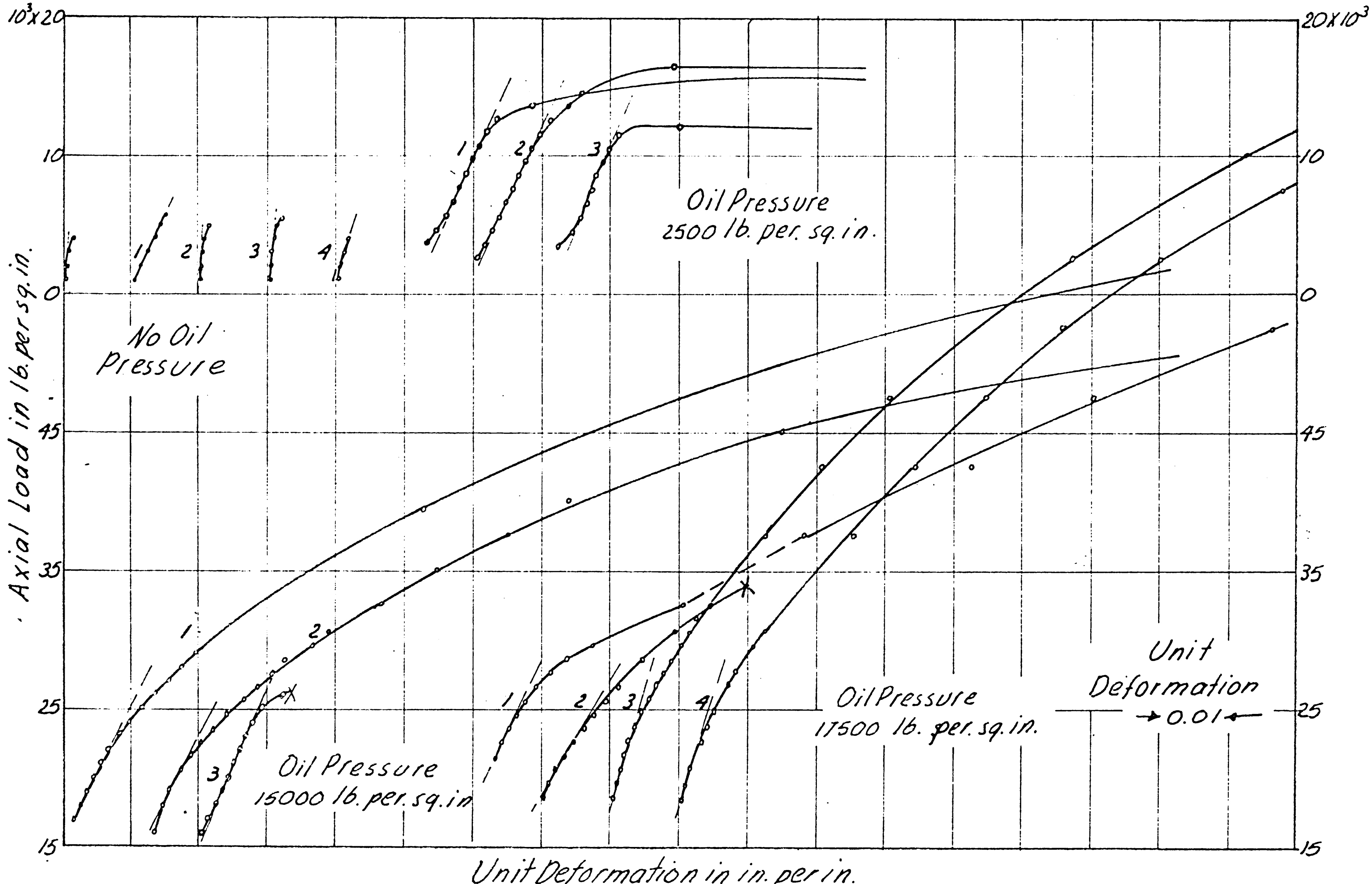


Fig. 11 Load Deformation Curves for Specimens with empty voids in Triaxial Compression
Group D

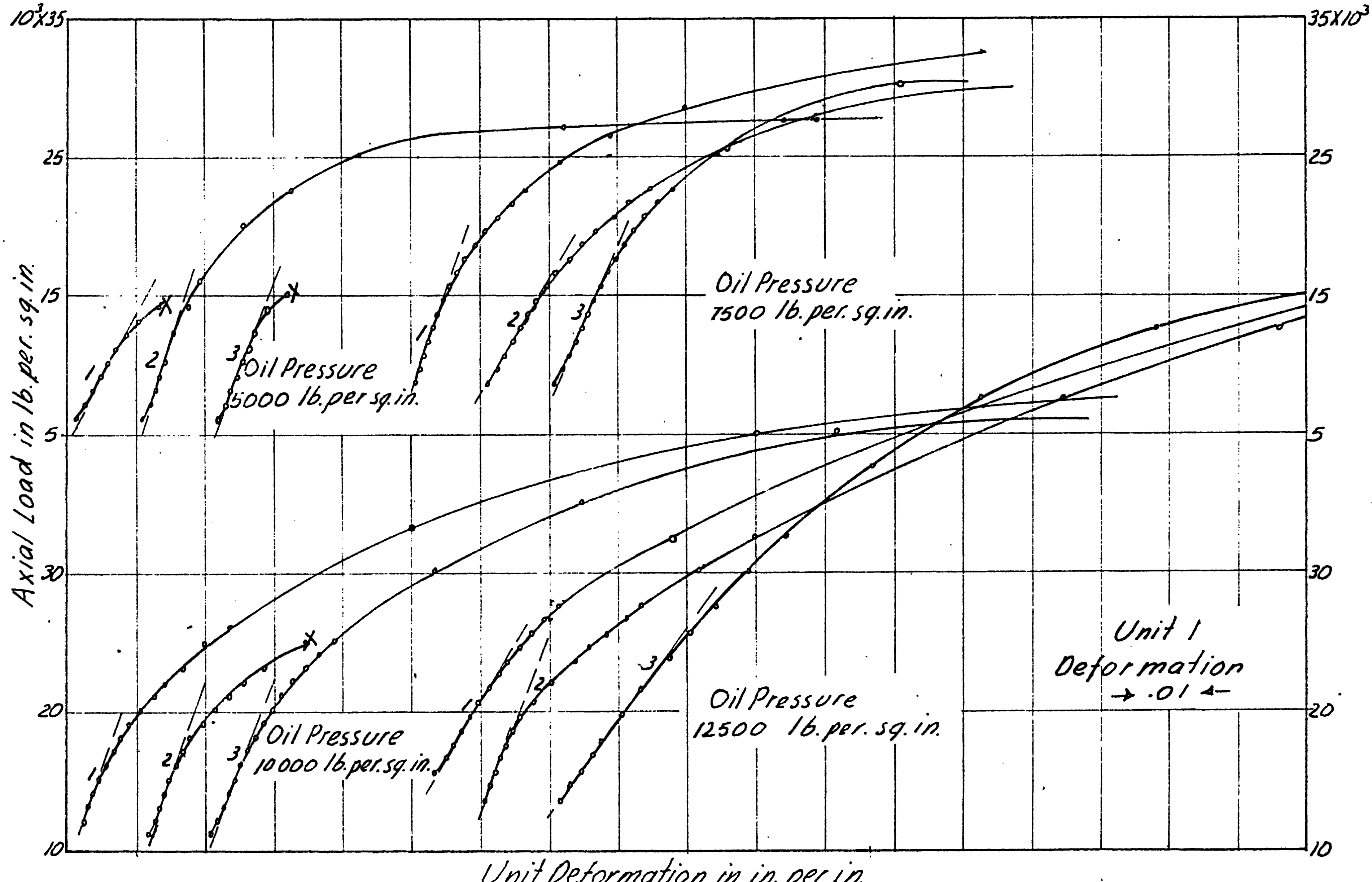


Fig. 12 Load Deformation Curves for specimens with empty voids in triaxial Compression
Group D

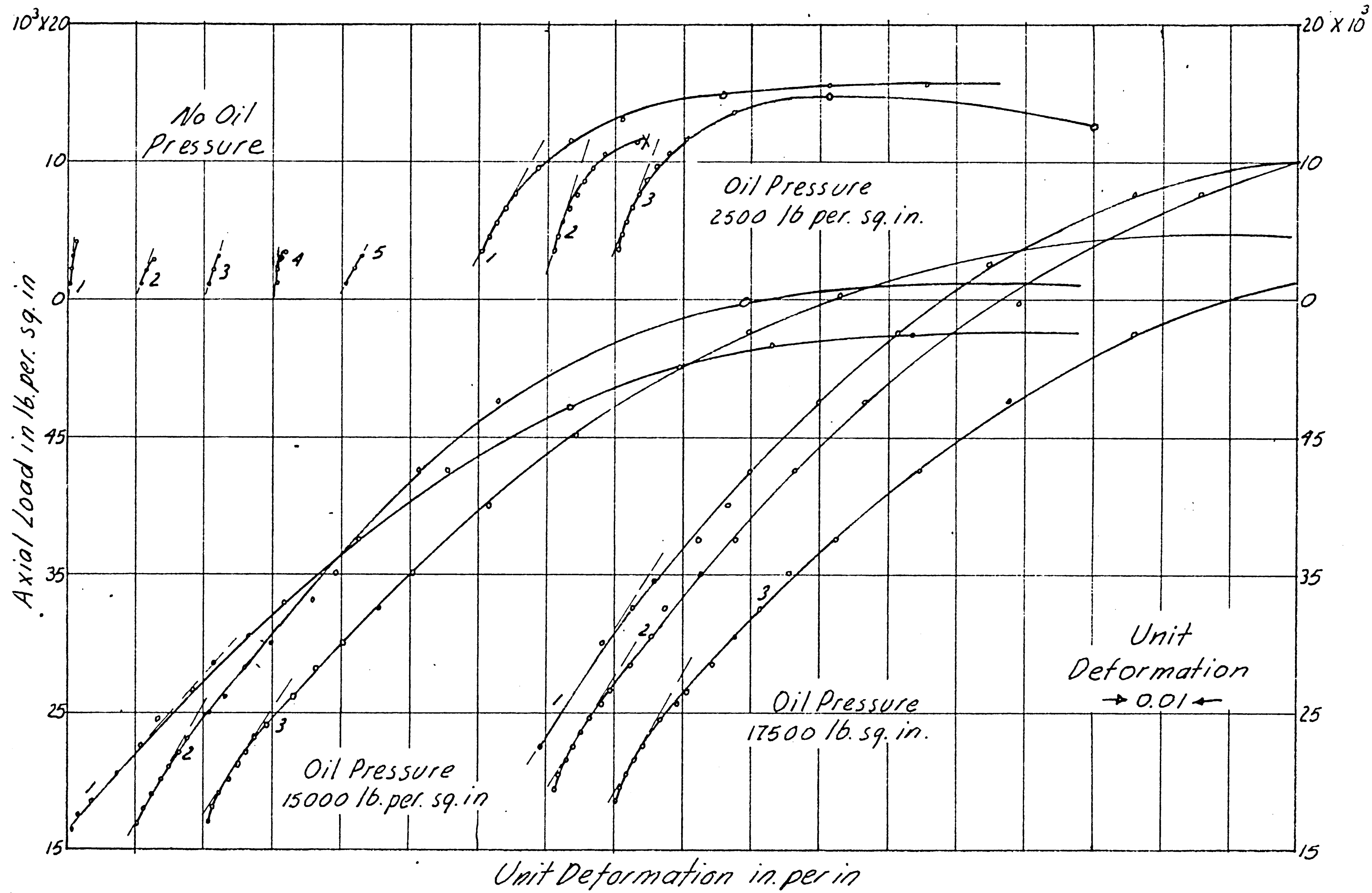
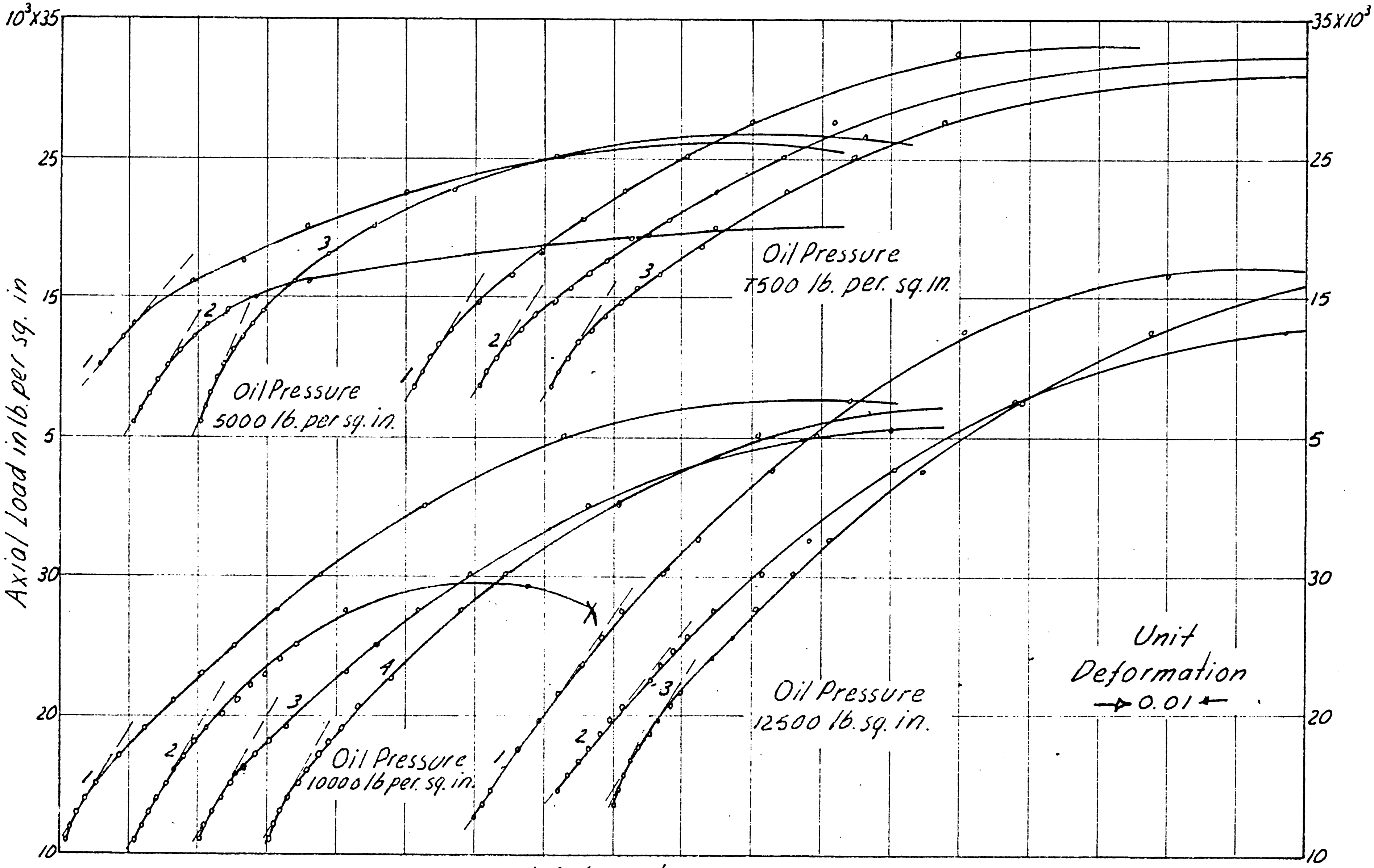


Fig. 13 Load Deformation Curves for specimens with empty voids in Triaxial Compression
Group H



Unit Deformation in in. per in.

Fig 14 Load Deformation Curves for specimens with empty voids in triaxial Compression
Group H

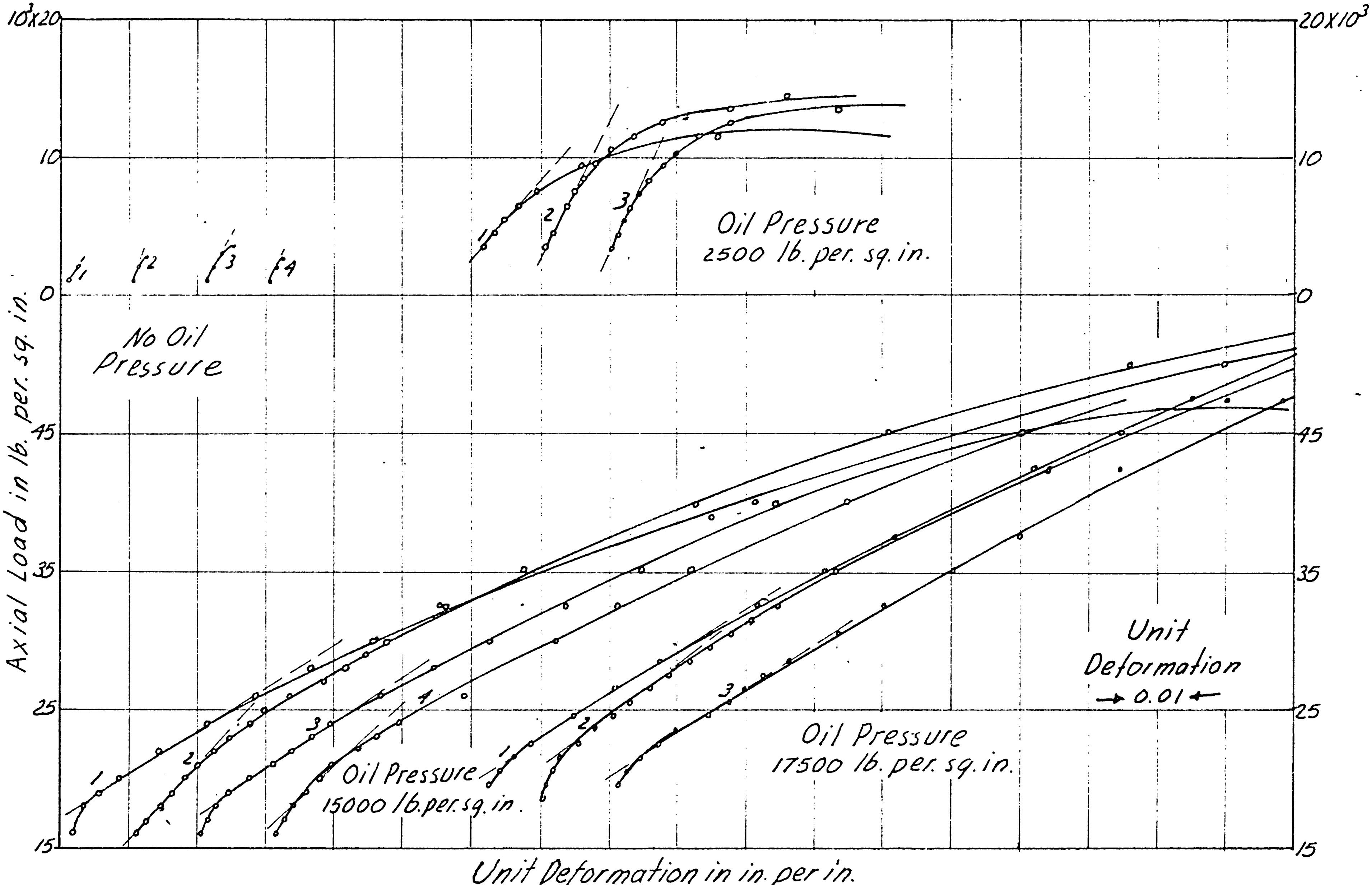


Fig. 15 Load Deformation Curves for specimens with empty voids in triaxial Compression Group J

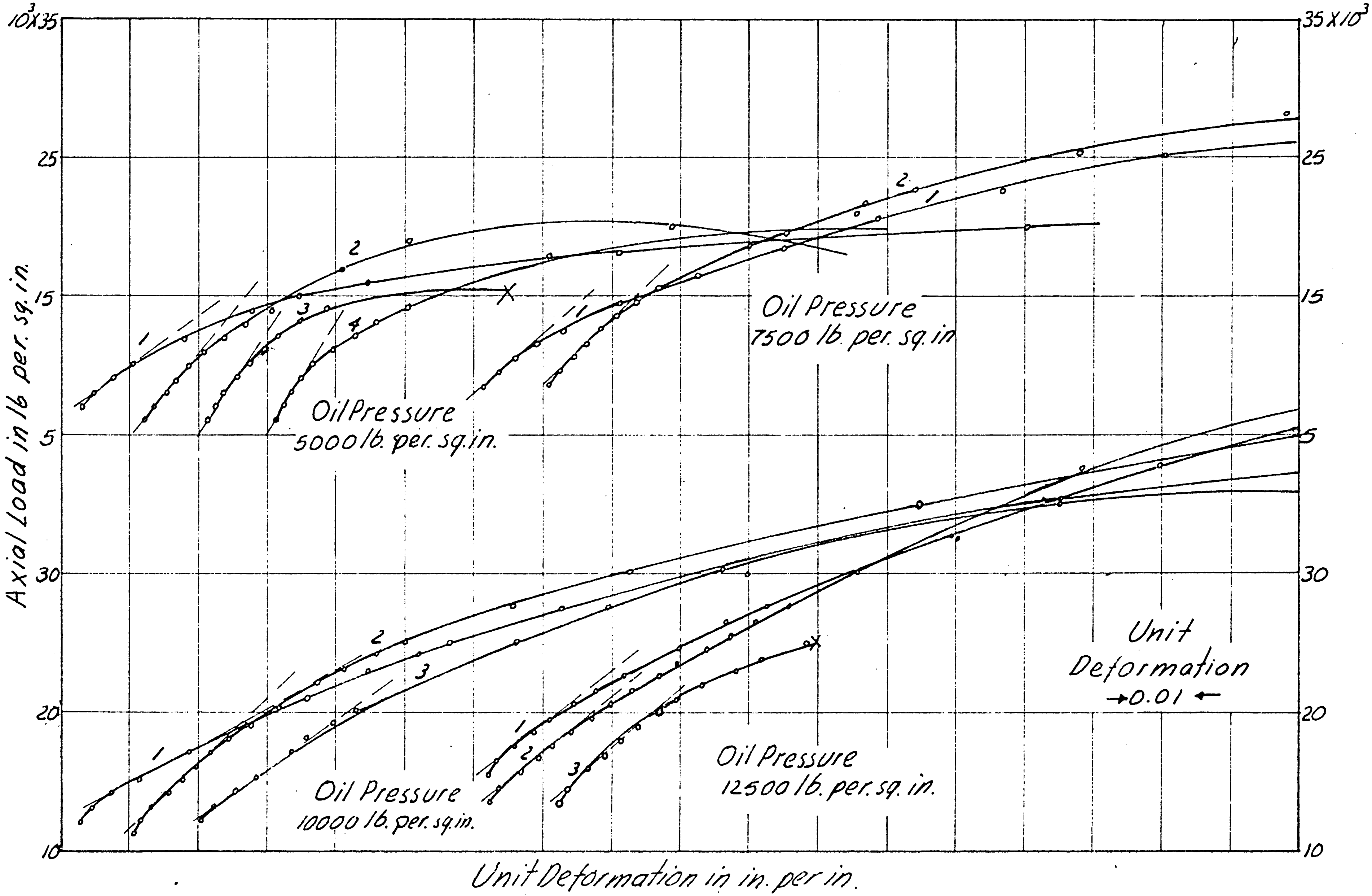


Fig. 16 Load Deformation Curves for specimens with empty voids in triaxial Compression
Group J

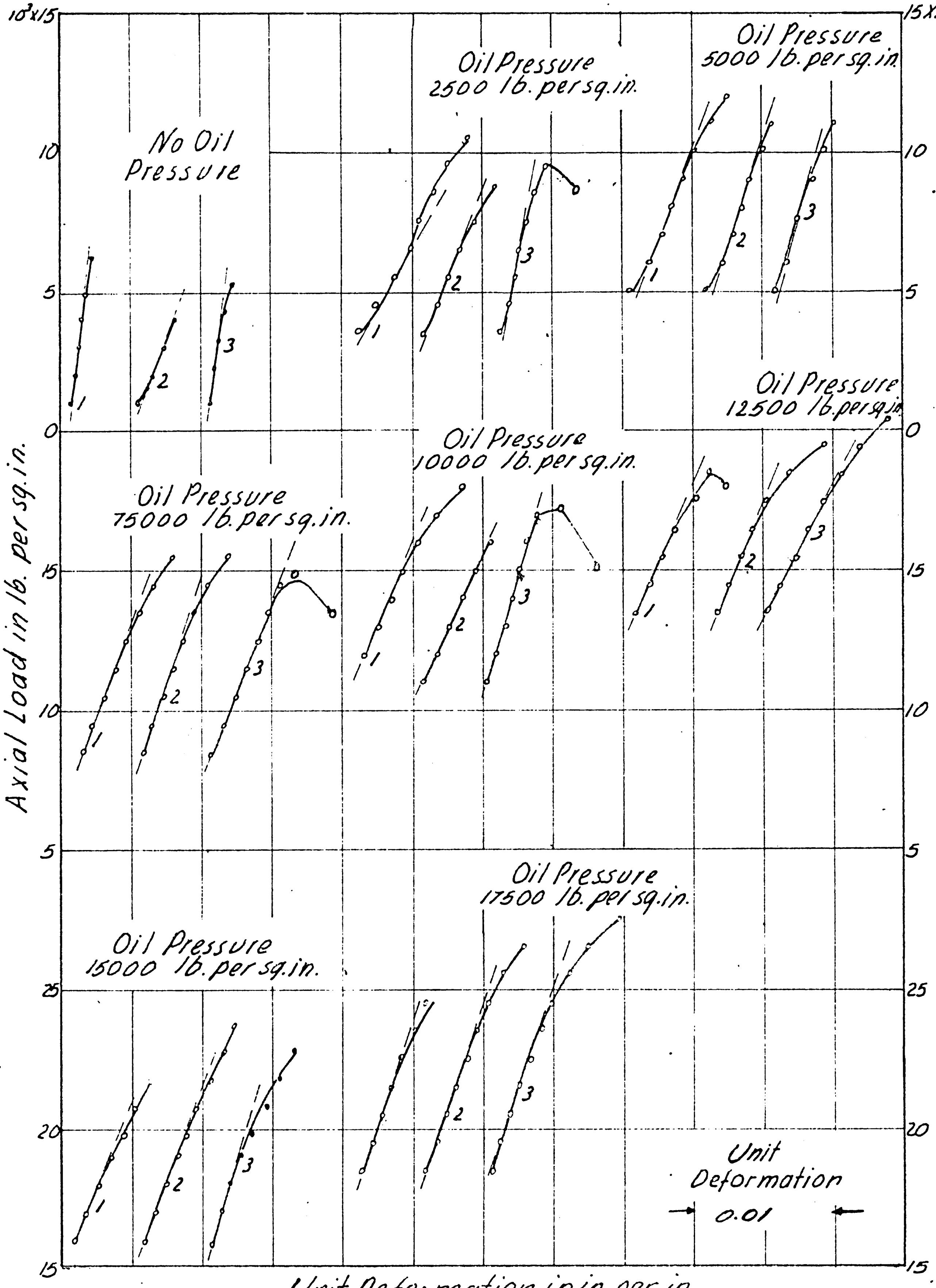


Fig. 18 Load Deformation Curves for Specimens in triaxial Compression with pore pressures equal to oil pressures
Group C

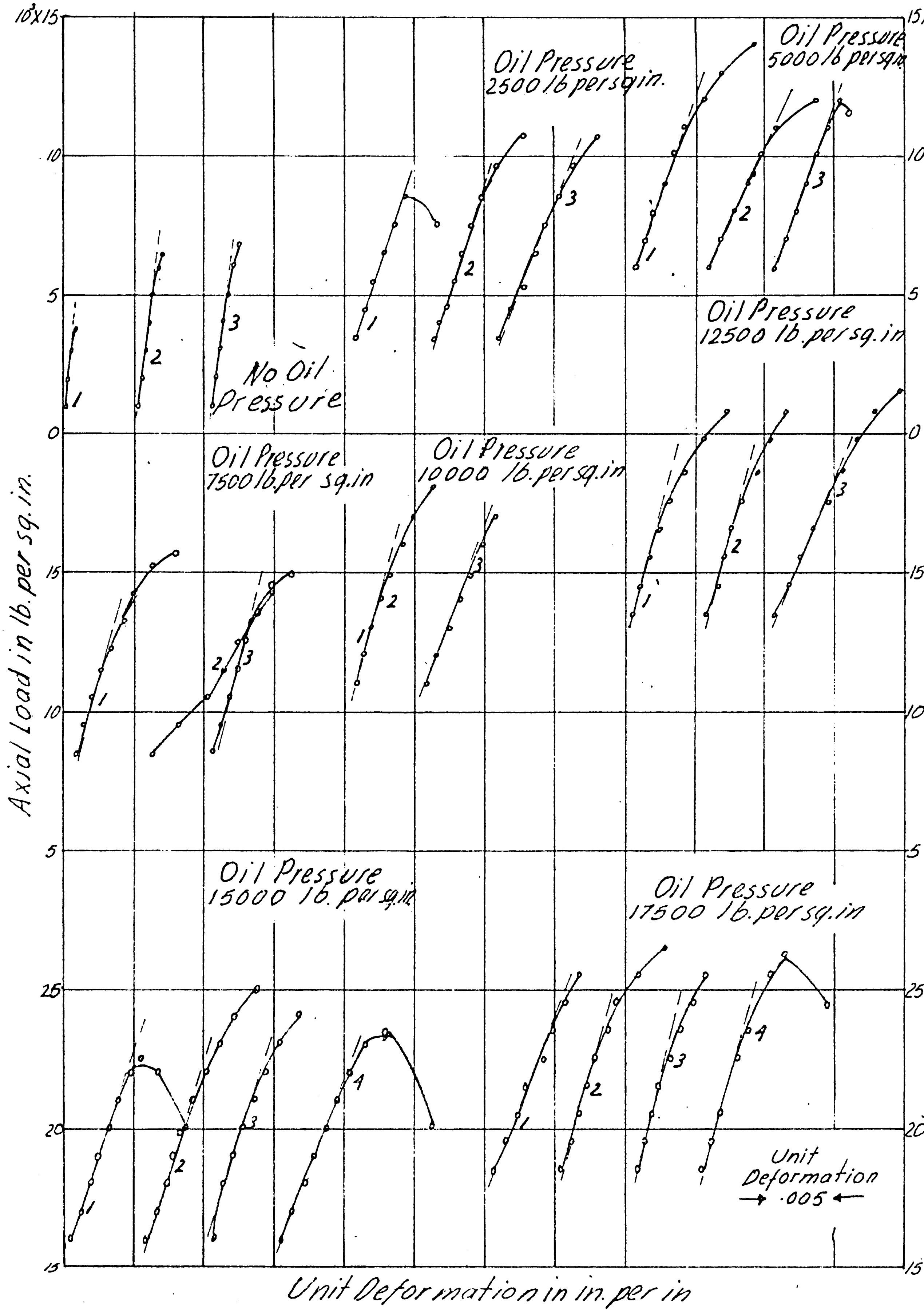


Fig.17 Load Deformation Curves for Specimens in triaxial Compression with pore pressures equal to oil pressures
Group E

