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WADC TECHNICAL REPORT 55-229

PERFORMANCE CHARACTERISTICS OF CUSHIONING MATERIALS IMPACTED UNDER A HEAVY WEIGHT HIGH IMPACT SHOCK MACHINE

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FOREWORD

This report was prepared by the Lowell Technological Institute Research Foundation under U. S. Air Force Contract No. AF 18 (600)-127. The contract was initiated under Project No. 6077, "Aerial Delivery Equipment", Task No. 73295, "Shock Absorbing Textiles", formerly RDO No. 612-12, "Textiles for High Speed Parachutes", and was administered under the direction of the Materials Laboratory, Directorate of Research, Wright Air Development Center, with Mr. J. H. Ross acting as project engineer.

This report covers the period of work from December 1954 to June 1955.

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ABSTRACT

The energy absorption characteristics of cushioning materials impacted under a heavy weight high impact shock machine and analyzed by an analog computer system are reported. The dynamic performance curves in the form of graphs of energy versus maximum stress and maximum stress versus maximum strain are given for a wide variety of materials.

PUBLICATION REVIEW

This report has been reviewed and is approved.

FOR THE COMMANDER:

M. R. WHITMORE
Technical Director
Materials Laboratory
Directorate of Research

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Contrails

TABLE OF CONTENTS

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Contrails

LIST OF TABLES

Approved for Public Release

Contrails

LIST OF TABLES (Continued)

Approved for Public Release

Contrails

LIST OF ILLUSTRATIONS

Approved for Public Release

Contrails

Approved for Public Release

Contrails

Approved for Public Release

Contrails

Approved for Public Release

Contrails

Approved for Public Release

Contrails

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Contrails

Approved for Public Release

Contrails

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Contrails

Approved for Public Release

Contrails

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Contrails

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Contrails

INTRODUCTION

Test Apparatus

The construction of test apparatus designed to evaluate the dynamic characteristics of cushioning materials has been described in a previous report.* Since the results reported herein were determined by means of that test facility, a brief summary of its description is presented.

A pneumatically-driven, flat impact hammer is made to impact cushioning material specimens supported on a rigid and essentially immovable anvil. An electrical contactor attached to the hammer runs along a vertical, linear resistance strip. The output voltage developed as the impact hammer compresses the test specimen provides a direct measurement of the displacement of the hammer as a function of time. During the impact, this voltage-time relationship is applied to an analog computer which automatically produces on an oscilloscope screen a simultaneous record of the displacement, velocity, acceleration, and energy voltage-analogs as a function of time. A camera provides a permanent record of the impact which is later analyzed for the actual physical values using formulae and scale factors based on the analog computer settings. This shock machine was designed and constructed to be used in the investigation of the performance of cushioning materials as described below.

Area of Investigation

The scope of the test conditions was determined on the basis of use of the cushioning materials considered in this work, namely, the aerial delivery of heavy cargos. These basic test conditions define the area of investigation.

1. The impacting hammer, throughout these tests, has a static weight of 1.28 psi over the area of the sample.

2. The circular test samples are 24 inches in diameter with nominal thicknesses of 2, 4, and 6 inches.

3. The velocity of the impact hammer at the time of initial contact with the test sample is varied from 20 to 50 ft/sec in increments of 5 ft/sec.

4. Tests are taken at three temperatures: $-67^{o}F$, $70^{o}F$, and $160^{o}F$.

* "Design and Development of a Heavy Weight High Impact Shock Machine." WADC Technical Report 54-573

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Criteria of Cushioning Material Performance

In any impact, there exists a force-time relationship where the force decelerating the impacting element generally increases with time to a maximum value and then falls off to zero. In the case of a cushioned package, the damage incurred by the protected item depends upon both the maximum value of the impact force and upon the shape of the force-time pulse; both the elements of force and time determine the amount of permanent deformation. The effect of force is patent; that of time is probably related to the ability of the material comprising the protected item to adjust and to accommodate itself, in a given time, to changes in force. Perhaps a study of the derivative of acceleration with respect to time in cushioned impacts would be pertinent. The time factor, as is well known, is also related to the natural frequency of vibration of the protected item; a pulse of the proper frequency can give rise to dangerous amplitudes of oscillation. However, both of these effects of time are related to the nature of the protected item and not to the cushion itself, although the cushion is the causative factor.

To establish a more easily measured criterion of cushioning material performance, one may reason as follows. In these several tests, the impacting element is always the same as regards the physical characteristics of size, weight, and construction. Now, for a given velocity of the impact hammer, the change in momentum (mass times velocity) which is experienced when the hammer velocity is reduced to zero, is always the same. Since by the impulse-momentum theorem, where the impulse or the area under the force-time curve, must equal the change in momentum, this area must also always be constant. Then, if one considers the maximum value of the force experienced in an impact as a measure of cushioning material performance, a cushion giving a lower value of maximum impact force would have to be accompanied by a longer pulse duration. If this were otherwise, the criterion of maximum force would be less valid. Actually, maximum acceleration in Gs (1G = 32.2 ft/sec) is measured in these tests rather than force. The maximum stress, for large values of acceleration is equal to the maximum acceleration times the static weight of the hammer.

To study the performance of the cushion under different entry velocities, the energy of the impact hammer at entry is plotted versus the maximum stress.

Similar to the load-deflection curves obtained from static measurements, dynamic maximum stress - maximum strain curves for the range of test velocities were plotted. Also, other data are presented in tabular form.

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PROCUREMENT OF MATERIALS

Early in the test program, manufacturers of cushioning materials or of materials which might be used for that purpose, were invited to participate in a cooperative program wherein selected materials would be tested in an effort to evaluate their performance under these special test conditions. An attempt was made to include as many different materials as necessary to represent the various categories used in the packaging field. The number of materials used in the packaging industry are many; consequently some cushioning materials may have been omitted inadvertently.

Large quantities of the materials tested in this program were required because of the comparatively large dimensions of each test specimen, the range of test velocities and the three different temperature conditions studied, and the desire to test each material at its optimum performance, that is, without subjecting a particular sample to repeated loading. For some materials, repeated loading was necessary. The failure of others to withstand repeated loading and the insufficient amounts of such materials on hand did not permit completion of the tests. Nevertheless, sufficient data were obtained to permit a comparison of the various cushioning materials.

Descriptions of the materials tested are presented in Table 1. Each material is identified in the report by the number assigned it in this table. The manufacturers of the materials and their (the manufacturers') designations for the materials are presented in the Appendix.

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PREPARATION OF TEST SPECIMENS

Fabrication of Test Specimens

Test specimens were fabricated in the shape of circular cylinders; the diameter of the circular bases was 24 inches and the thickness of the specimen was either 2, 4, or 6 inches. Sufficient layers of material were used to provide the aggregate thickness. Some of the specimens were cut with a band saw, others with shears. Fibrous materials which were in the form of layers were, in general, laid flat. Some of these materials, as duly noted, were arranged in rolls for end loading, that is, the rolled material was positioned so that the impact hammer would descend upon an end of it. In all cases, the 24 - inch diameter dimension was parallel to the flat surface of the impact hammer.

Conditioning of Test Specimens

For the tests at standard conditions, specimens were stored for 5 days on racks in the air-conditioned testing room maintained at 70° F and 65% relative humidity.

Cushioning materials tested at -67° F and 160° F were conditioned in a temperature chamber for three to four hours. At the time of the test, the specimen was removed from the temperature chamber, placed on the anvil, and impacted. (This operation takes no more than thirty seconds, but, undoubtedly permits a small temperature change to take place in the specimen.)

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THICKNESS MEASUREMENTS

Original Thickness

Original thickness was determined by loading the specimen uniformly with a plate to 0.02 psi. Measurements were taken on the circumference at 90° intervals and averaged.

Nominal Thickness

Since the actual thickness of each specimen was not an integral number of inches, depending on the thickness of the smallest layers comprising the aggregate thickness, nominal thickness refers to the nearest integral number of inches in the original thickness.

Static Load Thicknesses

The static load thickness under the stationary weight of the impact hammer (1.28 psi) before impact was determined by measurements of the cushion after the hammer had been allowed to rest on it for 30 seconds.

The static load thickness under the stationary weight of the impact hammer after impact was determined by taking measurements 30 seconds after the impact.

Thickness Before Impact

After the static load thickness before impact is obtained, the hammer is hoisted preparatory to firing. The thickness of the cushion at this time is referred to as the thickness before impact.

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OSCILLOSCOPE RECORD OF IMPACT

Explanation of Record

As mentioned earlier, the impact is recorded by photographing the face of the oscilloscope during the test. Figure 1 describes such a record. The moment of hammer entry is determined from the displacement curve using the measured projection of the linear resistance strip above the cushion. The physical values of the various curves are found by substituting the appropriate voltage readings and analog computer settings into the mathematical formulae developed in the work presentd in WADC Technical Report 54-573. Slide rule calculations complete the analysis.

Examples of Records

Figure 2 shows twelve photographs of the approximately 5-inch screen of the oscilloscope during various impacts. In these photographs, certain analog computer settings were adjusted by the operator to be different from one impact to the other in order to prevent maximum values from going off-scale.

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PRESENTATION OF RESULTS

Discussion of Terms Used

Several terms used in the figures and tables that present the results of this investigation are discussed in the following.

Energy Per Unit Volume is the kinetic energy (one-half the hammer mass times the square of the velocity) of the impact hammer just prior to impact. The hammer weight is 577 lbs; the unit volume is based upon the cross-sectional area of the 24-inch diameter sample and its original thickness.

Entry Velocity is the velocity of the impact hammer just prior to impact.

Maximum Stress is the maximum impact force occurring in the impact per square inch of contact area. It is given by the product of the maximum acceleration in Gs and the static weight of the impact hammer.

Maximum Force is the maximum value of force occurring in the impact over the whole area of the test specimen.

Maximum Compression is the maximum value of the compression or change in thickness occurring in the impact.

Maximum Strain is the ratio of the maximum compression to the thickness before impact. Materials subjected to repeated cycling would give less consistent values if the maximum strain had been referred to the original thickness.

Strain Before Impact under 1.28 psi load is the ratio of the compression of the sample under the static weight of the hammer before impact to the original thickness. Measurements were taken 30 seconds after the hammer was allowed to rest on the sample.

Strain After Impact under 1.28 psi load is the ratio of the compression in the sample under the static weight of the hammer 30 seconds after impact to the thickness before impact.

Resilience is the ratio, expressed as a percentage, of the energy returned to the impact hammer by the cushion during restitution, to the energy transferred to the cushion by the impact hammer during compression. The energy lost to the cushion (and transformed into internal energy) is the difference between the energy returned, and the energy transferred. Thus, $\text{Resilience} = \frac{\text{Energy Returned}}{\text{Energy Transferred}} \times 100\ (\%)$.

For an ideally elastic impact, the resilience is 100%; for an ideally

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inelastic impact, the resilience is zero. Since the kinetic energy varies as the square of the velocity, the ratio of the rebound or exit velocity to the entry velocity is given by the square root of the fractional resilience.

The energy returned is computed as the kinetic energy of the impact hammer upon rebound and energy transferred is computed as the kinetic energy of the impact hammer at entry. Although this does not take into account the energy lost to the environment as shock and vibration, the error is small; accepting this error is considered justified by virtue of the considerably greater amount of time that would be required to measure by integrating over the force-displacement function.

The Results In Graphical Form

Graphs of Energy per Unit Volume versus Maximum Stress and graphs of Maximum Stress versus Maximum Strain are presented for Materials Nos. 1 - 36 in Figures 4 through 193 inclusive. Since the kinetic energy is a function of the mass of the impact hammer and the square of the velocity, it was possible to draw a non-linear velocity scale along the energy axis. Of course, this velocity scale is valid only for the particular hammer mass used herein. The curves shown were drawn through or near plotted points representing impacts of about 5 ft/sec apart. The tests represent approximately 600 recorded and analyzed impacts.

Unless otherwise indicated on the figures, the results refer to the 70°F temperature condition. For the materials considered more effective, results are also shown for the conditions of -67°F and 160°F along with their counterpart graphs at 70°F when sufficient material was available to produce a complete curve.

Some of the figures relate to tests where the same specimen was impacted successively starting with the lower velocities. Cushioning materials in this category are Materials Nos. 5, 6, 7, 8, 9, 10, 11, and 13.

The Results In Tabular Form

In order to present strain data, values of resilience, and other information, test results are also given in tabular form for certain values of thickness and velocity. These appear in Tables 3 - 20 inclusive. Measurements for the strain before impact under the static weight of the hammer were not taken under the temperature conditions of -67°F and 160°F in order to minimize the time during which the temperature of the specimen was changing after it had been placed on the anvil preparatory to impact.

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The notation "No Data" under the Maximum Stress column in Tables 3 to 20 inclusive indicates that the maximum acceleration was too high to be recorded or that the material was not capable of being impacted safely at that velocity.

Table 20 summarizes the results for Materials Nos. 37 - 51 with data on impacts taken at various velocities. Insufficient quantities of these materials were on hand to make complete tests.

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VALIDITY OF THE DATA

Duplicability

The following test was made as a measure of the ability of the test apparatus to give identical results on separate specimens of a given cushioning material when tested a number of times under the same conditions. Four separate samples of Material No. 34, similar with respect to past history and subject only to the inherent variability associated with the process of manufacture, were impacted consecutively. An attempt was made to impact each at the same velocity within the limits of control of the impact hammer. The results are shown in Table 2. It is seen that the range of maximum acceleration values is consistent with the range of velocity values and the two lesser values of entry velocity have, associated with them, the two lesser values of maximum acceleration.

Statistical Problems

Under ideal test conditions, from the standpoint of obtaining statistical results on these materials, each impact might have been repeated several times, perhaps five, in order to obtain an average for the various physical values qualifying the impact. If this were done, the number of tests required would have reached large proportions. The number of tests for each material would be 3 temperature conditions times 3 thicknesses times 7 velocities times 5 repetitions, i.e., a total which would exceed 300 impacts. If each cushioning material specimen were impacted only once in order not to introduce the effects of repeated cycling, a cylindrical stack of cushions 24 inches in diameter and 105 ft. high would be required for each material tested under the various test conditions stated above. Instead, it was decided to make a general survey of cushioning materials at a sacrifice of statistical results embracing these limitations.

1. Specimens of materials on hand in insufficient amounts were impacted successively if the deterioration of the sample was not marked. These were Materials Nos. 5, 6, 7, 8, 9, 10, 11, and 13.

2. Tests at -67°F and 160°F were conducted only on 6-inch specimens of Materials Nos. 1 - 14, as permitted by quantities of each material on hand. Materials in this group which were not tested at these temperatures were Materials Nos. 2, 3, 12, and 14.

3. No repetitions of the same test under the same conditions were made to obtain a statistical average.

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Limitation of Maximum Shock Recordable

When the performance of a cushioning material deteriorated under increasingly stringent test conditions, the resulting short duration and high-valued force-time function would cause the velocity and acceleration curves to go off-scale as a result of the inability of the analog computer system to follow excessively high frequencies. Testing was terminated at that point, making it impossible to continue throughout the full range of desired test velocities. Although this difficulty may in part be obviated by the graphical method of analysis whereby double graphical differentiation of the displacement curve was possible, this was not done in the general test program since the failure of the cushion had been established; also, there is a limit to the maximum shock that the hammer can safely withstand.

Overall Accuracy of Results

Comparisons were made of the values of velocity and acceleration resulting from the analog computer output with those obtained by double graphical differentiation of the displacement analog. The results were in good agreement, differing by an amount less than the error in reading and estimating the voltage values by means of the volt calibration lines. The displacement analog is simply a record of the voltage developed by the hammer as it falls through the sample as a function of time. There is no reason to believe that measurements of voltage and time under these conditions suffer from a lack of precision.

In view of the several settings, readings, and adjustments required to effect a complete analysis of displacement, velocity, and acceleration in an impact, the overall accuracy is problematical. However, it is believed to be less than the inherent variability existing in the cushioning material specimens.

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DISCUSSION OF RESULTS

The test results reported relate to the performance of the materials under special test conditions. No inference is made with respect to other uses intended for them by the manufacturer, either as a cushioning material or otherwise.

Comparison of Composite Curves

The Energy Per Unit Volume - Maximum Stress curves are compared in Figure 3 for those materials on hand in sufficient amounts for complete tests. It should be noted that the range in maximum stress values is much smaller at the velocity of 20 ft/sec than at the velocity of 50 ft/sec where the higher-numbered materials extend to larger values of stress. Many of these have values of maximum stress at 20 ft/sec not appreciably different than those of more effective materials; in fact, the stress is less in some cases.

Of the materials tested, the expanded polystyrenes are the best energy absorbers. However, for Materials No. 2 and No. 3, the values of strain after impact indicate a serious amount of permanent set; also, for the low density polystyrene, Material No. 3, the maximum stress increases rapidly as the entry velocity increases beyond about 43 ft/sec.

Material No. 4 (wood fibreboard), Material No. 5 (the high density wool pad), and Material No. 6 (cane fiber board), in that order, follow the expanded polystyrenes in energy absorbing capacity.

The curves for the wool pads (Materials Nos. 5, 7, 8, 9, 10) at velocities less than 42 ft/sec show a correlation between density and performance, the higher density pads giving lower values of maximum stress. Beyond 42 ft/sec, some anomalies appear.

Materials Nos. 11 and 13, both expanded polyvinyl chloride, give low values of maximum stress at 20 ft/sec and then display larger values at the higher velocities. The higher density Material No. 11 shows a more favorable performance beyond 30 ft/sec.

Materials Nos. 12 and 14 are the best of the cotton wadding group tested. These two materials performed better when they were rolled for end loading than when they were laid flat.

Materials Nos. 16 - 36 give higher values of stress for comparable velocities.

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Effect of Temperature

The temperature effect upon Material No. 1 seems negligible within the precision of measurement possible. For the other expanded polystyrenes, Materials Nos. 2 and 3, insufficient data were obtainable to allow definite conclusions.

For material No. 4, wood fibreboard, there seems to be a negligible difference between its performance at 70°F and 160°F. At -67°F, there is a small decrease in effectiveness below 45 ft/sec and a small improvement above 45 ft/sec.

Although Materials Nos. 5, 7, 8, 9, and 10, the wool pads, and Material No. 6, cane fiber board, displayed some deterioration in performance at the low and high temperatures, it is quite possible that this was due to the fact that the same specimen was impacted in each case, i.e., the one sample was used for all determinations made consecutively. The order of the tests was towards increasing velocity; the tests at 160°F and -67°F followed the tests at 70°F.

Material No. 11, a polyvinyl chloride, exhibits a marked reduction in performance at the temperature of 160°F. It then shows a marked improvement in energy absorption at -67°F; however, this is based upon data obtained at only two velocities. At 16 ft/sec the sample broke into pieces; at 46 ft/sec it crumbled into powdered fragments.

The performance of Material No. 13, another polyvinyl chloride, was similarly affected by temperature, except that the sample did neither crumble nor break within the range of test velocities.

Some Aspects of Future Work

Cushioning materials giving the lowest values of maximum stress at 20 ft/sec do not give the lowest values at 50 ft/sec. It is conceivable that a combination of different cushioning materials or layers of different densities of the same cushioning material may be devised to give a more uniform and acceptable performance under a wide range of velocities.

Cellular structures are a promising group of materials. Tests on a type of paperboard material with a cellular structure have been conducted with the impact shock machine.*

Another item of interest is the correlation and comparison of results obtained from static tests with those obtained by dynamic means.

The design of gross textile structures based upon the understanding of the behavior of the small scale components has attracted increased attention; similar theoretical studies on cushioning materials are indicated.

*"Performance characteristics of Paper Honeycomb Cushioning Materials Impacted Under a Heavy Weight High Impact Shock Machine," WADC TR55-343.

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TABLE 1

DESCRIPTION OF CUSHIONING MATERIALS TESTED

Material Number	Description
1	Expanded polystyrene, 4.3-4.7 lbs/cu ft
2	Expanded polystyrene, 2.8-3.2 lbs/cu ft
3	Expanded polystyrene, 1.6-2.0 lbs/cu ft
4	Asphalt impregnated wood fibreboard
5	Extra firm wool pad, SAE Spec. No. F-3 20.8 lbs/cu ft
6	Cane fiber board 14-18 lbs/cu ft
7	Soft wool pad, SAE Spec. No. F-26 9.63 lbs/cu ft
8	Firm wool pad, SAE Spec. No. F-13 11.3 lbs/cu ft
9	Extra Firm wool pad, SAE Spec. No. F-7 16.4 lbs/cu ft
10	Soft wool pad, SAE Spec. No. F-26 9.63 lbs/cu ft
11	Polyvinyl chloride foam plastic 12 lbs/cu ft
12	Cotton wadding (blue) in rolls for end loading
13	Expanded unicellular polyvinyl chloride 6-8 lbs/cu ft
14	Cotton wadding (black) in rolls for end loading
15	Laminated crepe paper, 17 ply, in rolls for end loading
16	Cotton wadding (blue)
17	Cotton wadding (white) in rolls for end loading
18	Cotton wadding
19	Cotton wadding (black)
20	Cotton wadding in rolls for end loading
21	Cotton wadding (white)
22	Crepe cellulose wadding in rolls for end loading
23	Rubberized, curled, tampico fiber in rolls for end loading, 3.38 lbs/cu ft
24	Rubberized, curled, tampico fiber, 3.38 lbs/cu ft
25	Rubberized, curled, tampico fiber, 2.63 lbs/cu ft
26	Rubberized, curled, tampico fiber, 2.91 lbs/cu ft

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TABLE 1 (Continued)

DESCRIPTION OF CUSHIONING MATERIALS TESTED

Material Number	Description
27	Resin-bonded felt wadding in rolls for end loading 4.6 lbs/cu ft
28	Resin-bonded felt wadding, 4.3 lbs/cu ft
29	Resin-bonded felt wadding, 4.1 lbs/cu ft
30	Resin-bonded felt wadding, 3.4 lbs/cu ft
31	Resin-bonded felt wadding, 2.4 lbs/cu ft
32	Resin-bonded wood fiber felt, 3 lbs/cu ft
33	White cotton wadding
34	Rubberized curled hair, firm
35	Rubberized curled hair, medium
36	Rubberized curled hair
37	Corrugated paper wrapping, single-faced
38	Corrugated paper wrapping, single-faced
39	Corrugated paper wrapping, single-faced in rolls for end loading
40	Corrugated paper wrapping, without facing
41	Corrugated paper wrapping, without facing
42	Corrugated paper wrapping, without facing
43	Corrugated paper wrapping, without facing in rolls for end loading
44	Alternate layers of asphalt impregnated wood fiber board and wood fiber felt
45	Corrugated compressed fibrpus glass, 9.6 lbs/cu ft
46	Glass fiber roll, 4 lbs/cu ft
47	Paper layers
48	Wood wool pads with kraft wrapping
49	Alternate layers of composition rubber and wood fiber felt
50	Bulk ceramic fibers in porous cloth bag
51	Asphalt coated paper sheets with a macerated paper filler

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TABLE 2

COMPARISON OF DATA FOR TESTS ON FOUR SAMPLES OF MATERIAL NO. 34

Original Thickness (in.)	Max. Strain (in./in.)	Entry Velocity (ft./sec.)	Max. Acceleration (Gs)	Resilience (%)
6.00	0.937	20.8	354	19.9
5.94	0.950	19.6	326	22.3
6.00	0.937	19.1	326	20.6
6.00	0.937	20.2	354	21.1

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TABLE 3

SUMMARY OF RESULTS FOR MATERIALS NOS. 1 - 14
Nominal Thickness: 6 in. - Entry Velocity: 50 ft/sec

Mat'l. No.	Temp. (°F)	Max. Stress (psi)	STRAIN: Before Impact (1.28 psi load)	Max. During Impact	After Impact (1.28 psi load)	Resilience (%)
1	-67	255	—	0.58	0.43	4
1	70	255	0.02	0.58	0.33	7
1	160	255	—	0.58	—	14
2	-67	-	—	—	—	—
2	70	645	0.02	0.79	0.79	8.5
2	160	-	—	—	—	—
3	-67	-	—	—	—	—
3	70	No data	0.02	—	—	—
3	160	-	—	—	—	—
4	-67	610	—	0.37	0.08	29
4	70	710	0.01	0.46	0.10	19
4	160	675	—	0.48	0.09	24
5	-67	840	—	0.51	0.12	44
5	70	710	0.03	0.52	0.08	—
5	160	710	—	0.56	0.09	33
6	-67	1220	—	0.47	0.04	45
6	70	735	0.01	0.44	0.03	20
6	160	965	—	0.49	0.08	23
7	-67	1170	—	0.76	0.47	33
7	70	890	0.24	0.75	0.32	28
7	160	No Data	—	—	—	—

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TABLE 3 (Continued)

SUMMARY OF RESULTS FOR MATERIALS NOS. 1 – 14
Nominal Thickness: 6 in. – Entry Velocity: 50 ft/sec

Mat'l. No.	Temp. (°F)	Max. Stress (psi)	STRAIN: Before Impact (1.28 psi load)	Max. During Impact	After Impact (1.28 psi load)	Resilience (%)
8	-67	1080	—	0.69	0.20	41
8	70	850*	0.09	0.69*	—	—
8	160	1030	—	0.76	0.24	33
9	-67	965*	—	0.62*	—	—
9	70	925	0.09	0.57	0.17	42
9	160	840*	—	0.67	0.17	37
10	-67	1130	—	0.75	0.36	30
10	70	790*	0.23	0.73	—	—
10	160	1295*	—	0.81	0.40	33
11	-67	760*	—	0.80*	Sample Crumbled	—
11	70	1175	0.28	0.87	0.32	29
11	160	No Data	—	—	—	—
12	-67	-	—	—	—	—
12	70	1205*	0.03	0.80*	—	—
12	160	-	—	—	—	—
13	-67	635	—	0.59	0.28	11
13	70	1360*	0.37	0.92*	—	—
13	160	No Data	—	—	—	—
14	-67	-	—	—	—	—
14	70	No Data	—	—	—	—
14	160	-	—	—	—	—

*Extrapolated

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TABLE 4

SUMMARY OF RESULTS FOR MATERIALS NOS. 1 – 14
Nominal Thickness: 6 in. – Entry Velocity: 40 ft/sec

Mat'l. No.	Temp. (°F)	Max. Stress (psi)	STRAIN: Before Impact (1.28 psi load)	Max. During Impact	After Impact (1.28 psi load)	Resilience (%)
1	-67	220	--	0.40	0.24	6
1	70	220	0.01	0.40	0.24	6
1	160	220	--	0.40	0.24	6
2	-67	-	--	--	--	--
2	70	220	0.02	0.66	0.69	6.7
2	160	-	--	--	--	--
3	-67	-	--	--	--	--
3	70	240	0.02	0.81	0.77	19
3	160	-	--	--	--	--
4	-67	545	--	0.34	0.05	36
4	70	485	0.02	0.39	0.05	31
4	160	475	--	0.44	0.09	27
5	-67	560	--	0.45	.08	43
5	70	520	0.03	0.48	.06	36
5	160	595	--	0.54	.09	44
6	-67	760	--	0.41	.04	45
6	70	540	0.11	0.41	.05	25
6	160	620	--	0.46	.06	25
7	-67	800	--	0.72	0.33	40
7	70	645	0.22	0.74	0.38	31
7	160	800	--	0.80	0.34	35

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TABLE 4 (Continued)

SUMMARY OF RESULTS FOR MATERIALS NOS. 1 - 14
Nominal Thickness: 6 in. - Entry Velocity: 40 ft/sec

Mat'l. No.	Temp. (°F)	Max. Stress (psi)	STRAIN: Before Impact (1.28 psi load)	Max. During Impact	After Impact (1.28 psi load)	Resilience (%)
8	-67	675	--	0.66	0.21	43
8	70	570	0.08	0.66	0.17	42
8	160	675	--	0.71	0.22	34
9	-67	620	--	0.58	0.17	45
9	70	660	0.08	0.54	0.12	46
9	160	620	--	0.63	0.17	46
10	-67	760	--	0.73	0.36	30
10	70	685	0.23	0.73	0.25	34
10	160	850	--	0.79	0.40	42
11	-67	290*	--	0.61*	--	--
11	70	595	0.24	0.84	0.26	32
11	160	No Data	--	--	--	--
12	-67	-	--	--	--	--
12	70	675	0.04	0.77	0.32	23
12	160	-	--	--	--	--
13	-67	280	--	0.42	0.26	50
13	70	685	--	0.88	0.53	29
13	160	No Data	--	--	--	--
14	-67	-	--	--	--	--
14	70	750	0.07	0.78	0.47	19
14	160	-	--	--	--	--

*Extrapolated

Contrails

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Contrails

TABLE 5

SUMMARY OF RESULTS FOR MATERIALS NOS. 1 – 14
Nominal Thickness: 6 in. – Entry Velocity: 30 ft/sec

Mat'l. No.	Temp. (°F)	Max. Stress (psi)	STRAIN: Before Impact (1.28 psi load)	Max. During Impact	After Impact (1.28 psi load)	Resilience (%)
1	-67	–	—	—	—	--
1	70	220	0.01	0.28	0.14	5
1	160	–	—	—	—	—
2	-67	–	—	—	—	—
2	70	125	0.01	0.46	0.40	9
2	160	–	—	—	—	—
3	-67	–	—	—	—	--
3	70	205	0.01	0.77	0.65	15
3	160	–	—	—	—	--
4	-67	385	—	0.28	0.05	45
4	70	305	0.02	0.32	0.05	31
4	160	310	—	0.37	0.06	38
5	-67	345	—	0.39	0.07	45
5	70	330	0.03	0.41	0.05	36
5	160	380	—	0.49	0.09	50
6	-67	345	—	0.36	0.02	44
6	70	300	0.01	0.34	0.02	30
6	160	355	—	0.41	0.04	32
7	-67	430	—	0.68	0.38	36
7	70	380	0.20	0.72	0.32	39
7	160	400	—	0.76	0.43	39

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TABLE 5 (Continued)

SUMMARY OF RESULTS FOR MATERIALS NOS. 1 – 14
Nominal Thickness: 6 in. – Entry Velocity: 30 ft/sec

Mat'l. No.	Temp. (°F)	Max. Stress (psi)	STRAIN: Before Impact (1.28 psi load)	Max. During Impact	After Impact (1.28 psi load)	Resilience (%)
8	-67	380	—	0.61	0.19	44
8	70	345	0.10	0.59	0.14	49
8	160	405	—	0.66	0.20	42
9	-67	380	—	0.53	0.16	49
9	70	305	0.07	0.44	0.11	49
9	160	355	—	0.57	0.18	43
10	-67	405	—	0.68	0.33	32
10	70	380	0.06	0.71	0.32	33
10	160	475	—	0.75	0.37	47
11	-67	-	—	—	—	—
11	70	255	0.21	0.78	0.22	32
11	160	480	—	0.90	0.44	46
12	-67	-	—	—	—	—
12	70	330	0.04	0.71	0.28	23
12	160	-	—	—	—	—
13	-67	205	—	0.26	0.17	8
13	70	255	0.45	0.79	0.48	30
13	160	530	—	0.91	0.11	91
14	-67	-	—	—	—	—
14	70	330	0.04	0.74	0.44	20
14	160	-	—	—	—	—

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TABLE 6

SUMMARY OF RESULTS FOR MATERIALS NOS. 1 – 14
Nominal Thickness: 6 in. – Entry Velocity: 20 ft/sec

Mat'l. No.	Temp. (°F)	Max. Stress (psi)	STRAIN: Before Impact (1.28 psi load	Max. During Impact	After Impact (1.28 psi load)	Resilience (%)
1	-67	–	—	—	—	—
1	70	220	0.01	0.14	0.05	10
1	160	–	—	—	—	—
2	-67	–	—	—	—	—
2	70	110	0.01	0.30	0.10	10
2	160	–	—	—	—	—
3	-67	–	—	—	—	—
3	70	90	0.01	0.50	0.24	9
3	160	–	—	—	—	—
4	-67	230	—	0.21	0.03	56
4	70	175	0.01	0.23	0.02	44
4	160	170	—	0.31	0.05	45
5	-67	170	—	0.33	0.07	40
5	70	190	0.03	0.31	0.05	35
5	160	160	—	0.38	0.07	51
6	-67	230	—	0.31	0.03	49
6	70	170	0.01	0.23	0.03	34
6	160	160	—	0.35	0.06	38
7	-67	170	—	0.59	0.39	36
7	70	140	0.18	0.61	0.23	35
7	160	175	—	0.70	0.34	43

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TABLE 6 (Continued)

SUMMARY OF RESULTS FOR MATERIALS NOS. 1 – 14
Nominal Thickness: 6 in. – Entry Velocity: 20 ft/sec

Mat'l. No.	Temp. (°F)	Max. Stress (psi)	STRAIN: Before Impact (1.28 psi load)	Max. During Impact	After Impact (1.28 psi load)	Resilience (%)
8	-67	165	—	0.53	0.18	44
8	70	185	0.09	0.50	0.14	52
8	160	120	—	0.60	0.19	45
9	-67	175	—	0.46	0.17	46
9	70	165	0.09	0.36	0.10	45
9	160	150	—	0.50	0.15	47
10	-67	150	—	0.57	0.35	25
10	70	150	0.21	0.62	0.28	38
10	160	190	—	0.70	0.36	51
11	-67	110	—	0.38	0.22	40
11	70	90	0.16	0.67	0.17	32
11	160	120	—	0.77	0.34	52
12	-67	-	—	—	—	—
12	70	115	0.04	0.60	0.19	23
12	160	-	—	—	—	—
13	-67	165	—	0.10	0.08	21
13	70	90	0.37	0.70	0.46	30
13	160	115	—	0.84	0.10	86
14	-67	-	—	—	—	—
14	70	115	0.04	0.69	0.35	19
14	160	-	—	—	—	—

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TABLE 7

SUMMARY OF RESULTS FOR MATERIALS NOS. 1 - 14
Nominal Thickness: 4 in. - Entry Velocity: 50 ft/sec

Mat'l. No.	Max. Stress (psi)	STRAIN: Before Impact (1.28 psi load)	Max. During Impact	After Impact (1.28 psi load)	Resilience (%)
1	340	0.01	0.76	0.41	8
2	760	0.01	0.91	0.80	8
3	No Data	—	—	—	—
4	885	0.01	0.52	0.24	27
5	No Data	—	—	—	—
6	1080	0.00	0.54	0.07	22
7	1090*	0.27	0.81*	0.38	27
8	No Data	—	—	—	—
9	1200*	0.09	0.64*	0.15	51
10	No Data	0.26	—	—	—
11	No Data	—	—	—	—
12	No Data	—	—	—	—
13	No Data	—	—	—	—
14	No Data	—	—	—	—

*Extrapolated

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TABLE 8

SUMMARY OF RESULTS FOR MATERIALS NOS. 1 - 14
Nominal Thickness: 4 in. - Entry Velocity: 40 ft/sec

Mat'l. No.	Max. Stress (psi)	STRAIN: Before Impact (1.28 psi load)	Max. During Impact	After Impact (1.28 psi load)	Resilience (%)
1	255	0.01	0.32	0.26	7
2	280	0.01	0.83	0.75	10
3	655	0.02	0.94	0.83	19
4	595	0.01	0.49	0.06	25
5	685	0.03	0.52	0.07	33
6	685	0.02	0.48	0.07	22
7	895	0.27	0.81	0.33	33
8	710	0.09	0.70	0.15	32
9	775	0.07	0.59	0.13	48
10	985	0.25	0.80	0.31	27
11	835	0.21	0.83	0.20	29
12	No Data	0.06	—	—	—
13	-	—	—	—	—
14	No Data	—	—	—	—

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TABLE 9

SUMMARY OF RESULTS FOR MATERIALS NOS. 1 – 14
Nominal Thickness: 4 in. – Entry Velocity: 30 ft/sec

Mat'l. No.	Max. Stress (psi)	STRAIN: Before Impact (1.28 psi load)	Max. During Impact	After Impact (1.28 psi load)	Resilience (%)
1	235	0.01	0.28	0.16	7
2	145	0.01	0.62	0.42	5
3	235	0.01	0.83	0.71	13
4	365	0.01	0.37	0.04	29
5	435	0.03	0.46	0.05	36
6	415	0.02	0.40	.04	25
7	545	0.29	0.76	0.35	32
8	495	0.08	0.65	0.14	45
9	470	0.08	0.53	0.11	49
10	605	0.25	0.77	0.30	39
11	340	0.16	0.80	0.16	28
12	460	0.06	0.80	0.33	22
13	–	—	—	—	—
14	570	0.07	0.84	0.45	22

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TABLE 10

SUMMARY OF RESULTS FOR MATERIALS NOS. 1 - 14
Nominal Thickness: 4 in. - Entry Velocity: 20 ft/sec

Mat'l. No.	Max. Stress (psi)	STRAIN: Before Impact (1.28 psi load)	Max. During Impact	After Impact (1.28 psi load)	Resilience (%)
1	185	0.02	0.24	0.10	8
2	110	0.02	0.24	0.26	5
3	80	0.02	0.68	0.48	25
4	175	0.01	0.27	0.03	32
5	245	.03	0.38	.03	36
6	240	.02	0.27	.02	34
7	240	0.25	0.68	0.34	43
8	255	0.09	0.54	0.12	37
9	210	0.10	0.45	0.11	50
10	240	0.26	0.72	0.28	37
11	140	0.14	0.70	0.14	32
12	145	0.06	0.69	0.21	30
13	-	—	—	—	—
14	304	0.05	0.75	0.45	25

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TABLE 11

SUMMARY OF RESULTS FOR MATERIALS NOS. 1 - 14
Nominal Thickness: 2 in. - Entry Velocity: 40 ft/sec

Mat'l. No.	Max. Stress (psi)	STRAIN: Before Impact (1.28 psi load)	Max. During Impact	After Impact (1.28 psi load)	Resilience (%)
1	460	0.01	0.80	0.34	13
2	1070*	0.01	0.97*	0.75	13
3	No Data	—	—	—	—
4	785	0.02	0.58	0.13	16
5	800*	—	0.65*	—	—
6	1080	0.03	0.64	0.10	17
7	No Data	—	—	—	—
8	No Data	—	—	—	—
9	No Data	—	—	—	—
10	No Data	—	—	—	—
11	No Data	—	—	—	—
12	No Data	—	—	—	—
13	No Data	—	—	—	—
14	No Data	—	—	—	—

*Extrapolated

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TABLE 12

SUMMARY OF RESULTS FOR MATERIALS NOS. 1 - 14
Nominal Thickness: 2 in. - Entry Velocity: 30 ft/sec

Mat'l. No.	Max. Stress (psi)	STRAIN: Before Impact (1.28 psi load)	Max. During Impact	After Impact (1.28 psi load)	Resilience (%)
1	275	0.01	0.42	0.20	11
2	370	0.01	0.89	0.63	10
3	620	0.02	0.98	0.98	19
4	545	0.00	0.47	0.05	25
5	535	0.03	0.57	0.08	39
6	615	0.03	0.52	0.10	24
7	865*	—	0.78*	—	—
8	577	0.07	0.79	0.14	31
9	810	0.08	0.64	0.13	46
10	990	0.31	0.92	0.33	46
11	No Data	—	—	—	—
12	No Data	—	—	—	—
13	No Data	—	—	—	—
14	No Data	—	—	—	—

*Extrapolated

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TABLE 13

SUMMARY OF RESULTS FOR MATERIALS NOS. 1 - 14
Nominal Thickness: 2 in. - Entry Velocity: 20 ft/sec

Mat'l. No.	Max. Stress (psi)	STRAIN: Before Impact (1.28 psi load)	Max. During Impact	After Impact (1.28 psi load)	Resilience (%)
1	240	0.01	0.24	0.12	14
2	90	0.01	0.26	0.50	7
3	180	0.02	0.88	0.65	17
4	370	0.00	0.35	0.03	30
5	330	0.03	0.46	0.03	44
6	320	0.00	0.41	0.06	47
7	355	0.27	0.76	0.29	37
8	375	0.13	0.67	0.14	30
9	420	0.09	0.52	0.10	48
10	405	0.54	0.81	0.72	37
11	280	0.17	0.84	0.21	28
12	380	0.06	0.90	0.44	25
13	-	—	—	—	—
14	485	0.04	0.88	0.35	35

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TABLE 14

SUMMARY OF RESULTS FOR MATERIALS NOS. 15 - 36
Nominal Thickness: 6 in. - Entry Velocity: 40 ft/sec

Mat'l. No.	Max. Stress (psi)	STRAIN: Before Impact (1.28 psi load)	Max. During Impact	After Impact (1.28 psi load)	Resilience (%)
15	775	0.11	0.85	0.58	17
16	875	0.49	0.94	0.73	29
17	No Data	—	—	—	—
18	1015*	0.64	0.97*	0.86	30
19	No Data	—	—	—	—
20	No Data	—	—	—	—
21	No Data	—	—	—	—
22	1055	0.04	0.86	0.61	16
23	No Data	—	—	—	—
24	No Data	—	—	—	—
25	No Data	—	—	—	—
26	No Data	—	—	—	—
27	No Data	—	—	—	—
28	No Data	—	—	—	—
29	No Data	—	—	—	—
30	No Data	—	—	—	—
31	No Data	—	—	—	—
32	No Data	—	—	—	—
33	No Data	—	—	—	—
34	No Data	—	—	—	—
35	No Data	—	—	—	—
36	No Data	—	—	—	—

*Extrapolated

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TABLE 15

SUMMARY OF RESULTS FOR MATERIALS NOS. 15 – 36
Nominal Thickness: 6 in. – Entry Velocity: 30 ft/sec

Mat'l. No.	Max. Stress (psi)	STRAIN: Before Impact (1.28 psi load)	Max. During Impact	After Impact (1.28 psi load)	Resilience (%)
15	320	0.16	0.81	0.51	19
16	455	0.46	0.91	0.67	31
17	495	0.10	0.79	0.50	25
18	585	0.60	0.94	0.83	35
19	585	0.57	0.93	0.72	33
20	545	0.18	0.85	0.56	24
21	635	0.57	0.94	0.79	31
22	345	0.05	0.82	0.61	14
23	710	0.02	0.88	0.41	16
24	865	0.52	0.92	0.70	20
25	760	0.58	0.90	0.76	19
26	No Data	0.57	—	—	—
27	735	0.04	0.79	0.62	21
28	650	0.38	0.94	0.65	30
29	635	0.42	0.88	0.70	28
30	660	0.41	0.90	0.70	24
31	No Data	—	—	—	—
32	No Data	—	—	—	—
33	No Data	—	—	—	—
34	1015	0.46	0.95	0.70	24
35	No Data	—	—	—	—
36	No Data	—	—	—	—

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TABLE 16

SUMMARY OF RESULTS FOR MATERIALS NOS. 15 - 36
Nominal Thickness: 6 in. - Entry Velocity: 20 ft/sec

Mat'l. No.	Max. Stress (psi)	STRAIN: Before Impact (1.28 psi load)	Max. During Impact	After Impact (1.28 psi load)	Resilience (%)
15	140	0.16	0.76	0.51	27
16	205	0.49	0.86	0.66	33
17	180	0.11	0.73	0.46	24
18	255	0.64	0.89	0.75	37
19	215	0.52	0.89	0.65	36
20	215	0.22	0.71	0.52	21
21	240	0.55	0.84	0.64	45
22	125	0.03	0.80	0.55	17
23	180	0.03	0.83	0.26	13
24	315	0.54	0.89	0.71	16
25	405	0.46	0.89	0.65	20
26	430	0.58	0.92	0.72	19
27	190	0.03	0.70	0.55	21
28	255	0.38	0.93	0.65	27
29	420	0.42	0.84	0.67	25
30	230	0.40	0.84	0.63	22
31	380	0.59	0.92	0.79	26
32	230	0.44	0.80	0.52	46
33	405	0.10	0.96	0.58	47
34	430	0.48	0.94	0.65	21
35	585	0.67	0.98	0.78	19
36	545	0.40	0.94	0.63	34

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TABLE 17

SUMMARY OF RESULTS FOR MATERIALS NOS. 15 – 36
Nominal Thickness: 4 in. – Entry Velocity: 30 ft/sec

Mat'l. No.	Max. Stress (psi)	STRAIN: Before Impact (1.28 psi load)	Max. During Impact	After Impact (1.28 psi load)	Resilience (%)
15	710	0.38	0.86	0.51	25
16	685	0.48	0.94	0.65	32
17	735	0.14	0.89	0.47	22
18	No Data	0.63	--	--	--
19	No Data	0.63	--	--	--
20	850	0.22	0.93	0.62	25
21	815	0.53	0.99	0.77	37
22	430	0.07	0.82	0.61	13
23	No Data	--	--	--	--
24	No Data	0.06	--	--	--
25	No Data	0.51	--	--	--
26	No Data	--	--	--	--
27	No Data	--	--	--	--
28	No Data	--	--	--	--
29	No Data	--	--	--	--
30	No Data	--	--	--	--
31	No Data	--	--	--	--
32	595	0.34	0.92	0.62	37
33	No Data	--	--	--	--
34	No Data	0.46	--	--	--
35	No Data	--	--	--	--
36	No Data	--	--	--	--

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TABLE 18

SUMMARY OF RESULTS FOR MATERIALS NOS. 15 - 36
Nominal Thickness: 4 in. - Entry Velocity: 20 ft/sec

Mat'l. No.	Max. Stress (psi)	STRAIN: Before Impact (1.28 psi load)	Max. During Impact	After Impact (1.28 psi load)	Resilience (%)
15	380	0.35	0.82	0.51	25
16	685	0.45	0.94	0.64	36
17	190	0.11	0.77	0.46	22
18	330	0.61	0.98	0.77	42
19	370	0.58	0.96	0.59	40
20	315	0.24	0.84	0.58	24
21	305	0.56	0.92	0.67	39
22	180	0.01	0.76	0.56	13
23	285	0.03	0.85	0.34	18
24	535	0.57	0.89	0.70	18
25	495	0.53	0.96	0.71	20
26	No Data	0.63	—	—	—
27	No Data	—	—	—	—
28	No Data	—	—	—	—
29	No Data	—	—	—	—
30	No Data	—	—	—	—
31	No Data	—	—	—	—
32	265	0.01	0.87	0.24	31
33	No Data	—	—	—	—
34	520	0.46	0.97	0.65	21
35	No Data	0.70	—	0.78	17
36	No Data	0.42	—	0.69	36

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TABLE 19

SUMMARY OF RESULTS FOR MATERIALS NOS. 15 – 36
Nominal Thickness: 2 in. – Entry Velocity: 20 ft/sec

Mat'l. No.	Max. Stress (psi)	STRAIN: Before Impact (1.28 psi load)	Max. During Impact	After Impact (1.28 psi load)	Resilience (%)
15	No Data	—	—	—	—
16	No Data	0.52	—	—	—
17	430	0.03	0.86	0.39	21
18	570	0.61	0.98	0.86	40
19	No Data	0.12	—	—	—
20	635	0.23	0.96	0.87	20
21	No Data	0.59	—	0.84	36
22	No Data	—	—	—	—
23	1115	0.02	0.95	0.33	16
24	1045	0.50	0.95	0.75	21
25	No Data	0.63	—	0.77	17
26	875	0.63	0.96	0.78	16
27	No Data	—	—	—	—
28	No Data	—	—	—	—
29	No Data	—	—	—	—
30	No Data	—	—	—	—
31	No Data	—	—	—	—
32	395	0.42	0.98	0.55	43
33	No Data	—	—	—	—
34	No Data	0.51	—	—	—
35	No Data	—	—	—	—
36	No Data	—	—	—	—

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TABLE 20

SUMMARY OF RESULTS FOR MATERIALS NOS. 37 – 51

Mat'l. No.	Nominal Thickness (in.)	Entry Velocity (ft/sec)	Max. Stress (psi)	STRAIN: Before Impact (1.28 psi load)	Max. During Impact	After Impact (1.28 psi load)	Resilience (%)
37	6	32	495	0.11	0.80	0.59	17
38	6	36	345	0.10	0.80	0.60	18
39	2	23	260	0.02	0.73	0.50	13
40	6	34	890	0.15	0.84	0.73	34
41	6	31	745	0.13	0.90	0.41	23
42	6	33	840	0.13	0.86	0.76	21
43	2	28	655	0.02	0.94	0.70	22
44	6	32	350	0.13	0.55	0.31	23
45	5	34	595	0.21	0.74	0.32	41
46	6	31	710	0.09	0.84	0.57	36
47	6	32	745	0.35	0.64	0.69	31
48	6	33	770	0.38	0.86	0.65	17
49	6	36	1085	0.25	0.84	0.48	46
50	6	29	1385	0.49	0.91	Bag Exploded	33
51	4	25	260	0.02	0.84	0.83	22

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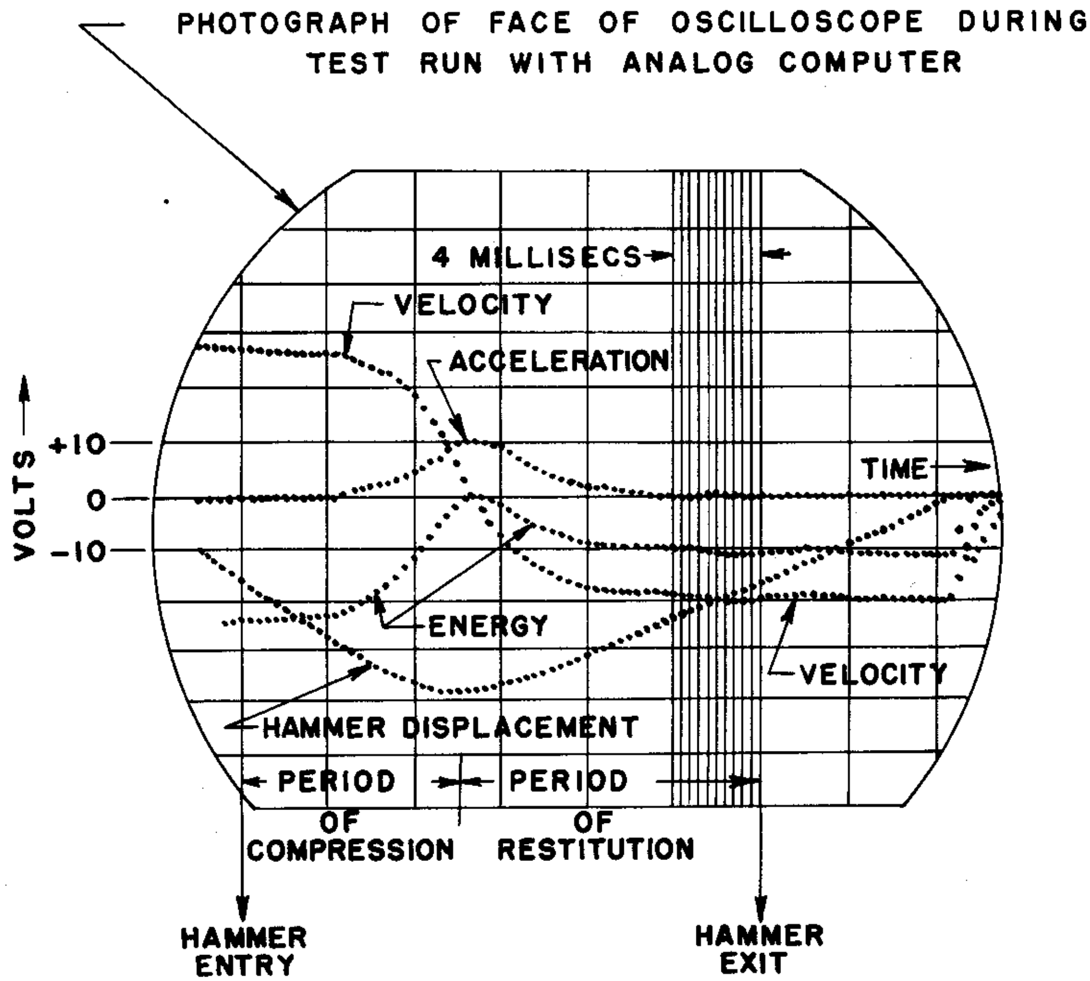

FIGURE 1. EXPLANATION OF OSCILLOSCOPE RECORD OF TEST RUN

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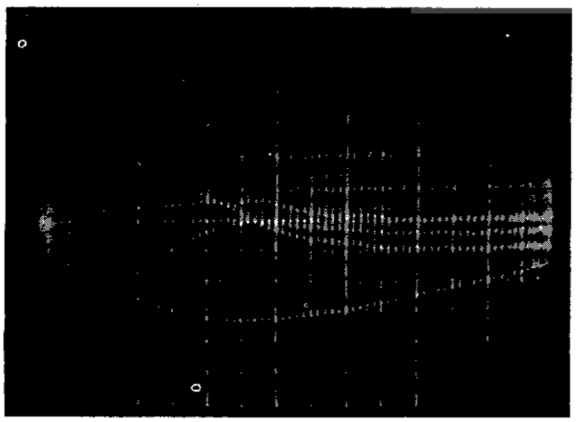
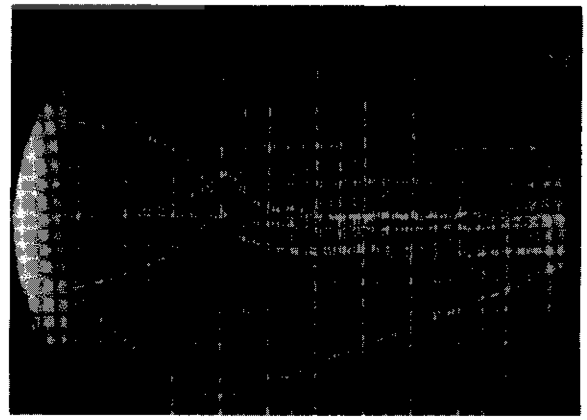


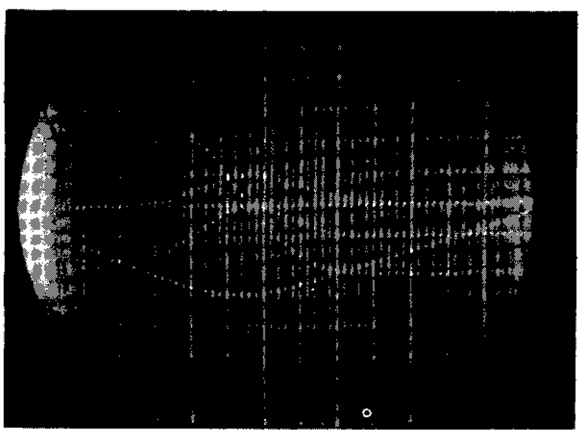
(a)

Material No. 1
Nominal Thickness: 6 in.
Temperature: 160° F
Entry Velocity: 47 ft/sec
Maximum Acceleration: 190 g



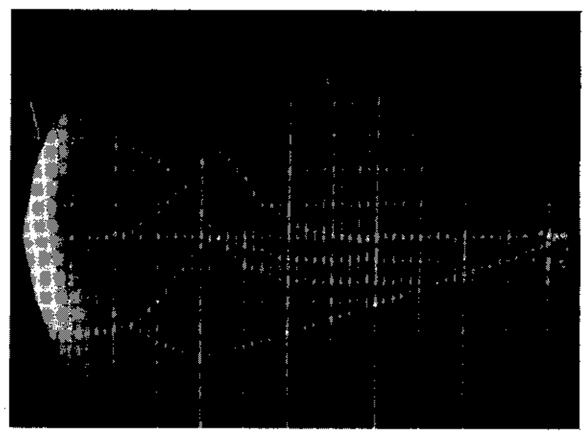
(b)

Material No. 3
Nominal Thickness: 6 in.
Temperature: −67° F
Entry Velocity: 38 ft/sec
Maximum Acceleration: 265 g



(c)

Material No. 4
Nominal Thickness: 6 in.
Temperature: − 67° F
Entry Velocity: 20 ft/sec
Maximum Acceleration: 176 g



(d)

Material No. 4
Nominal Thickness: 6 in.
Temperature: 160° F
Entry Velocity: 49 ft/sec
Maximum Acceleration: 510 g

Figure 2 (a,b,c,d). Examples of oscilloscope records of test runs.

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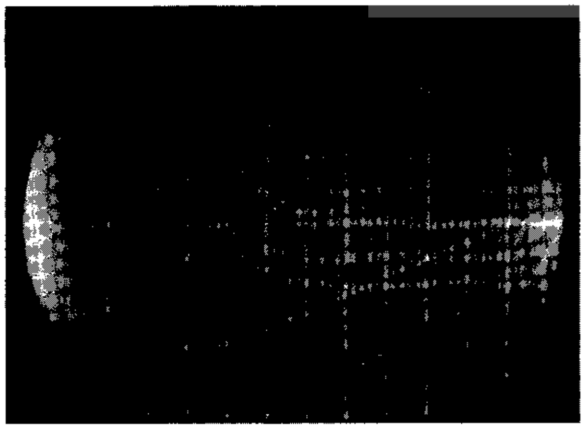
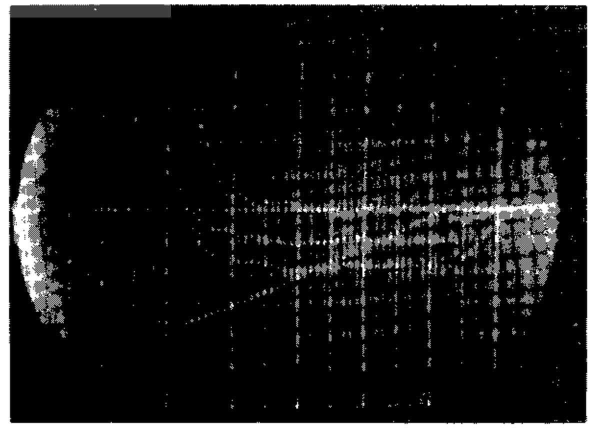


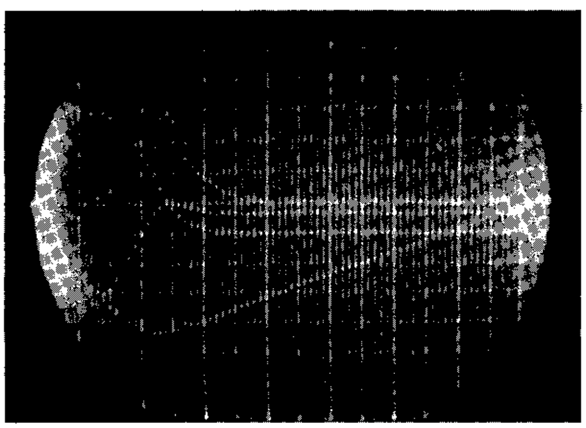
(e)

Material No. 5
Nominal Thickness: 6 in.
Temperature: 160° F
Entry Velocity: 46 ft/sec
Maximum Acceleration: 566 g



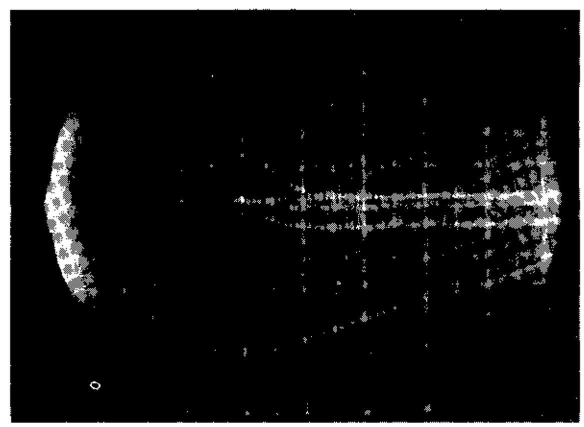
(f)

Material No. 8
Nominal Thickness: 6 in.
Temperature: -67° F
Entry Velocity: 48 ft/sec
Maximum Acceleration: 815 g



(g)

Material No. 13
Nominal Thickness: 6 in.
Temperature: -67° F
Entry Velocity: 50 ft/sec
Maximum Acceleration: 500 g



(h)

Material No. 13
Nominal Thickness: 6 in.
Temperature: -67° F
Entry Velocity: 43 ft/sec
Maximum Acceleration: 260 g

Figure 2 (e,f,g,h). Examples of oscelloscope records of test runs.

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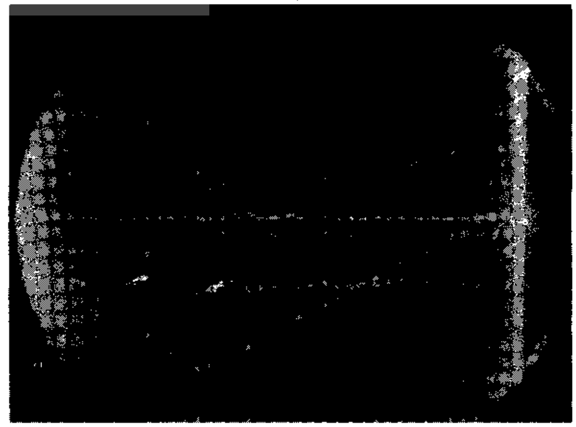
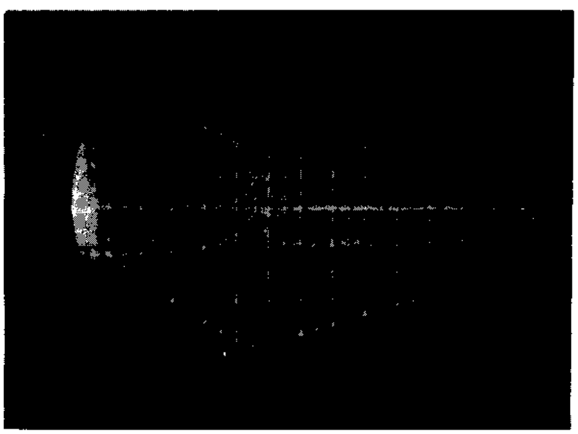
(i)

Material No. 9
Nominal Thickness: 6 in.
Temperature: 160° F
Entry Velocity: 28 ft/sec
Maximum Acceleration: 240 g



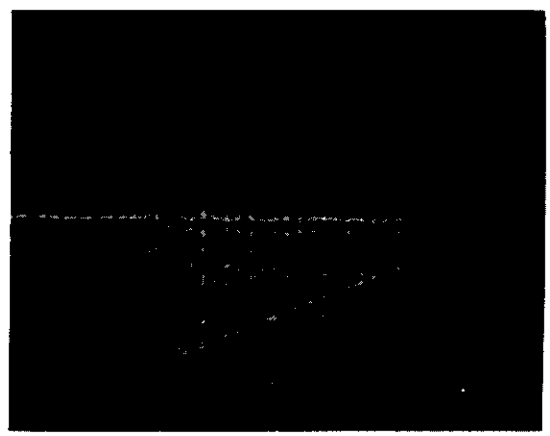
(j)

Material No. 33
Nominal Thickness: 6 in.
Temperature: 70° F
Entry Velocity: 20 ft/sec
Maximum Acceleration: 323 g



(k)

Material No. 23
Nominal Thickness: 4 in.
Temperature: 70° F
Entry Velocity: 20 ft/sec
Maximum Acceleration: 225 g



(l)

Material No. 34
Nominal Thickness: 6 in.
Temperature: 70° F
Entry Velocity: 20 ft/sec
Maximum Acceleration: 336 g

Figure 2 (i,j,k,l). Examples of oscilloscope records of test runs.

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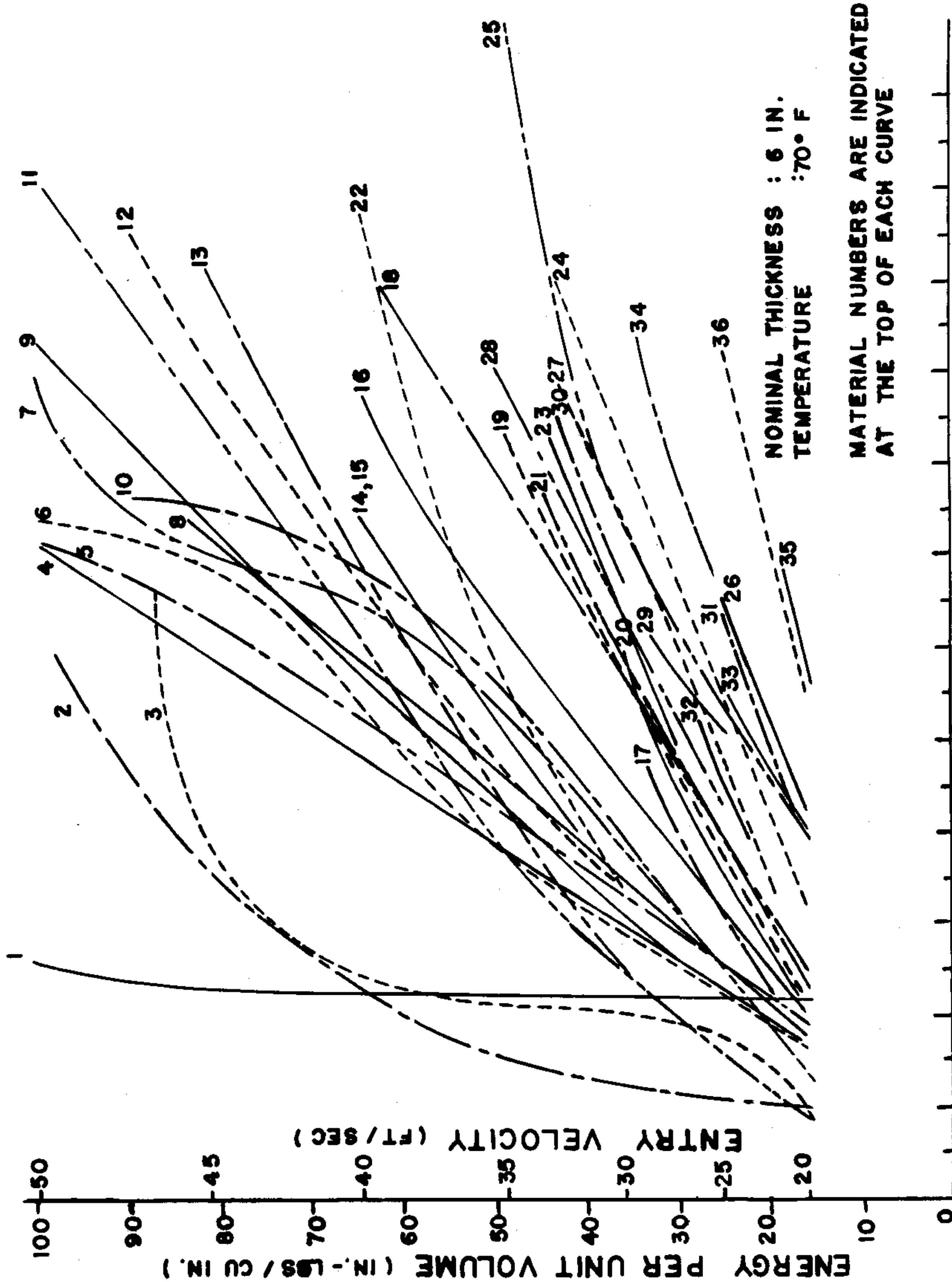

FIGURE 3 COMPARISON OF THE ENERGY PER UNIT VOLUME – MAXIMUM STRESS CURVES

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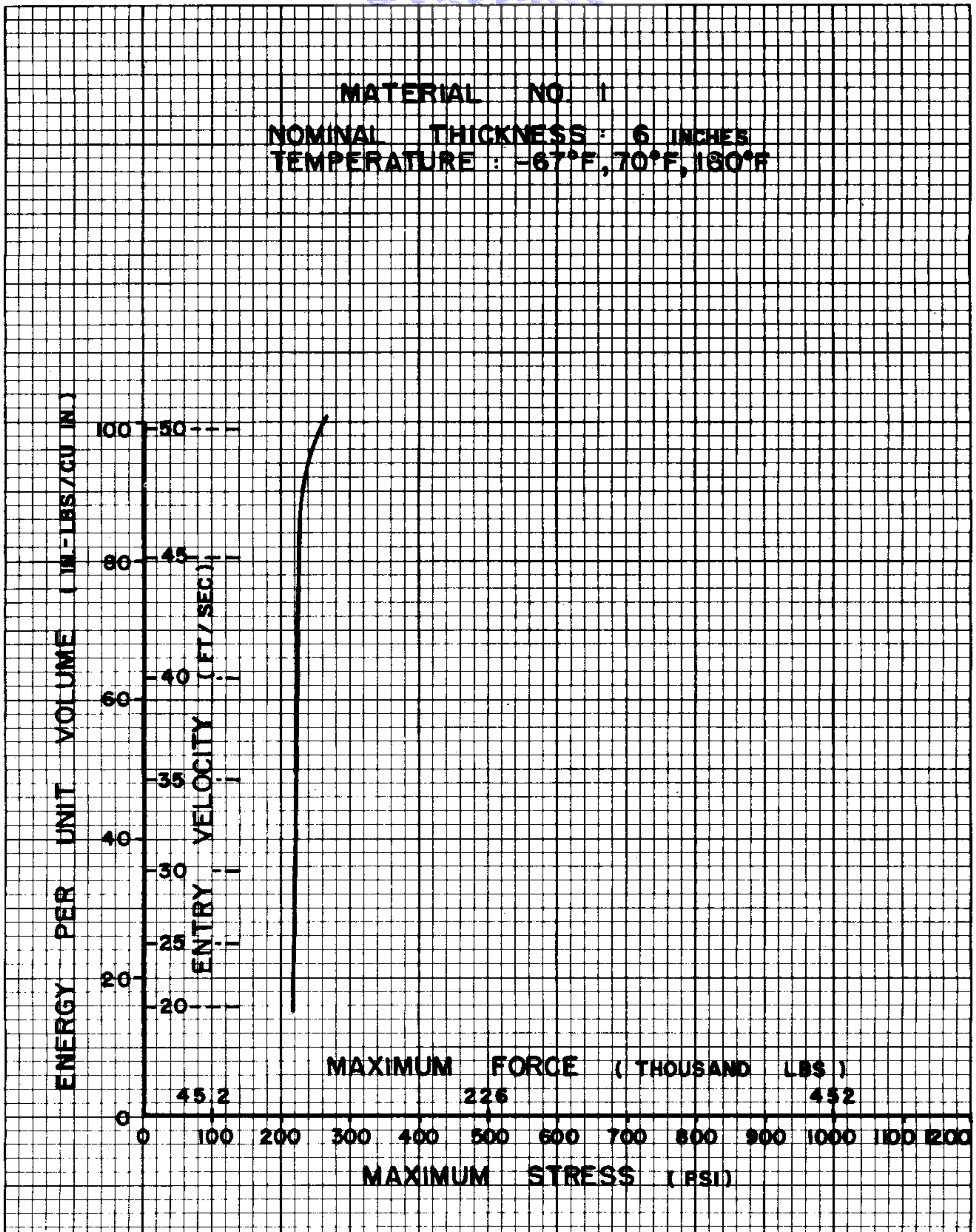

FIGURE 4 ENERGY PER UNIT VOLUME - MAXIMUM STRESS CURVE FOR 6 INCHES OF MATERIAL No. 1

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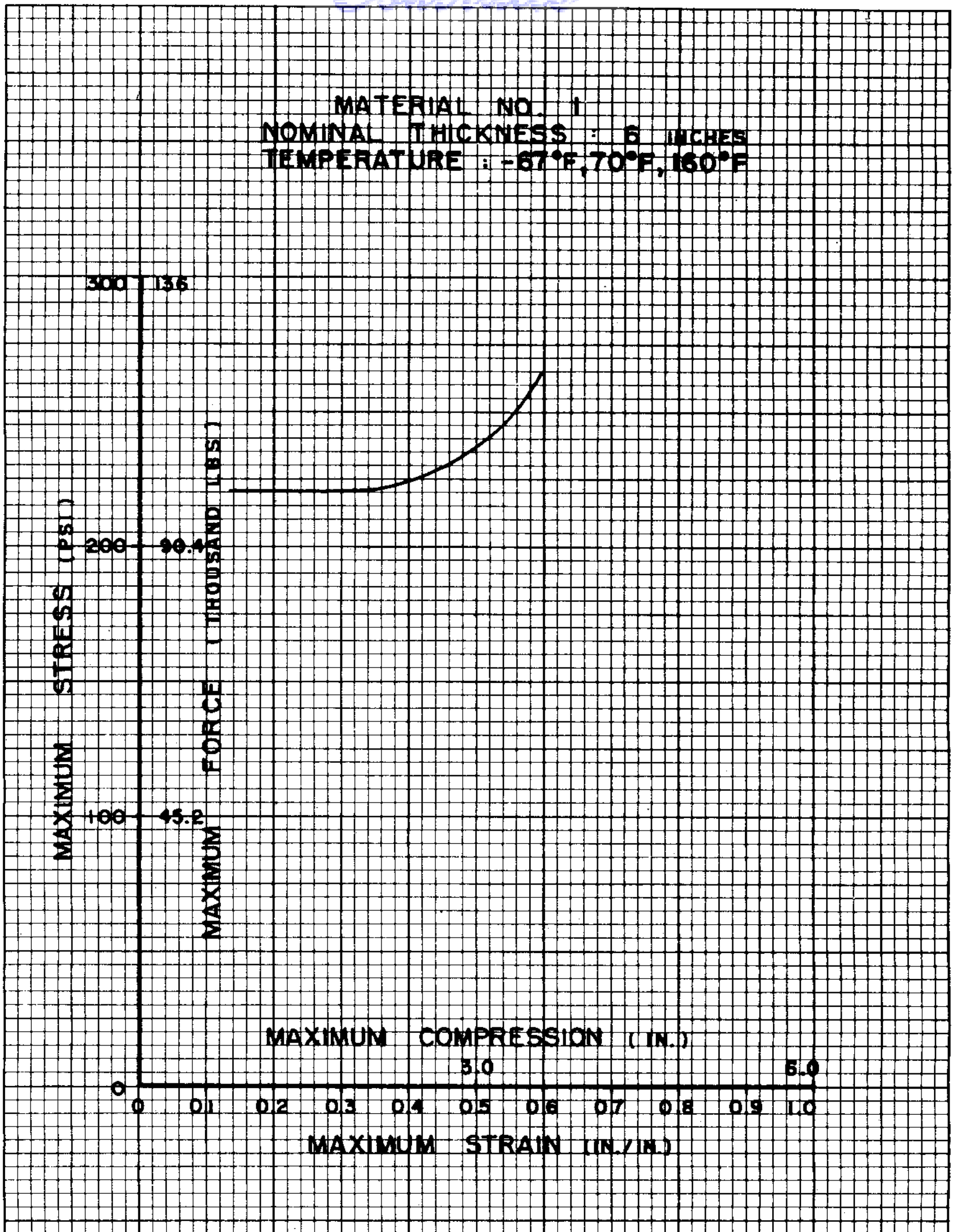

FIGURE 5. MAXIMUM STRESS - MAXIMUM STRAIN CURVE FOR 6 INCHES OF MATERIAL No. 1

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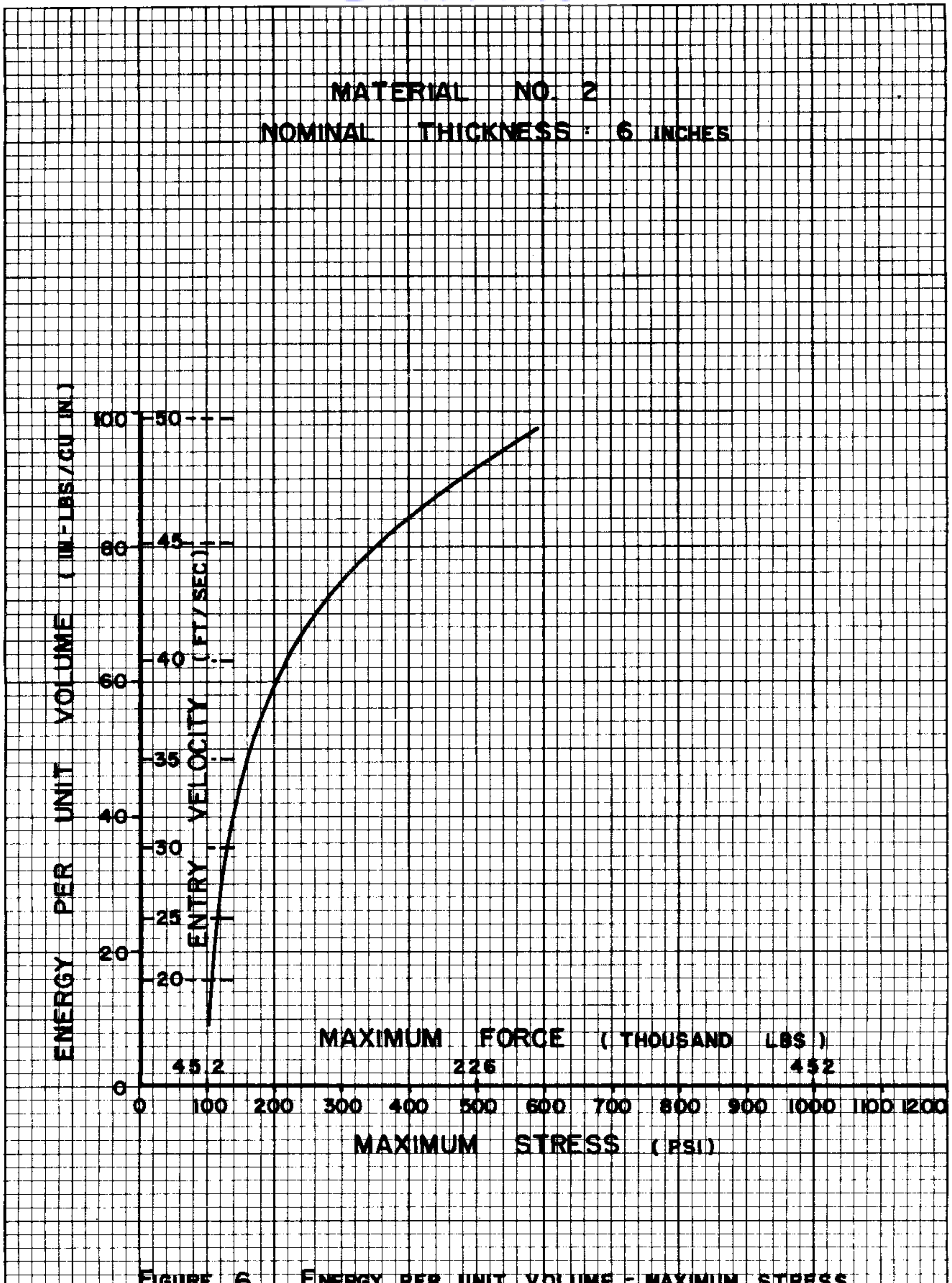

FIGURE 6 ENERGY PER UNIT VOLUME - MAXIMUM STRESS CURVE FOR 6 INCHES OF MATERIAL No. 2

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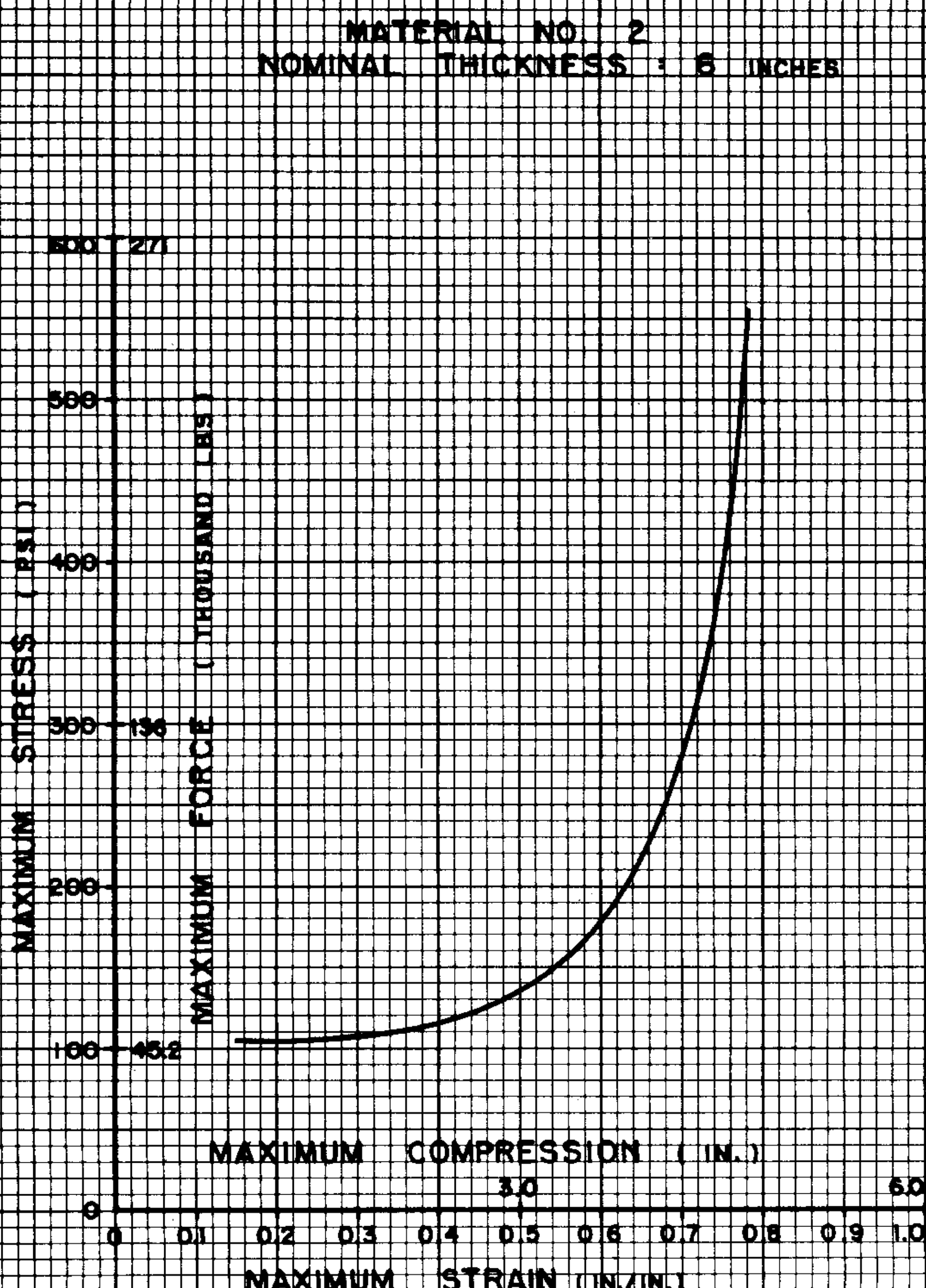

FIGURE 7. MAXIMUM STRESS - MAXIMUM STRAIN CURVE FOR 6 INCHES OF MATERIAL No. 2

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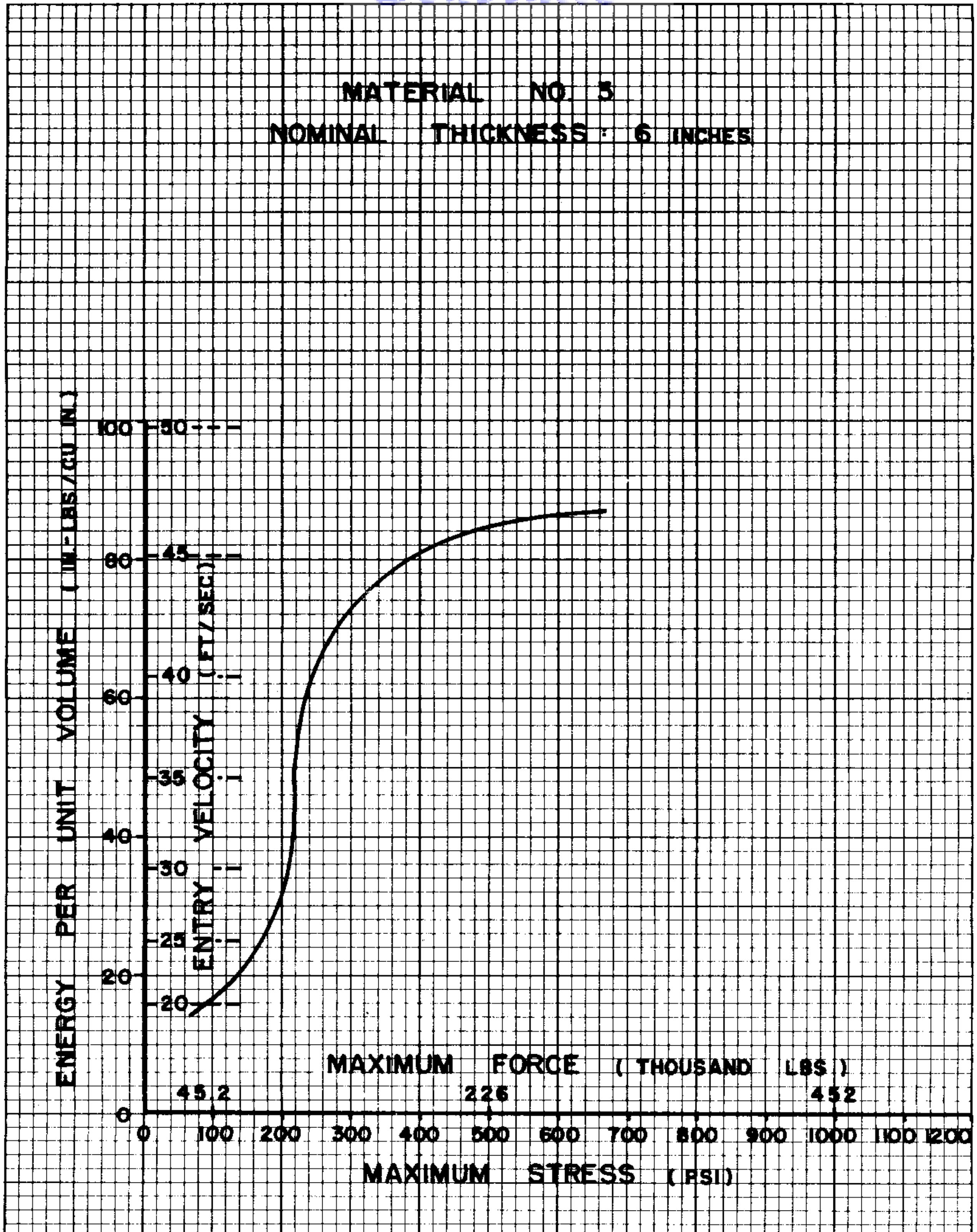

FIGURE 8 ENERGY PER UNIT VOLUME - MAXIMUM STRESS CURVE FOR 6 INCHES OF MATERIAL No. 3

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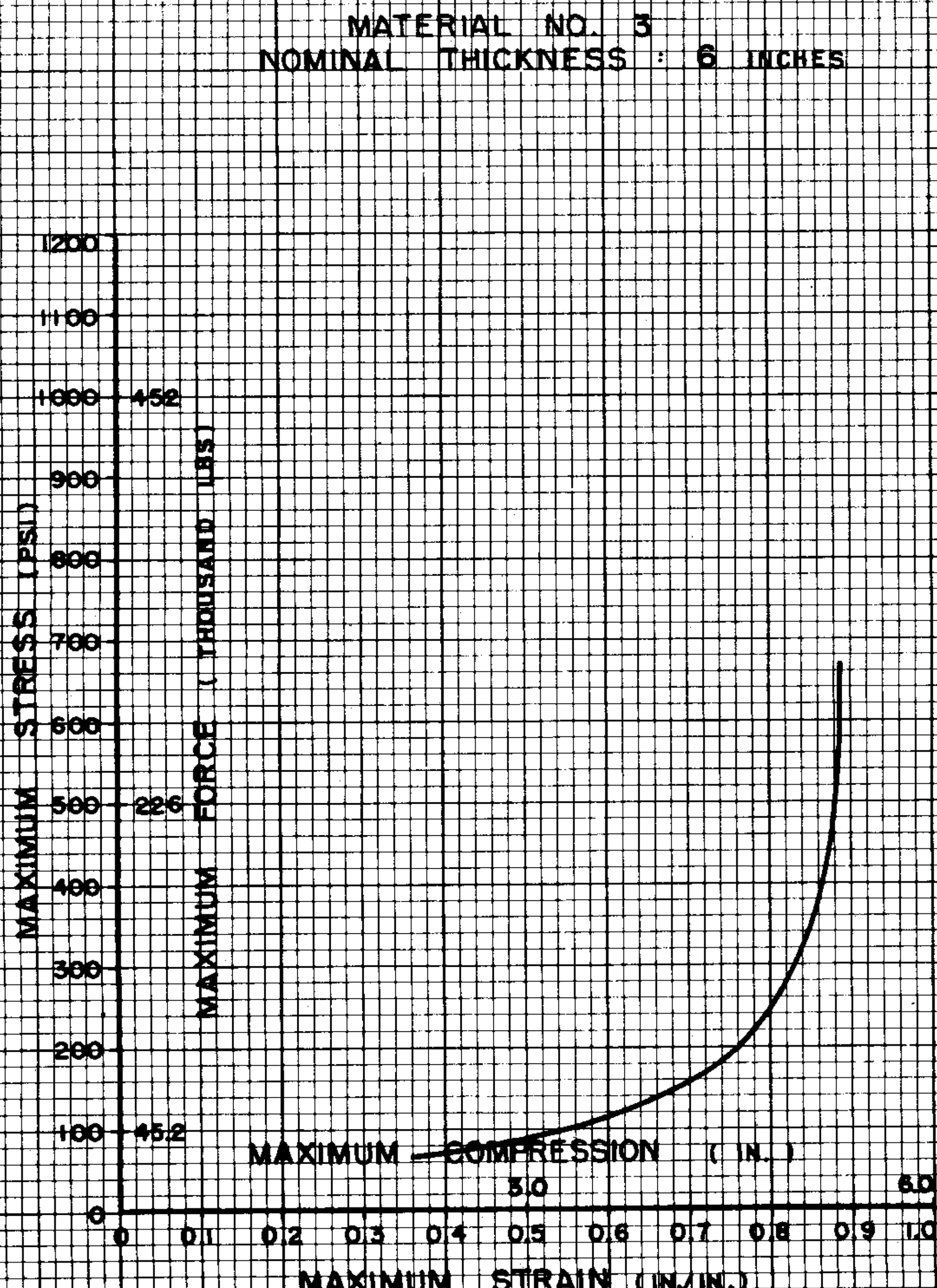

FIGURE 9 MAXIMUM STRESS - MAXIMUM STRAIN CURVE FOR 6 INCHES OF MATERIAL NO. 3

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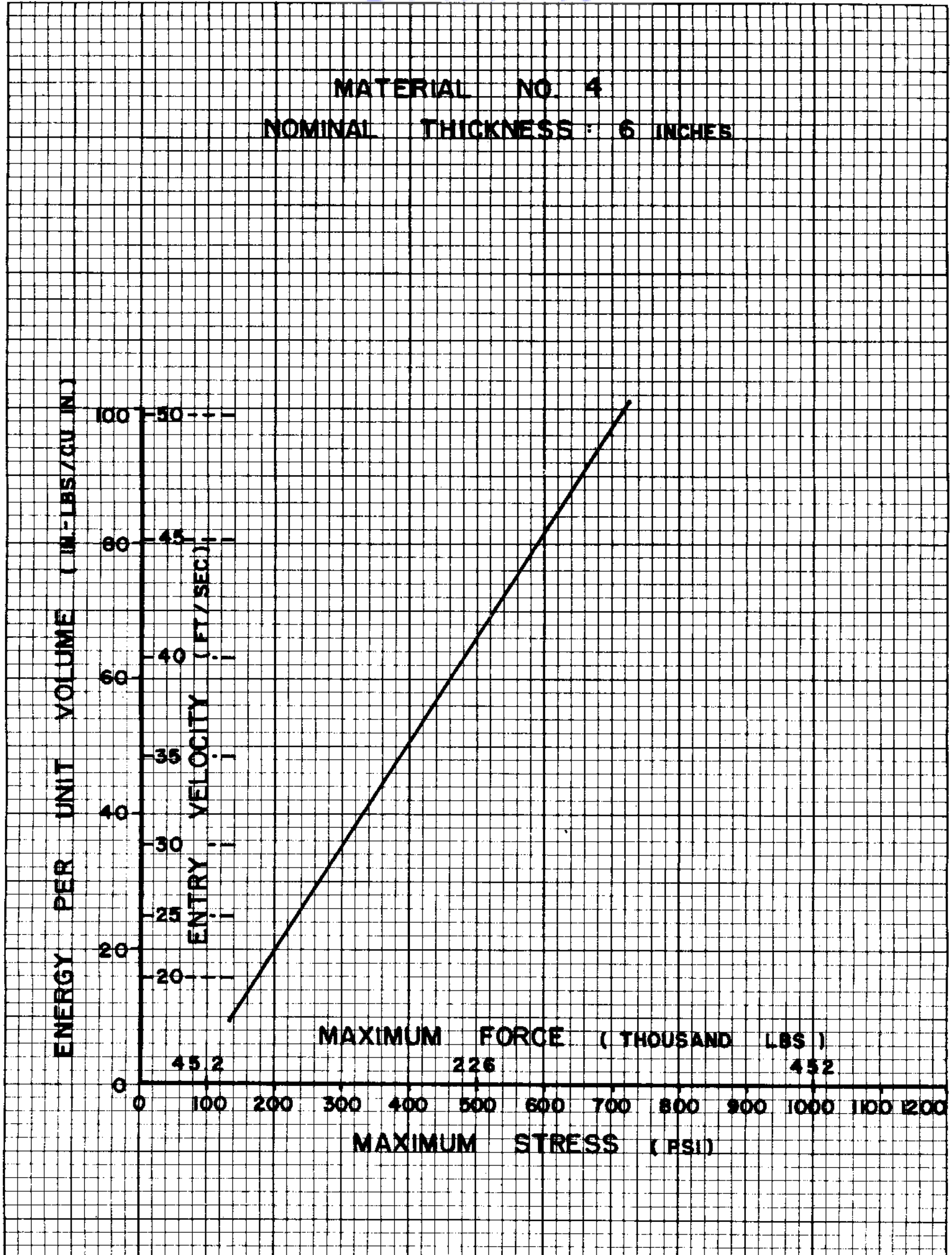

FIGURE 10 ENERGY PER UNIT VOLUME - MAXIMUM STRESS CURVE FOR 6 INCHES OF MATERIAL No. 4

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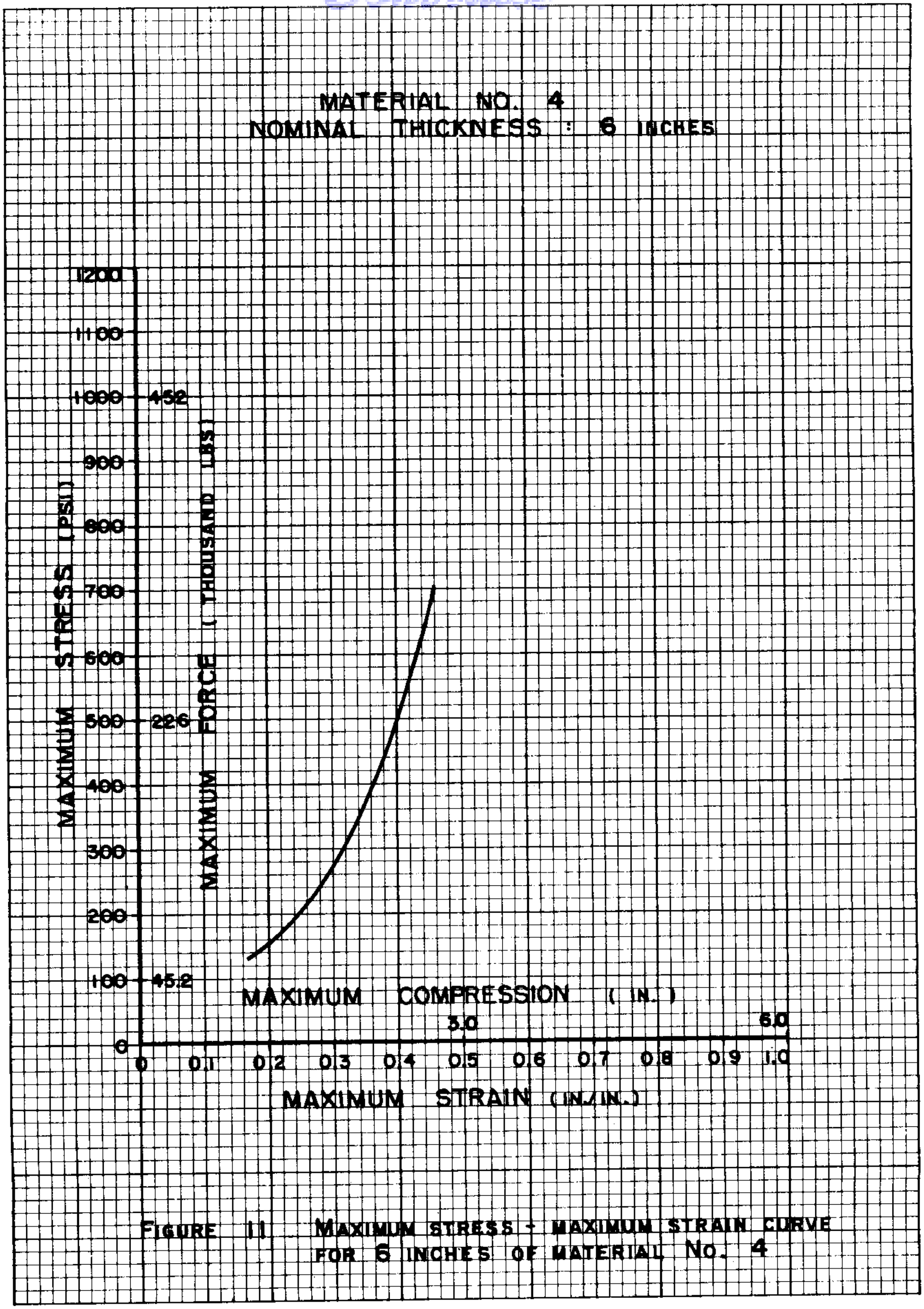

