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WADD TECHNICAL REPORT 60-450

**Correlation of Tensile Properties of Steel Castings and
Material Imperfections as Determined by Radiography**

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A Division of General Dynamics Corporation

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FOREWORD

This summary report was prepared by the Applied Manufacturing Research and Process Development Department of Convair, San Diego - A Division of General Dynamics Corporation, under contract AF33(616)-6622. This contract was initiated under Project No. 7360, "The Chemistry and Physics of Materials," Task No. 73606, "Non-destructive Methods," and was administered by the Metals and Ceramics Laboratory Materials Central, Directorate of Advanced Systems Technology, Wright Air Development Division, Wright-Patterson Air Force Base, Ohio, with Mr. Richard R. Rowand acting as Project Engineer.

This report covers the period of work from June 1959 to July 1960. The text was written by L. J. Mattek and R. D. Woodward.

The Pacific Alloy Corporation, El Cajon, California, Mr. R. I. Kernland, Metallurgist, contributed to this project by producing cast steel slabs containing intentionally introduced imperfections.

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ABSTRACT

The relationships between tensile properties of 410 stainless-steel castings and imperfections, as determined by radiography, have been investigated. The purpose was to establish confidence in a system of evaluating castings by radiographic inspection. Tensile properties investigated were: Tensile yield, tensile ultimate, elongation and modulus of elasticity; imperfections were: Gas holes, inclusions and porosity; thicknesses were: 0.1", 0.2", 0.3" and 0.6". Test specimens were heat treated to a 180,000 to 200,000 psi.

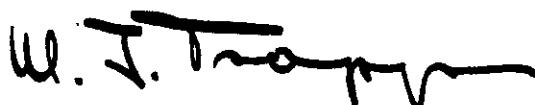
Statistical analysis of test results is presented.

Relationships between tensile properties and size or intensity of imperfections are represented in tables and graphs.

PUBLICATION REVIEW

This report has been reviewed and is approved.

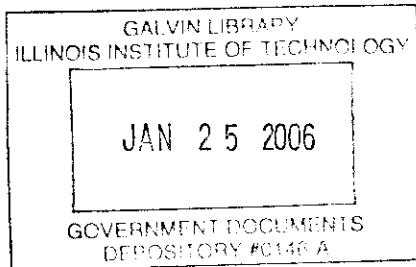
FOR THE COMMANDER:



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CORRELATION OF TENSILE PROPERTIES
OF STEEL CASTINGS AND MATERIAL
IMPERFECTIONS AS DETERMINED
BY RADIOGRAPHY

1. INTRODUCTION

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CORRELATION OF TENSILE PROPERTIES OF STEEL CASTINGS AND MATERIAL IMPERFECTIONS AS DETERMINED BY RADIOGRAPHY

1. INTRODUCTION

1.1 Background:

The current Mil Spec, MIL-C-6021 D - Castings, Classification and Inspection of (for Aeronautical Applications), specifies that radiographic acceptance standards for structural steel castings shall be in accordance with ASTM Standard E71-52. This standard is inadequate because it had not been correlated to strength or other properties, and generally applies to castings of relatively large cross section.

1.2 Objective and Purpose:

The objective of this project is to study the correlation between material imperfections in steel castings, as determined by radiography, and the tensile properties of the castings. Stated another way, the various types of imperfections, in varying intensities or sizes will be studied in relation to the load-carrying capacity of the castings. The degree of correlation will be determined for Type-410 stainless-steel castings in thicknesses of 0.1", 0.2", 0.3" and 0.6", at room temperature.

The purpose is to establish a measure of confidence in a system of evaluating castings by radiographic inspection. The measure of confidence, if satisfactory, may make desirable a change which would establish radiographic standards as the criteria of steel castings for aircraft structural uses.

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CORRELATION OF TENSILE PROPERTIES
OF STEEL CASTINGS AND MATERIAL
IMPERFECTIONS AS DETERMINED
BY RADIOGRAPHY

2. PROCEDURE

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2. PROCEDURE:

2.1 General Plan:

The general plan which was followed to determine the relationship or degree of correlation between tensile properties and material imperfections in steel castings, was:

- (1) Cast steel, in this project Type-410 stainless steel, having an analysis corresponding to AMS 5351B Specification, was cast in shell molds.
- (2) Material imperfections were intentionally introduced during the casting operation. These imperfections were: gas holes, inclusions and porosity.
- (3) Cast slabs, containing intentionally introduced imperfections, were radiographed; the radiographs were reviewed and test-coupon areas selected.
- (4) After locating suitable areas for removal of test coupons from the cast slabs, test coupons were removed and processed.
- (5) Test coupons usually were machined only on the edges, leaving the flat surfaces in the condition as received from the foundry.
- (6) After machining, the coupons were deburred and heat treated to be within the range, 180,000-200,000 psi, ultimate tensile strength.
- (7) Heat treatment was followed by descaling in a light sandblast.
- (8) Coupons were Magnafluxed and examined.
- (9) A radiographic analysis was made, followed by physical testing.

The degree of correlation was determined for tensile yield, tensile ultimate, percent elongation in two inches, and modulus of elasticity, as they were respectively related to material imperfections: gas holes, inclusion and porosity, which are tolerable to a degree in aeronautical castings. Gas-hole and inclusion imperfections were classified in one-millimeter-size increments. Porosity imperfections were divided into 10 intensities, described as intensity numbers; number 10 being regarded as the poorest possible attainable. Coupons were selected for all types of imperfections, in all sizes or intensities, to the extent that they were available. All tensile tests were conducted at room temperature. The individual test results, from which the correlations were determined by statistical analysis, are included as Appendix A, this report.

2.2 Equipment:

Equipment used for this project is listed in Appendix B, this report.

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2.3 Foundry Production:

2.3.1 Mold Sizes and Type -

The Pacific Alloy Corporation, El Cajon, California, produced cast slabs, 12" x 16" in 0.1", 0.2", and 0.3" thicknesses, and 16" x 24" cast slabs in 0.6" thickness. Shell-type molds were used with a high-grade zircon sand and Linoil or Bakelite resin as binders.

2.3.2 Intentional Introduction of Imperfections -

Inclusions were introduced in the castings by adding prepared metallurgical slag to the melt during casting. The slag was prepared by grinding, and sifting to desired sizes. Gas holes were promoted by adding a few drops of binding compound to the drag of the mold just prior to casting. Gases released by the undried binder, promoted the formation of gas holes. It was impossible to accurately regulate the size of the gas holes. Attempts to produce larger gas holes usually resulted in clusters of small gas holes. Porosity was introduced by casting with fewer risers than are required for sound castings. One side of the long dimension of each slab was fed over its entire length from the pouring well, in order to ensure that an adequate supply of hot metal was constantly available. This resulted in the feed side of the castings usually being sound, while porosity increased as the distance from this side increased. The feed side of each casting was marked.

2.3.3 Casting Problems -

Difficulties were encountered in casting full-size 0.1"-thick slabs. Due to the relatively large size of the cast slab, in relation to its thickness, the metal usually chilled before it filled the mold cavity. This difficulty was aggravated further by the introduction of imperfections. The surface of the castings was also affected adversely by the introduction of imperfections. The inclusions had a tendency to rise to the top surface of the castings. The liberation of gas, to introduce gas-hole imperfections, disturbed the solidification action so that poor surfaces resulted. Inadequate risers also promoted poor surfaces because of the inadequate supply of hot metal during solidification.

In order to aid in the introduction of the imperfections and obtain a full-size casting, it was usually necessary to superheat the melt. When the superheated melt contacted the mold binding material, carbonization usually occurred, which, in turn, resulted in carburization of the cast surface. Figure 1 shows massive carbides, near the cast surface, a result of carburization. The hardness of the heat-treated castings at the surface was in some cases, as much as 15 points, Rockwell C, harder than the interior of the castings.

Considering the carburized surfaces, other poor surface conditions, and the difficulty experienced in obtaining full-size castings

Contrails

(beam blockage) - 100% of the time

Surfaces will become very dark, necessitating a new facsimile and a new carbon emitter. This is a slow gathering process and can easily become a major problem for the hard-to-see areas. The best way to handle this is to never get into a situation where the tracking reference is being obscured at the same time as the electron beam. If required, turn off the beam to avoid the beam hitting the surface and causing a black-blade effect.

- Beam Blockage - 100% of the time

and Facsimile - 100% of the time

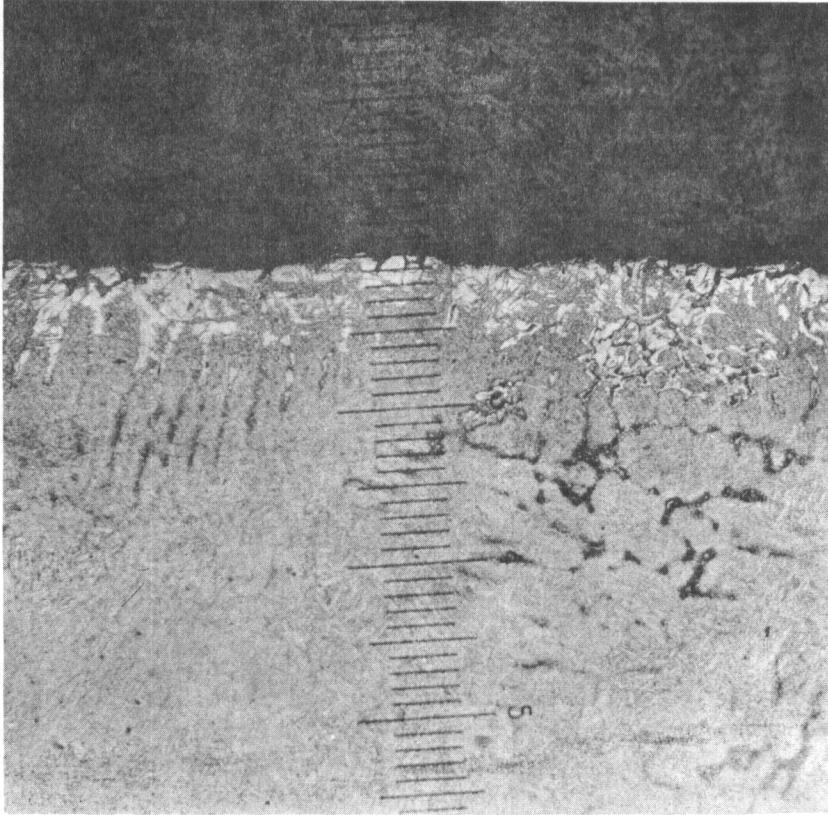


Figure 1 Photomicrograph Showing Carbon Pickup at As-Cast Surface, (Magnification 100X) Electrolytic Etch in 10% Oxalic Acid.

Controls

2.3.3 Casting Problems - (continued)

in 0.1" thicknesses, permission was requested from WADD to cast each slab 0.040" oversize in thickness. This request was granted. The excess thickness was later removed by grinding 0.020" from each flat surface. Grinding removed most of the carburized metal and rough surface. It also made it possible to obtain a greater percentage of full-size 0.1"-thick castings. Due to the removal of surface metal, the test results became more representative of all methods of molding steel castings, rather than being representative of the shell-mold process only.

2.3.4 Foundry Processing of Castings -

After the castings were stripped from the shell mold, they were given an immediate 3-hour process anneal at 1350F. The risers and gates were then removed by an abrasive wheel. After cleaning, the castings were normalized at 1850F to remove the effects of the abrasive cutting action. This was followed by annealing at 1300F to soften the casting for subsequent removal of the test coupon. The hardness of the castings at this stage was 12 to 23, Rockwell C; the thicker castings usually were somewhat harder. The normalizing treatment also reduced warpage, somewhat. After annealing, the castings were ground to remove approximately 0.020" from each flat surface. After grinding, the castings were given a light sandblast to remove residual stresses induced by the grinding operation. The castings were then radiographed by the foundry, and if satisfactory, were shipped to Convair, San Diego. The 0.1"-thick castings were too thin to hold securely for Blanchard grinding, instead, they were sandblasted to remove the scale and were radiographed without being ground.

2.4 Selection of Tensile Coupons:

2.4.1 Categorizing the Imperfections -

Before tensile test coupons could be selected from the radiographs of the casting slabs, it was necessary to set up categories for each type of imperfection. These categories had to be applicable to the present ASTM Standard E71-52 Radiograph References for Steel Castings. They also had to be flexible enough to be applied to other references which may be more restrictive. The categories dividing each type of material imperfection were, therefore, selected as follows: Gas-hole and inclusion-type imperfections were classified by measuring the maximum visible dimension of the flaw, as seen in the radiograph. The flaws were then divided into 1-millimeter-size differentials.

<u>Size Category</u>	<u>Maximum Dimension</u>
1	Up to 1 mm.
2	Over 1 mm., up to 2 mm.
3	Over 2 mm., up to 3 mm.
4	Over 3 mm., up to 4 mm.
5, 6, 7, etc.	Increasing 1 mm. for each successive size.

Controls

2.4.1 Categorizing the Imperfections - (continued)

Porosity imperfections were categorized by dividing the full spectrum of porosity intensities into 10 numbers. The most intense porosity (No. 10) was considered to be the most intense porosity that could be attained.

Porosity, as referred to in this project, is the internal-shrinkage type of porosity. As the project proceeded, a few examples of gas-type porosity became available. To the extent that these specimens were available, an analysis of the effect of this type of porosity was made. It is discussed in a separate section of this report, paragraph 6.1.5 - Gas Porosity.

2.4.2 Reference Blocks -

Before the final gradings were made for each test coupon, it was necessary to set up reference blocks containing the size or intensity of imperfection representative of each category. The reference blocks selected were approximately 2" x 2", agreeing with reference blocks now being considered by ASTM Committee E-7, Non-destructive Testing. Figure 2 is a diagram representing an X-ray film of reference blocks. In the diagram, the function of each area of the film is described. Figures 3 thru 8 are prints of radiographs of reference blocks, selected for the 0.2"- and 0.6"-thick material. Reference blocks are kept on file and are available for use whenever additional sets of reference radiographs are required. The 0.2"-thick reference blocks were used to grade the 0.1", 0.2" and 0.3"-thick test coupons. The 0.6"-thick reference blocks were used to grade the 0.6"-thick coupons.

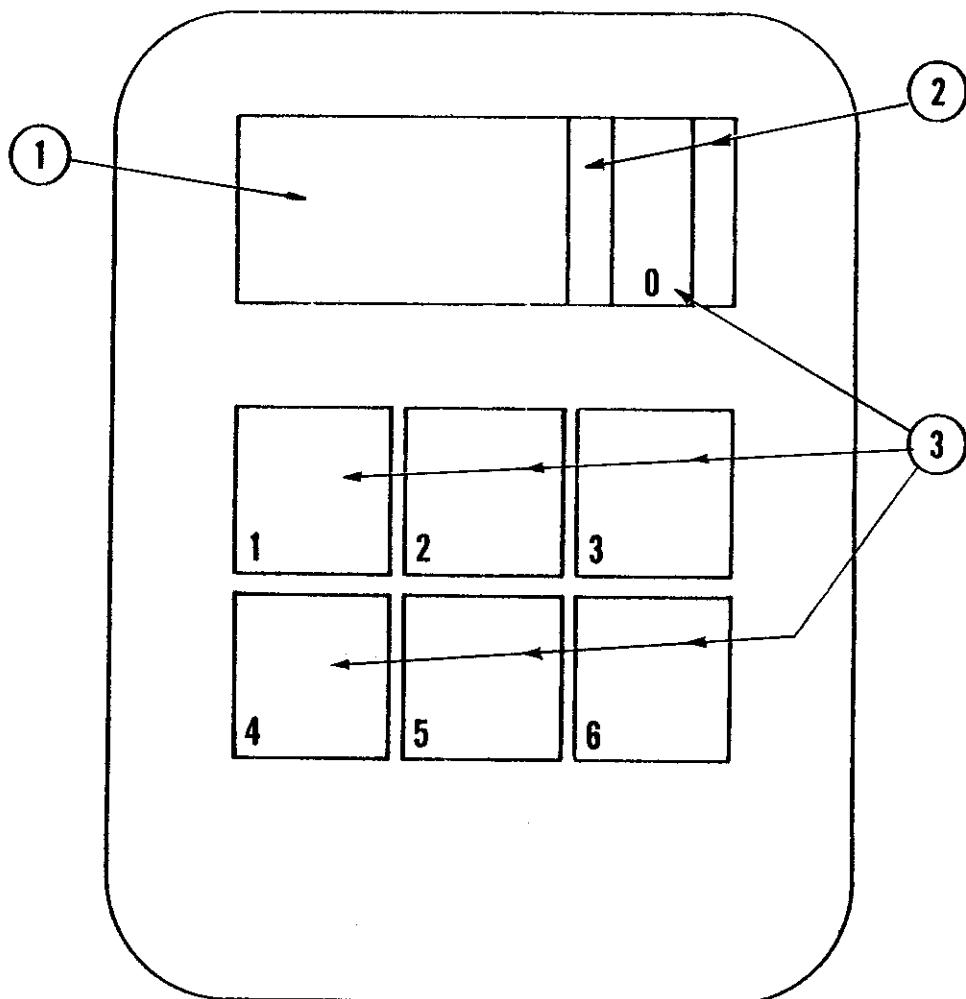
Test coupons for 0.1", 0.2" and 0.3"-thick material were Type F-2, Federal Test Methods (FTM) Standard 151, Method 211, (1/2" x 2" gage area). See "A" in Figure 9. Test coupons for 0.6"-thick material were a special size (1" x 4" gage area). Dimensions of the 0.6"-thick coupons are shown in Figure 10. They differ from the Type F-1 test coupons of FTM Standard 151, Method 211 in that a 4" gage length replaced the 8" gage length, and the test width was the minimum allowable, one inch. ("B" in Figure 9). The shorter gage length and minimum width were selected in order to obtain sufficient numbers of coupons from slabs available.

2.4.3 Selecting Tensile-Coupon Areas in Cast Slabs -

Flaw areas in castings were selected by viewing the radiographs on a film viewer. After the flaw was selected, a transparent (Plexiglas) template was so placed on the casting that the flaw was located within the gage area. The simulated coupon was then oriented to obtain the greatest possible yield of coupons per casting. The test area was outlined with a film pencil as shown in Figure 11.

When all possible test coupons had been located, the radiograph film was placed over the casting. Two corners of the film were

Controls



FILM SIZE - 8" x 10"

1. Title Block: WADD Report No., Thickness, Casting Material, and Imperfection
2. Control Blocks: Penetrameters, ss Indicates Stainless Steel, Numbers indicate Penetrometer Thickness when preceded by a decimal. In some cases two penetrameters were used, one having less thickness and one more than test specimen.
3. Reference Blocks: Imperfection is shown with size or intensity number below it. Zero indicates no defect.

Figure 2 - Description of Radiographic References for Imperfections

Contrails

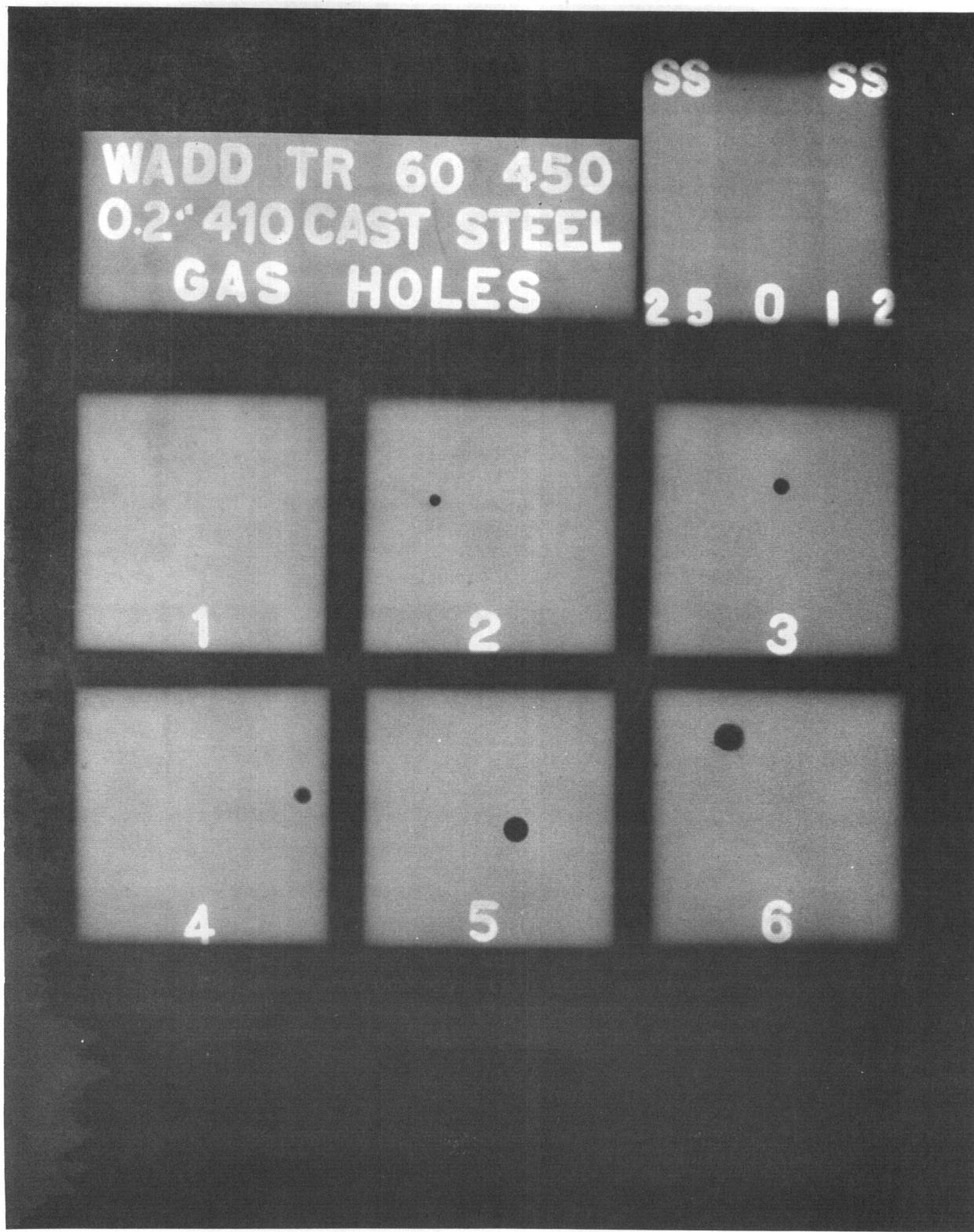


Figure 3. Reference Radiographs for Gas-Hole Imperfections.

Section Thickness - 0.2"

WADD TR 60-450

Contrails

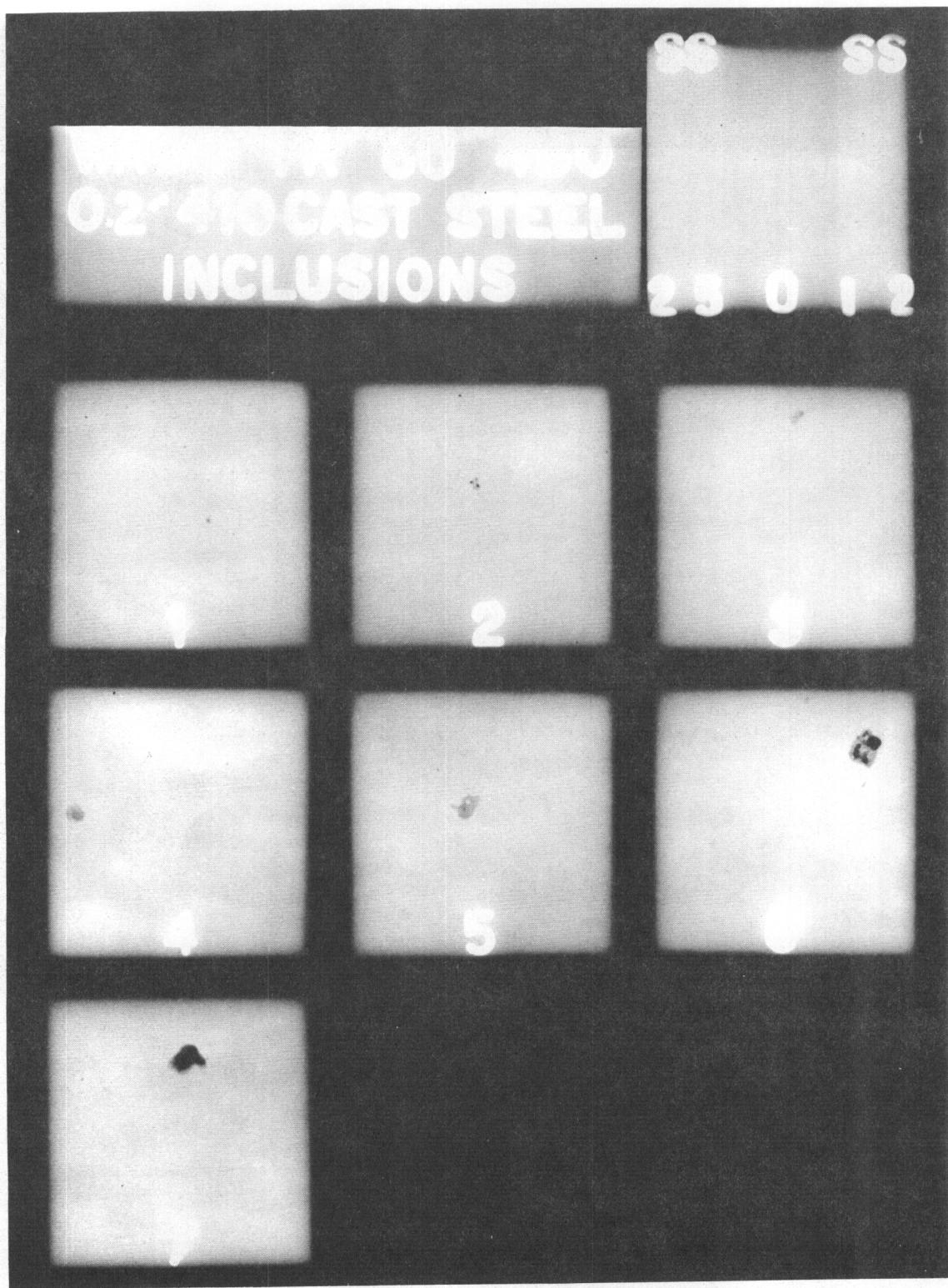


Figure 4 Reference Radiographs for Inclusion Imperfections.
Section Thickness - 0.2"

WADD TR 60-450

Contrans

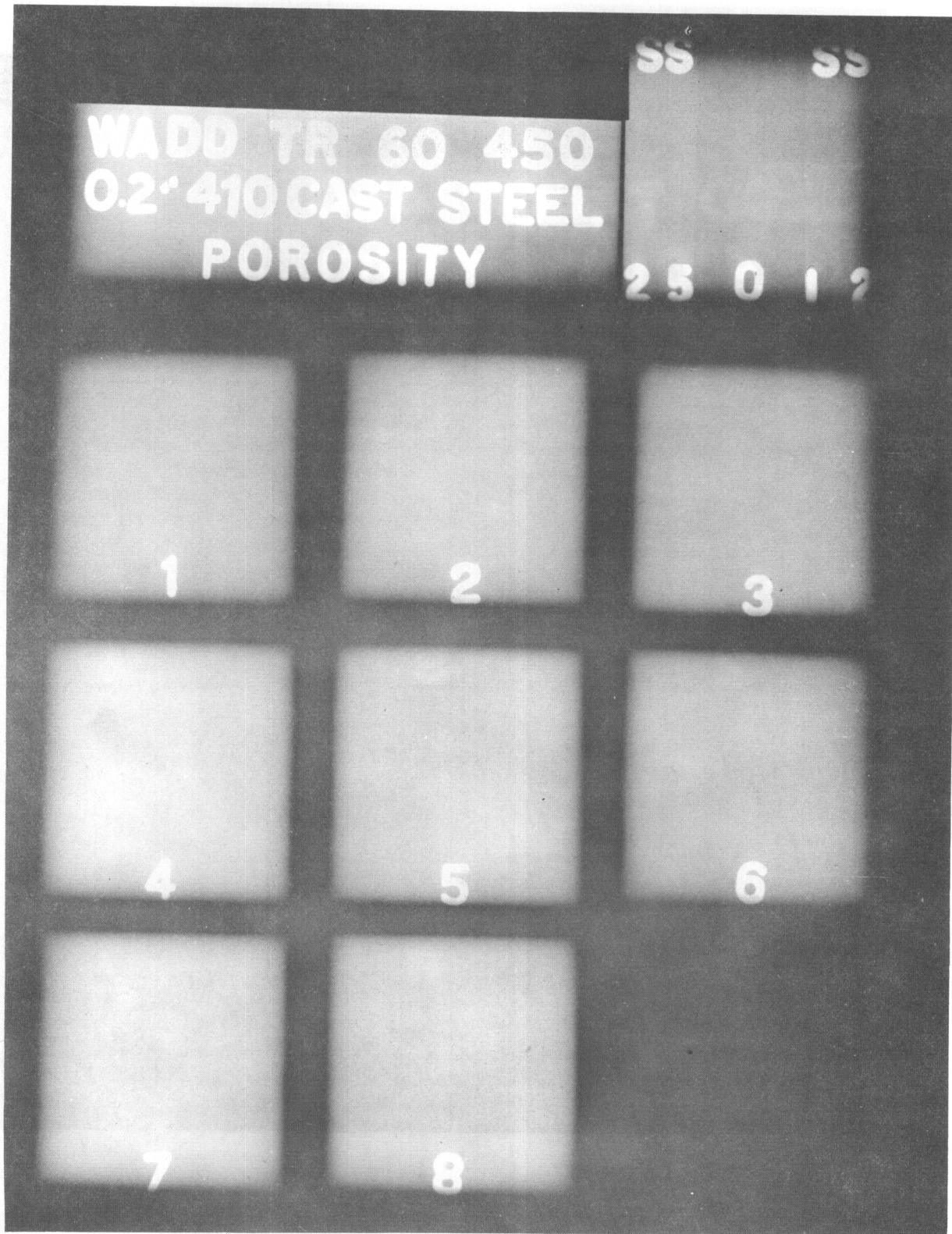


Figure 5 Reference Radiographs for Porosity Imperfections.
Section Thickness - 0.2"

WADD TR 60-450

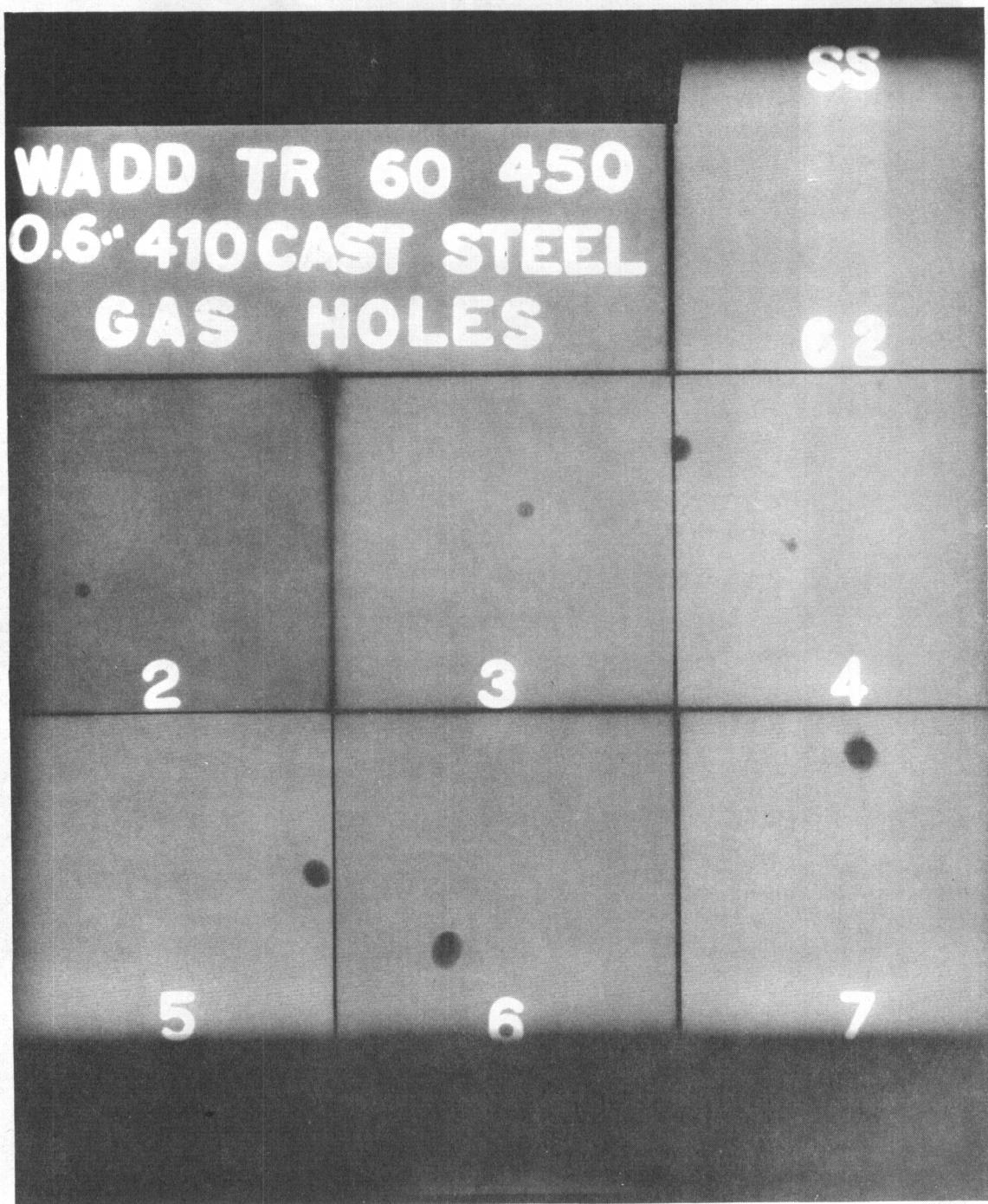


Figure 6 Reference Radiographs for Gas-Hole Imperfections.

Section Thickness - 0.6"

WADD TR 60-450

Contrails

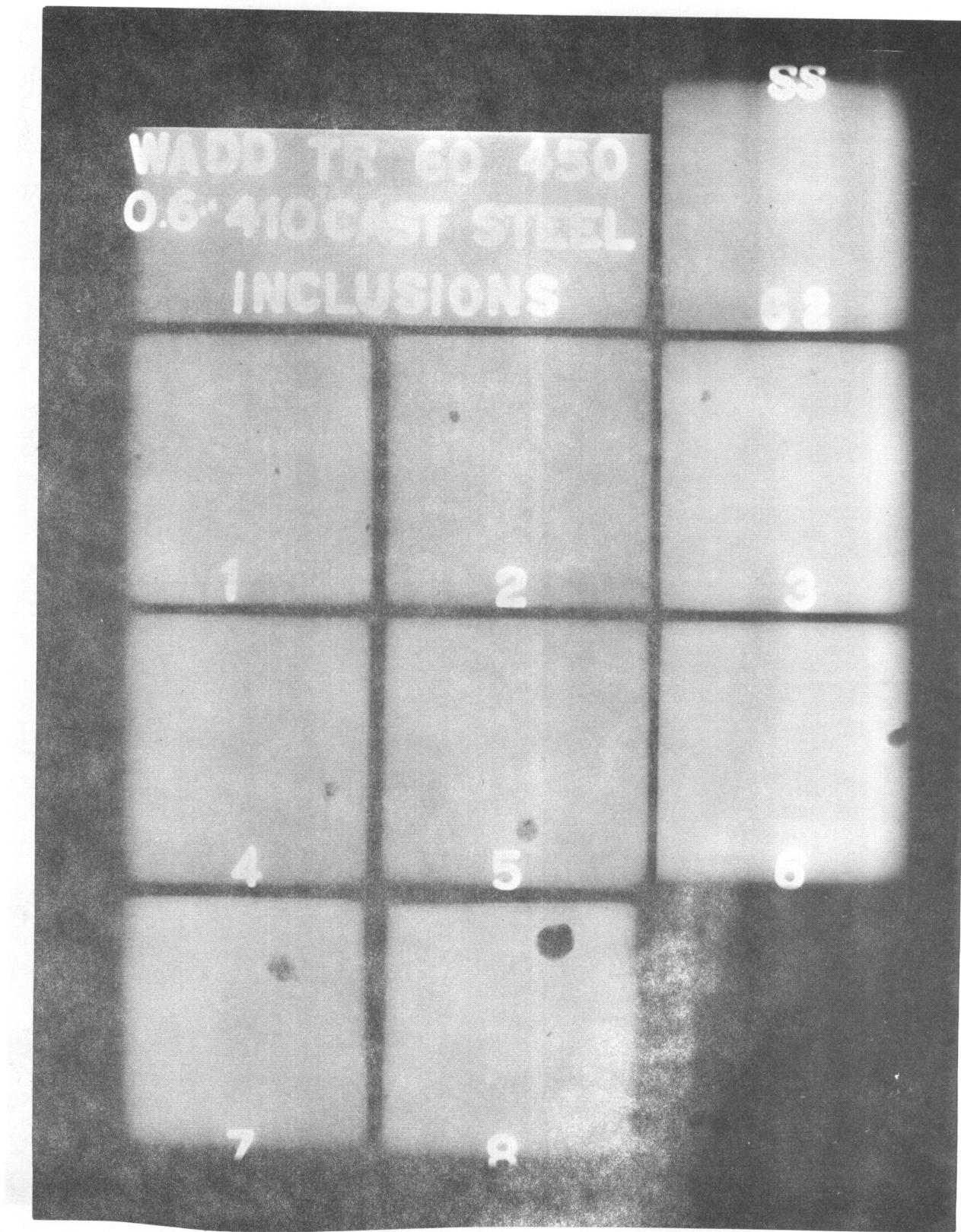


Figure 7 Reference Radiographs for Inclusion Imperfections.

Section Thickness - 0.6"

WADD TR 60-450

052-02-017 CIRAW

Contrails

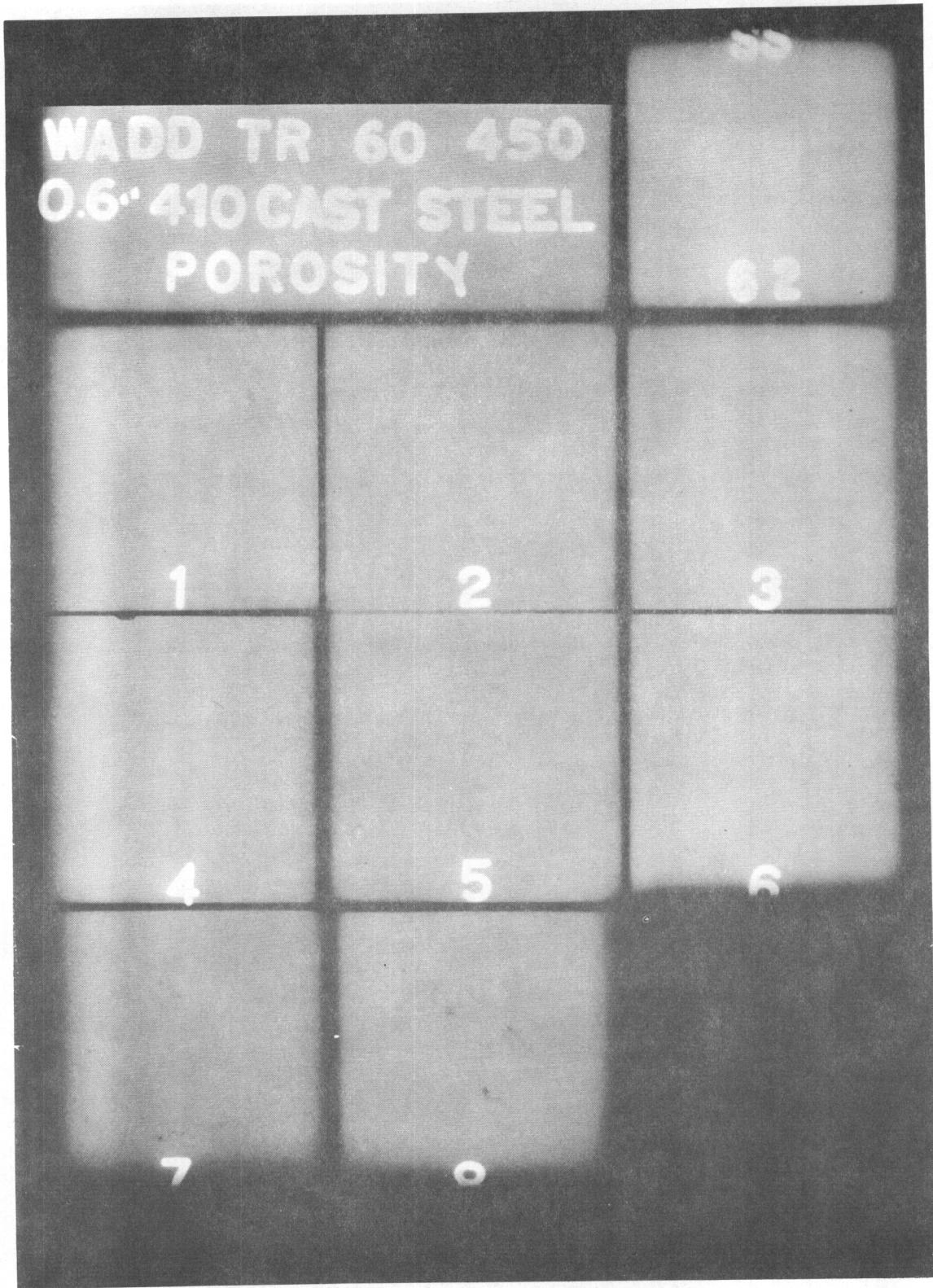


Figure 8 Reference Radiographs for Porosity Imperfections.

Section Thickness - 0.6"

WADD TR 60-450

Contrails

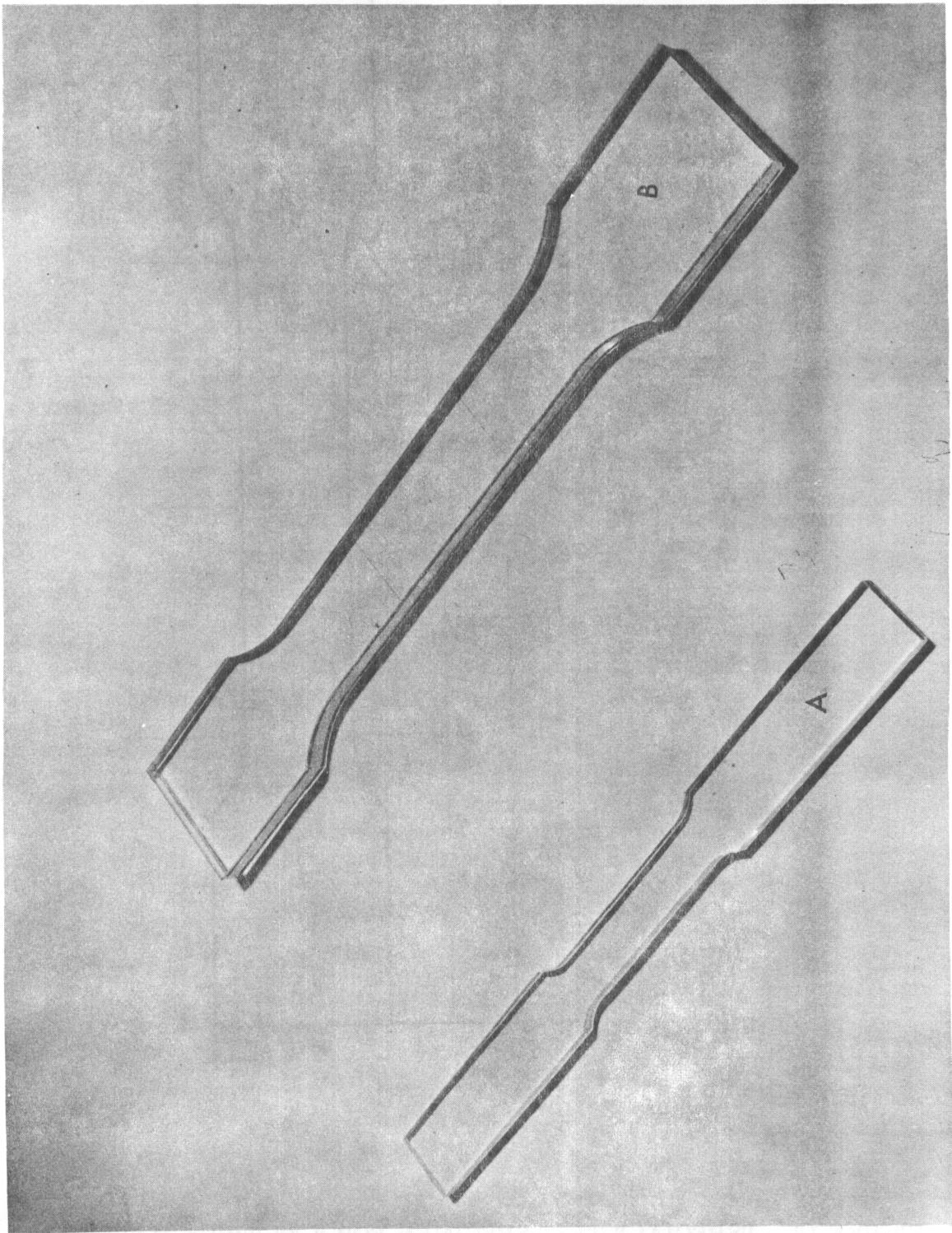


FIGURE 9

SIMULATED TENSILE TEST COUPONS MADE FROM PLEXIGLAS

WADD TR 60-450

Approved for Public Release

Controls

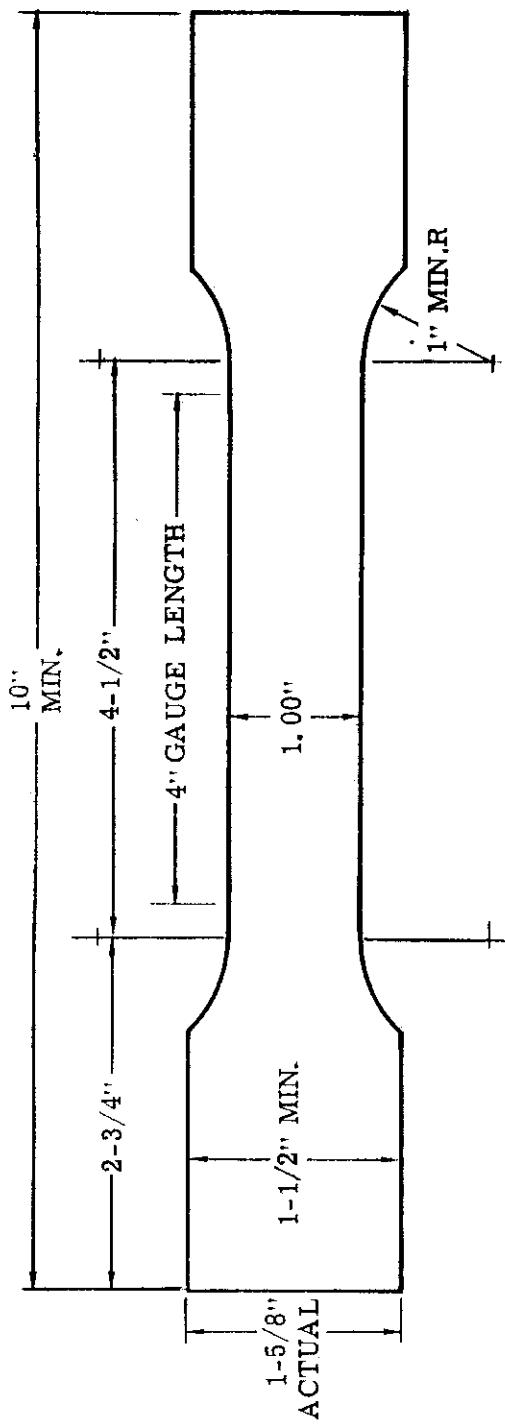


FIGURE 10. "SPECIAL" TEST SPECIMEN FOR 0.6"-THICK MATERIAL

WADD TR 60-450

Contrails

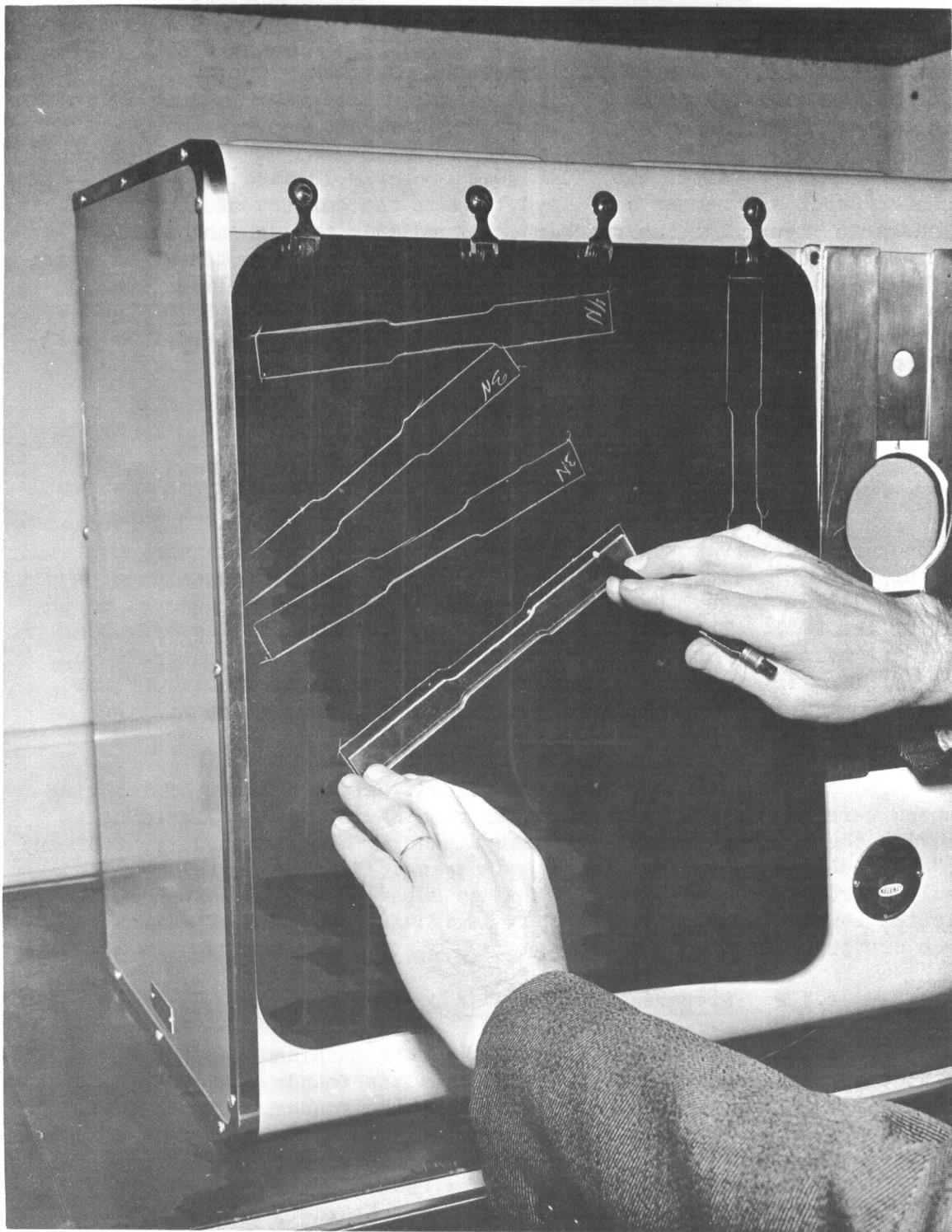


FIGURE 11.

LOCATING TENSILE TEST COUPONS ON X-RAY FILM

WADD TR 60-450

Controls

2.4.3 Selecting Tensile-Coupon Areas in Cast Slabs - (continued)

first trimmed to the outline of the casting; this made it possible to correctly align the film over the casting. See Figures 12 and 13. The cast slabs shown in the illustrations were 12" x 16"; these were representative of the 0.1", 0.2" and 0.3"-thick castings. One 14" x 17" X-ray film was adequate for each. The 0.6"-thick castings were 16" x 24"; this necessitated two 14" x 17" films per casting.

After the films were properly located on the castings, a center punch and hammer were used to mark the corners of each test coupon as shown in Figure 13; the punch marks were made through the film. The punch marks on the castings were then connected by white lines, as shown in Figure 14; the identity of each coupon was marked and later steel-stamped in the grip area of each coupon. It can be noted from Figures 12 and 14, that a considerable difference occurs in coupon yield from one casting slab to another.

2.5 Coupon Processing

2.5.1 Removing Test Blanks from the Casting Slabs -

Early in the project, the 0.1", 0.2" and 0.3" test-coupon blanks were removed from the castings by bandsawing. The 0.6"-thick coupons were removed by torch cutting. Torch cutting necessitated coupon blanks a little larger than finally required to allow for removal of the wall of the kerf. This surplus also prevented the hardening effect of the torch cut affecting the test area. The hardening effect penetrated up to 3/16" from the torch cut. Coupons had to be annealed at 1300F for 2 hours in order to soften the hardened area for subsequent milling operations.

As the project continued, better methods of removing coupons were developed. A substantial time savings was realized by removing the 0.1" and 0.2"-thick test blanks by shearing and the 0.3" and 0.6" test-coupon blanks by high-speed sawing. No detrimental warping resulted from the shearing action and no shear cracks were found. The friction sawing was much faster than bandsawing and more efficient than torch cutting.

2.5.2 Preparing Coupons for Testing -

The test-coupon blanks were machined only on the edges. The flat surfaces remained as received from the foundry, except for the 0.1"-thick material which was not ground by the foundry. Approximately 0.020" was removed from each flat surface of the 0.1"-thick test coupons by surface grinding. After the test-coupon blanks were milled to tensile coupons, they were deburred, heat treated, sandblasted, Magnafluxed, checked for hardness, and radiographed, in that order, before tensile testing. The heat treatment consisted of an austenitize treatment at 1825F (1 hour, minimum, for material up to 0.3" thick, 1.5 hours, minimum, for the 0.6"-thick material), oil quenched and tempered at 525F, for 2 hours, minimum. The heat-treat atmosphere during austenitizing was slightly oxidizing producing an oxide scale up to 0.0003" in depth.

Contrails

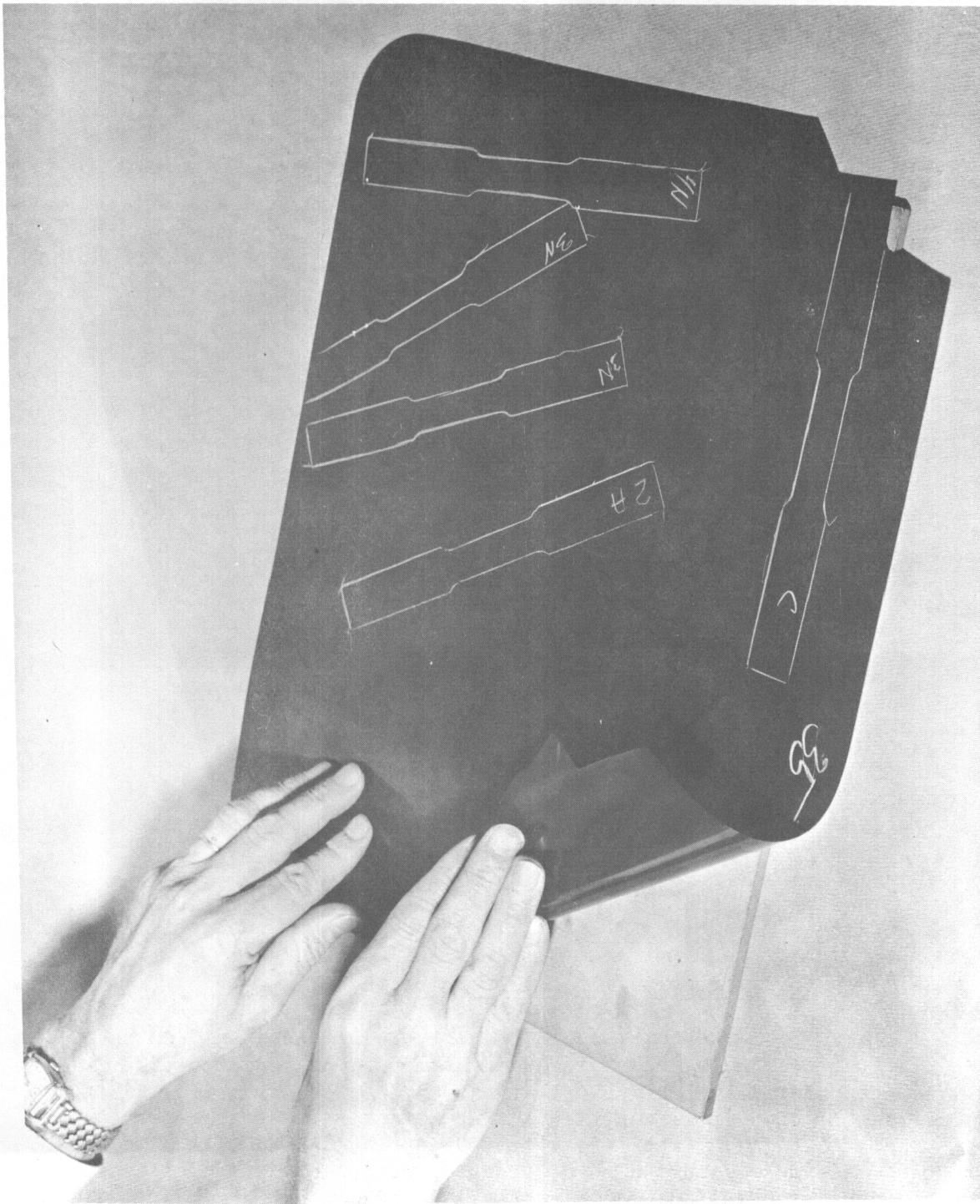


FIGURE 12.

PLACING X-RAY FILM, AFTER MARKING LOCATION OF TENSILE TEST COUPONS, ON CORRESPONDING CAST SLAB

WADD TR 60-450

Contrails



FIGURE 13.

MARKING CASTING BY CENTER PUNCHING THE CORNERS OF EACH TENSILE TEST COUPON THROUGH THE X-RAY FILM

WADD TR 60-450

Contrails

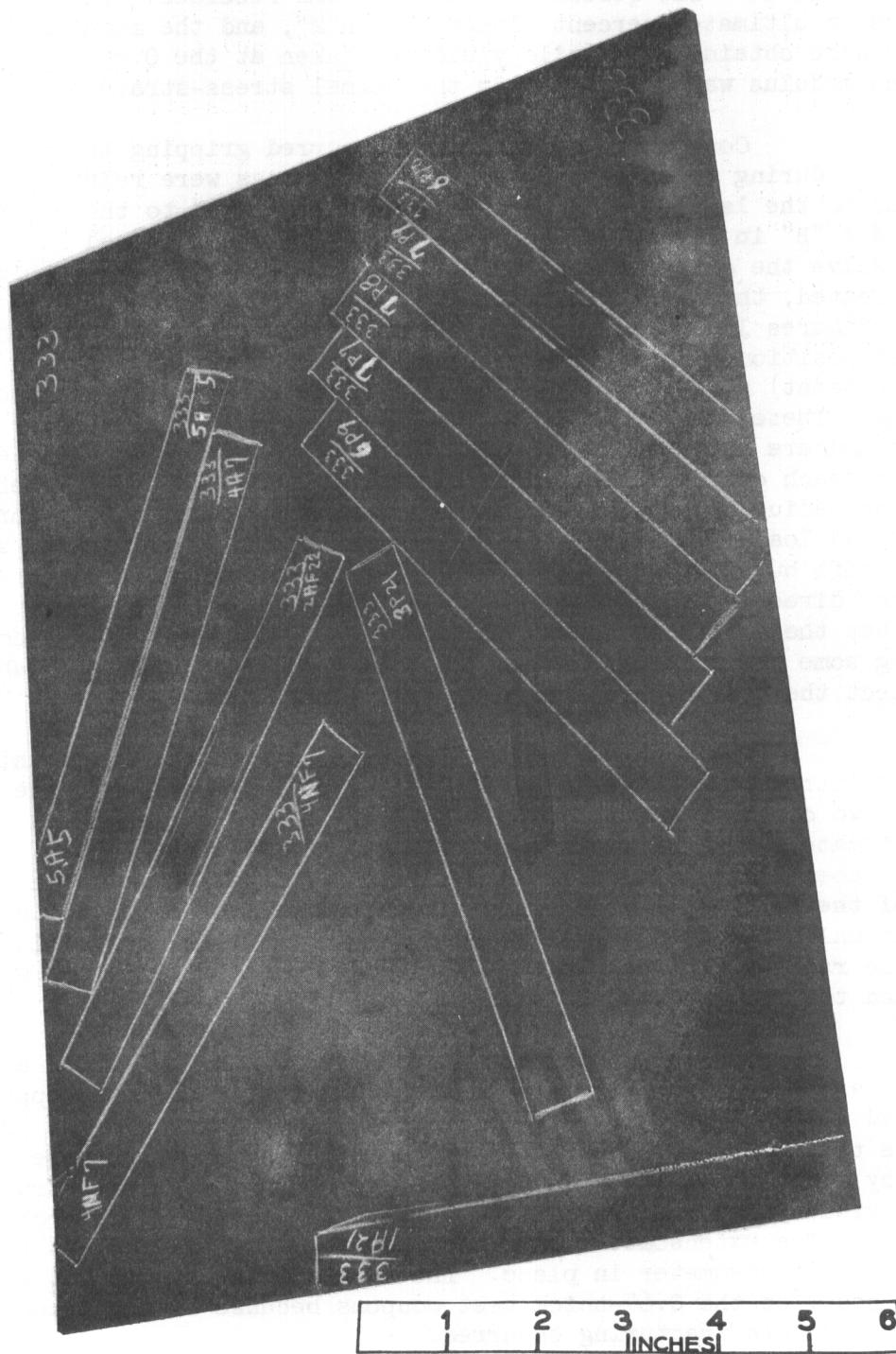


FIGURE 14. CAST SLAB SHOWING OUTLINES OF TENSILE TEST COUPONS

WADD TR 60-450

Convair

2.5.3 Coupon Testing -

The test coupons were tested at a strain rate of 0.005" per-inch per-minute. The stress-strain curve was recorded. The tensile yield, tensile ultimate, percent elongation in 2", and the modulus of elasticity were obtained. Tensile yield was taken at the 0.2% offset point. The modulus was obtained from the normal stress-strain curve.

Considerable difficulty occurred gripping the 0.6"-thick test coupons, during tensile testing. The grip areas were relatively small, in relation to the large load that had to be transmitted to these large coupons. See "B" in Figure 9. A new test fixture was designed in an effort to solve the gripping problem. Since many coupons were machined and heat treated, the new design was made to apply to the coupons already prepared. Figures 15 and 16 show two views of this fixture with a coupon in the test position. It was recognized during the designing period that a biaxial (moment) stress, might be introduced at the bearing areas of the bushing. These areas transmitted the load from the test machine to the coupon and are shown in Figure 15. This possibility made it necessary to remachine each coupon at the radius area to insure that the center point of the radius of each side of the test coupon was on a line normal to the applied load. To further ensure against biaxial, or torque, stresses, relatively soft bushings were inserted over the bearing bolts which were made to bear directly on the coupons. See "B" in Figure 16. It was intended that the soft bushings would improve the alignment of the coupon by allowing some yield at the bearing surface. In addition, the bushings would protect the bearing areas from excessive abrasion.

Tests conducted on five coupons indicated that this fixture did introduce biaxial stresses; two coupons fractured in the radius and two others fractured within half an inch of the radius. Tensile-ultimate-strength results lower than expected gave further indications that biaxial stresses were a factor. Other undesirable features of the new test fixture were the excessive time involved in loading and unloading, and the additional machining time involved in aligning the radii of the coupons. This design for a test fixture was rejected and the fixture was not used.

The 0.6"-thick test coupons were finally tested at another Convair facility having a relatively new test machine equipped with new jaw grips. This proved to be adequate for the task. The grip ends of the test coupons, machined later in the program, were increased in length by 1.5", to improve the grip. Since many test coupons fractured before the yield point was obtained, several extensometers were broken during tests. The extensometer failures occurred when the coupons fractured with the extensometer in place. The extensometer breakdowns were especially heavy on the 0.6"-thick test coupons because of the extensive shock generated when fracturing occurred.

Controls

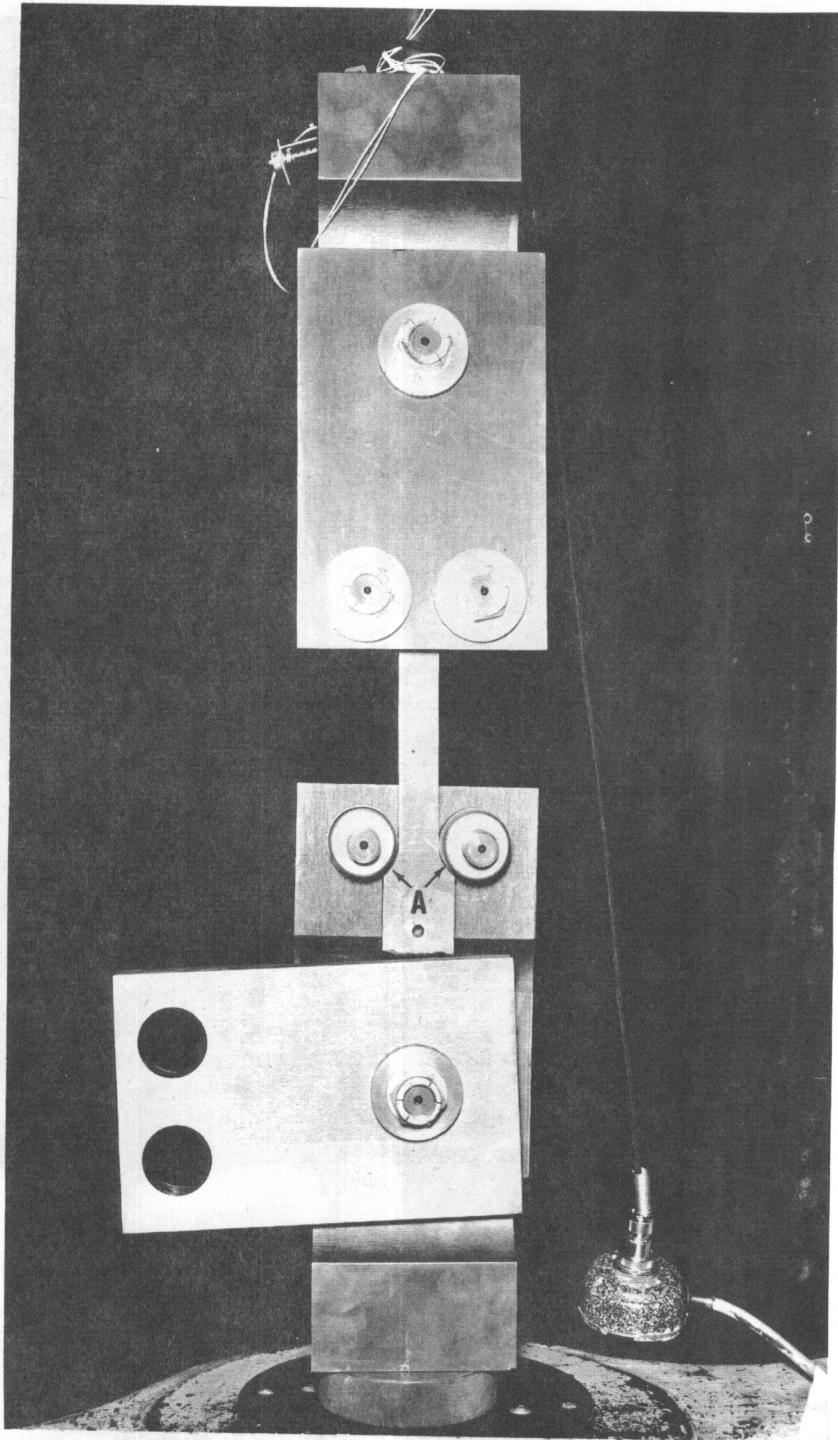


FIGURE 15. FRONT VIEW OF TEST FIXTURE
WITH ONE TENSION PLATE SWUNG ASIDE
TO SHOW TEST COUPON IN PLACE.

WADD TR 60-450

Contrails

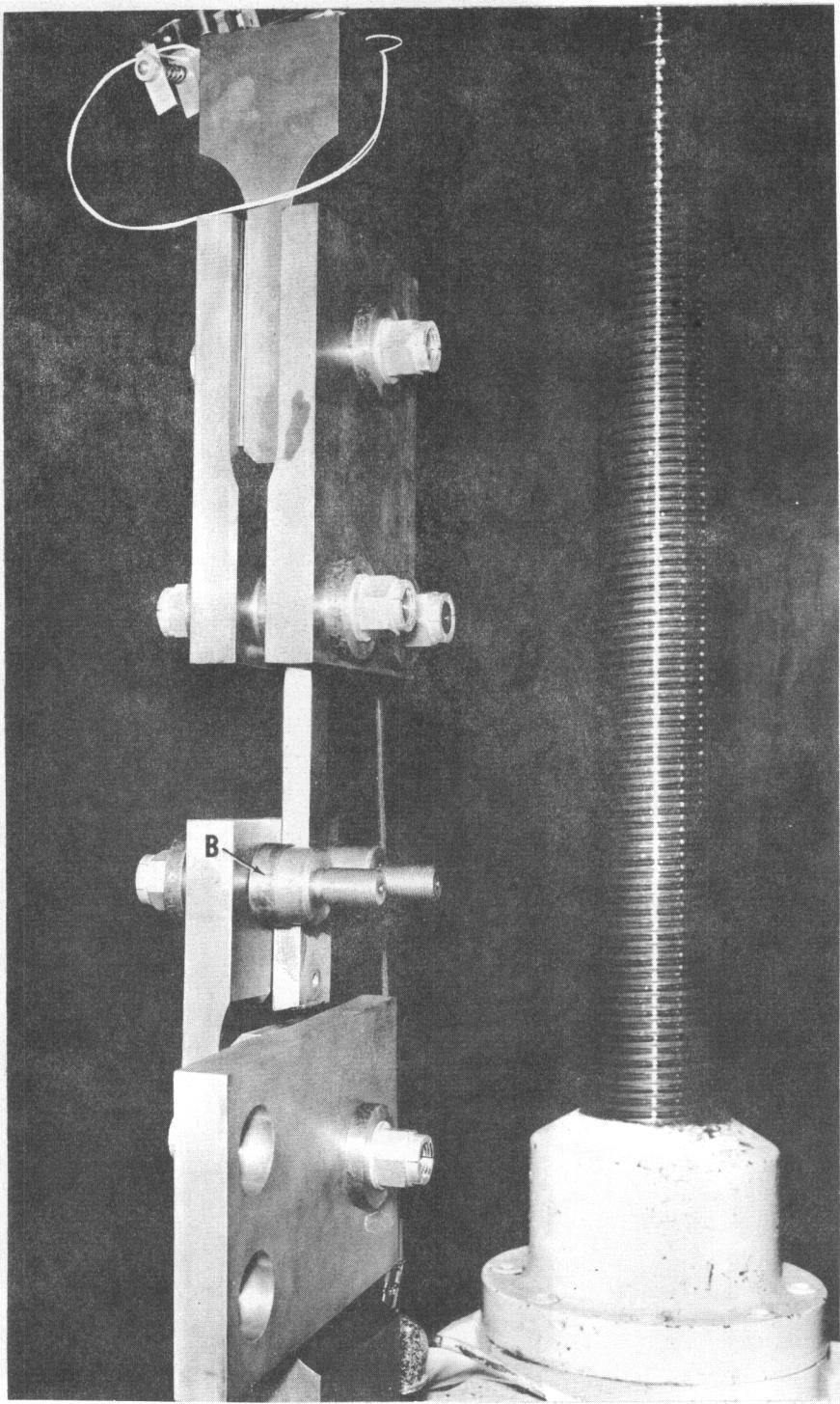


FIGURE 16. OBLIQUE VIEW OF TEST FIXTURE.

WADD TR 60-450

Contrails

CORRELATION OF TENSILE PROPERTIES
OF STEEL CASTINGS AND MATERIAL
IMPERFECTIONS AS DETERMINED
BY RADIOGRAPHY

3. DATA RELATING TO CASTINGS
USED FOR THIS PROJECT

Contrails

Convair

3. DATA RELATING TO THE CASTINGS USED FOR THIS PROJECT

3.1 Foundry Data

Table I lists heats poured at the foundry, castings from which were used for this project. Information includes: heat number, number of slabs supplied, thickness, foundry analysis of each heat, and the tensile-test properties, as determined by the foundry. The tensile tests were conducted on test bars, cast separately with each heat. These test bars were machined to the 0.505"-round test area, according to FTM Standard 151, Method 211, Type R1 Test Specimen. Some heats, from number 27 on, contained approximately 1% cobalt. Cobalt tends to improve the yield strength and reduce the sensitivity of the steel to notch effects.¹

3.2 Chemical-Analysis Checks

The equivalent of one heat out of each six supplied by the foundry was chemically analyzed at Convair. Table 2 lists the foundry analyses and check analyses for seven heats. Check analyses agreed closely with those determined by the foundry in all cases except two. The chromium for heat 3652 was analyzed as 11.40% by Convair and 12.34% by the foundry. Convair's analysis was rechecked and verified. The carbon analysis of heat 4012 was found to be 0.19% by Convair, versus 0.15%, reported by the foundry. This analysis was also substantiated by additional checks, as noted in Table 3 which shows carbon analyses of six different slabs from the heat in question.

3.3 Carbon and Chromium Fadeout Checks

Carbon and chromium analyses were made on a minimum of five slabs from each of three heats. These analyses were made to determine if carbon or chromium had a tendency to fadeout, as the heat approached the last slabs cast. The results are tabulated in Table 3. Although a very slight fadeout of chromium is noted on the last slabs cast, the degree of fadeout was insignificant.

¹Bhat, G. B. - "4137 Co - A New Steel for Rocket-Motor Cases" - Metals Progress, Vol. 77, No. 6, June 1960, pp. 75 - 79.

Controls

TABLE I
FOUNDRY DATA - MATERIAL SUPPLIED FOR THE PROGRAM

HEAT NO. (Pacific Alloy) Corporation)	NO OF SLABS AND THICKNESS			CHEMICAL			ANALYSIS			TENSILE PROPERTIES						
	0.1"	0.2"	0.3"	C	Mn	P	S	Si	Ni	Cr	Mo	Cu	Co	ULT. (ksi)	YIELD (ksi)	ELONG. % IN 2"
1. 3627	1	2		.13	.59	.010	.016	.37	.21	12.18	.01	.04		182.3	146.7	8.0
2. 3628	2	2	2	.13	.62	.019	.012	.38	.19	11.92	.02	.06		178.0	144.3	9.0
3. 3652	4	4		.11	.63	.015	.020	.42	.11	12.34	.03	.07		186.6	152.1	11.5
4. 3669		2		.095	.59	.014	.013	.43	.52	11.51	.02	.09		180.0	150.0	8.5
5. 3681		1		.10	.67	.019	.020	.58	.54	12.38	.02	.05		181.8	151.0	8.0
6. 3713		1		.12	.81	.030	.009	.38	.50	12.68	.01	.12		186.8	154.5	7.0
7. 3717	1			.12	.82	.010	.010	.66	.16	12.92	.34	.07		189.8	151.3	6.5
8. 3732		3		.095	.72	.017	.015	.50	.56	12.68	.04	.04		183.5	147.0	12.5
9. 3743	2	2	4	.10	.74	.011	.020	.38	.57	12.02	.01	.02		187.5	152.8	9.5
10. 3754	2	2	3	.11	.69	.019	.017	.66	.59	12.35	.05	.04		184.4	139.9	14.0
11. 3766	2	2	3	.13	.72	.016	.018	.33	.52	12.14	.02	.04		186.4	150.0	9.5
12. 3776	7	6		.13	.71	.018	.010	.64	.63	12.64	.02	.06		186.6	147.0	10.0
13. 3780	5		5	.10	.73	.015	.019	.79	.64	12.54	.02	.04		180.0	145.0	13.5
14. 3785		2	4	.11	.68	.011	.015	.48	.64	12.44	.04	.07		184.0	146.2	9.0
15. 3807		2	3	.10	.60	.023	.015	.78	.66	12.36	.02	.09		181.1	145.6	7.5
16. 3834	6	3	3	.11	.76	.026	.035	.61	.60	13.00	.01	.05		190.7	150.8	11.0
17. 3854	1	3	1	.14	.74	.025	.010	.53	.58	12.60	.01	.08		202.0	158.8	9.0
18. 3886		1	5	.12	.69	.018	.014	.52	.91	11.77	.02	.07		193.3	156.0	7.5
19. 3887	7	4	1	.14	.71	.016	.018	.60	.55	12.15	.04	.08		201.5	161.1	13.0
20. 3891	7	2	3	.15	.81	.026	.026	.93	.58	12.16	.04	.03		198.5	154.5	10.0
21. 3896		1	5	.14	.71	.023	.018	.61	.57	12.70	.02	.06		194.5	150.5	11.5
22. 3906		1	5	.14	.69	.016	.020	.64	.56	12.20	.02	.07		197.7	153.6	10.5
23. 3907		7	2	.14	.79	.023	.018	.75	.55	12.70	.02	.06		196.0	153.5	13.0
24. 3939	3			.13	.67	.019	.013	.45	.11	12.04	.02	.03		191.3	157.5	12.0
25. 3985	3		2	.12	.67	.021	.012	.62	.20	13.00	.01	.04		191.5	147.0	8.5
26. 3990	5	3	2	.14	.65	.019	.011	.64	.20	12.33	.01	.05		191.7	157.8	11.5
27. 3997	2	3	3	.13	.67	.011	.020	.52	.19	12.34	.03	.10		192.5	158.5	10.5

Controls

TABLE 1 (continued)
FOUNDRY DATA - MATERIAL SUPPLIED FOR THE PROGRAM

HEAT NO. (Pacific Alloy Corporation)	NO OF SLABS AND THICKNESS				CHEMICAL						ANALYSIS			TENSILE PROPERTIES			
	0.1"	0.2"	0.3"	0.6"	C	Mn	P	S	Si	Ni	Cr	Mo	Cu	Co	ULT. (ksi)	YIELD (ksi)	ELONG. % IN 2"
28.	4000	.5	3		.13	.80	.018	.016	.54	.49	.12.70	.02	.10	.62	192.5	152.3	11.0
29.	4003	5		4	.11	.80	.019	.008	.78	.60	.12.70	.05	.02	.66	178.8	141.8	6.0
30.	4009		9		.11	.56	.020	.018	.51	.27	.12.58	.02	.08		185.5	149.0	7.5
31.	4010		15		.13	.63	.019	.017	.63	.26	.12.40	.03	.04		194.0	151.5	10.0
32.	4012	6	3	4	.15	.72	.020	.016	.68	.28	.13.94	.02	.04	1.26	219.0	173.0	6.5
33.	4013	7		3	.14	.64	.021	.020	.64	.26	.12.28	.01	.07	1.07	197.0	160.4	8.5
34.	4015	6	3		.14	.59	.023	.010	.94	.22	.12.50	.02	.09	1.30	192.2	152.0	8.5
35.	4016	5		4	.15	.62	.014	.015	.67	.24	.12.48	.02	.10	.74	211.0	164.8	8.0
36.	4017		6		.13	.69	.017	.011	.72	.25	.12.54	.03	.11	1.11	187.5	149.3	9.0
37.	4019	7	2	2	.14	.68	.019	.009	.69	.26	.12.33	.03	.08	.91	187.8	149.0	8.5
38.	4021	5	4	2	.14	.65	.013	.008	.88	.25	.12.25	.02	.11	.83	195.3	155.5	11.0
39.	4029	1		4	.15	.66	.013	.015	.67	.31	.12.70	.02	.04	.89	196.0	162.3	9.5
40.	4035	6	5	3	.15	.64	.020	.010	.74	.30	.12.70	.02	.09	.69	204.3	161.0	5.0
41.	4139	6			.11	.59	.017	.020	.46	.13	.11.70	.02	.04		175.3	140.5	8.5

Controls

TABLE 2
CHEMICAL ANALYSIS CHECKS

ELEMENT	AMS 5351 SPEC.	HEAT 3776		HEAT 3743		HEAT 3652		HEAT 4010	
		FOUNDRY	CONVAIR	FOUNDRY	CONVAIR	FOUNDRY	CONVAIR	FOUNDRY	CONVAIR
C	0.15 Max. 1.00 Max.	0.13 0.71	0.14 0.66	0.10 0.74	0.12 0.66	0.11 0.63	0.12 0.54	0.13 0.63	0.14 0.58
Mn	0.04 Max.	0.018	0.019	0.011	0.024	0.015	0.018	0.019	0.016
P	0.04 Max.	0.010	0.019	0.020	0.018	0.020	0.016	0.017	0.014
S	1.50 Max.	0.64	0.58	0.38	0.30	0.42	0.58	0.63	0.68
Si	1.00 Max. 14. Max.	0.63 12.64	0.74 12.82	0.57 12.02	0.76 12.52	0.11 1.2.34	0.13 11.40**	0.26 12.40	0.10 12.57
Ni	0.50 Max.	0.02	0.03	0.01	0.02	0.03	0.02	0.03	0.03
Cr	0.50 Max.	0.06	0.05	0.02	0.06	0.07	0.05	0.04	0.04
Mo	0.50 Max.								
Cu	0.50 Max.								

ELEMENT	AMS 5351 SPEC.	HEAT 4012		HEAT 4035		HEAT 3854	
		FOUNDRY	CONVAIR	FOUNDRY	CONVAIR	FOUNDRY	CONVAIR
C	0.15 Max. 1.00 Max.	0.15 0.72	0.19* 0.66	0.15 0.64	0.15 0.58	0.14 0.74	0.16 0.71
Mn	0.04 Max.	0.020	0.017	0.020	0.017	0.025	0.019
P	0.04 Max.	0.016	0.018	0.010	0.014	0.010	0.016
S	1.50 Max.	0.68	0.66	0.74	0.59	0.53	0.60
Si	1.00 Max.	0.28	0.13	0.30	0.16	0.59	0.70
Ni	14. Max.	13.94	13.72	12.70	12.63	12.60	12.80
Cr	0.50 Max.	0.02	0.03	0.02	0.03	0.01	0.02
Mo	0.50 Max.	0.04	0.05	0.09	0.10	0.08	0.05
Cu	0.50 Max.						

* See Table III for additional Convair Carbon Analyses for Heat 4012

** Verified by rechecking

Controls

TABLE 3
CARBON AND CHROMIUM FADEOUT CHECKS

<u>HEAT 3743</u>			<u>HEAT 3776</u>				
FOUNDRY	SLAB NO.	C	FOUNDRY	SLAB NO.	C		
		Cr			Cr		
	35	0.13	12.82		58	0.15	12.57
	37	0.12	12.82		61	0.15	12.52
	39	0.12	12.82		65	0.14	12.62
	41	0.12	12.62		68	0.11	12.70
	42	0.14	12.70		70	0.12	12.33

<u>HEAT 4012</u>			
FOUNDRY	SLAB NO.	C	
		Cr	
	240	0.19	13.67
	241	0.19	13.72
	244	0.18	13.80
	249	0.19	13.48
	251	0.18	13.80
	252	0.18	13.48

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4. STATISTICAL ANALYSIS OF TEST DATA

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4. STATISTICAL ANALYSIS OF TEST DATA - AN INTRODUCTION

The statistical analysis of the data was planned to answer questions relating to:

4.1 Number of Test Specimens:

Due to technical difficulties, the number of test specimens previously estimated to be required for statistical adequacy was not always available. These estimates were: 15 for control specimens (having no defects) and 30 for specimens having intentionally introduced flaws. Statistical adequacy may be defined as a high probability that the average of a sample will be within plus or minus an allowed error of the true average. It was originally intended to test "how good" were our estimates of the number of samples required. In lieu of this, it now seems more important to test the adequacy of the number of samples actually tested. Thus, the first question the statistical analysis will answer is:

- (1) Was the number of specimens tested statistically adequate? This is computed from the following equation:¹

$$n = \left(\frac{t\hat{\sigma}}{E} \right)^2 \quad \dots \quad (1)$$

The t is from the t , or "Students" distribution,² and since a probability (confidence level) of 0.95 was desired, the tabulated value of the deviate is 2.

E (the allowable error) was established at 5% of the mean for tensile yield, tensile ultimate and modulus of elasticity; it was established at 15% for elongation.

$\hat{\sigma}$, (the sample standard deviation), and an estimate of the population standard deviation, was computed from the test data, using the following equations:

$$\hat{\sigma} = \sqrt{\frac{\sum Y^2}{N-1} - \frac{(\sum Y)^2}{N(N-1)}} \quad (\text{for small samples, less than 30}) \quad \dots \quad (2)$$

$$\hat{\sigma} = \sqrt{\frac{\sum Y^2}{N} - (\bar{Y})^2} \quad (\text{for large samples, 30 and over}) \quad \dots \quad (3)$$

¹Simon, L. E. - An Engineer's Manual of Statistical Methods. New York: John Wiley and Sons, Inc., 1944, p. 103.

²Duncan, A. J. - Quality Control and Industrial Statistics. Chicago (Homewood) Illinois: Richard D. Irwin, Inc., 1952, p. 114.

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Y is a tensile-property test value.

\bar{Y} is the average of the tensile-property test values.

N is the number of specimens actually tested.

The following example shows the computations necessary to determine n , equation (1). Data is taken from an actual test, Appendix A. paragraph A39.2. The test was for elongation, the Y values are in % in 2", and the defect classification is 2-mm-size gas holes.

\underline{Y}	\underline{Y}	\underline{Y}	
3.0	2.5	1.5	$\Sigma Y = 40.0$
3.5	4.0	2.0	
4.5	2.0	2.0	$\Sigma Y^2 = 116.0$
2.5	2.0	3.0	
2.5	2.5	2.5	$\bar{Y} = 2.66 \quad N = 15$

Using equation (2), we have:

$$\hat{\sigma} = \sqrt{\frac{116}{(15-1)} - \frac{(40)^2}{15(15-1)}} = 0.81$$

Computing E as 0.15×2.66 , we have: $E = 0.4$

Using equation (1), we have: $n = \left(\frac{2 \times 0.81}{0.4}\right)^2 = 16$, the number of test specimens required for statistical adequacy. It is to be understood that this holds only for this set of data. Another set of data may give a different result.

Comparing this result, 16, with the number of specimens actually tested, 15, we see that we have not quite achieved the statistical adequacy desired, i.e., we cannot quite depend on the computed average being within 15% of the true mean 95% of the time.

4.2 Upper and Lower Limits of Variability:

Making use of $\hat{\sigma}$, the estimate of the population standard deviation, the analysis will next investigate the extent to which the population (from which the test specimens are a sample) may be expected to vary. This will answer the following question:

- (2) If this experiment (project) were repeated indefinitely, what upper and lower tensile-property values would the test results, for a particular flaw size or intensity, be expected to assume?

This will be tested at the two-standard-deviation level as follows:
 $\bar{Y} \pm 2\hat{\sigma}$ = upper and lower limits of expected variability for 0.95 probability. These values will be plotted, answering the question:

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- (3) Is it possible that a casting, classified as having a flaw of a certain size or intensity, may have a tensile property in the range of a casting, classified as having a flaw of the same type, having a different intensity? (See Figure 17)

An example, using data from paragraph 4.1, where $\bar{Y} = 2.66$ and $\hat{\sigma} = 0.81$, is computed as follows: $2.66 \pm 2(0.81) = 1.04$ and 4.28 , from which one can say: the % of elongation in 2" of an individual casting may be expected to vary from 1.04 to 4.28, 95% of the time. Overlap is demonstrated by making a corresponding computation using data from three-mm-gas-hole test specimens, Appendix A, paragraph A39.3, with values of $\bar{Y} = 2.9$, $\hat{\sigma} = 0.52$. From this, $2.9 \pm 2(0.52) = 1.86$ and 3.94 .

4.3 Correlation:

Simple linear correlation, the relationship between flaw size or intensity (X) and average values of a tensile property (\bar{Y}), will also be examined. This relationship is expressed by the linear correlation coefficient, r . The linear correlation coefficient, r , is computed according to the following equation, in which N now has a value equal to the number of paired values (X , \bar{Y} 's) being correlated.

$$r = \frac{N\sum(X\bar{Y}) - (\sum X)(\sum \bar{Y})}{\sqrt{[N\sum X^2 - (\sum X)^2][N\sum \bar{Y}^2 - (\sum \bar{Y})^2]}} \quad (4)$$

The determination of r will answer the question:

- (4) How good is the relationship? Could such a relationship have occurred by chance alone?

An example, using data from Appendix A, paragraphs A39.0 through A39.5, and equation (4):

Values of X (Size of Gas Holes) in mm	Values of \bar{Y} (Average Tensile Property) in % in 2"
0 (no defects)	2.9
2	2.7
3	2.9
4	2.7
7.4 (Avg. of 5 & larger)	1.9 $\bar{Y} = 2.6$

N , the number of pairs (X , \bar{Y} 's) being correlated = 5.

$$\begin{aligned} \sum X &= 16.4 & \sum \bar{Y} &= 13.1 & (\sum X)^2 &= 269.0 & (\sum \bar{Y})^2 &= 171.6 \\ \sum XY &= 39.0 & \sum X^2 &= 83.8 & \sum \bar{Y}^2 &= 35.0 \end{aligned}$$

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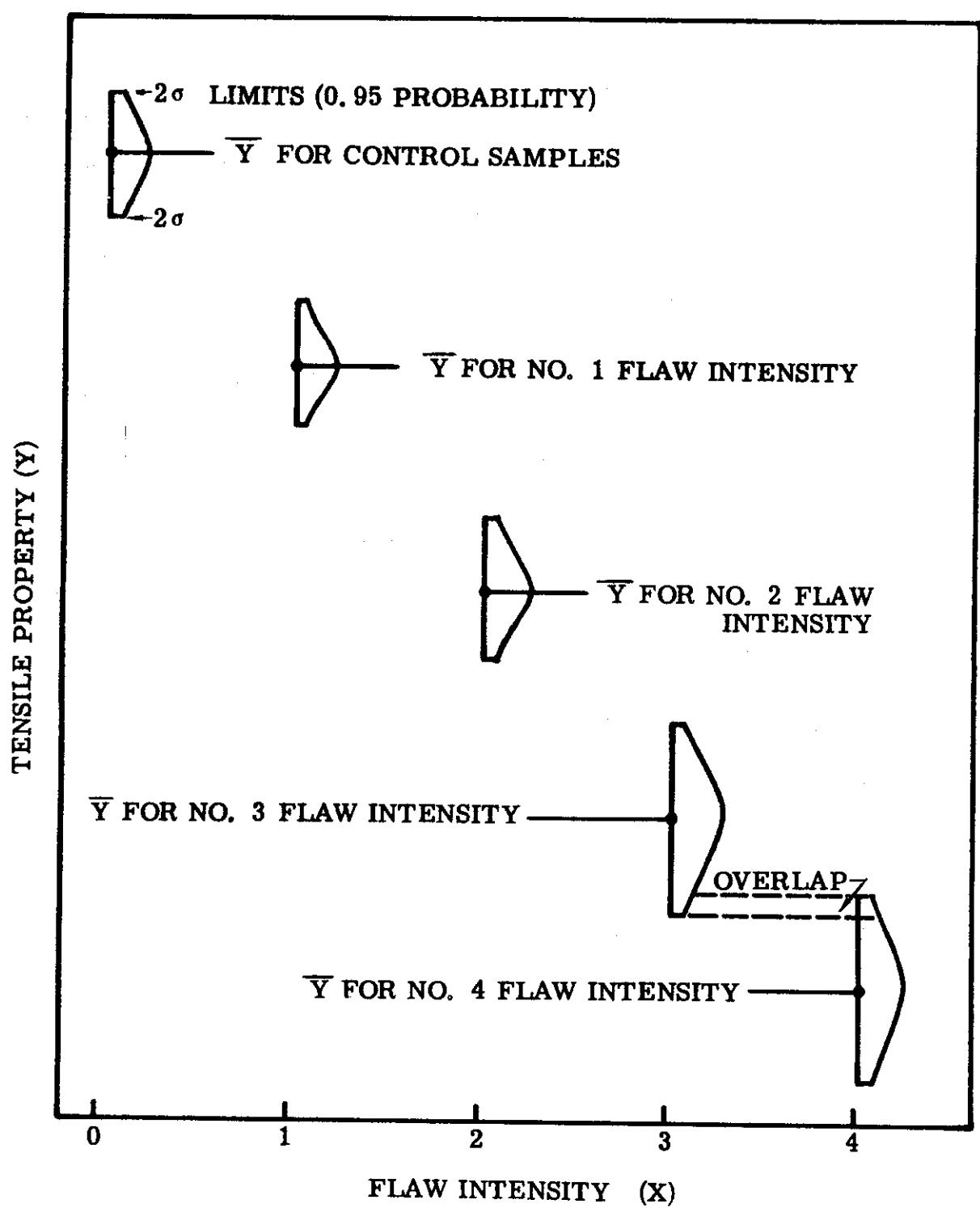


Figure 17. Theoretical Effects, Including Possible Ranges of Variation, of Increasing Flaw Intensities on a Tensile Property of Steel Castings.