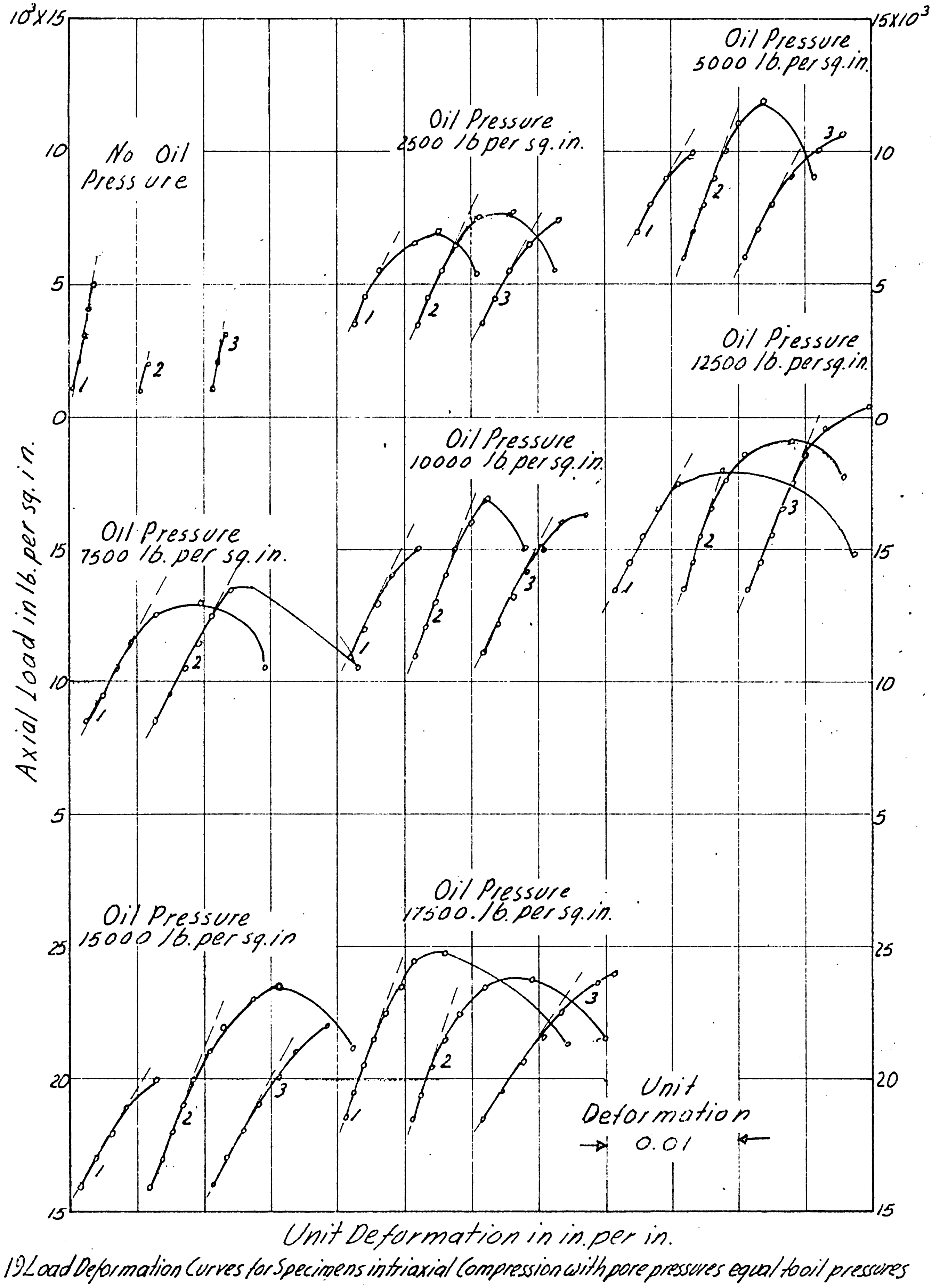


Fig. 19 Load Deformation Curves for Specimens in triaxial Compression with pore pressures equal to oil pressures

Group G

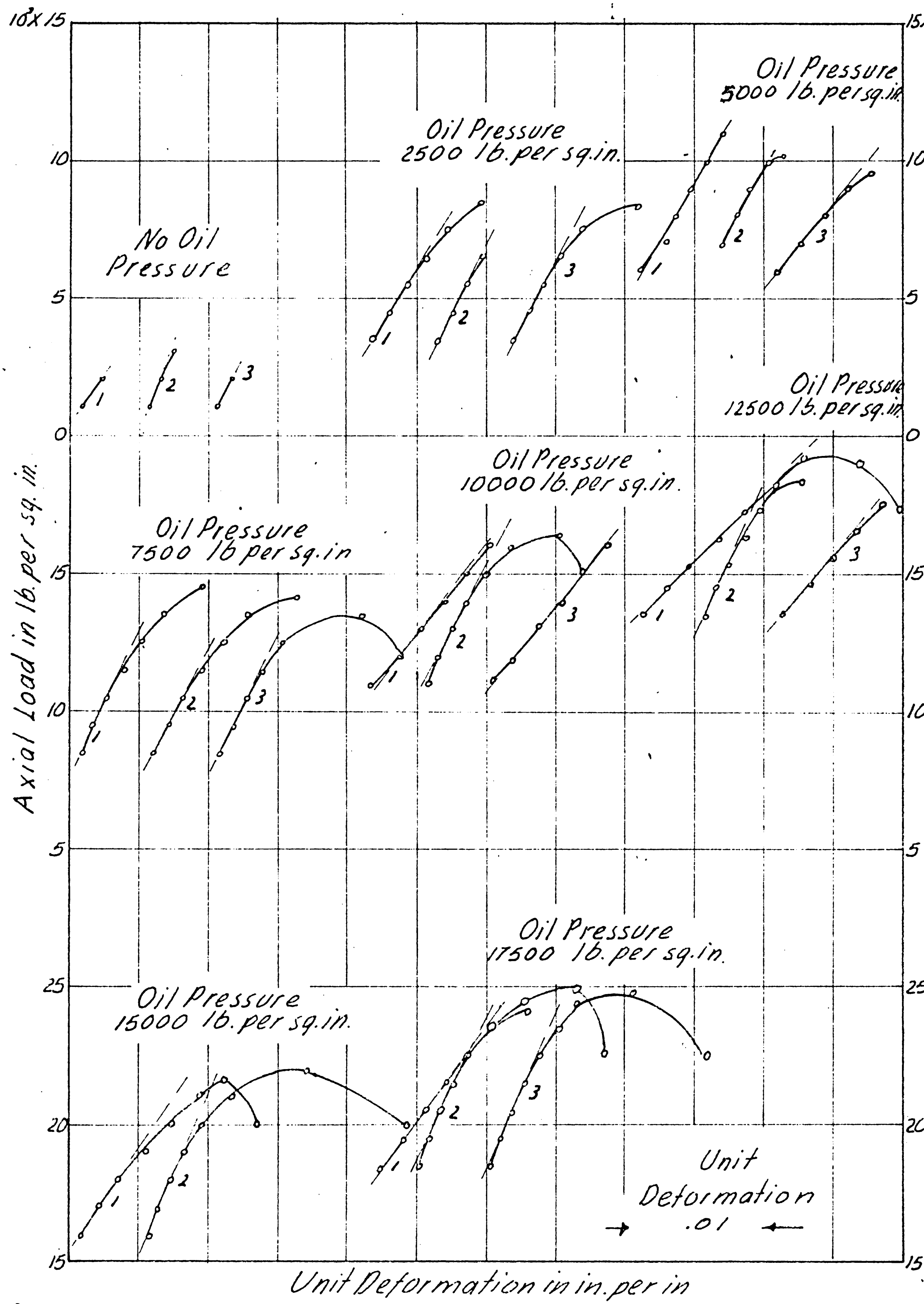


Fig. 20 Load Deformation Curves for Specimens in triaxial Compression with pore pressures equal to oil pressures
Group I

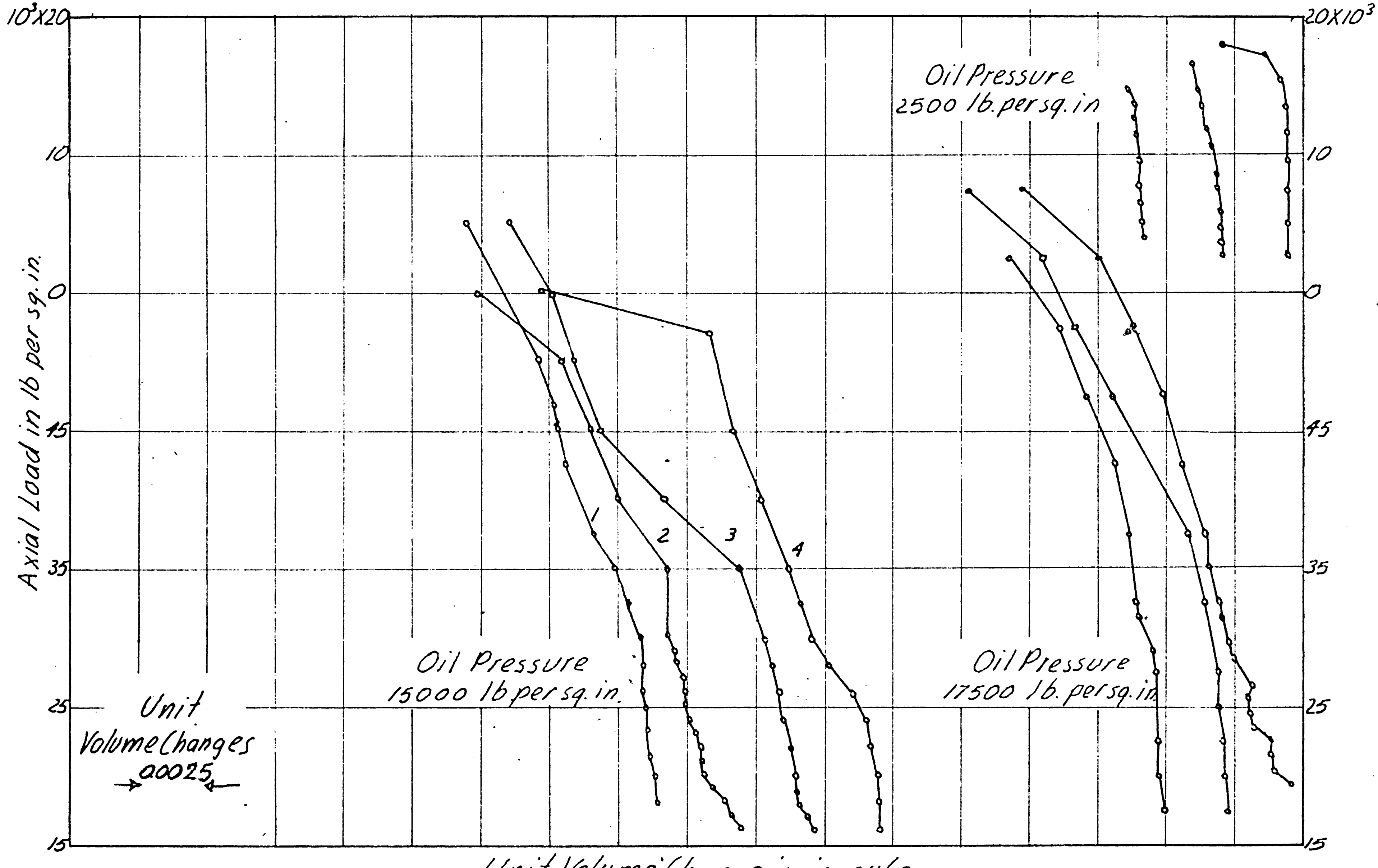


Fig 21 Volume Change Curves for Specimens with Empty Voids in Triaxial Compression
Group F

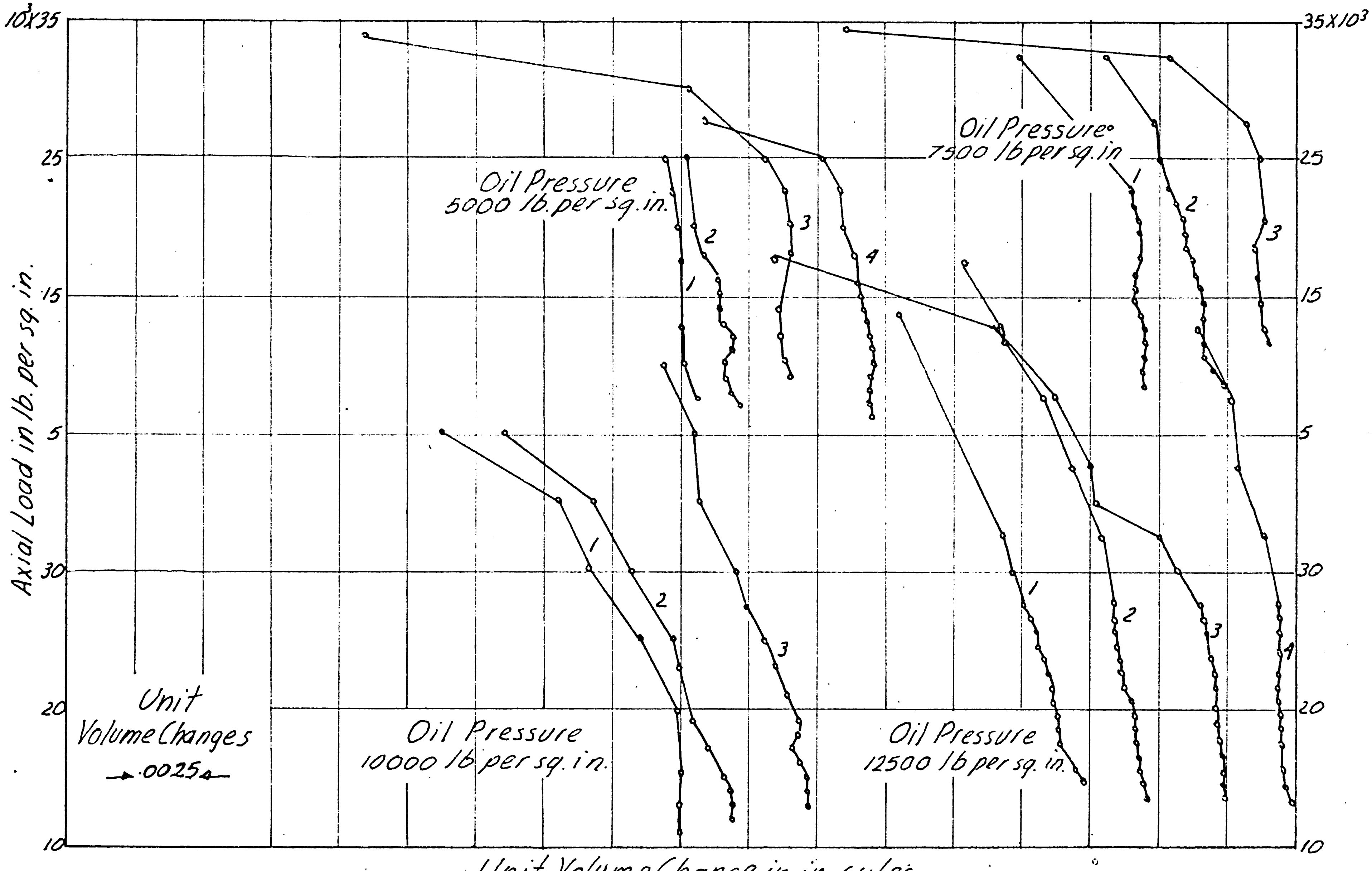


Fig 22 Volume Change Curves for Specimens with Empty Voids in Triaxial Compression
Group F

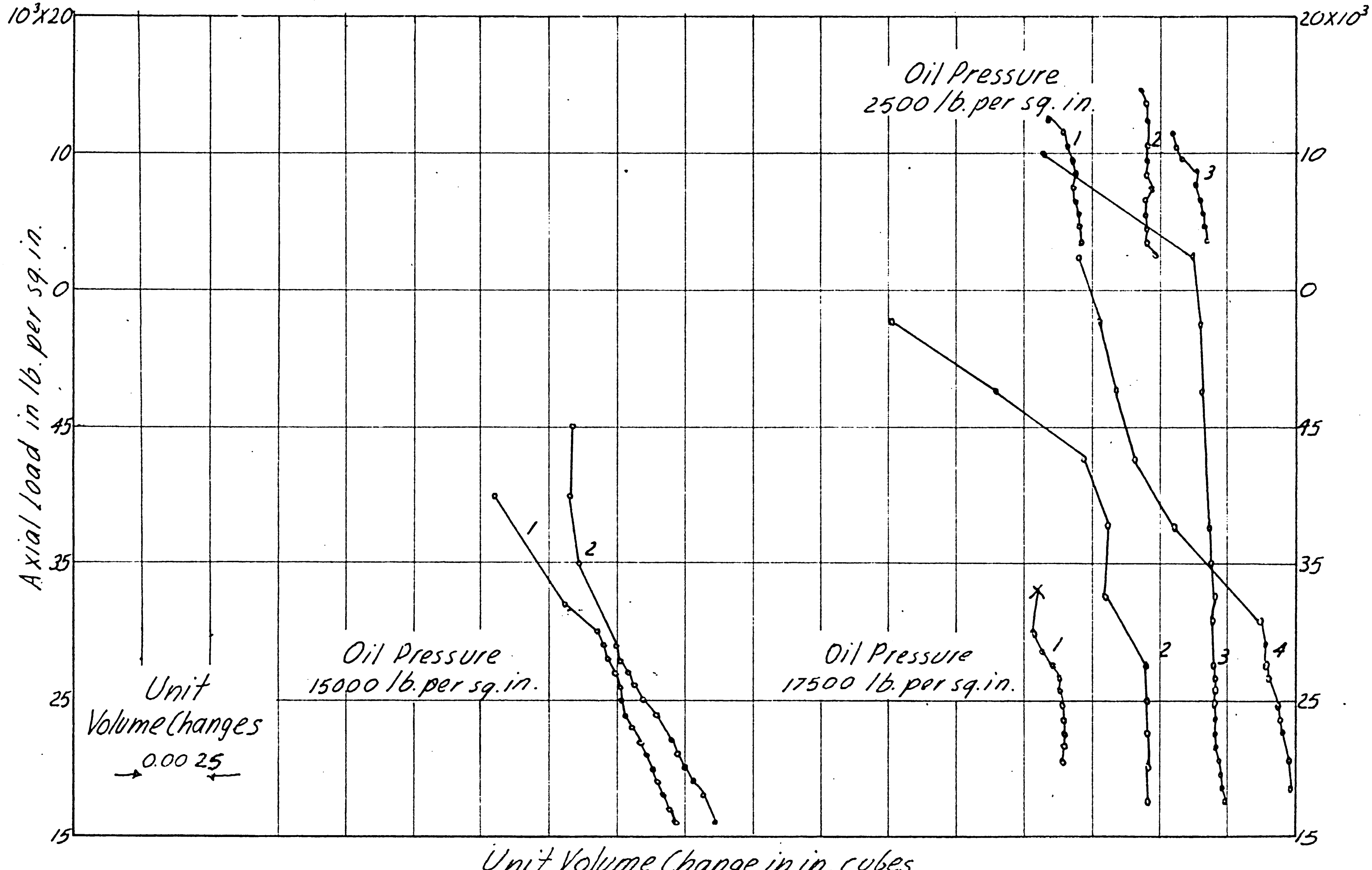


Fig 23 Volume Change Curves for Specimens with Empty Voids in Triaxial Compression
Group D

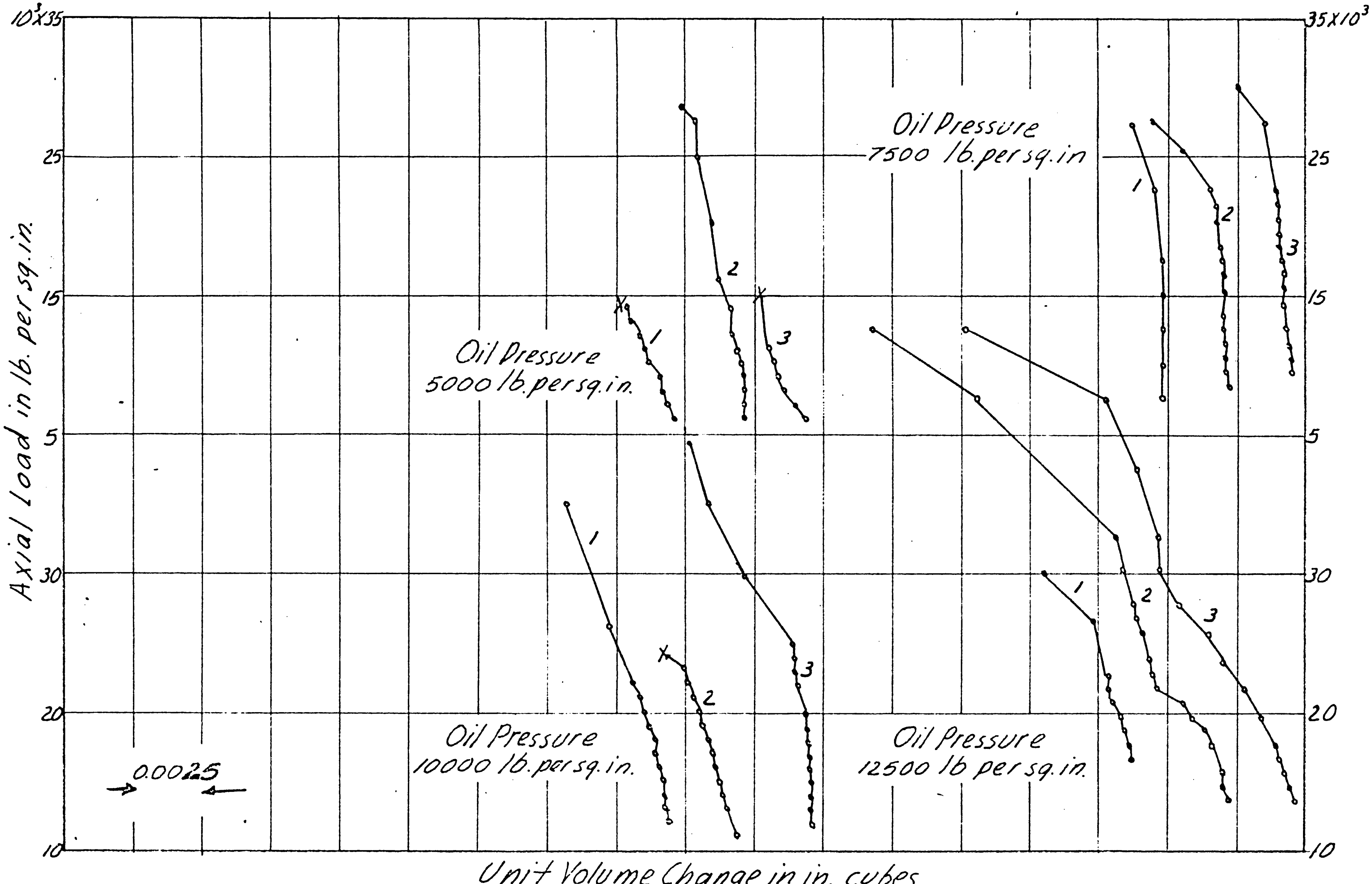


Fig 24 Volume Change Curves for Specimens with Empty Voids in Triaxial Compression
Group D

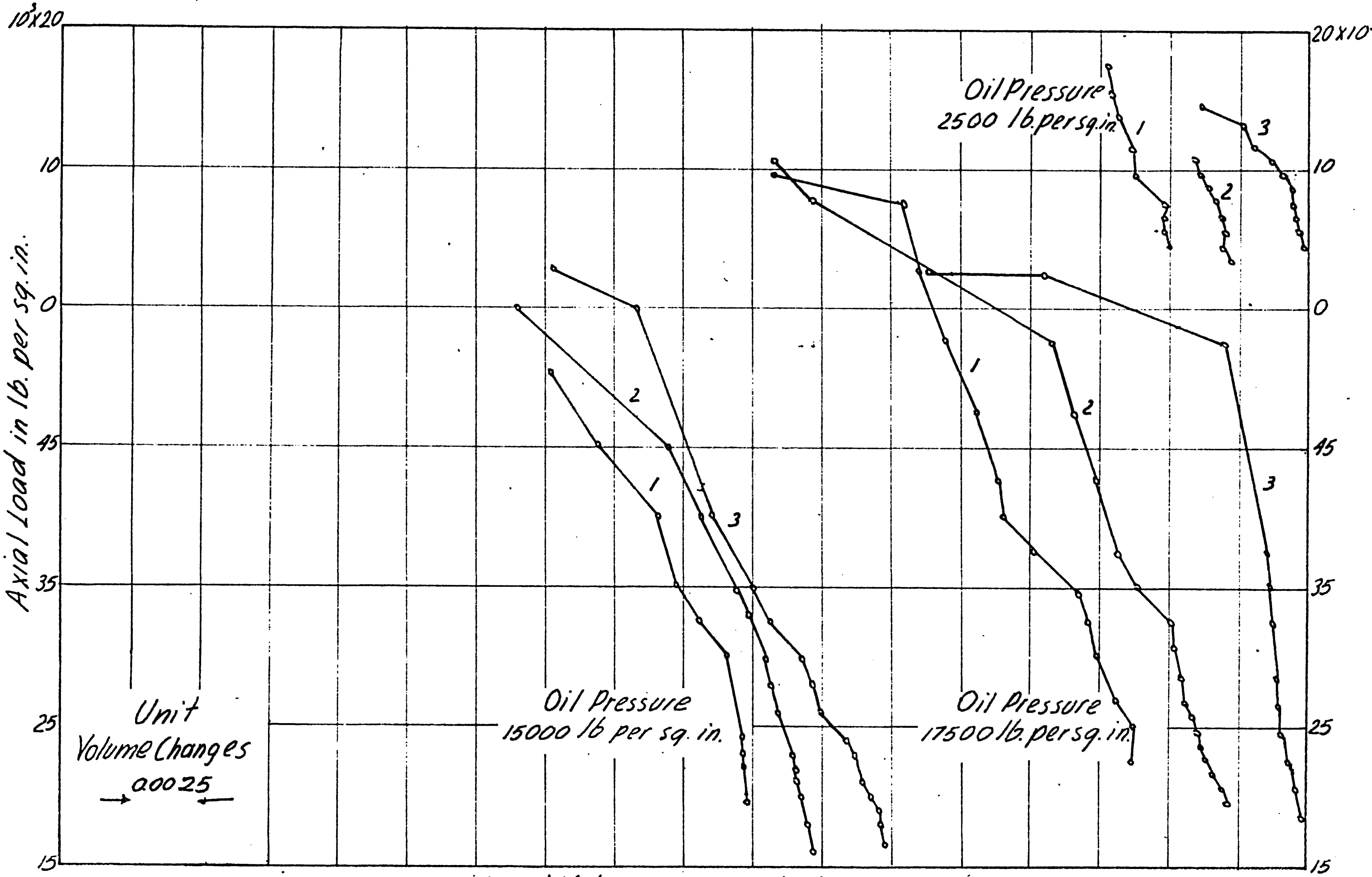
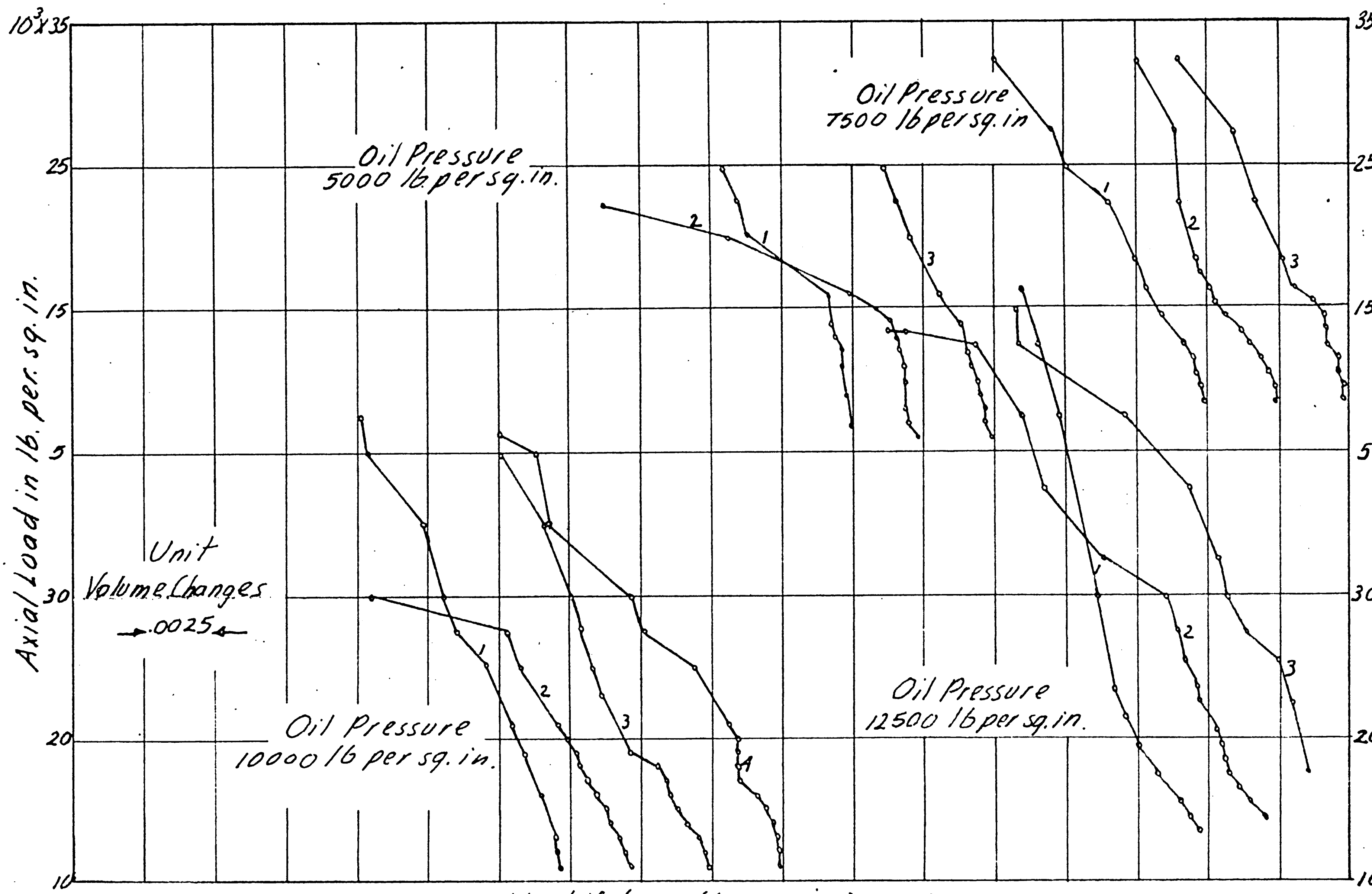