FIGURE 11 MAXIMUM STRESS - MAXIMUM STRAIN CURVE FOR 6 INCHES OF MATERIAL No. 4

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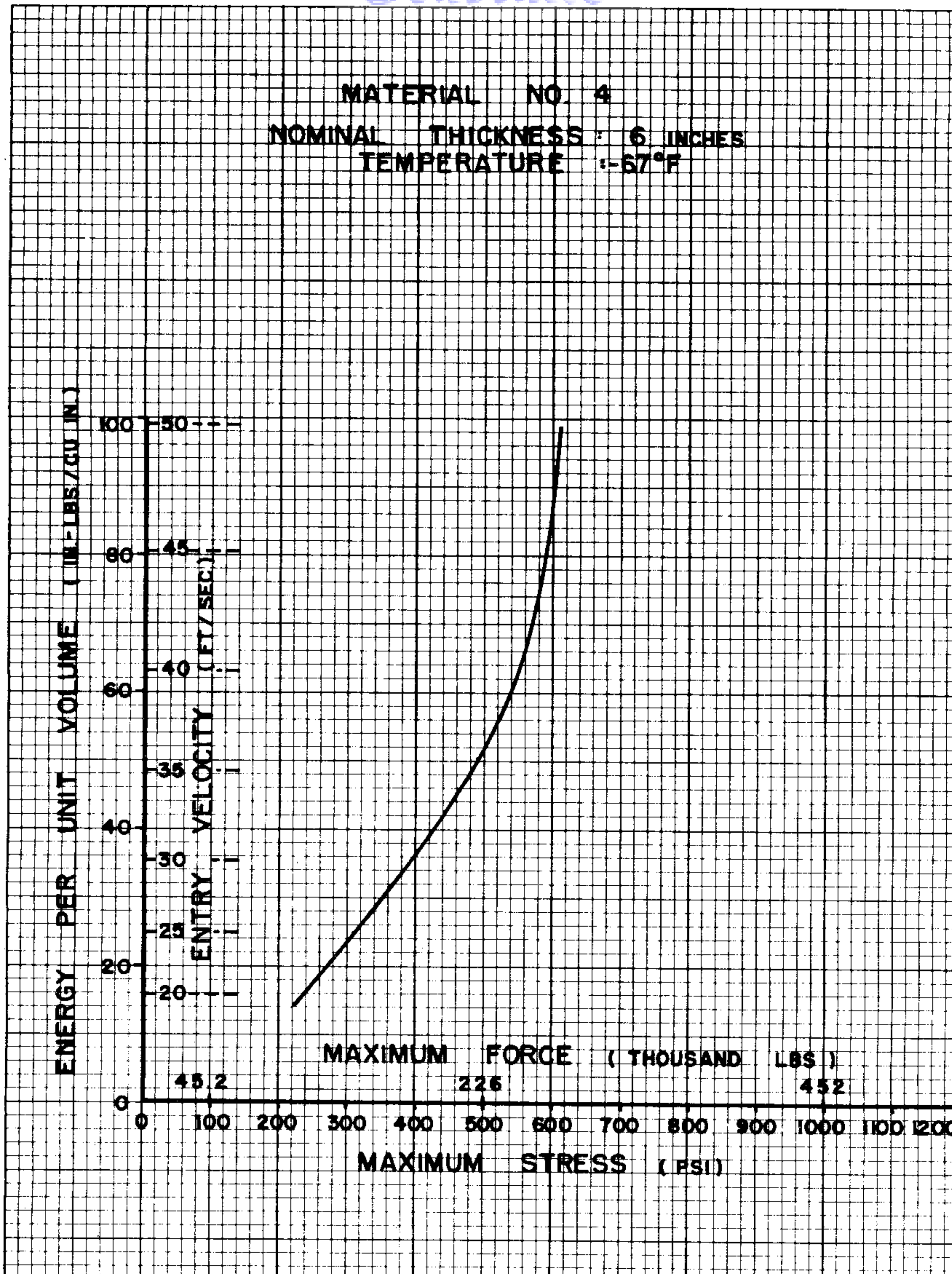

FIGURE 12 ENERGY PER UNIT VOLUME - MAXIMUM STRESS CURVE FOR 6 INCHES OF MATERIAL No. 4

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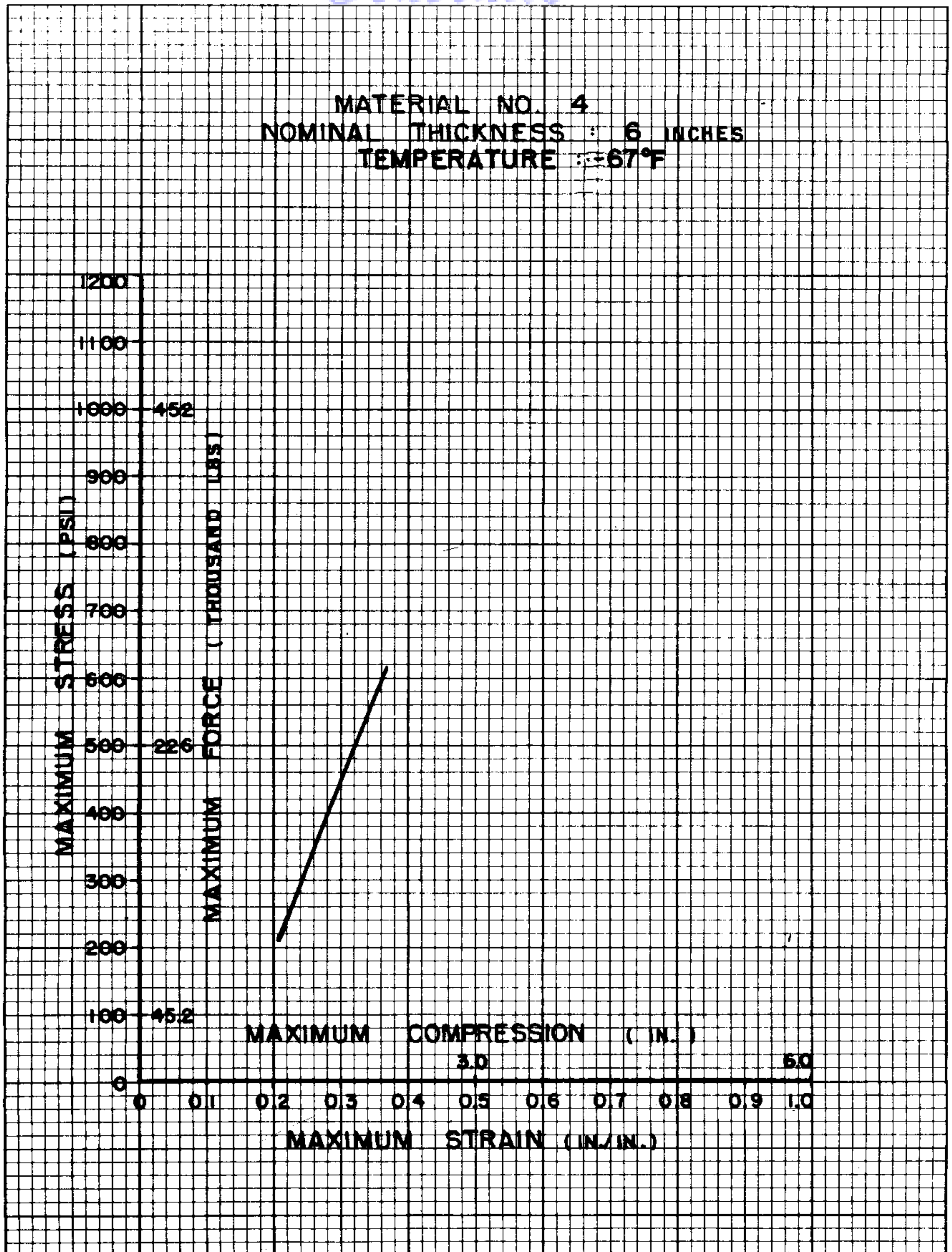

FIGURE 13 MAXIMUM STRESS - MAXIMUM STRAIN CURVE FOR 6 INCHES OF MATERIAL NO. 4

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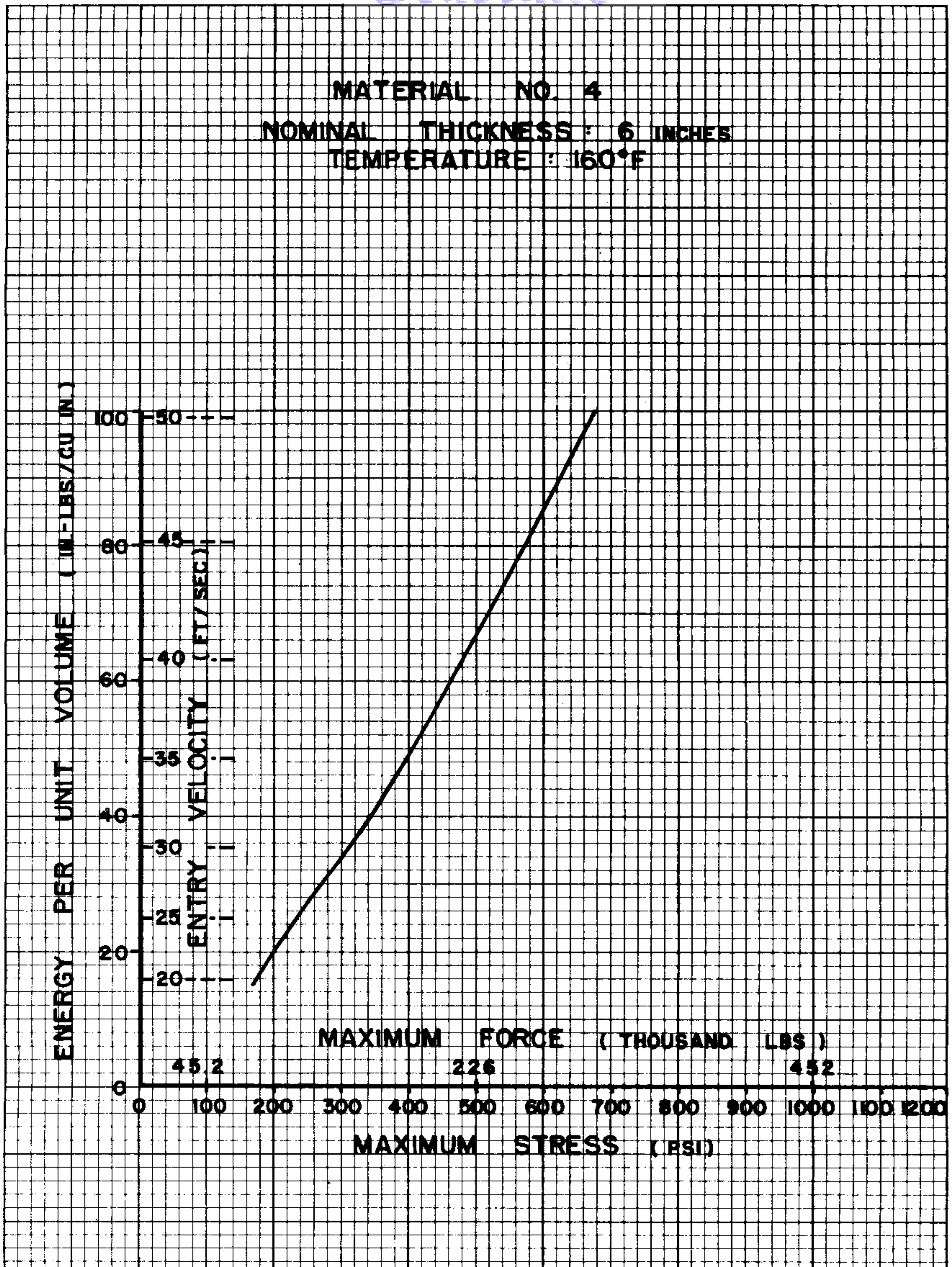

FIGURE 14 ENERGY PER UNIT VOLUME - MAXIMUM STRESS CURVE FOR 6 INCHES OF MATERIAL No. 4

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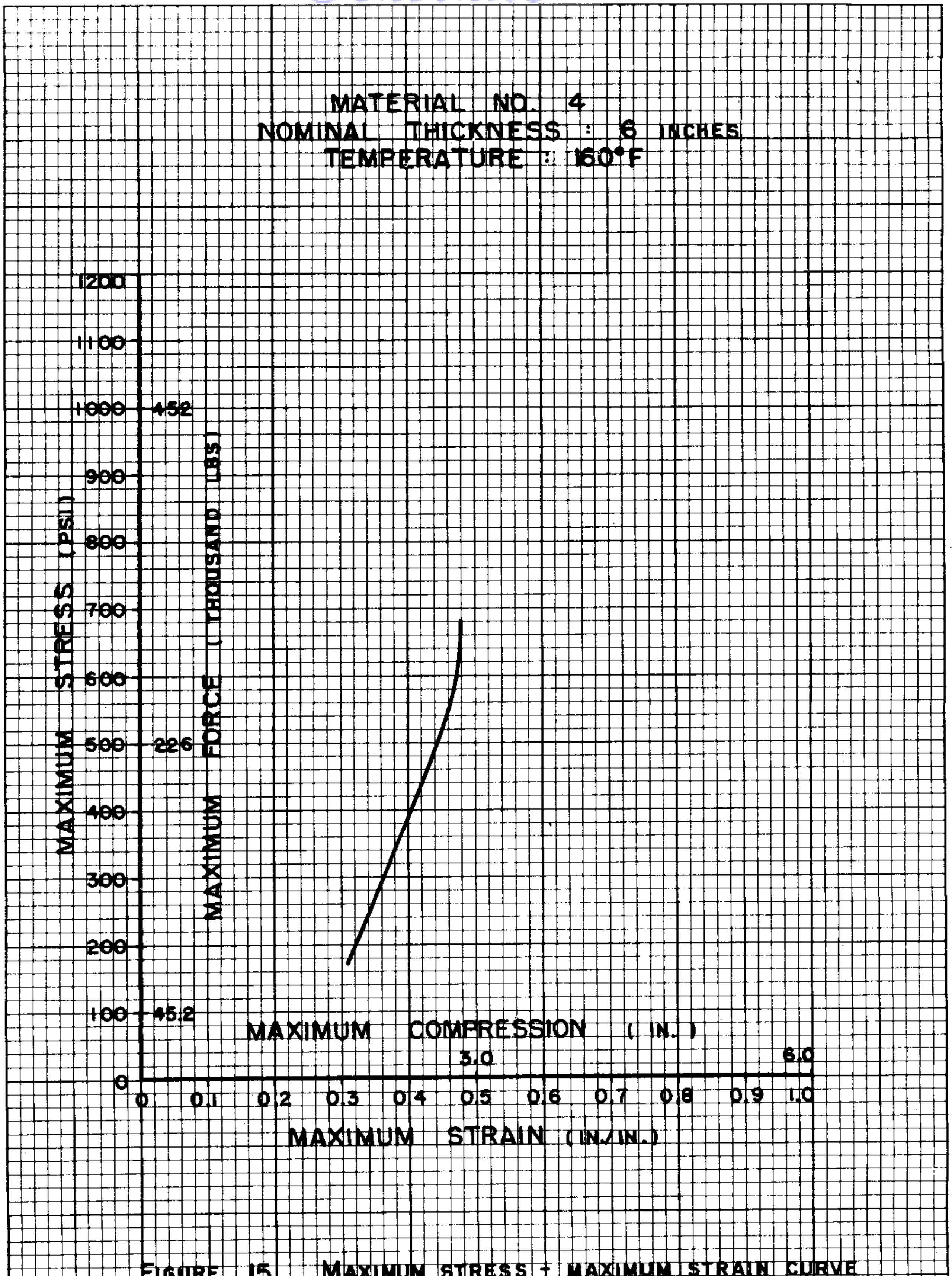

FIGURE 15 MAXIMUM STRESS - MAXIMUM STRAIN CURVE FOR 6 INCHES OF MATERIAL NO. 4

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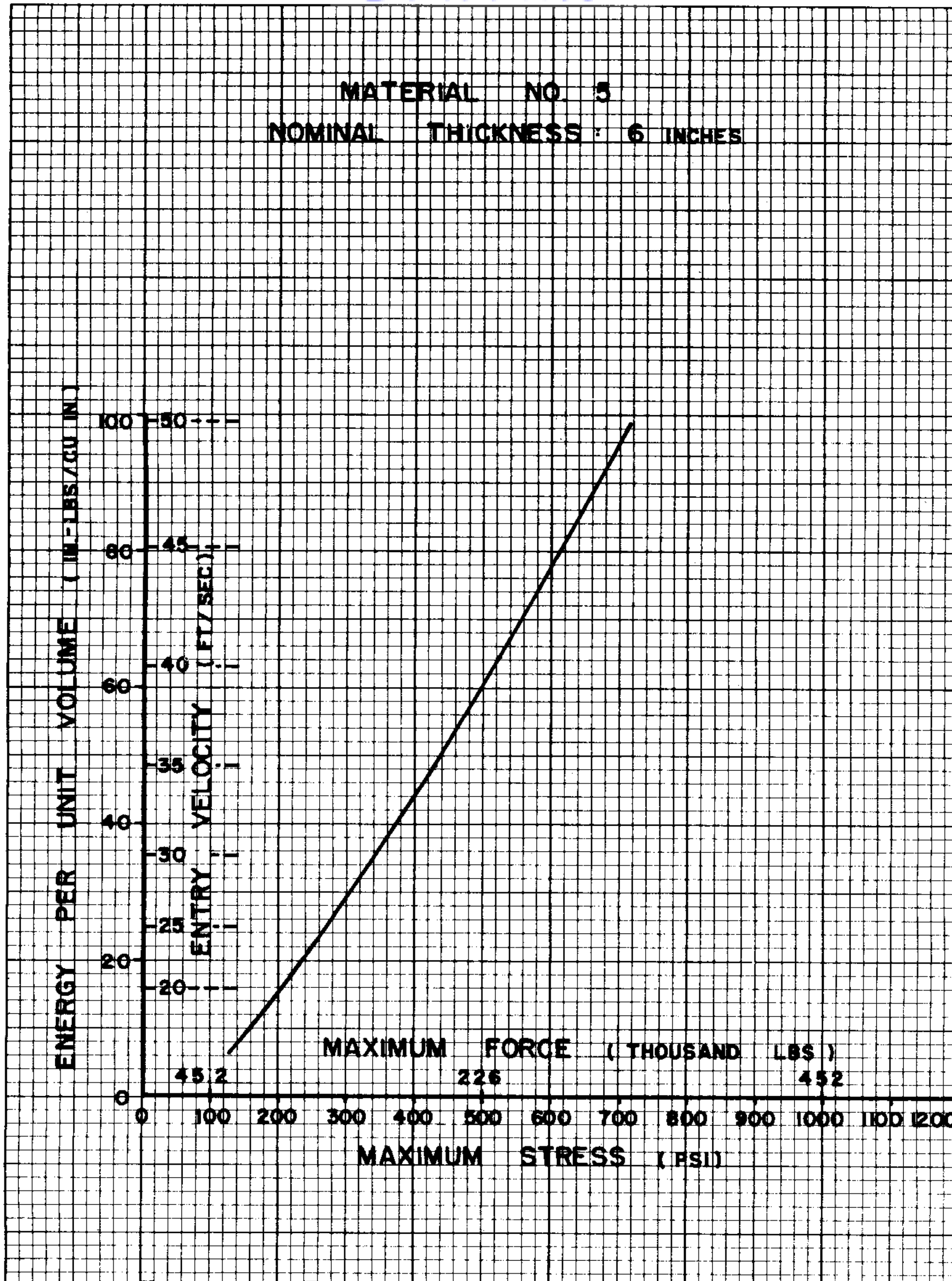

FIGURE 16 ENERGY PER UNIT VOLUME - MAXIMUM STRESS CURVE FOR 6 INCHES OF MATERIAL No. 5

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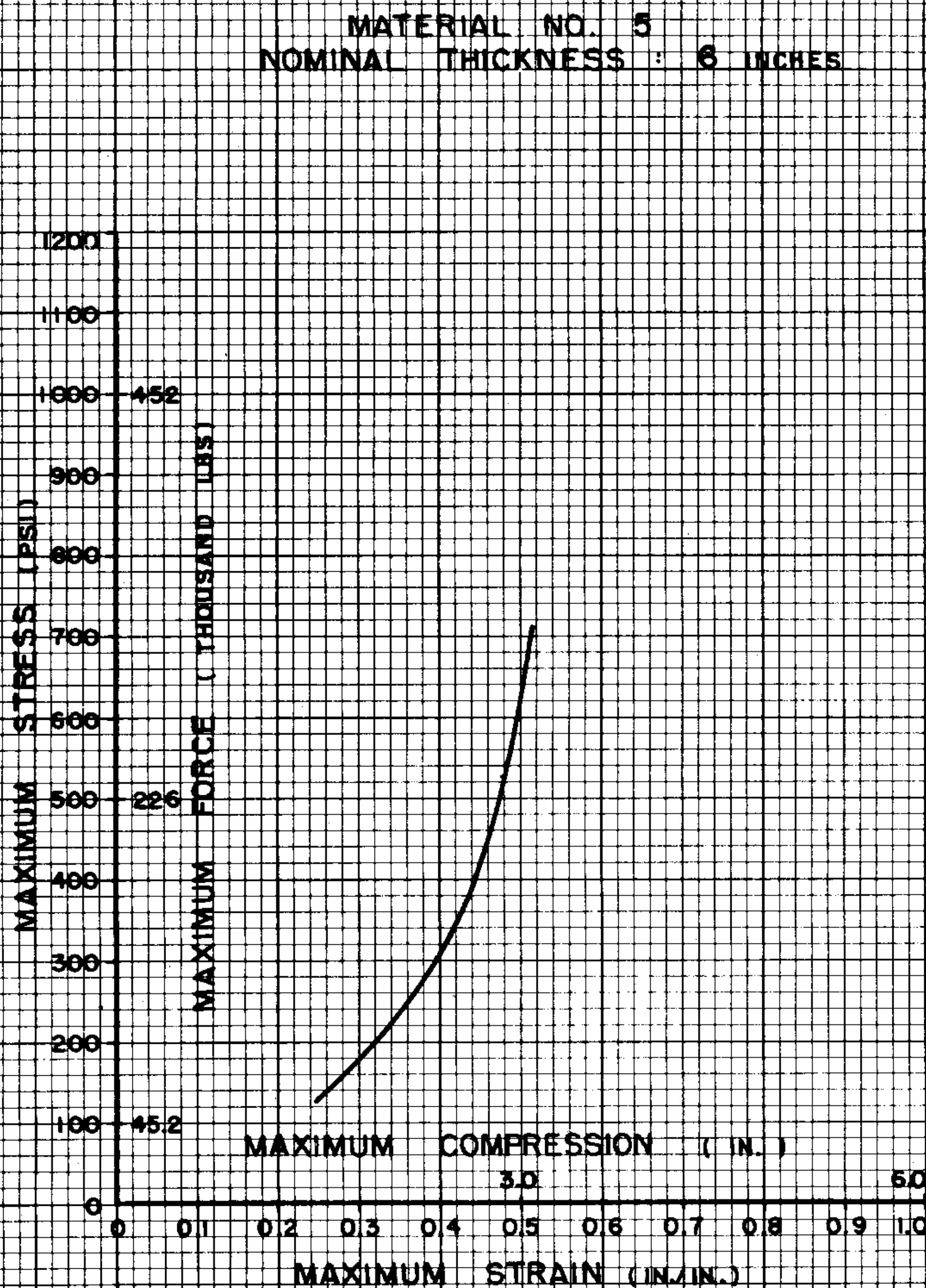

FIGURE 17 MAXIMUM STRESS - MAXIMUM STRAIN CURVE FOR 6 INCHES OF MATERIAL NO. 5

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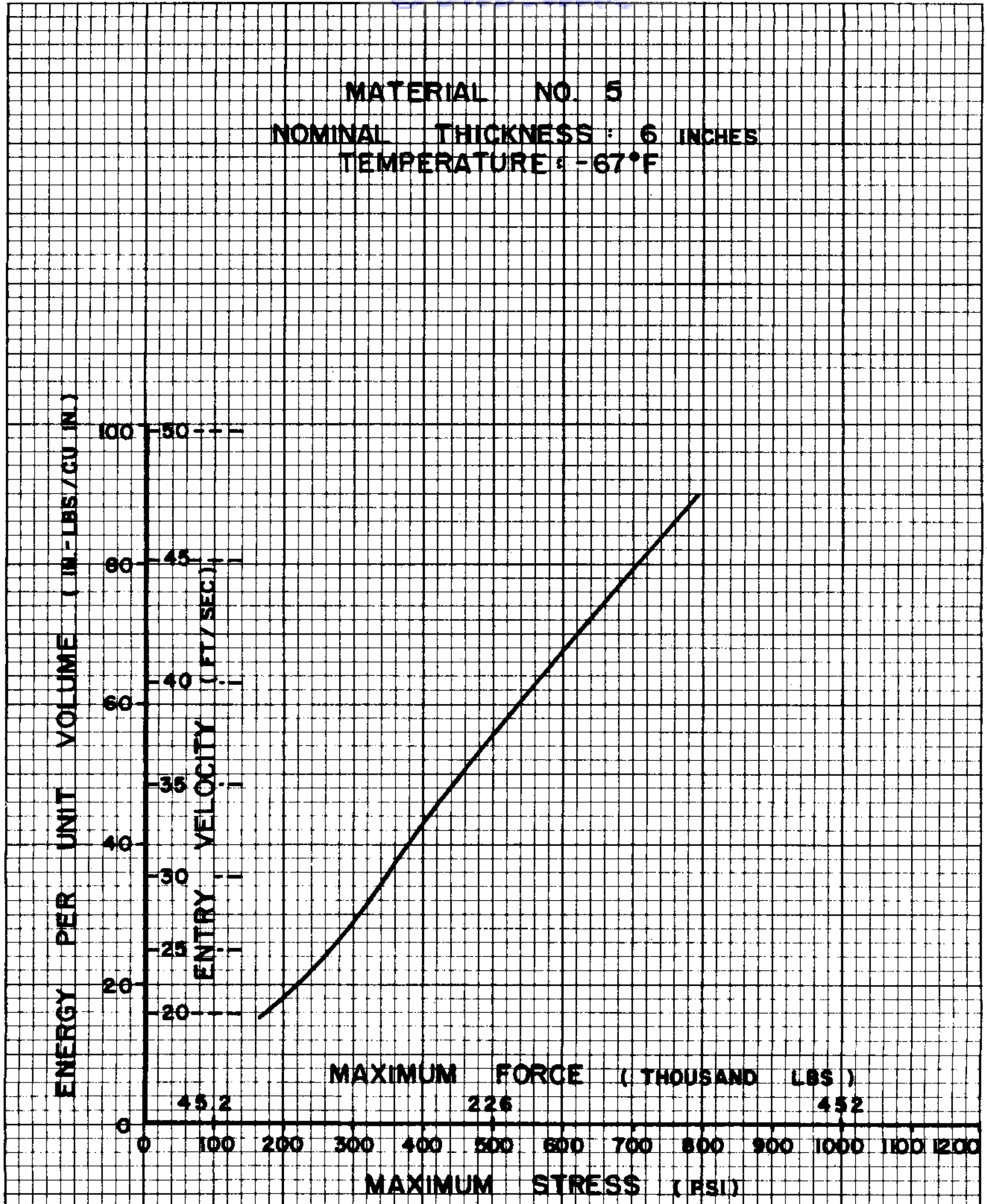

FIGURE 18 ENERGY PER UNIT VOLUME - MAXIMUM STRESS CURVE FOR 6 INCHES OF MATERIAL No. 5

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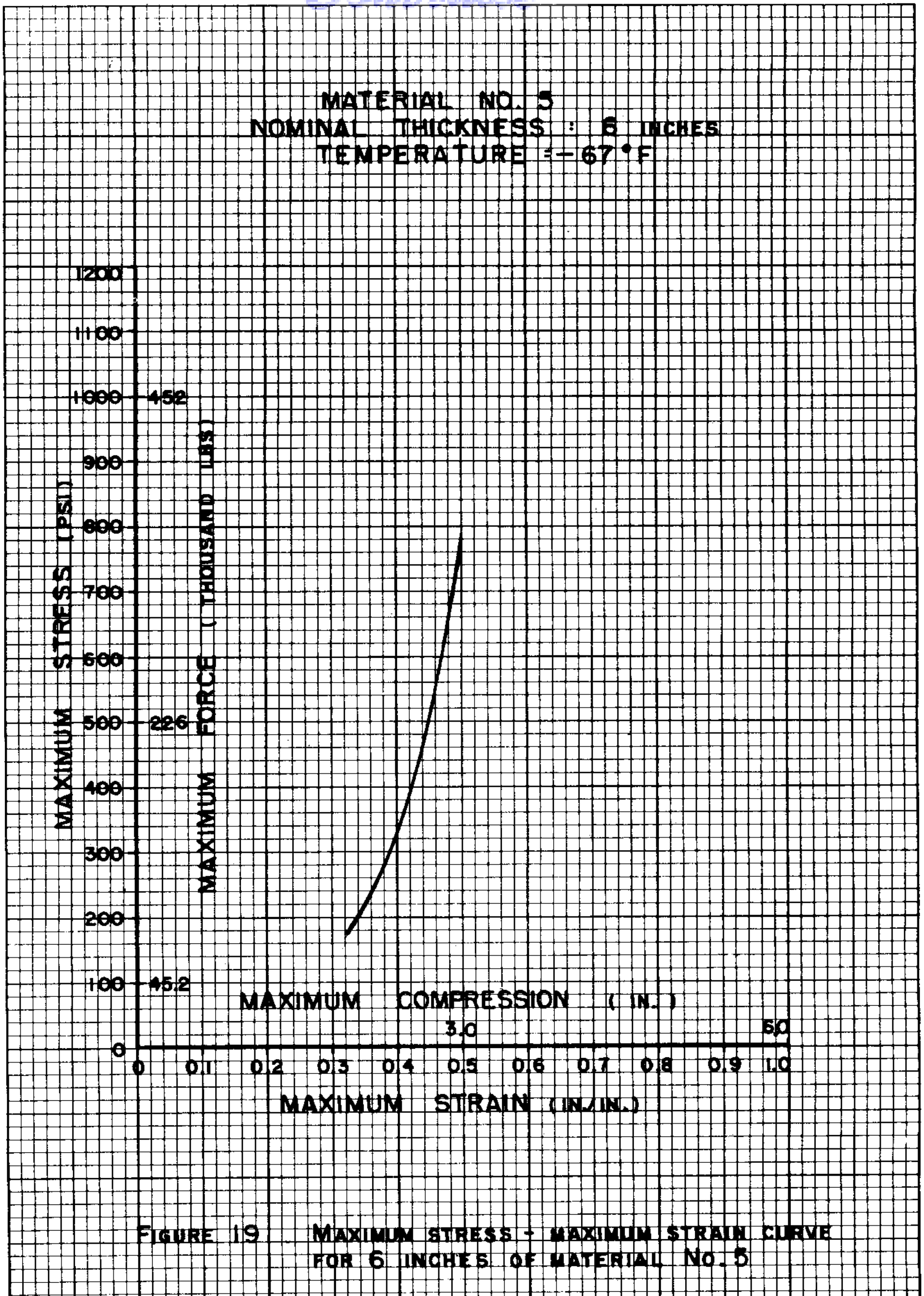

FIGURE 19 MAXIMUM STRESS - MAXIMUM STRAIN CURVE FOR 6 INCHES OF MATERIAL NO. 5

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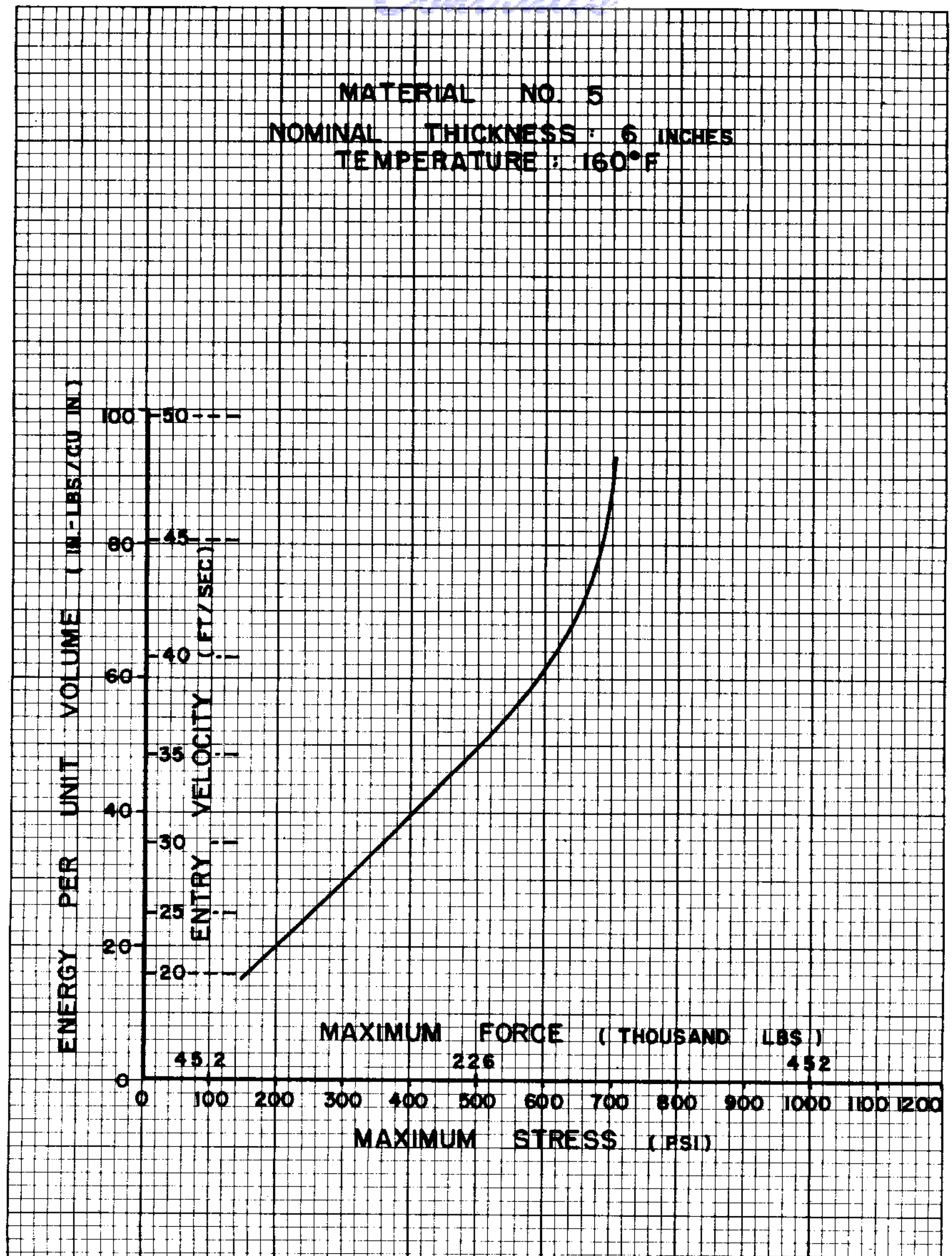

FIGURE 20 ENERGY PER UNIT VOLUME - MAXIMUM STRESS CURVE FOR 6 INCHES OF MATERIAL No. 5

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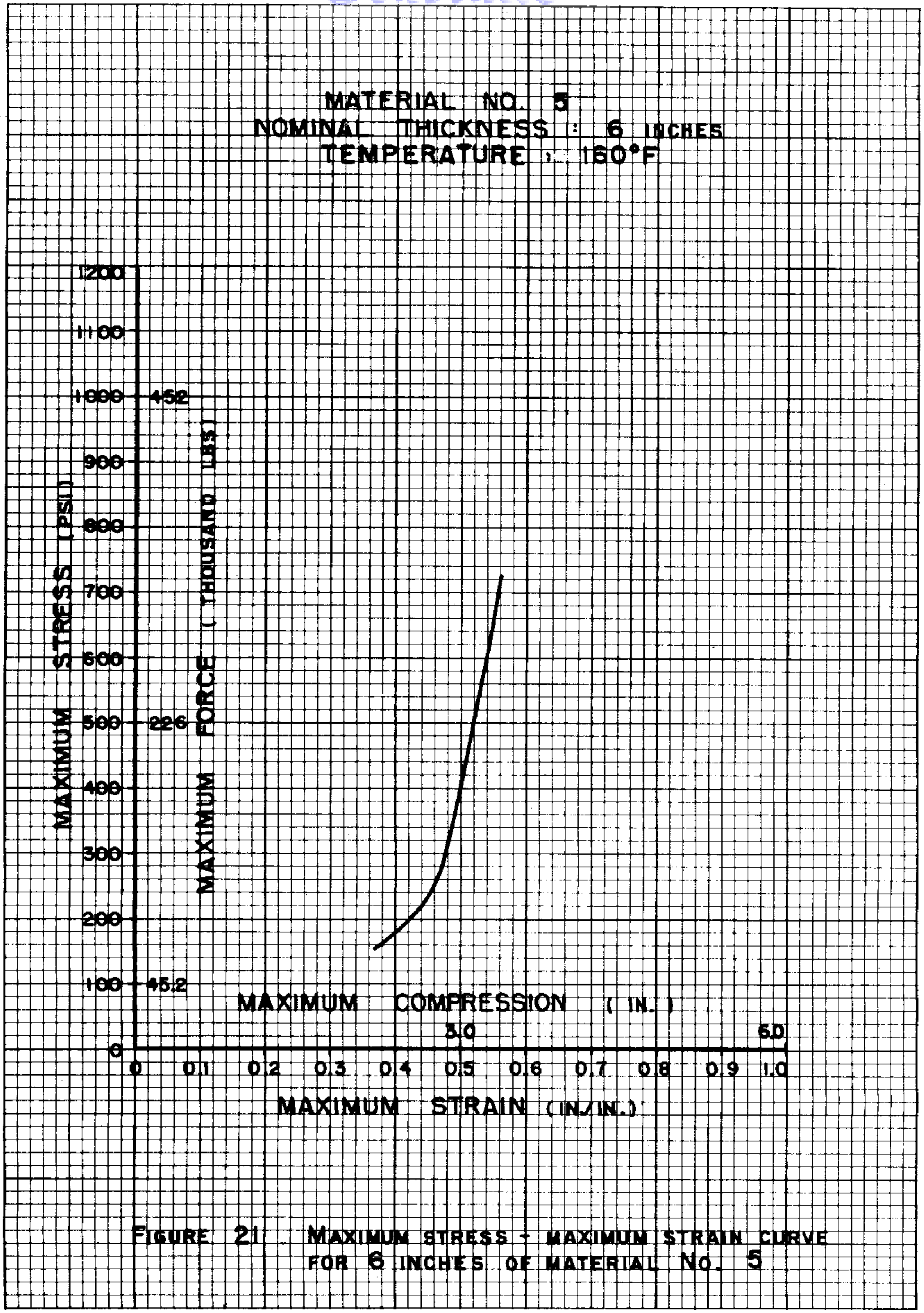

FIGURE 21 MAXIMUM STRESS - MAXIMUM STRAIN CURVE FOR 6 INCHES OF MATERIAL No. 5

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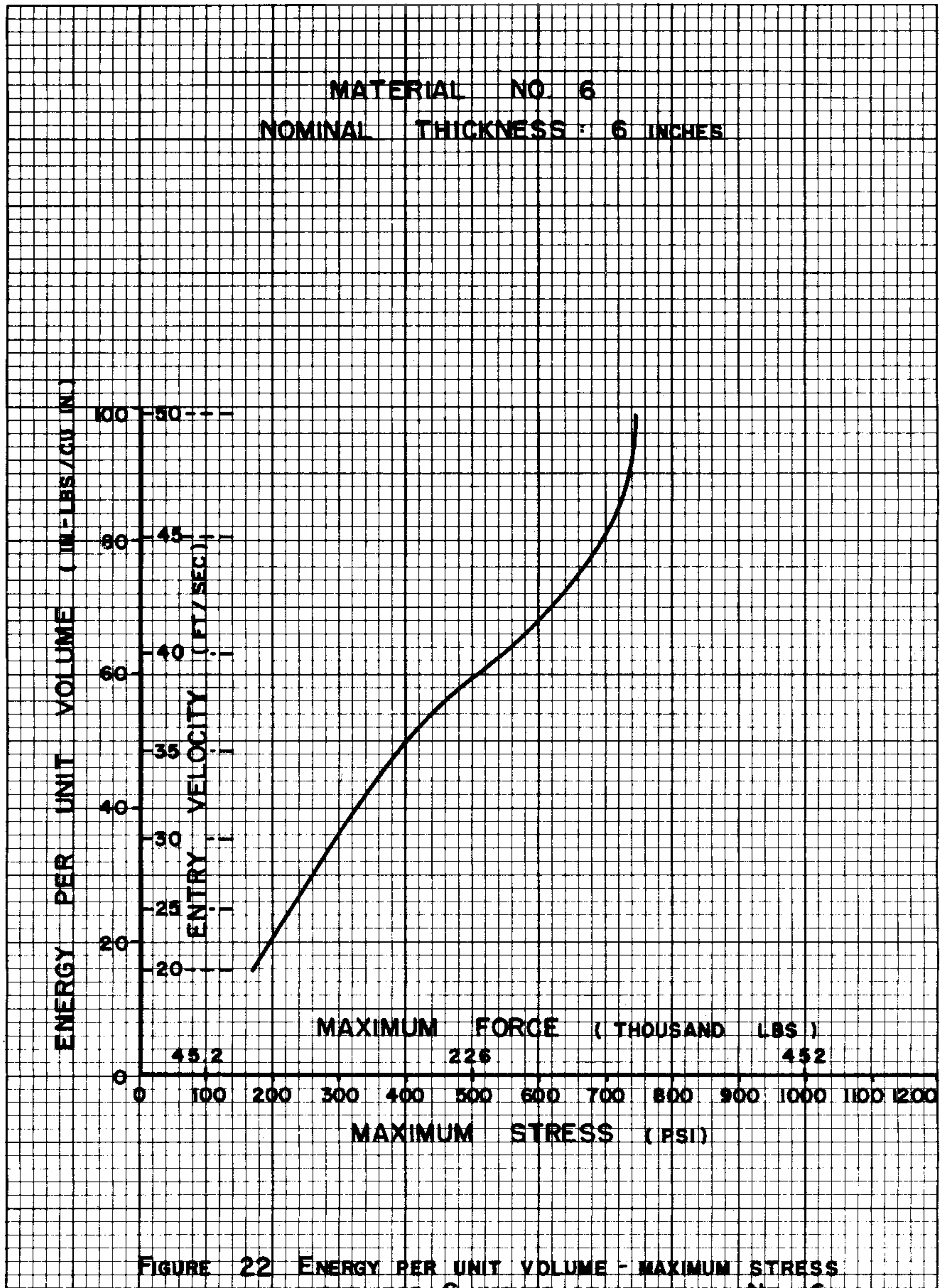

FIGURE 22 ENERGY PER UNIT VOLUME - MAXIMUM STRESS CURVE FOR 6 INCHES OF MATERIAL No. 6

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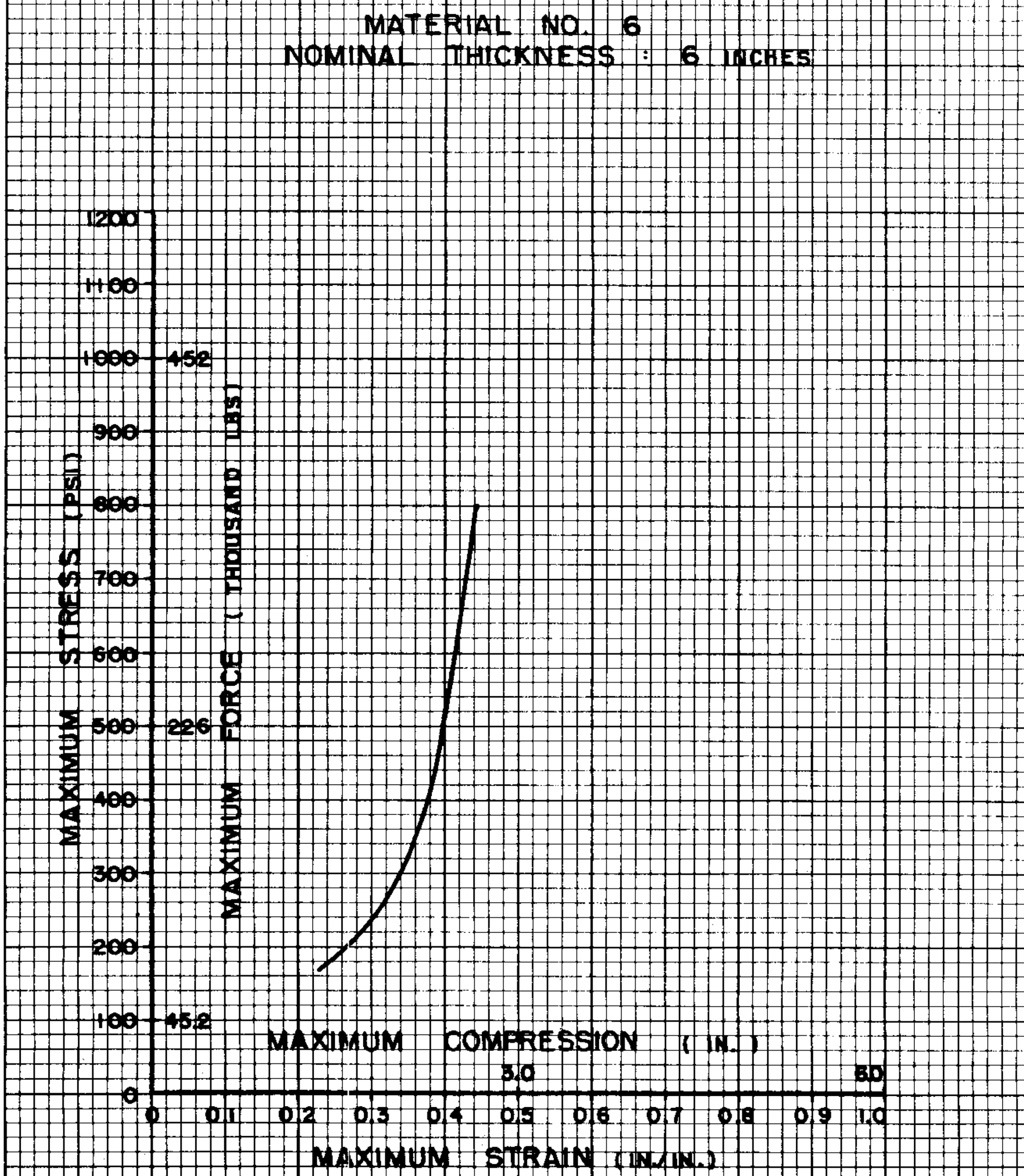

FIGURE 23 MAXIMUM STRESS - MAXIMUM STRAIN CURVE FOR 6 INCHES OF MATERIAL No. 6

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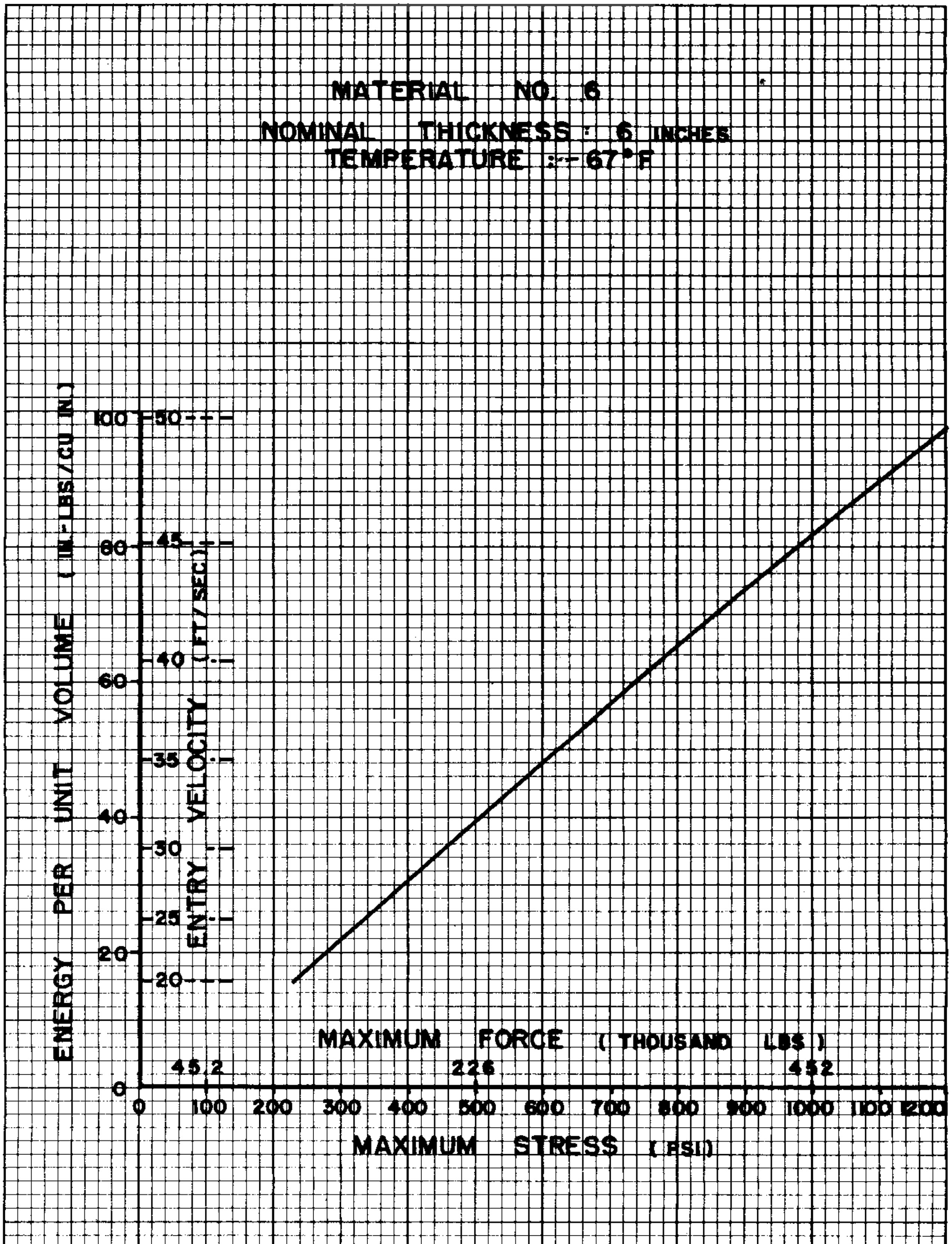

FIGURE 24 ENERGY PER UNIT VOLUME - MAXIMUM STRESS CURVE FOR 6 INCHES OF MATERIAL No. 6

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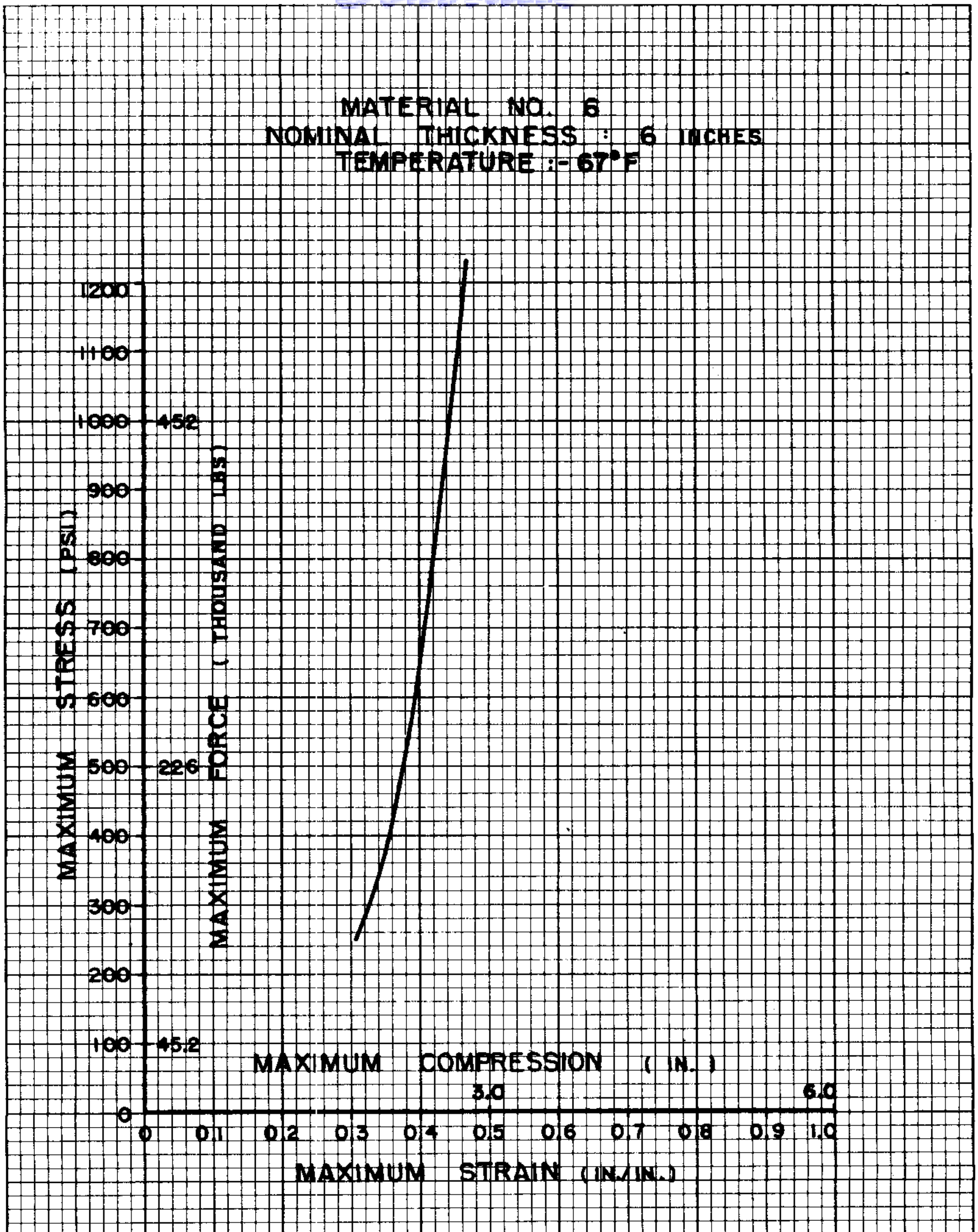

FIGURE 25 MAXIMUM STRESS - MAXIMUM STRAIN CURVE FOR 6 INCHES OF MATERIAL No. 6

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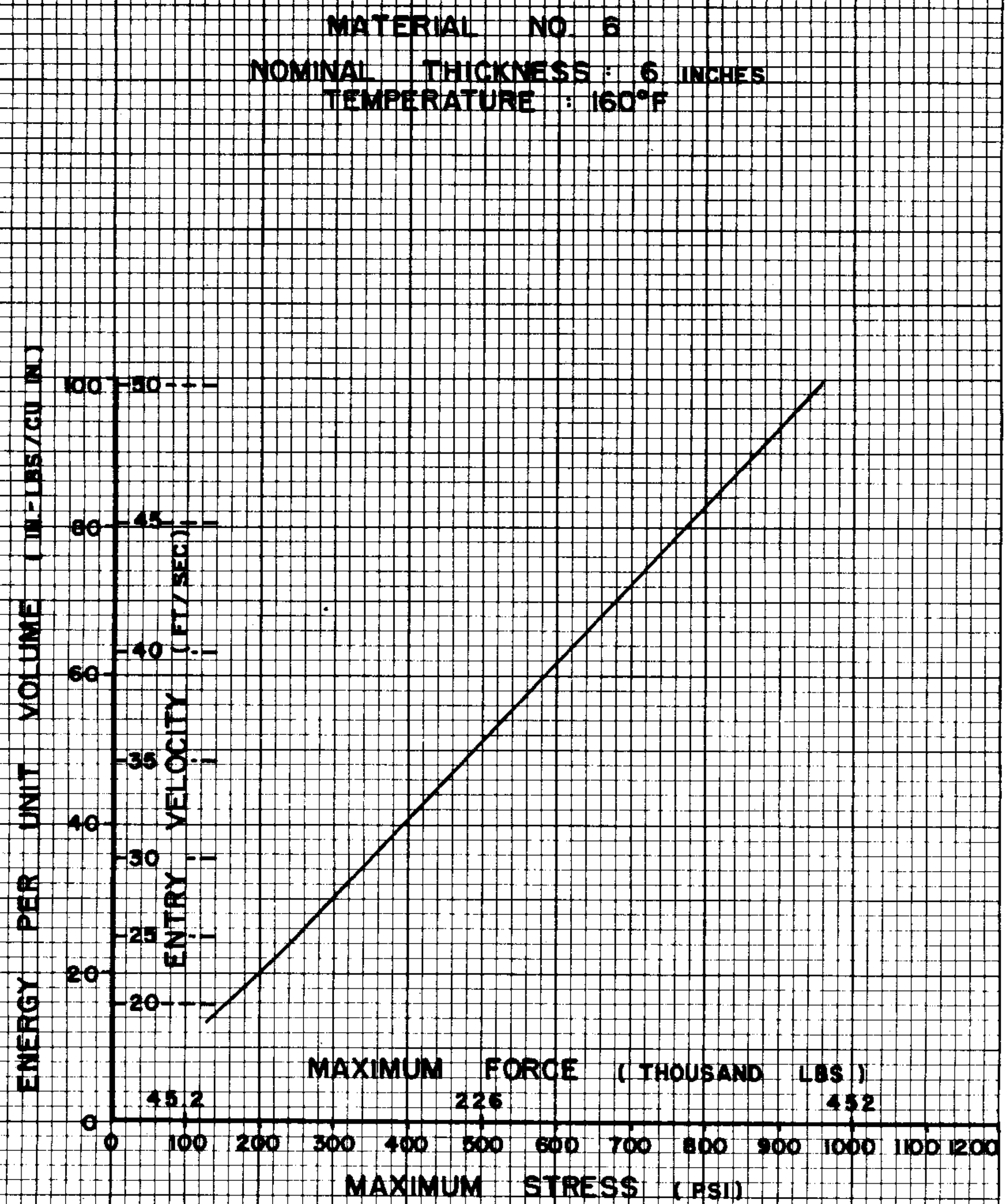

FIGURE 26 ENERGY PER UNIT VOLUME - MAXIMUM STRESS CURVE FOR 6 INCHES OF MATERIAL No. 6

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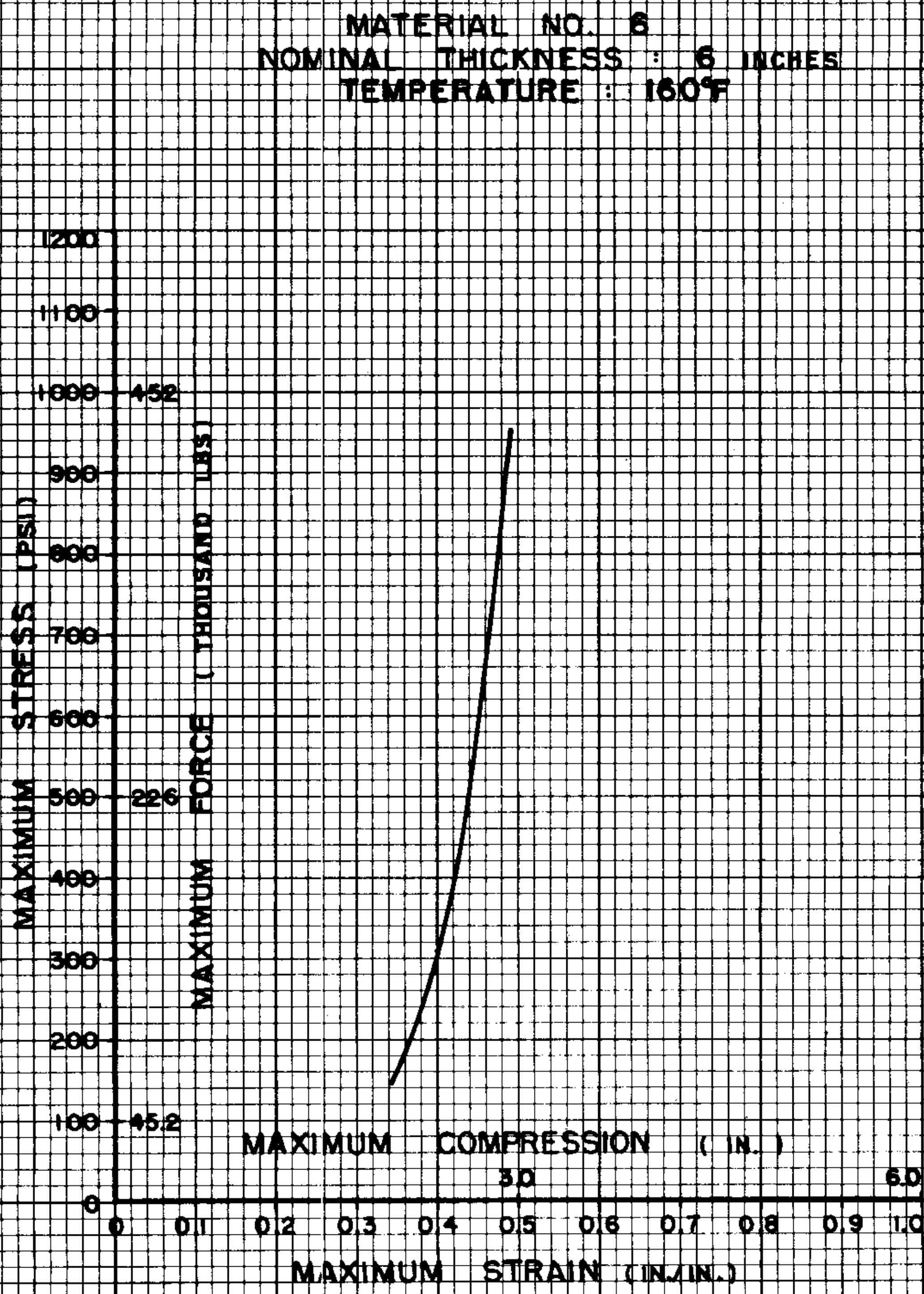

FIGURE 27 MAXIMUM STRESS - MAXIMUM STRAIN CURVE FOR 6 INCHES OF MATERIAL NO. 6

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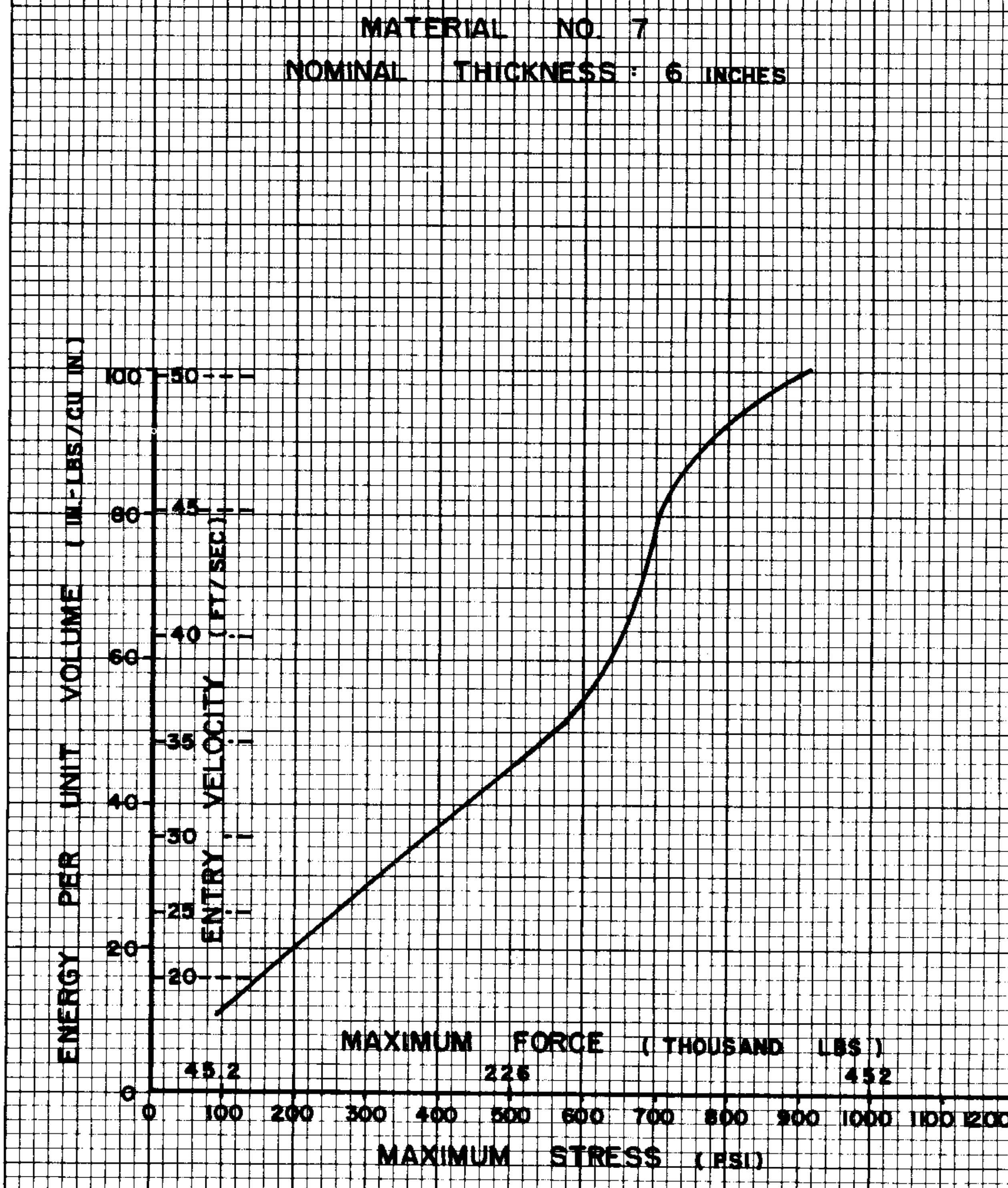

FIGURE 28 ENERGY PER UNIT VOLUME - MAXIMUM STRESS CURVE FOR 6 INCHES OF MATERIAL No. 7

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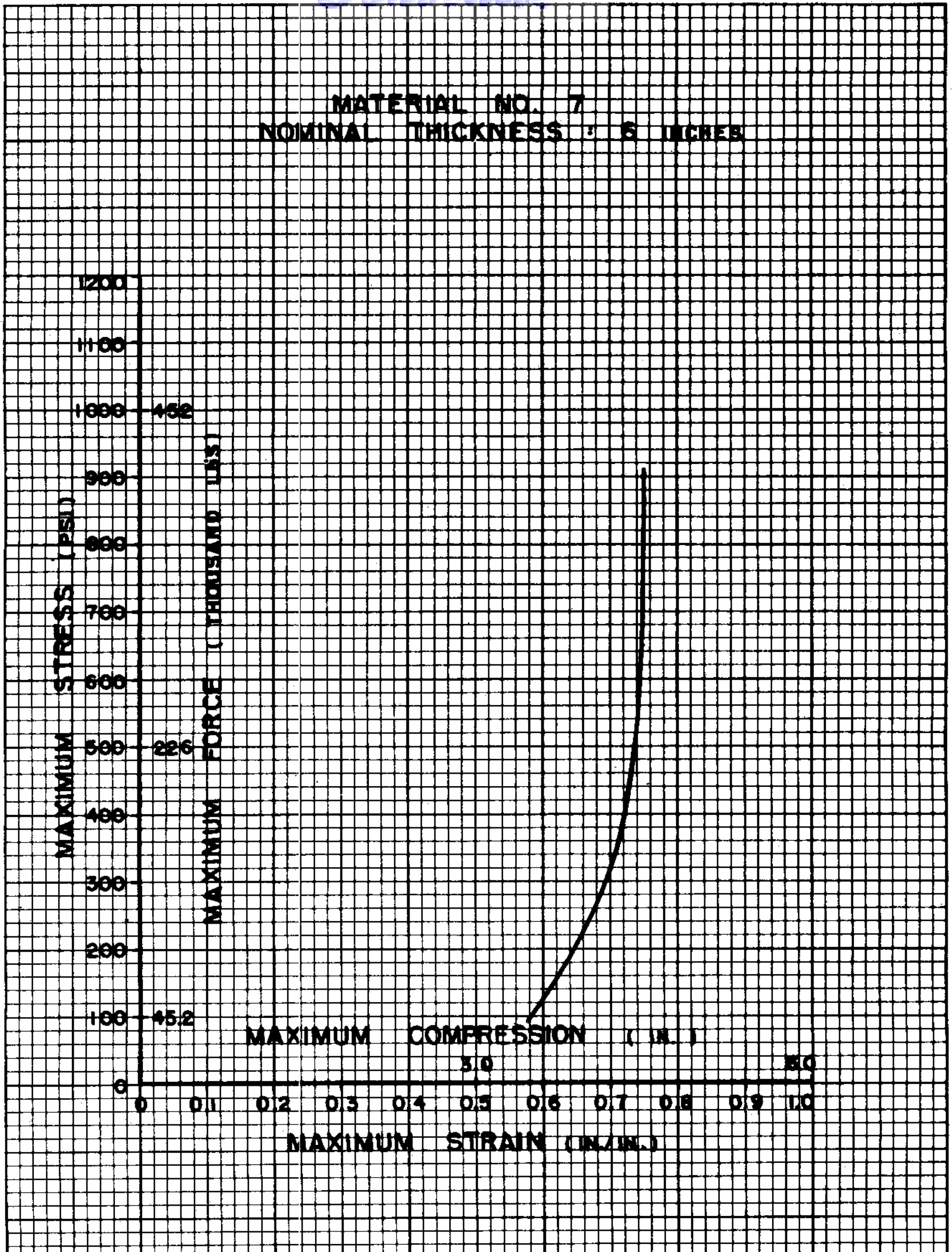

FIGURE 29. MAXIMUM STRESS - MAXIMUM STRAIN CURVE FOR 6 INCHES OF MATERIAL NO. 7

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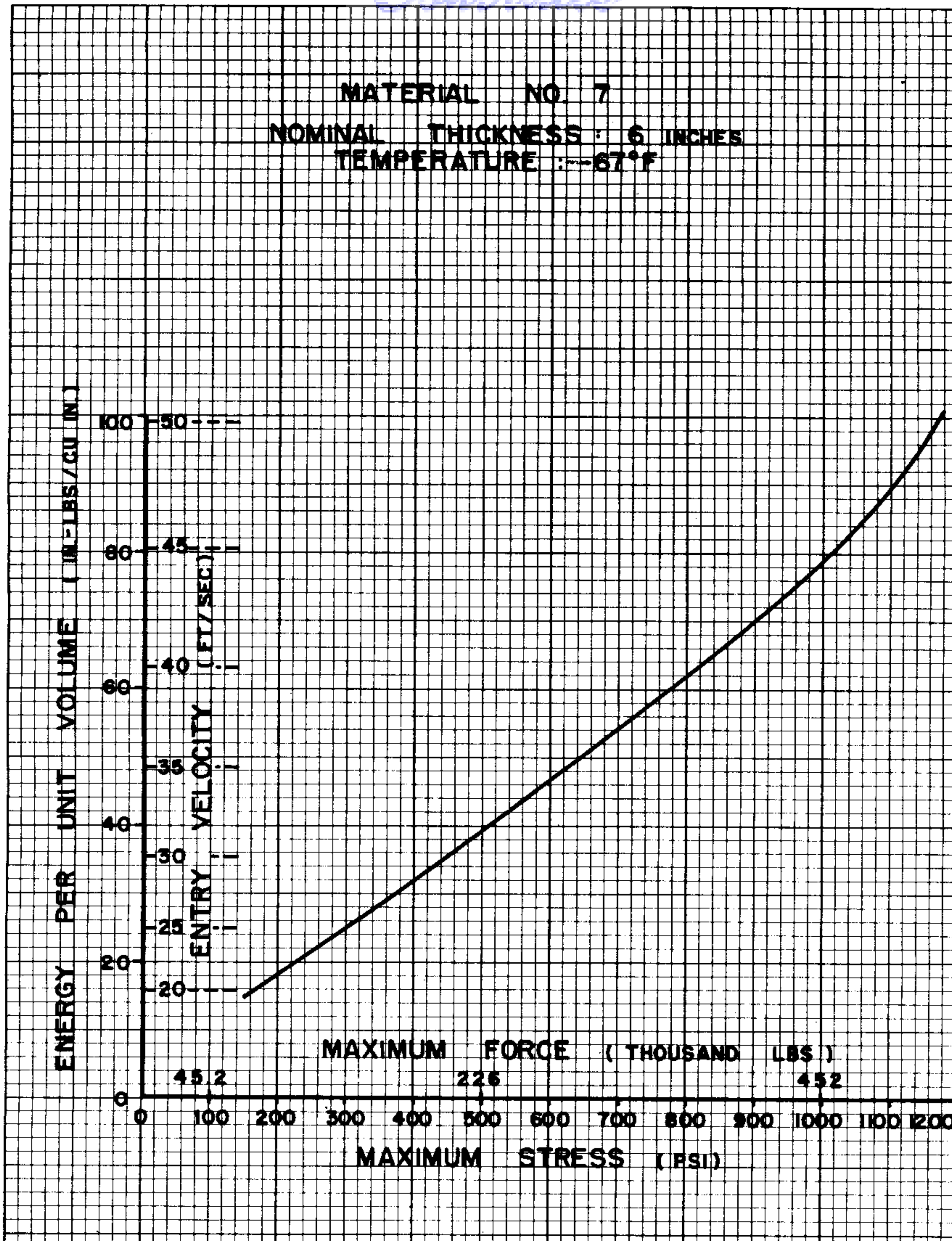

FIGURE 30 ENERGY PER UNIT VOLUME - MAXIMUM STRESS CURVE FOR 6 INCHES OF MATERIAL No. 7

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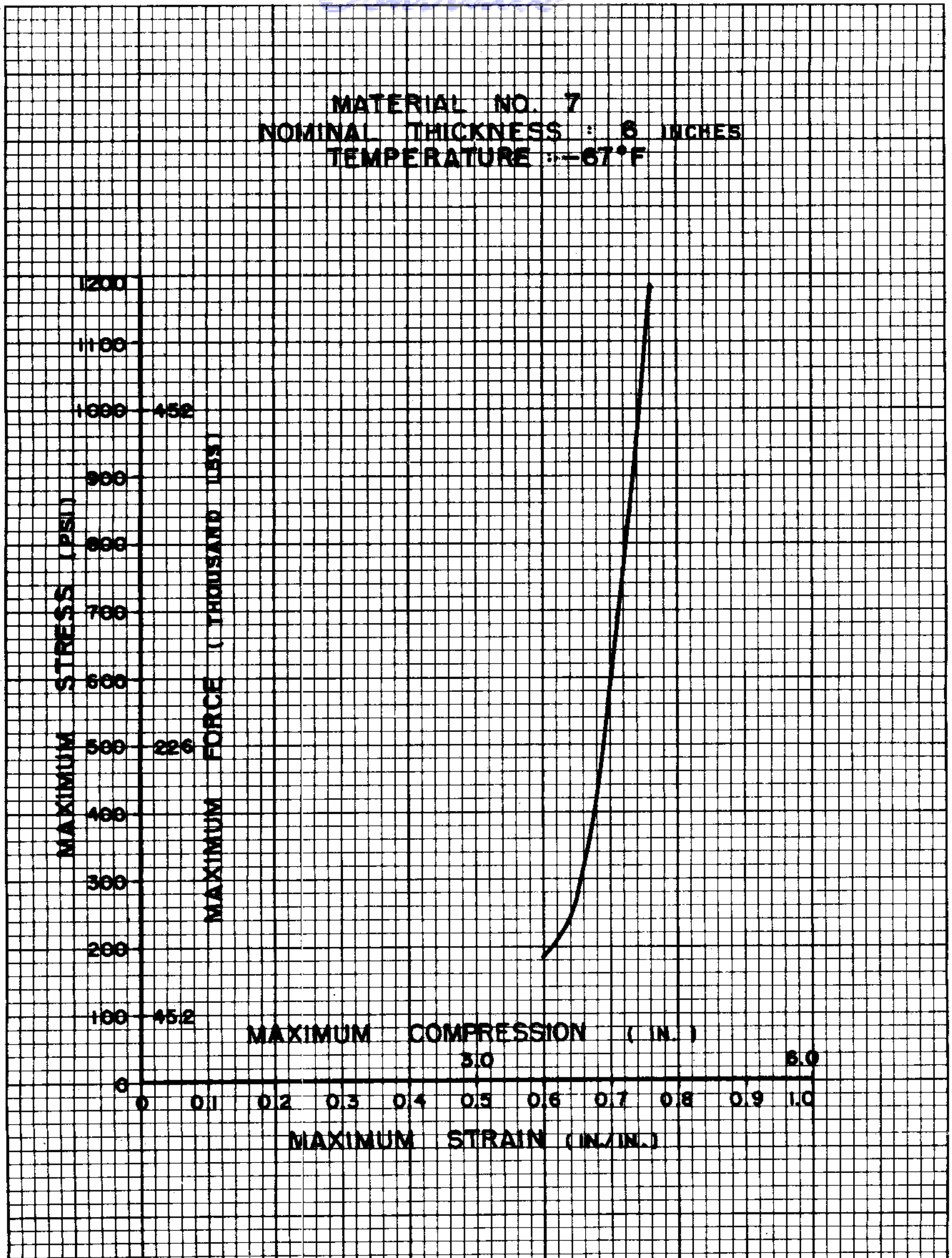

FIGURE 31 MAXIMUM STRESS - MAXIMUM STRAIN CURVE FOR 6 INCHES OF MATERIAL NO. 7

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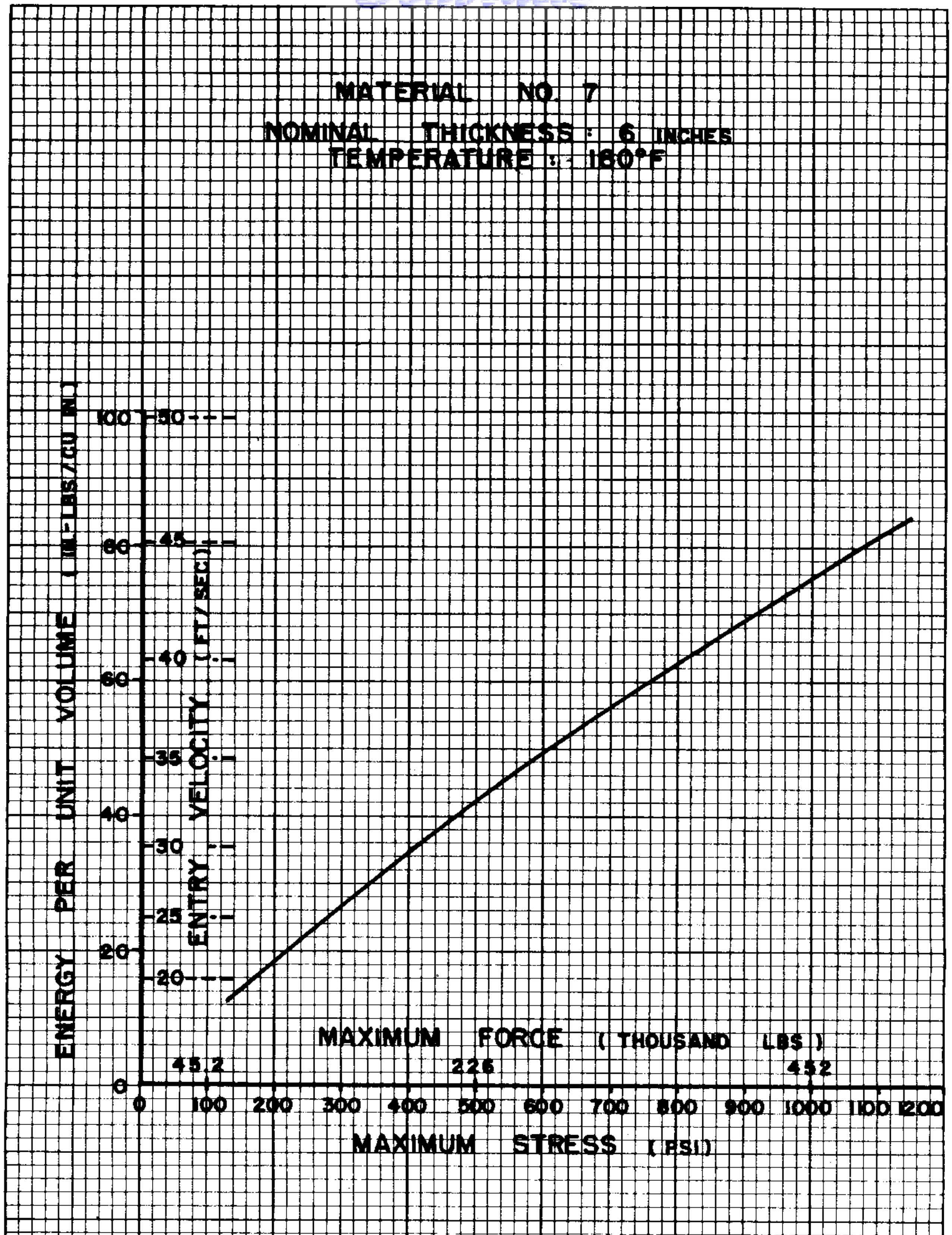

FIGURE 32 ENERGY PER UNIT VOLUME - MAXIMUM STRESS CURVE FOR 6 INCHES OF MATERIAL No. 7

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FIGURE 33 MAXIMUM STRESS - MAXIMUM STRAIN CURVE FOR 6 INCHES OF MATERIAL No. 7

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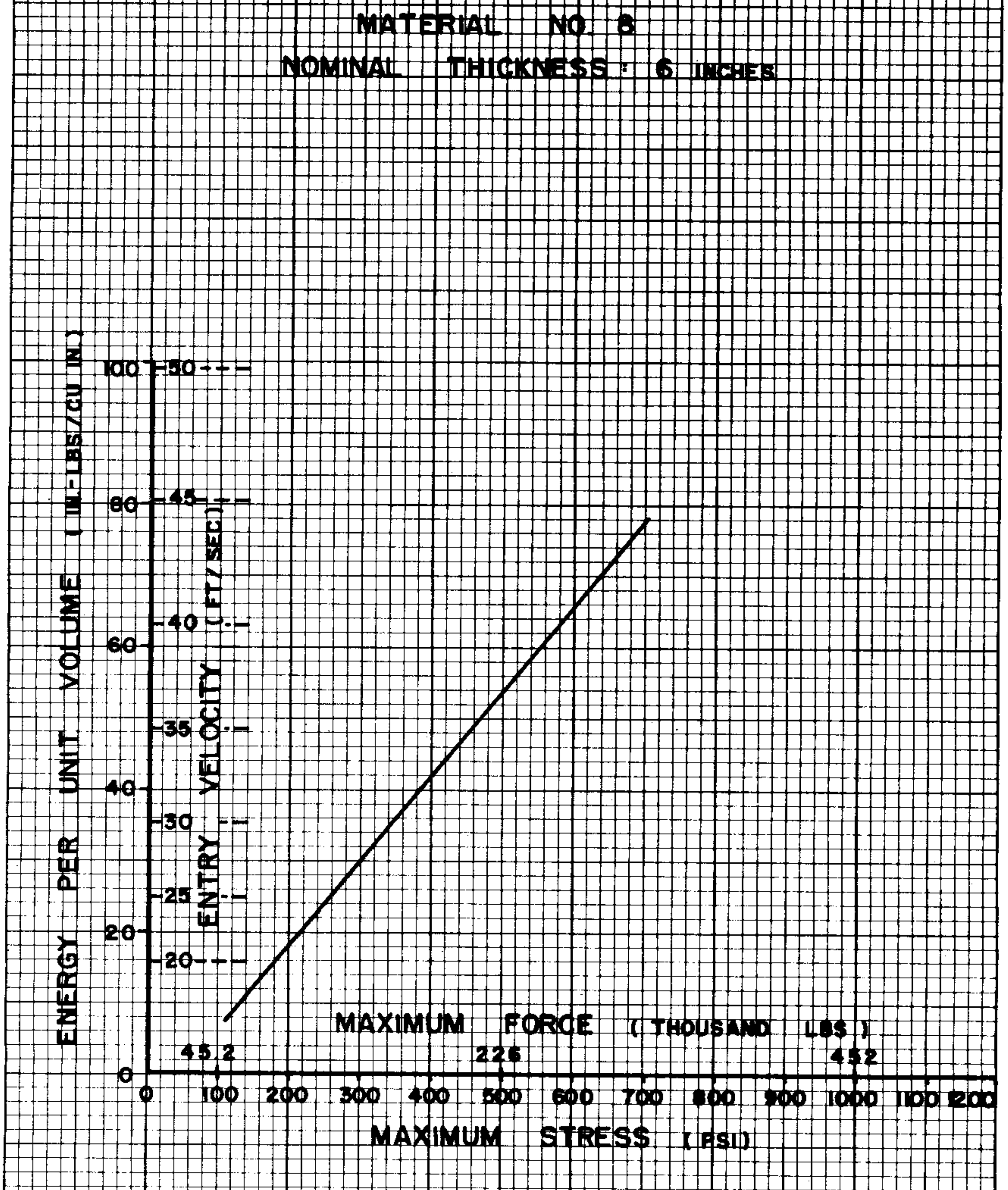

FIGURE 34 ENERGY PER UNIT VOLUME - MAXIMUM STRESS CURVE FOR 6 INCHES OF MATERIAL No. 8

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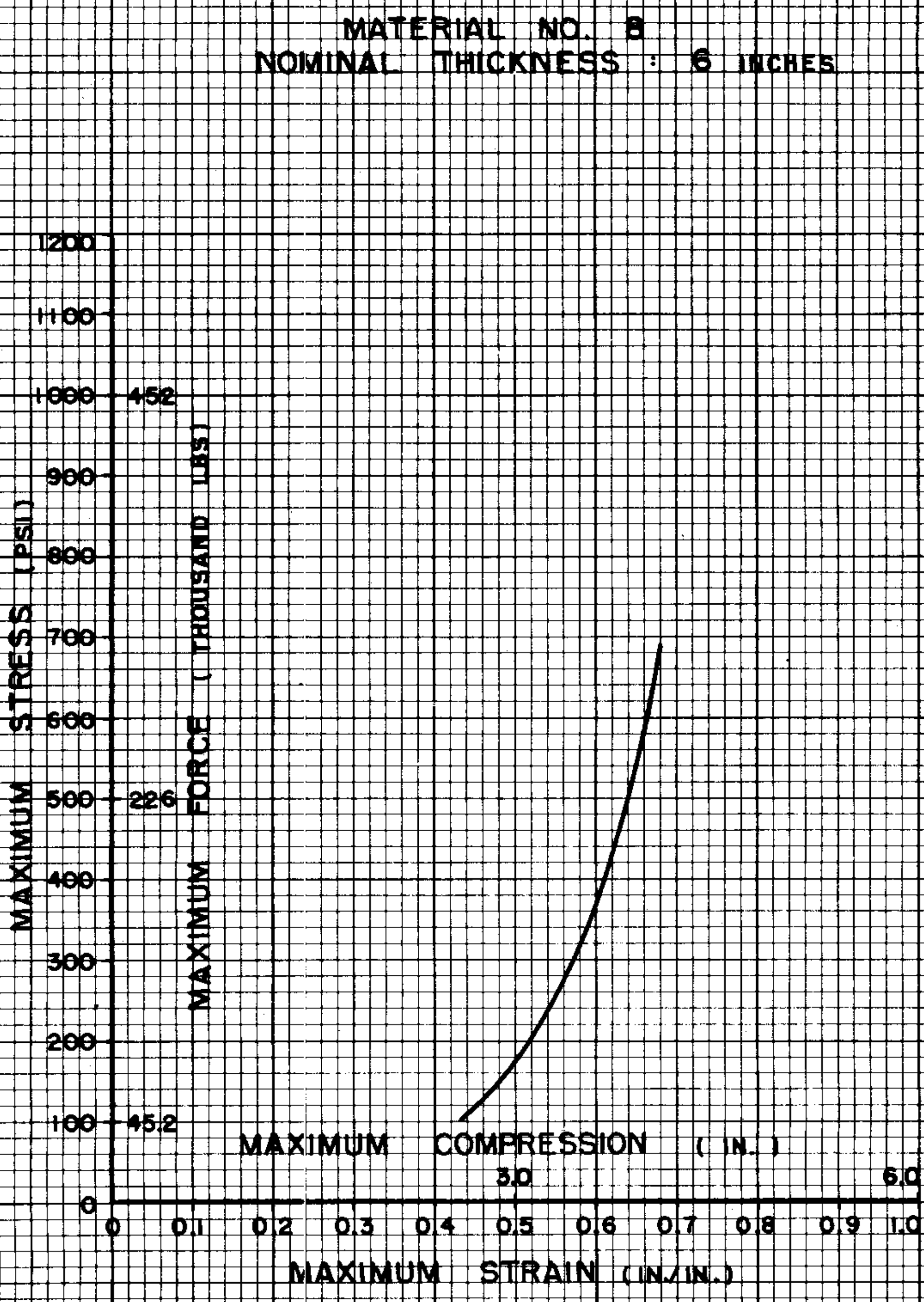

FIGURE 35 MAXIMUM STRESS - MAXIMUM STRAIN CURVE FOR 6 INCHES OF MATERIAL NO. 8

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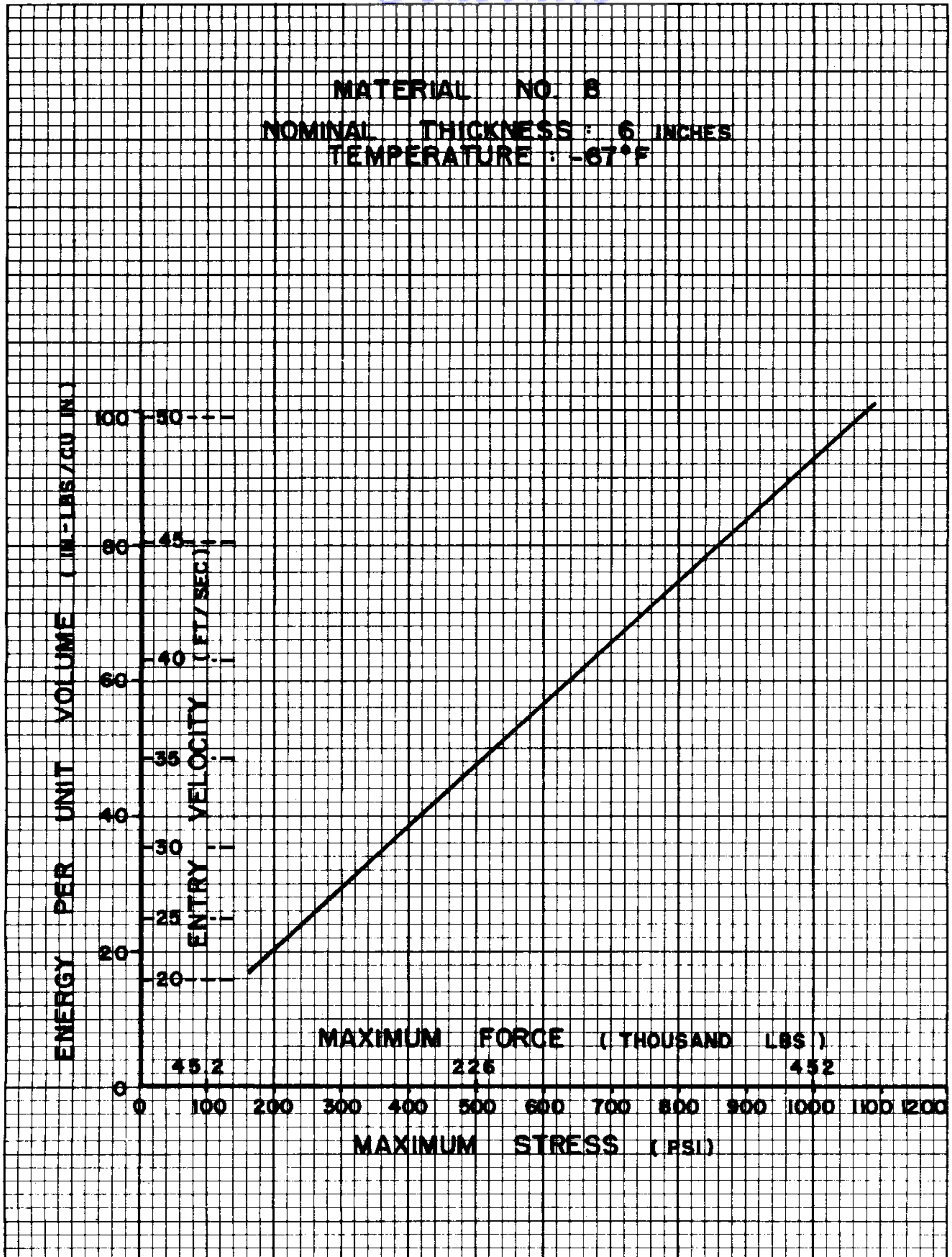

FIGURE 36 ENERGY PER UNIT VOLUME - MAXIMUM STRESS CURVE FOR 6 INCHES OF MATERIAL No. 8

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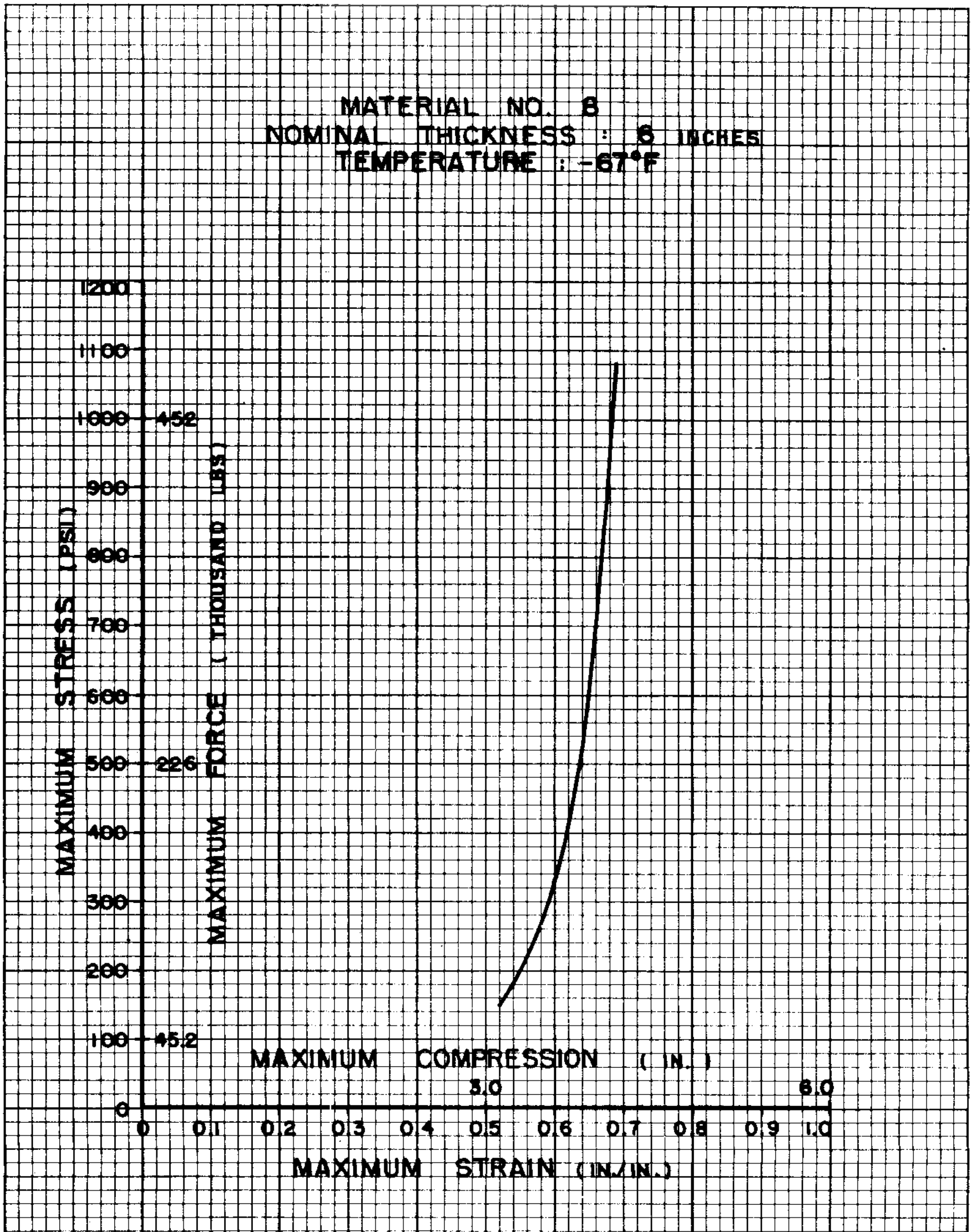

FIGURE 37 MAXIMUM STRESS - MAXIMUM STRAIN CURVE FOR 6 INCHES OF MATERIAL No. 8

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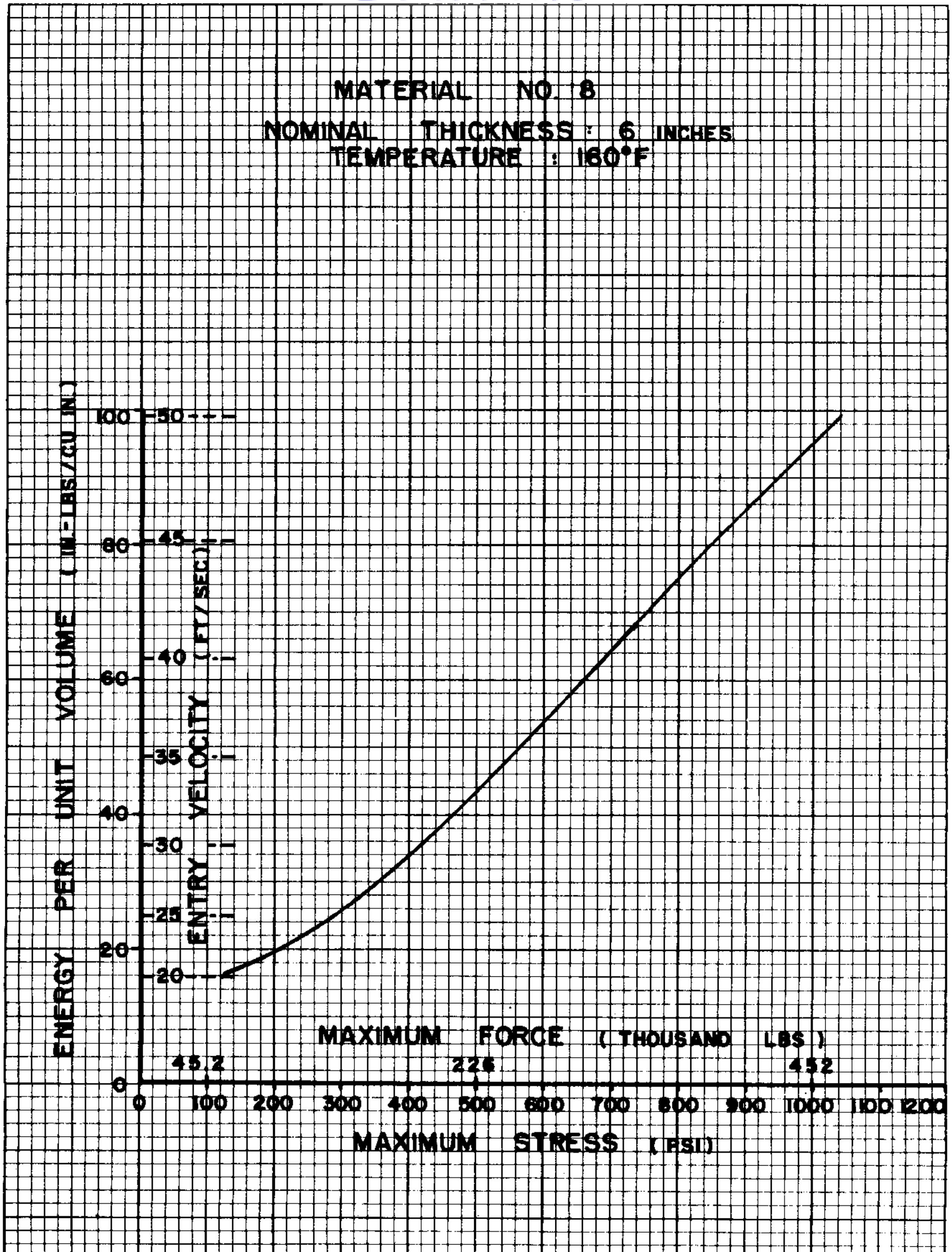