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$$r = \frac{5(39) - (16.4)(13.1)}{\sqrt{[5(83.8) - 269.0][5(35.0) - 17.2]}} = -0.92, \text{ the minus sign indicates an inverse relationship.}$$

This result, $r = -0.92$, indicates a very significant correlation for these particular average tensile-property values and their related flaw sizes. Statistically, such a result could occur by chance alone, only 1 time in 100.

4.4 Line of Regression:

In order to illustrate simple linear correlation, a line of regression is drawn between two points. These points are established on a graph in such a way that a "best fit" between the line of regression and the plotted values, representing average test results, is attained. To establish the line of regression, the following linear equation is used:

$$Y_c = a + bX \quad (Y_c \text{ represents the computed } Y \text{ value, not a test result}) \quad (5)$$

$$a = \frac{\Sigma X^2 \bar{Y} - \Sigma X \Sigma (\bar{XY})}{N \Sigma X^2 - (\Sigma X)^2} \quad (\text{the } Y\text{-axis intercept}) \quad - - - - - \quad (6)$$

$$b = \frac{N \Sigma (\bar{XY}) - \Sigma X \Sigma \bar{Y}}{N \Sigma X^2 - (\Sigma X)^2} \quad (\text{the slope of the regression line}) \quad - - - - - \quad (7)$$

After computing a and b , values are assigned to X , in the linear equation, and two values of Y_c are computed and plotted. The line of regression is drawn between these two points. (See Figure 18.) Computations using test results will not be made as they follow so closely the procedure for determining r , above. N , in these equations, continues to be the number of pairs (X , \bar{Y} 's) being correlated.

4.5 The "Standard Error of Estimate":

As with all things, there will be variability, or "scatter," of the averages of the test results about the line of regression. In order to make predictions of tensile properties from imperfections, as established by radiography, it will be necessary to determine the limits of this scatter. These limits are measured by the "standard error of estimate." The so-called "error" is computed as follows:

$$\hat{\sigma}_{Y_c} = \sqrt{1 - r^2} \times \sqrt{\frac{\sum (\bar{Y} - \bar{\bar{Y}})^2}{N - 2}} \quad - - - - - \quad (8)$$

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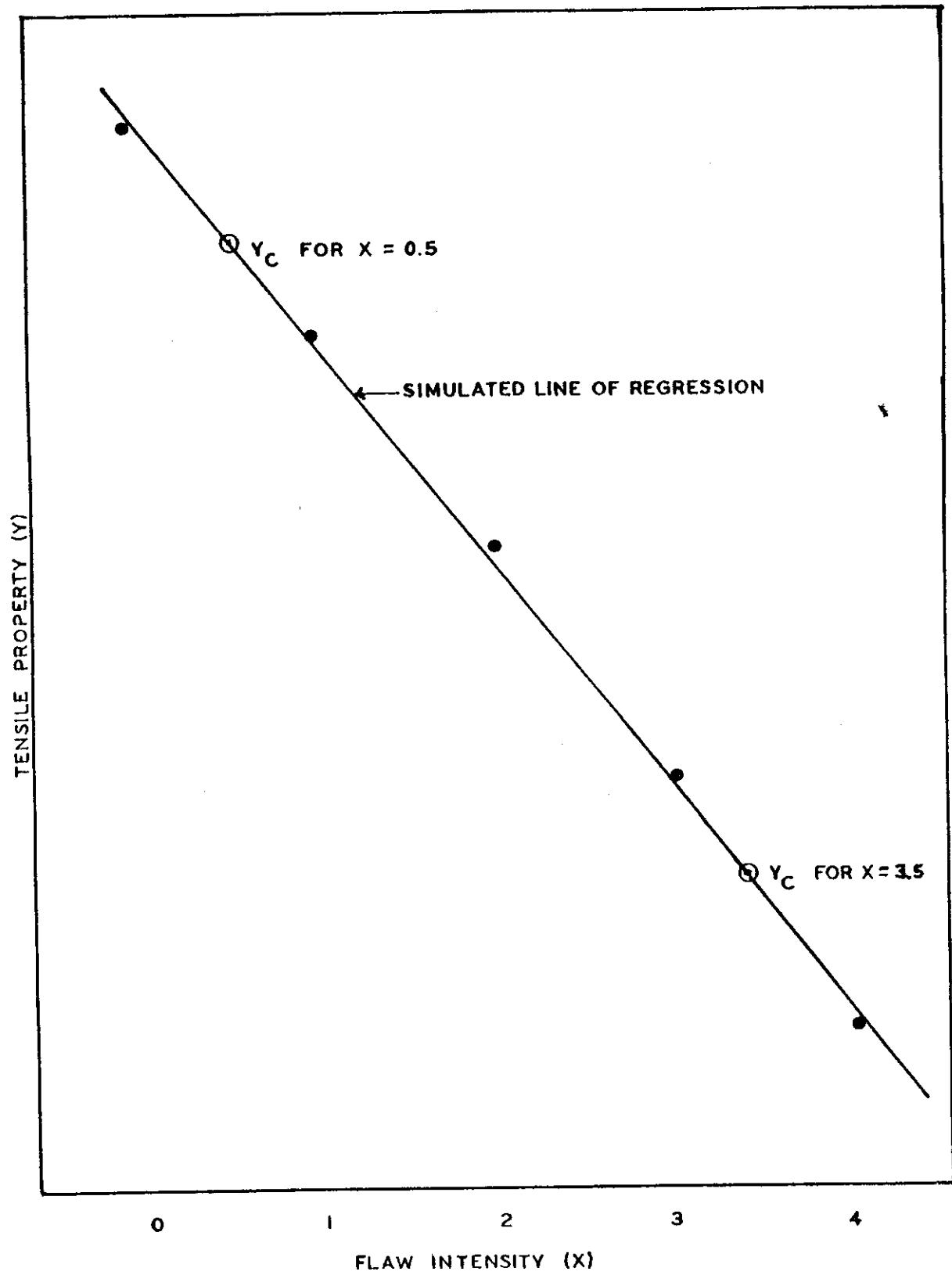


FIGURE 18. THEORETICAL REGRESSION LINE OF Y ON X.

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This result will be multiplied by 2 (for 0.95 probability) and the results plotted as dotted lines parallel to the line of regression. This will illustrate the extent to which the averages of the tensile-property test results may be expected to vary 95% of the time. (See Figure 19.) The following example uses data from paragraph 4.3 and equation (8).

Values of \bar{Y} (Average Tensile Property) in % in 2"	$\bar{Y} - \bar{\bar{Y}}$	$(\bar{Y} - \bar{\bar{Y}})^2$
2.9	0.3	0.09
2.7	0.1	0.01
2.9	0.3	0.09
2.7 $\bar{Y} = 2.6$	0.1	0.01
1.9	-0.7	0.49

$$N = 5, N - 2 = 3 \quad r = -0.92, r^2 = 0.85 \quad \Sigma(\bar{Y} - \bar{\bar{Y}})^2 = 0.69$$

$$\hat{\sigma}_{Y_c} = \sqrt{1 - 0.85} \times \sqrt{\frac{0.69}{3}} = 0.19$$

Multiplying this result by 2, we have 0.38, and dotted limit lines can be drawn parallel to the line of regression, above and below it, 0.38 units. In this case the units are in % elongation in 2".

4.6 Procedure for Making Predictions:

Figure 19 can be used to make simulated predictions of the average tensile property of a number of castings which have been examined by radiography and have been found to have imperfections as determined by radiography: Draw a vertical line from the flaw intensity, as determined by radiography (intensity 1 in Figure 19). This line will intersect both the upper and lower dotted limit lines bounding the "errors-of-the-estimate" at points a and b, Figure 19. From these intersecting points, draw two horizontal lines to intersect the tensile-property scale at points A and B, Figure 19. The predicted tensile property will have a value between the intersecting points, A and B, Figure 19.

By following the above procedure, one can answer the final question:

- (5) Within what limits can the average tensile property of a group of castings be estimated from a radiographically established flaw intensity?

4.7 Summary of Results, Graphical Presentation and Test Data

For each tensile property, each type of imperfection, and each size or intensity of imperfection the test results are presented on a summary sheet. Following each summary sheet, the data is presented graphically. The first graph depicts the anticipated range of values at 0.95 probability, and the second depicts the degree of relationship, or correlation. The test data from which the summaries and graphs were prepared is included as Appendix A.

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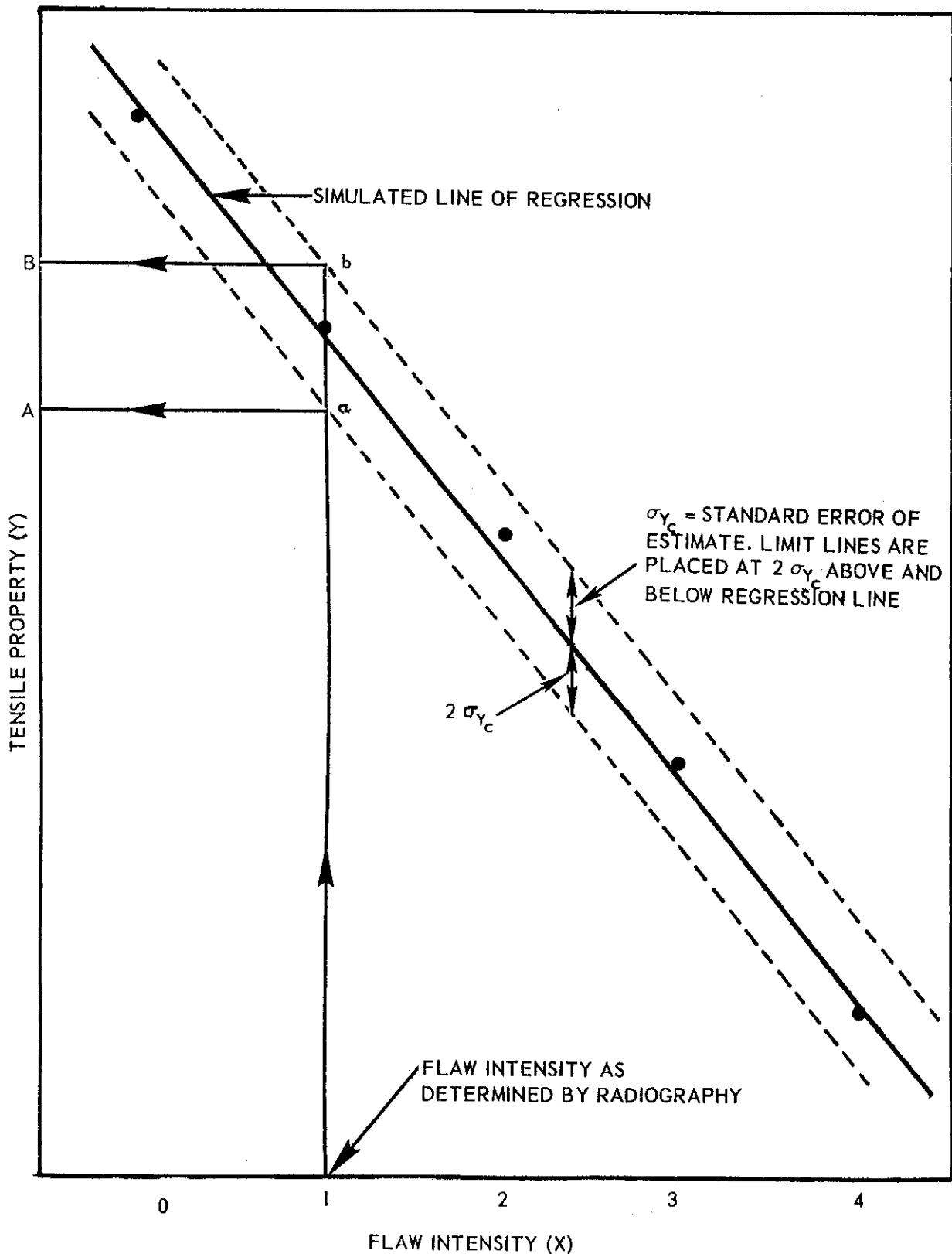


FIGURE 19. THEORETICAL REGRESSION OF Y ON X WITH CONTROL LIMITS PLACED AT TWO "STANDARD ERRORS OF ESTIMATE" ON EITHER SIDE OF THE REGRESSION LINE.

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5. SUMMARIES OF TEST RESULTS
AND
GRAPHICAL DISPLAYS

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5.1 SUMMARY OF RESULTS - TENSILE YIELD VS GAS HOLES - 0.1"-THICK MATERIAL

Number of specimens tested -	Control Specimens	Size of Gas Holes (diam. in millimeters)					<u>8.5*</u>
		<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	
36	9	9	7	7	6**	12**	
Statistically determined number required for 0.95 confidence that the average of the results approaches the true average -	3	3	4	4	2	9	95
Confidence level, if less than 0.95 -	-	-	-	-	-	***	***
The following results and statistical parameters are in ksi.							
Tensile yield (Average of test results) -	145	146	147	147	141	141	113
Estimate of the standard deviation -	5.7	6.1	6.6	6.6	4.9	10.5	27.4
Statistical limits for individuals:							
Lower limit (0.95 probability) -	134	133	133	132	120	58	
Upper limit (0.95 probability) -	157	159	160	160	162	162	167

CORRELATION ANALYSIS

Analysis was not made; no trend toward lower values, as size of gas holes increased, was present, except for the larger sizes of gas holes. Also, number of specimens for the larger size gas holes was not statistically adequate.

* Specimens having 6-mm-and-larger gas holes, averaging 8.5 mm.

** Number of specimens not adequate, see number required on line below

*** Value too low for confidence level to have a practical meaning.

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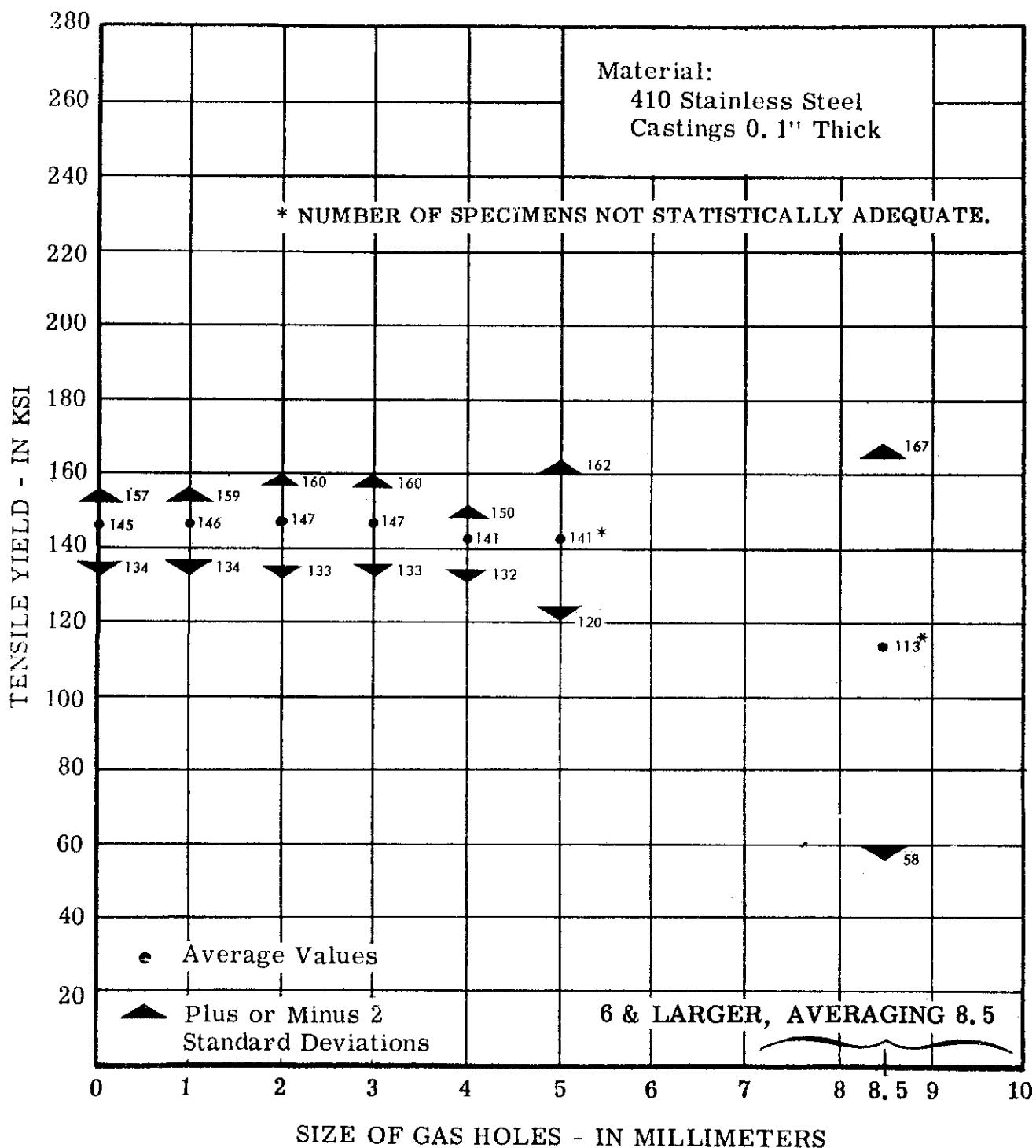


Figure 20. Tensile Yield vs Gas Holes - Range of Values

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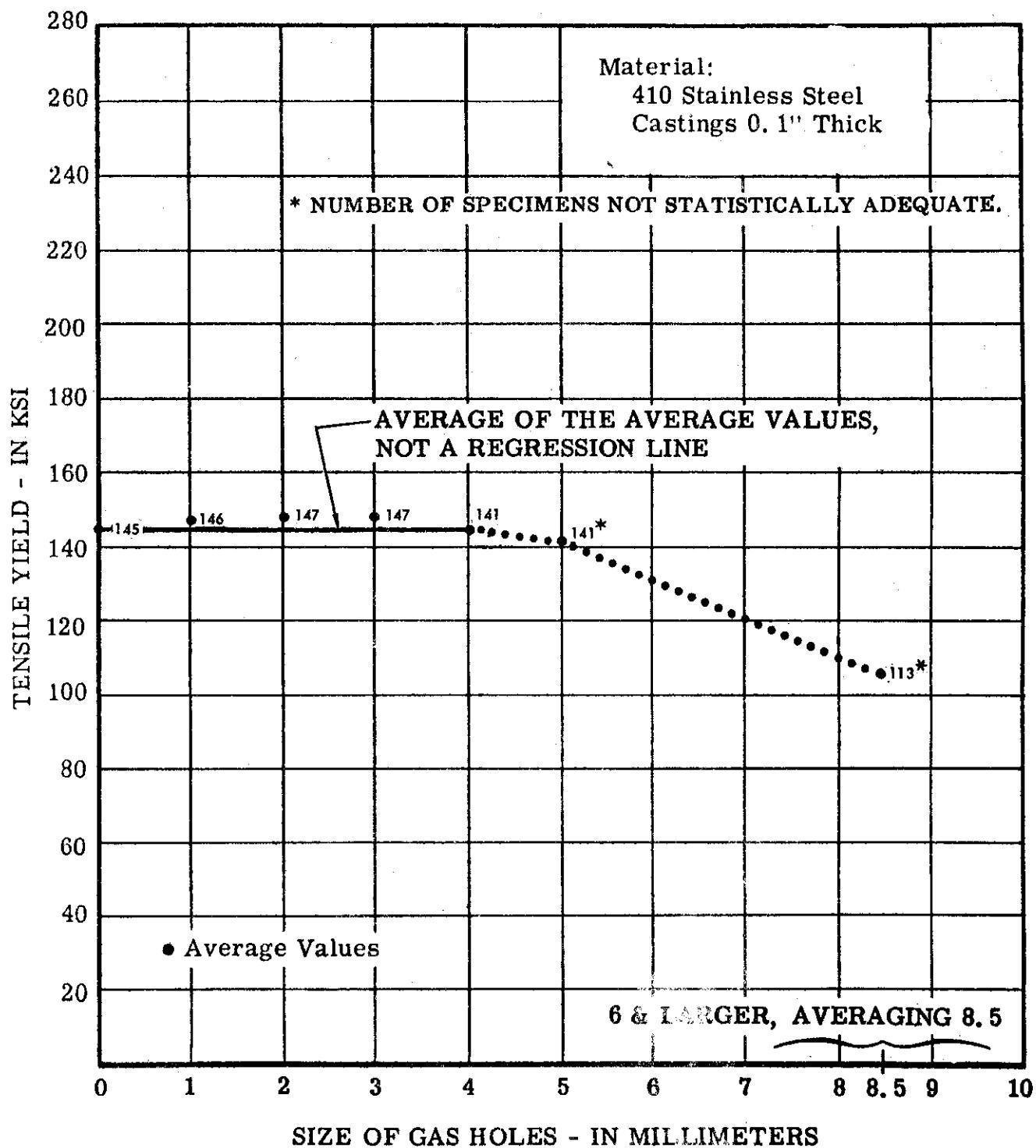


Figure 21. Tensile Yield vs Gas Holes - Correlation

5.2 SUMMARY OF RESULTS - TENSILE ULTIMATE VS. GAS HOLES - 0.1"-THICK MATERIAL

Number of specimens tested -	Control Specimens	Size of Gas Holes (diameter in millimeters)					<u>8.4*</u>
		<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	
37		10	10	7	7**	7***	16**

Statistically determined number required for 0.95 confidence that the average of the results approaches the true average -

Confidence level, if less than 0.95 -

The following results and statistical parameters are in ksi:

Tensile ultimate (average of test results) -	19.3	19.4	18.5	17.3	15.4	11.1
Estimate of the standard deviation -	7.3	10.2	13.7	10.2	11.9	13.4
Hardness (average Rockwell C) -	41.1	41.6	42.0	42.4	41.1	40.8
Tensile ultimate (adjusted to hardness) - *** -	19.7	19.4	18.3	17.8	16.1	11.0

Statistical limits for individuals:

Lower limit (0.95 probability) -	182	177	163	154	134	50
Upper limit (0.95 probability) -	212	217	221	204	202	187

CORRELATION ANALYSIS

Correlation coefficient = -0.94, minus sign indicates an inverse relationship. "Standard error of estimate" = 3.4 ksi

-
- * Specimens having 6-mm-and-larger gas holes, averaging 8.4 mm.
 - ** Number of specimens not adequate; see number required on line below.
 - *** Value too low for confidence level to have a practical meaning.
- Cannavaro 6.1.1

Contrails

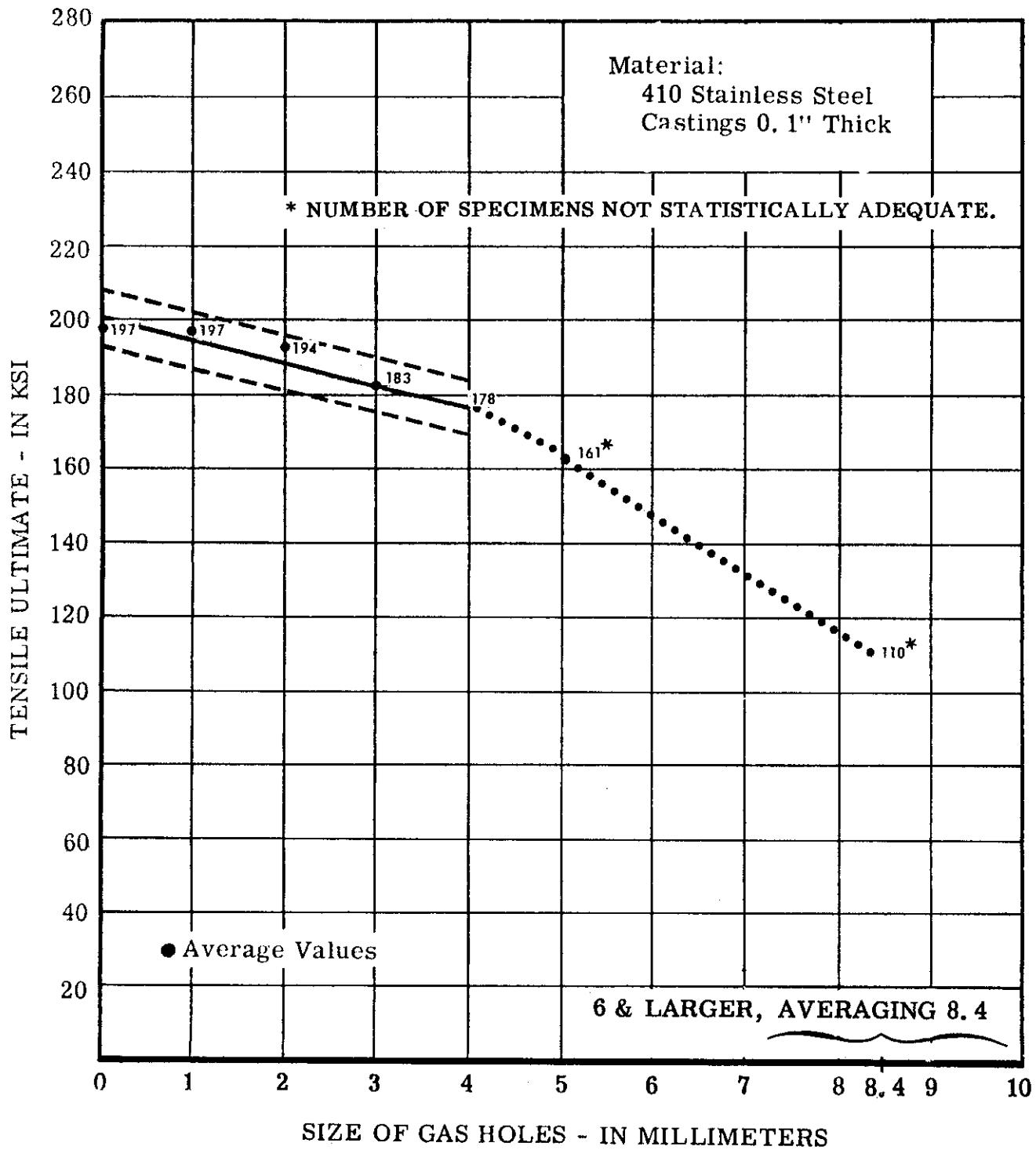


Figure 23. Tensile Ultimate vs Gas Holes - Correlation

5.3 SUMMARY OF RESULTS - ELONGATION VS. GAS HOLES - 0.1" THICK MATERIAL

	Control <u>Specimens</u>	Size of Gas Holes (diameter in millimeters)					<u>8.5*</u>
		<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	
Number of specimens tested -	37	10**	9**	7**	7**	5**	15**
Statistically determined number required for 0.95 confidence that the average of the results approaches the true average -	11	24	64	13	13	9	27
Confidence level, if less than 0.95 -	-	***	***	***	***	***	***
The following results and statistical parameters are in % in 2"							
Elongation (average of test results) -	7.5	7.1	3.9	2.9	2.4	2.3	2.3
Estimate of the standard deviation -	1.8	2.6	2.3	0.8	0.6	0.5	0.9
<u>Statistical limits for individuals:</u>							
Lower limit (0.95 probability) -	3.9	1.9	0	1.3	1.2	1.3	0.5
Upper limit (0.95 probability) -	11.1	12.3	8.5	4.5	3.6	3.3	4.1

CORRELATION ANALYSIS

Analysis was not made; data does lend itself to a straight-line relationship. Also, number of specimens was not statistically adequate.

-
- * Specimens having 6-mm-and-larger gas holes, averaging 8.5 mm.
 - ** Number of specimens not adequate, see number required on line below.
 - *** Value too low for confidence level to have a practical meaning.

Contrails

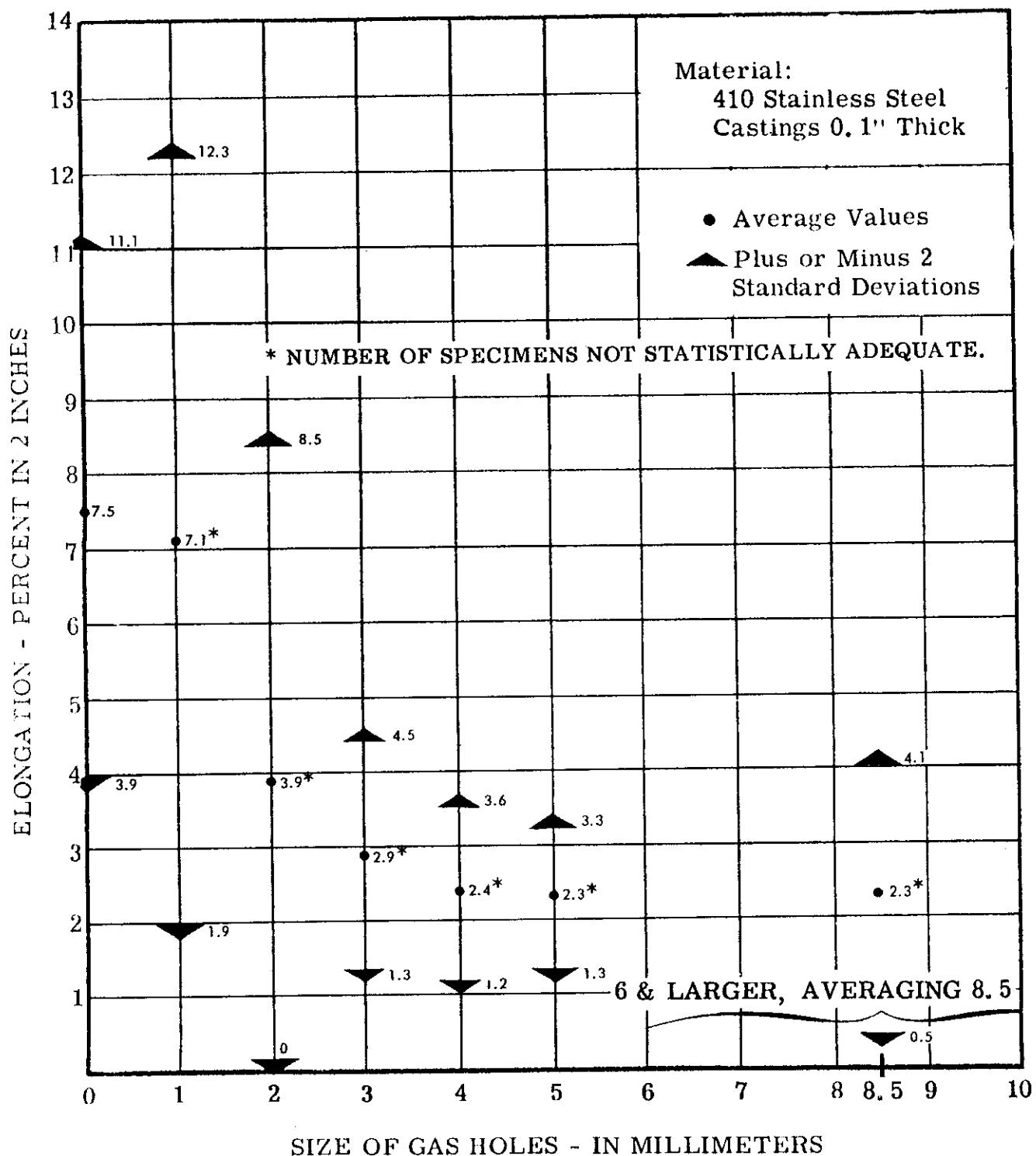


Figure 24. Elongation vs Gas Holes - Range of Values

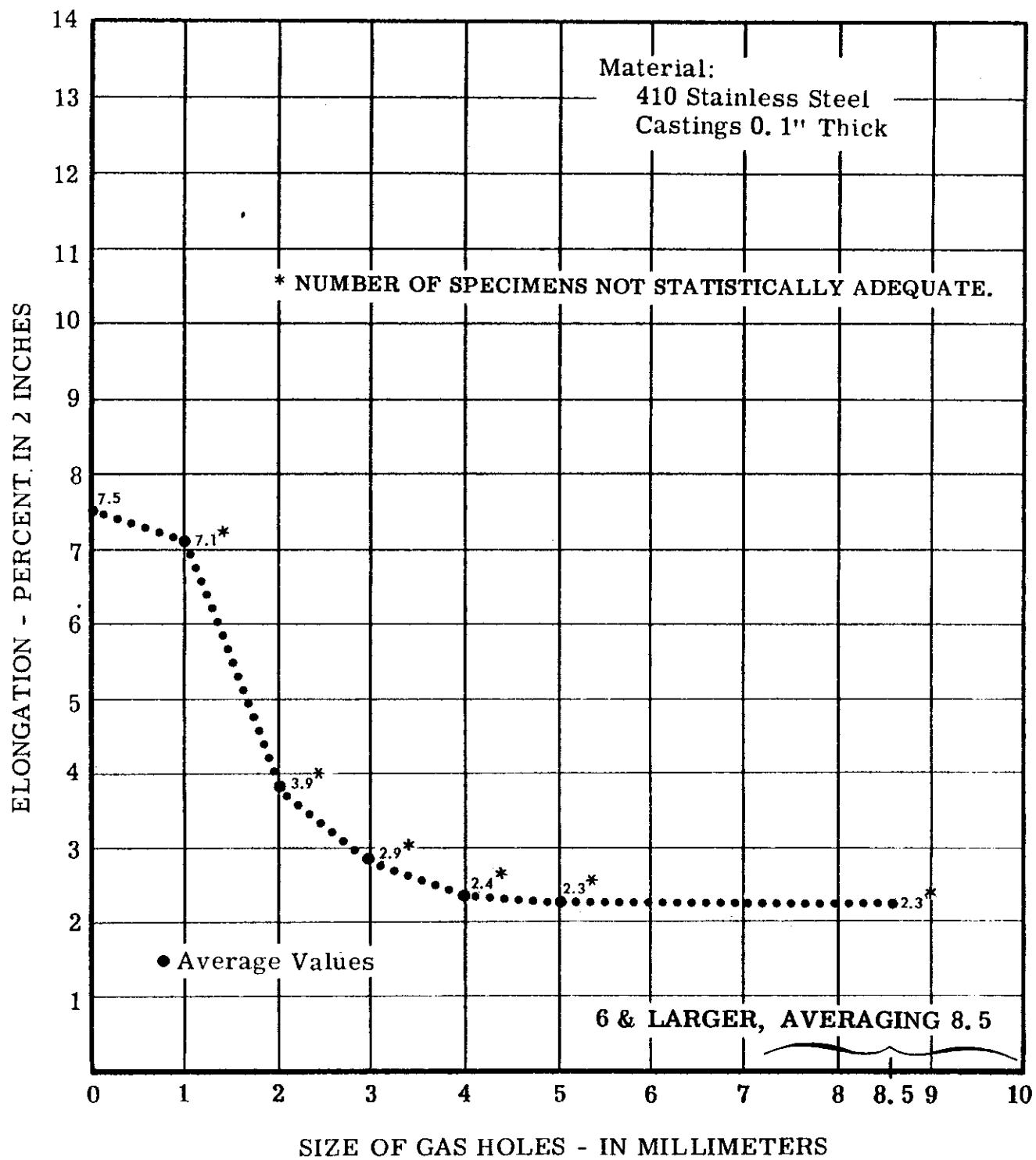


Figure 25. Elongation vs Gas Holes - Correlation

5.4 SUMMARY OF RESULTS - MODULUS OF ELASTICITY VS. GAS HOLES - 0.1"-THICK MATERIAL

	Control Specimens	Size of Gas Holes (diameter in millimeters)			
		<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>
Number of specimens tested -	37	10	9	7	7

Statistically determined number required for 0.95 confidence that the average of the results approaches the true average -

Confidence level, if less than 0.95 -

The following results and statistical parameters are in 10^6 psi

	Modulus of Elasticity (Average of results) -	29.8	29.9	30.1	29.0	27.7	24.9
	Estimate of the standard deviation -	1.6	1.1	1.5	1.4	1.5	2.5
<u>Statistical limits for individuals:</u>							
Lower limit (0.95 probability) -	26.6	27.6	26.9	27.2	26.0	22.7	31.1
Upper limit (0.95 probability) -	33.0	32.0	32.9	32.9	32.0	32.7	19.7

CORRELATION ANALYSIS

Analysis was not made; no trend toward lower values, as size of gas holes increased, was present, except for the larger sizes of gas holes. Also, number of specimens for larger size gas holes was not statistically adequate.

* Specimens having 6-mm-and-larger gas holes, averaging 8.1 mm.

** Number of specimens not adequate; see number required on line below.

*** Value too low for confidence level to have a practical meaning.

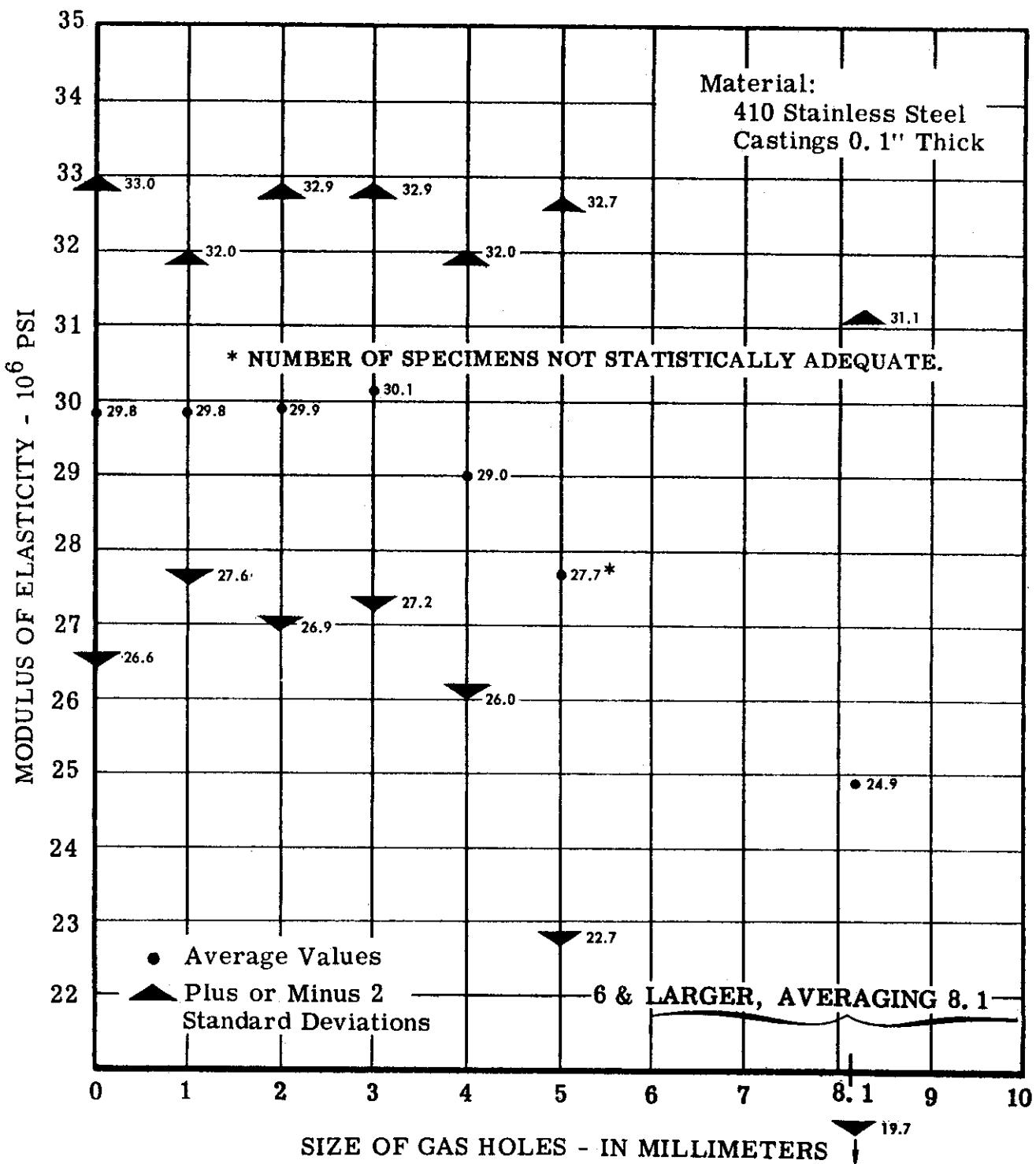


Figure 26. Modulus of Elasticity vs Gas Holes -- Range of Values

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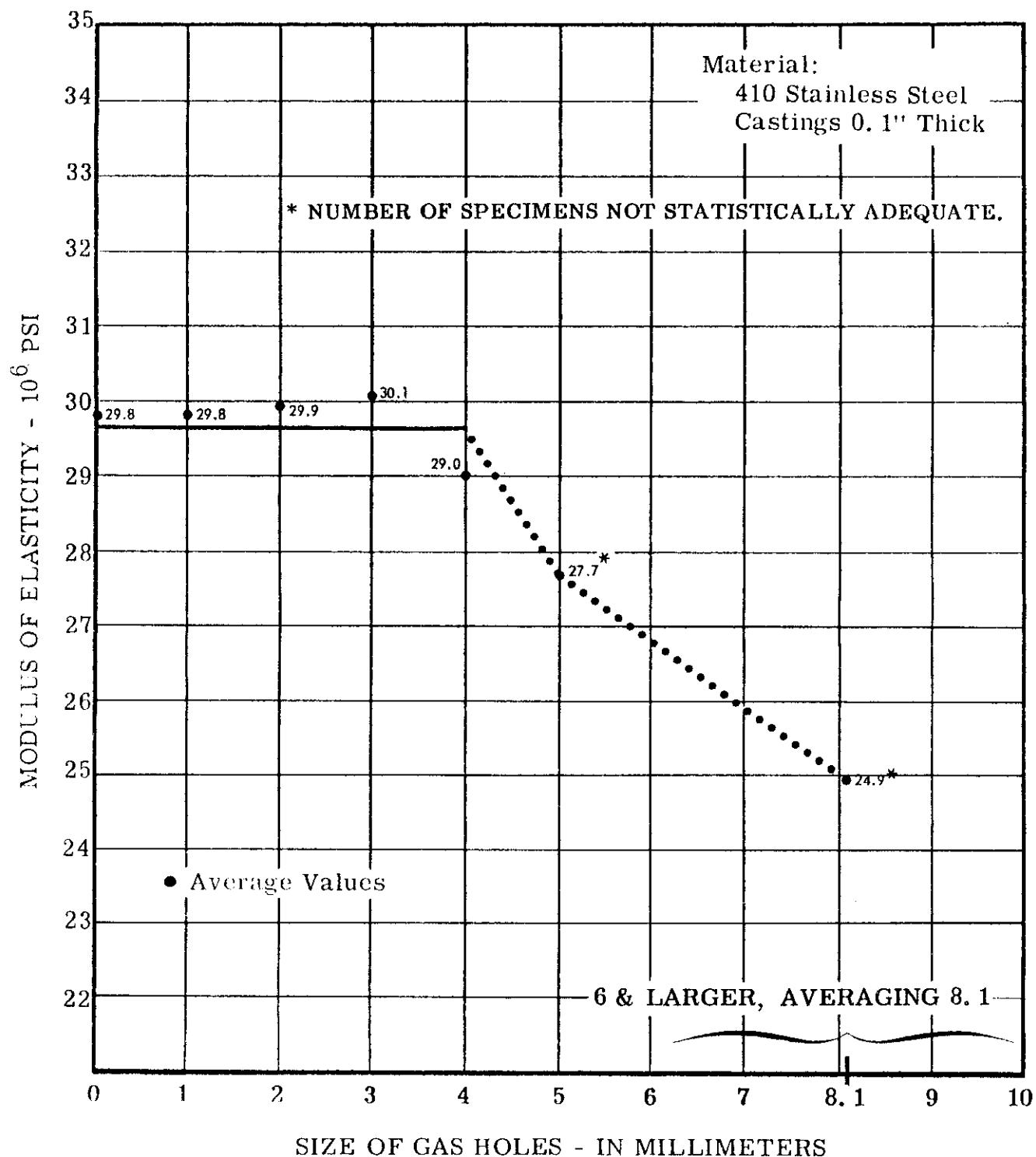


Figure 27. Modulus of Elasticity vs Gas Holes - Correlation

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5.5 SUMMARY OF RESULTS - TENSILE YIELD VS. INCLUSIONS - 0.1"-THICK MATERIAL

	Control Specimens	Size of Inclusions (diameter in millimeters)						<u>8.9*</u>
		<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	
Number of specimens tested	36	5	17	12	12	14	7**	8**
Statistically determined number required for 0.95 confidence that the average of the results approaches the true average -	3	3	4	3	4	12	9	66
Confidence level, if less than 0.95 -	-	-	-	-	-	-	***	***
The following results and statistical parameters are in ksi								
Tensile yield (average of test results) -	145	144	145	147	146	139	135	135
Estimate of the standard deviation	5.7	6.1	6.4	6.3	6.3	11.6	9.7	27.3
Statistical limits for individuals:								
Lower limit (0.95 probability) -	134	132	132	135	133	116	116	57
Upper limit (0.95 probability) -	157	156	158	160	159	162	154	179

CORRELATION ANALYSIS

Analysis was not made; no trend toward lower values, as size of inclusions increased, was present, except for the larger sizes of inclusions. Also, number of specimens for larger sizes of inclusions was not statistically adequate.

* Specimens having 8-mm-and-larger inclusions, averaging 8.9 mm.

** Number of specimens not adequate; see number required on line below.

*** Value too low for confidence level to have a practical meaning.

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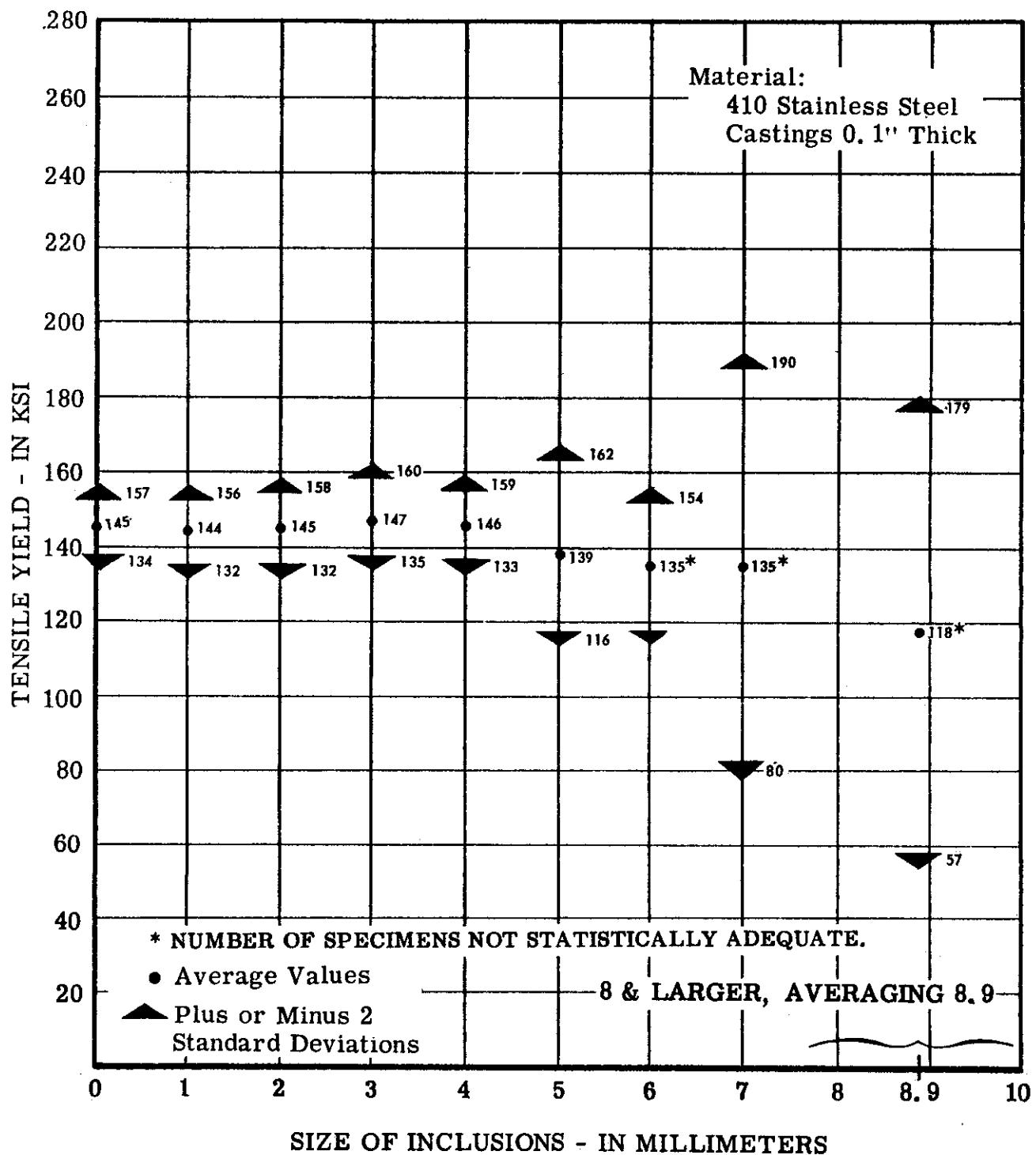


Figure 28. Tensile Yield vs Inclusions - Range of Values

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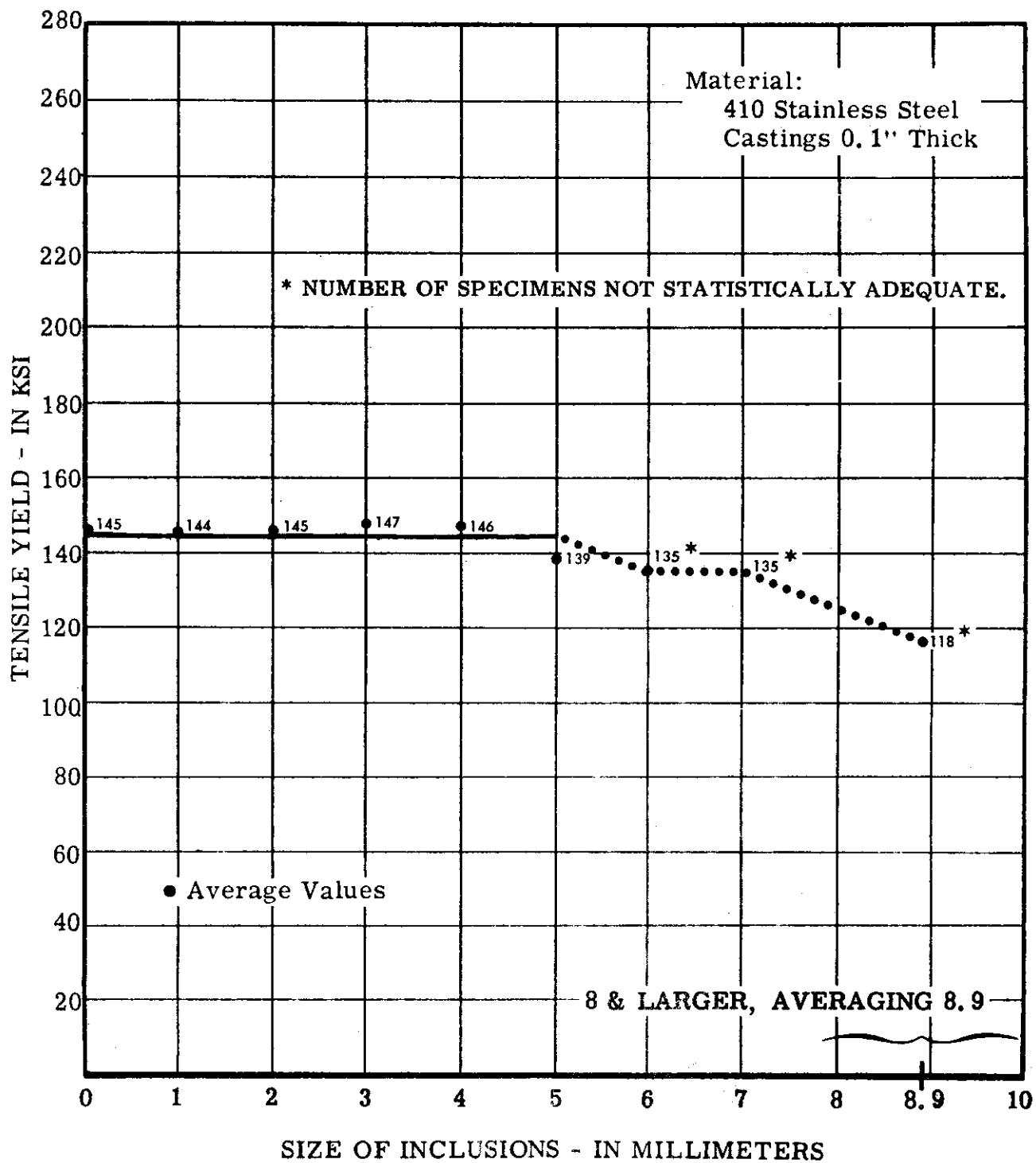


Figure 29. Tensile Yield vs Inclusions - Correlation

5.6 SUMMARY OF RESULTS - TENSILE ULTIMATE VS. INCLUSIONS - 0.1"-THICK MATERIAL

Control Specimens	Size of Inclusions (diameter in millimeters)						
	1	2	3	4	5	6	7
Number of specimens tested -	37	6	17	12	12	15**	9**

Statistically determined number required for 0.95 confidence that the average of the results approaches the true average -

Confidence level, if less than 0.95 -

The following results and statistical parameters are in ksi

Tensile ultimate (average of test results) -	193	192	187	179	179	161	145	154	133
Estimate of the standard deviation -	7.3	8.0	11.0	9.5	13.6	22.8	20.3	21.1	12.1
Hardness (Average Rockwell C) -***	41.1	41.2	41.9	41.7	42.1	41.6	41.3	41.6	41.4
Tensile ultimate (adjusted to hardness) -	197	197	187	181	178	163	149	157	136

Statistical limits for individuals:

Lower limit (0.95 probability) -	183	181	166	162	151	118	108	114	112
Upper limit (0.95 probability) -	211	213	210	200	205	209	189	199	160

CORRELATION ANALYSIS

Correlation coefficient = -0.97, minus sign indicates an inverse relationship. "Standard error of estimate" = 2.4 ksi

* Specimens having 8-mm-and-larger inclusions, averaging 8.9 mm.

** Number of specimens not adequate; see number required on line below.

*** Value too low for confidence level to have a practical meaning.

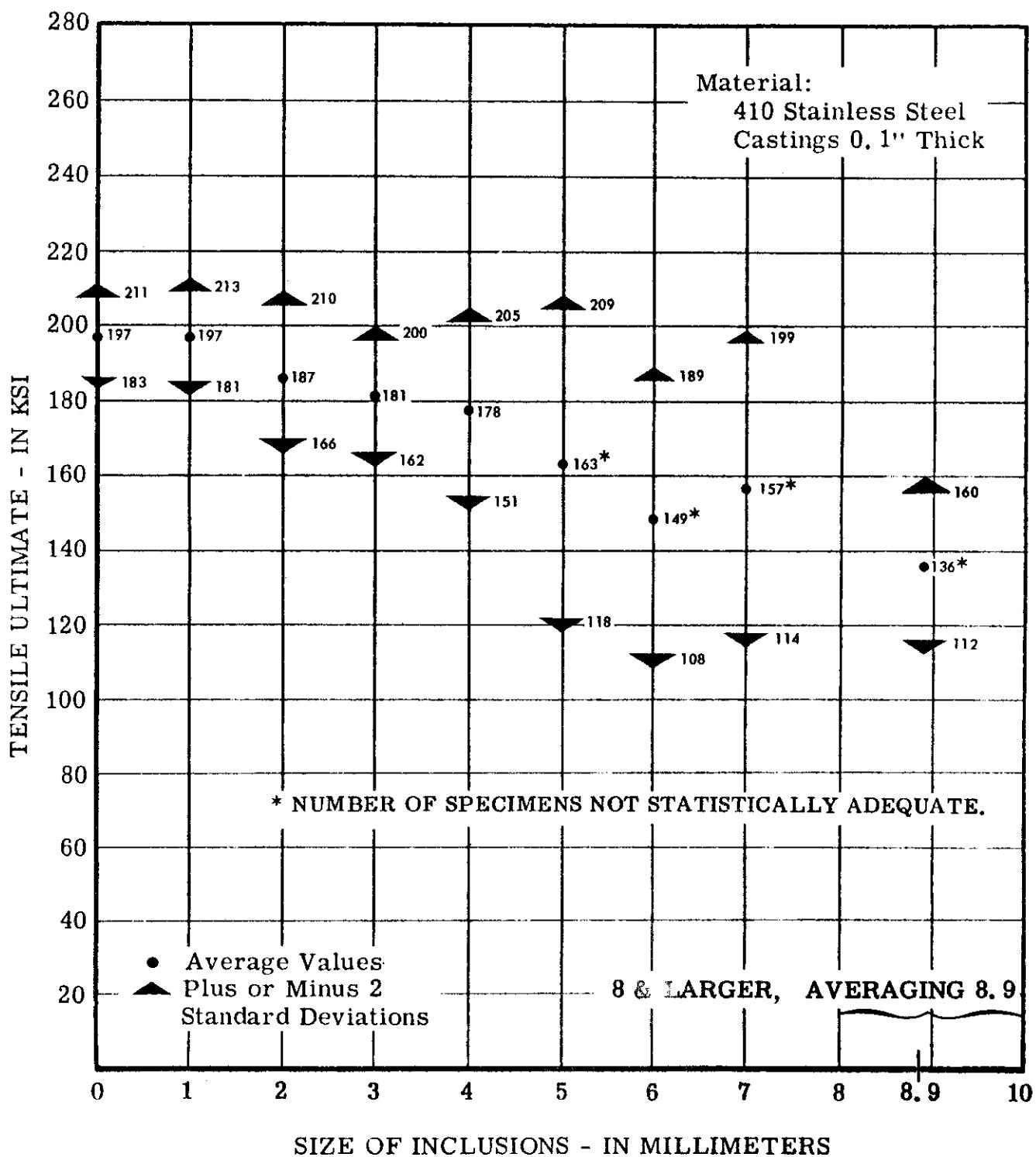


Figure 30. Tensile Ultimate vs Inclusions - Range of Values

Contrails

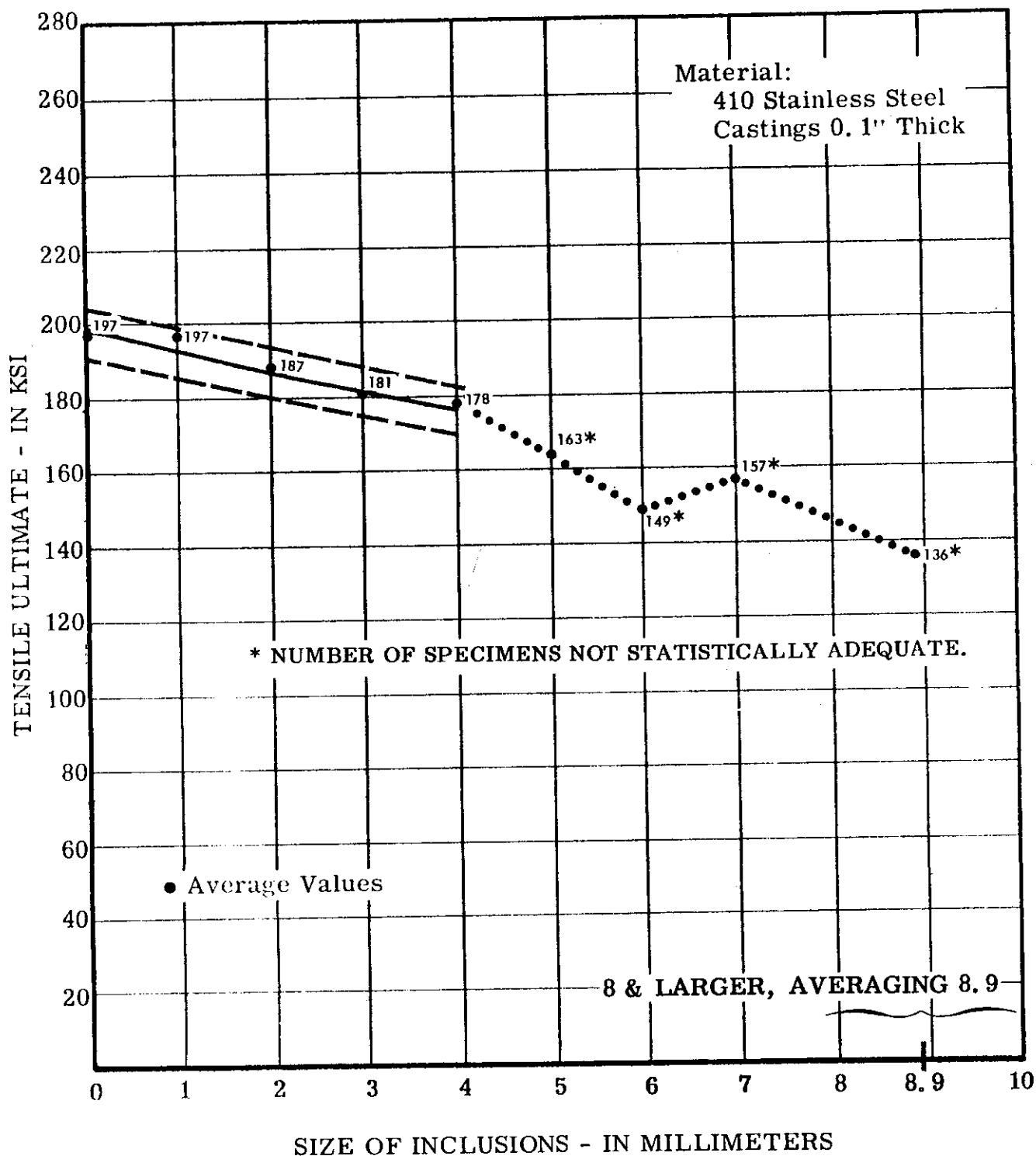


Figure 31. Tensile Ultimate vs Inclusions - Correlation

5.7 SUMMARY OF RESULTS - ELONGATION VS. INCLUSIONS - 0.1"-THICK MATERIAL

	Control Specimens	Size of Inclusions (diameter in millimeters)							
		<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8.9*</u>
Number of specimens tested -	37	6**	17**	12**	12**	15**	8**	7**	8**
Statistically determined number required for 0.95 confidence that the average of the results approaches the true average -	11	30	50	52	30	56	45	28	25
Confidence level, if less than 0.95 -	-	***	***	***	***	***	***	***	***
The following results and statistical parameters are in % in 2"									
Elongation (average of test results) -	7.5	6.1	4.6	3.3	2.8	2.6	2.5	2.2	2.7
Estimate of the standard deviation -	1.8	2.5	2.5	1.9	1.1	1.4	1.2	0.9	1.0
<u>Statistical limits for individuals:</u>									
Lower limit (0.95 probability) -	3.9	1.1	0	0	0.6	0	0.1	0.4	0.7
Upper limit (0.95 probability) -	11.1	11.1	9.6	7.1	5.0	5.4	4.9	4.0	4.7

CORRELATION ANALYSIS

Analysis was not made; data does not lend itself to a straight-line relationship. Also, number of specimens was not statistically adequate.

- * Specimens having 8-mm-and-larger inclusions, averaging 8.9 mm.
- ** Number of specimens not adequate; see number required on line below.
- *** Value too low for confidence level to have a practical meaning.

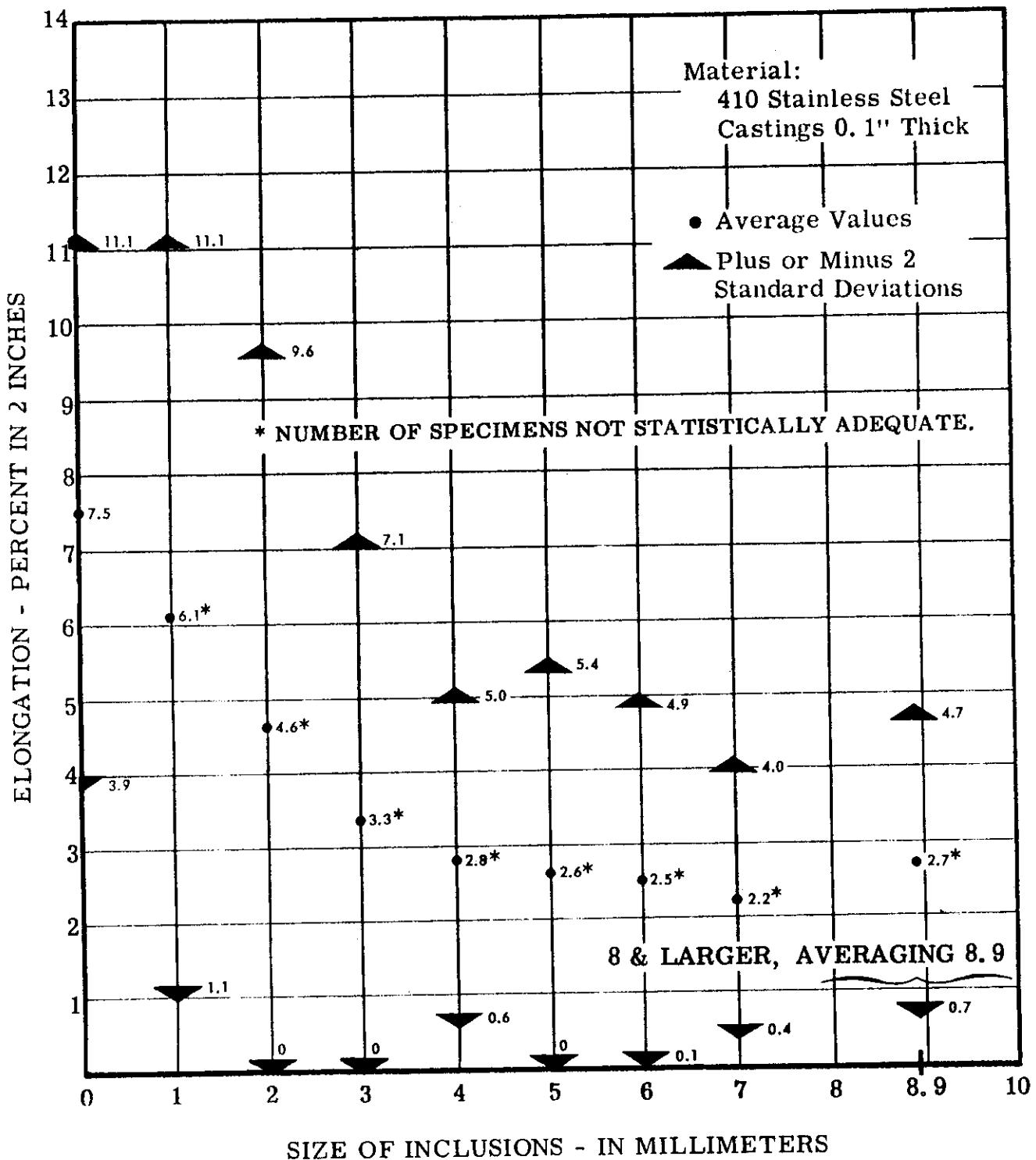


Figure 32. Elongation vs Inclusions - Range of Values

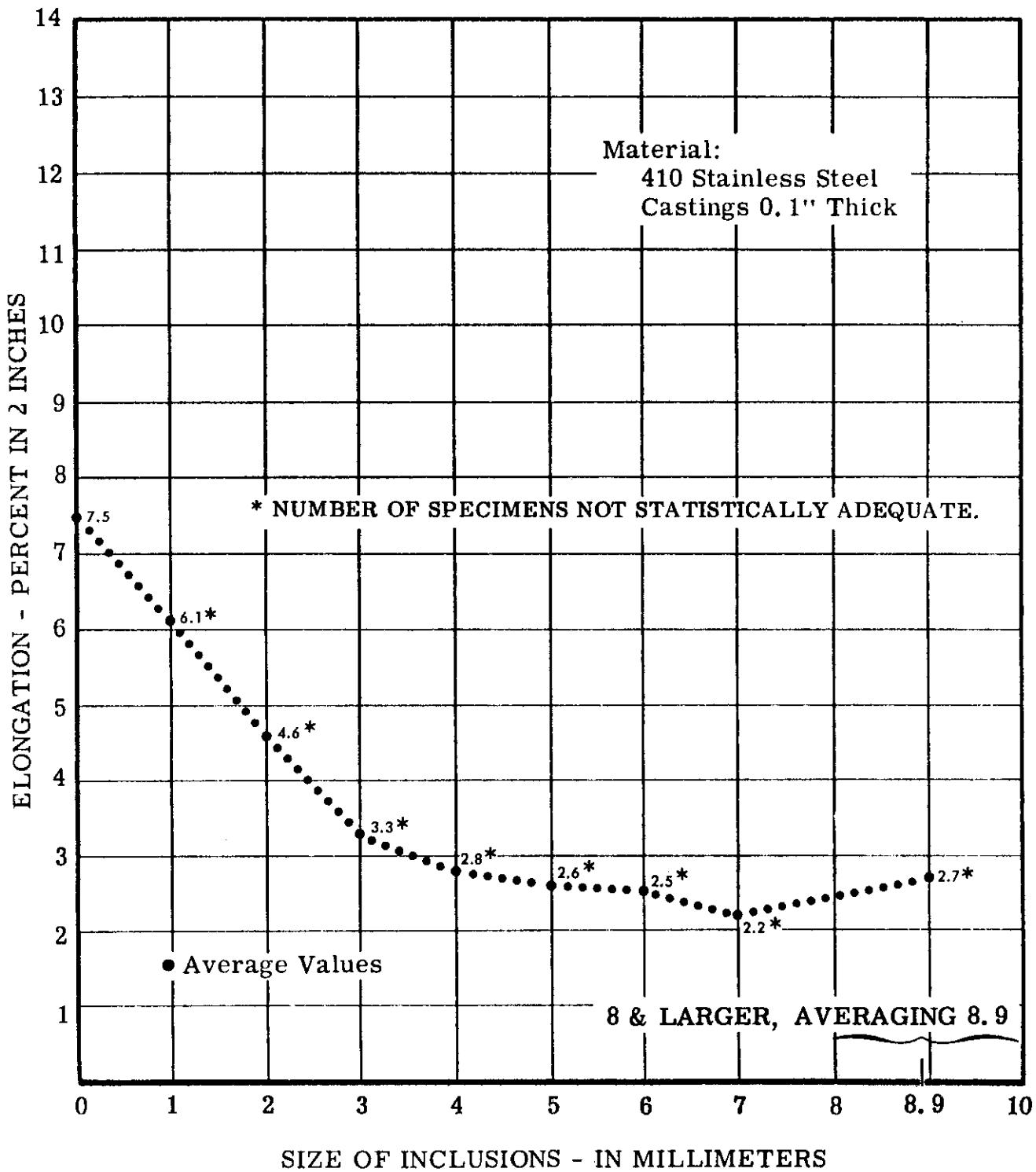


Figure 33. Elongation vs Inclusions - Correlation

Controls

5.8 SUMMARY OF RESULTS - MODULUS OF ELASTICITY VS. INCLUSIONS - 0.1"-THICK MATERIAL

Control <u>Specimens</u>	1	2	3	4	5	6	7	8, 6*
Number of specimens tested -	37	6	17	12	12	15	8	7
Statistically determined number required for 0.95 confidence that the average of the results approaches the true average -	5	2	9	4	2	7	3	2
Confidence level, if less than 0.95 -	-	-	-	-	-	-	-	-
The following results and statistical parameters are in 10^6 psi								
Modulus (average of test results) -	29.8	29.4	29.7	30.0	29.5	28.7	27.8	30.0
Estimate of the standard deviation -	1.6	0.8	2.1	2.1	1.5	1.0	1.0	1.5
<u>Statistical limits for individuals:</u>								
Lower limit (0.95 probability) -	26.6	27.8	25.5	27.0	27.5	25.1	25.8	27.0
Upper limit (0.95 probability) -	33.0	31.0	33.9	33.0	32.7	32.3	29.8	29.7

CORRELATION ANALYSIS

Analysis was not made; no trend toward lower values, as size of inclusions increased, was present.

-
- * Specimens having 8-mm-and-larger inclusions, averaging 8.6 mm.

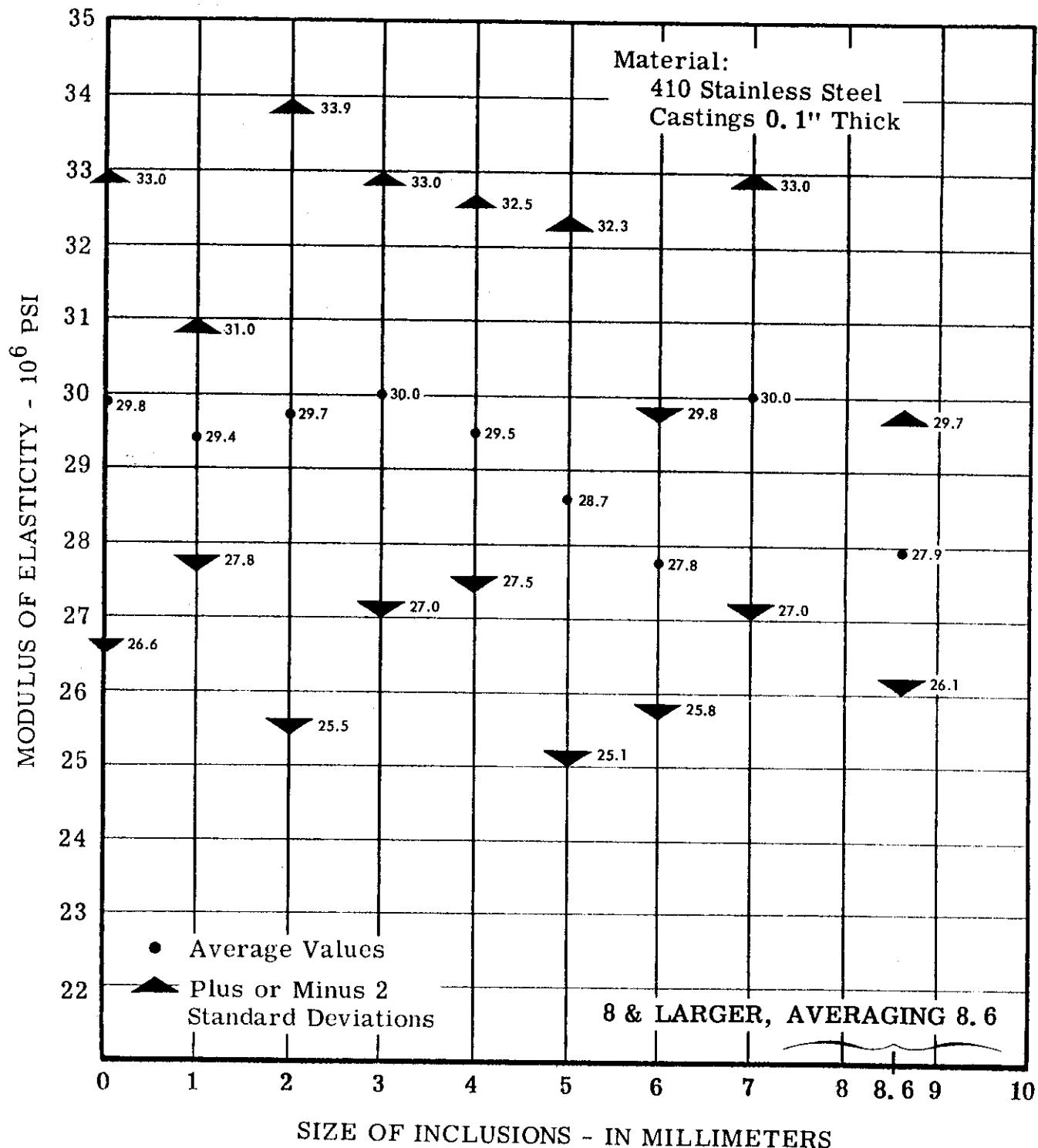


Figure 34. Modulus of Elasticity vs Inclusions - Range of Values

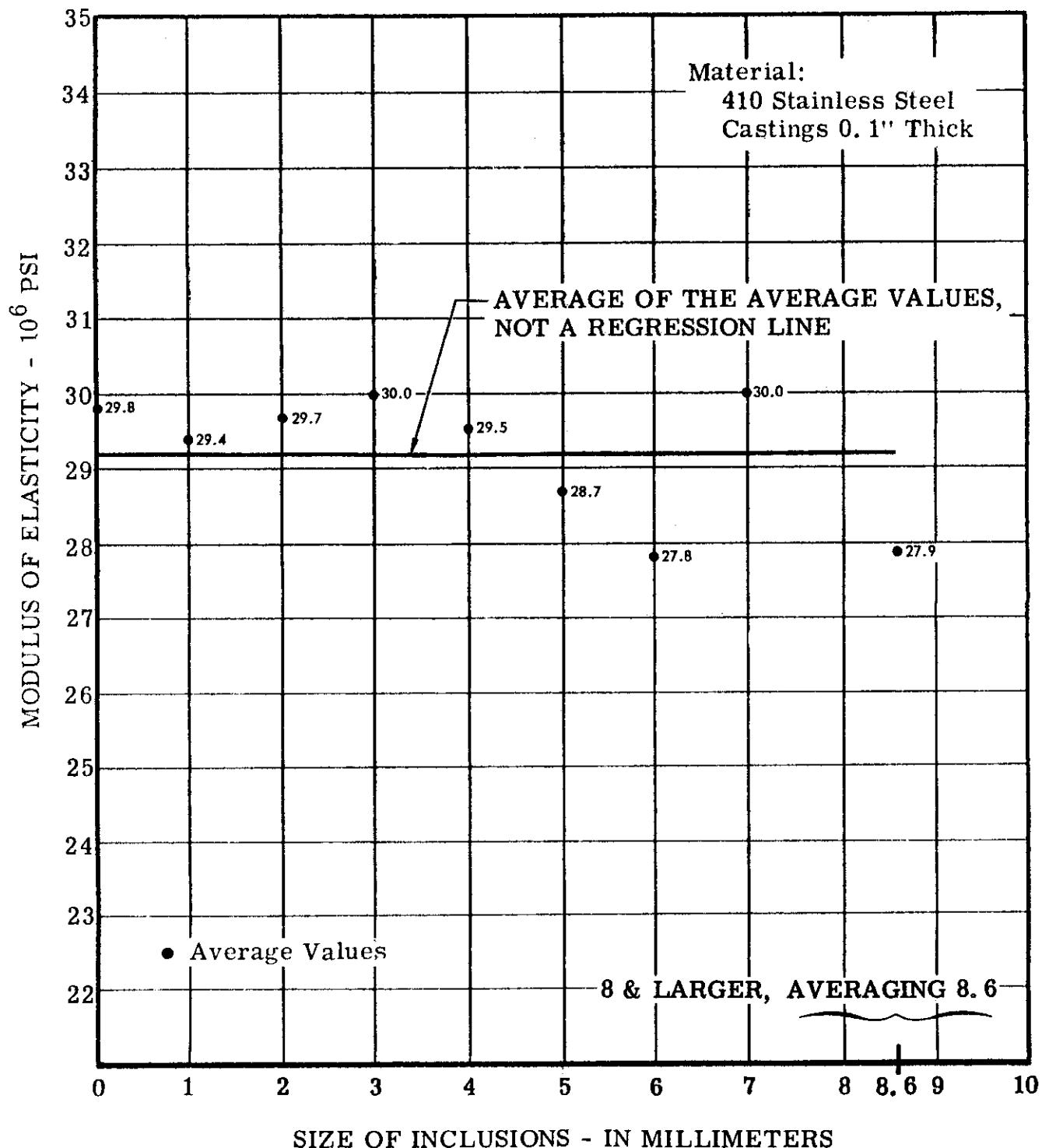


Figure 35. Modulus of Elasticity vs Inclusions - Correlation

5.9 SUMMARY OF RESULTS - TENSILE YIELD VS. POROSITY - 0.1"-THICK MATERIAL

<u>Control Specimens</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>
Number of specimens tested -	36	35	38	41	34	18	12	6
Statistically determined number required for 0.95 confidence that the average of the results approaches the true average -	3	2	3	3	4	2	1	2
Confidence level, if less than 0.95 -	-	-	-	-	-	-	-	**
The following results and statistical parameters are in ksi								
Tensile yield (average of test results) -	145	147	144	145	144	145	148	146
Estimate of the standard deviation -	5.7	4.0	5.4	6.1	7.0	4.5	3.6	5.3
<u>Statistical limits for individuals:</u>								
Lower limit (0.95 probability) -	134	139	133	133	130	136	141	138
Upper limit (0.95 probability) -	157	155	155	157	158	154	155	159

Lower limit (0.95 probability) -	134	139	133	133	130	136	141	138	114
Upper limit (0.95 probability) -	157	155	155	157	158	154	155	159	170

CORRELATION ANALYSIS

Analysis was not made; no trend toward lower values, as intensity of porosity increased, was present.

-
- * Number of specimens not adequate; see number required on line below.
 - ** Value too low for confidence level to have a practical meaning.

Contrails

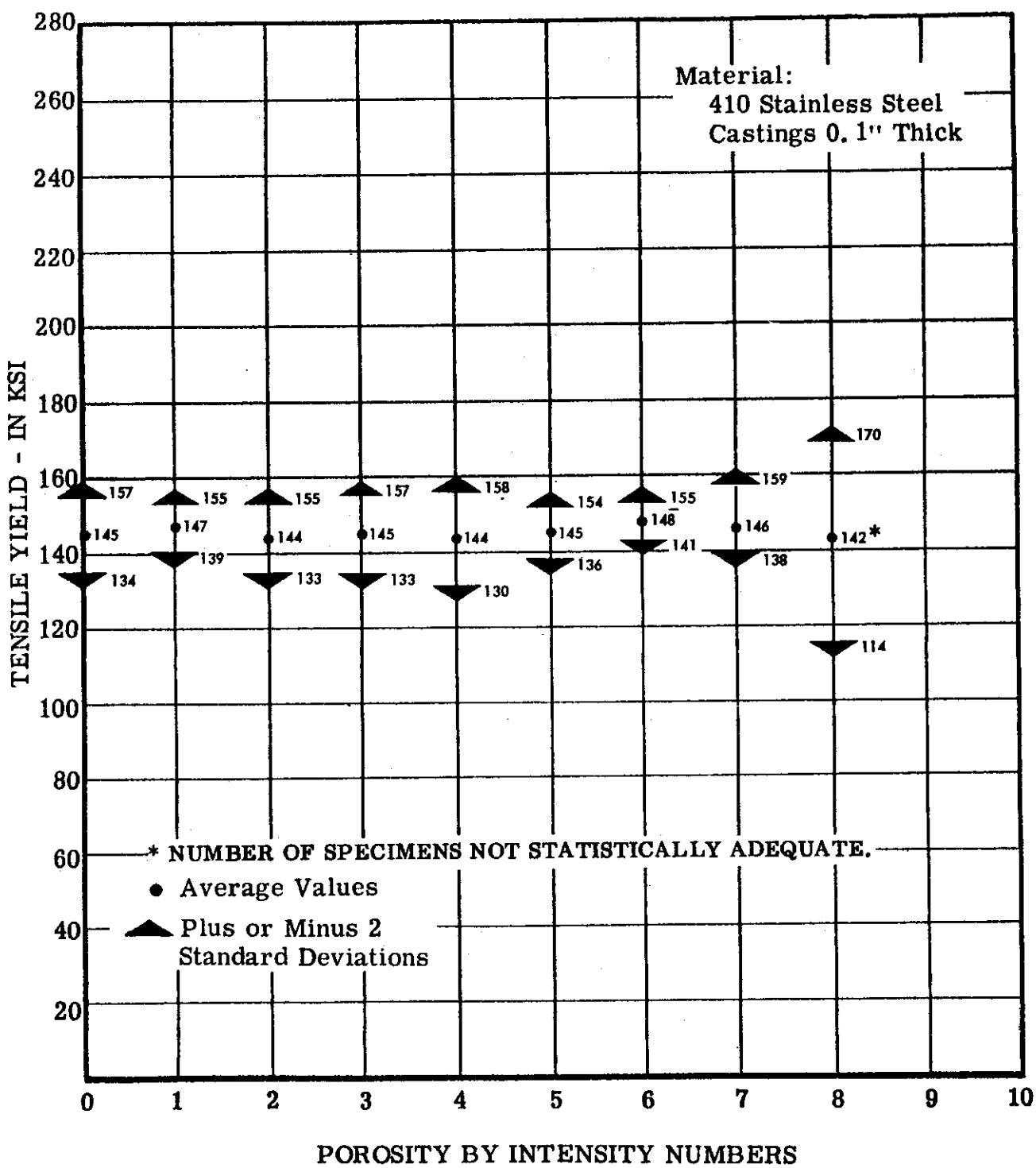


Figure 36. Tensile Yield vs Porosity - Range of Values

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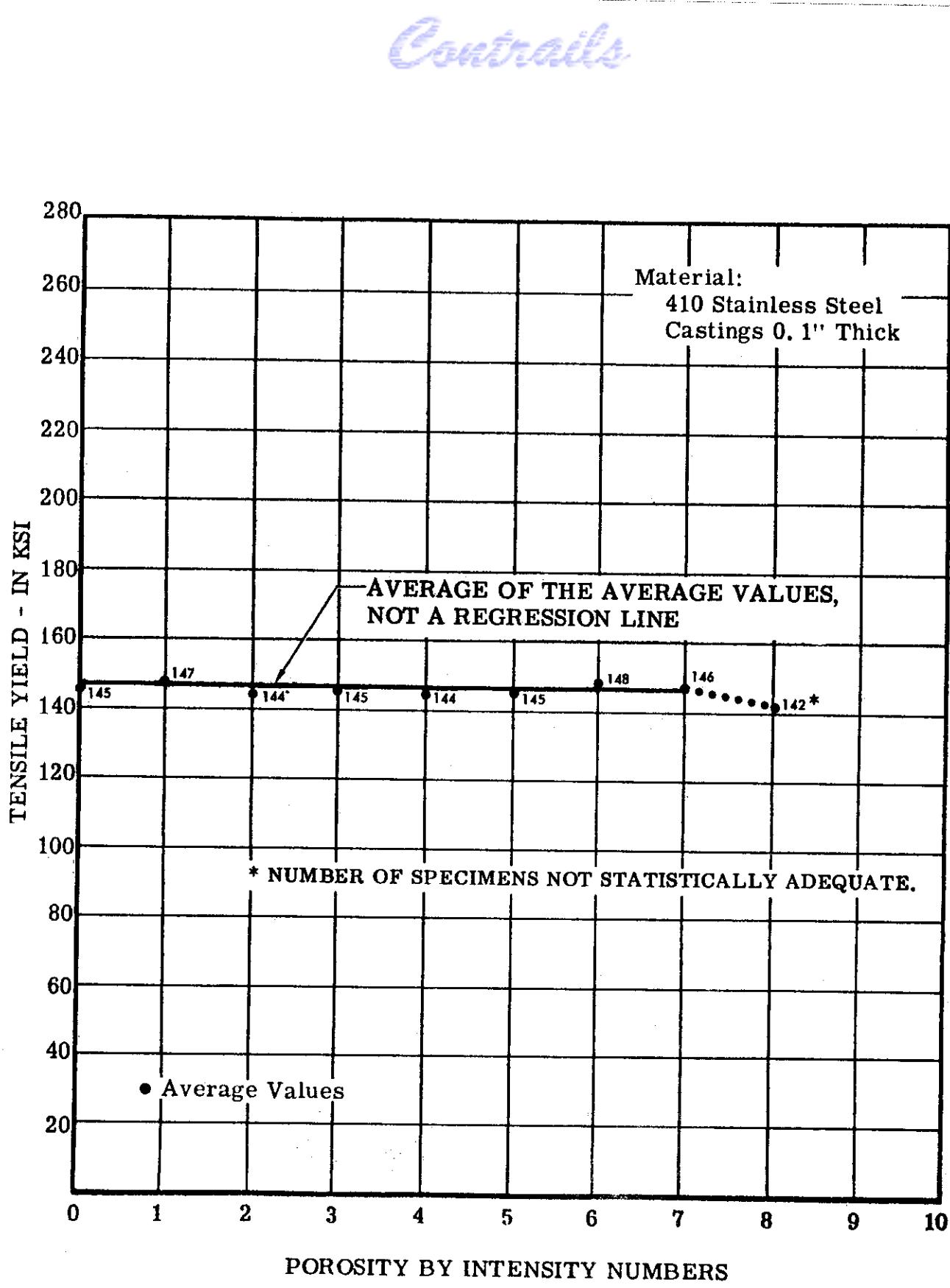


Figure 37. Tensile Yield vs Porosity - Correlation

WADD TR 60-450

5.10 SUMMARY OF RESULTS - TENSILE ULTIMATE VS. POROSITY - 0.1" THICK MATERIAL

	Control Specimens	Numbers, Indicating Intensity of Porosity						
	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8.2*</u>
Number of specimens tested -	37	35	38	42	36	21	12	7**

Statistically determined number required for 0.95 confidence that the average of the results approaches the true average -

Confidence level, if less than 0.95 -

The following results and statistical parameters are in ksi

Tensile ultimate (average of test results) -	193	187	185	182	176	172	173	163	161
Estimate of the standard deviation -	7.3	10.1	8.0	13.5	12.3	14.5	8.5	18.0	22.5
Hardness (average Rockwell C) -	41.1	41.2	41.0	41.7	41.5	41.7	41.8	40.9	42.0
Tensile Ultimate (adjusted to hardness) -***	197	191	190	183	179	173	174	163	161

Statistical limits for individuals:

Lower limit (0.95 probability) -	179	171	174	155	154	144	157	127	115
Upper limit (0.95 probability) -	211	211	206	210	204	202	191	199	206

CORRELATION ANALYSIS

Correlation coefficient = -0.98, minus sign indicates an inverse relationship. "Standard error of estimate" = 1.9 ksi

* Specimens having number-8-and-higher porosity intensity, averaging number -8.2

** Number of specimens not adequate; see number required on line below

*** Value too low for confidence level to have a practical meaning

**** See Paragraph 6.1.1

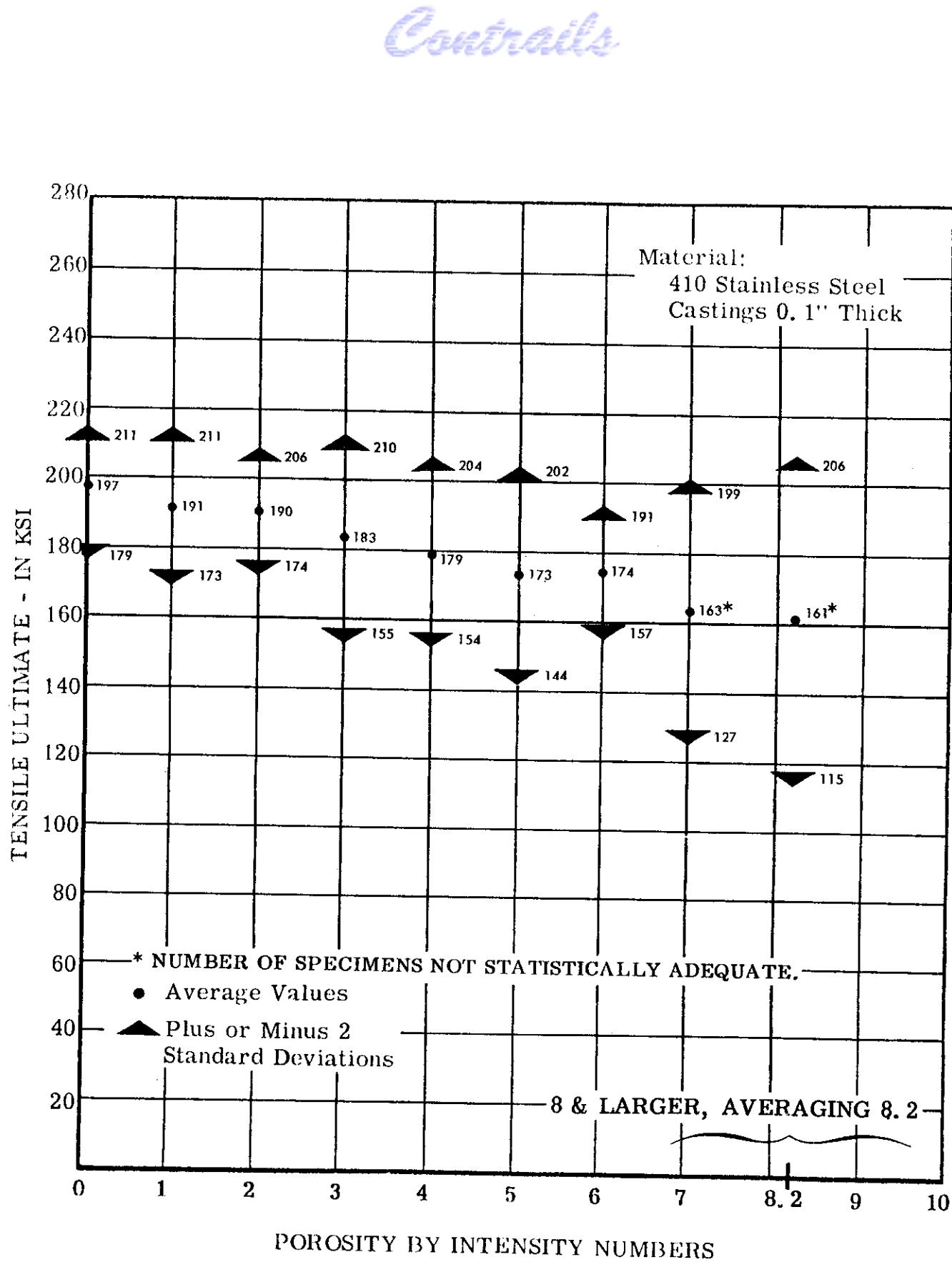


Figure 38. Tensile Ultimate vs Porosity - Range of Values

WADD TR 60-450

Contrails

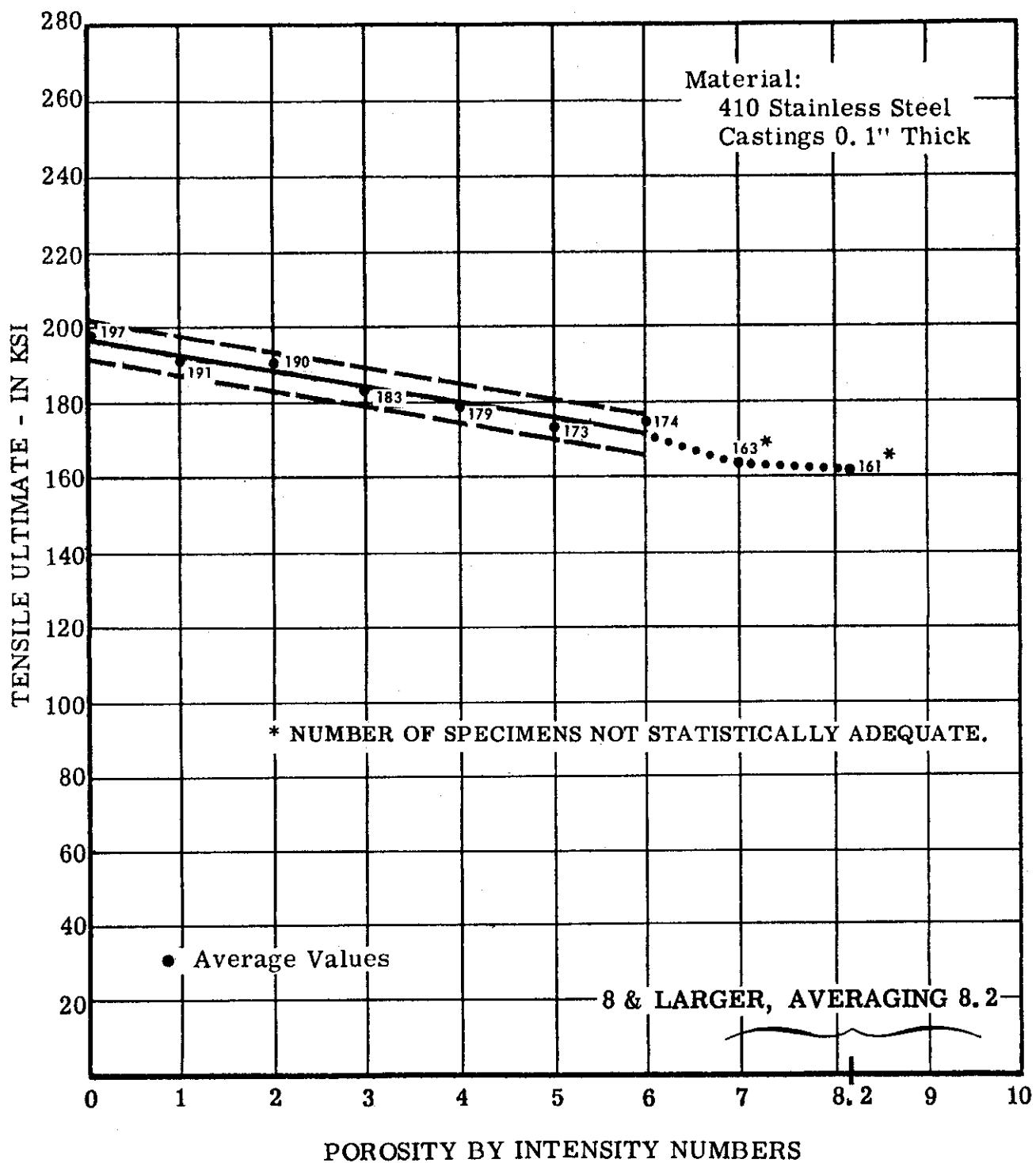


Figure 39. Tensile Ultimate vs Porosity - Correlation

WADD TR 60-450

5.11 SUMMARY OF RESULTS - ELONGATION VS. POROSITY - 0.1" THICK MATERIAL

	Control Specimens	Numbers, Indicating Intensity of Porosity						
	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>
Number of specimens tested -	37	34	37	41	32	14	10*	6*

Statistically determined number required for 0.95 confidence that the average of the results approaches the true average -

Confidence level, if less than 0.95 -

The following results and statistical parameters are in % in 2"

Elongation (average of test results) -	7.5	3.9	3.3	3.0	2.7	2.3	2.9	2.3	2.2
Estimate of the standard deviation -	1.8	1.7	1.3	1.1	0.9	0.5	1.2	0.5	0.5
<u>Statistical limits for individuals:</u>									
Lower limit (0.95 probability) -	3.9	0.5	0.7	0.8	0.9	1.3	0.5	1.3	1.2
Upper limit (0.95 probability) -	11.1	7.3	5.9	5.2	4.5	3.3	5.3	3.3	3.2

CORRELATION ANALYSIS

Analysis was not made; data does not lend itself to a straight-line relationship. Number of specimens having higher intensity porosity was not statistically adequate.