Fig 25 Volume Change Curves for Specimens with Empty Voids in Triaxial Compression
Group H



Unit Volume Change in in. cubes

Fig 26 Volume Change Curves for Specimens with Empty Voids in Triaxial Compression Group H

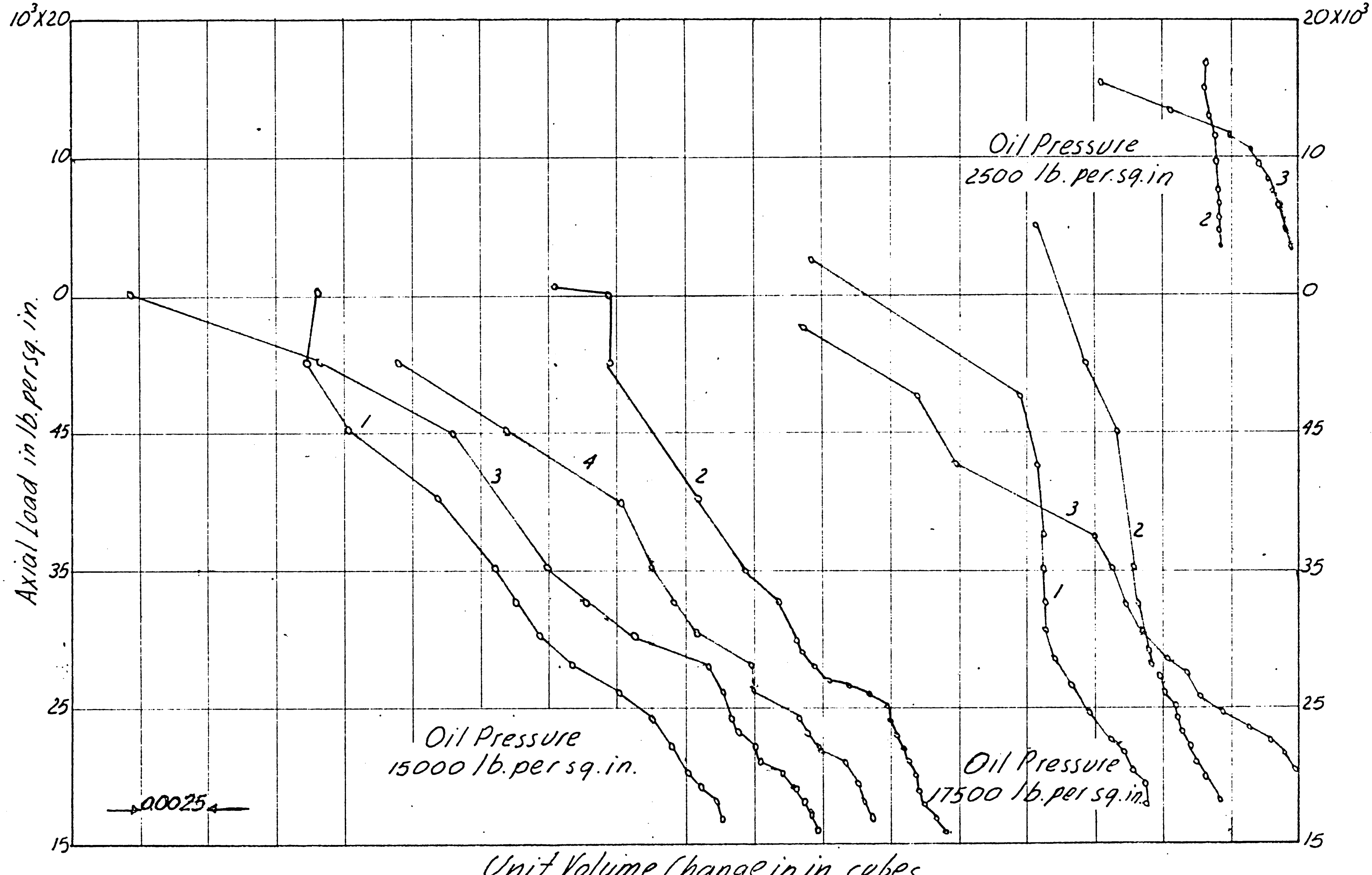


Fig 27 Volume Change Curves for Specimens with Empty Voids in Triaxial Compression
Group J

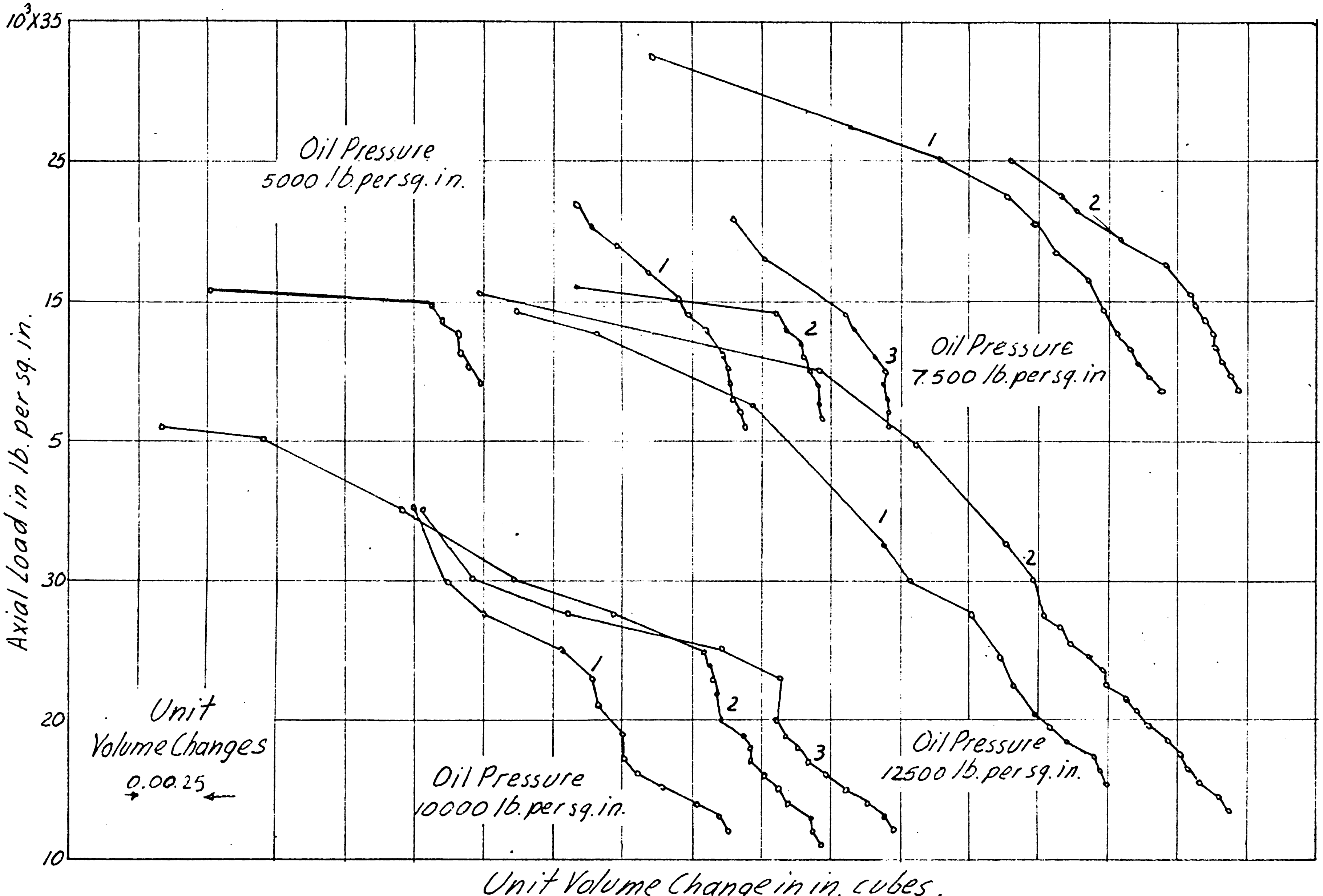
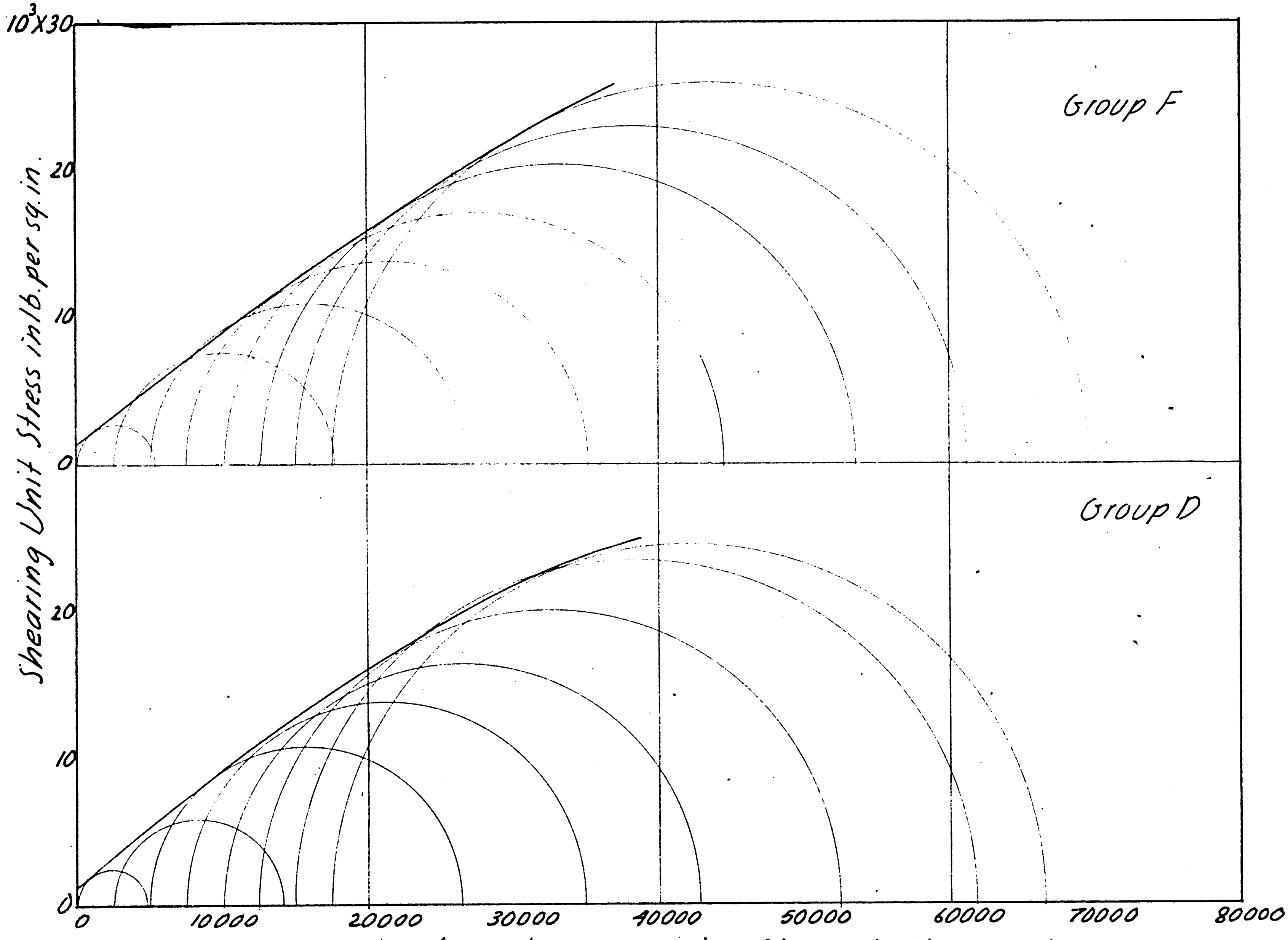
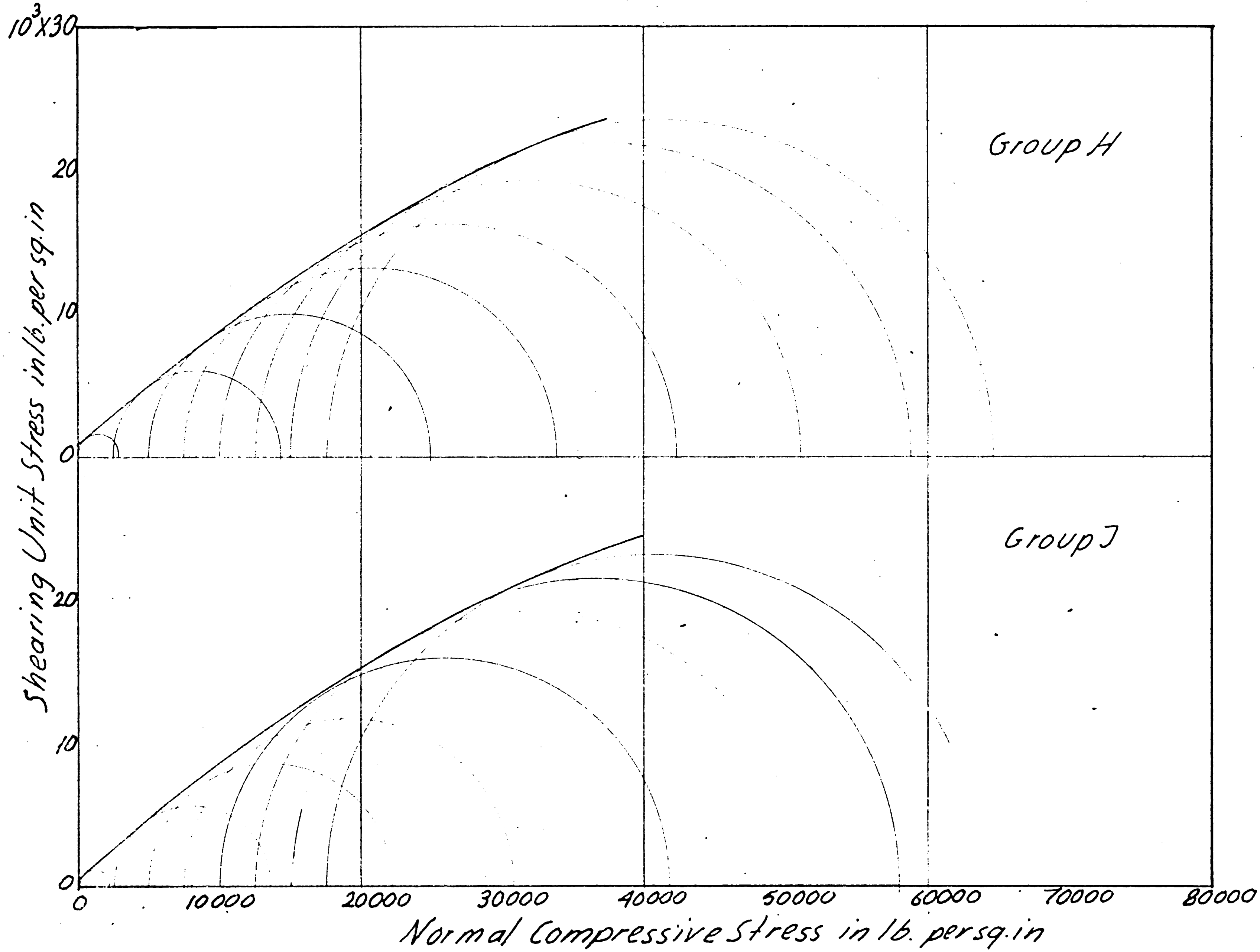


Fig 28 Volume Change Curves for Specimens with Empty Voids in Triaxial Compression
Group J



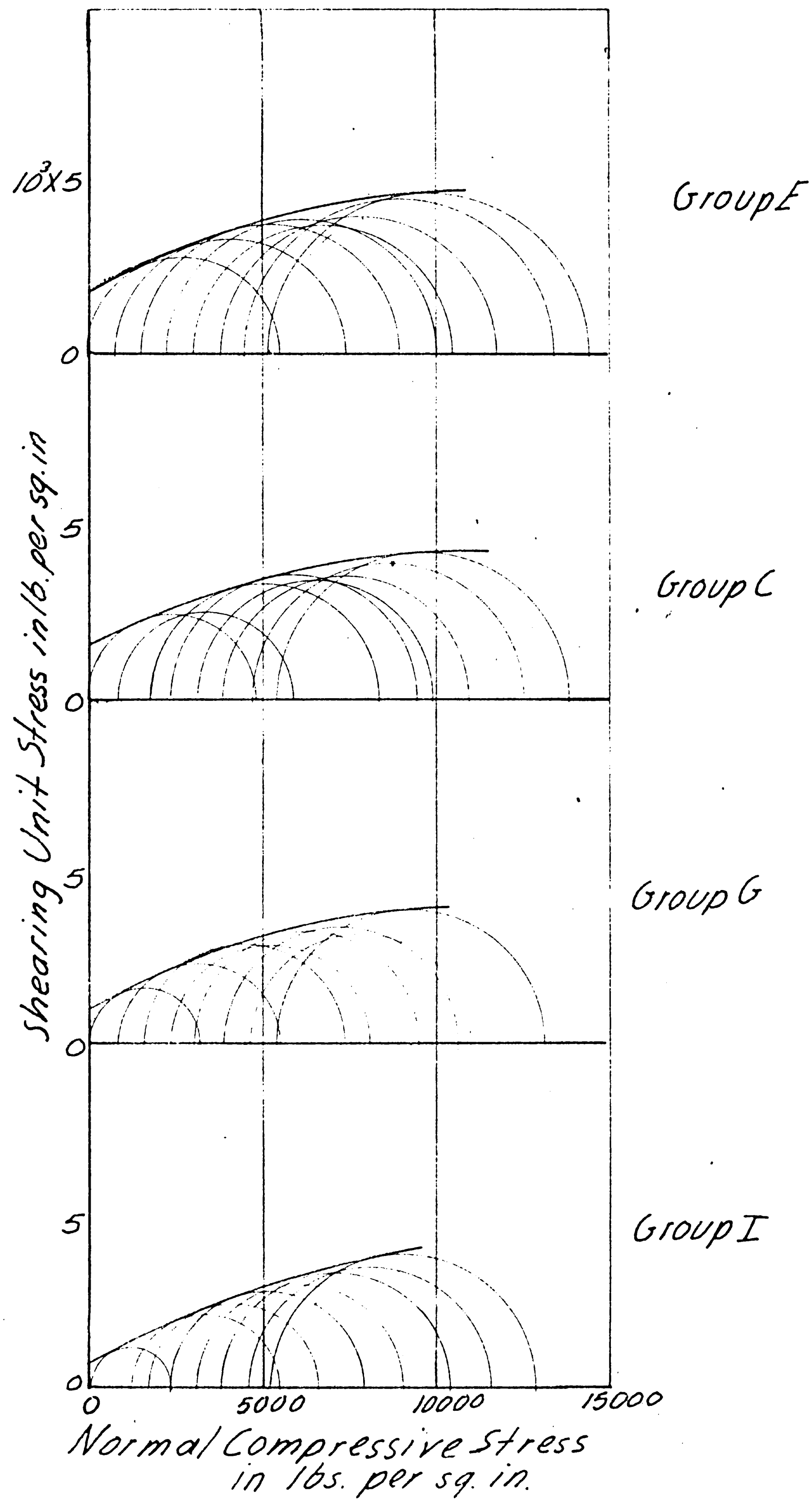
Group F
Group D
10³X30
20
10
0
20
10
0
0
10000
20000
30000
40000
50000
60000
70000
80000
Shearing Unit Stress in lb. per sq. in.
Normal Compressive Stress in lb. per sq. in.

Figure 29



10³X30
20
10
0
20
10
0
Group H
Group J
0
10000
20000
30000
40000
50000
60000
70000
80000
Shearing Unit Stress in lb. per sq.in
Normal Compressive Stress in lb. per sq.in

Figure 30



10³X5
Group E
0
5
Group C
0
5
Group G
0
5
Group I
0
0
5000
10000
15000
Shearing Unit Stress in lb. per sq. in
Normal Compressive Stress in lbs. per sq. in.

Figure 31

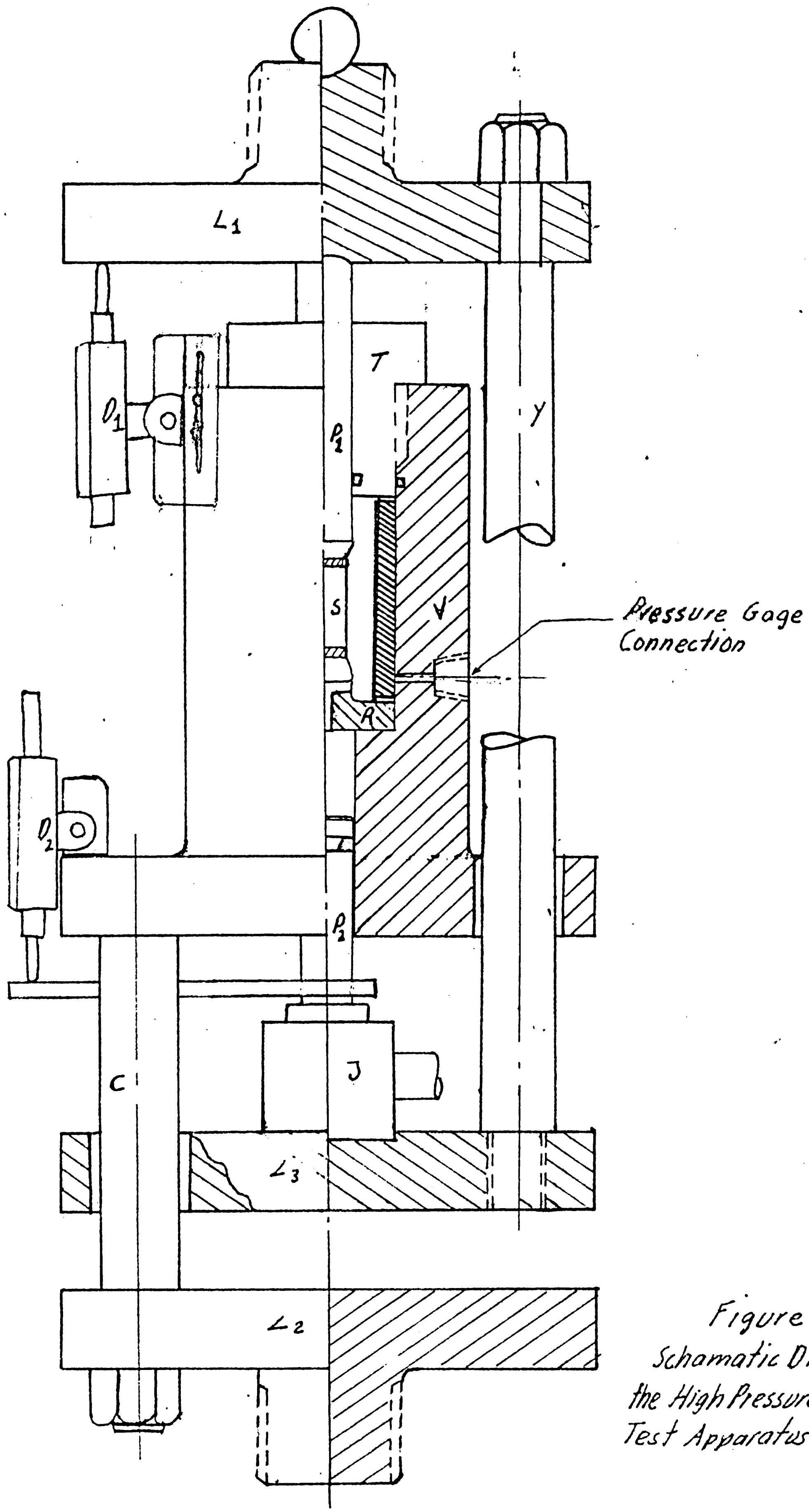


Figure 32
Schamatic Diagram of
the High Pressure Strength
Test Apparatus

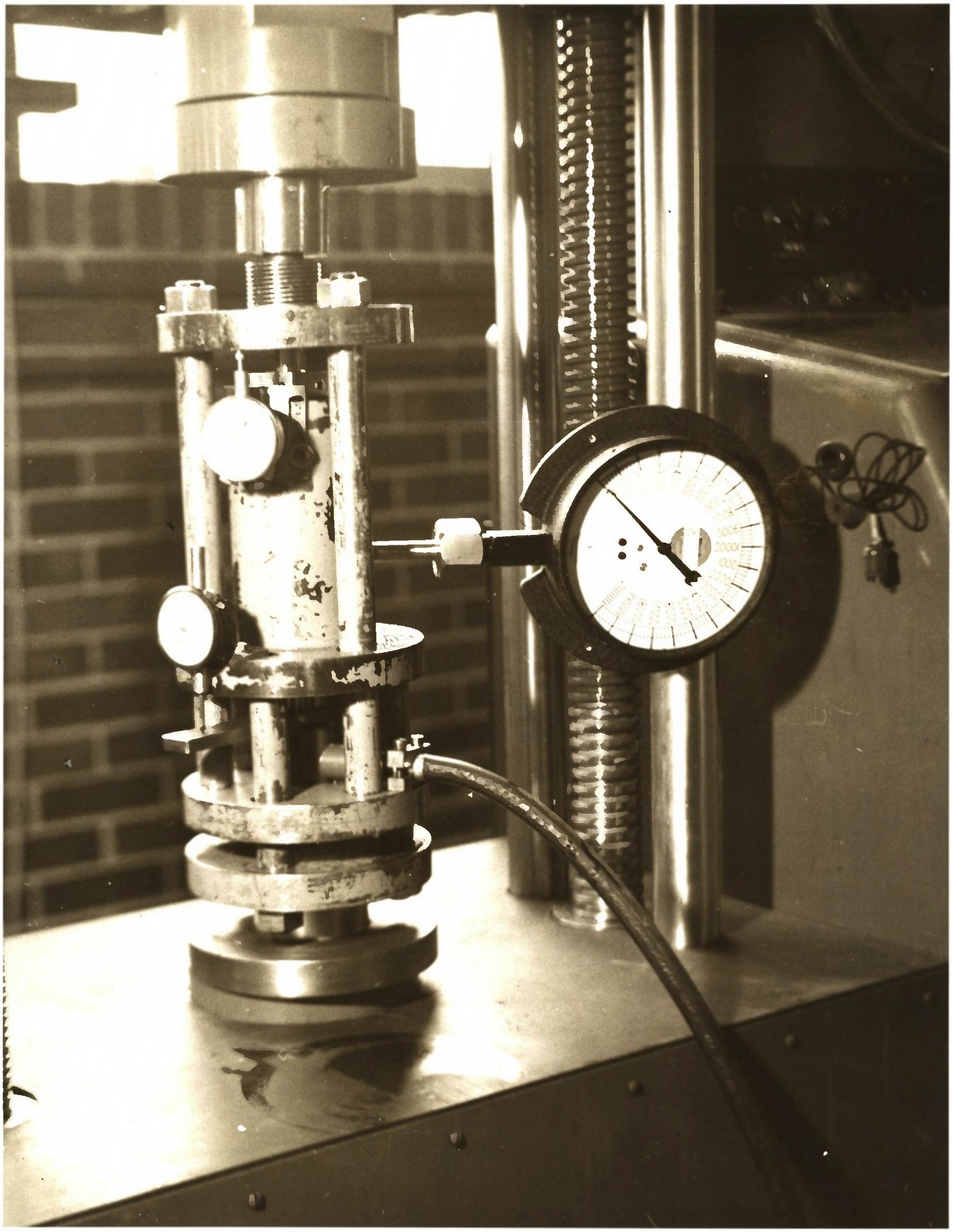


Figure 33

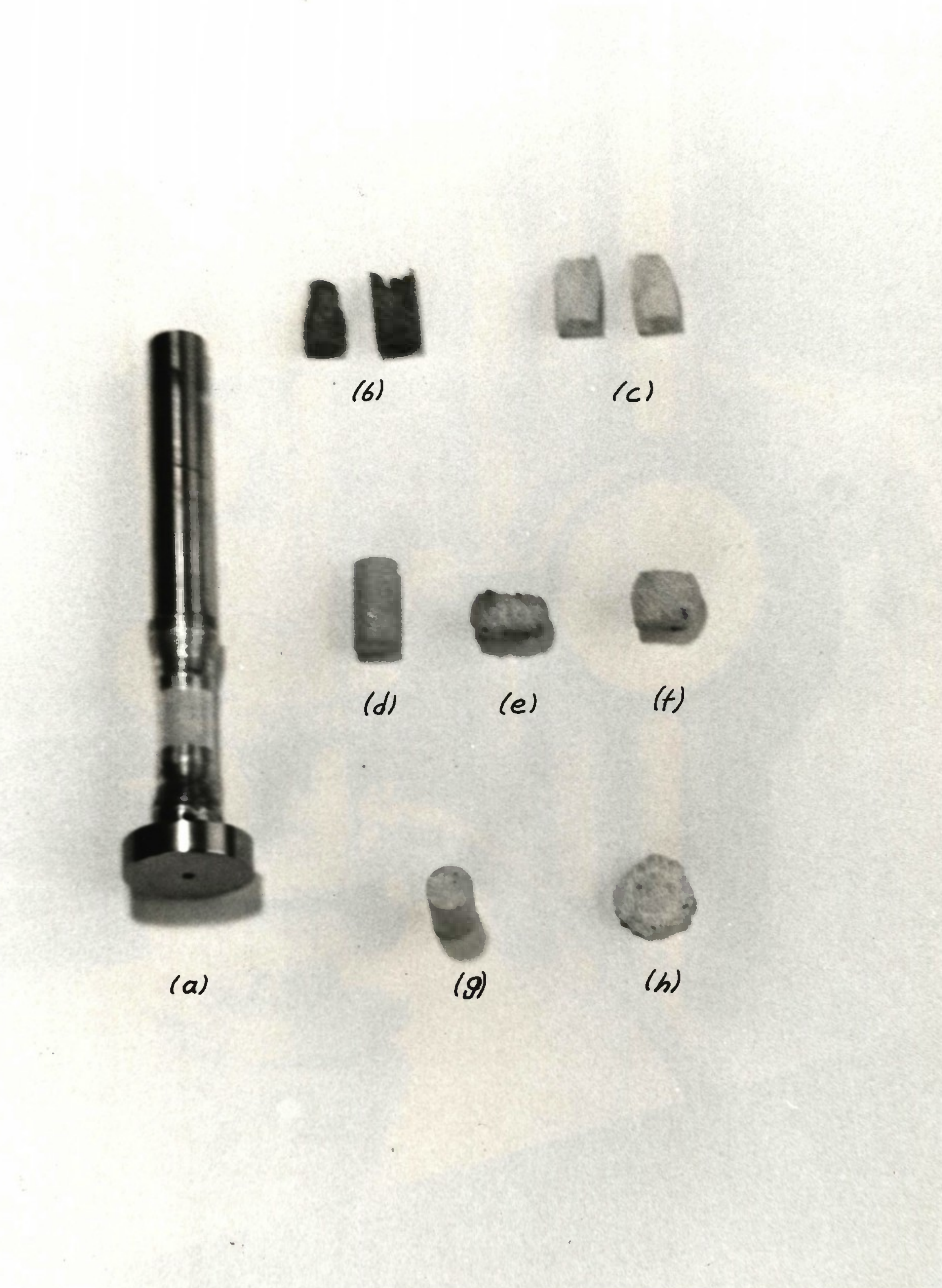


Figure 34

APPENDIX III

RECORDED DATA AND COMPUTATIONS

In this appendix to diffrentiate various experiments a certain designation used, such as 2 G 2500 .Where G is the concrete mixture, 2500 is the constant confining pressure, and 2 is the experiment number for that confining pressure. There are at least three experiments for each mixture at a certain confinig pressure. For further information about concrete mixtures refer paragraph two and Table 1 on page 20.