FIGURE 38 ENERGY PER UNIT VOLUME - MAXIMUM STRESS CURVE FOR 6 INCHES OF MATERIAL No. 8

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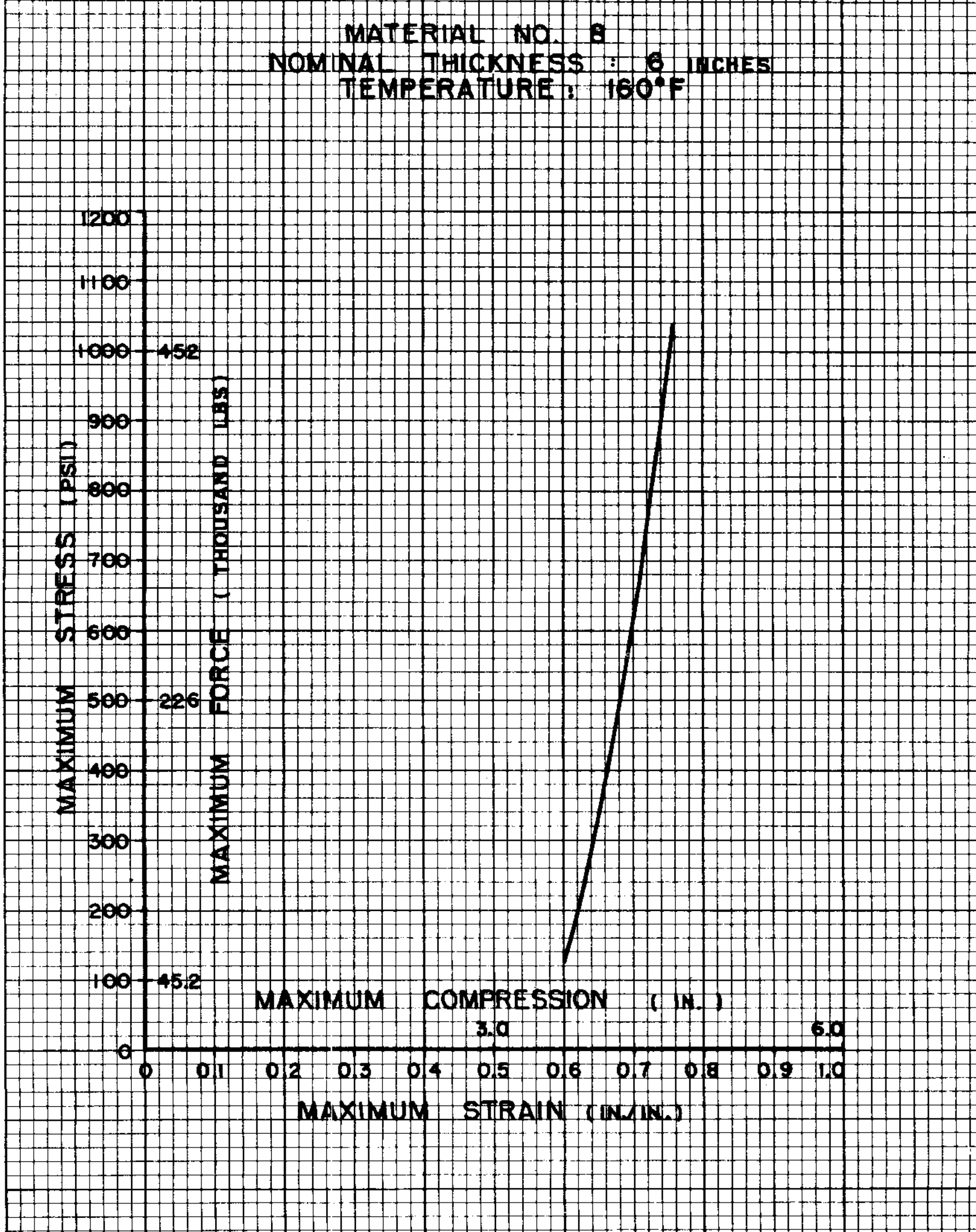

FIGURE 39 MAXIMUM STRESS - MAXIMUM STRAIN CURVE FOR 6 INCHES OF MATERIAL NO. 8

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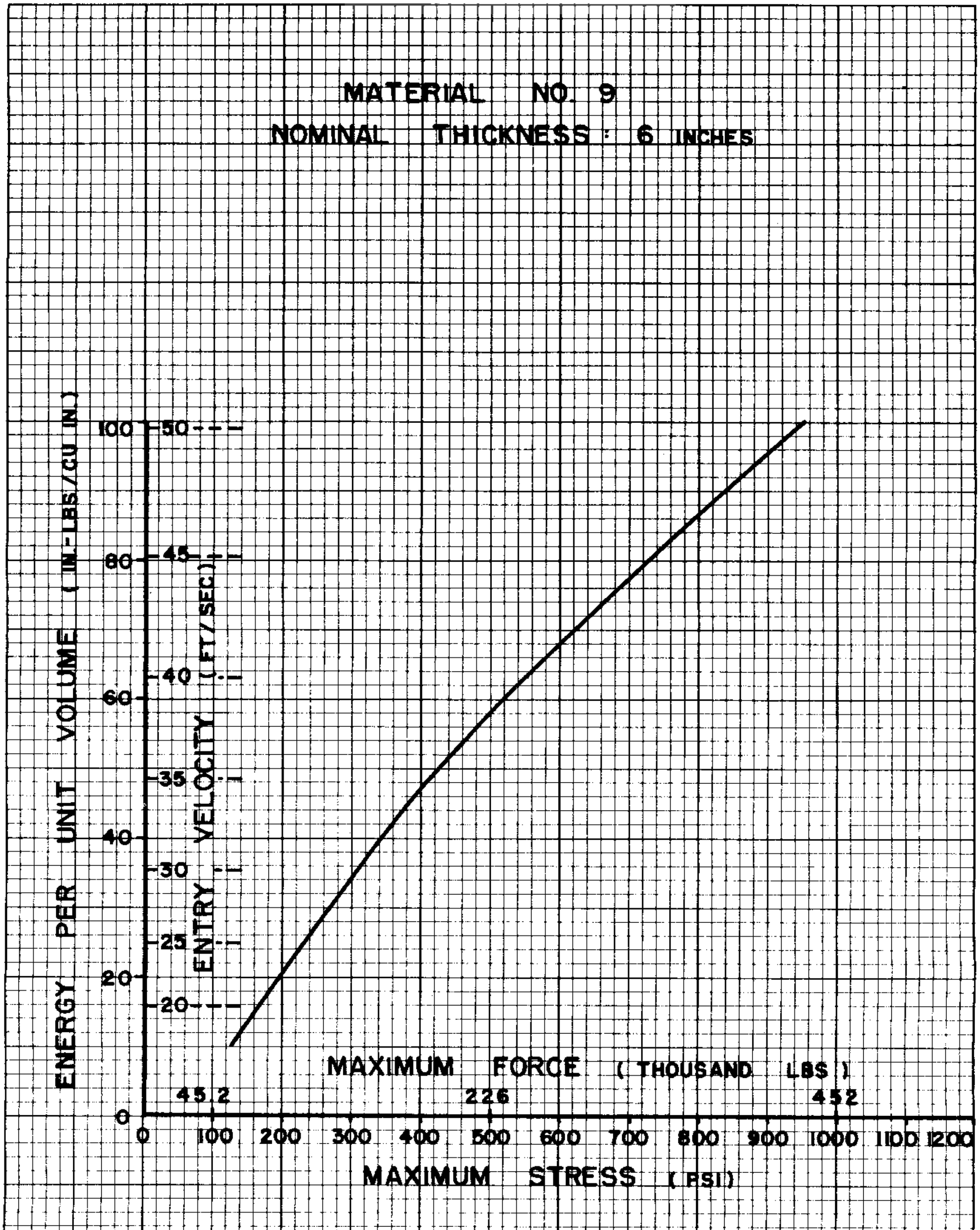

FIGURE 40 ENERGY PER UNIT VOLUME - MAXIMUM STRESS CURVE FOR 6 INCHES OF MATERIAL NO. 9

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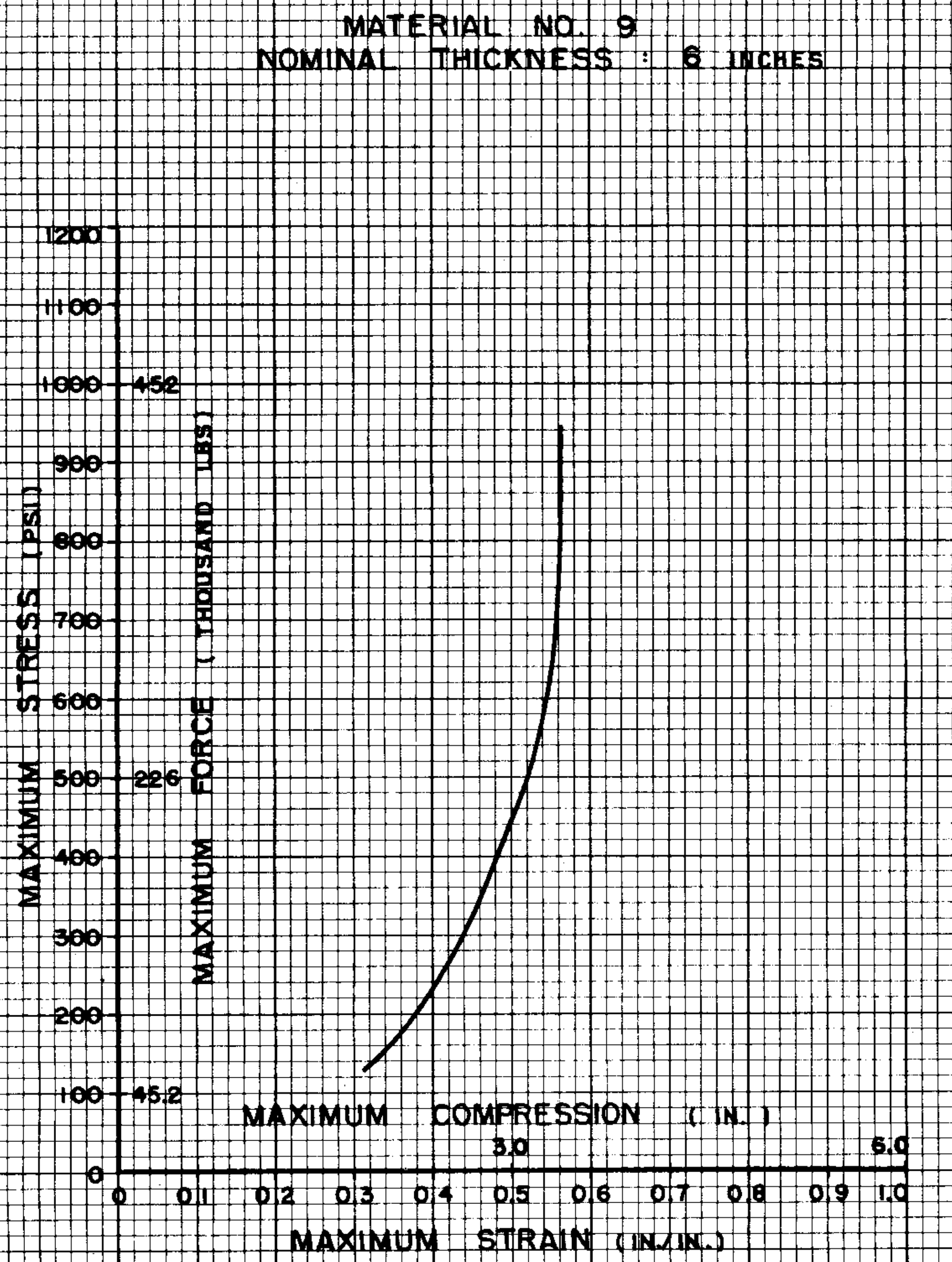

FIGURE 41 MAXIMUM STRESS - MAXIMUM STRAIN CURVE FOR 6 INCHES OF MATERIAL NO. 9

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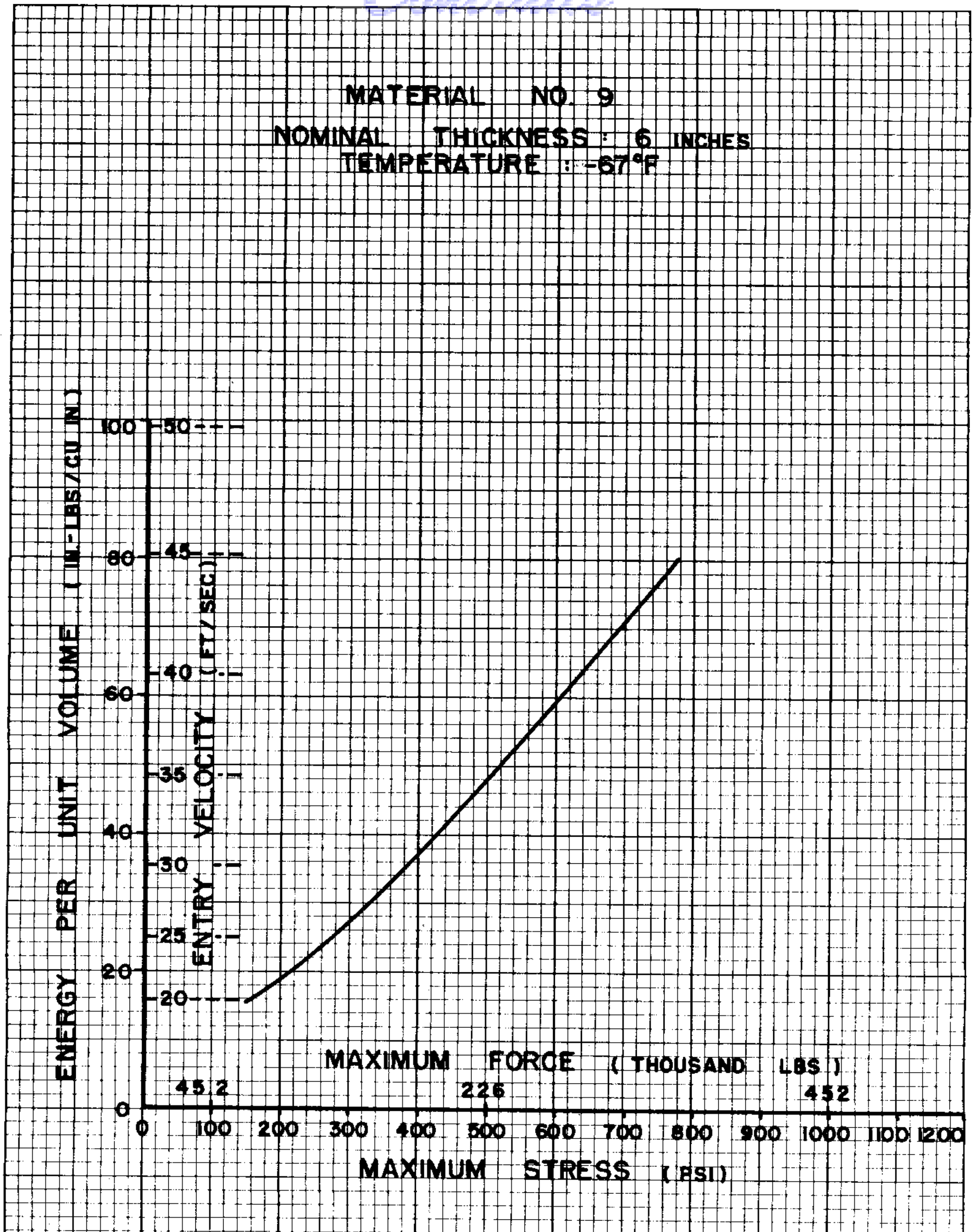

FIGURE 42 ENERGY PER UNIT VOLUME - MAXIMUM STRESS CURVE FOR 6 INCHES OF MATERIAL No. 9

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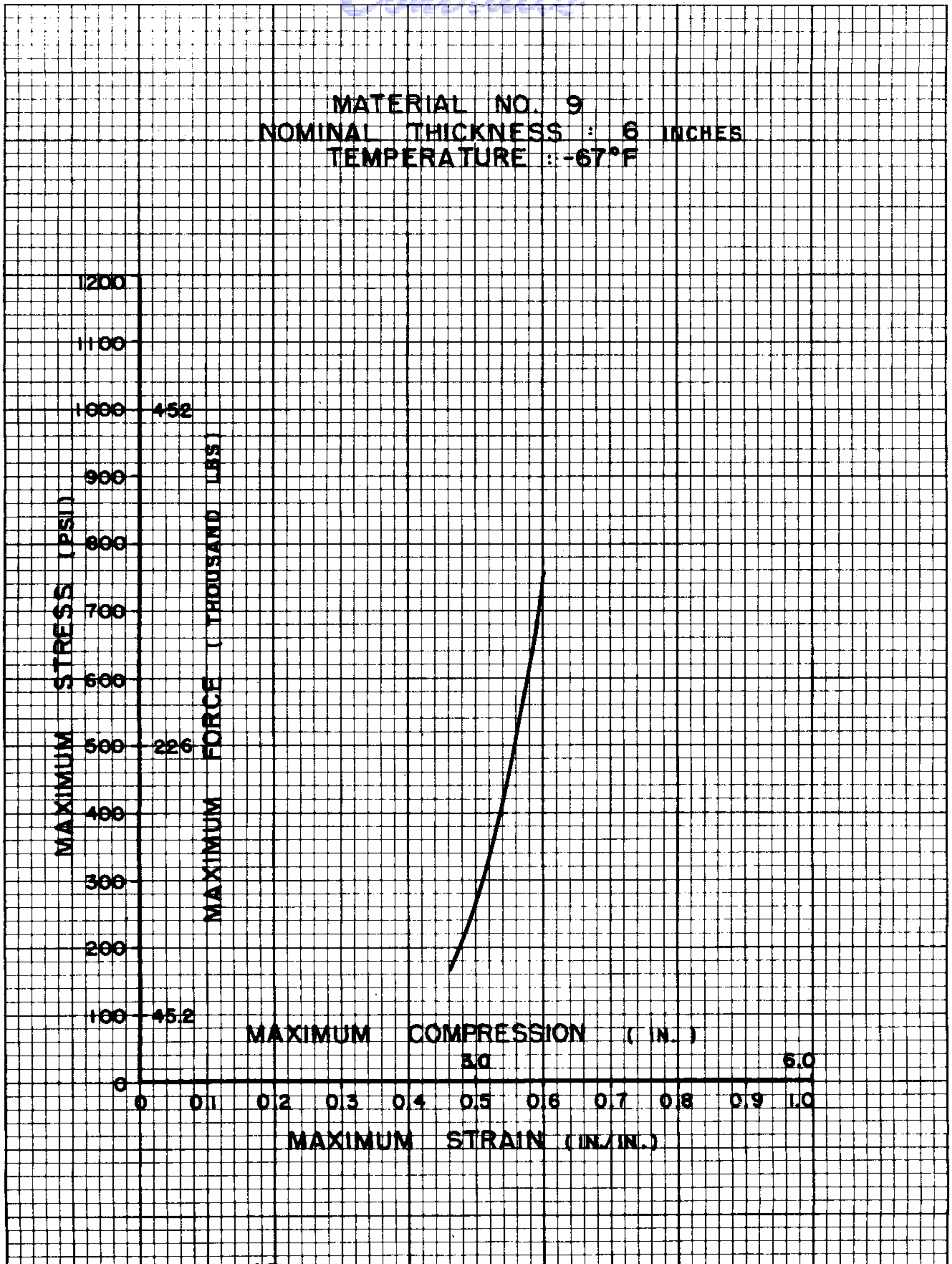

FIGURE 43 MAXIMUM STRESS - MAXIMUM STRAIN CURVE FOR 6 INCHES OF MATERIAL No. 9

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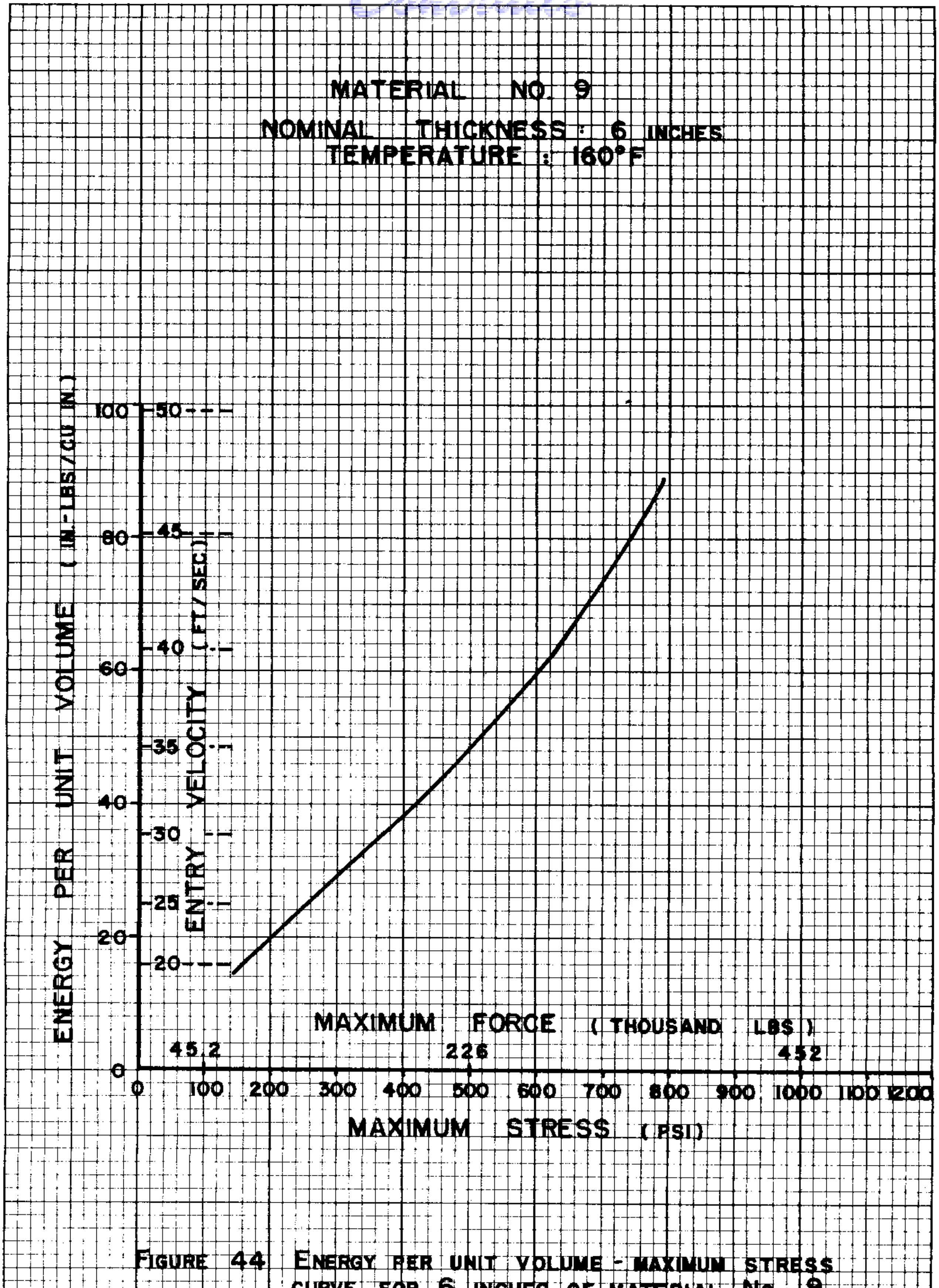

FIGURE 44 ENERGY PER UNIT VOLUME - MAXIMUM STRESS CURVE FOR 6 INCHES OF MATERIAL No. 9

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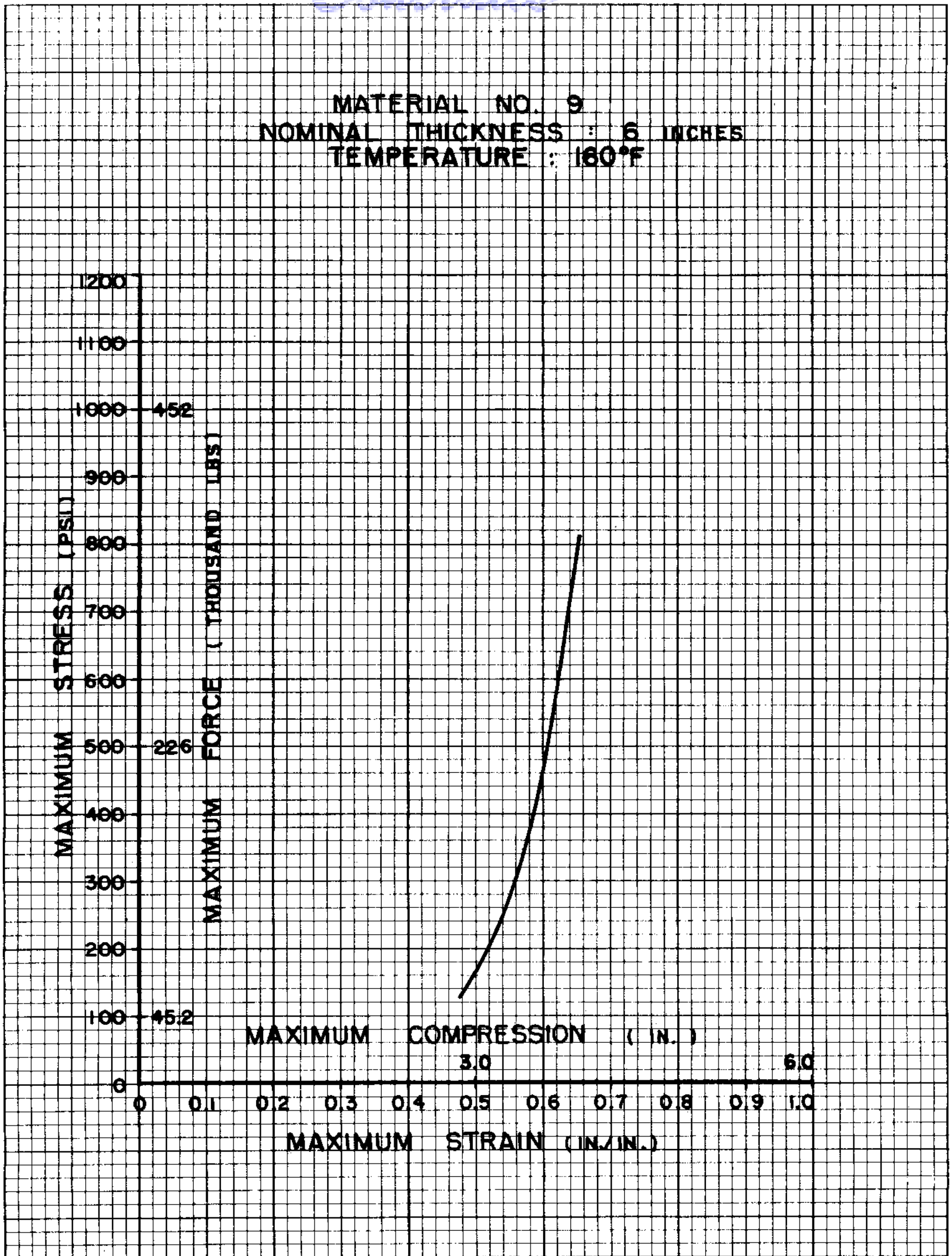

FIGURE 45 MAXIMUM STRESS - MAXIMUM STRAIN CURVE FOR 6 INCHES OF MATERIAL No. 9

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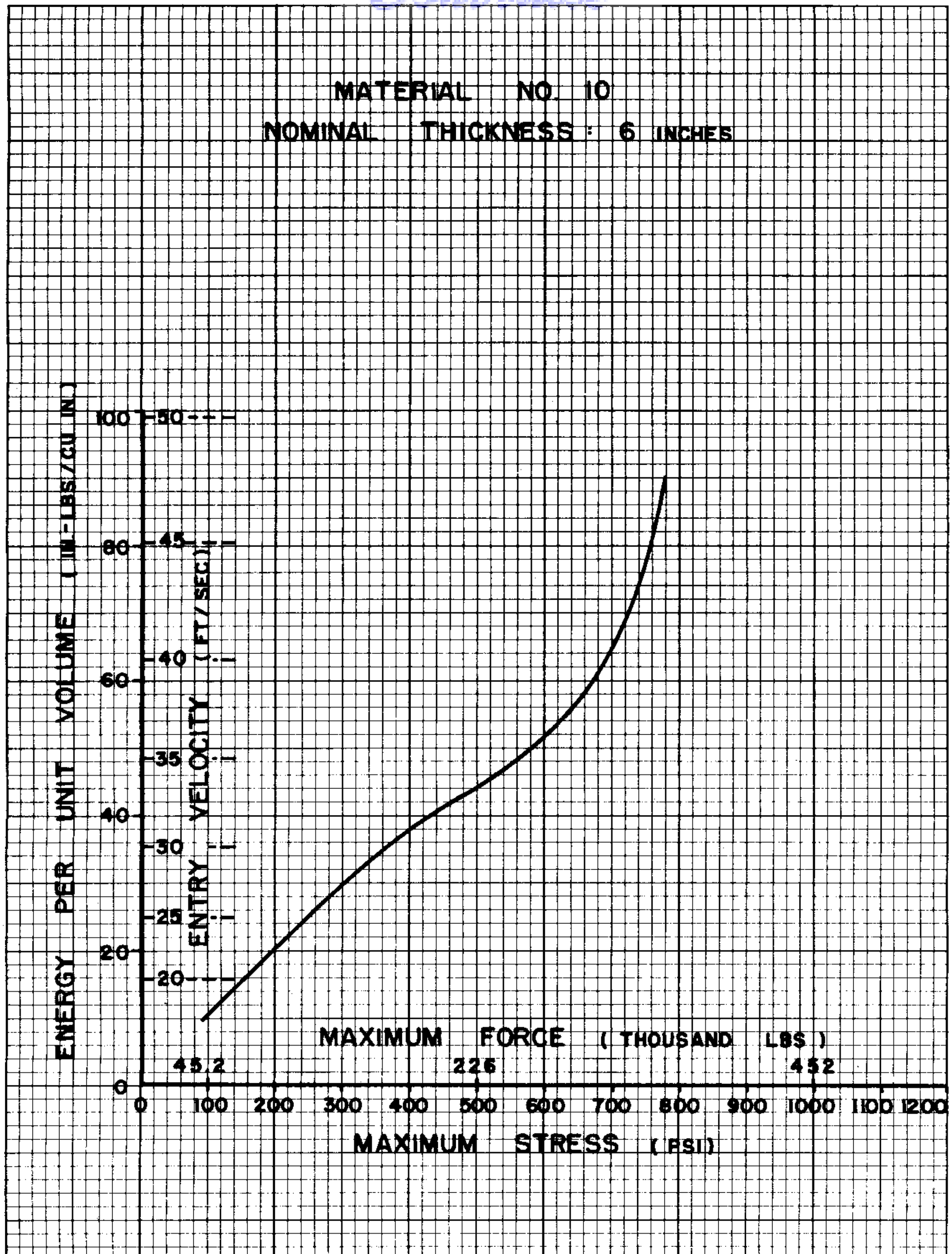

FIGURE 46 ENERGY PER UNIT VOLUME - MAXIMUM STRESS CURVE FOR 6 INCHES OF MATERIAL No. 10

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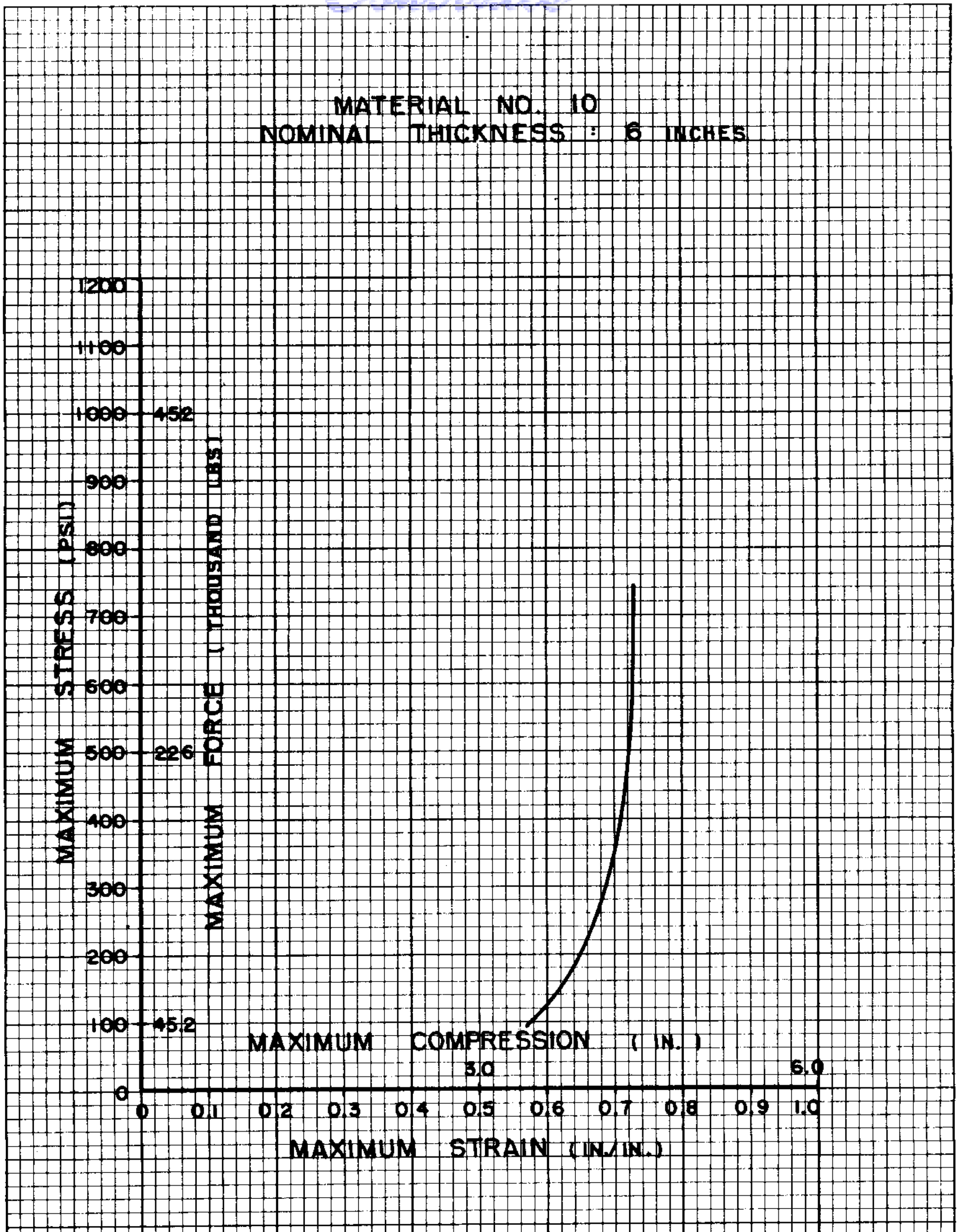

FIGURE 47 MAXIMUM STRESS - MAXIMUM STRAIN CURVE FOR 6 INCHES OF MATERIAL No. 10

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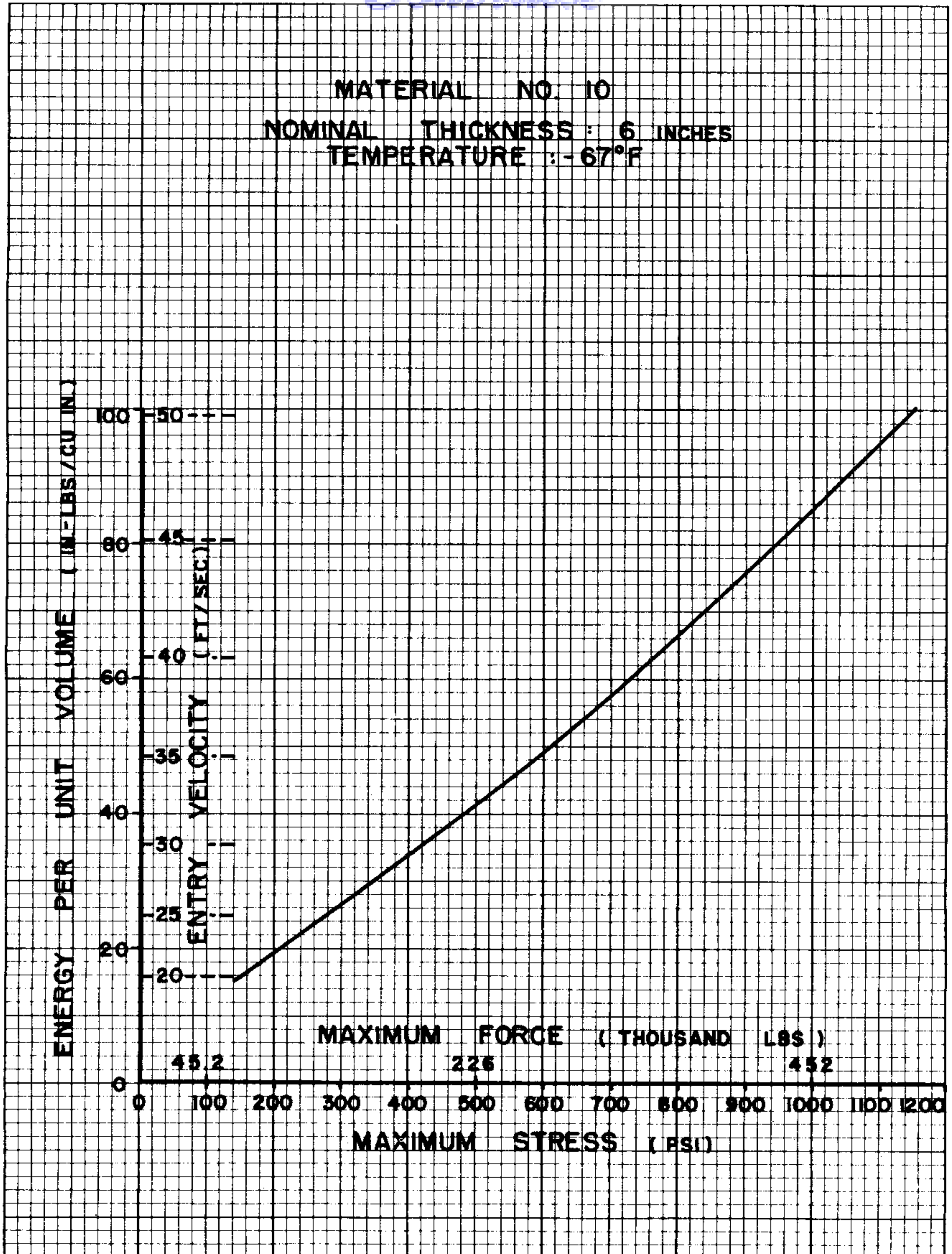

FIGURE 48 ENERGY PER UNIT VOLUME - MAXIMUM STRESS CURVE FOR 6 INCHES OF MATERIAL No. 10

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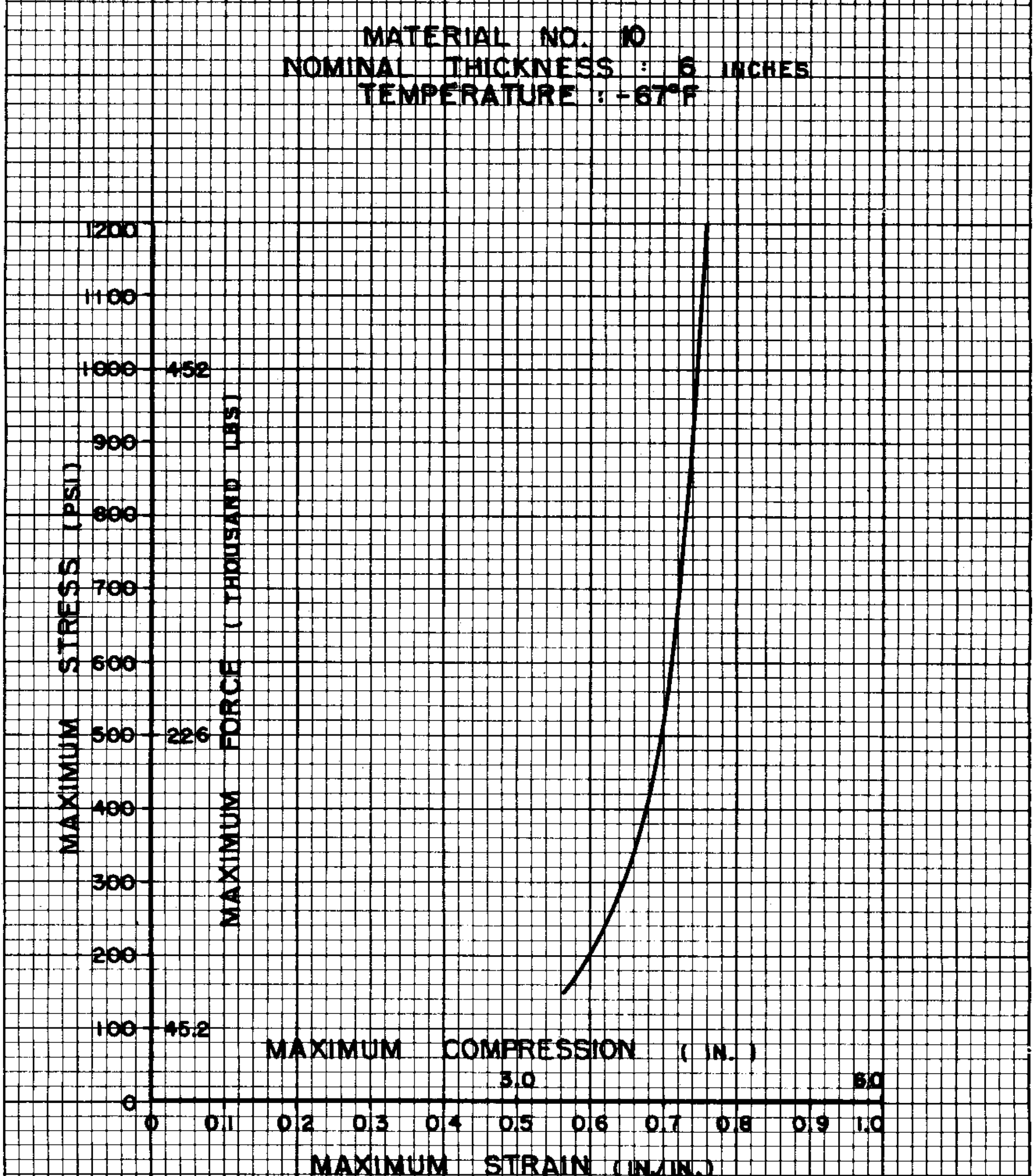

FIGURE 49 MAXIMUM STRESS - MAXIMUM STRAIN CURVE FOR 6 INCHES OF MATERIAL NO. 10

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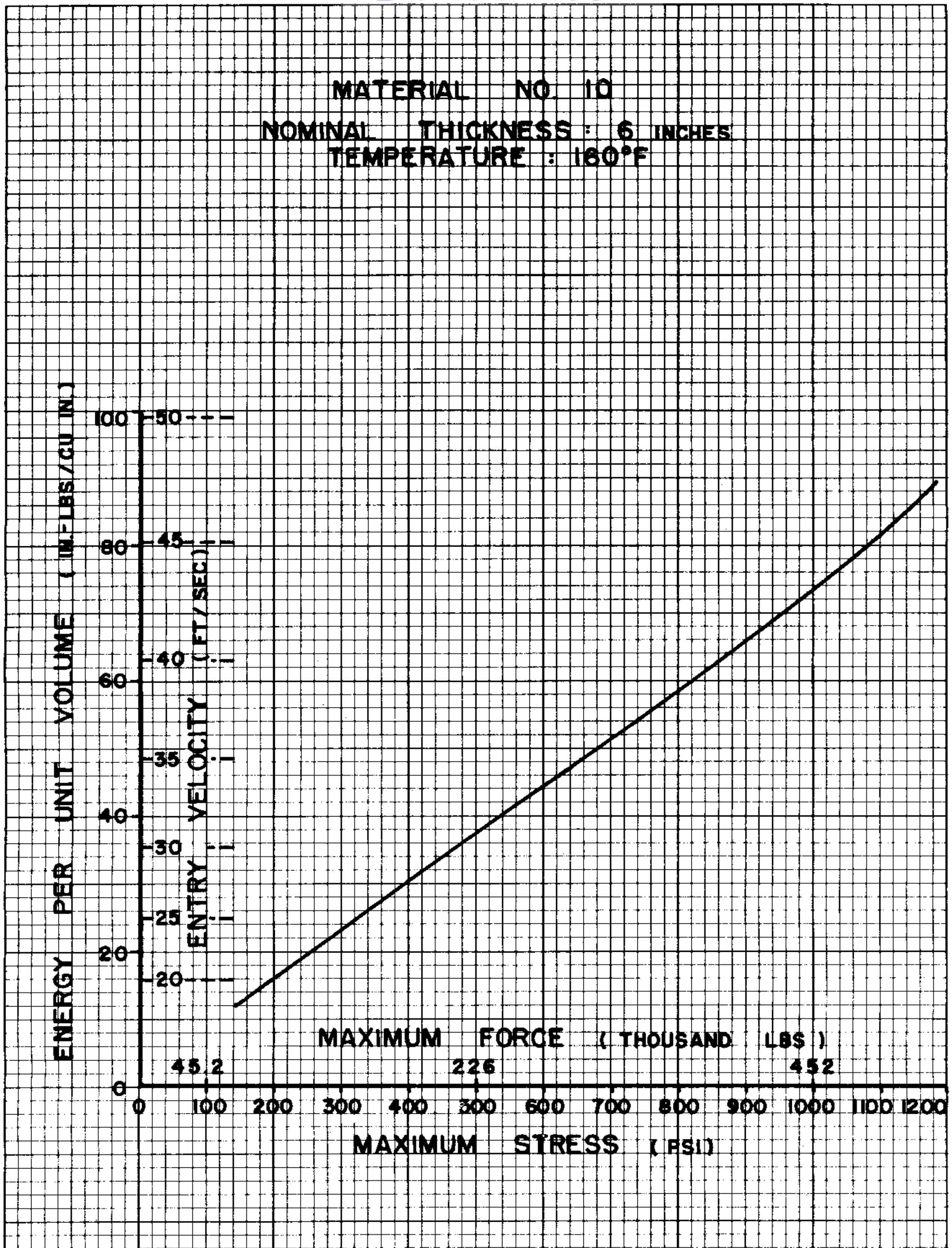

FIGURE 50 ENERGY PER UNIT VOLUME - MAXIMUM STRESS CURVE FOR 6 INCHES OF MATERIAL No. 10

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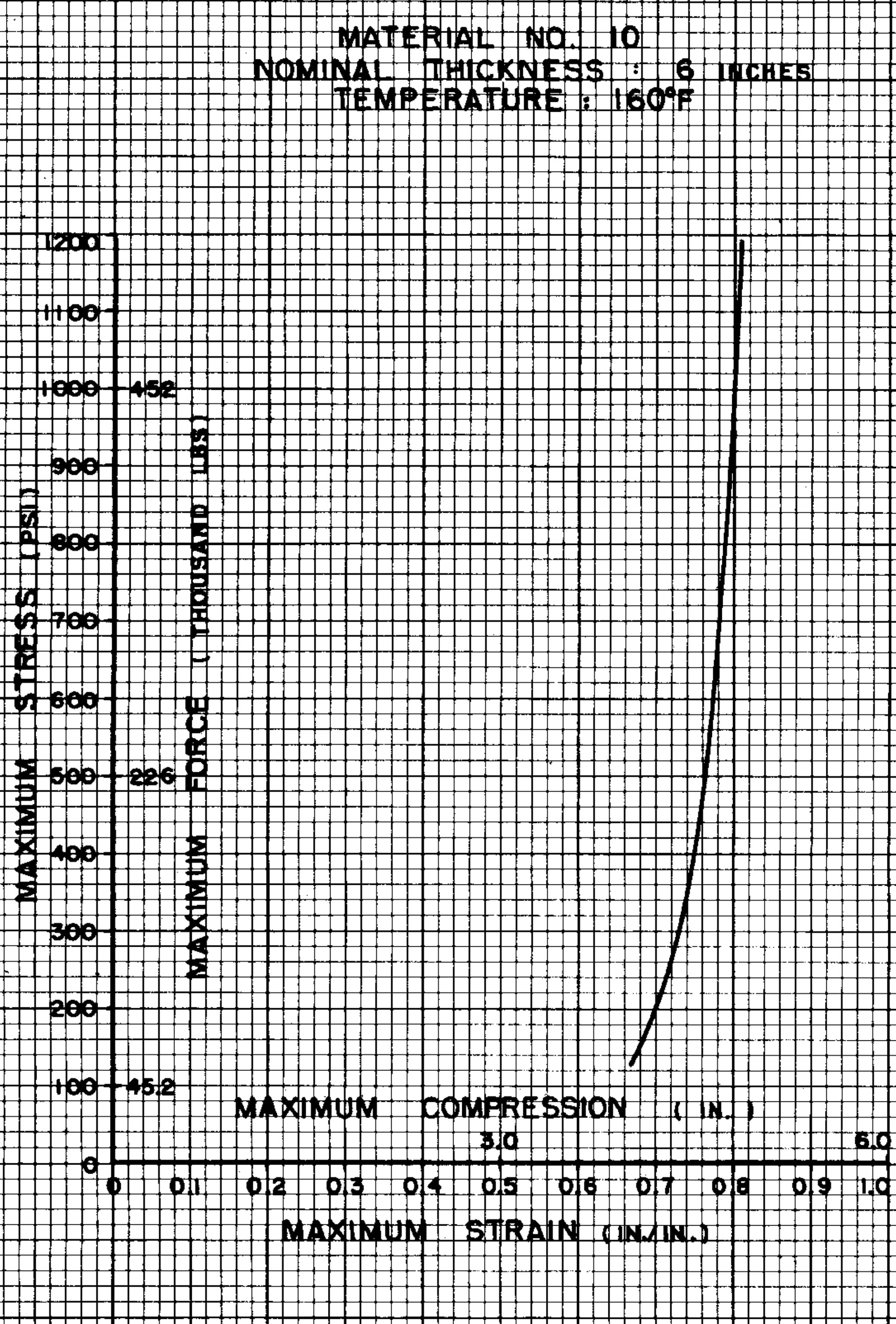

FIGURE 51 MAXIMUM STRESS - MAXIMUM STRAIN CURVE FOR 6 INCHES OF MATERIAL No. 10

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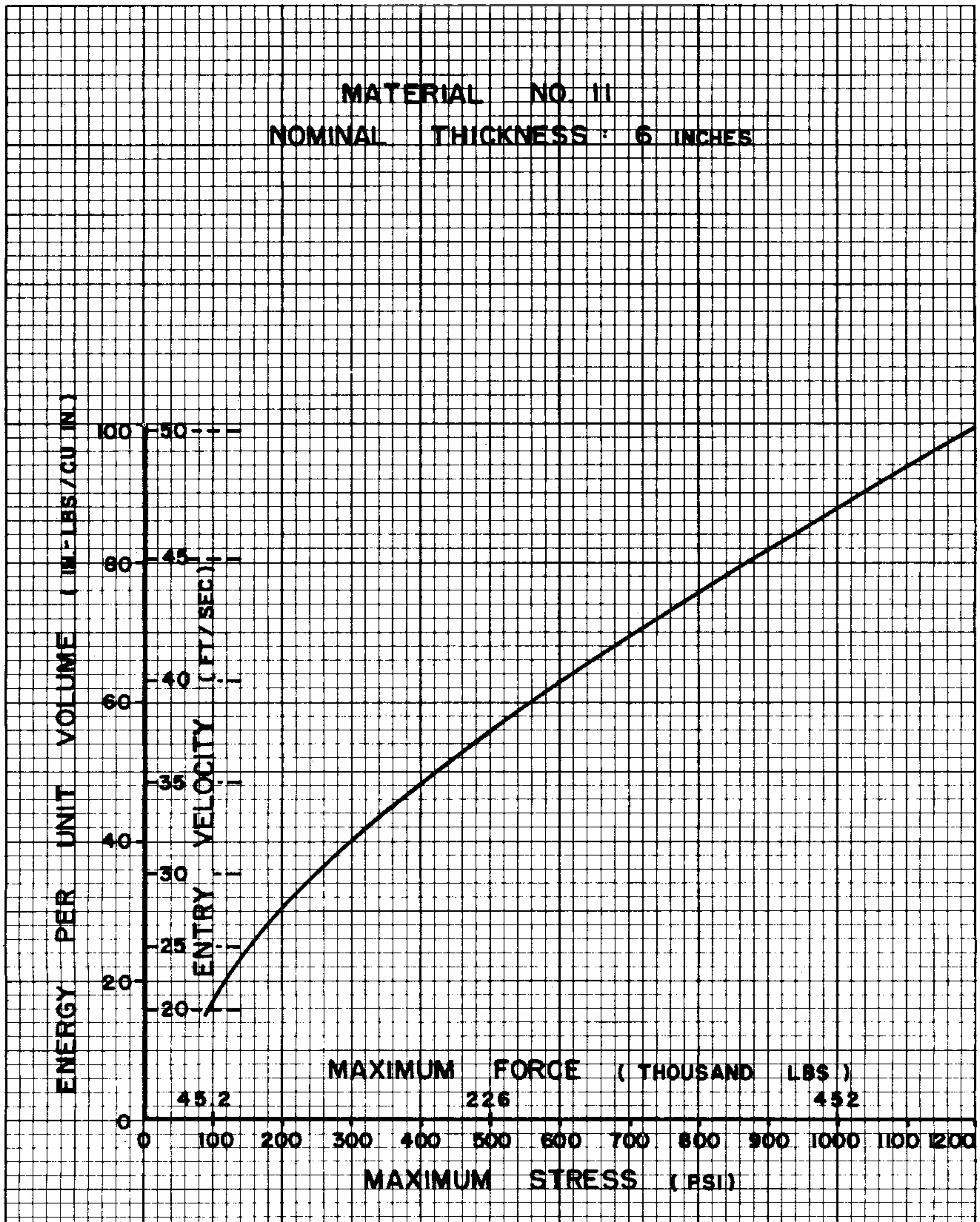

FIGURE 52 ENERGY PER UNIT VOLUME - MAXIMUM STRESS CURVE FOR 6 INCHES OF MATERIAL No. 11

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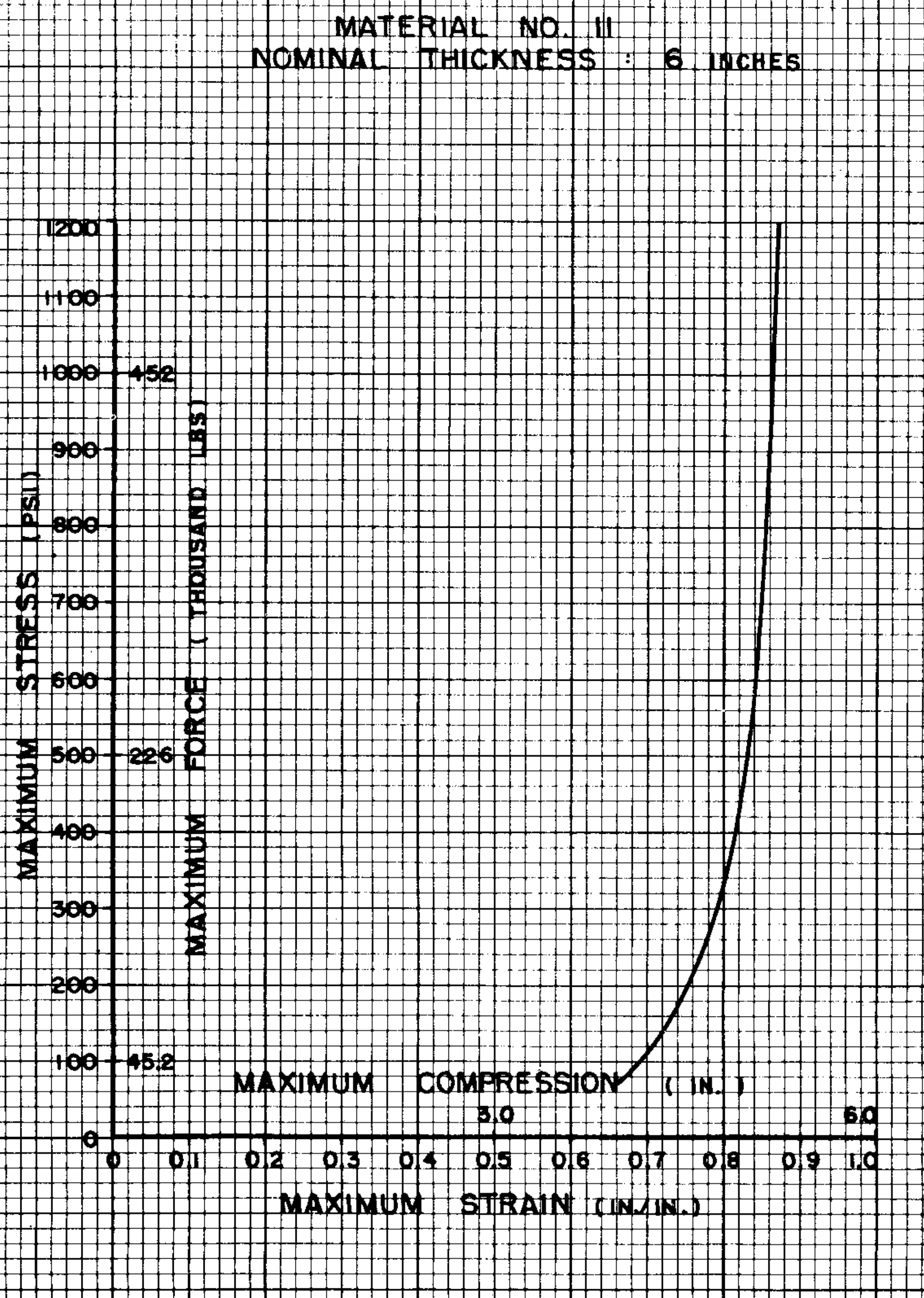

FIGURE 53 MAXIMUM STRESS - MAXIMUM STRAIN CURVE FOR 6 INCHES OF MATERIAL No. 11

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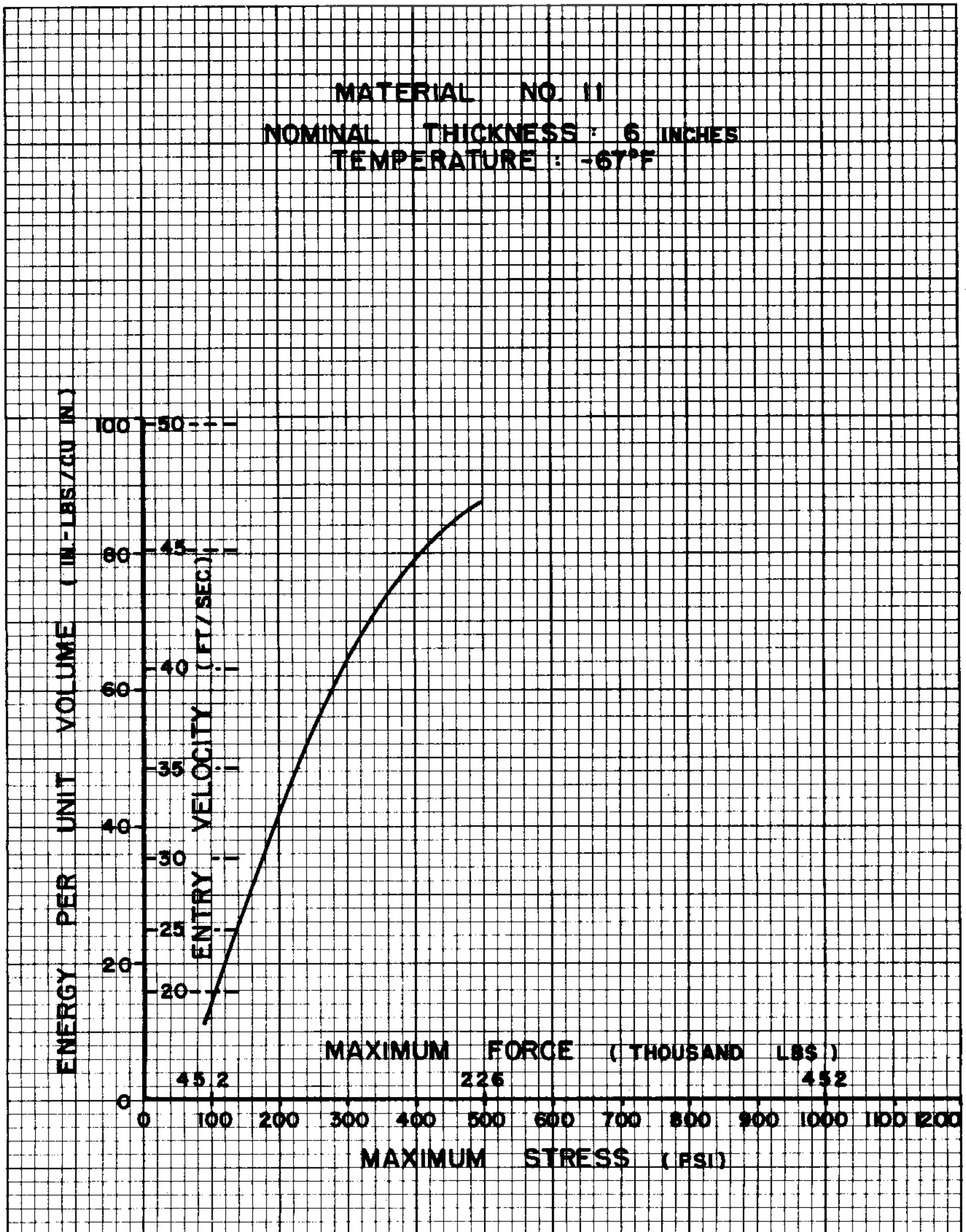

FIGURE 54 ENERGY PER UNIT VOLUME - MAXIMUM STRESS CURVE FOR 6 INCHES OF MATERIAL No. 11

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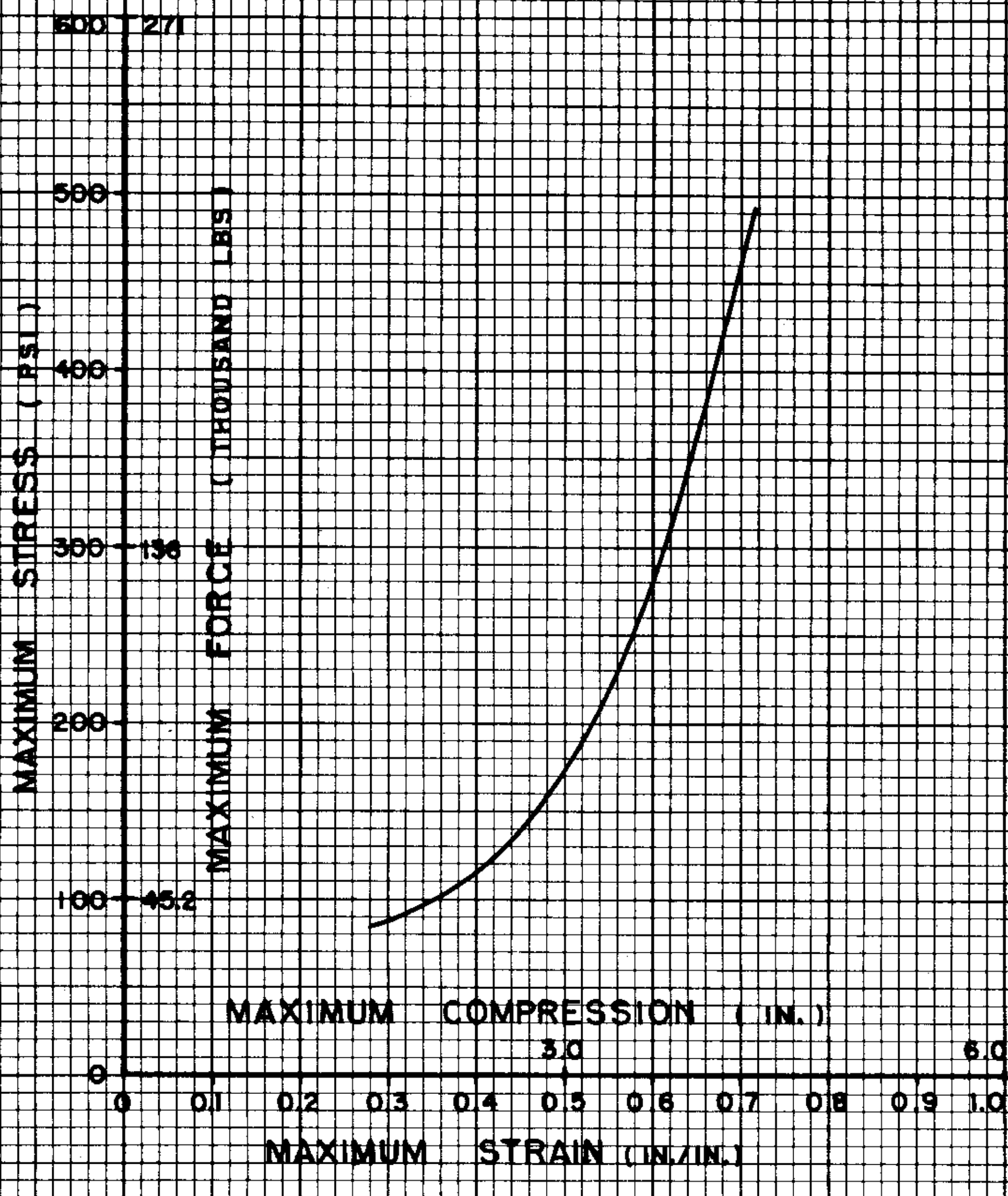

FIGURE 55. MAXIMUM STRESS - MAXIMUM STRAIN CURVE FOR 6 INCHES OF MATERIAL NO. 11

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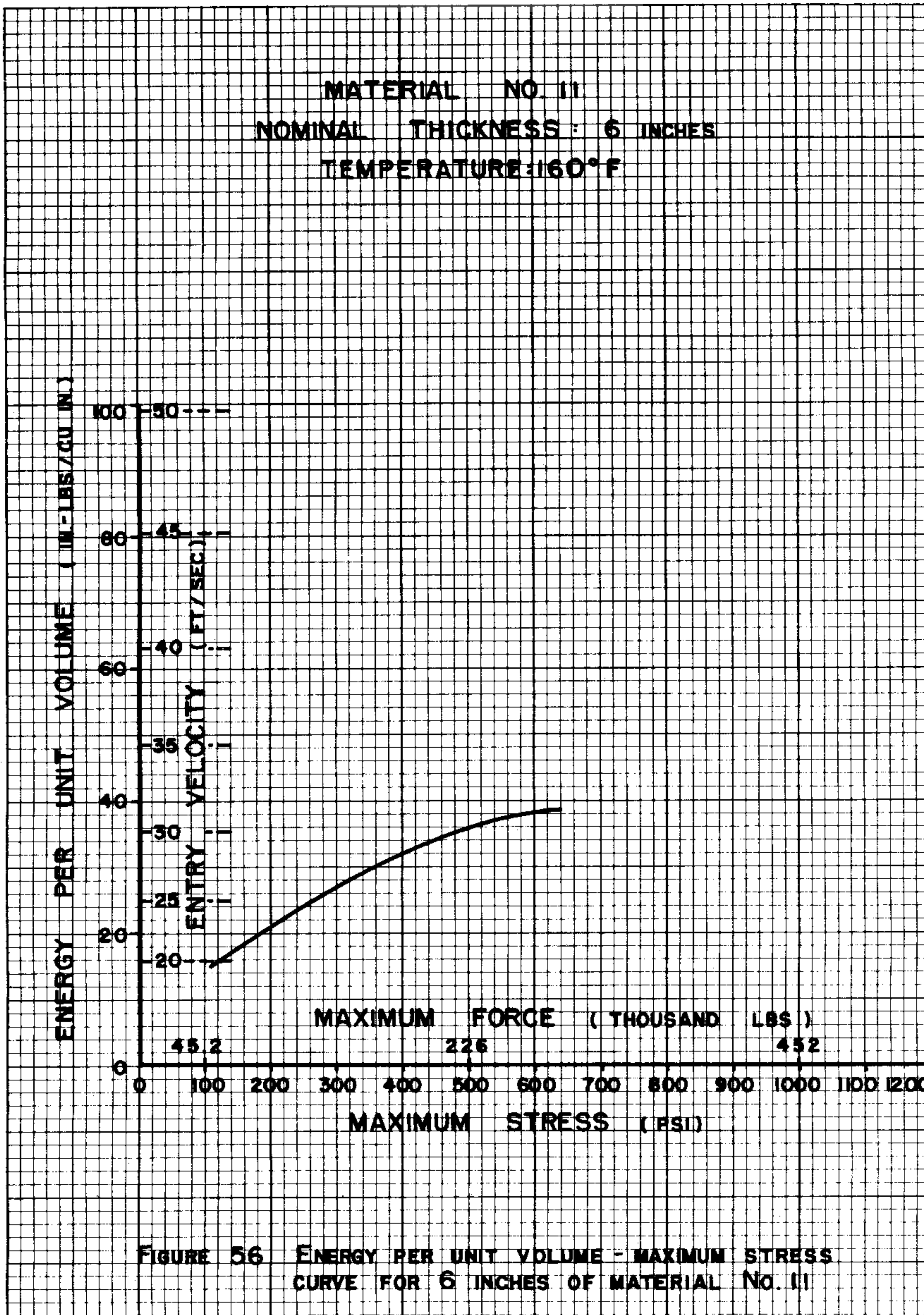

FIGURE 56 ENERGY PER UNIT VOLUME - MAXIMUM STRESS CURVE FOR 6 INCHES OF MATERIAL No. 11

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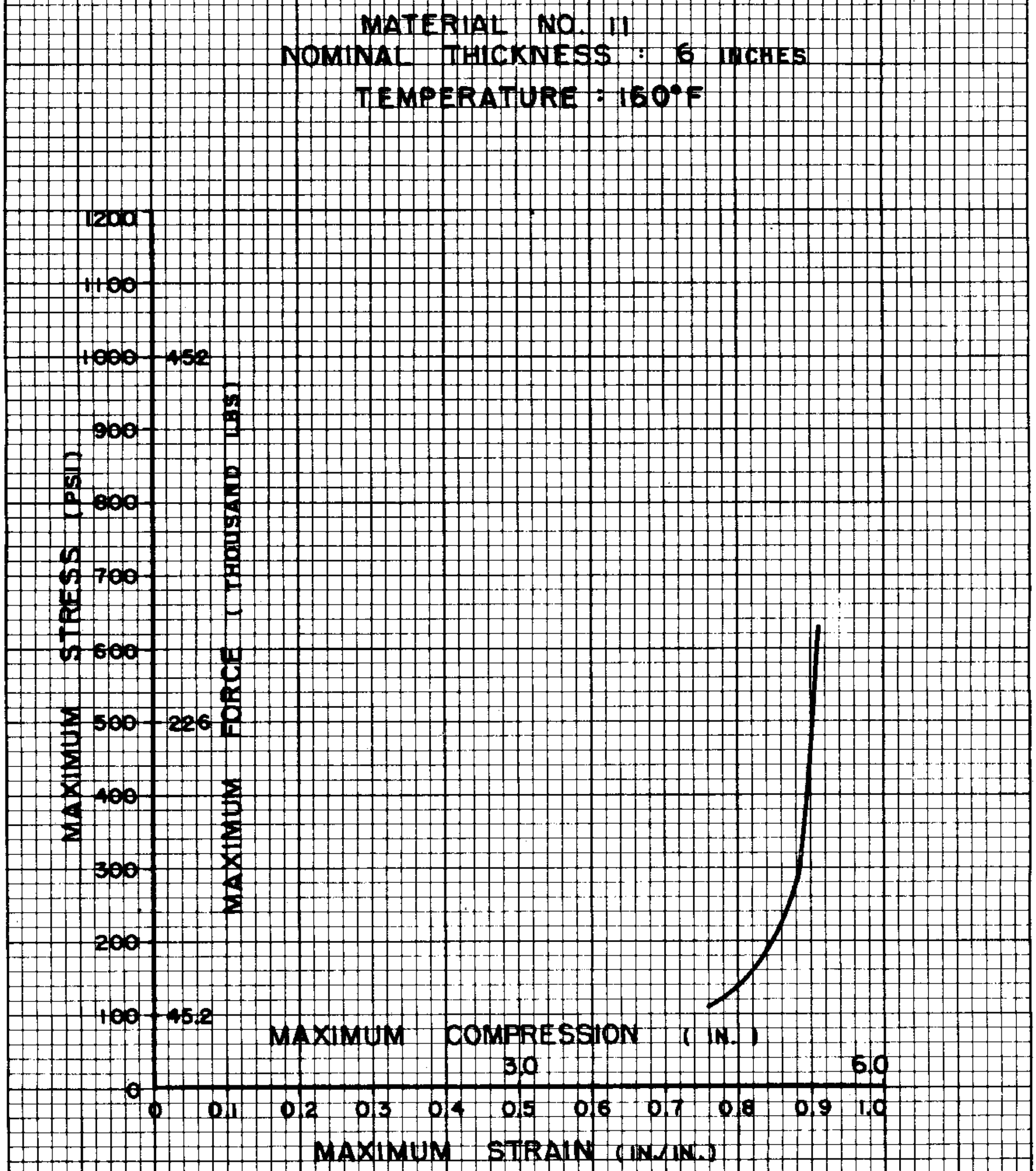

FIGURE 57 MAXIMUM STRESS - MAXIMUM STRAIN CURVE FOR 6 INCHES OF MATERIAL NO. 11

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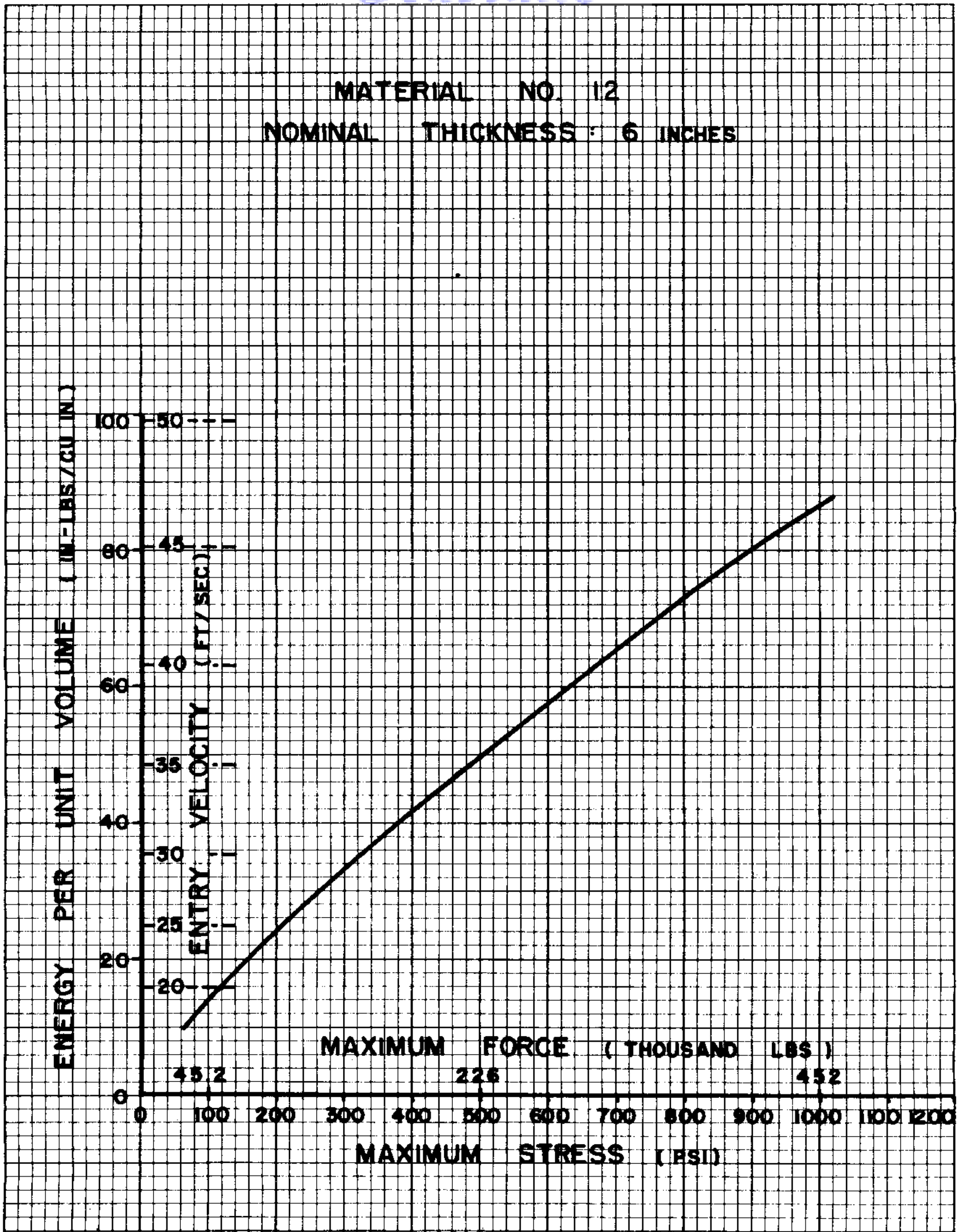

FIGURE 58. ENERGY PER UNIT VOLUME - MAXIMUM STRESS CURVE FOR 6 INCHES OF MATERIAL No. 12

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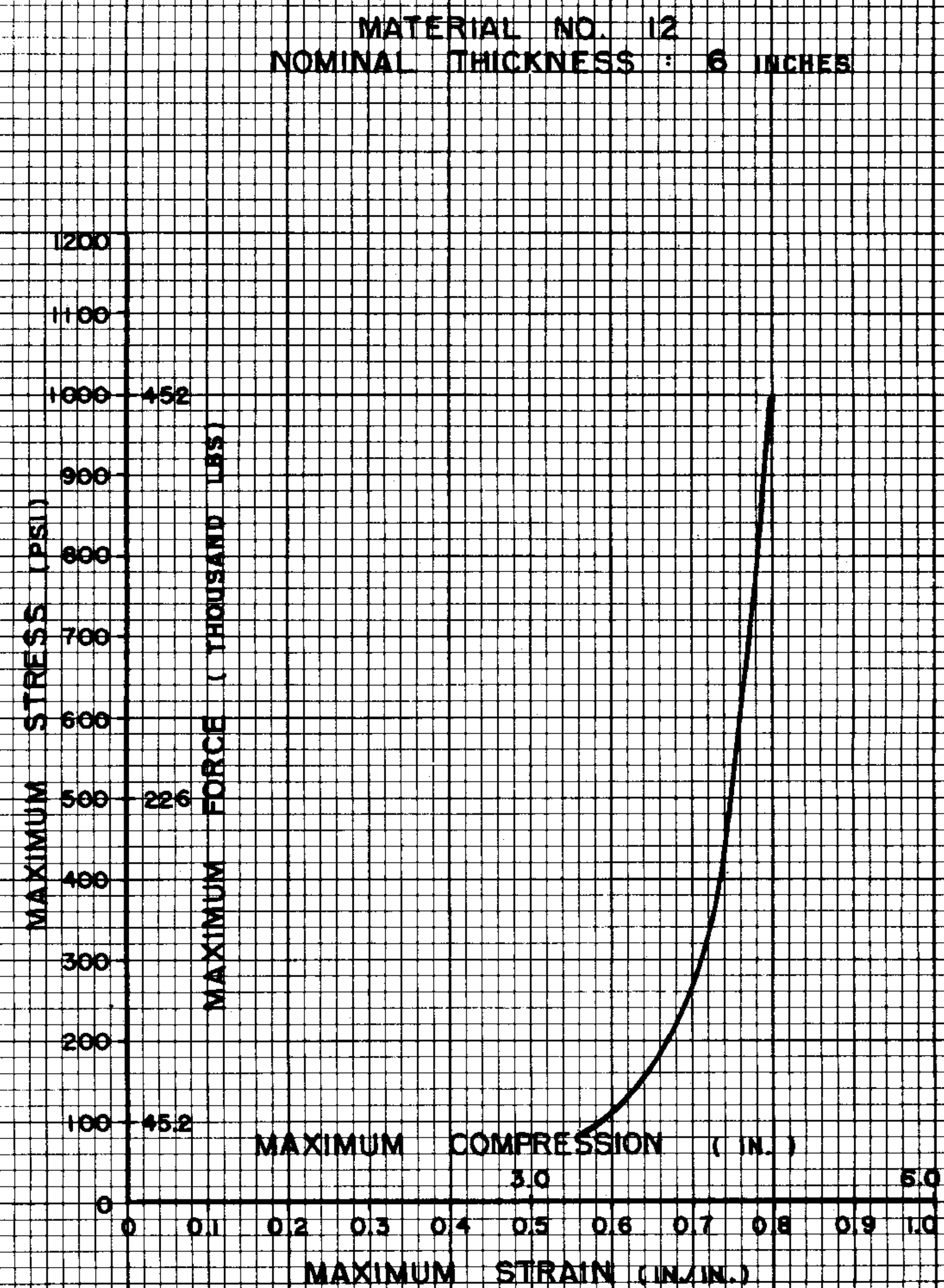

FIGURE 59. MAXIMUM STRESS - MAXIMUM STRAIN CURVE FOR 6 INCHES OF MATERIAL NO. 12

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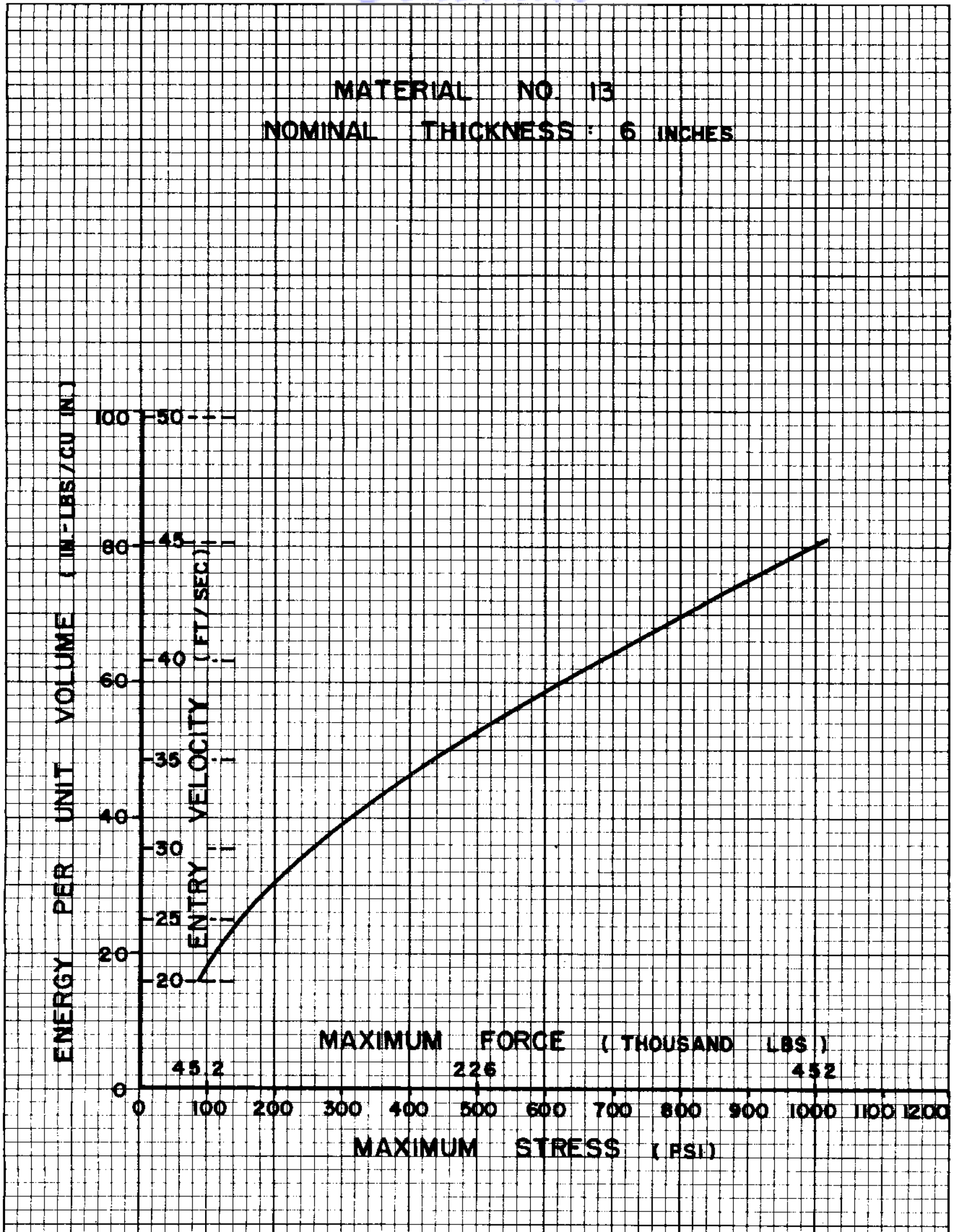

FIGURE 60 ENERGY PER UNIT VOLUME - MAXIMUM STRESS CURVE FOR 6 INCHES OF MATERIAL No. 13

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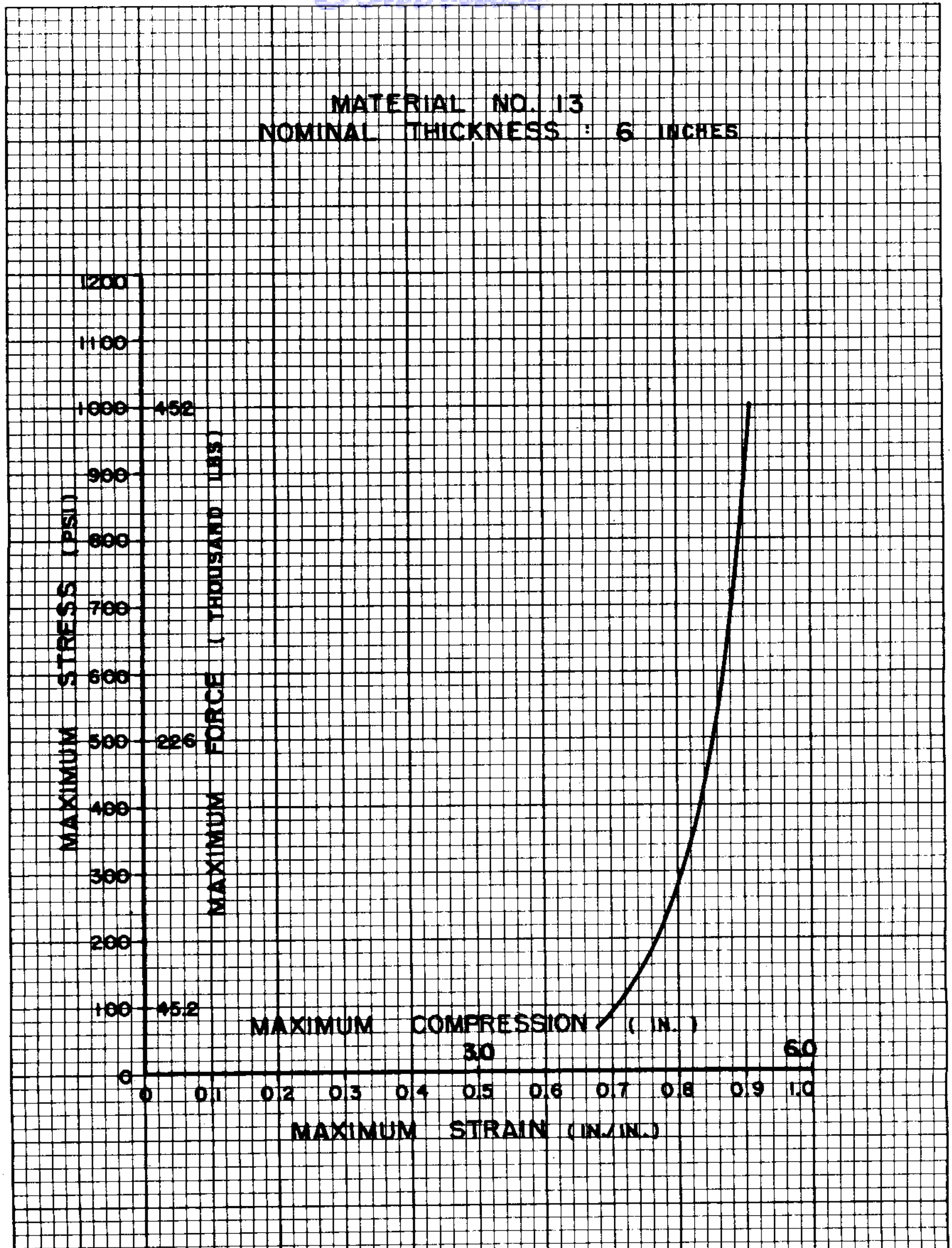

FIGURE 61 MAXIMUM STRESS - MAXIMUM STRAIN CURVE FOR 6 INCHES OF MATERIAL NO. 13

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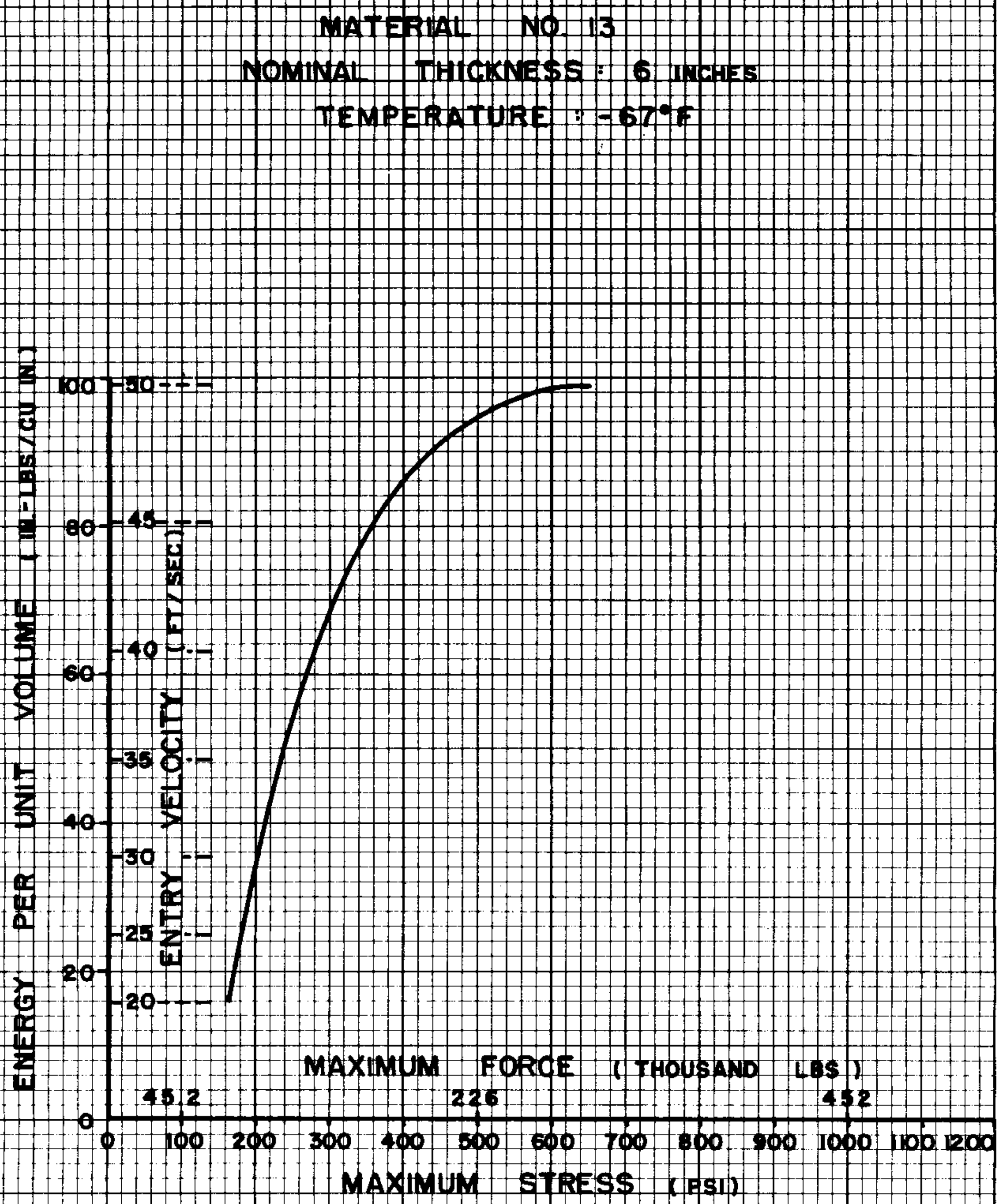

FIGURE 62 ENERGY PER UNIT VOLUME - MAXIMUM STRESS CURVE FOR 6 INCHES OF MATERIAL NO. 13

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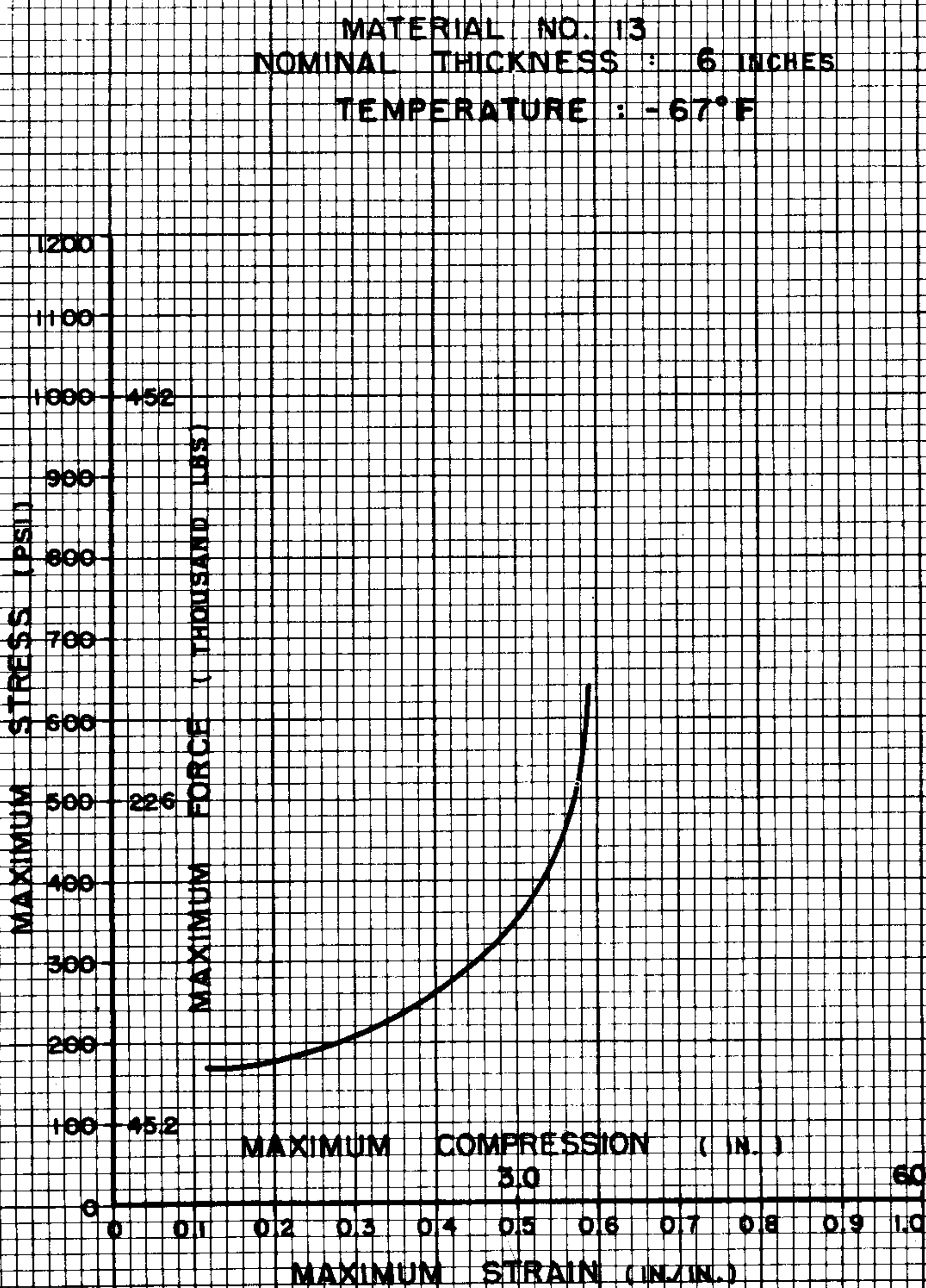

FIGURE 63 MAXIMUM STRESS - MAXIMUM STRAIN CURVE FOR 6 INCHES OF MATERIAL NO. 13

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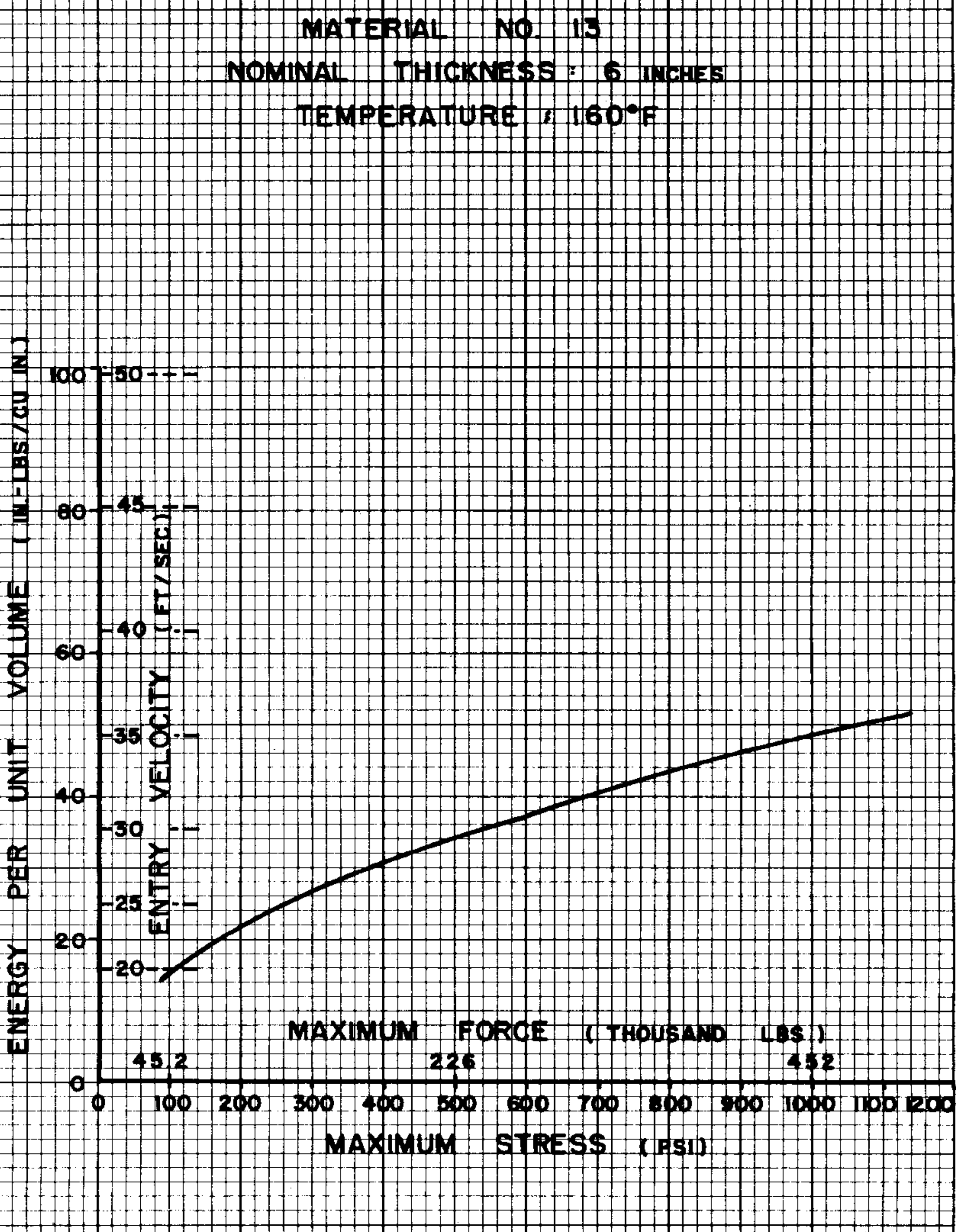