-
- * Number of specimens not adequate; see number required on line below.
 - ** Value too low for confidence level to have a practical meaning.

Contrails

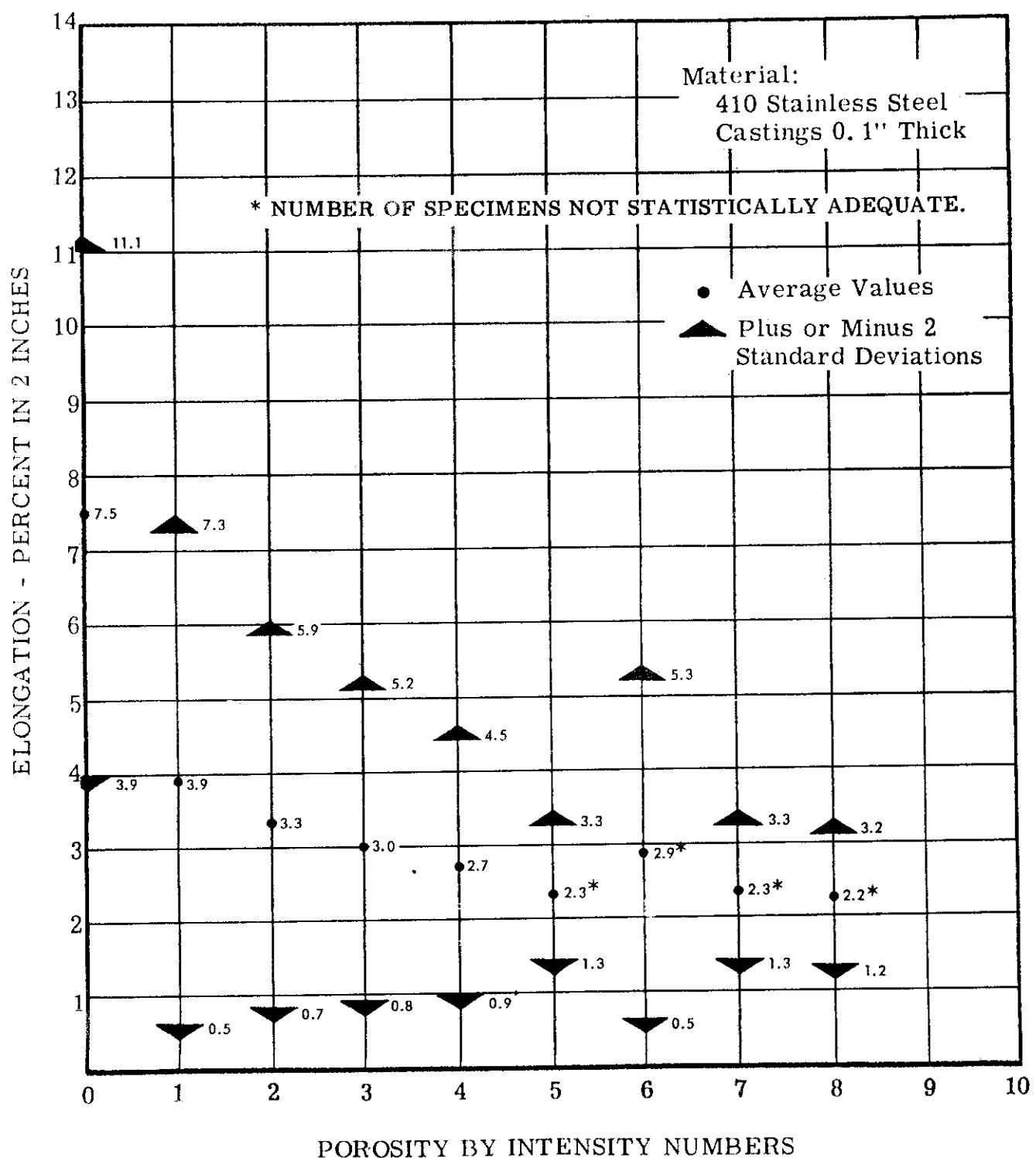


Figure 40. Elongation vs Porosity - Range of Values

WADD TR 60-450

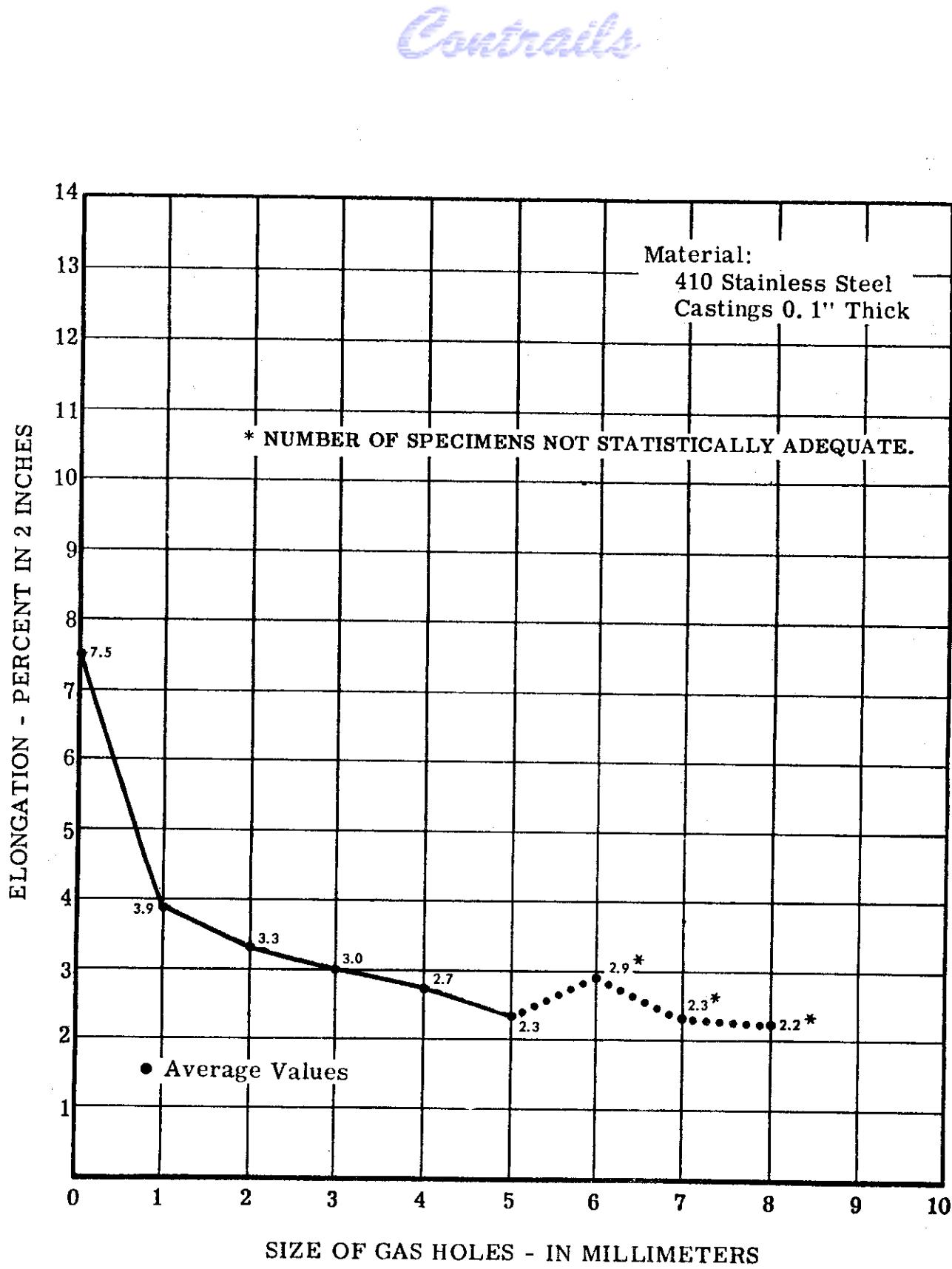


Figure 41. Elongation vs Porosity - Correlation

WADD TR 60-450

5.12 SUMMARY OF RESULTS - MODULUS OF ELASTICITY VS. POROSITY - 0.1" THICK MATERIAL

<u>Control Specimens</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>
Number of specimens tested -	37	35	38	42	36	21	12	7*

Statistically determined number required for 0.95 confidence that the average of the results approaches the true average -

Confidence level, if less than 0.95 -

The following results and statistical parameters are in 10^6 psi

Modulus (average of test results) -
Estimate of the standard deviation -

Statistical limits for individuals:

Lower limit (0.95 probability) -	26.6	27.9	25.4	25.5	26.7	26.7	25.8	25.2
Upper limit (0.95 probability) -	33.0	32.3	33.8	33.9	33.1	31.9	33.0	32.6

CORRELATION ANALYSIS

Analysis was not made; no trend toward lower values, as intensity of porosity increased, was present. Specimens having the highest intensity porosity showed some loss in modulus, but not by a significant amount.

* Number of specimens not adequate; see number required on line below.

** Value too low for confidence level to have a practical meaning.

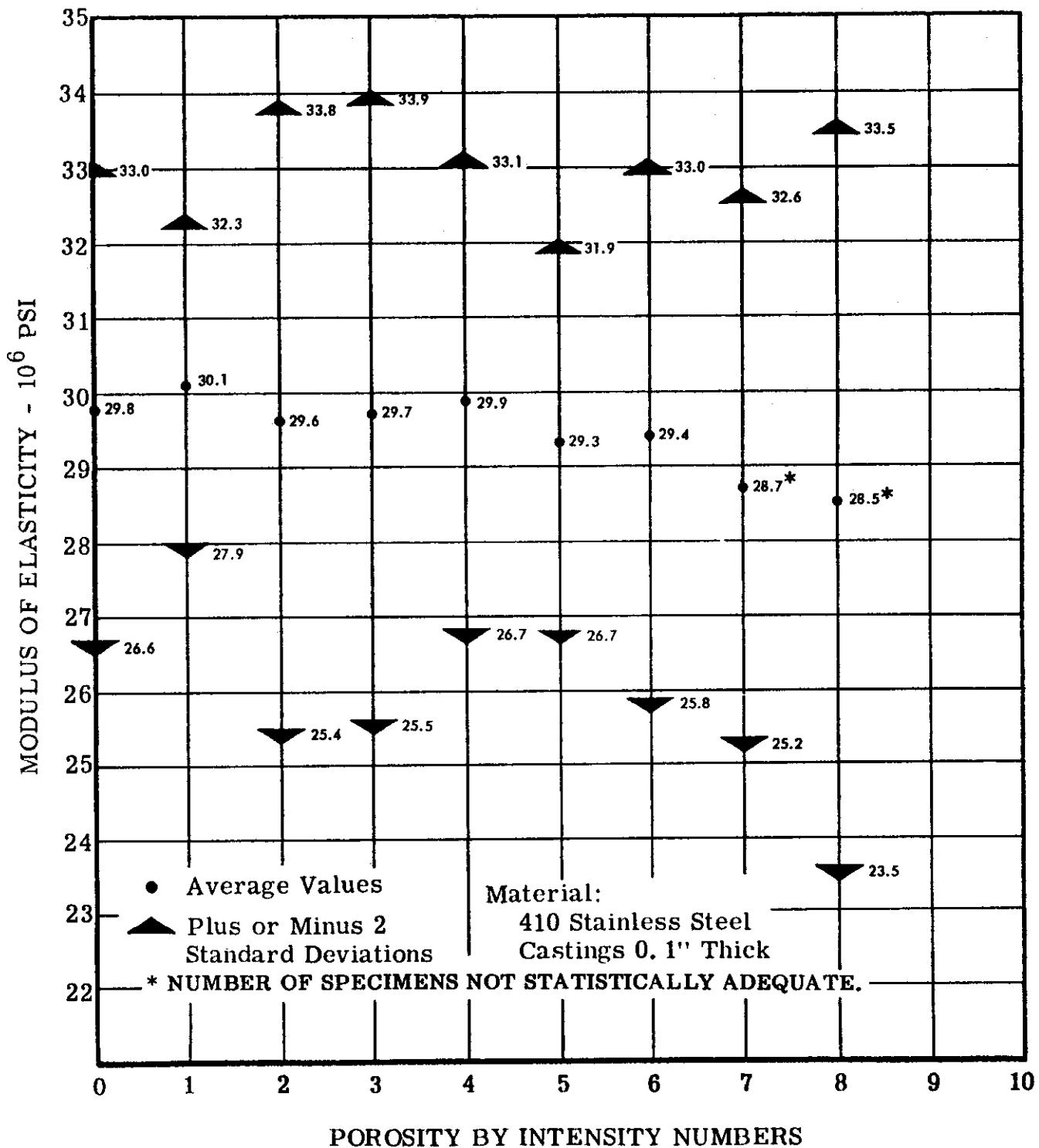


Figure 42. Modulus of Elasticity vs Porosity - Range of Values

Contrails

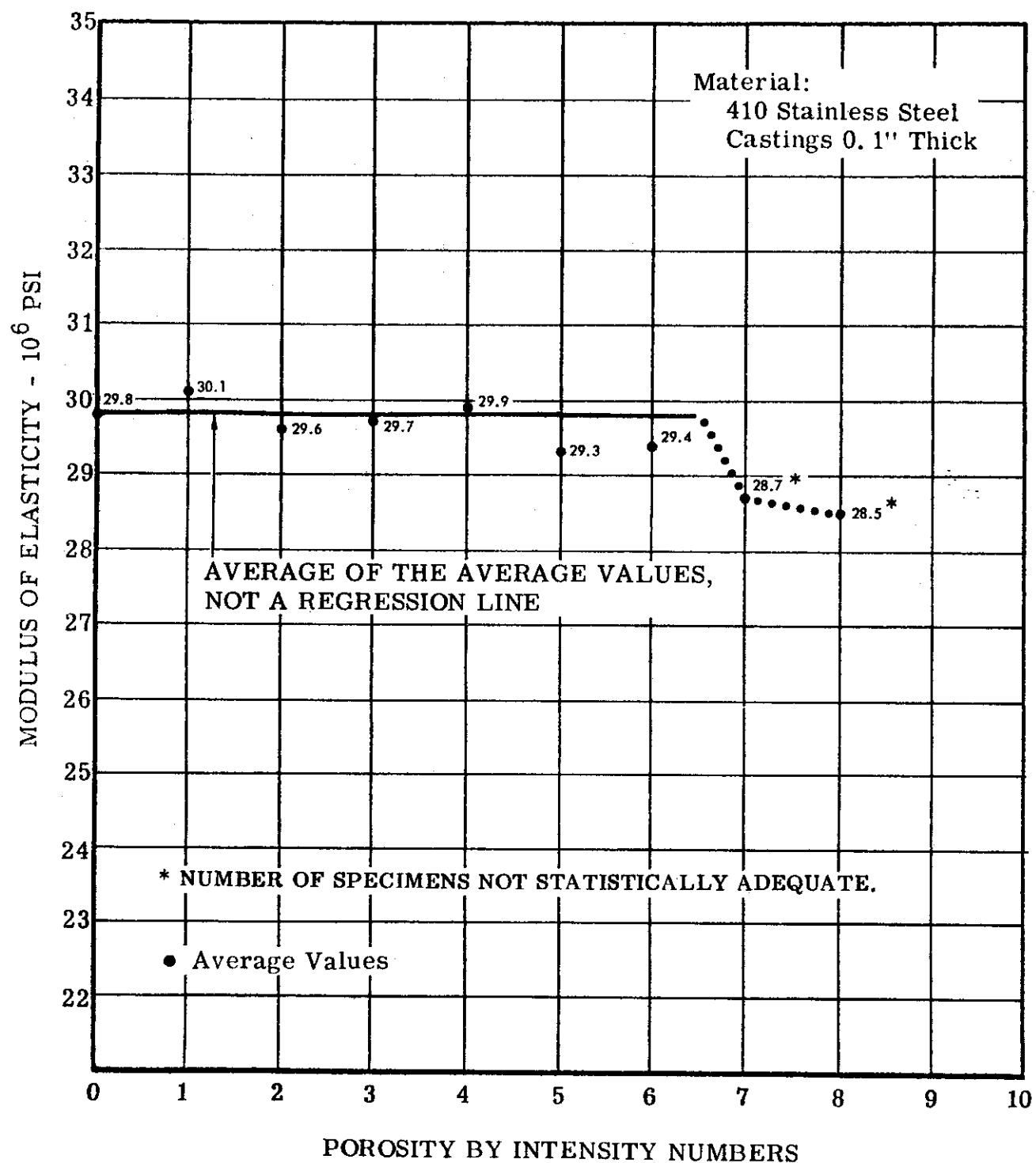


Figure 43. Modulus of Elasticity vs Porosity - Correlation

WADD TR 60-450

Contrails

5.13 SUMMARY OF RESULTS - TENSILE YIELD VS. GAS HOLES - 0.2"-THICK MATERIAL.

	Control Specimens	Size of Gas Holes (diam. in millimeters)			
		<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>
Number of specimens tested -	46	10	22	15	11

Statistically determined number required for 0.95 confidence that the average of the results approaches the true average -

Confidence level, if less than 0.95 -

The following results and statistical parameters are in ksi:

Tensile yield (Average of test results) - 147
 Estimate of the standard deviation - 7.5

Statistical limits for individuals:

Lower Limit (0.95 probability) -	132	143	135	128	138	78
Upper Limit (0.95 probability) -	162	158	160	163	159	178

CORRELATION ANALYSIS

Analysis was not made; no trend toward lower values, as size of gas holes increased, was present, except for the largest size gas holes. Also, number of specimens for largest size gas holes was not statistically adequate.

* Specimens having 5-mm-and-larger gas holes, averaging 6.5 mm.

** Number of specimens not adequate; see number required on line below.

*** Value too low for confidence level to have a practical meaning.

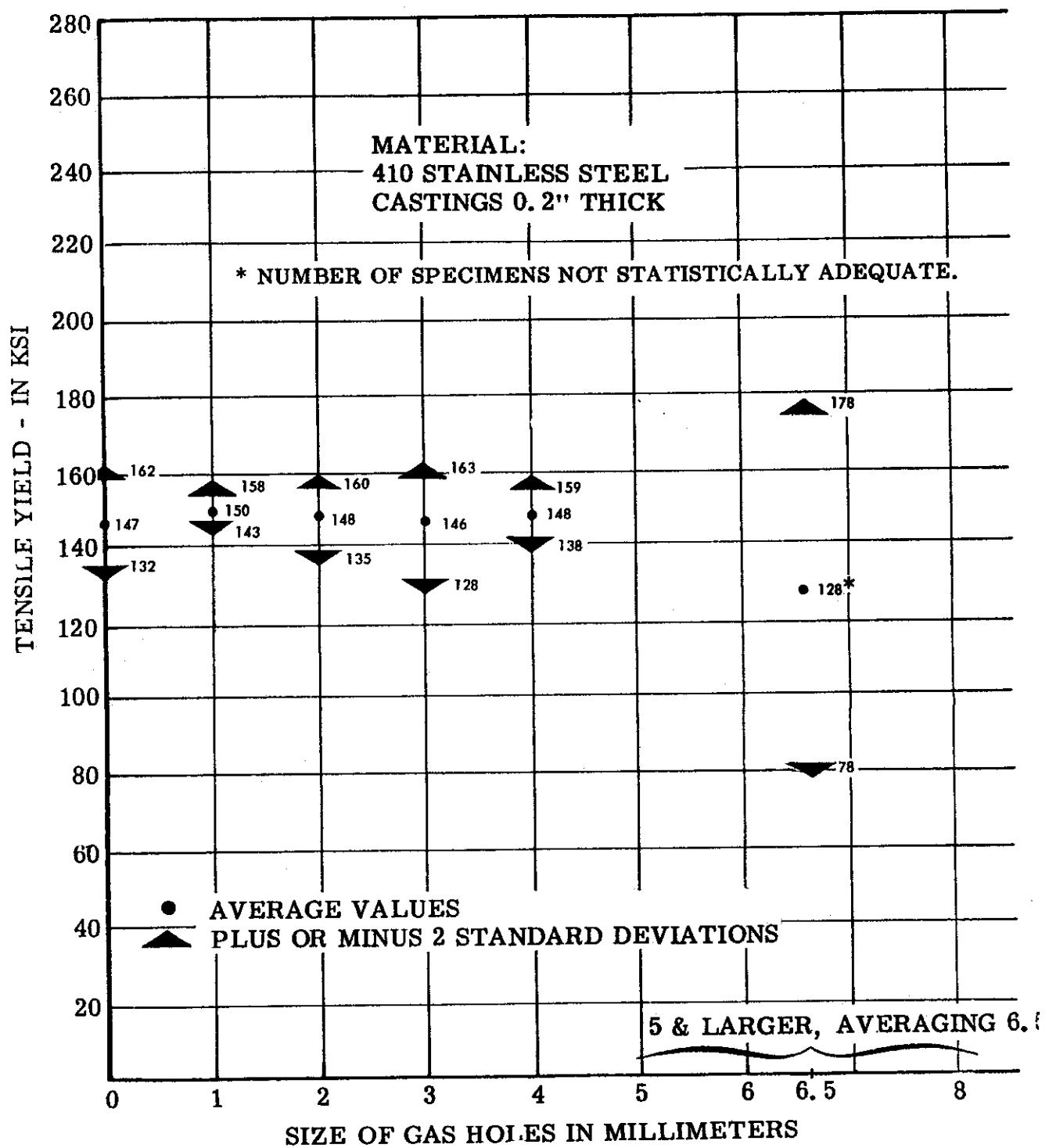


Figure 44. Tensile Yield vs Gas Holes - Range of Values

Contrails

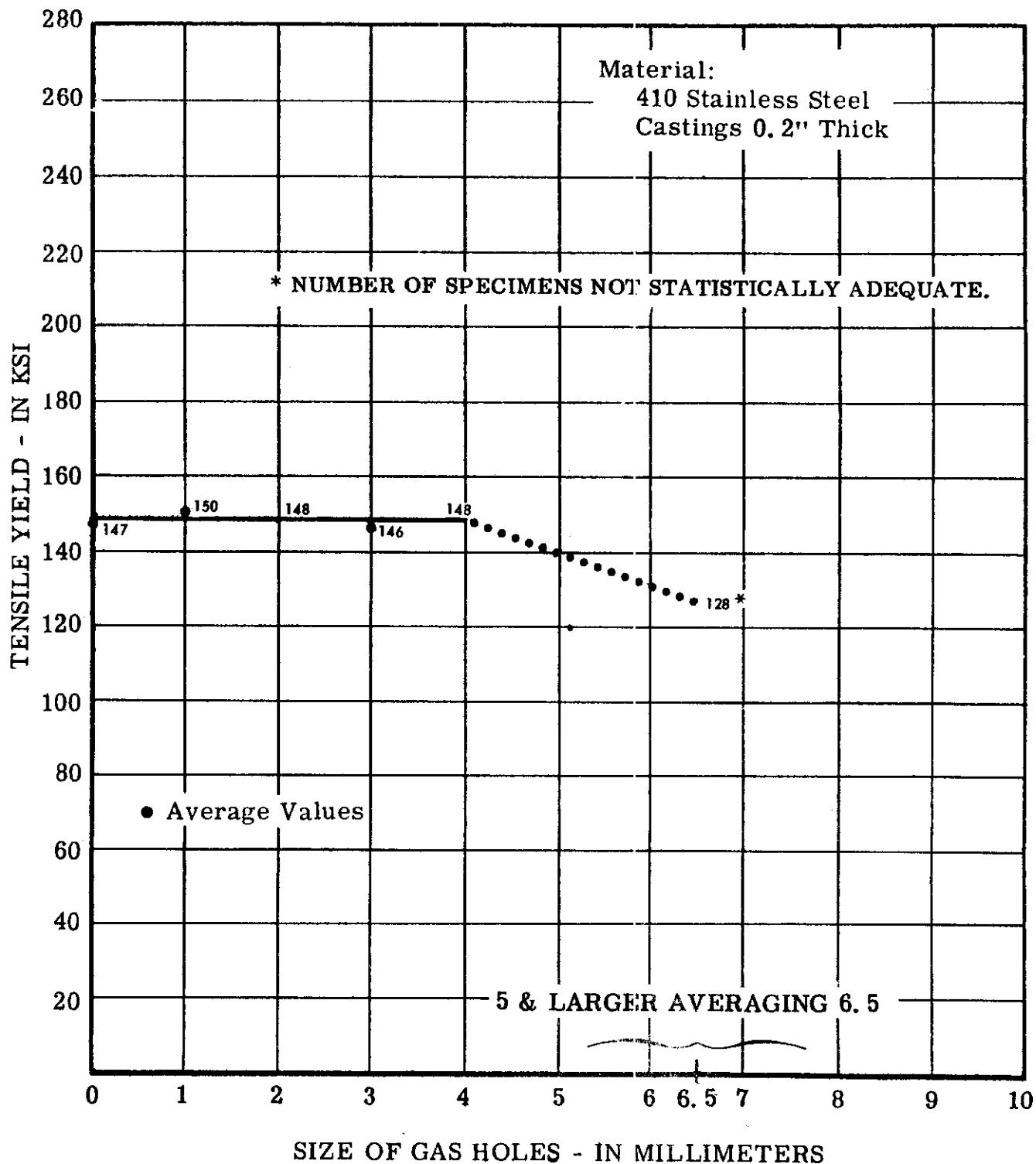


Figure 45. Tensile Yield vs Gas Holes - Correlation

WADD TR 60-450

5.14 SUMMARY OF RESULTS - TENSILE ULTIMATE VS. GAS HOLES - 0.2"-THICK MATERIAL

Control Specimens	Size of Gas Holes (diameter in millimeters)				
	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>6.8*</u>
Number of specimens tested -	46	10	22	15	11** 16**
Statistically determined number required for 0.95 confidence that the average of the results approaches the true average -	2	3	4	7	28 112
Confidence level, if less than 0.95	-	-	-	-	*** ***
The following results and statistical parameters are in ksi.					
Tensile ultimate (average of test results) -	197	202	193	186	175 144
Estimate of the standard deviation -	7.0	7.6	8.4	12.3	23.3 39.0
Hardness (average Rockwell C) -	41.0	42.6	41.7	42.4	42.3 43.2
Tensile ultimate (adjusted to hardness) ***	202	199	195	184	174 138
Statistical limits for individuals:					
Lower limit (0.95 probability) -	188	184	178	160	127 60
Upper limit (0.95) -	216	214	212	209	220 216

CORRELATION ANALYSIS

Correlation coefficient = -0.98, for 0.95 or better confidence level averages. "Standard error of estimate" = 2.1 ksi.

* Specimens having 5-mm-and-larger gas holes, averaging 6.8 mm.

** Number of specimens not adequate; see number required on line below.

*** Value too low for confidence level to have a practical meaning.

**** See paragraph 6.1.1

Contrails

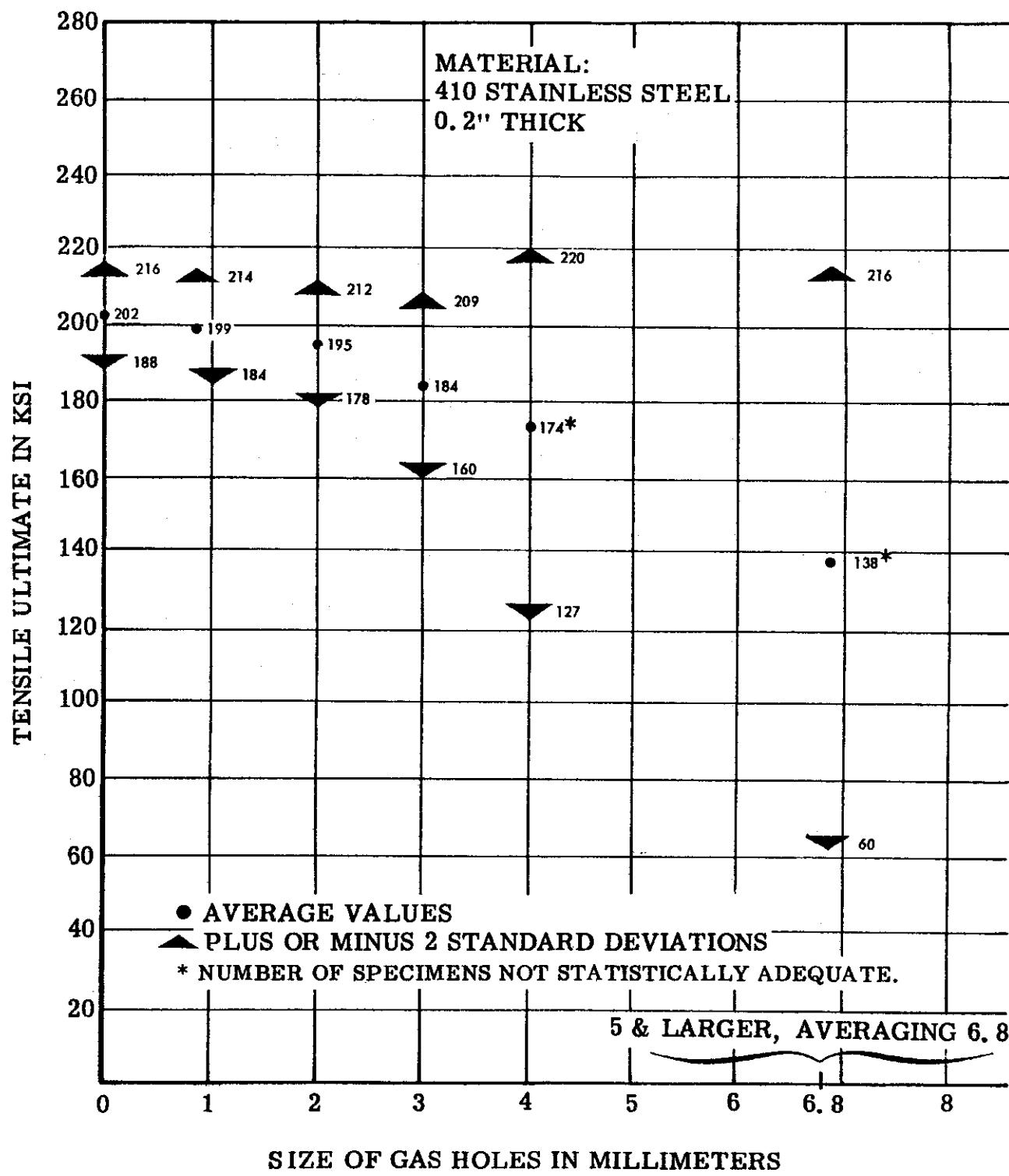


Figure 46. Tensile Ultimate vs Gas Holes - Range of Values

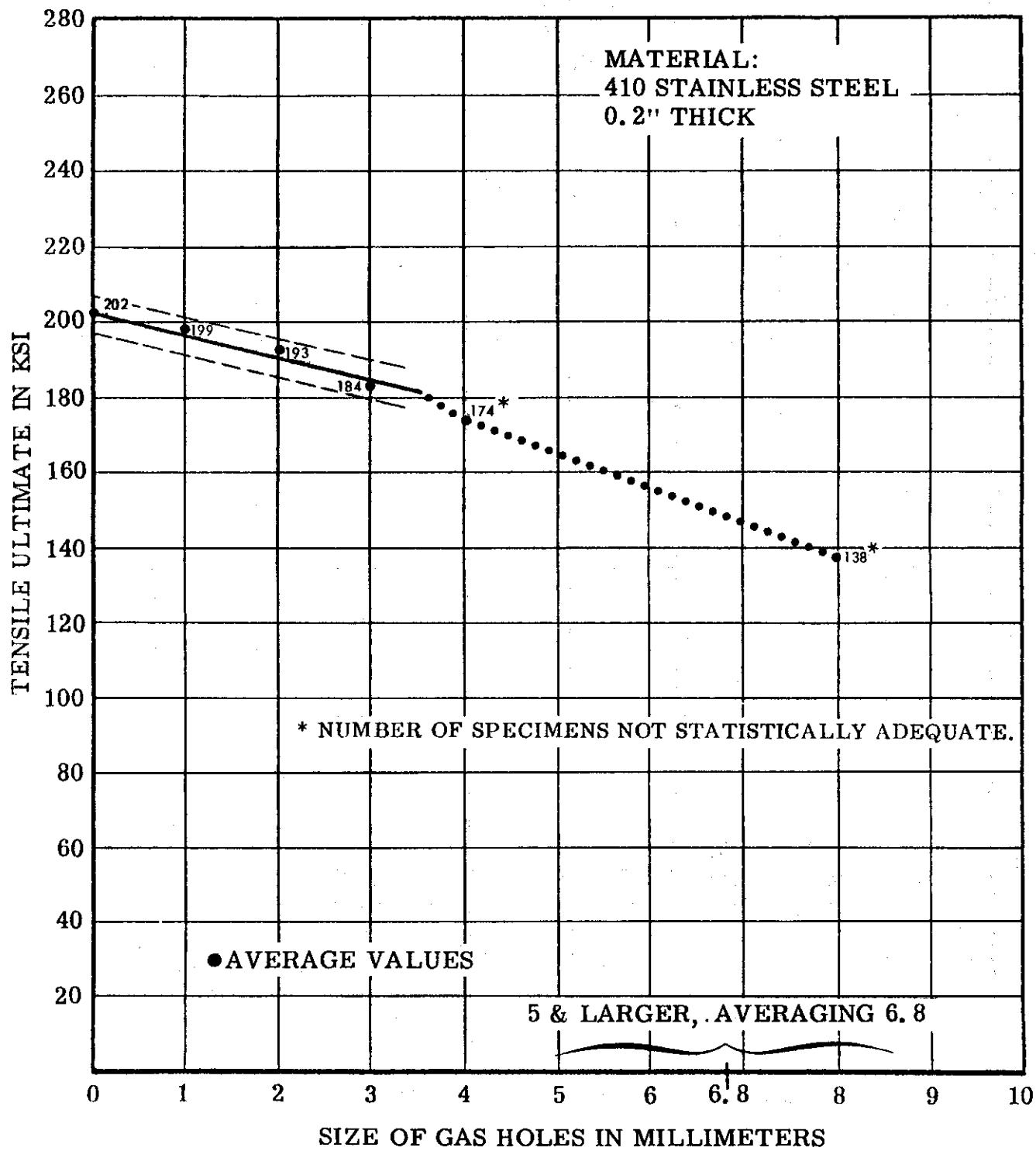


Figure 47. Tensile Ultimate vs Gas Holes - Correlation

WADD TR 60-450

Controls

5.15 SUMMARY OF RESULTS - ELONGATION VS. GAS HOLES - 0.2"-THICK MATERIAL

	Control Specimens	1	2	3	4	6.7*
Number of specimens tested -	45	10**	22**	15**	9**	14**
Statistically determined number required for 0.95 confidence that the average of the results approaches the true average -	21	11	53	55	65	35
Confidence level, if less than 0.95 -	-	0.92	***	***	***	***
The following results and statistical parameters are in % in 2"						
Elongation (average of test results) -	7.6	5.3	4.9	4.7	3.5	2.5
Estimate of the standard deviation -	2.6	1.3	2.7	2.6	2.1	1.1
Statistical limits for individuals:						
Lower limit (0.95 probability) -	2.4	2.7	0	0	0	0
Upper limit (0.95 probability) -	12.8	7.9	10.3	9.9	7.7	4.7

CORRELATION ANALYSIS

Analysis was not made; Number of samples from which averages were computed was not statistically adequate.

* Specimens having 5-mm-and-larger gas holes, averaging 6.7 mm.

** Number of specimens not adequate; see number required on line below.

*** Value too low for confidence level to have a practical meaning.

Contrails

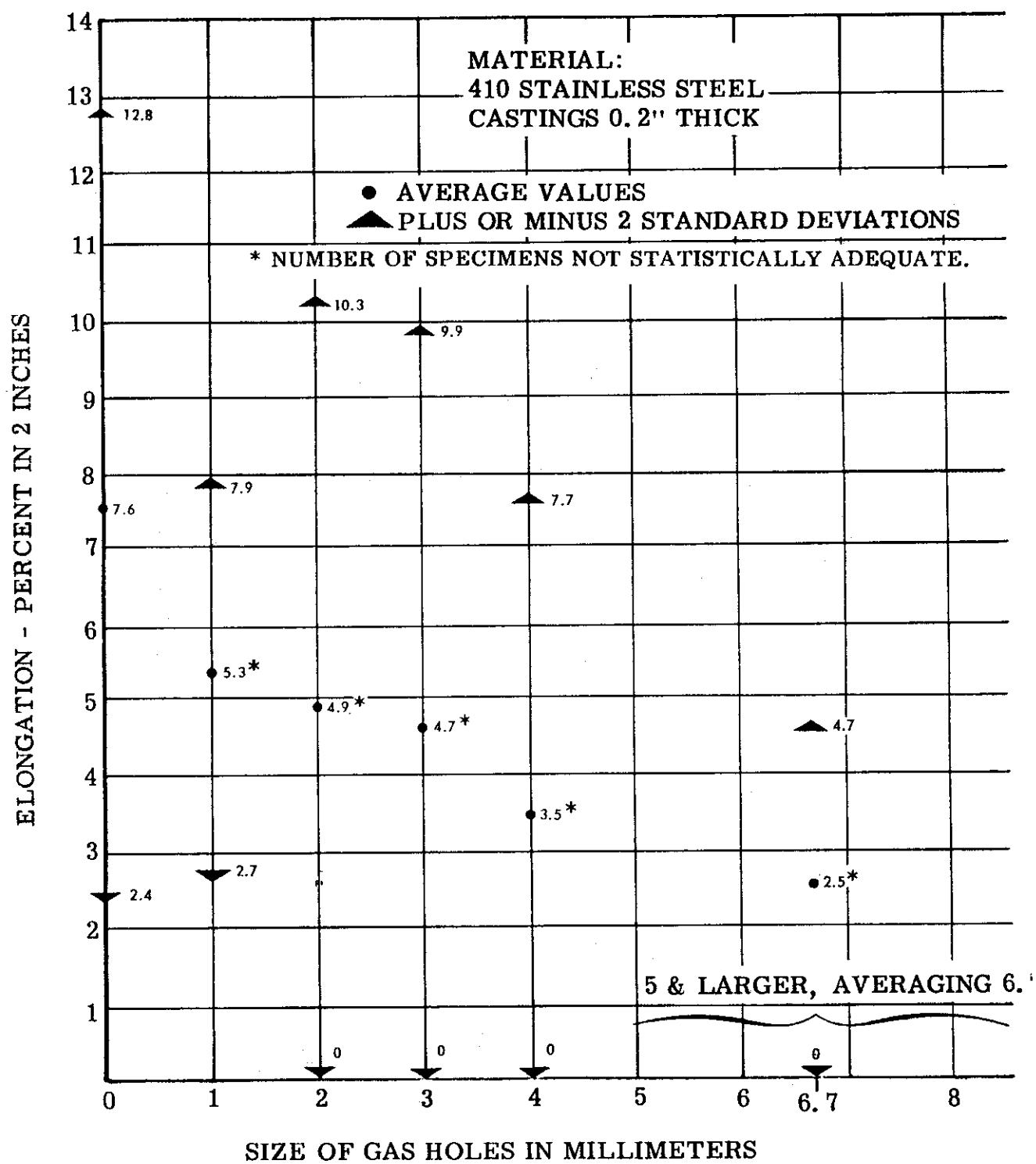


Figure 48. Elongation vs Gas Holes - Range of Values

Contrails

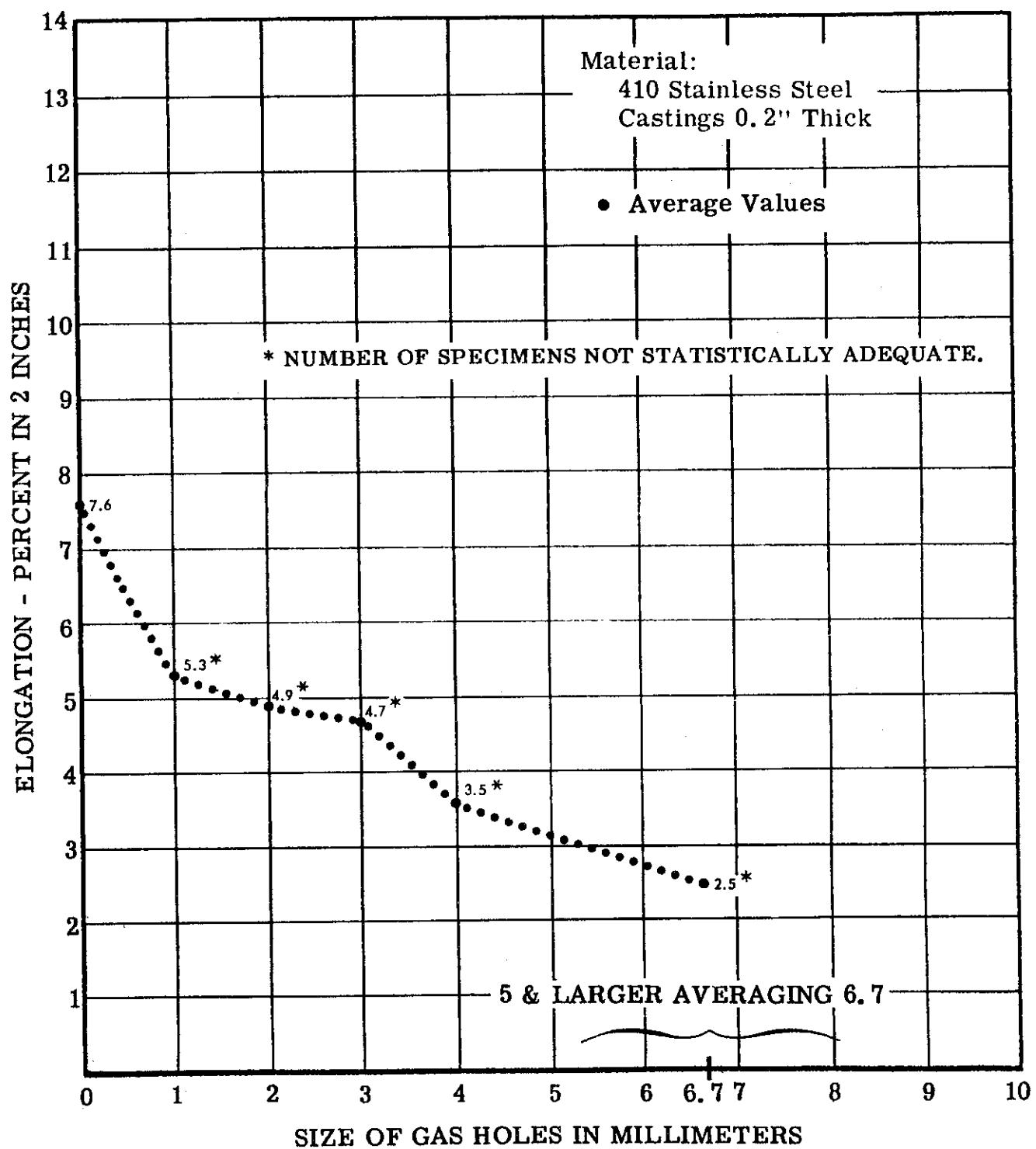


Figure 49. Elongation vs Gas Holes - Correlation

WADD TR 60-450

5.16 SUMMARY OF RESULTS - MODULUS OF ELASTICITY VS. GAS HOLES - 0.2"-THICK MATERIAL

<u>Control Specimens</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>6.1*</u>
Number of specimens tested -	46	10	22	16	11

Statistically determined number required for 0.95 confidence that the average of the results approaches the true average -

Confidence level, if less than 0.95 -	-	-	-	-	0.91
---------------------------------------	---	---	---	---	------

The following results and statistical parameters are in 10^6 psi

Modulus of Elasticity (Average of results) - 29.5
 Estimate of the standard deviation - 1.3

Statistical limits for individuals:

Lower limit (0.95 probability) - 27.0
 Upper limit (0.95 probability) - 32.2

CORRELATION ANALYSIS

Analysis was not made. No trend toward lower values, as size of gas holes increased, was present.

* Specimens having 5-mm-and-larger gas holes, averaging 6.1 mm.
 ** Number of specimens not adequate; see required number on line below.

Contrails

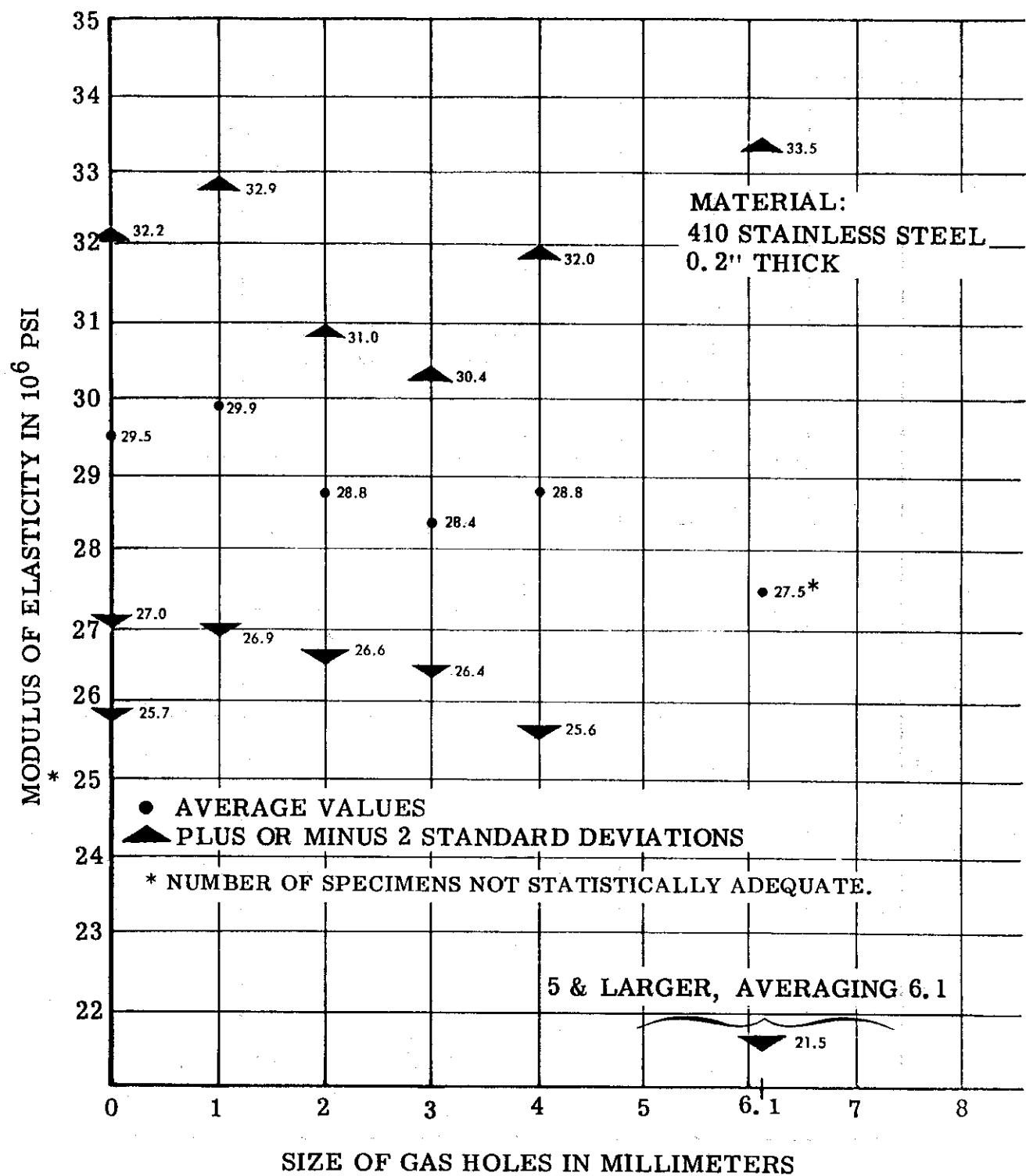


Figure 50. Modulus of Elasticity vs Gas Holes - Range of Values

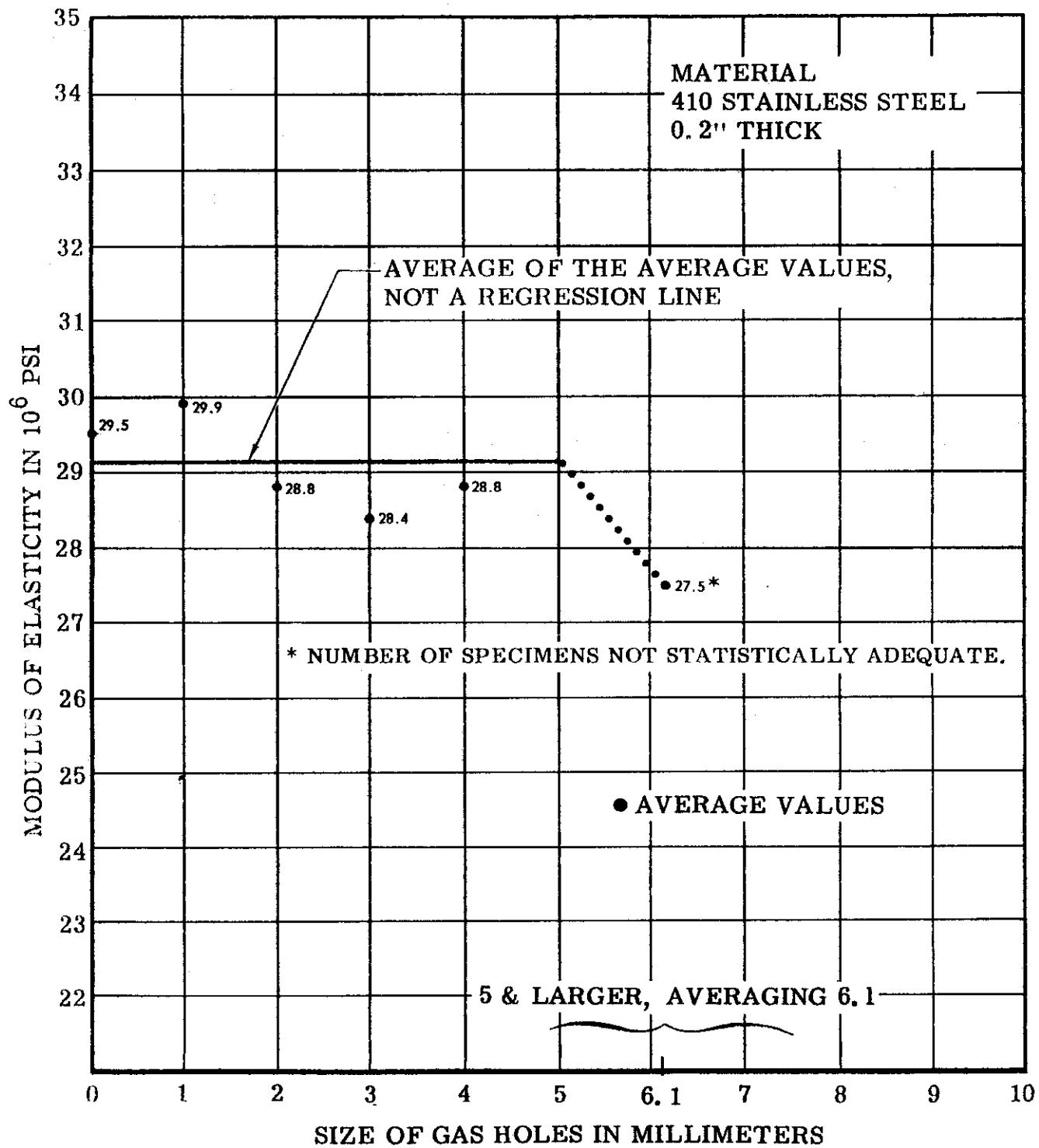


Figure 51. Modulus of Elasticity vs Gas Holes - Correlation

5.17 SUMMARY OF RESULTS - TENSILE YIELD VS. INCLUSIONS - 0.2"-THICK MATERIAL

	Control <u>Specimens</u>	Size of Inclusions (diameter in millimeters)					
		<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>
Number of specimens tested -	46	5	13	11	13	10	9
Statistically determined number required for 0.95 confidence that the average of the results approaches the true average -	5	2	4	3	4	3	2
Confidence level, if less than 0.95 -	-	-	-	-	-	-	***
The following results and statistical parameters are in ksi							
Tensile yield (average of test results) -	147	14.9	15.0	14.6	14.8	15.0	14.3
Estimate of the standard deviation	7.6	4.0	6.7	5.6	6.9	5.8	4.6
<u>97 Statistical limits for individuals:</u>							
Lower limit (0.95 probability) -	132	141	137	135	135	138	134
Upper limit (0.95 probability) -	162	157	164	157	162	161	158

CORRELATION ANALYSIS

Analysis was not made; no trend toward lower values, as size of inclusions increased, was present, except for the larger size inclusions. Also, number of specimens for largest size inclusions was not statistically adequate.

* Specimens having 7-mm-and-larger inclusions, averaging 8 mm.

** Number of specimens not adequate; see number required on line below.

*** Value too low for confidence level to have a practical meaning.

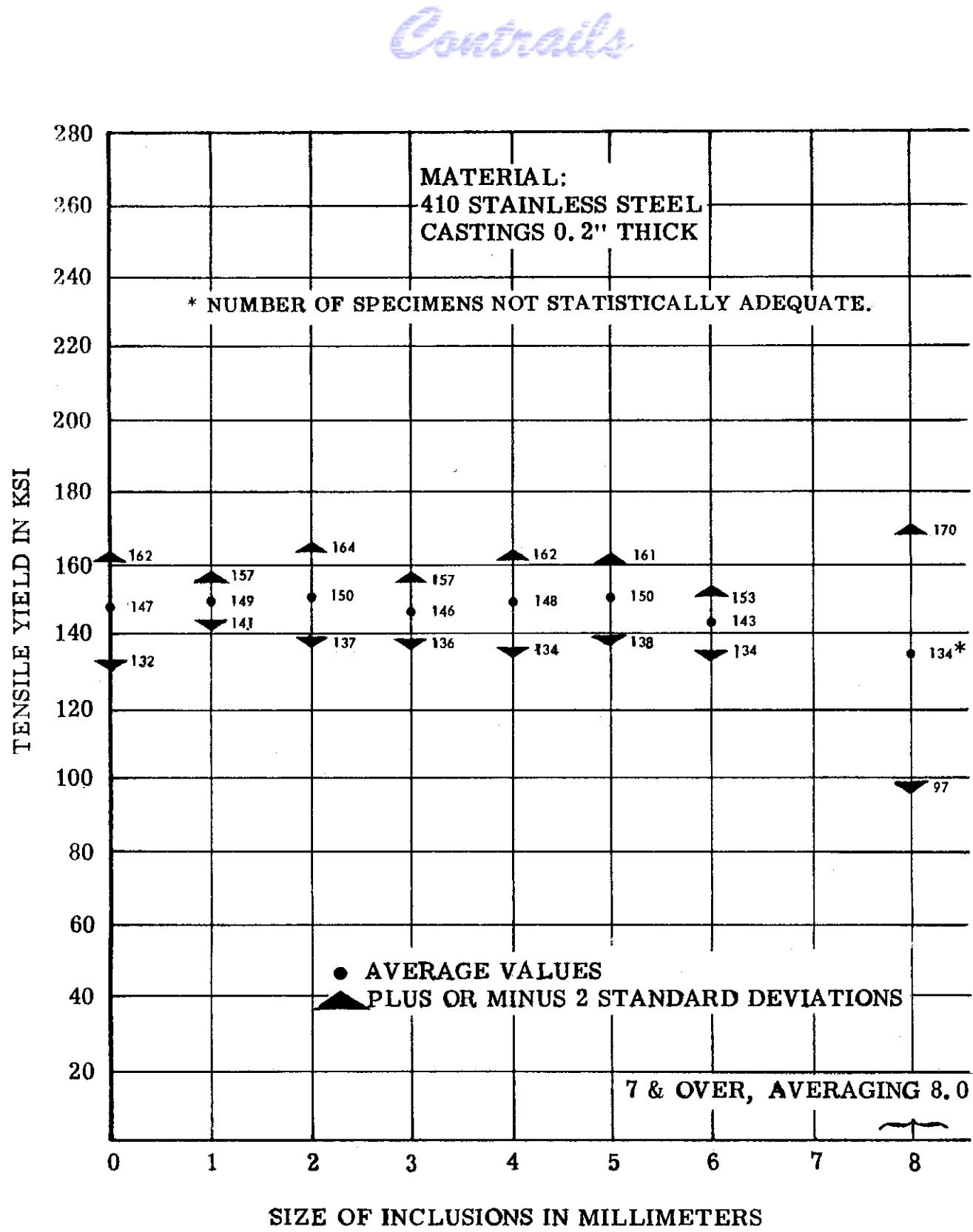


Figure 52. Tensile Yield vs Inclusions - Range of Values

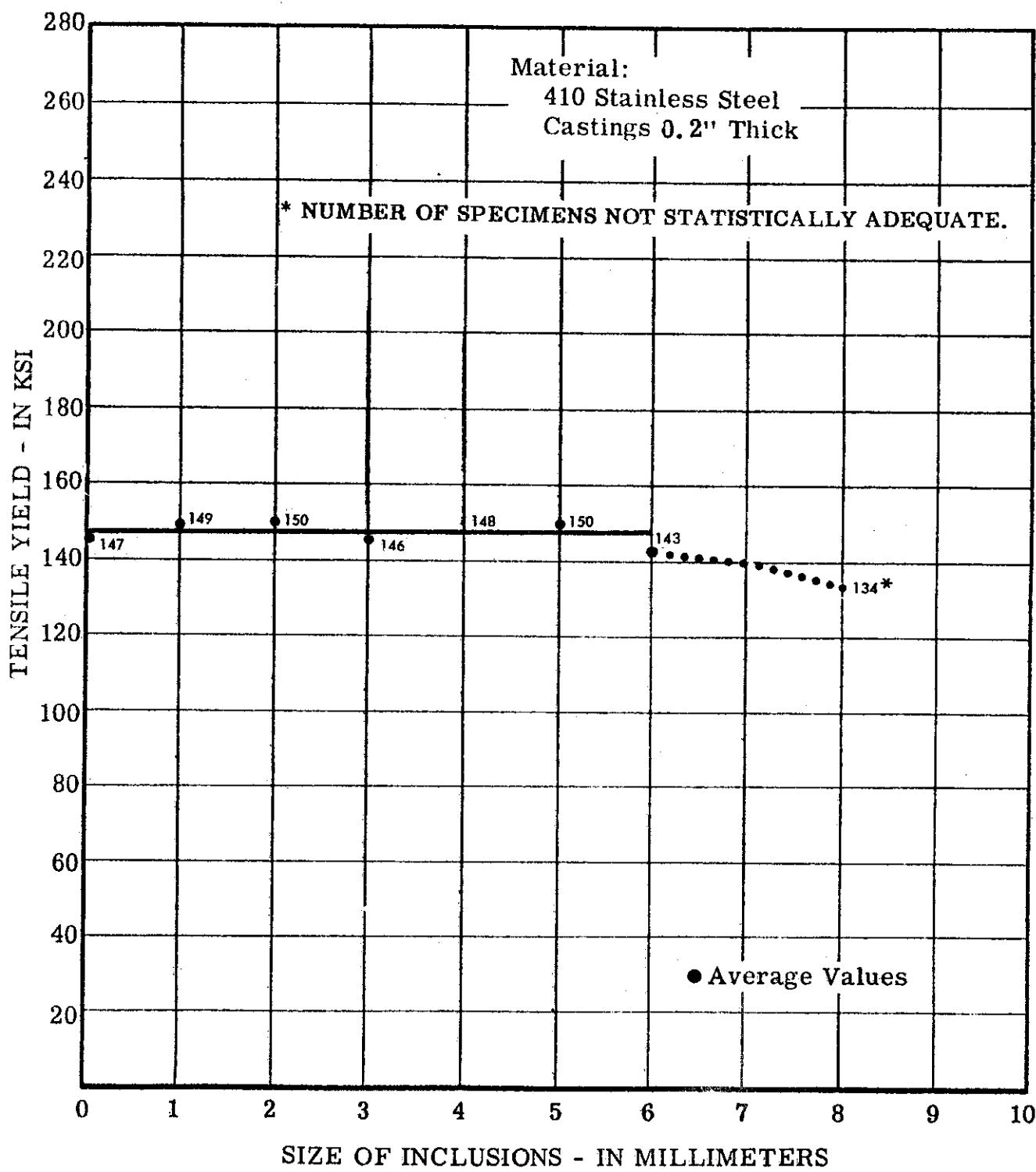


Figure 53. Tensile Yield vs Inclusions - Correlation

WADD TR 60-450

5.18 SUMMARY OF RESULTS - TENSILE ULTIMATE VS. INCLUSIONS - 0.2"-THICK MATERIAL

Number of specimens tested -	Control Specimens	Size of Inclusions (diameter in millimeters)					
		<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>
46	5	13	14**	14**	10**	9**	13**

Statistically determined number required for 0.95 confidence that the average of the results approaches the true average -

Confidence level, if less than 0.95 -

The following results and statistical parameters are in ksi

Tensile ultimate (average of test results) -	197	195	193	182	189	182	166	149
Estimate of the standard deviation -	7.0	5.7	14.2	21.2	20.7	10.5	18.7	29.5
Hardness (average Rockwell C) -	41.0	41.7	42.9	42.8	44.1	42.0	42.2	42.8
Tensile ultimate (adjusted to hardness) ****	202	197	188	178	178	177	165	145

Statistical limits for individuals:

Lower limit (0.95 probability) -	188	186	160	135	136	156	128	86
Upper limit (0.95 probability) -	216	208	217	220	219	198	202	204

CORRELATION ANALYSIS

Correlation coefficient = - 0.99, for 0.95 or better confidence level averages. "Standard error of estimate" = 1.3 ksi

* Specimens having 7-mm-and-larger inclusions, averaging 8 mm.

** Number of specimens not adequate; see number required on line below.

*** Value too low for confidence level to have a practical meaning.

**** See paragraph 6.1.1

Contrails

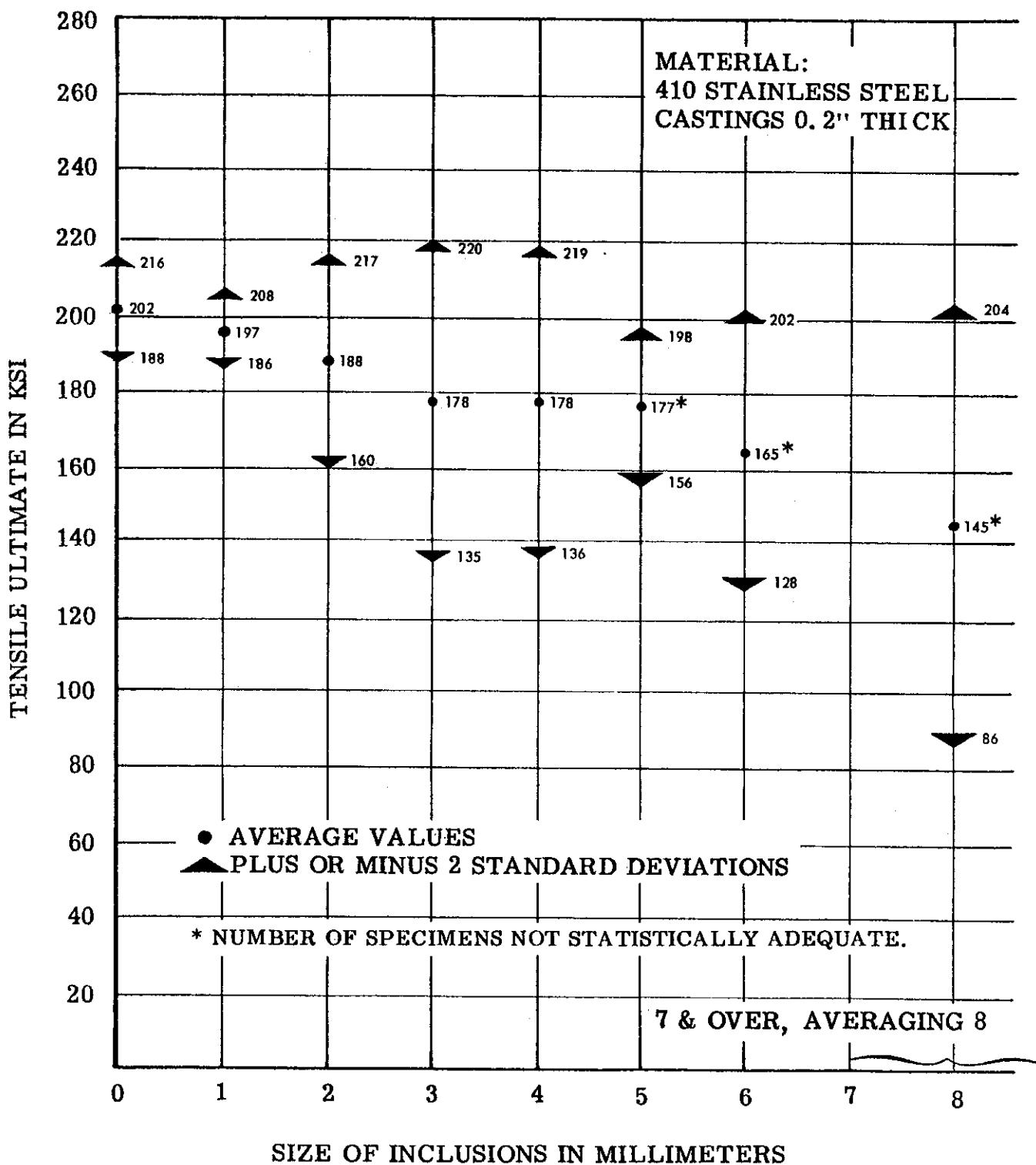


Figure 54. Tensile Ultimate vs Inclusions - Range of Values

Controls

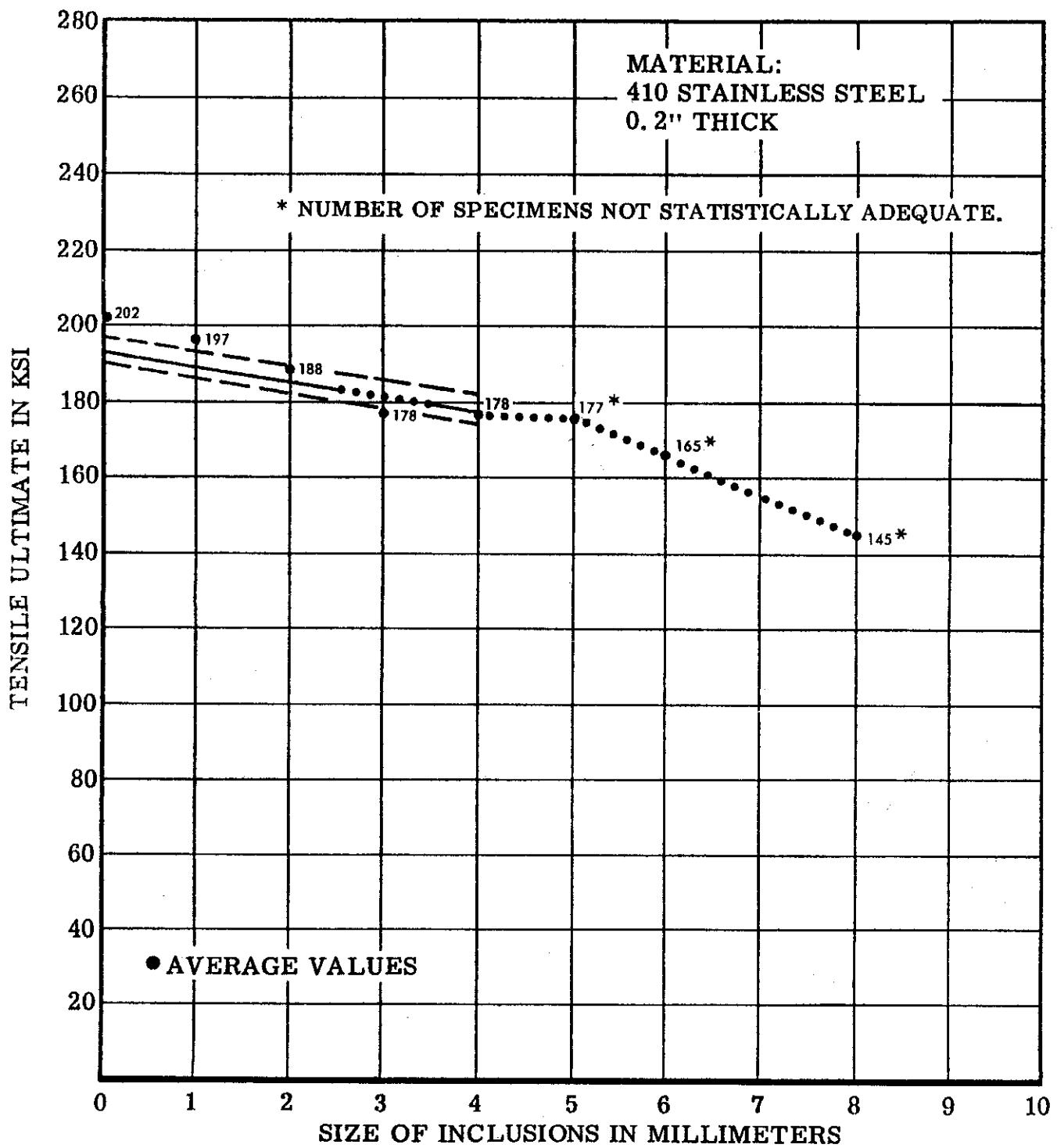


Figure 55. Tensile Ultimate vs Inclusions - Correlation

5. 19 SUMMARY OF RESULTS - ELONGATION VS. INCLUSIONS - 0.2"-THICK MATERIAL

Number of specimens tested -	Control Specimens	Size of Inclusions (diameter in millimeters)						
		1	2	3	4	5	6	7.5*
45	5**	12**	14**	14**	10**	8**	11**	

Statistically determined number required for 0.95 confidence that the average of the results approaches the true average -

Confidence level, if less than 0.95 -

The following results and statistical parameters are in % in 2"

Elongation (average of test results) -	7.6	8.0	5.0	4.0	4.0	3.8	2.9	2.2
Estimate of the standard deviation -	2.6	1.9	3.1	1.3	2.0	1.0	1.6	0.9
<u>Statistical limits for individuals:</u>								
Lower limit (0.95 probability) -	2.4	4.3	0	1.4	0	1.8	0	0.5
Upper limit (0.95 probability) -	12.8	11.7	11.2	6.6	8.0	5.8	6.2	3.9

CORRELATION ANALYSIS

Analysis was not made; number of samples from which averages were computed was not statistically adequate.

* Specimens having 7-mm-and-larger inclusions, averaging 7.5 mm.

** Number of specimens not adequate; see required number on line below.

*** Value too low for confidence level to have a practical meaning.

Contrails

ELONGATION - PERCENT IN 2 INCHES

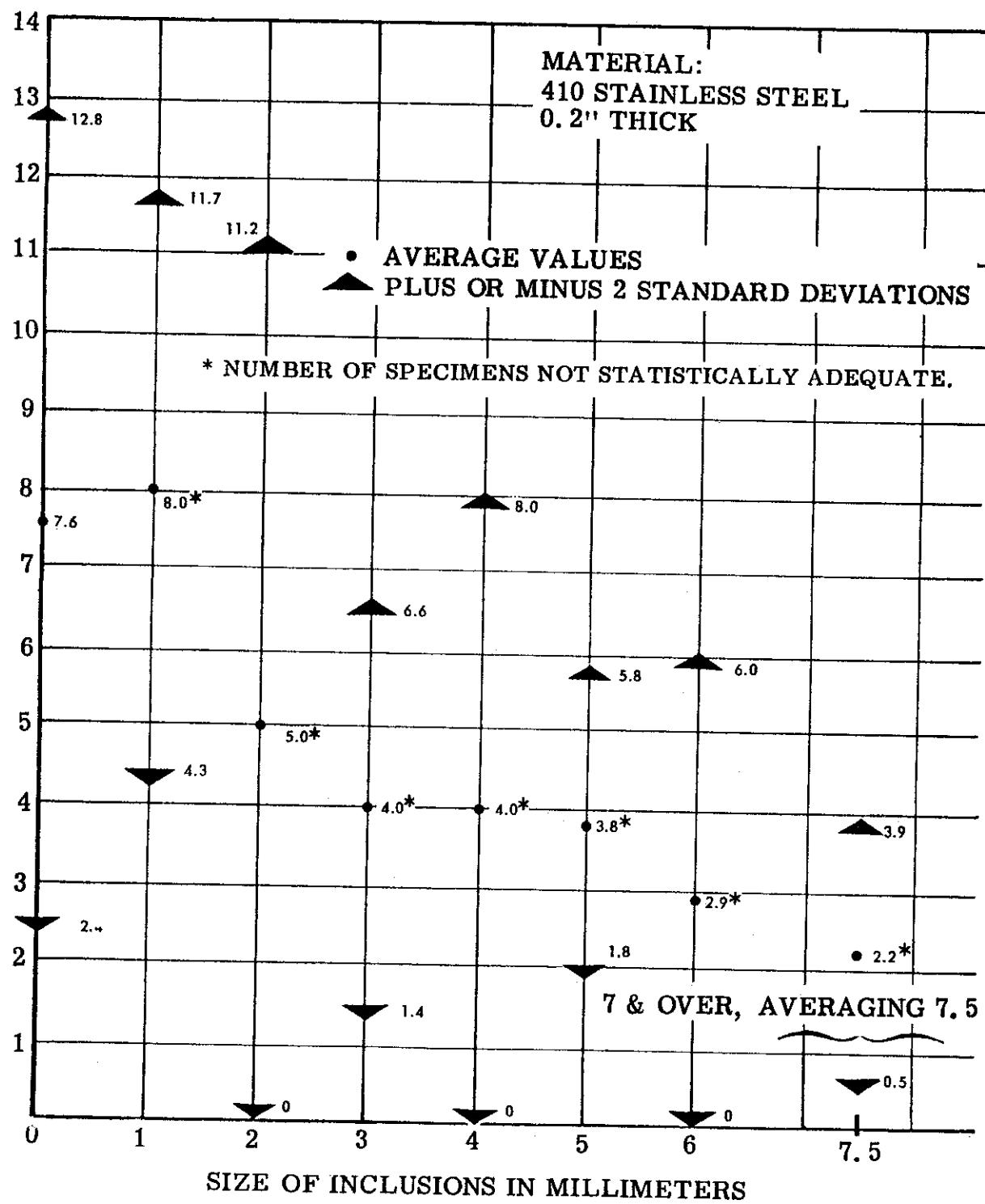


Figure 56. Elongation vs Inclusions - Range of Values

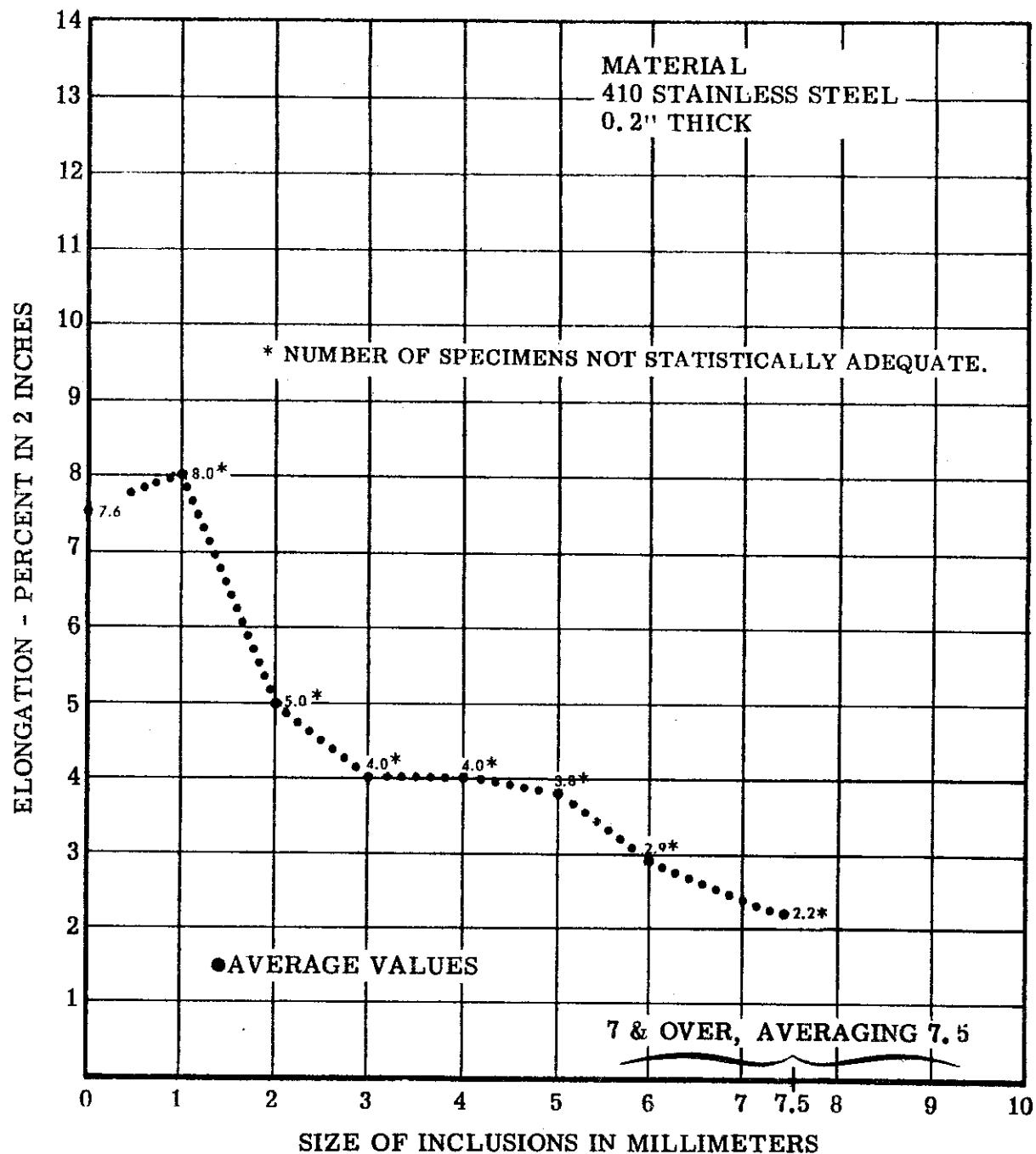


Figure 57. Elongation vs Inclusions - Correlation

5.20 SUMMARY OF RESULTS - MODULUS OF ELASTICITY VS. INCLUSIONS - 0.2"-THICK MATERIAL

WADD TR 60-450

Number of specimens tested -	Control Specimens	Size of Inclusions (diameter in millimeters)					
		<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>7.5*</u>
46	4	13	14	14	10	9	11

Statistically determined number required for 0.95 confidence that the average of the results approaches the true average -

4 -

Confidence level, if less than 0.95 -

- -

The following results and statistical parameters are in 10^6 psi

Modulus (average of test results) -	29.5	28.3	29.5	29.6	30.0	29.2	28.8	28.5
Estimate of the standard deviation -	1.3	1.1	1.2	1.2	1.3	2.0	1.6	1.6
<u>Limits for individuals :</u>								
Lower limit (0.95 probability) -	27.0	26.1	27.1	27.2	27.3	25.2	25.6	25.3
Upper limit (0.95 probability) -	32.2	30.5	31.9	32.0	32.7	33.2	32.0	31.7

CORRELATION ANALYSIS

Analysis was not made; no sustained trend toward lower values, as size of inclusions increased, was present.

* Specimens having 7-mm-and-larger inclusions, averaging 7.5 mm.

Contrails

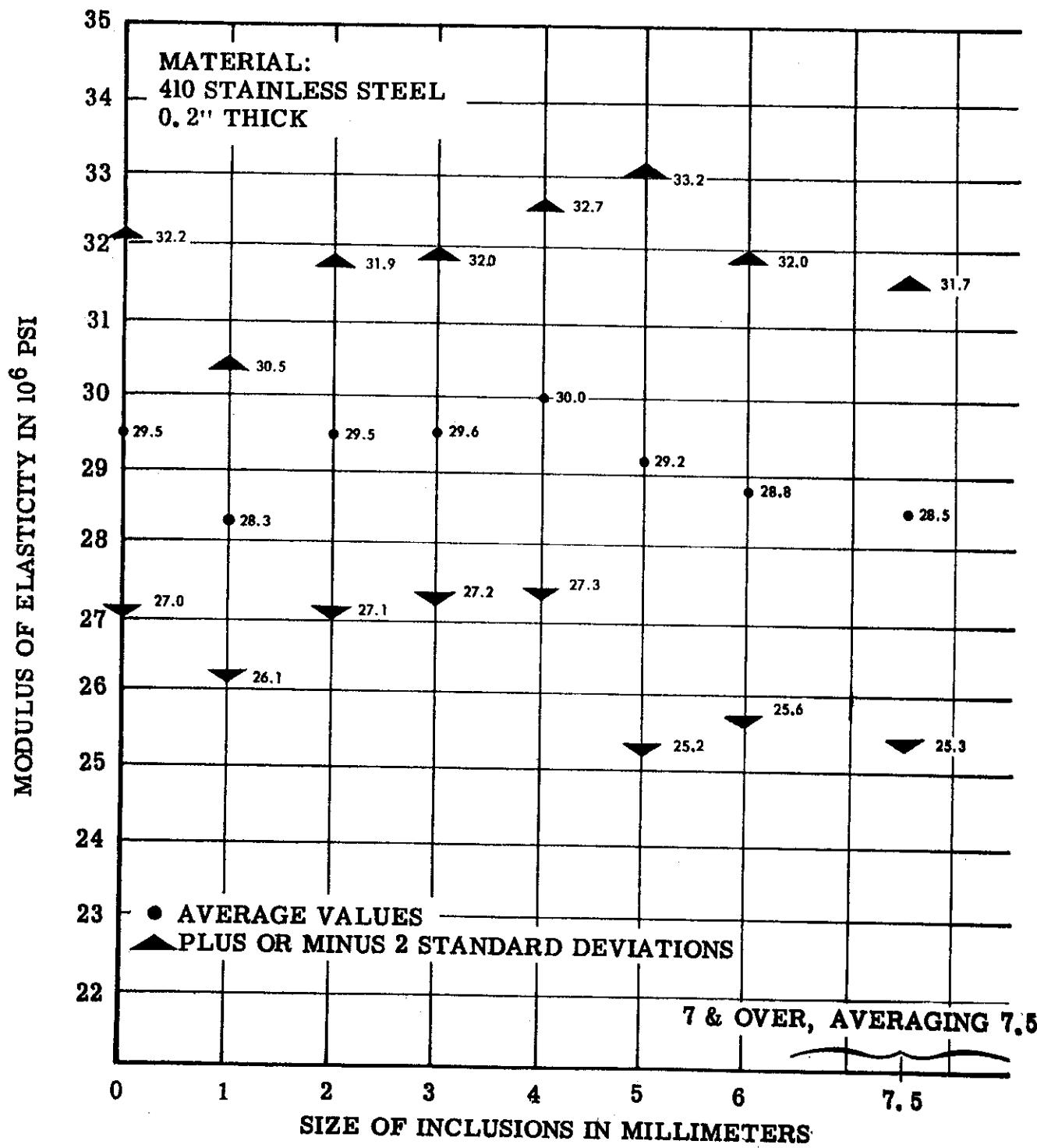


Figure 58. Modulus of Elasticity vs Inclusions - Range of Values

Contrails

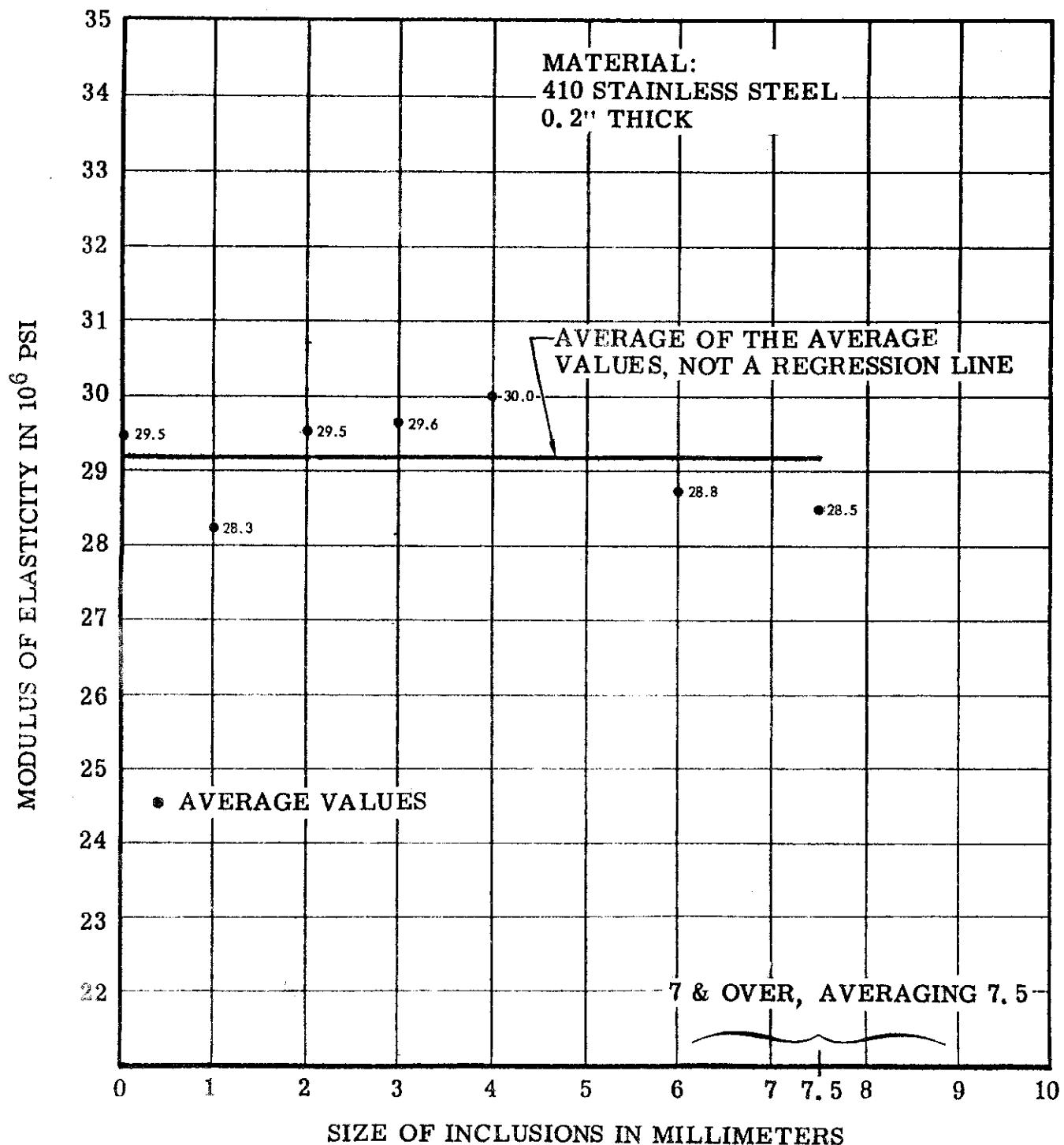


Figure 59. Modulus of Elasticity vs Inclusions - Correlation

WADD TR 60-450

5.21 SUMMARY OF RESULTS - TENSILE YIELD VS. POROSITY - 0.2"-THICK MATERIAL

Number of specimens tested -	Control Specimens	Numbers, Indicating Intensity of Porosity					
	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7.3*</u>
46	49	27	38	31	22	9	10

Statistically determined number required

for 0.95 confidence that the average of
the results approaches the true average -

Confidence level, if less than 0.95 -

The following results and statistical
parameters are in ksi

Tensile yield (average of test results) - 147
Estimate of the standard deviation - 7.6

Statistical limits for individuals:

Lower limit (0.95 probability) - 132
Upper limit (0.95 probability) - 162

CORRELATION ANALYSIS

Analysis was not made; no trend toward lower values, as intensity of porosity increased, was present.

* Specimens having number-7-and-higher porosity intensity, averaging, number -7.3.