Table of Contents

REFERENCE SHEET

Column

1	2	3	4	5	6	7	8	9	10
					In/in 10^{-4}	in/in 10^{-4}	Unit Deformation in/in 10-4	10^{-4}	Volume Change in^3/in 10^{-4}
		Lower Piston Readings			Upper Piston Readings				
Confining Pressure 16/in^2	Excess Axial Load lb.	Deflection in.x10^{-3}	Correction inx10^{-4}	Corrected Deflection in.x10^{-4}	Deflection inx10-4	Correction inx10^{-4}	Corrected Deflection inx10^{-4}	Change in Length of Pistons Inside Chamber in x10^{-4}	Volume Change Inside Chamber in.^{3}x10^{-4}
					Unit Deformation in/inx10^{-4}	Correction $\frac{\text{inx}10^{-4}}{\text{in}}$	Corrected Unit Deformation $\frac{\text{inx}10^{-4}}{\text{in}}$		
				Column 3 -Col.4			Col.6 -Col.7	Col. 8 -Col. 5	Col. 9 x 0.37 in.

Jacketed Groups D, F, H, J

Unjacketed Groups C, E, G, I

1D2-500

1	2	3	4	5	6	7	8	9	10
2500	0	185			145				
2500	200				44	16	28		
2500	400				65	18	47		
2500	600				79	20	59		
2500	800	179	52	52	90	22	68	16	6
2500	1000	178	8	60	100	24	72	12	4
2500	1200	177.5	3	63	109	26	83	20	7
2500	1400	176.5	8	71	12	26	92	21	8
2500	1600	176	3	74	131	30	101	27	10
2500	1800	175	8	82	145	32	113	31	11
2500	2000	173.5	13	95	162	34	128	33	14
2500	2170				216	36	180		

Ultimate load 2170lb

1D0

1	2	3	4	5	6	7	8	9	10
0	200				11	8	3		
0	400				16	10	6		
0	600				21	12	9		
0	800				28	14	14		

Ultimate loade 800 lb

1D5000

0	0	220			4				
2500	0	335			17				
5000	0	429			32				
5000	200	428.5	3	3	49	34	15	12	4
5000	400	428	3	6	64	36	28	22	8
5000	500	427.5	3	9	76	38	38	29	11
5000	800	426.5	8	17	89	40	49	32	12
5000	1000	425.8	5	22	101	42	59	37	14
5000	1200	425	6	28	114	44	70	42	15
5000	1400	424	8	36	129	46	83	47	17
5000	1600	422.5	13	49	151	48	103	54	20
5000	1800	420	23	72	182	50	132	60	27

Ultimate load 1800 lb

1D7500

1	2	3	4	5	6	7	8	9	10
0	0	0			0				
2500	0	141			15				
5000	0	230			34				
7500	0	317.5			52				
7500	200	317	3	3	60	54	6	3	1
7500	400	316.5	3	6	67	56	11	5	2
7500	600	315.5	8	14	75	58	17	3	1
7500	800	315	3	17	83	60	23	6	2
7500	1000	314	8	25	92	62	30	5	2
7500	1200	313	8	33	102	64	38	5	2
7500	1400	312	8	41	112	66	46	5	2
7500	1600	310.5	13	54	124	68	56	2	1
7500	1800	309.5	8	62	138	70	68	6	2
7500	2000	308.2	11	73	150	72	78	5	1
7500	2200	307	10	83	166	74	92	9	3
7500	2400	305.5	13	96	185	76	109	13	5
7500	2600	303.5	18	114	204	78	126	12	4
7500	2800	301.5	18	132	225	80	145	13	5
7500	3000	299.5	18	150	249	88	161	11	4
7500	3900	295	41	191	306	92	214	13	5
7500	3800	287.5	71	262	383	95	288	26	10
7500	4000	284	33	295	422	96	326	31	12
7500	4200	277.5	64	359	495	97	398	39	14

Ultimate Load 5000 lb

1D 10000

1	2	3	4	5	6	7	8	9	10
0	0	40			1				
2500	0	154			18				
5000	0	246			39				
7500	0								
10000	0	406.5			80				
10000	200	406	3	3					
10000	400	405.5	3	6	102	82	20	14	5
10000	600	405	3	9	111	84	27	18	7
10000	800	404	8	17	122	86	36	19	7
10000	1000	403	8	25	133	88	45	20	7
10000	1200	402	8	33	145	90	55	22	8
10000	1400	401	8	41	151	92	69	28	10
10000	1600	400	8	49	172	94	76	27	10
10000	1800	399	8	57	188	96	88	31	11
10000	2000	398	8	65	204	98	103	38	14
10000	2200	396.5	13	78	222	100	122	44	16
10000	2400	396	13	91	242	102	140	49	18
10000	2600	393.5	26	117	262	104	158	41	15
10000	2800	393			287	106	181		
10000	3000	390	31	148	301	108	193	45	17
10000	3200	388.5	13	161	342	110	232	71	26
10000	5000	352.5	339	500	730	120	610	110	40
					1130	130	1000		

Ultimate Load 6600 lb

1D12500

1	2	3	4	5	6	7	8	9	10
0	0	40							
2500	0	169			9				
5000	0	258			215				
7500	0	350			38				
10000	0	420			51				
12500	0	491.5			715				
12500	500	490	10	10	1025				
12500		490							
12500	600	490.5	4	14	116	76	30	16	6
12500	800	490.5		19	131	78	53	34	13
12500	1000	489	11	25	139	80	59	34	13
12500	1200	489		30	153	82	71	41	15
12500	1400	487.5	11	36	167	84	83	47	17
12500	1600	486.5	8	44	181	86	95	51	19
12500	1800	485.5	8	52	198	88	110	58	21
12500	2000	484	13	65	213	90	123	58	21
12500	2000	482.5	13	78	230	92	138	50	20
12500	2400	480	21	99	248	94	154	55	20
12500	2600	478.5	13	112	267	96	171	59	22
12500	2800	477	13	115	288	98	190	75	28
12500	3000				311	100	211		
12500	4000	463	140	260	500	120	380	120	44

Ultimate load 7650 lb

1D 15000

1	2	3	4	5	6	7	8	9	10
2500	0	120			15				
5000	0	210			31				
7500	0	393			48				
10000	0	487			64				
12500	0	453			75				
15000	0	515			89				
15000	200								
15000	400	515			100	93	7	7	3
15000	600	515			115	95	20	20	7
15000	800	515			125	97	428	28	10
15000	1000	514.5	3	3	134	99	35	32	12
15000	1200	514	3	6	145	101	44	38	14
15000	1400	513.5	3	9	158	103	55	46	17
15000	1600	512.5	8	17	173	105	68	51	19
15000	1800	511.5	8	25	190	107	83	58	21
15000	2000	510.2	11	36	207	109	98	62	23
15000	2200	508.5	15	51	227	111	116	65	23
15000	2400	507	13	64	246	113	133	69	26
15000	2600	505.5	13	77	268	115	153	76	28
15000	2800	504	13	90	289	117	172	82	30
15000	3000	502	18	108	313	119	194	86	32
15000	3400	497.5	21	129	379	123	256	127	47
15000	4000	491.5	54	183	406	127	279	109	40
15000	5000	475	155	338	658	133	527	189	70

Ultimate load 9300 lb

0	0	0							
2500	0	113			12				
5000	0	210			29				
7500	0								
10000	0	370			69				
15000	0	509			103				
17500	0	575			136				
17500	200								
17500	400								
17500	600								
17500	800	573.5	7	7	175	142	33	126	10
17500	1000	25	8	15	185	144	41	26	10
17500	1200	15	8	23	197	146	51	28	10
17500	1400	570.3	10	33	211	148	63	30	11
17500	1600	569	11	44	226	150	76	32	12
17500	1800	74	14	58	243	152	91	33	12
17500	2000	55	17	75	265	154	111	36	14
17500	2200	563	13	88	290	156	134	48	18
17500	2400	560	28	116	325	158	177	61	22
17500	2600								
17500	2800								
17500	3000	545	144	260	466	161	305	45	17

Oil got in

Ultimate Load

3560 lb

202500

0	0	90			7				
2500	0	231.5			3				
	200	231	3	3	4	32	8	5	2
2500	400	30.5	3	6	515	34	17	11	4
2500	600	229.5	8	14	62	36	26	12	4
2500	800	28.5	8	22	72	38	36	14	5
2500	1000	227.5	8	30	83	40	43	13	5
2500	1200	26.4	9	39	95	42	53	14	5
2500	1400	225.2	10	49	100	44	62	13	5
2500	1600	24	10	59	117	46	71	12	4
2500	1800	222.5	13	72	131	48	83	11	4
2500	2000	221	13	85	145	50	95	10	4
2500	2200	19.5	13	98	162	52	110	12	4
2500	2400	217	23	121	183	54	139	18	7

Cont'd. on next page.

2D2500 cont'd.

1	2	3	4	5	6	7	8	9	10
2500	2600	2145	23	144	212	56	156	12	4
2500					350	60	290		

Ultimate Load 3020 lb

2D0

1	2	3	4	5	6	7	8	9	10
0	0								
0	200				15	8	7		
0	400				26	10	16		
0	600				37	12	25		
0	800				48	14	34		
0	1000				58	16	42		
0	1120				67	18	49		

Ultimate load 1120 lb

2D 5000

1	2	3	4	5	6	7	8	9	10
0	0	1							
2500	0	126			14				
5000	0	217.5			37				
5000	200	217.5			40	39	10	10	4
5000	400	216.5	8	8	61	41	20	11	4
5000	600	215.5	8	16	71	43	28	12	4
5000	800	214.5	8	24	80	45	35	11	4
5000	1000	213.5	8	32	89	47	42	10	4
5000	1400	212-220	13	45	107-109	53	56	11	4
5000	1800	219	8	53	134	57	77	24	9
5000	2200	218	8	61	158	61	97	36	13
5000	2600								
5000	3000	212	52	113	225	69	156	43	16
5000	3500	206	55	168	300	73	227	59	22
5000	4000	296	95	263	400	77	323	60	22
5000	4220	257	385	648	800	80	720	72	27

Ultimate load 4220 lb

1	2	3	4	5	6	7	8	9	10
0	0	140			5				
2500	0	290			25				
5000	0	370			4				
7500	0	453			60				
10000	0	545			78				
10000	200	544.5	3	3	97	80	17	14	5
10000	400	544.5			105	82	23		
10000	600	544	3	6	115	84	31	25	9
10000	800	543.5	3	9	124	86	38	29	11
10000	1000	543	3	12	133	88	45	33	12
10000	1200	542	8	20	145	90	55	35	13
10000	1400	541	8	28	159	92	67	39	14
10000	1600	540	8	36	172	94	78	42	15
10000	1800	538.5	13	49	191	96	95	46	17
10000	2000	537	13	62	210	98	112	50	18
10000	2200	535.5	13	75	231	100	131	56	21
10000	2400	533.5	18	93	256	102	154	61	23
10000	2600	531	23	116	285	104	181	65	24
10000	2800	525	58	174	353	106	257	83	31

Oil got in
<u>Ultimate load 2800 lb</u>

<u>2D-7500</u>

0	0	45			6				
2500	0	161.5			20				
5000	0	256.5			36				
7500	0	334			53				
7500	200	334			64	55	9	9	3
7500	400	333	8	8	80	57	23	15	6
7500	600	331.5	13	21	93	59	34	13	5
7500	800	330	13	34	107	61	46	12	4
7500	1000	228.5	13	47	120	63	57	10	4
7500	1200	227	13	60	134	65	69	9	4
7500	1400	225.7	18	78	146	67	79	1	0
7500	1600	224.3	12	90	165	69	96	6	2
7500	1800	223	11	101	180	71	109	8	3
7500	2000	221.5	13	114	200	73	127	13	5
7500	2200	220	13	127	221	75	146	19	7
7500	2400	218	18	145	241	78	164	19	7
7500	2600	215.5	23	168	270	79	191	23	8
7500	2800	213	23	191	293	81	212	21	8

Cont'd. on next page.

2D-7500 Cont'd.

1	2	3	4	5	6	7	8	9	10
7500	3000	210.5	23	214	325	83	242	28	10
7500	3600	200	99	313	455	86	369	56	21
7500	4000	190	94	407	575	88	487	80	30
7500	4400								

Ultimate Load 6000 lb.

2D 12500

		25			3				
2500	0	155			19				
5000	0	247			315				
7500	0	328			465				
10000	0	405			64				
12500	0	484			85				
12500	200	484			92	87	5	5	2
12500	400	484			102	89	13	13	5
12500	600	483	6	6	111	91	20	14	5
12500	800	482.5	3	9	120	93	27	18	7
12500	1000	482	3	12	131	95	36	24	9
12500	1200	481.5-487.5	3	15	142	97	45	30	11
12500	1400	4888	5	20	156-160	103	57	37	14
12500	1600	488	6	26	179	105	74	48	18
12500									
12500	1800	486.5	11	37	220	107	113	76	28
12500	2000	485.5	8	45	236	109	127	82	30
12500	2200	484.5	8	53	250	111	139	86	32
12500	2400	483	13	66	270	113	157	81	30
12500	2600	481	18	84	300	115	185	101	37
12500	2800	478.5	23	107	328	117	211	104	39
12500	3000	476.5	18	125	350	119	231	106	40
12500	3500	468.5	75	200	448	123	317	117	43
12500	4000	460	75	275	525	127	398	123	45
	6000	426	270	595	990	141	849	254	94
	7000	405	200	795	1300	147	1153	358	132

Ultimate Load 8400 lb

2D 15000

1	2	3	4	5	6	7	8	9	10
		40							
2500	0	140			25				
5000	0	231			41				
7500	0	316			59				
10000	0	397			82				
12500	0	475			112				
15000	0	540			147				
15000	200	543.5			185	149	36	36	13
15000	400								
15000	600				202	153	49	49	18
15000	800				214	155	59	59	22
15000	1000	543	4	4	228	157	71	67	25
15000	1200	542	9	13	248	159	89	76	28
15000	1400	541	9	22	264	161	103	81	30
15000	1600	539.5	13	35	282	163	119	74	27
15000	1800	538	8	43	305	165	140	97	36
15000	2000	536.5	13	56	331	167	164	109	40
15000	2200	535	13	69	353	169	184	115	43
15000	2400	533	13	82	378	171	207	125	46
15000	2600	531-536	13	95	400-409	182	227	132	49
15000	2800	536	13	108	450	184	266	158	58
15000	3000	534.5	13	121	475	186	289	168	62
15000	3500	528	60	181	554	190	364	183	68
15000	4000	518	95	276	542	194	448	172	64
15000	5000	507	85	456	848	209	639	183	68
15000	6000	575	310	766	1165	215	950	184	68

Ultimate load 9000 lb

2D 17500

1	2	3	4	5	6	7	8	9	10
2500	0	108			14				
5000	0	194			335				
7500	0	275			525				
10000	0								
12500	0	224			10				
15000	0	494			135				
17500	0	560			180				
17500	200	560			186	182	4	4	1
17500	400	560			194	184	10	10	4
17500	600	559	8	8	206	186	20	12	4
17500	800	557.5	13	21	220	188	31	10	4
17500	1000	556	13	34	236	190	46	12	4
17500	1200	554	18	52	253	192	61	9	3
17500	1400	552.5	13	65	270	194	76	11	4
17500	1600	551	13	78	287	196	91	13	5
17500	1800	548.5	23	101	31	198	111	10	4
17500	2200	544	41	139	356	202	148	9	3
17500	2400	542				204			
17500	2600	540	36	145	404	206	198	53	20
17500	2800					208			
17500	3000	535	46	191	454	210	244	53	20
17500	4000	520	140	331	600	218	382	51	19
17500	5000	505	140	471	855	226	529	48	28
17500	6000	488.5	165	636	1050	232	800	164	61
17500	7000	462	255	891	1300	238	1062	271	100

Ultimate load 9600 lb

300

0	200				10	8	2		
0	400				14	10	4		
0	600				18	12	6		
0	800				23	14	9		
0	1000				29	16	13		

Ultimate Load 1000 lb

3D 2500

1	2	3	4	5	6	7	8	9	10
0	0	55			01				
2500	0	177.5			16				
2500	200	6.5	8	8	41	18	23	15	6
2500	400	5.3	10	18	62	20	42	24	9
2500	600	4.1	11	29	75	22	53	24	9
2500	800	3.5	4	33	85	24	61	28	10
2500	1000	3	3	36	96	26	70	34	12
2500	1200	2.2	6	42	103	28	75	33	12
2500	1400	1.8	2	44	119	30	89	45	17
2500	1600	1	6	50	130	32	98	48	18
2500	1800	0	8	58	146	34	112	54	20
2500	1840				234	34	200		

1840 lb Failure

3D-5000

2500	0	157			164				
5000	0	262			26				
5000	0								
5000	200	274			48	28	20	20	7
5000	400	273.5	3	3	615	30	31	28	9
5000	600	273	3	6	73	32	41	35	13
5000	800	272.5	3	9	85	34	51	42	15
5000	1000	272.5	3	12	95	36	59	47	17
5000	1200	271.5	3	15	105	38	67	52	19
5000					116	40	76		
5000	1800	269	19	34	127	44	83	49	18
5000	2000	266.5	23	57	157	46	111	54	20

Oil got in Ultimate load 2000 lb

3-D-7500

1	2	3	4	5	6	7	8	9	10
2500	0	196			21				
5000	0	283			38				
7500	0	360.5			56				
7500	200	360.5			64	58	6		
7500	400	360	3	3	79	60	19	16	6
7500	600	359	8	11	90	62	28	17	6
7500	800	358	8	19	100	64	36	17	6
7500	1000	357	8	27	111	66	45	18	7
7500	1200	356	8	35	121	68	53	18	7
7500	1400	355	8	43	132	70	62	19	7
7500	1600	854	8	51	143	72	71	20	7
7500	1800	353	8	59	156	74	82	23	7
7500	2000	351.5	13	72	169	76	93	21	8
7500	2200	350	13	85	184	78	106	21	8
7500	2400	348.5	13	98	200	80	120	22	8
7500	2600	347	13	111	218	82	136	25	9
7500	2800	345	18	129	238	84	154	25	9
7500	3000	343	18	147	260	86	174	27	10
7500	4000	327	150	297	438	94	334	37	14
7500	4500	312	140	437	600	98	502	65	24

Ultimate load 5200 lb

3D-10000

1	2	3	4	5	6	7	8	9	10
0		50							
2500		178			19				
5000		272			385				
7500		354			58				
10000		430			81				
10000	200	430			90	83	7	7	3
10000	400	429	8	8	99	85	14	6	2
10000	600	428	8	16	101	27	23	7	3
10000	800	427	8	24	120	89	31	7	3
10000	1000	426	8	32	132	91	42	10	4
10000	1200	425	8	40	143	93	50	10	4
10000	1400	424	8	48	155	95	60	12	4
10000	1600	423	8	56	169	97	72	16	6
10000	1800	421.6	12	68	182	99	83	15	6
10000	2000	420	14	82	198	101	97	15	6
10000	2200	419	8	90	213	103	110	20	20
10000	2400	417.5	13	103	230	105	125	22	8
10000	2600	416	13	116	258	107	146	30	11
10000	2800	414	18	134	270	109	161	27	10
10000	3000	412	18	152	294	111	183	31	11
10000	9000	401	100	252	450	119	331	79	29
10000	5000	382	180	432	670	127	543	111	41
10000	6000	345	360	792	1050	133	917	125	46

Ultimate load 6400-lb

1	2	3	4	5	6	7	8	9	10
2500	0	8			76				
5000	0	167			28				
	0								
12500	0	401.5			104				
12500	200	401	3	3	121	106	14	11	4
12500	400	400	8	11	137	108	29	18	7
12500	600	398.5	13	24	156	110	46	22	8
12500	800	397	13	37	178	112	66	29	10
12500	1000	395.5	13	50	194	114	80	30	11
12500	1400	393	11	61	223	118	105	44	16
12500	1800	391.5	11	72	252	129	130	58	21
12500	2200	389-398.5	21	93	288-292	126	176	83	30
12500	2600	396.5	16	109	335	120	205	96	35
12500	3000	394.5	16	115	374	134	240	125	46
12500	3500	391	30	145	427	138	289	144	53
12500	4000	386.5	50	195	482	142	340	145	53
12500	5000	375	105	300	615	150	465	165	61
12500	6000	361	130	430	780	156	624	194	72
12500	7000	347	130	560	1040	162	880	320	119
12500	7620	265	815	1375	1946	165	1780	305	113

Ultimate load 7620 lb

3D 15000

0	0	0			0		
2500	0	140			12		
5000	0	220			25		
7500	0				1		
10000	0	370			46		
12500	0	465			57		
15000	0	534.5			68		
15000	200	534.5			77	70	7
15000	400	533.0			90	72	18
15000	600	533			101	74	27
15000	800	532.5			111	76	35
15000	1000	532			121	78	44
15000	1200	531			13	80	50
15000	1400	530.2			139	82	57
15000	1600	529.5			148	84	64
15000	1800	528.4			15	86	74
15000	2000	527			176	88	88
15000	2200	523			210	90	120

Oil got in Ultimate Load 2200 lb

1	2	3	4	5	6	7	8	9	10
2500	0	123			17				
5000	0	212			375				
7500	0	391			57				
10000	0	370			82				
12500	0	446			107				
15000	0	507			133				
17500	0	669			16				
17500	200	668.5	3	3	17	167	4	1	0
17500	400	668	3	6	176	169	9	3	1
17500	600	667.5	3	9	182	171	11	2	1
17500	800	667	3	12	190	173	17	5	2
17500	1000	666.5	3	15	200	175	25	10	4
17500	1200	665.5	8	23	210	177	33	10	4
17500	1400	664.2-665	11	34	225	179	46	12	4
17500	1600	664	8	42	235	181	54	12	4
17500	1800	663	8	50	247	183	64	14	5
17500	2000	661.5	13	63	261	185	76	13	5
17500	2200	660	13	76	275	127	88	12	4
17500	2400	558.5	13	89	291	189	101	12	4
17500	2600	557	13	102	306	191	115	13	5
17500	2800	555.3	15	117	321	193	128	11	4
17500	3000	554	11	128	337	195	142	14	5
17500	3500	550	35	163	385	199	186	23	9
17500	4000	445.5	40	203	431	203	228	25	9
17500	5000	436.5	80	283	525	219	306	23	9
17500	6000	426	95	378	630	225	405	27	10
17500	7000	413	120	498	759	231	528	30	11
17500	8000	397	150	648	919	237	682	34	13
17500	9000	377.5	195	843	1163	240	923	80	30
17500	9500	323	540	1383	1800	242	1568	185	68

Ultimate Load 9500 lb

4D0

0	200				10	8	2		
0	400				15	10	5		
0	600				20	12	8		
0	800				24	14	11		
0	1000				31	16	15		
0	1100				38	18	20		

Ultimate Load 1100 lb

4D 17500

1	2	3	4	5	6	7	8	9	10
2500	0	90			14				
5000	0	179			26				
7500	0	258			42				
10000	0	335			63				
12500	0	406			86				
15000	0	464			111				
17500	0	536.5			1485				
17500	200	536	3	3	156	150	6	3	1
17500	400	535.5	3	6	162	152	10	4	1
17500	600	535	3	9	168	154	14	5	2
17500	800	534.5	3	12					
17500	1000	533.8	5	17	189	158	31	14	5
17500	1200	533	6	23	200	160	40	17	6
17500	1400	532	8	31	213	162	51	20	7
17500	1800	530	16	47	242	166	76	29	10
17500	2000	529	8	55	255	168	87	32	12
	2400	526	21	76	288	172	106	30	11
17500	2600	525	13	89	304	180	124	35	13
17500	4000	523.5	45	134	443	188	255	121	45
17500	5000	517.5	50	184	538	196	342	158	59
17500	6000	508.2	82	266	648	202	446	180	67
17500	7000	497.5	97	363	770	212	558	195	72
17500	8000	485	115	478	918	218	700	222	82
17500	9000	472			1108	224	884		
17500	9900	416							

Ultimate load 9900 lb

500

1	2	3	4	5	6	7	8	9	10
0	200						3		
0	400						7		
0	600						11		
0	780						15		

Ultimate load 780 lb

IF0

1	2	3	4	5	6	7	8	9	10
10	0								
	200				10	8	2		
	400				14.5	10	4.5		
	600				19	12	7		
	800				24	14	10		
	1000				32	16	16		

Ultimate 1000 lb.