FIGURE 64 ENERGY PER UNIT VOLUME - MAXIMUM STRESS CURVE FOR 6 INCHES OF MATERIAL NO. 13

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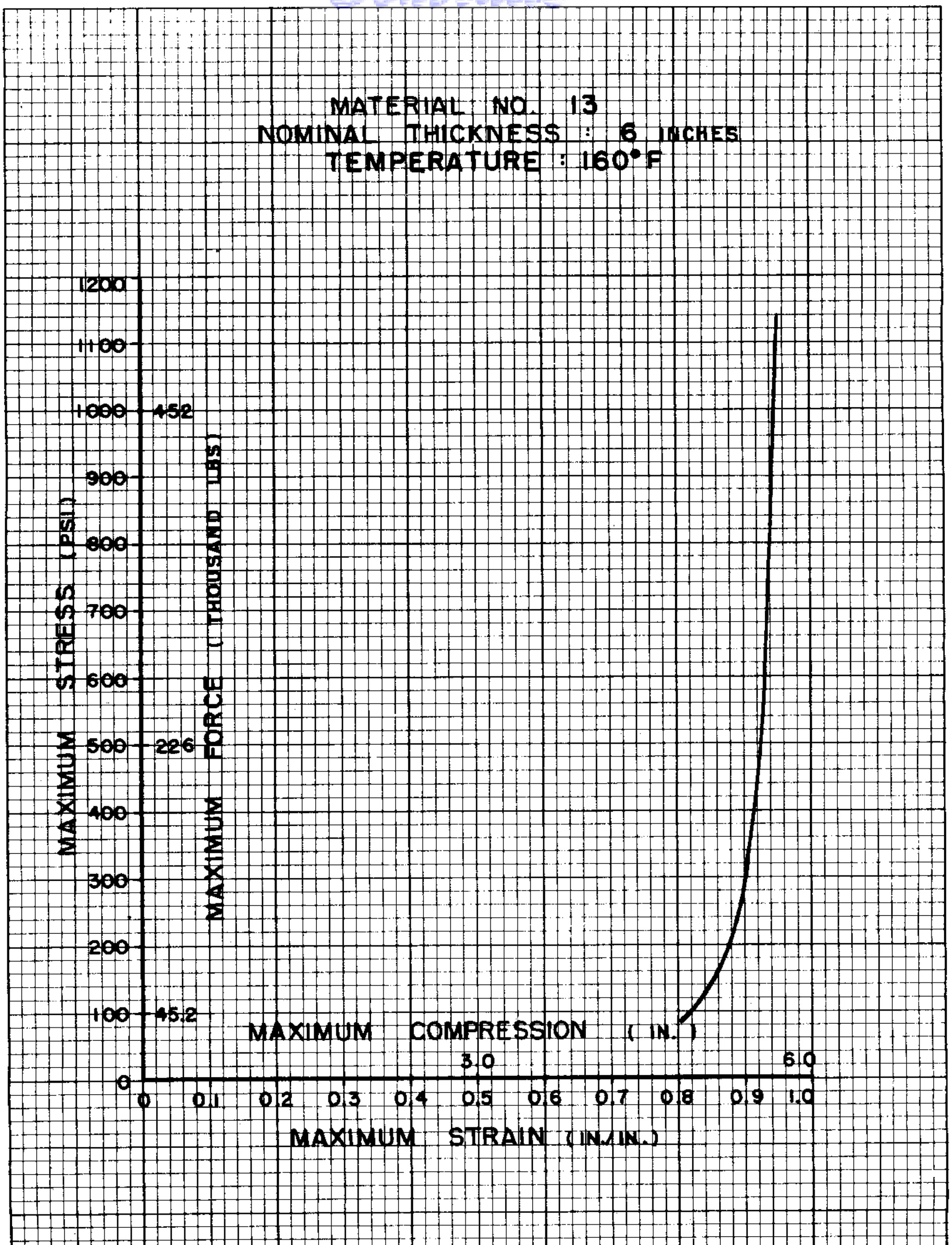

FIGURE 65 MAXIMUM STRESS - MAXIMUM STRAIN CURVE FOR 6 INCHES OF MATERIAL NO. 13

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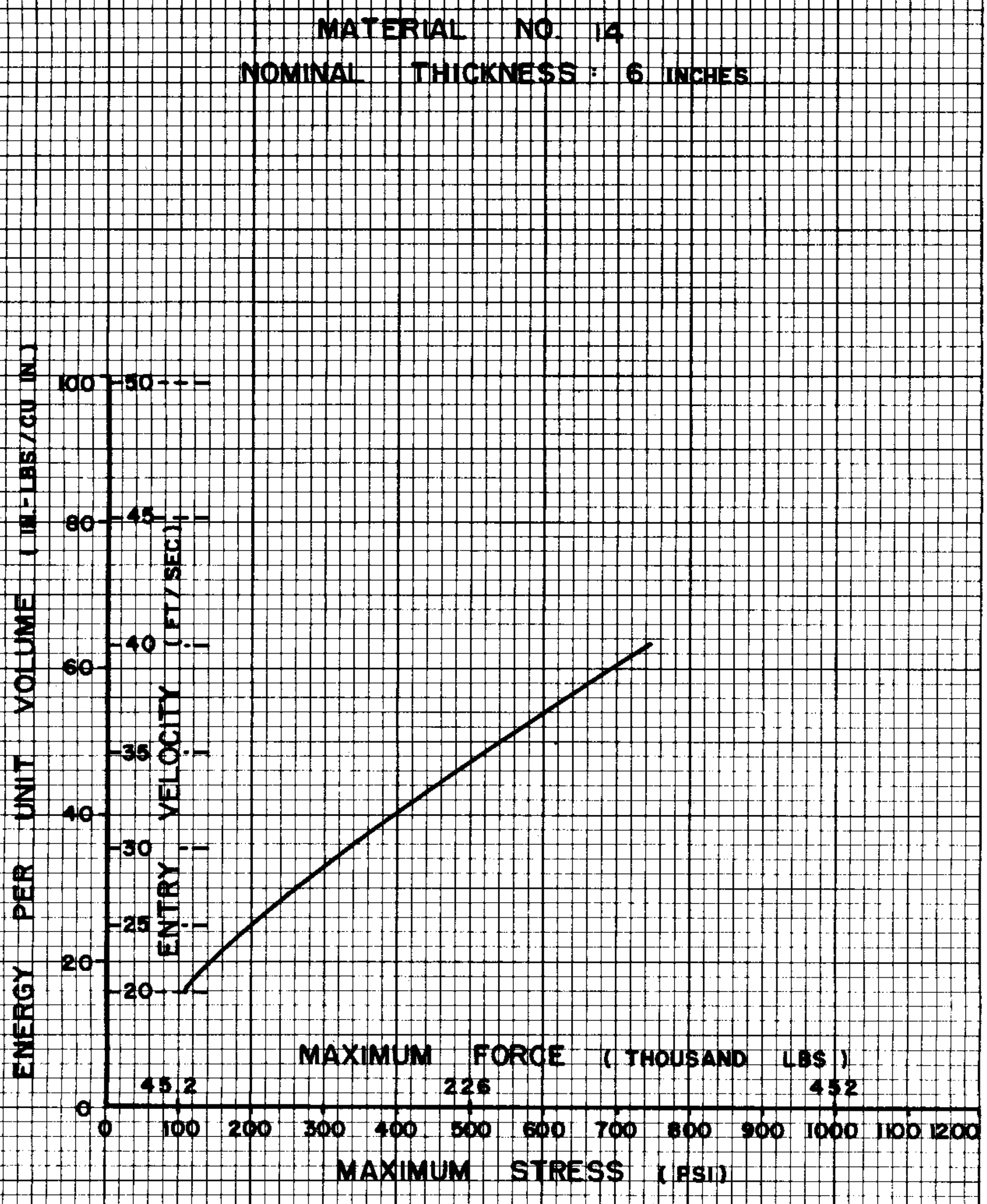

FIGURE 66 ENERGY PER UNIT VOLUME - MAXIMUM STRESS CURVE FOR 6 INCHES OF MATERIAL NO. 14

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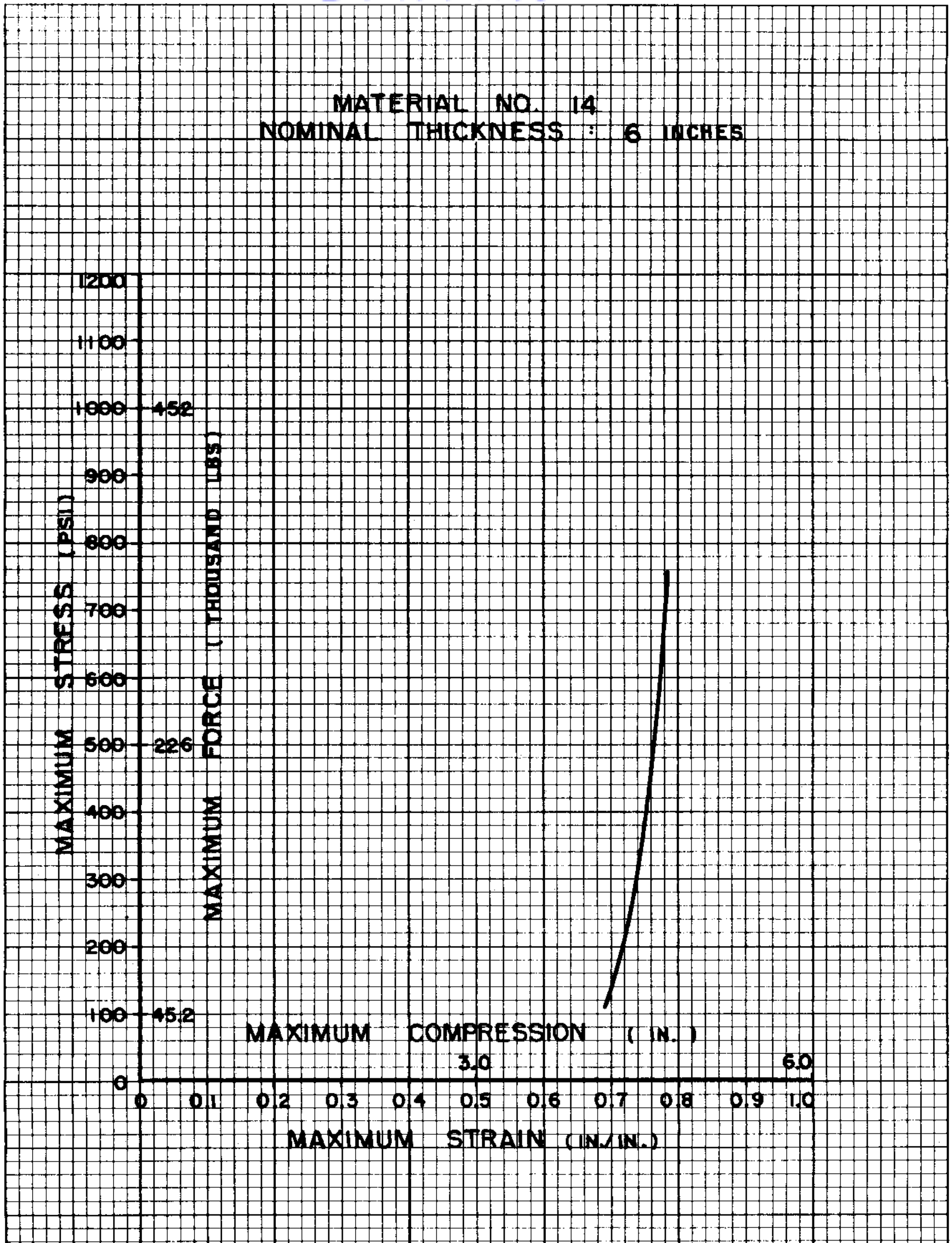

FIGURE 67 MAXIMUM STRESS - MAXIMUM STRAIN CURVE FOR 6 INCHES OF MATERIAL No. 14

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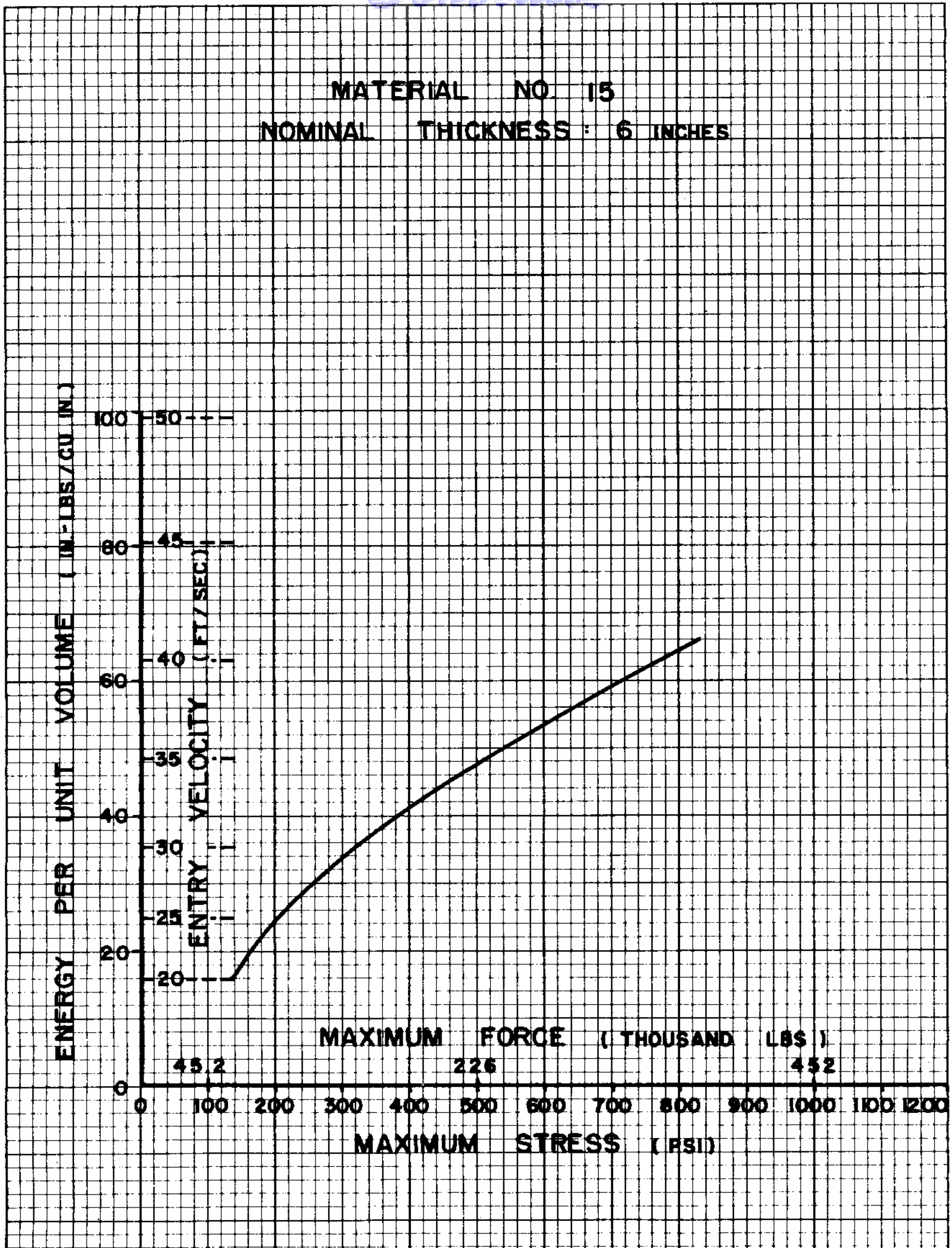

FIGURE 68 ENERGY PER UNIT VOLUME - MAXIMUM STRESS CURVE FOR 6 INCHES OF MATERIAL No. 15

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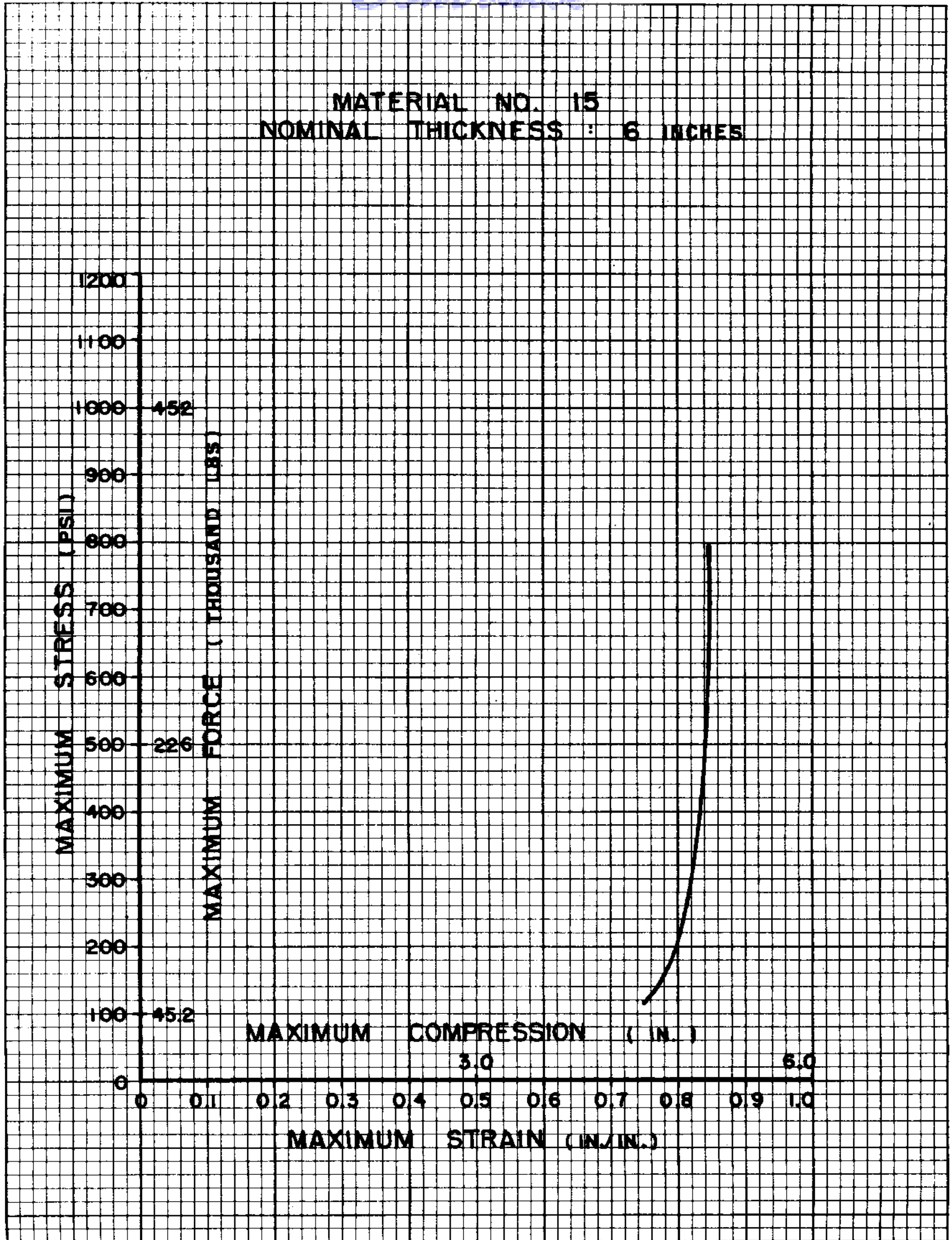

FIGURE 69. MAXIMUM STRESS - MAXIMUM STRAIN CURVE FOR 6 INCHES OF MATERIAL No. 15

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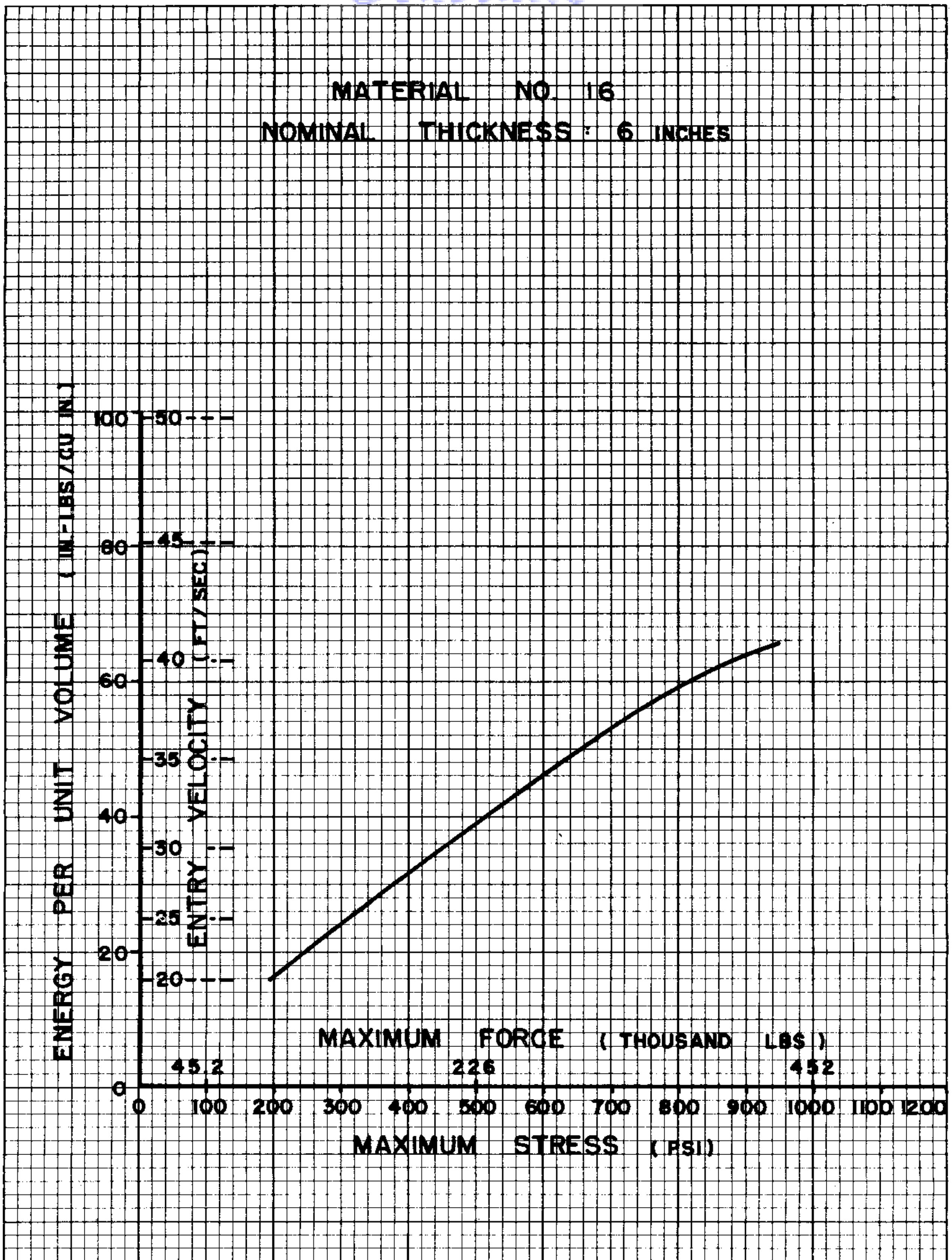

FIGURE 70 ENERGY PER UNIT VOLUME - MAXIMUM STRESS CURVE FOR 6 INCHES OF MATERIAL No. 16

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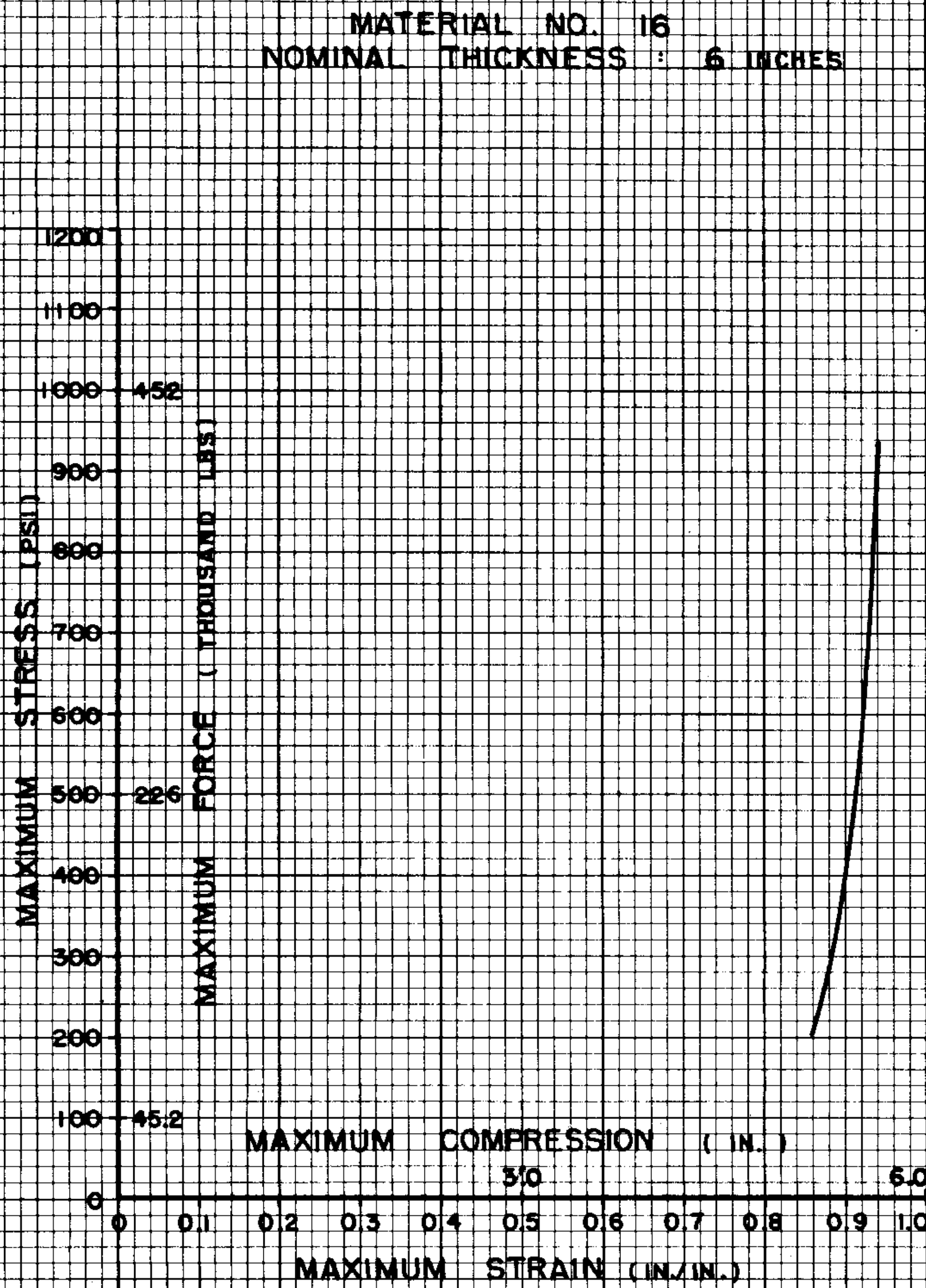

FIGURE 71 MAXIMUM STRESS - MAXIMUM STRAIN CURVE FOR 6 INCHES OF MATERIAL No. 16

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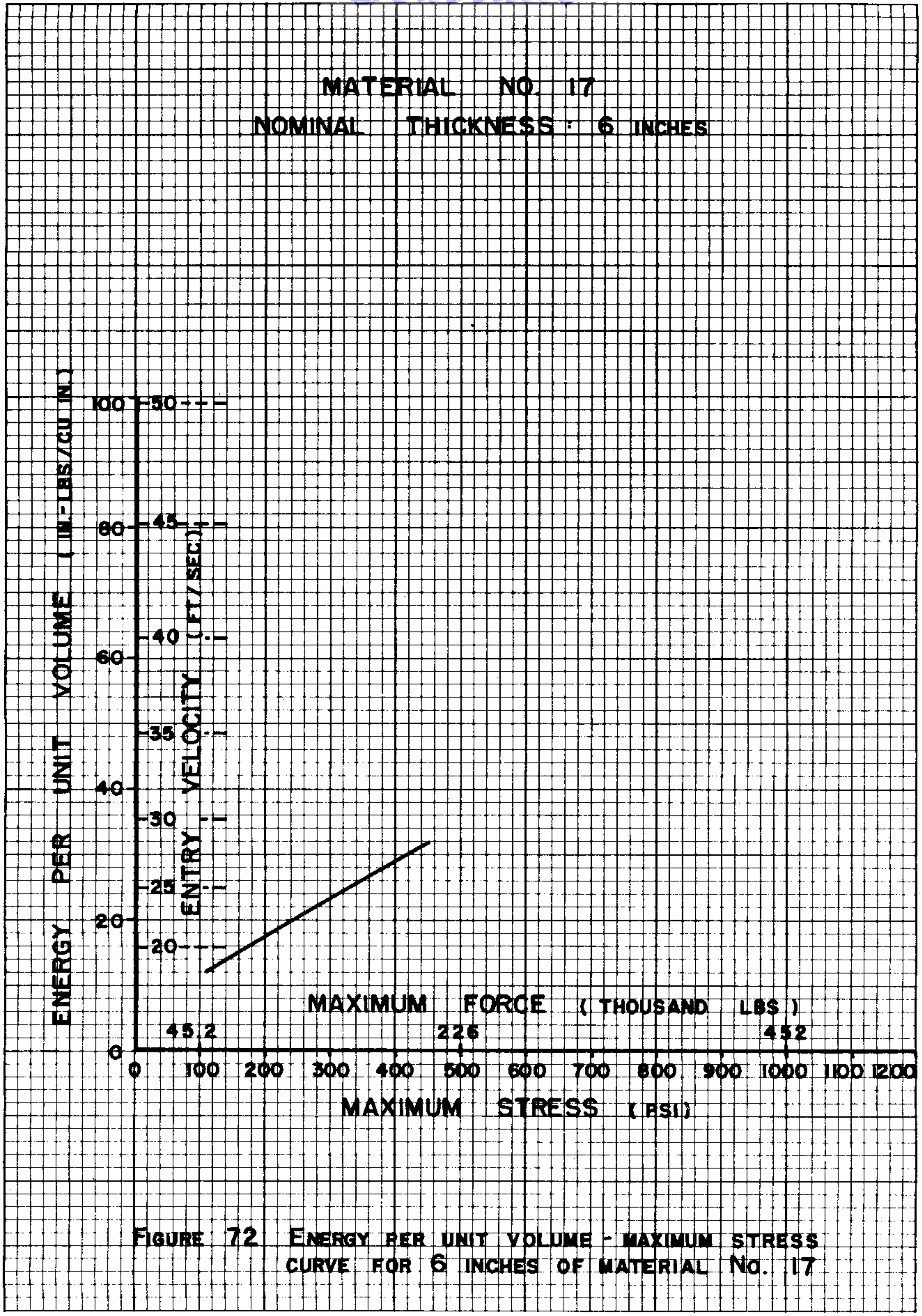

FIGURE 72 ENERGY PER UNIT VOLUME - MAXIMUM STRESS CURVE FOR 6 INCHES OF MATERIAL No. 17

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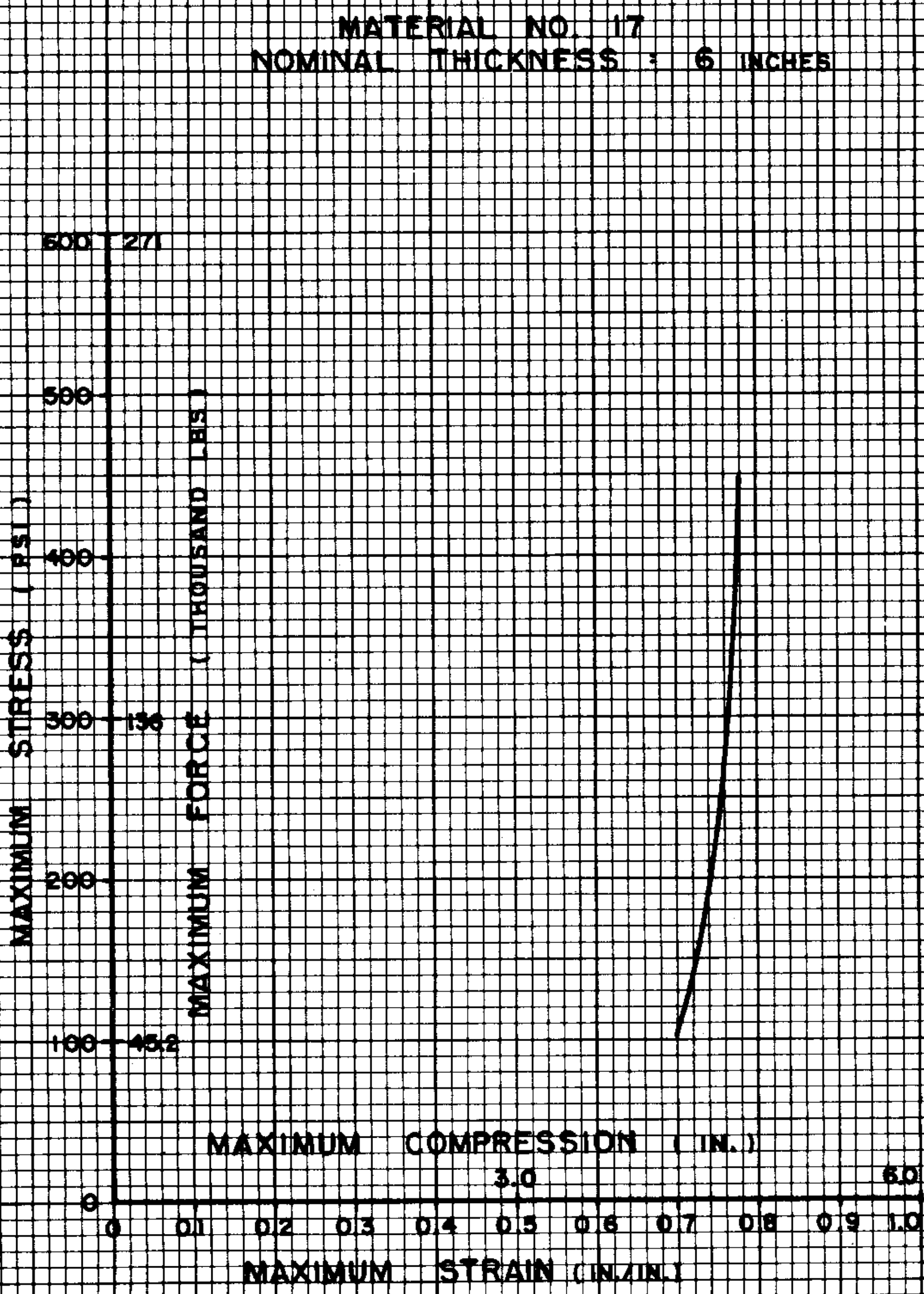

FIGURE 73. MAXIMUM STRESS - MAXIMUM STRAIN CURVE FOR 6 INCHES OF MATERIAL NO. 17

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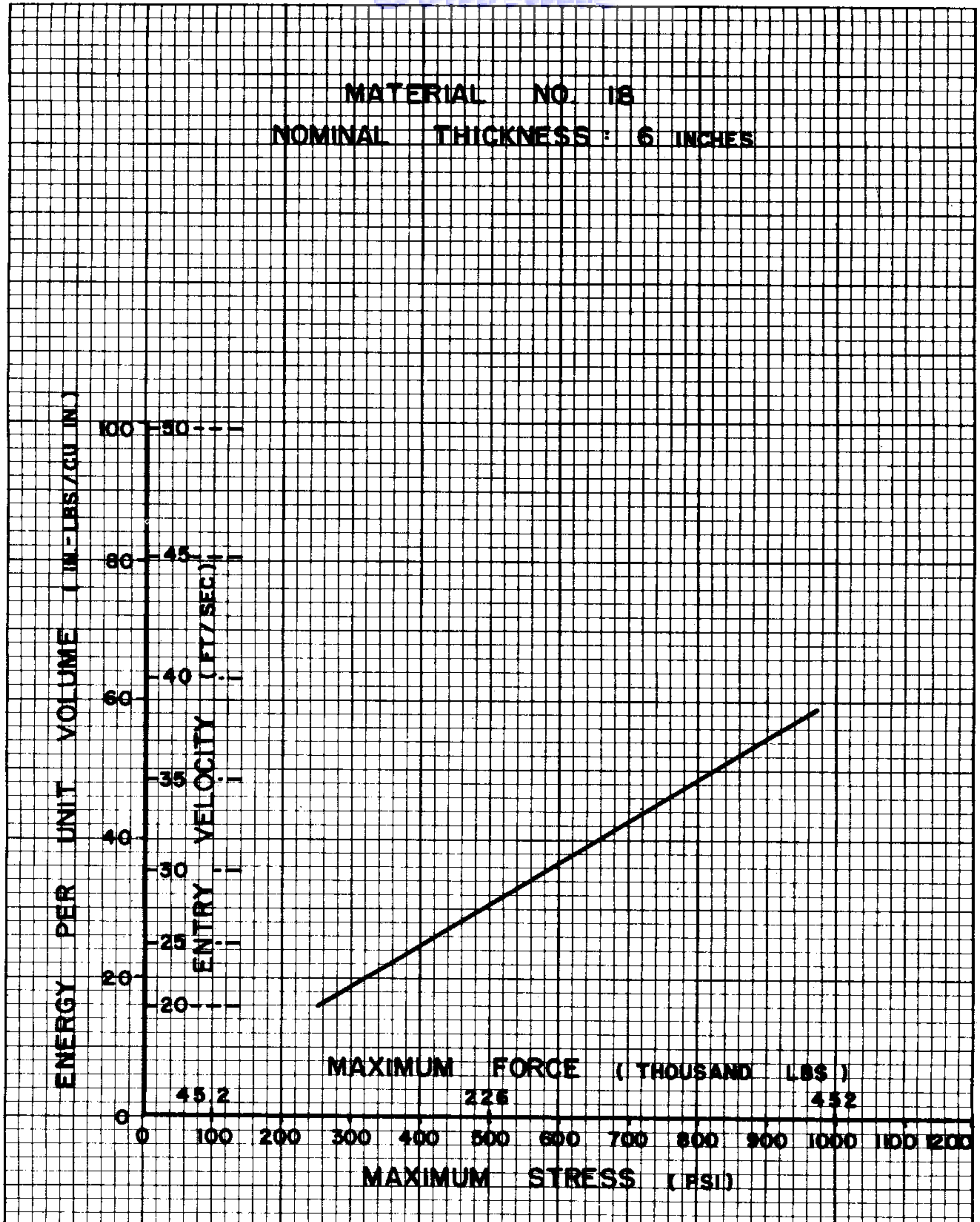

FIGURE 74 ENERGY PER UNIT VOLUME - MAXIMUM STRESS CURVE FOR 6 INCHES OF MATERIAL No. 18

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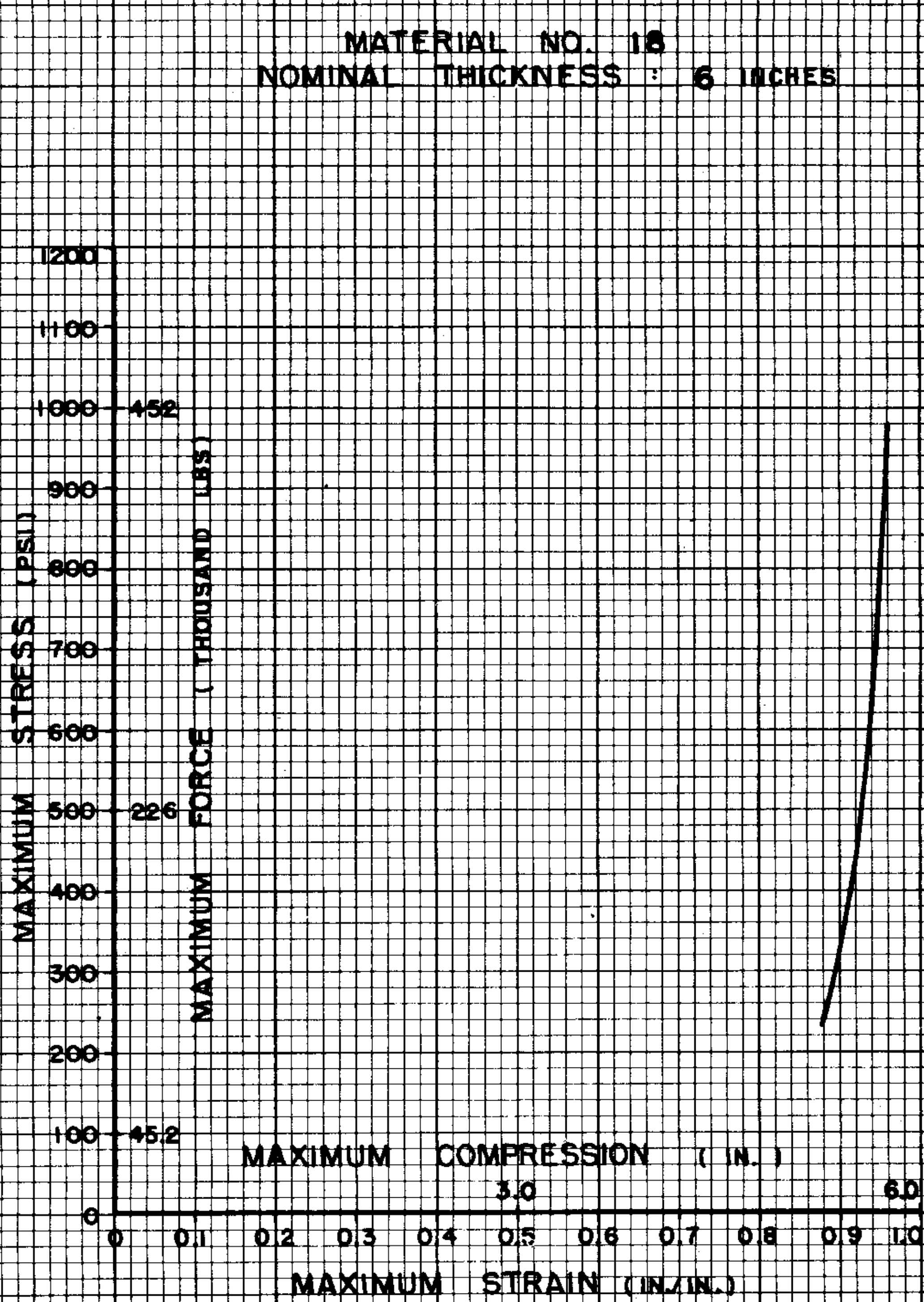

FIGURE 75 MAXIMUM STRESS - MAXIMUM STRAIN CURVE FOR 6 INCHES OF MATERIAL No. 18

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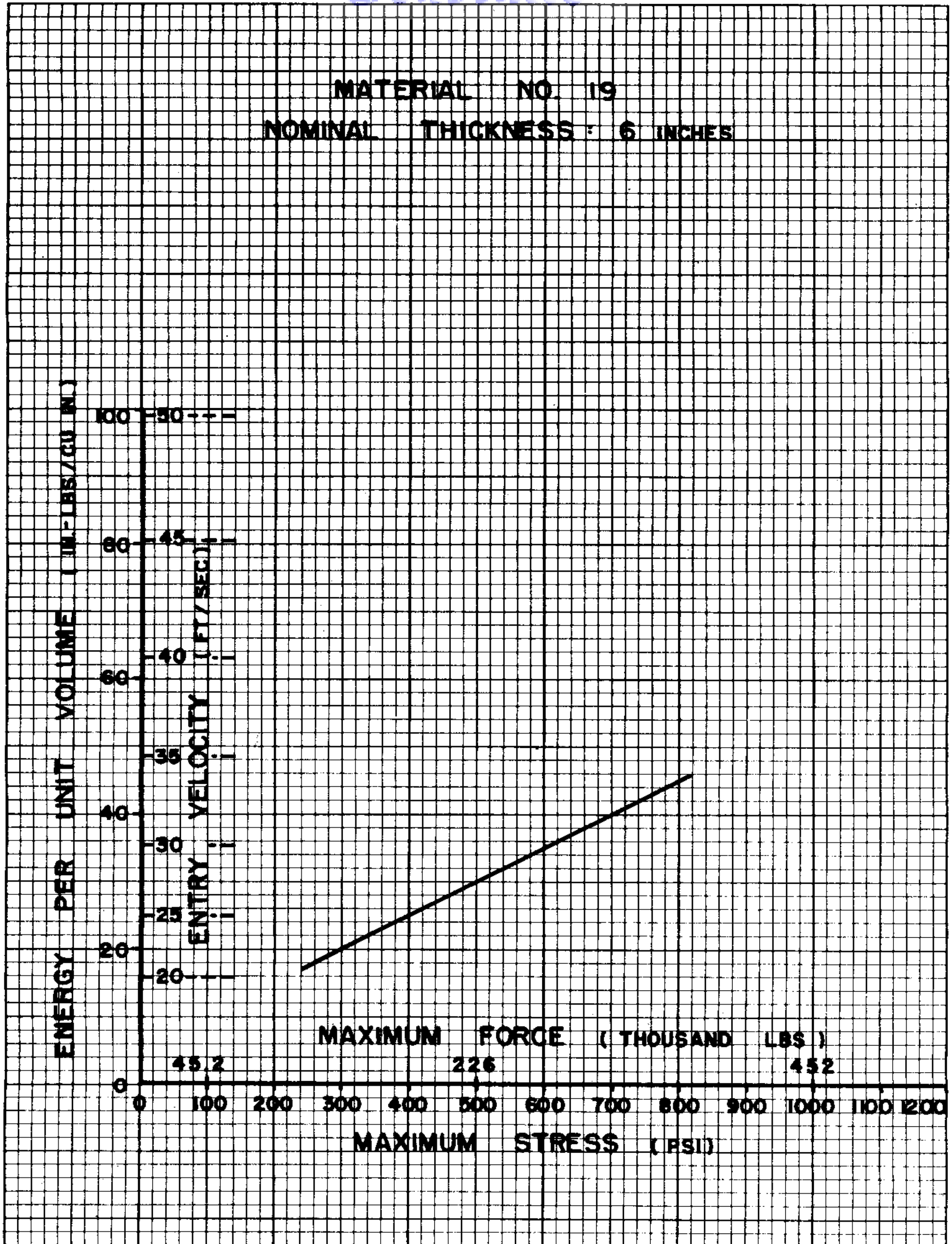

FIGURE 76 ENERGY PER UNIT VOLUME - MAXIMUM STRESS CURVE FOR 6 INCHES OF MATERIAL No. 19

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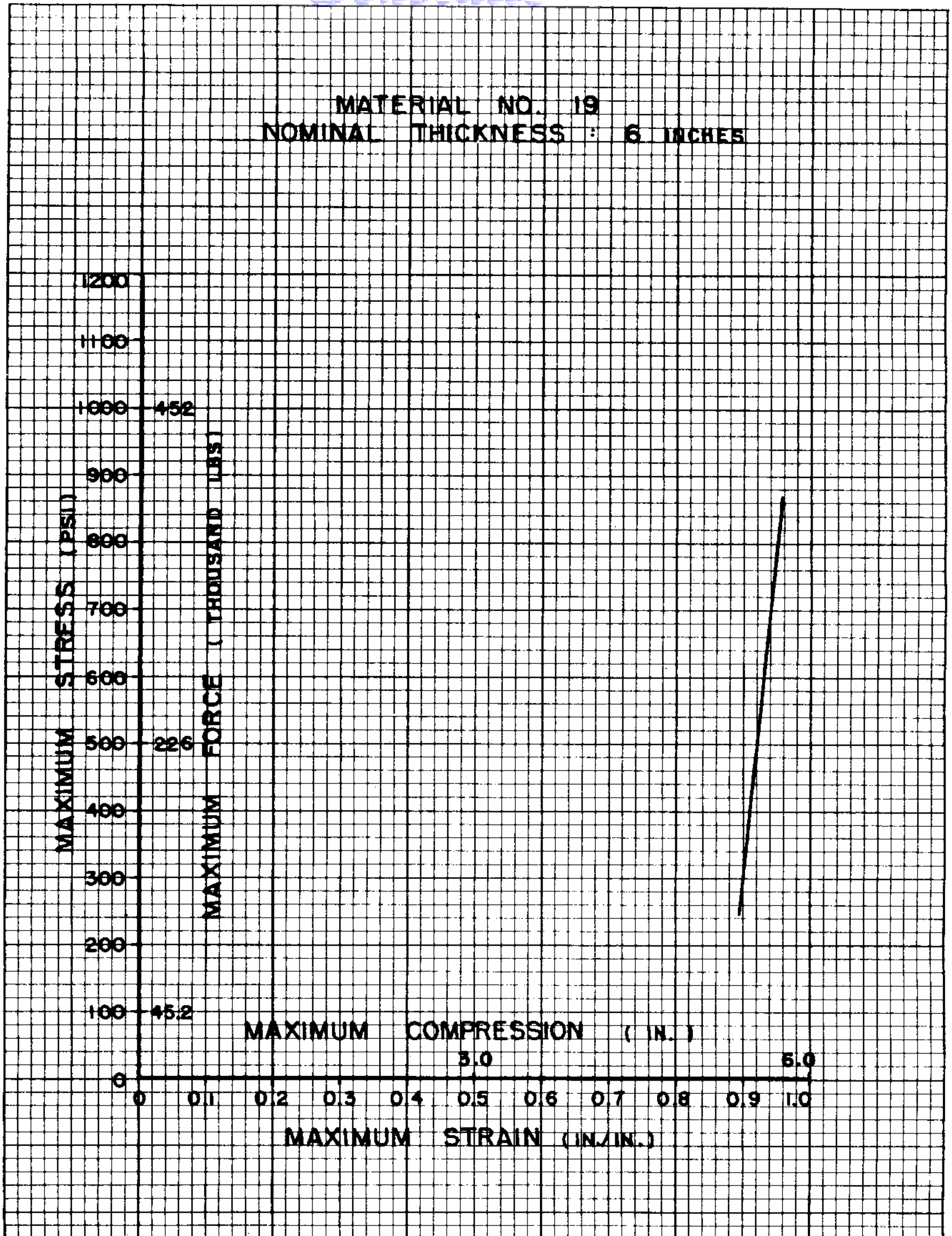

FIGURE 77 MAXIMUM STRESS - MAXIMUM STRAIN CURVE FOR 6 INCHES OF MATERIAL No. 19

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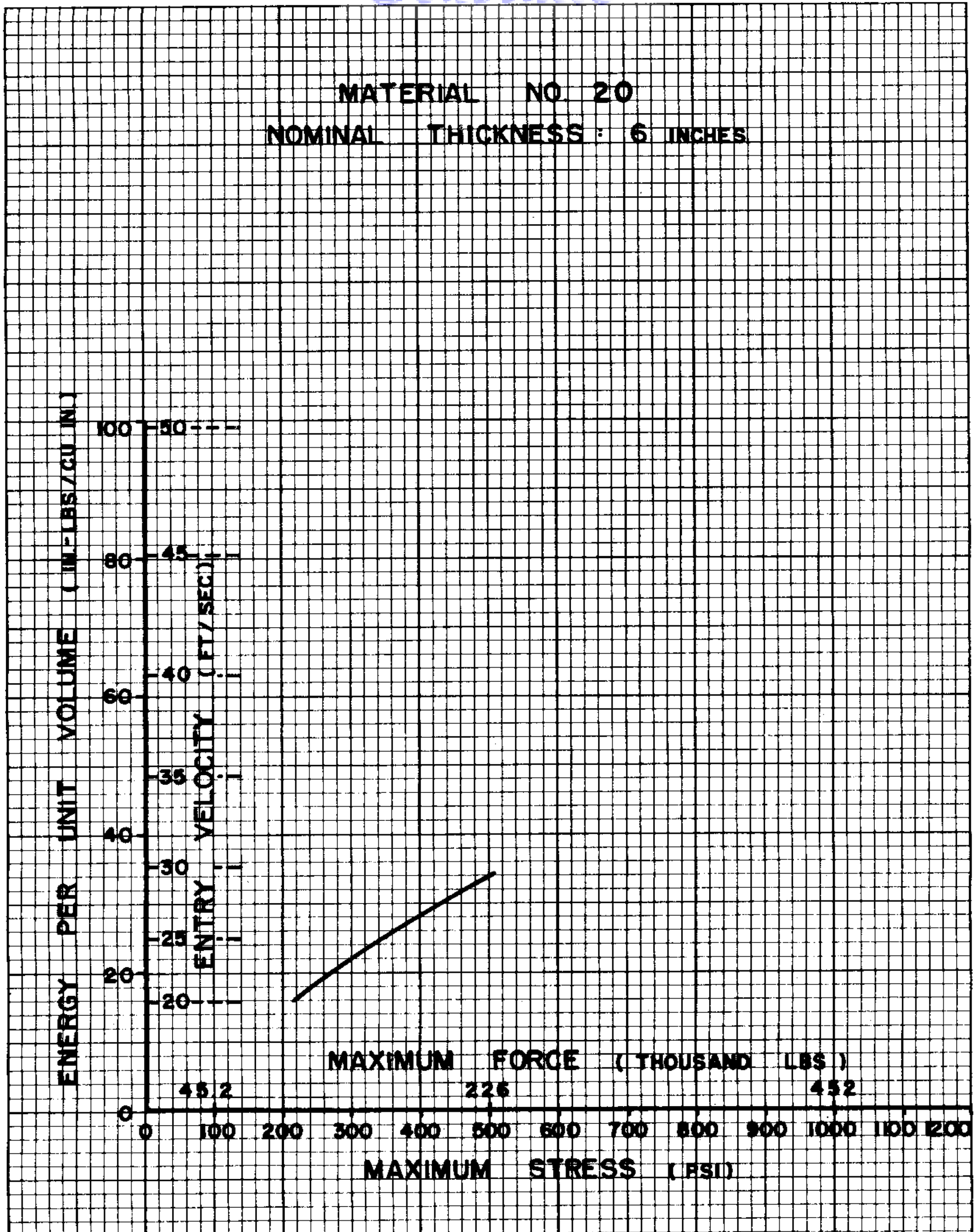

FIGURE 78 ENERGY PER UNIT VOLUME - MAXIMUM STRESS CURVE FOR 6 INCHES OF MATERIAL No. 20

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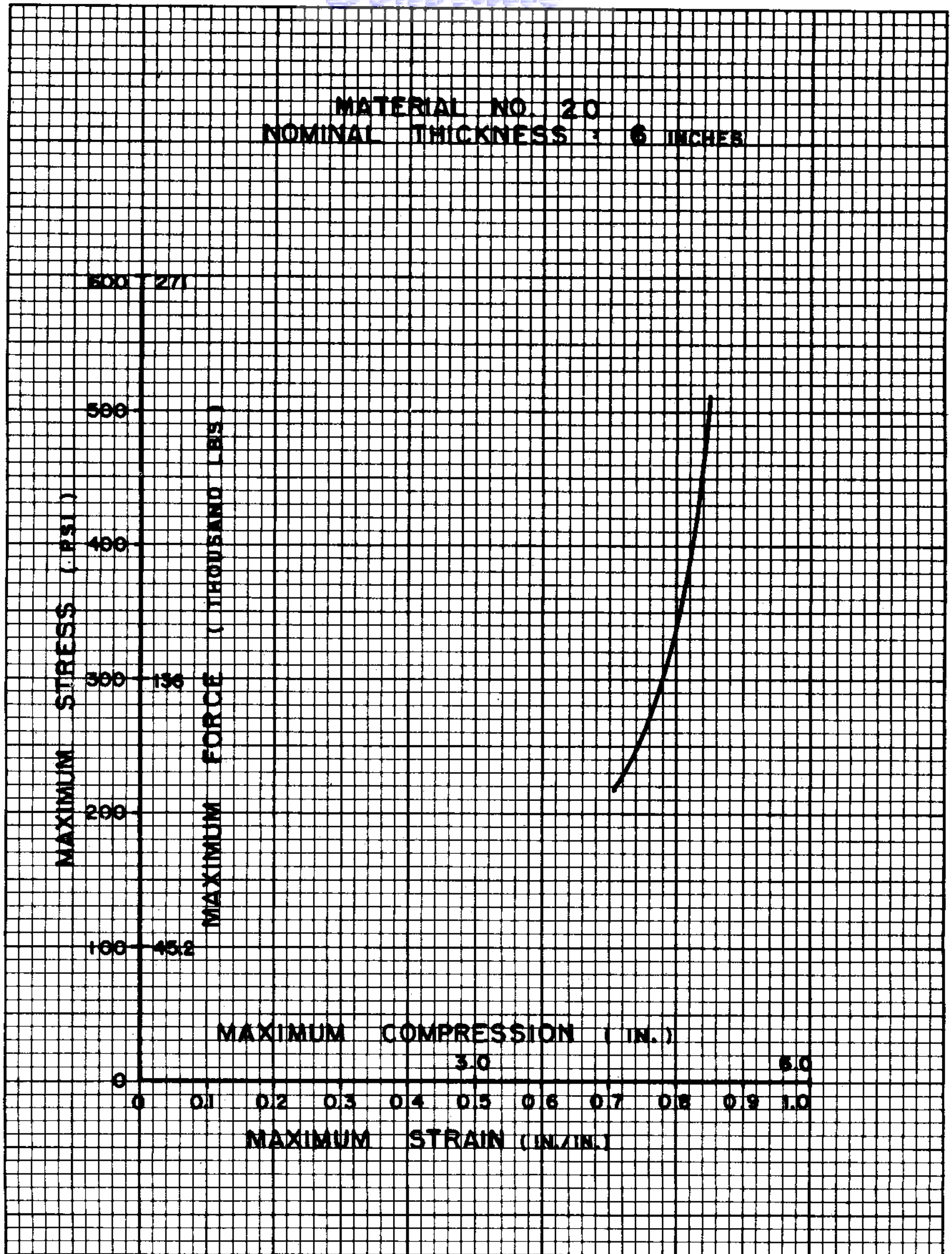

FIGURE 79. MAXIMUM STRESS - MAXIMUM STRAIN CURVE FOR 6 INCHES OF MATERIAL No. 20

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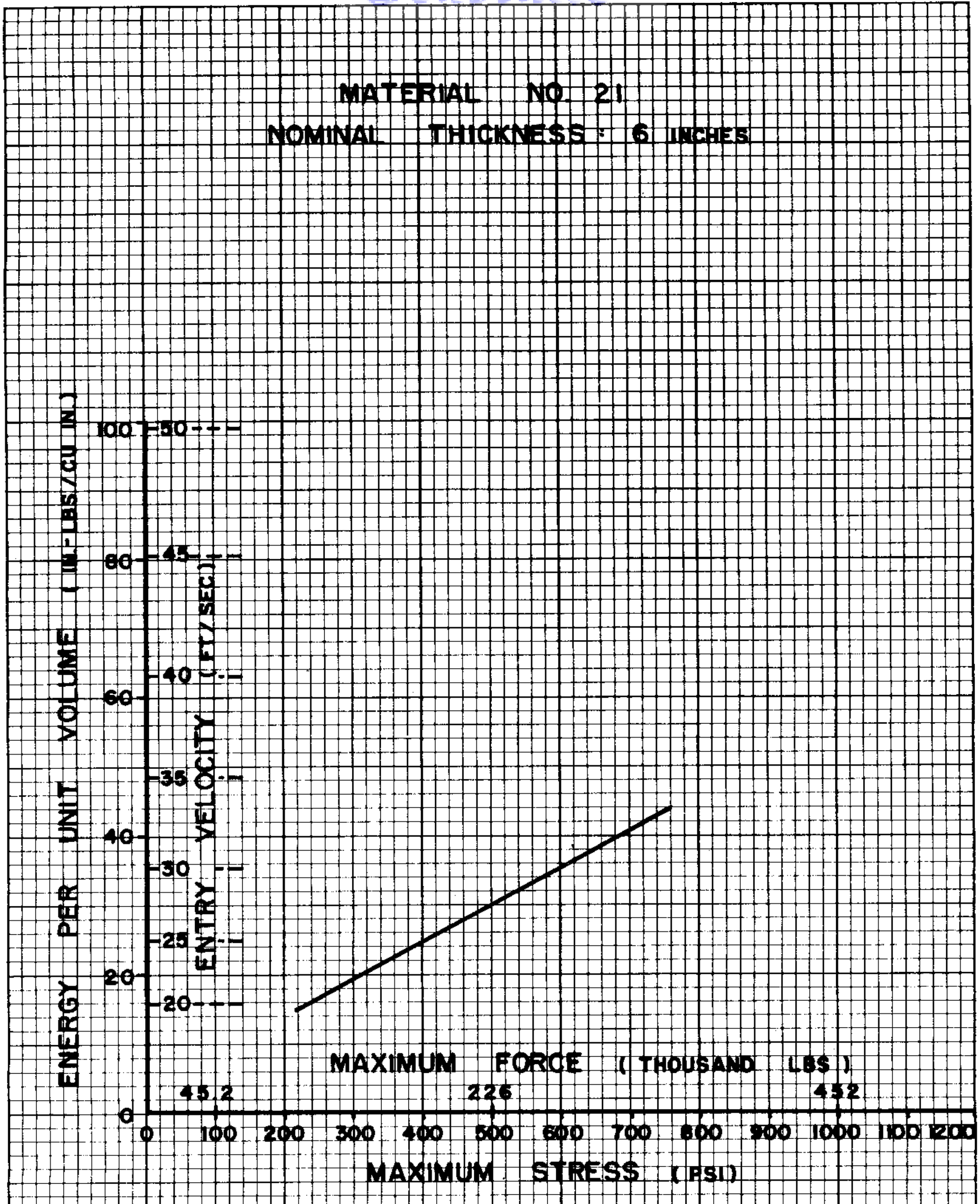

FIGURE 80 ENERGY PER UNIT VOLUME - MAXIMUM STRESS CURVE FOR 6 INCHES OF MATERIAL No. 21

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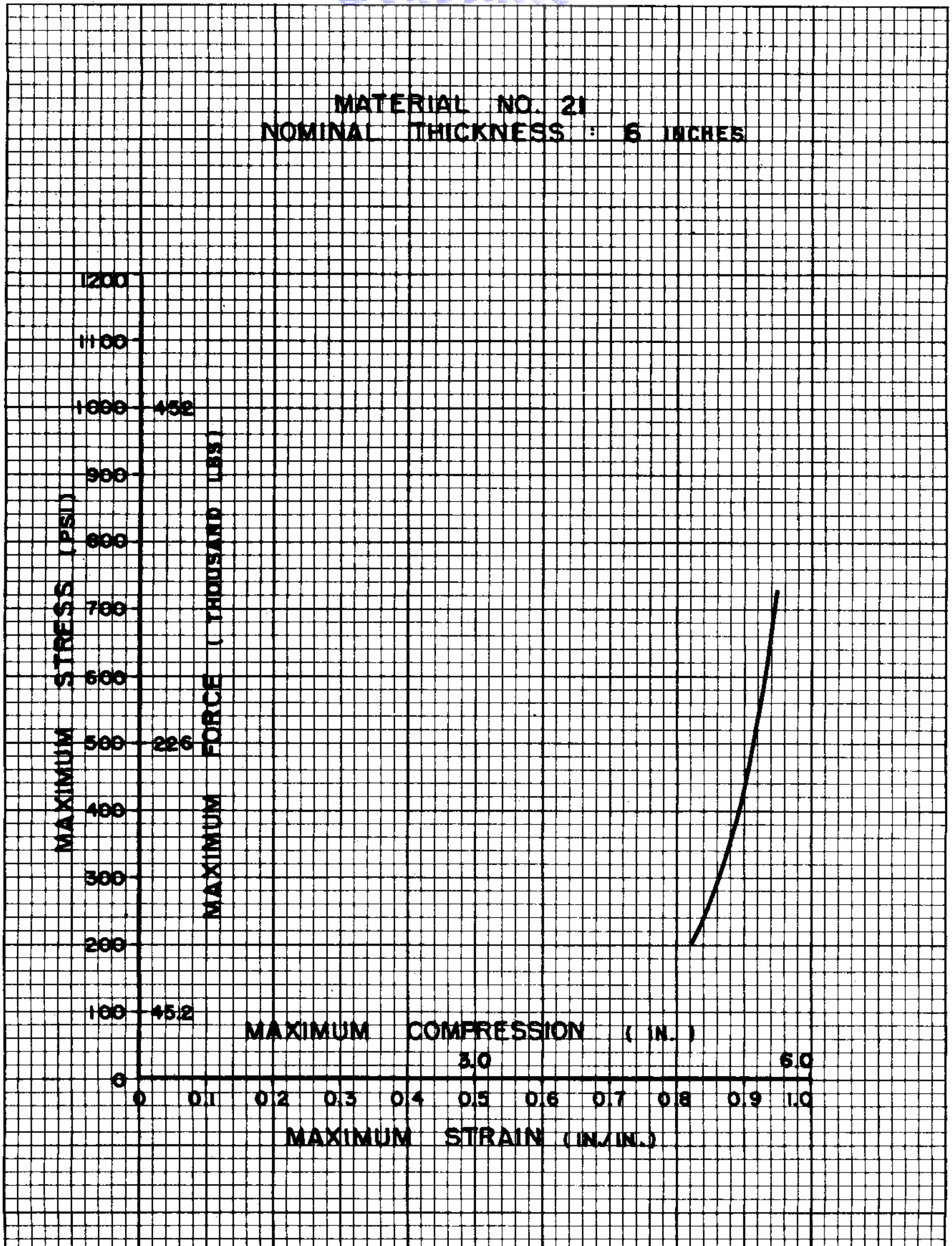

FIGURE 81 MAXIMUM STRESS - MAXIMUM STRAIN CURVE FOR 6 INCHES OF MATERIAL No. 21

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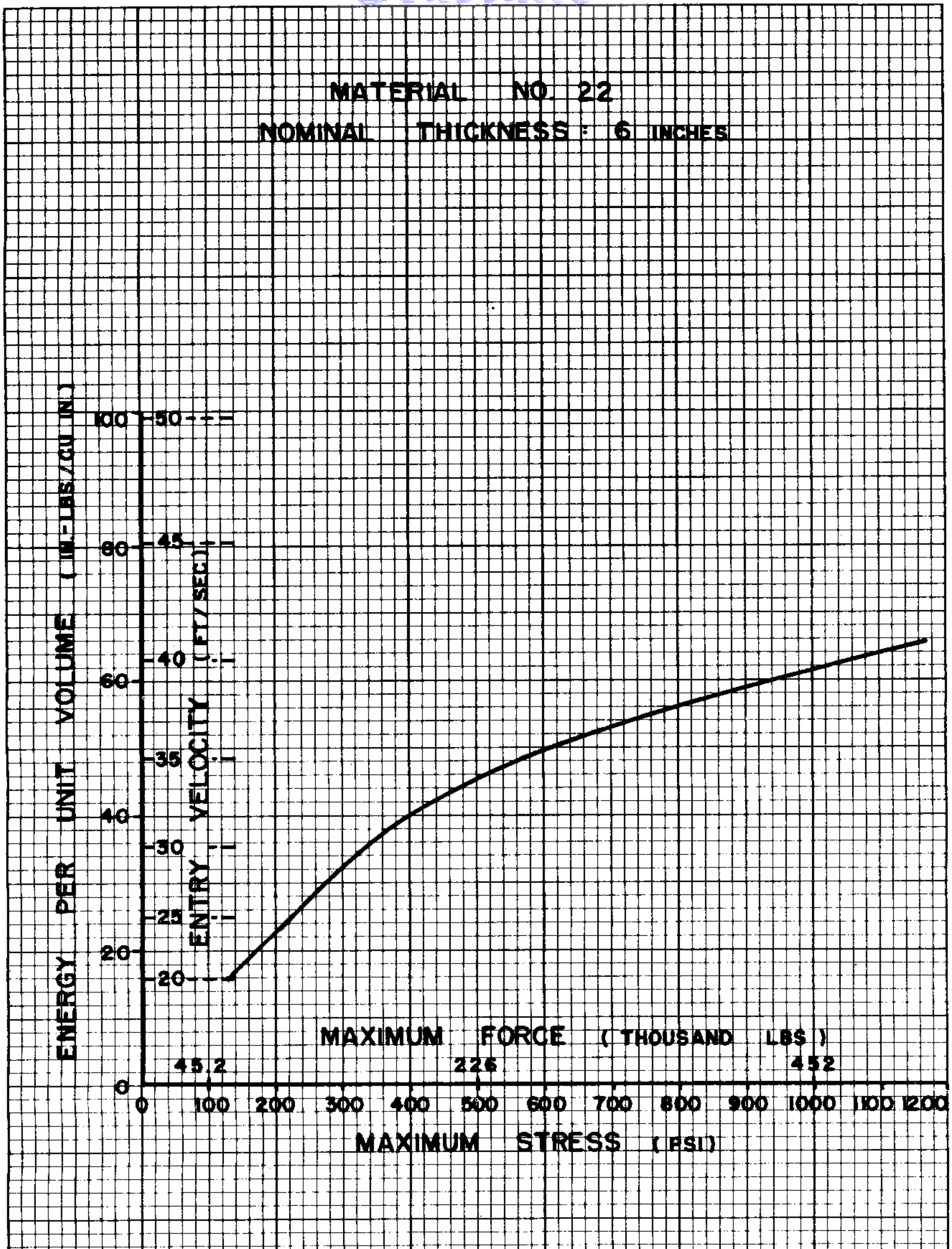

FIGURE 82 ENERGY PER UNIT VOLUME - MAXIMUM STRESS CURVE FOR 6 INCHES OF MATERIAL No. 22

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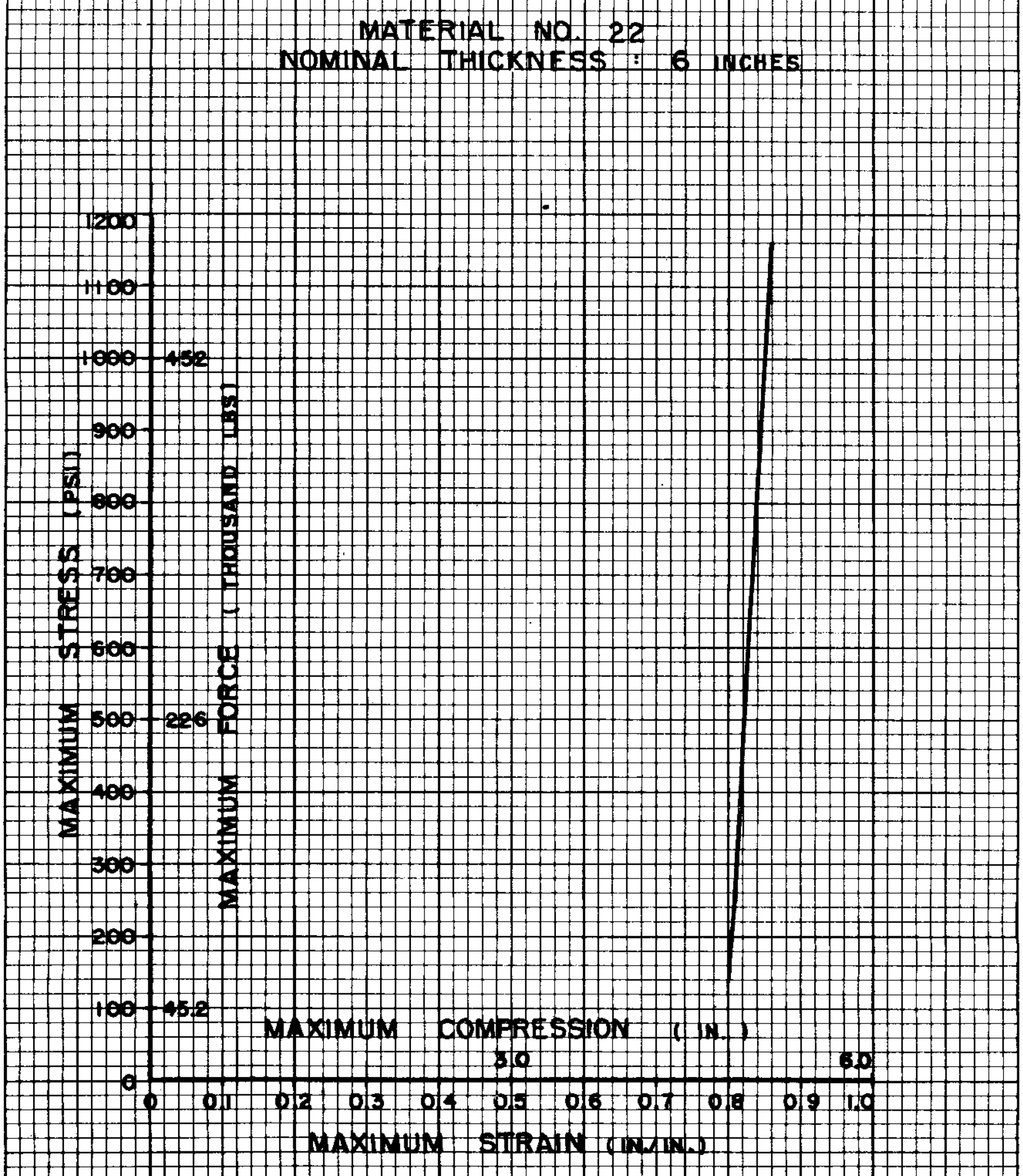

FIGURE 83 MAXIMUM STRESS - MAXIMUM STRAIN CURVE FOR 6 INCHES OF MATERIAL NO. 22

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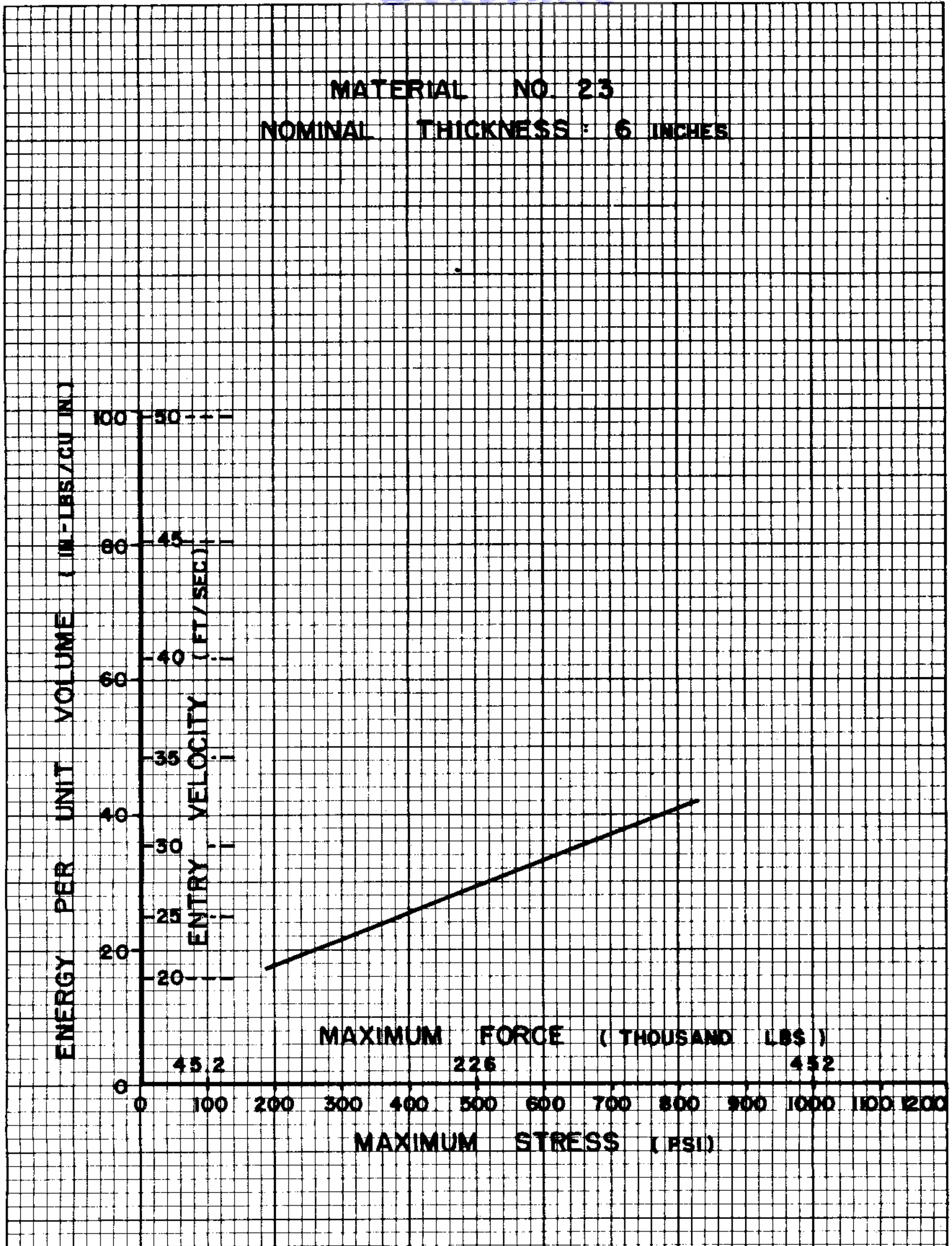

FIGURE 84 ENERGY PER UNIT VOLUME - MAXIMUM STRESS CURVE FOR 6 INCHES OF MATERIAL No. 23

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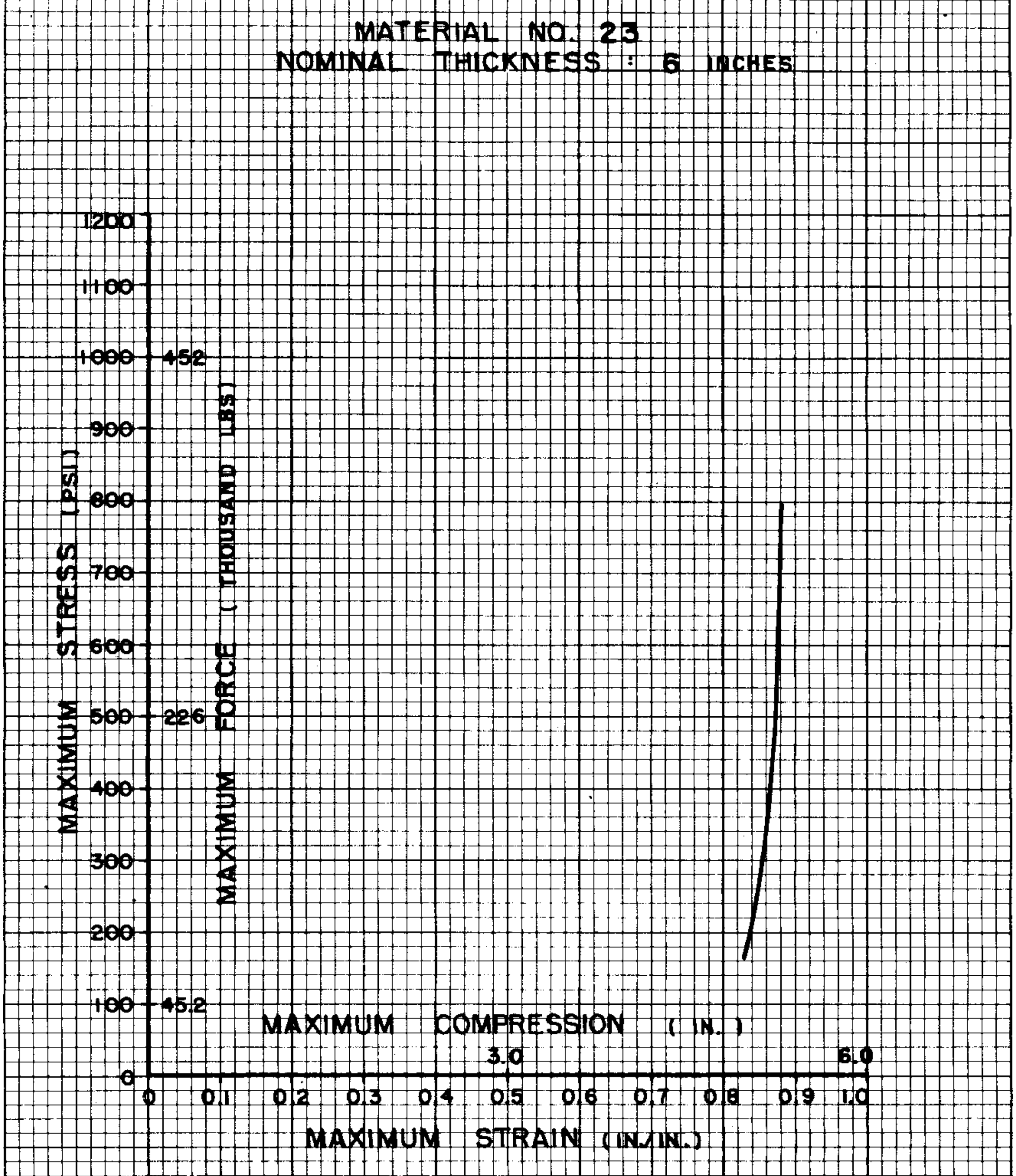

FIGURE 85 MAXIMUM STRESS - MAXIMUM STRAIN CURVE FOR 6 INCHES OF MATERIAL No. 23

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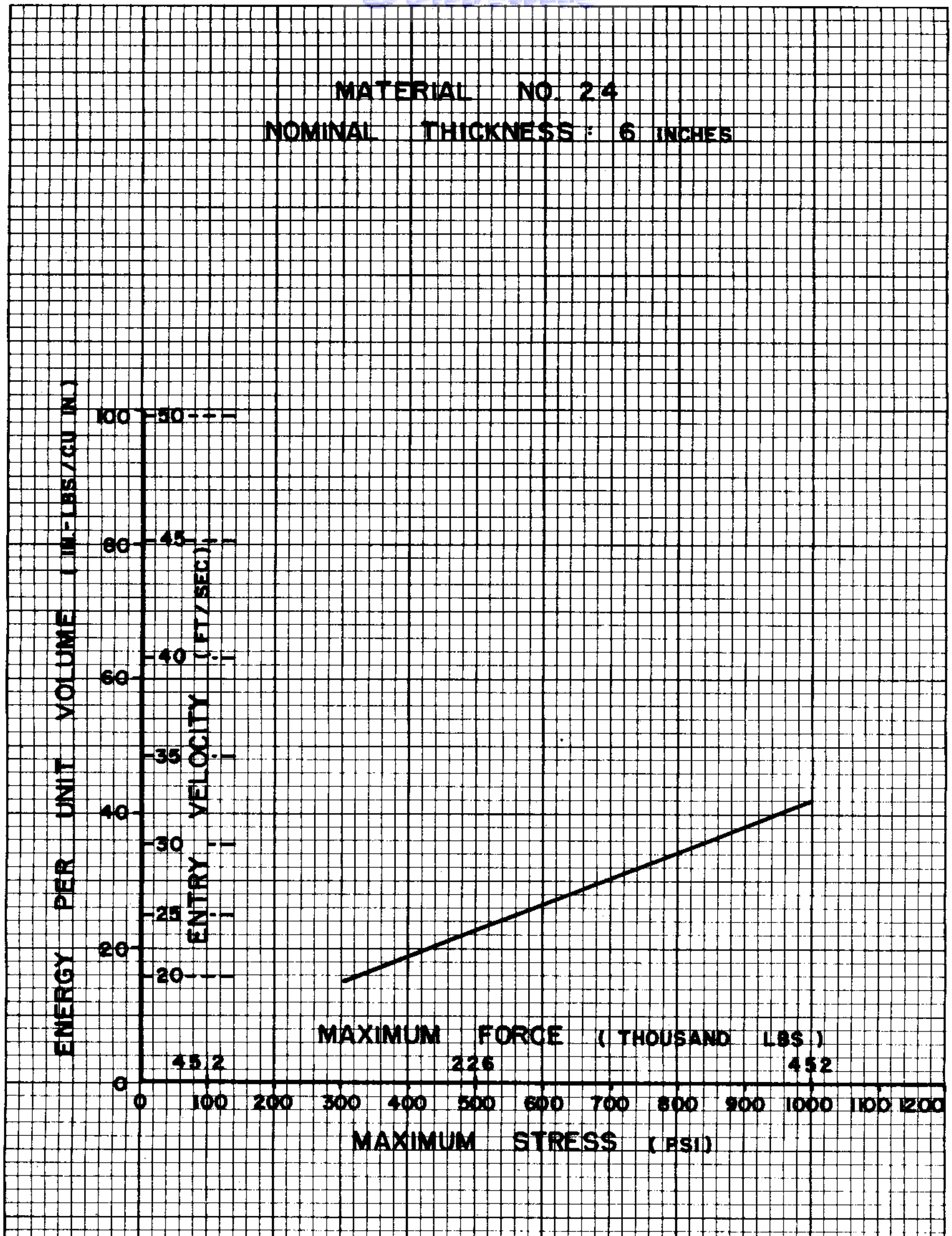

FIGURE 86 ENERGY PER UNIT VOLUME - MAXIMUM STRESS CURVE FOR 6 INCHES OF MATERIAL NO. 24

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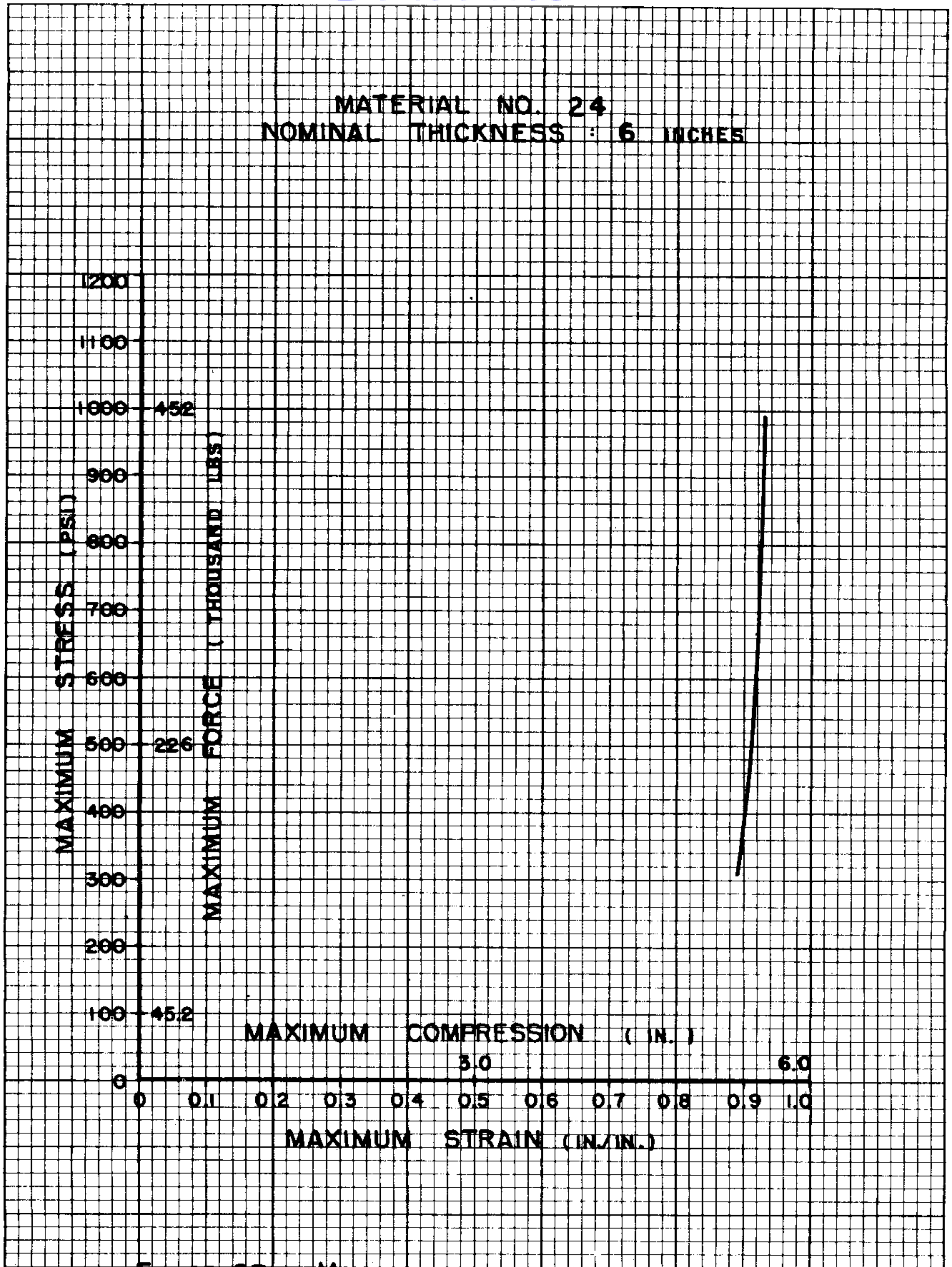

FIGURE 87 MAXIMUM STRESS - MAXIMUM STRAIN CURVE FOR 6 INCHES OF MATERIAL NO. 24

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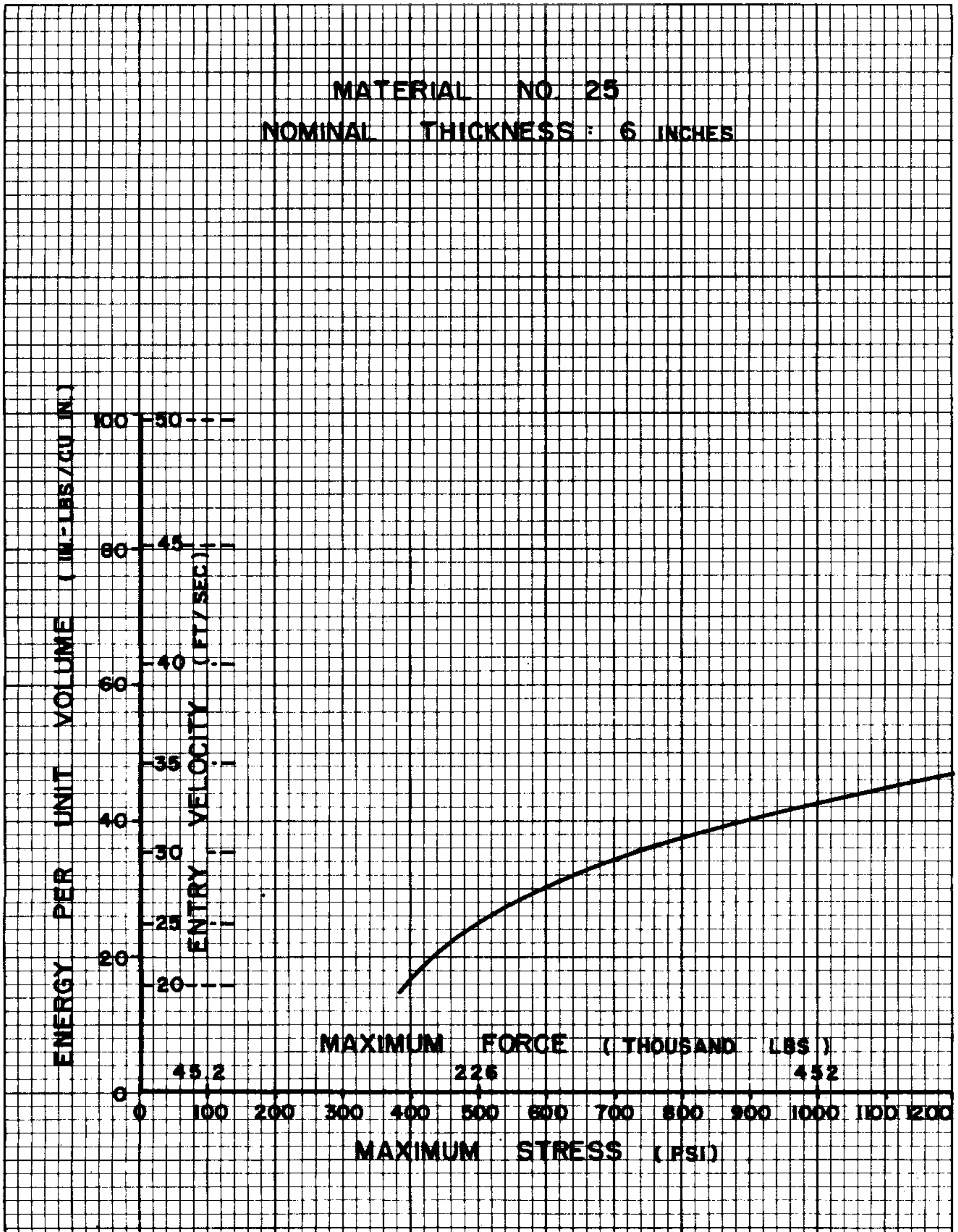

Figure 88 Energy per unit volume - maximum stress curve for 6 inches of material No. 25

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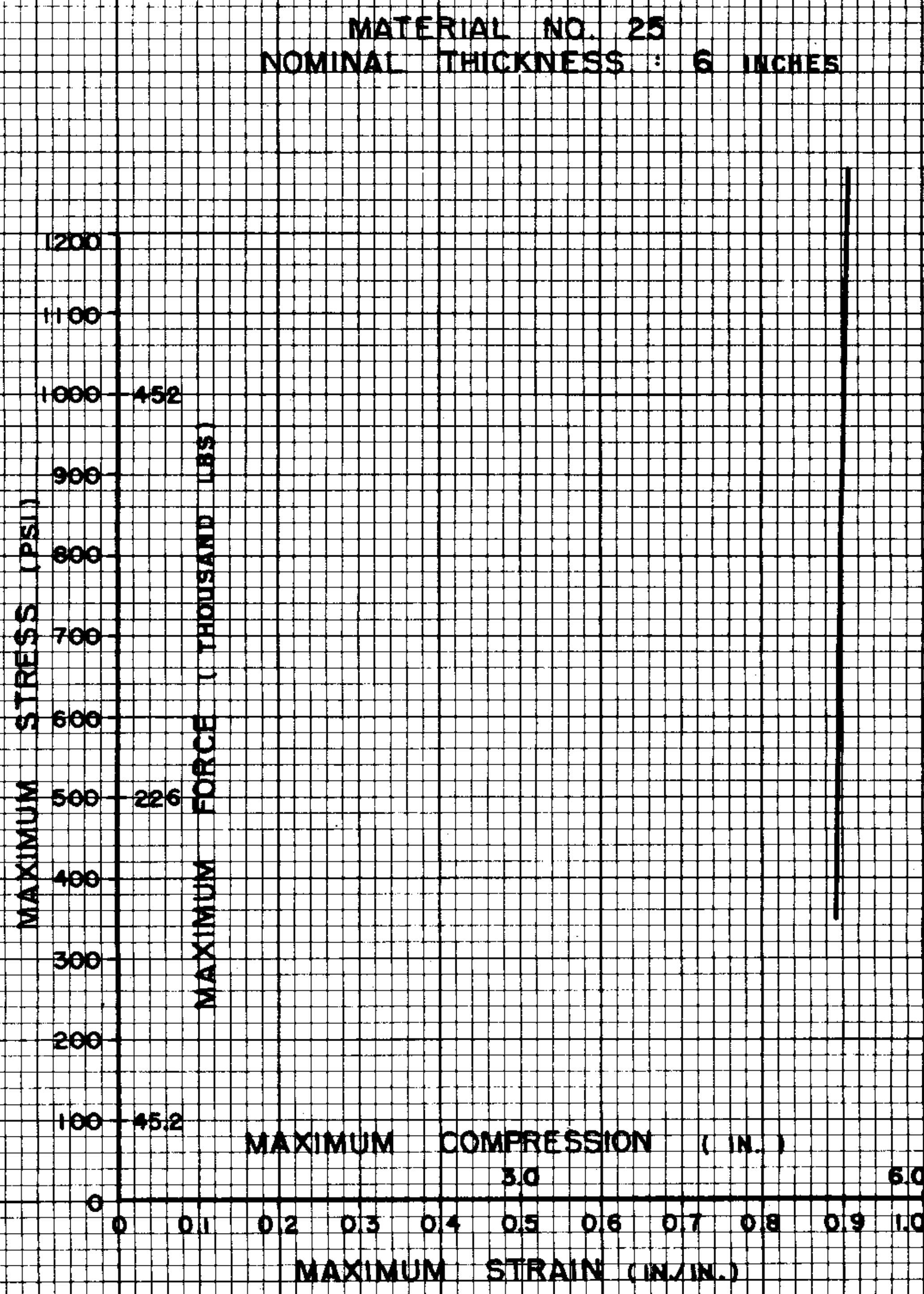

FIGURE 89 MAXIMUM STRESS - MAXIMUM STRAIN CURVE FOR 6 INCHES OF MATERIAL NO. 25

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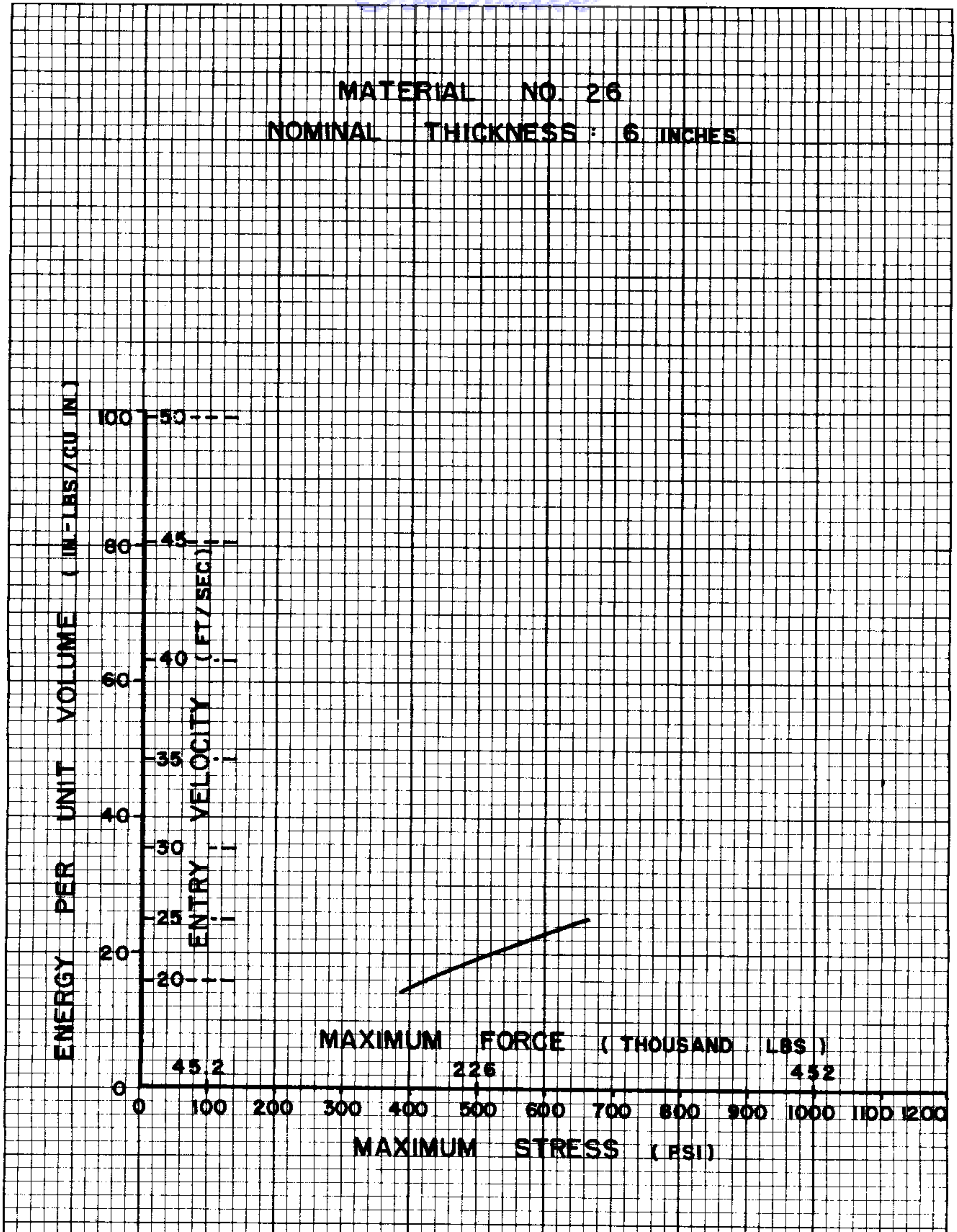