Contrails

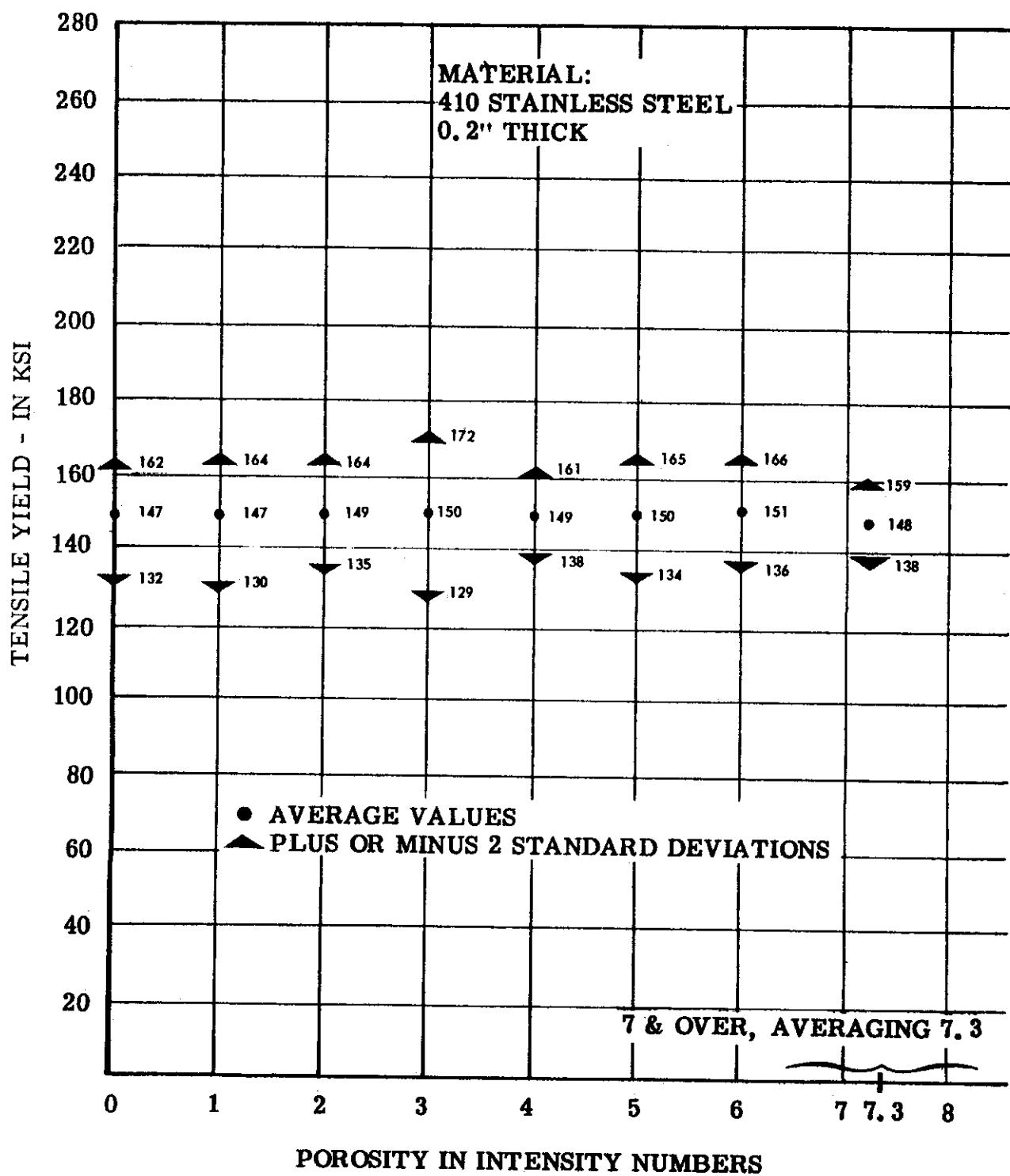


Figure 60. Tensile Yield vs Porosity - Range of Values

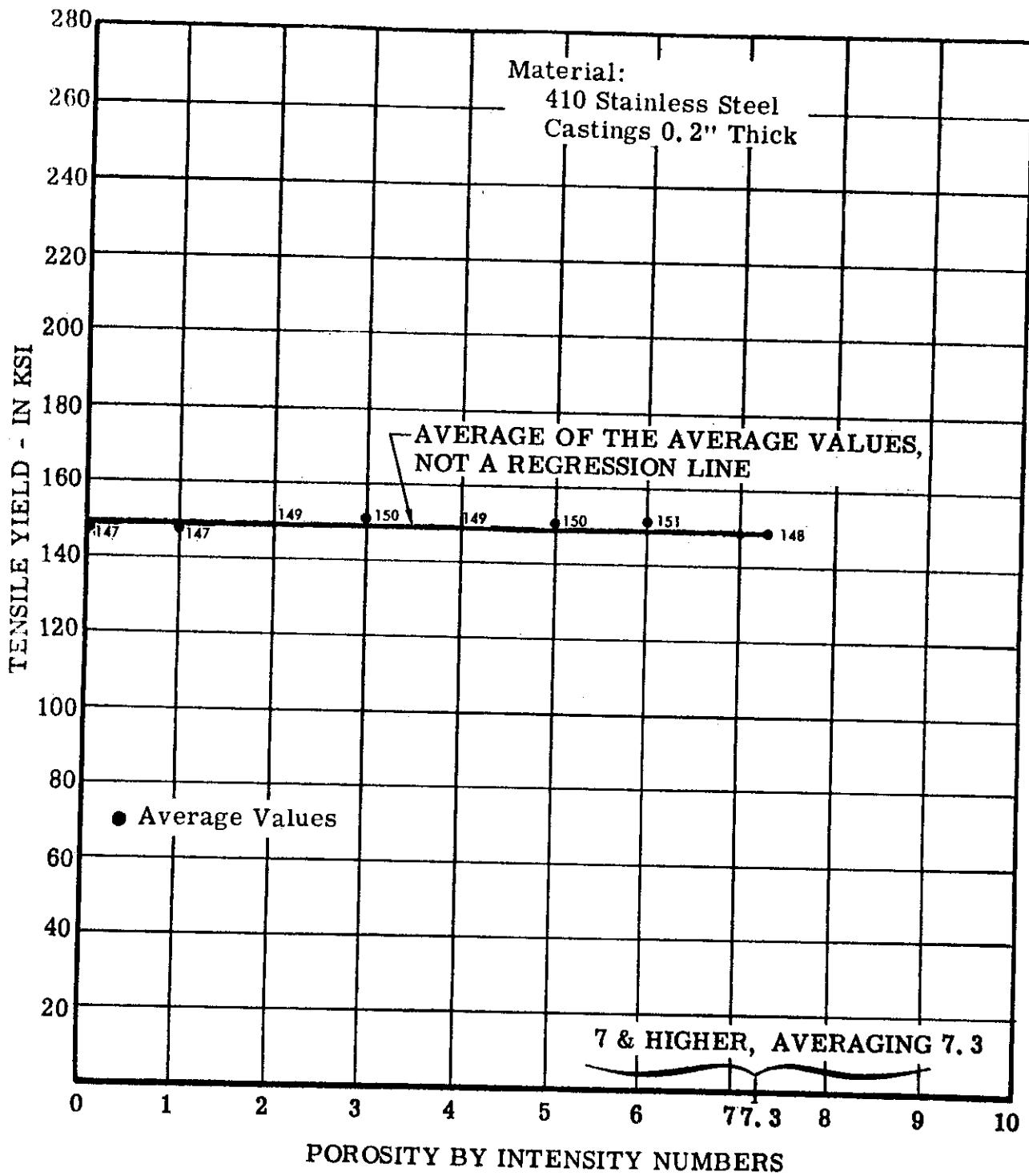


Figure 61. Tensile Yield vs Porosity - Correlation

5.22 SUMMARY OF RESULTS - TENSILE ULTIMATE VS. POROSITY - 0.2"-THICK MATERIAL

	Control Specimens	Numbers, Indicating Intensity of Porosity					
	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7.3*</u>
Number of specimens tested -	48	49	29	39	32	25	14** 14**

Statistically determined number required for 0.95 confidence that the average of the results approaches the true average -

Confidence level, if less than 0.95 -

The following results and statistical parameters are in ksi

Tensile ultimate (average of test results) -	197	192	185	184	181	170	163	162
Estimate of the standard deviation -	7.0	11.1	15.2	14.8	17.0	13.3	24.2	24.1
Hardness (average Rockwell C) -	41.0	42.5	42.5	43.1	43.9	44.1	42.1	44.1
Tensile ultimate (adjusted to hardness)**** 202	188	182	178	178	170	159	163	151

Statistical limits for individuals:

Lower limit (0.95 probability) -	188	166	152	149	136	132	114	101
Upper limit (0.95 probability) -	216	211	213	208	204	185	211	199

CORRELATION ANALYSIS

Correlation coefficient = - 0.98, minus sign indicates an inverse relationship. "Standard error of estimate" = 9.5 ksi.

* Specimens having number-7-and-higher porosity intensity, averaging number -7.3.

** Number of specimens not adequate, see number required on line below.

*** Value too low for confidence level to have a practical meaning.

**** See paragraph 6.1.1

Contrails

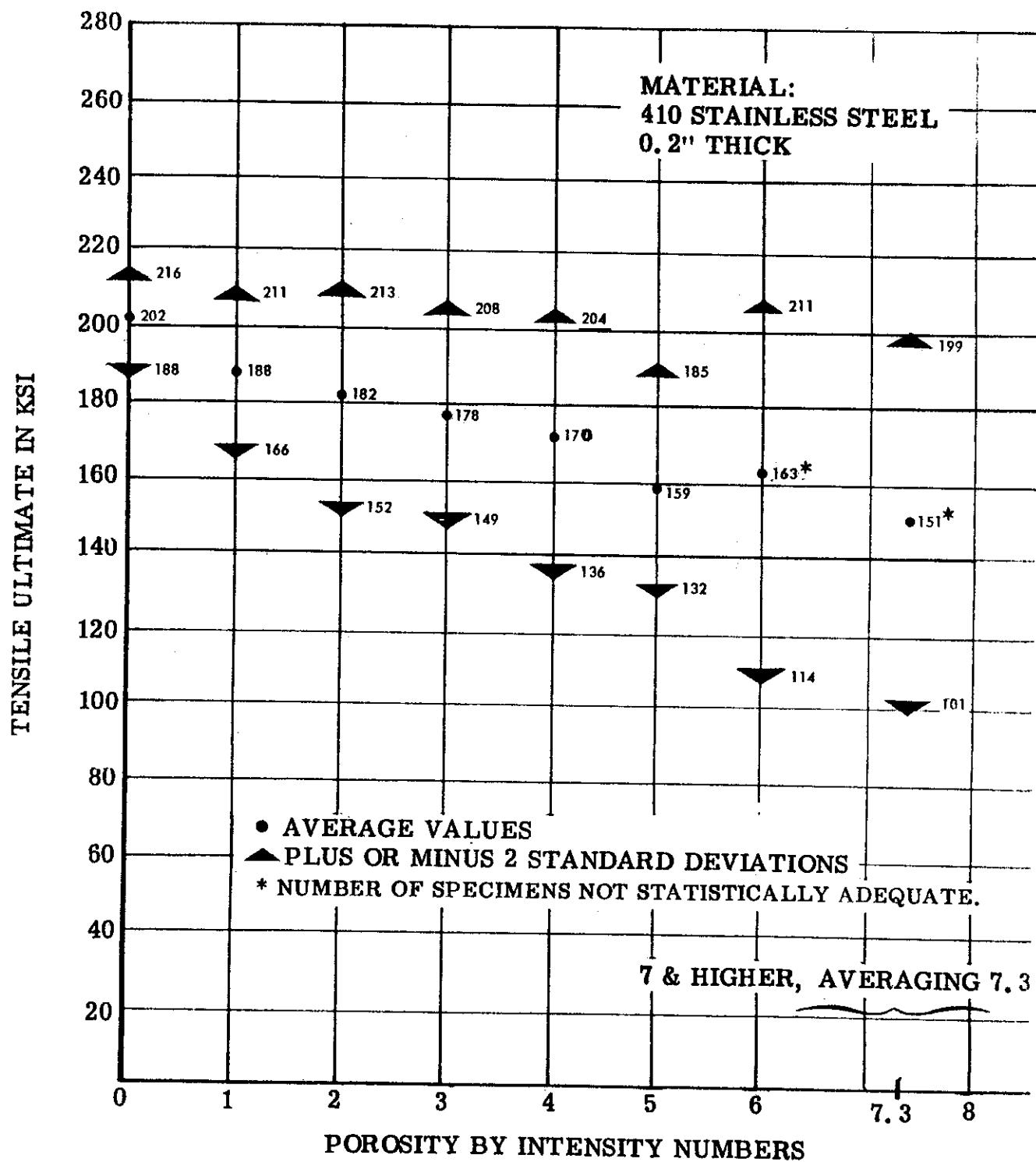


Figure 62. Tensile Ultimate vs Porosity - Range of Values

Contrails

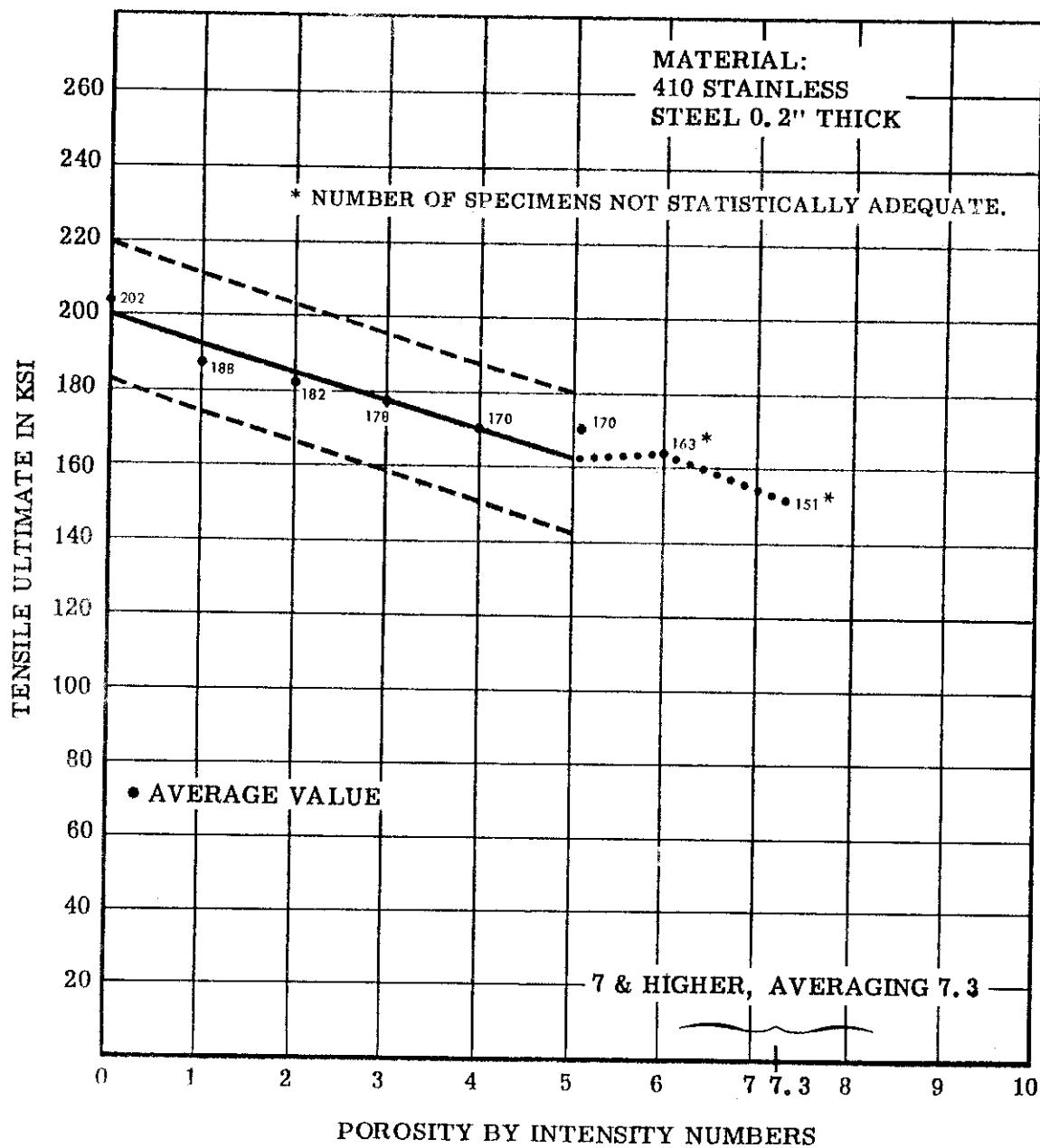


Figure 63. Tensile Ultimate vs Porosity - Correlation

WADD TR 60-450

5.23 SUMMARY OF RESULTS - ELONGATION VS. POROSITY - 0.2"-THICK MATERIAL

<u>Control Specimens</u>	<u>Numbers, Indicating Intensity of Porosity</u>					
<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7.3*</u>
45	48	29	36	31	21	13** 12**
Number of specimens tested -						
Statistically determined number required for 0.95 confidence that the average of the results approaches the true average -	21	36	16	14	13	14 25
Confidence level, if less than 0.95 -	-	-	-	-	-	0.94 ***
The following results and statistical parameters are in % in 2"						
Elongation (average of test results) -	7.6	4.3	3.1	2.8	2.6	2.6 2.3
Estimate of the standard deviation -	2.6	1.9	1.0	0.8	0.7	0.7 0.6
<u>Statistical limits for individuals:</u>						
Lower limit (0.95 probability) -	2.4	0.5	1.1	1.3	1.2	1.2 1.1
Upper limit (0.95 probability) -	12.8	8.1	5.1	4.3	4.0	4.0 3.5 4.2

CORRELATION ANALYSIS

Analysis was not made; data does not lend itself to a straight-line relationship. The "standard error of estimate" would be so large if linear correlation were used that predictions would be impractical.

-
- * Specimens having number-7-and-higher porosity intensity, averaging number -7.3.
 - ** Number of specimens not adequate; see number required on line below.
 - *** Value too low for confidence level to have a practical meaning.

Contrails

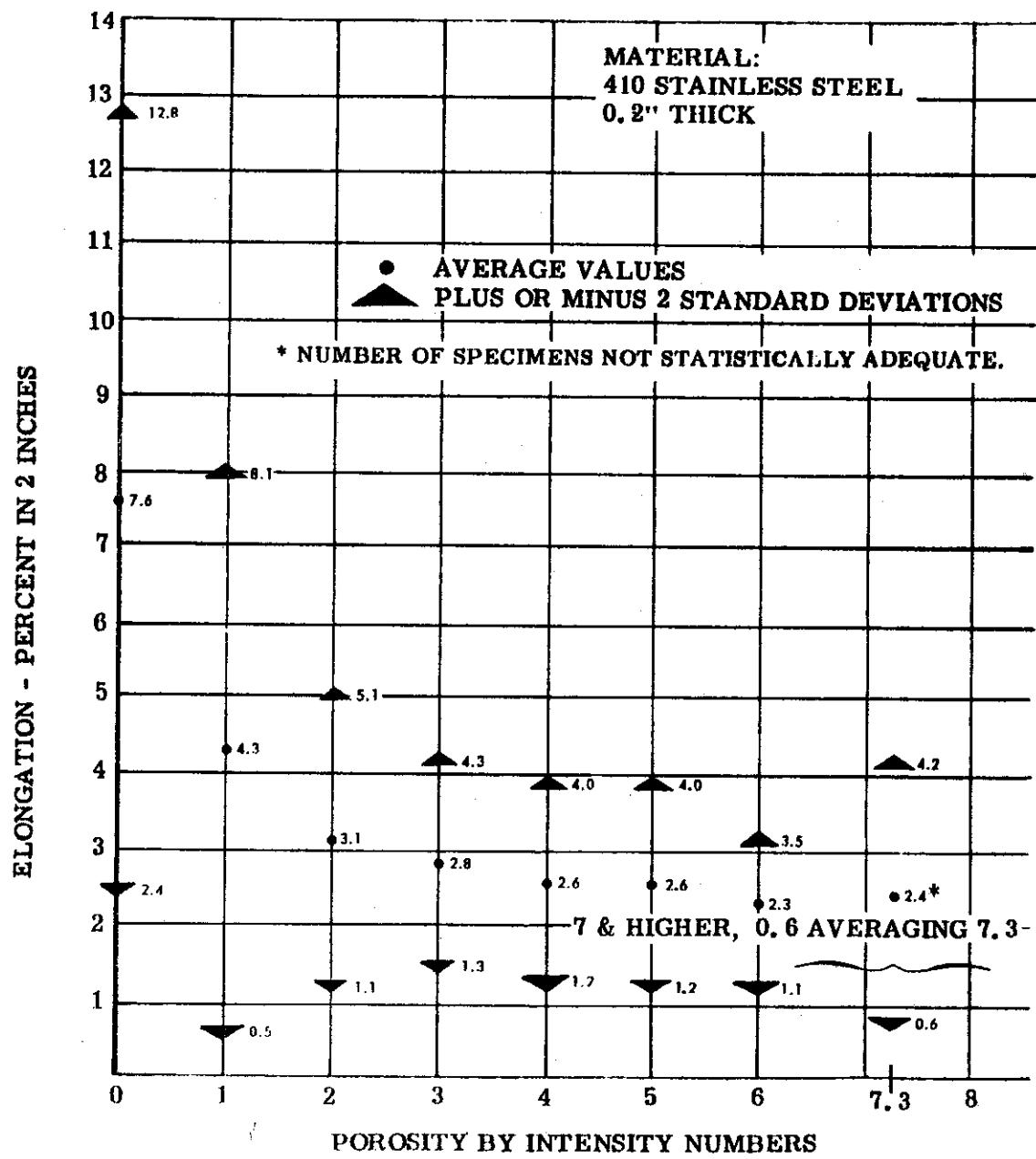


Figure 64. Elongation vs Porosity - Range of Values

Contrails

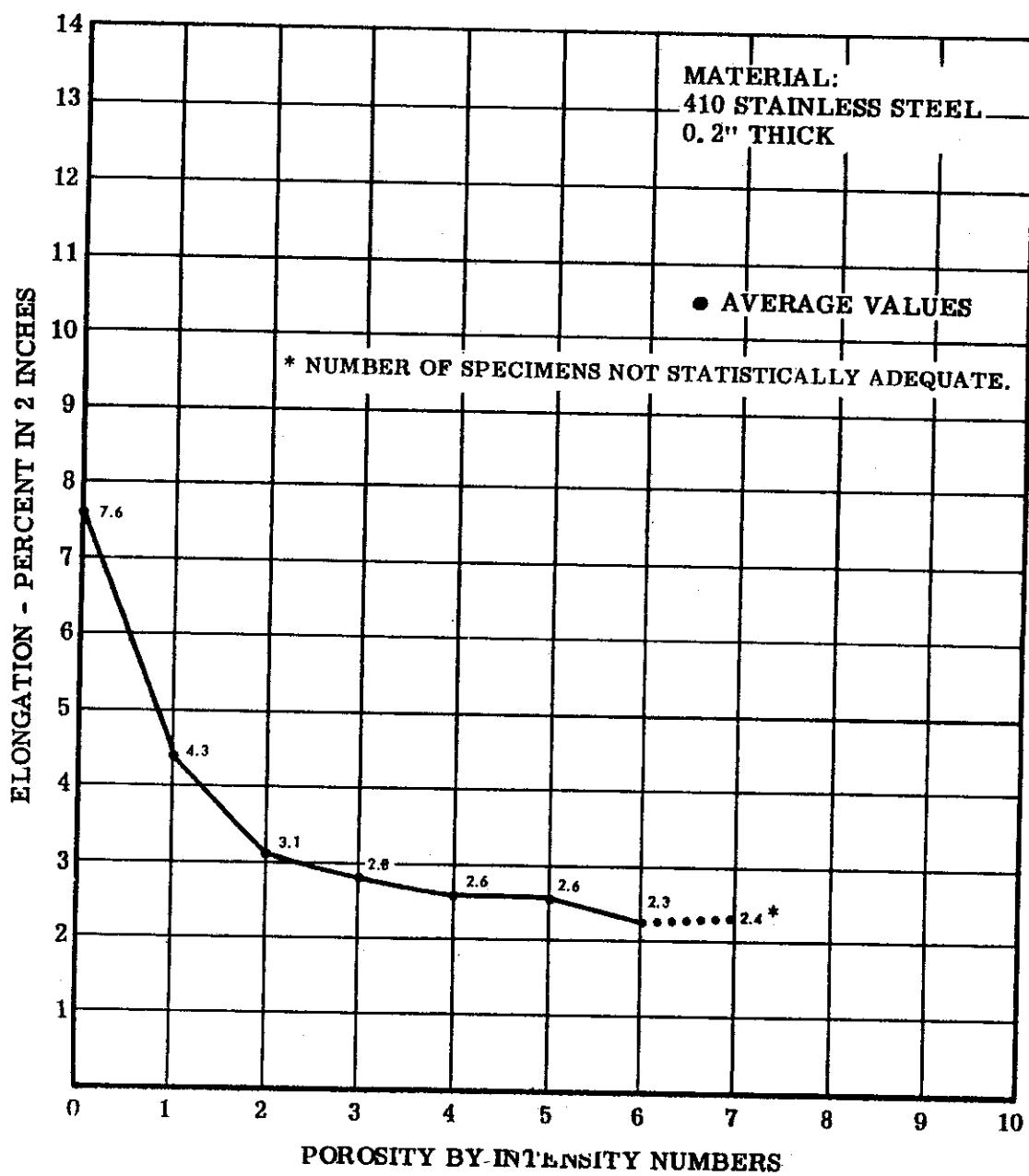


Figure 65. Elongation vs Porosity - Correlation

WADD TR 60-450

5.24 SUMMARY OF RESULTS - MODULUS OF ELASTICITY VS. POROSITY - 0.2"-THICK MATERIAL

WADD TR 60-450

<u>Control Specimens</u>	<u>Numbers, Indicating Intensity of Porosity</u>	<u>7.3*</u>					
<u>Number of specimens tested -</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7.3*</u>
46	49	29	39	32	25	13	14
Statistically determined number required for 0.95 confidence that the average of the results approaches the true average -	4	5	7	2	4	6	7
Confidence level, if less than 0.95 -	-	-	-	-	-	-	-
The following results and statistical parameters are in 10^6 psi							
Modulus (average of test results) -	29.5	29.5	28.5	29.3	28.7	29.0	28.7
Estimate of the standard deviation -	1.3	1.6	1.0	1.9	0.8	1.5	1.7
<u>Statistical limits for individuals:</u>							
Lower limit (0.95 probability) -	27.0	26.4	26.5	25.5	27.1	26.0	25.4
Upper limit (0.95 probability) -	32.2	32.6	30.5	33.1	30.3	32.0	32.6

CORRELATION ANALYSIS

Analysis was not made; no trend toward lower values, as intensity of porosity increased, was present.

* Specimens having number -7-and-higher porosity intensity, averaging number -7.3.

Contrails

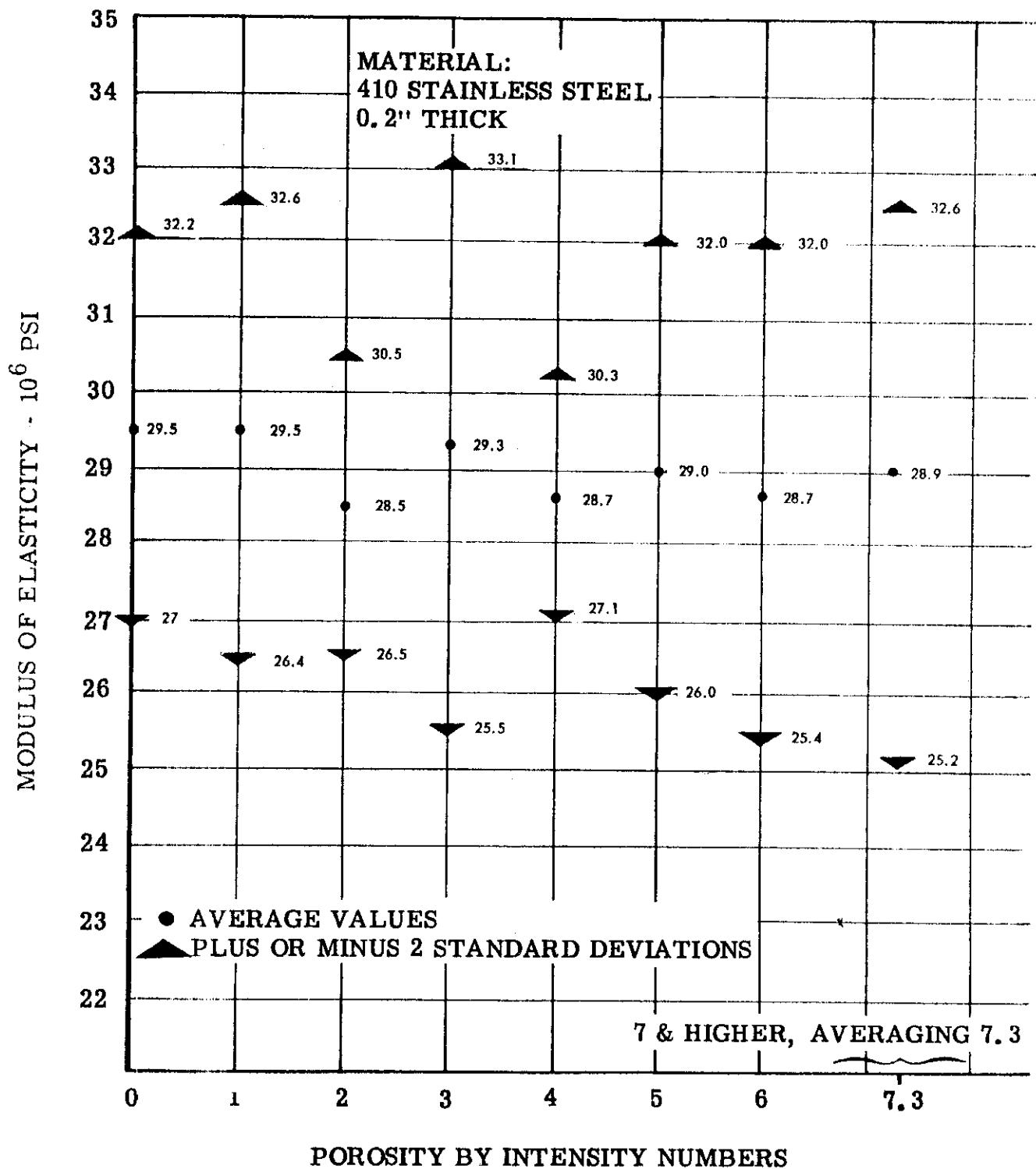


Figure 66. Modulus of Elasticity vs Porosity - Range of Values

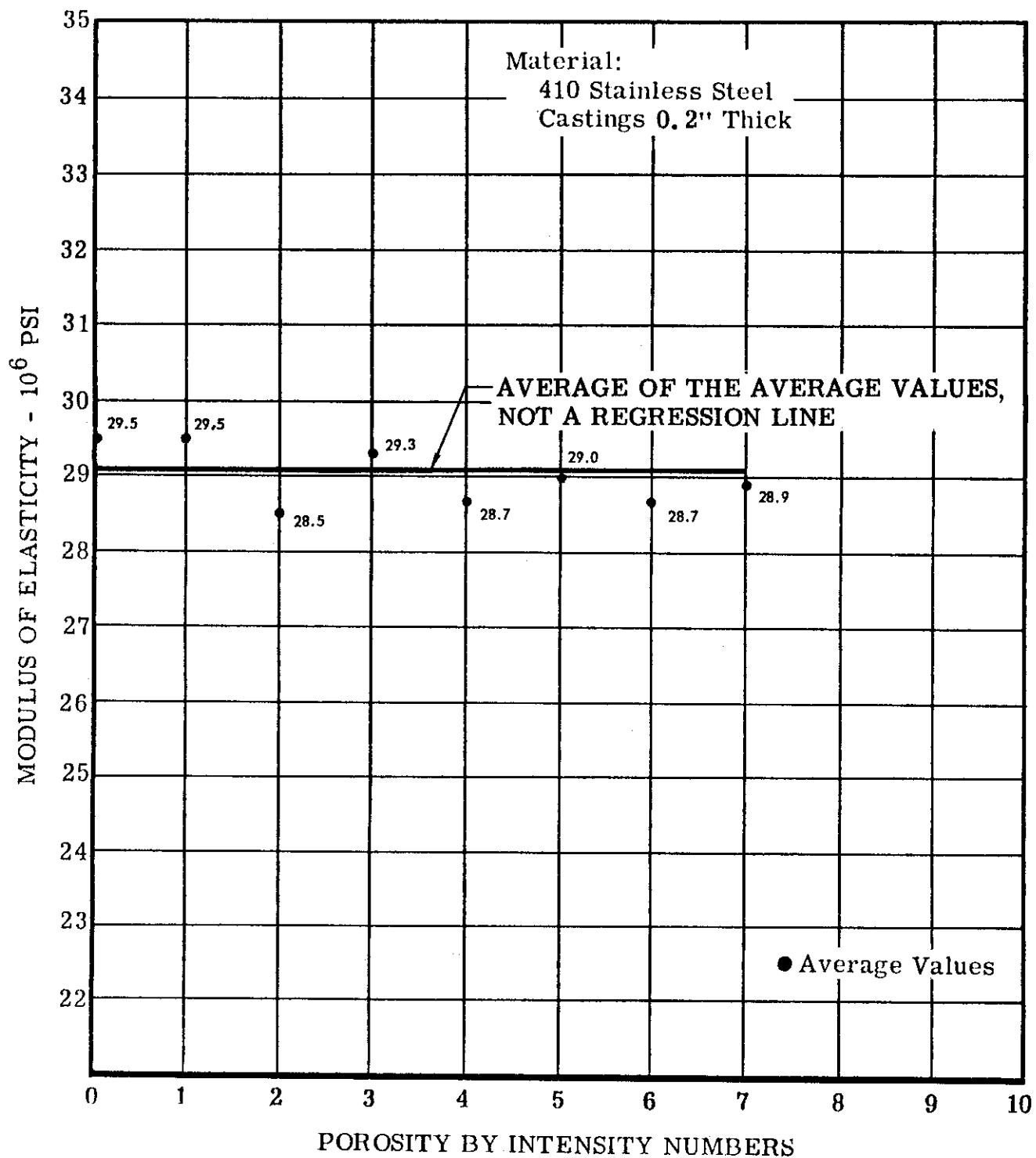


Figure 67. Modulus of Elasticity vs Porosity - Correlation

5.25 SUMMARY OF RESULTS - TENSILE YIELD VS. GAS HOLES - 0.31"-THICK MATERIAL

Number of specimens tested -	Control Specimens	Size of Gas Holes (diam. in millimeters)				
		1	2	3	4	5
67	9	16	10	9	7	11

Statistically determined number required for 0.95 confidence that the average of the results approaches the true average -

Confidence level, if less than 0.95 -

The following results and statistical parameters are in ksi:

Tensile yield (Average of test results) -
Estimate of the standard deviation -

Limits for individuals:

Lower limit (0.95 probability) -
Upper limit (0.95 probability) -

CORRELATION ANALYSIS

Analysis was not made; no trend toward lower values, as size of gas holes increased, was present.

-
- * Specimens having 6-mm-and-larger gas holes, averaging 7.9 mm.

Contrails

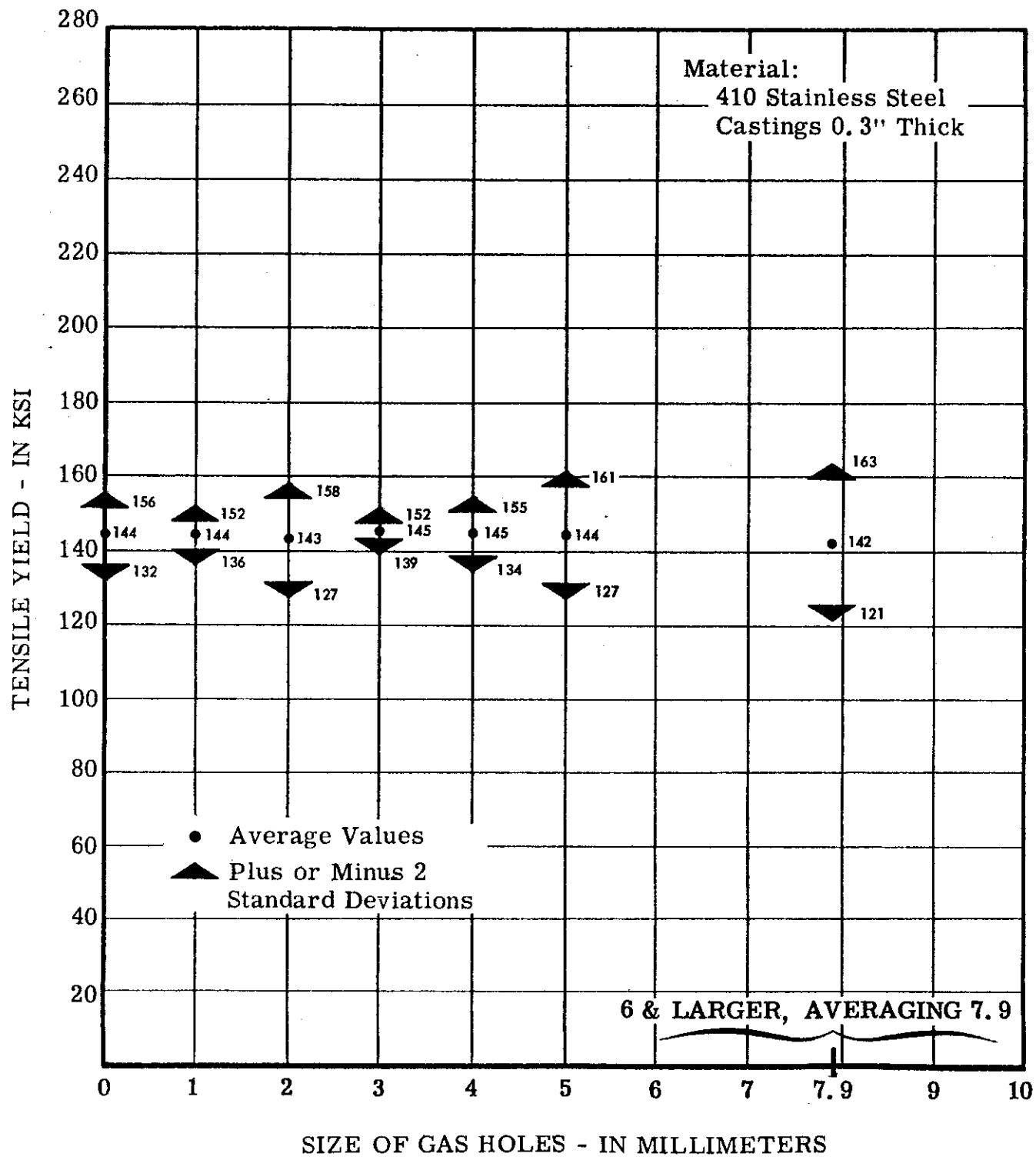


Figure 68. Tensile Yield vs Gas Holes - Range of Values

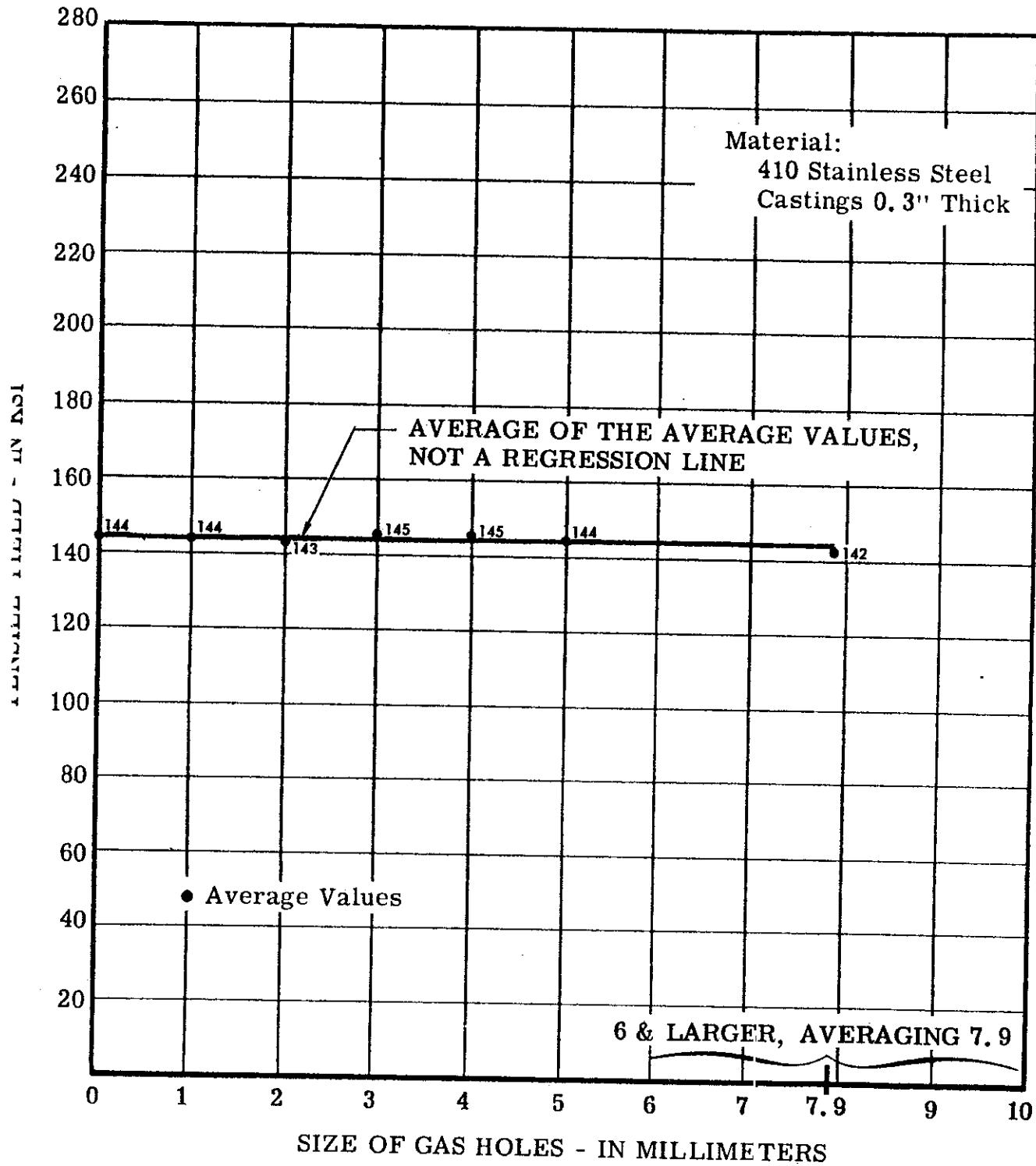


Figure 69. Tensile Yield vs Gas Holes - Correlation

WADD TR 60-450

5.26 SUMMARY OF RESULTS - TENSILE ULTIMATE VS. GAS HOLES - 0.31"-THICK MATERIAL

WADD TR 60-450

Number of specimens tested -	Control Specimens						Size of Gas Holes (diameter in millimeters)
	1	2	3	4	5	8.1	
67	9	16	11	10**	7	16**	

Statistically determined number required for 0.95 confidence that the average of the results approaches the true average -

Confidence level, if less than 0.95 -

The following results and statistical parameters are in ksi:

Tensile ultimate (average of test results) -	191	189	188	183	179	174	159
Estimate of the standard deviation -	7.6	5.8	6.2	12.6	16.8	10.3	26.4
Hardness (average Rockwell C) -	41.1	41.2	41.6	41.7	41.7	41.9	42.1
Tensile ultimate (adjusted to hardness)** -	195	194	190	184	181	174	158

Limits for individuals:

Lower limit (0.95 probability) -	180	182	178	159	147	154	105
Upper limit (0.95 probability) -	210	205	202	209	215	195	211

CORRELATION ANALYSIS

Correlation coefficient - 0.99, minus sign indicates an inverse relationship. "Standard error of estimate" 1.6 ksi.

* Specimens having 6-mm-and-larger gas holes, averaging 8.1 mm

** Number of specimens not adequate, see number required on line below

*** Value too low for confidence level to have a practical meaning

**** See paragraph 6.1.1

Contrails

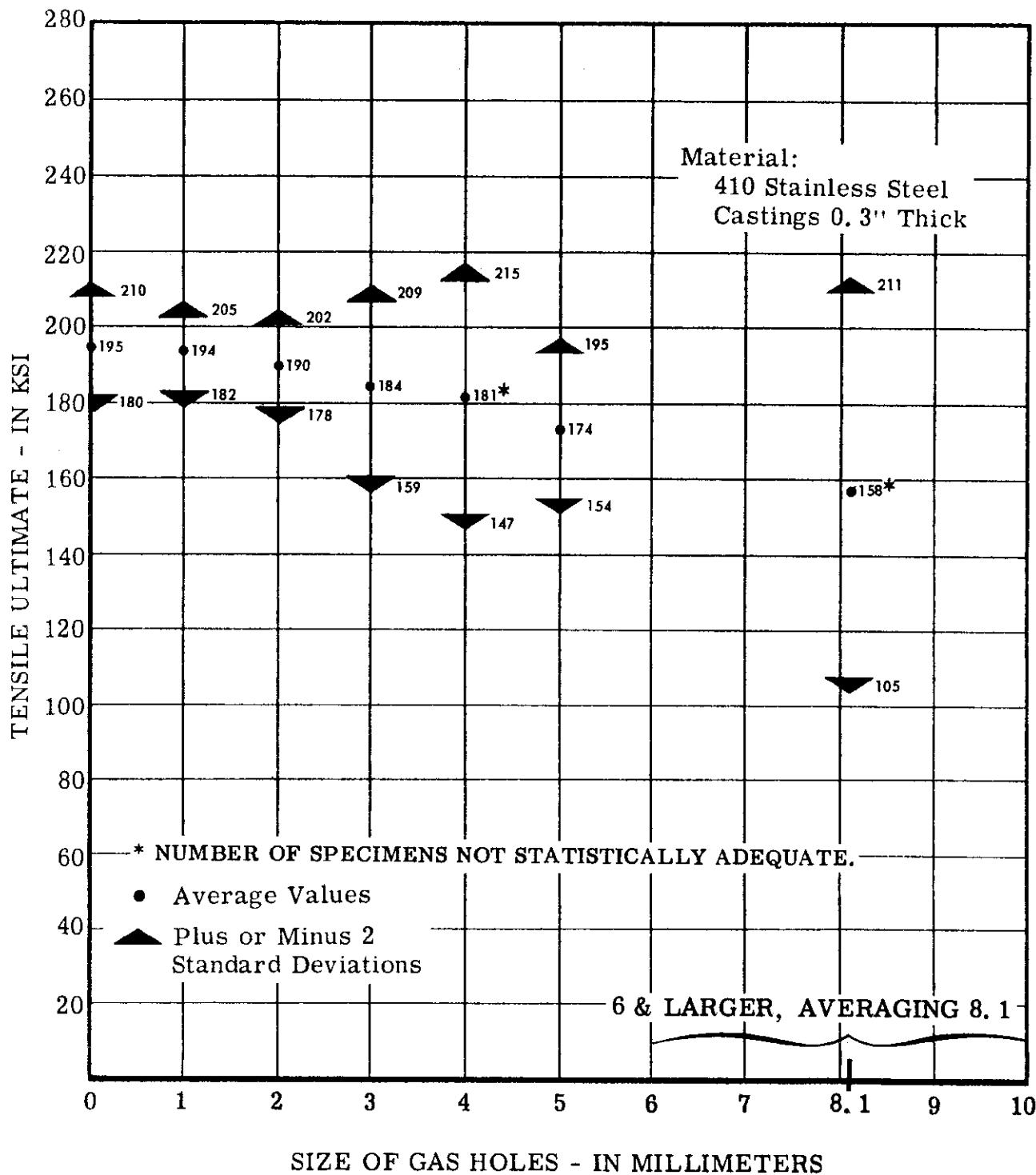


Figure 70. Tensile Ultimate vs Gas Holes - Range of Values

WADD TR 60-450

Contrails

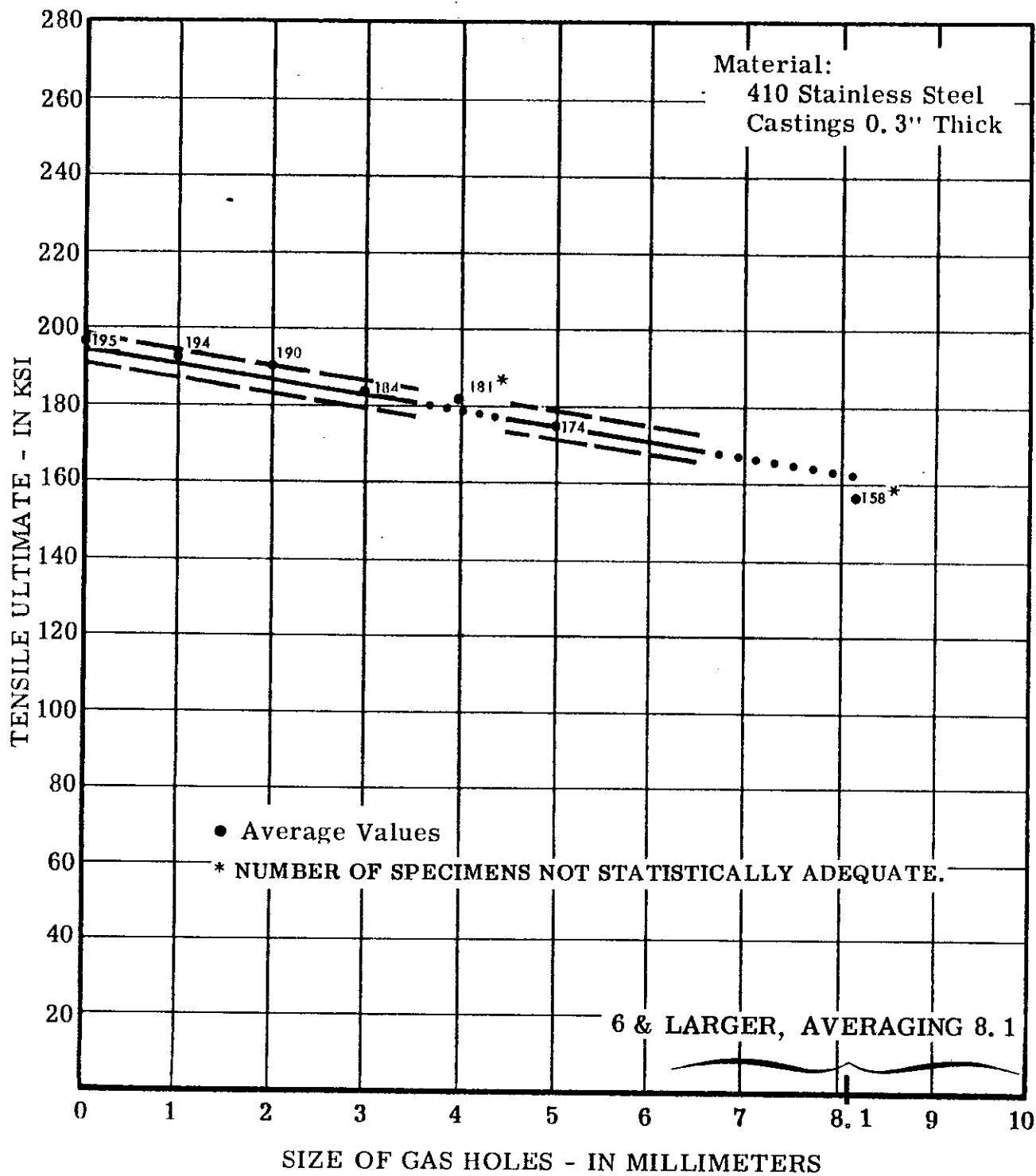


Figure 71. Tensile Ultimate vs Gas Holes - Correlation

5.27 SUMMARY OF RESULTS - ELONGATION VS. GAS HOLES - 0.3"-THICK MATERIAL

Control Specimens	Size of Gas Holes (diameter in millimeters)						
	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>		
Number of specimens tested -	67	9**	16**	11**	10**	7**	16**

Statistically determined number required for 0.95 confidence that the average of the results approaches the true average -

Confidence level, if less than 0.95 -

The following results and statistical parameters are in % in 2"

Elongation (average of test results) -	7.7	5.4	6.5	3.9	3.3	2.9	2.5
Estimate of the standard deviation -	3.2	2.7	3.3	2.2	2.7	1.2	1.3
<u>Limits for individuals:</u>							
Lower limit (0.95 probability) -	1.3	0	0	0	0	0.5	0
Upper limit (0.95 probability) -	14.1	10.8	13.1	8.3	8.7	5.3	5.1

CORRELATION ANALYSIS

Analysis was not made; number of samples from which averages were computed was not statistically adequate.

-
- * Specimens having 6-mm-and-larger gas holes, averaging 8.1 mm.
 - ** Number of specimens not adequate.
 - *** Value too low for confidence level to have a practical meaning.

Contrails

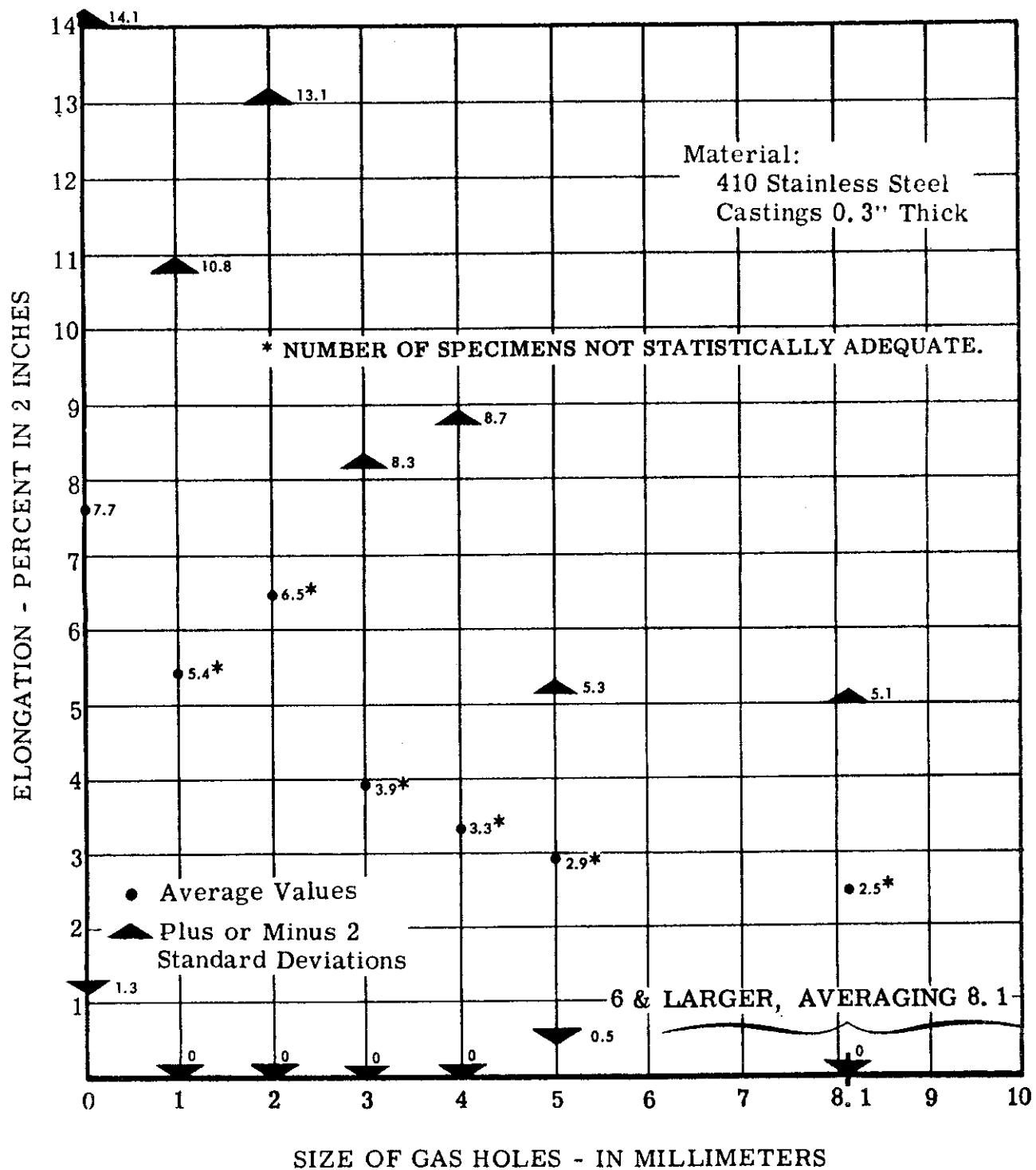


Figure 72. Elongation vs Gas Holes - Range of Values

Controls

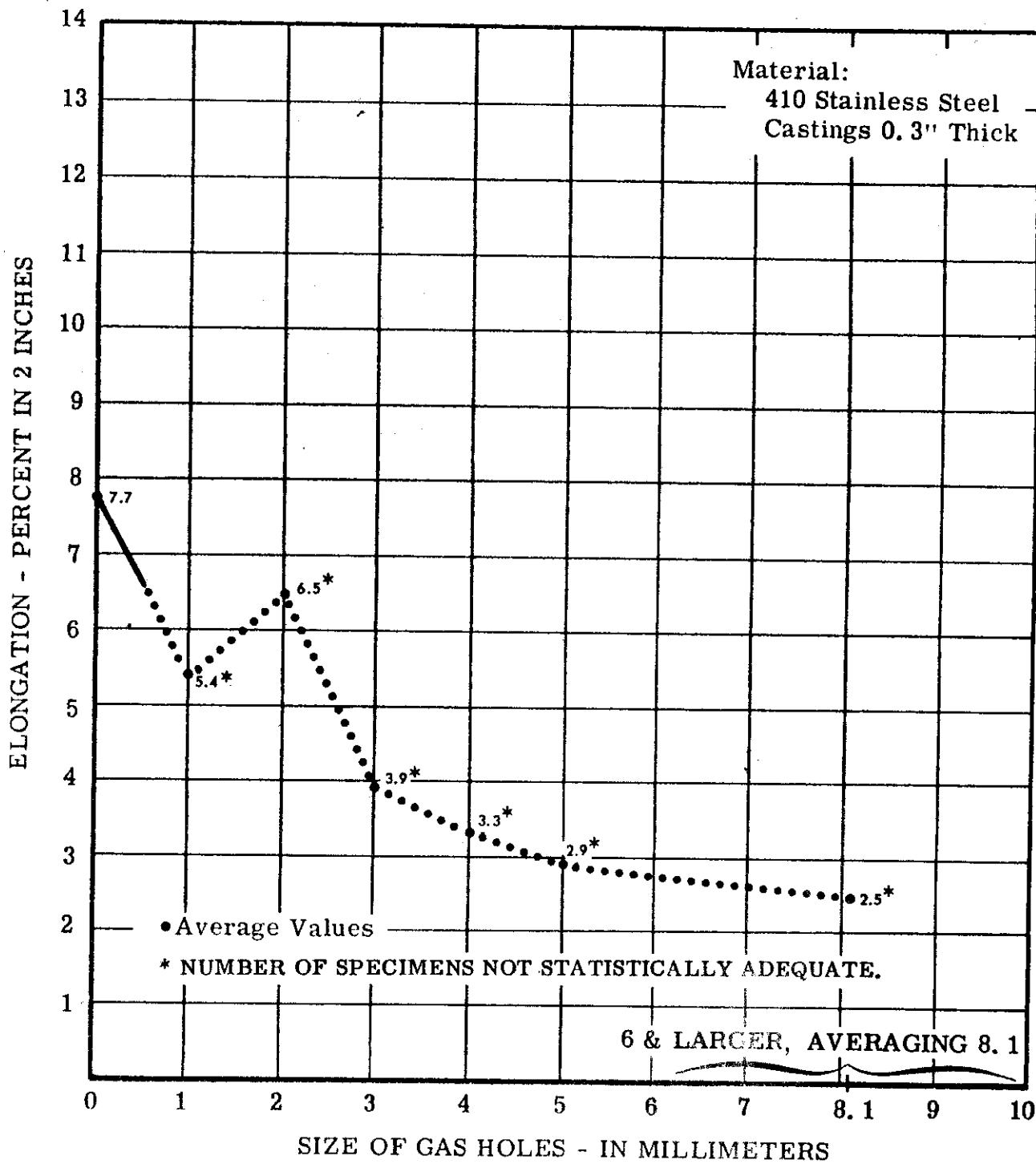


Figure 73. Elongation vs Gas Holes - Correlation

5.28 SUMMARY OF RESULTS - MODULUS OF ELASTICITY VS. GAS HOLES - 0.3"-THICK MATERIAL

WADD TR 60-450

	Control Specimens	Size of Gas Holes (diameter in millimeters)				
		<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>
Number of specimens tested -	67	9**	16	11	10	7
						16

Statistically determined number required for 0.95 confidence that the average of the results approaches the true average -

Confidence level, if less than 0.95 -

The following results and statistical parameters are in 10^6 psi

Modulus of Elasticity (Average of results) - 28.6
 Estimate of the standard deviation - 2.0

Limits for individuals:

Lower limit (0.95 probability) - 24.6
 Upper limit (0.95 probability) - 32.6

CORRELATION ANALYSIS

Analysis was not made; no trend toward lower values, as size of gas holes increased, was present.

* Specimens having 6-mm-and-larger gas holes, averaging 8.1 mm.

** Number of specimens not adequate; see number required on line below.

*** Value too low for confidence level to have a practical meaning.

Contrails

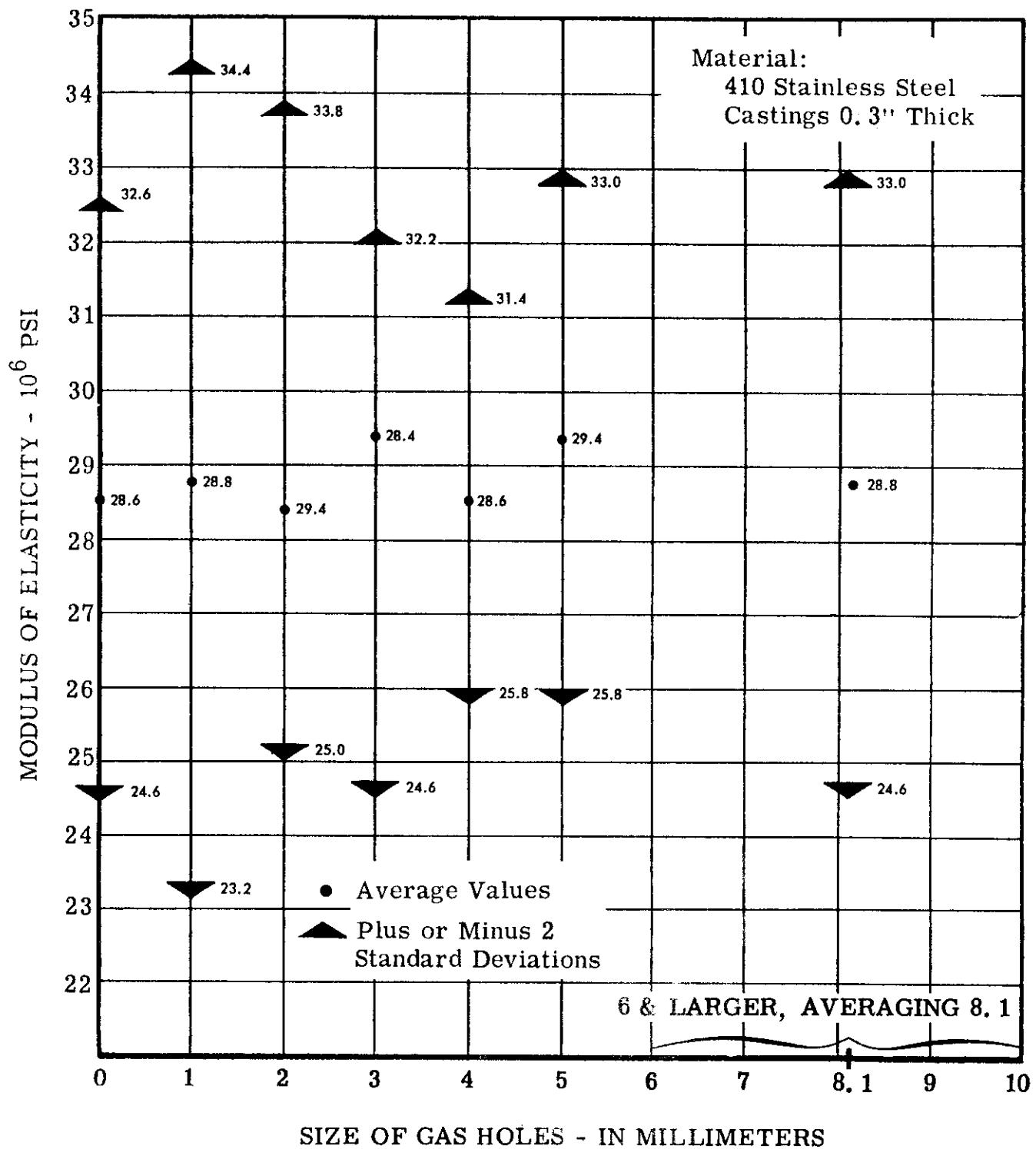


Figure 74. Modulus of Elasticity vs Gas Holes - Range of Values

WADD TR 60-450

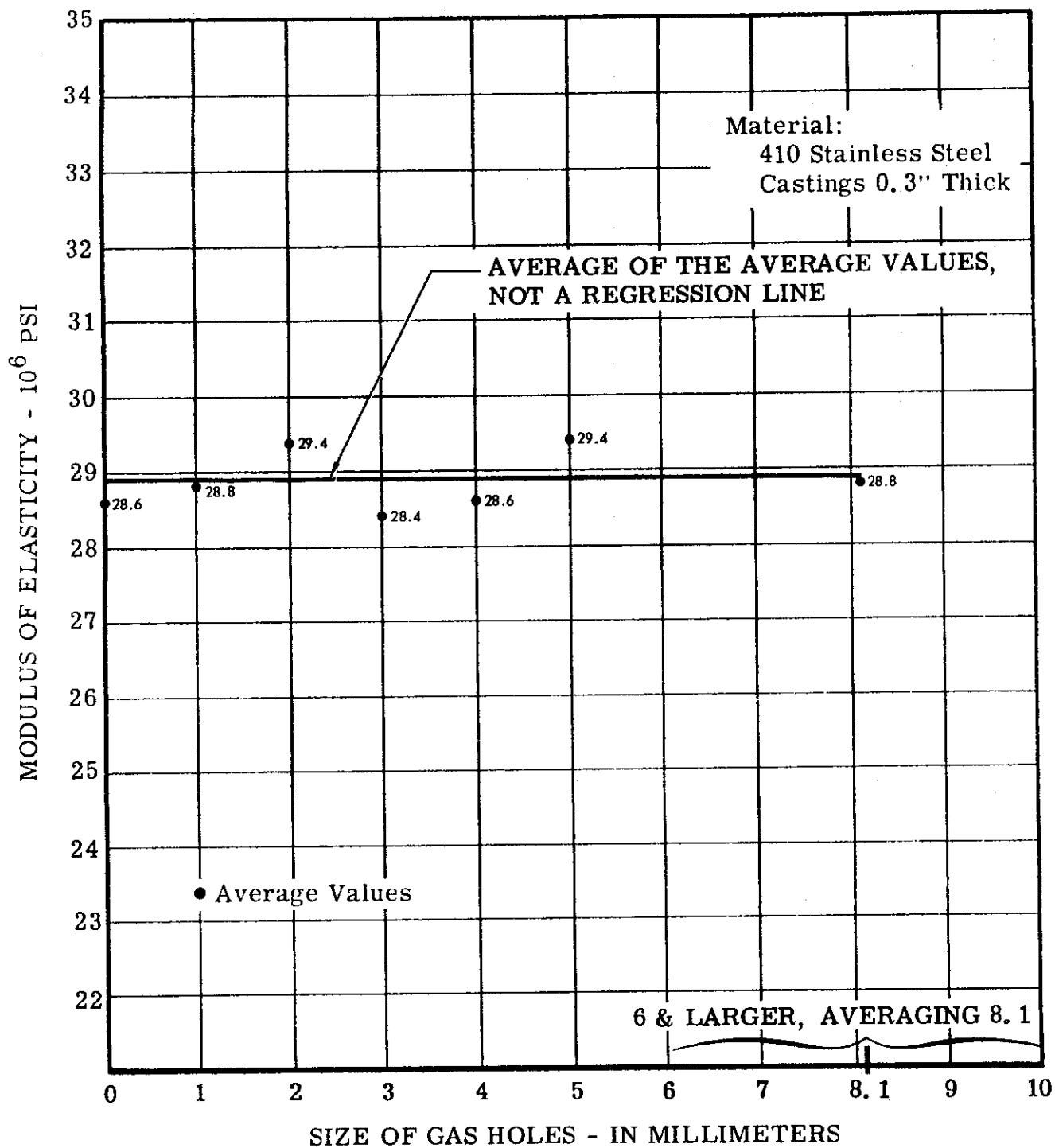


Figure 75. Modulus of Elasticity vs Gas Holes - Correlation

5.29 SUMMARY OF RESULTS - TENSILE YIELD VS. INCLUSIONS - 0.3"-THICK MATERIAL

Number of specimens tested -	Control Specimens	Size of Inclusions (diameter in millimeters)						<i>Controls</i>
		<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	
67	6	25	25	17	16	12	5	6**
3	2	3	2	2	3	3	5	36
-	-	-	-	-	-	-	-	***

Statistically determined number required
for 0.95 confidence that the average of
the results approaches the true average -

Confidence level, if less than 0.95 -

The following results and statistical
parameters are in ksi

Tensile yield (average of test results) -
Estimate of the standard deviation

Limits for individuals:

Lower limit (0.95 probability) -
Upper limit (0.95 probability) -

CORRELATION ANALYSIS

Analysis was not made; no trend toward lower values, as size of inclusions increased, was present.

* Specimens having 8-mm-and-larger inclusions, averaging 10mm.

** Number of specimens not adequate; see numbers required on line below.

*** Value too low for confidence level to have a practical meaning.

Contrails

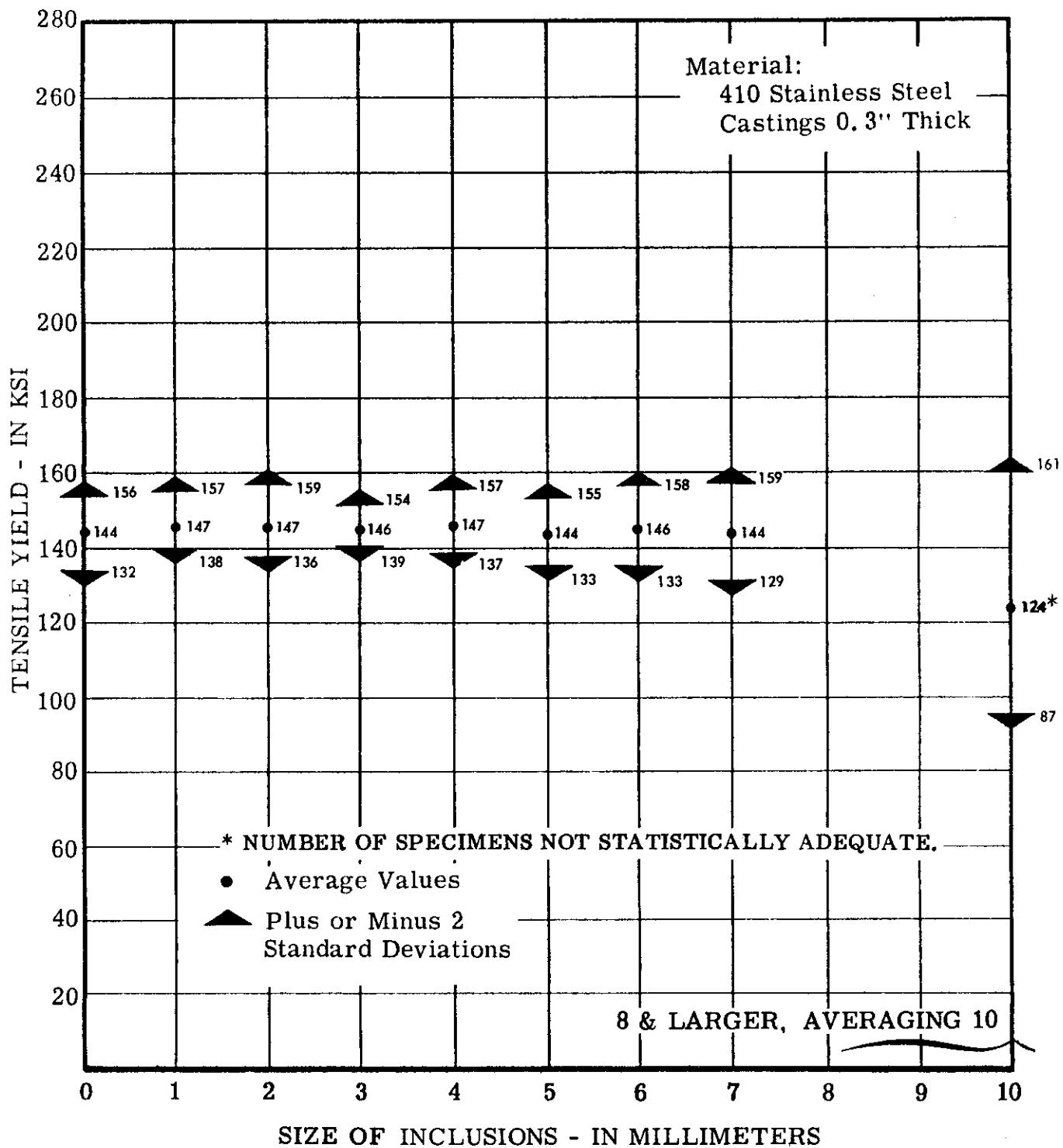


Figure 76. Tensile Yield vs Inclusions - Range of Values

WADD TR 60-450

Contrails

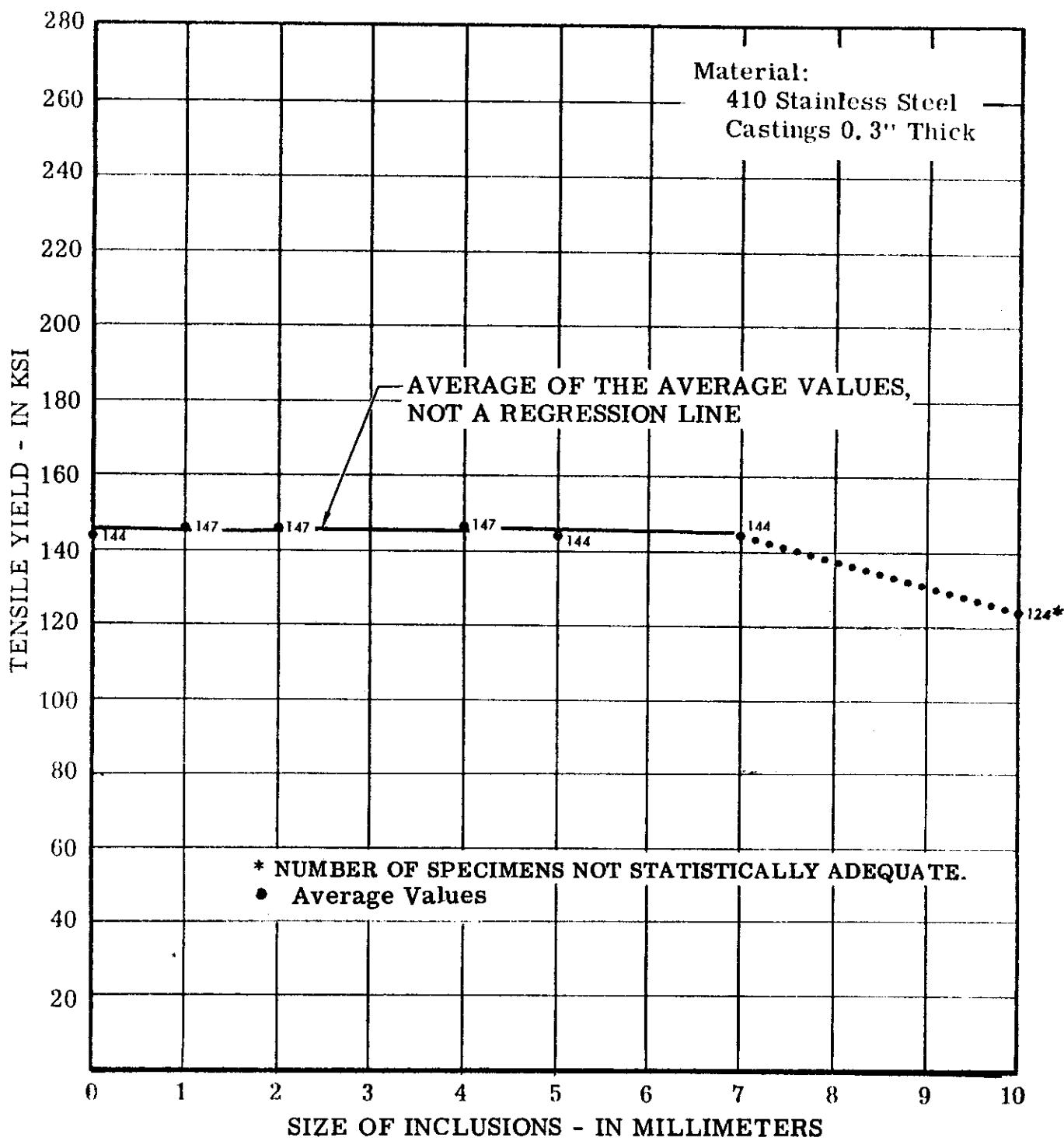


Figure 77. Tensile Yield vs Inclusions -Correlation

WADD TR 60-450

5.30 SUMMARY OF RESULTS - TENSILE ULTIMATE VS. INCLUSIONS - 0.3"-THICK MATERIAL

	Size of Inclusions (diameter in millimeters)						<u>9.5*</u>
<u>Control Specimens</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>
Number of specimens tested -	67	6	25	27	17	16	13**

Statistically determined number required for 0.95 confidence that the average of the results approaches the true average -

Confidence level, if less than 0.95 -

The following results and statistical parameters are in ksi

Tensile ultimate (average of test results) -
 Estimate of the standard deviation -
 Hardness (average Rockwell C) -
 Tensile ultimate (adjusted to hardness)***

Limits for individuals:

Lower limit (0.95 probability) -	180	181	175	165	170	186	136	95	56
Upper limit (0.95 probability) -	210	215	220	220	202	205	219	214	212

CORRELATION ANALYSIS

Correlation coefficient - 0.87, minus sign indicates an inverse relationship. "Standard error of estimate" = 11.5 ksi.

- * Specimens having 8-mm-and-larger inclusions, averaging 9.5 mm.
- ** Number of specimens not adequate, see number required on line below.
- *** Value too low for confidence level to have a practical meaning.
- **** See paragraph 6.1.1

Contrails

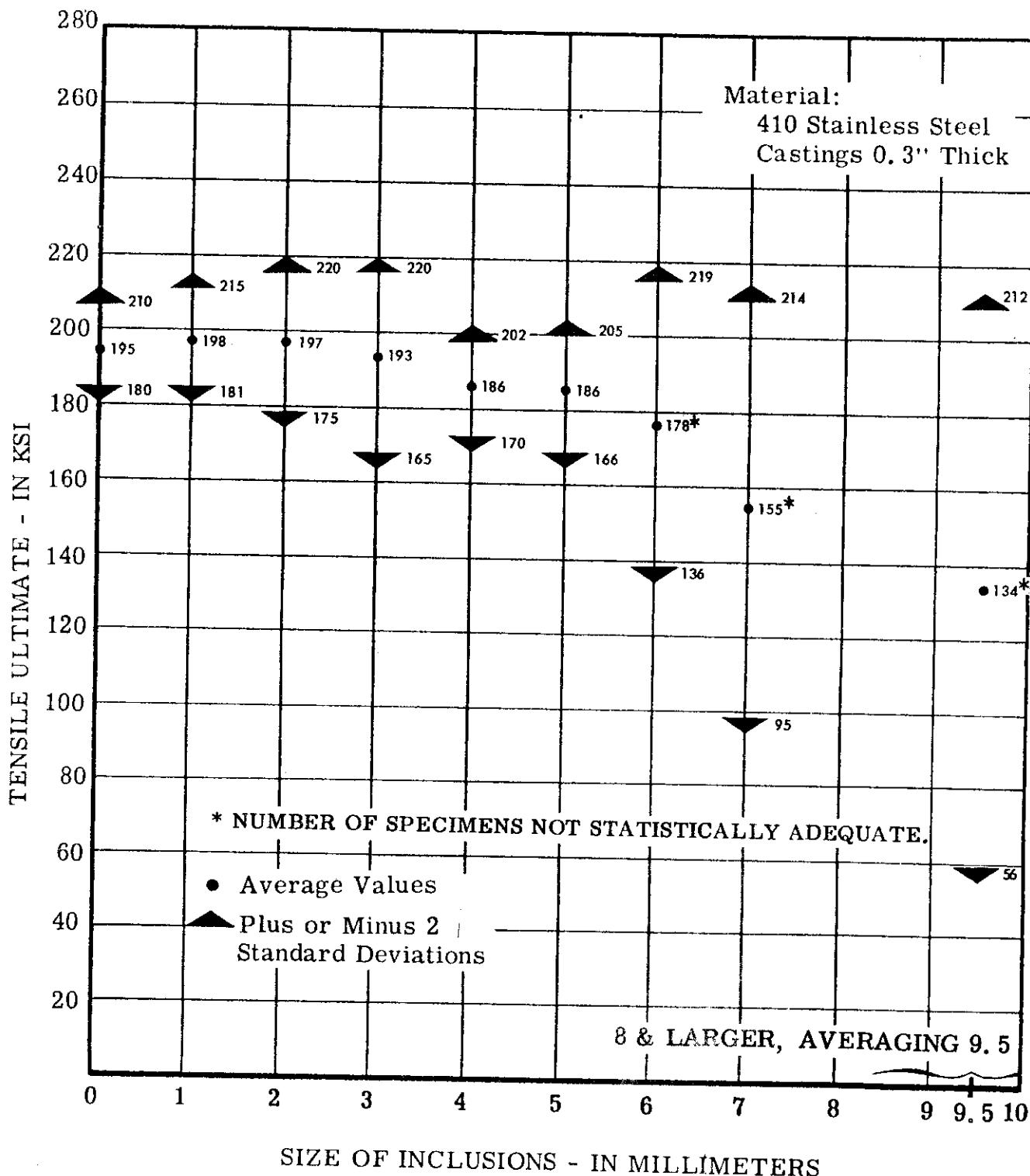


Figure 78. Tensile Ultimate vs Inclusions - Range of Values

Contrails

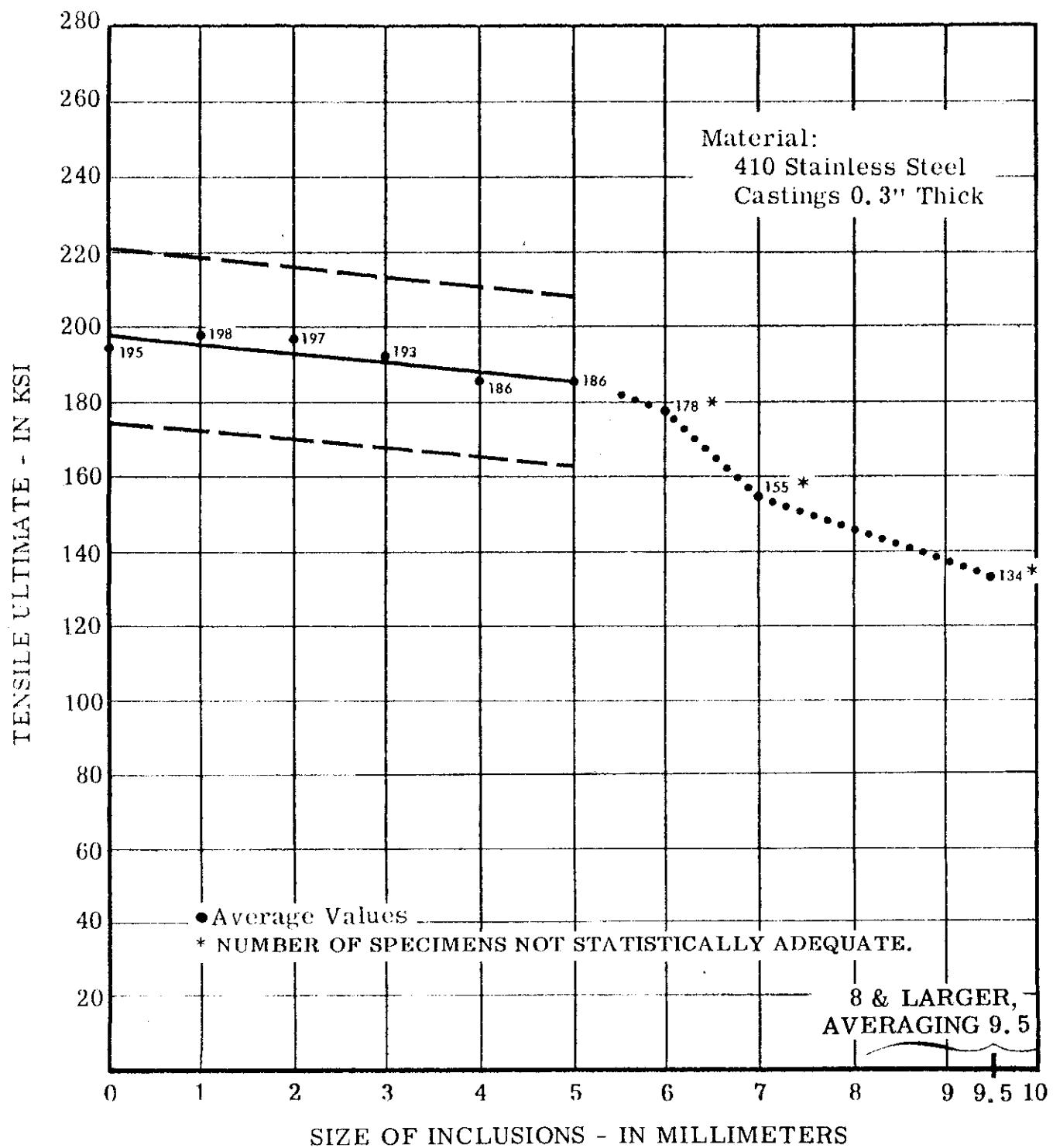


Figure 79. Tensile Ultimate vs Inclusions - Correlation

5.31 SUMMARY OF RESULTS - ELONGATION VS. INCLUSIONS - 0.3"-THICK MATERIAL

	Control Specimens	Size of Inclusions (diameter in millimeters)						
		1	2	3	4	5	6	7
Number of specimens tested -	67	6**	29**	27**	16**	16**	12**	7**
Statistically determined number required for 0.95 confidence that the average of the results approaches the true average -	31	22	61	56	32	35	16	22
Confidence level, if less than 0.95 -	-	***	***	***	***	***	***	***
The following results and statistical parameters are in % in 2"								
Elongation (average of test results) -	7.7	4.8	6.2	5.2	3.5	3.4	3.5	2.4
Estimate of the standard deviation -	3.2	1.7	3.6	2.9	2.0	1.5	1.0	0.8
Limits for individuals:								
Lower limit (0.95 probability) -	1.3	1.4	2.6	2.3	2.0	1.9	1.5	0.7
Upper limit (0.95 probability) -	14.1	8.2	9.9	8.2	4.9	4.9	5.5	4.1

Lower limit (0.95 probability) -	1.3	1.4	2.6	2.3	2.0	1.9	1.5	0.7	0.7
Upper limit (0.95 probability) -	14.1	8.2	9.9	8.2	4.9	4.9	5.5	4.1	3.2

CORRELATION ANALYSIS

Analysis was not made; number of samples from which averages were computed was not statistically adequate.

-
- * Specimens having 8-mm-and-larger inclusions, averaging 9.5 mm.
 - ** Number of specimens not adequate; see number required on line below.
 - *** Value too low for confidence level to have a practical meaning.

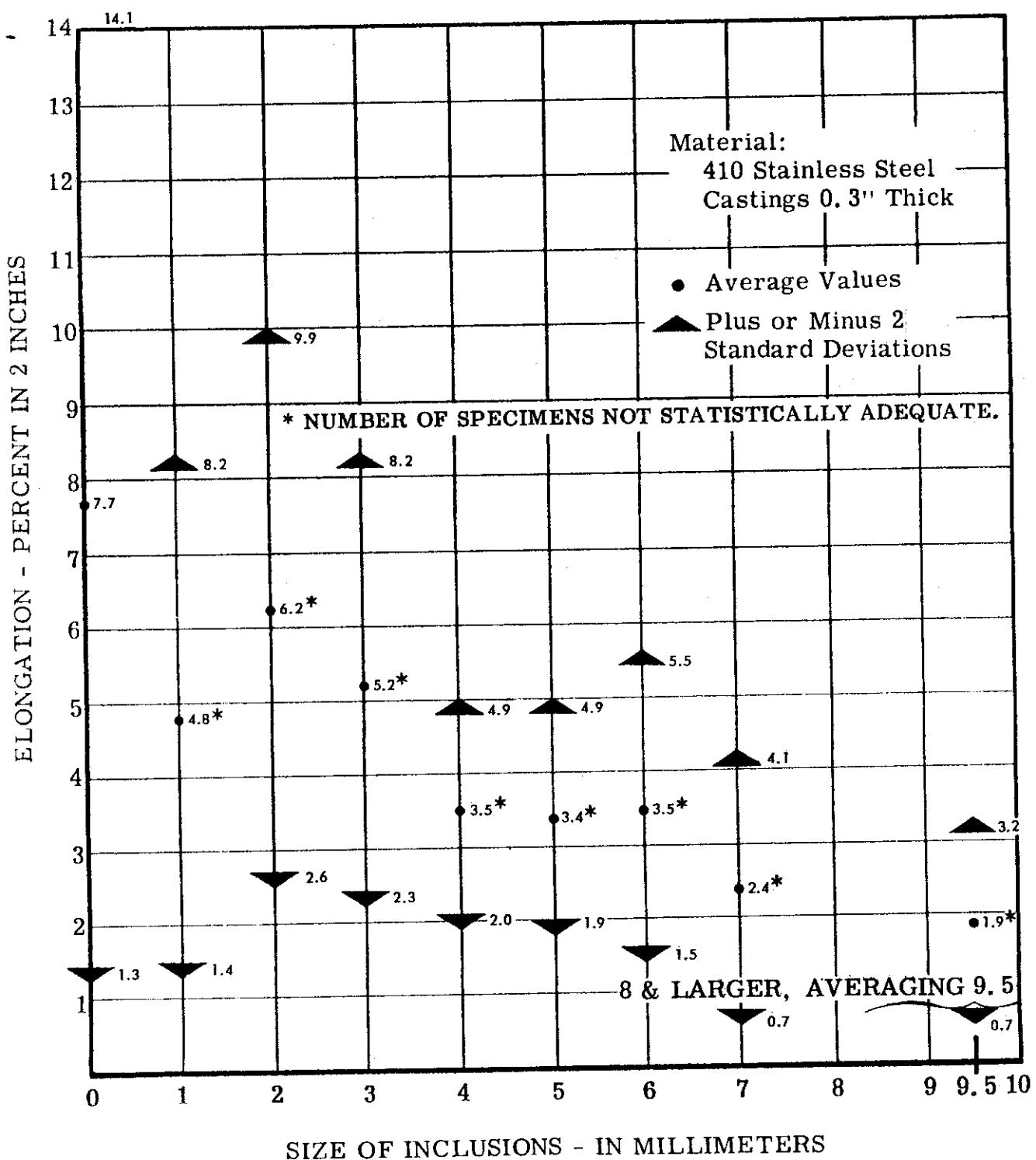


Figure 80. Elongation vs Inclusions - Range of Values

Contrails

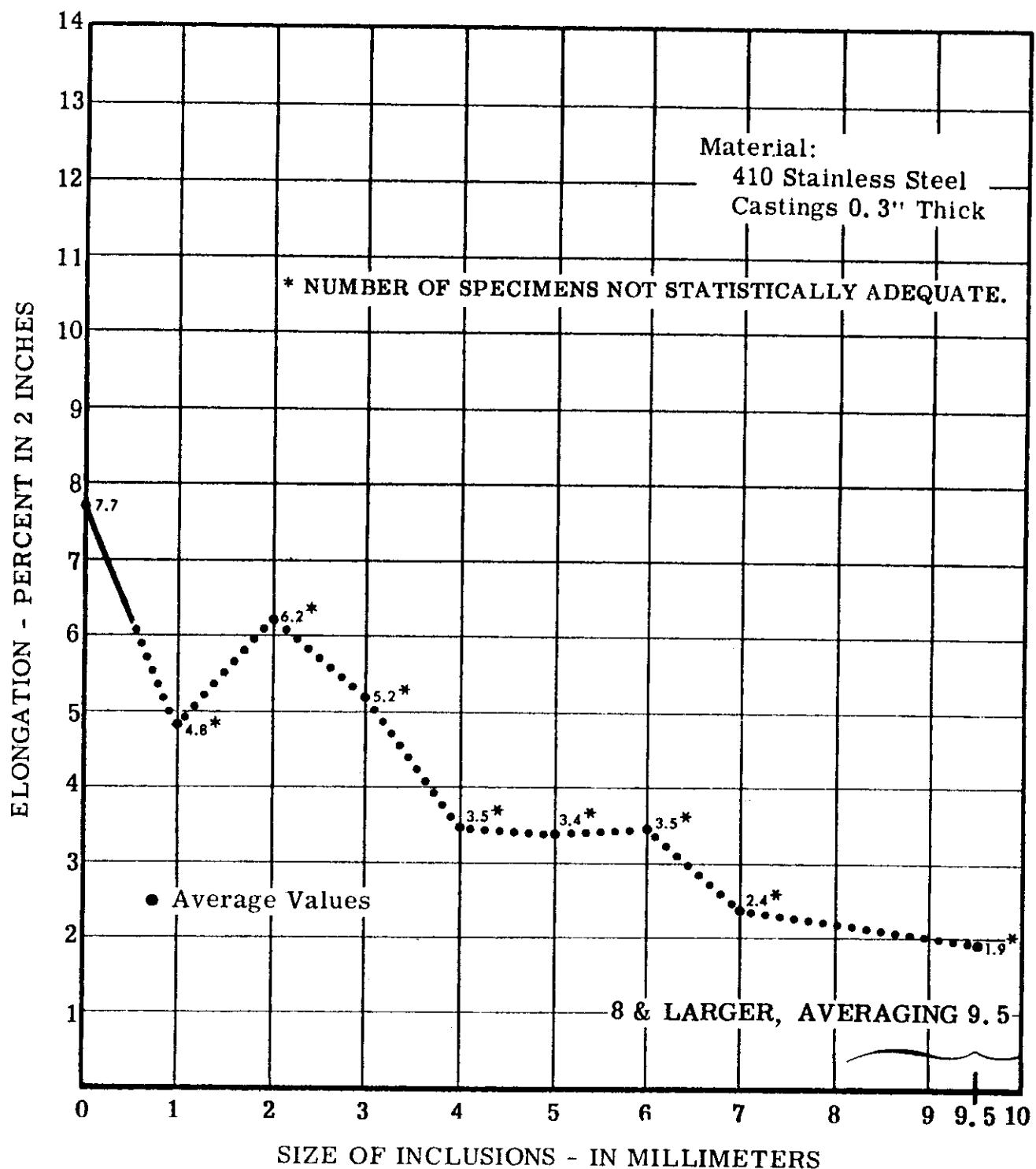


Figure 81. Elongation vs Inclusions - Correlation

WADD TR 60-450

5. ?' SUMMARY OF RESULTS - MODULUS OF ELASTICITY VS. INCLUSIONS - 0.3"-THICK MATERIAL

Number of specimens tested -	Control Specimens	Size of Inclusions (diameter in millimeters)							<u>9.5*</u>
		<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	
67		6	25	25	17	16	13	8	8

Statistically determined number required for 0.95 confidence that the average of the results approaches the true average -

Confidence level, if less than 0.95 -

The following results and statistical parameters are in 10^6 psi

Modulus (average of test results) -	28.6	28.3	28.6	29.3	28.9	29.4	29.6	28.7	28.3
Estimate of the standard deviation -	2.0	1.4	1.9	1.4	1.1	1.5	1.5	0.8	1.5
<u>Limits for individuals:</u>									
Lower limit (0.95 probability) -	24.6	25.5	24.8	26.5	26.7	26.4	26.1	27.1	26.4
Upper limit (0.95 probability) -	32.6	31.1	32.4	32.1	31.1	32.4	33.1	30.3	30.2

CORRELATION ANALYSIS

Analysis was not made; no trend toward lower values, as size of inclusions increased, was present.