IF2,500

1	2	3	4	5	6	7	8	9	10
2500	0	113	-	-	22				
	200	113	-	-	36	24	12	12	4
	400	112	8	8	55	26	29	21	8
	600	111	8	16	70	28	42	26	10
	800	110	8	24	85	30	55	31	11
	1000	109	8	32	95	32	63	31	11
	1200	108	8	40	107	34	73	33	12
	1400	107	8	48	118	36	82	34	13
	1600	106	8	56	132	38	94	38	14
	1800	104.5	13	69	145	40	105	36	13
	2000	102.5	18	87	162	42	120	33	12
	2200	100	23	110	184	44	140	30	11
	2400	97.5	25	133	210	46	164	31	12
	2600	94	33	166	250	48	202	36	13
	2800	91.5	23	189	327	50	277	88	33

Ultimate 288016

Oct 30-6
IF 5000

1	2	3	4	5	6	7	8	9	10
0									
2500	1	160			23				
5000		259.5			395				
	200	258.5	8	8	49	41	8	0	0
	4	257.5	8	16	60	43	17	1	0
	6	256.5	8	24	69	45	24	0	0
	8	255.5	8	32	79	47	32	0	0
	1000	255	3	35	86	49	37	2	1
	12	254	8	43	95	51	44	1	0
	14	253	8	51	103	53	50	0	0
	16	252	8	59	114	55	59	0	0
	18	250.5	8	67	125	57	68	1	0
	2000	249	8	75	139	59	80	5	2
	22	247.5	13	88	152	61	91	3	1
	24	245.5	18	106	169	63	106	0	0
	26	243.5	18	124	187	65	122	0	0
	28	241.5	18	142	208	67	141	0	0
	3000	239	23	165	228	69	169	4	1
	3500	232.5	60	225	305	73	230	5	2
	4000	220	120	345	435	77	358	13	5

Ultimate 4300 lb

IF 7,500

1	2	3	4	5	6	7	8	9	10
0									
2500		137			19				
5000		223			30				
7500		310			46				
	0					48			
	4	310			76	50	16	16	6
	6	300	14	14	95	52	43	29	
	8	305	28	42	114	54	60	14	5
	1000	303	18	60	129	56	73	13	5
	12	302	8	68	145	58	87	19	7
	14	301	8	76	157	60	97	21	8
	16	299.5	13	89	172	62	110	21	8
	18	298	13	102	187	64	123	21	8
	2000	296	18	120	204	66	138	18	7
	22	294.5	13	133	223	68	155	21	8
	24	292.5	18	151	290	70	170	19	7
	26	290	23	174	264	72	192	18	7
	28	288	18	192	289	74	215	23	9
	3000	285.5	23	225	331	76	250	24	10
	4000	269	1557	370	400	80	410	40	15
	5000	252	160	530	750	84	666	136	51

Ultimate 5200 lb

Oct 30-1
IF 10000

1	2	3	4	5	6	7	8	9	10
0	0			.5					
2500		250		1.8	13				
5000		315		3.3	36				
7500		389		5.4	485				
10000		473		7.1	60				
	200	470			62	62			
	4	469	6	6	73	64	9	3	1
	6	468	8	14	82	66	17	3	1
	8	467	8	22	90	68	22	0	
	1000	466	8	30	98	70	28	-2	1
	12	4655	3	33	105	72	33	0	
	14	465	3	36	113	74	39	3	1
	16	464	8	44	124	76	48	4	1
	1800	463	8	52	136	78	58	6	2
	2000	461.5	13	65	147	80	67	2	1
	22	460	13	78	16	82	78	0	
	24	458.5	13	91	178	84	94	3	1
	2600	457	13	104	195	86	109	52	
	3000	452.5	41	145	275	90	185	40	15
	4000	443	85	150	35	94	256	106	39
	5000	429	130	280	498	98	400	120	45
	6000	410	180	360	695	101	584	234	81

Ultimate 6400lb

Oct 30-2
IF 12,500

1	2	3	4	5	6	7	8	9	10
0	0	35			.2				
2500		155			1.8				
5000		2425			3.4				
7500		328			4.9				
10000		405			6.9				
12500		489			9.8				
	200	489			10.3	100	3	3	1
	400				11.4	102	12	12	4
	600				12.6	104	22	22	8
	800	488	2	2	13.9	106	33	31	11
	1000	486.8	10	12	15	108	42	30	11
	1200	485.8	8	20	16.1	110	51	31	11
	1400	485	6	26	17.4	112	62	36	13
	1600	483.5	13	39	18.9	114	75	36	13
	1800	482.5	13	52	20.5	116	89	37	14
	2000	481.2	11	63	22.0	118	102	39	15
	2200	480	10	73	23.8	120	118	45	17
	2400	478.5	13	86	25.8	122	136	50	19
	2600	477	13	99	27.5	124	151	52	19
	2800	475.5	13	112	27.4	126	168	56	21
	3000	474	13	125	31	128	187	62	23
	3500	469.5	40	165	37.3	132	241	76	28
	4000	465	40	205	42.7	136	291	86	32
	7800	422	385	590	93.5	153	780	190	70

Ultimate 7800 lb

Oct 30-4
IF 15000

1	2	3	4	5	6	7	8	9	10
	0	10			.2				
2500	0	125			17				
5000		215			30				
7500		300			42				
10000		378			58				
12500		457			80				
15000		527			107				
	200	527	0		116	110	6		
	400	527	0		127	112	15		
	600	526.8	0		136	114	22		
	800	526.5	1	1	145	116	30	29	11
	1000	526	3	4	154	118	36	32	12
	1200	525	8	12	162	120	42	30	11
	1400	524	8	20	173	122	51	31	11
	1600	523	8	28	184	124	60	32	12
	1800	522	8	36	197	126	71	35	13
	2000	521	8	44	211	128	83	39	14
	2200	520	8	52	224	130	84	42	15
	2400	518.8	10	62	237	132	105	43	16
	2600	517.5	11	73	252	134	118	45	17
	2800	515.8	15	88	269	136	123	35	13
	3000	514	16	104	288	138	150	46	17
	3500	510.5	30	134	333	142	191	57	21
	4000	507	30	164	380	146	234	70	26
	4500	503.5	30	194	433	150	283	89	33
	5500	93.5	85	279	546	154	392	123	45
	6000	488.5	45	323	608	157	451	128	47
	7000	74.5	130	453	759	160	599	146	54
	8000	52.5	210	663	942	163	790	127	47
	9000	23.5	280	943	1390	166	1230	287	106

Ultimate 9280lb

1F 17500

1	2	3	4	5	6	7	8
2500		87			15		
5000		179			28		
7500		265			45		
		340			60		
		425			83		
		483			102		
		556.5			132		
		556.5					
	200	556.5	0	0	136	134	2
	400	556.5	0	0	142	136	6
	600	556	1	1	148	138	10
	800	555	8	8	156	140	16
	1000	554	8	16	164	142	22
	1200	551.5	21	37	172	144	28
	1400	550	13	50	181	146	35
	1600	548.5	13	63	190	148	42
	1800	547	13	76	201	150	51
	2000	545	8	84	212	152	60
	2200	543.5	13	97	227	154	73
	2400	541.6	18	115	240	156	84
	2600	539.5	18		254	158	96
	2800	537.5	18		267	160	107
	3000	535.5	18		281	162	119
	4000	527			357	170	187
	5000	517			449	178	271
	6000	506			555	184	371
	7000	497.5			665	190	475
	8000	481			807	194	713
	9000	400			101	198	813

Ultimate 12000 lb

2 F.O

1	2	3	4	5	6	7	8
0					11	8	3
200					16	10	6
400					21	12	9
600					27	14	13
800					33	16	17
1000					42	18	24
1150					60	20	40

Ultimate 1150 lb

1	2	3	4	5	6	7	8	9	10
2500		127.5			18				
	200	127.5	0	0	28	20	8	8	3
	400	127	3	3	38	22	16	13	5
	600	126	6	9	48	24	24	15	6
	800	125	8	17	58	26	31	14	5
	1000	124	8	25	67	28	39	14	5
	1200	123	8	32	76	30	46	14	5
	1400	122-131	8	40	87	32	55	15	6
	1600	130	8	48	160	34	66	18	7
	1800	119	8	56	113	36	77	21	8
	2000	118	8	64	128	38	90	26	10
	2200	116.5	13	77	150	40	110	33	12
	2400	115	13	90	163	42	129	31	12
	2600	112	28	118	198	44	154	36	14
	2800	108	38	156	242	46	196	40	15
	3000								

Ultimate 2980lb

2F 7,500

1	2	3	4	5	6	7	8	9	10
2500		196			15				
5000		271			29				
7500		361			45				
	200	360.5	3	35	56	47	9	6	2
	400	360	3	6	71	49	22	16	6
	600	359	8	14	86	51	35	21	8
	800	358	8	22	96	53	43	21	8
	1000	357	8	30	103	55	48	18	7
	1200	356	8	38	119	57	52	24	9
	1400	355	8	46	130	59	71	25	9
	1600	354	8	54	143	61	82	28	10
	1800	353	8	62	156	63	93	31	11
	2000	352	8	70	167	65	104	34	12
	2200	351	8	78	185	67	118	40	15
	2400	349.5	13	91	200	69	131	40	15
	2600	348	13	104	219	71	148	44	16
	2800	346.5	13	117	240	73	167	50	19
	3000	345	13	130	263	75	188	58	22
	3500	339	55	185	332	79	253	68	25
	4000	332	65	250	415	83	332	72	27
	5000		240	490	699	91	608	118	44
27900									

Ultimates 420lb

Nov 4-1
2 F 5000

1	2	3	4	5	6	7	8	9	10
0									
2500		125			15				
5000		209			32				
7500					48				
10000	200	209							
	400	28.5	3	3	615	50	11	8	3
	600	208	3	6	77	52	25	19	7
	800	207	8	14	89	54	35	21	8
	1000	206	8	22	98	56	42	20	8
	1200	205	8	30	101	58	43	13	5
	1400	204	8	38	121	60	51	13	5
	1600	203	8	46	133	62	71	25	9
	1800	202	8	54	144	64	80	26	10
	2000	201	8	62	155	66	89	27	10
	2200	200	8	70	169	68	101	31	12
	2400	198.5	13	83	186	70	116	45	17
	2600				201	72	129	41	15
	2800	196	21	104	220	74	146		
	3000	194	18	112	245	78	167	55	20
	3500				327	82	245		
	4000	179	150	262	405	86	320	61	23

Ultimate 42801b

2F 10000

1	2	3	4	5	6	7	8	9	10
2500		161			28				
5000		252			48				
10000		411.5			103				
	200	411	3	3		105			
	400	410	8	11	133	107	26	15	6
	600	408.5	13	24	149	109	40	16	6
	800	407.5	8	32	163	111	52	20	7
	1000	406.5-412	8	40	177-180	116	64	24	9
	1400	411	6	46	208	120	88	42	15
	1800	409.3	13	59	240	124	116	57	21
	2200	407	19	78	273	128	144	66	24
	2600	404	26	104	311	132	179	75	28
	3000	400.5	31	135	353	136	217	82	30
	3500	395	50	185	412	140	242	57	21
	4000	389	55	240	480	144	336	116	43
	5000	378-384	110	350	650	148	502	152	57
	6000	370	130	480	875	152	723	243	90

Ultimate 6240 lb

Nov. 5-1
2F 12,500

1	2	3	4	5	6	7	8	9	10
2500		263			18				
5000		255			33				
7500		341			50				
10000		423			68				
12500		507			93				
	200	507			102	95	3	3	1
	400	506.5	3	3	109	97	12	9	3
	600	506	3	6	119	98	20	14	5
	800	505.5	3	9	130	101	29	20	7
	900	504.5	8	17	140	103	37	20	7
	1000	503.5	8	25	151	105	46	21	8
	1200	502.5	8	32	162	107	55	23	8
	1400	502	3	35	175	109	66	31	11
	1600	501	8	43	186	111	75	32	12
	1800	500	8	51	198	113	85	34	13
	2000								
	2200	499	6	57	212	117	75	38	14
	2400	498	8	65	225	119	106	41	15
	2600	497	8	73	238	121	117	44	16
	2800	495.5	13	86	252	123	129	42	16
	3000	494	13	99	266	125	141	42	16
	4000	487.5	55	154	350	133	217	57	21
	5000	479	75	229	455	141	314	85	32
	6000	69	90	319	578	147	431	112	42
	7000	55	90	409	733	163	570	161	50
	8000	30	240	649	101.1	167	842	193	71

Ultimate 8220 lb

2 F 15000

1	2	3	4	5	6	7	8	9	10
0	2500	107			165				
	5000	194			33				
	7500	280			53		65		
	10000	357			72				
	12500	436			98				
	15000	608			133			10	4
	200	607.5	1	1	146	135	11		
	400	607.5	0	1	159	137	22	21	8
	600	607.5	0	1	172	139	33	31	11
	800	607.5	0	1	183	141	42	41	15
	1000	607	0	1	194	143	51	50	18
	1200	606	8	9	206	145	61	51	19
	1400	605	8	17	219	147	72	55	20
	1600	604	8	25	235	151	84	59	22
	1800	603	8	33	250	153	97	64	24
	2000	602	8	41	264	155	109	68	25
	2200	600.5	13	54	282	157	125	71	26
	2400	599	13	67	302	159	143	66	24
	2600	597.5	13	80	319	161	158	78	29
	2800	596	13	93	336	163	163	80	30
	3000	594.5	13	106	357	165	192	86	32
	4000	586	75	181	440	173	267	86	32
	5000	576	90	271	589	181	408	137	51
	6000	564	110	381	720	189	531	150	56
	7000	548	150	531	905	195	710	179	66
	8000	534	130	661	115.9	210	949	288	103
	9000								

Multimate 8640

Nov. 4-1
2F 17,500

1	2	3	4	5	6	7	8	9	10
2500		126			21				
5000		218			38				
7500		300			60				
10000		375			81				
12500		455			111				
15000		522.5			138				
17500		574.5			176				
	200	574.5			172	172			
	400	574	31	3	178	173	5	2	1
	600	573.5	3	6	185	175	10	4	1
	800	573	3	9	192	177	15	6	2
	1000	572	8	17	205	179	26	9	3
	1200	571	8	25	217	181	36	11	4
	1400	570	8	32	229	183	46	14	4
	1600	568.5	13	45	244	185	59	14	4
	1800	567	13	58	259	187	72	14	4
	2000	565	18	76	275	189	86	10	4
	2200	563.5	13	89	292	191	101	12	4
	2400	562	13	102	310	193	117	15	5
	2600	560	18	110	328	195	133	23	9
	2800	558.5	13	123	348	197	151	29	10
	3000	557	13	136	366	199	167	31	11
	4000	547	90	226	467	207	260	34	13
	5000	537	90	316	583	215	368	52	19
	6000	526	80	396	696	221	475	79	29
	7000	520	30	426	762	227	535	100	37
	8000	526	30	456	850	633	617	161	57
	9000				1168	240	928		

Ultimate 9400 lb

0	0	0							
	200				11	8	3		
	400				17	10	7		
	600				25	12	13		
	800				34	14	20		
	1000				44	16	36		

Ultimate 1100 lb

3F 2500

2500		154.5			10				
	200	154.5				12			
	400	154	3	3	38	14	24	21	8
	600	153	8	11	45	16	29	18	7
	800	152	8	19	54	18	36	17	6
	1000	151	8	27	64	20	44	17	6
	1400	149	16	43	83	22	61	18	7
	1800	147	16	59	107	24	83	24	9
	2200	144	26	85	136	26	110	25	9
	2600	140	36	121	180	28	152	31	11
	3000	129.5	101	222	287	30	257	35	13
	3080	94	355	577	700	32	662	85	31
	2600	10			1500				

Ultimate 3060 lb

Jan 2-2 3F 5000

2500		140			21				
5000		226.5			41				
	200	226.5	0	0	54	43	11	11	4
	400	226	5	5	71	45	26	21	8
	600	224.5	15	20	86	47	39	19	7
	800	222.5	20	40	111	49	62	22	8
	1000	221	15	55	130	51	79	24	9
	1600	216.5	39	94	171	53	118	24	9
	1800	215-220.5	15	109	185-187	55	132	23	9
	2200	219	15	114	224	57	167	43	16
	2600	216	30	144	264	59	205	61	23
	3000	212.5	35	179	304	61	243	64	24
	3500	206	65	244	384	65	319	75	28
	4000	194	120	364	505	69	436	72	27
	4400	160	444	808	2000	73	1875	1067	370
	4400	80			2800				

Ultimate 4400 lb

2500		137			17				3
5000		218			31				
7500		311			54				
	200	311	0		74	56	8		
	400	311	0		83	58	25		
	600	311	0		91	60	31		
	800	310	10		100	62	38	28	10
	1000	309.5	15		111	64	47	32	12
	1400		15						
	1800	306	50		158	72	86	36	12
	2200	303	80		188	80	108	28	10
	2600	301	100		220	88	132	32	12
	3000	297.5	135		258	92	156	21	8
	3500	293	180		311	96	215	35	13
	4000	287	230		378	100	276	48	18
Starts to	5000	277	330		565	108	457	127	47
drop----	5700	226	440		1100	114	1086	446	165
	5400	115			2200				

5700 lb

3F 10000

25000		130			20				
50000		225			42				
10000		374.5			81				
	200	374.5			90	92	2		
	400	374	3	3	97	94	3	0	
	600	373.5	3	6	105	96	9	3	1
	800	373	3	9	112	98	14	5	2
	1000	372.5-381.5	3	12	123-125	102	23	16	4
	1200	381	3	15	138	104	34	17	7
	1400	380	8	23	153	106	47	24	9
	1600	379	8	37	158	108	50	19	7
	1800	378	8	39	169	110	59	20	7
	2200	376	16	55	198	112	86	31	12
	2600	374	16	71	226	116	110	39	15
	3000	372	16	87	260	120	140	53	20
	3500	368	25	112	308	124	184	72	27
	4000	363	40	152	361	128	233	81	30
	5000	352	100	252	500	132	368	116	43
	6000	335	160	412	670	138	532	120	45
	7000	295	390	802	1100	144	956	151	57
	6600	220			1700				

Ultimate 7000 lb

Nov. 10-1
3F 12,500

1	2	3	4	5	6	7	8	9	10
		100							
2500		222							
5000		301							
7500		384							
10000		462							
12500		538			113				
	200	538			118	115	3	3	1
	400	537	8	8	1295	117	12	4	1
	600	536	8	16	137	119	18	2	1
	800	535	8	24	146	121	25	1	0
	1000	534.5	13	27	155	123	32	5	2
	1200	534	3	30	166	125	41	11	4
	1400	533	8	38	177	127	50	12	4
	1600	531.5	13	51	191	129	62	11	4
	1800	530	13	64	206	131	75	11	4
	2000	528.5	13	77	221	133	88	11	4
	2200	527.5	8	85	240	135	105	20	7
	2400	526	13	98	257	139	122	24	9
	2600	524.5	13	112	275	143	132	20	7
	2800	523	13	125	295	147	148	23	9
	3000	521.5	13	138	318	151	167	29	10
	3500	517.5	35	173	380	155	225	52	19
	4000	513	40	213	441	159	282	69	25
	4500	508	45	258	550	163	387	129	48
	5000	502	55	313	678	167	511	138	50
	6000	487	140	453	84.3	173	670	169	63
	7000	466	220	673	107.6	179	897	224	84
	8000	435	300	973	1500	182	1418	445	105

Ultimate 8600 lb

3F 15000

1	2	3	4	5	6	7	8	9	10
2500					21				
5000		211			32				
10000		360			80				
15000		516			110				
	200	515.5	3	3	125	112	13	10	4
	400	514.7	6	9	142	114	28	19	7
	600	513.5	10	19	159	116	43	24	9
	800	511.5	13	32	178	118	60	28	10
	1000	510.5	13	45	194	120	74	29	11
	1400	508.5	16	61	220	124	96	35	13
	1800	506.8	14	75	245	128	117	42	15
	2200	504.5	19	94	272	132	140	46	17
	2600	502	21	115	303	136	167	52	19
	3000	499	26	141	341	140	201	60	22
	3500	494	45	186	385	144	241	55	20
	4000	492	15	201	437	148	289	88	32
	5000	487	40	241	560	152	408	167	58
	6000	482	40	281	870	160	510	229	85
	8000	457	290	571	1000	172	828	247	92
	9000	425	310	881	1330	178	1152	271	100
	9300	373	520	1391	1885	180	1705	314	116
	910	287	850	2241	2800	180	2620	379	140

Ultimate 9300 lb

Nov 11-1
9 F

1	2	3	4	5	6	7	8	9	10
2500		123			175	.8			
5000		311			33	1.2			
7500		395			525				
10000		475			725				
		554			96				

3F 17,500

		110			15				
2500					3				
5000		200			0				
7500		280			45				
10000		363			66				
12500		440			87				
15000		506			1085				
17500		568.5			133				
	200	567.5	8	8	142	135	7	0	
	400	566.5	8	16	155	137	18	2	1
	600	565.5	8	24	165	139	26	2	1
	800	567.5	8	32	177	141	36	4	1
	1000	567	3	35	188	143	45	10	4
	1200	566	8	43	192	145	53	10	4
	1400	565	8	51	208	147	61	10	4
	1600	564	8	59	220	149	71	12	4
	1800	563	8	67	233	151	82	15	5
	2000	561.7	10	77	246	153	93	16	6
	2200	560.5	11	88	260	155	104	16	6
	2400	559.5	8	96	272	157	115	19	7
	2600	558	13	109	287	159	128	19	7
	2800	556.5	13	112	300	161	139	27	10
	3000	555	13	125	315	163	152	27	10
	3200	553.5	13	138					
	3400	557							
	4000	559-553.5	55	193	389	171	238	45	17
	5000	546	65	258	476	179	297	39	14
	6000	537	80	338	670	185	485	147	45
	7000	526.5	95	433	780	191	589	156	58
	8000	515	105	528	915	197	718	190	70
	9000	512	17	545	1013	203	810	265	98

99001b

4F0

1	2	3	4	5	6	7	8	9	10
200					10	8	2		
400					14	10	4		
600					19	12	7		
800					24	14	10		
1000					37	16	21		

Ultimate 1000 lb

4F 5000

1	2	3	4	5	6	7	8	9	10
2500		116			20				
5000		289			31				
	200	208	8	8	55	33	22	14	5
	400	207	8	16	65	35	30	14	5
	600	206	8	24	73	37	36	12	4
	800	205	8	32	81	39	42	16	6
	1000	204	8	40	88	41	47	7	3
	1200	203.5	3	43	96	43	53	10	4
	1400	203-208.5	3	46	104-106	47	59	13	5
	1600	208	3	49	117	49	68	19	7
	1800	207.5	3	52	126	51	75	23	8
	2000	206.5	8	60	137	53	84	24	9
	2200	206	3	63	154	57	94	31	11
	2600	203.5	21	84	170	61	118	32	12
	3000	201	21	105	214	65	249	44	16
	3500	195	55	160	275	69	206	46	17
	4000	185	95	255	388	73	315	160	22
	4500	120	600	855	1100	77	1033	178	66

4500lb

4F 12500

1	2	3	4	5	6	7	8	9	10
0	0	100			5				
2500		208			19				
5000		298			34				
7500		382			50				
10000		467			68				
12000		539			105				
	200	539			109	104	5	5	2
	400	538.5	3	3	118	106	12	9	3
	600	537.5	8	11	130	108	22	11	4
	800	536.5	8	19	142	110	32	23	8
	1000	534	13	32	157	112	45	13	5
	1200	532.5	13	45	171	114	57	12	5
	1400	531.5-530	8	53	184	116	68	15	6
	1600	529	8	61	197	118	79	18	7
	1800	527	16	77	215	120	95	18	7
	2000	525	16	93	231	122	109	16	6
	2200	523.5	13	106	248	124	124	18	7
	2400	521.5	16	122	266	126	140	18	7
	2600	519	23	145	288	126	160	15	6
	2800	517	18	163	308	130	178	15	6
	3000	515	18	181	327	132	197	16	6
	4000	502	120	301	470	136	334	33	12
	5000	485	160	461	666	140	520	59	22
	6000	453.5	305	766	984	143	841	65	24
	7000	395	585	1351	1590	146	1444	93	34

Ultimate 7380 lb

4F 15000

1	2	3	4	5	6	7	8	9	10
25									
50		77			31				
75		157			45				
10									
12		297			85				
15		31.5			110				
	200	1	3	3	118	112	6	3	1
	400	0.5	3	6	125	114	11	5	2
	600	70	3	9	135	116	19	10	4
	800	169	8	17	146	118	28	11	4
	1000	168	8	25	159	120	39	14	5
	1200	167	8	32	172	122	50	18	7
	1400	166	8	40	184	126	58	18	7
	1600	165	8	48	196	128	68	20	7
	1800	164	8	56	208	130	78	22	8
	2200	162.5	11	67	238-242	136	108	41	15
	2600	172	11	78	279	140	139	61	23
	3000	171	6	84	308	144	164	80	30
	3500	168	25	109	350	148	202	93	34
	4000	164	35	144	398	152	246	102	38
	5000	156	70	214	500	156	344	130	48
	6000	147	80	294	617	162	455	161	59
	7000	135	110	404	745	168	567	163	61
	7400		140	544		170	730	186	69
	60000	115			9000				
	7400	60			1600				
	8000				270-227				
			1350	1750		540	2100	350	129

Ultimate 9000 lb

4F 17,500

1	2	3	6	7	8	4	5	9	10
2500		0	35						
7500		112	50						
10000		168	76						
15000		309	124						
17500		378	163						
	200	377	186	165	21	8	8	13	5
	400	376	213	168	45	15	16	29	11
	600	275	226	170	56	8	29	32	12
	800								
	1000	373	255	172	73	16	40	33	12
	1200	372	270	174	96	8	48	48	18
	1400	371	286	175	111	8	56	55	20
	1600	369.5	302	177	125	13	69	56	21
	1800	368	320	179	141	13	82	49	18
	2000	367	337	180	157	8	90	67	25
	2200	365.5	355	182	173	13	103	70	26
	2600	362.5	392	186	206	26	129	77	29
	3000	359	432	190	242	31	160	82	30
	3500	355	481	194	289	35	195	92	34
	4000	351	523	198	325	35	230	95	35
	5000	340	655	206	449	100	330	119	44
	6000	327	800	212	588	120	450	138	51
	7000	310	1095	218	777	160	610	167	62
	8000	262	1500	221	1280	470	1080	200	74
	9000	140	2800	224	2575	1220	2300	275	102

Ultimate 11740lb Sudden broke

1	2	3	4	5FO .5	6	7	8	9	10
	200				10	8	2		
	400				15	10	5		
	600				19.5	12	7.5		
	800				27	14	13		
	1000				35	16	19		
	1200				43	18	25		
	1300				59	20	39		

Ultimate 1300 lb

1J0

1	2	3	4	5	6	7	8	9	10
0	0			0	0				
0	200				21	80	13		
0	400				38	10	28		

Ultimate load 40016

1J2500

1	2	3	4	5	6	7	8	9	10
2500					19				
2500	200				34	21	14		
2500	400				54	23	31		
2500	600				72	25	47		
2500	800				93	27	66		
2500	1000				120	29	91		
2500	1800				380	37	353		
2500	2000				2000	38	1950		

Ultimate Load 2000 lb

1J5000

1	2	3	4	5	6	7	8	9	10
2500	0								
5000	0	231			65				
5000	200	230	8	8	85	67	18	10	4
5000	400	228.5	13	21	100	69	31	10	4
5000	600	226.5	18	39	120	71	49	10	4
5000	800	224	23	62	146	73	73	11	4
5000	1000	221	28	90	176	75	101	11	4
5000	1400	212	86	176	258	79	179	13	5
5000	1800	202	96	272	368	83	285	13	5
5000	2200	185	166	438	530	87	443	15	6
5000	2600	60	246	684	800	91	709	25	9
5000	8000	90	1696	1380	1500	75	1405	25	9

Ultimate load 3200 lb

1 J 7500

1	2	3	4	5	6	7	8	9	10
2500	0	140			33				
5000	0	227			66				
7500	0	331			115				
7500	200	331			134	117	17-	17	6
7500	400	330	8	8	154	119	35-	27	10
7500	600	328.5	13	21	180	121	59	38	14
7500	800	326	23	44	213	123	90	46	17
7500	1000	323	28	72	254	125	129	57	21
7500	1400	316	66	138	337	127	210	72	27
7500	1800	306	96	234	453	131	321	87	32
7500	2200	295	96	330	585	135	450	120	44
7500	2600	283.5	116	446	726	139	587	141	52
7500	3000	267.5-280	156	602	911-917	149	768	166	61
7500	3500	262	170	772	1155	53	1002	232	86
7500	4000	232	290	1062	1500	157	1350	288	130
7500	4800	111	1200	2262	4840	162	2778	516	190

Ultimate load 4820 lb

1 J 10000

1	2	3	4	5	6	7	8	9	10
2500	0	157			27				
5000	0	242			57				
10000	0	406.5			151				
10000	200								
10000	400	406.2	1	1	187	155	32-	31	12
10000	600	405.5	5	6	204	157	47-	41	15
10000	800	404.5-412	8	14	234-238	163	75	61	23
10000	1000	413	8	22	283	165	118	96	35
10000	1400	408	46	68	355	169	186	118	44
10000	1800	401	66	134	143	173	270	136	50
10000	2200	394	66	200	536	171	359	159	59
10000	2600	385	86	286	638	181	447	161	61
10000	3000	376-383.5	80	372	750-754	189	565	193	71
10000	3500	375	80	452	915	193	722	270	100
10000	4000	361	135	587	1081	197	873	306	113
10000	5000	315	450	1037	1575	205	1370	333	124
10000	6000	220	940	1977	2585	211	2316	339	125

Ultimate Load 6400 lb

1	2	3	4	5	6	7	8	9	10
2500	0	26			20				
5000	0	172			40				
7500	0	256			66				
10000	0	331			104				
12500	0	405.5			144				
12500	600	404	9	9	231	150	81	72	26
12500	800	403.5	3	12	242	152	90	78	28
12500	1000	402	13	25	261-267	154	117	82	30
12500	1200	410	8	33	307	158	145	112	41
12500	1400	409	8	41	332	160	168	127	46
12500	1600	406	28	69	370	162	204	135	59
12500	1800	403	28	97	406	164	238	141	52
12500	2000	401	18	115	446	166	276	161	59
12500	2400	394	66	181	530	174	356	175	64
12500	2800	388	56	237	600	178	412	175	64
12500	3000	383-389	48	285	665-669	284	485	200	73
12500	3500	383	55	340	800	288	612	262	96
12500	4000	370	125	465	950	292	760	295	106
12500	5000	345	240	705	1250	200	1060	355	130
12500	6000	313	310	1015	2000	206	1710	695	153
12500	7000	267	450	1465	2260	212	2040	575	210
12500	7400	218	480	1945	2800	213	2600	655	239

Ultimate load 7400 lb

1J 15000

2500	0	73			32				
5000	0	159			64				
10000	0	324			166				
15000	0	477			314				
	200								
15000	400	477			342				
15000	600	476.5	3	3	357	320	37-	34	13
15000	800	476	3	6	380	322	58-	52	19
15000	1000	474	16	22	411	324	87	65	24
15000	1400	469	46	68	477	228	149	81	30
15000	1800	464-466	46	114	550-554	330	214	100	37
15000	2200	462	36	150	620	338	282	132	49
15000	2600	458	36	186	710	342	368	182	67
15000	3000	452	54	240	790	346	454	214	78
15000	3500	443	85	325	910	350	560	235	87
15000	4000	433-443	95	420	1028-1033	359	675	255	94
15000	5000	423	190	610	1290	367	923	313	115
15000	6000	403	190	800	1575	373	1202	402	148

CONT. ON NEXT PAGE

1J 15000 cont'd.