FIGURE 90 ENERGY PER UNIT VOLUME - MAXIMUM STRESS CURVE FOR 6 INCHES OF MATERIAL No. 26

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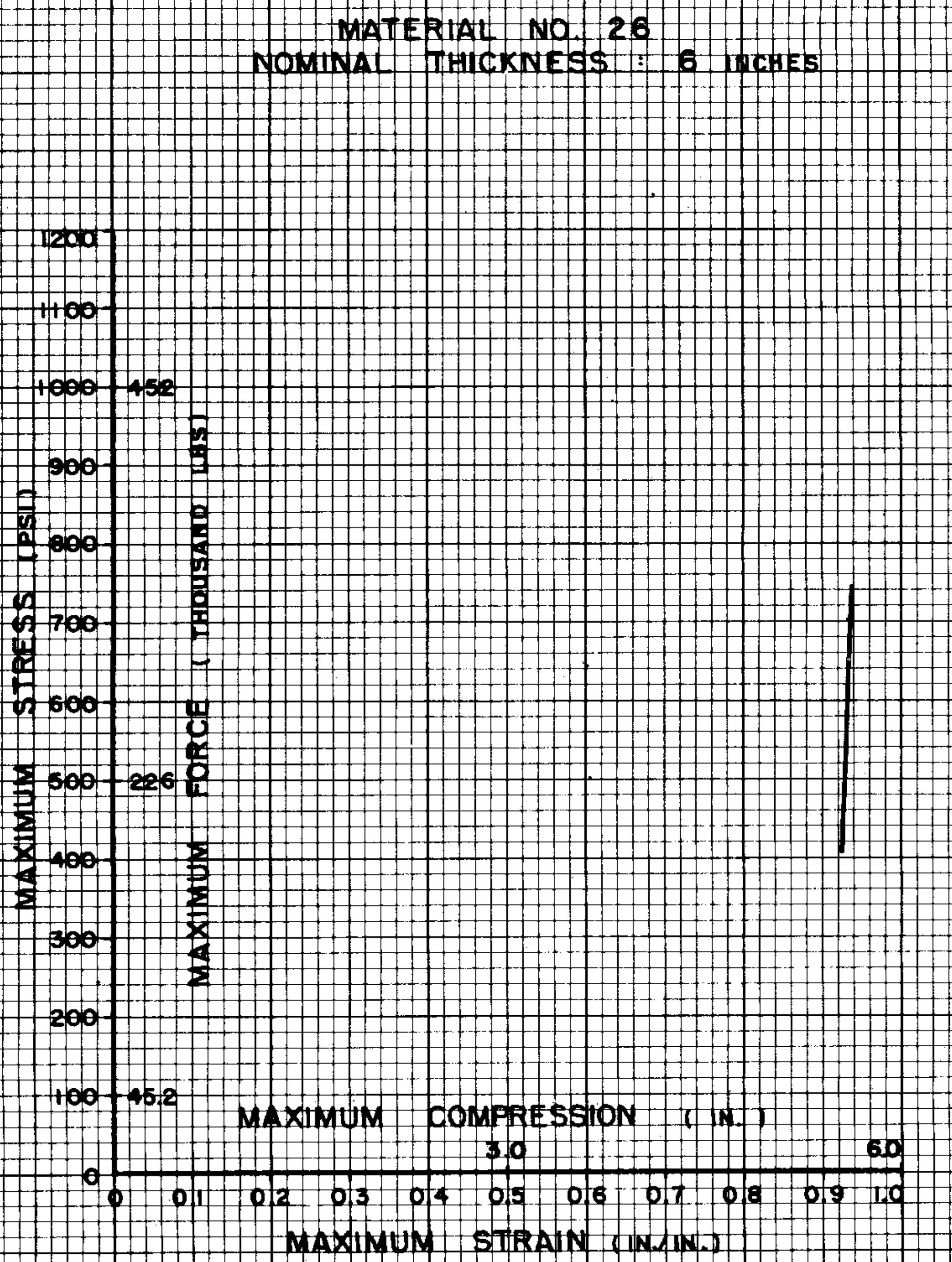

FIGURE 91 MAXIMUM STRESS - MAXIMUM STRAIN CURVE FOR 6 INCHES OF MATERIAL NO. 26

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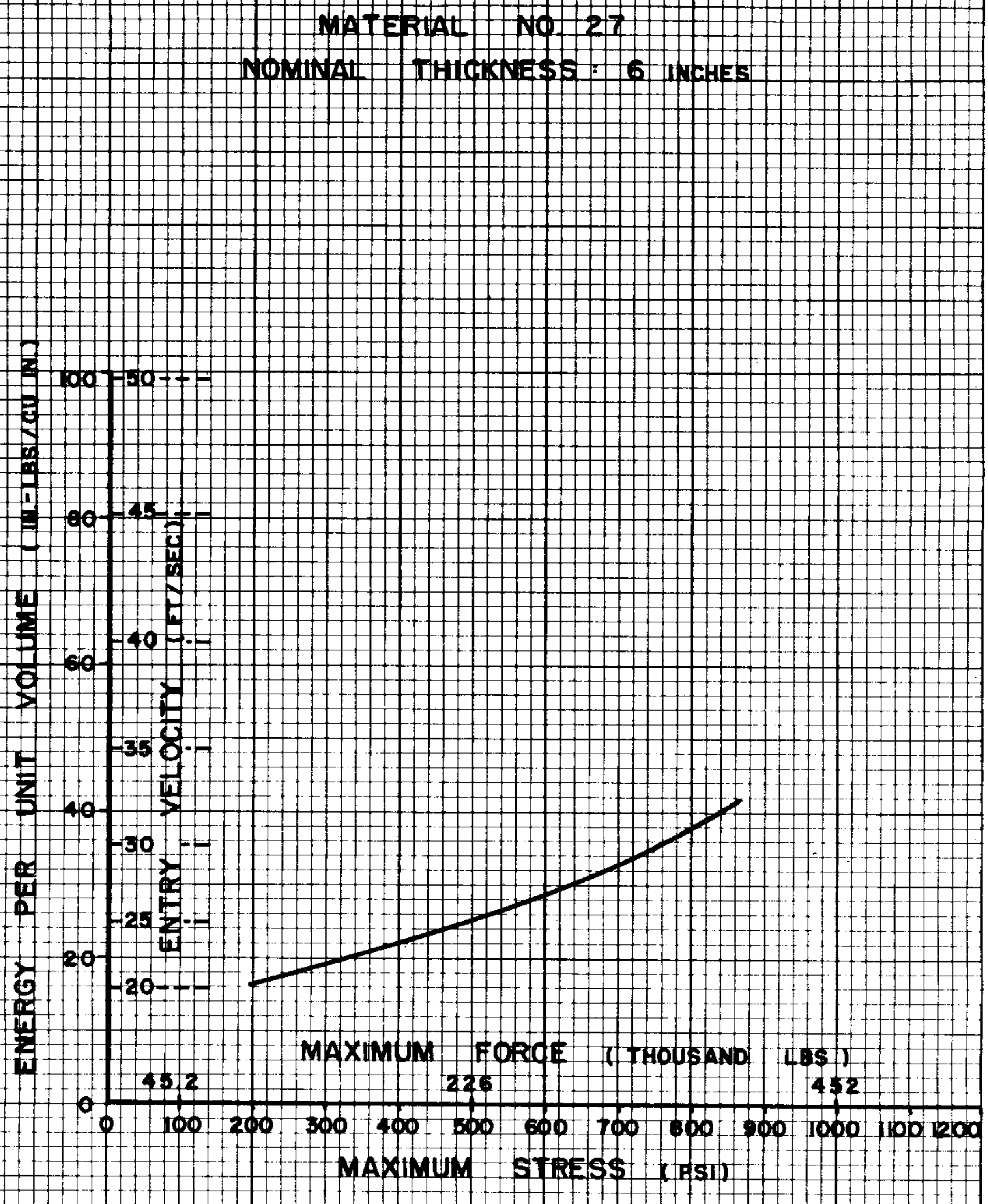

FIGURE 92 ENERGY PER UNIT VOLUME - MAXIMUM STRESS CURVE FOR 6 INCHES OF MATERIAL No. 27

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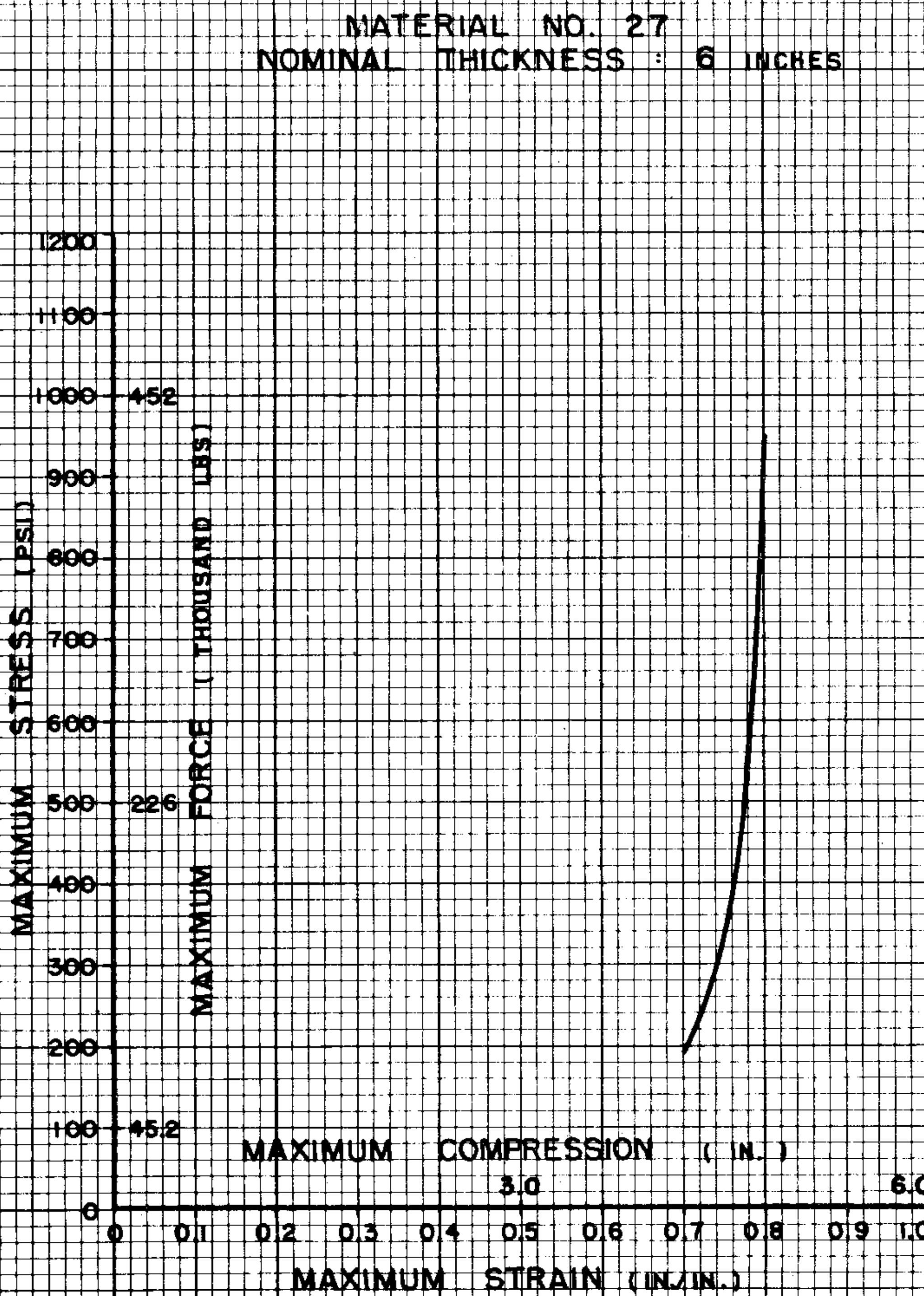

FIGURE 93 MAXIMUM STRESS - MAXIMUM STRAIN CURVE FOR 6 INCHES OF MATERIAL No. 27

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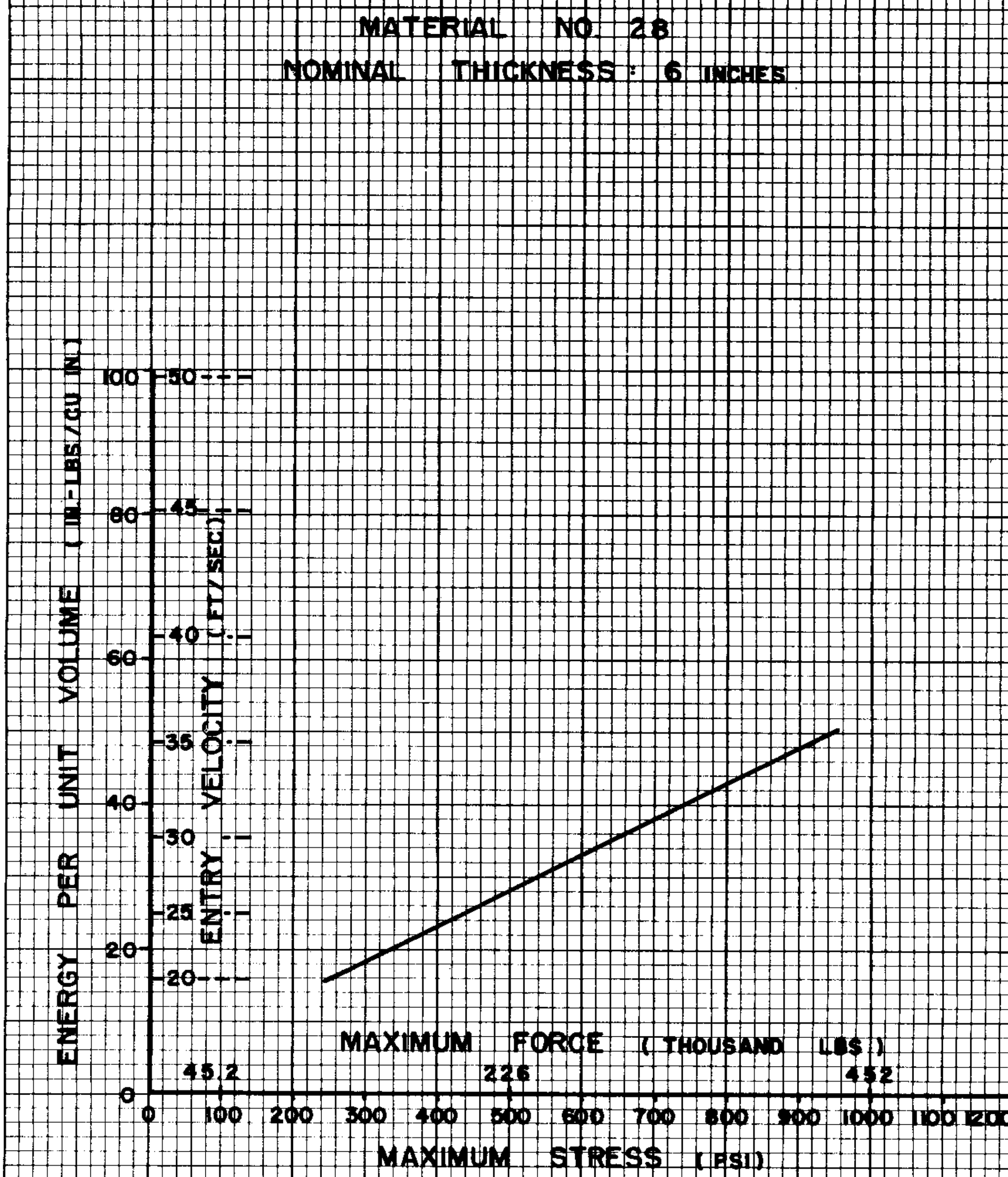

FIGURE 94 ENERGY PER UNIT VOLUME - MAXIMUM STRESS CURVE FOR 6 INCHES OF MATERIAL NO. 28

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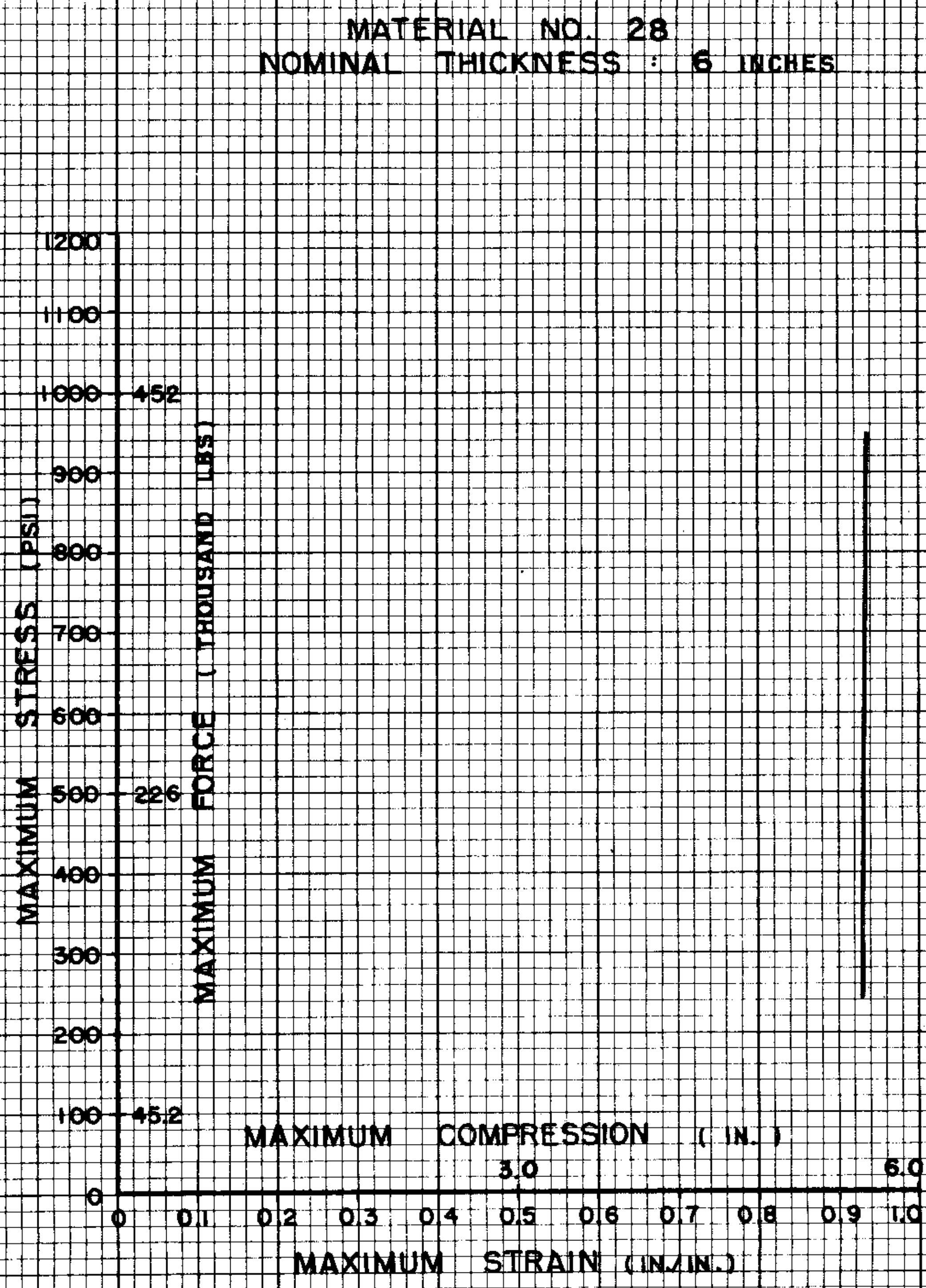

FIGURE 95 MAXIMUM STRESS - MAXIMUM STRAIN CURVE FOR 6 INCHES OF MATERIAL NO. 28

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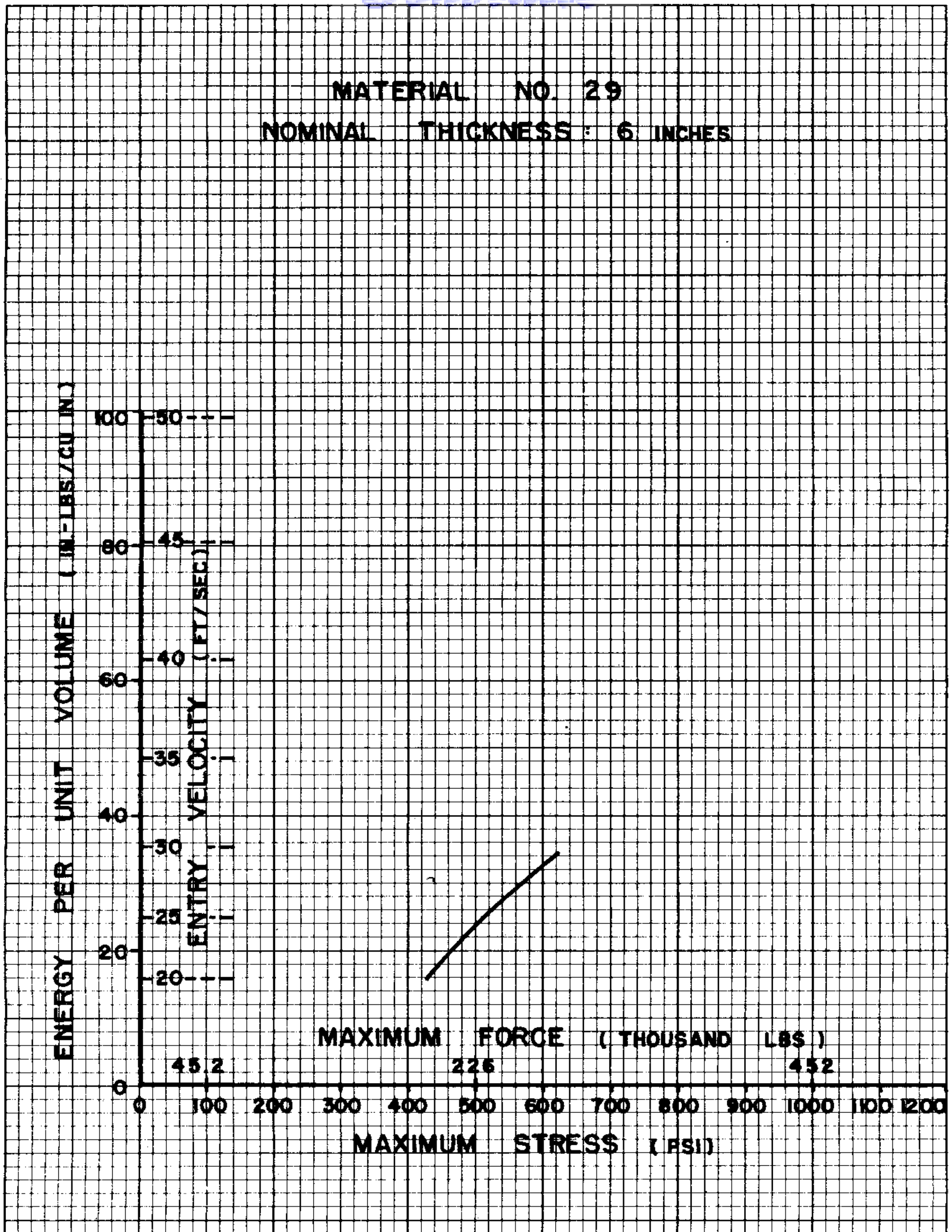

FIGURE 96 ENERGY PER UNIT VOLUME - MAXIMUM STRESS CURVE FOR 6 INCHES OF MATERIAL No. 29

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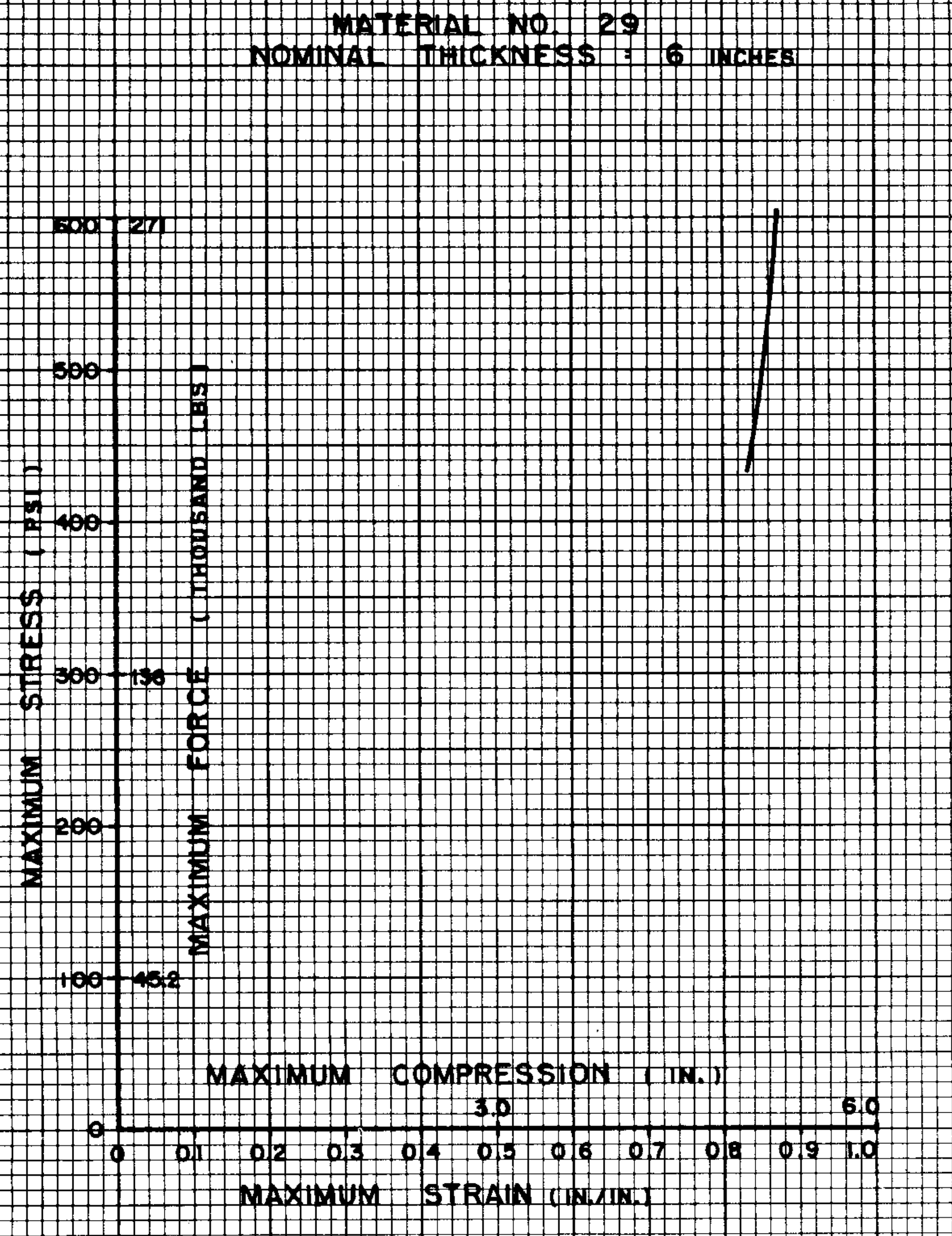

FIGURE 97. MAXIMUM STRESS - MAXIMUM STRAIN CURVE FOR 6 INCHES OF MATERIAL No. 29

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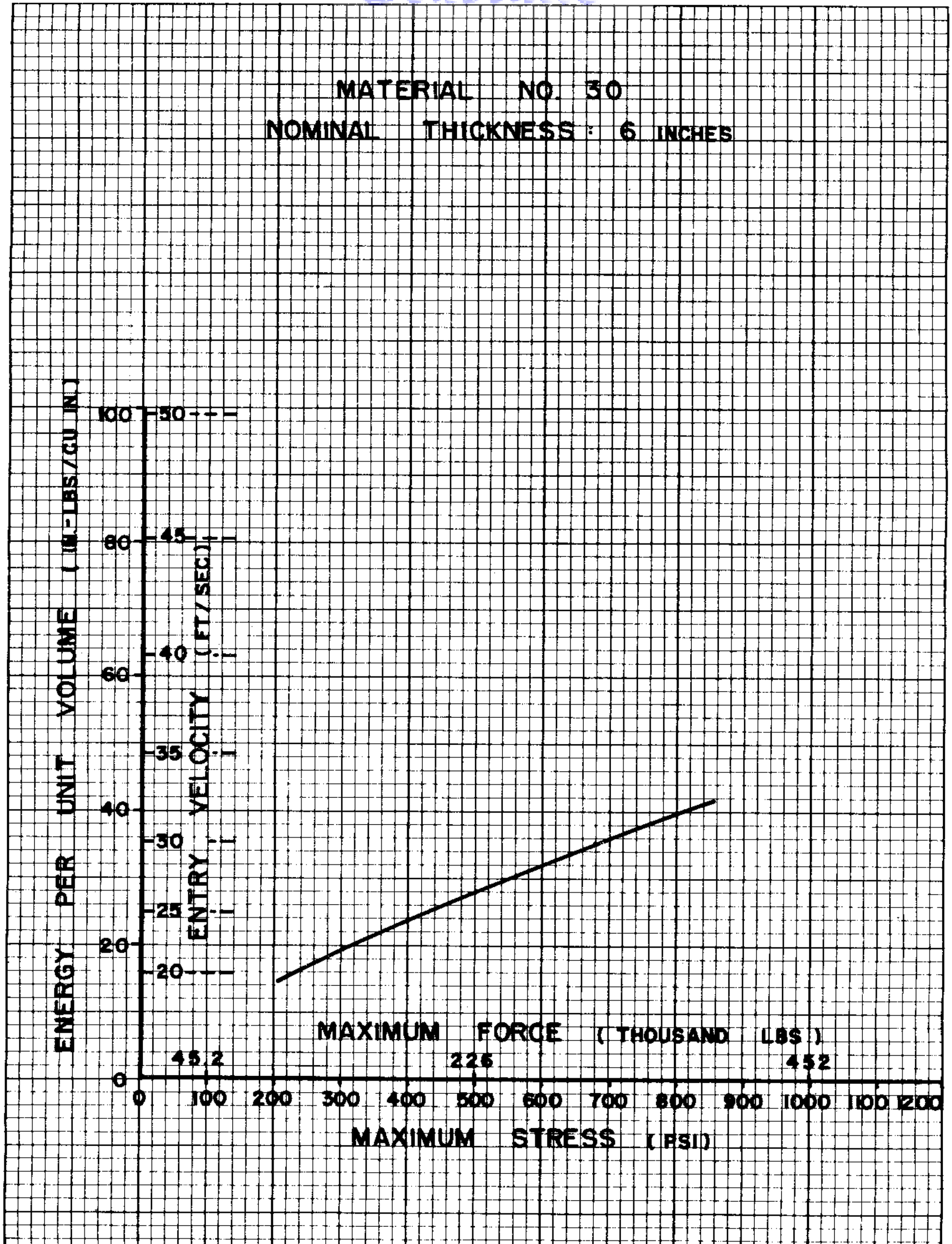

FIGURE 98 ENERGY PER UNIT VOLUME - MAXIMUM STRESS CURVE FOR 6 INCHES OF MATERIAL No. 30

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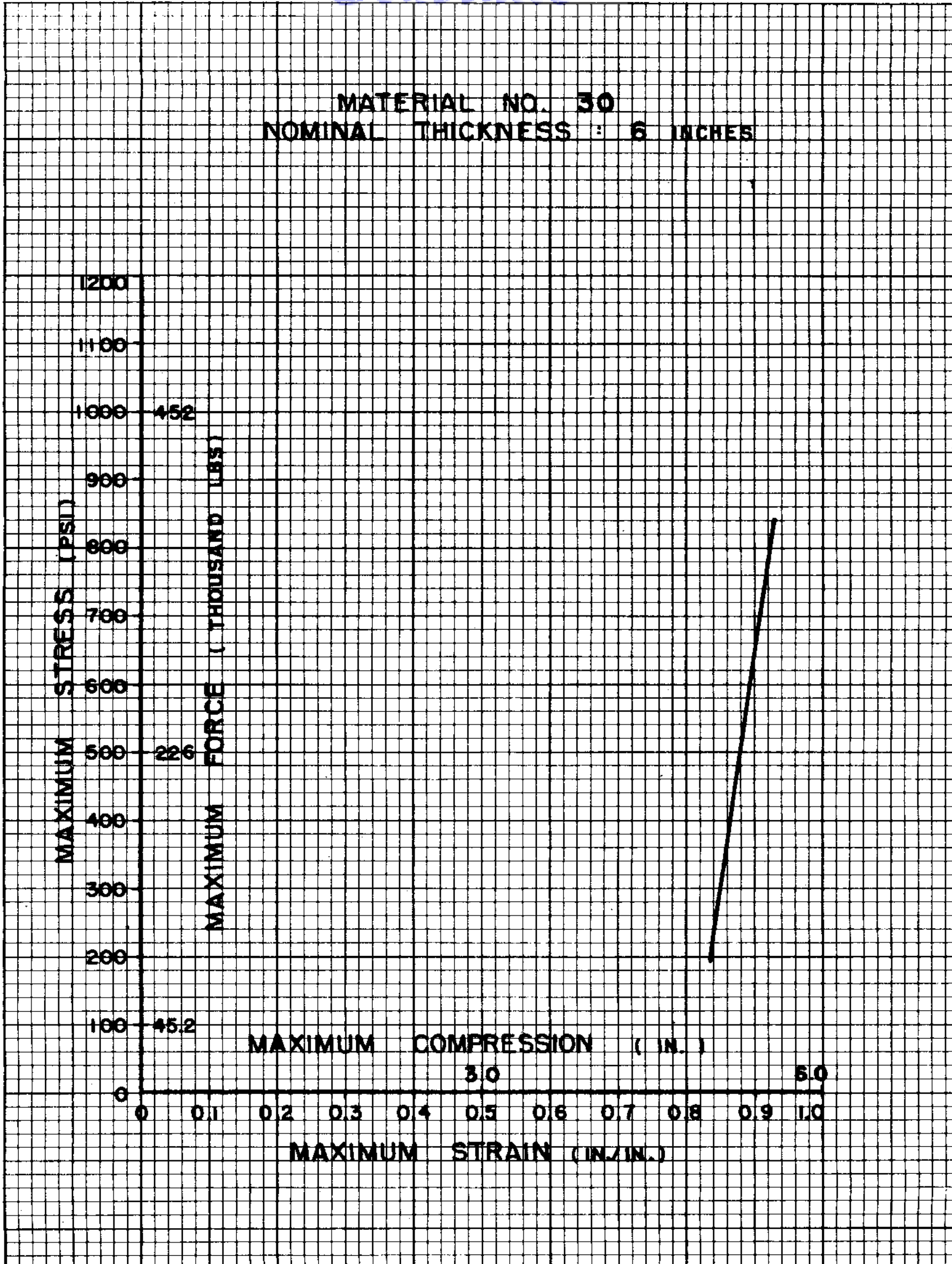

FIGURE 99 MAXIMUM STRESS - MAXIMUM STRAIN CURVE FOR 6 INCHES OF MATERIAL No. 30

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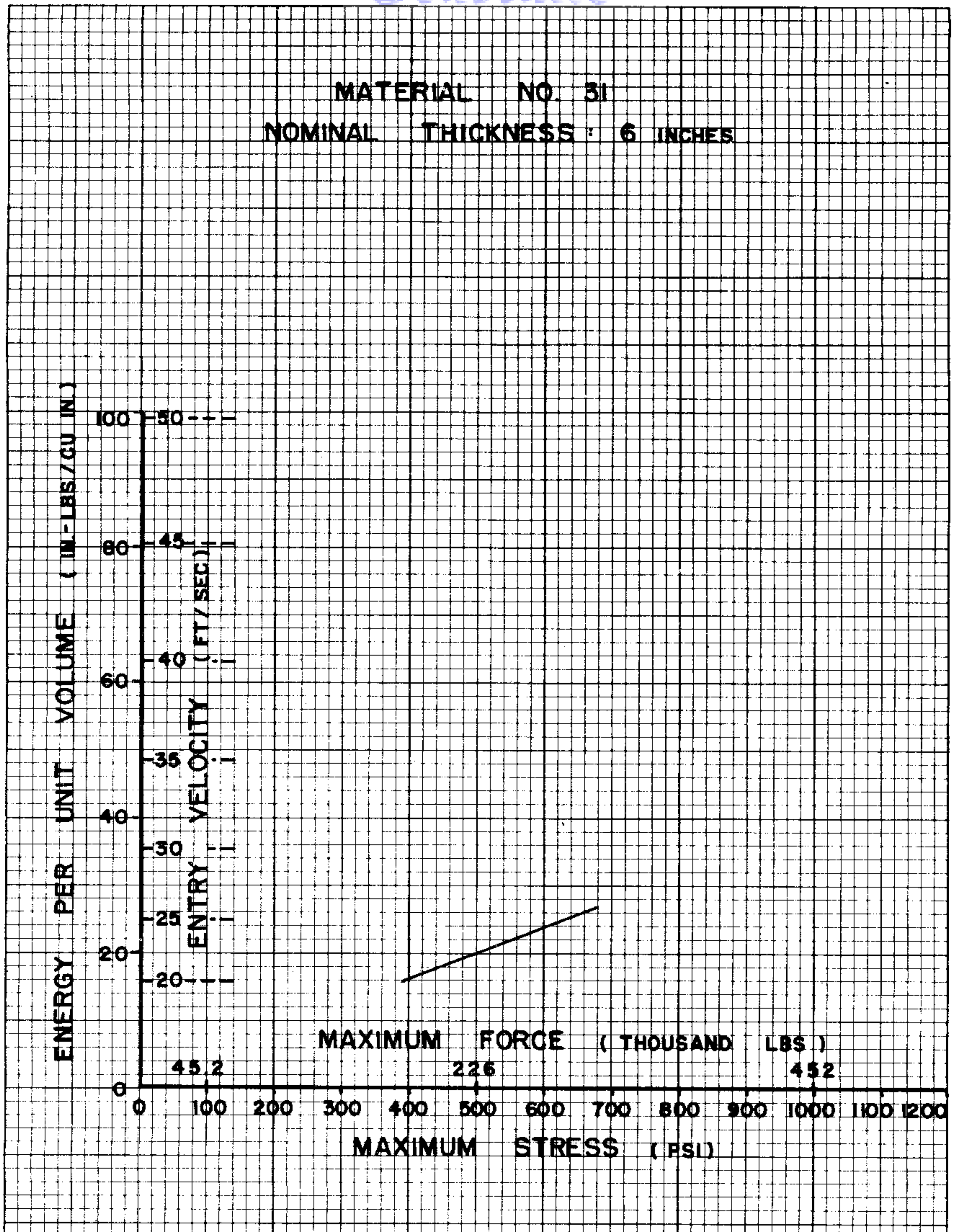

FIGURE 100 ENERGY PER UNIT VOLUME - MAXIMUM STRESS CURVE FOR 6 INCHES OF MATERIAL No. 31

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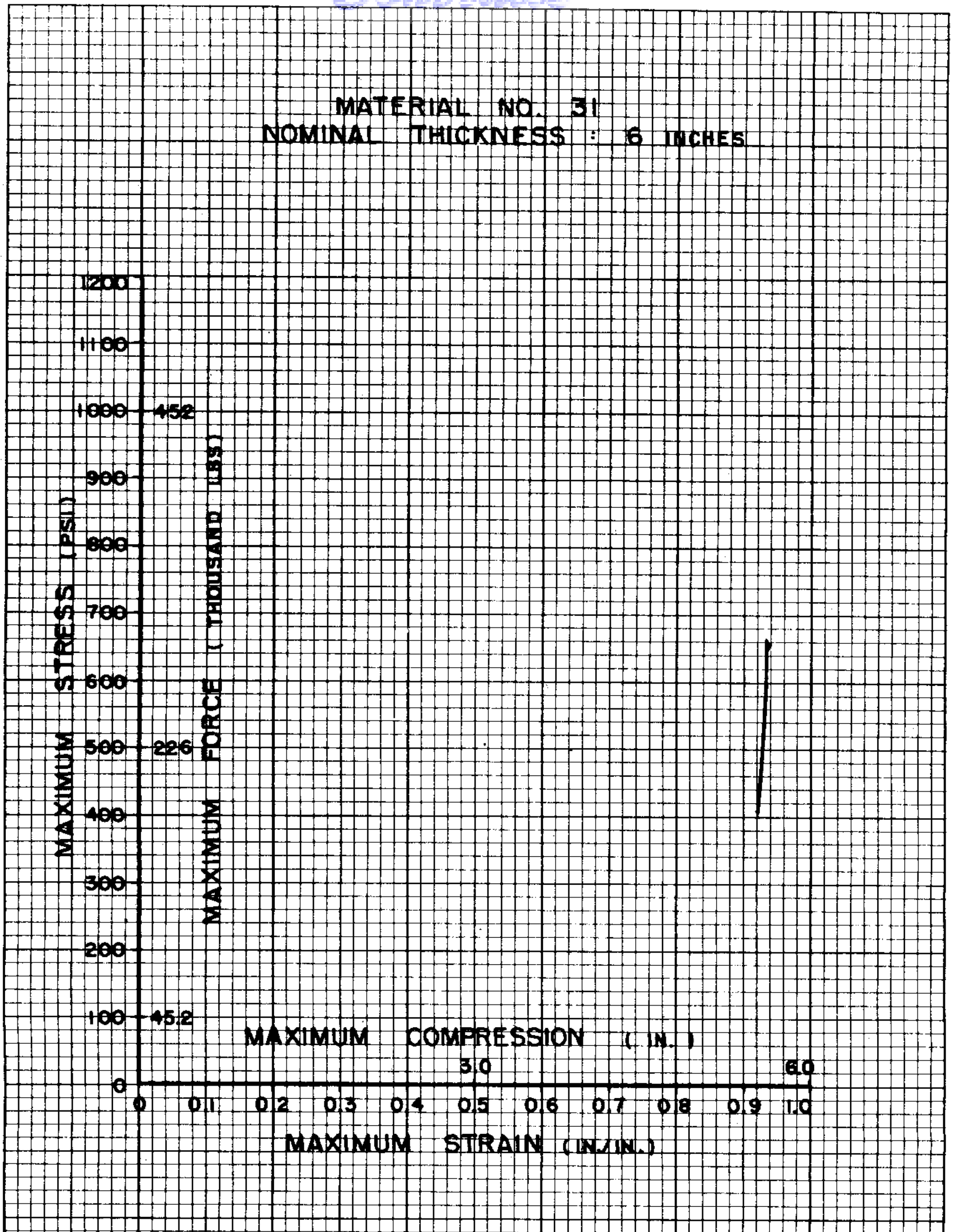

FIGURE 101 MAXIMUM STRESS - MAXIMUM STRAIN CURVE FOR 6 INCHES OF MATERIAL NO. 31

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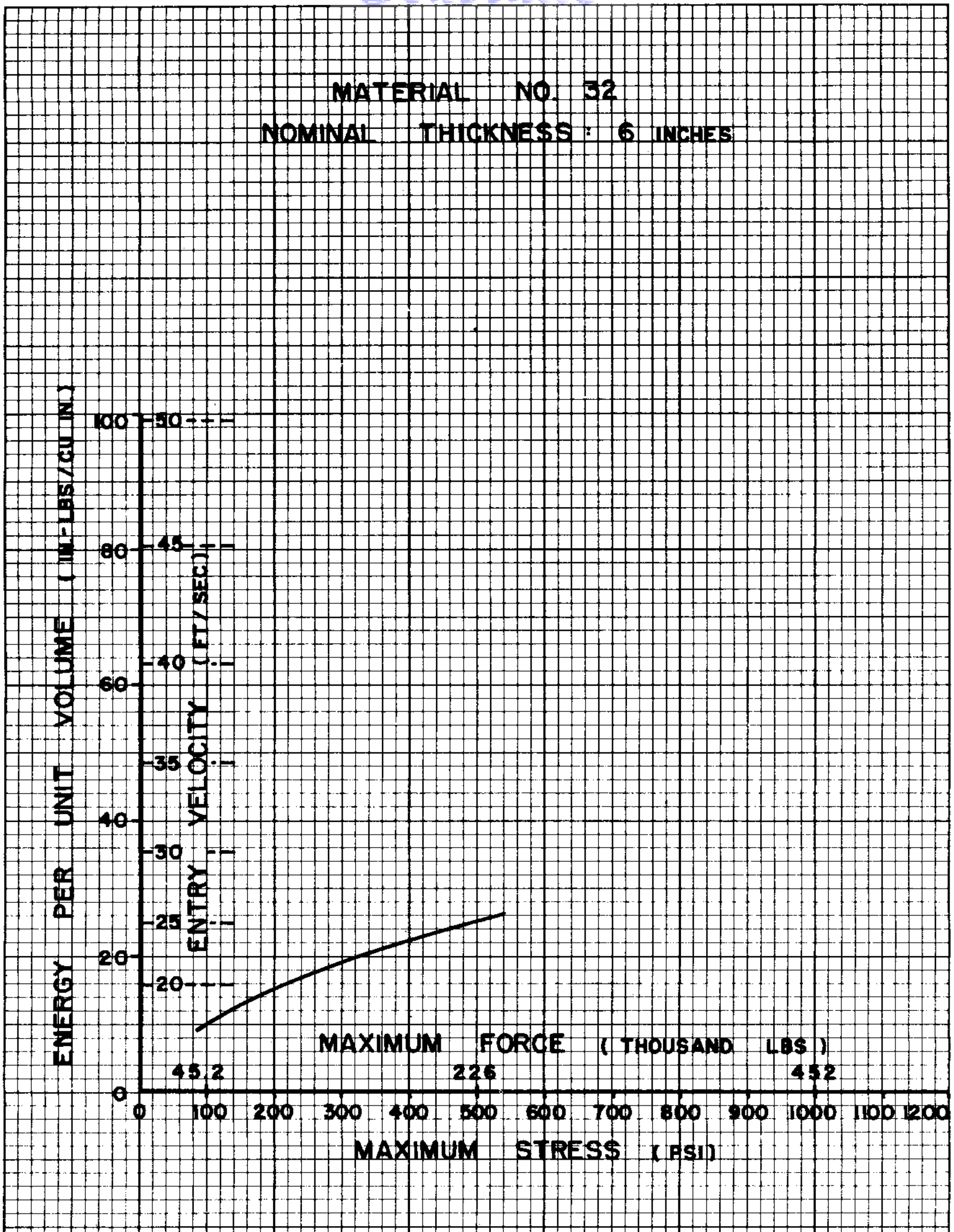

FIGURE 102 ENERGY PER UNIT VOLUME - MAXIMUM STRESS CURVE FOR 6 INCHES OF MATERIAL No. 32

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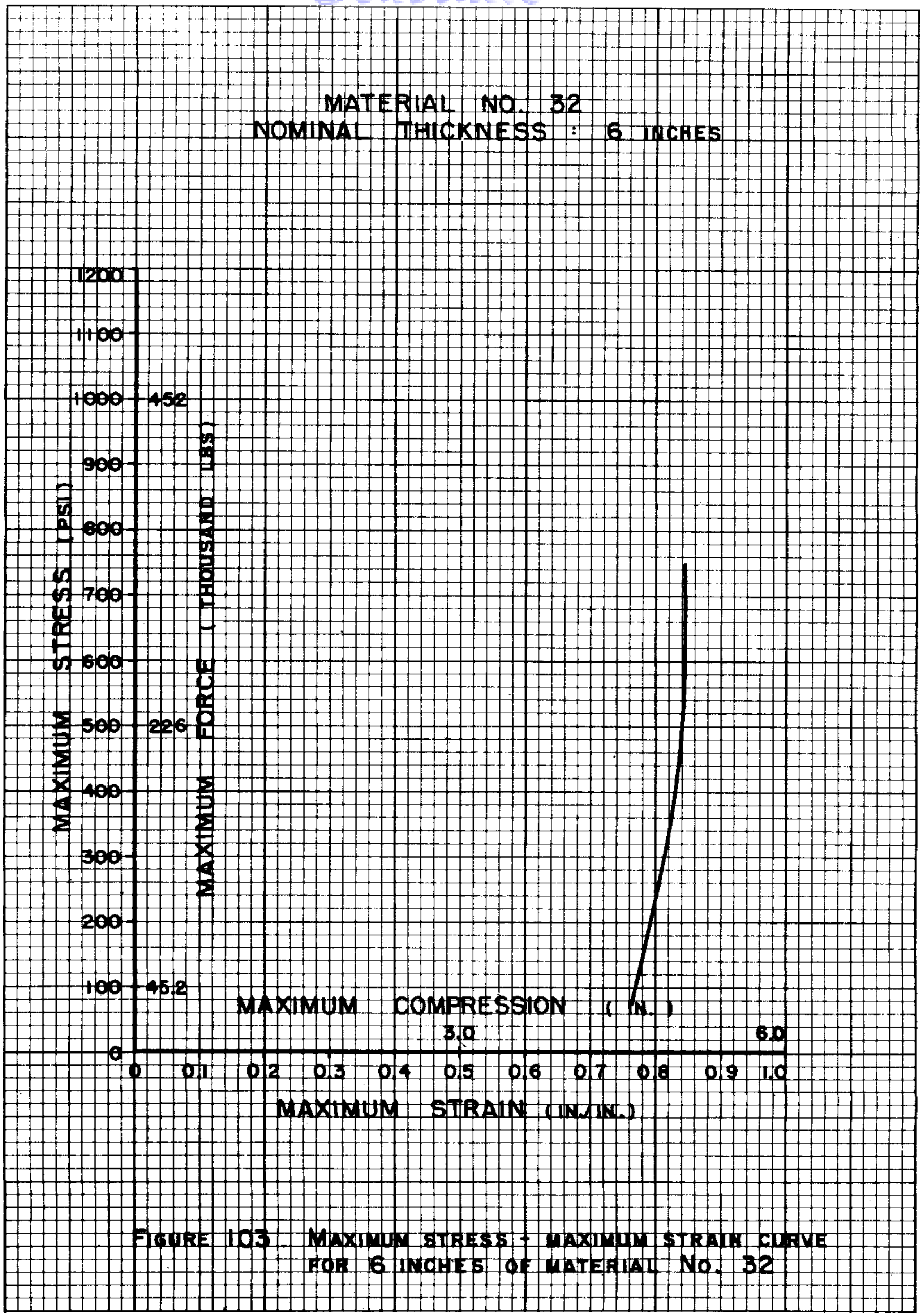

FIGURE 103 MAXIMUM STRESS - MAXIMUM STRAIN CURVE FOR 6 INCHES OF MATERIAL No. 32

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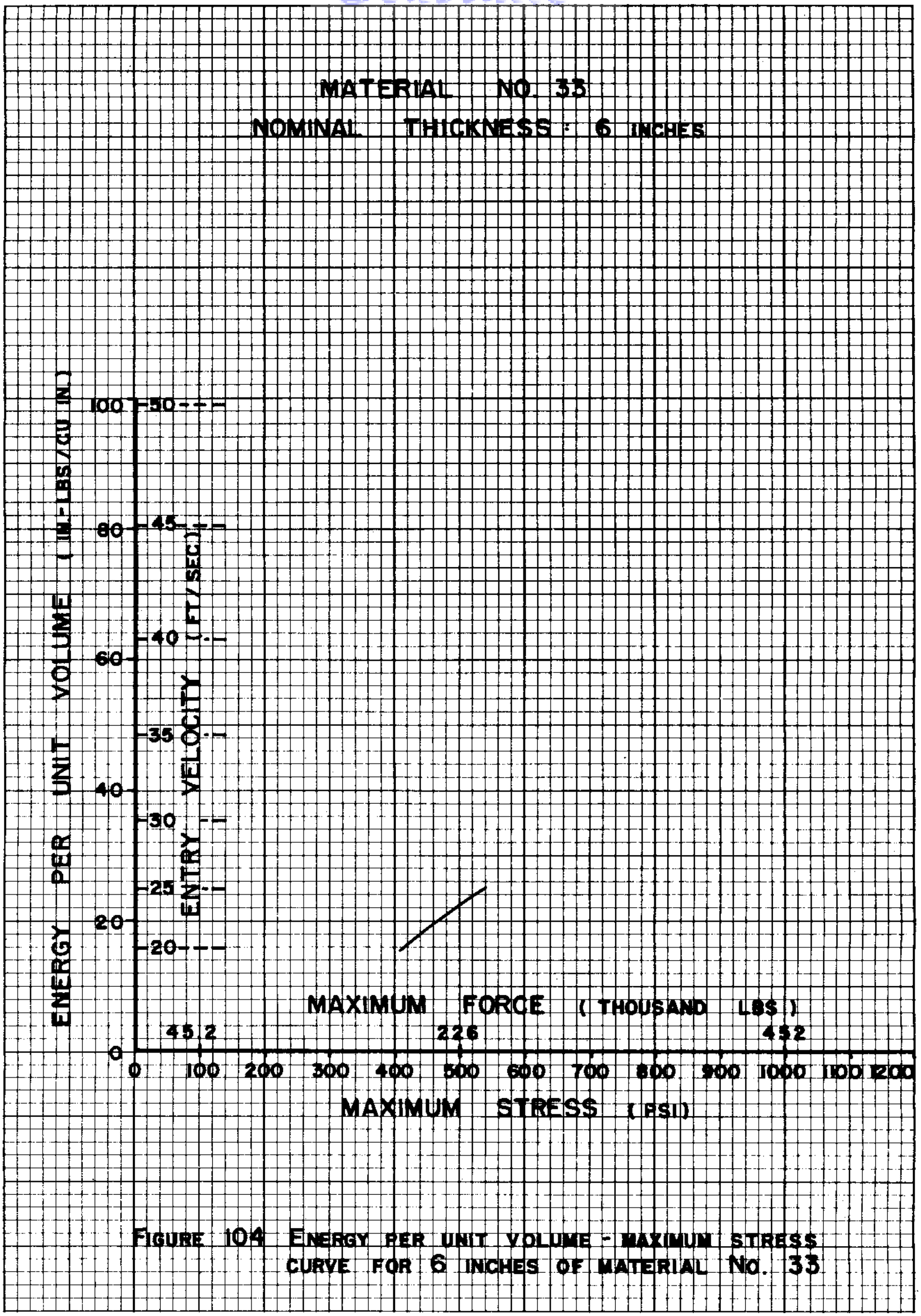

FIGURE 104 ENERGY PER UNIT VOLUME - MAXIMUM STRESS CURVE FOR 6 INCHES OF MATERIAL No. 33

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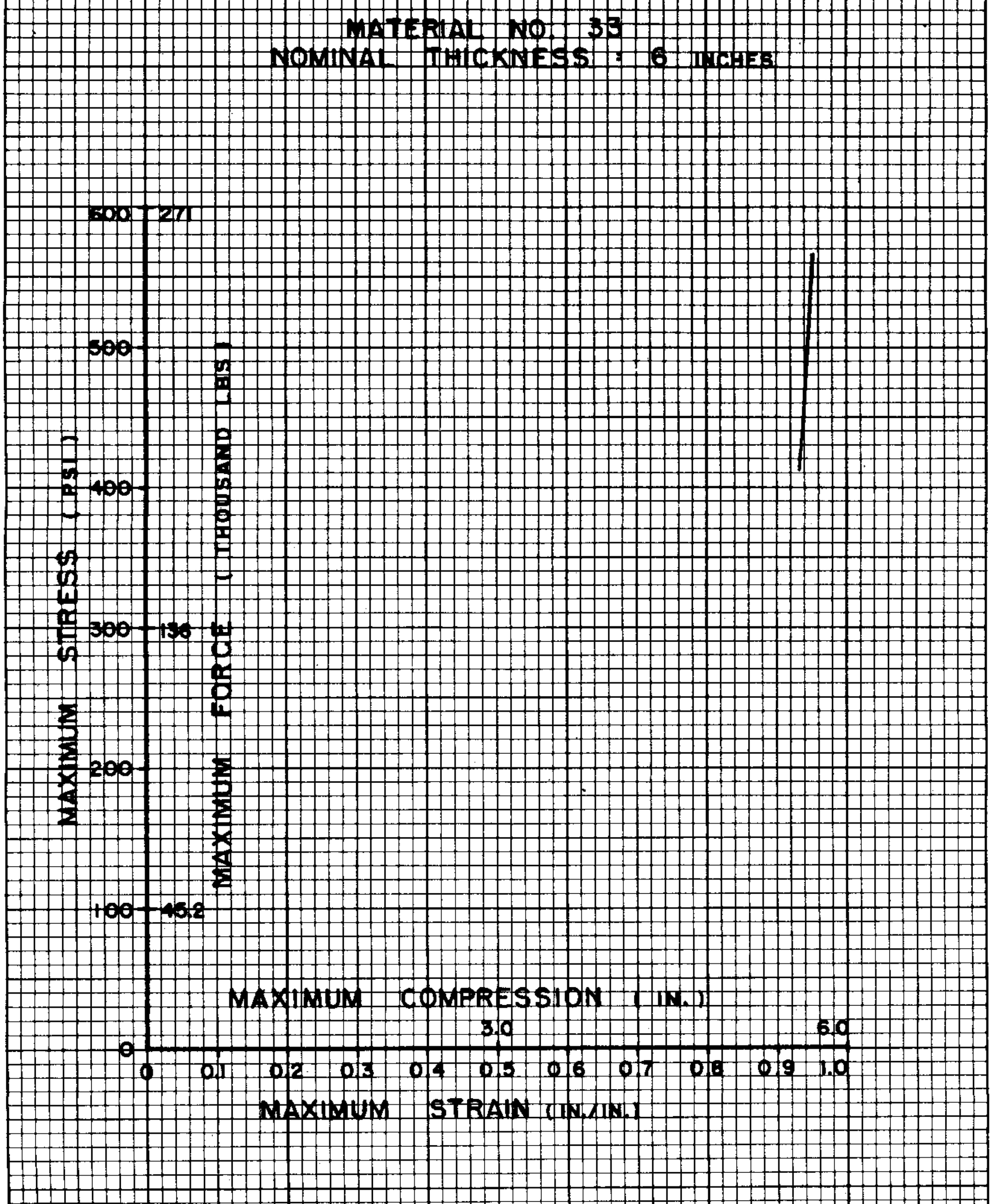

FIGURE 105. MAXIMUM STRESS - MAXIMUM STRAIN CURVE FOR 6 INCHES OF MATERIAL No. 33

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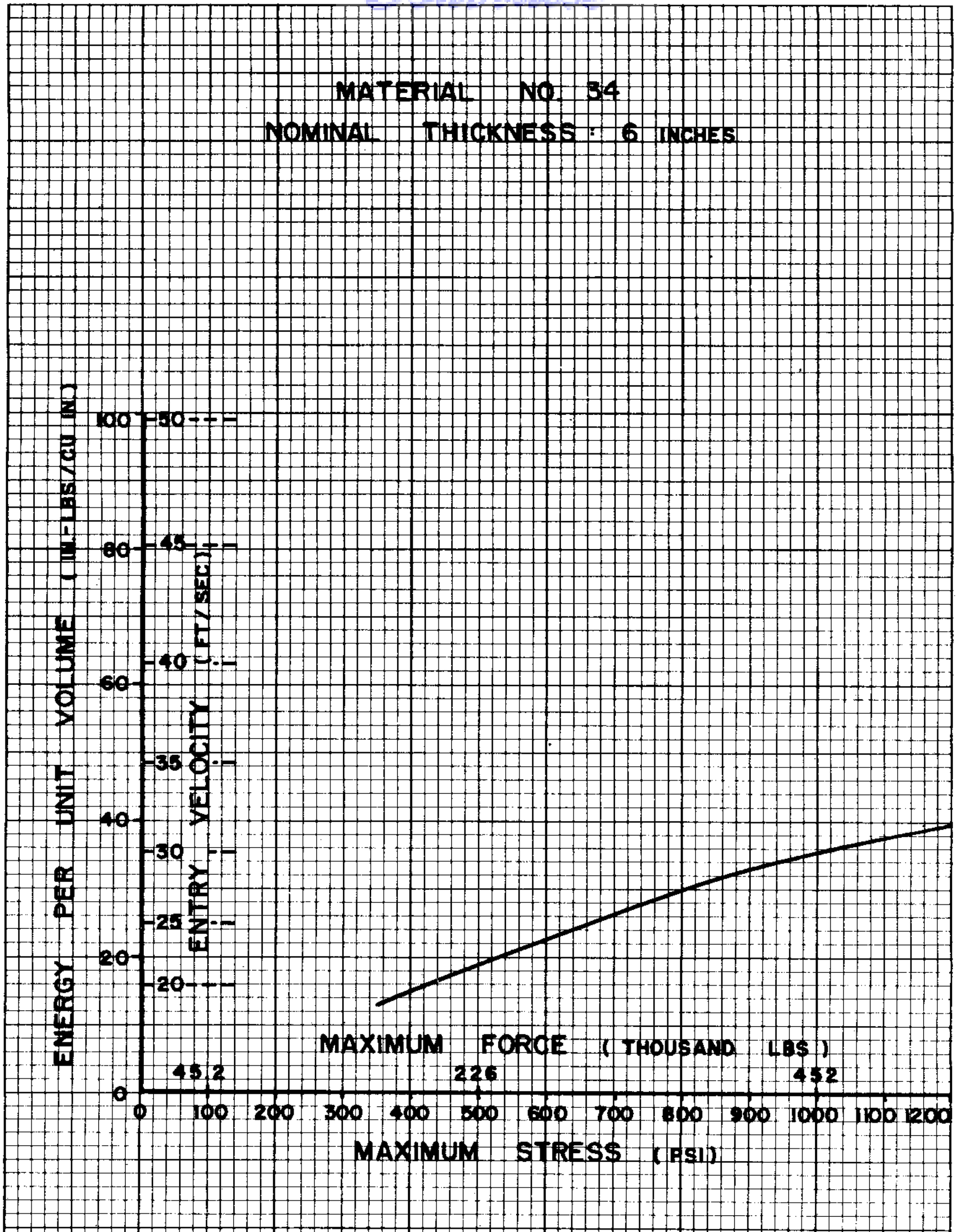

FIGURE 106 ENERGY PER UNIT VOLUME - MAXIMUM STRESS CURVE FOR 6 INCHES OF MATERIAL No. 34

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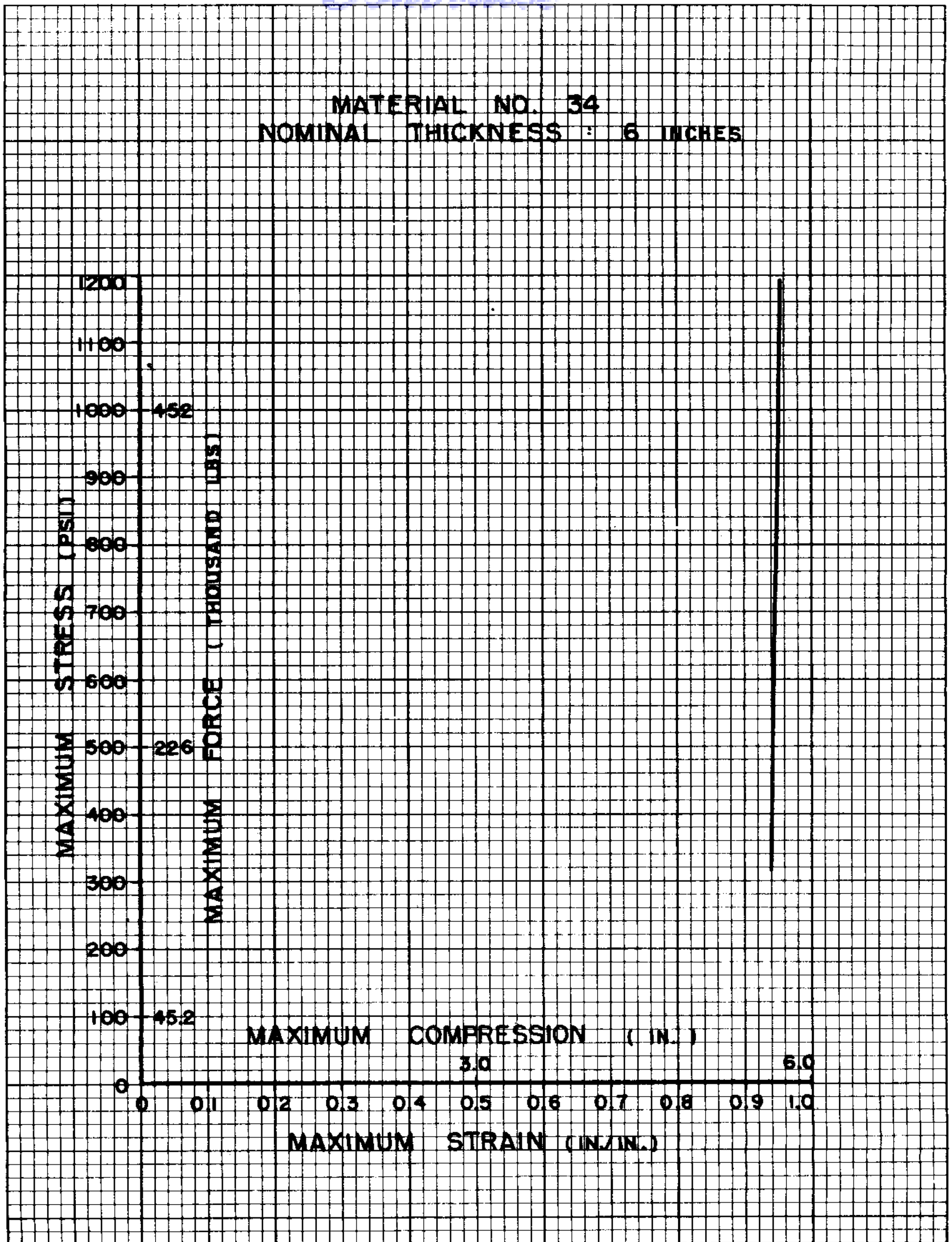

FIGURE 107 MAXIMUM STRESS - MAXIMUM STRAIN CURVE FOR 6 INCHES OF MATERIAL No. 34

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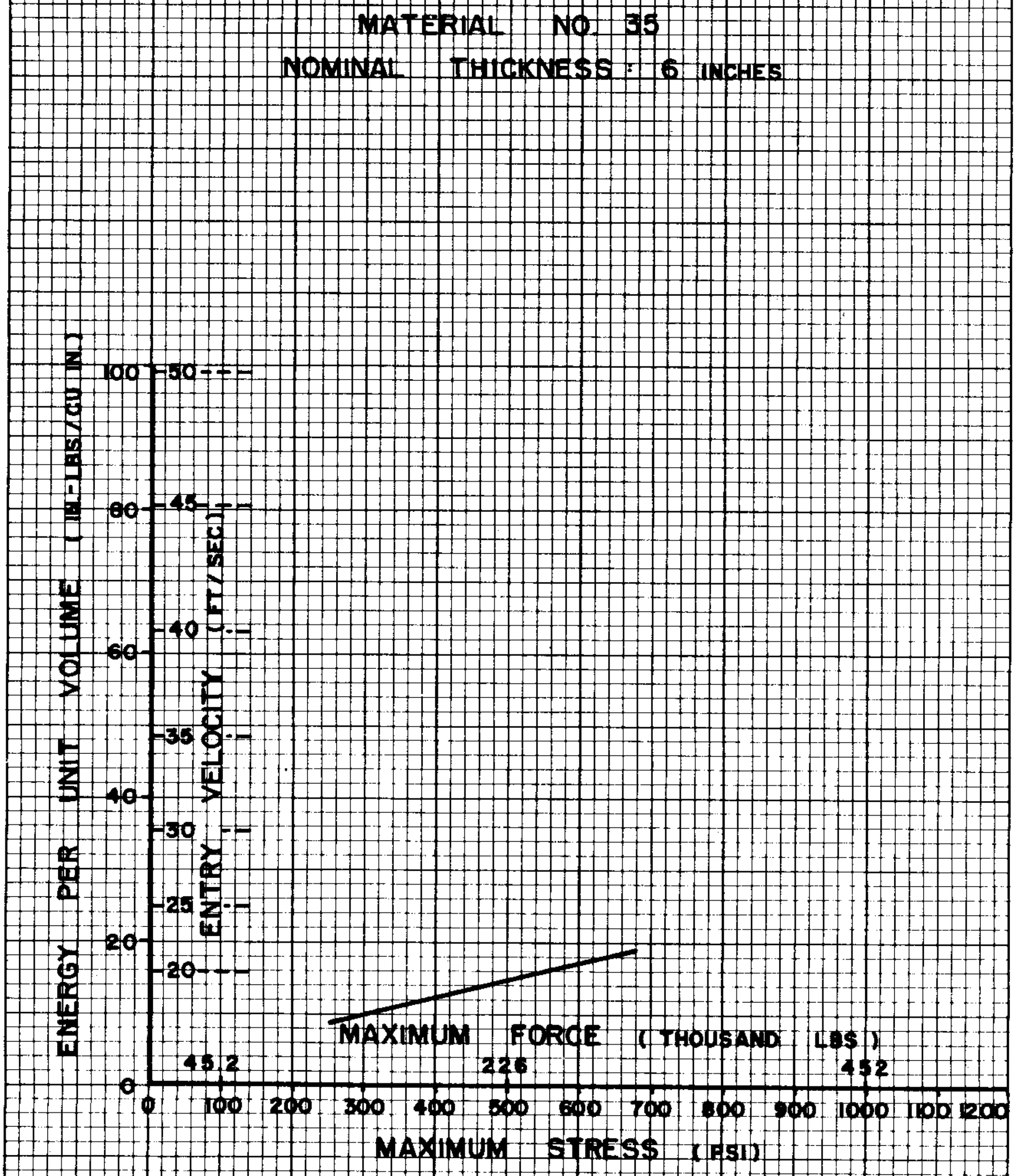

FIGURE 108 ENERGY PER UNIT VOLUME - MAXIMUM STRESS CURVE FOR 6 INCHES OF MATERIAL No. 35

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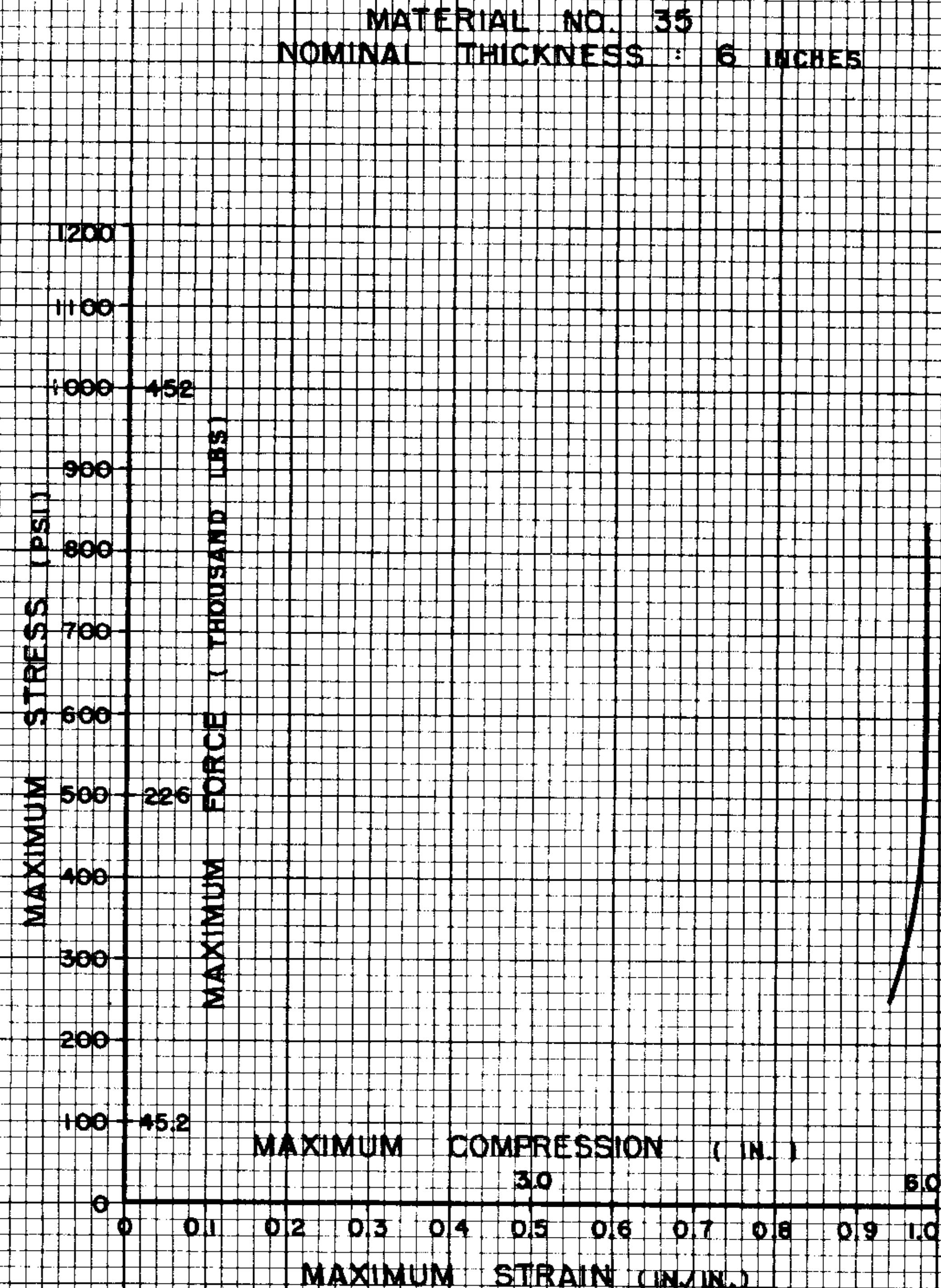

FIGURE 109 MAXIMUM STRESS - MAXIMUM STRAIN CURVE FOR 6 INCHES OF MATERIAL NO. 35

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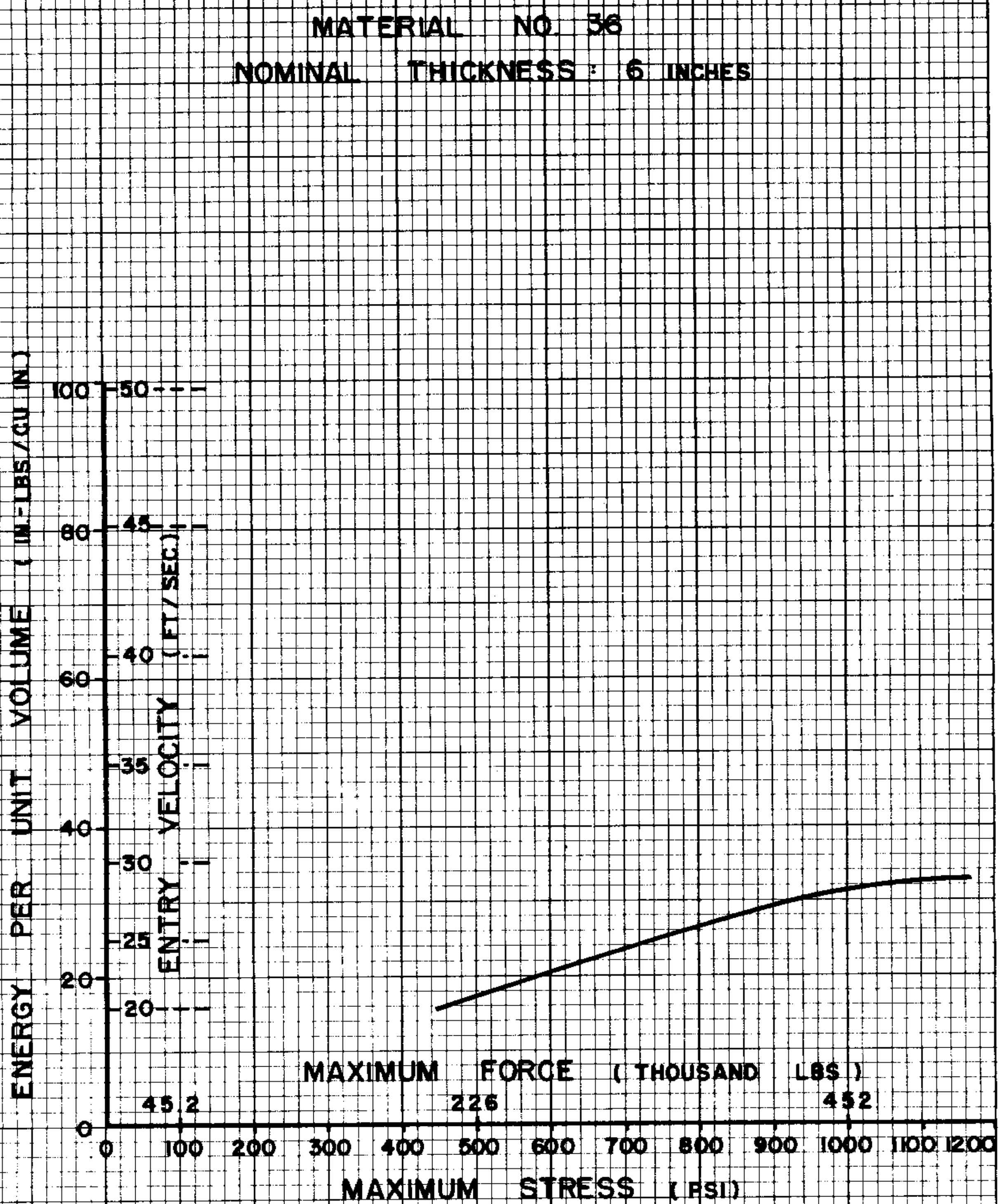

FIGURE 110 ENERGY PER UNIT VOLUME - MAXIMUM STRESS CURVE FOR 6 INCHES OF MATERIAL No. 36

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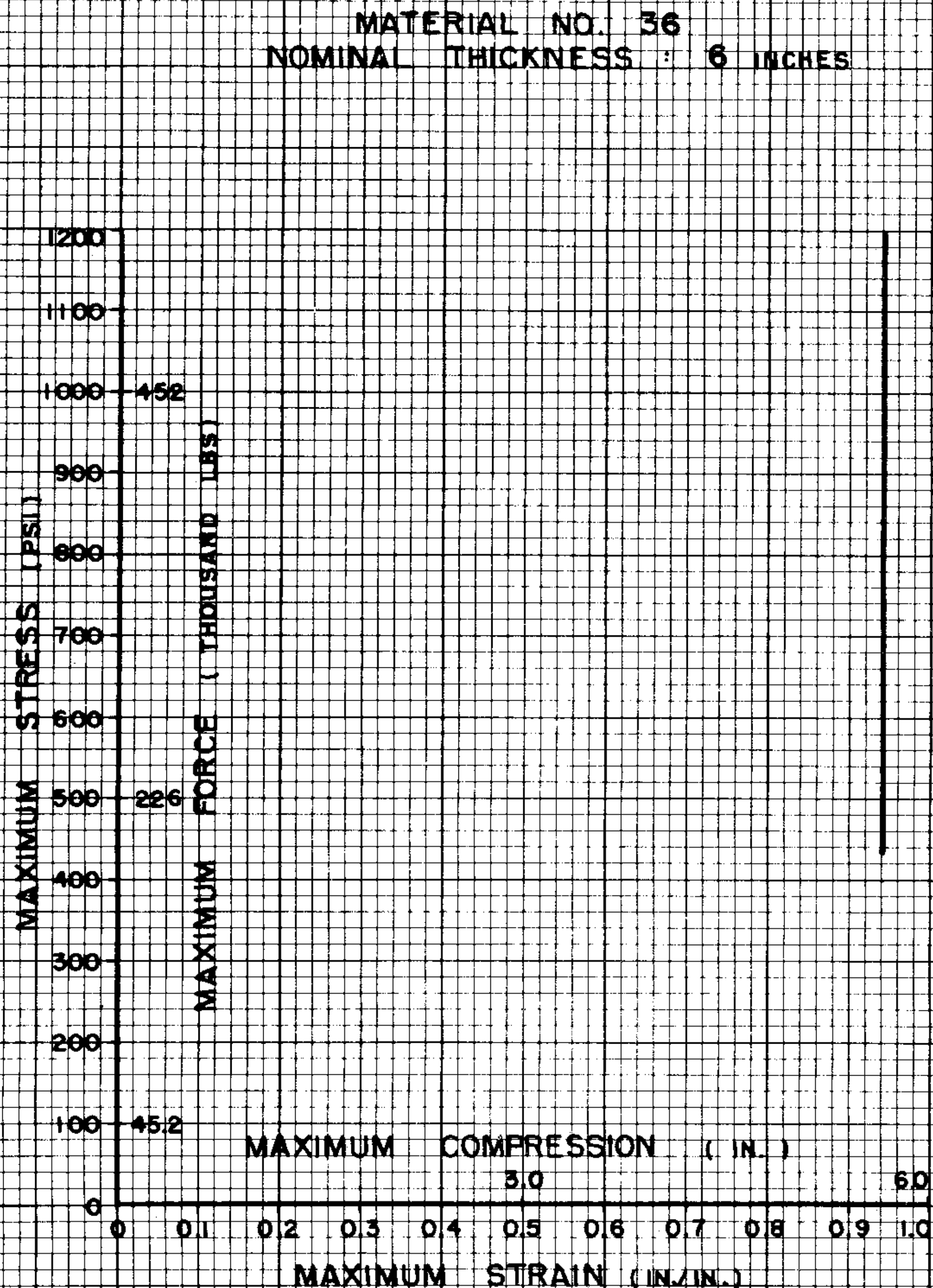

FIGURE 111 MAXIMUM STRESS - MAXIMUM STRAIN CURVE FOR 6 INCHES OF MATERIAL No. 36

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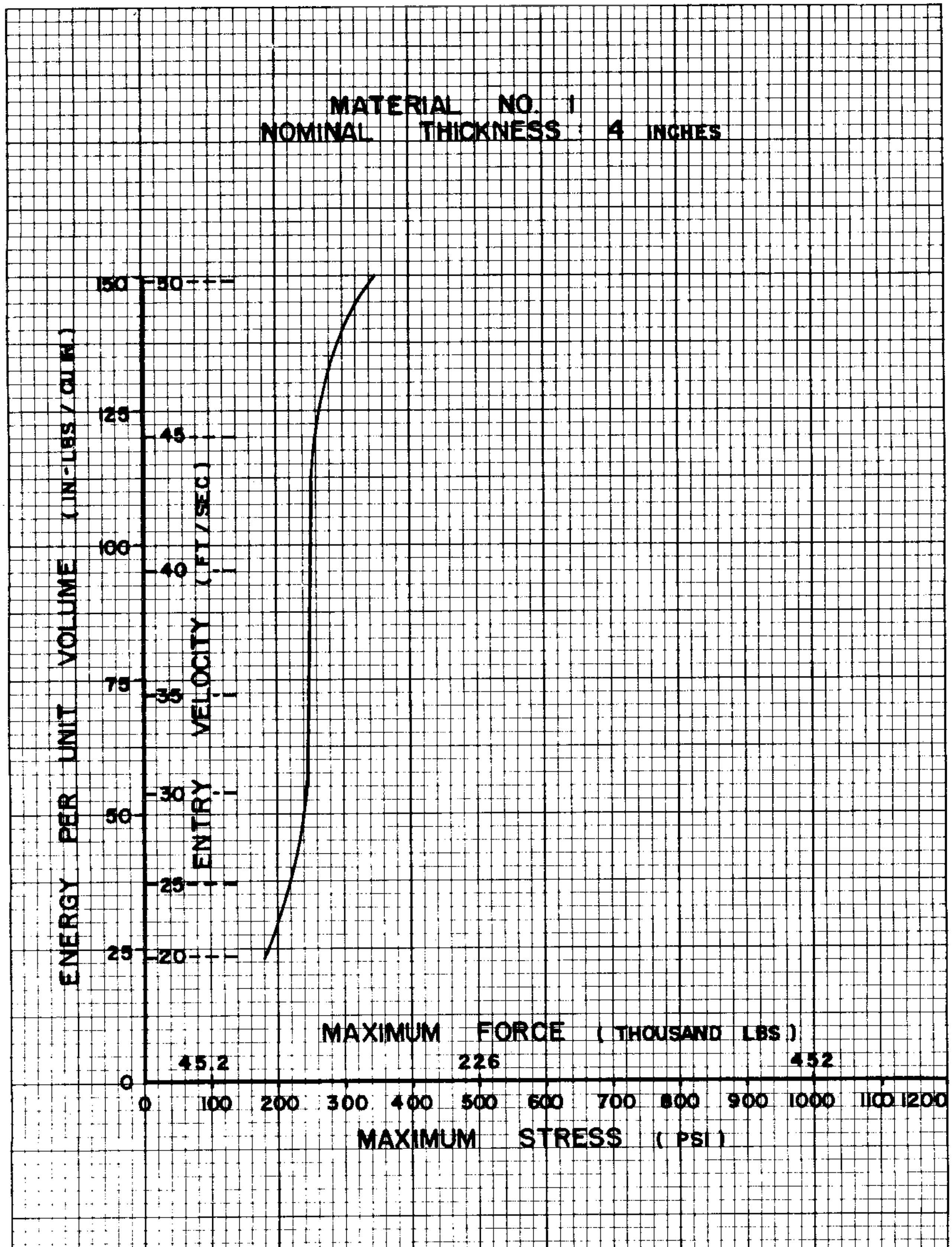

FIGURE 112 ENERGY PER UNIT VOLUME - MAXIMUM STRESS CURVE FOR 4 INCHES OF MATERIAL NO. 1

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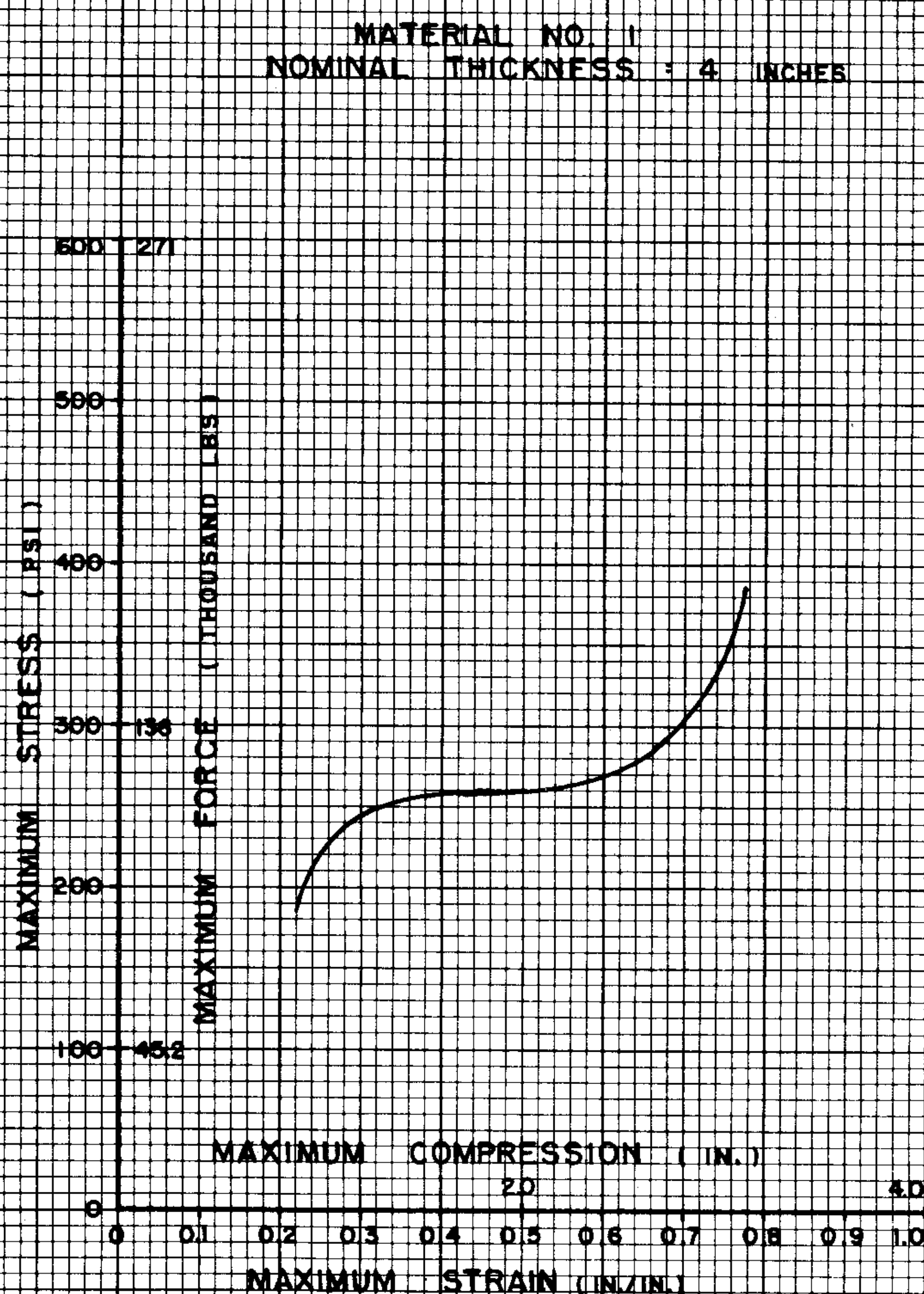

FIGURE 113. MAXIMUM STRESS - MAXIMUM STRAIN CURVE FOR 4 INCHES OF MATERIAL No. 1

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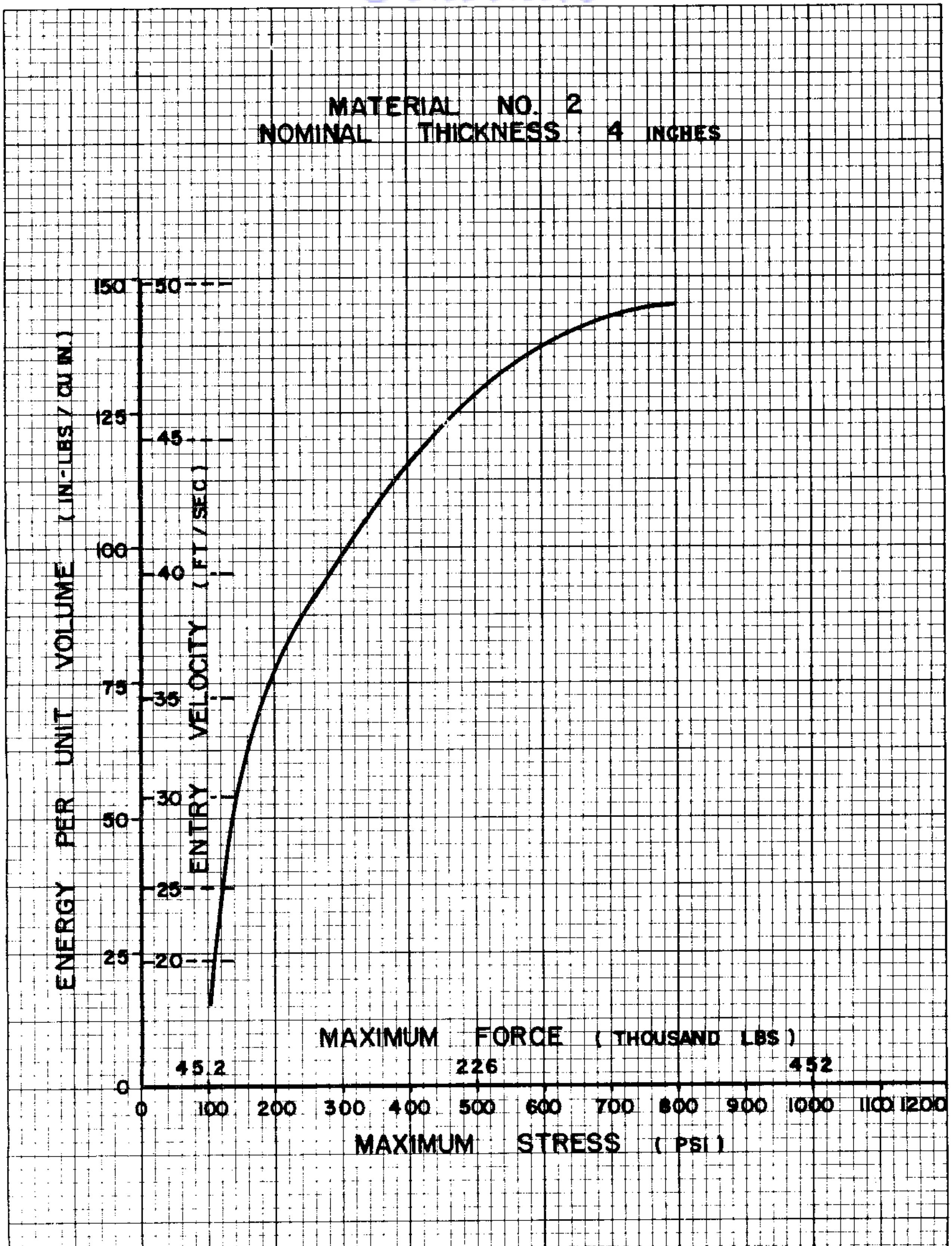

FIGURE 114 ENERGY PER UNIT VOLUME - MAXIMUM STRESS CURVE FOR 4 INCHES OF MATERIAL No. 2

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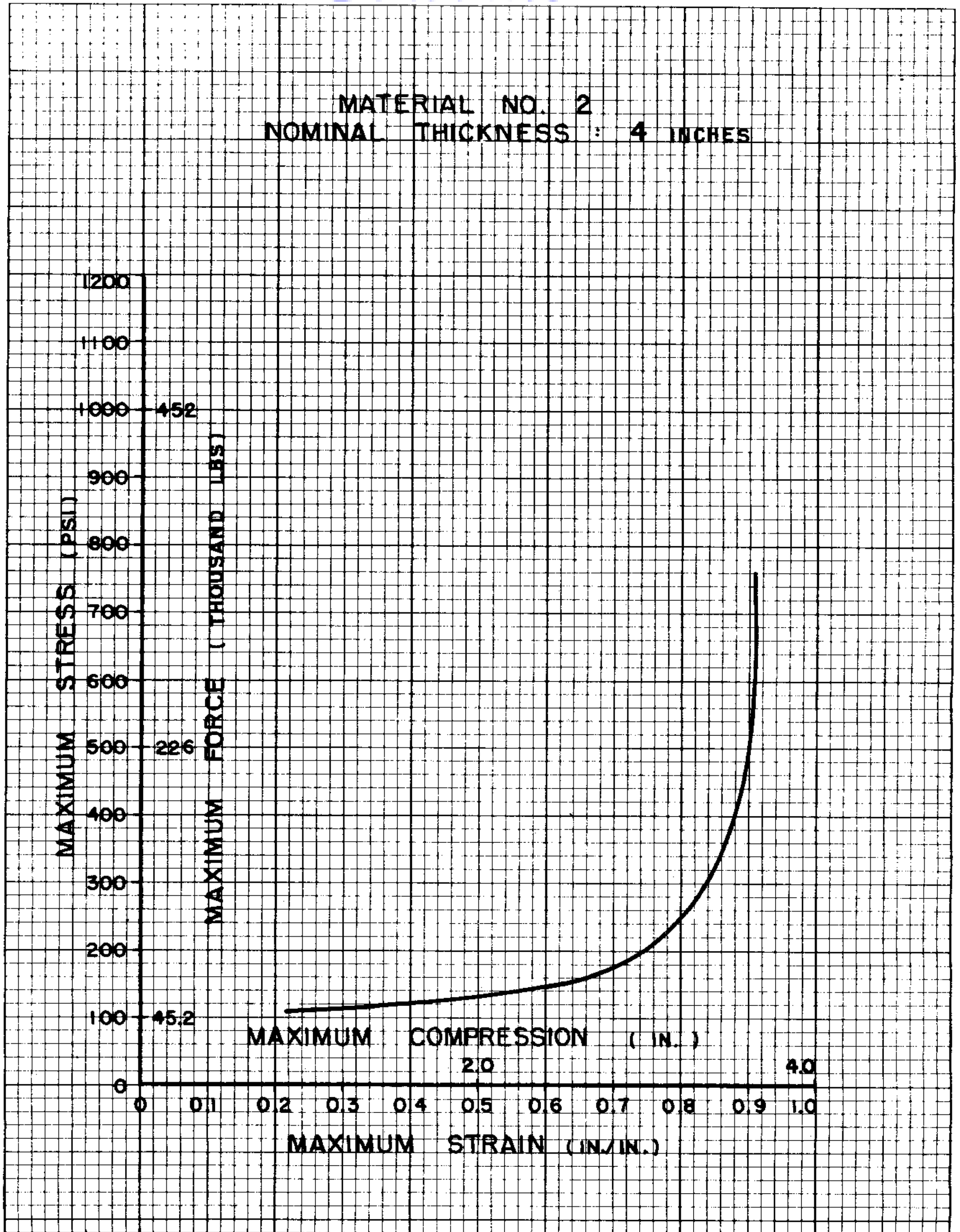

FIGURE 115 MAXIMUM STRESS - MAXIMUM STRAIN CURVE FOR 4 INCHES OF MATERIAL NO. 2

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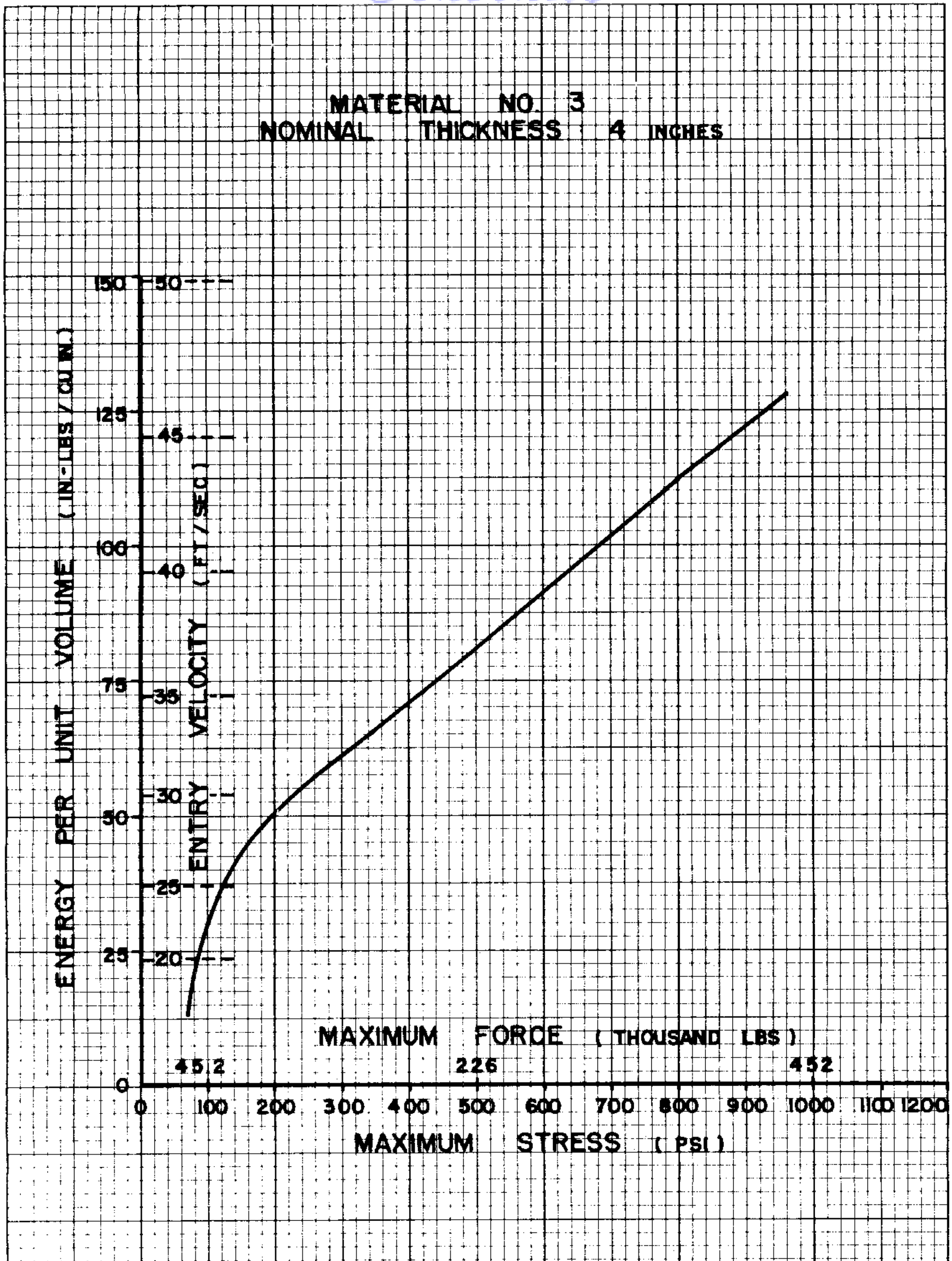