* Specimens having 8-mm-and-larger inclusions, averaging 9.5 mm.

** Number of specimens not adequate.

*** Value too low for confidence level to have a practical meaning.

Contrails

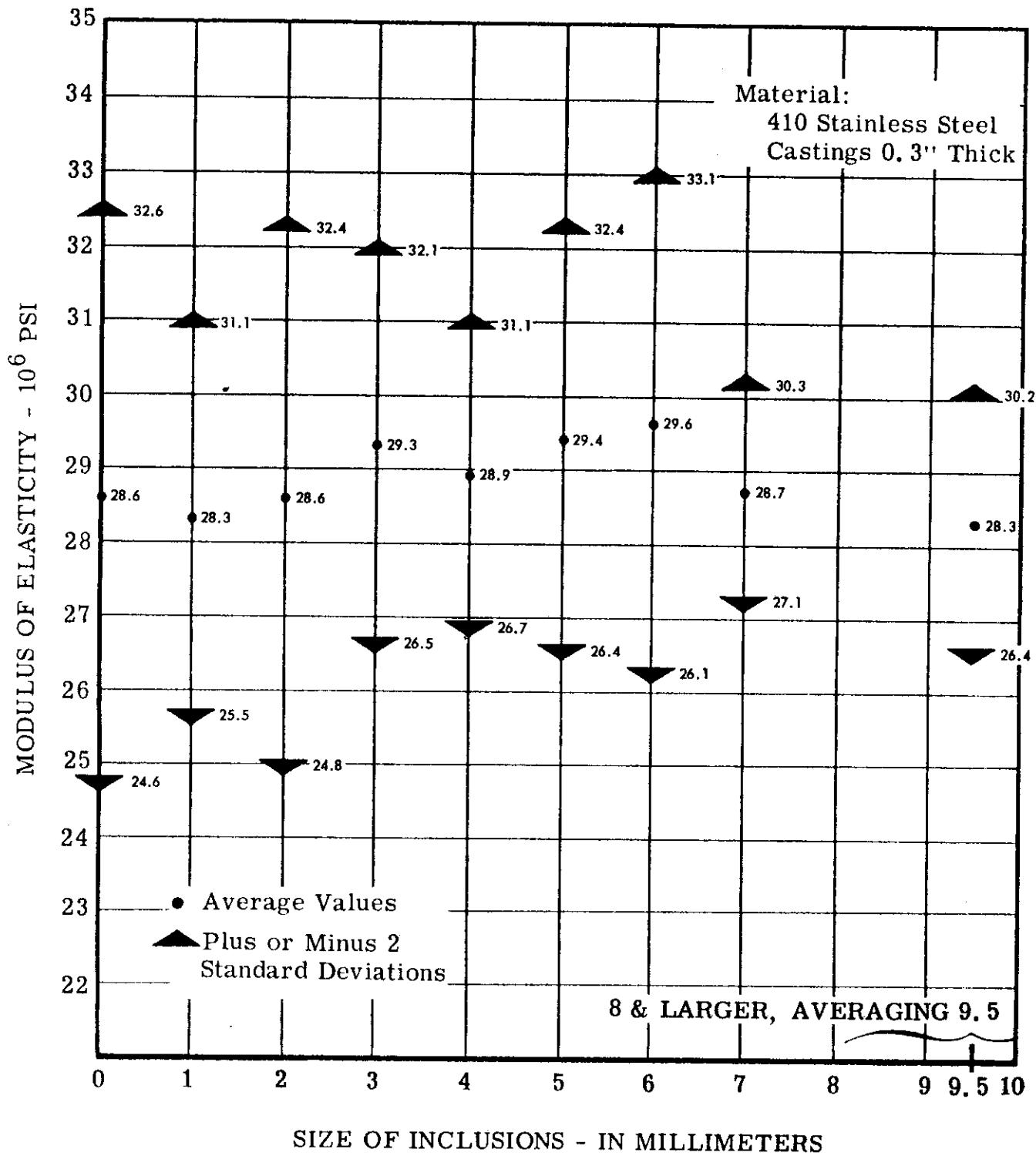


Figure 82. Modulus of Elasticity vs Inclusions - Range of Values

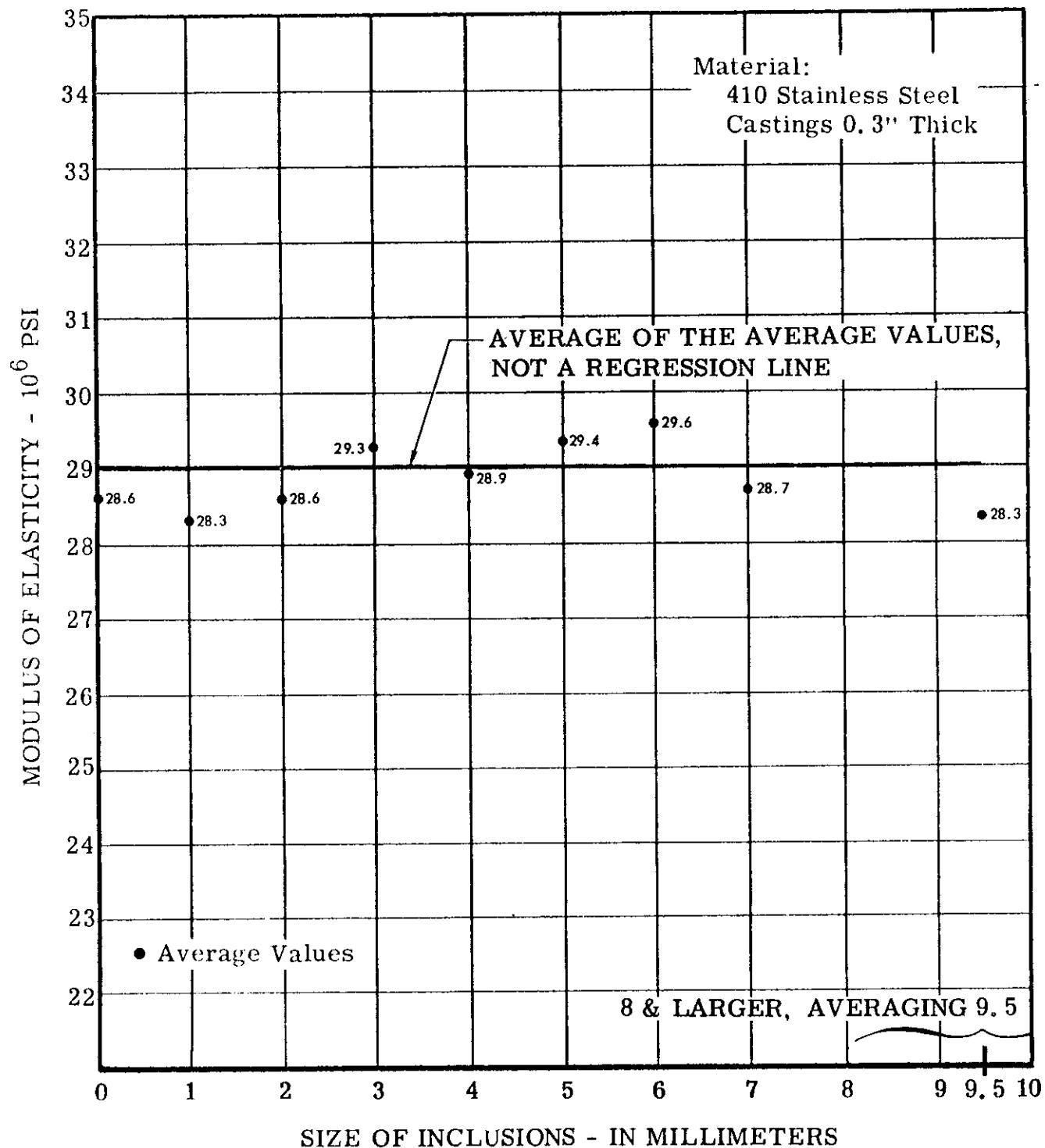


Figure 83. Modulus of Elasticity vs Inclusions - Correlation

5.33 SUMMARY OF RESULTS - TENSILE YIELD VS. POROSITY - 0.3"-THICK MATERIAL

Number of specimens tested -	Control Specimens	Numbers, Indicating Intensity of Porosity				
	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>5.2*</u>
	67	84	22	14	6	6

Statistically determined number required for 0.95 confidence that the average of the results approaches the true average -

Confidence level, if less than 0.95 -

The following results and statistical parameters are in ksi

Tensile yield (average of test results) -	144	144	145	145	142	
Estimate of the standard deviation -	6.0	6.1	7.2	3.9	7.9	5.9

Limits for individuals:

Lower limit (0.95 probability) -	132	132	130	138	129	130
Upper limit (0.95 probability) -	156	156	159	153	161	154

CORRELATION ANALYSIS

Analysis was not made; no trend toward lower values, as intensity of porosity increased, was present.

* Specimens having number -5-and-higher porosity intensity, averaging number 5.2 intensity.

Controls

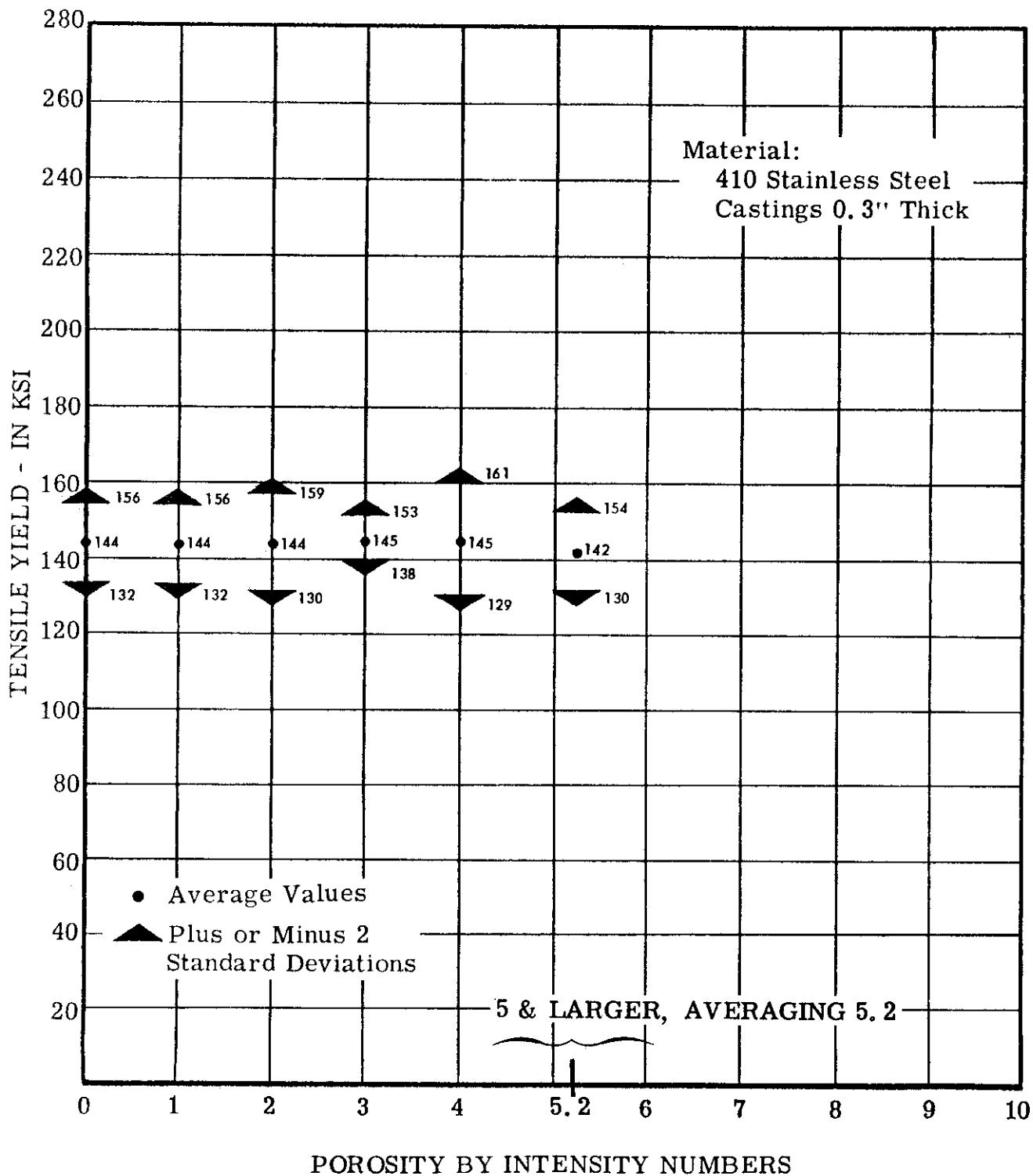


Figure 84. Tensile Yield vs Porosity - Range of Values

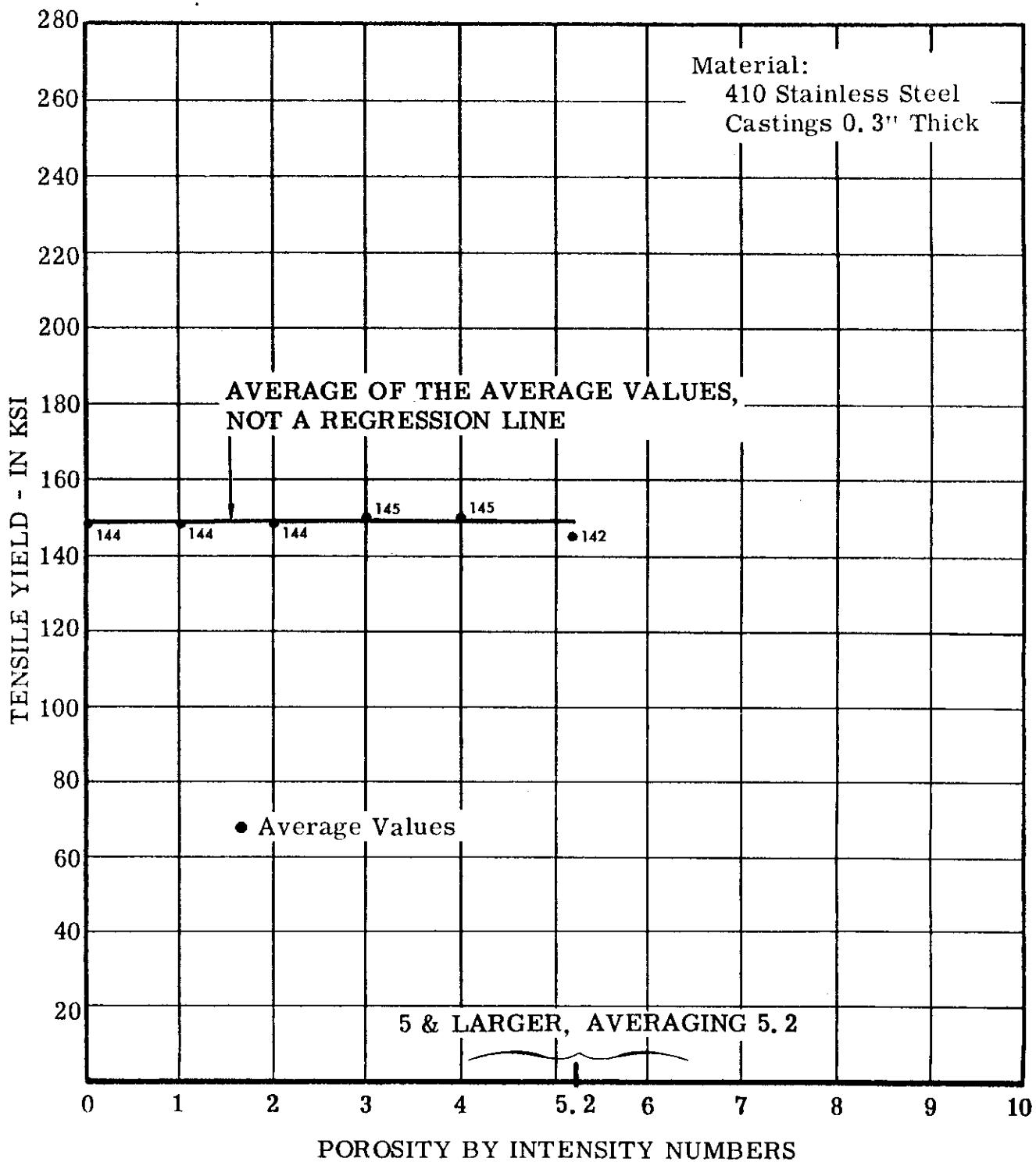


Figure 85. Tensile Yield vs Porosity - Correlation

5.34 SUMMARY OF RESULTS - TENSILE ULTIMATE VS. POROSITY - 0.3"-THICK MATERIAL

<u>Number of specimens tested</u>	<u>Control Specimens</u>	<u>Numbers, Indicating Intensity of Porosity</u>
67	84	23 15 7** 6***
		5 7 8 33 9

Statistically determined number required for 0.95 confidence that the average of the results approaches the true average -

Confidence level, if less than 0.95 -

The following results and statistical parameters are in ksi

Tensile ultimate (average of test results) -	191	184	172	172	164	172
Estimate of the standard deviation -	7.6	9.5	10.8	11.6	23.4	12.5
Hardness (average Rockwell C) -	41.1	40.8	40.7	40.8	39.7	39.9
Tensile ultimate (adjusted to hardness) -	195	190	179	178	176	183

Limits for individuals:

Lower limit (0.95 probability) -	180	171	158	155	129	158
Upper limit (0.95 probability) -	210	209	201	201	223	208

CORRELATION ANALYSIS

Correlation coefficient = - 0.96, minus sign indicates an inverse relationship. "Standard error of estimate" = 10.5 ksi.

* Specimens having number -5-and higher porosity intensity, averaging number 5.2 intensity.

** Number of specimens not adequate; see number required on line below.

*** Value too low for confidence level to have a practical meaning.

**** See paragraph 6.1.1

Contrails

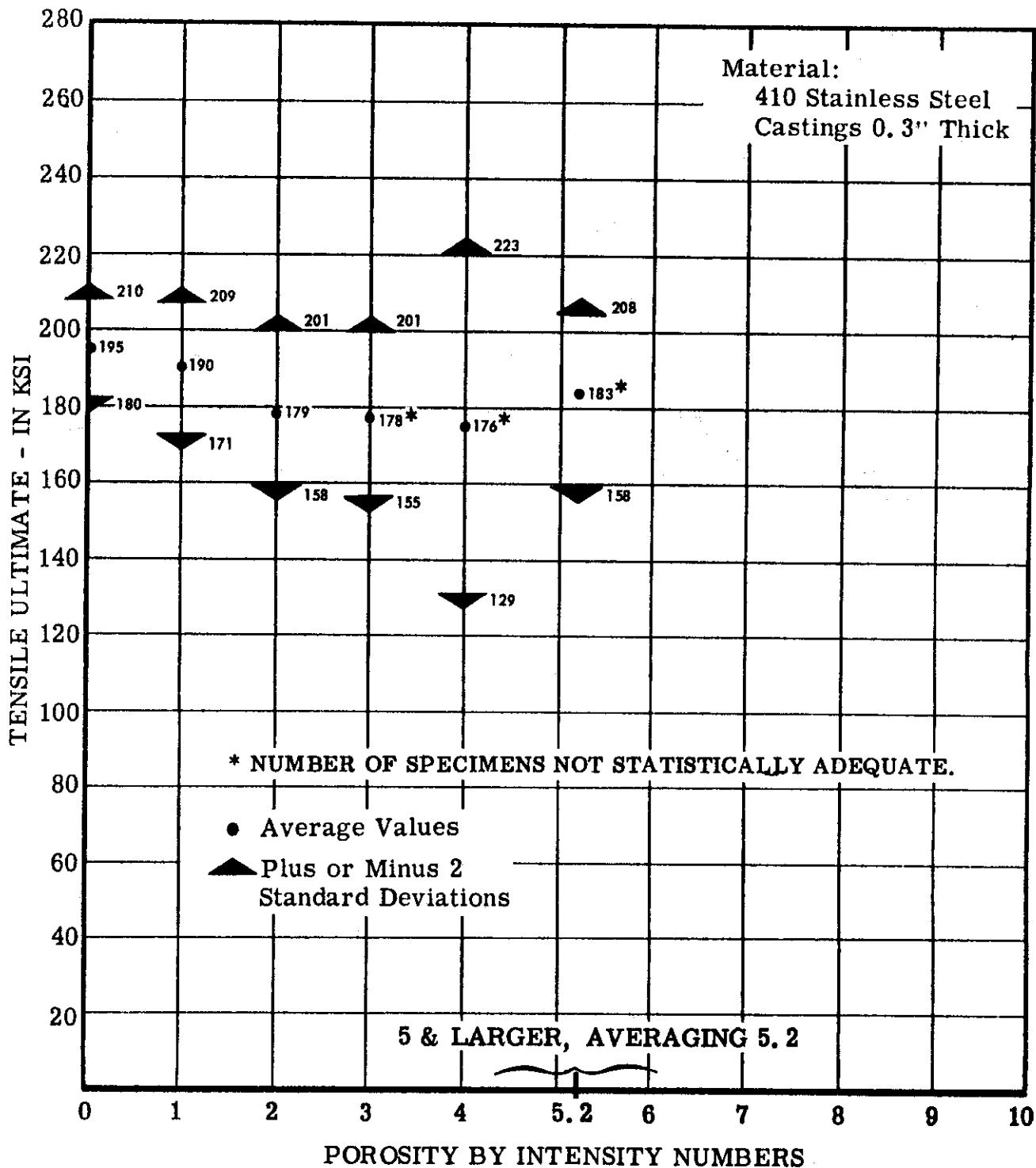


Figure 86. Tensile Ultimate vs Porosity - Range of Values

WADD TR 60-450

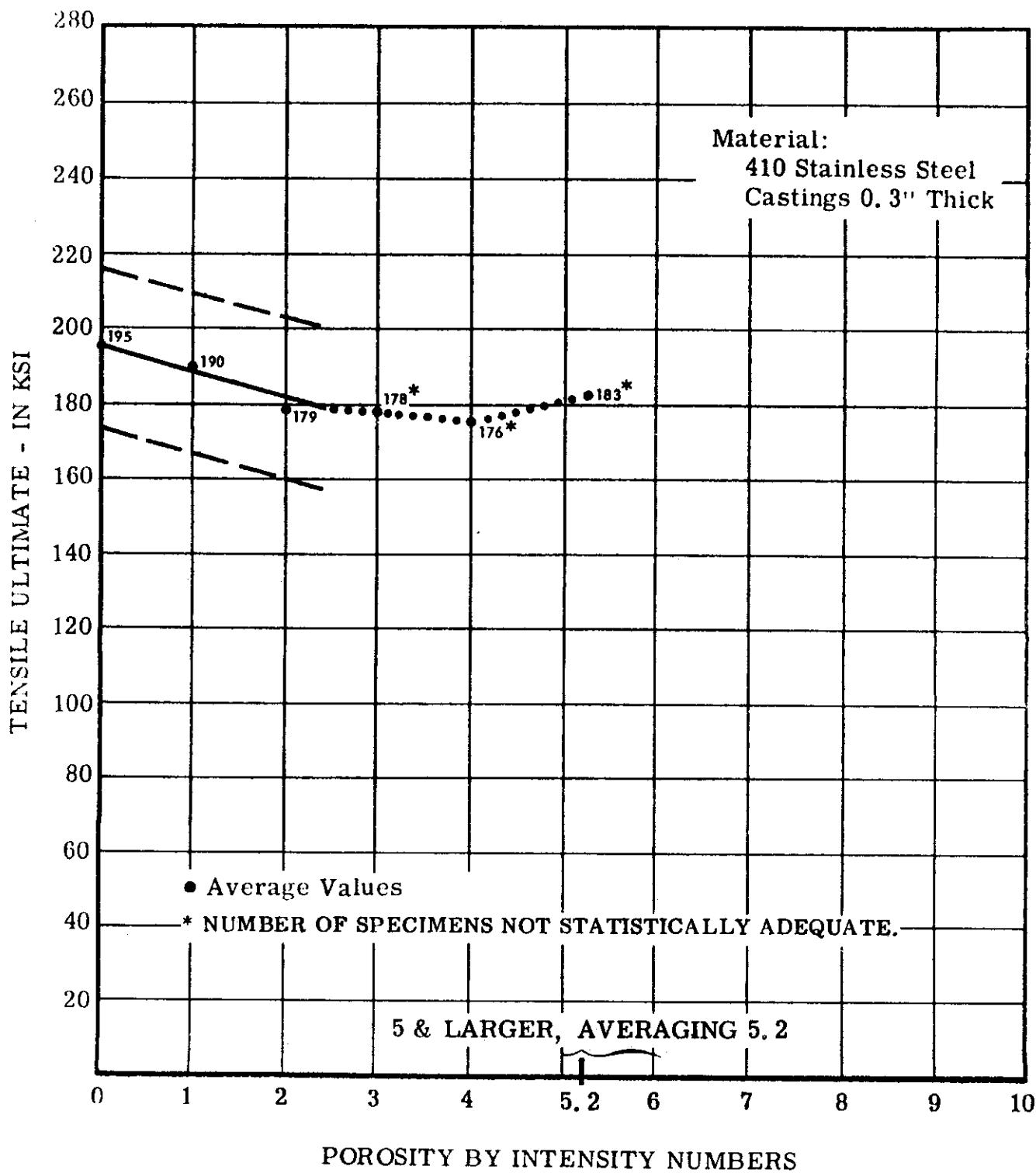


Figure 87. Tensile Ultimate vs Porosity - Correlation

WADD TR 60-450

5.35 SUMMARY OF RESULTS - ELONGATION VS. POROSITY - 0.3"-THICK MATERIAL

Control Specimens	Numbers, Indicating Intensity of Porosity
	<u>1</u> <u>2</u> <u>3</u> <u>4</u> <u>5.2*</u>
Number of specimens tested -	67

Number of specimens tested -

Statistically determined number required
for 0.95 confidence that the average of
the results approaches the true average -

Confidence level, if less than 0.95 -

The following results and statistical
parameters are in % in 2"

Control Specimens	Numbers, Indicating Intensity of Porosity
	<u>1</u> <u>2</u> <u>3</u> <u>4</u> <u>5.2*</u>
Number of specimens tested -	67
Statistically determined number required for 0.95 confidence that the average of the results approaches the true average -	31
Confidence level, if less than 0.95 -	-
The following results and statistical parameters are in % in 2"	
Elongation (average of test results) -	7.7
Estimate of the standard deviation -	3.2
Limits for individuals:	
Lower limit (0.95 probability) -	1.3
Upper limit (0.95 probability) -	14.1

Lower limit (0.95 probability) -
Upper limit (0.95 probability) -

CORRELATION ANALYSES

Analysis was not made; number of samples from which averages were computed was not statistically adequate.

* Specimens having number -5-and-higher porosity intensity, averaging number 5.2 intensity.

** Number of specimens not adequate; see number required on line below.

*** Value too low for confidence level to have a practical meaning.

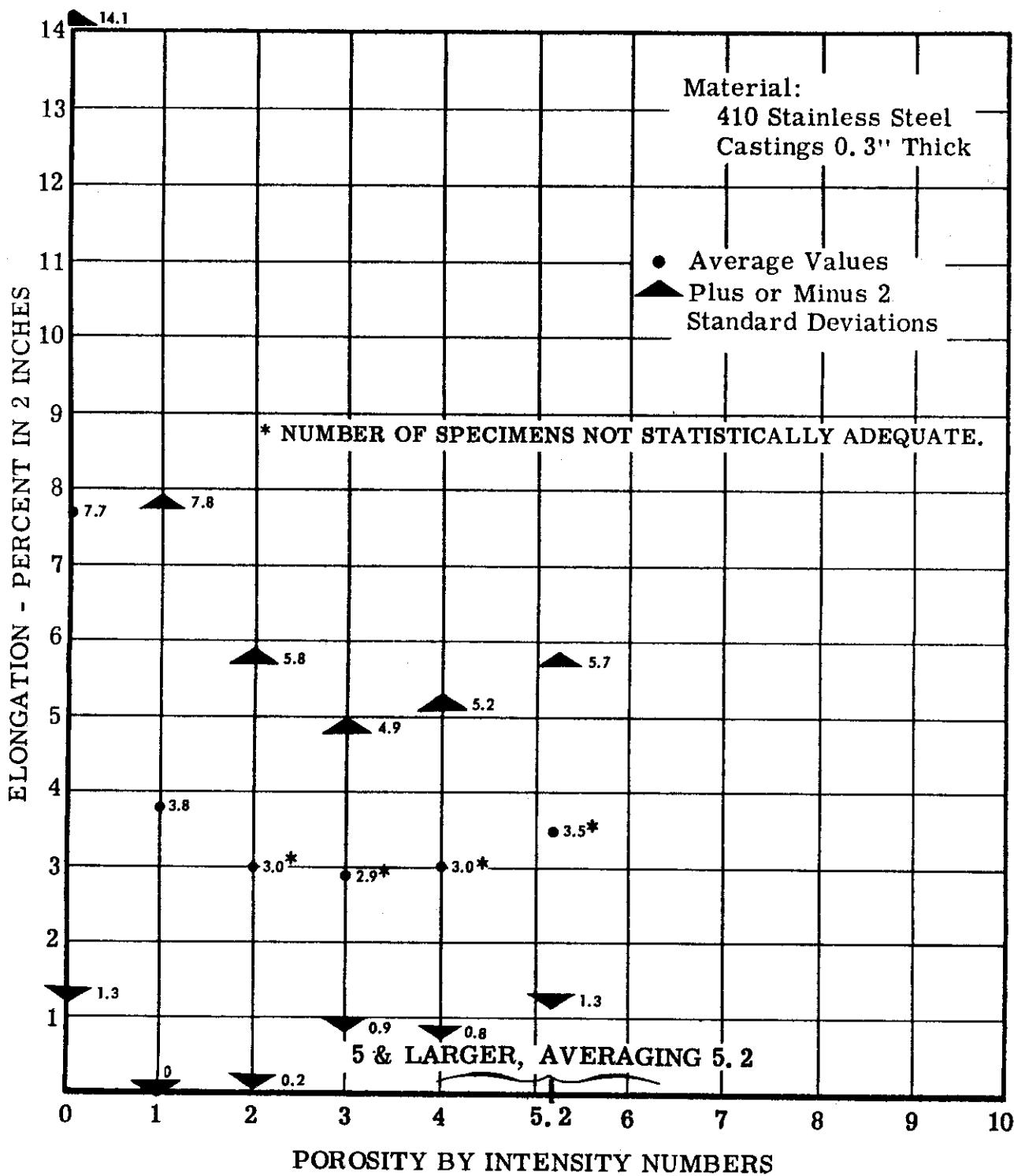


Figure 88. Elongation vs Porosity - Range of Values

WADD TR 60-450

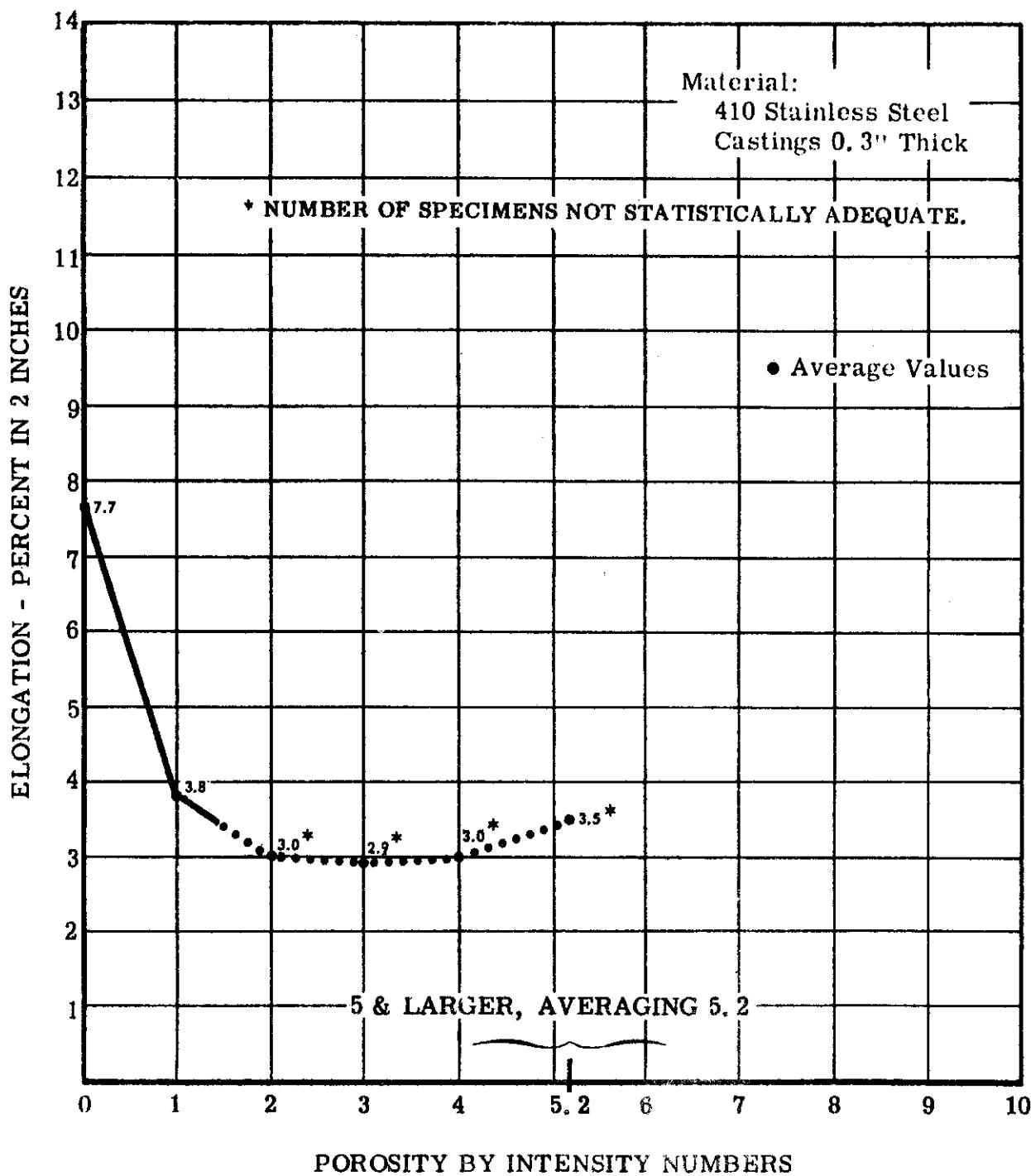


Figure 89. Elongation vs Porosity - Correlation

WADD TR 60-450

5.36 SUMMARY OF RESULTS - MODULUS OF ELASTICITY VS. POROSITY - 0.3"-THICK MATERIAL

<u>Control Specimens</u>	<u>Numbers, Indicating Intensity of Porosity</u>
<u>1</u>	<u>2</u>
<u>3</u>	<u>4</u>

Number of specimens tested -

Statistically determined number required
for 0.95 confidence that the average of
the results approaches the true average -

Confidence level, if less than 0.95 -

The following results and statistical
parameters are in 10⁶ psi

Modulus (average of test results) -
Estimate of the standard deviation -

Limits for individuals:

Lower limit (0.95 probability) -
Upper limit (0.95 probability) -

CORRELATION ANALYSIS

Analysis was not made; no trend toward lower values, as intensity of porosity increased, was present.

* Specimens having number -5-and-higher porosity intensity, averaging number 5.1 intensity.

Contrails

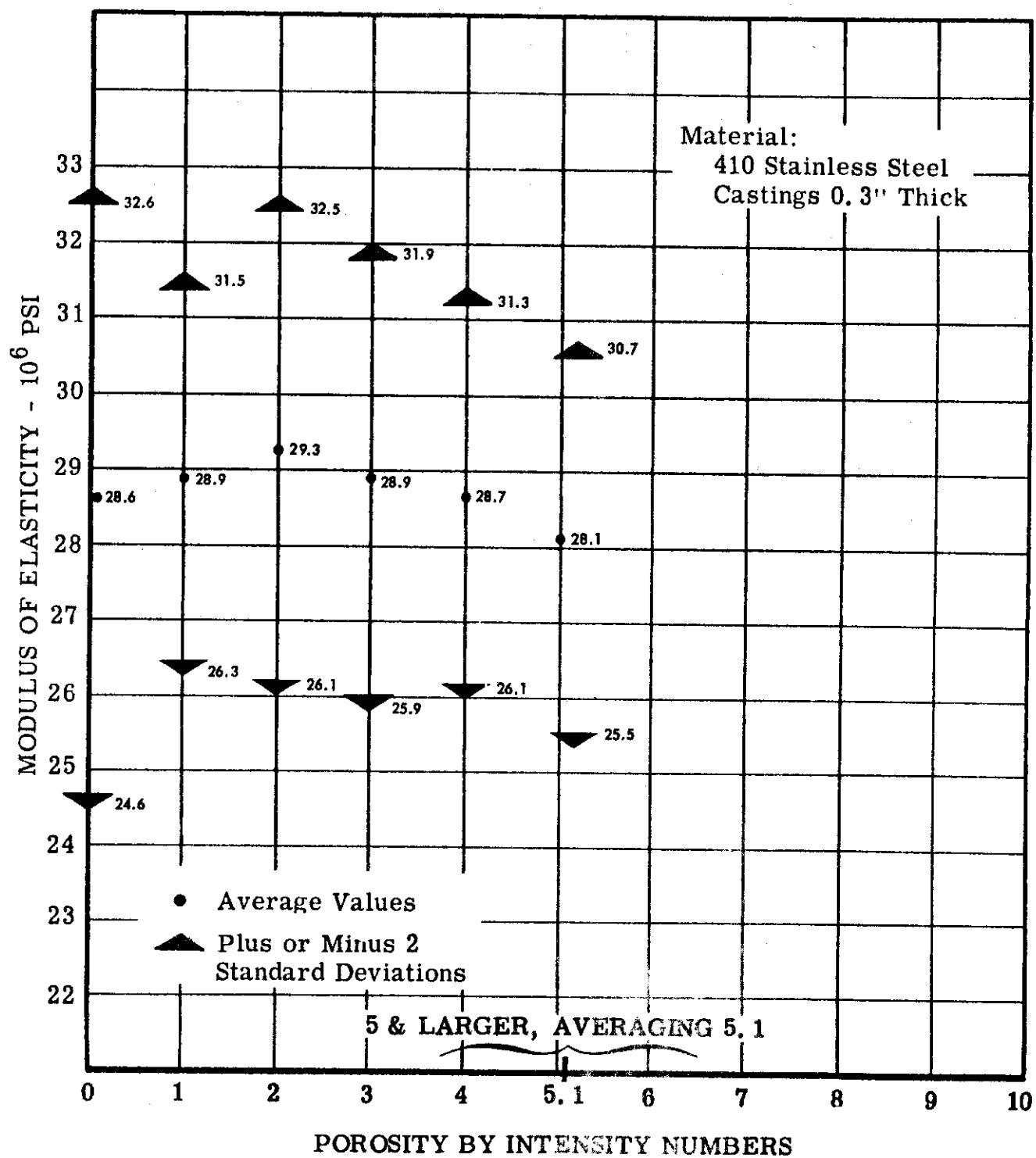


Figure 90. Modulus of Elasticity vs Porosity - Range of Values

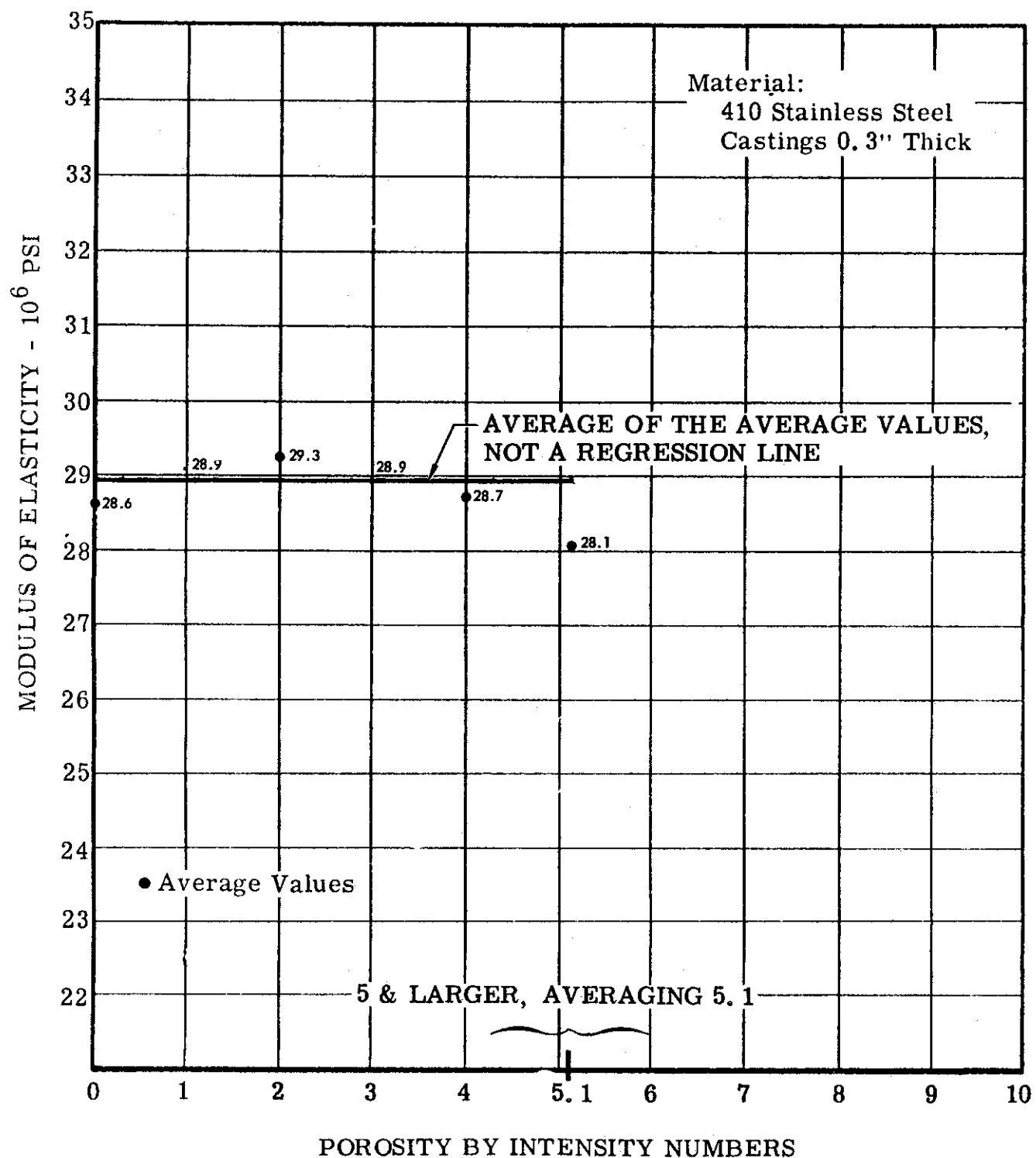


Figure 91. Modulus of Elasticity vs Porosity - Correlation

Contrails

5.37 SUMMARY OF RESULTS - TENSILE YIELD VS. GAS HOLES - 0.6"-THICK MATERIAL

WADD TR 60-450

	Control <u>Specimens</u>	Size of Gas Holes (diam. in millimeters)		
		2	3	5.9*

Number of specimens tested -

Statistically determined number required for 0.95 confidence that the average of the results approaches the true average -

Confidence level, if less than 0.95 -

The following results and statistical parameters are in ksi:

Tensile yield (Average of test results) -
Estimate of the standard deviation -

157

143	141	142	144
5.6	1.7	5.3	4.1

Limits for individuals:

Lower limit (0.95 probability) -	132	138	131	135
Upper limit (0.95 probability) -	154	145	152	152

CORRELATION ANALYSIS

Analysis was not made, no trend toward lower values, as size of gas holes increased, was present.

* Specimens having 4-mm-and-larger gas holes, averaging 5.9mm.

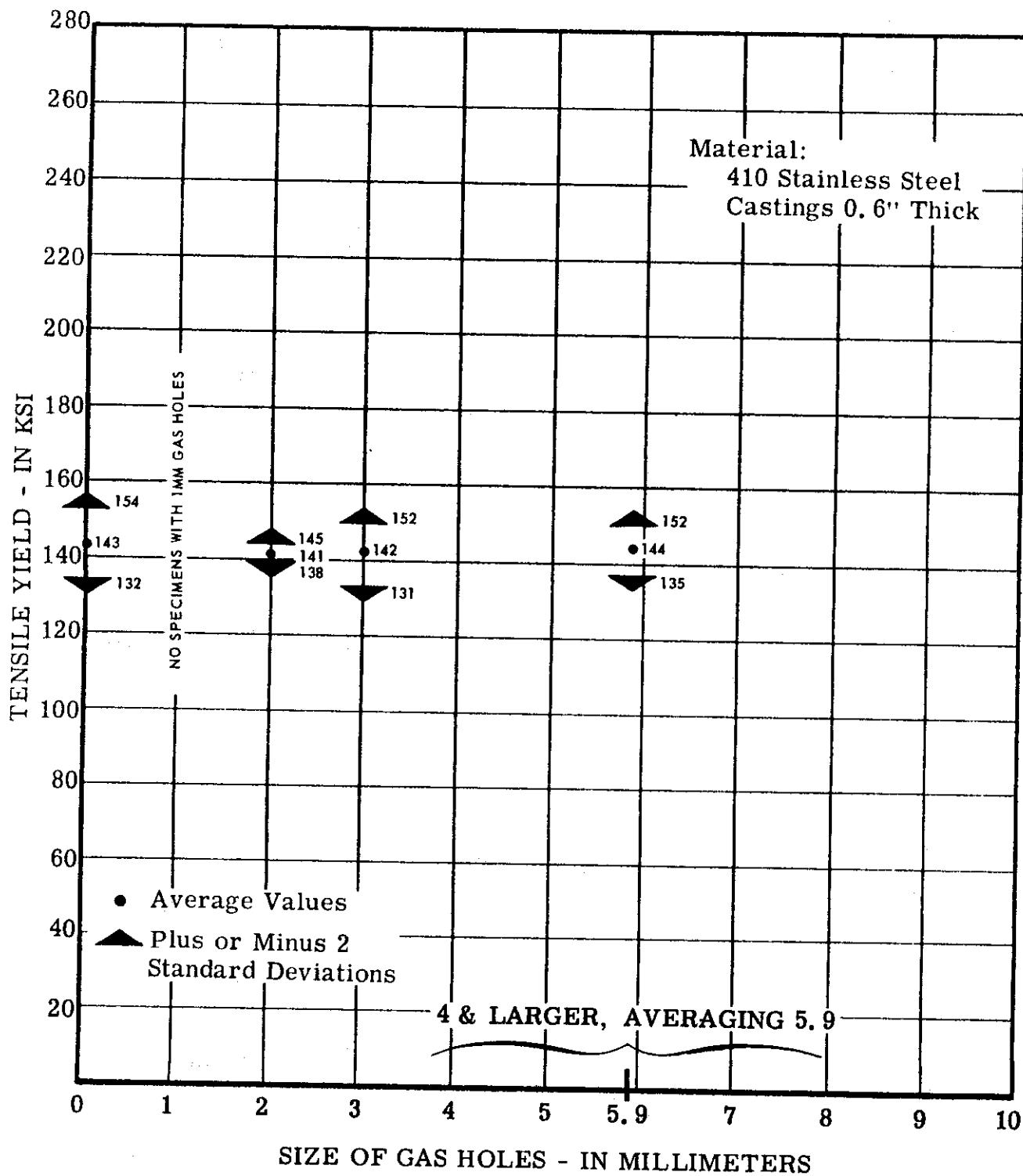


Figure 92. Tensile Yield vs Gas Holes - Range of Values

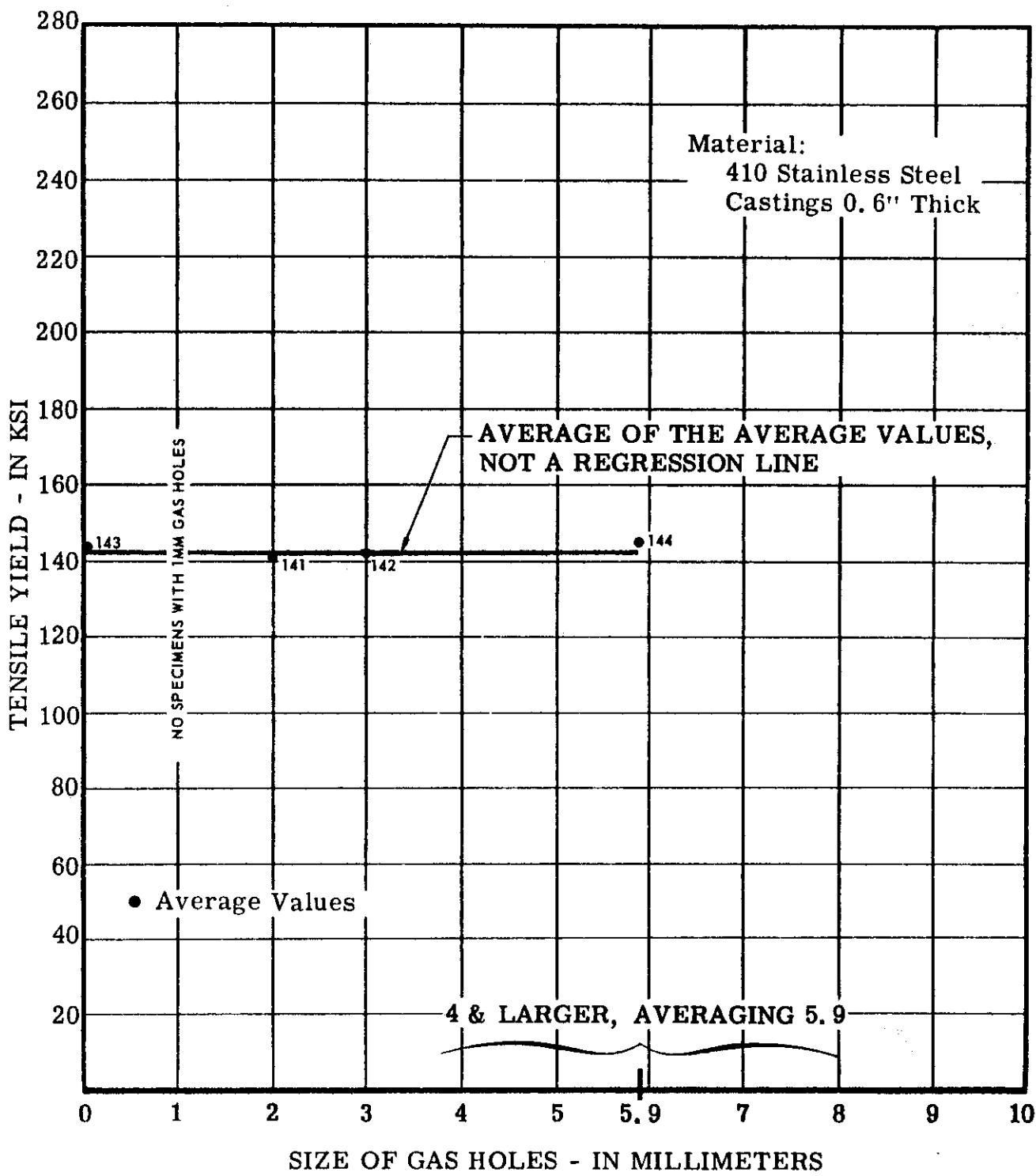


Figure 93. Tensile Yield vs Gas Holes - Correlation

5.38 SUMMARY OF RESULTS - TENSILE ULTIMATE VS. GAS HOLES - 0.6"-THICK MATERIAL

		Size of Gas Holes (diameter in millimeters)			
	Control Specimens	2	3	4	7.2*
Number of specimens tested -	105	13**	14	5**	12**

Statistically determined number required for 0.95 confidence that the average of the results approaches the true average -

Confidence level, if less than 0.95 -

The following results and statistical parameters are in ksi:

Tensile ultimate (average of test results) -	162	157	171	163	152
Estimate of the standard deviation -	16.2	19.5	10.8	29.3	13.7
Hardness (average Rockwell C) -	41.7	41.1	41.4	39.4	42.3
Tensile ultimate (adjusted to hardness) *** -	164	162	174	176	147

Limits for individuals:

Lower limit (0.95 probability) -	132	123	152	118	120
Upper limit (0.95 probability) -	196	201	196	235	175

CORRELATION ANALYSIS

Analysis was not made; number of specimens was not statistically adequate.

-
- * Specimens having 5-mm-and-larger gas holes, averaging 7.2 mm.
 - ** Number of specimens not adequate; see number required on line below.
 - *** Value too low for confidence level to have a practical meaning
 - **** See paragraph 6.1.1

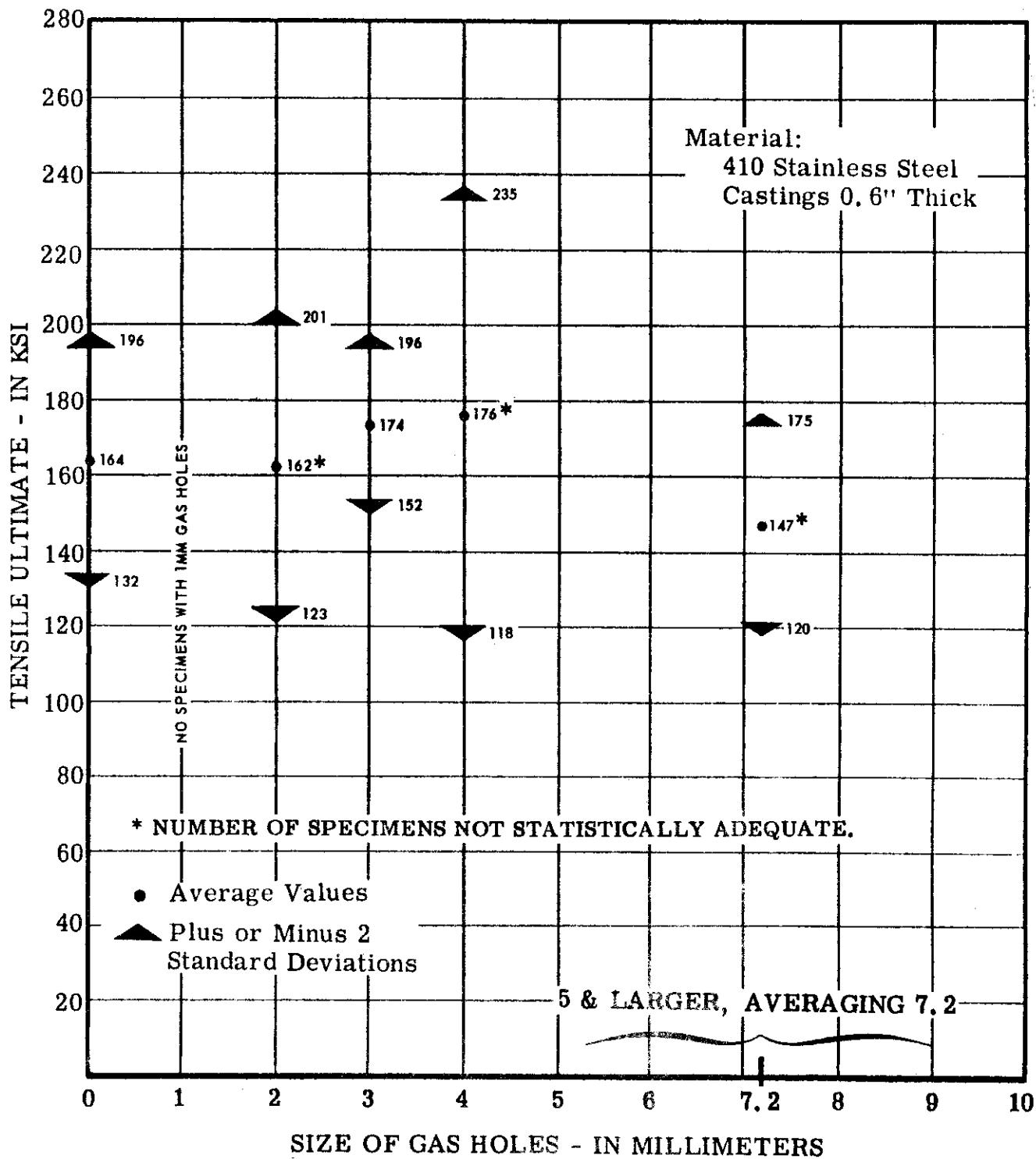


Figure 94. Tensile Ultimate vs Gas Holes - Range of Values

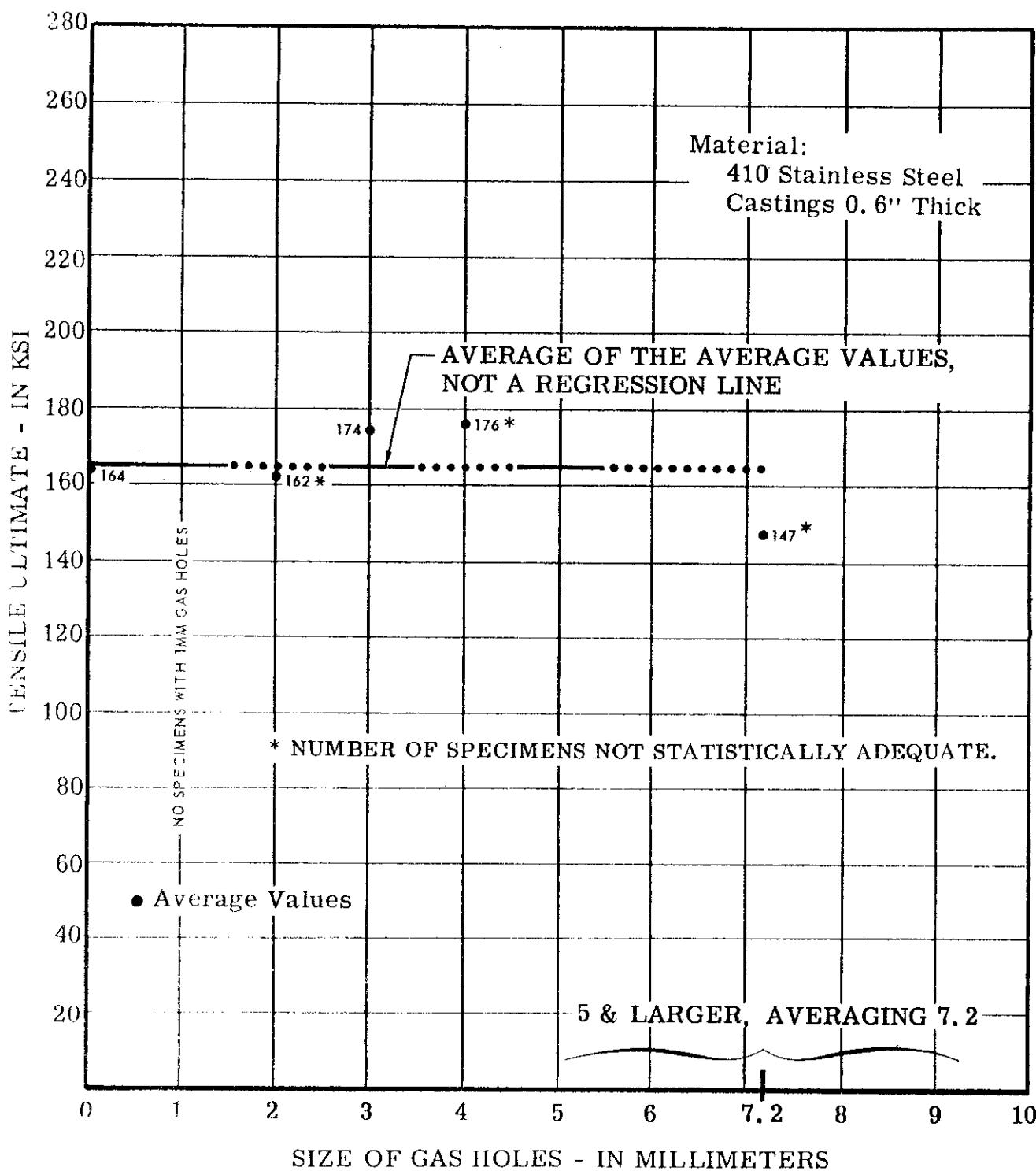


Figure 95. Tensile Ultimate vs Gas Holes - Correlation

WADD TR 60-450

5.39 SUMMARY OF RESULTS - ELONGATION VS. GAS HOLES - 0.6"-THICK MATERIAL

WADD TR 60-450

<u>Control Specimens</u>	Size of Gas Holes (diameter in millimeters)			
	<u>2</u>	<u>3</u>	<u>4</u>	<u>7.4*</u>
Number of specimens tested -	103	16**	14	5***
Statistically determined number required for 0.95 confidence that the average of the results approaches the true average -	72	22	5	58

Confidence level, if less than 0.95 -

The following results and statistical parameters are in % in 2"

Elongation (average of test results) -	2.9	2.6	2.9	2.7	2.0
Estimate of the standard deviation -	1.8	0.9	0.5	1.5	6.6
<u>Limits for individuals:</u>					
Lower limit (0.95 probability) -	0	0.8	2.0	0	0.8
Upper limit (0.95 probability) -	6.5	4.3	3.8	5.7	3.2

CORRELATION ANALYSIS

Analysis was not made; no trend toward lower values, as size of gas holes increased, was present. Also, in several instances, number of specimens was not statistically adequate.

* Specimens having 5-mm-and-larger gas holes, averaging 7.4 mm.

** Number of specimens not adequate; see number required on line below.

*** Value too low for confidence level to have a practical meaning.

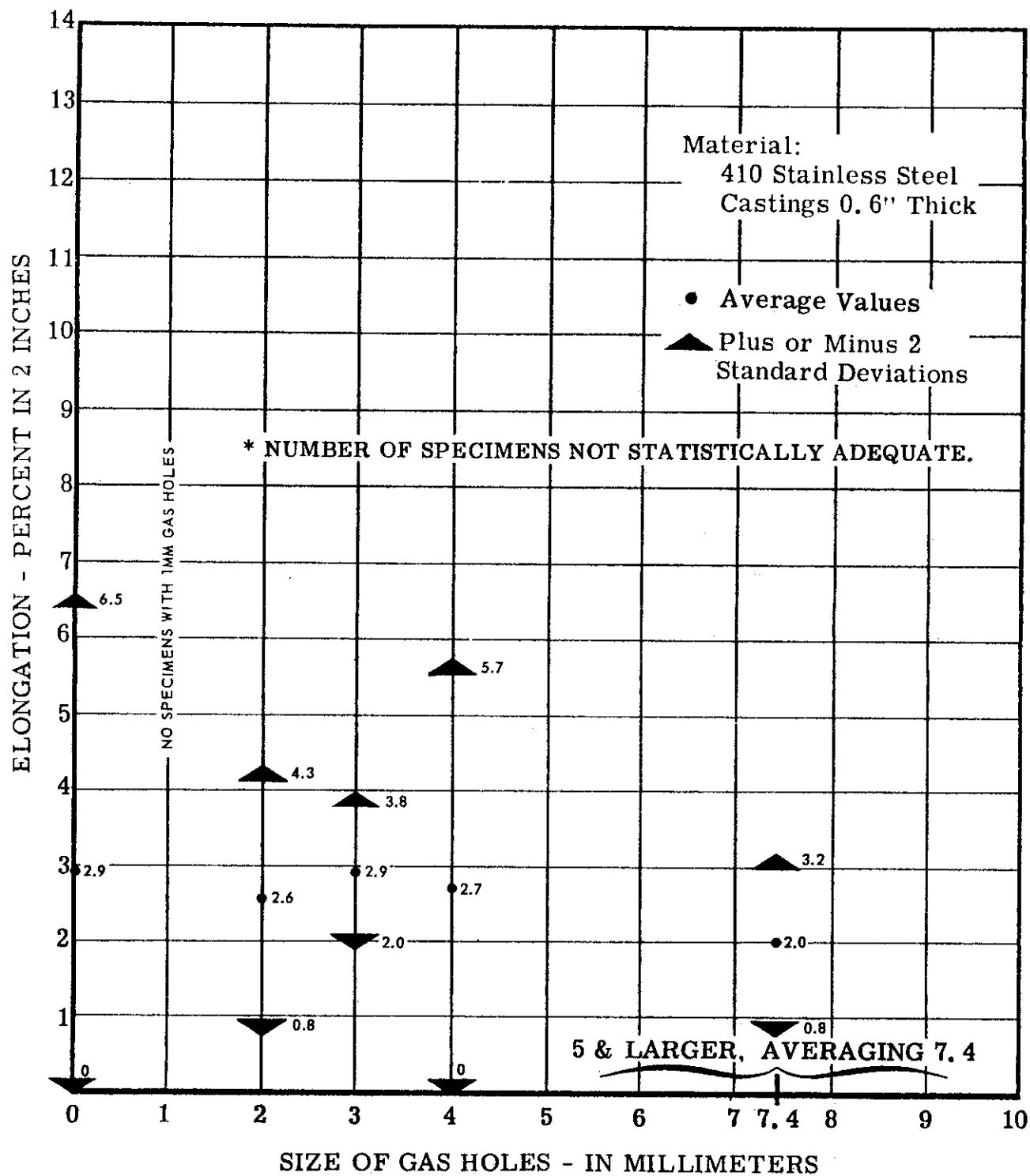


Figure 96. Elongation vs Gas Holes - Range of Values

WADD TR 60-450

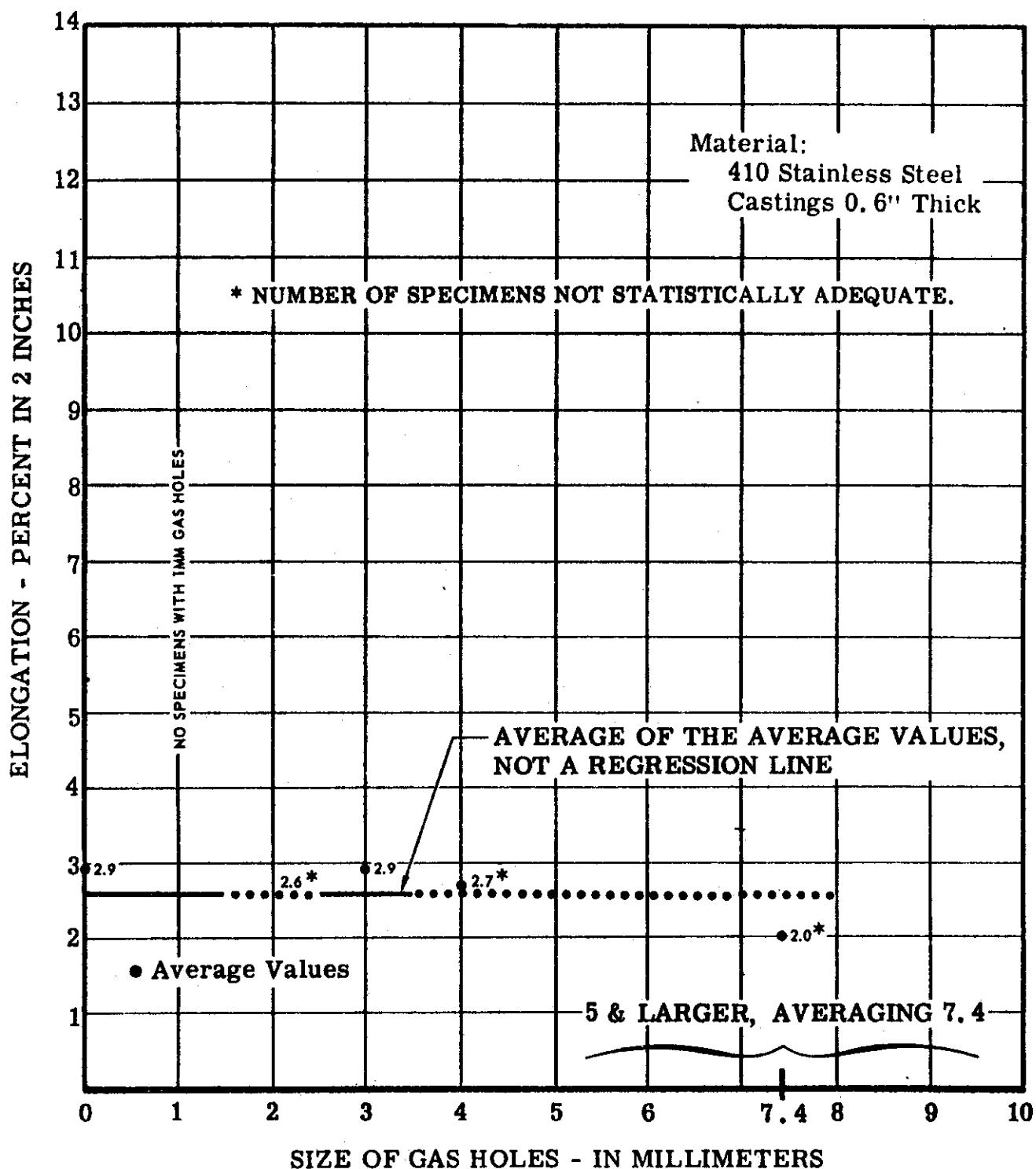


Figure 97. Elongation vs Gas Holes - Correlation

WADD TR 60-450

5.40 SUMMARY OF RESULTS - MODULUS OF ELASTICITY VS. GAS HOLES - 0.6"-THICK MATERIAL

	Control Specimens			Size of Gas Holes (diameter in millimeters)		
	<u>2</u>	<u>3</u>	<u>4</u>	<u>7.4*</u>		
Number of specimens tested -	99	15	11	5	11	

Statistically determined number required for 0.95 confidence that the average of the results approaches the true average -

Confidence level, if less than 0.95 -

The following results and statistical parameters are in 10^6 psi

Modulus of Elasticity (average of results) -	28.5	30.4	27.8	26.7	27.9
Estimate of the standard deviation -	2.1	2.1	1.0	0.5	2.0

Limits for individuals:

Lower limit (0.95 probability) -	24.3	26.2	25.8	25.8	25.9
Upper limit (0.95 probability) -	32.7	34.6	29.8	27.6	29.9

CORRELATION ANALYSIS

Analysis was not made; no trend toward lower values, as size of gas holes increased, was present.

* Specimens having 5-mm-and-larger gas holes, averaging 7.4 mm.

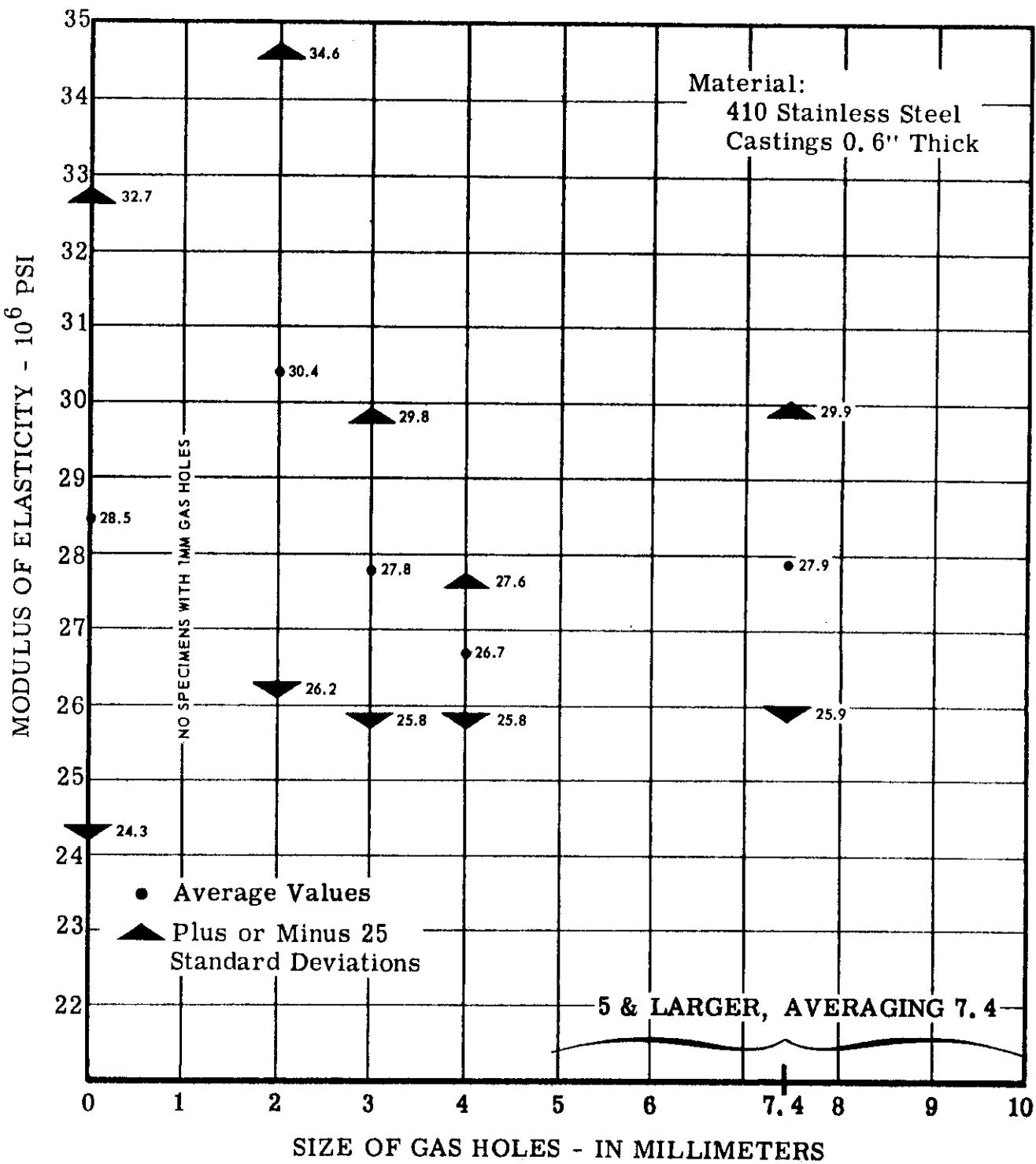


Figure 98. Modulus of Elasticity vs Gas Holes - Range of Values

WADD TR 60-450

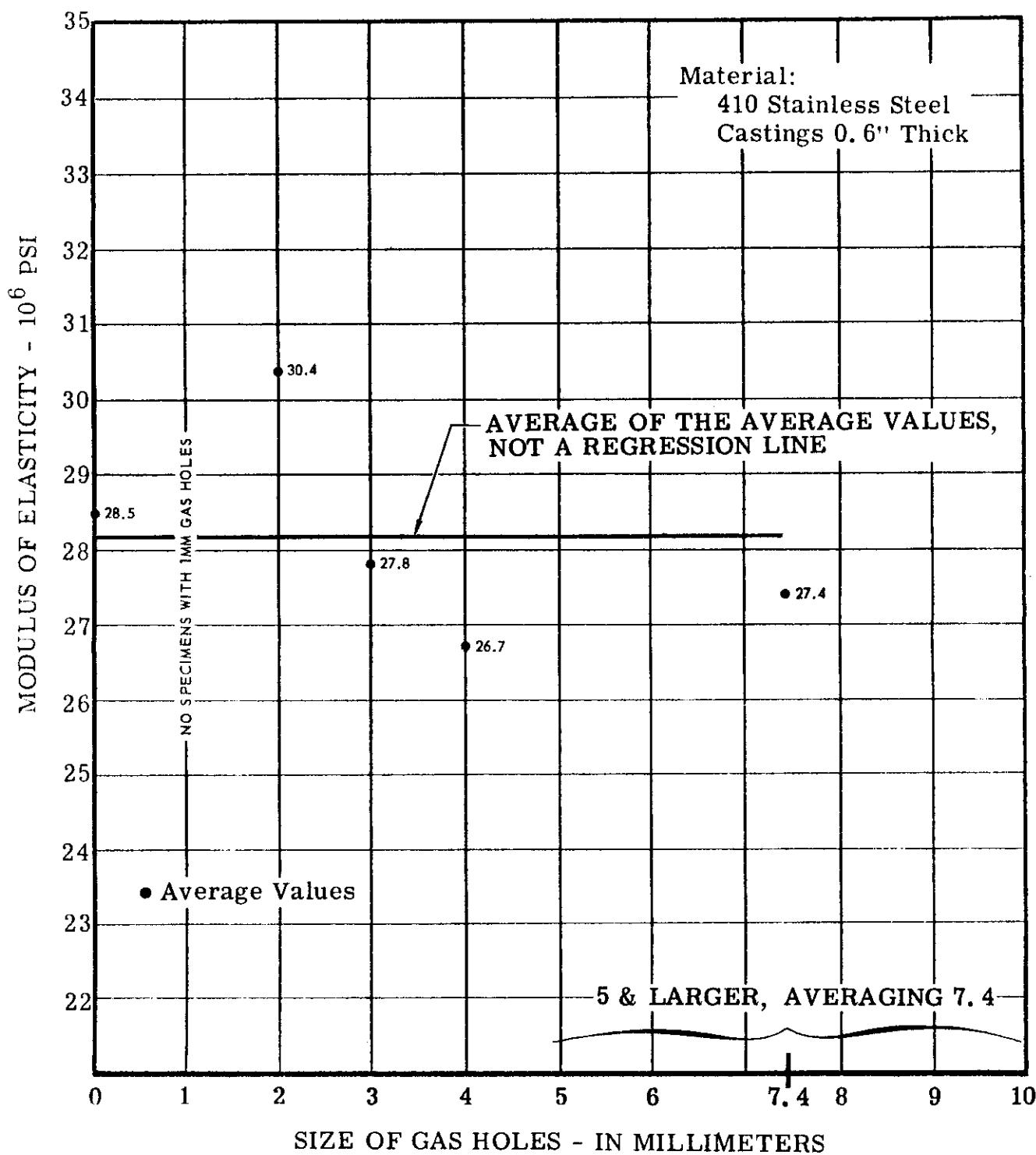


Figure 99. Modulus of Elasticity vs Gas Holes - Correlation

WADD TR 60-450

5.41 SUMMARY OF RESULTS - TENSILE YIELD VS. INCLUSIONS - 0.6"-THICK MATERIAL

		Size of Inclusions (diameter in millimeters)						
	Control Specimens	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>10.3*</u>
Number of specimens tested -	68	6	9	11	7	6	13	5**

Statistically determined number required for 0.95 confidence that the average of the results approaches the true average -

Confidence level, if less than 0.95 -

The following results and statistical parameters are in ksi

Tensile yield (average of test results) -
Estimate of the standard deviation

Limits for individuals:

Lower limit (0.95 probability) -
Upper limit (0.95 probability) -

CORRELATION ANALYSIS

Analysis was not made; no trend toward lower values, as size of inclusions increased, was present.

* Specimens having 8-mm-and-larger inclusions, averaging 10.3 mm.

** Number of specimens not adequate; see number required on line below.

*** Value too low for confidence level to have a practical meaning.

Contrails

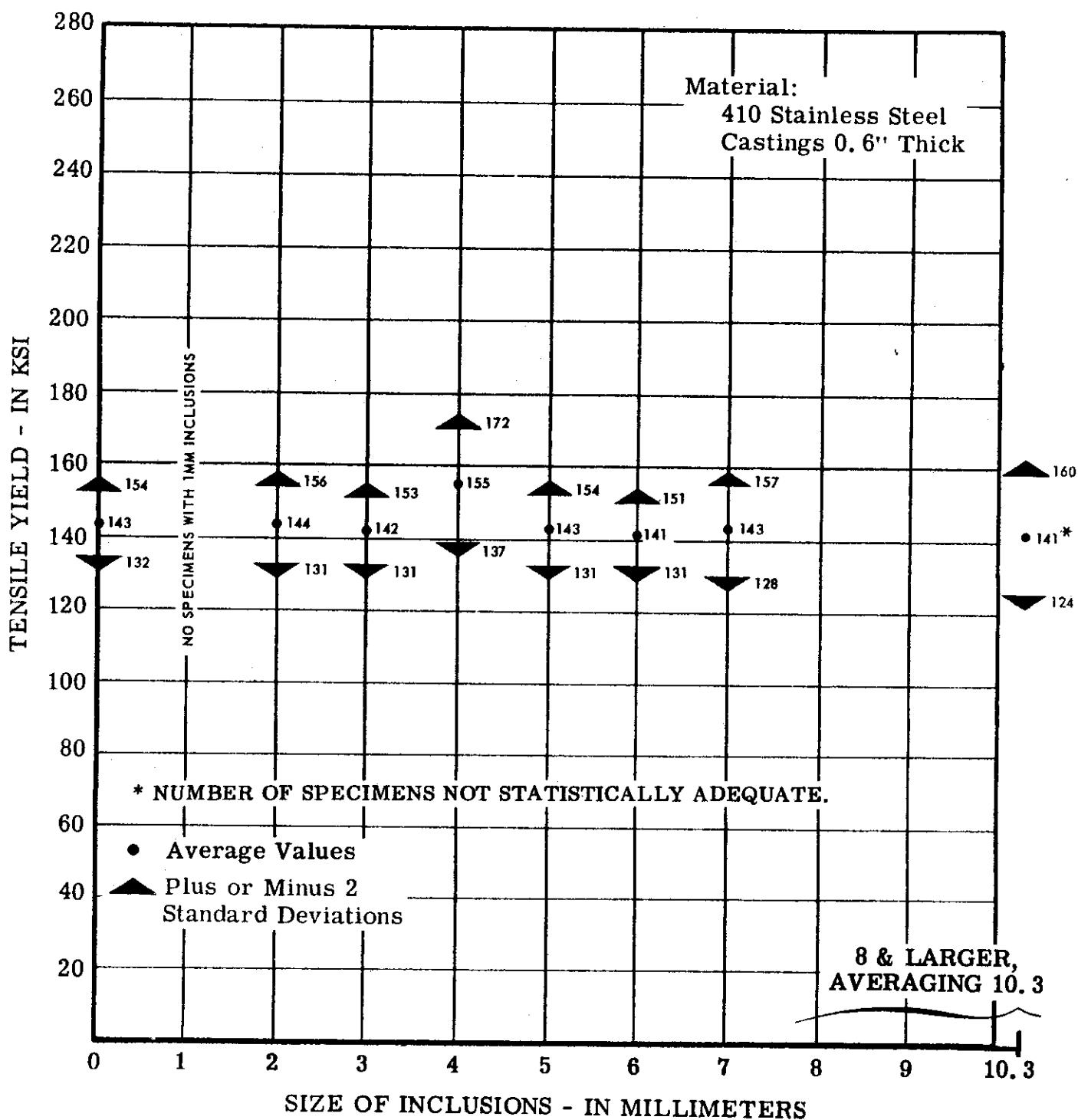


Figure 100. Tensile Yield vs Inclusions - Range of Values

WADD TR 60-450

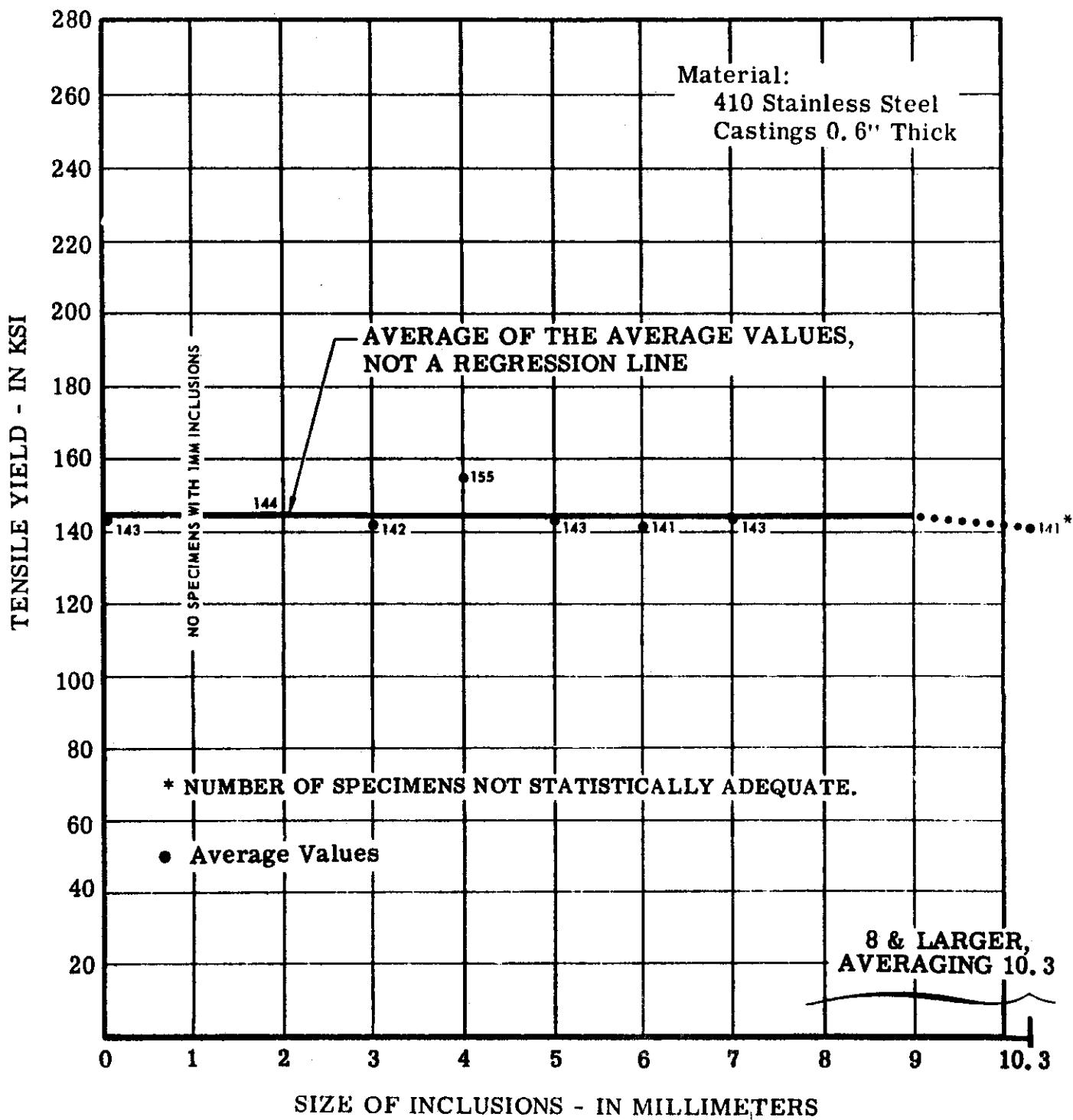


Figure 101. Tensile Yield vs Inclusions - Correlation

WADD TR 60-450

5.42 SUMMARY OF RESULTS - TENSILE ULTIMATE VS. INCLUSIONS - 0.61"-THICK MATERIAL

	Control Specimens	Size of Inclusions (diameter in millimeters)							
	2	3	4	5	6	7	8	10	13.8*
Number of specimens tested -	105	-	8**	13**	14	13**	7**	15**	10**
Statistically determined number required for 0.95 confidence that the average of the results approaches the true average -	16	-	37	20	11	17	23	21	25
Confidence level, if less than 0.95 -	-	-	***	***	-	***	***	***	***
The following results and statistical parameters are in ksi									
Tensile ultimate (average of test results) -	162	167	161	159	163	161	162	154	156
Estimate of the standard deviation -	16.2	25.2	17.6	12.9	16.5	18.9	18.2	18.9	16.3
Hardness (average Rockwell C) -	41.8	42.2	41.1	41.8	41.4	42.3	41.8	41.7	42.0
Tensile ultimate (adjusted to hardness) -****	164	166	160	166	159	163	155	156	163
Limits for individuals:									
Lower limit (0.95 probability) -	130	116	131	134	133	121	125	117	123
Upper limit (0.95 probability) -	195	216	201	188	199	197	199	193	189

CORRELATION ANALYSIS

Analysis was not made; except for control and 4-mm specimens, number of specimens was not statistically adequate.

* Specimens having 11-mm-and-larger inclusions, averaging 13.8 mm.