1	2	3	4	5	6	7	8	9	10
15000	7000	371-380	310	1110	1921-1933	383	1550	440	163
15000	8000	347	320	1430	2340	389	1860	430	159
15000	8600				3000				

Ultimate load 8600 lb

1j 17500

2500	0	106				26				
5000	0	183				48				
10000	0	349				140				
15000	0	493				270				
17500	0	558				339				
17500	200									
17500	400	556.5	3	3		371	343	28	25	9
17500	600	556.5	8	11		387	345	42-	31	12
17500	800	554	13	24		409	347	62-	28	14
17500	1000	552.5	13	37		436	349	87	50	19
	1400	548	41	78		502	353	149	71	26
	1800	543.5-550	41	119		565-570	362	208	89	34
17500	2200	545	46	165		638	366	272	107	40
17500	2600	538	65	231		718	370	348	117	43
17500	3000	531	66	297		789	374	415	118	44
17500	3500	521	95	392		891	378	513	121	45
	4000	510	105	497		998	382	616	119	44
	5000	487	220	717		1235	390	845	128	47
17500	6000	462	240	957		1490	396	1100	143	53
	7000	430	310	1267		1800	402	1400	133	49
	8000	387	420	1687		2444	408	2040	353	130

Ultimate load 8600 lb

2j0

0	0	0				0		
0	200					16	8	8
0	400					24	10	14
0	500					34	12	22

Ultimate load 500 lb

2J 2500

1	2	3	4	5	6	7	8	9	10
2500		82			20				
2500	200	85			29	22	7	7	3
2500	400	85			38	24	14	14	5
2500	600	84.5	3	3		26			
2500	800	83.5	8	11	61	28	33-	22	8
2500	1000	82.5	8	12	76	30	46-	27	10
2500	1200	81.5	8	27	92	32	60	33	12
2500	1400	80.5	8	35	111	34	77	42	15
2500	1600	78.5-86	18	53	136-139	39	100	47	17
2500	1800	84.5	13	66	174	41	133	67	25
2500	2000	81.5	28	94	218	43	175	81	30
2500	2200	76	53	147	278	45	273	126	47
2500	2400	65	108	255	403	47	356	101	27
2500	2460	10	5550	805	1000		950	400	148

Ultimate load 2460 lb

2j 5000

1	2	3	4	5	6	7	8	9	10
2500		95			20				
5000		180.5			49				
5000	200	178.5	8	8	765	51	25	17	6
5000	400	177.5	8	16	89	53	36	20	7
5000	600	176	13	23	106	53	53	30	11
5000	800	174.5	13	36	123	57	66	30	11
5000	1000	173	18	54	146	59	87	33	12
5000	1200	171-176.5	18	72	168-171	64	107	35	13
5000	1400	175	13	85	203	66	137	52	19
5000	1600	173	18	103	236	68	168	55	20
5000	1800	169.5	33	136	278	70	208	72	27
5000	2000	165.5	38	174	327	72	255	81	30
5000	2400	156-165	91	265	480-484	80	404	139	41
	2800	155	96	361	590	88	502	141	52
5000	3000	129	258	619	875	90	785	166	61
5000	3200	102	268	887	1150	92	1048	161	60
5000	3460	34	678	1565	1860	94	1746	181	67

Ultimate Load 3460 lb

1	2	3	4	5	6	7	8	9	10
2500	0	100			20				
5000	0	191			50				
7500	0	274			78				
	200	273.5-283.5	3	3	90-94	84	10	7	3
7500	400	288.5	8	11	113	86	17	6	6
7500	600	281.5	8	19	131	88	43	24	9
7500	800	280	13	32	151	90	61	29	11
7500	1000	278	18	50	174	92	82	32	12
7500	1200	276	18	68	203	94	109	41	15
7500	1400	274	18	86	232	96	136	50	18
7500	1600	271	28	114	266	98	168	54	80
	1800								
7500	2000	265	56	170	346	102	245	75	28
7500	2200	265			404	104	300		
7500	2400	262	28	198	451	106	355	157	58
7500	2600								
7500	2800	251	106	304	578	140	468	164	61
7500	3000	245	56	360	652	112-119	540	180	67
7500	3500	225	234.5-190	550	890-	893	780	230	85
7500	4000	211	230	780	1210	123	1087	307	112
					2800				

Ultimate load 4640 lb

2J 10000

1	2	3	4	5	6	7	8	9	10
2500	0	100			20				
5000	0	187			40				
7500	0	271			70				
10000	0	349			108				
	200	349			120	110	10	10	4
10000	400	348.5	3	3	130	112	18	15	6
10000	600	7.5	48	11	145	114	31	20	7
	800	6.5	8	19	165	116	59	40	15
10000	1000	356-351	8	27	186-190	122	78	51	19
	1200	350	8	35	222	124	98	63	23
	1400	349	8	43	249	126	118	75	28
10000	1600	347.5	13	66	270	128	142	76	28
	1800	345	23	89	305	130	175	86	32
	2000	342.5	23	112	340	132	218	106	39
10000	2400	336.5	56	168	415	136	279	111	41
	2600	333	33	201	453	138	315	114	42
10000	2800	329	38	239	500	140	360	121	44

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2J 10000

1	2	3	4	5	6	7	8	9	10
	3000	325	38	277	594	142	400	123	45
	3500	318	65	342	700	146	554	212	78
	4000	310	75	417	875	150	725	308	114
10000	5000	274	350	767	1300	158	1150	383	141
	6000	211	620	1387	2100	196	1950	563	205
10000	6200	145	658	2045	2800	202	2700	655	241

Ultimate load 6200 lb

2J 12500

1	2	3	4	5	6	7	8	9	10
2500	0	89			18				
5000	0	186			42				
7500	0	262			70				
10000	0	336			101				
12500	0	409.5			148				
12500	200	409-416	3	3	172-176	154	22	19	7
12500	400	415.5	3	6	198	156	32	26	10
	600	414.5	8	14	223	158	65	51	18
12500	800	412.5	18	32	250	160	90	58	21
12500	1000	411	13	45	272	162	110	65	23
	1200	409.5-412	13	58	301-305	168	137	79	28
	1400	410.5	13	71	340	170	170	99	36
12500	1600	408.5	18	89	367	172	195	106	39
	1800	406.5	18	107	400	174	226	119	43
12500	2000	404	23	130	435	176	269	139	51
	2200	401.5-407	23	153	469-474	183	291	139	51
	2400	405	18	171	524	185	339	158	57
12500	2600	402.5	23	194	558	187	371	177	64
12500	2800	400	23	217	597	189	468	191	69
	3000	396	38	255	645	191	454	199	73
12500	3500	386	95	350	755	194	561	211	77
	4000	375	105	455	890	198	692	237	86
12500	5000	360	140	595	1190	206	884	289	103
12500	6000	320	390	985	1630	212	1418	423	154
12500	7000	279	400	1385					
12500	7600	235	430	1815	2800	222	2578	763	279

Ultimate load 7600 lb

2J 1000

1	2	3	4	5	6	7	8	9	10
2500	0	123			28				
5000	0	230			48				
12500	0	455			134				
15000	0	531			192				
15000	200	531			206	174	12-	12	4
15000	400	530.5	3	3	223	196	27-	24	9
15000	600	529.5	8	11	244	198	46-	33	12
15000	800	528	13	24	261	200	61	37	14
15000	1000	526.5	13	37	281	202	79	42	15
15000	1200	325	13	50	304	204	100	50	18
15000	1400	223	18	68	330	206	124	56	21
15000	1600	221	18	86	357	208	149	63	23
15000	1800	218.5	23	109	387	210	177	68	25
15000	2000	216.5	18	127	418	121	197	70	26
15000	2200	214.5-223.5	18	145	440-455	220	235	90	33
15000	2400	222	13	158	508	222	286	128	47
15000	2600	220.5	13	171	537	224	313	142	53
15000	2800	218.5	18	189	570	226	344	155	57
15000	3000	516	23	212	603	228	375	163	60
15000	3500	508	75	287	704	232	462	175	65
15000	4000	500	75	362	807	236	571	209	77
15000	5000	480	190	552	1055	244	811	259	95
15000	6000	462	270	822	1350	250	1100	278	103
15000	7000	420	310	1132	1736	256	1480	348	128
15000	8000	352	670	1802	2400	262	2150	348	128
15000	8200				2800				

Ultimate load 8300 lb

1	2	3	4	5	6	7	8	9	10
2500	0	87			18				
5000	0	174			39				
7500	0	259			68				
10000	0	341			107				
12500	0	401			150				
15000	0	476			206				
17500	0	545			268				
17500	200	545			273	270	3	3	1
	400	545	3	3	281	272	9	6	2
17500	600	544.5	3	6	292	274	18-	12	4
17500	800	543	13	19	303	276	27	8	3
17500	1000	541.5	13	32	336	278	58	26	10
17500	1200	540	13	45	360	280	80	35	13
17500	1400	537.5	23	68	390	282	108	40	15
17500	1600	536	13	81	414	284	130	49	19
17500	1800	533.5	23	104	445	886	159	55	20
17500	2000	531.5	23	127	472	288	184	57	21
17500	2200	5285	23	150	507	290	217	67	25
17500	2400	526.5	23	173	535	292	243	70	26
17500	2600	523.5	23	196	569	294	275	79	29
17500	2800	520	31	227	605	296	309	82	30
17500	3000	516	35	262	645	298	347	85	31
17500	3500	508-517	75	337	740	311	429	92	24
17500	4000	508	85	422	835	315	520	98	36
17500	5000	487	200	622	1043	323	720	98	30
17500	6000	464	220	842	1279	329	950	108	40
17500	7000	442	210	1052	1542	335	1200	148	55
17500	8000	397	440	1492	1960	341	1620	128	47
17500	9000	315	780	2272	2800	344	2452	180	67

<u>Ultimate load 9200 lb</u>

<u>3J 2500</u>

1	2	3	4	5	6	7	8	9	10
2500	0				10				
2500	200				18	12	6		
2500	400				26	14	12		
2500	600				36	16	20		
2500	800				48	18	30		
2500	1000				61	20	41		
2500	1200				80	22	58		
2500	1400				102	24	78		
2500	1600				124	26	98		
2500	1800				153	28	125		
2500	2000				200	30	170		
	2200	Ultimate Load 2200 lb			362	32	330		

1	2	3	4	5	6	7	8	9	10
0	200				15	8	7		
0	400				26	10	16		
0	600				38	12	26		
0	620				52	14	38		
0									

Ultimate load 620 lb

3J 5000

2500	0	107			20				
5000	0	203.5			45				
5000	200	202.5	13	13	60	47	13	0	
5000	400	201.5	13	26	73	47	24	0	
5000	600	200-211	13	39	88-90	53	37	0	
5000	800	210	8	47	111	55	56	9	3
5000	1000	209	8	55	130	57	73	18	7
5000	1200	207.5	13	68	152	69	93	25	9
5000	1400	206	13	81	177	61	116	25	9
5000	1600	203.5	23	104	210	63	147	43	16
5000	1800	200	38	137	252	65	187	50	19
	2000	184	150	287	500	67	433	246	97
5000									

Oil got in specimen
Ultimate load 2000 lb

3J 10000

2500	0	60			20				
5000	0	160			50				
7500	0	233			78				
10000		312.5			119				
10000	200								
	400	312	3	3	142	123	9	6	2
10000	600	311	8	11	159	123	26	15	6
10000	800	310	8	19	178	127	51	32	12
10000	1000	308	18	37	208	129	89	52	19
10000	1200	306-310	18	55	227-230	135	95	40	15
10000	1400	309	8	43	271	137	134	91	33
10000	1600	307	18	61	300	139	160	99	37
10000	1800	304.5	23	84	338	141	197	113	42

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10000	2000	302	23	107	373	143	230	123	45
10000	2600	287	44	151	511	149	262	111	41
10000	3000	283-288	36	187	611-631	170	461	174	64
10000	3500	280	35	262	771	174	597	325	120
10000	4000	272	75	337	928	178	760	423	154
10000	5000	230-235	410	747	1440-1450	195	1250	503	176
10000	6000	267			1230	201	1030		

<u>Ultimate load 6000 lb</u>

<u>3J 12500</u>

2500	0	244			24				
5000	0	330			36				
7500	0	412			65				
10000	0	487			88				
12500	0	550			95				
12500	200	564			120	97	23		
12500	400	564			132	99	33		
12500	600	564			164	101	63		
12500	800	564			191	103	88		
12500	1000	564			215	105	110		
12500	1200	564			243	107	136		
12500	1400	563.8			277	109	168		
12500	1600	563			301	111	190		
12500	1800	562			343	113	230		
12500	2000	561			394	115	279		
12500	2200	559.5			428	117	311		
12500	2400	557.5			499	119	380		

<u>Oil got in Ultimate load 2420 lb</u>

<u>3J 15000</u>

2500	0	52			20				
5000	0	147			43				
7500	0	216			68				
10000	0	293			104				
12500	0	365			150				
15000	0	434			209				
15000	200	434.5	3	3	219	211	8	5	2
15000	400	434	3	6	228	213	15-	9	3
15000	600	433.5	3	9	243	215	28-	19	7
15000	800	432	13	22	264	217	47	25	9
	1000	430.5-437	13	35	292-297	224	73	38	14
15000	1200	435.5	13	48	336	226	110	62	23

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1	2	3	4	5	6	7	8	9	10
	1400	434	13	61	365	228	137	66	24
15000	1600	431.5	23	84	398	231	167	83	31
	1800	429	23	107	428	233	195	88	33
15000	2200	423.5	61	168	505	238	268	100	37
	2600	417	61	229	582	241	341	112	41
	3000	411-416	56	235	665-668	245	423	188	69
15000	3500	409	65	300	782	249	533	233	86
	4000	401	75	375	900	253	647	272	100
	5000	379	210	585	1100	261	3840	255	94
	6000	353-370	250	835	1460-465	267	1200	365	135
15000	7000	340	290	1125	1890	273	1620	495	183
15000	8000	300	390	1515	2470	274	2200	685	253

Ultimate load 8450 lb

3J 17500

2500	0								
5000	0				40				
7500	0	93			73				
1000	0	162			108				
12500	0	232			159				
15000	0	309			210				
17500	0	360			270				
17500	200	359							
	400	358	16	16	290	274	16	0	
17500	600	357	8	24	304	276	28-	4	1
	800	356	38	32	325	278	47-	15	6
17500	1000	355	8	40	350	280	70	30	11
	1200	354-360	8	48	380	282	98	50	18
	1400	358.5	13	61	430	284	146	75	28
	1600	357	13	74	459	286	173	99	37
	1800	355	18	92	486	288	198	106	39
17500	2000	353	18	110	522	990	222	112	41
17500	2200	351	18	128	554	292	262	134	49
	2600	345	56	184	627	296	331	147	54
	3000	340	44	228	703	300	400	172	64
	3500	331	85	313	804	304	500	187	69
17500	4000	322	85	398	910	308	600	202	75
	5000	312	90	488	1145	316	829	341	126
	6000	299	120	600	1390	322	978	378	140
17500	7000	272	260	860	1680	328	1352	492	182
	8600	237	340	1200	2250	330	1920	720	265
17500	9200	200	370	1570	2600	333	2266	696	266

Ultimate Load 9200 lb

1	2	3	4	5	6	7	8	9	10
0	200				16	8	8		
0	400				27	10	17		
0	430				38	12	26		

Ultimate load 430 lb

4J 5000

1	2	3	4	5	6	7	8	9	10
2500	0	110			20				
5000	0	199			50				
	200	198.5	3	3	65	52	13	10	4
5000	400	197.5	8	11	76	54	22	11	4
	600	196.5	13	24	90	56	34	10	4
5000	800	195	8	32	107	58	49	17	6
5000	1000	172.5-204.5	21	53	126	60	66	13	5
5000	1200	202	23	76	160	62	98	22	8
5000	1400	200	18	94	192	64	128	34	13
5000	1600	198	18	112	223	66	157	45	17
5000	1800	194	38	150	270	68	202	52	19
	2200	184	98	248	387	70	317	69	26
5000	2600	171	128	376	581	74	506	130	49
5000	3200	72	986	1362	1600	78	1522	160	60

Ultimate load 3300 lb

4J 15000

1	2	3	4	5	6	7	8	9	10
2500	0	62			20				
5000	0	148			40				
7500	0								
10000	0	303			111				
12500	0	382			168				
15000	0	452			224				
15000	200	452			244	226	18		
	400	451	8	8	256	228	28	20	7
15000	600	450	8	16	270	230	40	24	9
15000	800	448.5	13	29	291	232	59	30	11
	1000	447	13	42	317	234	73	31	11
	1200	446-450	8	50	345-351	252	99	49	17
15000	1400	448.5	13	63	389	254	135	72	27
	1600	447	13	76	417	256	161	85	31
15000	1800	445	18	94	450	258	192	98	36
	2200	439	54	149	550	262	288	139	51

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4J 15000 Cont'd.

1	2	3	4	5	6	7	8	9	10
15000	2600	334.41	46	195	594-600	272	328	133	49
	3000	437.5	31	226	695	276	420	194	72
15000	3500	430.5	70	296	790	280	510	214	79
	4000	421.1	85	381	900	284	616	235	87
15000	5000	400-405	205	586	1141-1148	277	652	206	98
	6000	380	180	766	1440	305	1145	379	140
15000	7000	353	326	1020	1820	311	1509	489	180
15000	8000	396-414			2500	317	2200		

Ultimate 8400 lb

1HO

0	200				10	8	2		
0	400				15	10	5		
0	600				19	12	7		
0	800				27	14	13		

Ultimate load 800 lb

1H 2500

2500	0	127			26				
2500	200	126	8	8	36	28	8	0	0
	400	125	8	16	47	30	17	1	0
2500	600	124	8	24	60	32	28	4	1
2500	800	123	8	32	74	34	40	8	2
	1000	121.5-126	13	45	89-90	37	53	8	2
2500	1400	124	16	61	129	39	90	27	13
	1800	119.5	41	102	178	41	137	35	13
2500	2200	113	61	163	255	43	212	49	18
2500	2600	100	126	289	398	45	353	64	23
	2800	67	327	616	700	46	154	38	24

Ultimate load 2820 lb

1	2	3	4	5	6	7	8	9	10
2500	0	360			18				
5000	0	461			40				
	200	460	8	8		42			
5000	400	469	8	16		44			
	600	468	8	24		46			
5000	800	467	8	32	100	48	52	20	7
	1000	456	8	40		50			
	1200	455	8	48	111	52	58	10	4
5000	1400	453.5	13	61	126	54	72	11	4
	1600	452	13	74	145	56	89	15	5
	1800	450.5	13	87	164	58	106	19	7
	2200	440	19	106	185	60	125	19	7
	2500	454	33	139	254	65	189	50	18
5000	3000	457	25	164	335	70	265	101	37
	3500	448	85	249	433	74	359	110	40
5000	4000	435	125	374	575	78	497	123	45

Ultimate 4000 lb

1H 17500

1	2	3	4	5	6	7	8	9	10
2500	0	30			19				
5000	0	112			37				
7500	0	191			58				
10000	0	276			87				
12500	0	351			120				
15000	0	415			151				
17500	0	481			185				
17500	1000	474	60	60	290	195	95	35	13
	1200								
	1400								
17500	1600								
	1800								
17500	2000								
	2500	467	55	115	391	207	183	68	25
17500	2800	464.5	23	138	422	209	213	75	27
	3000	463	13	141	437	211	226	85	31
	3200								
	3400	460-469.5	26	167	471	215	258	91	33
	4000	466.5	20	187	540	219	321	134	49
	4500	464.5	15	202	588	223	361	163	59
	5000	461	30	232	625	227	398	166	61
	6000	452.5	75	307	739	233	496	189	69
	7000	443	85	392	850	239	611	219	80

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1H 10000

1	2	3	4	5	6	7	8	9	10
2500	0	81			2.0				
5000	0	167			35				
7500	0	258			57				
10000	0	343.5			92				
10000	200	343	3	3	105	94	11	8	3
10000	400	342.5	3	6	112	96	16	10	4
10000	600	341.5	8	14	122	98	24	10	4
10000	800	340	13	37	139	100	39	2	1
	1000	338.5-341.5	13	50	153-155	104	51	1	0
10000	1400	340	11	61	195	108	87	26	9
10000	1800	337.5	21	82	235	112	123	41	15
10000	2200	334.5	26	108	280	116	164	56	20
10000	2600	331	31	139	326	120	206	67	24
	3000	327-331	36	175	376-378	126	252	77	28
10000	3500	327.5	30	205	444	130	314	109	39
	4000	322	50	255	511	134	377	122	44
10000	5000	308-312	130	385	668-671	145	526	141	51
	6000	896	150	535	887	161	726	191	70
	6500	375	205	740	1100	169	940	200	73

Ultimate load 6600 lb

1H 7500

2500	0	92			13				
7500	0	251			47				
	200	250	8	8	62	49	13	5	2
7500	400	249	8	16	75	51	24	8	3
	600	248	8	24	89	53	36	12	4
7500	800	247	8	32	100	55	45	13	5
	1000	246-250	8	40	122-124	59	65	25	9
7500	1400	248	16	56	165	61	104	48	17
	1800	245	26	82	215	63	-152	60	22
7500	2200	240	46	128	265	67	198	70	26
	2600	235	46	174	326	71	255	81	30
7500	3000	230-238.5	46	220	380-392	76	316	96	35
	3500	334	46	260	481	80	401	141	51
	4000	325	85	345	580	84	496	151	55
7500	5000	299	250	590	887	92	795	205	75

Ultimate Load 5280 lb

1H 15000

1	2	3	4	5	6	7	8	9	10
2500	0	187			18				
5000	0	269			41				
10000	0	436			107				
12500	0	512			141				
15000	0	572			175				
	200	571.5	3	3	181	177	4	1	0
15000	400	570.5	8	11	190	179	11	0	
15000	600	569.5	8	19	200	181	19	0	
15000	1000	566.7	23	42	223	183	43	1	0
15000	1400	563.7	26	68	262	185	77	9	3
	1800	560.3	30	98	297	187	110	12	4
15000	2200	556.3	36	134	337	191	136	2	1
	2600	552	39	173	381	195	186	13	5
15000	3000	546	36	209	414	199	215	16	6
	3500	547	4	213	470	203	267	54	20
15000	4000	544	30	243	527	207	320	75	28
	5000	535.5	85	328	643	215	428	100	37
15000	6000	526.5	80	408	779	221	558	150	56
	7000	513.7	128	536	962	226	736	200	74
15000	7800				1265	230	1035		

Ultimate load 7970 lb

1H 12500

2500	0	167			20				
10000	0	416			83				
12500	0	495			113				
12500	200	494.5	3	3	130	115	15	12	4
	400	494	3	6	143	117	26	20	7
12500	600	493.5	3	9	157	119	38	29	10
	1000	492.5-494.5	6	15	189-192	124	66	51	18
12500	1400	493	11	26	224	128	96	70	25
	1800	490	16	42	257	136	121	79	29
12500	2200	488	26	68	298	142	156	88	33
	2600	484.5	31	99	335	148	187	88	33
12500	3000	481.5	26	125	376	152	214	89	33
	3500	478.5-473	45	170	432-435	160	275	105	38
12500	4000	460.5	70	240	488	164	324	84	31
	5000	472	75	315	602	172	430	155	36
12500	6000	461.5	95	410	730	178	552	142	52
	7000	447	125	535	895	194	701	166	61
12500	7800	417	290	825	1200	200	1000	176	64

1	2	3	4	5	6	7	8	9	10
	8000	431	110	502	991	245	746	244	89
	7000	410	200	702	1216	251	965	263	96
	9400	393	166	863	1416	257	1256	388	142
Ultimate load 9600 lb									
2H0									
	0				0				
0	200				17	8	9		
0	400				25	10	15		
0	520				35	12	23		
Ultimate load 520 lb									
2H 2500									
2500		172			20				
	200	171.5–181	3	3	37.5-39	24	15	12	4
	400	180.5	3	6	45	26	19	13	5
	600	179.5	8	14	54	28	26	12	4
	800	179	3	17	64	30	34	17	6
	1000	178.5	3	20	75	32	43	23	8
	1200	178	3	23	87	34	53	30	11
	1400	177	8	31	105	36	69	38	14
	1600	175	16	47	125	38	87	40	15
	1740				170	40	130		
Ultimate load 1740 lb									
2H 5000									
2500	10	160			22				
5000	0	243			43				
5000	200	242.5-257	3	3	53-55	47	8	5	2
	400	256.5	3	6	68	47	19	13	5
5000	600	255.5	8	14	81	51	30	16	5
5000	800	254.	13	37	95	53	42	5	2
	1000	253	8	45	112	55	57	12	4
5000	1200	251.5	13	58	132	57	75	17	6
	1400	250	13	71	153	59	94	23	8
5000	1600	248	18	89	176	61	115	26	9

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1	2	3	4	5	6	7	8	9	10
5000	1600	248	18	89	176	61	115	26	9
	1800	246	18	107	204	63	141	34	12
5000	2000	242.5-253	33	140	249-251	68	183	43	15
	2200	248	48	188	330	70	260	72	26
	2800	208	394	582	800	76	725	143	52
5000	3000	196	118	700	920	78	847	187	66
	3500	124	715	1415	1800	80	1720	305	112
	3600	25			2800	2700			

Ultimate 3800 lb

2H 75

1	2	3	4	5	6	7	8	9	10
2500	0	8			20				
5000	0	75			43				
7500	0	160.5			78				
7500	200	160	3	3	88	80	8	5	2
	400	159	8	11	98	82	16	5	2
7500	600	158	8	19	115	84	31	12	4
7500	800	157	8	27	133	86	47	20	7
	1000	150	8	35	153	88	65	30	11
7500	1200	154.5-163	13	48	175-179	94	85	37	13
	1400	161.5	13	61	210	96	114	53	19
7500	1600	160	13	74	234	98	136	62	23
	1800	158	18	92	261	100	161	69	25
	2000	156	18	110	291	102	189	79	28
7500	2200	153	28	138	322	104	218	80	29
	2400	151	28	166	356	106	250	84	30
7500	2600	148	28	194	387	108	279	85	31
7500	3000	142.5	54	248	456	112	344	96	35
	3500	1355-1435	65	353	550-562	120	442	89	33
	4000	137	60	413	640	124	516	103	37
7500	5000	70	650	1063	1330	132	1200	187	50
7500	5040	000			2000	135	1965		

Ultimate load 5040 lb

2H 10

1	2	3	4	5	6	7	8	9	10
2500	0				20				
5000	0				39				
7500	0				60				
10000	0	351.5			86				
10000	200	351	3	3	98-100	90	10	7	3

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1	2	3	4	5	6	7	8	9	10
10000	400	550.5-358	3	6	113	92	21	15	5
10000	600	358.5	3	9	124	94	30	21	7
	800	359	3	12	136	96	40	28	10
10000	1000	358	8	20	152	98	54	34	12
10000	1200	357.5	3	23	165	100	65	42	15
	1400	356.5	8	31	182	102	80	49	18
	1600	355.5	8	39	200	104	96	57	21
10000	1800	354	13	52	218	106	112	60	22
	2000	352.5-362.5	13	65	239-242	108	134	69	25
10000	2200	361	13	78	268	110	158	80	29
	2400	359.5	13	91	290	112	178	87	32
10000	2600	358.5	8	98	312	114	198	99	36
	2800	357	13	112	336	116	220	108	38
10000	3000	355.5	13	125	359	118	241	116	42
	3500	349	55	180	435	122	313	133	48
10000	3800	335	137	317	700	127	575	258	54

Oil gets in Ultimate load 3800 lb

2H 12500

2500	0	82			20				
5000	0	170			36				
7500	0	251			61				
10000	0	327			93				
12600	0	402			136				
12600	400	401-410.5	116	6	162-167	145	22	16	6
	600	411	3	9	185	147	38	29	11
	800	410.5	3	12	200	149	51	39	14
12600	1000	409.5	8	20	215	151	64	44	16
	1200	408.5	8	28	234	153	81	53	19
12600	1400	407	13	41	252	155	97	56	20
	1600	405.5	13	53	272	157	115	62	23
	2000	402.5	26	79	317	159	158	79	29
	2200	401	13	92	330	161	169	77	28
	2400	399.5	13	105	352	163	189	84	31
	2600	398	13	118	374	165	209	91	33
	3000	393.5	41	159	425	167	258	92	36
	3500	388	50	209	490	171	319	110	40
12600	4000	383-387	45	214	555-558	175	383	170	62
	5000	380	65	279	690	183	507	228	83
12600	6000	364	155	434	870	101	680	246	91
	7000	329-333	340	774	1257-1267	199	1070	296	108
	7200	300	328	1102	1700	200	1500	400	146

Ultimate load 7200 lb

1	2	3	4	5	6	7	8	9	10
2500	0	45			20				
5000	0	130			40				
7500	0	212			60				
10000	0								
12500	0	363			121				
15000	0	440			159				
	400	339	3	3	172	163	9	6	2
	600	338.5	3	6	180	165	15	9	3
	800	338	3	9	192	167	25	16	5
	1000	337	8	17	209	169	40	23	8
	1200	336	8	25	221	171	50	25	9
	1400	335	8	33	237	173	64	31	11
	1600	333.5	13	46	254	175	79	33	13
	2200	329	39	85	310	179	131	46	17
	2600	326.5	21	106	345	183	162	56	21
	3000	323	31	137	387	187	200	63	23
	3600	317	49	186	452	191	261	75	27
	4000	314	26	212	403	195	298	86	31
	5000	305-311	85	297	615-625	213	412	115	42
	6000	302	85	382	750	219	531	149	5
	8000	287	140	522	1120	225	895	373	13
	8600	231	540	1062	1500	227	1275	213	79

ULTIMATE LOAD 8600 lb

2H-17500

1	2	3	4	5	6	7	8	9	10
10000	0	65			107				
12500	0	145			140				
15000	0	222			170				
17500	0	268			201				
	200	268	0	0					
	400	268.5	3	3	220	205	15	12	4
	600	268	3	6	228	207	21	15	5
	800	267.5	3	9	240	209	31	22	8
	1000	267	3	12	252	211	41	29	11
	1200	266	8	20	268	213	55	35	13
	1400	265	8	28	282	215	67	39	14
	1600	264	8	36	298	217	81	45	16
	1800	263	8	44	314	219	95	51	18
	2200	260	26	70	350	225	125	55	20
	2600	257.5	21	91	384	228	156	65	23
	3000	255	21	112	418	233	175	63	23
	3500	258	25	137	475	237	238	101	37

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1	2	3	4	5	6	7	8	9	10
	4000	256	25	162	520	241	279	117	43
	5000	249	60	222	610	249	361	139	51
	6000	240	80	302	720	255	465	163	59
	7000	233.5	55	357	800	261	539	182	67
	8000	230	25	382	955	267	638	306	112
	9000	213	160	542	1130	270	960	418	153
	9650	180	325	867	1500	273	1225	458	1660
			ULTIMATE LOAD 9650 lb						
			3H 5000						
2500	0	200			20				
5000	0	288			44				
5000	200	288	0		52	46	6	6	2
	400	287.5	3	3	59	48	11	8	3
5000	600	286.5	8	11	69	50	19	8	3
5000	800	286	3	14	80	52	28	14	5
5000	1000	285	8	22	91	54	37	15	6
	1200	284	8	30	107	56	51	21	8
5000	1400	283	8	38	122	58	64	26	9
	1600	282	8	46	130	60	79	33	12
5000	1800	280-288	16	62	159-161	65	96	34	12
	2200	285	26	88	209	69	140	52	19
5000	2600	282	26	114	261	73	188	74	27
	3000	276	56	170	328	77	251	81	27
	3500	265	105	275	450	81	369	94	34
5000	3900	250	145	420	608	85	515	105	38
			ULTIMATE LOAD 3900 LB						
			3H 7500						
2500	0	4			20				
5000	0	98			43				
7500	0	186			74				
	200	185	8	8	87	76	11	3	1
7500	400	184	8	16	98	78	20	4	1
	600	182.5	13	23	114	80	34	11	4
	800	181	13	36	130	82	48	12	4
7500	1000	179	8	44	151	84	67	23	8
7500	1200	176.5	23	67	174	86	88	21	8
	1400	174.5	18	85	198	88	110	25	9
	1600	173-183.5	13	98	222-225	93	133	35	13

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3H 7500 Cont'd.