FIGURE 116 ENERGY PER UNIT VOLUME - MAXIMUM STRESS CURVE FOR 4 INCHES OF MATERIAL NO. 3

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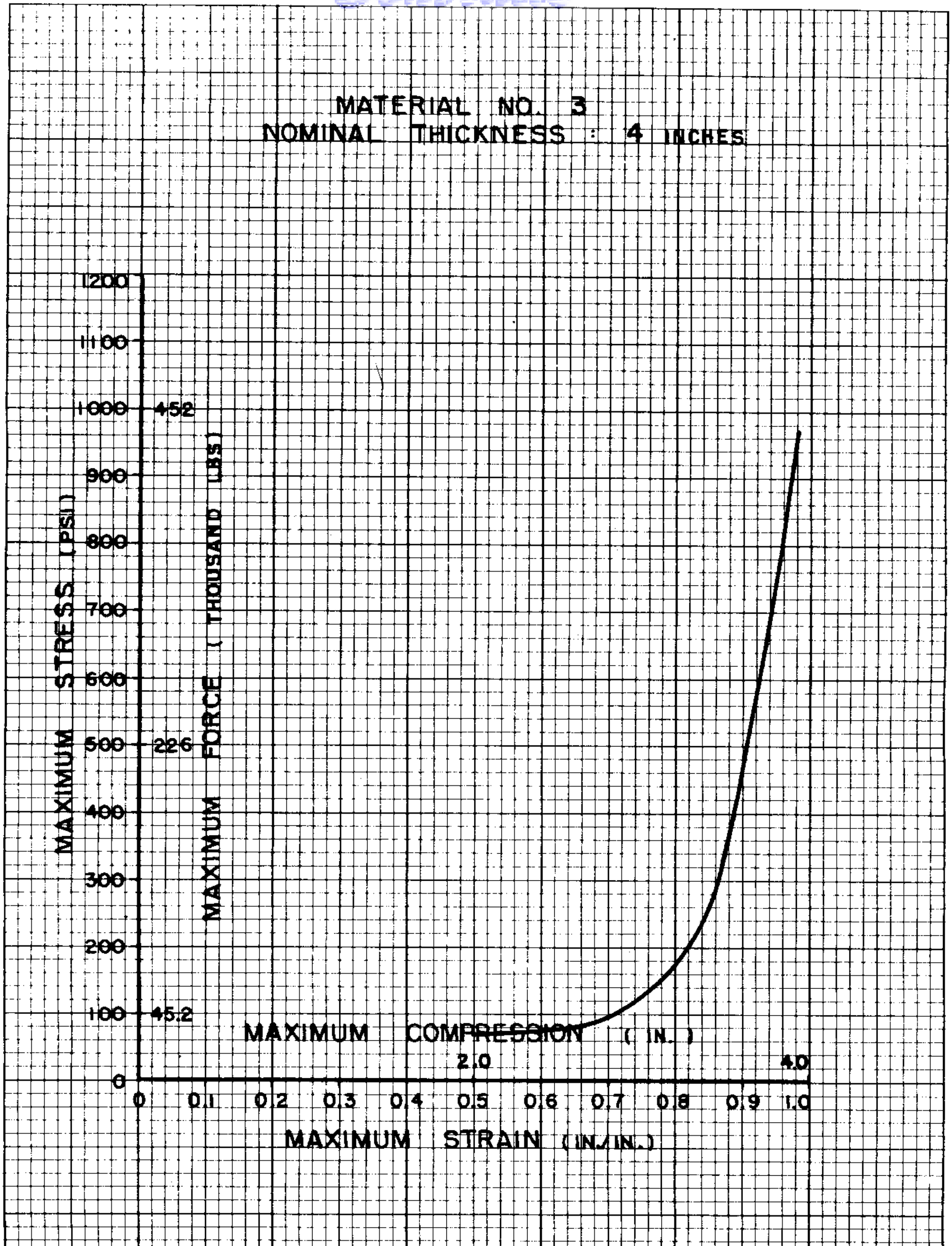

FIGURE 117 MAXIMUM STRESS - MAXIMUM STRAIN CURVE FOR 4 INCHES OF MATERIAL No. 3

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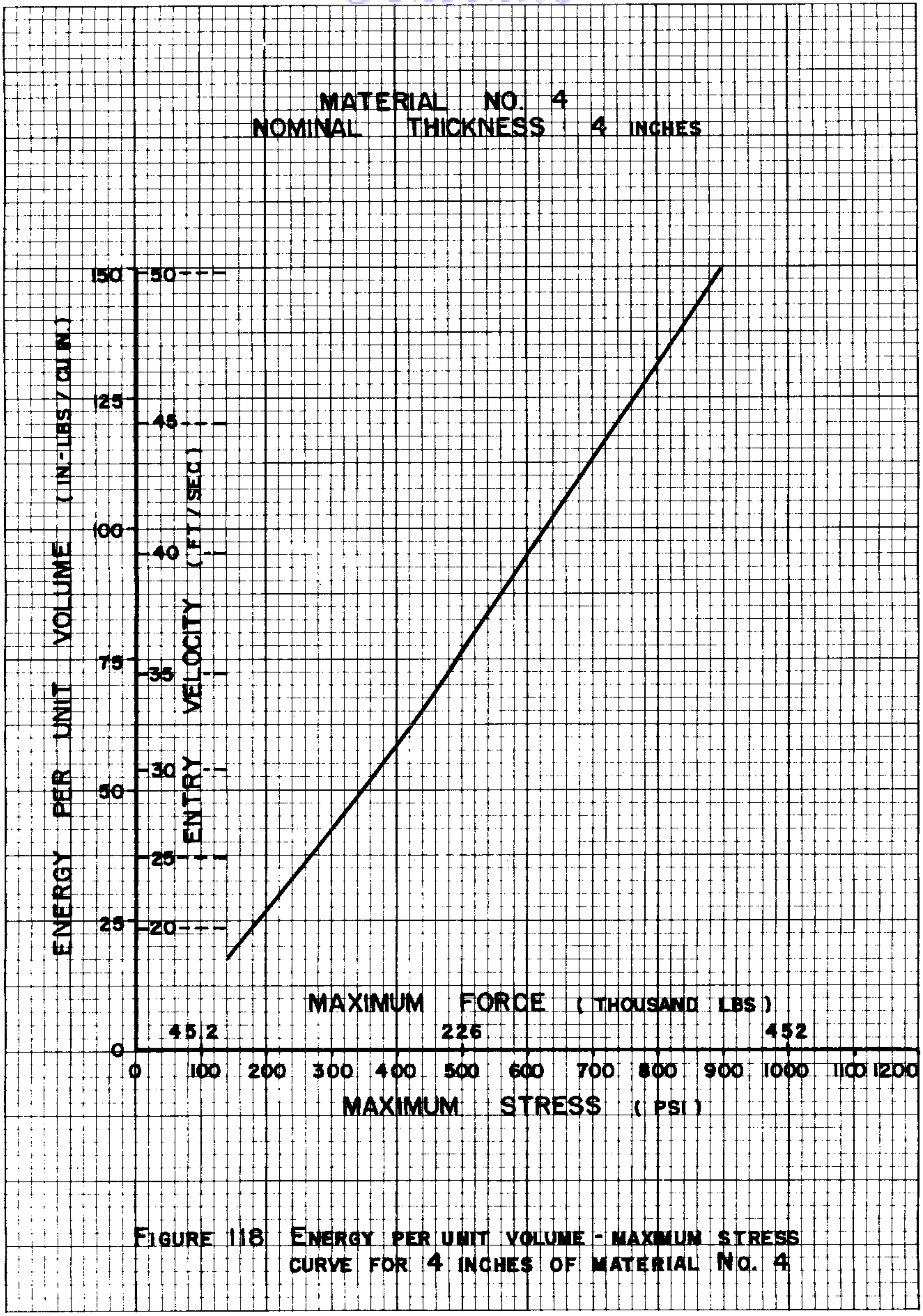

FIGURE 118 ENERGY PER UNIT VOLUME - MAXIMUM STRESS CURVE FOR 4 INCHES OF MATERIAL NO. 4

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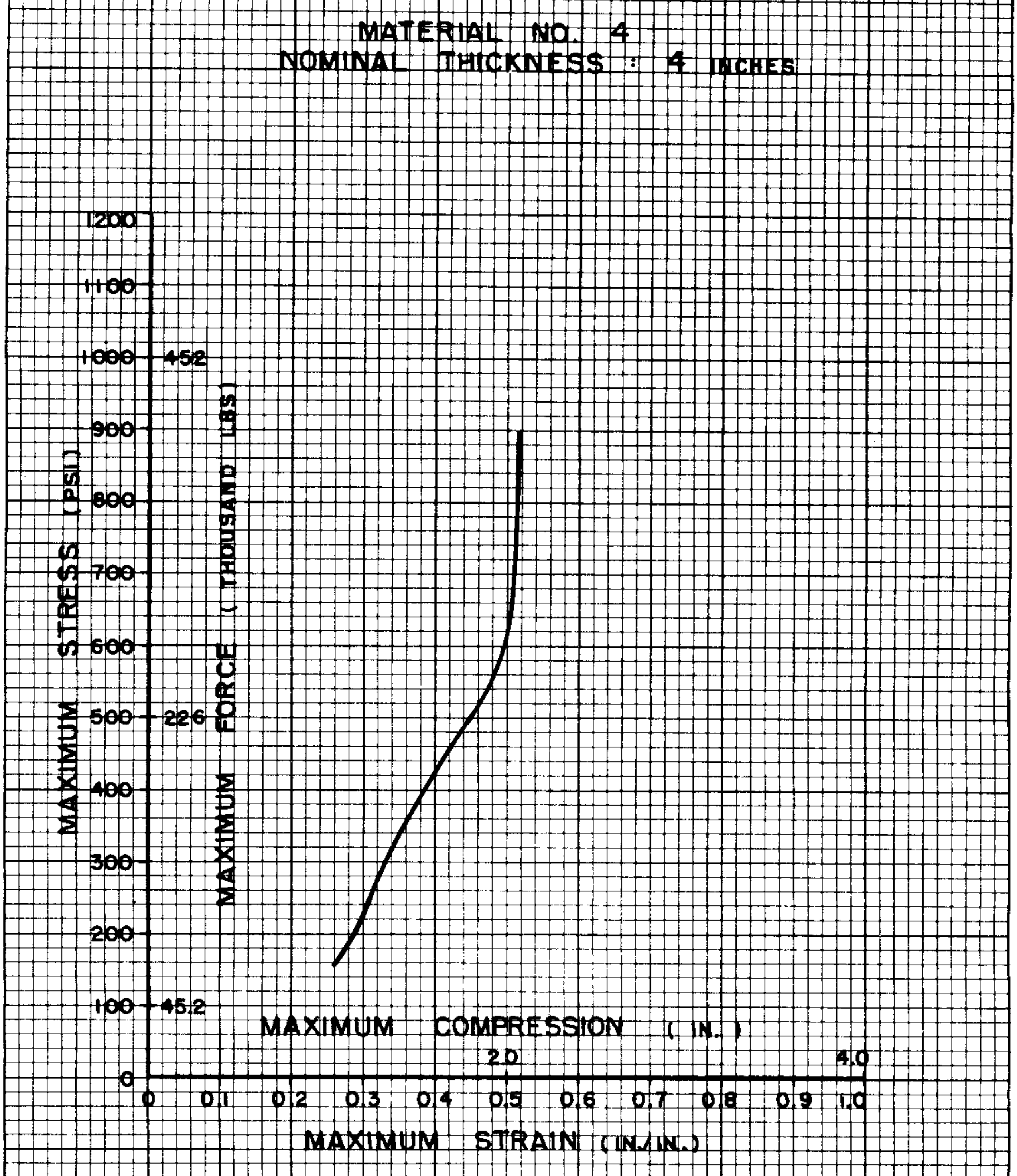

FIGURE 119. MAXIMUM STRESS - MAXIMUM STRAIN CURVE FOR 4 INCHES OF MATERIAL NO. 4

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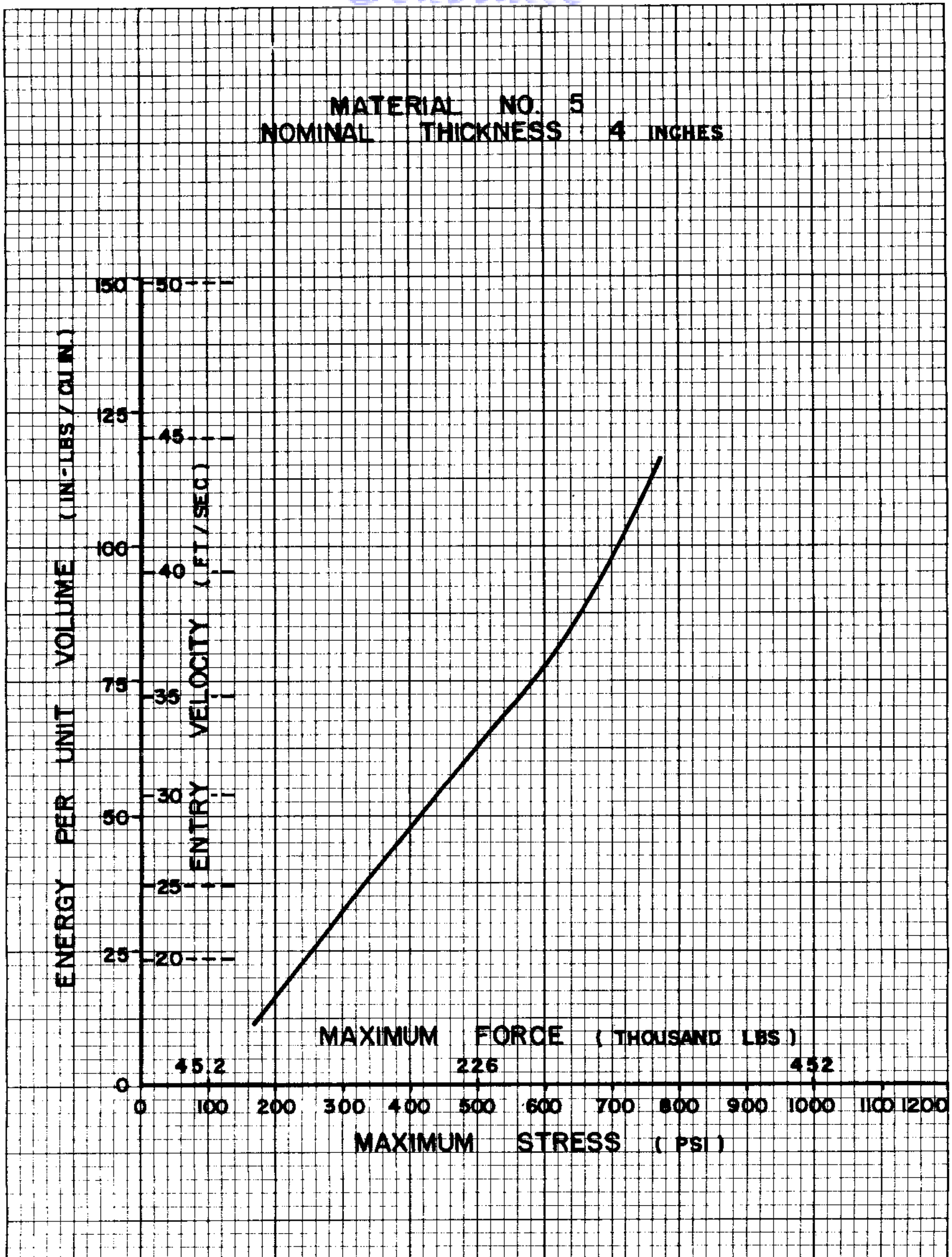

FIGURE 120 ENERGY PER UNIT VOLUME - MAXIMUM STRESS CURVE FOR 4 INCHES OF MATERIAL No. 5

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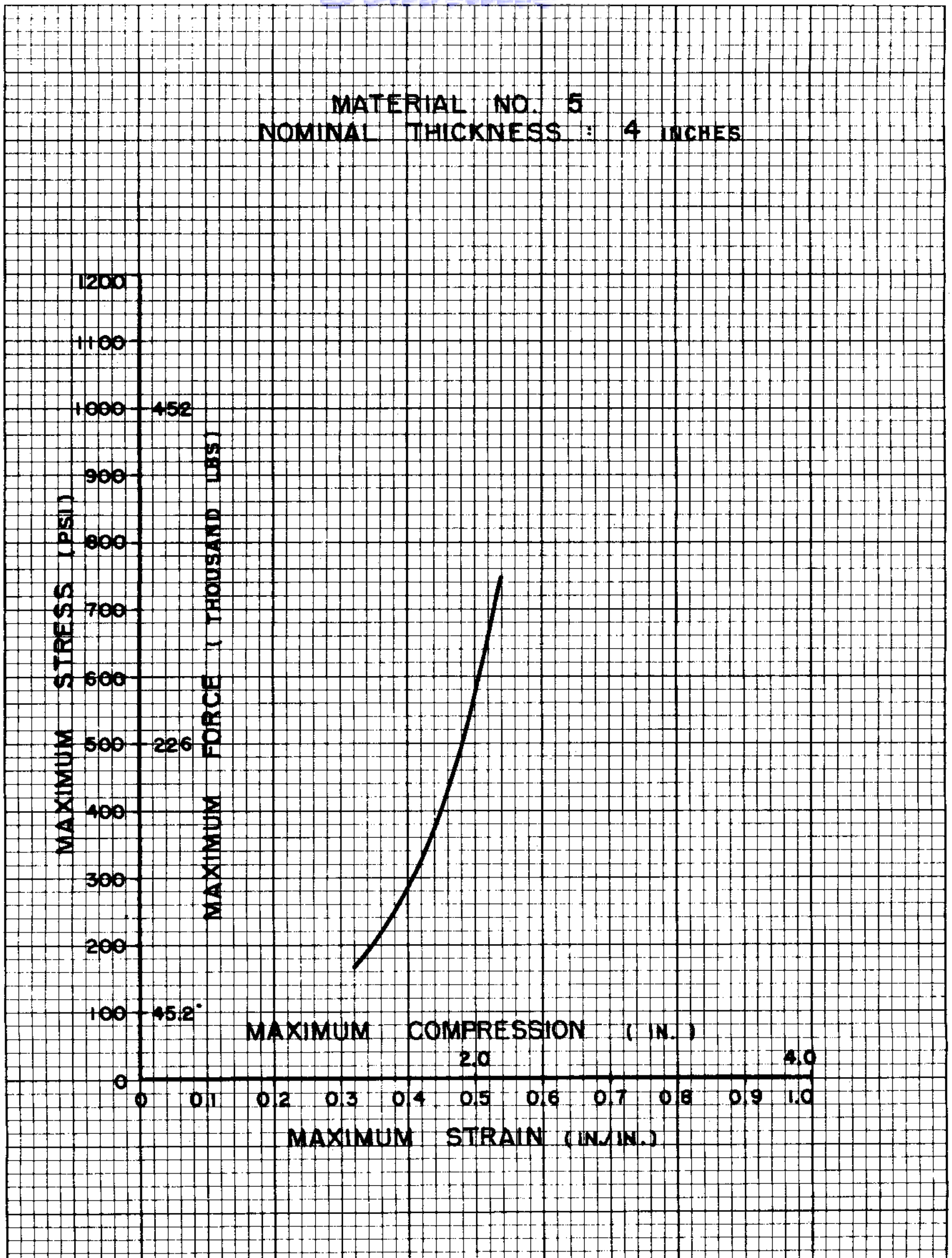

FIGURE 121 MAXIMUM STRESS - MAXIMUM STRAIN CURVE FOR 4 INCHES OF MATERIAL NO. 5

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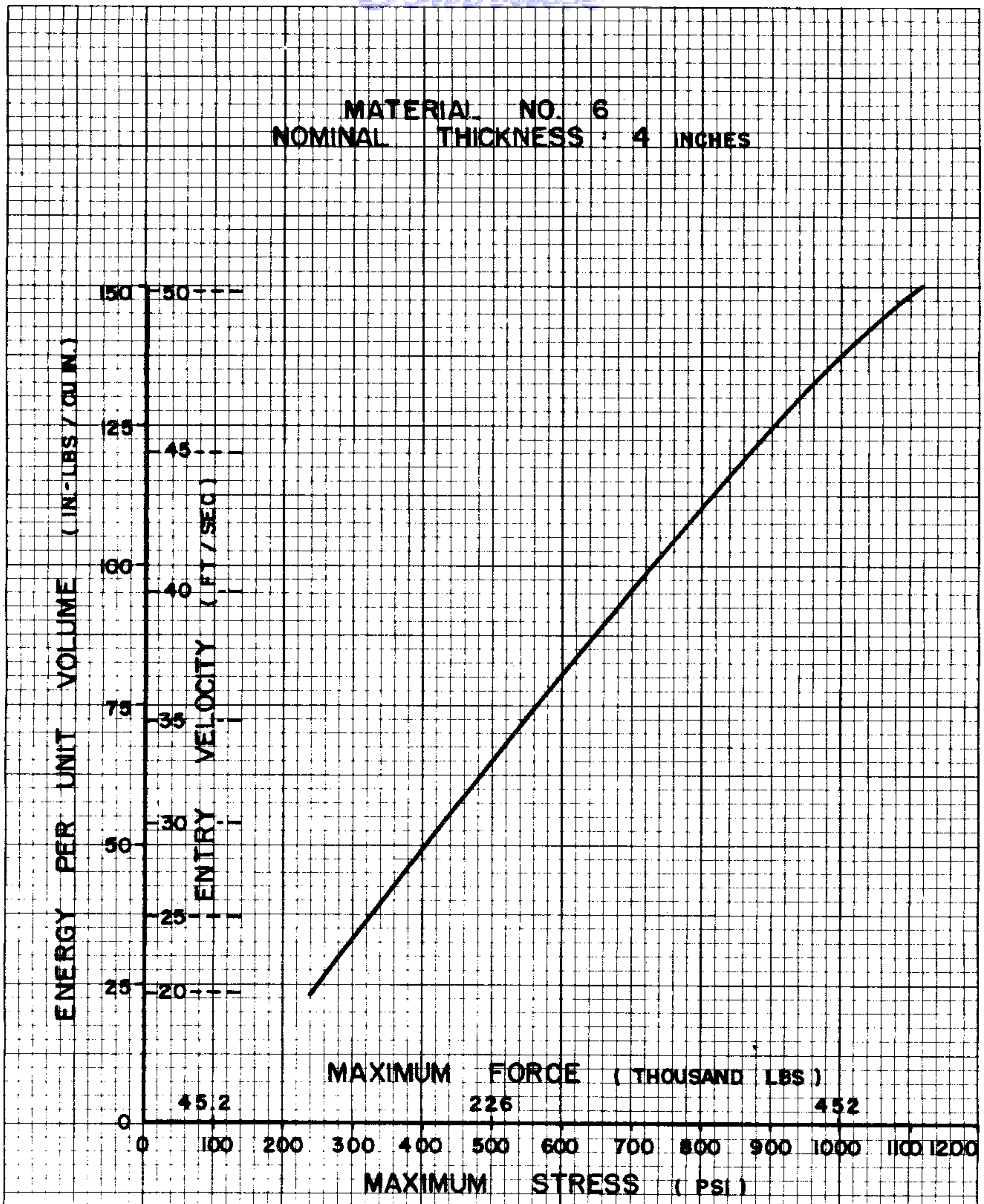

FIGURE 122 ENERGY PER UNIT VOLUME - MAXIMUM STRESS CURVE FOR 4 INCHES OF MATERIAL No. 6

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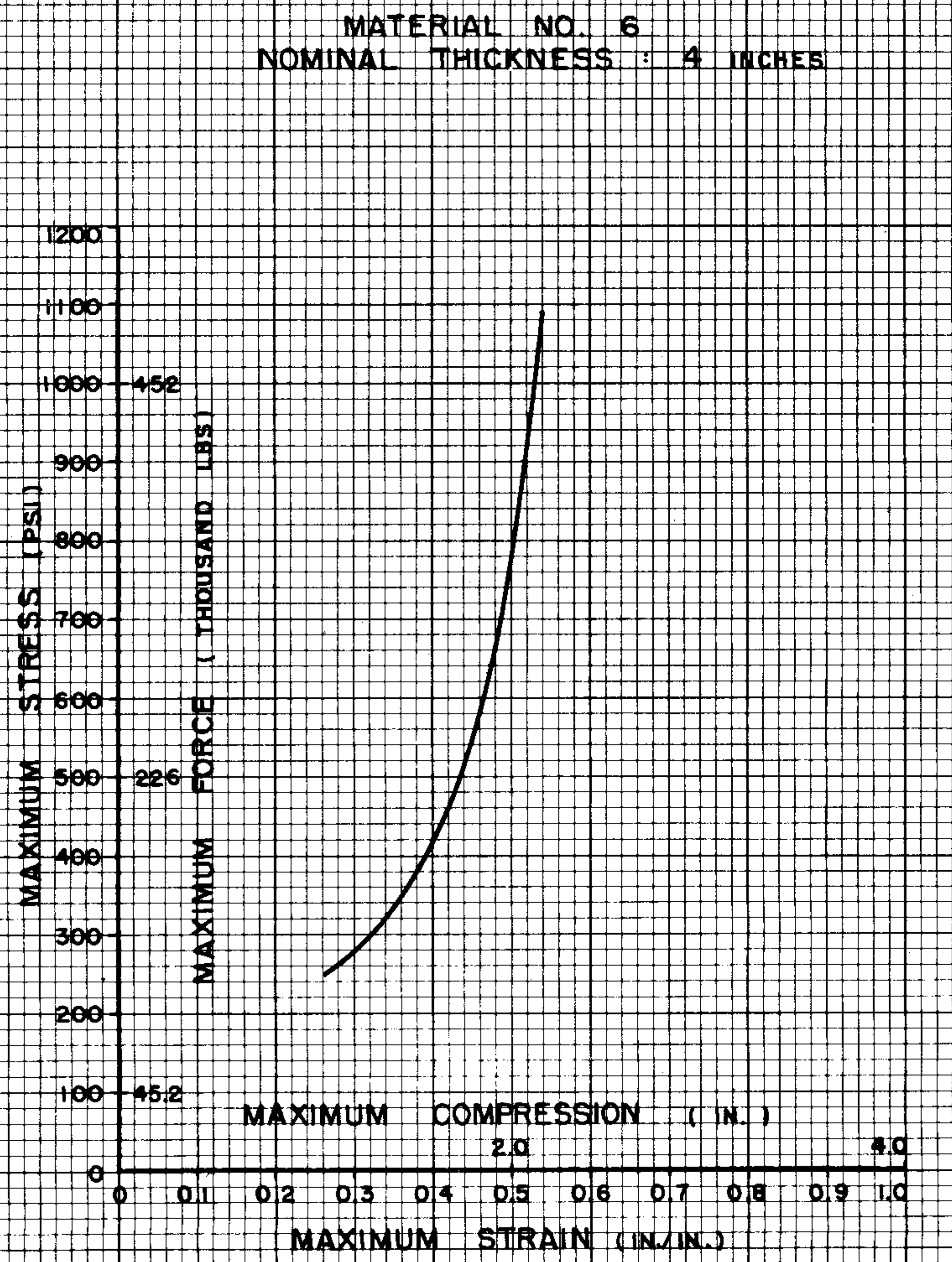

FIGURE 123. MAXIMUM STRESS - MAXIMUM STRAIN CURVE FOR 4 INCHES OF MATERIAL No. 6

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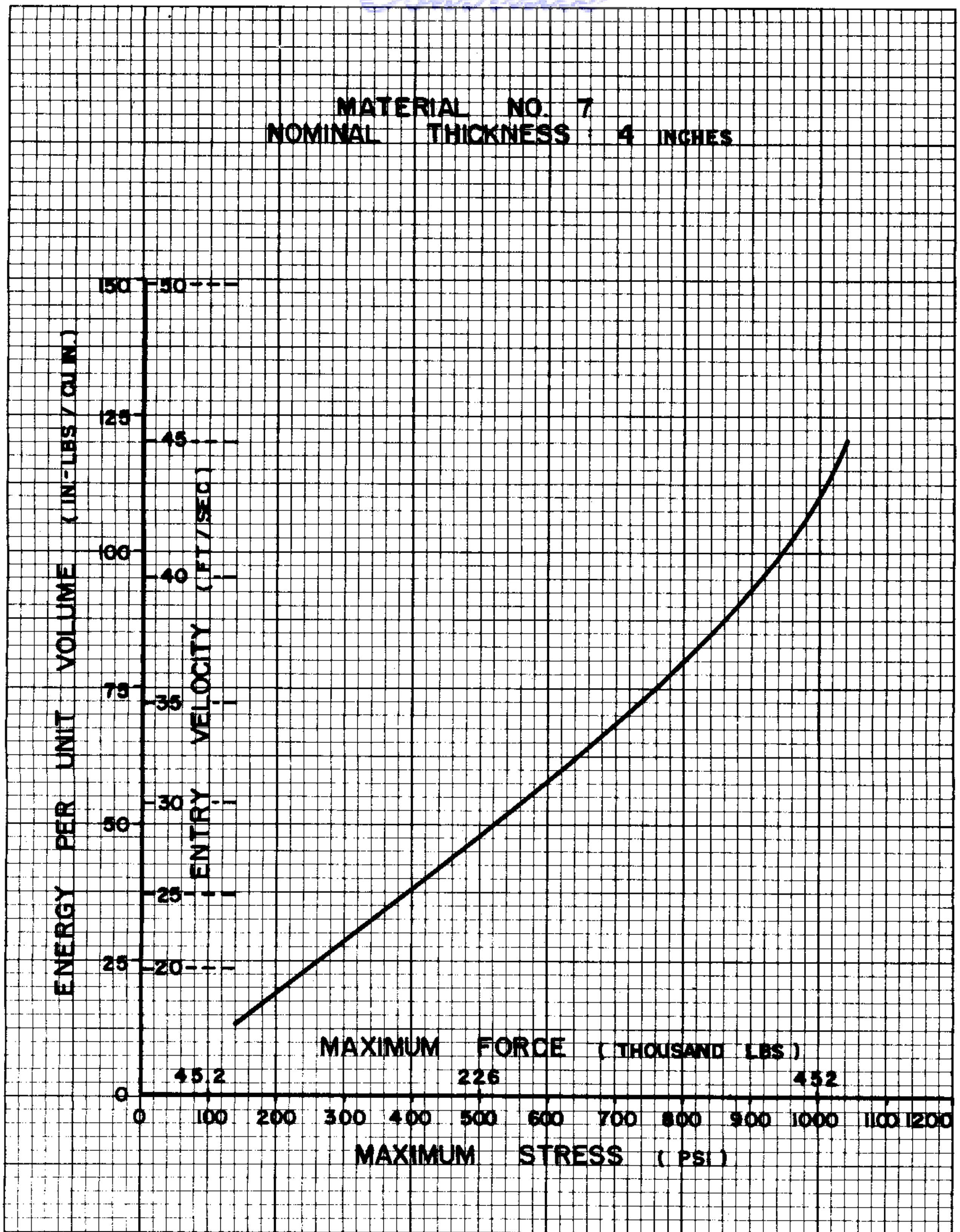

FIGURE 124 ENERGY PER UNIT VOLUME - MAXIMUM STRESS CURVE FOR 4 INCHES OF MATERIAL NO. 7

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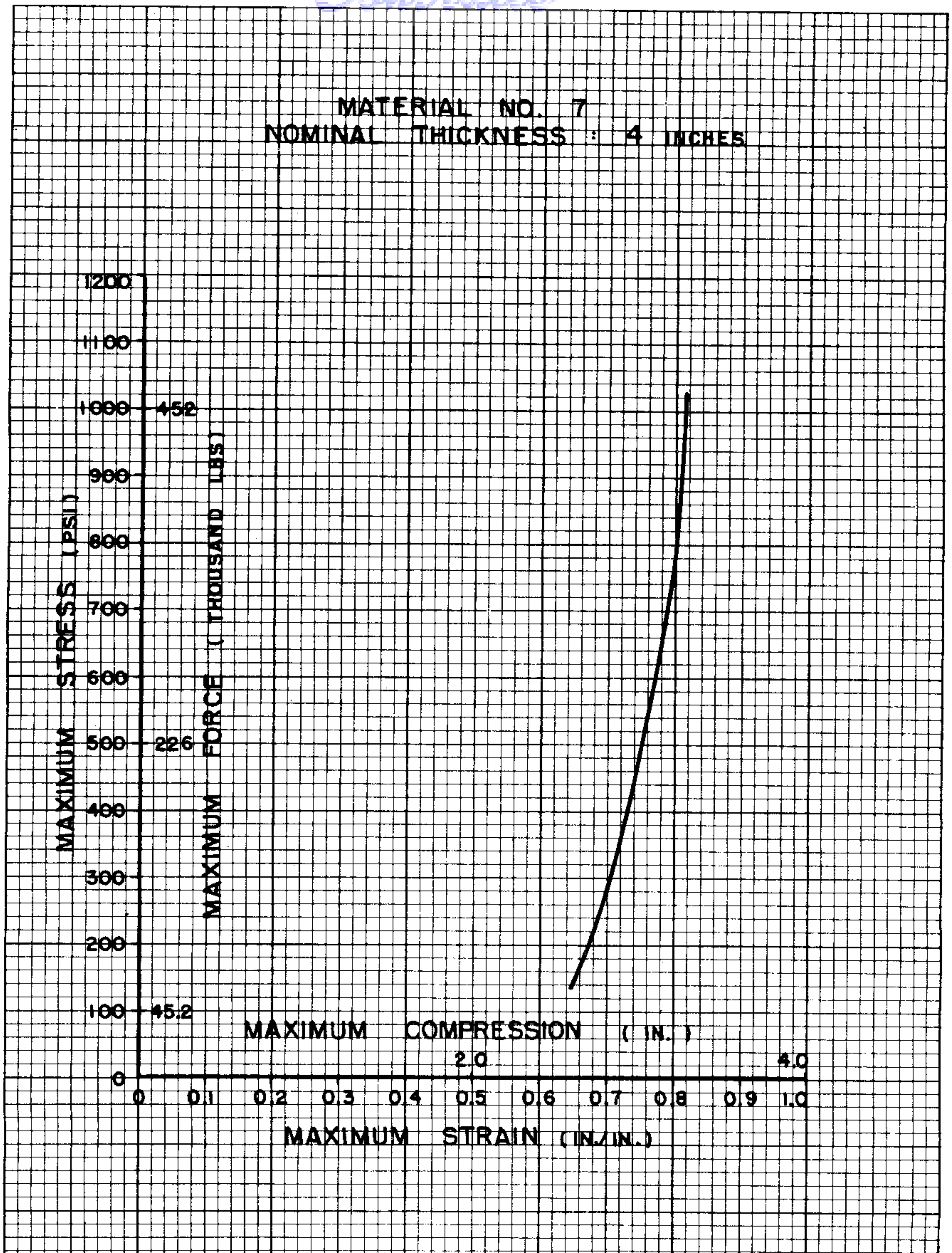

FIGURE 125. MAXIMUM STRESS - MAXIMUM STRAIN CURVE FOR 4 INCHES OF MATERIAL No. 7

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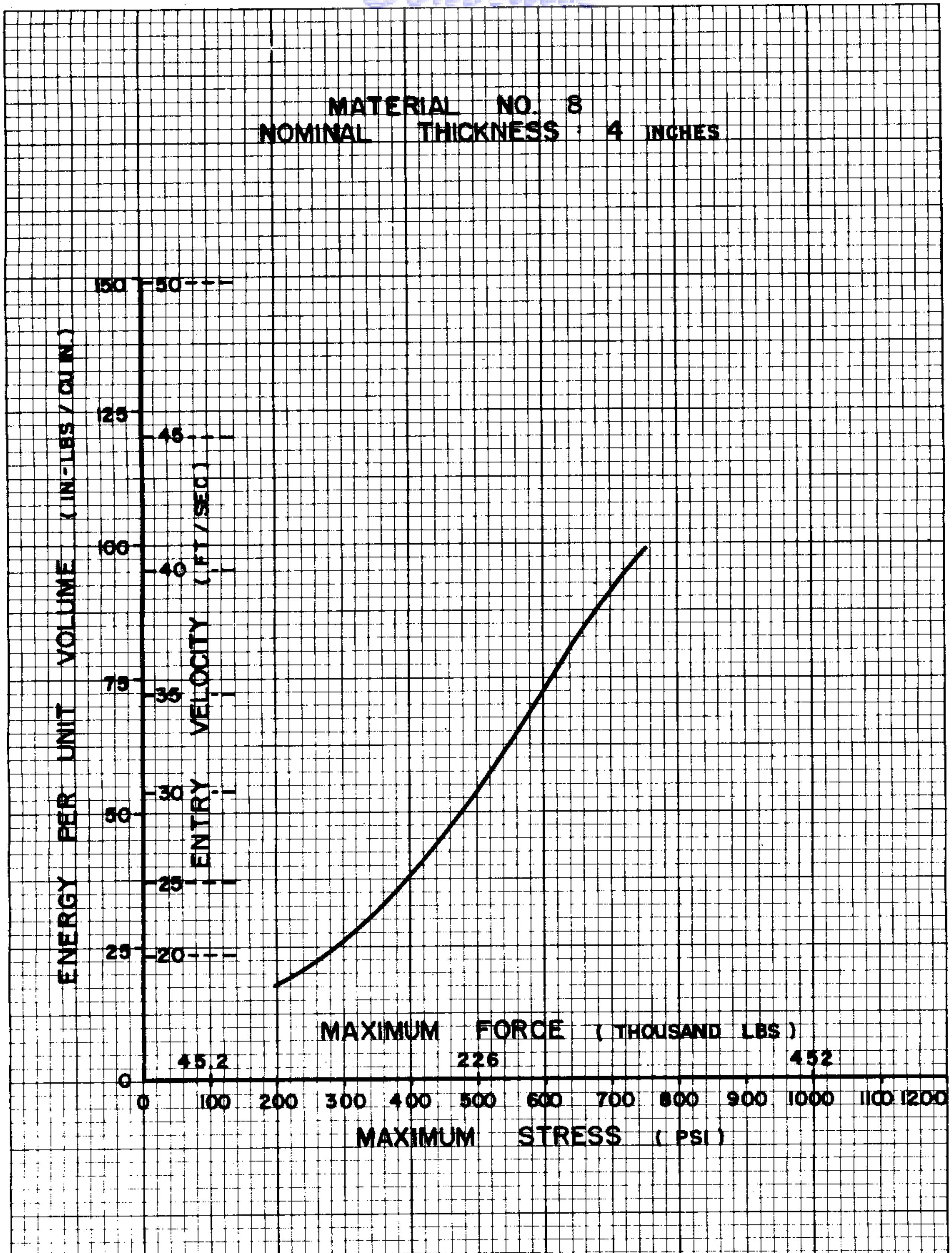

FIGURE 126 ENERGY PER UNIT VOLUME - MAXIMUM STRESS CURVE FOR 4 INCHES OF MATERIAL NO. 8

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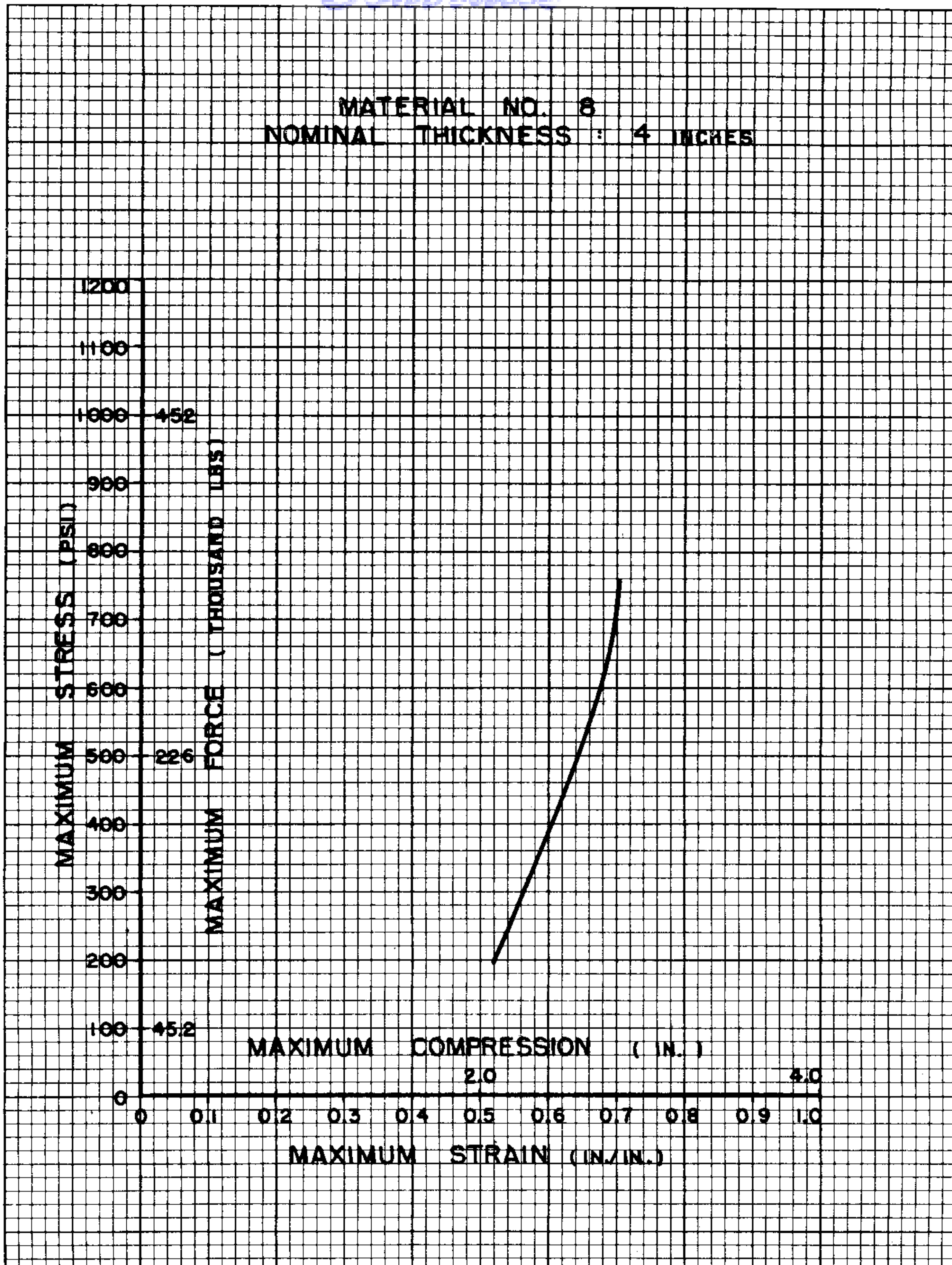

FIGURE 127. MAXIMUM STRESS - MAXIMUM STRAIN CURVE FOR 4 INCHES OF MATERIAL No. 8

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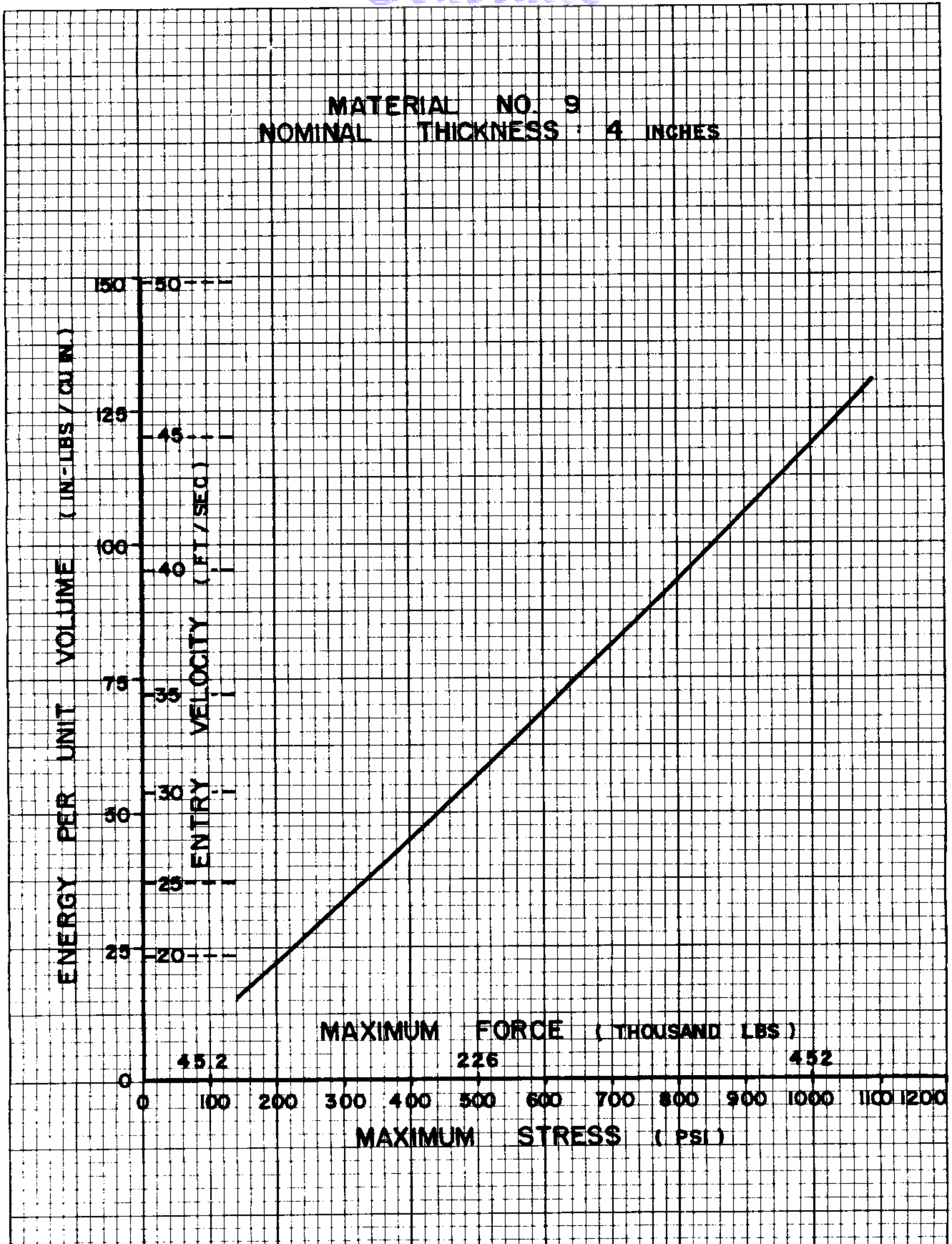

FIGURE 128 ENERGY PER UNIT VOLUME - MAXIMUM STRESS CURVE FOR 4 INCHES OF MATERIAL No. 9

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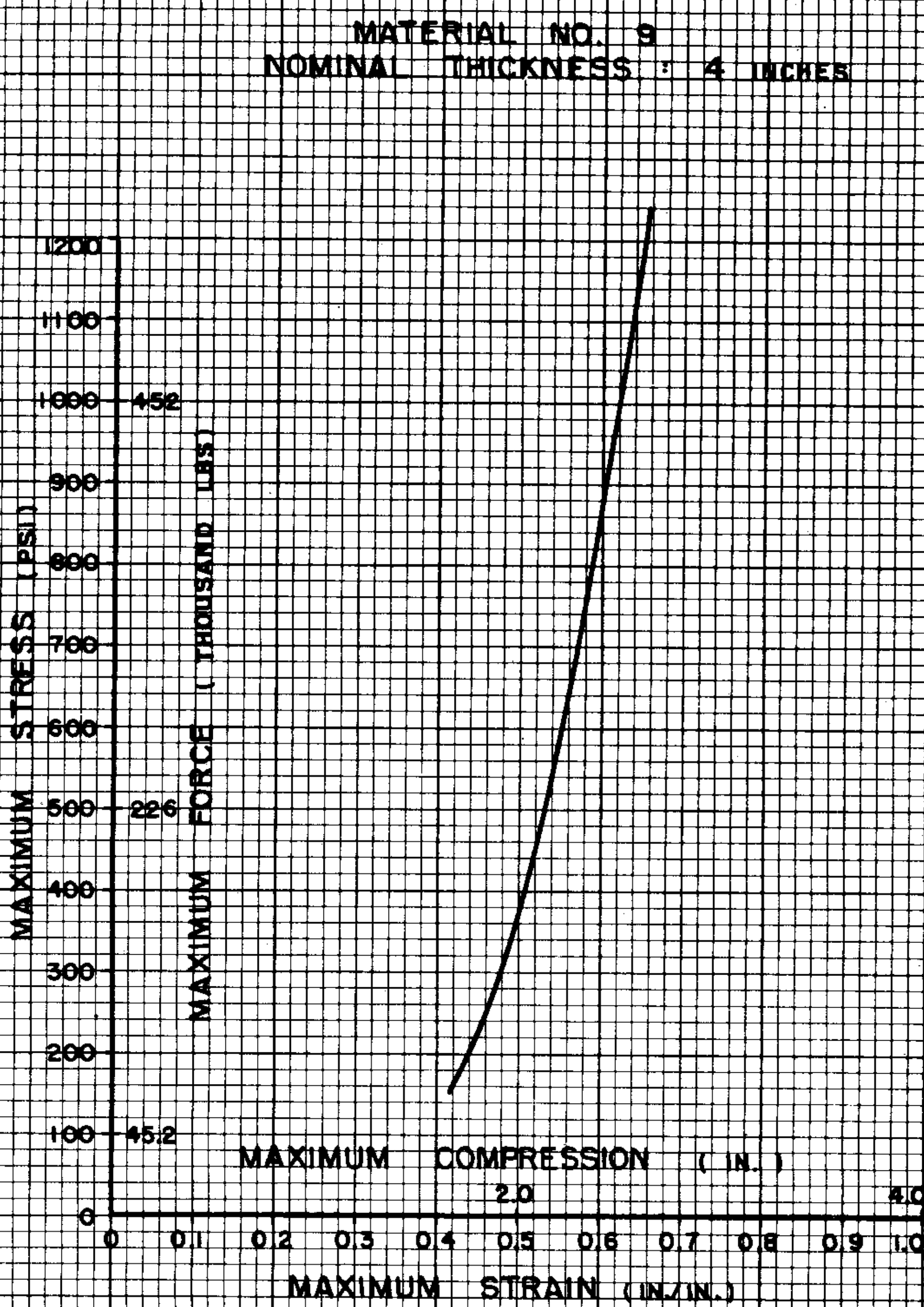

FIGURE 129. MAXIMUM STRESS - MAXIMUM STRAIN CURVE FOR 4 INCHES OF MATERIAL No. 9

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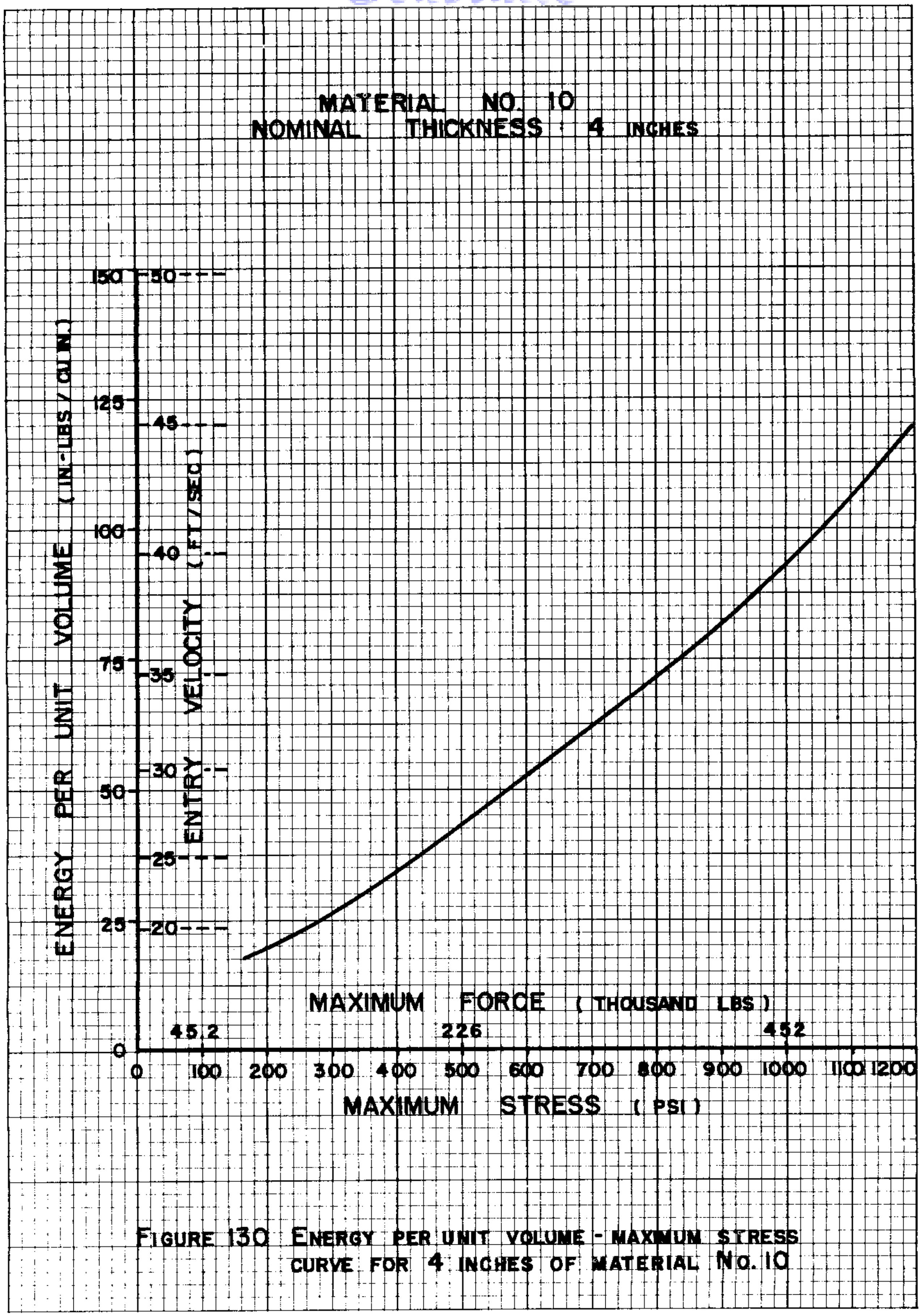

FIGURE 130 ENERGY PER UNIT VOLUME - MAXIMUM STRESS CURVE FOR 4 INCHES OF MATERIAL NO. 10

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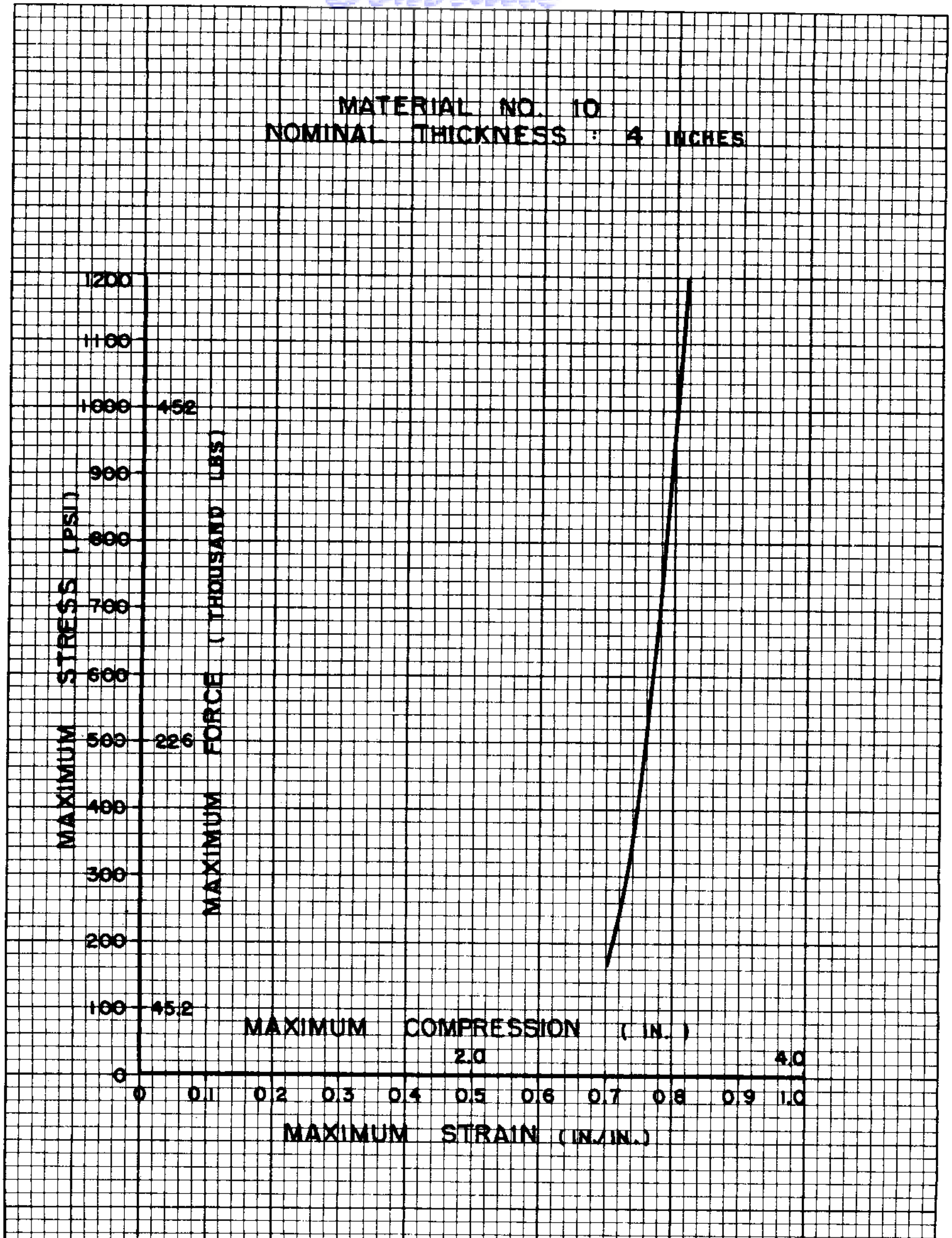

FIGURE 131. MAXIMUM STRESS - MAXIMUM STRAIN CURVE FOR 4 INCHES OF MATERIAL No. 10

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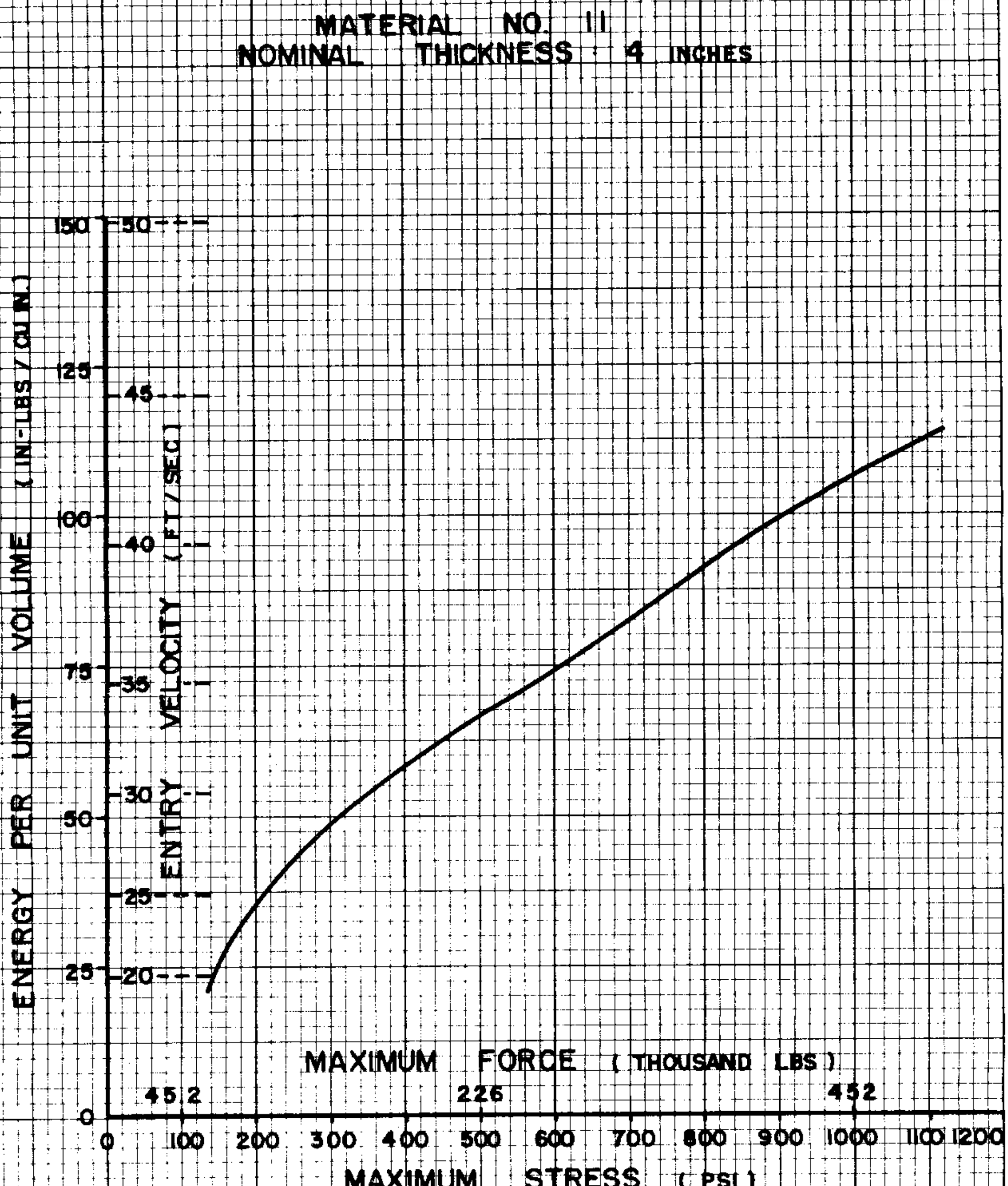

FIGURE 132 ENERGY PER UNIT VOLUME - MAXIMUM STRESS CURVE FOR 4 INCHES OF MATERIAL No. 11

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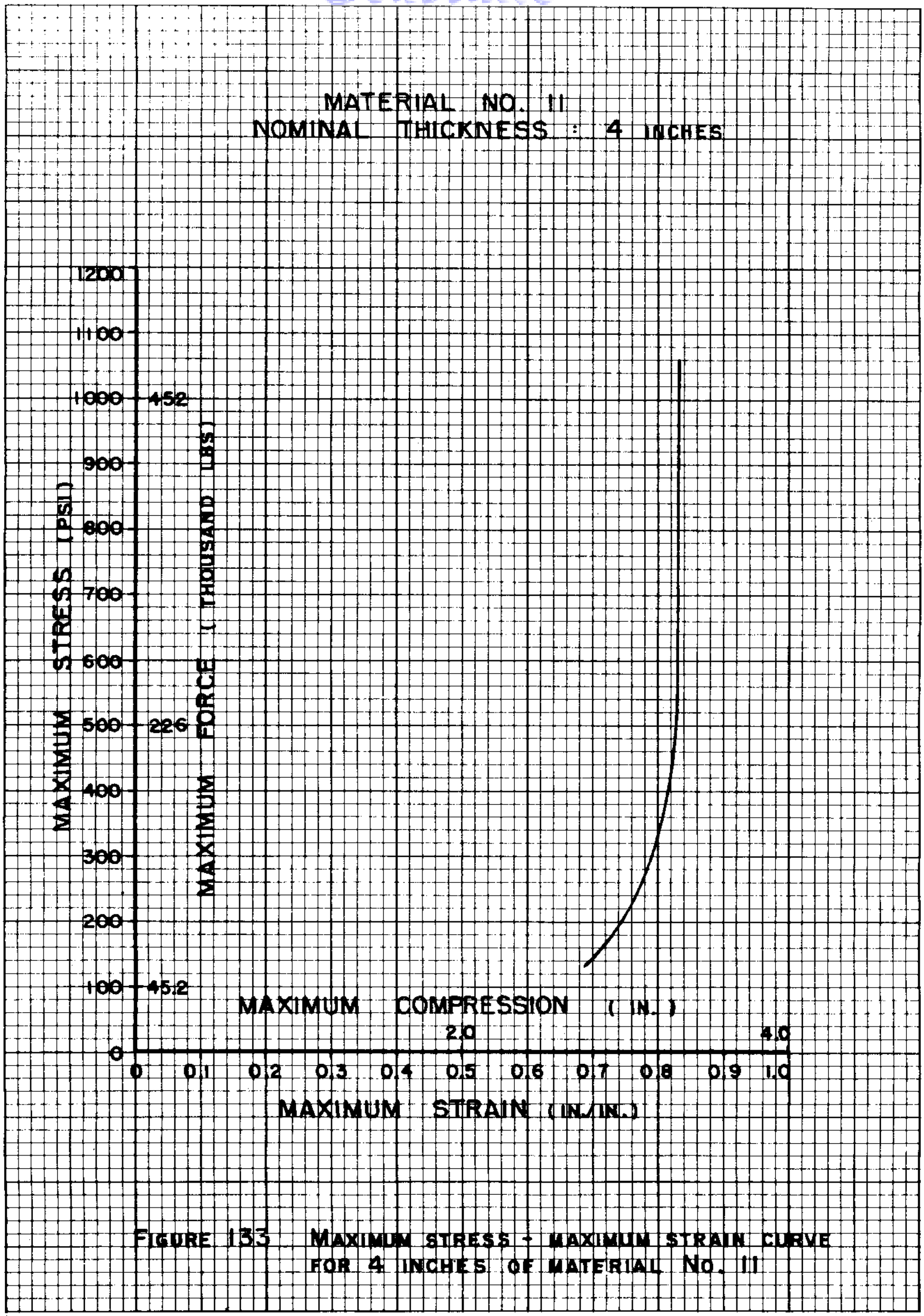

FIGURE 133 MAXIMUM STRESS - MAXIMUM STRAIN CURVE FOR 4 INCHES OF MATERIAL No. 11

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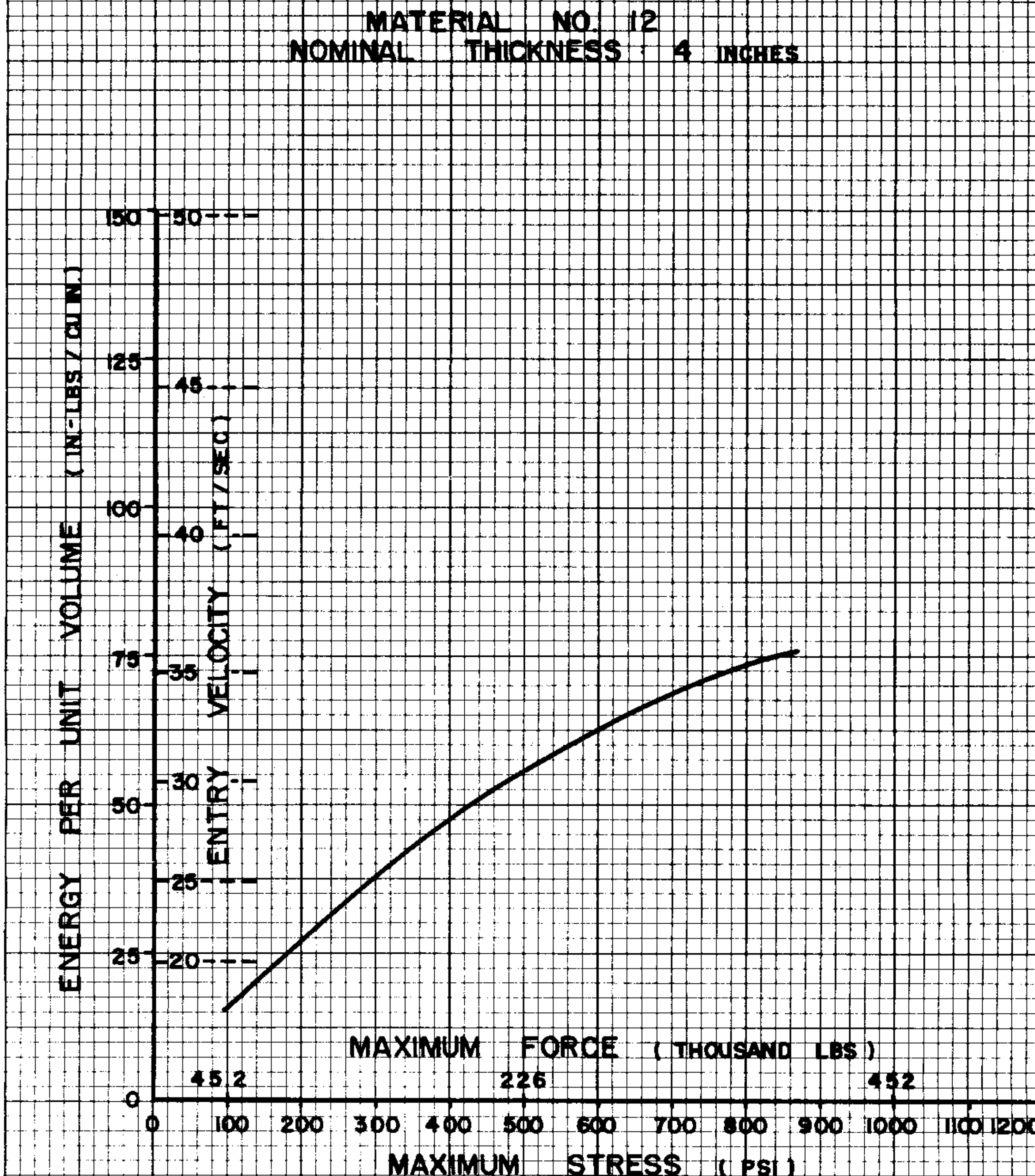

FIGURE 134 ENERGY PER UNIT VOLUME - MAXIMUM STRESS CURVE FOR 4 INCHES OF MATERIAL No. 12

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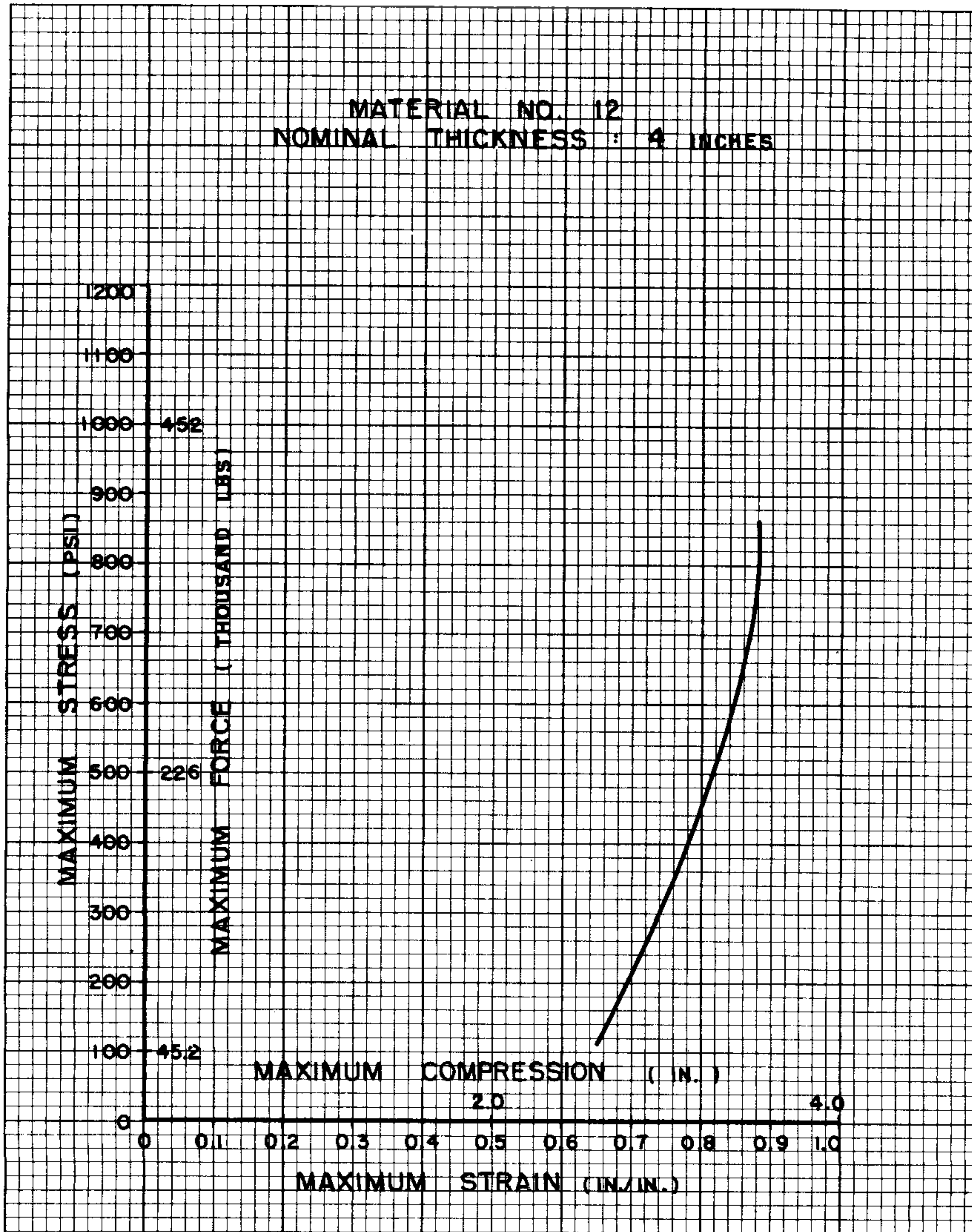

FIGURE 135. MAXIMUM STRESS - MAXIMUM STRAIN CURVE FOR 4 INCHES OF MATERIAL No. 12

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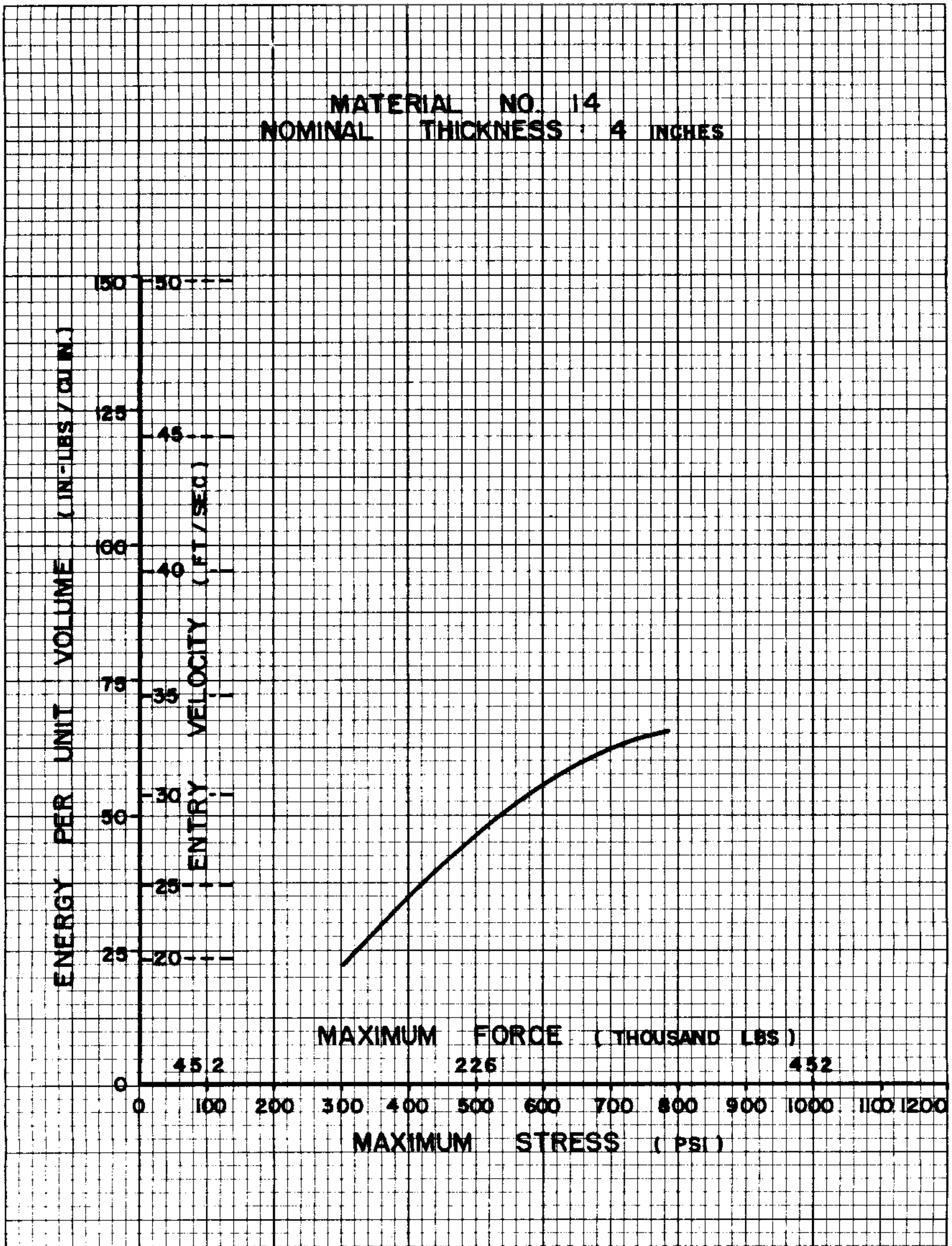

FIGURE 136 ENERGY PER UNIT VOLUME - MAXIMUM STRESS CURVE FOR 4 INCHES OF MATERIAL NO. 14

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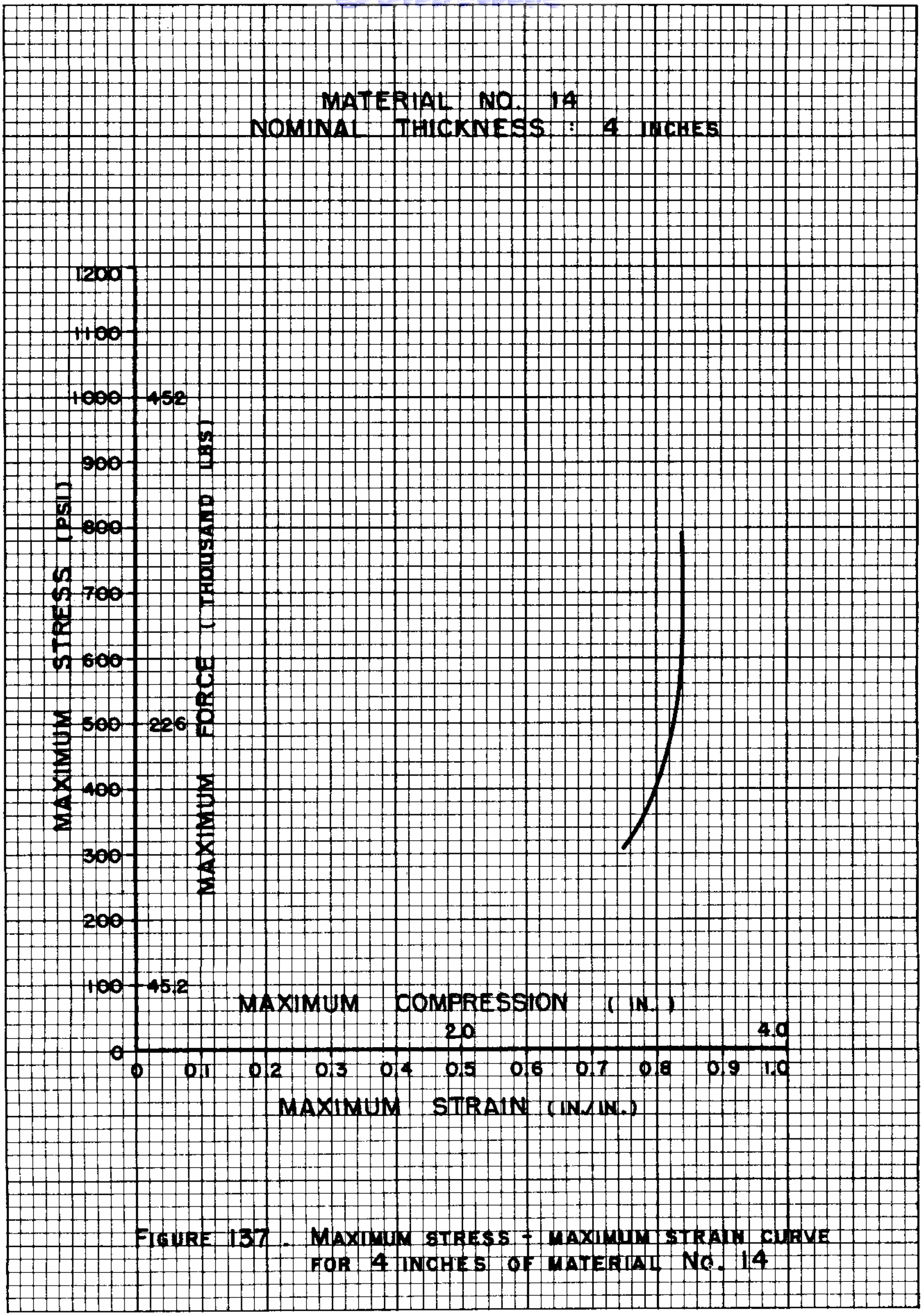

FIGURE 137. MAXIMUM STRESS - MAXIMUM STRAIN CURVE FOR 4 INCHES OF MATERIAL NO. 14

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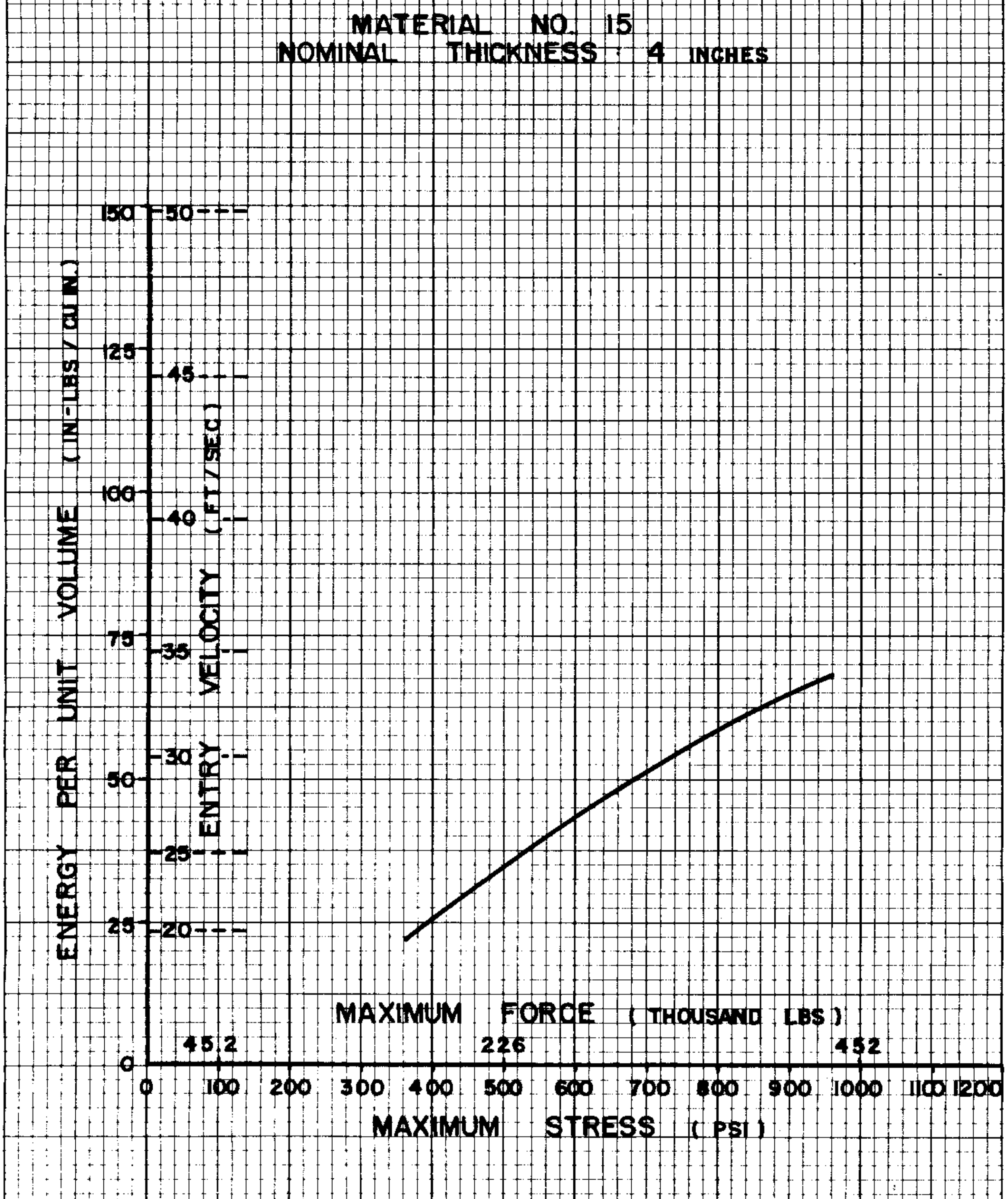

FIGURE 138 ENERGY PER UNIT VOLUME - MAXIMUM STRESS CURVE FOR 4 INCHES OF MATERIAL No. 15

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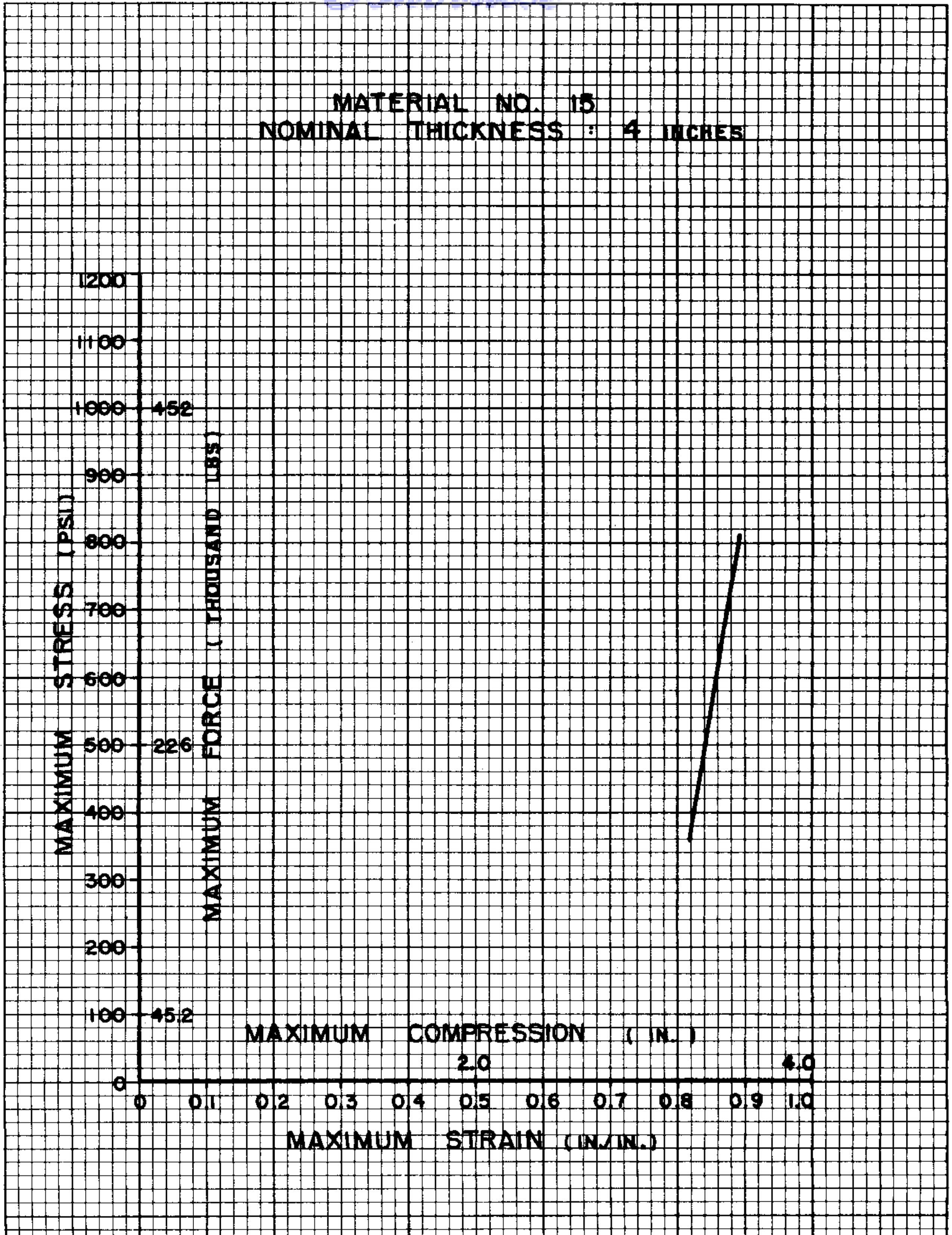

FIGURE 139. MAXIMUM STRESS - MAXIMUM STRAIN CURVE FOR 4 INCHES OF MATERIAL No. 15

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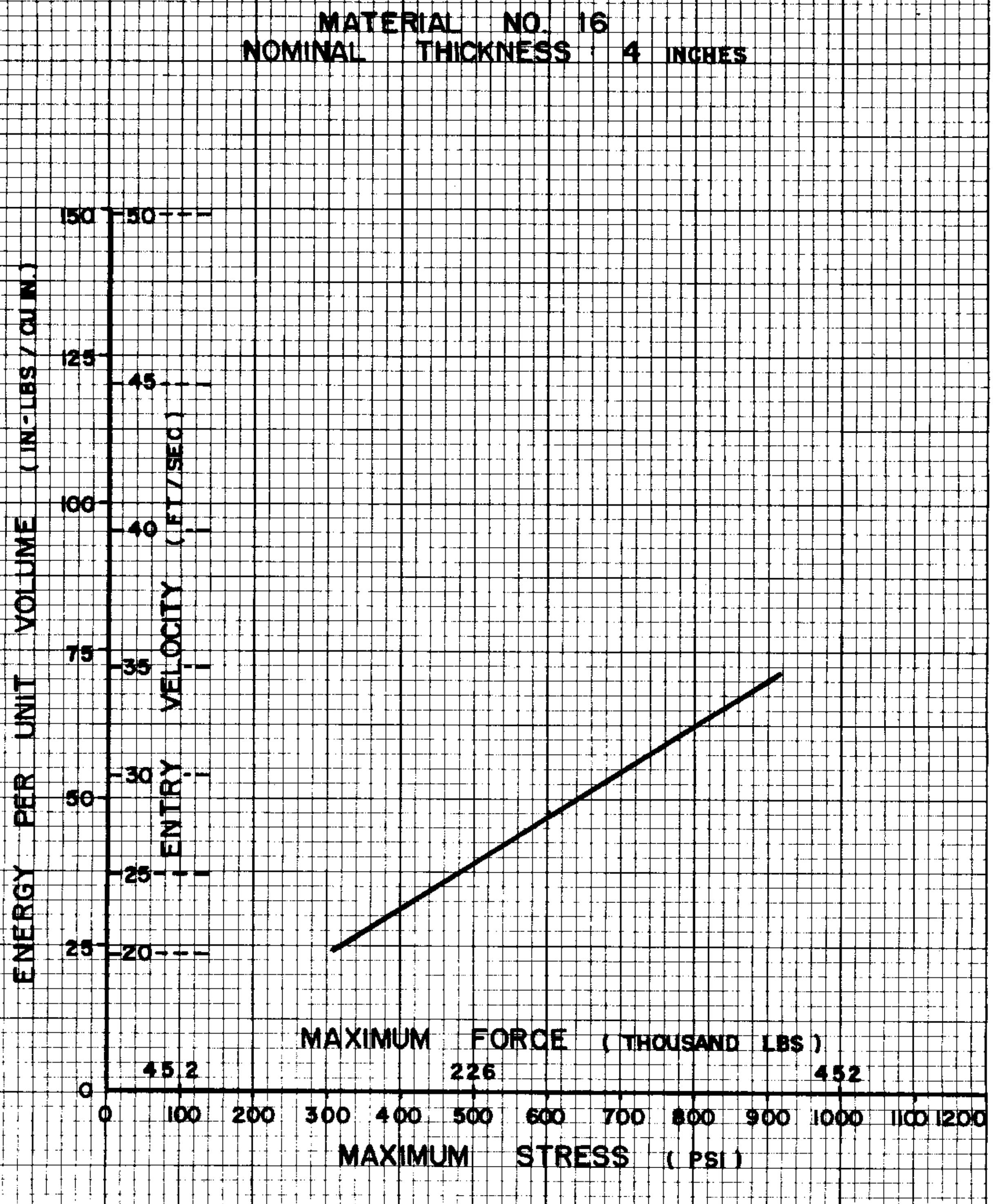

FIGURE 140 ENERGY PER UNIT VOLUME - MAXIMUM STRESS CURVE FOR 4 INCHES OF MATERIAL No. 16

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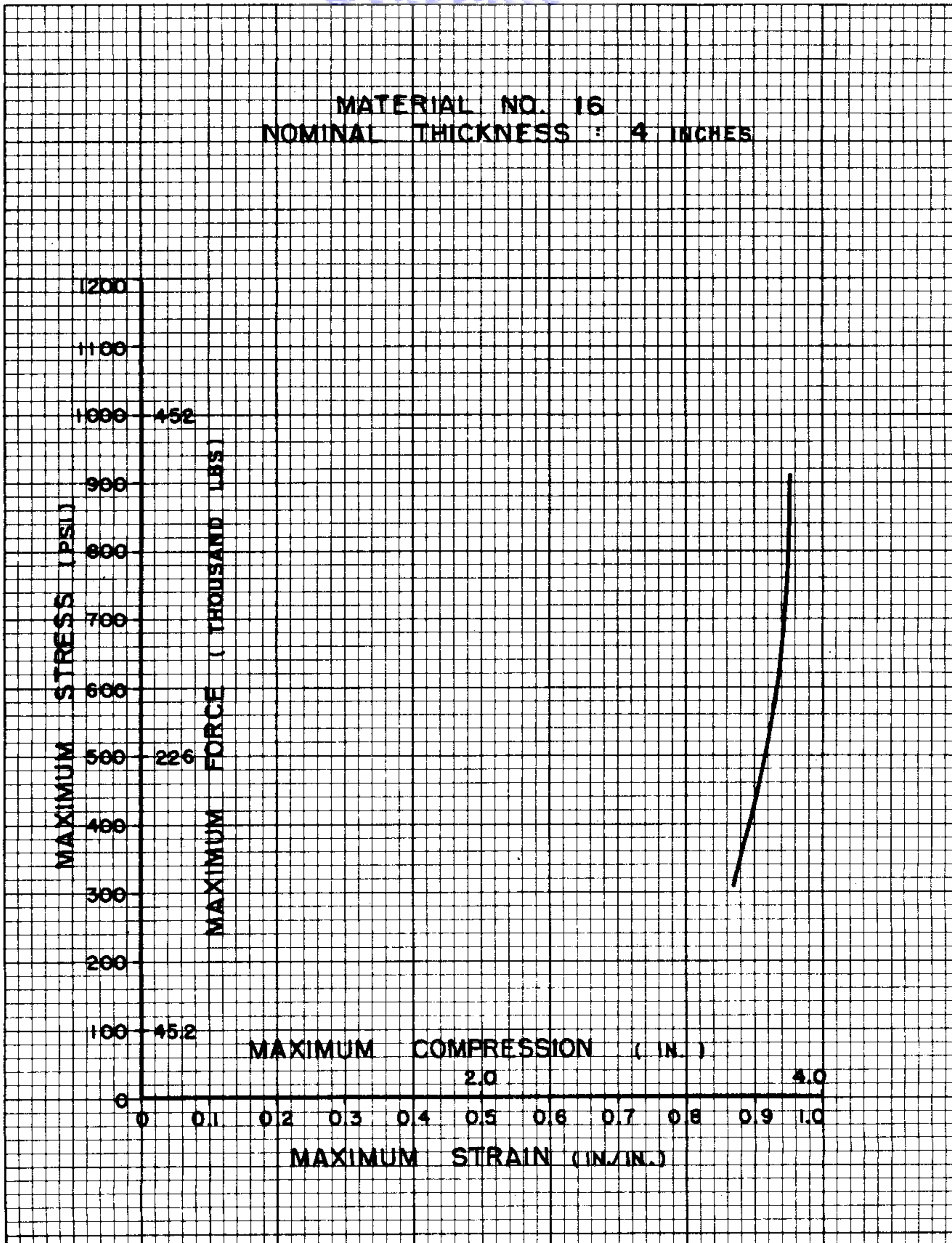