** Number of specimens not adequate; see number required on line below.

*** Value too low for confidence level to have a practical meaning.

**** See paragraph 6.1.1

Contrails

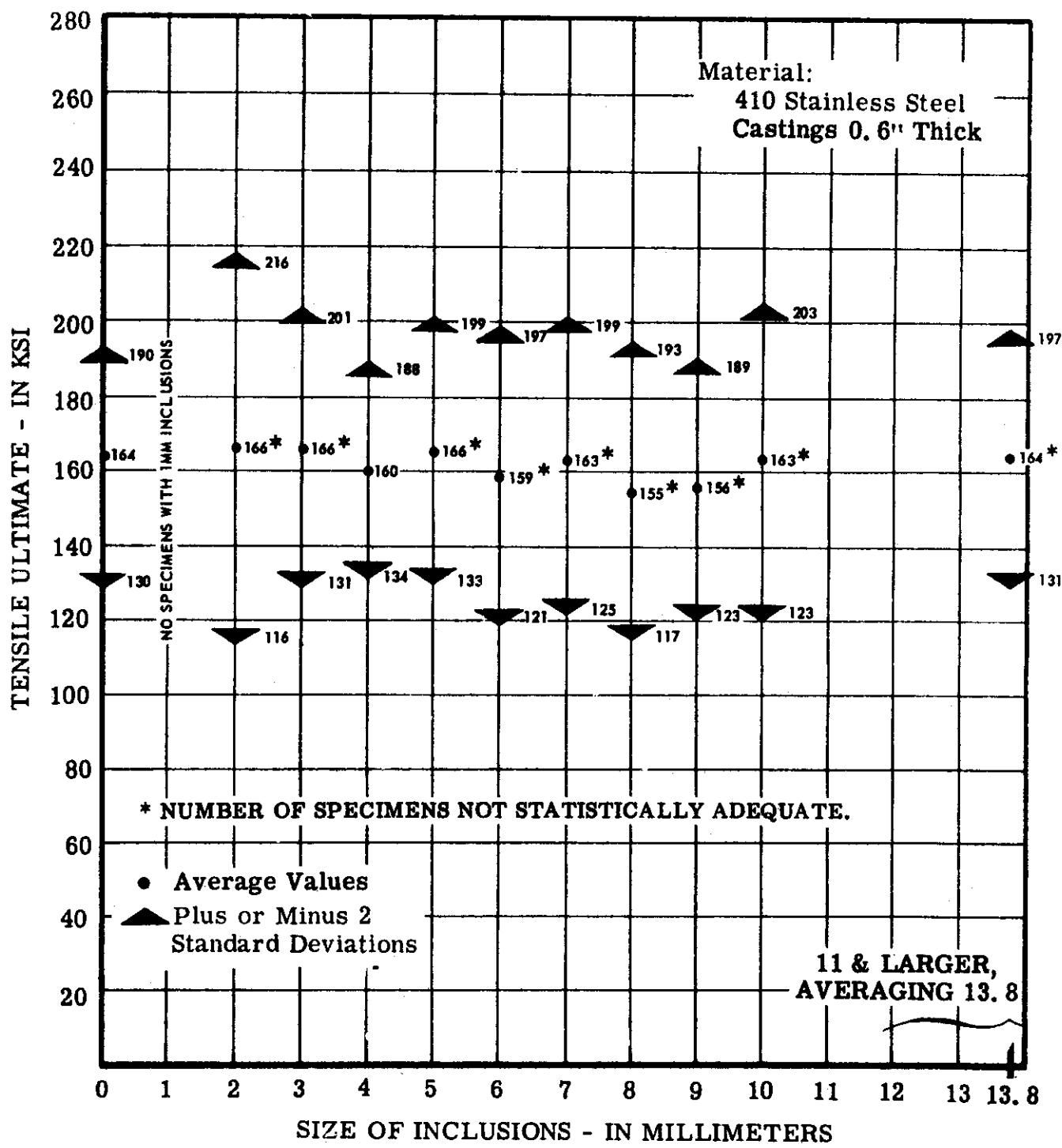


Figure 102. Tensile Ultimate vs Inclusions - Range of Values

WADD TR 60-450

Contrails

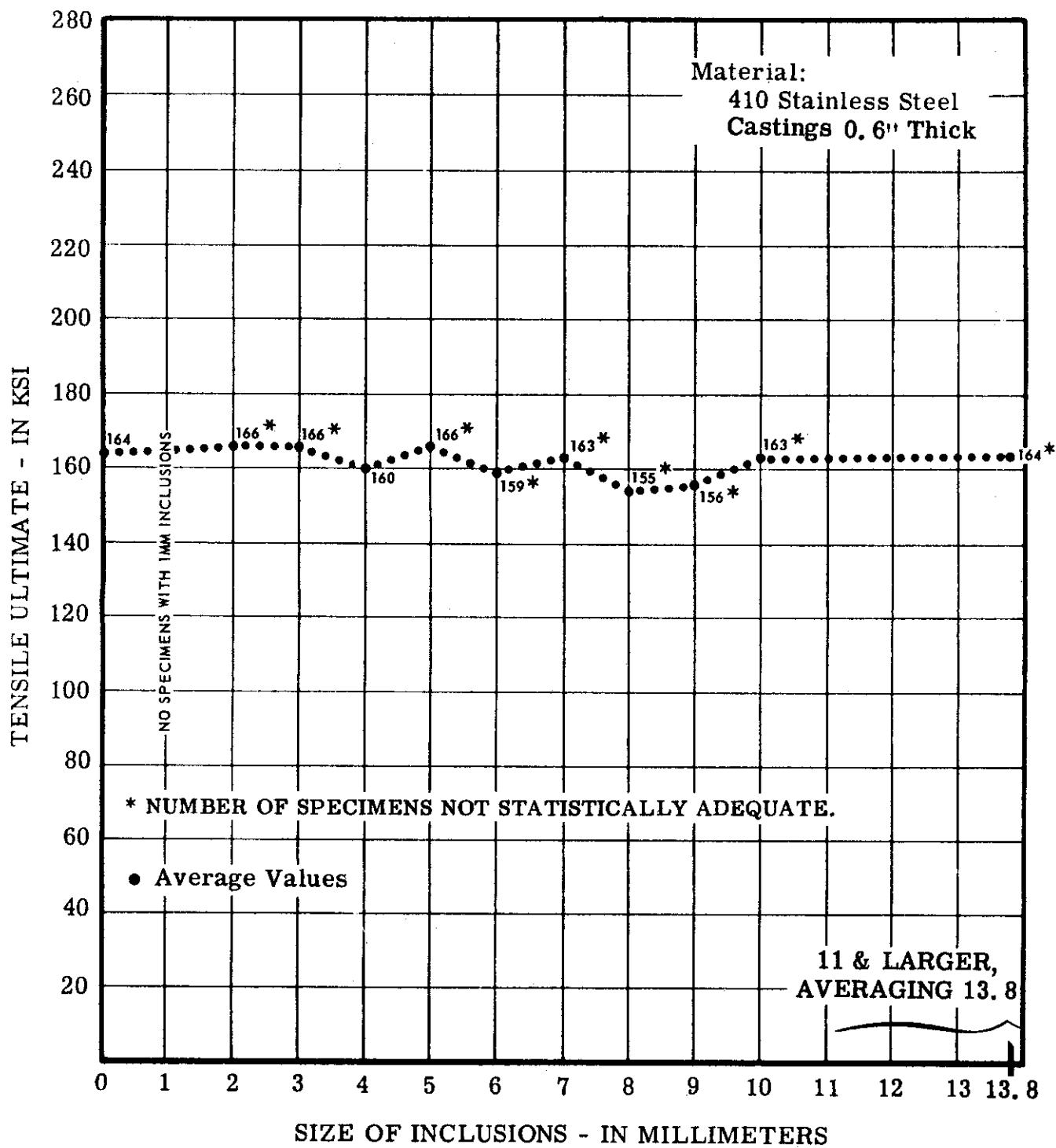


Figure 103. Tensile Ultimate vs Inclusions - Correlation

WADD TR 60-450

5.43 SUMMARY OF RESULTS - ELONGATION VS. INCLUSIONS - 0.6"-THICK MATERIAL

Control <u>Specimens</u>	Size of Inclusions (diameter in millimeters)							<u>9</u>	<u>10</u>	<u>13.8*</u>
	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>			
Number of specimens tested -	103	8**	13**	14**	13**	7**	14**	10**	4**	6
Statistically determined number required for 0.95 confidence that the average of the results approaches the true average -	72	192	74	34	18	9	17	55	5	4
Confidence level, if less than 0.95 -	-	***	***	***	***	***	***	***	***	-

The following results and statistical parameters are in % in 2"

Elongation (average of test results) -

Estimate of the standard deviation -

Limits for individuals:

Lower limit (0.95 probability) -	0	0	0	0.3	0.9	1.7	0.8	0	1.0	1.6
Upper limit (0.95 probability) -	6.5	14.5	6.5	4.3	4.1	4.1	4.0	5.4	2.2	3.2

CORRELATION ANALYSIS

Analysis was not made; number of specimens was not statistically adequate.

-
- * Specimens having 11-mm-and-larger inclusions, averaging 13.8 mm.
 - ** Number of specimens not adequate; see numbers required on line below.
 - *** Value too low for confidence level to have a practical meaning.

Contrails

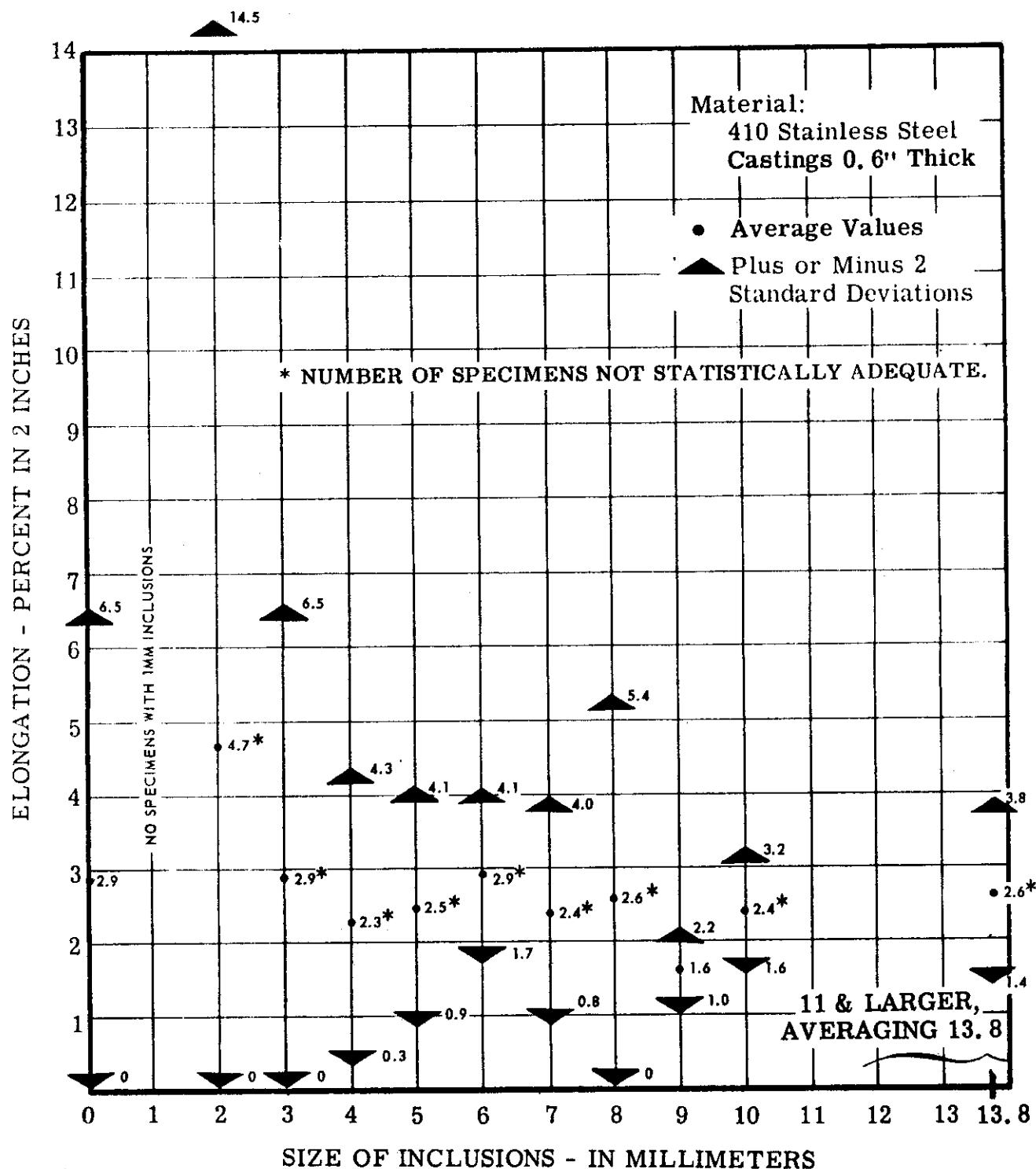


Figure 104. Elongation vs Inclusions - Range of Values

WADD TR 60-450

Contrails

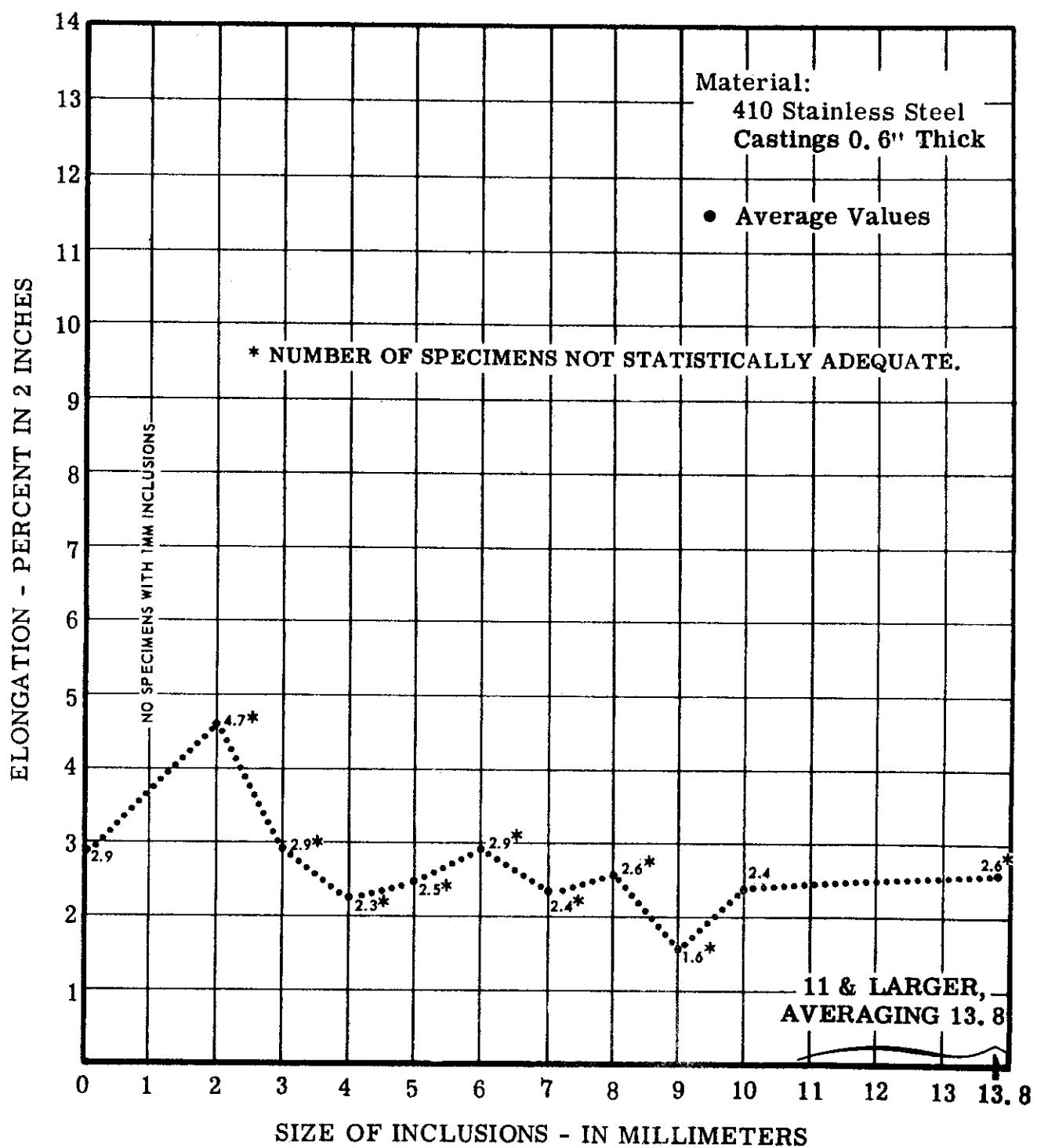


Figure 105. Elongation vs Inclusions - Correlation

WADD TR 60-450

5.44 SUMMARY OF RESULTS - MODULUS OF ELASTICITY VS. INCLUSIONS - 0.6"-THICK MATERIAL

Control Specimens	Size of Inclusions (diameter in millimeters)							<u>13.8*</u>
	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	
Number of specimens tested -	99	7	13	14	13	7**	15	10** 4** 6 9**
Statistically determined number required for 0.95 confidence that the average of the results approaches the true average -	9	7	7	12	10	9	12	11 12 5 16 ***
Confidence level, if less than 0.95 -	-	-	-	-	-	-	-	-
The following results and statistical parameters are in 10^6 psi								
Modulus (average of test results) -	28.5	27.5	27.9	29.0	28.9	28.0	29.4	28.9
Estimate of the standard deviation -	2.1	1.7	1.7	2.5	2.4	2.0	2.5	2.4
Limits for individuals:								
Lower limit (0.95 probability) -	24.3	24.1	24.5	24.0	24.5	24.0	24.4	24.1
Upper limit (0.95 probability) -	32.7	30.9	31.3	34.0	33.3	32.0	34.4	33.7

CORRELATION ANALYSIS

Analysis was not made; trend to lower values of modulus of elasticity, as size of inclusions increased was not present; also, number of specimens, for larger size inclusions, was not statistically adequate.

* Specimens having 11-mm-and-larger inclusions, averaging 13.8 mm.

** Number of specimens not adequate; see number required on line below.

*** Value too low for confidence level to have a practical meaning.

Contrails

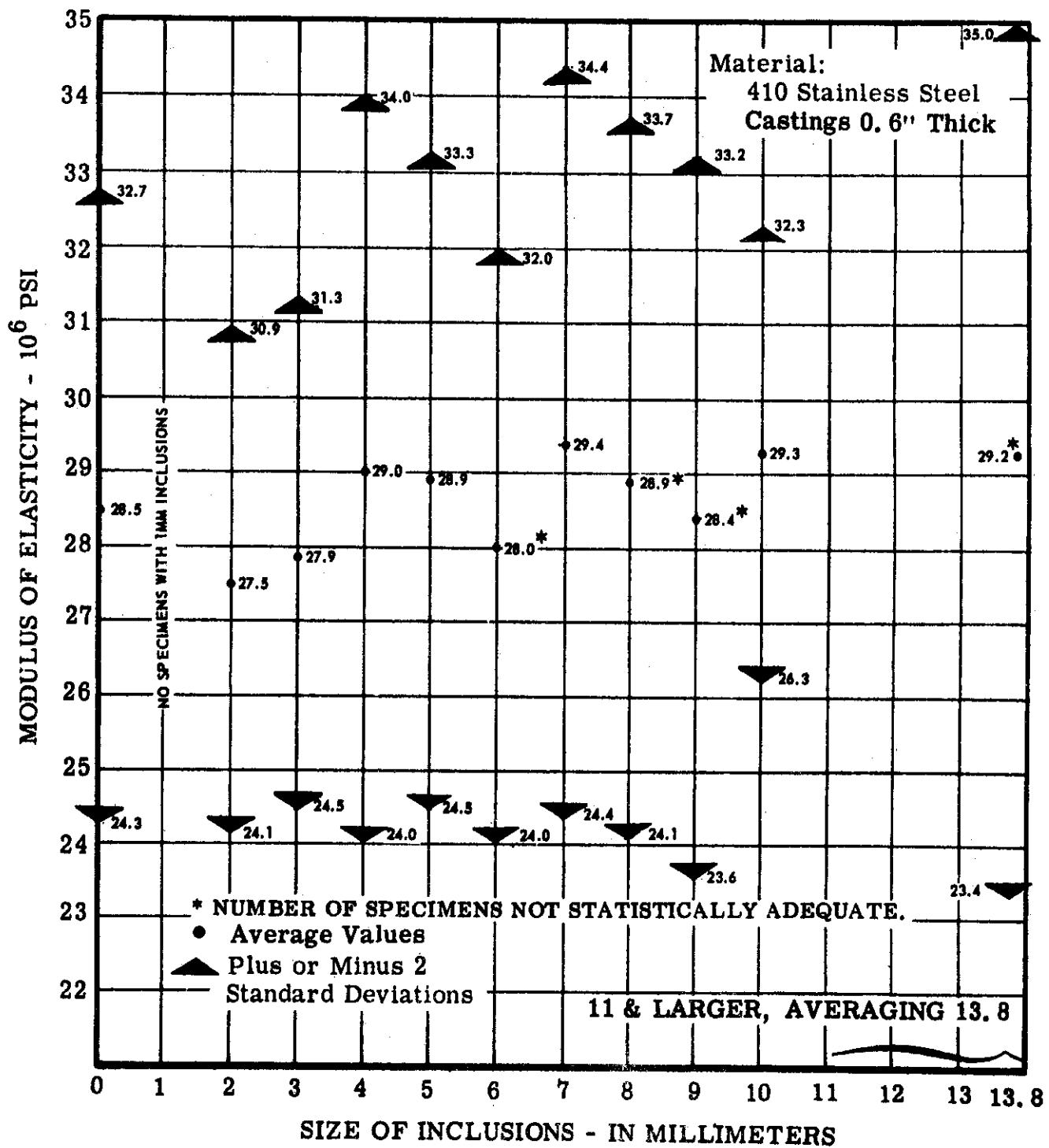


Figure 106. Modulus of Elasticity vs Inclusions - Range of Values

WADD TR 60-450

Contrails

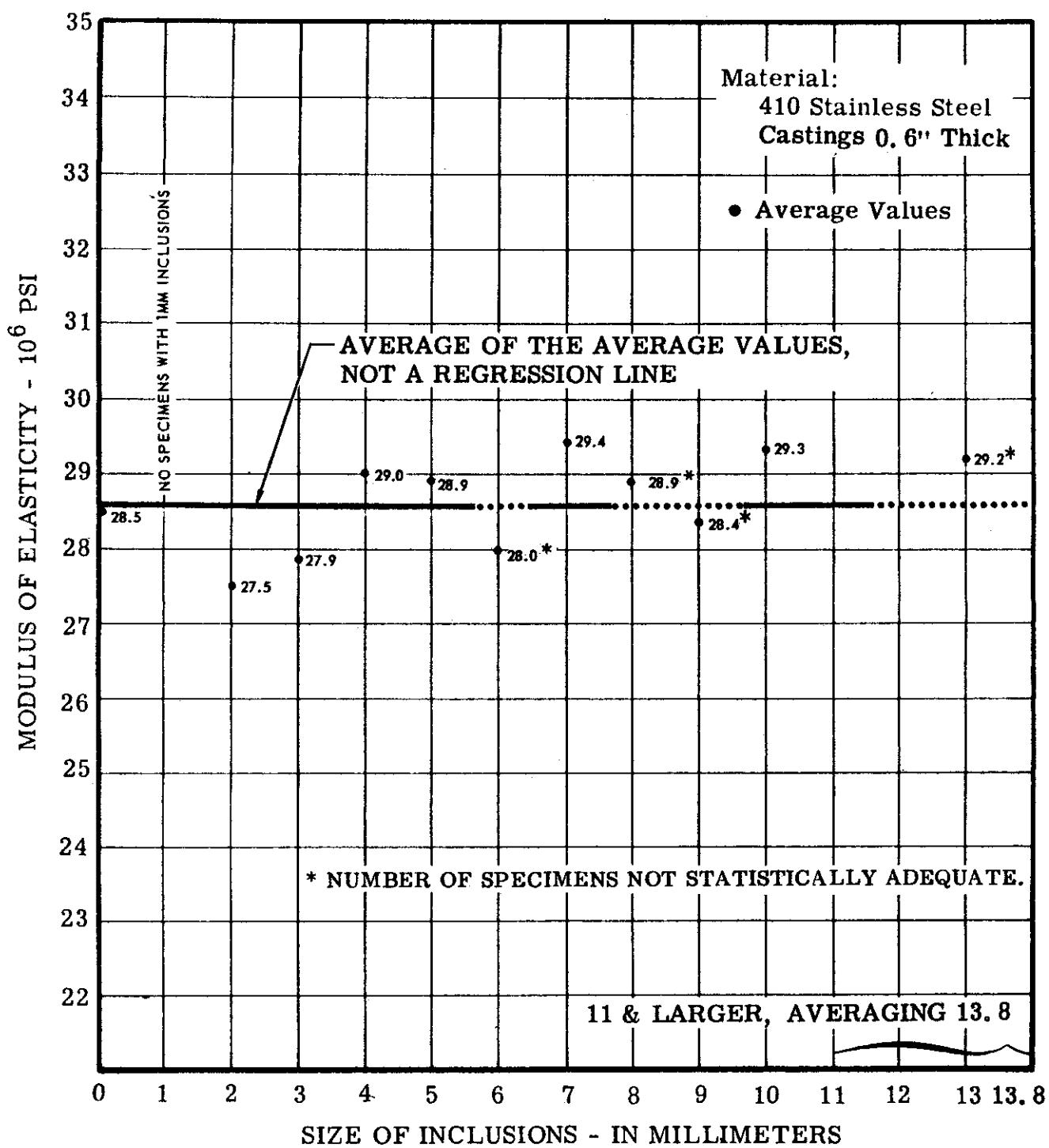


Figure 107. Modulus of Elasticity vs Inclusions - Correlation

WADD TR 60-450

Controls

5.45 SUMMARY OF RESULTS - TENSILE YIELD VS. POROSITY - 0.6"-THICK MATERIAL

	Control Specimens	Numbers, Indicating Intensity of Porosity					
		<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>7.3*</u>
Number of specimens tested -	68	75	27	18	6	5**	3
Statistically determined number required for 0.95 confidence that the average of the results approaches the true average -	3	4	3	7	1	7	2
Confidence level, if less than 0.95 -	-	-	-	-	-	***	-
The following results and statistical parameters are in ksi							
Tensile yield (average of test results) -	143	141	139	136	139	136	134
Estimate of the standard deviation -	5.6	6.2	5.6	8.8	3.3	8.5	4.6
Limits for individuals:							
Lower limit (0.95 probability) -	132	129	128	119	132	119	125
Upper limit (0.95 probability) -	154	154	156	154	145	153	143

CORRELATION ANALYSIS

Correlation coefficient = - 0.91, minus sign indicates an inverse relationship. "Standard error of estimate" = 1.5 ksi.

* Specimens having number 6-and-higher porosity intensity, averaging number 7.3.

** Number of specimens not adequate; see number required on line below.

*** Value too low for confidence level to have a practical meaning.

Contrails

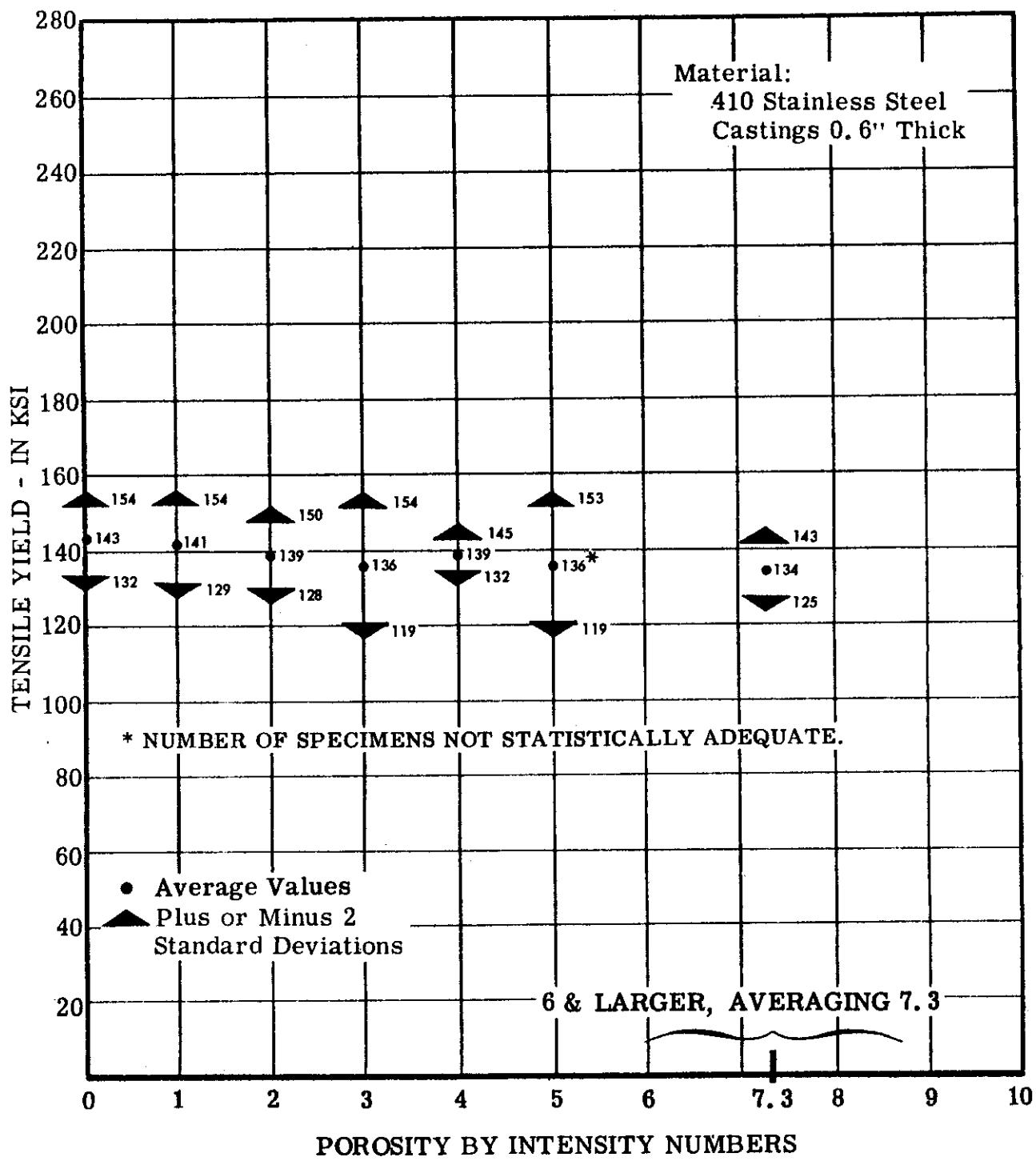


Figure 108. Tensile Yield vs Porosity - Range of Values

WADD TR 60-450

Contrails

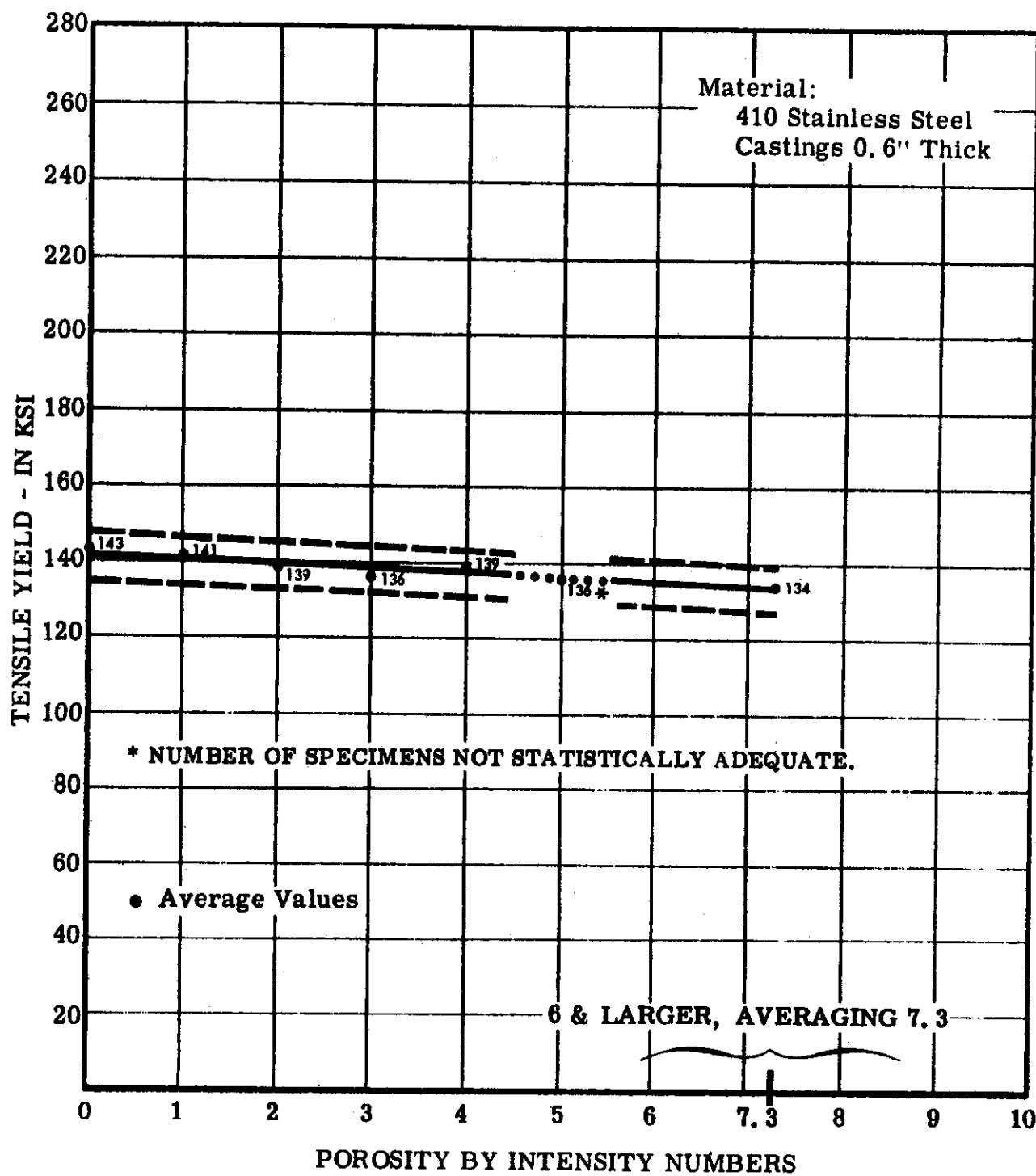


Figure 109. Tensile Yield vs Porosity - Correlation

WADD TR 60-450

5.46 SUMMARY OF RESULTS - TENSILE ULTIMATE VS. POROSITY - 0.6"-THICK MATERIAL

<u>Control Specimens</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>
Number of specimens tested -	105	103	50	29	10	14*	6	5*
Statistically determined number required for 0.95 confidence that the average of the results approaches the true average -	16	17	14	17	2	38	5	17
Confidence level, if less than 0.95 -	-	-	-	-	**	-	**	**

The following results and statistical parameters are in ksi

Tensile ultimate (average of test results) -	162	154	147	144	149	136	130	129
Estimate of the standard deviation -	16.2	15.6	13.6	14.8	5.2	20.8	7.2	13.3
Hardness (average Rockwell C) -	41.8	41.2	40.2	40.4	41.2	41.0	40.7	40.7
Tensile ultimate (adjusted to hardness) -***	164	158	156	153	153	146	137	124
Limits for individuals:								
Lower limit (0.95 probability) -	130	127	129	123	143	105	123	97
Upper limit (0.95 probability) -	195	189	183	182	164	188	151	151

CORRELATION ANALYSIS

Correlation coefficient = - 0.95, minus sign indicates an inverse relationship. "Standard error of estimate" = 3.0 ksi.

* Number of specimens not adequate; see number required on line below.

** Value too low for confidence level to have a practical meaning.

*** See paragraph 6.1.1

Contrails

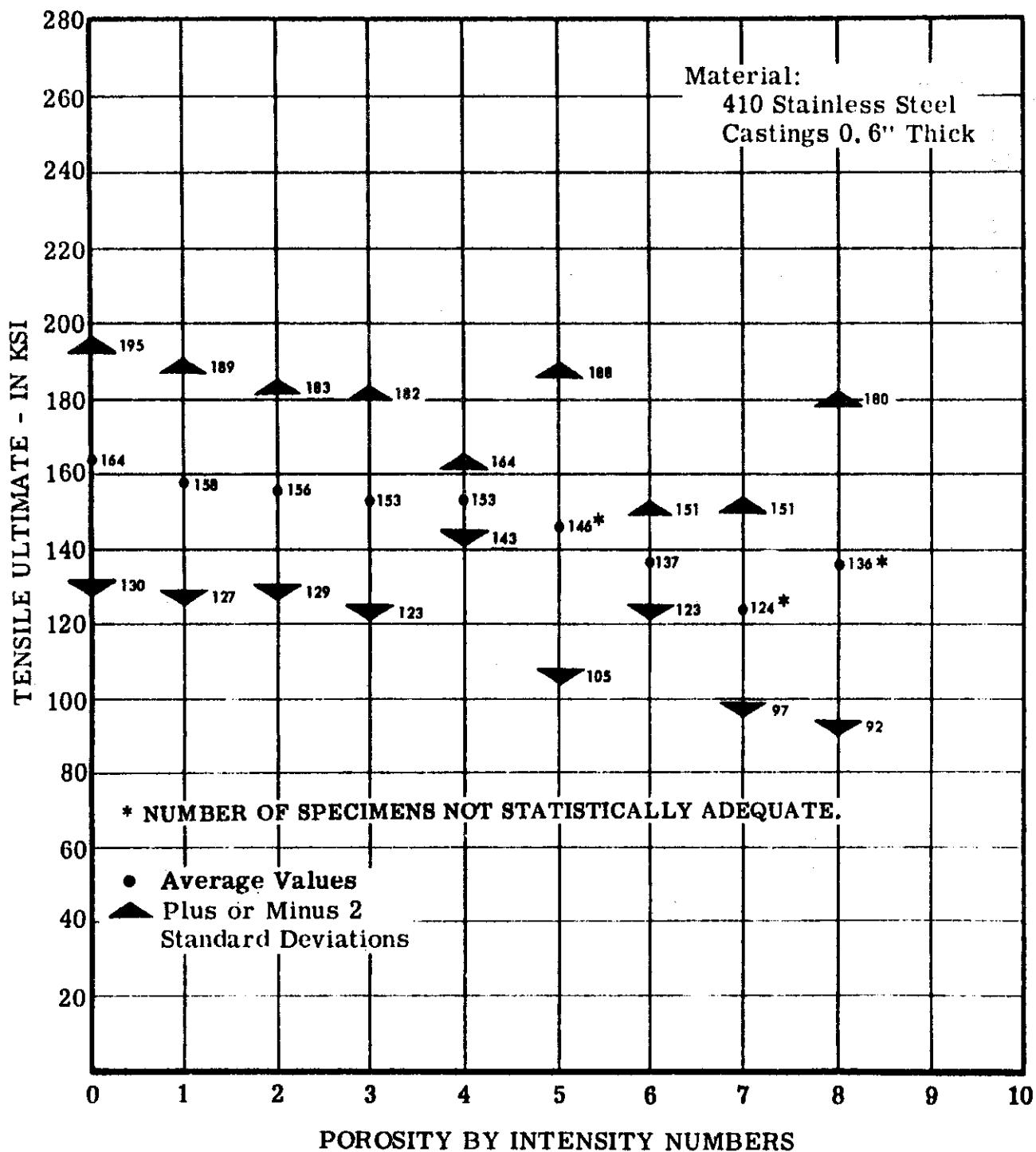


Figure 110. Tensile Ultimate vs Porosity - Range of Values

WADD TR 60-450

Contrails

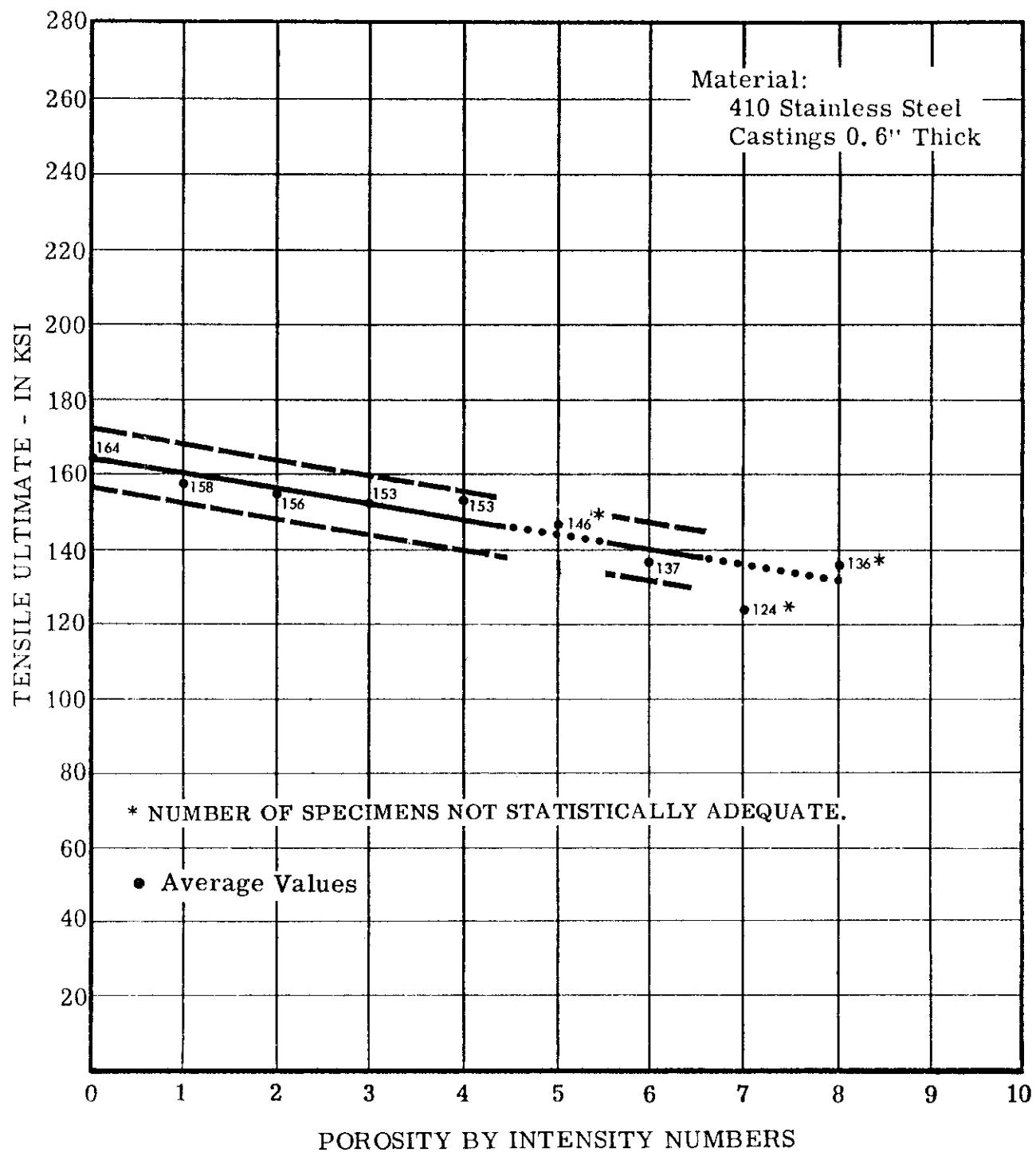


Figure 111. Tensile Ultimate vs Porosity - Correlation

WADD TR 60-450

Controls

5.47 SUMMARY OF RESULTS - ELONGATION VS. POROSITY - 0.6"-THICK MATERIAL

<u>Control Specimens</u>	<u>Numbers, Indicating Intensity of Porosity</u>	<u>7.4*</u>				
<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7.4*</u>
105	97	48	28	10**	9**	6***

Number of specimens tested -

Statistically determined number required for 0.95 confidence that the average of the results approaches the true average -

Confidence level, if less than 0.95 -

The following results and statistical parameters are in % in 2"

Elongation (average of test results) -
Estimate of the standard deviation -

Limits for individuals:

Lower limit (0.95 probability) -	0	0.8	0.9	0.9	0.2	0.7	0.4	0.4
Upper limit (0.95 probability) -	6.5	4.0	4.5	3.7	5.8	3.5	3.6	4.2

CORRELATION ANALYSIS

Correlation coefficient = - 0.76, minus sign indicates an inverse relationship. "Standard error of estimate" = 0.21 % in 2".

* Specimens having number 7-and-higher porosity intensity, averaging number 7.4.

** Number of specimens not adequate; see number required on line below.

*** Value too low for confidence level to have a practical meaning.

Contrails

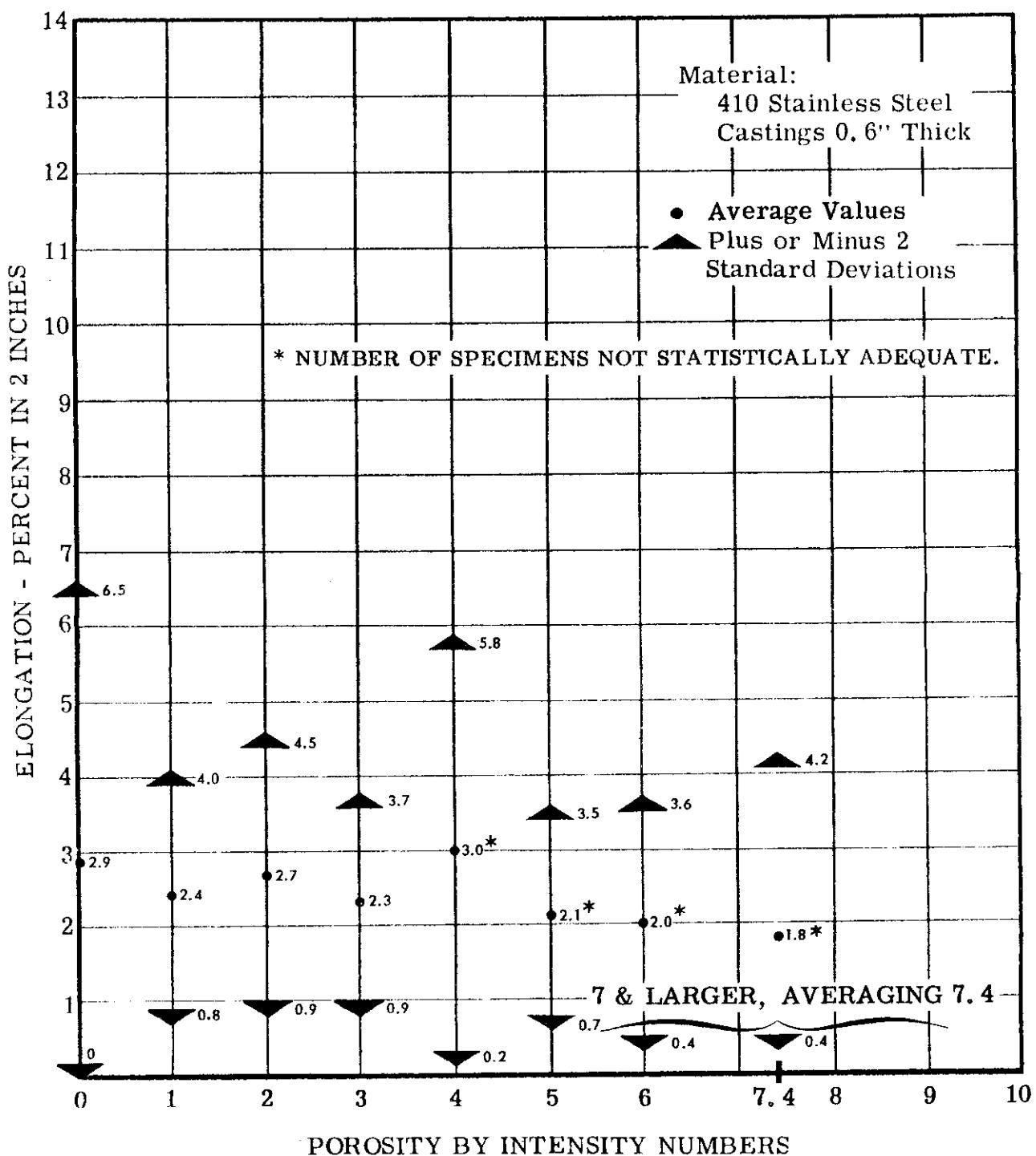


Figure 112. Elongation vs Porosity - Range of Values

WADD TR 60-450

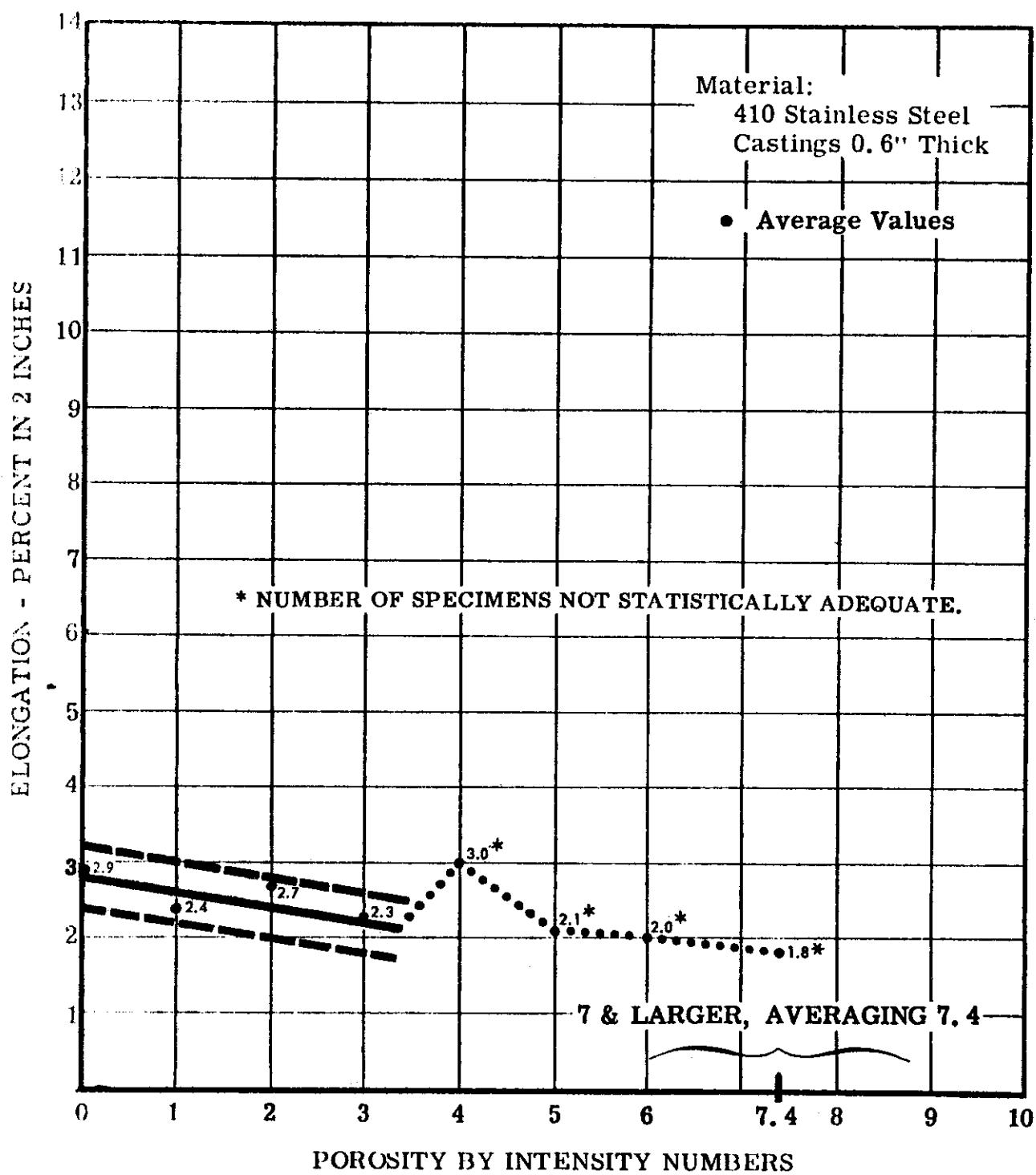


Figure 113. Elongation vs Porosity - Correlation

WADD TR 60-450

5.48 SUMMARY OF RESULTS - MODULUS OF ELASTICITY VS. POROSITY - 0.6"-THICK MATERIAL

	Control Specimens	Numbers, Indicating Intensity of Porosity						
	1	2	3	4	5	6	7	8
Number of specimens tested -	99	102	43	26	10*	12	4	5
Statistically determined number required for 0.95 confidence that the average of the results approaches the true average -	9	8	12	11	13	10	3	20
Confidence level, if less than 0.95 -	-	-	-	-	**	-	-	**
The following results and statistical parameters are in 10^6 psi								
Modulus (average of test results) -	28.5	28.4	29.4	29.0	27.8	30.1	29.5	27.3
Estimate of the standard deviation -	2.1	1.9	2.5	2.4	2.5	2.3	1.3	1.0
Limits for individuals:								
Lower limit (0.95 probability) -	24.3	25.0	24.4	24.2	22.9	25.5	26.9	25.3
Upper limit (0.95 probability) -	32.7	32.6	34.4	33.8	32.8	34.7	32.1	29.3

CORRELATION ANALYSIS

Analysis was not made; no trend toward lower values, as intensity of porosity increased, was present.

-
- * Number of specimens not adequate; see number required on line below.
 - ** Value too low for confidence level to have a practical meaning.

Contrails

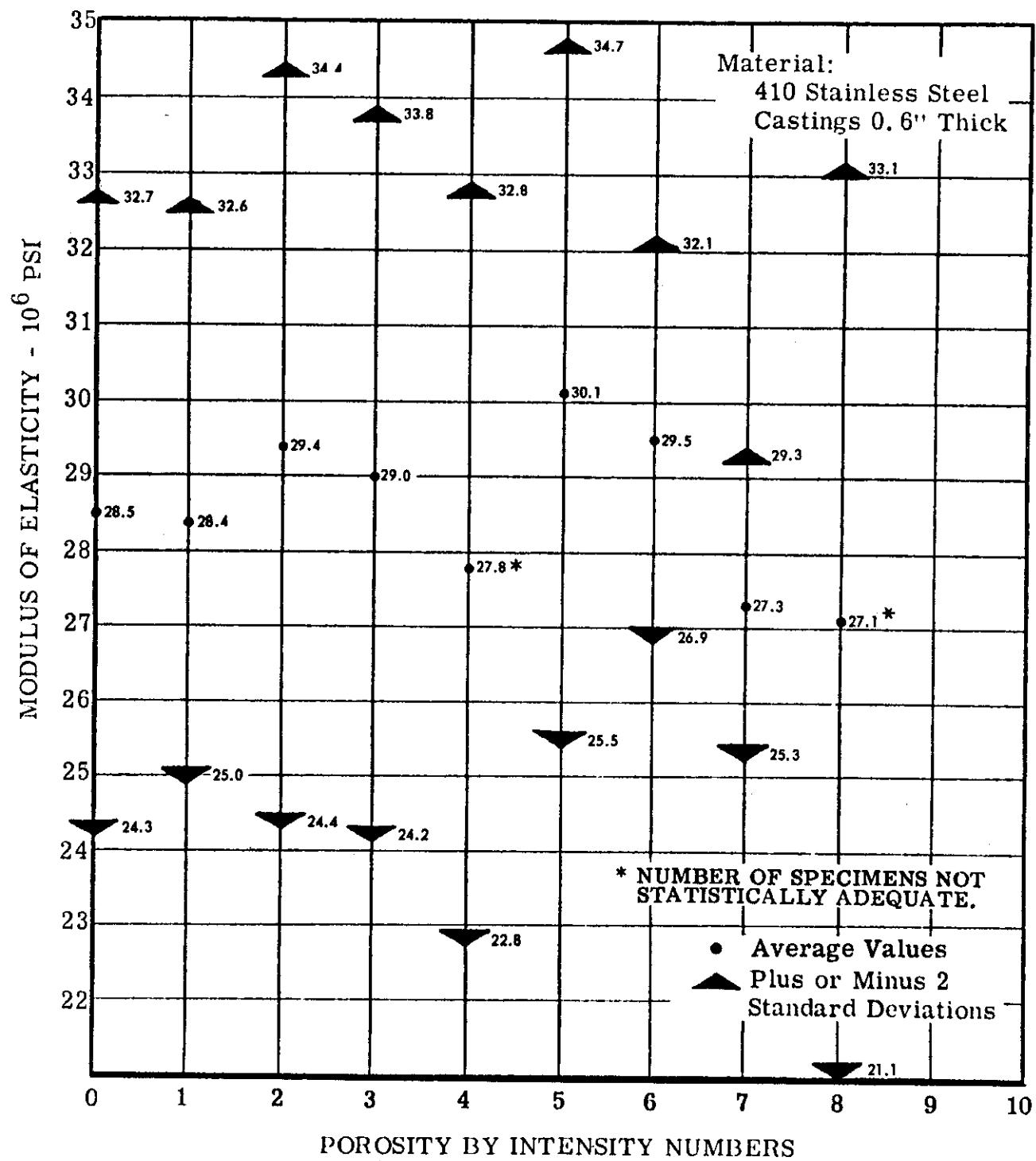


Figure 114. Modulus of Elasticity vs Porosity - Range of Values

WADD TR 60-450

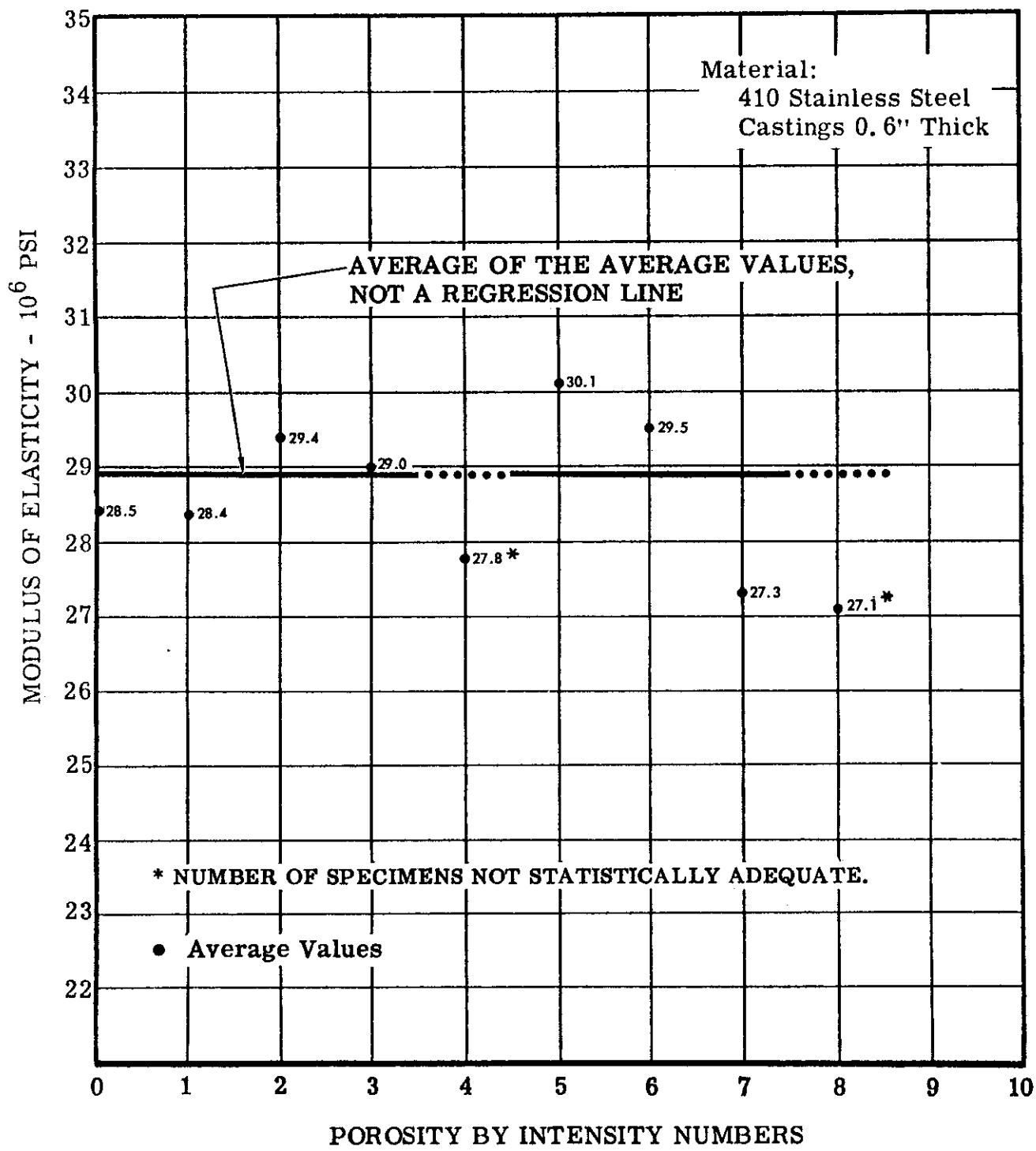


Figure 115. Modulus of Elasticity vs Porosity - Correlation

5.49 SUMMARY OF RESULTS - TENSILE YIELD VS. GAS POROSITY - 0.2" and 0.3" MATERIAL (COMBINED)

Control Specimens	Size of Gas Porosity (in millimeters)	1	2	3	4	5	6	7	8	9	10	11	12
Number of specimens tested -	113	*	1	2	*	3	3	8	6	3	5	3	2

Statistically determined number required for 0.95 confidence that the average of the results approaches the true average -

These values were not computed. In most cases it was recognized that the number of specimens was not statistically adequate.

Test data (Individuals)	**	-	137	145	-	143	138	143	144	152	140	146	138
			143			144	137	137	142	142	144	140	140
						142	162	134	143	138	136	150	
								144	134	152			
								134	137	150			
								145	113				
								143					
								154					
Tensile yield (Average of test results)		146	-	137	144	-	143	146	142	136	144	145	139

The estimate of the standard deviation and statistical limits for individuals were not computed.

CORRELATION ANALYSIS

Analysis was not made; no trend toward lower values, as size of gas porosity increased, was present. Also, number of specimens was not statistically adequate.

-
- * No specimens available with 1-mm-or 4-mm-size gas porosity
 - ** Values are listed in Appendix A, paragraphs A13.1 and A25.1

Contrails

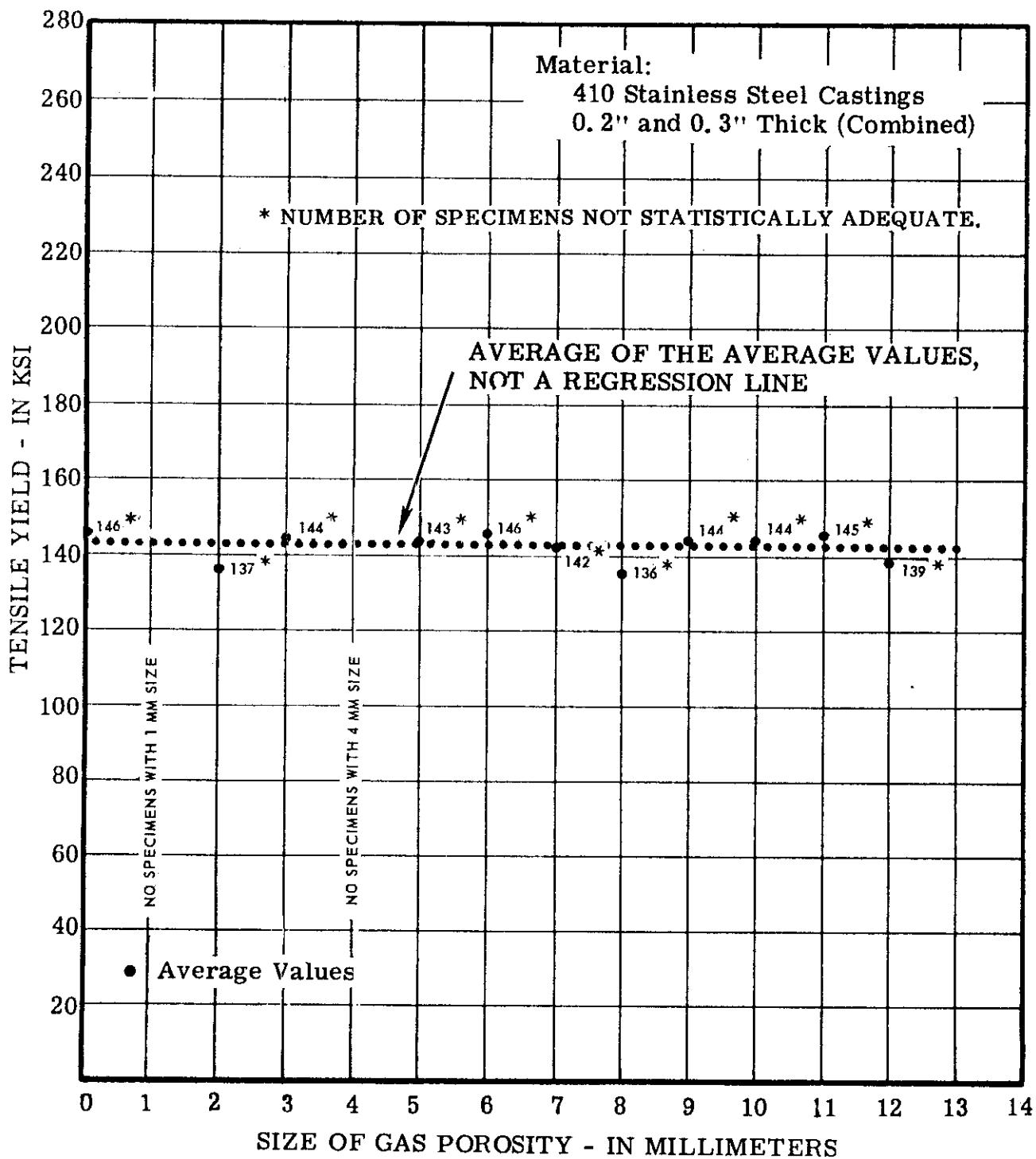


Figure 116. Tensile Yield vs Gas Porosity - Correlation.

5.50 SUMMARY OF RESULTS - TENSILE ULTIMATE VS. GAS POROSITY - 0.2" AND 0.3" MATERIAL (COMBINED)

Number of specimens tested -	Control Specimens	Size of Gas Porosity (in millimeters)								<u>11</u>	<u>12</u>
		<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>		
113	*	1	2	*	3	4	8	6	3	5	3

Statistically determined number required for 0.95 confidence that the average of the results approaches the true average -

These values were not computed. In most cases it was recognized that the number of specimens was not statistically adequate.

Test data (Individuals)

**	-	174	196	-	182	172	180	181	159	167	158
		179			165	189	175	157	185	190	179
					179	194	164	115	176	159	171
						214	164	176		178	
							178	171		165	178
							187	179			163
								190			176

Tensile ultimate (Average of test results)

198

-

174

187

-

175

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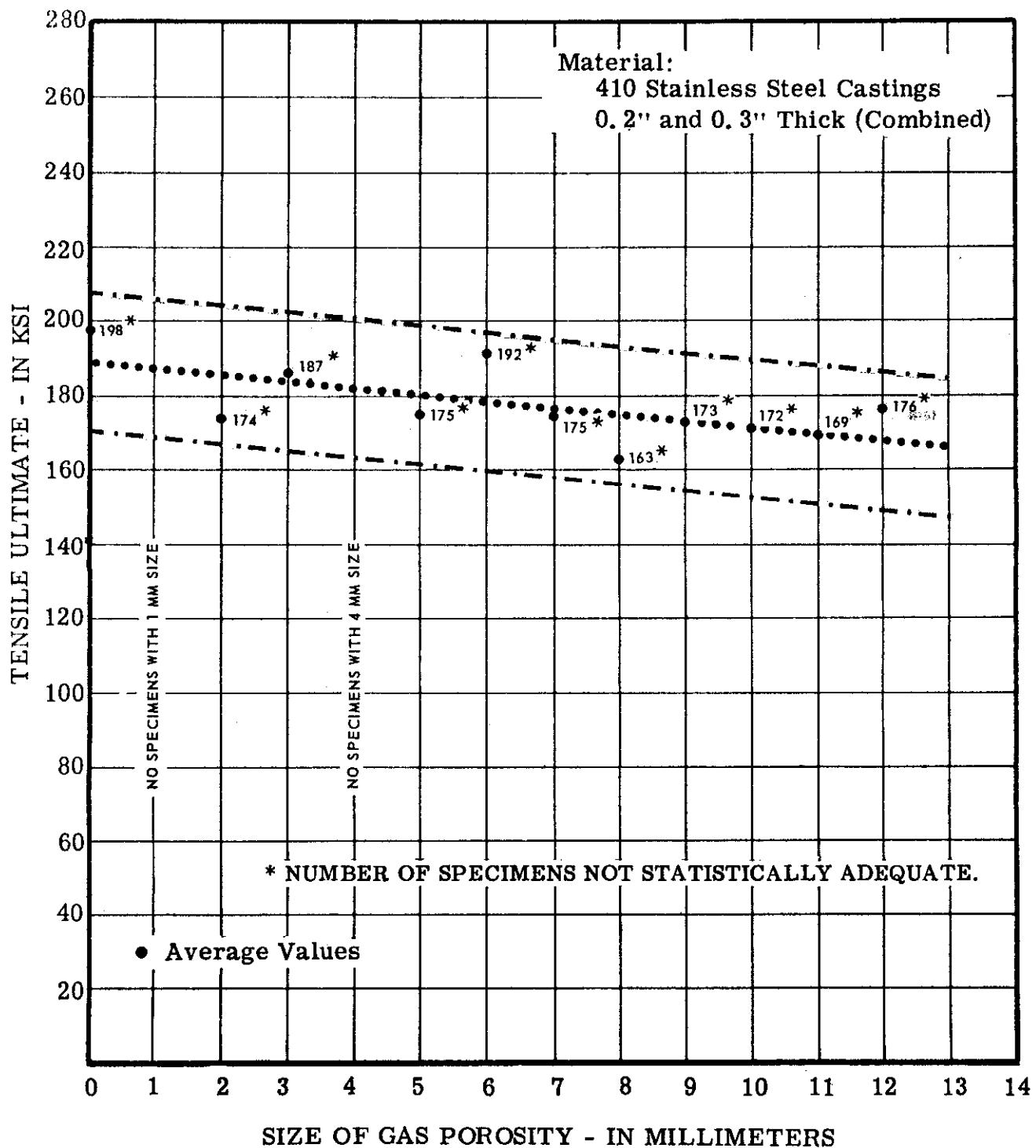


Figure 117. Tensile Ultimate vs Gas Porosity - Correlation

WADD TR 60-450

5.51 SUMMARY OF RESULTS - ELONGATION VS. GAS POROSITY 0.2" AND 0.3" MATERIAL (COMBINED)

		Size of Gas Porosity (in millimeters)													
		Control	Specimens	1	2	3	4	5	6	7	8	9	10	11	12
Number of specimens tested -	113	*	1	2	*	3	4	8	5	3	5	3	5	3	2
Statistically determined number required for 0.95 confidence that the average of the results approaches the true average -															

These values were not computed. In most cases it was recognized that the number of specimens was not statistically adequate.

Test data (Individuals)	**	-	2.0	4.0	-	4.0	2.5	2.5	2.5	3.0	2.5	3.0	2.5	3.0
			3.5			4.5	3.0	2.5	3.0	5.5	4.0	2.0	3.5	
						2.0	1.5	2.5	2.0	2.0	3.5	2.5		
							2.0		2.5	3.0		3.5		
									5.5	2.5				
Elongation (Average of test results)			7.6	-	2.0	3.8	-	3.5	2.3	3.4	2.6	3.5	4.1	2.5

The estimate of the standard deviation and statistical limits for individuals were not computed

CORRELATION ANALYSIS

Analysis was not made; no trend toward lower values, as size of gas porosity increased, was present. Also, number of specimens was not statistically adequate.

* No specimens available with 1-mm-or 4-mm-size gas porosity

** Values are listed in Appendix A, paragraphs A13.1 and A25.1

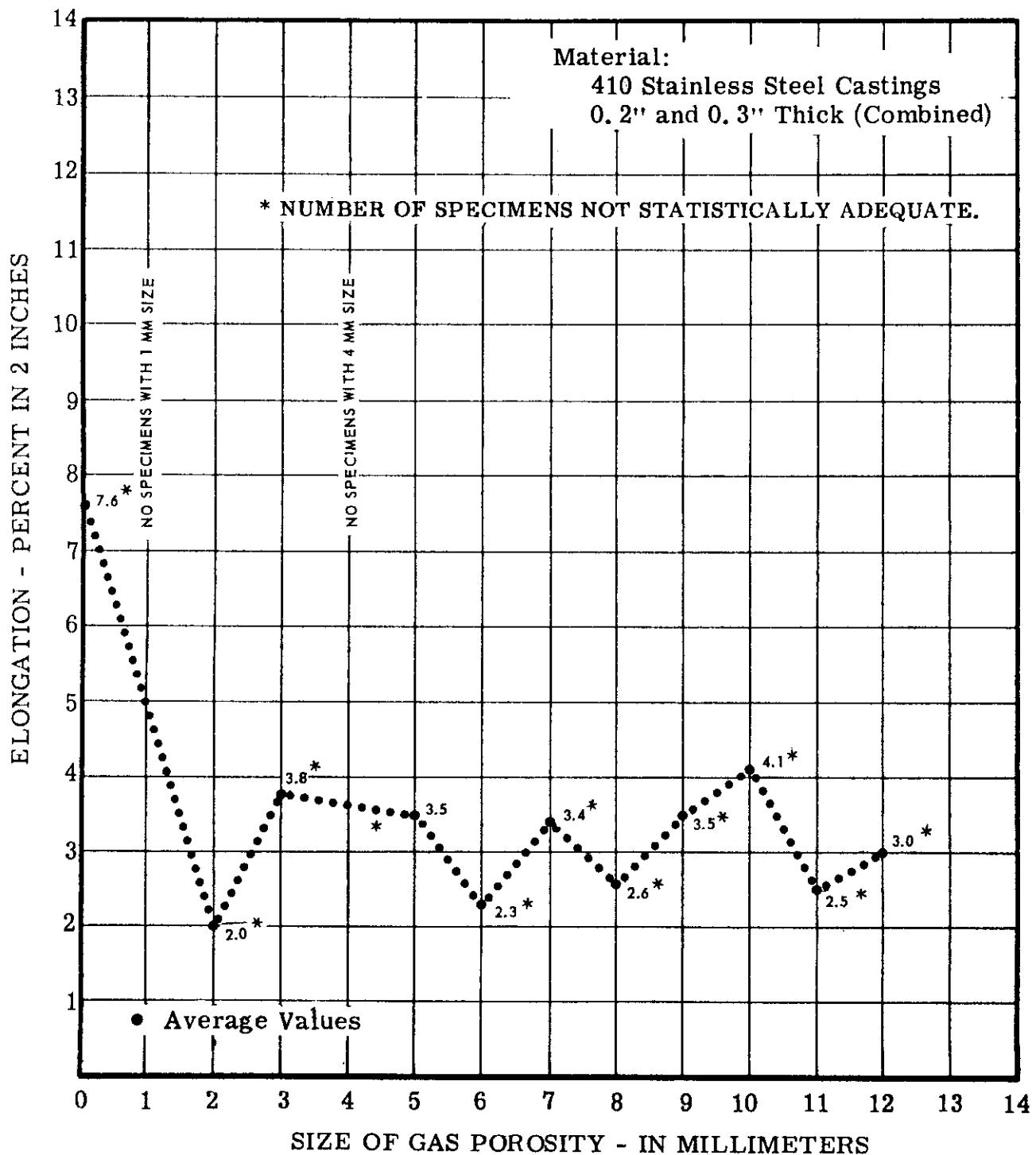


Figure 118. Elongation vs Gas Porosity - Correlation

5.52 | SUMMARY OF RESULTS - MODULUS OF ELASTICITY VS. GAS POROSITY 0.2" AND 0.3" MATERIAL (COMBINED)

	Control Specimens	Size of Gas Porosity (in millimeters)										<u>12</u>
		<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>	<u>10</u>	
Number of specimens tested -	113	*	1	2	*	3	4	8	6	3	5	2

Statistically determined number required for 0.95 confidence that the average of the results approaches the true average -

These values were not computed. In most cases it was recognized that the number of specimens was not statistically adequate.

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Test data (Individuals)	*	-	30.7	30.2	-	28.0	30.4	28.0	29.5	28.4	28.7	29.2
			26.1	26.7	29.8	28.7	28.4	27.2	27.2	27.2	26.8	30.0
				28.2	30.0	30.6	29.3	26.9	26.9	28.4		
					28.0	31.4	29.7					
						31.2	29.0	27.5	27.5			
							27.8	25.9	27.7			
								31.2	31.2			
									27.7			

29.6

Modulus of Elasticity (Average of test results)

29.2 - 30.7 28.2 - 27.6 29.6 29.6 28.6 28.2 28.1 26.8 29.6

The estimate of the standard deviation and statistical limits for individuals were not computed

CORRELATION ANALYSIS

Analysis was not made; no trend toward lower values, as size of gas porosity increased, was present. Also, number of specimens was not statistically adequate.

- * No specimens available with 1-mm-or 4-mm-size gas porosity
** Values are listed in Appendix A, paragraphs A13.1 and A25.1

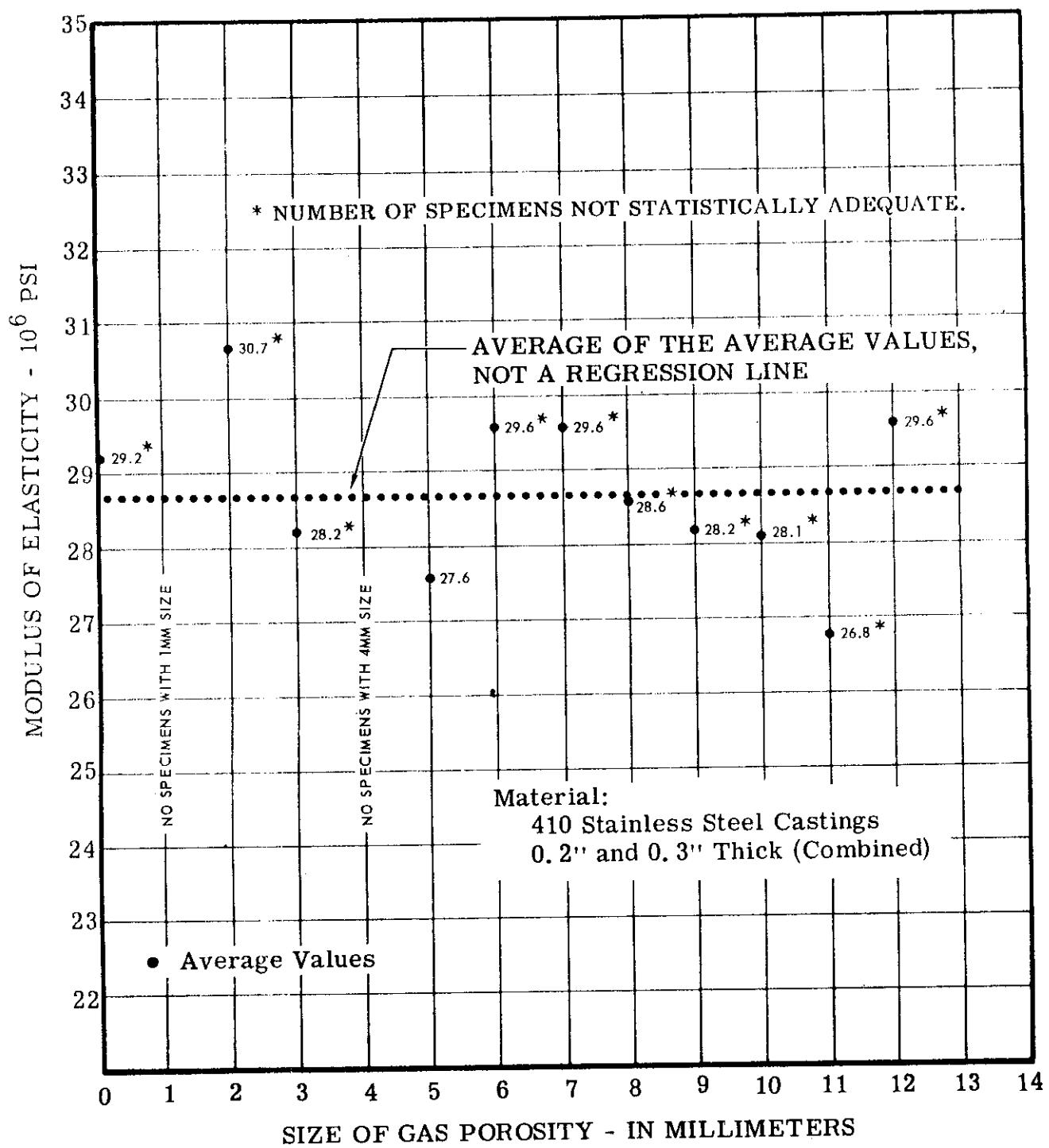


Figure 119. Modulus of Elasticity vs Gas Porosity - Correlation

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Contrails

CORRELATION OF TENSILE PROPERTIES
OF STEEL CASTINGS AND MATERIAL
IMPERFECTIONS AS DETERMINED
BY RADIOGRAPHY

6. DISCUSSION OF TEST RESULTS

WADD TR 60-450

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Controls

6. DISCUSSION OF TEST RESULTS

6.1 Correlation of Tensile Properties to Material Imperfections:

6.1.1 General -

Figures 120, 121 and 122 summarize the entire spectrum of test results obtained with material having intentionally introduced imperfections: gas holes, inclusions, and porosity, respectively. The averages of the tensile properties, except for modulus of elasticity, are plotted against the size or intensity of the imperfection. Modulus-of-elasticity results were not plotted because they did not indicate any reduction in value, as the size or intensity of the imperfection increased. Modulus averages for each type of flaw and thickness of material are listed below:

<u>Type of Imperfection</u>	<u>Thickness of Casting (in inches)</u>	<u>Average Modulus of Elasticity (in 10^6 psi)</u>
Gas Holes	0.1	28.7
	0.2	29.5
	0.3	28.9
	0.6	28.3
Inclusions	0.1	28.1
	0.2	29.3
	0.3	28.9
	0.6	28.6
Porosity	0.1	29.4
	0.2	29.2
	0.3	29.0
	0.6	28.8

There is a tendency for the modulus values to drop off slightly as the thickness of the casting increases. However, 0.1"-thick castings containing gas holes and inclusions gave results counter to this trend.

The averages of results of tensile-property testing at the foundry for all 41 heats (all thicknesses) are listed below. In addition, Convair test results obtained with control coupons (no defects) for 40 heats (0.1"-, 0.2"- and 0.3"-thick material) and for 23 heats (0.6"-thick material) are listed.

Contrails

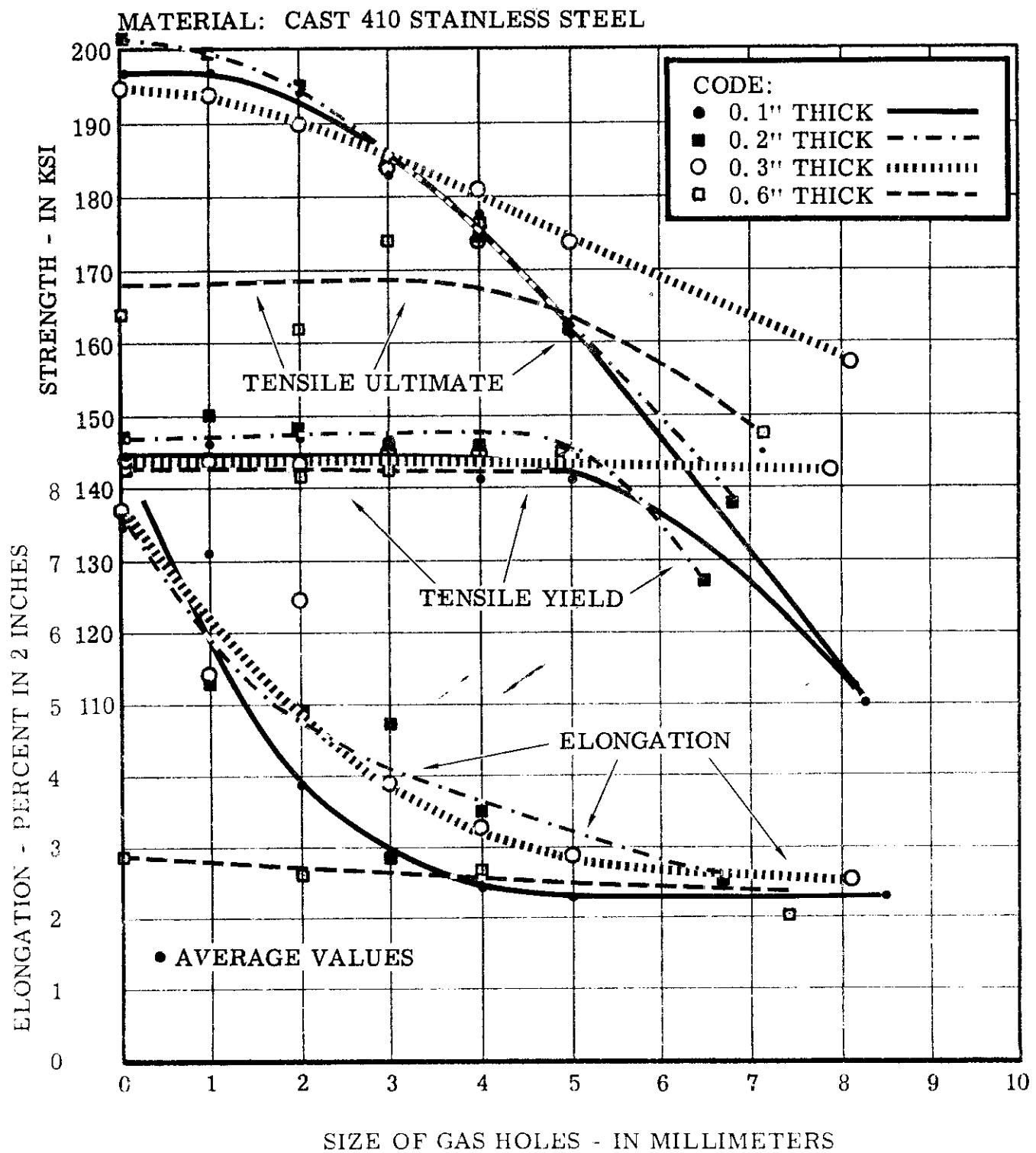


Figure 120 Tensile Properties vs Gas Holes

WADD TR 66-450

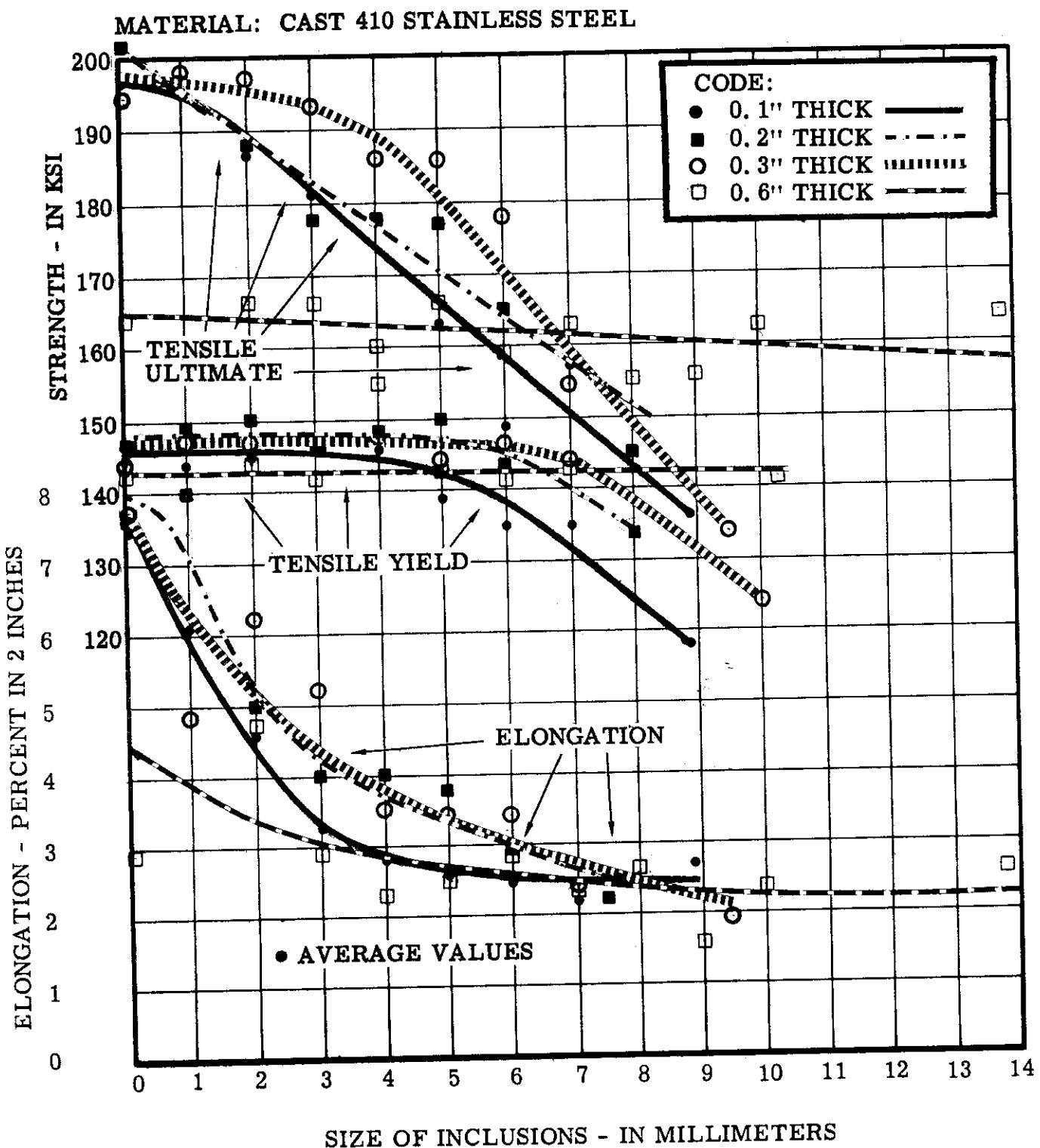


Figure 121 Tensile Property Values vs Inclusions

WADD TR 60-450

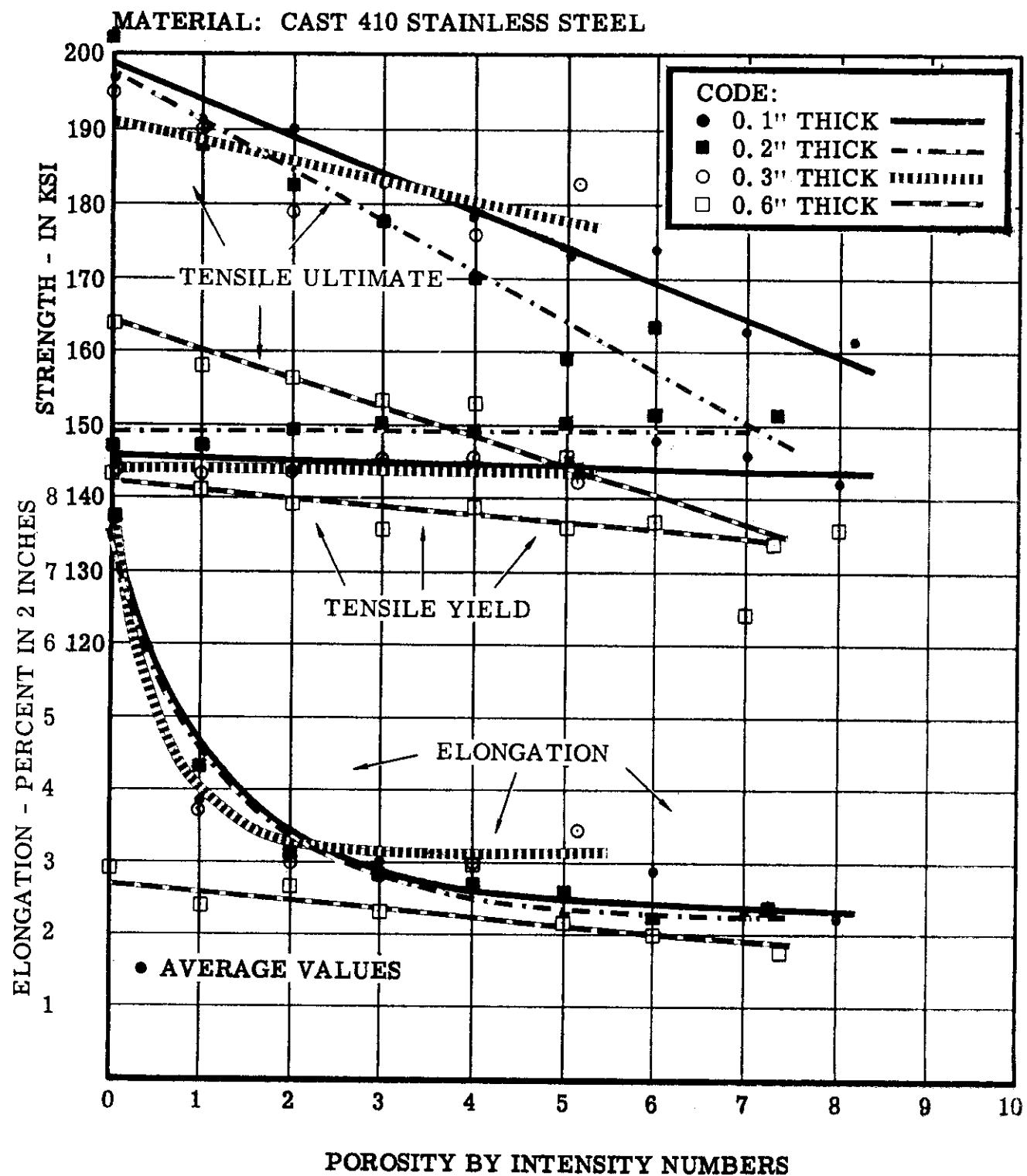


Figure 122 Tensile Properties vs Porosity

WADD TR 60-450

Controls

6.1.1 General - (continued)

COMPARATIVE TENSILE TEST RESULTS

	Tensile Yield (ksi)	Tensile Ultimate (ksi)	Elongation % in 2"
FOUNDRY TESTS			
41 Heats (all thicknesses) ¹	152.3	190.7	9.5
CONVAIR TESTS			
40 Heats (150 coupons) ² - 0.1", 0.2" and 0.3" thick	147.1	193.0	7.5
23 Heats (103 coupons) ³ - 0.6" thick	143.2	162.4	2.9

Test results with control coupons (no defects) at Convair for 0.1"-, 0.2"- and 0.3"-thick material are generally comparable to foundry results. Percent elongation is low; this is probably due to coupon configuration, and the fact that the surfaces of the flat coupons were in the foundry-prepared condition. Results with the 0.6"-thick control coupons are unusually low. This fact is more fully discussed in paragraph 6.2.