1	2	3	4	5	6	7	8	9	10
7500	1800	182	13	111	262	75	167	56	20
	2200	177	46	157	320	77	223	66	24
	2600	172	46	203	384	101	280	77	28
7500	3000	166	56	259	455	105	350	91	33
	3500	155	105	364	557	109	448	84	31
7500	4000	145	95	459	685	114	571	112	41
	5000	59	850	1309	1580	117	1473	164	60

ULTIMATE LOAD 5200 lb

3H 10000

2500	0	98			20				
5000	0	183			42				
7500	0	260			64				
10000	0	346			100				
	200	345.5	3	3	107	102	5	2	1
10000	400	345	3	6	114	104	10	4	2
	600	344.5	3	9	127	106	21	12	4
10000	800	344	3	12	142	108	34	22	8
	1000	343	3	15	159	110	49	34	12
	1200	341.5	8	23	177	112	65	42	15
	1400	340	13	36	195	114	81	45	16
	1600	398.5	13	49	219-222	119	103	54	19
	1800	343.5-344.5	8	57	251	121	130	77	28
10000	2200					125			
	2600	338	47	104	340	129	211	107	39
	3000	334	36	140	389	134	255	115	42
10000	3500	328	55	195	457	138	319	124	45
	4000	321	65	260	537	142	395	135	49
	5000	306	140	400	711	150	561	161	59
10000	5980	276-290	290	690	1042-1047	158	890	200	73

Ultimate Load 5980

1	2	3	4	5	6	7	8	9	10
2500	0	175.5			20				
	200	175	3	3	27	22	5	2	1
2500	400	174.5	3	6	35	24	11	5	2
	600	174	3	9	44	26	18	9	3
2500	800	173.5	3	12	54	28	26	14	5
	1000	172	3	15	65	30	35	20	7
2500	1200	171	13	28	30	32	48	20	7
2500	1400	170	3	36	95	34	61	25	9
	1600	179-180	8	44	114-116	36	80	36	13
2500	1800	178	18	52	146	38	108	56	20
	2200	172	56	108	225	42	173	65	24
	2400	159	126	234	359	46	313	79	39
2500	2000	120	370	624	750	48	702	78	39

Ultimate Load 2400 lb

3H 12500

2500	0	80			20				
5000	0	173			40				
7500	0	258			60				
10000	0	327			84				
12500	0	407			121				
	200	407	-	-	127	123	4	4	2
12500	400	407	-	-	135	125	10	10	4
	600	406.5	3	3	145	127	18	15	5
	800	406	3	6	158	129	29	23	8
12500	1000	405	8	14	171	131	40	26	9
	1200	404	8	22	186	133	53	31	11
	1400	403	8	30	201	135	66	36	13
	1600	402	8	38	219	137	82	44	16
12500	1800	400.5	13	51	238	132	99	48	17
	2400	397.5-404	24	75	275-279	147	132	57	21
12500	2600	402	16	91	322	148	173	72	26
	3000	400	16	107	362	153	209	102	37
	3500	396	35	142	416	157	259	117	43
12500	4000	391	45	187	472	161	311	124	45
	5000	380-388	100	282	610-613	169	444	157	57
12500	6000	379	80	367	762	175	587	220	80
	7000	361	160	527	960	181	780	253	92
	7580	314	480	1007	1440	184	1260	253	72

Ultimate Load 7580 lb.

3HO

1	2	3	4	5	6	7	8	9	10
0	200				13	8	5		
0	400				22	10	12		
0	600				31	12	19		

Ultimate load 600 lb

3H 15000

1	2	3	4	5	6	7	8	9	10
2500	0	80			20				
5000	0	169			38				
7500	0	265			57				
10000	0								
12500	0	395			115				
15000	0	470			154				
15000	200	470	0	0					
15000	400	469.5	3	3	168	158	10	7	3
15000	600	469.0	3	6	176	160	16	10	4
15000	800	468.5	8	14	188	162	26	12	4
15000	1000	468	3	17	204	164	40	23	8
15000	1200	467.5	3	20	219	166	53	33	12
	1400	466.5	8	28	233	168	65	37	13
15000	1600	465	13	41	249	170	79	38	14
	1800	464	8	49	268	172	96	47	17
15000	2200	462-465	16	65	307-311	176	135	70	26
	2600	463	16	81	352	180	170	89	33
15000	3000	460	26	107	391	184	207	100	36
	3500	457	25	132	445	188	257	125	45
15000	4000	452	35	167	499	192	307	140	51
	5000	444-450	70	237	613-617	200	417	180	66
15000	6000	441	80	317	750	206	544	227	83
	7000	420	200	517	905	212	693	176	64
15000	8000	404-408	150	667	1145-1149	218	931	264	935
	9000	320	876	1543	2100	221	1880	337	123

Ultimate Load 9640 lb.

3H 17500

1	2	3	4	5	6	7	8	9	10
2500	0	117			20				
5000	0	205			45				
7500	0								
10000	0	355			104				
12500	0								
15000	0	497			184				
17500	0	559			217				
17500	200	558.5	3	3	226	220	6	3	1
	400	558	3	6	233	222	11	5	2
17500	600	557	8	14	244	224	20	8	3
	800	556	8	22	258	226	32	10	4
17500	1000	555-561	8	30	273-278	230	45	15	6
	1200	560	8	38	295	232	63	25	9
17500	1400	559	8	46	301	234	67	21	8
	1600	557	18	64	330	236	94	30	11
17500	1800	555	18	82	347	238	109	27	10
17500									
	2200	551-554	36	118	388-393	247	146	28	10
	2600	550	36	154	425	251	174	20	7
17500	3000	547	26	180	470	255	215	35	12
	3500	542	45	225	515	259	256	31	12
17500	4000	535	65	290	580	263	327	37	14
17500	5000	520	140	430	720	271	449	19	7
	6000	509	100	530	850	277	573	43	16
17500	7000	490	180	710	1040	283	791	61	30
	8000	458	310	1020	1560	286	1274	254	94

Ultimate load 8600 lb

4HO

1	2	3	4	5	6	7	8	9	10
0	200				10	8	2		
0	400				16	10	6		
0	600				21	12	9		
0	650				24	13	11		

Ultimate load 650 lb

4H 10000

1	2	3	4	5	6	7	8	9	10
2500	0	166			20				
5000	0	249			39				
7500	0								
10000	0	413.5							
10000	200	413.5	0	0		115			
10000	400	413	3	3	123	117	6	3	1
10000	600	412.5	3	6	129	119	10	4	2
10000	800	412	3	9	138	121	17	8	3
10000	1000	411.5	3	12	152	123	29	17	6
10000	1200	410.5	8	20	170	125	45	25	9
10000	1400	410	3	23	185	127	55	35	15
10000	1600	409	8	31	204	129	75	44	16
10000	1800	407	18	49	221	131	90	41	16
10000	2000	405.5	13	62	242	133	109	47	17
10000	2200	403.5-408	18	80	263-267	135	132	52	19
10000	2600	406	16	96	322	141	181	85	31
10000	3500	400	49	145	433	154	279	134	49
	4000	394-398	55	200	502-506	162	344	144	53
10000	5000	389	80	280	675	168	507	227	83
10000	6000	369	190	470	880	174	706	236	85
10000	6300	305	630	1100	1530	177	1370	270	99

Ultimate load 6300 lb

5H0

1	2	3	4	5	6	7	8	9	10
0									
	200				15	8	7		
	400				27	10	17		

Ultimate load 430 lb

<u>1C0</u>

1	2	3	4	5	6	7	8	9	10
0	200				19	8	11		
0	400				27	10	17		
0	600				37	12	25		
0	800				46	14	32		

<u>Ultimate load 800 lb</u>

Broke into three pieces Angles 28° and 16°

<u>1C 2500</u>

1	2	3	4	5	6	7	8	9	10
2500	0	292			15				
2500	200	293.5			32	17	15		
	400	292.5			45	19	26		
2500	600	291.5			58	21	37		
2500	800	290.5			68	23	45		
	1000	289			79	25	54		
2500	1200	287.5			92	27	65		
	1400	286			104	29	75		
	1450	284.5			121	31	90		

<u>Ultimate load 1450 lb</u>

Broke into two pieces some longitodinal splitting. Angle 31°

1C 5000

1	2	3	4	5	6	7	8	9	10
2500	0	130			14				
5000	0	228			20				
5000	200	227			28	22	6		
5000	400	226			43	24	19		
	600	225			53	26	27		
5000	800	224			64	28	36		
	1000	223			74	30	44		
	1200	221.5			85	32	53		
	1400	220.5			96	34	62		
5000	1600	219			112	36	76		

Ultimate load 1760 lb

Mostly longitudinal splitting Angle 22°

1C 7500

1	2	3	4	5	6	7	8	9	10
2500	0	339			5				
5000	0	416			10				
7500	0	519.5			17				
7500	200	518.5			35	21	15		
7500	400	517.5			44	23	21		
	600	516.5			54	25	29		
7500	800	515.5			64	27	38		
	1000	514.5			75	29	46		
	1200	513			85	31	54		
7500	1400	511.5			98	33	65		
7500	1600	510			113	35	78		

Ultimate load 1600 lb

Piece Damaged

1C 10000

1	2	3	4	5	6	7	8	9	10
0		140							
2500	0	276			14				
5000	0	362			21				
7500	0	445			25				
10000	0	534			34				
10000									
10000	200	533.5	3	3		36			
10000	400	532.5	8	11	53	38	15	4	1
	600	531.5	8	19	62	40	22	3	1
	800	530.5	8	27	76	42	34	7	3
	1000	529.5	8	35	86	44	42-	7	3
10000	1200	528.5	8	43	98	46	52	9	3
	1400	527.5	8	51	113	48	65	14	5
10000	1500	526	13	64	130	50	80	16	6

Ultimate load 1520 lb

Piece damaged

1C 12500

1	2	3	4	5	6	7	8	9	10
2500	0	217			11				
5000	0	300			19				
7500	0	390			24				
10000	0	471			32				
12500	0	553.5			41				
	200	553			52	43	9	9	3
	400	552.5	8	8	64	45	18	10	4
	600	551.5	8	16	75	47	28	12	4
12500	800	551	3	19	85	49	36-	17	6
	1000	550	8	27	95	51	44	17	6
	1200	449	8	35	105	53	52	17	6
	1220	448	8	43	116	55	61	25	9
	1100	447	8		128	57	71	26	10

Ultimate load 1220 lb

Broke into two pieces Angles 31° and 29°

IC 15000

1	2	3	4	5	6	7	8	9	10
2500	0	167			13				
5000	0	260			18				
7500	0	341			22				
10000	0	428			29				
12500	0	494			34				
15000	0	563			44				
15000	200	563			53	46	7-		
15000	400	562.5	3	3	64	48	16	13	5
	600	561.5	8	11	75	50	25	14	5
15000	800	560.5-562.5	8	19	85	52	33-	14	5
15000	1000	563.5	8	27	98	54	44	17	6
	1200	563	3	30	107	56	51	21	8
15000	1300	562.5	3	33	117	58	59	26	10
	1350	561.5	8	41	130	60	70	29	11

Ultimate load 1350 lb

IC 17500

1	2	3	4	5	6	7	8	9	10
2500	0	108			13				
5000	0	209			20				
7500	0	286			23				
10000	0	370			30				
12500	0	450			38				
15000	0	507			47				
17500	0	575			56				
	200	574	8	8	70	58	12-	4	1
17500	400	573.5	3	11	80	60	20	9	3
	600	573	3	14	89	62	27	13	5
	800	572	8	22	97	64	33-	11	4
17500	1000	571	8	30	107	66	41	11	4
	1200	570	8	38	117	68	49	11	4
	1300	569	8	46	128	70	58	12	4

Ultimate load 1300 lb

Broke into two pieces, angle 28° 30 m
Longitidunal splitting.

2C0

1	2	3	4	5	6	7	8	9	10
0	200				16	8	8		
0	400				21	10	11		
0	600				25	12	13		
0	800				29	14	15		
0	1000				34.5	16	18.5		
0	1240				43	18	25		

Ultimate load 1240 lb.

Broke into two pieces. Angle 26°

2C2500

2500	0				17				
	200	27			27	19	8		
	400	36			36	21	15		
	600	44			44	23	21		
	800	51			51	25	26		
	1000	58			58	27	31		

Ultimate load 1020 lb.

Piece damaged

2C5000

1	2	3	4	5	6	7	8	9	10
2500		44			20				
5000		129			39				
	200				49	41	8		
	400				60	43	17		
	600	126			70	45	25		
	800	125			80	47	33		
	1000	123.5			93	49	44		
	1340	121			108	50	58		

Ultimate load 1340 lb.

Broke into two pieces; some longitudinal splitting. Angle 30°

2C7500

1	2	3	4	5	6	7	8	9	10
2500	0	138			16				
5000	0	229			25				
7500	0	319			33				
	200				43	35	8	8	3
	400	318.8			51	37	13	13	5
	600	318	6	6	61	39	21	15	5
	800	317	8	14	69	41	28	14	5
	1000	316	8	22	78	43	35	13	5
	1200	315.5	3	25	88	45	43	18	7
	1400	315.0	3	28	100	47	53	25	9
	1600				116	49	67		

Ultimate load 1680 lb.

Broke into two pieces. Angle 34°

2C10, 000

1	2	3	4	5	6	7	8	9	10
2500	0	175			8				
5000	0	271			13				
7500	0	355			16				
10000	0	437			24				
	200	436.5	3	3	34	26	8	6	2
	400	435.5	8	11	45	28	17	6	2
	600	435	3	14	55	30	25	11	4
	800	434	8	22	66	32	34	12	4
	1000	433	8	30	77	34	43	13	5
	1050	432	8	38	90	36	54	16	6

Ultimate load 1050 lb.

Broke into two pieces. Angle 22°. Some longitudinal splitting.

2C12, 500

1	2	3	4	5	6	7	8	9	10
2500	0	185			15				
5000	0	283			22				
7500	0	359			29				
10000	0	445			35				
12500	0	520			43				
	200	521	8	8	59	45	14	6	2
	400	522	8	16	70	47	23	7	3
	600	521.5	3	19	80	49	31	12	4
	800	521	3	22	91	51	40	18	7
	1000	519.5	3	25	104	53	51	26	10
	1200	518	13	38	122	55	67	29	11
	1400	515	28	66	150	57	93	27	10

Ultimate load 1400 lb.

Broke into two pieces. Angle 31° and 30°

2C17, 500

1	2	3	4	5	6	7	8	9	10
2500	0	88			20				
5000	0	177			25				
7500	0	262			32				
10000	0	341			41				
12500	0								
15000	0	482			60				
17500	0	548.5			71				
	200	548	3	3	81	73	8	5	2
	400	547.5	3	6	90	75	15	9	3
	600	546.5	8	14	99	77	22	8	3
	800	555.5	8	22	108	79	29	7	3
	1000	555	3	25	118	81	37	12	4
	1200	554	8	33	127	83	44	11	4
	1400	553	8	41	137	85	52	11	4
	1600	551.5	13	54	150	87	63	9	3
	1800				166	89	77		

Ultimate load 1800 lb.

Piece damaged.

3CO

0	200				14	8	6
	400				20	10	10
	600				25	12	13
	860				30	14	16

Ultimate load 860 lb.

Broke into two pieces. Some longitudinal splitting 32°.

3C2500

1	2	3	4	5	6	7	8	9	10
2500	0	117			16				
	200	116	8	8	30	18	12	4	1
	400	115	8	16	38	20	18	2	1
	600	114.6	3	19	44	22	22	3	1
	800	114	3	22	49	24	25	3	1
	1000	114	0	22	55	26	29	7	3
	1200	113	8	30	64	28	36	6	2
	1400	112	8	38	75	30	46	8	3
	1200	110	16	56	100	32	68	12	4

Ultimate load 1410 lb.

Broke into three pieces, some longitudinal splitting. Angles 32° and 21°.

3C5000

1	2	3	4	5	6	7	8	9	10
2500	0	109			11				
5000	0	203			22				
	200	203			32	24	8	8	3
	400	202.8	0	0	43	26	17	17	6
	600	202.5	2	2	51	28	23	21	8
	800	202.5	8	10	58	30	28	18	7
	1000	201.5	8	18	67	32	35	17	6
	1200	200.5	8	26	76	34	42	16	6

Ultimate load 1200 lb.

Piece damaged

3C 7500

1	2	3	4	5	6	7	8	9	10
2500	0	285			16				
5000	0	375			28				
7500	0	468			38				
	200	467			45	40	5		
	400				57	42	15		
	600	466			67	44	23		
	800	465			76	46	30		
	1000	464			85	48	37		
	1200	463			95	50	45		
	1400	461.5			106	52	54		
	1470	460			121	54	57		
	1200	455			150	56	94		

Ultimate load 1470 lb.

Broke into two pieces, some longitudinal splitting. Angles 31° and 30°.

3C10, 000

0	0	120			4		
2500	0	238			15		
5000	0	329			25		
7500	0	421			34		
10000	0	503			44		
	200	503			49	46	3
	400				57	48	9
	600	502.5			65	50	15
	800	502			72	52	20
	1000				79	54	25
	1200				87	56	31
	1400	500			97	58	39
	1420				115	60	55
	1000				150	62	88

Ultimate load 1420 lb.
Piece damaged.

3C12,500

1	2	3	4	5	6	7	8	9	10
0	0	110			6				
2500	0	237			14				
5000	0	330			23				
7500	0	416			33				
10000	0	496			44				
12500	0	579			60				
	200	579			63	62	1		
	400		3	3	75	64	11	8	3
	600	578	3	6	88	66	22	16	6
	800		3	9	100	68	32	23	9
	1000	577	3	12	113	70	43	31	11
	1200	575	18	30	126	72	54	24	9
	1400	573	13	43	143	74	69	26	10
	1600	572	13	56	165	76	89	33	12

Broke into three pieces, some longitudinal splitting. Angles 30° and 24°.

3C15,000

1	2	3	4	5	6	7	8	9	10
15000	0	406			40				
	200	405.5			49	42	7		
	400	405			58	44	14		
	600	404			67	46	21		
	800	403			77	48	29		
	1000	402			87	50	37		
	1200	401			99	52	47		
	1400	400			111	54	57		
	1600	399			124	56	68		

Ultimate load 1600 lb.

Broke into two pieces. Angles 30° and 28°.

3C17, 500

1	2	3	4	5	6	7	8	9	10
2500	0								
5000	0	129			29				
7500	0	210			38				
10000	0	290			47				
12500	0								
15000	0	427			65				
17500	0	486			79				
	200				84	80	4		
	400				92	82	10		
	600	486			101	84	17		
	800	485.5			110	86	24		
	1000	485			120	88	32		
	1200	484			130	90	40		
	1400	483			140	92	48		
	1600	482			155	94	61		
	1800	481			170	96	74		
	1900	479			190	98	92		
	1910	477			220	100	110		

Ultimate load 1910 lb.

Broke into two pieces. Angles 30°

IE0

1	2	3	4	5	6	7	8	9	10
0	200				18	8	10		
0	400				25	10	15		
0	600				31	12	19		
0	800				41	14	27		
0	950				54	16	38		

Ultimate load 950 lb

Two pieces with some small pieces angle 30°

IE 2500

1	2	3	4	5	6	7	8	9	10
2500	0	321			15				
2500	200	320	8	8	24	17	7	1	0
2500	400	319.5	3	11	33	19	14	3	1
2500	600	318.7	3	14	41	21	20	6	2
2500	800	318	3	17	50	23	28	11	4
2500	1000	317	8	25	60	25	35	10	4
2500	1040	316	8	33	70	27	43	10	4
2500	1000	312.5			98	31	67	3	1

Ultimate load 1040 lb

Piece damaged

IE 5000

1	2	3	4	5	6	7	8	9	10
2500	0				14				
5000	0	515			22				
5000	200	524.5			32	24	8		
5000	400	524			40	26	16		
5000	600	523.5			49	28	21		
5000	800	522.5			57	30	27		
5000	1000	521.9			66	32	34		
5000	1200	521			77	34	43		
5000	1400	520			87	36	51		
5000	1600	519			100	38	62		
5000	1800	516.5			130	40	90		

Ultimate Strength 1800 lb

Broke into two pieces angle 29°

IE 10000

1	2	3	4	5	6	7	8	9	10
		140			6				
2500	0	284			13				
5000	0	375			19				
7500	0	458			25				
10000	0	546			34				
10000	200	545	3	3	43	36	7	4	1
10000	400	544	3	6	55	38	17-	11	1
10000	600	543	3	9	67	40	27	18	7
10000	800	542	3	12	79	42	37-	25	9
10000	1000	540	8	20	92	44	48	28	10
10000	1200	538.5	13	33	106	46	60	28	10
10000	1400	536.5	18	51	126	48	78	27	10

Ultimate load 1580 lb

Broke two pieces; major piece angles 22° the other 34°

IE 75000

		200							
2500	0	328			10				
5000	0	414			20				
7500	0	504.5			28				
7500	200	503	3	3	37	30	7-	4	1
7500	400	502.5	8	11	45	32	13	2	1
7500	600	501.5	8	19	53	34	19	0	0
7500	800	502.5-503.5	8	27	62	36	26-	1	0
7500	1000	502.5	8	35	71	38	33	2	1
7500	1200	501.5	8	43	81	40	41	2	1
7500	1400	500.5	8	51	91	42	49	2	1
7500	1600	499.5	8	59	106	44	62	3	1
7500	1700	477.5	18	77	126	46	80	3	1

Ultimate load 1700 lb

Broke into two pieces Angle 32°

IE 17500

1	2	3	4	5	6	7	8	9	10
2500	0	116			19				
5000	0	214			22				
7500	0	292			26				
10000	0	375			35				
12500	0	450			42				
15000	0	510			49				
17500	0	573.5			58				
17500	200	573			67	60	7		
17500	400	572			77	62	15		
17500	600	571-576.5			88	64	24		
17500	800				95-100	66	29		
17500	1000	574.5			109	68	41		
17500	1200	573.5			119	70	49		
17500	1400	572.5			129	72	57		
17500	1600	571.5			141	74	67		

Ultimate load 1600 lb

Broke into two pieces Angles 34° and 33°

2E0

1	2	3	4	5	6	7	8	9	10
0	200				12	8	4		
0	400				16.5	10	6.5		
0	600				21.5	12	9.5		
0	800				25.5	14	11.5		
0	1000				30.5	16	14.5		
0	1200				35	18	17		
0	1300				41	20	21		

Ultimate load 1300 lb

Broke into two pieces Angle 35°

2E 2500

1	2	3	4	5	6	7	8	9	10
2500	0	305			20				
2500	200	304	8	8	34	22	12	4	1
2500	400	303	8	16	44	24	20	4	1
2500	600	302	8	29	53	26	27	3	1
2500	800	301	8	32	61	28	33-	1	0
2500	1000	300	8	40	71	30	40-	0	0
2500	1200	298.5	13	53	81	32	48	0	0
2500	1400	297	13	66	93	34	59	0	0
2500	1600	295.7	11	77	113	36	77	1	0

Ultimate load 1600 lb

Broke into two pieces angles 34° and 30°

2E 7500

1	2	3	4	5	6	7	8	9	10
2500	0	257			14				
5000	0	338			23				
7500	0	423.5			31				
7500	200	422.5	8	8	46	33	13	13	5
7500	400	420.5	18	26	65	35	30-	4	1
7500	600	418	13	39	88	37	51	12	4
7500	800	417	8	47	102	39	63	16	6
7500	1000	415.5	13	60	114	41	73-	3	1
7500	1200	414	13	73	126	43	83	10	4
7500	1400	412.5	13	86	144	45	99	13	5

Ultimate load 1400 lb

Broke into two pieces angle 30°

2E 5000

1	2	3	4	5	6	7	8	9	10
2500	0	290			14				
5000	0	384.5			22				
5000	200	383.5	8	8	34	24	10-	2	1
5000	400	382	13	21	44	26	19	2	1
5000	600	381	8	29	57	28	29	0	0
5000	800	380	8	37	68	30	38	1	0
5000	1000	378.5	13	50	80	32	48	2	1
5000	1200	377.5	8	58	91	34	57	1	0
5000	1400	375	23	81	123	36	87	6	2

Ultimate load 1400 lb

Broke into two pieces angles 29° and 23°

2E 10000

1	2	3	4	5	6	7	8	9	10
2500	0	149			9				
5000	0	238			14				
7500	0	312			24				
10000	0	400			36				
10000	200	400			45	37	8		
	400	399			55	39	16		
10000	600	378			66	41	25		
	800	397			75	43	32		
10000	1000	396			85	45	40		
10000	1200	395			96	47	49		
	1400	394			108	49	59		

Ultimate load 1600 lb

Broke into three major pieces Angle 24° and 16°

2E 12500

2500	0	234			13				
5000	0	325			21				
7500	0	401			31				
10000	0	480			41				
12500	0	561			50				
	200	560			60	52	8		
12500	400	559			70	54	16		
	600	559			76	56	20		
12500	800	558.5			84	58	26		
	1000	557.5			73	60	33		
12500	1200	557			104	62	42		
12500	1400	556			116	64	52		
12500	1600	554.5			130	66	64		

Ultimate load 1600 lb

Broke into two pieces angle = 33°

2E 17500

1	2	3	4	5	6	7	8	9	10
2500	0	80			10				
5000	0	173			15				
7500	0	263			23				
10000	0	338			30				
12500	0	4413			38				
15000	0	5480			44				
17500	0	5548			47				
	200	547.5	3	3	54	49	5	5	2
17500	400	547	3	6	62	51	12	6	2
17500	600	546.5	3	9	70	53	17	8	3
	800	546	3	17	78	55	23	6	2
17500	1000	545	8	25	86	57	29	4	1
	1200	544	8	33	97	59	38	5	2
	1400	543	8	41	109	61	48	7	3
17500	1600	542	8	49	123	63	60	12	4
	1800	540	18	67	144	65	79	22	8

Broke into two pieces angle 34° Ultimate load 1840 lb

2E 15000

1	2	3	4	5	6	7	8	9	10
2500	0	151			18				
5000	0	239			23				
7500	0	325			28				
10000	0	409			335				
12500	0	485			389				
15000	0	559			48				
					59	50	9-	9	3
15000	400	558	8	8	69	52	17	9	3
	600	557	8	16	78	54	24	8	3
	800	556.5	3	19	84	56	28	9	3
15000	1000	556.0	3	22	93	58	35	13	5
	1200	555	8	36	102	60	42	12	4
	1400	554	8	38	114	62	52	14	5
15000	1600	553	8	46	126	64	62	16	6
	1800	552	8	54	140	66	74	20	7
	2000				158	68	90		

Ultimate load 2000 lb

Piece Damaged

3E0

1	2	3	4	5	6	7	8	9	10
0	200				15	8	7		
0	400				19.5	10	9.5		
0	600				24	12	12		
0	800				28	14	14		
0	1000				33	16	17		
0	1100				40	18	22		
					45	20	25		

Ultimate load 1160 lb

Broke into two pieces 33°

3E 2500

1	2	3	4	5	6	7	8	9	10
2500	0	207			24				
2500	200	205	8	8	36	26	10	2	1
	400	204	8	16	45	28	17	1	0
2500	600	203.5	13	29	57	30	27	2	1
	800	202.5	8	37	67	32	35	2	1
	1000	201.5	8	45	77	34	43	2	1
2500	1200	200.5	13	58	88	36	52	6	2
	1400	199.5	8	66	100	38	62	4	1
2500	1600	198	13	79	120	40	80	1	0

Piece Damaged

Ultimate load 1600 lb

3E 5000

1	2	3	4	5	6	7	8	9	10
2500		152			20				
5000		237			32				
	200	236.5	3	3	42	34	8	5	2
5000	400	235.5	8	11	52	36	16	5	2
	600	234.5	8	19	61	38	23	4	1
5000	800	233.5	8	27	70	40	30	3	1
	1000	232.5	8	35	79	42	37	2	1
5000	1200	231.5	8	43	88	44	44	1	0
	1220	230.5	8	51	99	46	53	2	1
5000	1200	229.5	8	59	110	48	62	3	

Ultimate load 1220 lb

Broke into three pieces angles = 34° and 22°

3E7500

1	2	3	4	5	6	7	8	9	10
2500	0	393			22				
5000	0	490			36				
7500	0	573.5			50				
	200				58	52	6		
7500	400				66	54	12		
	600				74	56	18		
7500	800				82	58	24		
	1000				90	60	30		
	1200				100	62	38		
7500	1400				112	64	48		
	1460				131	66	65		

Ultimate load 1460 lb

Piece Damaged

3E 12500

1	2	3	4	5	6	7	8	9	10
2500	0	170			10				
5000	0	272			20				
7500	0	350			26				
10000	0	435			30				
12500	0	508.5			36				
	200				46	38	8	8	3
12500	400	507.5	8	8	57	40	17	9	3
	600	506.5-519.5	8	16	67-70	42	25	9	3
	800	518.5	8	24	80	44	36-	12	4
12500	1000	518		27	90	46	44	18	7
	1200	517	8	35	102	48	54	19	7
12500	1400	515.8	10	45	115	50	65	20	7
	1600	514.5	11	56	131	52	79	13	5
	1800	512.5	18	74	152	54	98	24	9

Ultimate load 1800 lb

Piece Damaged

3E 15000

1	2	3	4	5	6	7	8	9	10
2500	0	175			14				
5000	0	255			24				
10000	0	412			45				
15000	0	553			66				
	200	552.5-561	3	3	76	68	08-	5	2
15000		55							
	400	560	8	11	85	70	15	4	1
15000	600	559	8	19	95	72	23-	4	1
	800	558.5	3	22	103	74	29	6	2
	1000	558	3	25	113	76	37	12	4
15000	1200	557	8	33	123	78	45	12	4
	1400	556	8	41	135	80	55	14	5
15000	1600	554.5	13	54	152	82	70	16	6

Ultimate load 1600 lb

Broke into two pieces 32°

3E 17500

1	2	3	4	5	6	7	8	9	10
2500		125			24				
5000		215			29				
10000		373			47				
15000		415			65				
17500		577.5			74				
17500	200	577	3	3	86	76	10	7	3
	400	576	3	6	92	78	14-	6	2
17500	600	575.5	8	14	99	80	19	5	2
	800	574	13	27	107	82	25	0	
	1000	573	8	35	117	84	33-	0	
17500	1200	572.5	3	38	127	86	41	3	1
	1400	571.8	6	44	139	88	51	7	3
17500	1600	570.5	11	55	152	90	63	8	3

Ultimate load 1810 lb

Broke into two pieces 34°

4E 15000

1	2	3	4	5	6	7	8	9	10
2500	0	183			20				
5000	0	268			29				
7500	0	42							
10000	0	424			48				
12500	0	497			58				
15000	0	567			68				
	200	567.5	3	3	76	70	6	3	1
15000	400	566	3	6	86	72	14	8	3
	600	565.5	3	9	96	74	22	13	5
15000	800	565	3	12	105	76	29	17	6
	1000	564	3	15	115	78	37	22	8
	1200	563	8	23	125	80	45	22	8
15000	1400	562	8	31	136	82	54	23	9
	1600	561	8	39	150	84	66	27	10
	1700	559.5	13	52	165	26	79	27	10
15000	1000	556	33	65	200	88	112	47	17
	800	550	60	125	260	90	170	45	17

Ultimate load 1700 lb

Broke into two pieces 22°

4E 17500

1	2	3	4	5	6	7	8	9	10
2500	0	77			20				
5000	0	162			30				
7500	0	250			38				
10000	0	330			47				
12500	0								
15000	0	462			64				
17500	0	533.5			74				
	200	533	3	3	82	76	6	3	1
17500	400	533	8	11	97	78	13	2	1
	600	533	0	11	99	80	19	8	3
17500	800	533	0	11	106	82	25	7	3
	1000	532.5	0	11	115	84	31	20	7
17500	1200	532	3	14	125	86	39	25	9
	1400	531							
	1600	530.5	22	36	145	90	55	19	7
17500	1750	529.5	8	44	155	92	62	18	7
	1400	528	13	57	175	94	91	24	9

Piece damaged

Ultimate load 1700 lb

1G0

1	2	3	4	5	6	7	8	9	10
0	0								
	200				10	8	2		
	400				16	10	6		
	600				21	12	9		
	800				26	14	12		
	920				33	16	17		

Ultimate load 920 lb.