FIGURE 141. MAXIMUM STRESS - MAXIMUM STRAIN CURVE FOR 4 INCHES OF MATERIAL No. 16

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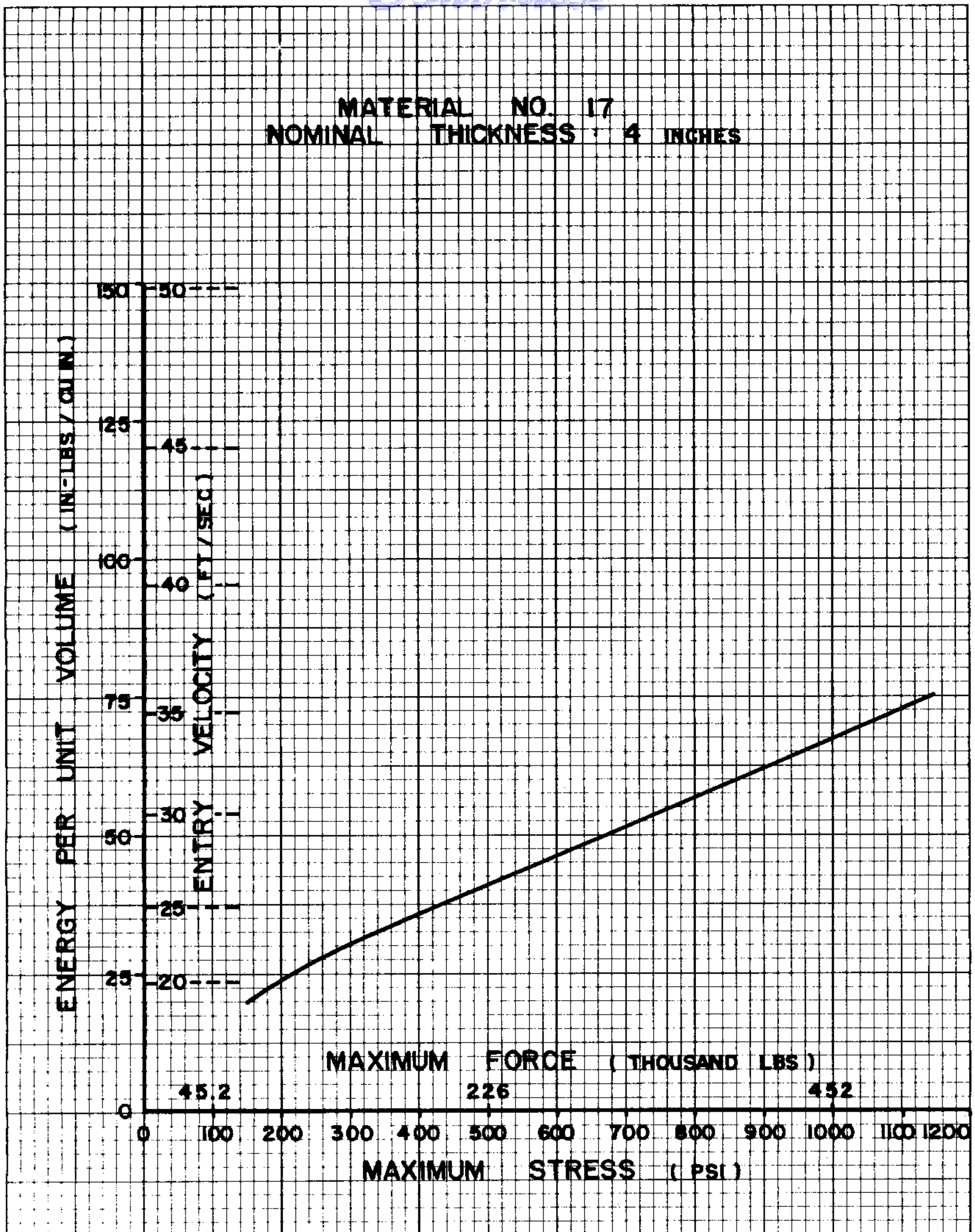

FIGURE 142 ENERGY PER UNIT VOLUME - MAXIMUM STRESS CURVE FOR 4 INCHES OF MATERIAL NO. 17

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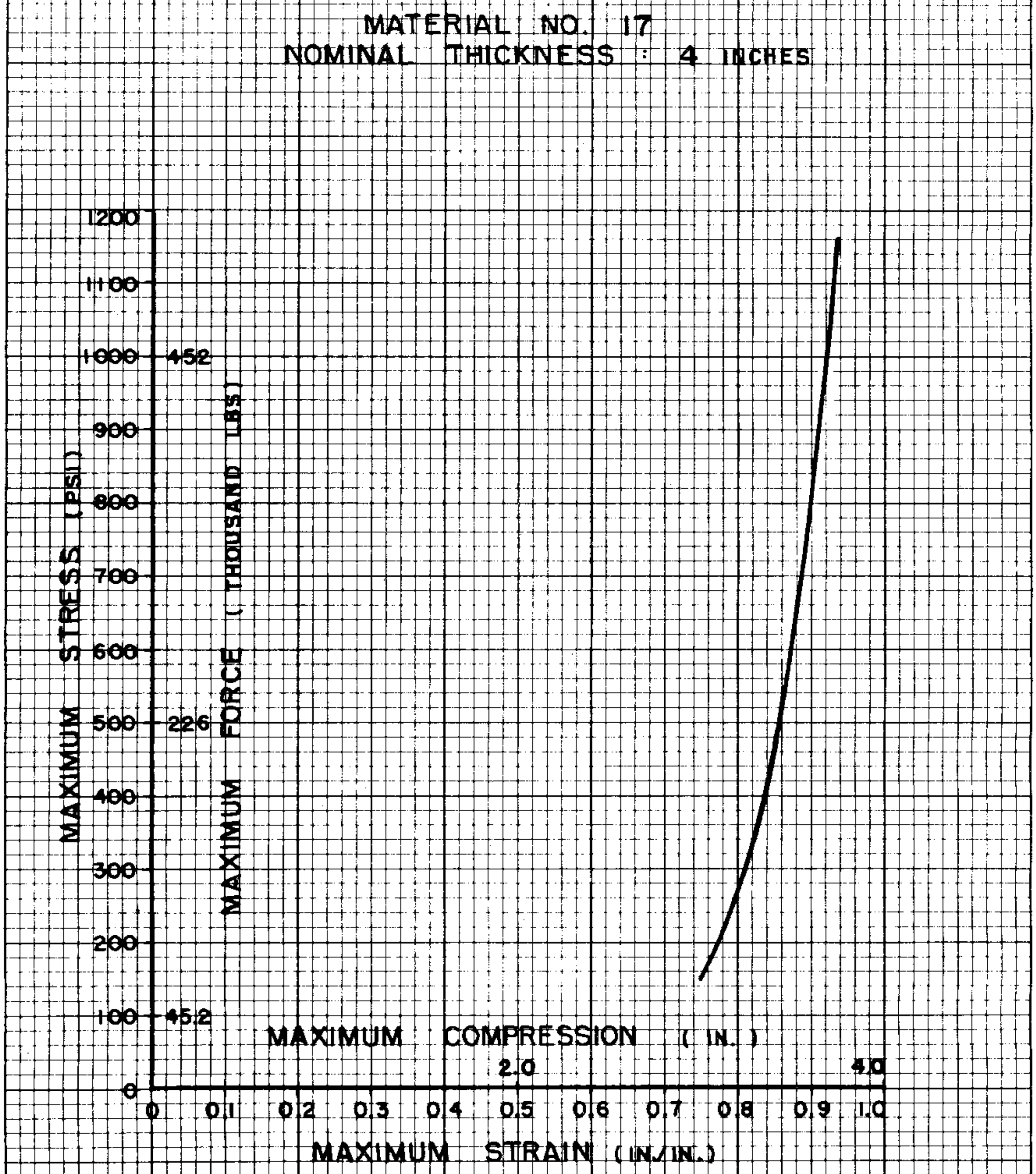

FIGURE 143 MAXIMUM STRESS - MAXIMUM STRAIN CURVE FOR 4 INCHES OF MATERIAL NO. 17

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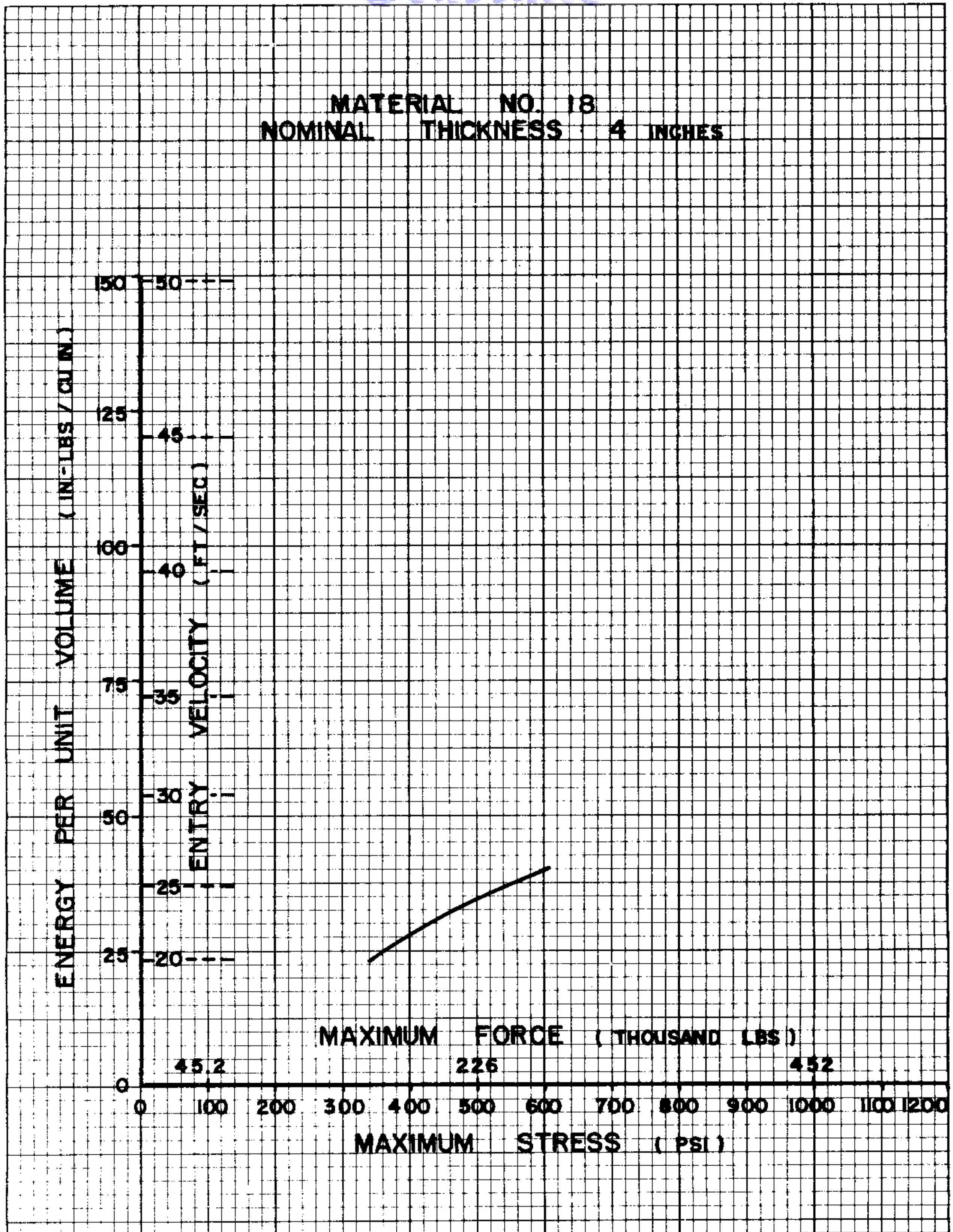

FIGURE 144 ENERGY PER UNIT VOLUME - MAXIMUM STRESS CURVE FOR 4 INCHES OF MATERIAL NO. 18

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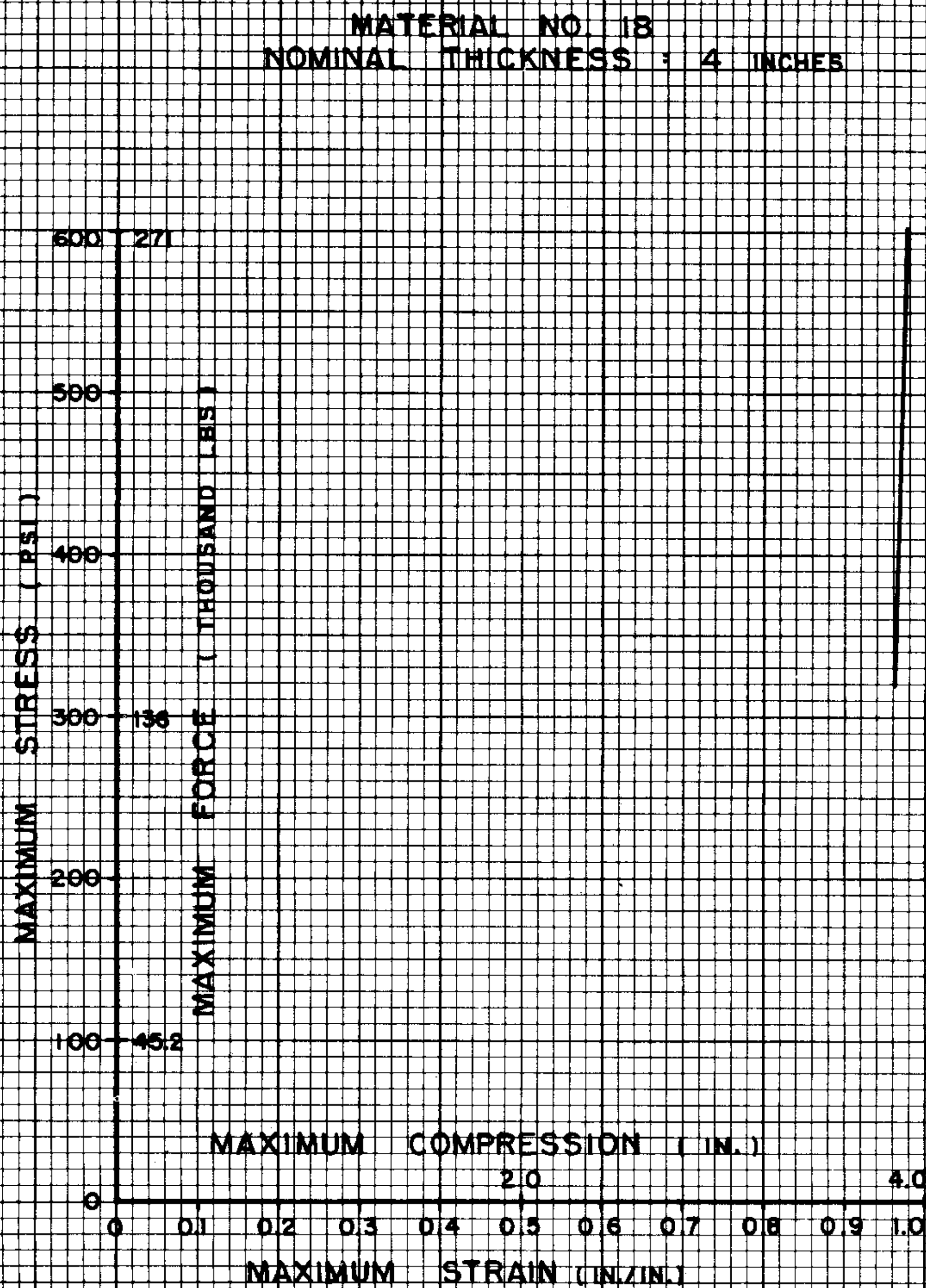

FIGURE 145. MAXIMUM STRESS - MAXIMUM STRAIN CURVE FOR 4 INCHES OF MATERIAL NO. 18

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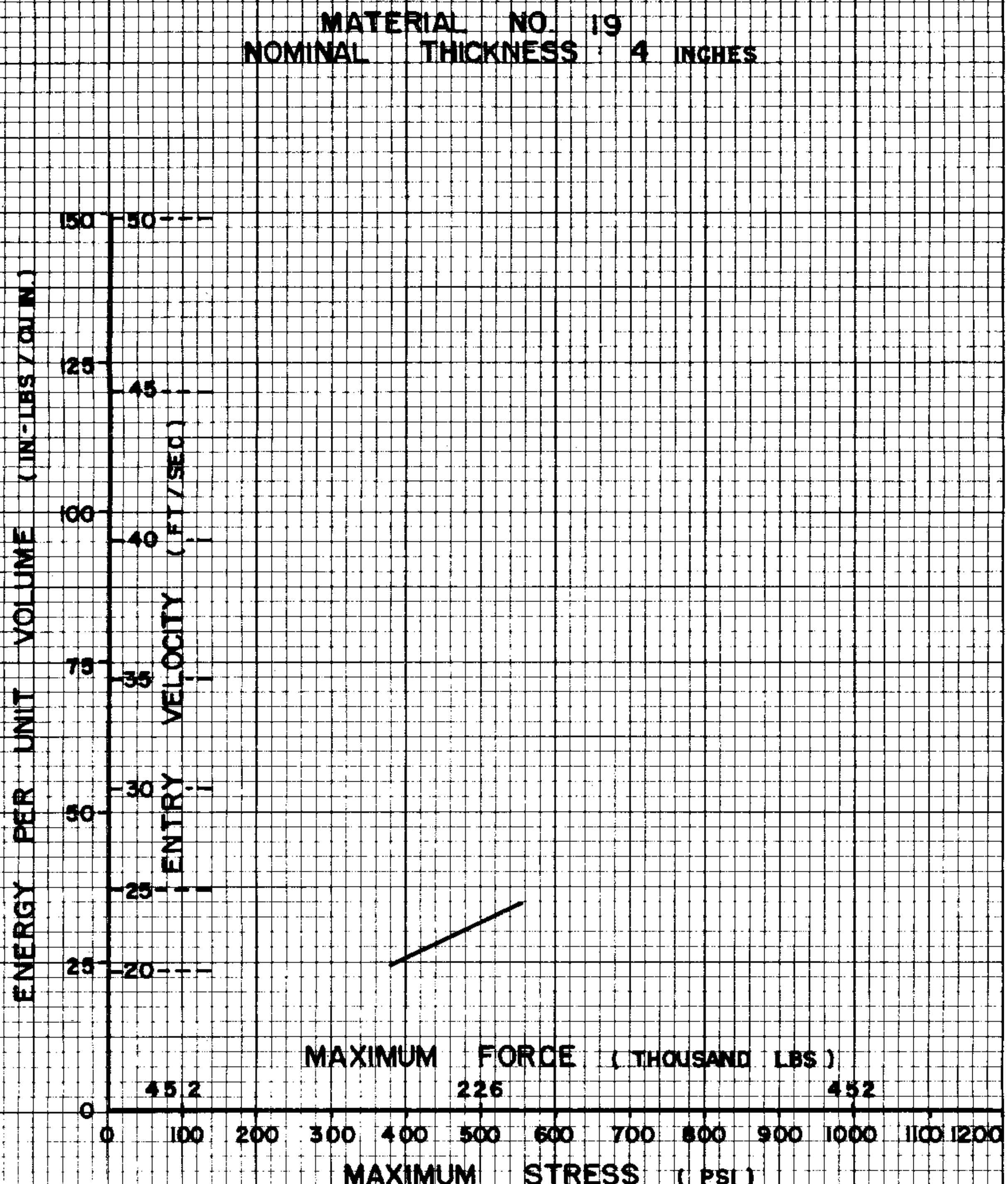

FIGURE 146 ENERGY PER UNIT VOLUME - MAXIMUM STRESS CURVE FOR 4 INCHES OF MATERIAL NO. 19

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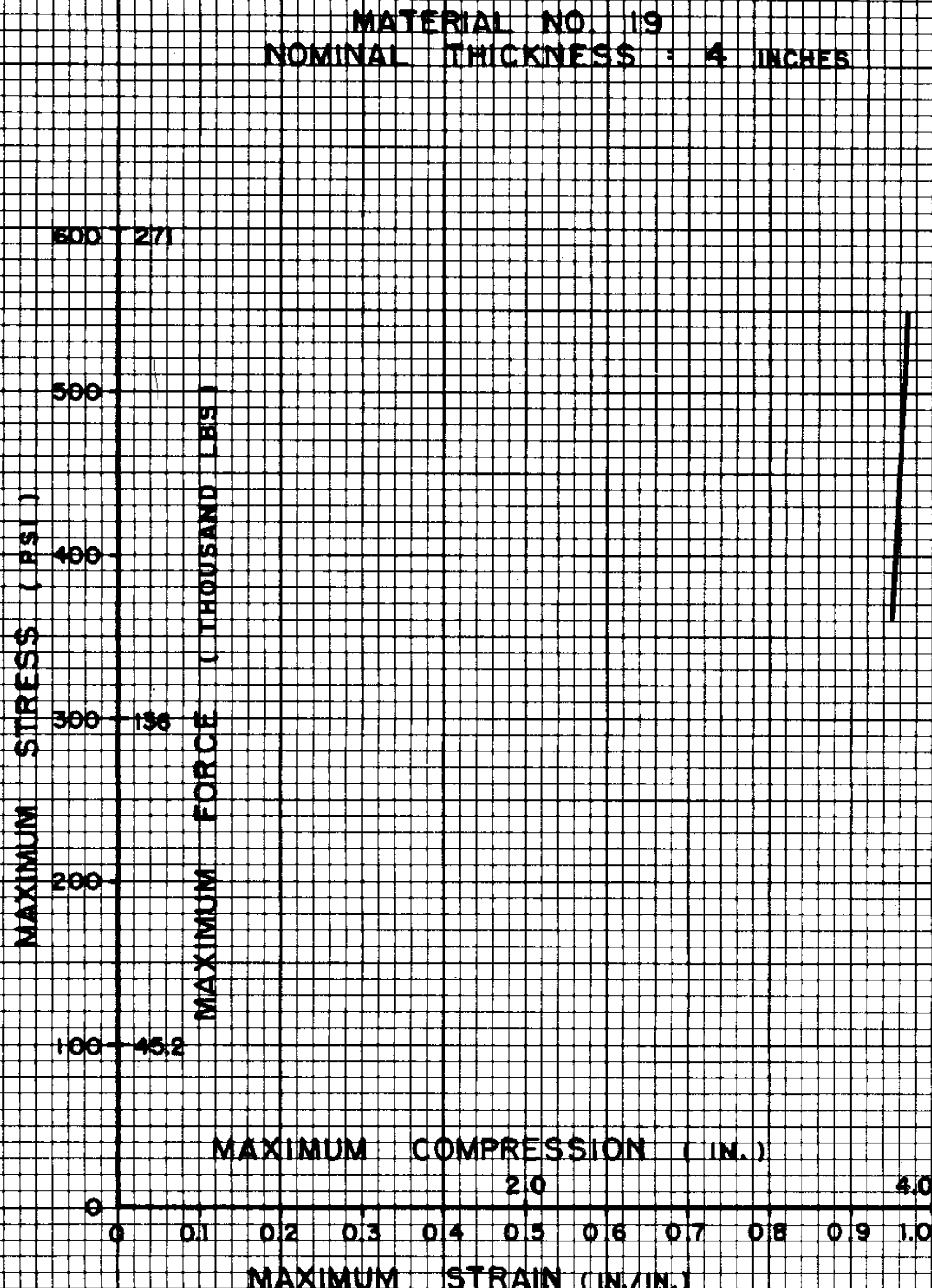

FIGURE 147. MAXIMUM STRESS - MAXIMUM STRAIN CURVE FOR 4 INCHES OF MATERIAL No. 19

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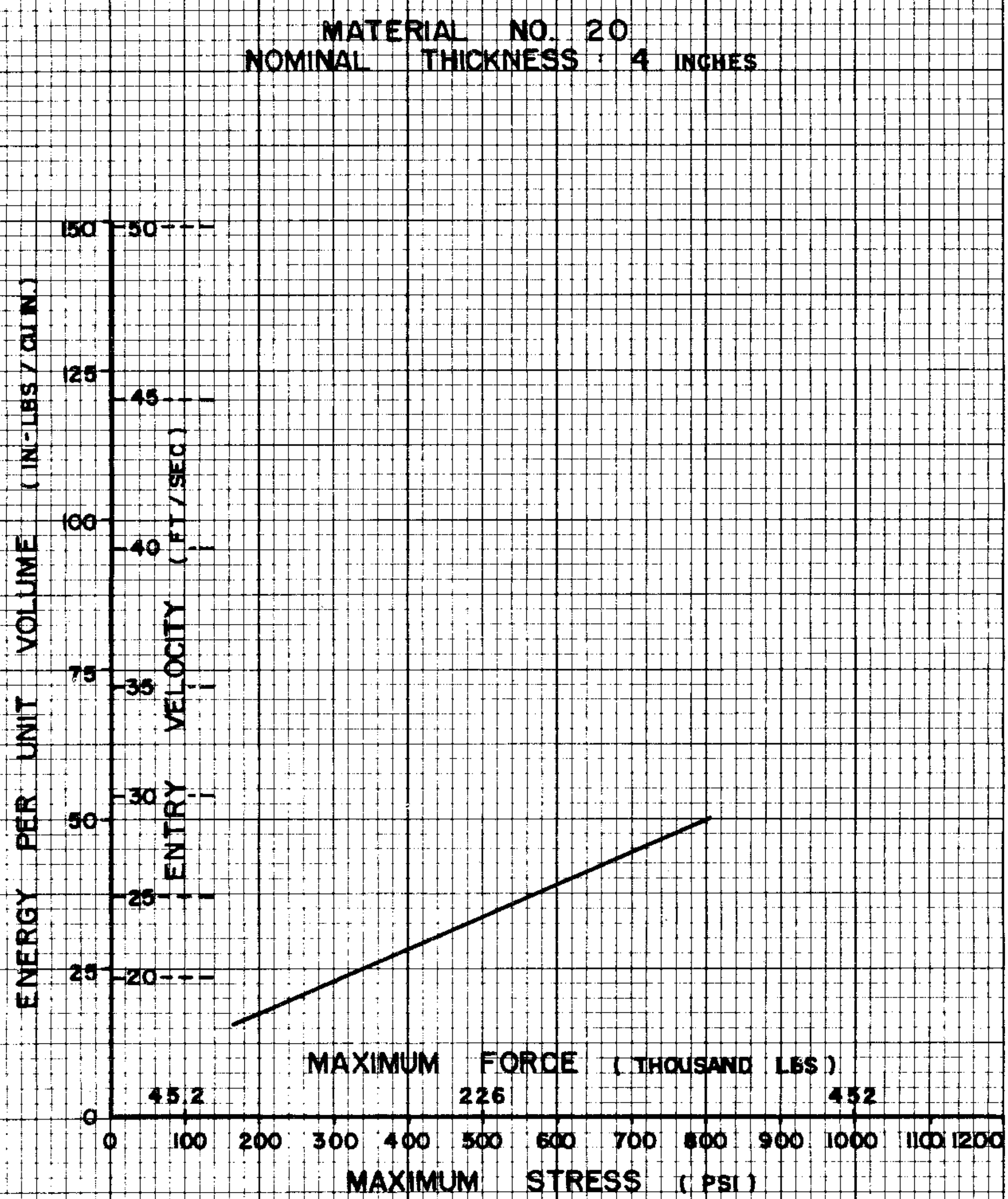

FIGURE 148 ENERGY PER UNIT VOLUME - MAXIMUM STRESS CURVE FOR 4 INCHES OF MATERIAL NO. 20

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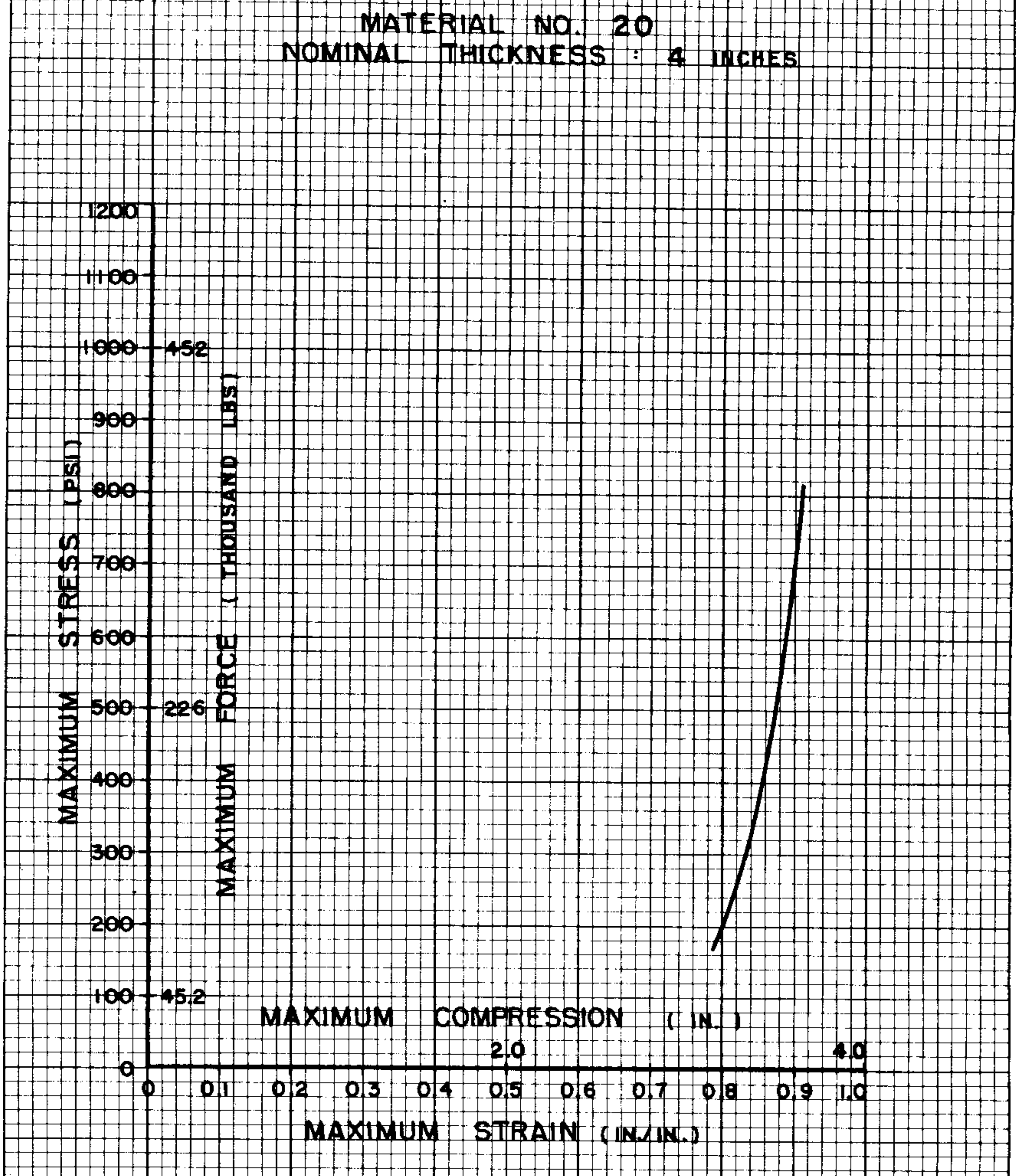

FIGURE 149 MAXIMUM STRESS - MAXIMUM STRAIN CURVE FOR 4 INCHES OF MATERIAL No. 20

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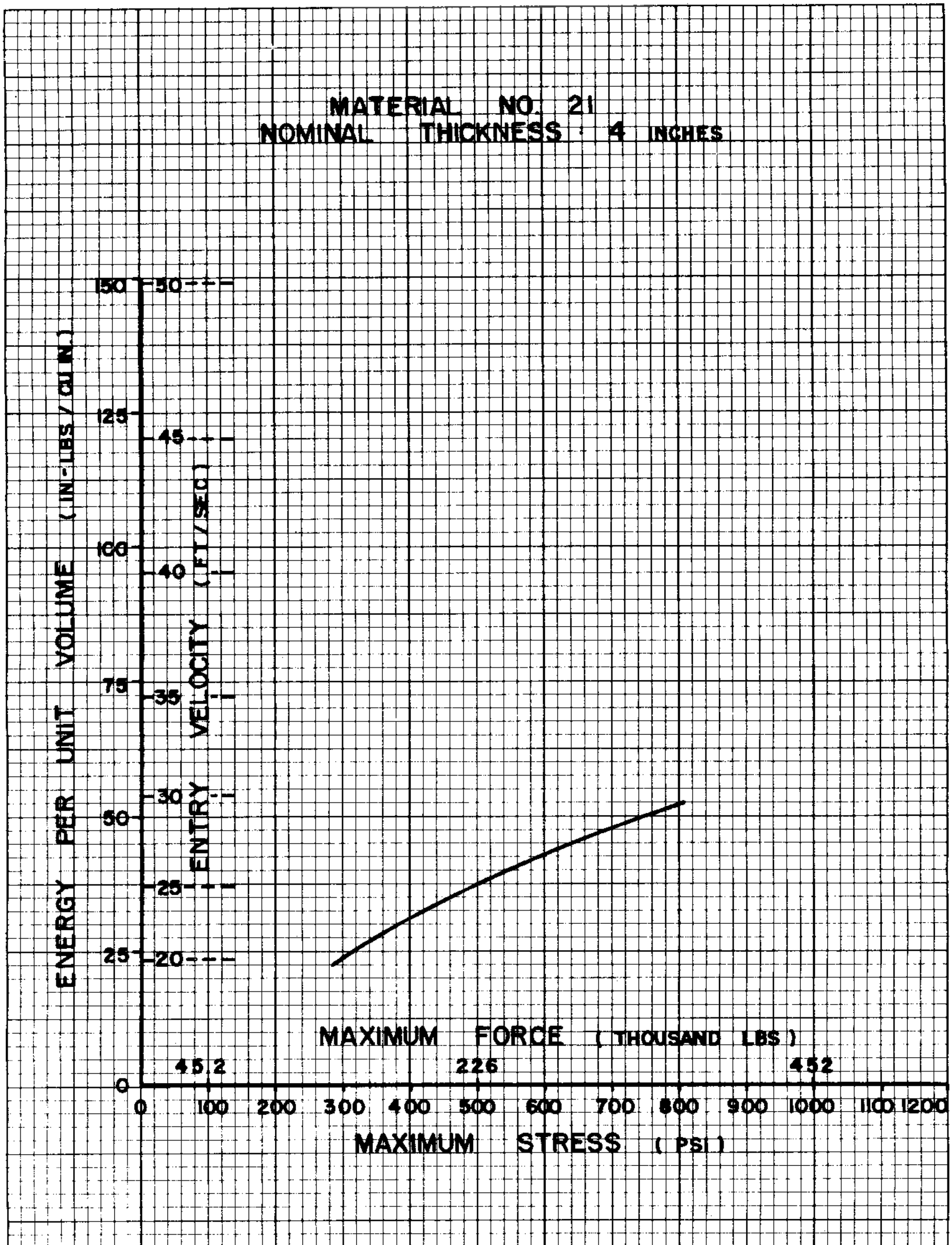

FIGURE 150 ENERGY PER UNIT VOLUME - MAXIMUM STRESS CURVE FOR 4 INCHES OF MATERIAL No. 21

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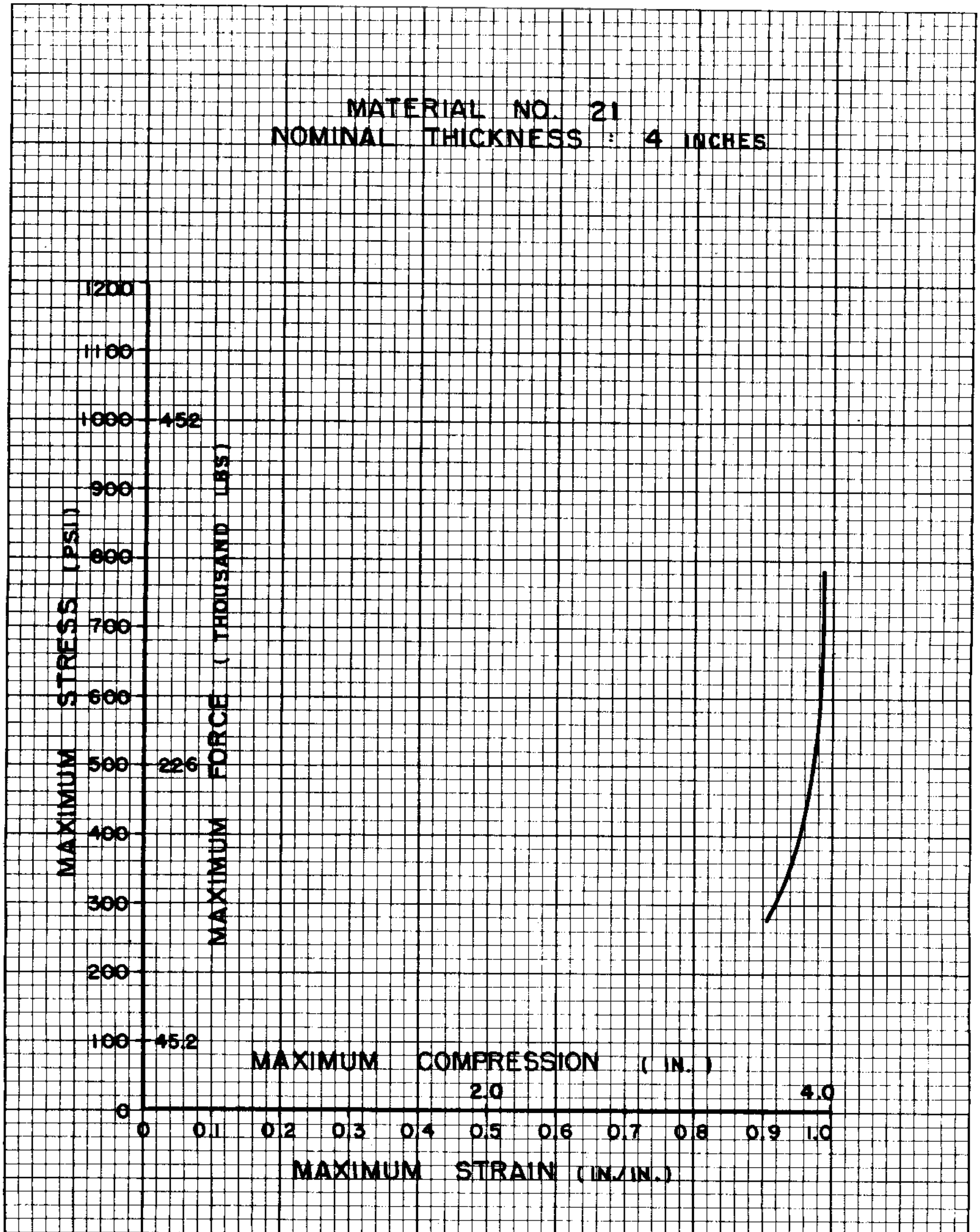

FIGURE 151 MAXIMUM STRESS - MAXIMUM STRAIN CURVE FOR 4 INCHES OF MATERIAL No. 21

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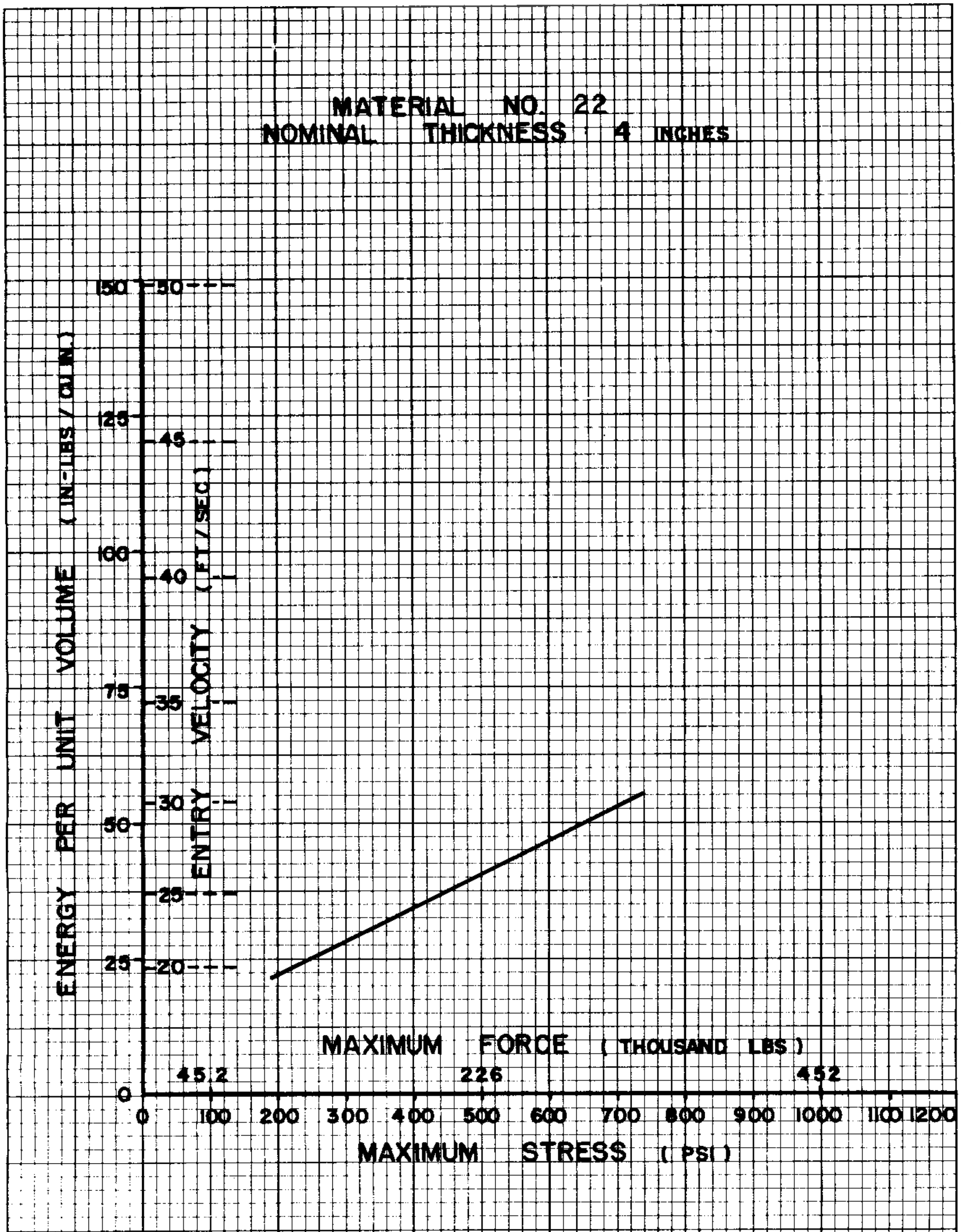

FIGURE 152 ENERGY PER UNIT VOLUME - MAXIMUM STRESS CURVE FOR 4 INCHES OF MATERIAL No. 22

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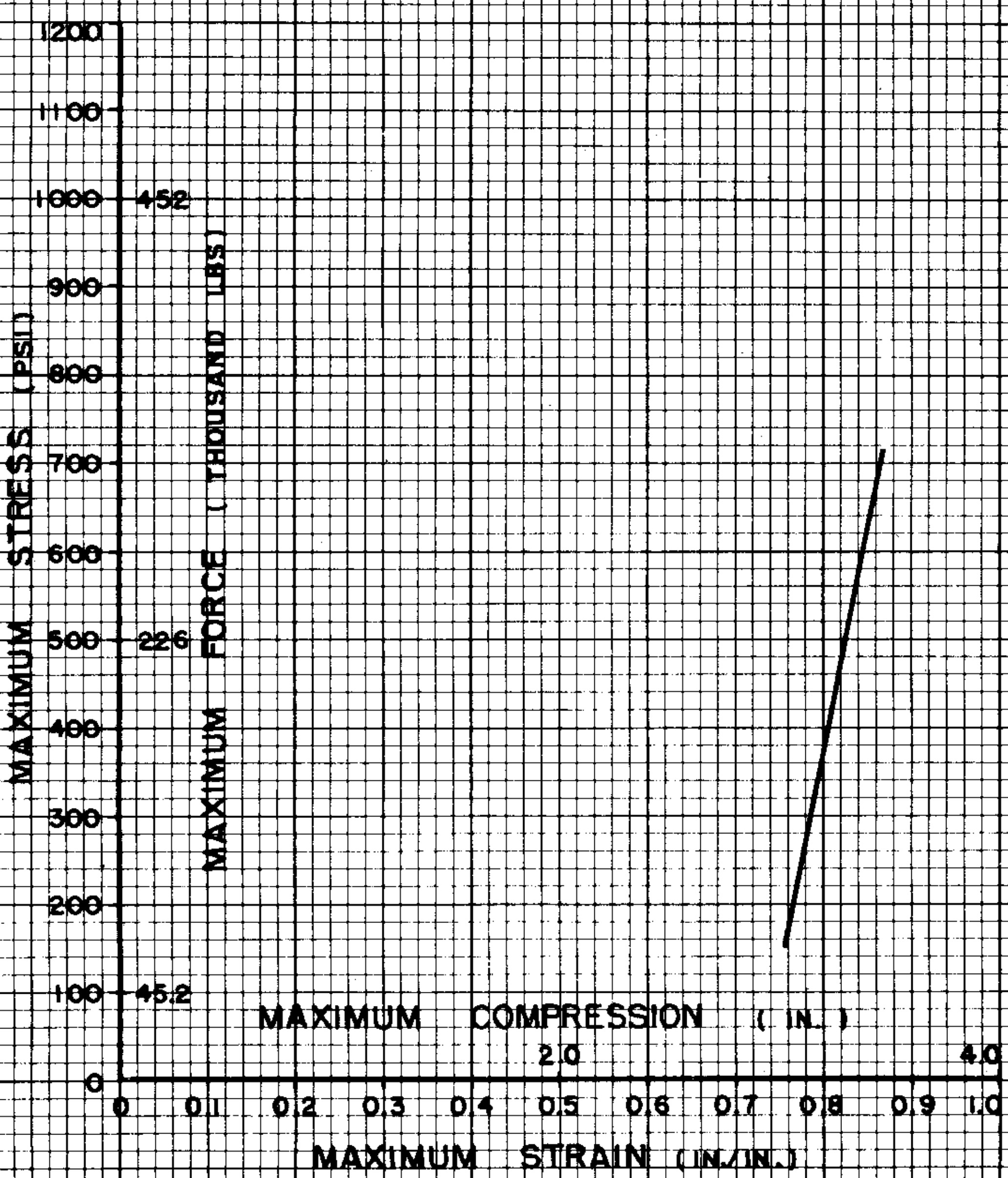

FIGURE 153 MAXIMUM STRESS - MAXIMUM STRAIN CURVE FOR 4 INCHES OF MATERIAL NO. 22

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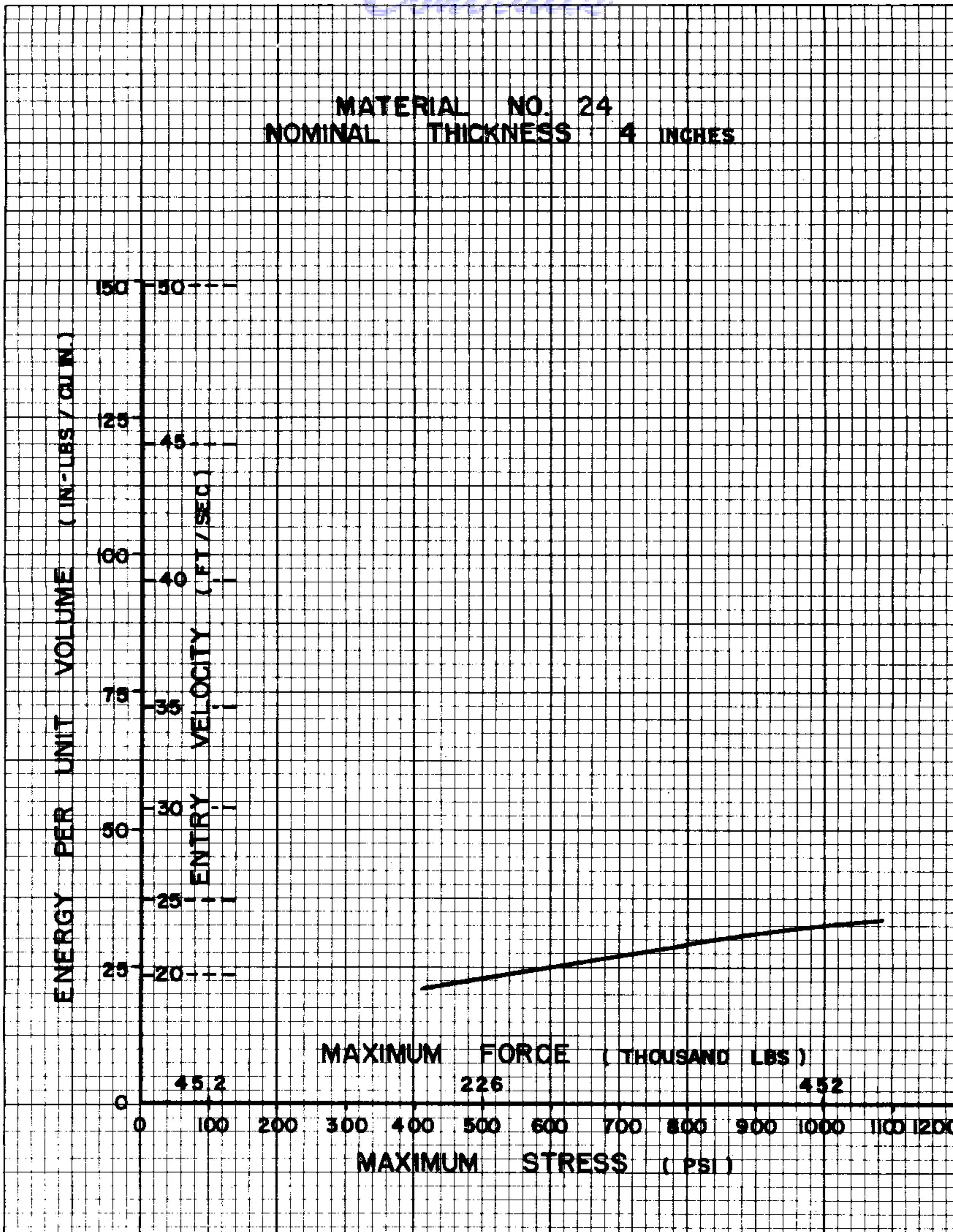

FIGURE 154 ENERGY PER UNIT VOLUME - MAXIMUM STRESS CURVE FOR 4 INCHES OF MATERIAL No. 24

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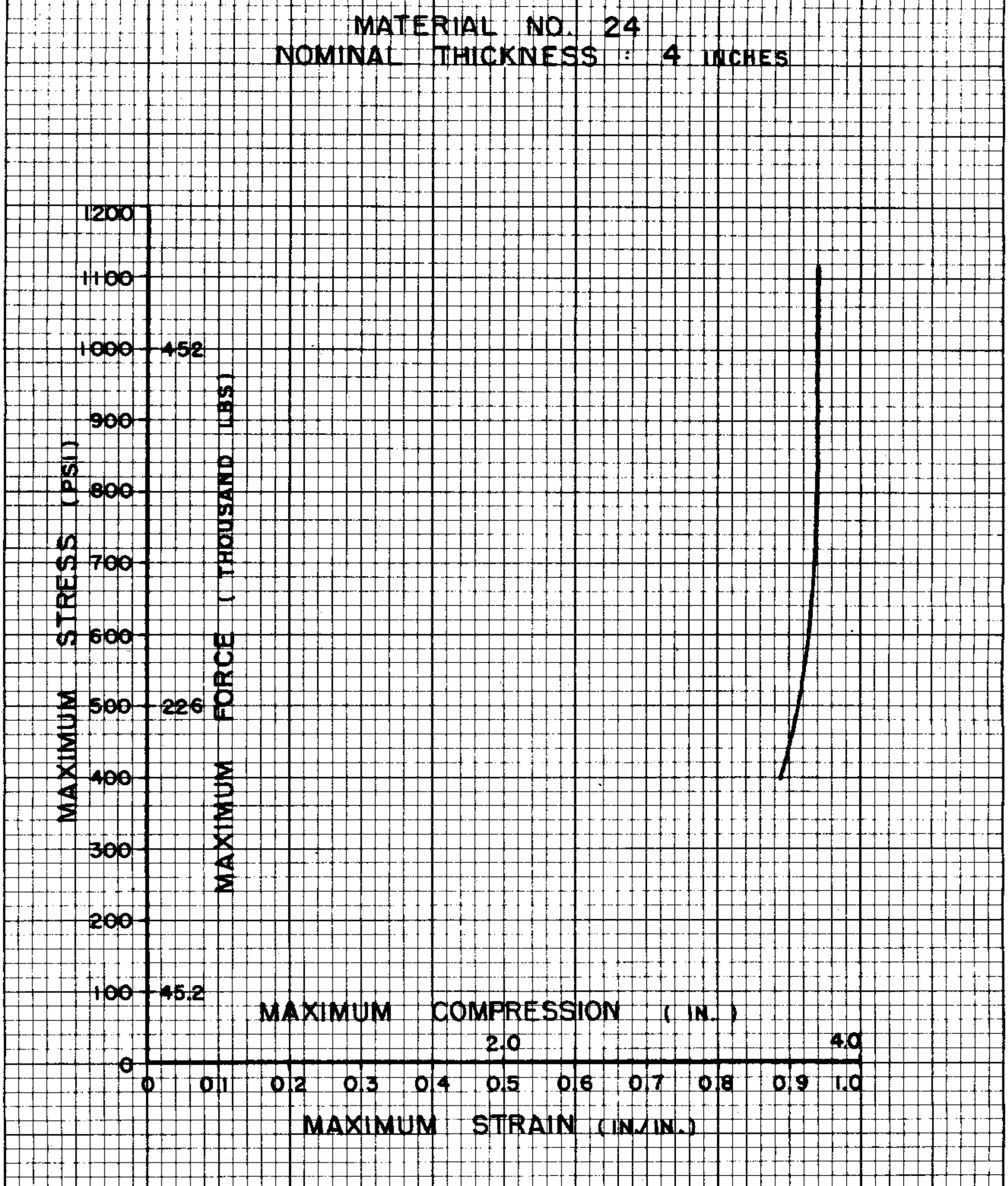

FIGURE 155 MAXIMUM STRESS - MAXIMUM STRAIN CURVE FOR 4 INCHES OF MATERIAL No. 24

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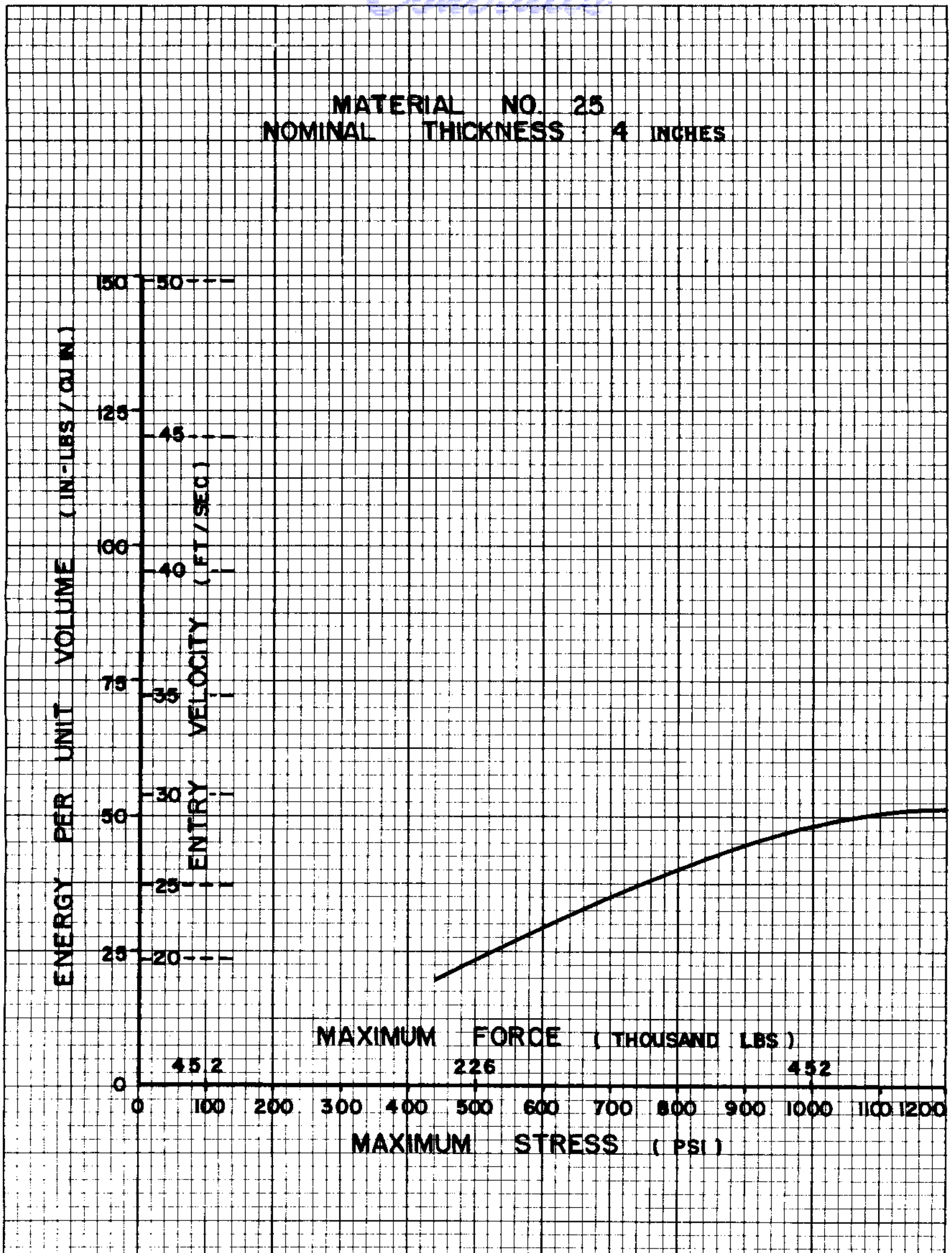

FIGURE 156 ENERGY PER UNIT VOLUME - MAXIMUM STRESS CURVE FOR 4 INCHES OF MATERIAL No. 25

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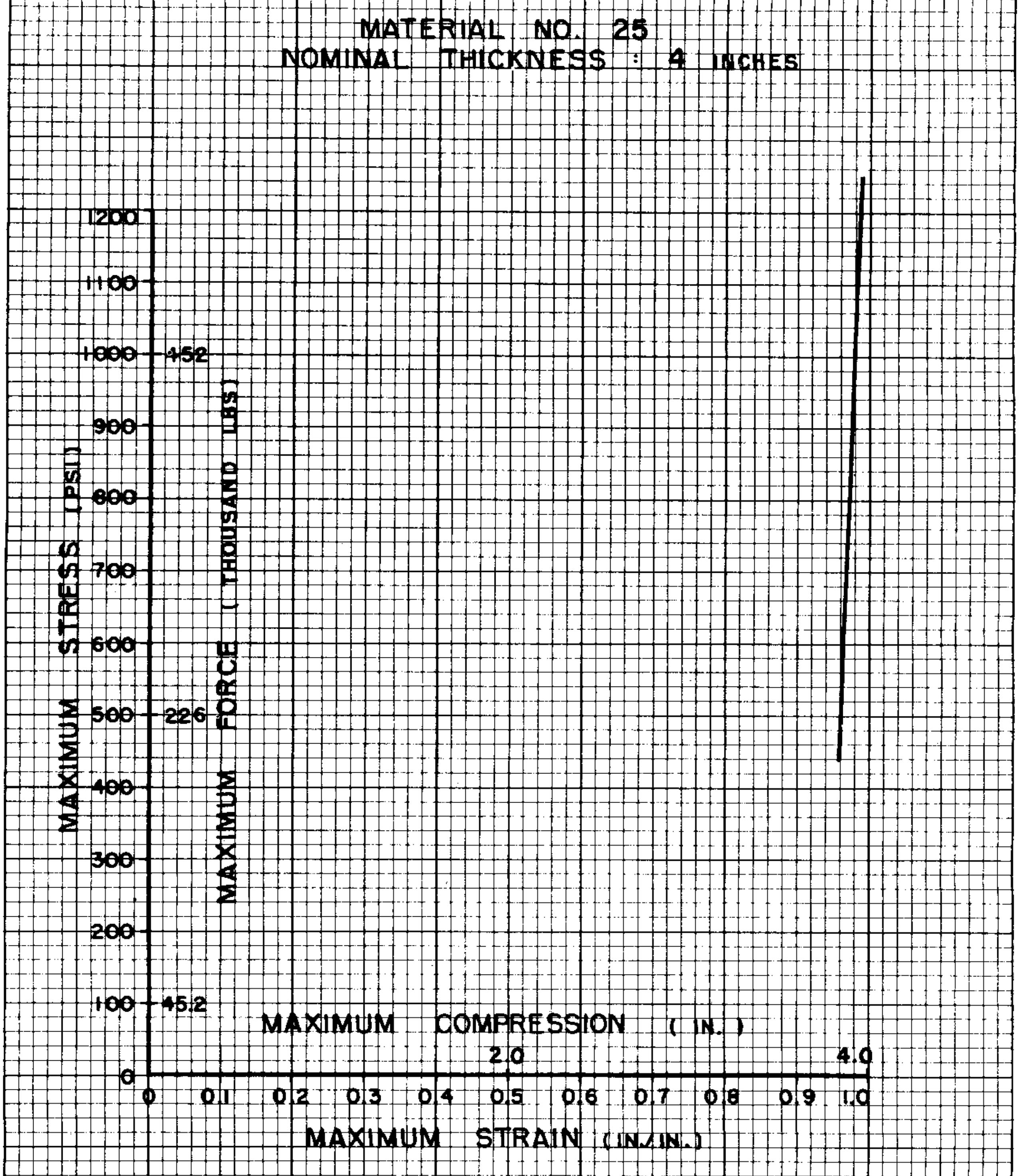

FIGURE 157 MAXIMUM STRESS - MAXIMUM STRAIN CURVE FOR 4 INCHES OF MATERIAL No. 25

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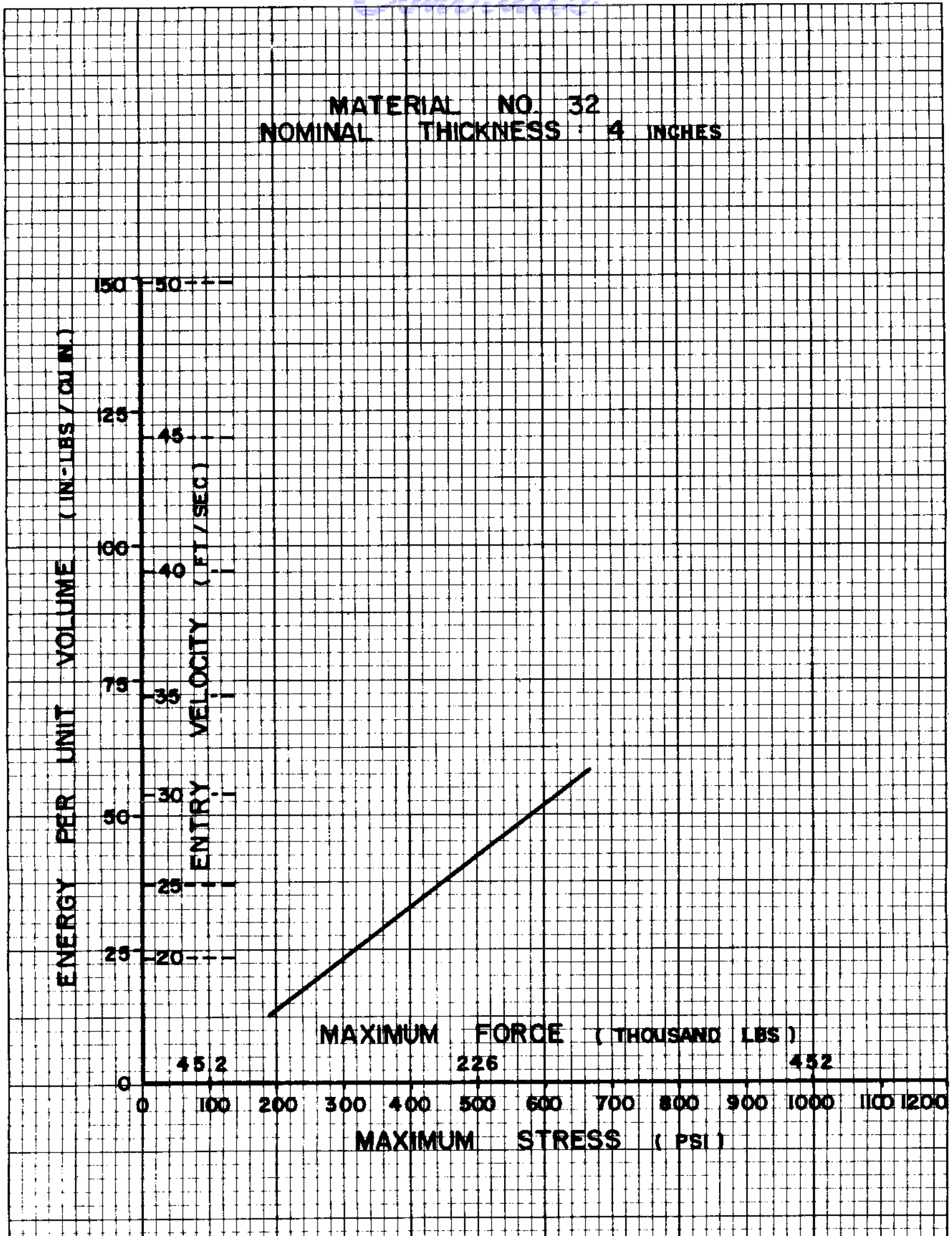

FIGURE 158 ENERGY PER UNIT VOLUME - MAXIMUM STRESS CURVE FOR 4 INCHES OF MATERIAL No. 32

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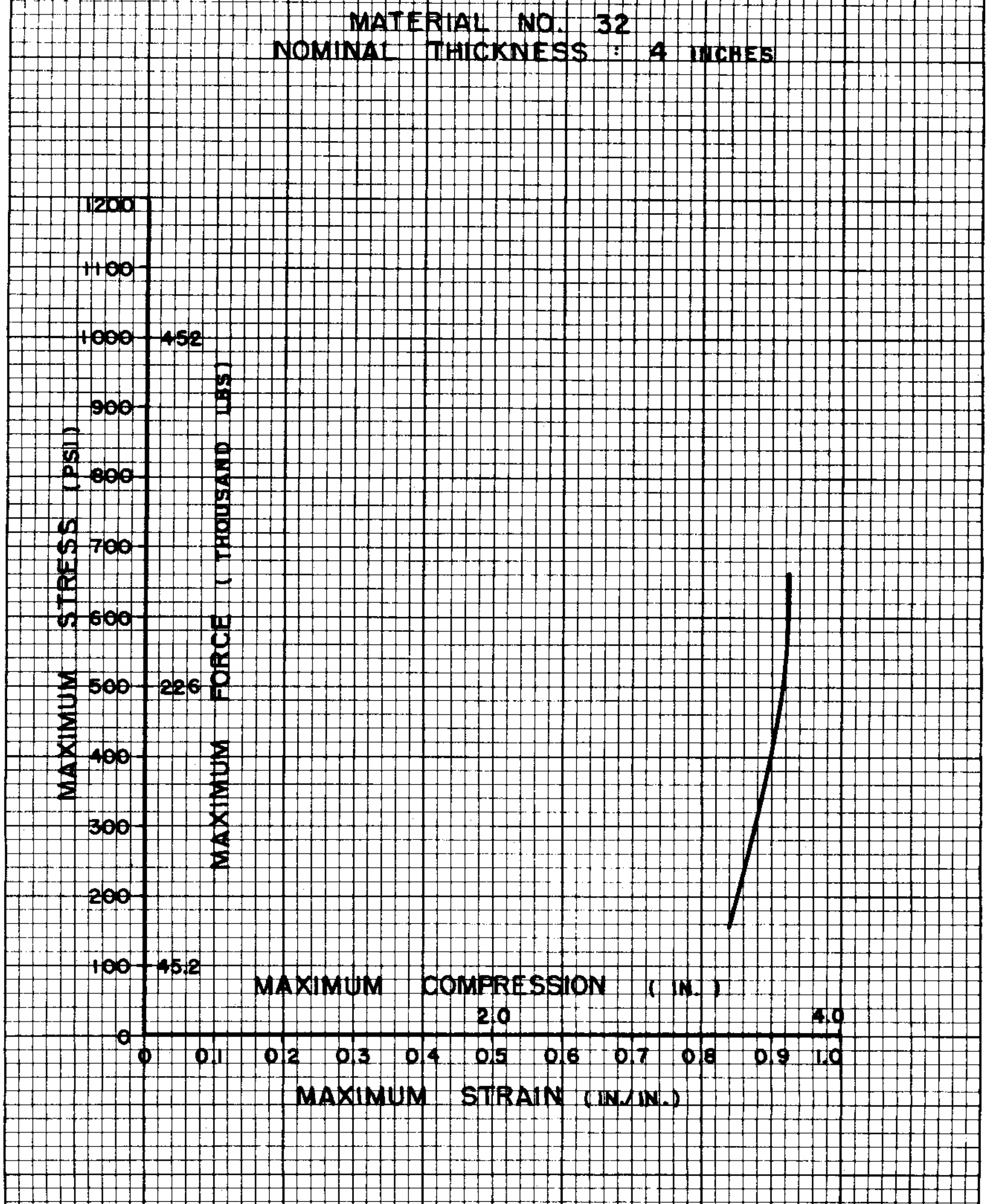

FIGURE 159 MAXIMUM STRESS - MAXIMUM STRAIN CURVE FOR 4 INCHES OF MATERIAL No. 32

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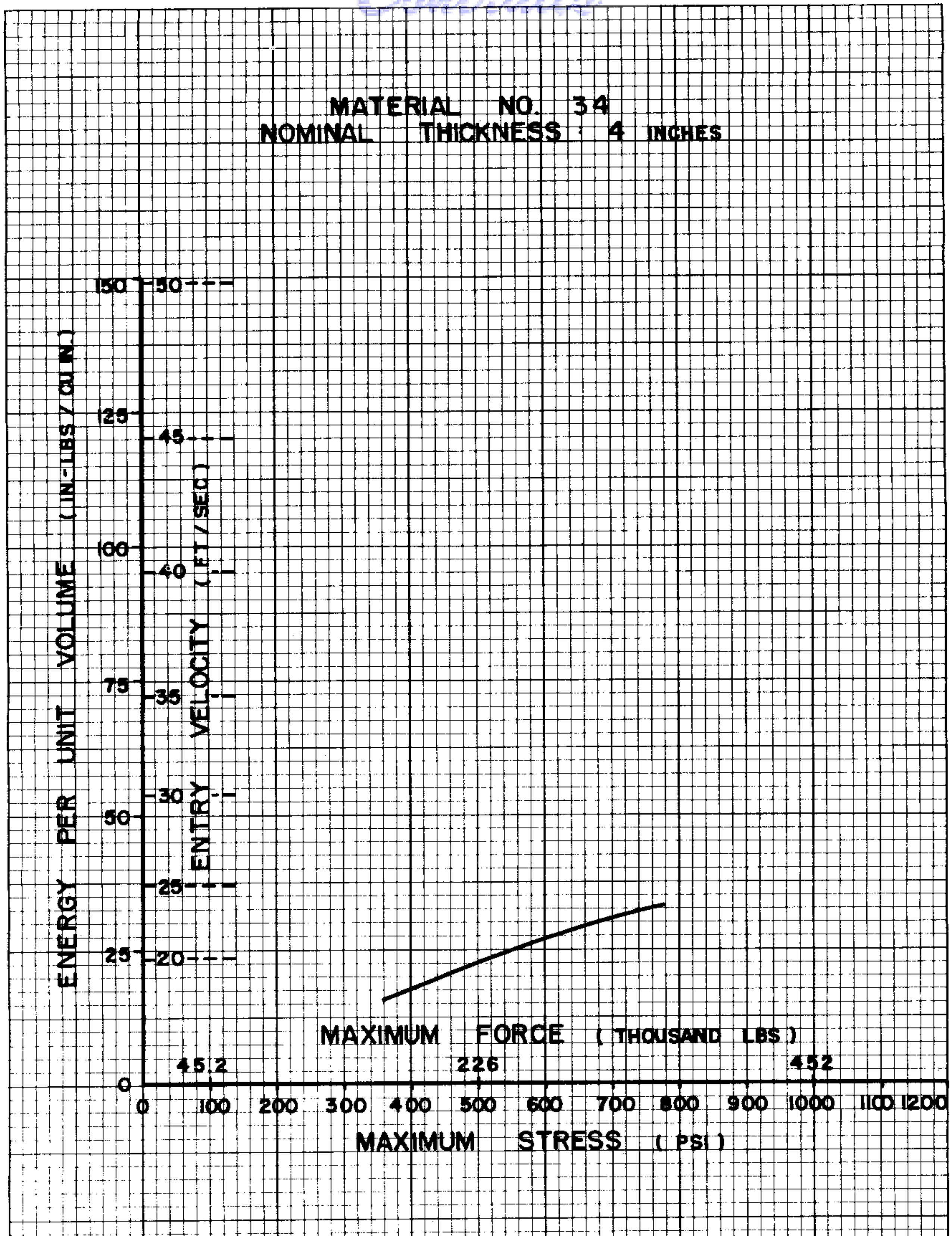

FIGURE 160 ENERGY PER UNIT VOLUME - MAXIMUM STRESS CURVE FOR 4 INCHES OF MATERIAL NO. 34

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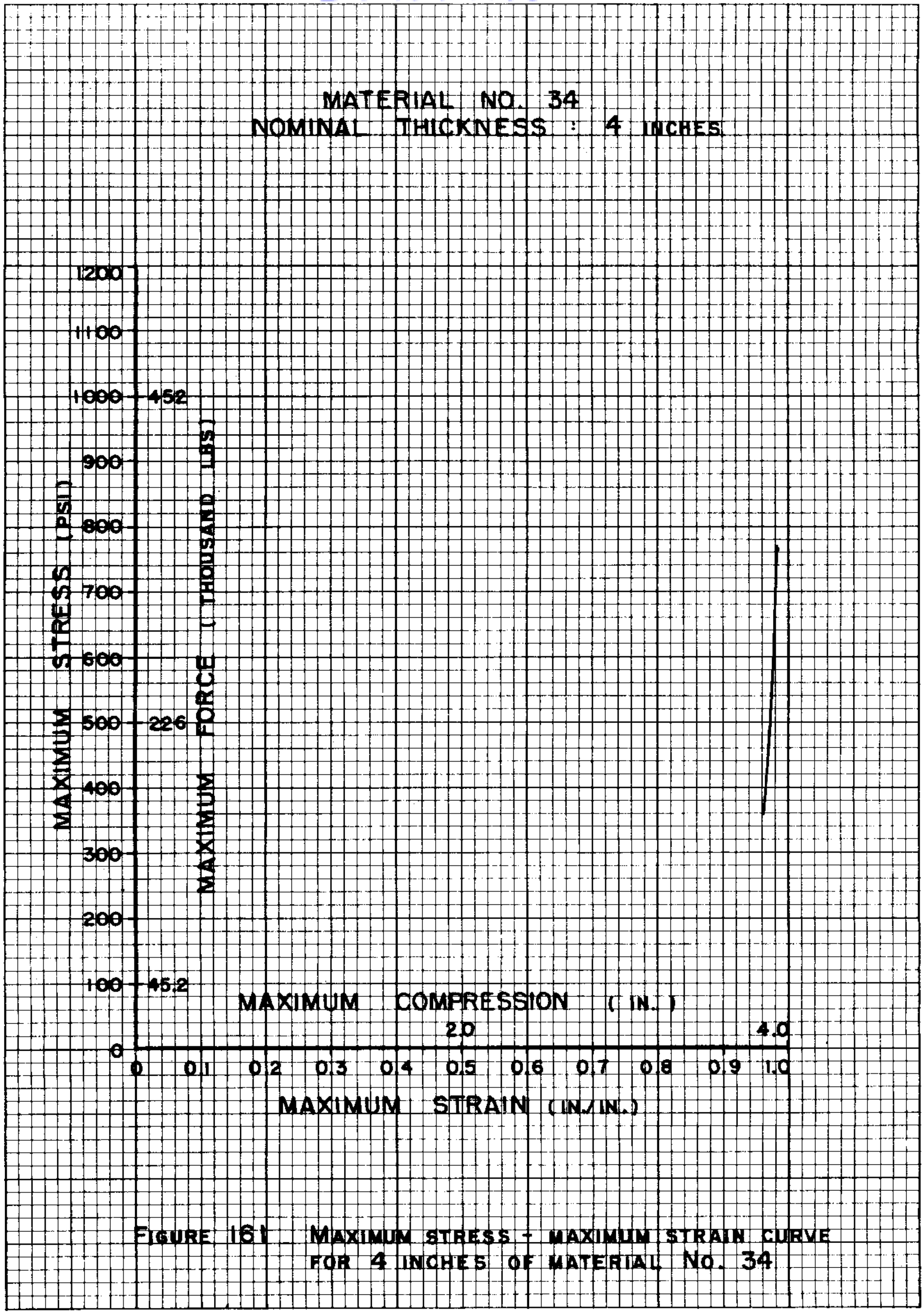

FIGURE 161 MAXIMUM STRESS - MAXIMUM STRAIN CURVE FOR 4 INCHES OF MATERIAL No. 34

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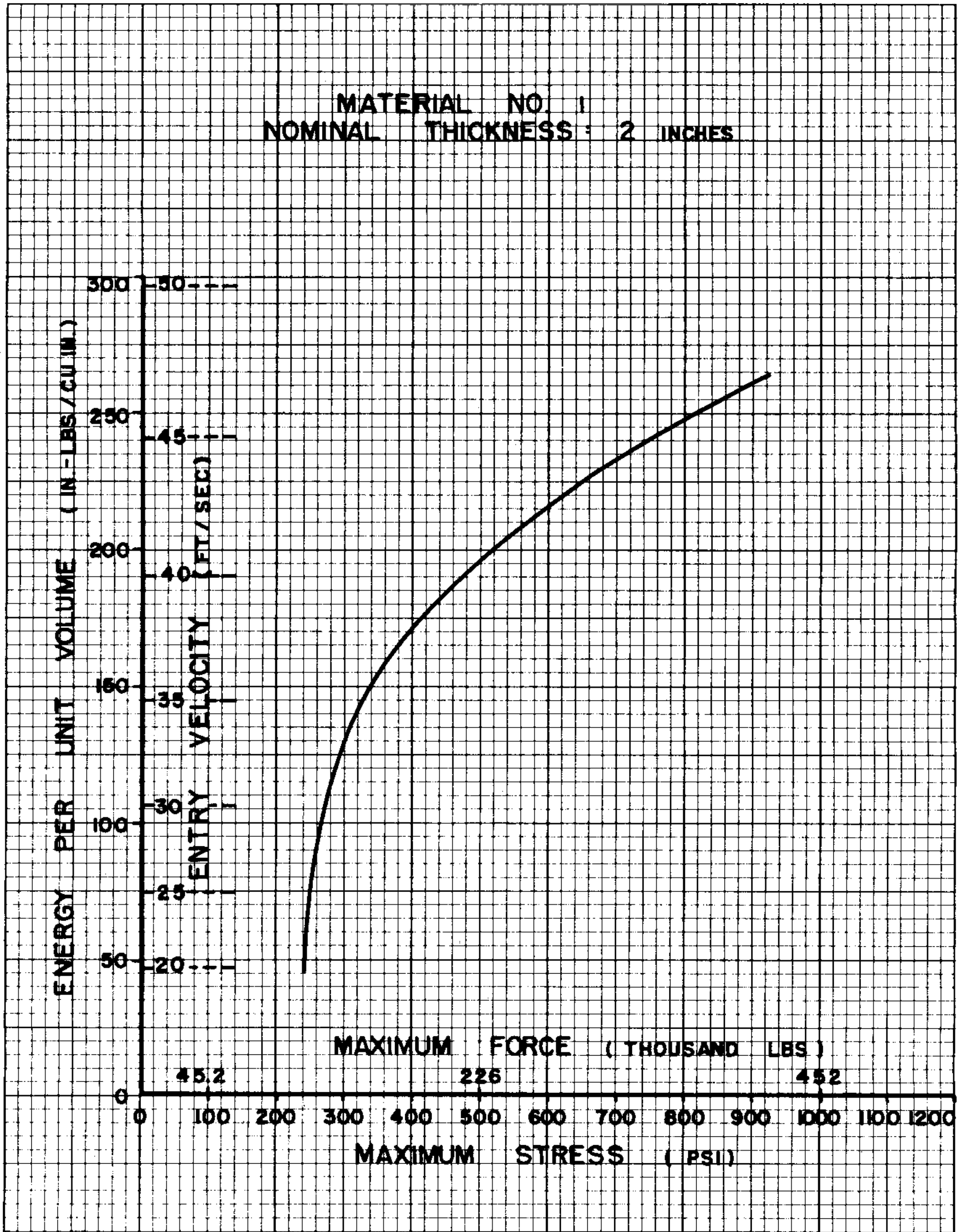

FIGURE 162 ENERGY PER UNIT VOLUME - MAXIMUM STRESS CURVE FOR 2 INCHES OF MATERIAL No. 1

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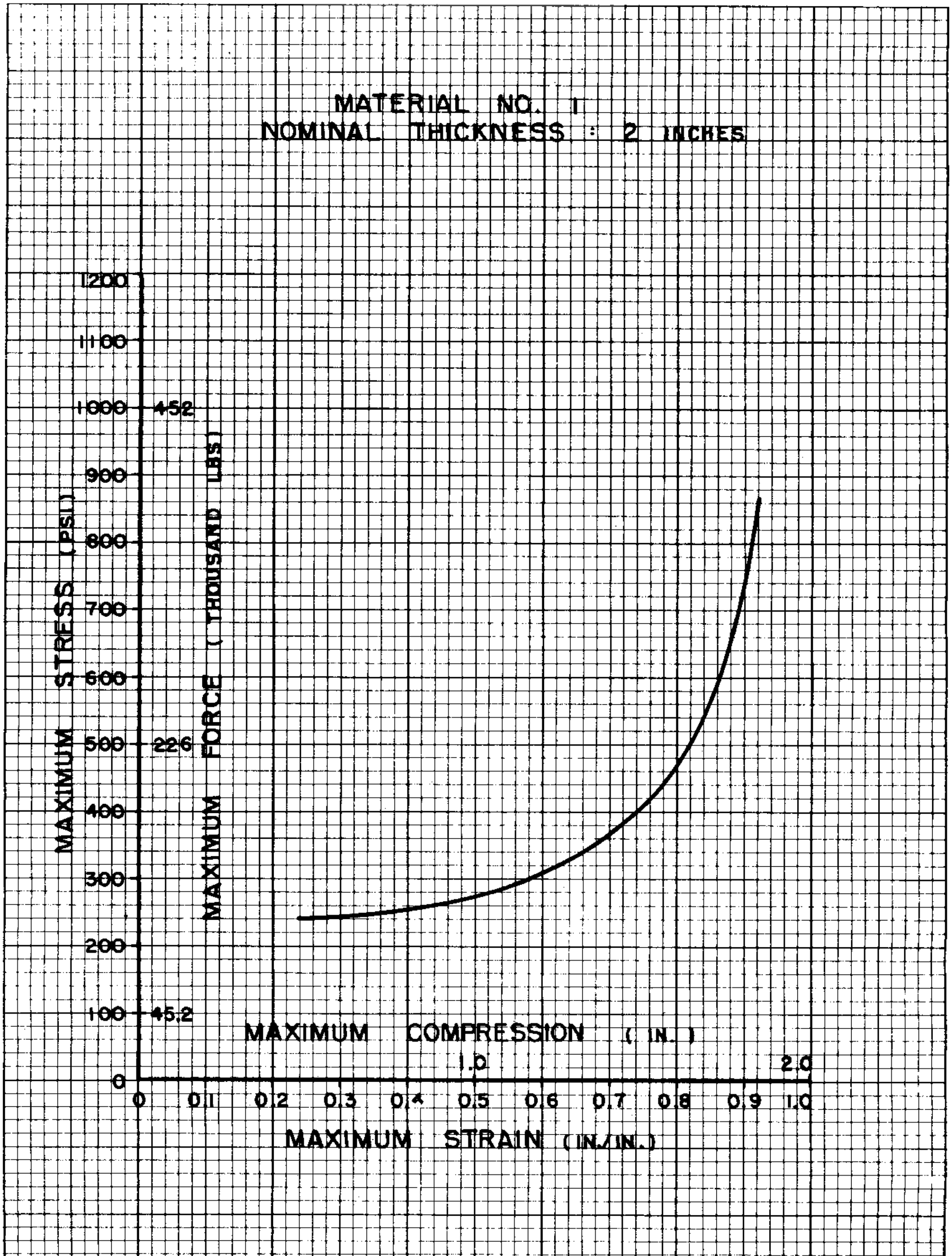

FIGURE 163. MAXIMUM STRESS - MAXIMUM STRAIN CURVE FOR 2 INCHES OF MATERIAL No. 1

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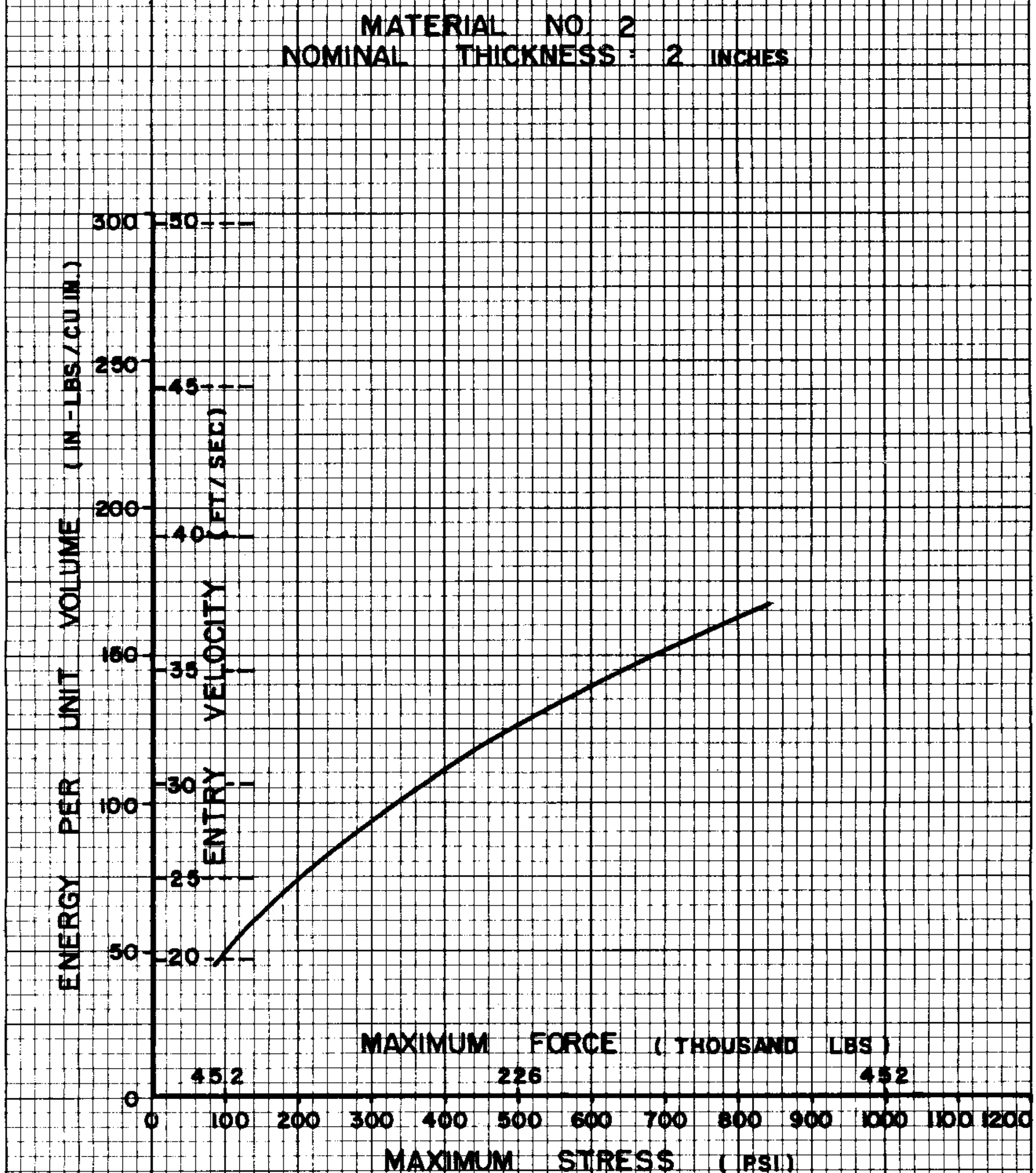

FIGURE 164 ENERGY PER UNIT VOLUME - MAXIMUM STRESS CURVE FOR 2 INCHES OF MATERIAL NO. 2

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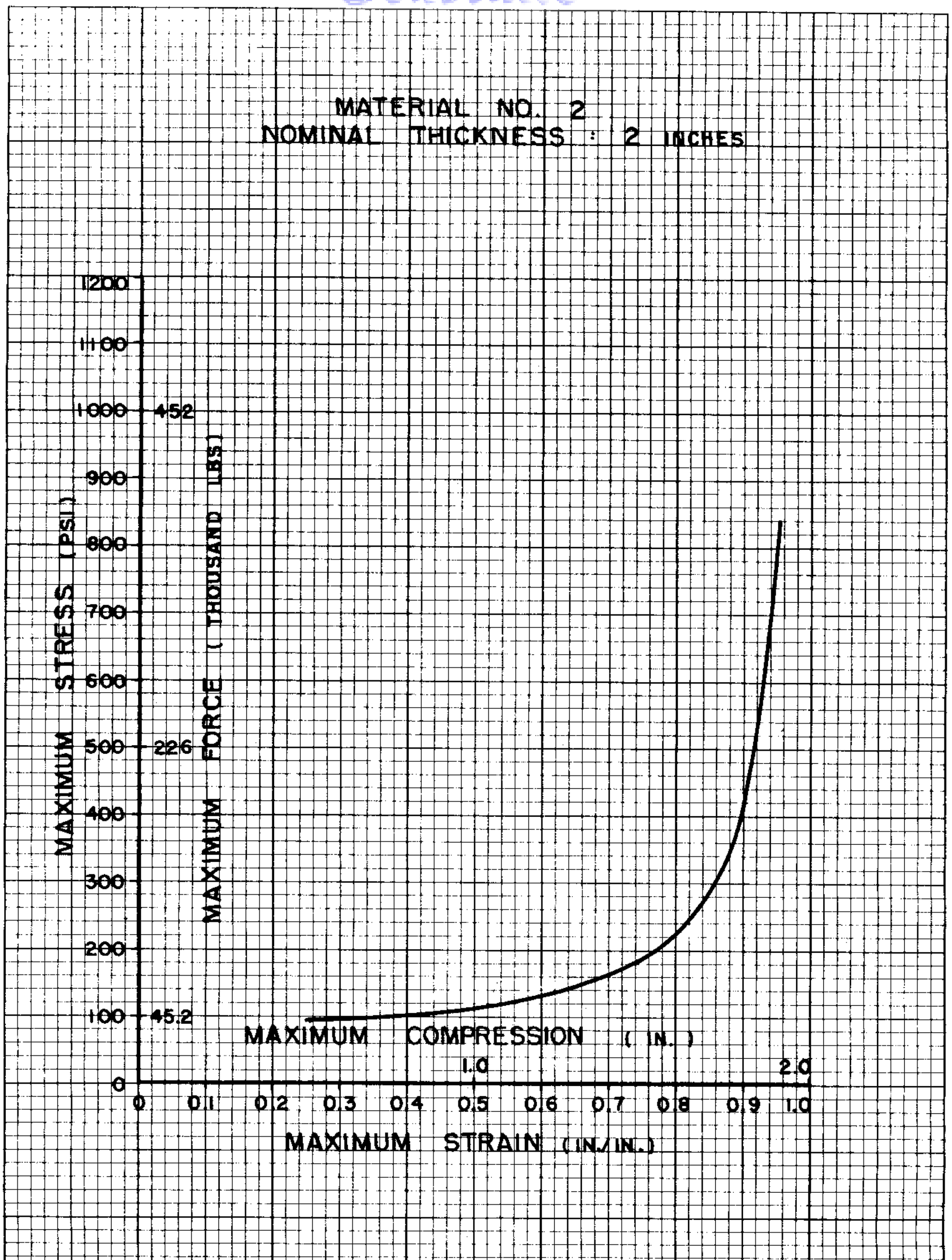

FIGURE 165 MAXIMUM STRESS - MAXIMUM STRAIN CURVE FOR 2 INCHES OF MATERIAL No. 2

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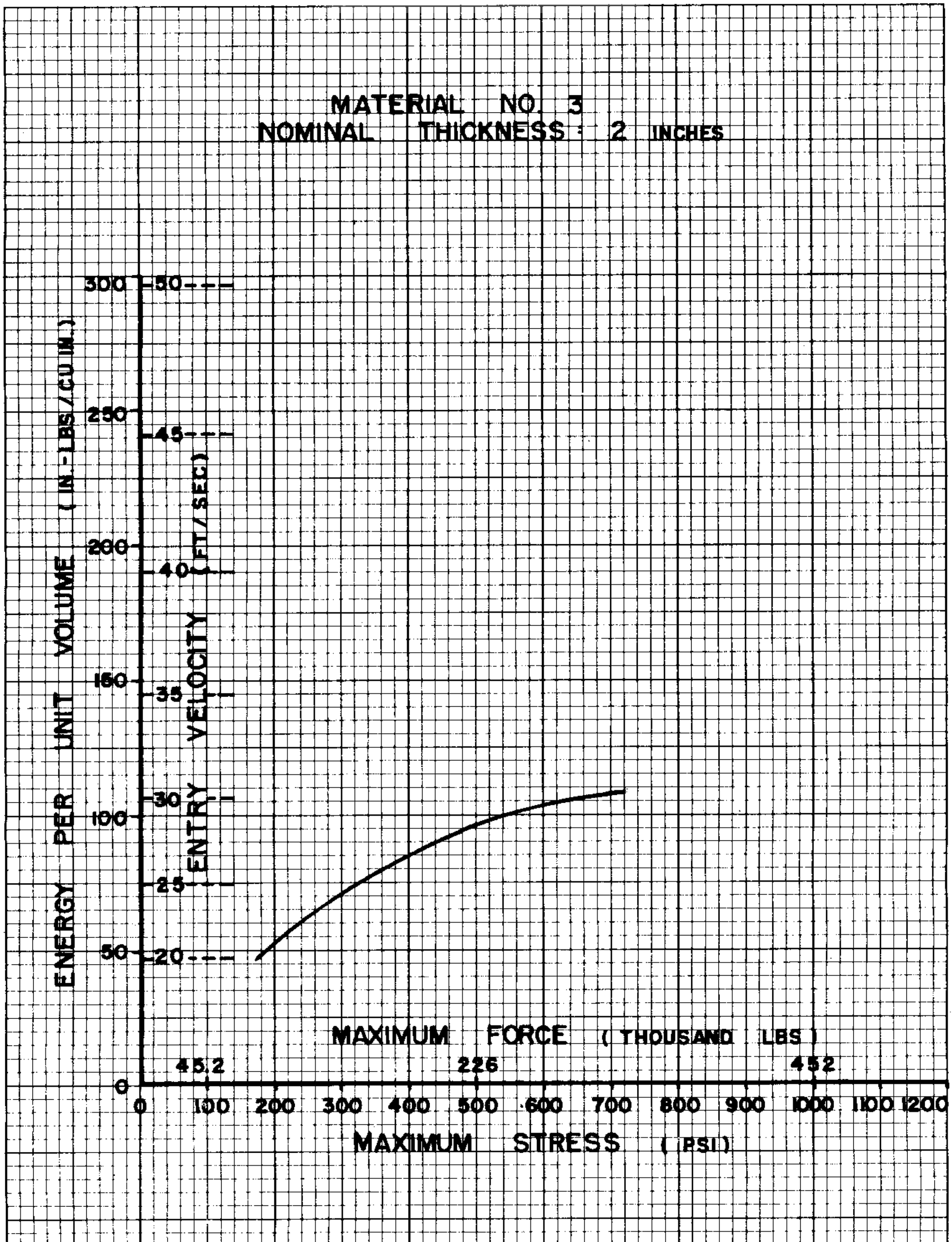

FIGURE 166 ENERGY PER UNIT VOLUME - MAXIMUM STRESS CURVE FOR 2 INCHES OF MATERIAL No. 3

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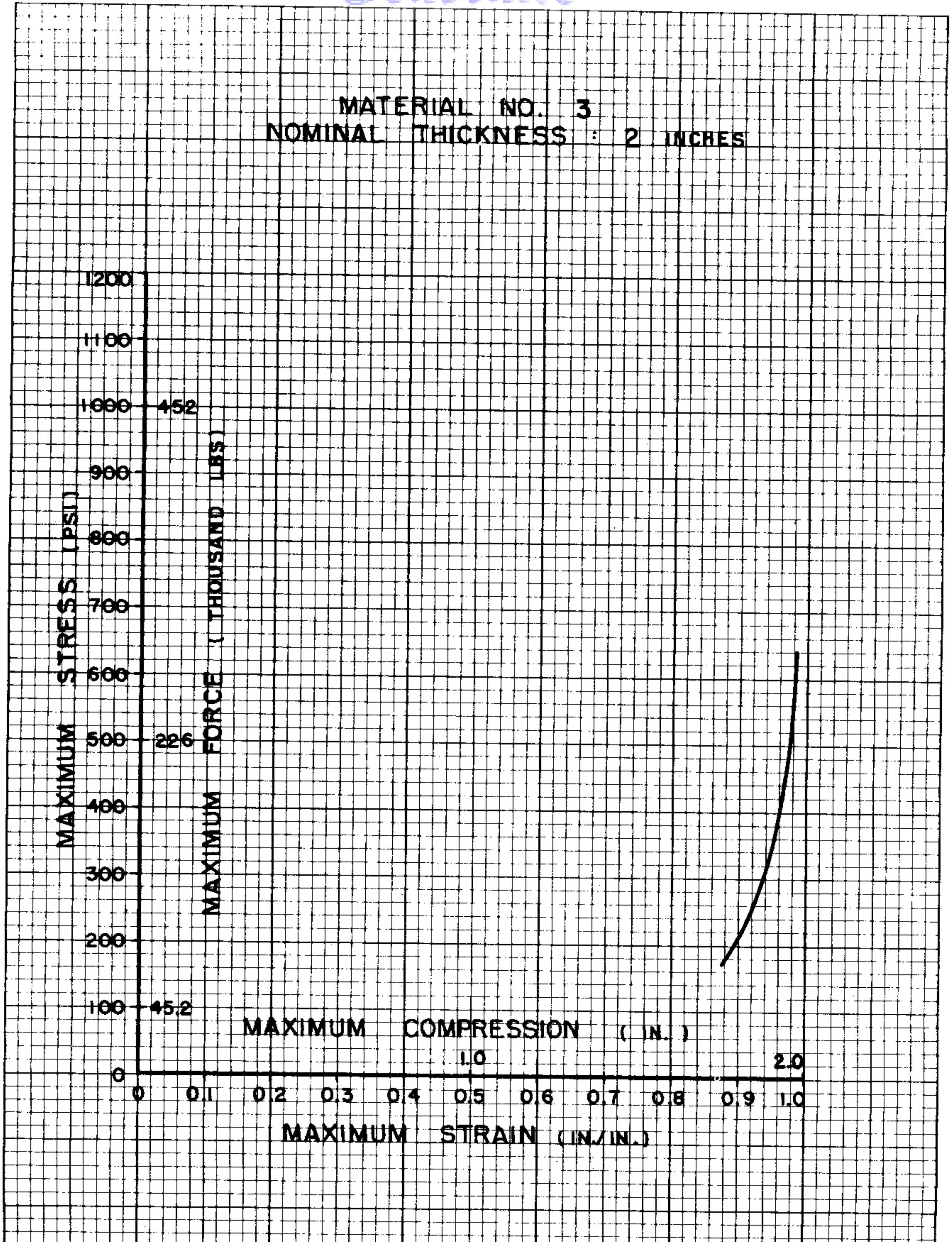