In addition to the results with the 0.6"-thick control coupons being low, test results with the 0.6"-thick castings, containing intentionally introduced imperfections, were also unusually low. This condition was particularly evident, with the ultimate-strength and percent-elongation tests when flaw sizes or intensities were small.

The effects of imperfections on the 0.1"-, 0.2"- and 0.3"-thick castings generally follow similar patterns for each thickness.

The relationships between tensile yield and material imperfections followed similar patterns in all cases. With gas-hole and inclusion imperfections, the tensile yield dropped off as the tensile-ultimate values approached to 20 ksi and less of the yield strength. This tendency to depress the yield strength was not apparent with test specimens having porosity imperfections. Yield strength is apparently not affected by an increase in the thickness of the castings.

Regression curves for percent elongation drop off much more rapidly as a result of low-intensity porosity than they do with small gas-hole and inclusion imperfections. The general pattern of the relationship, however, remains the same. The main reason for dividing porosity

-
1. Type R-1 coupons per Federal Test Methods Std. 151, Method 211
 2. Type F-2 coupons per Federal Test Methods Std. 151, Method 211
 3. "Special" coupons. See paragraph 2.4.3, this report.

Controls

6.1.1 General - (continued)

imperfections into intensities, differing by small amounts, was in consideration of the rapid loss in percent elongation values.

Before the regression curves for tensile-ultimate test results were plotted, test results were first adjusted by relating the average tensile-ultimate test results to an average Rockwell hardness reading. A base of Rockwell C-42, was chosen, since it represented the value closest to the average, for most of the tensile-coupon hardness values. In the majority of cases, this adjustment improved the relationship between tensile ultimate and the flaw size or intensity, i.e., the plot of the tensile results against the flaw size or intensity was generally more uniform after the adjustment was applied. There were a few cases, however, where this improvement did not materialize.

Procedure was as follows: From tensile-ultimate/Rockwell-hardness charts^{1,2}, the difference in tensile-ultimate values for Rockwell readings between C-39.1 and C-45.7 is 35 ksi. This averages out at 0.53 ksi for each 0.1 Rockwell-C hardness increase. Applying this ratio to test results from this project, we

- (1) Increased the tensile-ultimate value by 0.53 ksi for each 0.1 Rockwell-C hardness value that it tested, below Rockwell C-42.
- (2) Reduced the tensile-ultimate value by 0.53 ksi for each 0.1 Rockwell-C value that it tested, above Rockwell C-42.

The effects of gas holes and inclusions on the tensile-ultimate values decrease as the thickness of the casting increases. No corresponding trend is apparent when considering tensile-ultimate values in relation to porosity and casting thickness.

6.1.2 Gas-Hole Imperfections -

The tensile-ultimate regression curves for 0.1"-and 0.2"-thick material, Figure 120, tend toward convexity. The curve for 0.3"-thick material more nearly approaches a straight line. Yield strength held constant until it was approached within 20 ksi or less by the tensile-ultimate results. Depressed tensile-yield values are apparent with the 0.1"-and 0.2"-thick castings. Percent-elongation values drop off rather rapidly, with values for the 0.1"-thick material dropping off most rapidly.

The maximum size of gas holes to meet a set of minimum values for various tensile properties follows:

-
1. American Society for Metals, Metals Handbook, Cleveland: 1948, p. 100.
 2. Federal Test Methods Standards No. 151, Method 241, 17 July 1956.

Controls

6.1.2 Gas-Hole Imperfections - (continued)

<u>Tensile Property</u>	<u>Minimum Value</u>	<u>Casting Thickness (in inches)</u>	<u>Maximum Gas-Hole Size (mm)</u>
Ultimate Strength	175,000 psi	0.1	Approx. 4
		0.2	" 4
		0.3	" 4
Yield Strength	135,000 psi	0.1	Approx. 6
		0.2	" 6
		0.3	Over 8
Percent Elongation	6 percent	0.1	Approx. 1
		0.2	" 1
		0.3	" 1

6.1.3 Inclusion Imperfections -

A straight line or a convex relationship is seen when tensile-ultimate values are plotted against the size of inclusions (Figure 121). In this case, the 0.3"-thick material displays the convex tendency.

For each tensile property, the pattern of the curves are similar to the gas-hole patterns, the yield dropping-off when depressed by low ultimate values. The slopes of the percent-elongation, and ultimate-strengths curves are similar. The tendency for the thinner castings to be affected to a greater degree is more pronounced with material having inclusion imperfections.

The maximum size of inclusions to meet a set of minimum values for various tensile properties follows:

<u>Tensile Property</u>	<u>Minimum Value</u>	<u>Casting Thickness (in inches)</u>	<u>Maximum Inclusion Size (mm)</u>
Ultimate Strength	175,000 psi	0.1	3 plus
		0.2	4 plus
		0.3	5 plus
Tensile Strength	135,000 psi	0.1	6 plus
		0.2	7 plus
		0.3	8 plus
Percent Elongation	6 percent	0.1	Approx. 1
		0.2	1 plus
		0.3	1 plus

Controls

6.1.4 Porosity Imperfections -

Figure 122 illustrates the relationships between the tensile properties and porosity imperfections. The ultimate-strength relationship shows a tendency to vary from a straight line to slightly concave curve. The degree of concavity appears to increase with the thickness of the casting. There is no tendency for thinner castings to be more affected by a given intensity of porosity than thicker castings. This is because the same degree of porosity in a thicker casting requires a relatively greater amount of porosity. The yield strength does not display any tendency to drop-off as the ultimate approaches the yield values. The percent elongation does drop-off very rapidly with porous material, even when the intensity is low.

The maximum intensity of porosity to meet a set of minimum requirements for various tensile properties follows:

<u>Tensile Property</u>	<u>Minimum Value</u>	<u>Casting Thickness (in inches)</u>	<u>Maximum Porosity Intensity</u>
Ultimate Strength	175,000 psi	0.1	Approx. 5
		0.2	3 plus
		0.3	5 plus
Yield Strength	135,000 psi	0.1	Over 8
		0.2	Over 7
		0.3	Over 5
Percent Elongation	6 percent	0.1	Approx. 1/3
		0.2	" 1/3
		0.3	" 1/3

6.1.5 Gas-Porosity Imperfections -

As many examples of gas porosity as possible were obtained from coupons available. Gas porosity, when viewed microscopically, appears as fine gas holes, as shown in Figure 123. Shrink porosity on the other hand is an intergranular condition. The radiographs of gas porosity usually appears star-shaped with numerous "fingers" radiating from a "focal point" (Figure 124). The mechanics of the formation of gas-type porosity are apparently related to the collapse of a gas bubble during the casting process. Since partially cooled molten metal is somewhat sluggish, complete exhausting of the gas, when a bubble collapses, does not occur. The residual gas forms "fingers" around the position of the original gas hole. The point where the gas escapes from the casting appears as a "focal point" from which the "fingers" radiate. The "focal point" of the gas-porosity "star" usually extends to the casting surface, giving evidence that it was at this point that the gas of the collapsing bubble escaped.

Contrails

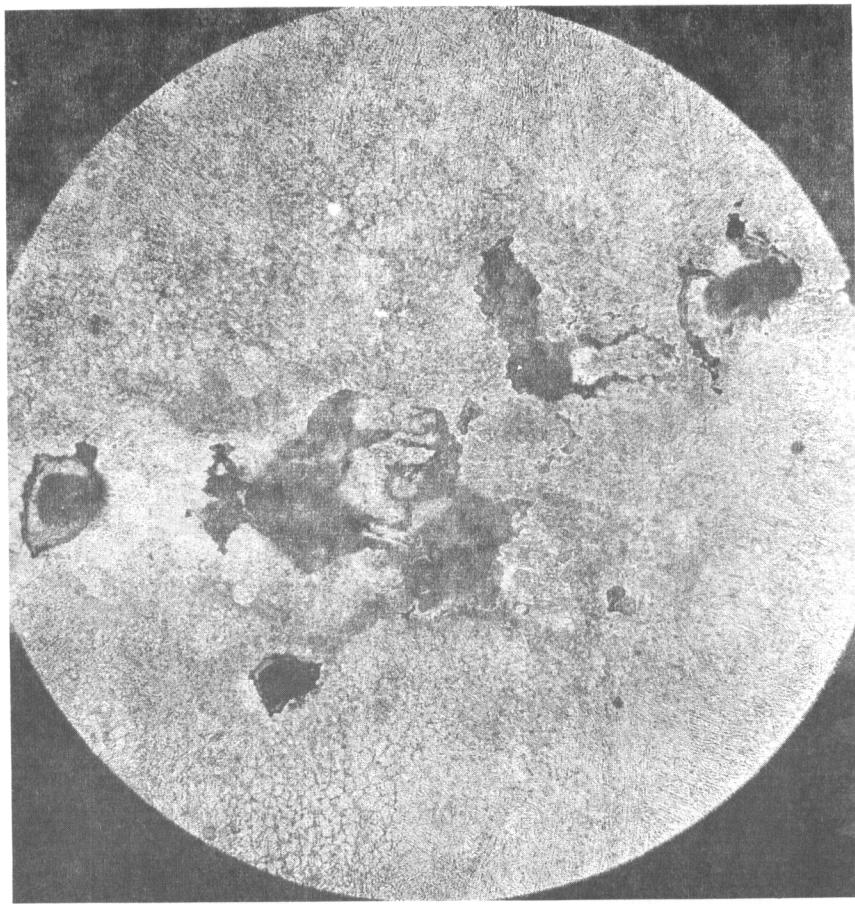


Figure 123 Photomicrograph Showing Gas-Type Porosity Voids in Network Area (Shown Below). Magnification 60X

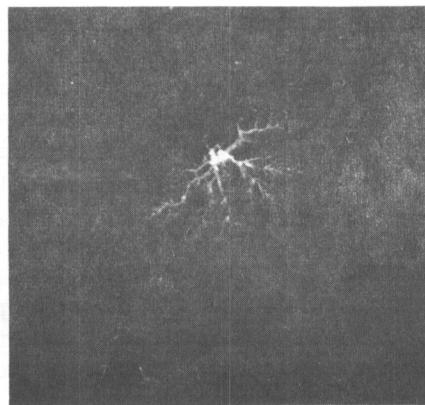


Figure 124 Print of an X-ray Film Showing Gas-Type Porosity.

Controls

6.1.5 Gas-Porosity Imperfections - (continued)

For the most part, all the test specimens which fractured in the gas-porosity areas were 0.2"- and 0.3"-thick coupons. A number of 0.6"-thick coupons which contained gas porosity fractured in positions other than gas-porosity areas, areas which usually contained low-intensity shrink porosity, or areas free of imperfections. The gas-type-porosity specimens were graded by measuring the maximum size of the area covered by the "fingers"; they were grouped into one-millimeter-size categories, the same as was done with gas-hole and inclusion imperfections. The summaries of test results and graphical displays for gas-porosity imperfections are covered in pages 193 thru 200. The regression line for ultimate strength shows that the effect of this type of porosity is not severe, in comparison to other types of material imperfections. Wherever a tensile test coupon contained another type of imperfection, along with gas porosity, it almost invariably fractured in the area having the other type of imperfection, or in an area free from flaws. The yield strength was not affected by gas porosity. The effect on percent elongation, however, was drastic, resulting in a sharp drop in elongation when any gas porosity was present. Percent elongation for gas-type porosity levelled-off slightly above the levelling-off point for shrink porosity (approximately 3.5%, compared to 2.75%). The number of specimens having gas-porosity imperfections, was not sufficient to justify a statistical analysis.

6.1.6 Test Coupons - A Recapitulation of, -

A total of 1608 test coupons were obtained from the cast slabs. The division of coupons among the thicknesses tested is listed below:

<u>Material Thickness</u>	<u>Number of Coupons Tested</u>
0.1"	405
0.2"	409
0.3"	391
0.6"	<u>403</u>
Total -	1608

Fifty three coupons were disqualified from consideration due to fracturing in the grip or radius areas, or to cracks, mostly the hot-tear type, or to cold shuts. Many coupons containing gas holes or inclusions actually fractured in areas which were free from imperfections. When this happened, the coupons were classified as control (defect-free) coupons. When the statistical analysis was made, the coupons which contained gas holes and inclusions, but which fractured in control areas, free of imperfections, were included in the flaw category as well as in the control (defect-free) category. For example, coupons having gas-hole imperfections (0.6"-thick material) fractured in control (defect-free) areas up to 87% in one case. Coupons having inclusions (0.6"-thick material) fractured in areas free from imperfections up to 70% in one case. The number of coupons containing gas

Controls

6.1.6 Test Coupons - A Recapitulation of, - (Continued)

holes or inclusions, which fractured in imperfection-free areas, was much less with the thinner castings. For example, the maximum percent of imperfection-free fractures occurring in any gas-hole category for 0.2"-thick castings was only 30%. Coupons having imperfections which fractured in flaw-free areas usually displayed a higher percent elongation, on the average, than those which fractured in the flaw area. For 0.6"-thick material, however, this was not apparent.

Classifying coupons, as stated above, can be justified because, in determining strength of cast material, we are endeavoring to find the strength of the material having imperfections, whether the fracture occurred in the flaw area, or not. Many castings which contained imperfections failed in areas which are radiographically free of imperfections. In effect, we are analyzing strength-to-imperfection relationships under intentionally imposed conditions, by the technique employed in this project.

When porosity imperfections were present, the fracture almost invariably occurred in the porous area. In addition, if a gas hole or an inclusion was present in a coupon containing porosity, the fracture was almost invariably in the porous area. Exceptions occurred only when the gas-hole or inclusion was very large. A plausible explanation for this fracture pattern is that it was due to the sharp drop in elongation values whenever porosity was present. The strain, occurring after the yield strength had been obtained, during testing, tends to pinpoint the fracture within porous areas, because of the low degree of elongation in the porous material.

Because of the conditions explained above, many coupons which were intended for gas-hole or inclusion tests were transferred to porosity categories after a review of the fracture areas. Therefore, less coupons were categorized as gas-hole and inclusion imperfections and a larger number of specimens was classified as having a porosity-type imperfection.

6.1.7 Confidence in the Test Results -

The number of samples required for 0.95 probability, in order that the average of the test results approached, within an allowable error, the true population average, were available for most of the tensile-yield and modulus-of-elasticity determinations. Values obtained indicate that both properties tend not to be affected by flaw size or intensity. The yield-strength results for gas-hole and inclusion imperfections were usually depressed when the tensile-ultimate values approached to within 20 ksi of the yield strength. This relationship and attendant depression of the tensile yield was not evident until after the ultimate strength had reached a value well below the minimum, usually specified for Type -410 cast steel, i.e., 175 ksi.

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6.1.7 Confidence in the Test Results - (continued)

Adequacy of sampling for tensile-ultimate values was usually achieved. For some imperfections, causing marginally reduced values, slightly over 175 ksi, we did not have a statistically adequate number of samples. However, sufficient evidence was obtained in adjacent areas to produce a definite trend in the regression curves. By extrapolating the regression curves thru areas of inadequate sampling, there is sufficient evidence to indicate reliable values for the marginal areas. Usually, sampling was insufficient only in those categories where the values were already well below useful, structural requirements, i.e., strength areas from which castings would not be applied to aeronautical applications.

6.1.8 Statistical Adequacy of Number of Specimens Required for Percent Elongation Tests -

The statistical analysis of the results of percent-elongation tests, for adequacy of number of samples, was computed by using an acceptable error term equal to 0.15 (15%) of the mean value. Adequacy of number of samples for other tensile properties was computed by using an acceptable error term of 0.05 (5%) of the mean value. To have used this same error term (0.05) for % elongation would not have been realistic. The minimum increment to which elongation test results are normally read amounts to 1/2 of one percent (0.01" in 2"). A 6% elongation result, subject to an error in reading of 1/2 of one percent, may introduce an error in the reported results of 8.33%. That is because 1/2 of 1% is 1/12th of 6%, or 8.33% of the result reported. Sometimes, values of percent elongation are subject to reading errors having even higher percentages. For instance, 1/2 of 1% is 1/6th of 3% or 16.66%. Since the percent-elongation test results in this project vary quite extensively, the 0.15 acceptable error figure does not appear unreasonable. Even with this relatively high value, there were still many categories for which the determination of the number of samples required for statistical adequacy far exceeded the number of specimens tested.

6.2 Abnormally Low Tensile-Ultimate Strength and Percent Elongation for 0.6"-Thick Test Coupons:

Figures 120, 121 and 122 indicate that the results of tensile-ultimate and percent-elongation tests for the 0.6"-thick coupons were abnormally low. An investigation was made to determine if a plausible explanation for the low results could be found. It has been reported that considerable difficulty was experienced in accurately testing these larger coupons and, because of this, parts of the group were tested at three different locations. The principal difficulty was maintaining a firm grip on the test coupons. The cross section of the gage area of these coupons was 0.6" square inches, and on many occasions loads of over 100,000 pounds had to be transmitted from the test jaws to the test coupons. It wasn't until a relatively new test machine, having new test jaws, was used that the test procedure could be conducted without experiencing gripping troubles. One facet of the investigation of causes of low test results was to determine if significantly

Controls

6.2 Abnormally Low Tensile-Ultimate Strength and Percent Elongation for 0.6"-Thick Test Coupons: (continued)

different results were obtained at the three different test locations.

Tests performed at the three locations were separated into groups according to test location. Tensile-ultimate test results, for specimens containing intensity-1 porosity, were selected for an analysis of variance because this defect category had the largest number of specimens tested at each of the three locations. The analysis of variance was chosen because it is a statistical technique that discerns with a high degree of probability (0.95) whether there is any difference in the average test results, because of the specimens having been tested at three different locations. Tensile ultimate test data and the analysis of variance follows.

TENSILE TEST RESULTS; TESTS RUN AT THREE LOCATIONS

(0.6"-thick material, having an intensity-1 porosity imperfection)

	Location (1)		Location (2)		Location (3)	
	Tensile Ultimate (ksi)	Column One <u>Squared</u>	Tensile Ultimate (ksi)	Column Two <u>Squared</u>	Tensile Ultimate (ksi)	Column Three <u>Squared</u>
	141.2	19,940	167.0	27,890	167.3	27,990
	149.6	22,380	169.2	28,630	-	-
	158.2	25,030	170.8	29,170	-	-
	155.7	24,240	178.9	32,010	Balance of data is in Appendix A, para-	
	147.7	21,820	152.7	23,320	graph A46.2	
	157.0	24,650	149.4	22,320		
	146.5	21,460	133.9	17,930		
	-	-	166.2	27,620	170.0	28,900
Totals:	1055.9	159,520	1288.1	208,890	13,527.6	2,102,610
Average	150.8	22,789	161.0	26,111	153.7	23,893
Number of Tests:	7 at location (1)	8 at location (2)	88 at location (3)			

ANALYSIS OF VARIANCE TABLE

<u>Source of Variation</u>	<u>Degrees of Freedom</u>	<u>Sum of Squares</u>	<u>Mean Sum of Squares</u>	<u>F Ratio</u>
Between locations	v-1	SST	MSt	MSt/MSE
Within locations	n-v	SSE	MSE	
Totals	n-1	SST		

Controls

ANALYSIS OF VARIANCE TABLE (continued)

v = Number of locations = 3; v - 1 = 2

n = Number of test specimens = 103; n - v = 100

Correction factor = $(1055.9 + 1288.1 + 13,527.6)^2 / 103 = 2,445,706$

SST = 159,520 + 208,890 + 2,102,610 - 2,445,706 = 25,314

SSt = $(1055.9)^2 / 7 + (1288.1)^2 / 8 + (13,527.6)^2 / 88 - 2,445,706 = 468$

SSE (by difference) = 25,314 - 468 = 24,846

MSt = SSt/v - 1 = 468/2 = 234

MSE = SSE/n-v = 24,846/100 = 248

F ratio = MSt/MSE = 234/248 = 0.94

Reconstructing the Analysis of Variance Table we now have:

<u>Source of Variation</u>	<u>Degrees of Freedom</u>	<u>Sum of Squares</u>	<u>Mean Sum of Squares</u>	<u>F Ratio</u>
Between locations	2	468	234	0.94
Within locations	<u>100</u>	<u>24,846</u>	248	
Totals:	102	25,314		

The observed mean squares ratio, 0.94, does not exceed the critical tabulated F-value (3.10)¹ for 2 and 100 degrees of freedom. The hypothesis that there is no difference between test results obtained at the three different locations is accepted, and it can be concluded that testing procedure was not a factor in the abnormally low test results.

An inspection of the fractured tensile coupons was made to determine if poor elongation was due to poor sample preparation or test technique. The surface condition of the coupons were found to be good. The light sand blast after heat treatment left the surface very uniform from sample to sample. The jaw-grip areas indicated a lack of eccentric loading during the test operation. No evidence could be found to indicate that the test technique was in any way responsible.

In order to determine if the heat treatment resulted in uniform hardness throughout the test-coupon cross sections, a few coupons were

¹ibid, p. 618, footnote 2, p. 39, this report

Controls

6.2 Abnormally Low Tensile-Ultimate Strength and Percent Elongation for 0.6"-Thick Test Coupons: (continued)

sectioned for hardness tests. In general, the surface hardness of the 0.6"-thick coupons was similar to the surface hardness of the thinner coupons. The cross section hardness results of the 0.6"-thick coupons indicated a very uniform hardness from the surface to the center of the coupons as follows:

Test No.	Edge Hardness (Subsurface) Rockwell C	Center Hardness Rockwell C
1	43.0 - 44.0	43.0 - 44.0
2	43.5 - 44.0	43.5 - 44.5
3	42.0 - 44.0	42.0 - 43.0
4	42.0 - 44.5	43.5 - 44.0

Microscopic examination of these coupons showed no apparent differences in structure from the surface to the center. It can be concluded that the heat treatment of the coupons resulted in a uniform strength level throughout the cross section and that edge hardness was representative of the full cross section. The heat treatment could not, therefore, be considered a factor in causing the abnormally low test results.

For lack of definite evidence, it was decided to determine if the relatively large, rectangular cross section of the test coupons was a factor in causing low test results. Therefore, two test coupons 0.2" thick, were machined from the center of the 0.6"-thick casting and two other coupons, 0.2" thick, were machined, keeping one surface in the as-foundry-prepared condition. Two coupons, therefore, represented surface material and two represented center material of the 0.6"-thick castings. They were all machined to type F-2 coupons the same as were used for the 0.1", 0.2" and 0.3"-thick castings. The material used in preparing these test specimens was from a cast slab from which two control coupons had previously been tested in full 0.6"-thick section. The results of the original 0.6"-thick control-coupon tests and the four 0.2"-thick, type F-2 coupon tests, cut from the same cast slab follows:

Controls

6.2 Abnormally Low Tensile-Ultimate Strength and Percent Elongation
for 0.6"-Thick Test Coupons: (continued)

<u>Test Conditions</u>	<u>Tensile Yield (ksi)</u>	<u>Tensile Ultimate (ksi)</u>	<u>% Elongation in 2"</u>
Control 1 - 0.6" thick	145.1	150.1	2.0
Control 2 - 0.6" thick	137.3	149.0	2.0
Surface 1 - 0.2" thick (F-2 coupon)	146.9	199.8	8.0
Surface 2 - 0.2" thick (F-2 coupon)	151.6	201.2	7.5
Center 1 - 0.2" thick* (F-2 coupon)	132.4	180.3	4.5
Center 2 - 0.2" thick (F-2 coupon)	143.5	195.6	10.5

From these test results, it can be seen that material obtained from the center and from the surface of the 0.6"-thick casting, but machined to 0.2"-thick, type F-2 coupons and heat treated, produced normal test results. Material from the same slab, when heat treated and tested as 0.6"-thick "special" coupon produces abnormally low tensile ultimate and percent elongation results. This is an indication that the 0.6"-thick by 1.0"-wide gauge area of the "special" coupons was in some way responsible for the low test results.

In order to obtain additional evidence that the size and shape of the "special" test coupon was a factor in the low test results, other tests were conducted. Two 0.6"-thick test coupons were cut from a cast slab, along with two additional pieces, 0.6" x 1.0" x 9". The machined, 0.6"-thick test coupons and the 0.6" x 1.0" x 9" pieces were heat treated together. After heat treatment, two 0.2"-thick, type F-2 coupons were machined from the 0.6" x 1.0" x 9" material. By doing this, the heat treatment of the two F-2 coupons was effected in the same manner as the 0.6" x 1.0" section, the same as the gage area of the "special" coupons. After heat treatment, the two F-2 coupons were milled and ground. This procedure was followed through to determine if heat treatment of the 0.6"-thick section was responsible for the low test results. One type F-2 coupon was obtained from the center section and one was obtained from a surface section of the 0.6"-thick castings. One of the surfaces of the coupon from the surface section was left in the same condition as it was received from the foundry.

*Contained porosity (Intensity No. 3)

Controls

6.2 Abnormally Low Tensile-Ultimate Strength and Percent Elongation for 0.6"-Thick Test Coupons: (continued)

Inadvertently, the test material was from a cast slab of high hardenability. The slab chosen contained 0.19% carbon (heat 4012). After heat treatment, the final hardness was on the high side, approximately Rockwell C-48. These coupons were then retempered to reduce the hardness. Following the first regular temper at 525F, the coupons were subjected to a second temper at 600F. The hardness was only slightly reduced by the second temper. The final hardness of the coupons was Rockwell C-47 to 48. The results of the tensile tests follow:

Test No.	Coupon Type	Location in 0.6"- Thick Cast Slab	Tensile	% Elongation
			Ultimate (ksi)	in 2 inches
1	0.6" Thick, "Special"	Full Section	169.8	1.5
2	0.6" Thick, "Special"	Full Section	154.3*	1.0*
3	0.2" Thick, Type F-2	Surface 0.2"	226.0	4.0
4	0.2" Thick, Type F-2	Center 0.2"	168.0**	1.0*

*Test No. 2 contained intensity-1 porosity.

**Test No. 4 contained intensity-6 porosity.

The properties of Test Nos. 3 and 4 can be considered normal. The tensile-ultimate result of Test No. 3 is high, in accord with the high hardenability of the material. Tensile ultimate for Test No. 4 is also slightly higher than the 155 ksi value, normal for 0.2"-thick coupon, containing intensity-6 porosity. This is also due to high hardenability. Tensile results for Tests Nos. 1 and 2 are abnormally low. These results furnish further indications that the 0.6"-thick, rectangular cross section, 1"-wide gage area is responsible for the low test results.

Apparently, the size and shape of the "special"-coupon gage area was not conducive to normal elongation results. Out of 103 test results (control specimens) for 0.6"-thick castings, only 6 had 6% elongation, or more. One specimen had 16% elongation; this result was rechecked and was proved to be correct. The averages of the six coupons, compared to all control specimens follow:

	Average Tensile Ultimate (ksi)	Average % Elongation (in 2 inches)
6 Specimens Having 6% Elongation, or more -	192.6	8.6
All Control Coupons -	162.4	2.9

Controls

6.2 Abnormally Low Tensile-Ultimate Strength and Percent Elongation for 0.6"-Thick Test Coupons: (continued)

These figures indicate that when good elongation results are obtained, normal tensile-ultimate values are also obtained.

It is conceivable that brittle fractures are promoted by rectangularly shaped coupons, having relatively large cross sections and high strength values. It is also possible that there is some "critical size" of the cross section, for the strength level involved, above which elongation results will tend to drop off rapidly. The fractures of the 0.6"-thick coupons were consistently brittle. This agrees with the findings that very little additional ultimate strength was obtained, once the yield point was exceeded.

The large, rectangularly shaped coupons are apparently not affected by a double-temper operation. The 0.6"-thick coupons, specially prepared and tested, above, were double tempered. This did not improve the abnormally low tensile-ultimate and elongation results. The double-temper treatment rules out the possibility that residual austenite was a factor.

6.3 Effects of the Human Element on Radiographic Readings:

The radiographs of coupons from the 0.3"-thick castings were read by three experienced radiographers, each operating independently. These radiographers had previously read the 0.1"-and 0.2"-thick test coupons in accordance with the reference radiographs (Figures 3, 4, and 5). They were considered to be experienced when working with the radiographic references. The gradings of the 0.1"- and 0.2"-thick coupons were the result of a concensus of opinions, in each case. For the 0.3"-thick coupons, the three sets of individual readings were averaged to obtain the final grading for each coupon. A comparison of the individual readings with the averages are represented graphically in Figure 125 and 126.

From Figure 125 and 126, it can be seen that Reader No. 2 agreed with the average reading most often, 82% of the time, while Reader No. 3, agreed the least often, 71% of the time. Disagreement, in this case, meant the total number of readings differing from the average regardless of the amount of difference. A realistic comparison of the degrees of difference for each individual cannot be made, because in some cases where there were differences of more than one degree, a general discussion undoubtedly influenced the final reading. From Figure 126, it can be seen that Reader No. 1 tends to downgrade more than the other readers; he indicates that larger sizes or higher intensity flaws are present than Reader No. 2. Reader No. 3 interprets flaws as having the smallest size or intensity.

Contrails

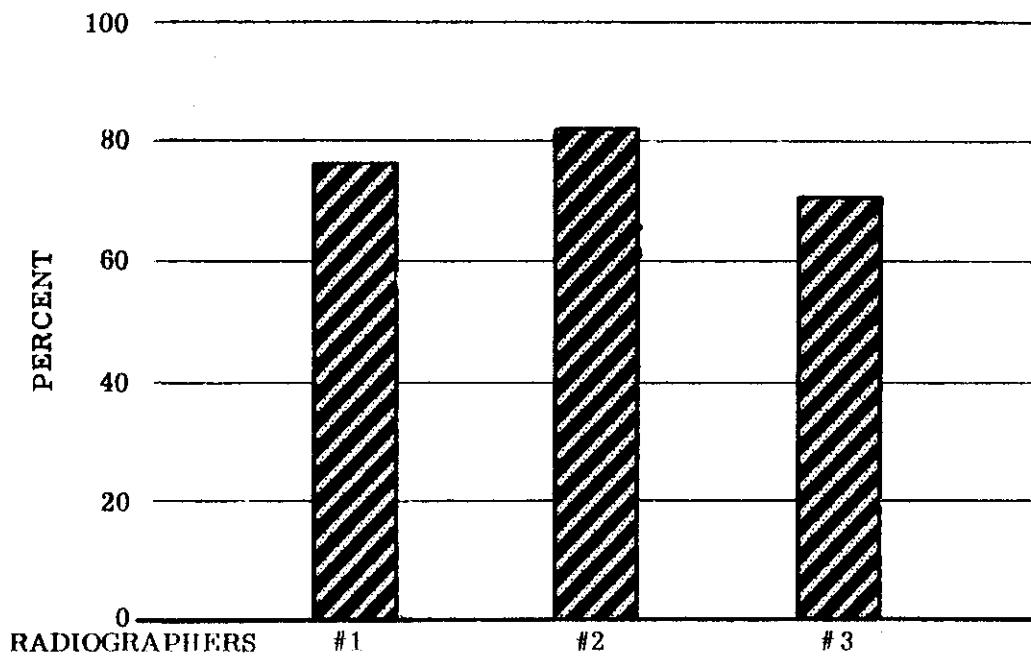


Figure 125. Percent of the Time Radiographers Obtained Readings Identical to the Average.

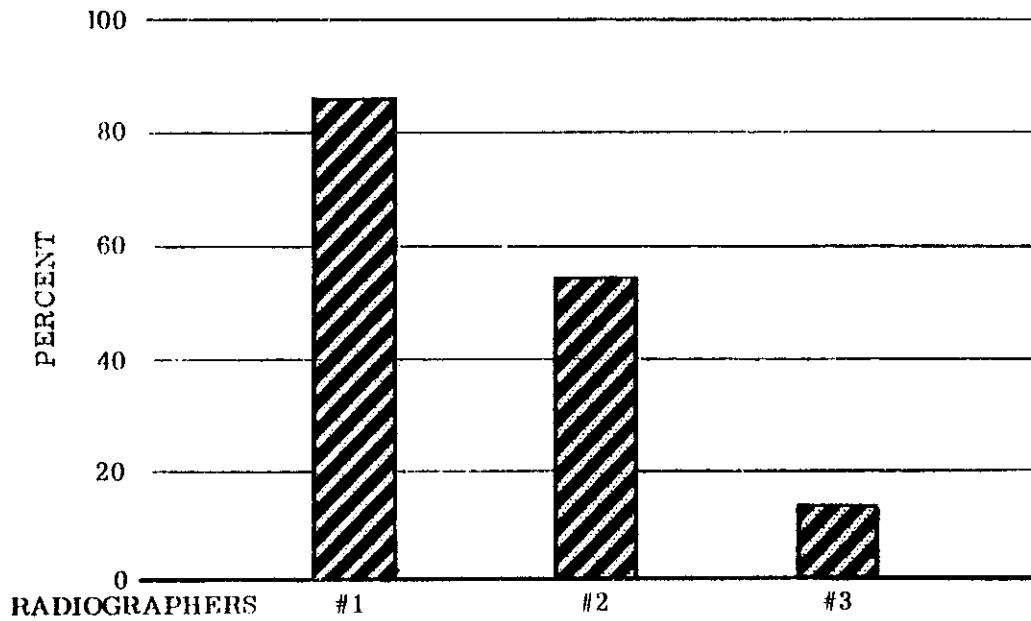


Figure 126. Percent of the Time Radiographers Readings Differing from the Average was Greater Than the Average.

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Controls

6.4 Sensitivity of Elongation Test Results to Imperfections:

A check was made which tends to show the lack of ability to read the full measure of the effect of imperfections into a radiographic grading. A comparison of average, percent-elongation results from all control coupons with control coupons which were obtained from selected areas of the casting, having the most ideal casting conditions, showed higher elongation results from the selected areas:

	CASTING THICKNESS		
	<u>0.1"</u>	<u>0.2"</u>	<u>0.3"</u>
Avg % Elong. (all controls) -	7.5	7.6	7.7
Avg % Elong. (selected controls) -	8.1	8.6	10.1

The percent elongation is very sensitive to effects of imperfections. This was previously shown by the rapid loss in elongation resulting when specimens had very small-size or low-intensity imperfections. The above comparisons indicate that control coupons which were obtained from random locations (all control coupons) probably contained a degree of imperfections which was not apparent from radiographic inspection. These imperfections, although not noticed in the radiograph, resulted in lower elongation values.

The selected control coupons were taken from the same location in each casting, adjacent and parallel to the gating area. The long length of each casting was gated continuously over its entire length. Through this area, a considerable amount of hot metal passed to feed the other parts of the casting. The metal which finally came to rest in this area was hotter than the metal in other parts of the casting. This area was also assured of a plentiful supply of additional hot metal from the casting-well riser. These two facts resulted in the most ideal casting conditions occurring here.

6.5 Relationships Between Grain Size, Cast Sections and Casting Temperatures:

One sample was usually taken from each heat and each casting thickness for a grain-size check. They were taken only for information purposes. The average grain size of samples, taken in each casting thickness, displayed a definite trend. As the casting thickness increased, the grain size also increased. This is shown in Figure 127.

A fixed relationship apparently does not exist between grain size and the temperature of the melt, prior to casting. Figure 128, which displays information about 0.2"-thick castings, indicates this lack of correlation. Generally; the grain size is a function of the rate of solidification of the casting.

In these castings, the solidifications rate is not influenced as much by the temperature of the melt as by the conditions of the casting

Contrails

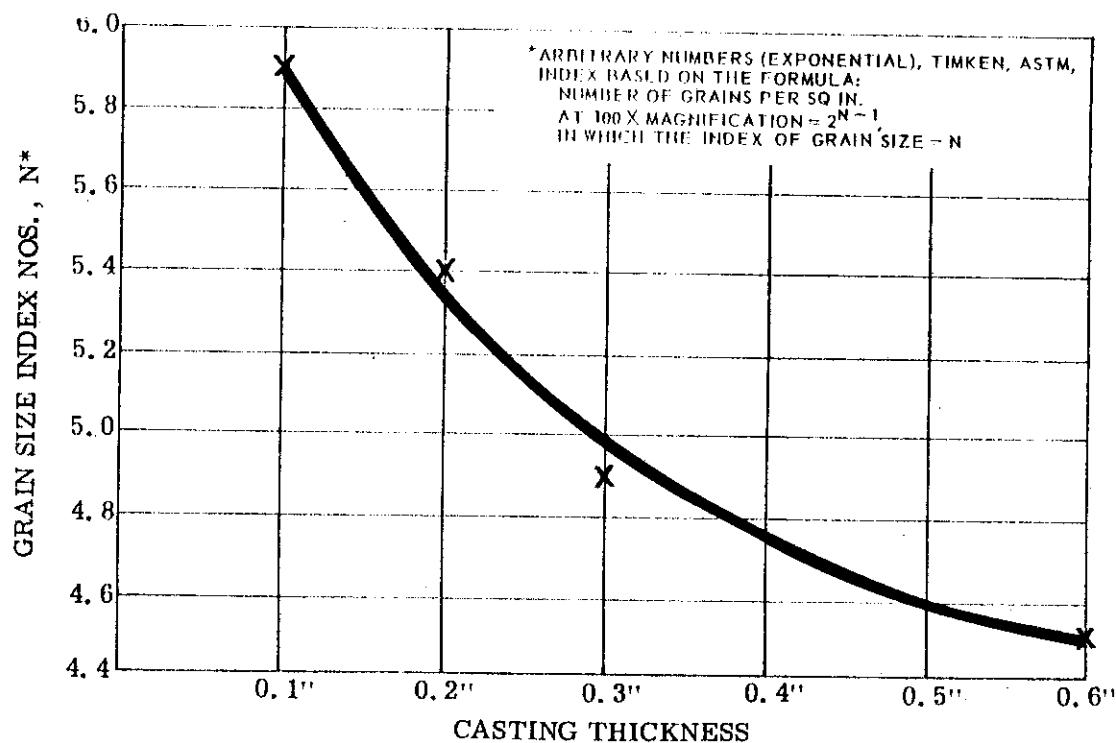


Figure 127. Grain Size vs Casting Thickness

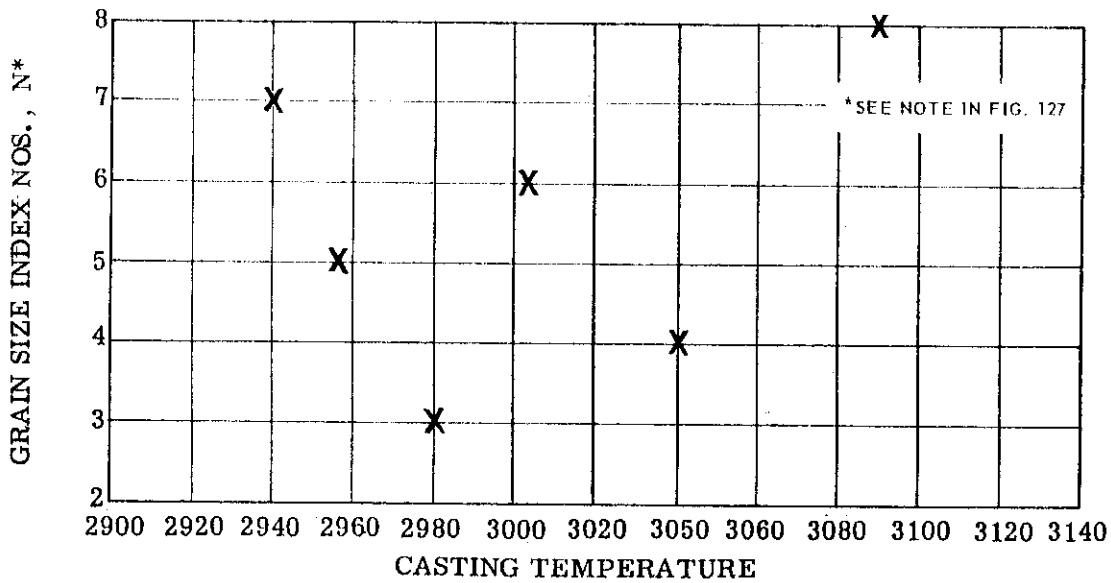


Figure 128. Grain Size vs Casting Temperature for 0.2" Thick Castings.

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6.5 Relationships Between Grain Size, Cast Sections and Casting Temperatures: (continued)

process. For example, the degree of cooling of the metal, as it is poured into the casting, is affected by many factors:

- (1) The pouring rate.
- (2) The flow pattern of the melt in the pouring well, mold cavity and risers.
- (3) The temperature of the mold.
- (4) The number of risers.
- (5) Other factors affecting cooling rate.

All of these vary greatly from casting to casting. This variation may also be large from area to area within a casting. The influence of section size, however, is quite constant for each thickness. Consequently trends affecting grain size develop with section size, as shown in Figure 127. The average temperature of the metal poured into the thinner molds was higher than that of the metal poured into the heavier molds. This can be seen in Table 4. Temperature - mold-thickness relationships were intentionally controlled in order to aid in casting the thinner cast slabs.

TABLE 4 - GRAIN SIZE AND POURING TEMPERATURES OF CAST SLABS

0.1"-THICK CASTINGS		0.2"-THICK CASTINGS		0.3"-THICK CASTINGS		0.6"-THICK CASTINGS	
Grain Size *	Pouring Temperature °F						
6	3110	8	3090	6	3150	4	3000
7	3030	4	3110	4	3100	6	3000
6	3040	5	3110	5	2880	5	2900
7	2950	3	2980	5	2950	5	2950
7	3000	4	2990	4	-	5	2900
5	2920	5	2740	5	2950	5	2950
5	3100	5	2890	5	2920	5	-
6	3150	6	3050	4	2990	3	2975
6	3000	6	2960	3	2880	3	2890
5	2960	5	3020	4	2980	4	-
7	2970	7	2940	4	3050	4	2980
5	3020	5	2880	6	2920	3	2970
6	3000	5	2950	7	3000	4	3000
5	3000	6	2950	6	2850	5	2950
5	3030	6	3030	6	2900	6	3020
6	3000	5	3050	4	3020	5	3050
6	3013	6	2980	4	2950	2970	2967
Avg.	5.9	5.4	5.0	4.9	Avg.	4.5	2969
					Avg.	4.9	2980
							3000
							2987
							2987
							2969

* See Figure 127 for method of designating grain size, page 223

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7. CONCLUSIONS

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7. CONCLUSIONS

7.1 Test Results with 0.1"-, 0.2"- and 0.3"- Thick Castings:

Generally, tests were run in sufficient numbers for statistical adequacy at a 0.95 confidence level. Results can be used to support engineering designs and structural stress analyses. Applications should be limited to type-410 stainless steel, cast in shell molds, heat treated to 175 ksi ultimate strength (minimum) at room temperature, and a maximum thickness of approximately 0.350".

7.2 Test Results with 0.6"-Thick Castings:

The tensile-ultimate and percent-elongation results with 0.6"-thick material were unusually low in comparison to those obtained at Convair with the thinner castings (paragraph 2.4.3 and Figures 120, 121 and 122). They are also unusually low in comparison to tensile properties resulting from foundry tests, using Type R-1 - 0.505" diameter test coupons.¹ The large number of tests and the extensive investigation, described in paragraph 6.2, indicate that the results obtained with the 0.6"-thick coupons are related to the size and shape of the coupon, for the strength level of the metal tested. Apparently the cross section of the test specimen and size of the coupon are not conducive to "necking-down" during tensile testing. The end result was that the coupons fractured with a brittle fracture, shortly after the metal reached the yield point, where plastic flow became a factor during testing.

It can be concluded, therefore, that the properties obtained from test coupons having relatively large cross sections (0.6" by 1.0") are more indicative of conditions encountered when a correspondingly thick casting is stressed in service.

The size of type F-2 and the R-1 test coupons is apparently below the "critical size" for type-410 steel, heat treated to 175 ksi, minimum. The "special" coupon size used with 0.6"-thick material is evidently larger than the "critical size." The "critical size" is considered to be that size, beyond which the percent-elongation values drop off rapidly. The low-elongation results (brittle fractures) tends to limit the ultimate-strength values to values slightly above the yield strength. Application of the test results, developed by this project, with 0.6"-thick material to engineering design and stress analyses should, therefore, be limited to the tensile-yield and modulus-of-elasticity correlations. In essence, in the application of the results of this study to design, the tensile-yield properties rather than tensile ultimate should be considered.

It is also concluded that, since material imperfections have little or no effect on the yield strength, they need not be considered as limiting factors when designing to yield strength. This holds true

¹Federal Test Methods Standards No. 151, Method 211.

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7.2 Test Results with 0.6"-Thick Castings": (continued)

at least up to the size or intensity of imperfections which were supported by adequate sampling. This conclusion is further supported by the fact that many fractures occurred at locations other than gas-hole and inclusion areas, as indicated by radiography. In one case, 87% of the fractures occurred in areas other than those having radiographically discernible gas-hole or inclusion imperfections.

In contrast to other imperfections, porosity does affect the yield strength of 0.6"-thick material, but only to a minor degree (Figure 122).

7.3 Similarity of Gas-Hole and Inclusion Effects on Tensile Properties:

The tensile values obtained with test coupons containing gas holes and inclusions of equal sizes, are comparable. The possibility exists that the values could be combined, having the advantage that one set of results would be applicable for both types of imperfections. During the radiographic reading of these imperfections, it was often impossible to differentiate between these two types, especially if they were round and of even density. Positive identification could be made only after fracturing occurred. This was accomplished by examining the fracture. If the imperfection appeared to be irregularly shaped and of varying density, it usually was an inclusion-type imperfection.

7.4 Heat-Treatment Effects on the Appearance of Radiographs:

No evidence was found which would indicate that the heat treatment of 410 cast-steel alloy had any effects on the appearance of the radiographs. However, all cast slabs were process annealed after casting; they were then normalized and reannealed before the initial radiographs were made. It was only possible, therefore, to compare radiographs of material which had received the above heat treatments to radiographs of the material which was additionally heat treated as follows:

Austenitized 1 hour, minimum, at 1825F.

Oil Quench

Temper 2 hours, minimum, at 525F.

No differences in the appearance of the radiographs could be ascribed to this additional heat treatment.

7.5 Application to Weldments:

The correlations obtained in this study may be applied to steel weldments of type-410 composition, since weldments, in reality, are cast structures.

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CORRELATION OF TENSILE PROPERTIES
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8. RECOMMENDATIONS

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8. RECOMMENDATIONS:

8.1 Additional Work Required:

Supplementary information is needed in order to determine if correlations, which were developed in this project for type-410 cast steel, can be applied to all heat-treatable steel castings suitable for aeronautical applications. Additional work is required as follows:

- (1) Correlations should be determined for 0.4"-thick, type-410 cast steel to obtain additional information on castings having thicknesses between 0.3" and 0.6". It is required that type F-2 coupons be used; metal would be cast in shell molds and coupons would be processed as in this project. This investigation is necessary to complete the analysis of mass effects.
- (2) Correlations with 0.2"-thick type-410 cast steel, made by molding methods, other than shell molding, i.e., ceramic-shell, lost-wax, poured-hot method and ceramic molding, poured cold. This data would supply information to determine if results obtained with one casting method hold true with other casting methods.
- (3) Correlations, using an alloy, heat treated to the approximate level of type-410 cast steel, such as, 17-4PH cast steel, heat treated to 180-210 ksi, cast in shell molds, 0.1" and 0.3" thick. Results of this work would show if the hardening method (martensitic vs. precipitation hardening) causes any difference in relationships to imperfections between different cast steels, heat treated to comparable strength levels.
- (4) Correlation using an alloy heat treated to three different strength levels, such as, type-4340, modified, heat treated to 150-180 ksi, 200 to 220 ksi, and 240-260 ksi, cast in shell molds, 0.1" and 0.3" thick. Results would indicate if one alloy, heat treated to different strength levels, effects any change in the relationships to imperfections.
- (5) Correlations using a hot-work die steel, such as AISI class H-11, heat treated to 260-280 ksi, cast in shell molds 0.1" and 0.3" thick. These tests would show if a hot-work die steel would produce comparable relationships.

It is recommended that these tests be so conducted that correlations could be determined between tensile yield, tensile ultimate, and percent elongation, when related respectively to the following imperfections: gas holes, inclusions and shrink porosity. The work recommended would also determine whether or not gas-hole and inclusion imperfections could be combined as a defect classification. See paragraph 7.3, above.

8.2 Radiographic Reference Blocks:

Test blocks from which radiographic reference films were obtained are approximately 2" x 2", conforming to a size being considered

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8.2 Radiographic Reference Blocks: (continued)

by ASTM. It is recommended that consideration be given to changing the size of the test blocks, to conform to the gage area of the tensile test coupon, from which tensile properties are obtained. This would require 1/2" x 2" blocks representing each category, size or intensity of imperfection for 0.1", 0.2"- and 0.3"-thick castings and 1" x 2" blocks for 0.6"-thick castings.

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CORRELATION OF TENSILE PROPERTIES
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APPENDIX A - TEST DATA

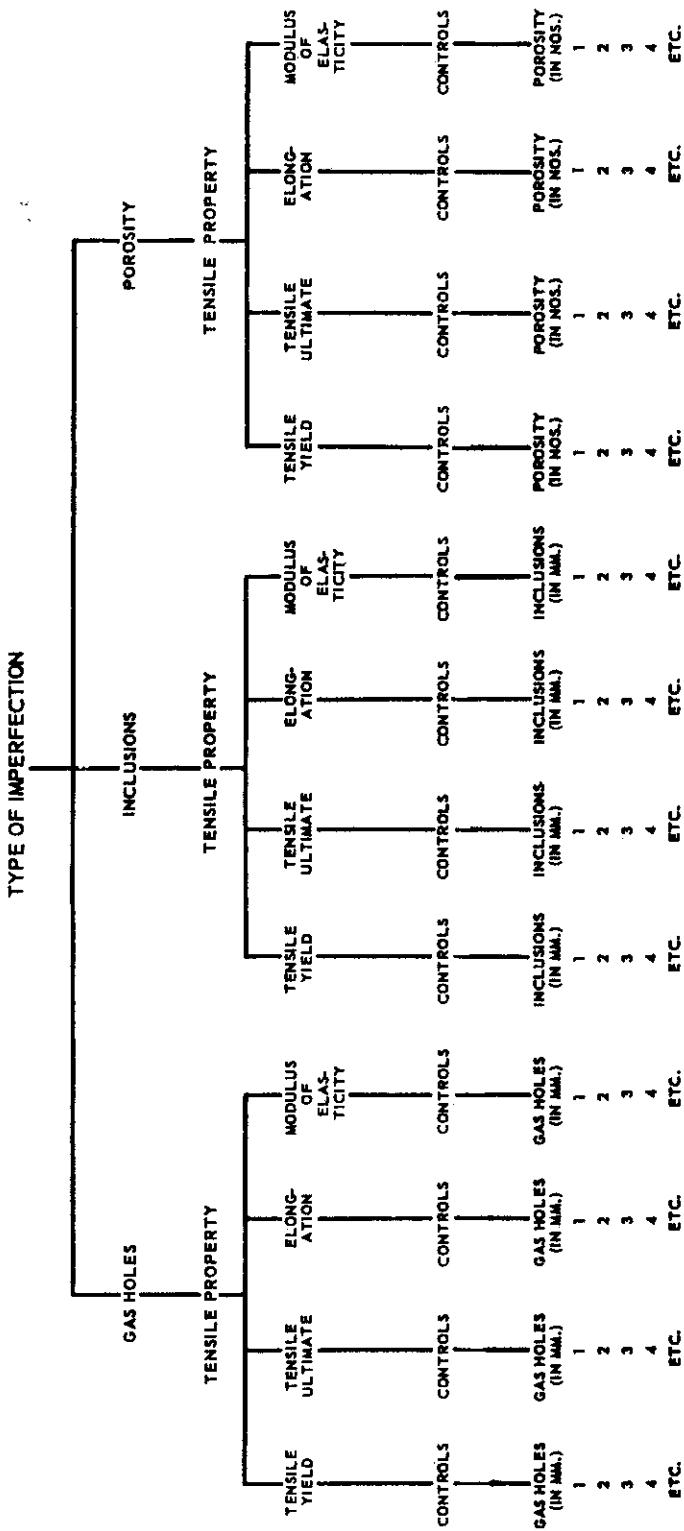
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TENSILE PROPERTIES VS IMPERFECTIONS, AS DETERMINED BY RADIOGRAPHY

TEST DATA IS TABULATED ON THE FOLLOWING PAGES FOR 0.1"-THICK SPECIMENS OF 410 STAINLESS-STEEL CASTINGS. IT HAS BEEN SUBDIVIDED ACCORDING TO THE FOLLOWING ARRANGEMENT:



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APPENDIX A

A1. TENSILE-YIELD TEST DATA - IMPERFECTION: GAS HOLES - 0.1"-THICK MATERIAL

A1.1. Control Test Specimens (no defects) - Y values are in ksi:

Y	Y	Y	Y	Y	Y
140.2	139.6	149.3	158.4	150.6	138.3
138.2	151.2	148.3	149.5	146.8	144.5
139.4	147.8	149.7	146.4	140.3	143.9
148.9	150.0	153.8	144.1	138.6	133.8
142.7	146.0	150.6	140.7	157.5	139.0
140.4	144.1	150.5	140.6	144.7	137.7

A1.2 One-mm-Size Test Specimens - Y values are in ksi:

Y	Y	Y
137.4	147.1	146.0
141.2	156.0	149.5
149.6	140.2	151.2

A1.3 Two-mm-Size Test Specimens - Y values are in ksi:

Y	Y	Y
151.5	148.8	135.8
144.0	155.6	146.4
145.2	138.1	153.8

A1.4 Three-mm-Size Test Specimens - Y values are in ksi:

Y	Y	Y	Y
150.1	140.1	147.3	135.4
153.2	152.4	147.6	

A1.5 Four-mm-Size Test Specimens - Y values are in ksi:

Y	Y	Y	Y
149.0	151.8	141.4	139.9
146.9	144.7	153.3	

A1.6 Five-mm-Size Test Specimens - Y values are in ksi:

Y	Y	Y
124.3	142.3	156.7
145.9	142.6	135.5

A1.7 Six-mm-Size-and-Larger Test Specimens, Averaging 8.5 - Y values are in ksi:

Y (6mm)	Y (8mm)	Y (9mm)	Y (10mm)	Y (11mm)
102.3	155.8	90.9	116.3	64.6
140.6	108.0	100.9		157.2
116.3	89.4			
110.3				

$\bar{Y} = 112.7$

Controls

APPENDIX A

A2. TENSILE-ULTIMATE TEST DATA - IMPERFECTION: GAS HOLES -0.1"-THICK MATERIAL

A2.1 Control Test Specimens (no defects) Y values are in ksi:

Y	Y	Y	Y	Y	Y	Y
186.4	179.0	201.4	197.3	189.7	190.6	189.3
181.9	183.6	198.4	204.2	196.4	182.7	
185.7	201.4	207.0	193.6	191.5	189.3	
200.0	206.8	203.1	195.1	187.8	195.2	$\bar{Y} = 192.6$

A2.2 One-mm-Size Test Specimens - Y values are in ksi:

Y	Y	Y	Y
180.3	203.9	186.4	183.6
186.3	202.5	190.5	
205.4	204.4	204.2	$\bar{Y} = 194.8$

A2.3 Two-mm-Size Test Specimens - Y values are in ksi:

Y	Y	Y	Y
177.6	206.9	178.0	203.1
192.7	204.0	171.3	
205.1	206.8	193.6	$\bar{Y} = 193.9$

A2.4 Three-mm-Size Test Specimens - Y values are in ksi:

Y	Y	Y	Y
193.0	196.8	186.9	180.4
186.3	189.1	165.4	$\bar{Y} = 185.4$

A2.5 Four-mm-Size Test Specimens - Y values are in ksi:

Y	Y	Y	Y
173.0	162.5	160.5	162.5
191.6	179.1	181.7	$\bar{Y} = 173.0$

A2.6 Five-mm-Size Test Specimens - Y values are in ksi:

Y	Y	Y	Y
157.0	160.1	168.7	125.9
154.2	158.7	154.9	$\bar{Y} = 154.2$

A2.7 Six-mm-size-and-Larger Test Specimens, Averaging 8.4 - Y values are in ksi:

Y (6mm)	Y (6mm)	Y (8mm)	Y (9mm)	Y (10mm)	Y (11mm)
79.3	128.3	167.5	91.7	113.1	160.6
105.0	116.5	108.0	105.3	133.9	69.1
149.6		90.4	97.3	66.1	$\bar{Y} = 111.4$

Controls

APPENDIX A

A3. ELONGATION TEST DATA - IMPERFECTION: GAS HOLES -0.1"-THICK MATERIAL

A3.1 Control Test Specimens (no defects) - Y values are in % in 2":

Y	Y	Y	Y	Y	Y	Y
6.5	6.5	7.5	5.0	9.5	6.0	8.0
8.0	11.0	10.0	8.0	7.5	7.0	
8.5	4.0	5.0	4.0	7.5	7.0	$\bar{Y} = 7.5$
9.5	10.0	8.5	8.5	6.0	7.0	
4.0	9.0	6.5	9.0	6.5	10.0	
4.0	7.5	8.5	9.0	6.5	9.0	

A3.2 One-mm-Size Test Specimens - Y values in % in 2":

Y	Y	Y	Y	Y
4.0	5.0	4.5	6.5	8.0
7.0	5.0	11.0	9.0	11.0

A3.3 Two-mm-Size Test Specimens - Y values are in % in 2":

Y	Y	Y	Y	Y
2.5	3.5	3.5	1.0	8.5
5.0	5.0	2.5	4.0	$\bar{Y} = 3.9$

A3.4 Three-mm-Size Test Specimens - Y values are in % in 2":

Y	Y	Y	Y
2.0	1.5	2.5	2.5
3.5	2.5	2.0	$\bar{Y} = 2.4$

A3.5 Four-mm-Size Test Specimens - Y values are in % in 2":

Y	Y	Y	Y
2.0	1.5	2.5	2.5
3.5	2.5	2.0	$\bar{Y} = 2.4$

A3.6 Five-mm-Size Test Specimens - Y values are in % in 2":

Y	Y	Y
2.5	2.0	2.0
2.0	3.0	$\bar{Y} = 2.4$

A3.7 Six-mm-Size-and-Larger Test Specimens, Averaging 8.5mm - Y values are in % in 2":

Y (6mm)	Y (8mm)	Y (9mm)	Y (10mm)	Y (11mm)
5.0	2.5	2.0	2.0	3.5
1.5	2.0	1.5	2.0	1.5
2.5	2.0	2.5		2.5
2.0				$\bar{Y} = 2.3$

Controls

APPENDIX A

A4. MODULUS-OF-ELASTICITY TEST DATA - IMPERFECTION: GAS HOLES - 0.1"-THICK MATERIAL

A4.1 Control Test Specimens (no defects) - Y values are in 10^6 psi:

| <u>Y</u> |
|----------|----------|----------|----------|----------|----------|------------------|
| 32.0 | 29.4 | 28.3 | 31.8 | 29.1 | 27.5 | 29.1 |
| 28.1 | 28.0 | 30.4 | 31.8 | 31.7 | 26.9 | |
| 30.1 | 31.0 | 30.4 | 29.7 | 30.4 | 28.6 | $\bar{Y} = 29.8$ |
| 29.5 | 29.1 | 31.4 | 30.0 | 28.4 | 30.5 | |
| 28.9 | 28.9 | 28.4 | 31.5 | 29.4 | 26.6 | |
| 31.9 | 29.1 | 30.8 | 33.8 | 30.0 | 29.4 | |

A4.2 One-mm-Size Test Specimens - Y values are in 10^6 psi:

<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>
29.7	29.2	29.4	32.0	31.8
29.4	30.0	29.9	28.9	28.0 $\bar{Y} = 29.8$

A4.3 Two-mm-Size Test Specimens - Y values are in 10^6 psi:

<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>
28.6	31.8	30.2	29.7	
26.8	30.8	29.4	30.4	31.4 $\bar{Y} = 29.9$

A4.4 Three-mm-Size Test Specimens - Y values are in 10^6 psi:

<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>
29.8	32.0	30.4	31.6	$\bar{Y} = 30.1$
27.3	30.0	29.9		

A4.5 Four-mm-Size Test Specimens - Y values are in 10^6 psi:

<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>
28.6	29.6	28.4	31.7
27.8	27.1	29.7	$\bar{Y} = 29.0$

A4.6 Five-mm-Size Test Specimens - Y values are in 10^6 psi:

<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>
25.3	27.2	31.8	29.2
27.6	24.4	28.6	$\bar{Y} = 27.7$

A4.7 Six-mm-Size-and-Larger Test Specimens, Averaging 8.1 mm - Y values are in 10^6 psi:

<u>Y (6mm)</u>	<u>Y (6mm)</u>	<u>Y (8mm)</u>	<u>Y (9mm)</u>	<u>Y (10mm)</u>
27.5	24.2	29.5	23.5	26.2
23.8	22.8	20.8	21.4	25.8
29.3		24.4		22.8
				26.3

Controls

APPENDIX A

A5. TENSILE-YIELD TEST DATA - IMPERFECTION: INCLUSIONS -0.1"-THICK MATERIAL

A5.1 Control Test Specimens (no defects) -

Data for control test specimens was presented in paragraph A1.1

A5.2 One-mm-Size Test Specimens - Y values are in ksi:

Y	Y	Y	
143.2	150.6	149.3	
137.4	138.6		$\bar{Y} = 143.8$

A5.3 Two-mm-Size Test Specimens - Y values are in ksi:

Y	Y	Y	Y	Y	Y
142.7	145.2	149.4	145.5	147.0	148.6
158.7	150.1	145.9	145.2	135.4	146.8
142.4	142.6	149.1	129.6	138.2	
					$\bar{Y} = 144.8$

A5.4 Three-mm-Size Test Specimens - Y values are in ksi:

Y	Y	Y	Y	
155.6	137.8	145.3	148.1	
157.9	151.9	139.3	140.3	$\bar{Y} = 147.3$
152.6	146.8	146.7	144.7	

A5.5 Four-mm-Size Test Specimens - Y values are in ksi:

Y	Y	Y	Y	
146.1	153.6	141.9	149.6	
151.7	145.6	138.4	135.3	
154.3	151.6	137.3	146.3	$\bar{Y} = 146.0$

A5.6 Five-mm-Size Test Specimens - Y values are in ksi:

Y	Y	Y	Y	Y
138.6	154.0	136.9	143.6	147.6
135.8	153.8	122.5	140.5	133.7
152.7	140.3	136.6	112.8	
				$\bar{Y} = 139.2$

A5.7 Six-mm-Size Test Specimens - Y values are in ksi:

Y	Y	Y	Y	
117.5	142.2	145.2	127.4	
134.6	136.7	141.4		$\bar{Y} = 135.0$

Controls

APPENDIX A

A5.8 Seven-mm-Size Test Specimens - Y values are in ksi:

$$\begin{array}{cccc} \overline{Y} & \overline{Y} & \overline{Y} & \overline{Y} \\ 154.7 & 150.4 & 150.0 & 80.1 \\ 149.7 & 150.3 & 105.5 & 142.0 \end{array} \quad \bar{Y} = 135.3$$

A5.9 Eight-mm-Size-and-Larger Test Specimens, Averaging 8.9 -
Y values are in ksi:

$$\begin{array}{ccccc} \overline{Y} (8mm) & \overline{Y} (8mm) & \overline{Y} (9mm) & \overline{Y} (10mm) & \overline{Y} (11mm) \\ 97.9 & 153.7 & 113.5 & 147.5 & 72.4 \\ 124.2 & 147.9 & 87.5 & & \end{array} \quad \bar{Y} = 118.1$$

A6. TENSILE-ULTIMATE TEST DATA - IMPERFECTION: INCLUSIONS - 0.1" -
THICK MATERIAL

A6.1 Control Test Specimens (no defects):

Data for control test specimens was presented in paragraph A2.1.

A6.2 One-mm-Size Test Specimens: Y values are in ksi:

$$\begin{array}{ccc} \overline{Y} & \overline{Y} & \overline{Y} \\ 203.2 & 185.7 & 187.8 \\ 190.9 & 201.6 & 184.5 \end{array} \quad \bar{Y} = 192.3$$

A6.3 Two-mm-Size Test Specimens - Y values are in ksi:

$$\begin{array}{ccccccc} \overline{Y} & \overline{Y} & \overline{Y} & \overline{Y} & \overline{Y} & \overline{Y} & \overline{Y} \\ 192.1 & 169.4 & 185.2 & 172.7 & 192.4 & 198.6 \\ 188.9 & 196.2 & 173.0 & 187.7 & 180.4 & 196.4 \\ 201.8 & 183.1 & 197.9 & 171.9 & 181.9 & & \end{array} \quad \bar{Y} = 187.0$$

A6.4 Three-mm-Size Test Specimens - Y values are in ksi:

$$\begin{array}{cccc} \overline{Y} & \overline{Y} & \overline{Y} & \overline{Y} \\ 180.7 & 158.8 & 179.7 & 168.3 \\ 186.8 & 172.7 & 180.6 & 191.5 \\ 176.5 & 186.8 & 176.2 & 188.9 \end{array} \quad \bar{Y} = 179.1$$

A6.5 Four-mm-Size Test Specimens - Y values are in ksi:

$$\begin{array}{cccc} \overline{Y} & \overline{Y} & \overline{Y} & \overline{Y} \\ 162.8 & 179.6 & 164.3 & 189.5 \\ 159.8 & 196.6 & 175.1 & 166.1 \\ 196.7 & 191.3 & 190.8 & 180.7 \end{array} \quad \bar{Y} = 179.4$$

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APPENDIX A

A6.6 Five-mm-Size Test Specimens - Y values are in ksi:

Y	Y	Y	Y	Y
180.9	191.9	141.3	164.5	114.0
147.3	179.1	142.1	190.9	172.9
179.2	162.5	130.5	171.0	153.1
				$\bar{Y} = 161.4$

A6.7 Six-mm-Size Test Specimens - Y values are in ksi:

Y	Y	Y	Y	Y
132.9	136.4	169.4	121.8	133.2
121.7	167.2	150.5	172.4	
				$\bar{Y} = 145.1$

A6.8 Seven-mm-Size Test Specimens - Y values are in ksi:

Y	Y	Y	Y
170.5	185.0	150.0	88.2
190.7	188.3	107.0	156.2
			$\bar{Y} = 154.5$

A6.9 Eight-mm-and-Larger Test Specimens, Averaging 8.9 - Y values are in ksi:

Y (8mm)	Y (8mm)	Y (9mm)	Y (10mm)	Y (11mm)
98.8	177.8	126.3	170.9	89.7
136.1	173.8	87.5		
				$\bar{Y} = 89.7$

A7. ELONGATION TEST DATA - IMPERFECTION: INCLUSIONS - 0.1"-THICK MATERIAL

A7.1 Control Test Specimens (no defects) -

Data for control test specimens was presented in paragraph A3.1.

A7.2 One-mm-Size Test Specimens - Y values are in % in 2":

Y	Y	Y
3.0	8.5	6.0
3.5	6.5	9.0
		$\bar{Y} = 6.1$

A7.3 Two-mm-Size Test Specimens - Y values are in % in 2":

Y	Y	Y	Y	Y	Y
4.0	5.0	3.5	2.0	2.0	10.0
7.5	4.0	2.0	2.5	2.0	7.5
5.5	3.5	6.0	3.5	8.0	
					$\bar{Y} = 4.6$

A7.4 Three-mm-Size Test Specimens - Y values are in % in 2":

Y	Y	Y	Y
2.5	2.0	1.0	2.0
3.5	2.5	3.5	7.5
2.0	3.5	3.0	6.5
			$\bar{Y} = 3.3$

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A7.5 Four-mm-Size Test Specimens - Y values are in % in 2":

Y	Y	Y	Y
1.0	2.0	2.5	3.0
2.5	4.2	1.5	2.5
3.0	2.5	3.0	5.0

$$\bar{Y} = 2.8$$

A7.6 Five-mm-Size Test Specimens - Y values are in % in 2":

Y	Y	Y	Y	Y
6.5	4.0	2.5	1.5	1.5
1.5	1.0	1.5	2.5	2.0
3.5	3.0	1.5	2.5	4.0

$$\bar{Y} = 2.6$$

A7.7 Six-mm-Size Test Specimens - Y values are in % in 2":

Y	Y	Y	Y
3.5	2.0	1.5	2.5
2.0	5.0	1.0	2.5

$$\bar{Y} = 2.5$$

A7.8 Seven-mm-Size Test Specimens - Y values are in % in 2":

Y	Y	Y	Y
3.5	3.0	1.5	1.5
2.5	2.0	1.5	

$$\bar{Y} = 2.2$$

A7.9 Eight-mm-and-Larger Test Specimens, Averaging 8.9 mm -
Y values are in % in 2":

Y (8mm)	Y (8mm)	Y (9mm)	Y (10mm)	Y (11mm)
1.5	4.0	2.0	3.5	2.5
1.5	4.0	3.0		

$$\bar{Y} = 2.7$$

A8. MODULUS-OF-ELASTICITY TEST DATA- IMPERFECTION: INCLUSIONS -
0.1"-THICK MATERIAL

A8.1 Control Test Specimens (no defects)

Data for control test specimens was presented in paragraph A4.1.

A8.2 One-mm-Size Test Specimens-Y values are in 10^6 psi:

Y	Y	Y
29.6	30.1	28.4
30.2	28.4	29.4

$$\bar{Y} = 29.4$$

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A8.3 Two-mm-Size Test Specimens - Y values are in 10^6 psi:

<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>
28.9	29.2	28.4	29.8	31.0	30.4
25.9	28.5	30.8	31.8	31.6	31.7
27.3	31.2	33.5	26.9	28.1	$\bar{Y} = 29.7$

A8.4 Three-mm-Size Test Specimens - Y values are in 10^6 psi:

<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>
28.0	30.0	31.5	29.5
30.1	30.3	31.7	30.4
26.8	30.0	32.0	30.3

A8.5 Four-mm-Size Test Specimens - Y values are in 10^6 psi:

<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>
29.8	29.2	29.3	31.0
28.6	28.2	29.6	29.6
29.3	29.4	28.1	31.8

A8.6 Five-mm-Size Test Specimens - Y values are in 10^6 psi:

<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>
28.8	29.4	29.4	30.3	26.5
31.8	30.5	25.5	29.0	30.9
28.4	25.6	28.8	29.5	26.8

A8.7 Six-mm-Size Test Specimens - Y values are in 10^6 psi:

<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>
27.7	27.3	28.7	26.5
26.9	29.9	27.3	27.9

$$\bar{Y} = 27.8$$

A8.8 Seven-mm-Size Test Specimens - Y values are in 10^6 psi:

<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>
30.4	27.3	30.0	30.0
29.8	30.3	32.5	$\bar{Y} = 30.0$

A8.9 Eight-mm-and-Larger Test Specimens, Averaging 8.6 mm - Y values are in 10^6 psi:

<u>Y (8mm)</u>	<u>Y (9mm)</u>	<u>Y (10mm)</u>
27.2	26.8	28.5
29.1		$\bar{Y} = 27.9$
27.9		

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A9. TENSILE-YIELD TEST DATA-IMPERFECTION: POROSITY - 0.1"-THICK MATERIAL

A9.1 Control Test Specimens (no defects)

Data for control test specimens was presented in paragraph Al.1

A9.2 Intensity-1 Test Specimens - Y values are in ksi:

Y	Y	Y	Y	Y	Y
144.6	146.9	139.5	147.5	148.6	149.3
139.9	152.5	144.9	146.2	142.8	148.4
143.8	156.7	138.5	145.2	144.7	151.5
156.5	151.0	152.6	137.3	151.5	143.9
147.9	149.6	142.5	159.0	138.0	147.1
148.6	154.9	144.2	144.4	146.7	$\bar{Y} = 147.1$

A9.3 Intensity-2 Test Specimens - Y values are in ksi:

Y	Y	Y	Y	Y	Y
144.5	132.3	145.1	136.2	146.3	143.7
144.5	147.7	152.9	138.9	134.7	141.7
150.3	147.3	147.4	148.4	131.1	140.2
150.3	146.7	146.1	149.3	138.8	
152.5	151.7	156.3	136.9	151.9	$\bar{Y} = 145.5$
150.7	148.3	157.5	143.1	144.6	
145.4	147.1	148.5	146.5	142.8	

A9.4 Intensity-3 Test Specimens - Y values are in ksi:

Y	Y	Y	Y	Y	Y
137.0	154.4	145.5	157.4	145.6	145.4
129.3	142.6	151.7	153.7	145.2	143.3
140.2	138.8	149.0	151.2	144.5	144.1
143.0	150.4	141.9	141.7	140.2	142.2
147.3	147.8	148.1	126.3	145.5	149.2
146.6	150.1	150.0	147.9	144.5	145.6
147.6	149.2	157.8	143.9	140.2	$\bar{Y} = 145.5$

A9.5 Intensity-4 Test Specimens - Y values are in ksi:

Y	Y	Y	Y	Y	Y
138.6	151.7	145.3	146.0	147.4	151.1
137.7	138.9	133.9	137.8	121.3	150.4
144.4	153.3	143.8	141.6	153.6	148.0
147.9	149.5	146.6	137.3	143.8	144.9
151.2	153.5	140.7	141.4	140.3	
152.3	149.8	142.9	140.9	143.7	$\bar{Y} = 144.5$

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A9.6 Intensity-5 Test Specimens - Y values are in ksi:

Y	Y	Y	Y	Y
145.5	146.7	140.0	145.4	153.3
138.4	142.1	142.1	145.9	148.1
150.4	144.5	142.2	145.6	
150.3	149.8	143.9	135.4	$\bar{Y} = 145.0$

A9.7 Intensity-6 Test Specimens - Y values are in ksi:

Y	Y	Y	Y
145.5	145.0	155.9	146.9
147.9	140.9	145.8	149.1
151.8	146.1	148.1	149.3

A9.8 Intensity-7 Test Specimens - Y values are in ksi:

Y	Y	Y
144.4	145.9	140.6
151.2	149.9	144.7

A9.9 Intensity-8 Test Specimens - Y values are in ksi:

Y	Y	Y	Y
153.5	140.5	150.7	143.7
147.1	145.9	108.2	149.3

A10 TENSILE-ULTIMATE TEST DATA - IMPERFECTION: POROSITY - 0.1"-THICK MATERIAL

A10.1 Control Test Specimens (no defects)

Data for control test specimens was presented in paragraph A2.1.

A10.2 Intensity-1 Test Specimens - Y values are in ksi:

Y	Y	Y	Y	Y	Y
190.5	183.9	194.3	186.6	192.6	189.9
185.9	196.4	194.4	193.8	197.9	192.3
192.7	191.3	198.7	188.9	165.0	189.8
179.4	187.7	154.4	190.0	187.3	193.8
182.5	174.1	176.5	196.1	190.7	164.8
180.3	196.4	195.5	192.7	182.2	$\bar{Y} = 186.5$

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A10.3 Intensity-2 Test Specimens - Y values are in ksi:

Y	Y	Y	Y	Y	Y
183.2	169.9	187.8	184.1	180.9	182.5
183.5	192.2	191.2	181.5	169.2	177.9
194.3	198.0	191.7	187.6	178.7	176.3
172.0	194.0	198.0	182.3	173.5	
187.9	186.9	190.7	186.6	183.8	$\bar{Y} = 184.7$
189.9	189.5	189.8	180.6	189.9	
178.1	168.6	197.7	177.5	191.3	

A10.4 Intensity-3 Test Specimens - Y values are in ksi:

Y	Y	Y	Y	Y	Y
179.3	167.8	181.8	182.5	180.7	164.9
181.3	174.3	186.9	162.6	181.2	188.2
189.8	187.1	189.8	197.8	188.3	171.8
192.6	189.4	184.7	184.7	142.1	164.7
181.1	195.8	196.0	164.1	172.2	184.9
168.3	191.2	198.2	192.9	145.5	170.6
185.0	204.3	207.2	195.1	183.2	191.6

A10.5 Intensity-4 Test Specimens - Y values are in ksi:

Y	Y	Y	Y	Y	Y
164.6	181.6	167.3	184.1	189.3	187.1
177.8	175.4	181.1	171.6	161.1	
190.7	177.2	184.1	166.9	182.0	
174.3	134.2	170.0	189.6	160.0	$\bar{Y} = 176.0$
177.5	184.5	181.5	180.2	189.8	
174.7	166.4	178.2	156.9	197.0	
193.9	183.0	171.1	158.4	172.9	

A10.6 Intensity-5 Test Specimens - Y values are in ksi:

Y	Y	Y	Y	Y	Y
168.4	161.6	169.2	194.3	186.4	183.8
186.9	176.2	162.5	176.6	163.4	
140.6	167.8	178.6	176.1	164.1	
142.2	156.4	190.3	169.6	186.4	$\bar{Y} = 171.5$

A10.7 Intensity-6 Test Specimens - Y values are in ksi:

Y	Y	Y	Y
182.9	154.7	173.6	178.5
180.8	166.9	168.8	176.9
175.3	184.5	167.8	168.6

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A10.8 Intensity-7 Test Specimens - Y values are in ksi:

<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>
136.8	173.0	161.9	156.6
190.7	147.2	174.1	
			$\bar{Y} = 162.9$

A10.9 Intensity-8-and-Higher Test Specimens, Averaging Intensity 8.2 - Y values are in ksi:

<u>Y(Intensity 8)</u>	<u>Y(Intensity 8)</u>	<u>Y(Intensity 8)</u>	<u>Y(Intensity 9)</u>
187.0	162.2	122.2	162.1
158.3	177.9	182.5	141.6
124.3	176.7	172.4	
			$\bar{Y} = 160.7$

All. ELONGATION TEST DATA-IMPERFECTION: POROSITY - 0.1"-THICK MATERIAL

All.1 Control Test Specimens (no defects) -

Data for control test specimens was presented in paragraph A3.1

All.2 Intensity-1 Test Specimens - Y values are in % in 2":

<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>
6.5	3.5	5.5	3.0	2.5	5.0
5.0	5.0	2.0	3.0	2.0	7.5
6.0	3.5	9.0	3.0	2.5	3.5
2.0	2.5	2.0	4.5	3.0	2.0
2.5	2.5	4.0	4.0	3.0	
3.5	5.5	3.0	7.0	3.0	$\bar{Y} = 3.9$

All.3 Intensity-2 Test Specimens - Y values are in % in 2":

| <u>Y</u> |
|----------|----------|----------|----------|----------|----------|-----------------|
| 3.5 | 4.0 | 3.0 | 3.0 | 1.5 | 5.0 | 3.0 |
| 2.0 | 5.0 | 2.0 | 6.5 | 5.0 | 3.0 | |
| 1.0 | 2.5 | 2.5 | 4.5 | 3.0 | 5.0 | |
| 1.5 | 4.5 | 2.5 | 2.5 | 3.5 | 5.0 | |
| 2.5 | 3.5 | 4.0 | 3.0 | 3.0 | 2.5 | |
| 2.5 | 2.0 | 6.0 | 2.5 | 3.0 | 2.5 | $\bar{Y} = 3.3$ |

All.4 Intensity-3 Test Specimens - Y values are in % in 2":

<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>
6.0	6.0	2.0	3.0	2.0	3.0
3.0	4.5	2.0	2.5	2.0	2.0
3.0	3.5	2.5	3.0	2.5	3.0
3.0	3.0	2.0	3.5	1.5	2.0
2.0	2.5	4.0	3.0	1.5	4.0
3.0	3.0	4.0	3.5	2.0	2.0
2.5	5.5	4.5	3.5	2.5	

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All.5 Intensity-4 Test Specimens - Y values are in % in 2":

Y	Y	Y	Y	Y	Y	Y
4.5	2.5	4.0	2.5	2.5	2.5	2.0
5.0	2.0	2.0	2.5	2.0	2.5	3.0
3.0	3.0	2.5	3.0	4.0	2.0	
2.0	2.5	1.5	2.5	2.0	3.0	$\bar{Y} = 2.7$
2.5	2.0	2.0	2.0	5.5	2.5	

All.6 Intensity-5 Test Specimens - Y values are in % in 2":

Y	Y	Y	Y	Y
2.5	2.5	2.0	2.0	1.0
3.5	2.0	2.5	2.5	2.5
2.0	2.5	2.5	2.5	$\bar{Y} = 2.3$

All.7 Intensity-6 Test Specimens - Y values are in % in 2":

Y	Y	Y	Y	Y
1.5	2.0	2.0	2.5	5.0
3.0	3.0	2.5	2.5	5.0

All.8 Intensity-7 Test Specimens - Y values are in % in 2":

Y	Y	Y
2.5	2.5	1.5
3.0	2.5	2.0

$\bar{Y} = 2.3$

All.9 Intensity-8 Test Specimens - Y values are in % in 2":

Y	Y	Y	Y	Y
3.0	1.5	2.5	2.0	1.5
2.5	2.0	2.5	2.5	$\bar{Y} = 2.2$

All.10 MODULUS-OF-ELASTICITY TEST DATA - IMPERFECTION: POROSITY 0.1"-THICK MATERIAL

All2.1 Control Test Specimens (no defects)

Data for control test specimens was presented in paragraph A4.1.

All2.2 Intensity-1 Test Specimens - Y values are in 10^6 psi:

Y	Y	Y	Y	Y	Y
27.2	27.8	29.0	30.1	31.1	32.6
29.5	31.2	30.5	29.1	29.1	31.0
30.0	30.3	30.1	28.6	28.4	27.9
27.0	27.5	34.2	29.6	28.8	31.9
29.8	31.6	32.8	32.4	31.2	28.9
30.0	31.6	32.0	33.0	28.4	$\bar{Y} = 30.1$

Controls

APPENDIX A

A12.3 Intensity-2 Test Specimens - Y values are in 10^6 psi:

Y	Y	Y	Y	Y	Y
26.5	26.8	31.8	29.7	30.7	28.6
29.0	31.0	26.3	27.1	32.5	30.9
30.5	28.3	33.1	30.2	31.8	28.2
28.1	29.2	30.4	30.3	33.4	
28.2	31.0	28.4	30.1	24.2	$\bar{Y} = 29.6$
31.8	27.0	29.4	27.4	30.7	
28.4	29.5	29.1	30.7	28.9	

A12.4 Intensity-3 Test Specimens - Y values are in 10^6 psi:

Y	Y	Y	Y	Y	Y
28.9	27.9	30.2	27.7	29.2	32.9
27.7	27.7	31.0	27.1	31.8	33.4
32.8	29.6	30.6	30.4	25.8	27.8
33.5	29.1	28.8	26.7	28.9	28.4
26.6	30.2	32.6	27.3	33.3	$\bar{Y} = 29.7$
28.8	29.4	30.9	31.2	27.6	32.3
29.5	29.2	26.9	31.9	29.1	29.1

A12.5 Intensity-4 Test Specimens - Y values are in 10^6 psi:

Y	Y	Y	Y	Y	Y
28.3	32.8	30.9	28.8	29.7	30.6
29.2	30.3	29.6	30.2	31.3	
28.9	27.6	27.4	31.0	29.3	
30.2	31.0	32.7	30.1	29.1	
29.1	28.9	29.5	28.6	30.4	$\bar{Y} = 29.9$
23.5	30.3	31.0	30.3	29.4	
31.1	32.4	29.5	30.8	33.2	

A12.6 Intensity-5 Test Specimens - Y values are in 10^6 psi:

Y	Y	Y	Y	Y	Y
29.3	26.6	29.2	28.5	28.6	29.4
29.6	29.8	29.7	28.5	31.5	
26.1	31.1	29.8	27.5	29.8	$\bar{Y} = 29.6$
29.6	29.9	30.6	30.3	30.2	

A12.7 Intensity-6 Test Specimens - Y values are in 10^6 psi:

Y	Y	Y	Y
29.0	28.5	28.6	29.3
31.6	27.0	33.0	30.5
30.0	30.3	26.7	28.6

$$Y = 29.4$$

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A12.8 Intensity-7 Test Specimens - Y values are in 10^6 psi:

<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>
29.5	25.1	29.4	29.1
28.9	27.2	31.6	

$$\bar{Y} = 28.7$$

A12.9 Intensity-8 Test Specimens - Y values are in 10^6 psi:

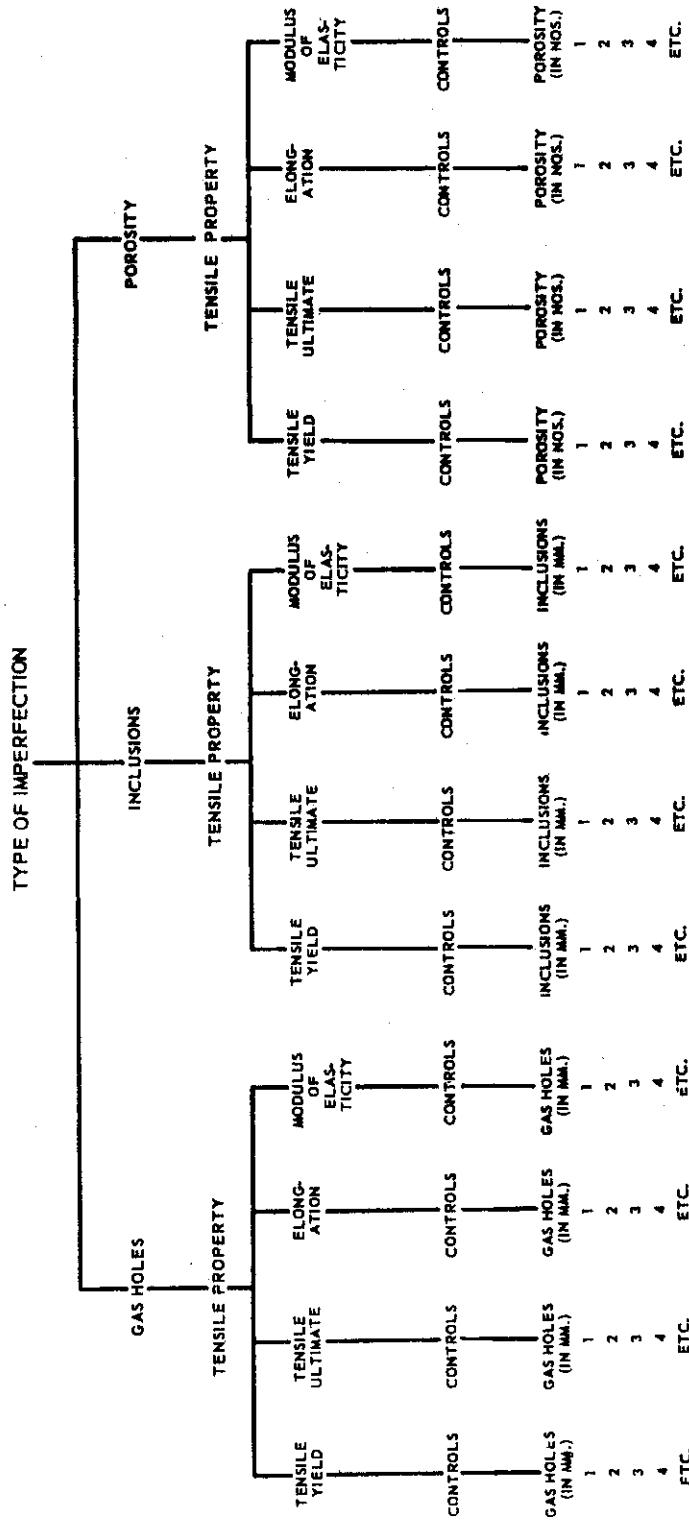
<u>Y</u>	<u>Y</u>	<u>Y</u>
26.0	29.4	23.2
29.2	29.7	28.6
29.6	31.6	29.2

$$\bar{Y} = 28.5$$

Contrails

TENSILE PROPERTIES VS IMPERFECTIONS, AS DETERMINED BY RADIOGRAPHY

TEST DATA IS TABULATED ON THE FOLLOWING PAGES FOR 0.2"-THICK SPECIMENS OF 410 STAINLESS-STEEL CASTINGS. IT HAS BEEN SUBDIVIDED ACCORDING TO THE FOLLOWING ARRANGEMENT:



WADD TR 60-450

Controls

APPENDIX A

A13. TENSILE-YIELD TEST DATA - IMPERFECTION: GAS HOLES - 0.2"-THICK MATERIAL

A13.1 Control Test Specimens (no defects) - Y values are in ksi:

\bar{Y}	\bar{Y}	\bar{Y}	\bar{Y}	\bar{Y}	\bar{Y}
151.5	145.4	148.5	144.4	152.5	143.8
151.5	144.7	137.4	152.4	146.6	154.1
132.3	148.1	153.4	158.3	142.1	148.8
143.1	150.9	150.2	155.2	150.3	150.0
138.7	141.4	145.6	155.2	137.0	146.2
147.8	147.0	134.8	153.0	158.2	148.4
143.5	137.7	158.3	151.0	143.3	
143.0	139.0	151.1	150.8	146.1	$\bar{Y} = 147.4$

A13.2 One-mm-Size Test Specimens - Y values are in ksi:

\bar{Y}	\bar{Y}	\bar{Y}	\bar{Y}	\bar{Y}	
151.9	150.4	152.2	144.0	153.4	
150.3	156.2	144.1	151.5	150.2	$\bar{Y} = 150.4$

A13.3 Two-mm-Size Test Specimens - Y values are in ksi:

\bar{Y}	\bar{Y}	\bar{Y}	\bar{Y}	\bar{Y}	\bar{Y}
150.6	135.2	143.0	142.0	154.4	148.5
139.6	142.3	155.3	154.9	154.6	142.4
147.2	152.7	144.5	147.1	143.0	
146.2	155.6	150.3	152.6	145.4	$\bar{Y} = 147.6$

A13.4 Three-mm-Size Test Specimens - Y values are in ksi:

\bar{Y}	\bar{Y}	\bar{Y}	\bar{Y}	\bar{Y}	
140.9	153.6	141.6	121.4	141.3	
143.9	150.1	147.9	143.4	142.1	$\bar{Y} = 145.8$
156.6	152.2	158.9	140.2	149.5	

A13.5 Four-mm-Size Test Specimens - Y values are in ksi:

\bar{Y}	\bar{Y}	\bar{Y}	\bar{Y}	
141.7	150.0	157.8	139.9	
142.2	145.7	152.8	146.3	
145.2	145.6	153.5		$\bar{Y} = 148.3$

A13.6 Five-mm-Size-and-Larger Test Specimens, Averaging 6.5 mm - Y values are in ksi:

$\bar{Y} (5\text{mm})$	$\bar{Y} (6\text{mm})$	$\bar{Y} (7\text{mm})$	$\bar{Y} (9\text{mm})$	$\bar{Y} (10\text{mm})$
135.2	87.4	88.3	96.9	134.2
143.5	128.3	150.2		
150.5	138.3	153.5		
152.3	107.3			$\bar{Y} = 128.1$

Controls

APPENDIX A

A14. TENSILE-ULTIMATE TEST DATA - IMPERFECTION: GAS HOLES 0.2"-THICK MATERIAL

A14.1 Control Test Specimens (no defects) - Y values are in ksi:

Y	Y	Y	Y	Y	Y
193.1	190.4	201.5	212.2	204.3	188.7
188.5	190.9	202.7	206.6	192.8	193.1
192.4	202.9	207.4	199.1	186.5	208.5
189.3	195.8	202.0	211.8	194.4	196.1
191.2	191.0	193.5	207.7	191.8	195.3
196.4	198.0	185.4	193.5	201.1	194.8
195.6	191.1	187.9	204.8	185.5	
189.9	189.0	206.8	212.3	192.7	$\bar{Y} = 196.7$

A14.2 One-mm-Size Test Specimens - Y values are in ksi:

Y	Y	Y	Y	Y	
196.8	206.0	214.0	191.9	207.4	
204.5	210.7	195.9	193.1	202.0	$\bar{Y} = 202.2$

A14.3 Two-mm-Size Test Specimens - Y values are in ksi:

Y	Y	Y	Y	Y	Y
186.7	192.9	191.4	189.9	184.4	201.5
182.0	192.6	207.9	197.1	210.9	186.5
184.2	187.6	193.9	195.2	189.9	
196.7	201.6	187.4	207.7	190.4	$\bar{Y} = 193.5$

A14.4 Three-mm-Size Test Specimens - Y values are in ksi:

Y	Y	Y	Y	Y	
159.3	158.8	190.4	173.1	202.5	
193.7	204.5	189.5	185.1	212.0	
026.3	198.7	150.9	182.3	185.5	$\bar{Y} = 186.2$

A14.5 Four-mm-Size Test Specimens - Y values are in ksi:

Y	Y	Y	Y	
141.7	205.7	178.4	211.5	
195.2	163.3	152.8	160.0	$\bar{Y} = 175.3$
191.9	175.1	153.5		

A14.6 Five-mm-Size-and-Larger Test Specimens, Averaging 6.8 mm - Y values are in ksi:

Y (5mm)	Y (6mm)	Y (7mm)	Y (9mm)	Y (10mm)
169.8	87.9	89.3	101.7	159.5
185.4	138.4	167.2		136.6
183.2	157.3	198.0		101.1
205.6	107.3			
117.5				$\bar{Y} = 144.1$

Contrails

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A15. ELONGATION TEST DATA - IMPERFECTION: GAS HOLES - 0.2"-THICK MATERIAL

A15.1 Control Test Specimens (no defects) - Y values are in % in 2":

<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	
5.0	11.0	5.0	7.5	10.0	
7.5	11.0	6.0	3.0	6.0	
9.0	11.5	11.0	7.5	10.0	
6.5	6.5	9.0	8.5	3.0	
10.0	9.5	5.0	7.5	5.0	$\bar{Y} = 7.6$
3.5	9.5	8.5	7.0	7.0	
8.0	12.0	7.5	7.0	12.0	
6.0	8.5	3.5	5.0	7.5	
9.0	11.0	5.0	3.0	11.0	

A15.2 One-mm-Size Test Specimens - Y values are in % in 2":

<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	
4.5	8.5	5.0	5.0	5.0	$\bar{Y} = 5.3$
6.0	4.0	4.0	5.0	6.0	

A15.3 Two-mm-Size Test Specimens - Y values are in % in 2":

<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>
4.0	2.5	9.5	5.0	5.0	8.5
3.0	10.0	2.5	1.5	2.5	7.0
4.0	2.5	2.5	4.0	6.0	
8.0	5.0	2.5	5.0	9.0	

A15.4 Three-mm-Size Test Specimens - Y values are in % in 2":

<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	
2.5	1.5	5.0	4.5	3.0	
8.5	3.5	4.0	5.0	6.0	$\bar{Y} = 4.7$
11.0	4.0	2.0	7.5	3.0	

A15.5 Four-mm-Size Test Specimens - Y values are in % in 2":

<u>Y</u>	<u>Y</u>	<u>Y</u>	
3.0	3.0	1.5	
5.0	3.0	7.5	$\bar{Y} = 3.5$
5.5	1.0	2.0	

A15.6 Fivé-mm-Size-and-Larger Test Specimens, Averaging 6.7 mm - Y values are in % in 2":

<u>Y (5mm)</u>	<u>Y (6mm)</u>	<u>Y (7mm)</u>	<u>Y (9mm)</u>	<u>Y (10mm)</u>
3.5	2.5	2.0	1.0	2.0
3.0	2.0	2.0		1.5
2.0	3.5	3.5		
5.0	1.5			$\bar{Y} = 2.5$

Controls

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A16. MODULUS-OF-ELASTICITY TEST DATA - IMPERFECTION: GAS HOLES ~ 0.2"-THICK MATERIAL

A16.1 Control Test Specimens (no defects) - Y values are in 10^6 psi:

<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>
29.1	28.4	20.5	31.6	29.9	29.5
28.6	31.2	28.3	31.8	30.4	
27.7	29.8	24.2	30.1	30.0	
26.2	28.5	30.3	30.4	30.1	
28.5	29.6	28.4	29.2	31.5	$\bar{Y} = 29.5$
32.1	27.4	29.6	28.0	30.2	
28.9	28.8	30.7	28.8	30.7	
29.3	27.2	28.7	29.2	29.7	
29.2	28.7	29.2	30.3	29.5	

A16.2 One-mm-Size Test Specimens - Y values are in 10^6 psi:

<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	
31.7	30.7	32.0	27.8	30.5	
28.1	30.4	30.5	29.1	28.3	$\bar{Y} = 29.9$

A16.3 Two-mm-Size Test Specimens - Y values are in 10^6 psi:

<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>
28.4	30.8	27.2	29.7	28.7	27.2
30.9	27.2	29.1	30.3	29.3	29.2
28.5	26.4	29.0	28.7	29.3	
28.9	26.9	29.2	30.0	29.2	$\bar{Y} = 28.8$

A16.4 Three-mm-Size Test Specimens - Y values are in 10^6 psi:

<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>
26.5	29.4	27.1	27.0	27.5	29.1
27.7	28.5	28.8	30.4	29.0	
28.7	28.4	28.8	28.4	28.7	$\bar{Y} = 28.4$

A16.5 Four-mm-Size Test Specimens - Y values are in 10^6 psi:

<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	
31.8	29.7	28.7	32.7	
29.2	28.1	29.4	28.1	$\bar{Y} = 28.8$
24.6	29.3	28.5		

A16.6 Five-mm-Size-and-Larger Test Specimens, Averaging 6.1 mm - Y values are in 10^6 psi:

<u>Y (5mm)</u>	<u>Y (6mm)</u>	<u>Y (7mm)</u>	<u>Y (9mm)</u>	<u>Y (10mm)</u>
27.5	22.6	19.9	28.1	29.4
29.9	26.7	27.8		26.8
31.5	27.7	28.7		29.6
31.3	28.2			
24.6				$\bar{Y} = 27.5$

Controls

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A17. TENSILE-YIELD TEST DATA - IMPERFECTION: INCLUSIONS - 0.2"-THICK MATERIAL

A17.1 Control Test Specimens (no defects):

Data for control test specimens was presented in paragraph A13.1.