Broke into two pieces. Angle 29°

1G2500

2500	0	167			20				
	200	166	8	8	34	22	12	4	1
	400	165	8	16	45	24	21	5	2
	600	163.5	13	29	57	26	31	2	1
	800	162	13	42	75	28	57	15	6
	900	159	29	71	105	30	75	4	1
	600	156	24	95	135		102	7	3

Ultimate load 920 lb.

Piece damaged.

1G5000

1	2	3	4	5	6	7	8	9	10
2500	0	170			20				
5000	0	255			31				
	200					33			
	400	253	16	16	60	35	25	9	3
	600	252	8	24	71	37	33	9	3
	800	251	8	32	85	39	46	14	5
	900	249	18	50	105	41	64	14	5

Ultimate load 900 lb.

Broke into two pieces, small pieces. Angle 28°.

1G7500

1	2	3	4	5	6	7	8	9	10
2500	0	59			20				
5000	0	156			33				
7500	0	230.5			45				
	200	237.5	8	8	59	47	12	4	1
	400	236.5	8	16	73	49	24	8	3
	600	235	13	29	85	51	34	5	2
	800	233.5	13	42	97	53	44	+2	1
	1000	231	23	65	118	55	63	-2	1
	1200	227	29	94	155	56	99	5	2
	600	222	50	144	200		146	2	1

Ultimate load 1200 lb.

Broke into three pieces. Angles 31° and 22°

1G10, 000

1	2	3	4	5	6	7	8	9	10
2500	0	185			20				
5000	0	274			31				
7500	0	351			40				
10000		433.5			50				
	200	432.5	8	8	62	52	10	2	1
	400	431.5	8	16	74	54	20	4	1
	600	430	13	29	85	56	29	0	
	800	429	8	37	99	58	41	4	1
	1000	427	18	54	120	60	60	6	2

Ultimate load 1150 lb.

Broke into two pieces. Angle 28°

1G12, 500

1	2	3	4	5	6	7	8	9	10
2500	0	160			20				
5000	0	252			30				
7500	0	337			40				
10000	0	415			51				
12500		490			57				
	100	489	8	8					
	200	488.5	3	11	67	59	8	3	1
	300	488	3	14					
	400	487.5	3	17	79	61	18	3	1
	500	487.0	4	21					
	600	486	7	28	91	63	28	0	0
	800	485	8	36	103	65	38	2	1
	1000	483.5	13	49	120	67	53	4	1
	1090	480	34	83	155	68	87	4	1
	300	470	97	180	253		185	5	2

Ultimate load 1090 lb.

Piece damaged.

1G15,000

1	2	3	4	5	6	7	8	9	10
2500	0								
5000	0								
7500	0				40				
10000	0				52				
12500	0								
15000	0				73				
	200	253			79	75	4		
	400	254.5			94	77	17		
	600	253.5			109	79	30		
	800	252			125	81	44		
	1000	250			145	83	62		

Ultimate load 1100 lb.

Broke into two pieces. Angle 30°.

1G17,500

1	2	3	4	5	6	7	8	9	10
2500	0	70			20				
5000		163			33				
7500	0	260			47				
10000		321			57				
12500	0								
15000		456			74				
17500	0	524			81				
	200	524			89	83	6	6	2
	400	523			96	85	11	11	4
	600	523.5	3	3	105	87	18	15	6
	800	523	3	6	113	89	24	15	6
	1000	522.5	3	9	124	91	33	16	6
	1200	521.5	8	17	140	93	47	17	6
	1400	520	13	30	150	95	55	7	3
	1450	518	18	48	178	97	81		
		--stays slowly decreases							
	800	504	90	138	267	92	175	37	12

Ultimate load 1450 lb.

Broke into two pieces. Angle 28°

<u>2G0</u>

1	2	3	4	5	6	7	8	9	10
0	200				12	8	4		
0	400				19	10	9		

Ultimate load 400 lb

Broke two pieces Angle 27°

<u>2LG 2500</u>

1	2	3	4	5	6	7	8	9	10
2500	0	455			20				
	200	455			33	22	11		
2500	400	454			42	24	18		
	600	453			53	26	27		
	800	451.5			66	28	38		
2500	1000	458.5			86	30	56		
	1120	458			110		80		
2500	600	435			143		110		

Ultimate load 1120 lb

Broke into two pieces; some small pieces Angle 28°

<u>2G5000</u>

1	2	3	4	5	6	7	8	9	10
2500	0	209			20				
5000	0	308			35				
	200	307.5			46	37	9-		
5000	400	306.5			54	39	15		
	600	305.5			63	41	22		
5000	800	309.5			74	43	31-		
	1000	303.5			85	45	40		
	1200	302.0			97	47	50		
5000	1330	300			117	49	68		
	800	296			155	50	105		
5000	600	292			210	50	160		

<u>Ultimate load 1330 lb</u>

Broke into two pieces. Angle 27°. Some small pieces.

2G 7500

1	2	3	4	5	6	7	8	9	10
2500	0	289			20				
5000	0	376			36				
7600	0	467			51				
	200	466			65	53	12		
7600	400	464.5			79	55	24-		
	600	463.5			92	57	35-		
7600	800	462.5			103	59	44		
	1000	461.5			115	61	54		
	1040	460			131	63	68		
7600	1000	468.5			152	65	87		

Ultimate load 1040 lb

Broke two pieces. Angle 29°

2G 12500

1	2	3	4	5	6	7	8	9	10
2500	0	73			20				
5000	0	171			29				
7500	0	240			37				
1000	0	329			47				
12500	0	402.5			57				
	200				66	59	7		
12500	400				75	61	14		
12500	600	401.5			84	63	21		
	800	401			94	65	29		
12500	1000	400			107	67	40		
	1200	398			125	69	56		
	1300	395			160	70	90		
12500	1000	391			200		130		
	600	388			255		185		

Ultimate load 1300 lb

2G 10000

1	2	3	4	5	6	7	8	9	10
2500	0	228			20				
5000	0	325			31				
7500	0								
10000	0	489			49				
10000	200	489			60	51	9		
	400	488.5			68	53	15		
	600	488			78	55	23		
10000	800	487.5			87	57	30		
	1000	486.5			95	59	36		
10000	1200	485.5			110	61	49		
	1400	484			125	63	62		
10000	1000	482			155	65	90		

Ultimate load 1400 lb

Broke into two pieces. Angle 30°

2G 15000

1	2	3	4	5	6	7	8	9	10
2500	0				20				
5000	0	188			28				
7500	0	276			36				
10000	0	357			47				
12500	0	425			54				
15000	0	488			67				
	200	489			77	69	8		
	400	488.5			88	71	17		
	600	488			98	73	25		
	800	487.5			107	75	32		
	1000	486.5			117	77	40		
	1200	485.5			131	78	52		
	1400	484			145	81	64		
	1000	482			168	83	85		
	1700	480			190	84	106		
	1200	475			260		165		
	800	472			390		305		

2GI 7500

1	2	3	4	5	6	7	8	9	10
2500	0	32			20				
5000	0	136			36				
7500	0	227			45				
10000	0	300			55				
12500	0	373			63				
15000	0	439			71				
17500	0	505			80				
	200	505			88	82	6		
17500	400	505			95	84	11		
	600	504			105	86	19		
	800	503			116	88	28		
17500	1000	502			130	90	40		
	1100	500			151	92	59		
	1160	497			187	93	94		
17500	800	492			242				

Ultimate load 1160 lb

3G0

0	200				17	8	9		
0	400				24	10	14		
0	570				31	12	19		

Ultimate load 570 lb

Broke into two pieces. Angle 29°

3G 2500

2500	0	158			13				
	200	149			25	15	10		
	400	148			36	17	19		
	600	147			48	19	29		
2500	800	146			65	21	44		
	1000	144			88	23	65		

Ultimate load 1000 lb

Broke into two pieces. Some small pieces Angles 30° and 29°

3G 5000

1	2	3	4	5	6	7	8	9	10
2500	0	220			21				
5000	0	300			32				
	200	299			39	34	05		
5000	400	298			51	36	14		
	600	297			63	38	25		
5000	800	296			81	40	41		
	1000	295			104	42	62		
5000	1100	293			120	44	76		

Broke into two pieces Angle 22° Some small pieces.

3G 10000

1	2	3	4	5	6	7	8	9	10
2500	0	170			7				
5000	0	269			12				
7500	0	351			15				
10000	0	432			21				
	200	432			33	23	10		
10000	400	431			45	25	20		
	600	430			58	27	31		
10000	800	429			71	29	42		
	1000	428			85	31	54		
10000	1200	426			99	33	66		
	1300	424			114	35	79		

Ultimate load 1300 lb

Broke into two pieces Angle 29°

3G 12500

1	2	3	4	5	6	7	8	9	10
2500	0	53			20				
5000	0	149			34				
7500	0	227			44				
10000	0	299			54				
12500	0	373			63				
	200	373			70	65	5		
12500	400	372.5			81	67	14		
	600	372			91	69	23		
	800	371.5			102	71	31		
	1000	370.5			112	73	39		
	1200	369.5			125	75	50		
	1400	368			142	77	65		
12500	1600	363			198	79	119		
	1200	359			240		160		
	1000	357			268		190		

Ultimate load 1600 lb

Piece damaged

3G 15000

1	2	3	4	5	6	7	8	9	10
2500	0	170			20				
5000	0	250			30				
7500	0								
10000	0	407			47				
12500	0								
15000	0	548			68				
15000	200	548			78	70	8		
	400	447.5			91	72	19		
15000	600	546.5			104	74	30		
	800	545.5			118	76	42		
	1000	544			133	78	55		
15000	1200	542.5			150	80	70		
	1350	540			164	81	83		

Ultimate load 1350 lb

Price damaged -

3G 17500

1	2	3	4	5	6	7	8	9	10
2500	0	130			20				
5000		220			26				
7500	0								
10000		378			43				
12500	0								
15000		420			62				
17500	0	582			72				
17500	200	581			81	74	7		
	400	580			98	76	22		
17500	600	578			115	78	37		
	800	576			134	80	54		
	1000	574			156	82	74		
17500	1200	572			179	84	95		
	1300	570			196	86	110		

Ultimate load 1300 lb

Broke into two pieces. Angle 28°

110

0	200				22	8	14
0	400				33	10	23

Ultimate load 400 lb

Broke into many pieces.

112500

2500	0	69			20				
	200	67.5	13	13	40	22	18-	6	2
2500	400	66	8	21	55	24	31	10	4
	600	65	8	29	69	26	43	14	5
2500	800	63.5	13	42	82	28	54-	12	4
	1000	62	13	55	100	30	70	15	6
	1200	59	28	83	130	32	98	15	6

Ultimate load 1240 lb

Broke into three pieces. Angles 24° and 18°

11 5000

1	2	3	4	5	6	7	8	9	10
2500	0	226							
5000	0	332			20				
	200	331			33	22	11-		
5000	400	330			54	24	30		
	600	299.5			62	26	36		
5000	800	299			74	28	46-		
5000	1000	298			88	30	58		
	1200	297			103	32	71		

Ultimate load 1200 lb

Broke into two major pieces with several small pieces angle 22°

11 7500

2500	0	322			20				
5000	0	411			34				
7500	0	515			57				
7500	200	514.5	3	3	68	59	9-	6	2
	400				78	61	17		
7500	600	514	3	6	90	63	27	21	8
	800	513	8	14	105	65	40-	26	10
	1820	512	8	22	120	67	53	31	11
7500	1200	510.5	13	35	138	69	69	34	13
	1400	508.5	18	53	165	71	94	41	15

Ultimate load 1440 lb

Broke into two major pieces Angle 22°

11 10000

2500	0				20				
5000	0				35				
7500	0	60			57				
10000	0	147.5			79				
	200	146.5	8	8	99	81	18-	10	4
10000	400	145	13	21	121	83	38	17	6
	600	144	8	29	139	85	54	25	9
10000	800	143	8	37	159	87	72-	35	13
	1000	141.5	13	50	177	89	88	38	14
10000	1050	140	13	63	195	91	104	41	15

Ultimate load 1050 lb

Piece damaged

II 12500

1	2	3	4	5	6	7	8	9	10
2500	0	184			20				
5000	0	276			36				
7500		361			57				
10000	0	437			80				
12500	0	523			129				
	200	523			144	131	13-		
12500	400	522.5	3	3	162	133	29-	26	10
	600	521.5	8	11	181	135	46	35	13
	800	520.5	8	19	204	137	67	48	17
12500	1000	519	13	32	223	139	84	52	19
	1200	517	18	50	250	141	109	59	22
	1220	515.5	13	63	270	143	127	64	24

Ultimate load 1220 lb

II 15000

1	2	3	4	5	6	7	8	9	10
2500	0	12			21				
5000	0	102			31				
10000	0	259			62				
12500	0	343			89				
15000	0	415			140				
	200				150	142	8-		
	400	414.5	3	3	166	144	22-	19	
15000	600	414	3	6	181	146	35	29	
	800	413	8	14	202	148	54	40	
15000	1000	412	8	22	222	150	72	50	
		410.5	13	35	245	152	93	58	
	1280	409	13	48	270	154	116	68	
15000	1000	407.5	13	61	291	156	135	74	

Ultimate load 1280 lb

Broke into two pieces. Angle 24°

11 17500

1	2	3	4	5	6	7	8	9	10
2500	0	54			20				
5000		148			28				
7500	0	244			40				
10000	0								
12500		286			80				
15000	0	467			100				
17500		532.5			125				
	200	531.5	8	8	151	127	24		
17500	400	530	13	21	171	129	42		
	600	529	8	29	188	131	57		
	800	528	8	37	206	133	73		
17500	1000	526.5	11	48	222	135	87		
						137			
	1200	523.5	24	72	238	139	99		
17500	1300	521.5	16	88	275	41	134		

Ultimate load 1300 lb

Piece damaged.

210

1	2	3	4	5	6	7	8	9	10
					16	8	8		
0	200				26	10	16		
0	400				37	12	25		
0	500								

Ultimate load 500 lb

Broke into two major pieces with some small pieces Angles 23° and 21°

21 2500

1	2	3	4	5	6	7	8	9	10
2500	0	240.5			20				
	200	239.5			36	22	14-		
2500	400	238			49	24	25		
	600	237			61	26	35		
	620	235.5			75	28	47-		
2500	400	233.5			92	30	62		

Ultimate load 620 lb

Broke into two pieces with some small pieces angle 21°

21 5000

1	2	3	4	5	6	7	8	9	10
2500	0	267			20				
5000	0	362			29				
5000	200								
5000	400	360			52	33	19		
5000	600	359			62	35	27		
5000	200	358			75	37	38		
	900	356			93	39	54		

Ultimate load 900 lb

Piece damaged.

21 7500

1	2	3	4	5	6	7	8	9	10
2500	0	160			20				
5000	0	240			30				
7500	0	329			38				
	200	328			51	40	11-		
7500	400	327.5-339			65-69	46	23		
	600	337.5			82	48	34		
7500	800	336.5			96	50	46-		
	1000	335			112	52	60		
	1200	333			133	54	79		
7500	1260	330			170	56	114		

Ultimate load 1260 lb

Broke into two pieces   Angle 20°

21 10000

1	2	3	4	5	6	7	8	9	10
2500	0	240			20				
5000	0	326			30				
7500	0	415			42				
10000	0	492			54				
	200	491.5			66	56	10		
10000	400	491			73	58	15		
	600	490.5			85	60	25-		
	800	490			98	62	36		
10000	1000	490.5			115	64	51		
	1200	498			135	66	69		
10000	1250	496			170	68	102		
	1000	494			190	70	120		

Ultimate load 1250
Piece damaged

21 12500

1	2	3	4	5	6	7	8	9	10
2500	0	198			20				
5000	0	283			32				
7500	0	373			42				
1000	0	444			54				
12500	0	520			64				
	200	520			73	66	7-		
12500	400	519			82	68	14-		
	600				93	70	23-		
12500	800	518			105	72	33-		
	1000	517			120	74	46		
	1200	514.5			195	76	69		
12500	1360	510			195	78	117		
	1000	508			230	80	15		

Piece damaged. Ultimate load 1350 +

21 17500

1	2	3	4	5	6	7	8	9	10
2500	0	51			20				
5000	0	142			25				
7500	0	220			35				
10000	0	295			46				
12500	0	374			58				
15000	0	441			68				
17500	0	500			77				
	200				81	79	3-		
	400				91	81	10		
17500	600	499.5			100	63	17		
	800	499			111	65	26-		
17500	1000	498.5			125	86	38		
	1200	497.5			143	89	54		
17500	1400	495			168	91	77		
17500	1500	491.5			210	92	118		
	1000	485			280	94	186		

Ultimate load 1500 lb.

Broke into two pieces, Angle 28°

21 15000

1	2	3	4	5	6	7	8	9	10
2500	0	164			20				
5000	0	255			26				
7500		332			40				
1000		413			52				
12500	0	486			63				
1500		557			75				
	260	557			86	77	9-		
	400	557			92	79	13		
	600	556.5			104	81	23-		
	800	556			116	83	33-		
	1000	555.5			131	85	45		
	1200	554			155	87	67		
	1400	548			210	89	121		
	1000	540			285	91	194		

Ultimate load 1400 lb

Broke into two pieces angle 21°

310

1	2	3	4	5	6	7	8	9	10
0	200				14	8	6		
0	300				16	10	16		

Ultimate load 300 lb

Broke into two pieces. Angle 24°

31 2.5

1	2	3	4	5	6	7	8	9	10
2500	0	175			20				
	200	173			41	22	19		
2500	400	171.5			55	24	31		
	600	170			67	26	41		
2500	800	168.5			80	28	52		
	1000	167			97	30	67		
2500	1140	163			140	32	108		

Ultimate load 1140 lb

31 5000

1	2	3	4	5	6	7	8	9	10
2500	0	109			20				
5000	0	208			33				
5000	200	207			44	35	9		
	400	206			62	37	25		
5000	600	204.5			81	39	42		
	800	203			100	41	59		
5000	900	201			119	43	76		

Ultimate load 920 lb

Broke into two pieces, with some small pieces. Angles 23° and 22°.

31 7500

1	2	3	4	5	6	7	8	9	10
2500	0	78			20				
5000	0	166			28				
75000	0	260			36				
	200	260			47	38	9		
75000	400	259.5			59	40	19		
	600	258.5			70	42	28		
75000	800	257			83	44	39		
	1000	255.5			100	46	54		
75000	1200	254			160	48	112		
75000	800	244			200	50	150		

Ultimate load 1200 lb

Broke into two pieces with some small pieces. Angle 24°

31 10000

1	2	3	4	5	6	7	8	9	10
2500	0	180			20				
5000	0	265			28				
7500	0								
10000	0	419			48				
	200	418.5			54	50	4		
10000	400	418			73	52	21		
	600	416.7			92	54	38		
	800	415			110	56	54		
10000	1000	413			130	58	72		
10000	1200	411			145	60	85		

Ultimate load 1270 lb

Broke into three major pieces. Angle 20°.

31 12500

1	2	3	4	5	6	7	8	9	10
2500	0	70			20				
5000	0	159			30				
7500	0	250			38				
10000	0	330			46				
12500	0	421			52				
	200	420			71	54	17		
12500	400	418.5			91	56	35		
	600	417			109	58	51		
	800	415			128	60	68		
12500	1000	413.5			147	62	85		
	1200	413			168	64	104		
	1280	410			178	66	112		

Ultimate load 1280 lb

Broke into two pieces. Angle 31°

31 17500

1	2	3	4	5	6	7	8	9	10
2500	0	63			20				
5000	0	156			27				
7500	0	243			37				
10000									
12500	0	382			58				
15000	0	452			66				
17500	0	519			75				
	200				82	77	5-		
17500	400	518.5			90	79	11		
	600	518			100	81	19		
17500	800	517			110	83	27-		
	1000	516			123	85	38		
	1200	515			110	87	53		
	1400	512			170	89	81		
17500	1480	510			195	90	105		
	1000	505			255	92			

Ultimate load 1480 lb

Piece damaged

Appendix 3

FAILURE OF A MATERIAL COMPOSED OF NON-ISOTROPIC ELEMENTS

by Anton Brandtzaeg

Mr. Brandtzaeg's failure theory has been discussed in the analysis section. In this section an abstract of the theory will be given. Mr. Brandtzaeg considers an elastic material with a constant Poisson's ratio, u, and modulus of elasticity, E. All elements have different directions of weaknesses and until a limiting tensile stress occurs they can only fail with a plastic sliding at a limiting shearing stress and that action is governed by Coulomb's equation.

$$\tau_{lim} = \tau_o \quad \tan \theta (\sigma) \tag{18}$$

In this theory different notations for elements and material have to be used to differentiate between the two. Notations for the material are the same as before, and for elements will be presented as they occur. In Equation 18 σ is the normal stress, σ_o is the shearing strength, θ is the angle of internal friction, and τ_{lim} is the limiting shearing stress in the elements.

From figure 35a the stresses on a plane in the direction of weakness are:

$$\sigma = \sigma_1 \sin^2 \phi + \sigma_2 \cos^2 \phi \tag{19}$$

$$\tau = \frac{\sigma_1 - \sigma_2}{2} \sin 2\phi \tag{20}$$

$$\sigma_v = \frac{1}{3}(\sigma_1 + 2\sigma_2) \tag{21}$$

where σ_1 and σ_2 are the normal stresses in axial and lateral directions respectively. Combining equations 19 and 21:

$$\sigma = \sigma_v + \frac{\sigma_1 + \sigma_2}{2}\left(\frac{1}{3} - \cos 2\phi\right) \tag{22}$$

where tan θ = cot 2 θ and $\phi_o = \frac{\pi}{4} - \frac{\theta}{2}$ introducing angle and

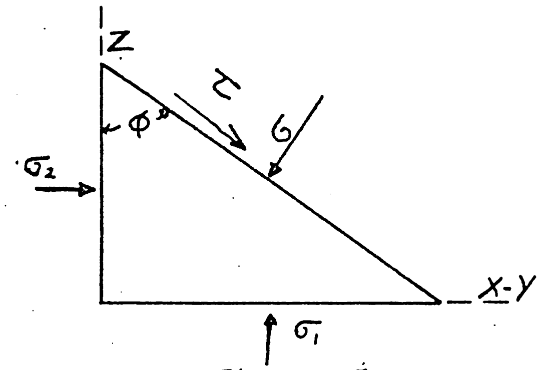
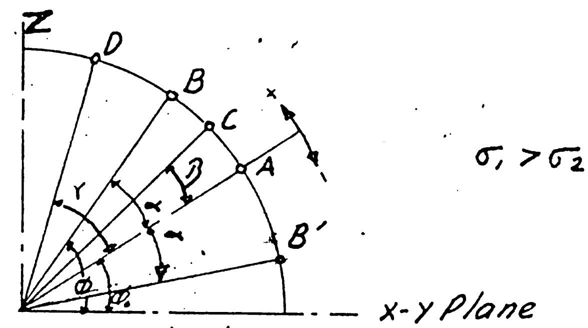


Figure 35 (a)



B to B_1 plastic elements
X-Y Plane to B_1 } elastic elements
B to Z axis }

Figure 35 (b)

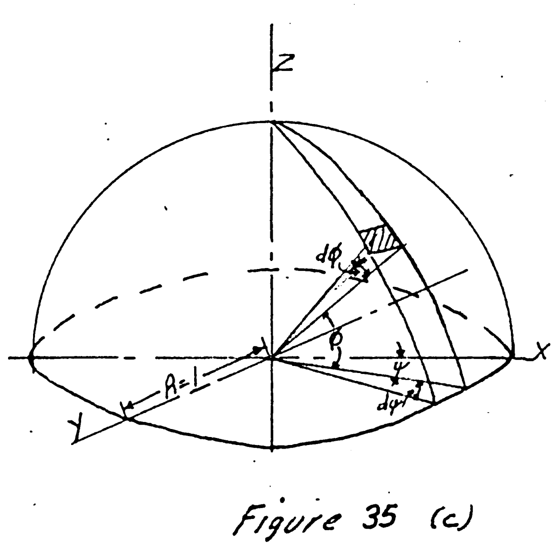


Figure 35 (c)

combining equations 18 and 20 and 22:

$$\left(\frac{\sigma_1 - \sigma_2}{2}\right)_{lim} = \frac{K + F\sigma_V}{\cos 2(\phi - \phi_0) - \frac{1}{3}F} \tag{23}$$

where $K = \tau_0 \sin 2\phi_0$; $F = \cos 2\phi_0$

This is the necessary condition for plastic equilibrium and a limiting value that the difference between the principal stresses can never exceed. If it is below this limit the element is elastic and as long as the stress difference is equal to this limit the element deforms plastically. Elements that have the lowest limiting stress difference values will reach the plastic stage first, for which ϕ will be equal to ϕ for $\sigma_1 > \sigma_2$.

Now consider figure 35b where plasticity spreads from point A to both directions. At A, $\phi = \phi_0$ where the elements first started to plastic action are represented. Points between B and B′, such as C, defined by angle β, have been deforming plastically for some time. Elements B and B′ with an angle α are just becoming plastic. Elements between the x-y plane and B′ or between the z-axis and B are elastic.

α: is a constant which defines the extent that loading has made the material plastic.

β: is a variable for a given stress situation defining plastic elements with the same direction of weaknesses.

γ: is a variable for a given stress situation defining elements in the elastic range.

Suffix γ and β are used for stresses in elastic and plastic elements respectively. Substituting in equation 23 we get stress difference equations for elastic and plastic elements. Stresses in elastic elements are the same as in an element just passing the plastic stage. Combining equations 21 and 23 with $B = \phi - \phi_0$ or $\alpha = \phi - \phi_0$ for plastic and elastic elements respectively the principal stresses in an elastic element are:

$$\sigma_{\gamma 1} = \sigma_v + \frac{2}{3}(\sigma_{\gamma 1} - \sigma_{\gamma 2}) = \sigma_v + 4\,\frac{K + F\sigma_v}{3\cos 2\alpha - F} \qquad (24a)$$

$$\sigma_{\gamma 2} = \sigma_v - \frac{1}{3}(\sigma_{\gamma 1} - \sigma_{\gamma 2}) = \sigma_v - 2\,\frac{K + F\sigma_v}{3\cos 2\alpha - F} \qquad (24b)$$

in a plastic element are:

$$\sigma_{\beta 1} = \sigma_v + 4\,\frac{K + F\sigma_v}{3\cos 2\beta - F} \qquad (25a)$$

$$\sigma_{\beta 2} = \sigma_v - 2\,\frac{K + F\sigma_v}{3\cos 2\beta - F} \qquad (25b)$$

Mr. Brandtzaeg assumes elements in a cubical shape with a side length d, so that the number of elements in a unit volume is:

$$N = 1/d^3$$

A unit volume contains all geometrically possible directions of weaknesses of the elements. Mr. Brandtzaeg further assumes normals of unit length from the origin of coordinates, to the direction of the weaknesses of the elements. These elements could be represented as a point on a hemisphere (Fig. 35c), which contains all elements in a unit volume. The number of elements in a small area of the hemisphere:

$$dN = \frac{N}{2\pi}\,dA = \frac{1}{2\pi d^3}\cos\phi\,d\phi\,d\psi \qquad (26)$$

In a unit volume N elements exert forces on each other. Some of these balance inside the unit volume. The number of forces that should be balanced by the average stress in the material is $N_f = N$, so that equation 26 becomes:

$$dN_f = \frac{1}{2\pi d^2}\cos\phi\,d\phi\,d\psi \qquad (27)$$

Substituting into equation 27 $\gamma + \phi_0$ or $\beta + \phi_0$ for ϕ, we find the elementary forces in dN_f elements in an axial direction, exerted by elastic elements:

$$df_{\gamma 1} = \frac{1}{2\pi}\,\sigma_{\gamma 1}\cos(\gamma + \phi_0)\,d\gamma\,d\psi$$

by plastic elements:

$$df_{\beta_1} = \frac{1}{2\pi} \sigma_{\beta_1} \cos(\beta + \phi_0)\, d\beta\, d\psi$$

In a lateral direction, exerted by elastic elements:

$$df_{\gamma_2} = \frac{1}{2\pi} \sigma_{\gamma_2} \cos(\gamma + \phi_0)\, d\gamma\, d\psi$$

by plastic elements:

$$df_{\beta_2} = \frac{1}{2\pi} \sigma_{\beta_2} \cos(\beta + \phi_0)\, d\beta\, d\psi$$

The principal average stresses may now be obtained by double integration with respect to ψ (between limits 0 and 2 π) and γ or β (between $\phi = 0$ and $\phi = \pi/2$). This covers all the hemisphere and as a result all the elements in a unit volume. The equations for the principal average stresses are:

$$f_1 = \sigma_v + 4 R_\alpha (K + F\sigma_v) \qquad (28a)$$

$$f_2 = \sigma_v - 2 R_\alpha (K + F\sigma_v) \qquad (28b)$$

$$f_v = \frac{1}{3}(f_1 + 2f_2) = \sigma_v \qquad (28c)$$

where

$$R_\alpha = \frac{1 - 2\cos\phi_0 \sin\alpha}{3\cos 2\alpha - F} + \frac{\cos\phi_0}{6\sqrt{1/2 - 1/6F}} \ln \frac{\sqrt{1/2 - 1/6F} + \sin\alpha}{\sqrt{1/2 - 1/6F} - \sin\alpha} \qquad (28d)$$

Equation 28c shows that volume stress in the material is equal to the volume stress in an element. Combining equations 28a, b, and c:

$$f_1 = f_2 \frac{1 + 4FR_\alpha}{1 - 2FR_\alpha} + K \frac{6R_\alpha}{1 - 2FR_\alpha} \qquad (29a)$$

$$f_2 = f_1 \frac{1 - 2FR_\alpha}{1 + 4FR_\alpha} - K \frac{6R_\alpha}{1 + 4FR_\alpha} \qquad (29b)$$

$$f_v = \sigma_v = \frac{f_1 - 4KR_\alpha}{1 + 4FR_\alpha} = \frac{f_2 + 2KR_\alpha}{1 - 2FR_\alpha} \qquad (29c)$$

By substituting volume stress from equation 29c into equations 24 and 25, stresses in elements could be expressed in terms of principal average stresses. To find deflections, remembering that all elements deform alike, deformation of material is equal to deformation of individual elements. The unit deformation of the material is found by combining equations 21, 29c and 30 with values of stress differences.

For an elastic element equations of deflection are:

$$\varepsilon_1 = \frac{1}{E}(\sigma_1 - 2\mu\,\sigma_2) \tag{30a}$$

$$\varepsilon_2 = \frac{1}{E}\left[\sigma_2 - \mu(\sigma_1 + \sigma_2)\right] \tag{30b}$$