FIGURE 167 MAXIMUM STRESS - MAXIMUM STRAIN CURVE FOR 2 INCHES OF MATERIAL No. 3

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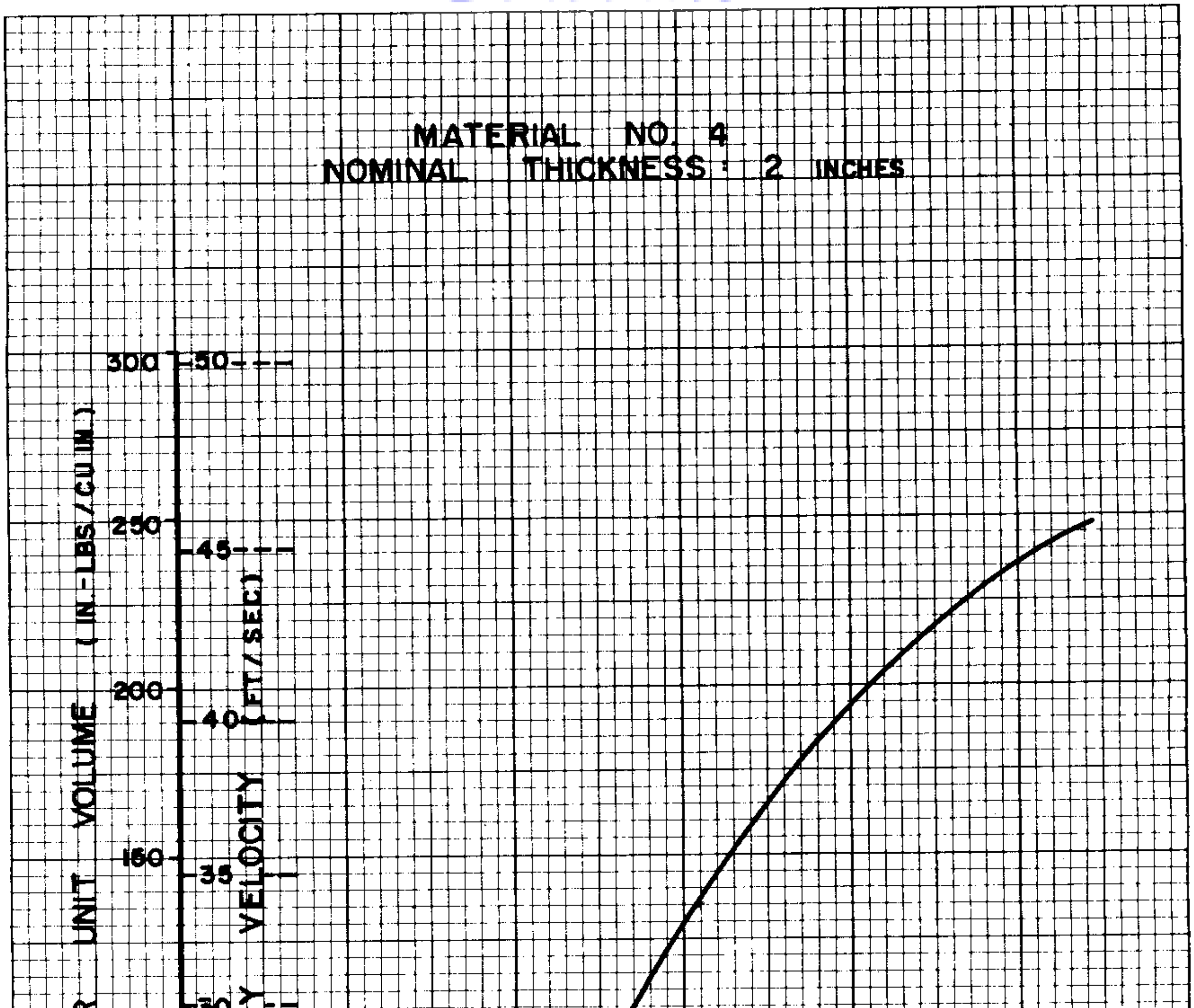

FIGURE 168 ENERGY PER UNIT VOLUME - MAXIMUM STRESS CURVE FOR 2 INCHES OF MATERIAL NO. 4

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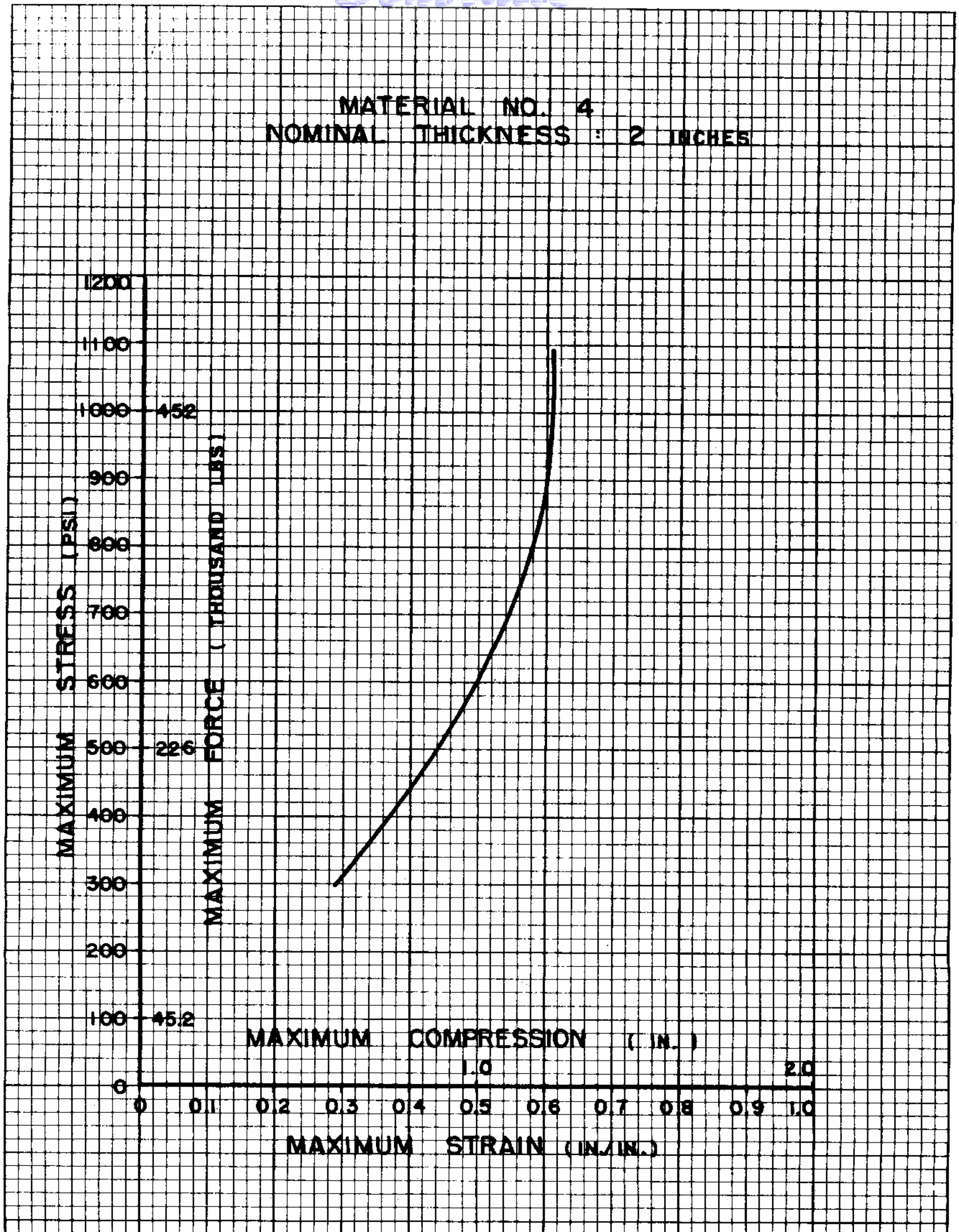

FIGURE 169 MAXIMUM STRESS - MAXIMUM STRAIN CURVE FOR 2 INCHES OF MATERIAL NO. 4

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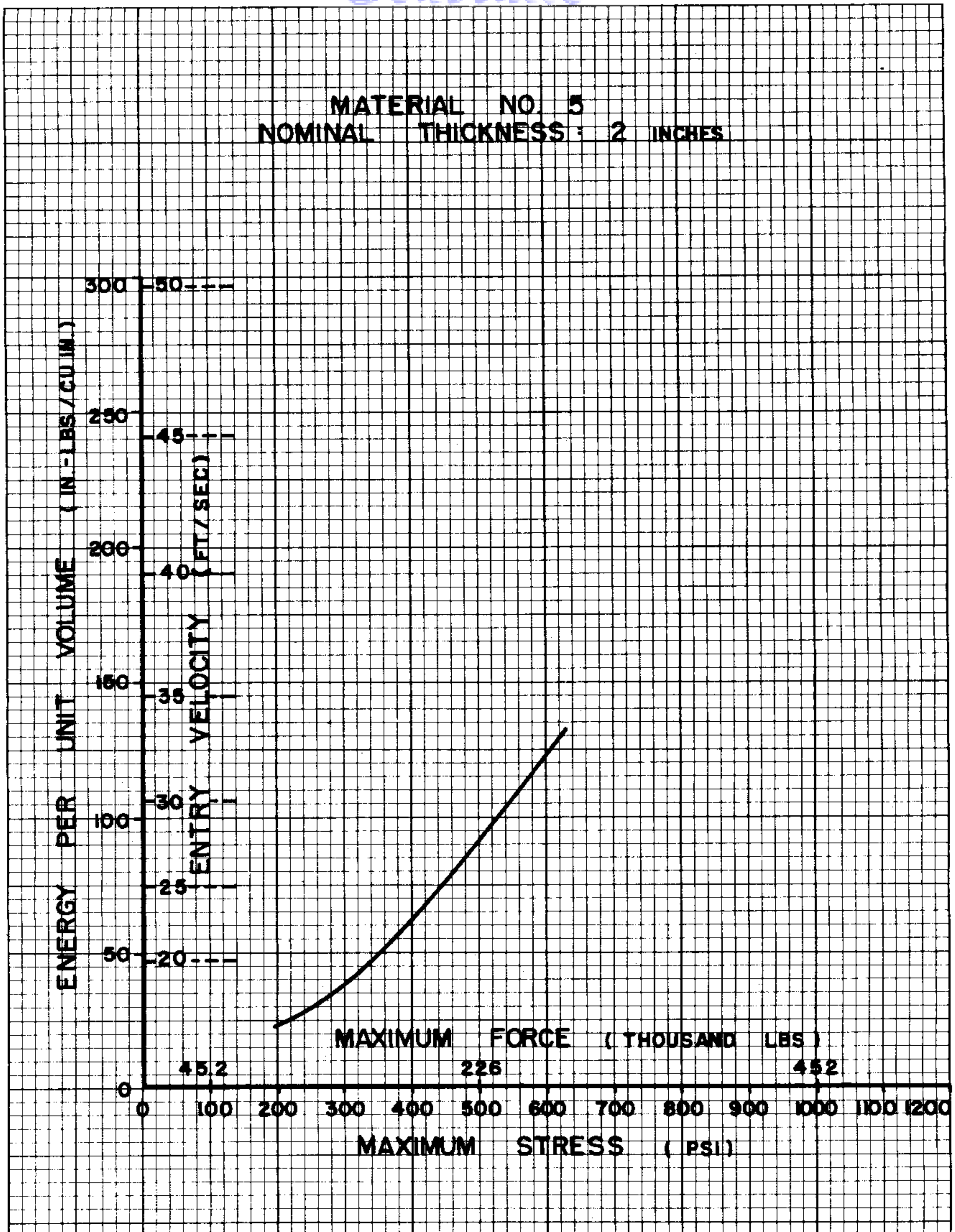

FIGURE 170 ENERGY PER UNIT VOLUME - MAXIMUM STRESS CURVE FOR 2 INCHES OF MATERIAL NO. 5

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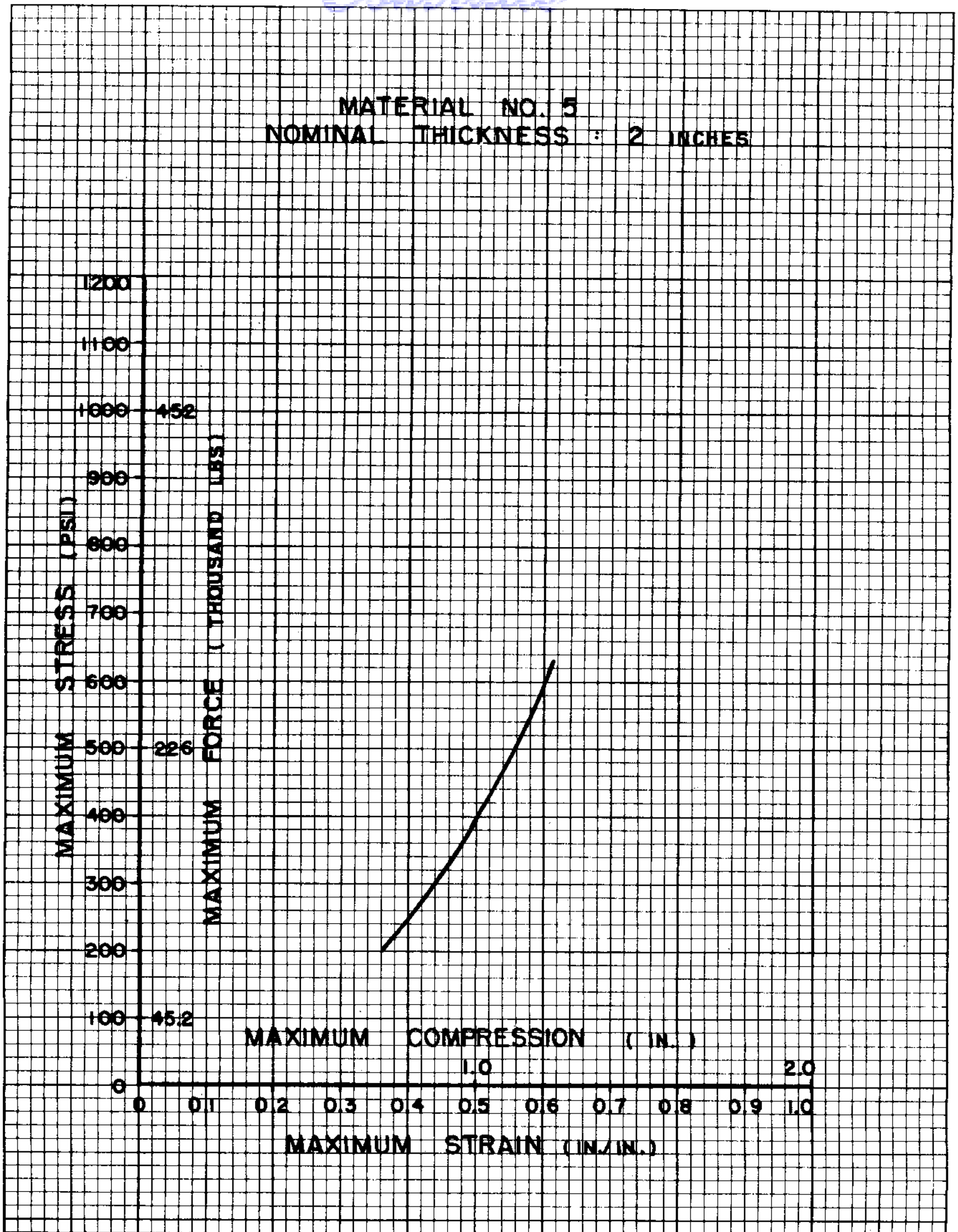

FIGURE 171 MAXIMUM STRESS - MAXIMUM STRAIN CURVE FOR 2 INCHES OF MATERIAL No. 5

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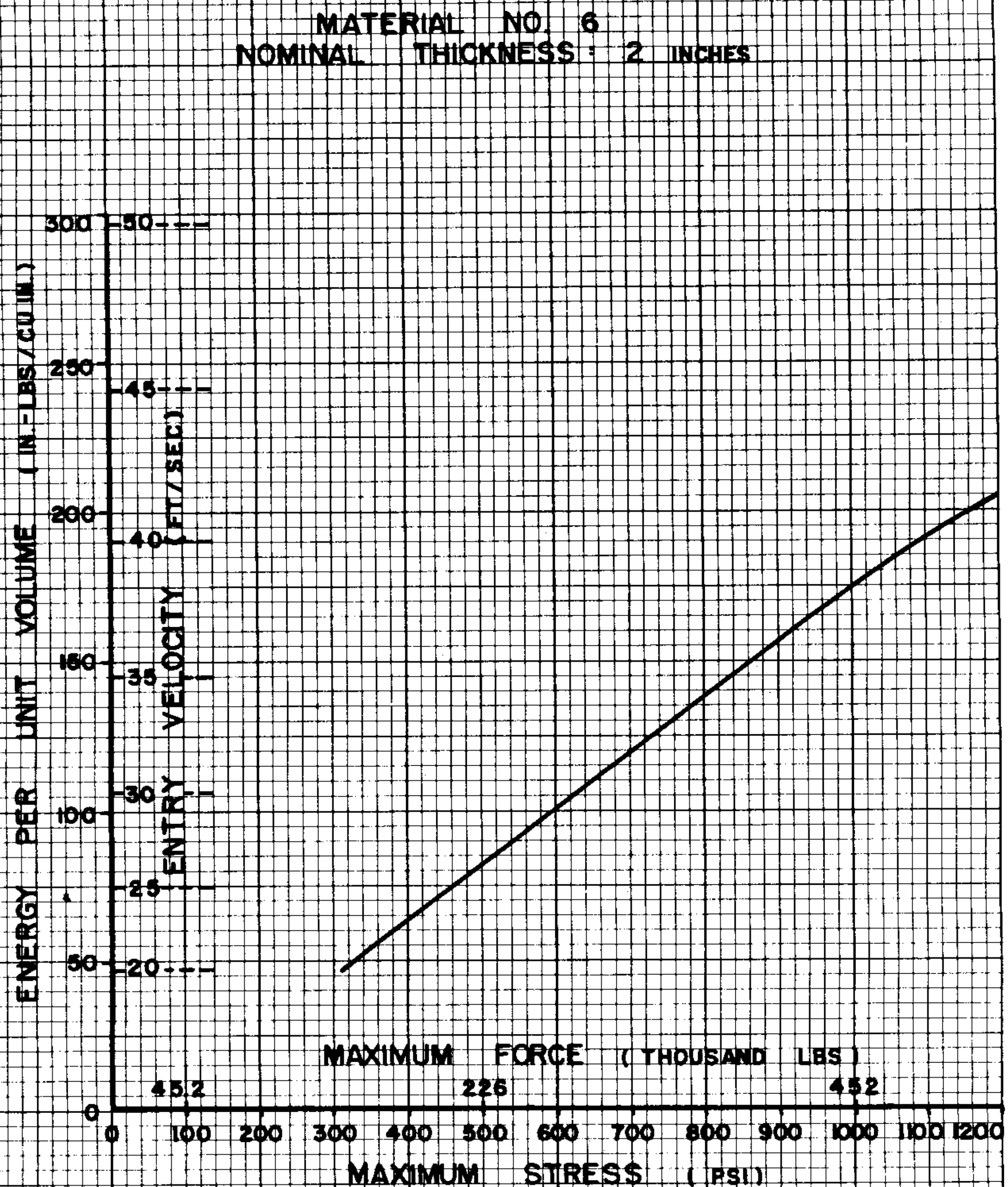

FIGURE 172 ENERGY PER UNIT VOLUME - MAXIMUM STRESS CURVE FOR 2 INCHES OF MATERIAL NO. 6

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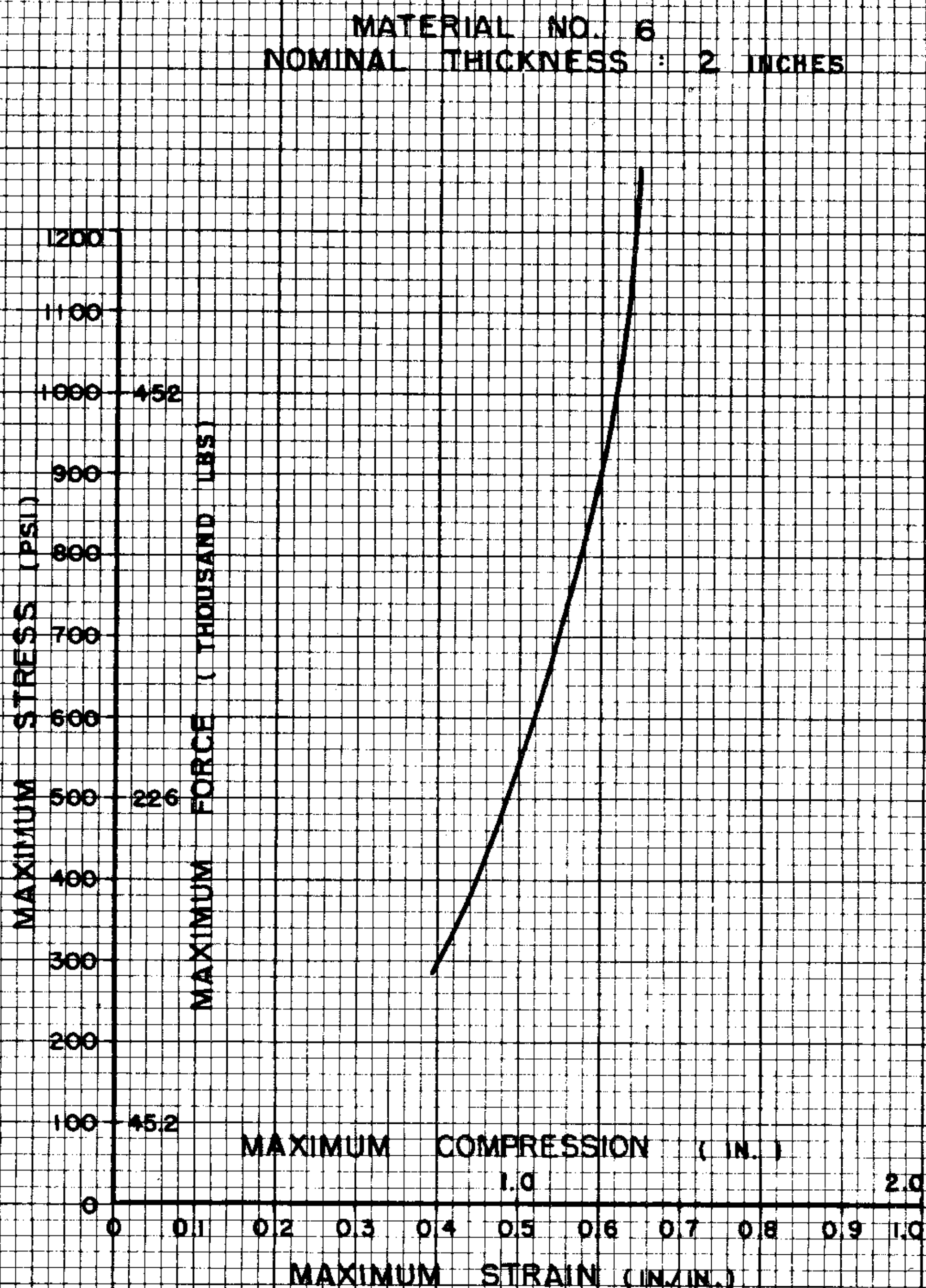

FIGURE 173 MAXIMUM STRESS - MAXIMUM STRAIN CURVE FOR 2 INCHES OF MATERIAL No. 6

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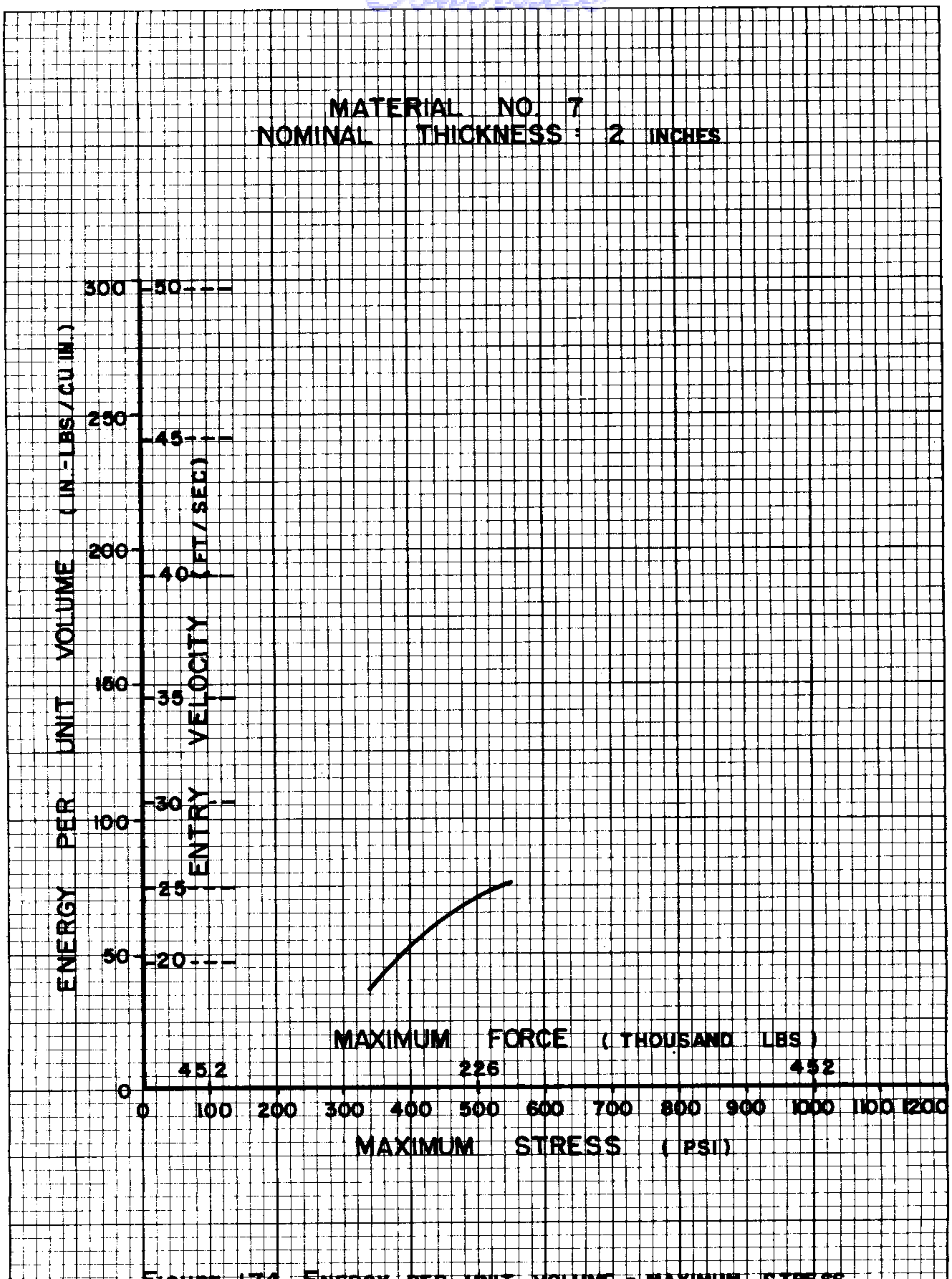

FIGURE 174 ENERGY PER UNIT VOLUME - MAXIMUM STRESS CURVE FOR 2 INCHES OF MATERIAL NO. 7

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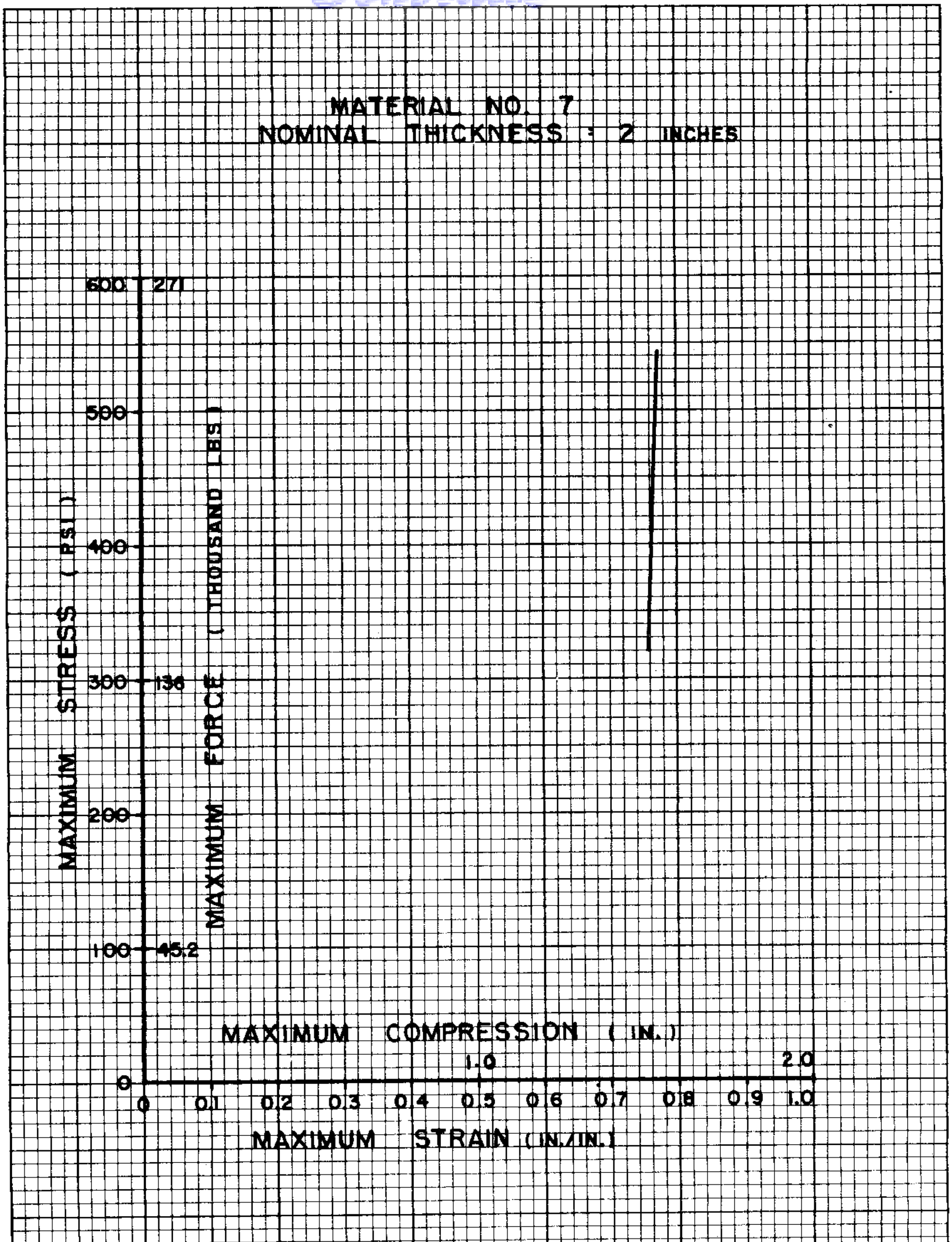

FIGURE 175. MAXIMUM STRESS - MAXIMUM STRAIN CURVE FOR 2 INCHES OF MATERIAL NO. 7

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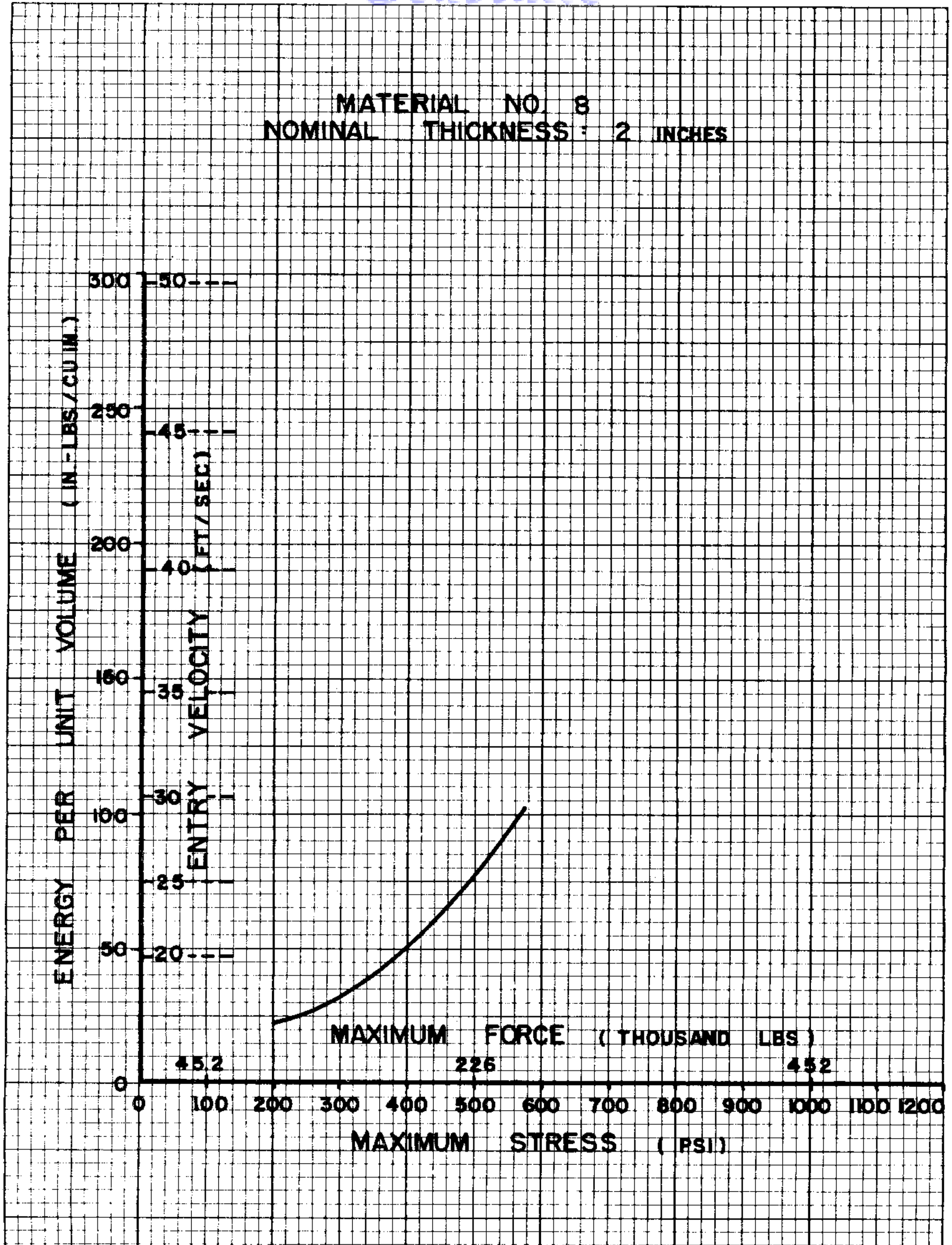

FIGURE 176 ENERGY PER UNIT VOLUME - MAXIMUM STRESS CURVE FOR 2 INCHES OF MATERIAL NO. 8

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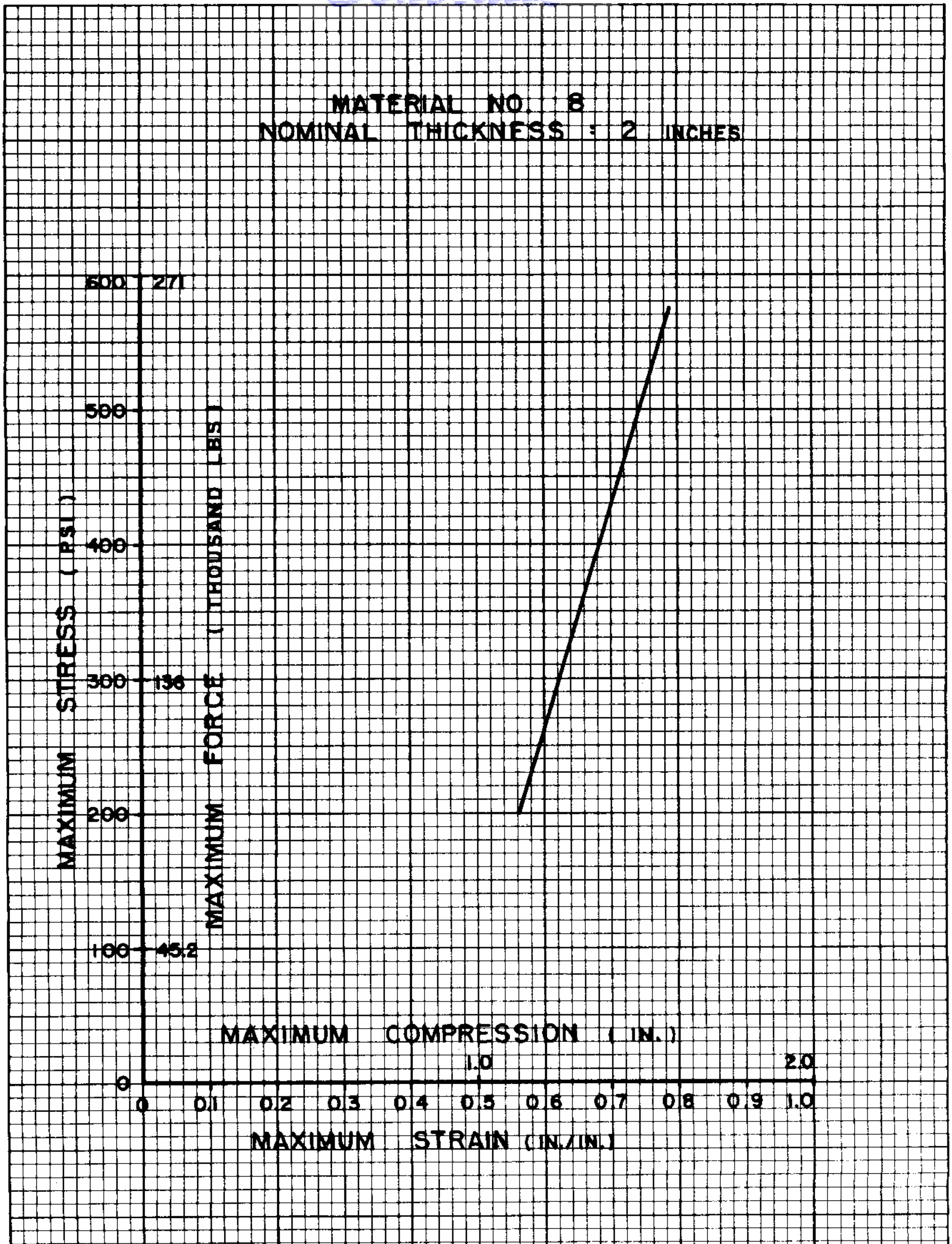

FIGURE 177. MAXIMUM STRESS - MAXIMUM STRAIN CURVE FOR 2 INCHES OF MATERIAL No. 8

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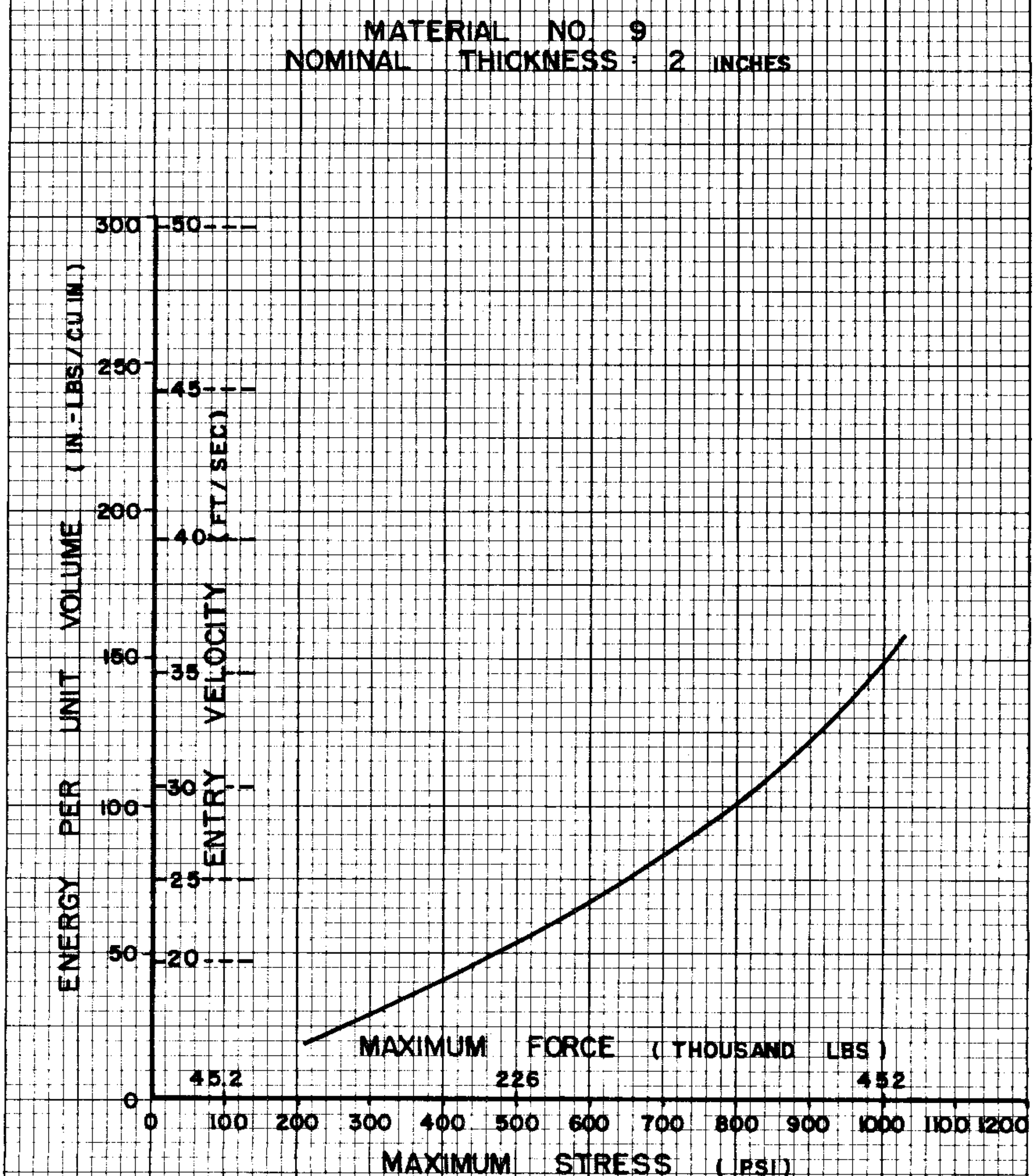

FIGURE 178 ENERGY PER UNIT VOLUME - MAXIMUM STRESS CURVE FOR 2 INCHES OF MATERIAL NO. 9

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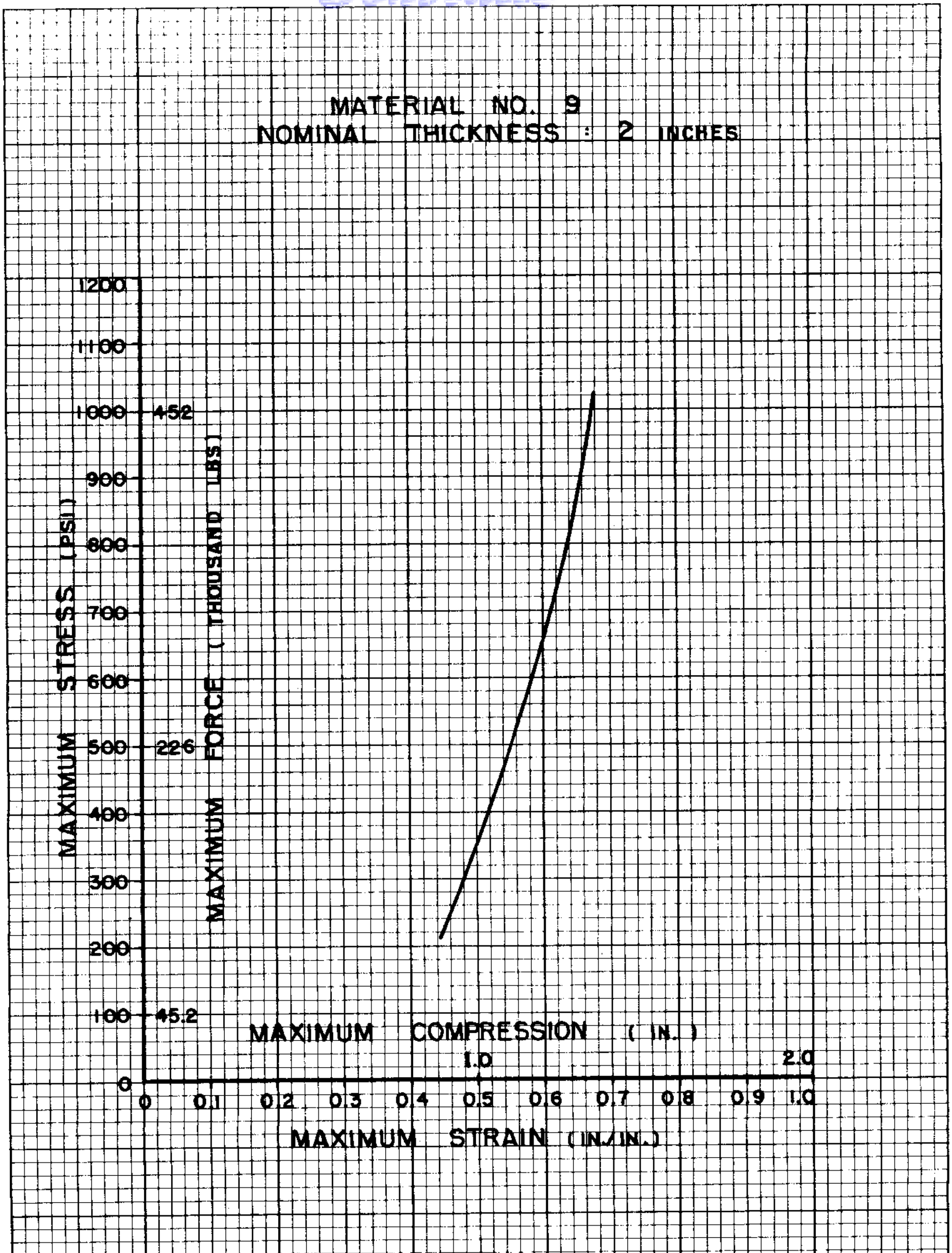

FIGURE 179 MAXIMUM STRESS - MAXIMUM STRAIN CURVE FOR 2 INCHES OF MATERIAL NO. 9

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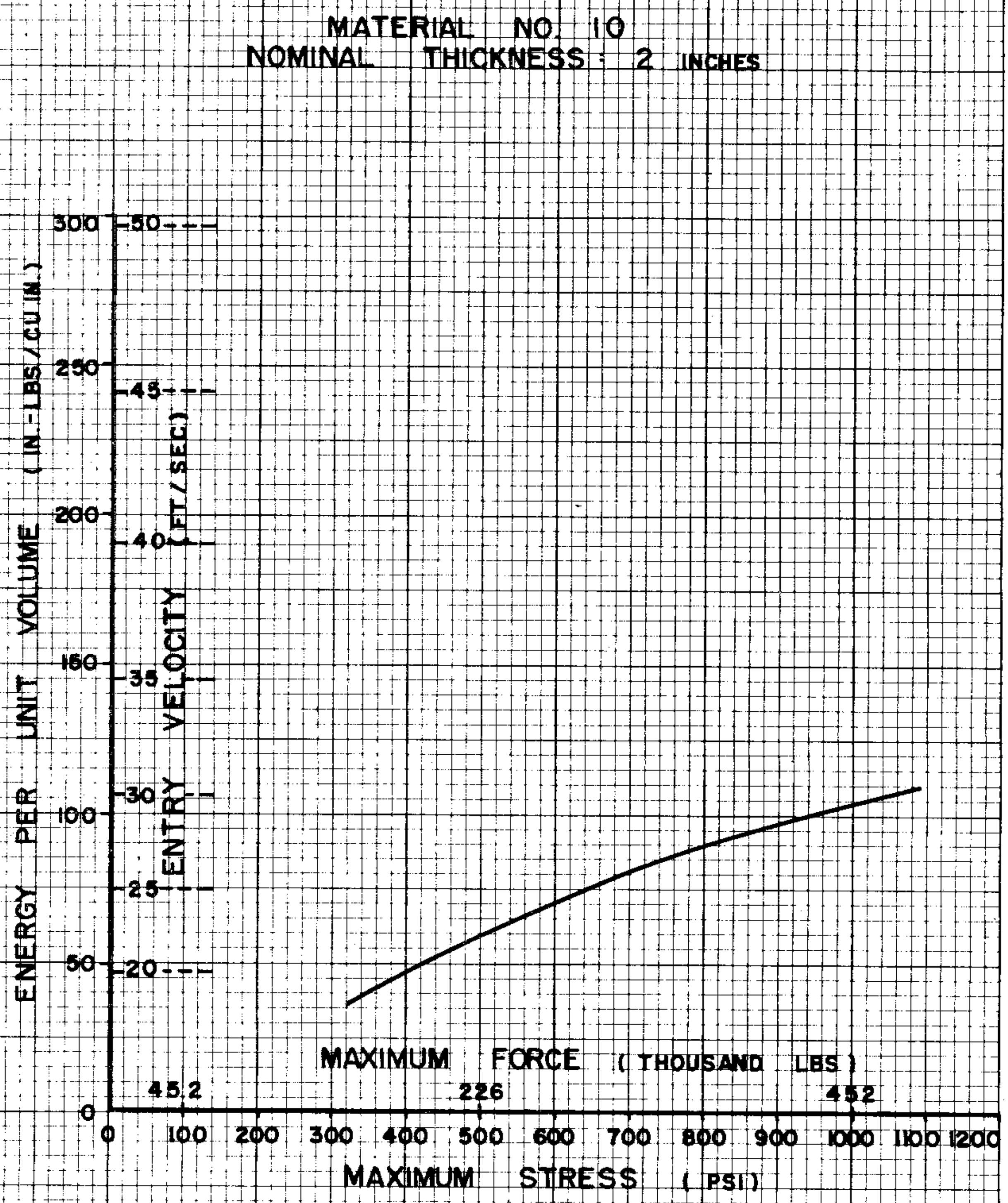

FIGURE 180 ENERGY PER UNIT VOLUME - MAXIMUM STRESS CURVE FOR 2 INCHES OF MATERIAL No. 10

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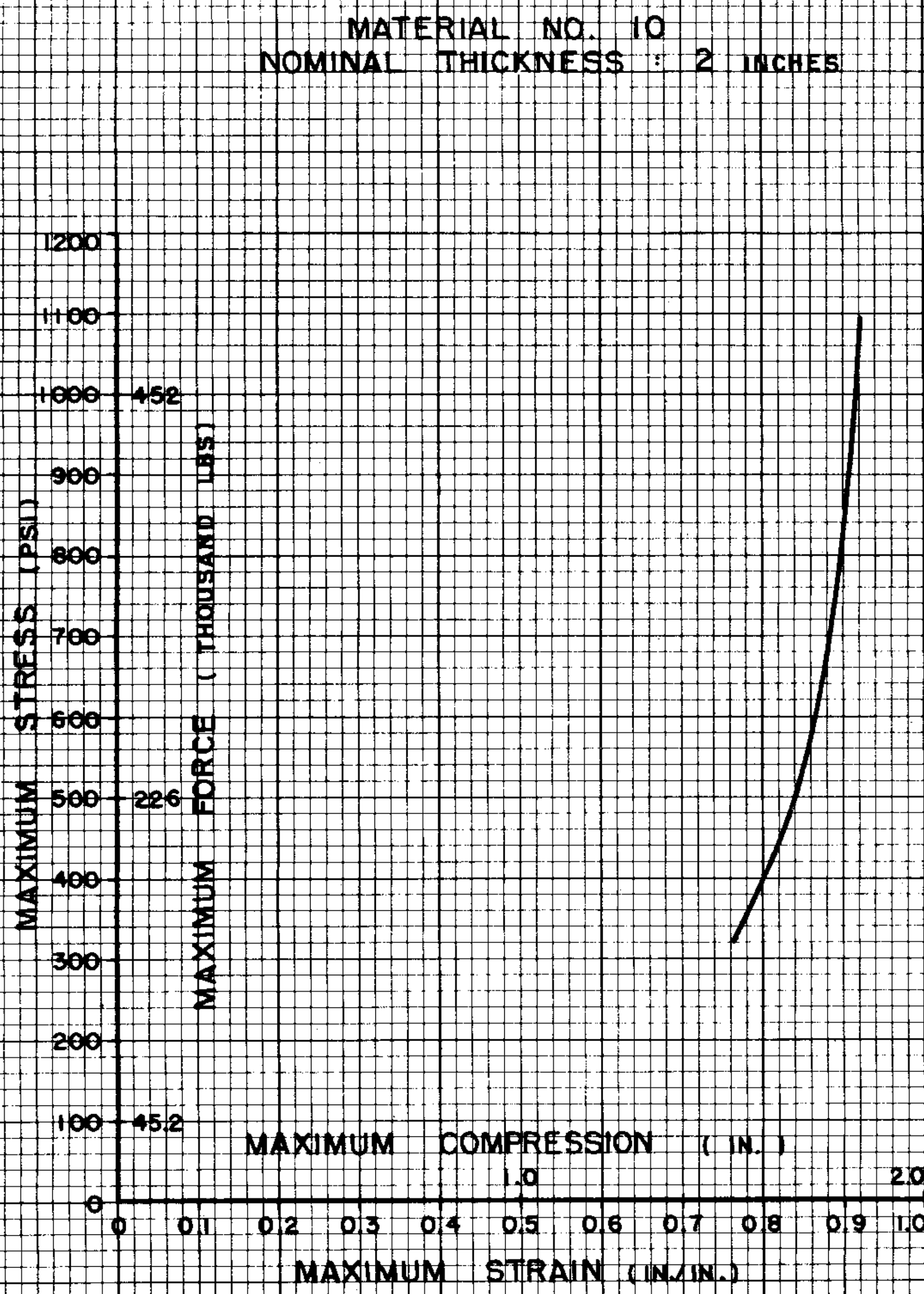

FIGURE 181 MAXIMUM STRESS - MAXIMUM STRAIN CURVE FOR 2 INCHES OF MATERIAL No. 10

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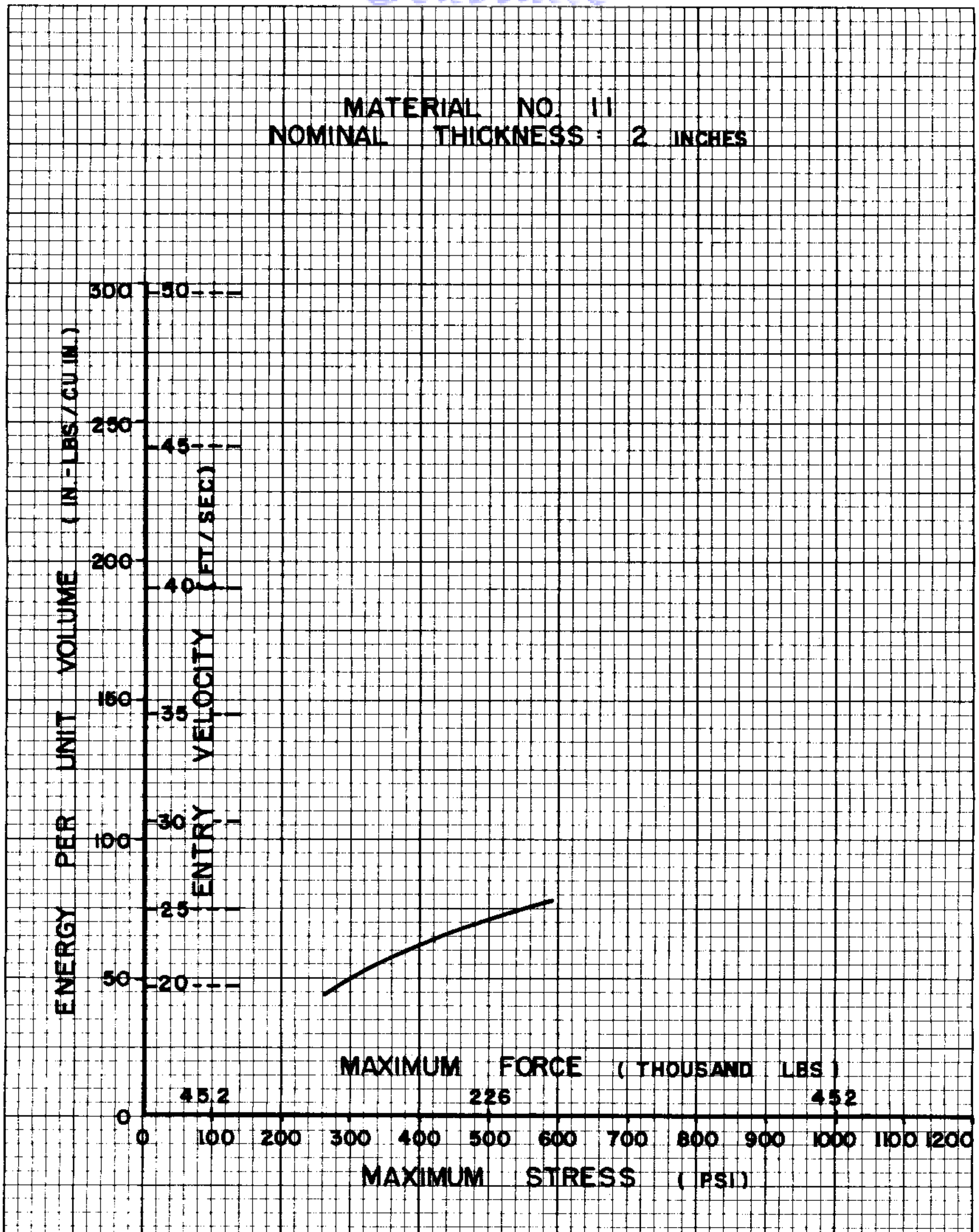

FIGURE 182 ENERGY PER UNIT VOLUME - MAXIMUM STRESS CURVE FOR 2 INCHES OF MATERIAL NO. 11

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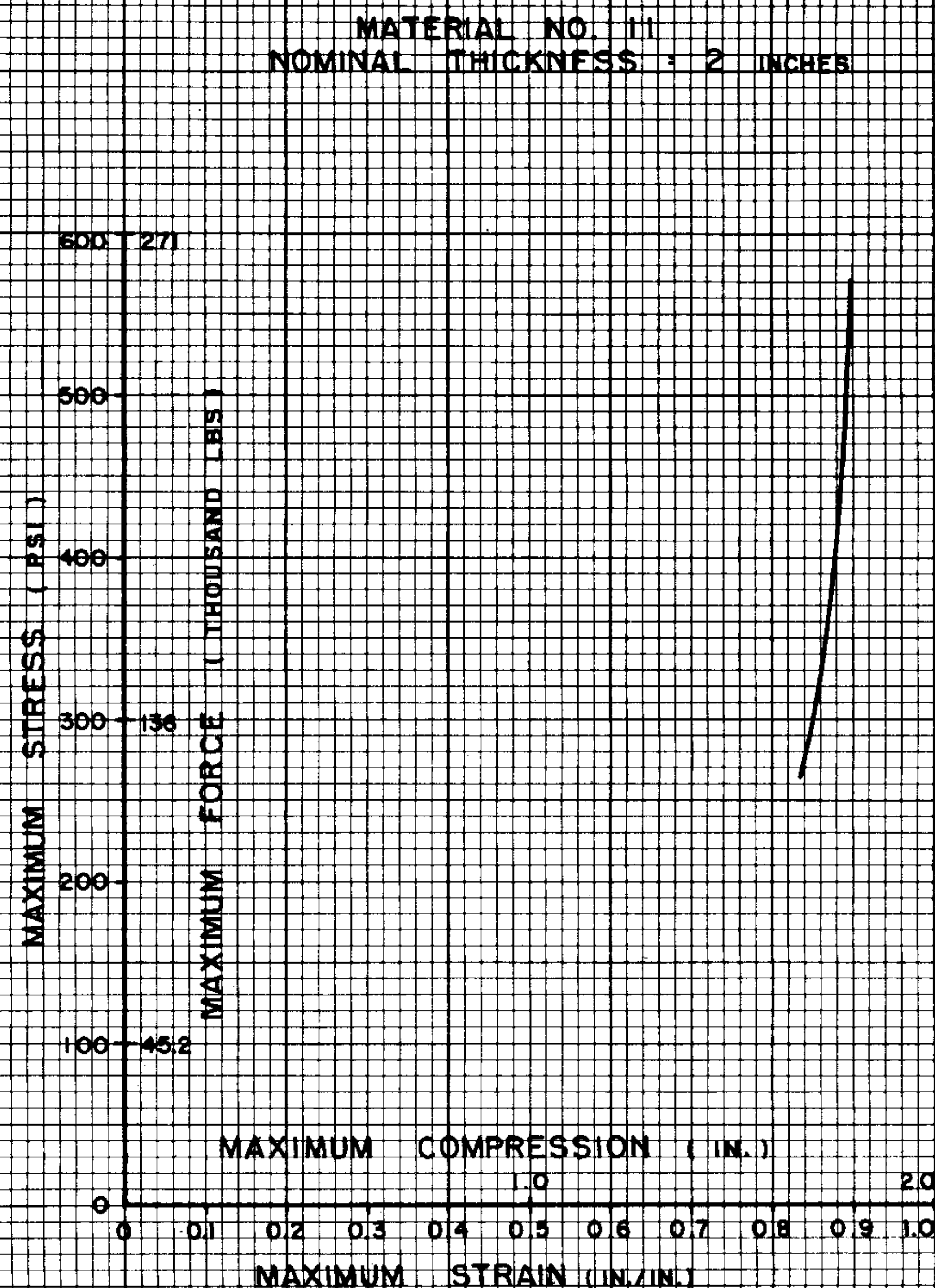

FIGURE 183. MAXIMUM STRESS - MAXIMUM STRAIN CURVE FOR 2 INCHES OF MATERIAL No. 11

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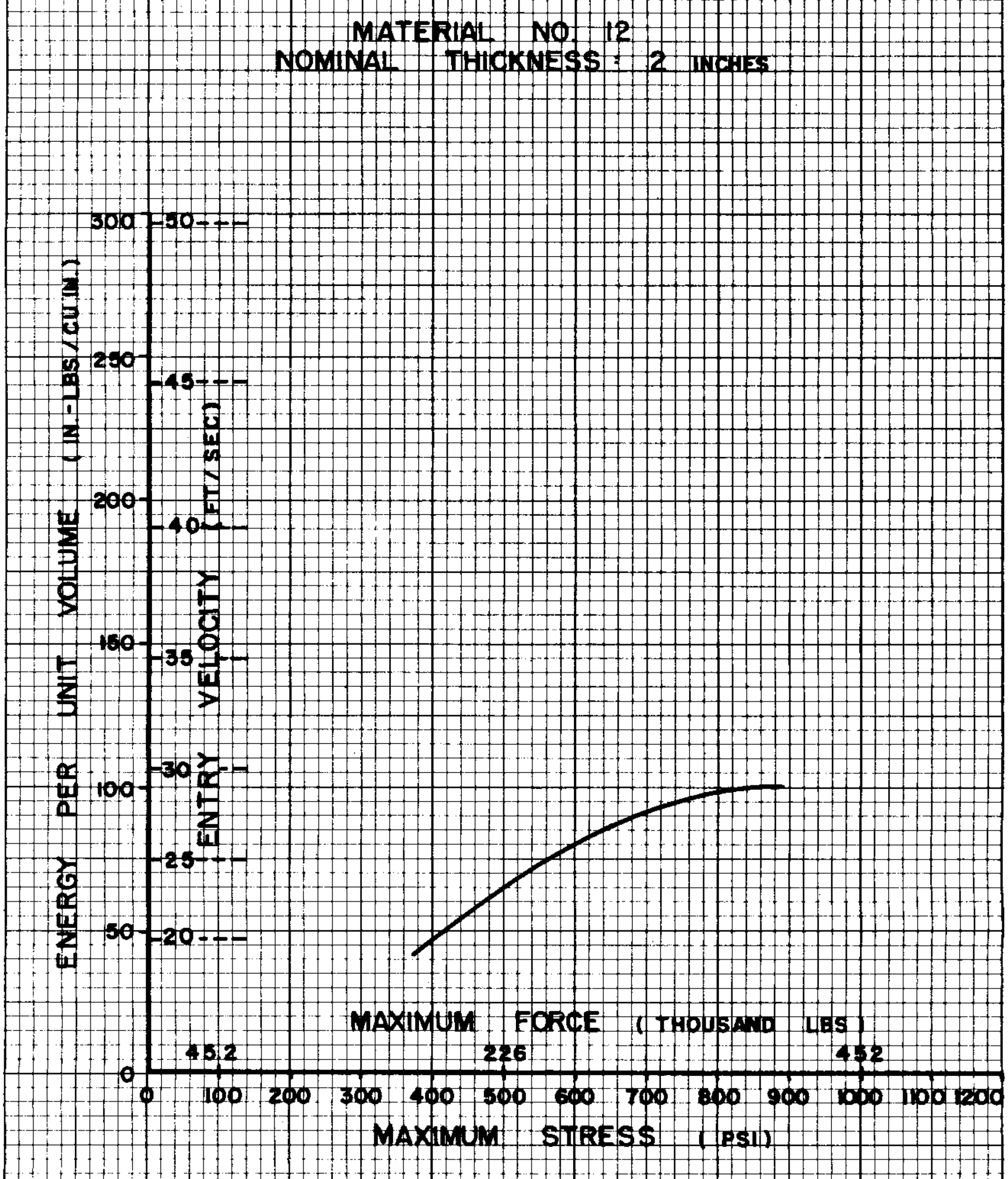

FIGURE 184 ENERGY PER UNIT VOLUME - MAXIMUM STRESS CURVE FOR 2 INCHES OF MATERIAL NO. 12

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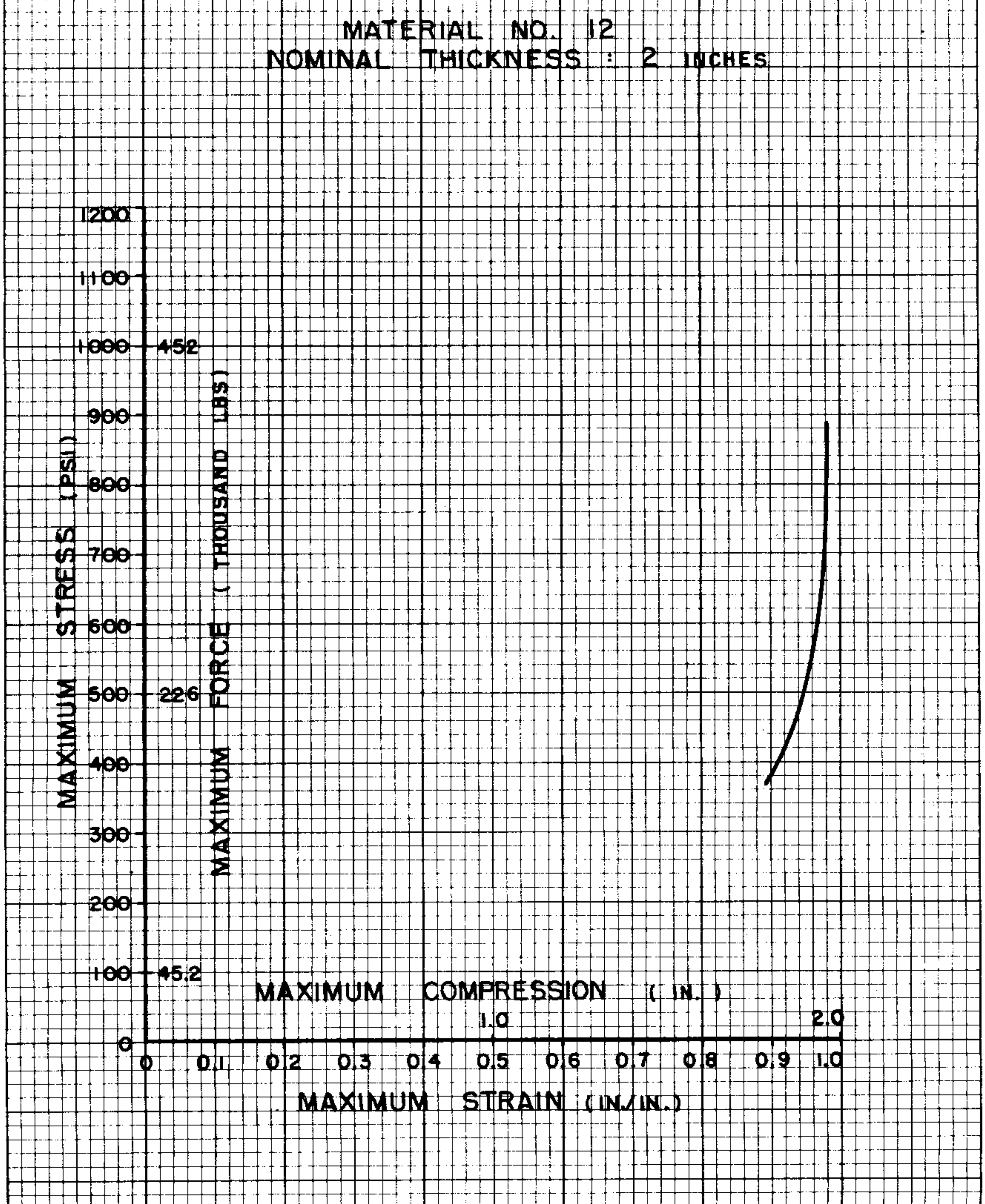

FIGURE 185 MAXIMUM STRESS - MAXIMUM STRAIN CURVE FOR 2 INCHES OF MATERIAL NO. 12

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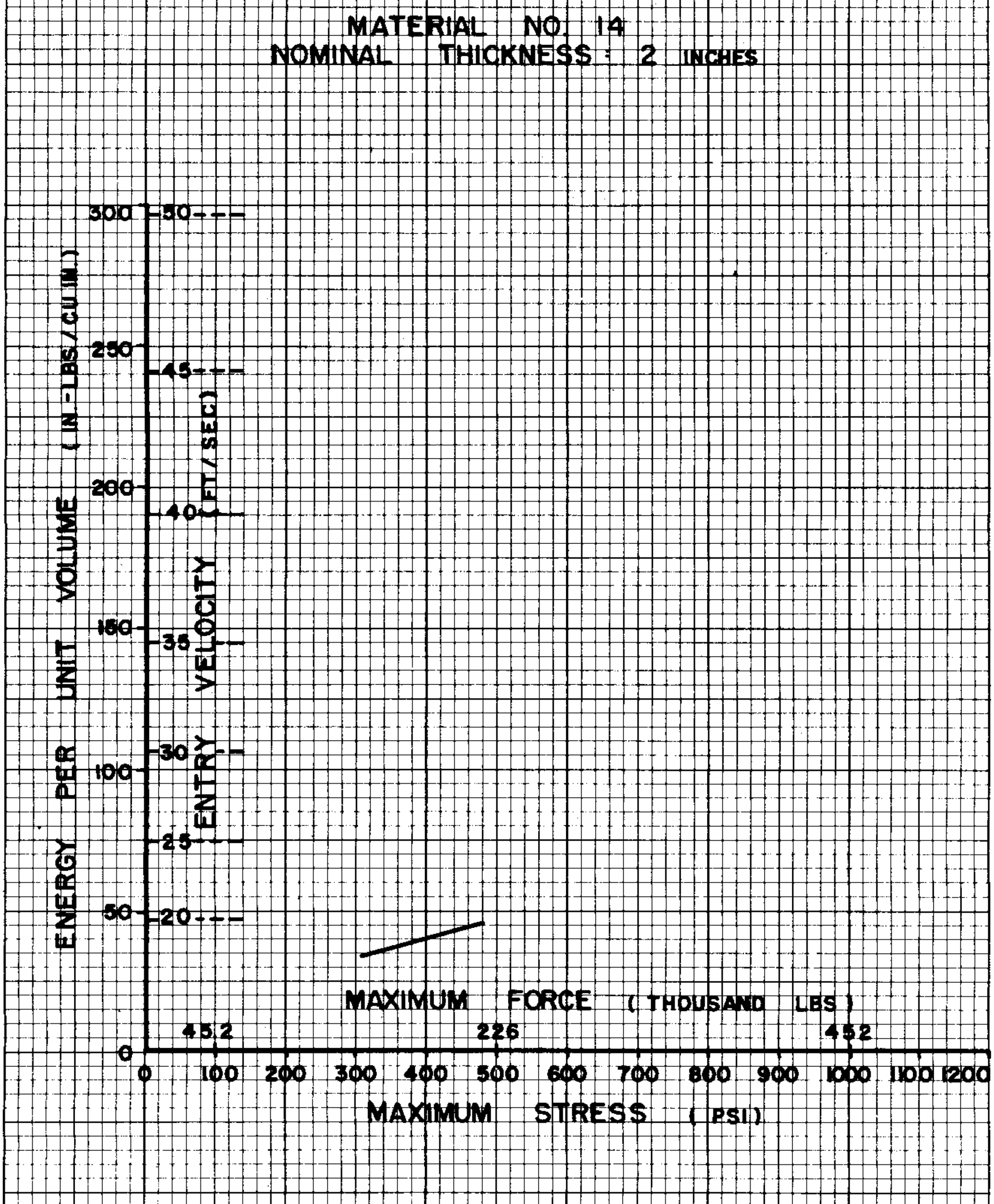

FIGURE 186 ENERGY PER UNIT VOLUME - MAXIMUM STRESS CURVE FOR 2 INCHES OF MATERIAL No. 14

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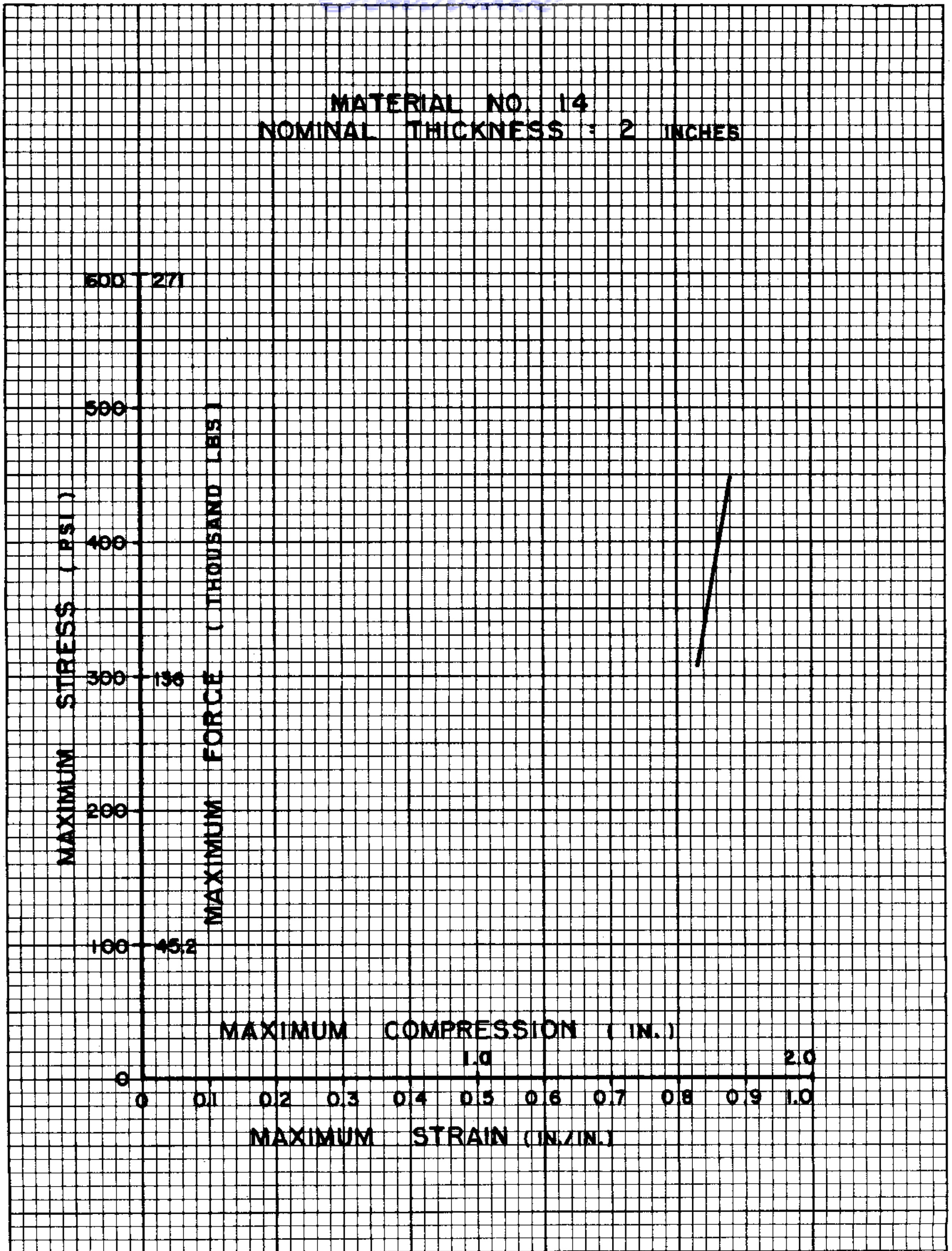

FIGURE 187. MAXIMUM STRESS - MAXIMUM STRAIN CURVE FOR 2 INCHES OF MATERIAL NO. 14

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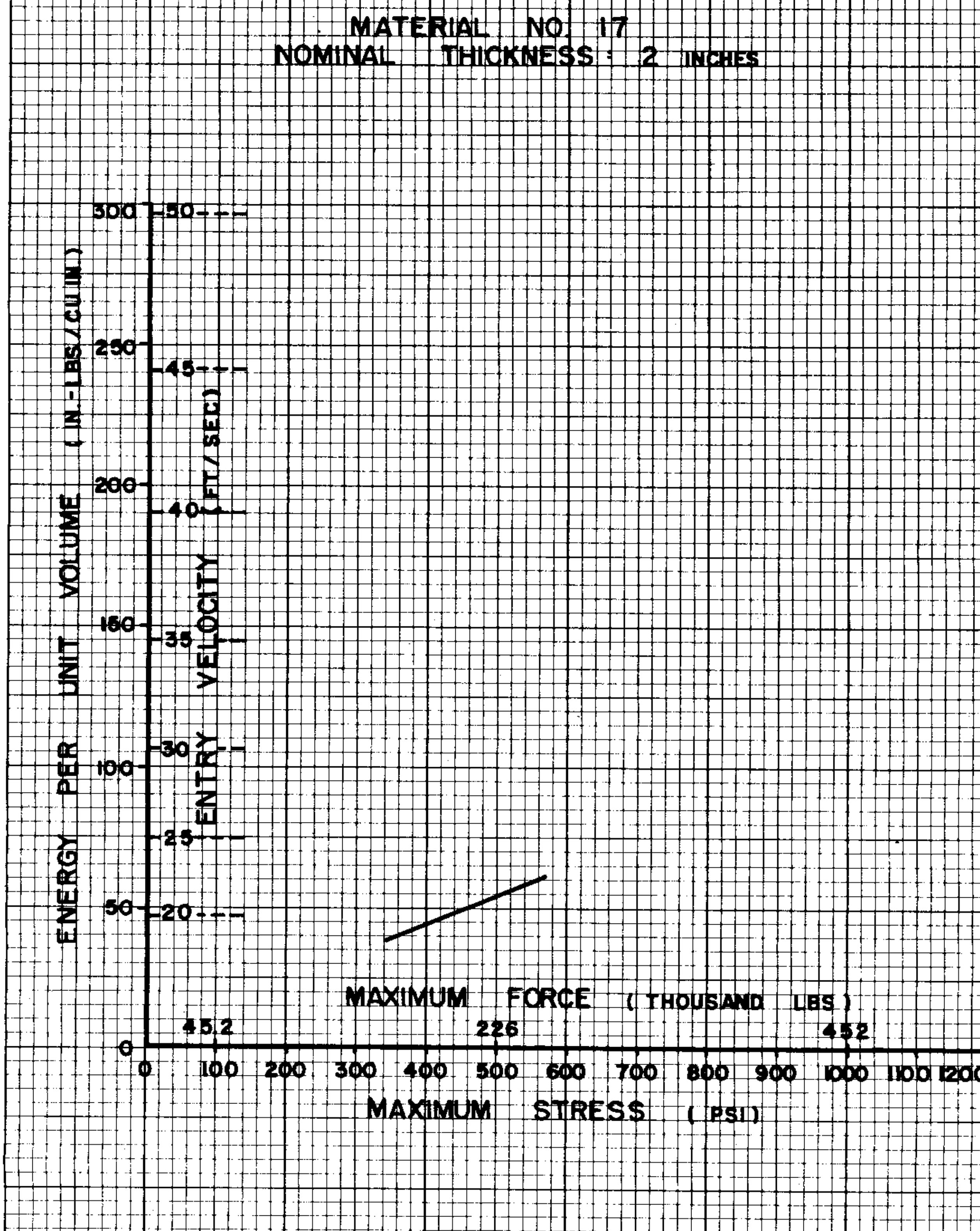

FIGURE 188 ENERGY PER UNIT VOLUME - MAXIMUM STRESS CURVE FOR 2 INCHES OF MATERIAL No. 17

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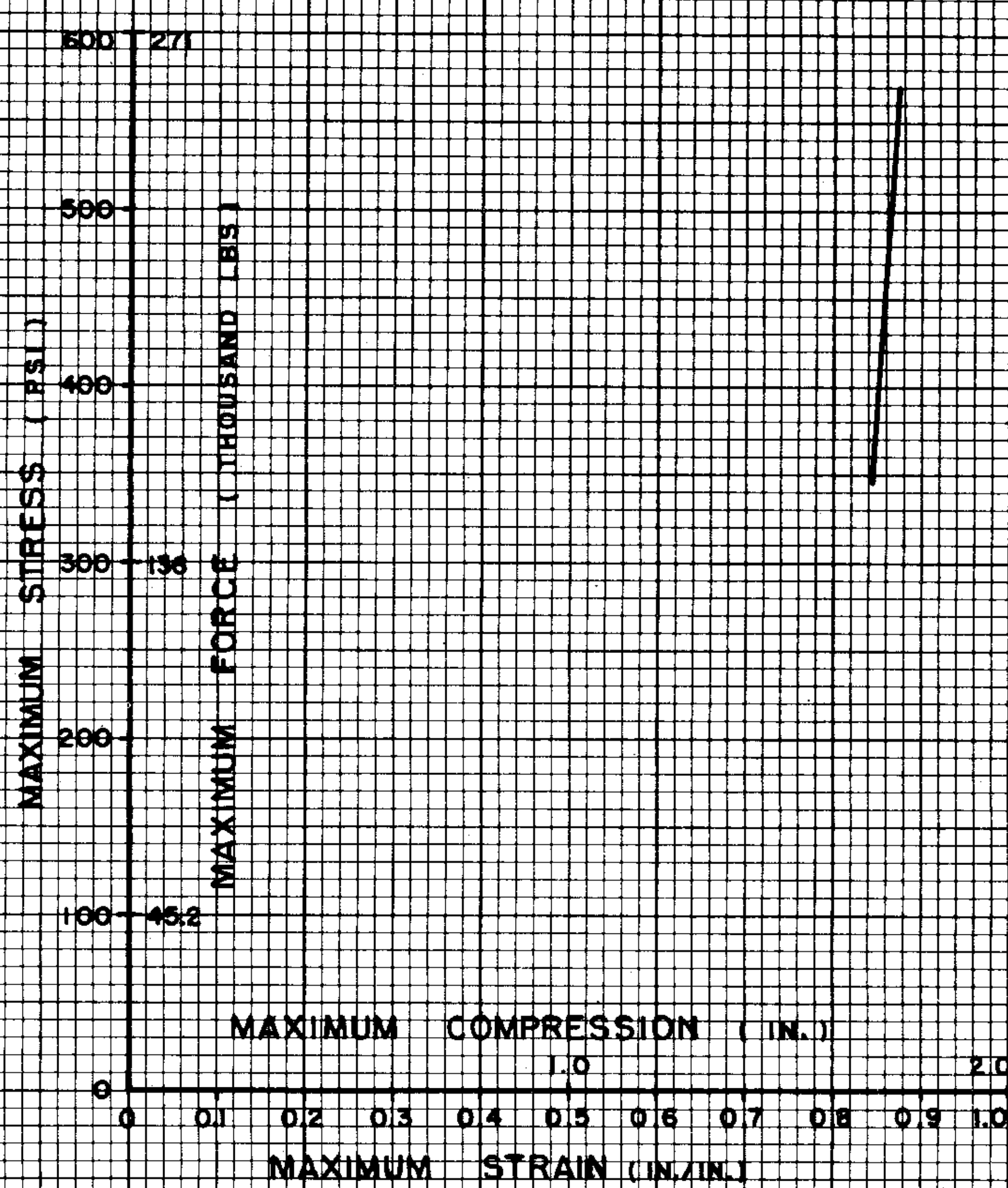

FIGURE 189. MAXIMUM STRESS - MAXIMUM STRAIN CURVE FOR 2 INCHES OF MATERIAL No. 17

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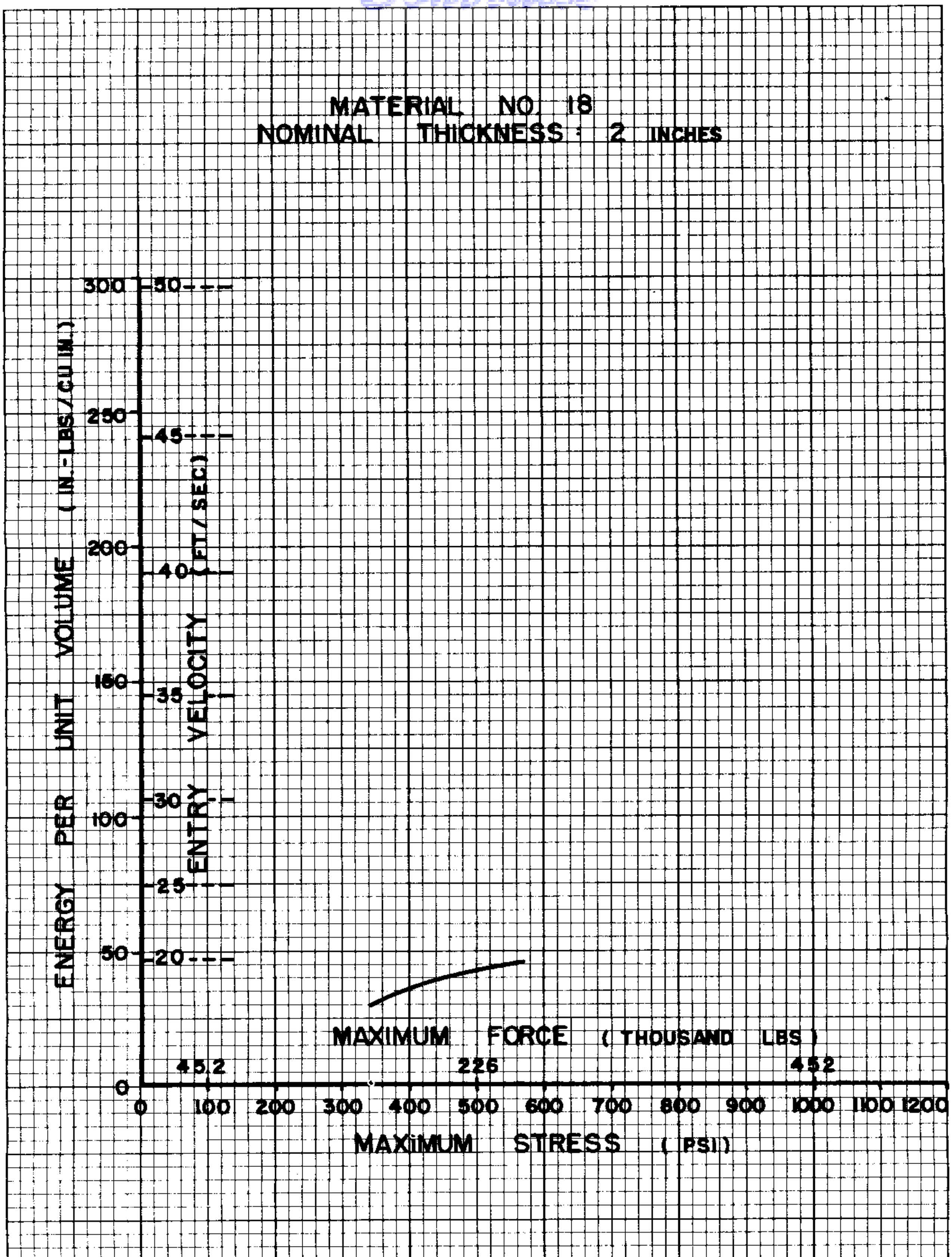

FIGURE 190 ENERGY PER UNIT VOLUME - MAXIMUM STRESS CURVE FOR 2 INCHES OF MATERIAL NO. 18

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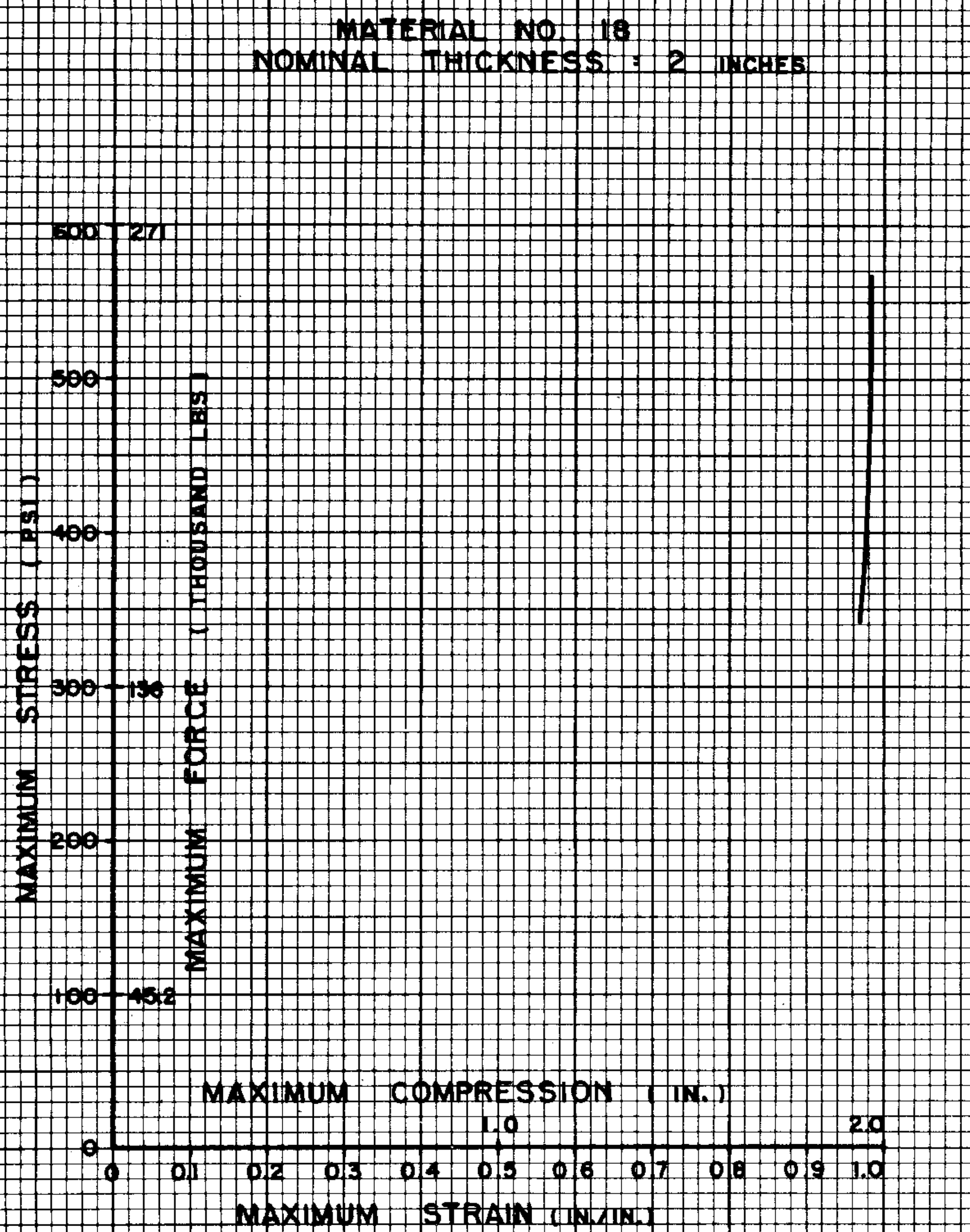

FIGURE 191 . MAXIMUM STRESS - MAXIMUM STRAIN CURVE FOR 2 INCHES OF MATERIAL No. 18

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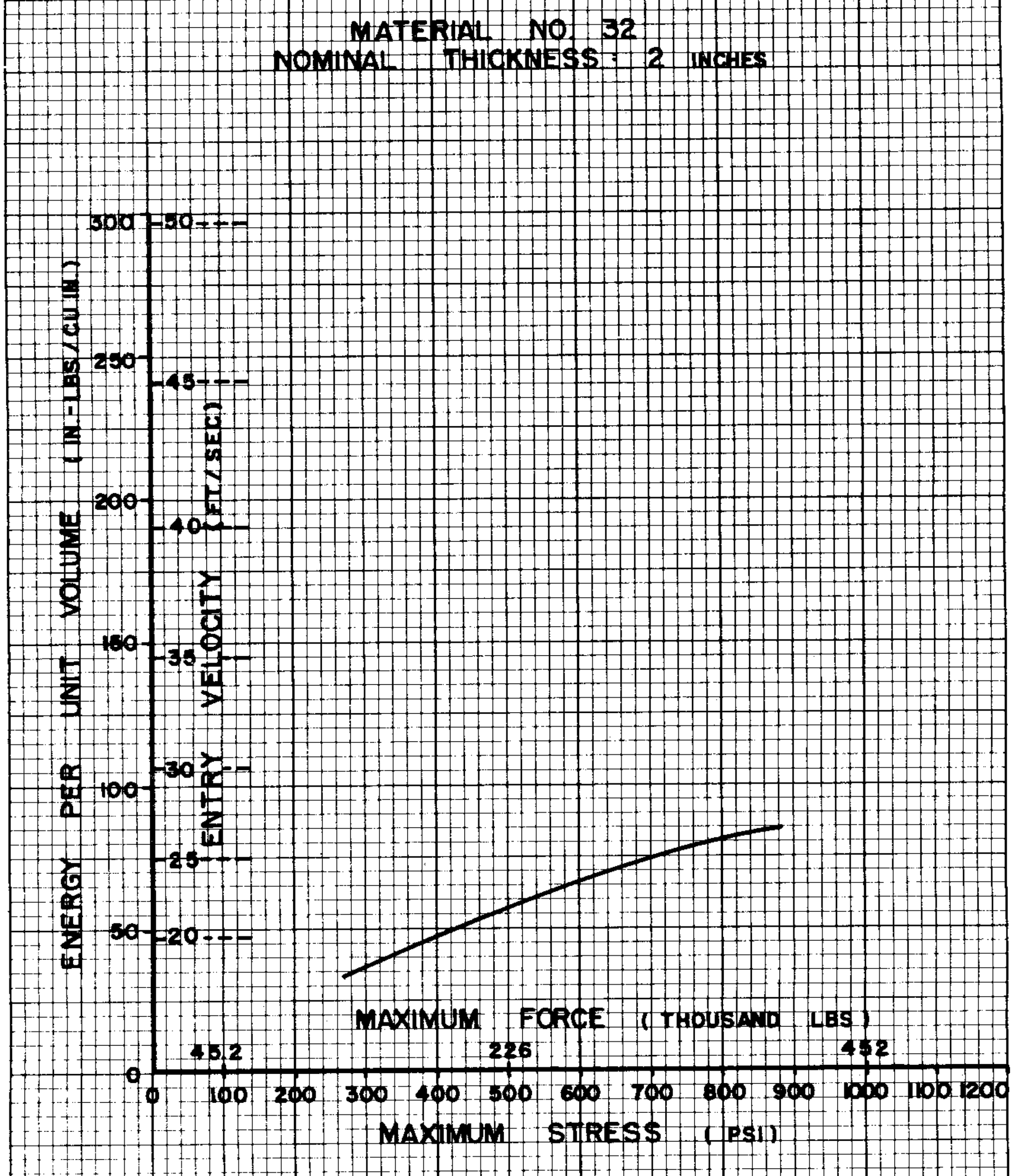

FIGURE 192 ENERGY PER UNIT VOLUME - MAXIMUM STRESS CURVE FOR 2 INCHES OF MATERIAL No. 32

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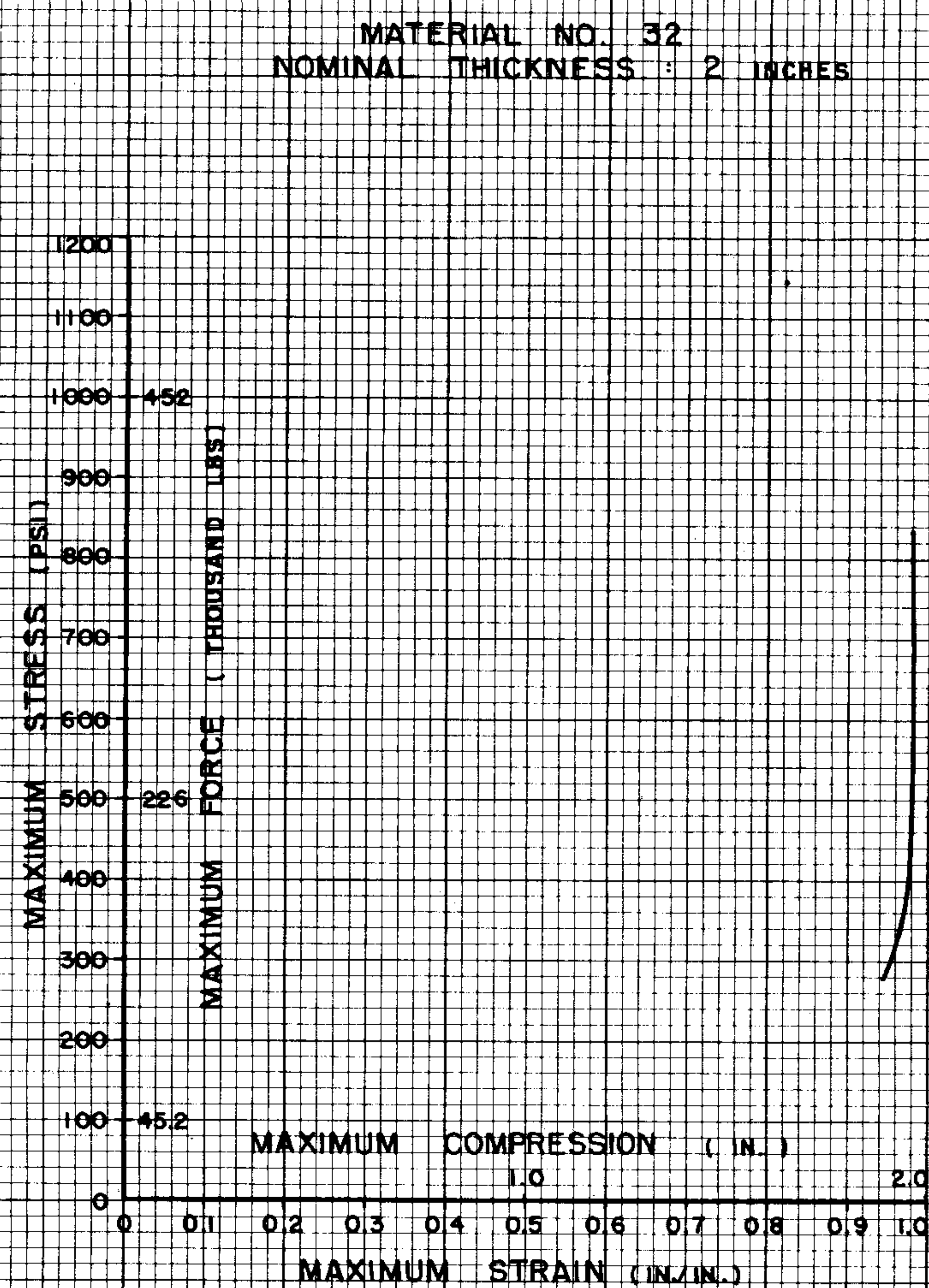

FIGURE 193 MAXIMUM STRESS - MAXIMUM STRAIN CURVE FOR 2 INCHES OF MATERIAL NO. 32

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