A17.2 One-mm-Size Test Specimens - Y values are in ksi:

\bar{Y}	\bar{Y}
151.5	145.7
154.4	144.7
$\bar{Y} = 148.9$	

A17.3 Two-mm-Size Test Specimens - Y values are in ksi:

\bar{Y}	\bar{Y}	\bar{Y}	\bar{Y}	\bar{Y}
147.5	154.5	141.4	152.4	150.3
156.6	155.2	139.0	155.2	
149.7	139.5	158.3	155.2	$\bar{Y} = 150.4$

A17.4 Three-mm-Size Test Specimens - Y values are in ksi:

\bar{Y}	\bar{Y}	\bar{Y}	\bar{Y}
147.3	150.7	142.4	138.5
141.5	143.6	144.0	139.7
154.1	145.2	154.2	$\bar{Y} = 145.6$

A17.5 Four-mm-Size Test Specimens - Y values are in ksi:

\bar{Y}	\bar{Y}	\bar{Y}	\bar{Y}	\bar{Y}
147.2	141.4	155.5	146.2	140.1
147.0	149.9	163.0	140.1	
147.7	153.0	154.9	142.4	$\bar{Y} = 148.3$

A17.6 Five-mm-Size Test Specimens - Y values are in ksi:

\bar{Y}	\bar{Y}	\bar{Y}	\bar{Y}
146.2	154.0	144.4	141.7
153.4	154.4	140.3	
156.7	148.0	156.9	$\bar{Y} = 149.6$

A17.7 Six-mm-Size Test Specimens - Y values are in ksi:

\bar{Y}	\bar{Y}	\bar{Y}	\bar{Y}	\bar{Y}
133.8	151.3	141.7	145.7	144.4
143.5	142.1	145.4	141.9	$\bar{Y} = 143.3$

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A17.8 Seven-mm-Size-and-Larger Test Specimens, Averaging 8 mm - Y values are in ksi:

<u>Y (7mm)</u>	<u>Y (8mm)</u>	<u>Y (10mm)</u>	<u>Y (11mm)</u>
145.1	139.4	131.7	92.5
141.6	118.5		
144.7			
152.0			
137.4			
		$\bar{Y} = 133.7$	

A18. TENSILE-ULTIMATE TEST DATA - IMPERFECTION: INCLUSIONS - 0.2"-THICK MATERIAL

A18.1 Control Test Specimens (no defects):

Data for control test specimens was presented in paragraph A14.1.

A18.2 One-mm-Size Test Specimens - Y values are in ksi:

<u>Y</u>	<u>Y</u>	<u>Y</u>
188.5	194.8	190.9
199.9	202.5	
		$\bar{Y} = 195.3$

A18.3 Two-mm-Size Test Specimens - Y values are in ksi:

<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>
174.5	203.8	191.0	206.6	194.4
159.9	196.3	189.0	211.8	
200.5	188.7	187.9	207.7	$\bar{Y} = 193.2$

A18.4 Three-mm-Size Test Specimens - Y values are in ksi:

<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>
202.4	154.5	191.9	192.2	179.0
151.2	175.8	187.4	193.7	170.5
139.2	212.8	190.0	205.0	$\bar{Y} = 181.8$

A18.5 Four-mm-Size Test Specimens - Y values are in ksi:

<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>
165.5	203.1	193.5	201.9	180.3
198.3	196.5	180.6	187.5	152.3
205.0	213.1	212.4	154.5	$\bar{Y} = 188.9$

A18.6 Five-mm-Size Test Specimens - Y values are in ksi:

<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>
166.0	170.4	164.8	178.9
183.1	185.1	183.5	
203.5	186.2	197.0	$\bar{Y} = 181.9$

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A18.7 Six-mm-Size Test Specimens - Y values are in ksi:

<u>Y</u>	<u>Y</u>	<u>Y</u>	
144.6	169.5	149.8	
173.9	182.3	149.8	$\bar{Y} = 166.0$
183.9	182.9	157.7	

A18.8 Seven-mm-Size-and-Larger Test Specimens, Averaging 8mm - Y values are in ksi:

<u>Y (7mm)</u>	<u>Y (8mm)</u>	<u>Y (10mm)</u>	
151.6	171.8	141.8	
161.2	118.5	126.7	
137.8	199.1	94.5	
185.6			$\bar{Y} = 149.2$
157.2			
131.1			
162.9			

A19. ELONGATION TEST DATA - IMPERFECTION: INCLUSIONS - 0.2"-THICK MATERIAL

A19.1 Control Test Specimens (no defects):

Data for control test specimens was presented in paragraph A15.1.

A19.2 One-mm-Size Test Specimens - Y values are in % in 2":

<u>Y</u>	<u>Y</u>	<u>Y</u>	
7.5	11.0	6.0	
8.0	7.5		$\bar{Y} = 8.0$

A19.3 Two-mm-Size Test Specimens - Y values are in % in 2":

<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	
1.5	3.5	6.5	5.0	
1.5	2.0	12.0	7.5	
3.5	4.0	7.5	5.0	$\bar{Y} = 5.0$

A19.4 Three-mm-Size Test Specimens - Y values are in % in 2":

<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	
8.5	1.5	3.0	5.0	7.5	
2.5	3.5	3.0	5.0	4.0	
1.0	4.5	4.0	3.0		$\bar{Y} = 4.0$

A19.5 Four-mm-Size Test Specimens - Y values are in % in 2":

<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	
2.0	3.5	3.5	4.0	3.0	
9.5	5.0	4.5	2.5	2.5	
6.5	4.0	3.5	2.5		$\bar{Y} = 4.0$

Contrails

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A19.6 Five-mm-Size Test Specimens - Y values are in % in 2":

\bar{Y}	\bar{Y}	\bar{Y}	\bar{Y}
4.0	3.5	2.0	2.5
3.5	4.0	4.5	
3.5	5.0	5.0	$\bar{Y} = 3.8$

A19.7 Six-mm-Size Test Specimens - Y values are in % in 2":

\bar{Y}	\bar{Y}	\bar{Y}
1.5	2.0	1.0
5.0	5.0	1.5
3.0	4.0	$\bar{Y} = 2.9$

A19.8 Seven-mm-Size-and-Larger Test Specimens, Averaging 7.5 mm - Y values are in % in 2":

\bar{Y} (7mm)	\bar{Y} (8mm)	\bar{Y} (10mm)
2.5	2.5	2.0
3.0	3.0	
0.5	3.0	
3.0		
1.5		
1.0		$\bar{Y} = 2.2$
2.0		

A20. MODULUS-OF-ELASTICITY TEST DATA - IMPERFECTION: INCLUSIONS - 0.2"-THICK MATERIAL

A20.1 Control Test Specimens (no defects):

Data for control test specimens was presented in paragraph A16.1.

A20.2 One-mm-Size Test Specimen - Y values are in 10^6 psi:

\bar{Y}	\bar{Y}
28.6	29.5
26.8	28.4

$\bar{Y} = 28.3$

A20.3 Two-mm-Size Test Specimens - Y values are in 10^6 psi:

\bar{Y}	\bar{Y}	\bar{Y}	\bar{Y}	\bar{Y}
28.1	30.7	28.5	28.6	30.3
28.6	29.2	28.8	31.6	
29.2	29.7	28.4	31.8	$\bar{Y} = 29.5$

A20.4 Three-mm-Size Test Specimens - Y values are in 10^6 psi:

\bar{Y}	\bar{Y}	\bar{Y}	\bar{Y}	\bar{Y}
29.6	29.6	29.6	33.0	31.4
27.2	29.3	28.3	30.4	29.4
29.0	29.2	29.7	29.3	$\bar{Y} = 29.6$

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A20.5 Four-mm-Size Test Specimens - Y values are in 10^6 psi:

\bar{Y}	\bar{Y}	\bar{Y}	\bar{Y}	\bar{Y}
30.4	30.2	30.2	31.8	26.4
29.6	30.0	29.8	31.7	29.3
30.4	30.8	30.4	28.5	$\bar{Y} = 30.0$

A20.6 Five-mm-Size Test Specimens - Y values are in 10^6 psi:

\bar{Y}	\bar{Y}	\bar{Y}	\bar{Y}
31.3	30.3	29.5	21.0
31.5	26.4	27.9	
31.7	28.2	27.0	$\bar{Y} = 29.2$

A20.7 Six-mm-Size Test Specimens - Y values are in 10^6 psi:

\bar{Y}	\bar{Y}	\bar{Y}
28.6	30.4	28.3
26.2	28.5	27.3
31.5	29.5	28.6
		$\bar{Y} = 28.8$

A20.8 Seven-mm-Size-and-Larger Test Specimens, Averaging 7.5 mm - Y values are in 10^6 psi:

\bar{Y} (7mm)	\bar{Y} (8mm)	\bar{Y} (10mm)
29.2	30.6	28.4
26.8	26.3	
28.7	31.3	
29.1		$\bar{Y} = 28.5$
29.1		
27.3		
27.2		

A21. TENSILE-YIELD TEST DATA - IMPERFECTION: POROSITY - 0.2"-THICK MATERIAL

A21.1 Control Test Specimens (no defects) -

Data for control test specimens was presented in paragraph A13.1.

A21.2 Intensity-1 Test Specimens - Y values are in ksi:

\bar{Y}	\bar{Y}						
141.5	142.7	124.7	154.5	144.5	146.2	147.5	
140.4	149.6	143.9	151.2	157.7	168.5		
139.6	145.8	153.9	157.5	154.1	153.4		
140.4	154.4	138.5	154.7	143.9	150.4	$\bar{Y} = 147.2$	
140.6	152.0	139.9	153.4	144.4	139.9		
127.2	146.8	157.7	159.3	156.9	137.0		
145.3	126.1	162.9	141.0	144.6	139.9		
143.6	145.2	154.4	141.5	140.4	153.7		

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A21.3 Intensity-2 Test Specimens - Y values are in ksi:

Y	Y	Y	Y	Y
166.2	145.5	154.5	149.0	150.5
139.5	144.5	156.2	132.5	143.1
141.4	159.2	152.3	145.9	158.8
144.5	149.0	164.6	145.6	
140.8	154.7	148.6	141.0	$\bar{Y} = 149.3$
150.3	154.5	148.2	151.2	

A21.4 Intensity-3 Test Specimens - Y values are in ksi:

Y	Y	Y	Y	Y	Y
151.3	145.2	146.4	153.4	150.9	152.9
149.1	155.1	152.9	152.8	152.3	153.4
132.9	145.9	143.3	154.5	153.7	151.4
142.2	148.5	153.4	162.2	142.7	
145.5	145.0	156.4	154.5	157.8	$\bar{Y} = 149.7$
139.3	142.6	153.5	152.7	154.1	
140.3	151.1	151.4	153.6	156.4	

A21.5 Intensity-4 Test Specimens - Y values are in ksi:

Y	Y	Y	Y	Y	Y
130.2	142.7	149.4	152.7	144.0	142.2
142.5	142.1	153.1	152.6	144.7	
138.6	153.1	154.5	152.2	152.4	
146.5	152.1	151.9	152.3	144.9	$\bar{Y} = 149.1$
153.3	149.7	152.6	151.5	154.2	
149.9	154.7	153.9	154.5	152.6	

A21.6 Intensity-5 Test Specimens - Y values are in ksi:

Y	Y	Y	Y	Y	Y
131.2	148.5	154.5	153.3	156.1	163.6
128.4	152.6	152.5	143.9	153.0	149.4
148.3	150.3	151.9	142.0	154.2	
147.6	154.9	153.0	153.0	151.6	$\bar{Y} = 149.7$

A21.7 Intensity-6 Test Specimens - Y values are in ksi:

Y	Y	Y
150.1	153.2	141.5
150.6	153.5	156.1
152.5	152.7	$\bar{Y} = 150.8$
		146.6

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A21.8 Intensity-7 and-Higher Test Specimens, Averaging 7.3 -
Y values are in ksi:

<u>Y (Intensity-7)</u>	<u>Y (Intensity-8)</u>
142.8	141.6
143.6	142.2
150.4	153.6
150.4	
151.6	
154.2	Y = 148.5
154.7	

A22. TENSILE-ULTIMATE TEST DATA-IMPERFECTION: POROSITY - 0.2"-THICK MATERIAL

A22.1 Control Test Specimens (no defects) -

Data for control test specimens was presented in paragraph A14.1.

A22.2 Intensity-1 Test Specimens - Y values are in ksi:

Y	Y	Y	Y	Y	Y	Y
189.1	189.0	161.3	200.5	193.6	190.1	195.5
194.1	203.2	179.1	207.9	197.5	195.5	
187.5	190.4	198.8	173.1	189.1	203.9	
191.2	199.9	187.7	219.8	192.5	185.8	
182.6	203.0	186.2	186.1	190.1	179.8	Y = 191.5
185.2	199.8	197.3	194.5	216.6	180.4	
194.4	167.5	178.5	185.9	188.5	193.0	
188.4	193.5	203.2	192.1	187.6	195.0	

A22.3 Intensity-2 Test Specimens - Y values are in ksi:

Y	Y	Y	Y	Y	Y
192.1	184.1	195.5	198.1	174.2	
180.6	166.1	187.5	196.0	168.2	
187.8	124.2	207.1	203.9	186.3	Y = 184.9
184.1	191.4	180.7	176.9	187.8	
176.1	188.6	204.5	179.1	196.9	
198.8	200.0	189.9	156.3		

A22.4 Intensity-3 Test Specimens - Y values are in ksi:

Y	Y	Y	Y	Y	Y	Y
157.9	179.6	194.6	189.6	199.2	184.4	182.1
162.0	176.5	201.4	191.6	172.7	183.2	202.9
179.4	192.3	184.4	201.8	189.8	211.9	161.9
183.8	193.0	168.6	197.5	182.5	156.3	
181.4	199.1	186.2	198.0	185.0	144.5	Y = 184.1
183.1	186.0	205.9	183.1	180.7	165.7	

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A22.5 Intensity-4 Test Specimens - Y values are in ksi:

Y	Y	Y	Y	Y	Y
174.0	172.3	190.2	202.3	187.7	182.2
172.6	153.2	198.6	188.7	159.9	142.2
181.0	211.3	183.5	174.5	157.7	
183.9	194.3	204.5	172.9	161.9	$\bar{Y} = 180.6$
184.7	194.5	199.9	197.7	149.6	
175.5	184.4	178.5	204.8	158.7	

A22.6 Intensity-5 Test Specimens - Y values are in ksi:

Y	Y	Y	Y	Y
169.8	206.8	194.7	161.7	178.6
160.8	185.1	177.8	165.0	145.6
192.7	191.1	176.7	155.7	197.1
162.1	178.9	143.9	145.9	149.4
187.7	162.4	160.2	171.4	129.5

A22.7 Intensity-6 Test Specimens - Y values are in ksi:

Y	Y	Y	Y	Y
112.5	183.0	172.4	165.0	179.9
176.3	190.2	179.5	140.6	142.3
187.1	177.1	143.6	136.0	$\bar{Y} = 163.3$

A22.8 Intensity-7 and Higher Test Specimens, Averaging 7.3 - Y values are in ksi:

Y (Intensity 7)	Y (Intensity 7)	Y (Intensity 8)
147.7	184.2	163.8
180.2	142.9	161.0
170.9	160.9	196.1
170.3	137.5	108.2
195.3	146.3	$\bar{Y} = 161.8$

A23. ELONGATION TEST DATA - IMPERFECTION: POROSITY - 0.2"-THICK MATERIAL

A23.1 Control Test Specimens (no defects)

Data for control test specimens was presented in paragraph A15.1.

A23.2 Intensity-1 Test Specimens - Y values are in % in 2":

Y	Y	Y	Y	Y
3.0	3.0	5.0	3.0	4.0
4.5	8.0	3.5	4.0	2.5
9.0	6.0	6.5	2.0	2.5
4.0	4.5	5.0	1.8	4.5
7.0	4.0	7.5	4.0	4.0
2.0	3.5	2.5	2.5	4.5
3.0	7.0	6.5	2.5	2.5
8.0	3.0	2.5	2.5	3.0
9.0	1.5	3.5	5.0	
6.0	5.0	2.5	5.0	$\bar{Y} = 4.3$

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A23.3 Intensity-2 Test Specimens - Y values are in % in 2":

<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>
4.0	3.0	2.5	4.0	3.0
3.0	1.5	2.5	4.0	2.5
4.0	1.0	3.5	5.0	4.0
3.5	4.0	3.0	3.0	4.0
1.5	3.0	3.5	2.5	1.5
4.0	3.5	3.5	2.5	$\bar{Y} = 3.1$

A23.4 Intensity-3 Test Specimens - Y values in % in 2":

<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>
2.5	2.0	3.0	1.5	2.5	5.0
3.0	3.5	1.5	1.5	3.0	
3.0	3.5	4.0	2.5	2.5	
2.5	5.0	4.5	3.5	2.5	
3.5	2.0	2.5	2.0	5.0	$\bar{Y} = 2.8$
1.5	2.5	2.5	1.5	2.0	
1.0	3.0	2.5	3.5	2.5	

A23.5 Intensity-4 Test Specimens - Y values are in % in 2":

<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>
3.0	1.5	3.0	2.5	2.5	2.5
3.0	2.0	2.5	2.0	2.0	
2.5	1.5	2.5	2.5	2.0	$\bar{Y} = 2.6$
2.5	2.5	4.0	2.5	2.0	
3.0	2.5	4.0	3.0	3.0	
2.0	3.0	3.0	5.0	1.0	

A23.6 Intensity-5 Test Specimens - Y values are in % in 2":

<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>
3.0	3.0	2.5	3.0	2.0	2.0
2.5	2.5	3.0	2.0		
3.5	3.0	2.5	5.0	2.0	$\bar{Y} = 2.6$
2.5	2.0	2.5	2.5	2.0	

A23.7 Intensity-6 Test Specimens - Y values are in % in 2":

<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>
1.5	2.5	2.5	2.0	2.0
2.0	2.5	4.0	2.0	
2.5	2.5	1.5	2.0	$\bar{Y} = 2.3$

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A23.8 Intensity-7-and-Higher Test Specimens, Averaging 7.3 -
Y values in % in 2":

Y (Intensity-7)	Y (Intensity-7)	Y (Intensity-8)
3.0	2.5	3.0
2.5	1.5	2.5
2.0	2.0	1.5
2.5	2.0	
4.0		

A24. MODULUS-OF-ELASTICITY TEST DATA-IMPERFECTION: POROSITY - 0.2"-THICK MATERIAL

A24.1 Control Test Specimens (no defects) -

Data for control test specimens was presented in A16.1.

A24.2 Intensity-1 Test Specimens - Y values are in 10^6 psi:

Y	Y	Y	Y	Y
28.5	29.0	29.0	27.8	29.7
28.2	26.8	30.3	30.0	35.5
31.5	30.0	29.2	29.8	30.2
28.4	29.0	27.8	27.9	28.2
29.1	25.6	29.0	32.0	30.0
28.9	27.5	31.8	29.2	30.7
30.3	23.7	30.3	28.9	30.2
28.5	28.2	35.0	31.9	30.0
29.2	30.3	27.7	30.0	31.5
29.2	27.6	27.8	31.3	

A24.3 Intensity-2 Test Specimens - Y values are in 10^6 psi:

Y	Y	Y	Y	Y
27.7	27.7	29.6	28.6	29.2
26.8	29.8	29.2	28.9	
28.9	24.5	28.3	32.4	
28.8	29.6	28.4	30.0	
25.6	29.4	28.3	29.0	28.5
24.5	29.6	28.3	28.0	
27.9	29.7	28.4	29.4	

A24.4 Intensity-3 Test Specimens - Y values are in 10^6 psi:

Y	Y	Y	Y	Y
27.6	26.3	28.6	31.1	32.1
27.4	28.6	30.1	30.8	27.8
30.6	30.4	30.8	30.5	30.2
28.6	28.7	30.4	29.8	30.8
28.5	28.7	29.5	29.8	26.0
28.9	29.2	29.9	29.2	30.8
29.0	28.6	28.3	27.0	29.4
26.2	28.6	31.6	31.5	

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A24.5 Intensity-4 Test Specimens - Y values are in 10^6 psi:

Y	Y	Y	Y	Y	Y
29.7	28.7	28.3	31.5	28.9	28.9
26.6	29.9	28.4	26.2	26.6	29.6
28.7	31.0	28.3	29.0	30.2	
29.3	25.9	29.8	26.8	30.0	
27.7	29.0	28.2	24.8	29.4	$\bar{Y} = 28.7$
28.2	29.2	30.7	28.9	29.5	

A24.6 Intensity-5 Test Specimens - Y values are in 10^6 psi:

Y	Y	Y	Y	Y
29.3	29.5	29.5	29.0	28.4
27.2	30.3	28.2	28.4	27.8
29.3	29.0	31.4	29.4	32.8
30.5	27.8	26.0	28.6	28.1
27.4	27.0	30.7	29.0	31.1

A24.7 Intensity-6 Test Specimens - Y values are in 10^6 psi:

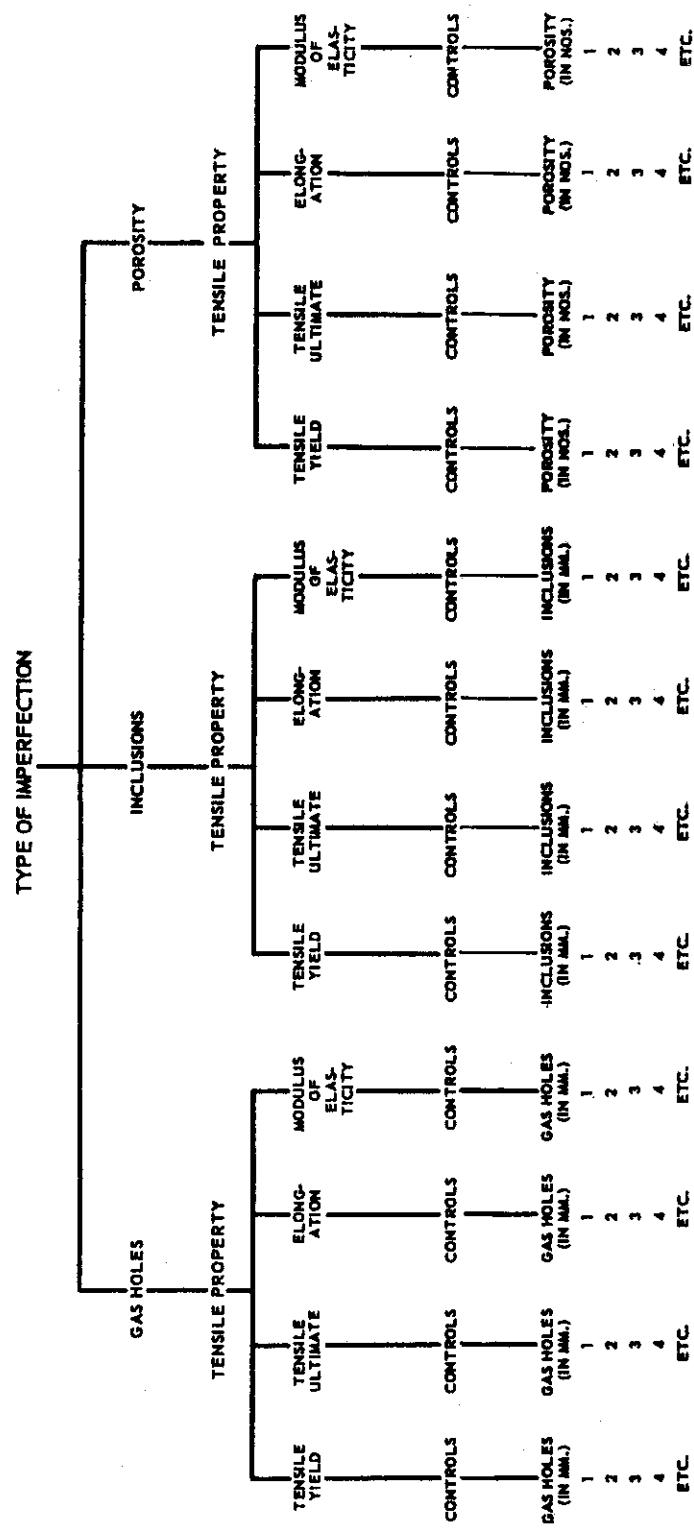
Y	Y	Y	Y	Y
24.7	30.0	32.4	29.0	28.6
28.4	28.8	29.0	28.8	
28.4	29.0	28.8	27.7	$\bar{Y} = 28.7$

A24.8 Intensity-7-and-Higher Test Specimens, Averaging 7.3 - Y values are in 10^6 psi:

Y (Intensity-7)	Y (Intensity-7)	Y (Intensity-8)
31.0	29.2	24.8
30.2	27.5	27.0
28.6	28.3	29.6
30.3	30.7	28.4
30.5	29.2	

TENSILE PROPERTIES VS IMPERFECTIONS, AS DETERMINED BY RADIOPH.

TEST DATA IS TABULATED ON THE FOLLOWING PAGES FOR 0.3"-THICK SPECIMENS OF 410 STAINLESS-STEEL CASTINGS. IT HAS BEEN SUBDIVIDED ACCORDING TO THE FOLLOWING ARRANGEMENT.



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A25. TENSILE-YIELD TEST DATA - IMPERFECTION: GAS HOLES - 0.3"-THICK MATERIAL

A25.1 Control Test Specimens (no defects) - Y values are in ksi:

Y	Y	Y	Y	Y	Y	Y
152.0	141.6	139.0	155.2	149.2	147.3	141.0
143.1	143.7	152.9	135.2	147.4	138.3	145.3
153.9	141.1	140.7	148.2	138.9	133.6	137.8
137.1	142.5	150.1	160.1	138.7	145.2	141.9
133.7	144.7	140.9	157.6	143.4	144.8	143.4
145.0	137.3	143.3	145.2	143.4	151.8	142.3
152.0	141.3	144.9	145.2	142.7	142.6	144.1
142.7	136.7	159.9	140.7	149.7	147.2	
148.2	142.2	136.2	143.1	141.7	153.8	
135.2	143.3	147.5	148.2	133.5	147.4	$\bar{Y} = 144.3$

A25.2 One-mm-Size Test Specimens - Y values are in ksi:

Y	Y	Y	Y	Y
143.0	147.8	142.7	135.2	144.8
144.2	148.2	148.2	143.4	
				$\bar{Y} = 142.2$

A25.3 Two-mm-Size Test Specimens - Y values are in ksi:

Y	Y	Y	Y	Y
146.9	129.5	148.5	148.0	150.1
146.7	134.2	148.4	145.0	143.4
125.8	148.8	132.5	146.7	142.7
				$\bar{Y} = 142.8$

A25.4 Three-mm-Size Test Specimens - Y values are in ksi:

Y	Y	Y	Y	Y
143.2	142.9	145.8	146.6	143.6
151.5	141.5	146.4	149.0	142.5
				$\bar{Y} = 145.3$

A25.5 Four-mm-Size Test Specimens - Y values are in ksi:

Y	Y	Y	Y	Y
143.1	147.7	141.2	138.3	141.1
150.7	147.5	139.9	151.8	
				$\bar{Y} = 144.6$

A25.6 Five-mm-Size Test Specimens - Y values are in ksi:

Y	Y	Y	Y
133.5	154.2	142.8	145.1
155.8	135.2	144.5	
			$\bar{Y} = 144.4$

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A25.7 Six-mm-Size and Larger Test Specimens, Averaging 7.9 mm -
Y values are in ksi:

<u>Y (6mm)</u>	<u>Y (7mm)</u>	<u>Y (8mm)</u>	<u>Y (9mm)</u>	<u>Y (10mm)</u>
136.6	154.0	146.0	151.8	140.0
136.8	117.7	137.0		145.4
		143.3		
		155.3		$\bar{Y} = 142.2$

A26. TENSILE-ULTIMATE-TEST DATA - IMPERFECTION: GAS HOLES - 0.3"-THICK MATERIAL

A26.1 Control Test Specimens (no defects) - Y values are in ksi:

| <u>Y</u> |
|----------|----------|----------|----------|----------|----------|-------------------|
| 192.1 | 180.0 | 186.7 | 195.6 | 200.3 | 190.9 | 191.7 |
| 189.2 | 197.9 | 196.2 | 177.9 | 195.6 | 188.8 | 193.0 |
| 184.9 | 193.3 | 192.4 | 187.6 | 195.7 | 190.6 | 180.2 |
| 190.9 | 184.6 | 198.5 | 217.7 | 204.6 | 202.4 | 187.8 |
| 182.3 | 198.4 | 191.6 | 190.2 | 183.9 | 198.5 | 195.4 |
| 183.2 | 186.1 | 192.6 | 176.4 | 191.2 | 185.6 | 185.9 |
| 189.0 | 189.5 | 193.4 | 195.2 | 178.2 | 188.8 | 191.9 |
| 188.2 | 188.5 | 206.8 | 191.0 | 180.9 | 195.4 | |
| 193.0 | 189.6 | 180.9 | 194.7 | 182.6 | 186.5 | |
| 187.9 | 198.2 | 190.4 | 202.9 | 180.1 | 178.4 | $\bar{Y} = 190.6$ |

A26.2 One-mm-Size Test Specimens - Y values are in ksi:

<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>
187.4	179.3	188.2	187.9	198.5
192.3	191.9	193.0	183.9	
				$\bar{Y} = 189.2$

A26.3 Two-mm-Size Test Specimens - Y values are in ksi:

<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>
189.0	192.6	179.2	190.8	198.1	180.9
192.4	194.6	185.2	183.6	191.2	
182.6	191.2	180.9	192.4	178.2	$\bar{Y} = 187.7$

A26.4 Three-mm-Size Test Specimens - Y values are in ksi:

<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>
190.4	191.5	191.8	162.0	181.6	184.6
193.3	184.9	187.5	186.5	154.5	

$\bar{Y} = 182.6$

A26.5 Four-mm-Size Test Specimens - Y values are in ksi:

<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>
187.0	142.1	160.0	181.9	190.2
197.7	191.0	182.7	172.2	186.4

$\bar{Y} = 179.1$

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A26.6 Five-mm-Size Test Specimens - Y values are in ksi:

\bar{Y}	\bar{Y}	\bar{Y}	\bar{Y}
189.5	165.7	164.3	187.4
167.7	170.7	170.8	
$\bar{Y} = 173.7$			

A26.7 Six-mm-Size-and-Larger Test Specimens, Averaging 8.1 mm - Y values are in ksi:

\bar{Y} (6mm)	\bar{Y} (7mm)	\bar{Y} (8mm)	\bar{Y} (9mm)	\bar{Y} (10mm)	\bar{Y} (12mm)
177.6	139.7	146.8	178.3	169.9	90.6
157.9	137.6	177.2		138.2	
191.1	186.9	181.2		181.4	
					$\bar{Y} = 158.5$

A27. ELONGATION TEST DATA - IMPERFECTIONS: GAS HOLES - 0.3"-THICK MATERIAL

A27.1 Control Test Specimens (no defects) - Y values are in % in 2":

| \bar{Y} |
|-----------|-----------|-----------|-----------|-----------|-----------|-----------------|
| 6.5 | 14.0 | 10.5 | 4.5 | 7.0 | 10.0 | 10.0 |
| 8.5 | 12.5 | 11.0 | 7.5 | 7.5 | 9.0 | 5.0 |
| 3.0 | 7.5 | 10.0 | 3.5 | 8.0 | 6.0 | 4.0 |
| 11.0 | 3.5 | 7.0 | 6.0 | 11.0 | 5.0 | 7.0 |
| 11.0 | 9.0 | 6.0 | 2.5 | 3.0 | 5.0 | 10.0 |
| 10.0 | 11.5 | 9.5 | 3.0 | 10.0 | 7.0 | 12.5 |
| 10.5 | 8.5 | 11.0 | 3.5 | 2.5 | 7.5 | 13.0 |
| 4.0 | 12.0 | 8.5 | 7.5 | 10.0 | 4.5 | |
| 6.0 | 11.0 | 14.0 | 8.5 | 6.0 | 2.5 | |
| 11.0 | 4.0 | 9.0 | 5.0 | 5.0 | 2.0 | |
| | | | | | | $\bar{Y} = 7.7$ |

A27.2 One-mm-Size Test Specimens - Y values are in % in 2":

\bar{Y}	\bar{Y}	\bar{Y}	\bar{Y}	\bar{Y}
4.0	3.5	4.0	11.0	5.0
8.5	4.0	6.0	3.0	
				$\bar{Y} = 5.4$

A27.3 Two-mm-Size Test Specimens - Y values are in % in 2":

\bar{Y}	\bar{Y}	\bar{Y}	\bar{Y}	\bar{Y}	\bar{Y}
4.0	10.0	2.0	4.0	7.0	10.0
6.0	14.0	3.0	10.0	10.0	
5.0	6.5	4.5	6.0	2.5	
					$\bar{Y} = 6.5$

A27.4 Three-mm-Size Test Specimens - Y values are in % in 2":

\bar{Y}	\bar{Y}	\bar{Y}	\bar{Y}	\bar{Y}	\bar{Y}
4.5	5.5	7.5	2.0	2.5	3.5
8.0	3.0	2.5	2.5	1.5	
					$\bar{Y} = 3.9$

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A27.5 Four-mm-Size Test Specimens - Y values are in % in 2":

<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>
7.5	1.5	2.0	1.5	4.0
4.0	3.0	2.5	3.5	3.5

$$\bar{Y} = 3.3$$

A27.6 Five-mm-Size Test Specimens - Y values are in % in 2":

<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>
5.0	1.5	2.0	3.0
2.5	4.0	2.5	

$$\bar{Y} = 2.9$$

A27.7 Six-mm-Size-and-Larger Test Specimens, averaging 8.1 mm - Y values are in % in 2":

<u>Y (6mm)</u>	<u>Y (7mm)</u>	<u>Y (8mm)</u>	<u>Y (9mm)</u>	<u>Y (10mm)</u>	<u>Y (12mm)</u>
6.5	2.0	2.0	2.5	2.5	1.5
2.5	1.5	4.5		2.0	
2.0	2.5	4.0		3.0	
	1.5	2.5			

$$\bar{Y} = 2.7$$

A28. MODULUS-OF-ELASTICITY TEST DATA - IMPERFECTION: GAS HOLES - 0.3"-THICK MATERIAL

A28.1 Control Test Specimens (no defects) - Y values are in 10^6 psi:

| <u>Y</u> |
|----------|----------|----------|----------|----------|----------|----------|
| 27.5 | 30.5 | 28.9 | 26.3 | 30.2 | 29.3 | 29.1 |
| 28.3 | 30.5 | 27.3 | 29.8 | 30.1 | 27.8 | 29.7 |
| 28.3 | 29.2 | 28.4 | 34.5 | 30.6 | 29.0 | 28.6 |
| 31.2 | 31.9 | 26.8 | 29.0 | 30.5 | 28.1 | 30.3 |
| 26.3 | 29.6 | 27.7 | 31.0 | 29.3 | 29.7 | 28.7 |
| 23.7 | 30.1 | 27.5 | 29.3 | 29.8 | 29.0 | 29.2 |
| 26.4 | 28.6 | 22.6 | 28.2 | 27.4 | 28.2 | 28.0 |
| 28.2 | 29.9 | 25.0 | 27.2 | 29.2 | 27.9 | |
| 27.2 | 26.3 | 28.2 | 28.6 | 27.6 | 29.7 | |
| 32.0 | 28.2 | 24.5 | 29.9 | 26.5 | 30.2 | |

$$\bar{Y} = 28.6$$

A28.2 One-mm-Size Test Specimens - Y values are in 10^6 psi:

<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>
27.1	31.4	28.2	32.0	29.7
22.6	27.8	27.2	29.3	

$$\bar{Y} = 28.4$$

A28.3 Two-mm-Size Test Specimens - Y values are in 10^6 psi:

<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>
27.3	27.0	31.0	31.1	26.2	29.2
27.3	32.3	30.8	23.7	29.8	
28.0	28.0	30.6	27.3	27.4	

$$\bar{Y} = 28.6$$

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A28.4 Three-mm-Size Test Specimens - Y values are in 10^6 psi:

<u>Y</u> 24.8	<u>Y</u> 29.0	<u>Y</u> 29.5	<u>Y</u> 28.5	<u>Y</u> 29.5	<u>Y</u> 31.9	
28.1	30.7	26.9	28.8	29.6		$\bar{Y} = 28.8$

A28.5 Four-mm-Size Test Specimens - Y values are in 10^6 psi:

<u>Y</u> 23.7	<u>Y</u> 29.0	<u>Y</u> 32.6	<u>Y</u> 30.9	<u>Y</u> 27.5		
31.0	29.0	27.7	29.2	33.2		$\bar{Y} = 29.4$

A28.6 Five-mm-Size Test Specimens - Y values are in 10^6 psi:

<u>Y</u> 29.4	<u>Y</u> 26.7	<u>Y</u> 29.8	<u>Y</u> 30.9			
29.5	27.6	32.2			$\bar{Y} = 29.4$	

A28.7 Six-mm-Size-and-Larger Test Specimens, Averaging 8.1 - Y values are in 10^6 psi:

<u>Y (6mm)</u>	<u>Y (7mm)</u>	<u>Y (8mm)</u>	<u>Y (9mm)</u>	<u>Y (10mm)</u>	<u>Y (12mm)</u>
26.4	31.2	30.2	32.1	28.7	25.8
25.9	29.3	28.9		26.6	
31.4	28.7	29.6		30.8	
	26.6	28.8			$\bar{Y} = 28.8$

A29. TENSILE-YIELD TEST DATA - IMPERFECTION: INCLUSIONS - 0.3"-THICK MATERIAL

A29.1 Control Test Specimens (no defects) -

Data for control test specimens was presented in paragraph A25.1.

A29.2 One-mm-Size Test Specimens - Y values are in ksi:

<u>Y</u> 140.7	<u>Y</u> 152.6	<u>Y</u> 151.9			
147.4	147.4	144.2		$\bar{Y} = 147.4$	

A29.3 Two-mm-Size Test Specimens - Y values are in ksi:

<u>Y</u> 153.8	<u>Y</u> 139.3	<u>Y</u> 146.2	<u>Y</u> 149.1	<u>Y</u> 144.9	
147.2	155.4	139.2	151.2	159.9	
132.6	150.0	149.0	146.9	149.2	
149.2	149.9	150.0	140.9	147.4	$\bar{Y} = 147.3$
139.2	146.0	150.8	143.3	151.8	

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A29.4 Three-mm-Size Test Specimens - Y values are in ksi:

Y	Y	Y	Y	Y
140.1	147.6	151.2	152.9	143.7
141.3	146.5	144.2	146.8	136.2
147.5	141.9	144.7	149.0	140.7
152.9	144.8	145.3	147.9	147.4
153.4	145.8	149.7	151.1	145.3 $\bar{Y} = 146.3$

A29.5 Four-mm-Size Test Specimens - Y values are in ksi:

Y	Y	Y	Y	Y
141.7	157.3	152.6	147.8	141.7
138.5	148.9	144.1	156.2	
143.2	148.7	145.0	145.2	$\bar{Y} = 146.8$
144.5	148.4	146.6	145.2	

A29.6 Five-mm-Size Test Specimens - Y values are in ksi:

Y	Y	Y	Y	Y	Y
141.1	150.0	138.8	140.2	147.4	141.9
148.0	143.9	147.5	137.6	148.8	
148.2	137.0	155.9	144.5	137.8	$\bar{Y} = 144.3$

A29.7 Six-mm-Size Test Specimens - Y values are in ksi:

Y	Y	Y	Y	Y	Y
135.7	141.9	153.9	139.3	146.8	143.1
139.9	147.8	157.6	145.2	149.2	145.2 $\bar{Y} = 145.5$

A29.8 Seven-mm-Size Test Specimens - Y values are in ksi:

Y	Y	Y
134.9	142.4	155.8
145.2	144.0	$\bar{Y} = 144.4$

A29.9 Eight-mm-Size-and-Larger Test Specimens, Averaging 10.0 mm - Y values are in ksi:

Y (8mm)	Y (10mm)	Y (12mm)
145.6	119.9	128.6
137.5	118.8	92.6 $\bar{Y} = 123.9$

A30. TENSILE-ULTIMATE TEST DATA - IMPERFECTION: INCLUSIONS - 0.3"-THICK MATERIAL

A30.1 Control Test Specimens (no defects):

Data for control test specimens was presented in paragraph A26.1.

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A30.2 One-mm-Size Test Specimens - Y values are in ksi:

<u>Y</u>	<u>Y</u>	<u>Y</u>	
179.3	196.9	194.6	
185.6	200.0	195.0	$\bar{Y} = 191.9$

A30.3 Two-mm-Size Test Specimens - Y values are in ksi:

<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>
164.9	202.3	199.9	195.1	200.3
180.8	204.9	199.1	191.6	195.6
181.6	206.1	187.9	192.6	185.6
186.3	204.4	200.9	193.4	195.4
215.3	170.8	203.6	206.8	186.5
				$\bar{Y} = 194.1$

A30.4 Three-mm-Size Test Specimens - Y values are in ksi:

<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>
181.7	197.3	197.3	141.7	199.1	178.4
184.6	194.7	186.9	195.4	205.9	193.0
192.2	195.5	167.7	173.1	197.9	
208.0	189.3	191.9	192.7	180.9	$\bar{Y} = 190.2$
208.7	190.5	194.8	205.1	191.0	

A30.5 Four-mm-Size Test Specimens - Y values are in ksi:

<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>
183.4	215.1	196.6	190.6	190.1
182.7	185.9	159.1	195.6	
186.7	187.2	185.3	176.4	$\bar{Y} = 188.5$
186.3	201.9	186.5	195.2	

A30.6 Five-mm-Size Test Specimens - Y values are in ksi:

<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>
171.4	191.2	183.4	180.1	197.8	187.8
186.6	178.8	186.8	164.5	198.8	
197.2	175.1	175.4	190.6	180.2	$\bar{Y} = 184.1$

A30.7 Six-mm-Size Test Specimens - Y values are in ksi:

<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>
161.0	160.6	181.1	125.8	195.4
188.4	208.1	182.6	189.8	
166.3	191.7	161.4	181.1	$\bar{Y} = 176.4$

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A30.8 Seven-mm-Size Test Specimens - Y values are in ksi:

<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>
120.6	182.1	115.2	135.9
141.8	184.6	180.8	179.0
$\bar{Y} = 155.0$			

A30.9 Eight-mm-Size-and-Larger Test Specimens, Averaging 9.5 mm -
Y values are in ksi:

<u>Y (8mm)</u>	<u>Y (10mm)</u>	<u>Y (12mm)</u>
115.3	142.2	161.1
63.4	124.0	96.3
174.9		
170.6		
$\bar{Y} = 131.0$		

A31. ELONGATION TEST DATA - IMPERFECTION: INCLUSIONS - 0.3"-THICK MATERIAL

A31.1 Control Test Specimens (no defects) -

Data for control test specimens was presented in A27.1.

A31.2 One-mm-Size Test Specimens - Y values are in % in 2":

<u>Y</u>	<u>Y</u>	<u>Y</u>
3.5	7.5	3.0
4.0	5.0	6.0
$\bar{Y} = 4.8$		

A31.3 Two-mm-Size Test Specimens - Y values are in % in 2":

<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>
2.5	10.0	8.0	4.0	7.0	14.0
2.5	5.5	7.5	6.0	7.5	7.5
11.0	5.0	3.0	9.5	7.0	2.0
4.0	5.5	4.5	11.0	4.5	5.0
6.0	2.0	8.0	8.5	2.5	
$\bar{Y} = 6.2$					

A31.4 Three-mm-Size Test Specimens - Y values are in % in 2":

<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>
4.0	4.5	4.0	2.0	5.0	2.0
10.0	4.0	3.0	5.0	6.0	5.0
4.0	7.5	3.0	2.5	12.5	
4.5	3.5	4.0	4.0	14.0	
5.0	3.0	5.0	7.0	7.5	
$\bar{Y} = 5.2$					

A31.5 Four-mm-Size Test Specimens - Y values are in % in 2":

<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>
4.5	3.5	1.5	2.0	2.5	3.0
5.5	6.0	5.0	1.5	4.5	
3.5	3.5	4.0	2.0	3.0	
$\bar{Y} = 3.5$					

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A31.6 Five-mm-Size Test Specimens - Y values are in % in 2":

<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>
2.5	4.5	2.5	2.5	4.5	7.0
3.0	1.5	2.0	3.0	5.0	
4.0	1.5	2.5	5.0	4.0	$\bar{Y} = 3.4$

A31.7 Six-mm-Size Test Specimens - Y values are in % in 2":

<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>
3.5	3.5	5.0	4.0	2.5	3.0
5.0	1.5	3.0	3.0	3.0	5.0

A31.8 Seven-mm-Size Test Specimens - Y values are in % in 2":

<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>
3.0	3.5	3.0	2.0
2.0	2.5	1.0	

$$\bar{Y} = 2.4$$

A31.9 Eight-mm-Size-and-Larger Test Specimens, Averaging 9.5 mm - Y values are in % in 2":

<u>Y (8mm)</u>	<u>Y (10mm)</u>	<u>Y (12mm)</u>
1.5	2.0	1.0
1.5	2.0	2.0
2.5		
3.0		

$$\bar{Y} = 1.9$$

A32. MODULUS-OF-ELASTICITY TEST DATA - IMPERFECTION: INCLUSIONS - 0.3"-THICK MATERIAL

A32.1 Control Test Specimens (no defects) -

Data for control test specimens was presented in paragraph A28.1.

A32.2 One-mm-Size Test Specimens - Y values are in 10^6 psi:

<u>Y</u>	<u>Y</u>	<u>Y</u>
29.6	29.0	28.7
25.7	27.8	28.7

$$\bar{Y} = 28.3$$

A32.3 Two-mm-Size Test Specimens - Y values are in 10^6 psi:

<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>
29.2	29.3	29.8	29.5	30.2
26.7	26.7	32.1	27.7	30.1
29.6	30.3	29.0	27.5	29.0
28.2	30.4	28.4	22.6	27.9
27.1	28.5	29.9	25.6	29.7

$$\bar{Y} = 28.6$$

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A32.4 Three-mm-Size Test Specimens - Y values are in 10^6 psi:

<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>
28.5	27.8	29.4	28.8	30.5
31.6	30.4	26.7	28.4	28.2
30.3	29.2	28.7	28.8	27.2
28.9	31.5	29.8	29.4	30.2 $\bar{Y} = 29.3$

A32.5 Four-mm-Size Test Specimens - Y values are in 10^6 psi:

<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>
28.8	29.1	27.4	31.2	29.0	28.2
28.8	29.8	29.3	29.9	26.3	29.7
30.0	27.8	28.9	28.4	29.3	$\bar{Y} = 28.9$

A32.6 Five-mm-Size Test Specimens - Y values are in 10^6 psi:

<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>
28.2	29.9	31.0	28.2	31.6	30.3
30.2	27.5	27.9	28.5	30.4	
28.6	29.2	27.8	32.9	28.6	$\bar{Y} = 29.4$

A32.7 Six-mm-Size Test Specimens - Y values are in 10^6 psi:

<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>
27.9	27.8	28.7	26.8	33.0
30.6	30.2	29.0	28.8	
29.6	29.5	29.8	32.9	$\bar{Y} = 29.6$

A32.8 Seven-mm-Size Test Specimens - Y values are in 10^6 psi:

<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>
27.9	29.3	28.3	27.8
30.0	28.9	27.4	28.9 $\bar{Y} = 28.7$

A32.9 Eight-mm-Size-and-Larger Test Specimens, Averaging 9.5 - Y values are in 10^6 psi:

<u>Y (8mm)</u>	<u>Y (10mm)</u>	<u>Y (12mm)</u>
28.4	27.7	27.3
31.7	27.8	28.3
27.8		
27.6		
		$\bar{Y} = 28.3$

A33. TENSILE-YIELD TEST DATA - IMPERFECTION: POROSITY - 0.3%" - THICK MATERIAL

A33.1 Control Test Specimens (no defects) -

Data for control test specimens was presented in paragraph A25.1.

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A33.2 Intensity-1 Test Specimens - Y values are in ksi:

<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>
153.2	142.6	142.9	145.2	156.7	144.5
152.0	145.6	131.6	154.8	146.6	155.1
145.3	146.6	139.6	155.3	142.7	148.9
139.2	138.2	146.0	150.9	140.9	142.3
139.0	137.2	142.1	150.0	147.3	146.3
137.5	140.7	145.2	143.4	142.3	138.3
130.2	141.3	139.5	149.3	146.4	135.3
135.4	140.8	143.1	149.8	146.9	133.5
136.1	144.0	139.8	140.1	151.9	156.6
134.7	139.5	138.8	117.4	143.0	145.4
134.1	141.2	150.9	147.3	146.8	150.7
137.1	140.1	139.5	154.9	160.4	145.9
141.6	139.1	135.7	149.1	150.2	141.7
151.3	143.2	146.1	153.3	146.2	144.4
					$\bar{Y} = 143.9$

A33.3 Intensity-2 Test Specimens - Y values are in ksi:

<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>
152.9	136.4	135.1	156.7	143.0	141.4
152.7	133.7	140.3	144.3	146.4	145.1
151.5	135.7	142.3	135.4	144.2	
154.3	136.1	140.9	152.5	152.6	$\bar{Y} = 144.3$

A33.4 Intensity-3 Test Specimens - Y values are in ksi:

<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>
151.7	140.9	141.9	148.3	143.5
149.9	133.8	134.5	144.5	150.6
149.2	151.7	149.3	147.7	
				$\bar{Y} = 145.5$

A33.5 Intensity-4 Test Specimens - Y values are in ksi:

<u>Y</u>	<u>Y</u>	<u>Y</u>
149.8	137.7	155.4
134.2	145.6	149.0
		$\bar{Y} = 145.2$

A33.6 Intensity-5-and-Higher Test Specimens, Averaging 5.2 - Y values are in ksi:

<u>Y (Intensity 5)</u>	<u>Y (Intensity 6)</u>
139.2	136.8
145.2	
152.8	
137.6	
140.9	
	$\bar{Y} = 142.1$

Controls

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A34. TENSILE-ULTIMATE TEST DATA - IMPERFECTION: POROSITY - 0.3"- THICK MATERIAL

A34.1 Control Test Specimens (no defects)

Data for control test specimens was presented in paragraph A26.1.

A34.2 Intensity-1 Test Specimens - Y values are in ksi:

Y	Y	Y	Y	Y	Y
182.4	194.4	175.9	190.4	205.0	175.4
176.7	189.2	182.0	181.3	178.6	191.7
156.1	199.5	175.2	173.5	193.5	167.0
182.8	175.5	187.0	186.2	187.2	189.3
178.4	188.0	173.3	175.9	188.4	188.5
178.2	179.2	182.7	194.9	187.1	186.8
166.0	188.4	186.4	196.1	193.2	178.3
168.2	189.9	169.9	198.7	197.7	166.1
170.1	196.5	189.0	196.6	187.9	166.9
164.5	182.7	181.6	173.3	189.2	178.6
164.7	174.9	190.6	197.1	189.9	191.7
179.9	182.1	196.3	179.6	190.7	190.0
187.0	167.4	178.3	190.1	168.4	190.1
198.6	170.9	189.9	191.2	194.6	182.8

$$\bar{Y} = 183.5$$

A34.3 Intensity-2 Test Specimens - Y values are in ksi:

Y	Y	Y	Y	Y	Y
170.8	148.0	150.0	180.1	176.8	180.3
180.3	158.8	190.6	191.2	173.1	160.6
184.1	162.4	176.8	172.8	173.3	180.0
166.1	160.0	164.8	177.4	179.7	

$$\bar{Y} = 172.1$$

A34.4 Intensity-3 Test Specimens - Y values are in ksi:

Y	Y	Y	Y	Y
170.3	184.9	189.3	169.6	158.2
162.5	150.0	179.2	181.4	178.7
161.4	183.2	159.9	167.3	180.5

$$\bar{Y} = 171.8$$

A34.5 Intensity-4 Test Specimens - Y values are in ksi:

Y	Y	Y	Y
180.8	173.6	116.7	156.2
159.5	186.2	173.8	

$$\bar{Y} = 163.9$$

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A34.6 Intensity-5 and Higher Test Specimens, Averaging 5.9 -
Y values are in ksi:

<u>Y (Intensity 5)</u>	<u>Y (Intensity 6)</u>
162.3	186.0
171.7	
187.4	
157.2	$\bar{Y} = 171.8$
166.4	

A35. ELONGATION TEST DATA - IMPERFECTION: POROSITY - 0.3"-THICK MATERIAL

A35.1 Control Test Specimens (no defects)

Data for control test specimens was presented in paragraph A27.1.

A35.2 Intensity-1 Test Specimens - Y values are in % in 2":

<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>
3.0	8.0	4.5	2.5	2.5	2.5
4.0	8.5	4.5	2.5	2.5	2.0
3.0	6.0	4.0	3.0	7.5	2.5
3.0	2.5	2.5	3.0	2.0	4.0
2.5	5.0	5.0	6.5	2.5	2.5
3.5	3.5	4.0	4.0	4.5	2.5
2.5	4.5	2.5	6.0	2.0	2.5
2.5	4.0	10.0	4.5	2.0	2.0
3.0	6.0	4.0	6.5	6.0	2.5
3.0	3.5	3.0	4.0	4.5	2.0
2.0	3.5	4.5	1.5	4.5	2.0
5.0	2.5	12.5	2.5	2.0	3.0
10.0	2.5	5.5	1.5	3.0	2.5
5.5	2.5	5.0	3.5	2.5	

$\bar{Y} = 3.8$

A35.3 Intensity-2 Test Specimens - Y values are in % in 2":

<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>
3.0	1.5	2.0	4.0	2.0	2.0
3.0	2.5	7.0	2.5	3.0	5.0
3.5	2.0	3.0	4.0	3.5	
2.5	2.0	2.5	3.5	2.5	$\bar{Y} = 3.0$

A35.4 Intensity-3 Test Specimens - Y values are in % in 2":

<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>
2.5	4.5	4.5	2.5	1.5
3.0	2.0	4.5	2.0	4.0
2.5	3.5	2.5	2.5	2.0

$\bar{Y} = 2.9$

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A35.5 Intensity-4 Test Specimens - Y values are in % in 2":

<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	
4.0	2.5	2.5	2.5	
2.0	5.0	2.5		$\bar{Y} = 3.0$

A35.6 Intensity-5-and-Higher Test Specimens, Averaging 5.2 -
Y values are in % in 2":

<u>Y (Intensity 5)</u>	<u>Y (Intensity 6)</u>
2.0	5.0
2.5	
4.0	$\bar{Y} = 3.5$
4.0	
3.5	

A36. MODULUS-OF-ELASTICITY TEST DATA - IMPERFECTION: POROSITY - 0.3"- THICK MATERIAL

A36.1 Control test Specimens (no defects) -

Data for control test specimens was presented in para-
graph A28.1.

A36.2 Intensity-1 Test Specimens - Y values are in 10^6 psi:

<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>
28.4	27.7	28.2	28.5	29.8	29.5
27.3	27.0	27.7	28.6	28.4	28.6
25.6	27.0	30.3	29.9	28.8	28.7
30.4	29.3	28.7	32.1	27.9	29.5
29.1	29.6	28.2	28.1	29.2	30.5
28.3	26.4	28.4	28.8	31.0	30.0
26.4	29.9	28.2	29.2	30.0	32.0
28.8	27.6	27.8	29.8	31.8	29.8
28.9	30.3	31.2	28.8	27.8	29.8
30.1	30.2	28.1	30.3	29.7	27.5
30.8	28.3	28.7	27.6	29.0	30.6
28.3	29.9	28.7	30.6	29.0	29.7
28.6	28.3	28.1	29.8	28.7	27.8
27.8	28.5	28.8	31.0	29.2	$\bar{Y} = 29.0$

A36.3 Intensity-2 Test Specimens - Y values are in 10^6 psi:

<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>
27.4	31.5	30.3	31.7	29.0	31.9
28.2	30.5	26.5	29.7	30.3	28.8
27.7	30.8	30.4	29.8	27.8	27.5
29.1	26.4	28.5	30.5	30.5	$\bar{Y} = 29.3$

Controls

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A36.4 Intensity-3 Test Specimens - Y values are in 10^6 psi:

\bar{Y}	\bar{Y}	\bar{Y}	\bar{Y}	\bar{Y}
28.6	28.4	30.7	26.5	30.3
27.5	28.5	31.7	27.5	28.2
28.0	29.0	29.9	30.3	$\bar{Y} = 28.9$

A36.5 Intensity-4 Test Specimens - Y values are in 10^6 psi:

\bar{Y}	\bar{Y}	\bar{Y}	\bar{Y}
26.2	29.3	29.5	30.3
29.4	27.5	28.7	$\bar{Y} = 28.7$

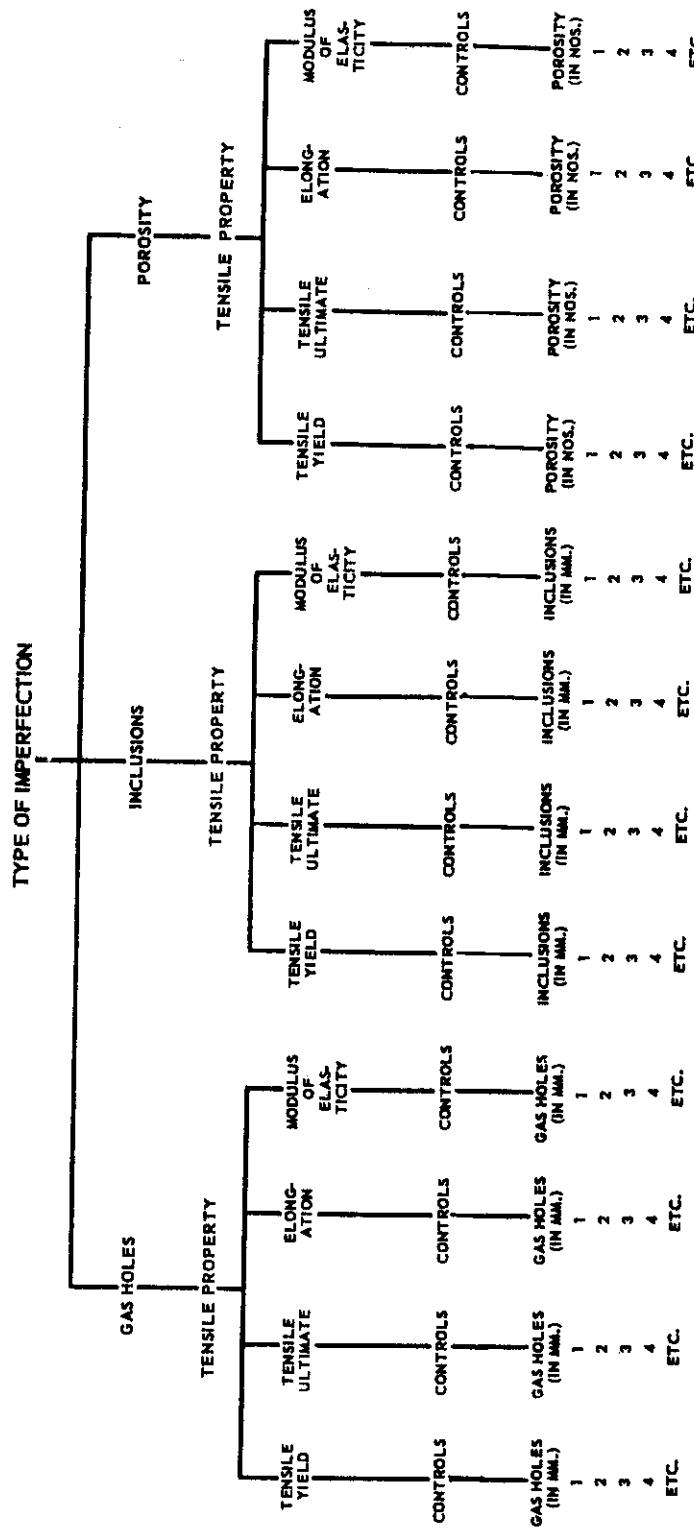
A36.6 Intensity-5-and-Higher Test Specimens, Averaging 5.2 - Y values are in 10^6 psi:

<u>Y (Intensity 5)</u>	<u>Y (Intensity 6)</u>
27.6	26.6
28.4	
30.0	
29.5	
27.9	$\bar{Y} = 28.1$
27.0	

Contracts

TENSILE PROPERTIES VS IMPERFECTIONS, AS DETERMINED BY RADIOGRAPHY

TEST DATA IS TABULATED ON THE FOLLOWING PAGES FOR 0.6"-THICK SPECIMENS OF 410 STAINLESS-STEEL CASTINGS. IT HAS BEEN SUBDIVIDED ACCORDING TO THE FOLLOWING ARRANGEMENT:



Controls

APPENDIX A

A37. TENSILE-YIELD TEST DATA - IMPERFECTION: GAS HOLES - 0.6"-THICK MATERIAL

A37.1 Control Test Specimens (no defects) - Y values are in ksi:

Y	Y	Y	Y	Y	Y
145.2	151.8	148.2	141.7	138.0	142.5
139.2	140.6	141.9	144.9	141.0	144.7
144.9	142.2	135.0	137.3	137.2	145.1
141.9	134.4	151.8	131.3	135.4	140.4
141.8	149.2	147.0	142.7	138.4	139.5
141.7	141.6	154.4	142.4	137.0	137.3
141.3	149.6	149.1	139.8	138.6	144.8
141.1	152.8	147.9	138.5	138.3	143.0
148.0	151.1	152.6	145.1	132.7	
141.3	149.0	150.5	142.7	136.6	
155.2	152.5	142.7	147.0	134.9	
150.9	150.6	140.7	138.9	143.6	Y = 143.2

A37.2 Two-mm-Size Test Specimens - Y values are in ksi:

Y	Y	Y	Y
142.6	141.9	140.6	142.5
142.1	141.3	138.5	Y = 141.4

A37.3 Three-mm-Size Test Specimens - Y values are in ksi:

Y	Y	Y	Y	Y
140.8	142.2	149.6	131.3	138.4
143.1	134.4	145.9	147.0	144.7

A37.4 Four-mm-Size-and-Larger Test Specimens, Averaging 5.9 mm - Y values are in ksi:

Y (4mm)	Y (5mm)	Y (6mm)	Y (8mm)	Y (9mm)
142.7	149.2	146.5	140.2	147.6
140.4	138.6			Y = 143.6

A38. TENSILE-ULTIMATE TEST DATA - IMPERFECTION: GAS HOLES - 0.6"-THICK MATERIAL

Controls

APPENDIX A

A38.1 Control Test Specimens (no defects) - Y values are in ksi:

\bar{Y}	\bar{Y}	\bar{Y}	\bar{Y}	\bar{Y}	\bar{Y}
181.8	148.3	170.7	156.9	186.8	194.8
188.5	153.8	146.6	157.6	171.0	147.6
195.3	131.8	152.4	182.3	173.7	159.5
158.2	164.2	161.8	160.6	174.1	192.6
166.9	181.1	189.2	133.7	159.1	161.0
143.6	131.2	137.7	191.2	171.8	143.7
159.2	163.6	156.2	170.9	145.7	178.6
191.4	171.4	149.9	194.6	141.5	133.7
148.1	170.2	160.8	147.0	172.7	185.2
152.0	155.8	158.4	147.7	174.2	110.5
142.4	162.2	193.8	158.1	177.7	149.0
141.7	166.0	162.3	174.2	143.9	160.6
164.6	195.0	160.9	177.5	147.5	139.5
163.0	172.2	158.4	169.9	144.2	142.3
159.8	175.8	176.1	176.2	152.7	193.1
140.2	168.2	169.1	172.8	168.0	
146.0	153.4	184.1	150.1	170.6	
138.2	178.0	145.1	134.6	162.6	$\bar{Y} = 162.4$

A38.2 Two-mm-Size Test Specimens - Y values are in ksi:

\bar{Y}	\bar{Y}	\bar{Y}	\bar{Y}	\bar{Y}
169.2	142.4	140.2	174.2	143.7
172.0	131.2	146.0	172.8	
158.2	163.6	138.2	192.6	$\bar{Y} = 157.3$

A38.3 Three-mm-Size Test Specimens - Y values are in ksi:

\bar{Y}	\bar{Y}	\bar{Y}	\bar{Y}	\bar{Y}
177.6	171.4	164.6	169.9	174.2
149.3	170.2	170.9	176.2	161.0
167.3	195.0	177.3	171.0	$\bar{Y} = 171.1$

A38.4 Four-mm-Size Test Specimens - Y values are in ksi:

\bar{Y}	\bar{Y}	\bar{Y}	\bar{Y}	\bar{Y}	\bar{Y}
166.9	134.6	186.8	185.2	139.5	$\bar{Y} = 162.6$

A38.5 Five-mm-Size-and-Larger Test Specimens, Averaging 7.2 mm - Y values are in ksi:

$\bar{Y} (5\text{mm})$	$\bar{Y} (6\text{mm})$	$\bar{Y} (7\text{mm})$	$\bar{Y} (8\text{mm})$	$\bar{Y} (9\text{mm})$	$\bar{Y} (10\text{mm})$
139.7	181.8	153.8	152.8	144.5	131.8
155.8			136.8	164.0	
152.7				162.2	
142.3					$\bar{Y} = 153.5$

Contrails

APPENDIX A

A39. ELONGATION TEST DATA - IMPERFECTION: GAS HOLES 0.6"-THICK MATERIAL

A39.1 Control Test Specimens (no defects) - Y values are in % in 2":

\bar{Y}	\bar{Y}	\bar{Y}	\bar{Y}	\bar{Y}	\bar{Y}
3.5	2.5	1.5	3.0	3.5	2.0
6.0	2.0	2.5	3.5	3.0	2.5
8.0	2.0	2.0	2.0	3.5	2.5
4.5	3.5	3.0	1.0	3.5	1.0
1.5	2.5	1.0	6.5	3.5	3.0
3.0	4.0	3.5	3.0	1.5	1.5
8.5	2.5	1.5	16.0	3.0	5.0
3.0	3.5	3.0	1.5	3.0	2.5
3.5	3.0	1.5	2.5	4.0	2.0
2.5	2.0	2.5	2.5	1.5	2.0
1.5	3.0	2.0	2.0	1.0	1.5
3.0	3.0	1.5	3.0	2.0	2.0
3.0	1.5	2.0	3.5	2.5	4.0
2.0	1.5	2.0	2.5	3.0	
2.0	2.0	3.5	3.0	2.5	
2.0	1.5	2.5	2.0	2.5	$\bar{Y} = 2.9$
2.5	3.0	1.5	2.0	6.5	
2.5	3.5	2.5	3.5	2.5	

A39.2 Two-mm-Size Test Specimens - Y values are in % in 2":

\bar{Y}	\bar{Y}	\bar{Y}	\bar{Y}	\bar{Y}	\bar{Y}
3.0	2.5	4.0	2.5	2.0	1.0
3.5	2.5	2.0	1.5	3.0	
4.5	2.5	2.0	2.0	2.5	$\bar{Y} = 2.7$

A39.3 Three-mm-Size Test Specimens - Y values are in % in 2":

\bar{Y}	\bar{Y}	\bar{Y}	\bar{Y}	\bar{Y}	
3.5	2.5	3.0	3.5	3.0	
2.5	3.5	3.0	2.5	2.5	
2.0	3.0	3.0	3.5		$\bar{Y} = 2.9$

A39.4 Four-mm-Size Test Specimens - Y values are in % in 2":

\bar{Y}	\bar{Y}	\bar{Y}	\bar{Y}	\bar{Y}	
1.5	2.0	3.5	5.0	1.5	$\bar{Y} = 2.7$

A39.5 Five-mm-Size-and-Larger Test Specimens, Averaging 7.4 mm - Y values are in % in 2":

<u>Y (5mm)</u>	<u>Y (6mm)</u>	<u>Y (7mm)</u>	<u>Y (8mm)</u>	<u>Y (9mm)</u>	<u>Y (10mm)</u>
1.5	2.0	2.5	2.0	2.0	2.0
3.0			1.0	1.5	
2.5				2.0	$\bar{Y} = 1.9$

Controls

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A40. MODULUS-OF-ELASTICITY TEST DATA - IMPERFECTION: GAS HOLES - 0.6"-THICK MATERIAL

A40.1 Control Test Specimens (no defects) - Y values are in 10^6 psi:

Y	Y	Y	Y	Y	Y
29.8	28.1	33.1	29.9	24.8	27.4
30.0	29.3	30.1	24.9	30.7	28.3
29.0	30.3	29.6	28.1	28.4	33.3
29.8	30.2	27.8	27.3	26.3	27.1
27.3	29.6	29.2	29.0	27.2	31.7
27.9	33.5	28.5	28.7	29.9	27.3
28.4	28.3	28.2	26.0	28.3	26.6
28.5	28.2	29.5	27.3	29.0	26.4
28.0	23.9	27.7	25.9	32.5	27.7
29.6	26.0	31.4	26.4	29.6	27.6
29.6	26.2	34.5	27.6	28.9	27.6
29.9	28.9	27.7	25.7	28.4	26.9
30.8	29.5	25.2	27.5	29.0	27.5
27.5	30.1	24.3	26.5	30.5	25.8
32.4	29.8	29.6	26.5	30.6	
28.0	24.5	25.8	26.4	28.9	
33.0	30.0	30.8	28.1	29.1	$\bar{Y} = 28.5$

A40.2 Two-mm-Size Test Specimens - Y values are in 10^6 psi:

Y	Y	Y	Y	Y
28.5	29.6	32.4	28.6	27.8
30.9	29.6	28.0	32.7	33.3
29.8	33.5	33.0	26.9	31.7

A40.3 Three-mm-Size Test Specimens - Y values are in 10^6 psi:

Y	Y	Y	Y	Y	Y
25.5	28.7	28.2	27.9	28.1	27.1
26.9	28.3	28.9	27.3	29.0	

A40.4 Four-mm-Size Test Specimens - Y values are in 10^6 psi:

Y	Y	Y	Y	Y	Y
27.3	26.5	26.4	26.4	26.9	$\bar{Y} = 26.7$

A40.5 Five-mm-Size-and-Larger Test Specimens, Averaging 7.4 mm - Y values are in 10^6 psi:

Y (5mm)	Y (6mm)	Y (7mm)	Y (8mm)	Y (9mm)	Y (10mm)
25.7	31.0	28.1	27.8	28.9	29.3
23.9			28.2	28.9	
29.0				26.0	$\bar{Y} = 28.5$

Controls

APPENDIX A

A41. TENSILE-YIELD TEST DATA - IMPERFECTION: INCLUSIONS - 0.6"-THICK MATERIAL

A41.1 Control Test Specimens (no defects)

Data for control test specimens was presented in paragraph A37.1.

A41.2 Two-mm-Size Test Specimens - Y values are in ksi:

\bar{Y}	\bar{Y}	\bar{Y}
149.7	152.8	142.7
141.2	137.3	139.8
$\bar{Y} = 143.9$		

A41.3 Three-mm-Size Test Specimens - Y values are in ksi:

\bar{Y}	\bar{Y}	\bar{Y}	\bar{Y}	\bar{Y}
145.2	139.5	136.0	142.4	149.0
141.4	149.0	132.7	141.5	
$\bar{Y} = 141.9$				

A41.4 Four-mm-Size Test Specimens - Y values are in ksi:

\bar{Y}	\bar{Y}	\bar{Y}	\bar{Y}	\bar{Y}	\bar{Y}
137.5	135.8	149.2	141.2	152.5	137.3
172.4	144.9	137.5	151.1	137.0	
$\bar{Y} = 140.6$					

A41.5 Five-mm-Size Test Specimens - Y values are in ksi:

\bar{Y}	\bar{Y}	\bar{Y}	\bar{Y}
136.8	136.0	148.2	138.9
143.0	150.6	144.9	
$\bar{Y} = 142.6$			

A41.6 Six-mm-Size Test Specimens - Y values are in ksi:

\bar{Y}	\bar{Y}	\bar{Y}
139.4	141.9	132.7
146.9	141.7	143.0
$\bar{Y} = 140.9$		

A41.7 Seven-mm-Size Test Specimens - Y values are in ksi:

\bar{Y}	\bar{Y}	\bar{Y}	\bar{Y}	\bar{Y}
136.6	138.7	135.0	154.4	138.2
153.8	136.1	151.8	137.7	
150.0	140.2	147.0	138.0	$\bar{Y} = 142.9$

A41.8 Eight-mm-Size-and-Larger Test Specimens, Averaging 10.0 mm - Y values are in ksi:

$\bar{Y} (8\text{mm})$	$\bar{Y} (9\text{mm})$	$\bar{Y} (10\text{mm})$	$\bar{Y} (11\text{mm})$	$\bar{Y} (12\text{mm})$	$\bar{Y} (13\text{mm})$
128.3	149.1	136.5	138.9	139.1	132.0
152.3	152.6	142.7	150.9		
147.9		142.4	142.7		$\bar{Y} (15\text{mm})$
134.9		139.7	145.1		115.5
143.6		143.1			
$\bar{Y} = 140.9$					

Controls

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A42. TENSILE-ULTIMATE TEST DATA - IMPERFECTION: INCLUSIONS - 0.6"-THICK MATERIAL

A42.1 Control Test Specimens (no defects):

Data for control test specimens was presented in paragraph A38.1.

A42.2 Two-mm-Size Test Specimens - Y values are in ksi:

Y	Y	Y	Y
149.0	145.7	172.2	194.6
197.4	131.2	191.2	158.1
$\bar{Y} = 167.4$			

A42.3 Three-mm-Size Test Specimens - Y values are in ksi:

Y	Y	Y	Y	Y
175.5	185.1	143.7	147.7	168.2
191.4	170.8	160.6	133.7	
141.2	160.8	147.0	166.0	$\bar{Y} = 160.9$

A42.4 Four-mm-Size Test Specimens - Y values are in ksi:

Y	Y	Y	Y	Y
153.6	163.4	175.8	133.7	149.0
164.5	177.0	153.4	177.7	160.5
168.2	155.5	148.3	147.5	$\bar{Y} = 159.1$

A42.5 Five-mm-Size Test Specimens - Y values are in ksi:

Y	Y	Y	Y	Y
160.1	187.2	146.6	182.3	144.2
174.3	178.0	152.4	173.7	
168.7	170.7	137.7	143.9	$\bar{Y} = 163.1$ ~

A42.6 Six-mm-Size Test Specimens - Y values are in ksi:

Y	Y	Y	Y	Y
150.0	130.7	157.6	173.1	
152.3	189.2	170.6		$\bar{Y} = 160.5$

A42.7 Seven-mm-Size Test Specimens - Y values are in ksi:

Y	Y	Y	Y	Y
162.0	170.0	156.2	173.8	174.1
190.9	153.1	149.9	162.3	168.0
107.1	168.9	158.4	172.1	$\bar{Y} = 162.0$

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A42.8 Eight-mm-Size Test Specimens - Y values are in ksi:

\bar{Y}	\bar{Y}	\bar{Y}	\bar{Y}	\bar{Y}
139.2	133.4	128.7	158.4	147.6
163.9	149.6	160.8	194.8	159.5
$\bar{Y} = 153.6$				

A42.9 Nine-mm-Size Test Specimens - Y values are in ksi:

\bar{Y}	\bar{Y}	\bar{Y}	\bar{Y}
140.1	160.9	176.1	145.1
$\bar{Y} = 155.6$			

A42.10 Ten-mm-Size Test Specimens - Y values are in ksi:

\bar{Y}	\bar{Y}	\bar{Y}
126.8	184.1	143.2
162.9	149.1	152.7
$\bar{Y} = 153.1$		

A42.11 Eleven-mm-and-Larger Test Specimens, Averaging 13.8 mm -
Y values are in ksi:

\bar{Y} (11mm)	\bar{Y} (12mm)	\bar{Y} (13mm)	\bar{Y} (15mm)	\bar{Y} (20mm)
146.0	159.6	151.1	147.0	133.6
163.0				170.5
184.1				
178.6				$\bar{Y} = 159.3$

A43. ELONGATION TEST DATA - IMPERFECTION: INCLUSIONS - 0.6"-THICK MATERIAL

A43.1 Control Test Specimens (no defects)

Data for control test specimens was presented in para-graph A39.1.

A43.2 Two-mm-Size Test Specimens - Y values are in % in 2":

\bar{Y}	\bar{Y}	\bar{Y}	\bar{Y}
4.5	2.5	1.5	10.6
2.5	1.5	6.5	2.5
$\bar{Y} = 4.7$			

A43.3 Three-mm-Size Test Specimens - Y values are in % in 2":

\bar{Y}	\bar{Y}	\bar{Y}	\bar{Y}	\bar{Y}
3.0	2.5	2.0	2.5	2.0
8.5	2.0	2.0	1.5	
2.5	4.0	1.5	3.0	$\bar{Y} = 2.9$

A43.4 Four-mm-Size Test Specimens - Y values are in % in 2":

\bar{Y}	\bar{Y}	\bar{Y}	\bar{Y}	\bar{Y}
4.0	1.5	1.5	1.0	2.0
3.0	3.5	1.5	4.0	2.5
2.0	2.5	2.5	1.0	$\bar{Y} = 2.3$

Controls

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A43.5 Five-mm-Size Test Specimens - Y values are in % in 2":

<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>
3.0	3.0	1.5	3.5	2.0
2.5	3.0	2.5	3.0	
2.5	3.5	1.0	1.5	$\bar{Y} = 2.5$

A43.6 Six-mm-Size Test Specimens - Y values are in % in 2":

<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	
2.0	3.0	3.0	4.0	
2.5	3.0	2.5		$\bar{Y} = 2.9$

A43.7 Seven-mm-Size Test Specimens - Y values are in % in 2":

<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>
2.0	3.0	1.5	2.0	3.0
2.5	3.0	1.5	2.0	2.5
1.0	3.5	2.5	3.5	
				$\bar{Y} = 2.4$

A43.8 Eight-mm-Size Test Specimens - Y values are in % in 2":

<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>
2.0	2.0	2.0	2.0	2.5
1.5	2.0	3.0	6.5	2.0
				$\bar{Y} = 2.6$

A43.9 Nine-mm-Size Test Specimens - Y values are in % in 2":

<u>Y</u>	<u>Y</u>	<u>Y</u>	<u>Y</u>	
1.5	1.5	2.0	1.5	
				$\bar{Y} = 1.6$

A43.10 Ten-mm-Size Test Specimens - Y values are in % in 2":

<u>Y</u>	<u>Y</u>	<u>Y</u>	
2.0	2.5	2.0	
2.5	2.5	3.0	$\bar{Y} = 2.4$

A43.11 Eleven-mm-Size-and-Larger Test Specimens, Averaging 13.8 mm
Y values are in % in 2":

<u>Y</u> (11mm)	<u>Y</u> (12mm)	<u>Y</u> (13mm)	<u>Y</u> (15mm)	<u>Y</u> (20mm)
2.0	2.0	3.5	2.5	1.5
3.0				3.0
2.5				
3.0				$\bar{Y} = 2.6$

A44. MODULUS-OF-ELASTICITY TEST DATA - IMPERFECTION: INCLUSIONS - 0.6"-THICK MATERIAL

A44.1 Control Test Specimens (no defects)

Data for control test specimens was presented in paragraph A40.1.

Controls

APPENDIX A

A44.2 Two-mm-Size Test Specimens - Y values are in 10^6 psi:

\bar{Y}	\bar{Y}	\bar{Y}	\bar{Y}	
29.0	28.2	26.0	25.7	
28.2	29.5	25.9		$\bar{Y} = 27.5$

A44.3 Three-mm-Size Test Specimens - Y values are in 10^6 psi:

\bar{Y}	\bar{Y}	\bar{Y}	\bar{Y}	\bar{Y}
30.4	27.2	26.5	27.6	28.0
28.5	27.2	29.0	26.6	
26.9	31.8	26.4	26.2	$\bar{Y} = 27.9$

A44.4 Four-mm-Size Test Specimens - Y values are in 10^6 psi:

\bar{Y}	\bar{Y}	\bar{Y}	\bar{Y}	\bar{Y}
27.7	31.0	30.1	28.7	27.6
32.5	32.6	24.5	32.5	27.7
27.8	26.8	28.1	28.9	$\bar{Y} = 29.0$

A44.5 Five-mm-Size Test Specimens - Y values are in 10^6 psi:

\bar{Y}	\bar{Y}	\bar{Y}	\bar{Y}	\bar{Y}
31.5	28.8	30.1	27.3	28.4
25.0	30.0	29.6	24.8	
28.4	33.1	28.5	29.6	$\bar{Y} = 28.9$

A44.6 Six-mm-Size Test Specimens - Y values are in 10^6 psi:

\bar{Y}	\bar{Y}	\bar{Y}	\bar{Y}	
29.2	25.2	28.1	25.8	
27.7	29.2	30.6		$\bar{Y} = 28.0$

A44.7 Seven-mm-Size Test Specimens - Y values are in 10^6 psi:

\bar{Y}	\bar{Y}	\bar{Y}	\bar{Y}	\bar{Y}
30.9	31.2	28.2	34.5	30.7
30.2	27.3	29.5	27.7	30.5
24.8	28.6	26.4	31.4	28.9
				$\bar{Y} = 29.4$

A44.8 Eight-mm-Size Test Specimens - Y values are in 10^6 psi:

\bar{Y}	\bar{Y}	\bar{Y}	\bar{Y}	\bar{Y}
29.1	29.2	33.0	24.3	27.4
28.9	31.6	27.7	29.1	28.3
				$\bar{Y} = 28.9$

A44.9 Nine-mm-Size Test Specimens - Y values are in 10^6 psi:

\bar{Y}	\bar{Y}	\bar{Y}	\bar{Y}	
31.0	25.2	29.6	27.9	
				$\bar{Y} = 28.4$

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A44.10 Ten-mm-Size Test Specimens - Y values are in 10^6 psi:

<u>Y</u>	<u>Y</u>	<u>Y</u>	
29.5	30.8	31.0	
28.1	28.3	27.8	$\bar{Y} = 29.3$

A44.11 Eleven-mm-Size-and-Larger Test Specimens, Averaging 13.8 mm -
Y values are in 10^6 psi:

<u>Y (11mm)</u>	<u>Y (12mm)</u>	<u>Y (13mm)</u>	<u>Y (15mm)</u>	<u>Y (20mm)</u>
31.6	31.0	27.0	25.0	33.0
30.8				26.2
30.8				
27.3				$\bar{Y} = 29.2$

A45. TENSILE-YIELD TEST DATA - IMPERFECTION: POROSITY - 0.6"-THICK MATERIAL

A45.1 Control Test Specimens (no defects)

Data for control test specimens was presented in paragraph A37.1.

A45.2 Intensity-1 Test Specimens - Y values are in ksi:

| <u>Y</u> |
|----------|----------|----------|----------|----------|----------|-------------------|
| 145.0 | 143.1 | 119.6 | 154.1 | 141.4 | 141.0 | 140.4 |
| 141.2 | 140.8 | 112.6 | 138.8 | 134.1 | 137.0 | 142.2 |
| 150.8 | 133.8 | 151.2 | 137.3 | 143.4 | 135.4 | 144.6 |
| 144.3 | 142.9 | 151.8 | 137.3 | 138.8 | 133.7 | |
| 141.2 | 137.2 | 148.6 | 139.0 | 142.5 | 140.1 | |
| 143.7 | 140.4 | 153.6 | 139.7 | 145.1 | 136.2 | $\bar{Y} = 141.3$ |
| 142.2 | 144.5 | 150.5 | 145.2 | 123.1 | 141.1 | |
| 141.8 | 150.6 | 143.6 | 138.4 | 135.7 | 142.4 | |
| 142.7 | 151.8 | 153.3 | 146.4 | 142.7 | 137.3 | |
| 143.4 | 139.7 | 147.4 | 138.1 | 147.0 | 136.2 | |
| 131.7 | 139.6 | 147.3 | 144.5 | 138.0 | 136.0 | |
| 145.9 | 129.8 | 150.6 | 139.6 | 138.0 | 151.2 | |

A45.3 Intensity-2 Test Specimens - Y values are in ksi:

| <u>Y</u> |
|----------|----------|----------|----------|----------|----------|-------------------|
| 143.0 | 142.4 | 143.7 | 123.4 | 139.2 | 133.8 | 132.4 |
| 145.3 | 136.9 | 140.0 | 143.6 | 148.6 | 136.7 | 139.1 |
| 139.2 | 138.3 | 140.8 | 143.2 | 139.7 | 137.5 | 140.1 |
| 142.2 | 140.6 | 142.5 | 142.4 | 137.0 | 126.1 | |
| | | | | | | $\bar{Y} = 139.2$ |

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A45.4 Intensity-3 Test Specimens - Y values are in ksi:

Y 144.0	Y 132.6	Y 137.4	Y 145.1	Y 140.7	Y 133.7	
139.6	114.0	137.9	139.5	138.1	138.6	
142.4	133.7	147.5	132.8	117.6	138.6	Y = 136.4

A45.5 Intensity-4 Test Specimens - Y values are in ksi:

Y 141.2	Y 138.1	Y 135.3	Y 136.0	Y 138.2	Y 143.5	Y = 138.7
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A45.6 Intensity-5 Test Specimens - Y values are in ksi:

Y 128.0	Y 129.0	Y 149.2	Y 138.6	Y 135.5	Y 136.1	
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A45.7 Intensity-6-and-Higher Test Specimens, Averaging 7.3 - Y values are in ksi:

Y (Intensity 6) 139.2	Y (Intensity 8) 131.6		
	131.8		Y = 134.2

A46. TENSILE-ULTIMATE TEST DATA - IMPERFECTION: POROSITY - 0.6"-THICK MATERIAL

A46.1 Control Test Specimens (no defects)

Data for control test specimens was presented in paragraph A38.1.

A46.2 Intensity-1 Test Specimens - Y values are in ksi:

Y 167.0	Y 126.9	Y 186.2	Y 142.3	Y 159.2	Y 141.5	Y 170.0	
169.2	158.5	139.2	138.6	158.0	172.7		
170.8	155.1	130.6	158.4	159.8	155.8		
167.3	171.6	192.7	141.8	163.7	171.9		
141.2	153.5	160.9	178.8	154.9	137.3		
149.6	159.8	164.2	130.3	175.9	148.2		
158.2	141.5	156.7	166.3	155.1	154.8		
155.7	143.5	143.3	153.3	157.4	151.7	Y = 154.1	
147.7	129.1	160.5	177.3	178.4	168.8		
157.0	124.5	130.3	145.0	134.6	156.6		
146.5	122.5	134.0	153.2	186.8	131.2		
178.9	135.6	129.0	167.2	171.0	169.2		
166.2	130.6	148.4	176.7	173.7	157.4		
152.7	153.6	172.1	147.8	174.1	161.2		
149.4	134.2	159.5	147.6	159.1	142.1		
133.9	130.0	162.4	164.7	171.8	156.4		
166.2	128.0	138.7	135.6	145.7	148.0		

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A46.3 Intensity-2 Test Specimens - Y values are in ksi:

Y	Y	Y	Y	Y	Y	Y
143.0	141.5	146.7	119.4	171.6	170.5	133.8
161.8	143.9	143.3	134.5	147.7	158.6	136.4
172.1	166.6	143.9	135.5	156.2	148.1	
148.0	128.6	140.8	134.1	155.5	143.4	$\bar{Y} = 147.0$
139.2	127.8	144.8	142.3	147.7	138.4	
149.0	165.5	137.3	155.3	153.0	139.4	
172.8	155.9	131.7	129.5	163.9	149.2	
139.8	173.9	126.0	130.3	163.9	145.8	

A46.4 Intensity-3 Test Specimens - Y values are in ksi:

Y	Y	Y	Y	Y	Y
161.3	132.6	174.0	138.1	147.9	129.3
154.1	114.0	154.9	132.1	124.0	131.9
161.4	133.7	139.5	135.5	156.5	169.8
157.9	137.6	136.2	159.2	155.8	147.5
159.5	138.9	136.6	124.2	138.2	$\bar{Y} = 144.2$

A46.5 Intensity-4 Test Specimens - Y values are in ksi:

Y	Y	Y	Y	Y
159.0	158.7	139.1	173.5	133.8
140.3	140.2	146.6	161.7	132.3

$$\bar{Y} = 149.1$$

A46.6 Intensity-5 Test Specimens - Y values are in ksi:

Y	Y	Y	Y	Y
154.0	137.7	171.9	112.3	124.7
123.0	134.6	155.1	101.9	171.1
118.4	131.4	132.4	132.5	$\bar{Y} = 135.8$

A46.7 Intensity-6 Test Specimens - Y values are in ksi:

Y	Y	Y	Y	Y	Y
133.1	126.1	139.2	134.5	128.1	118.8

$$\bar{Y} = 130.0$$

A46.8 Intensity-7 Test Specimens - Y values are in ksi:

Y	Y	Y	Y	Y
143.6	146.4	119.1	120.9	122.5

$$\bar{Y} = 130.5$$

A46.9 Intensity-8 Test Specimens - Y values are in ksi:

Y	Y	Y
131.6	149.5	105.7

$$\bar{Y} = 128.9$$

Controls

APPENDIX A

A47. ELONGATION TEST DATA - IMPERFECTION: POROSITY - 0.6"-THICK MATERIAL

A47.1 Control Test Specimens (no defects)

Data for control test specimens was presented in paragraph A39.1.

A47.2 Intensity-1 Test Specimens - Y values are in % in 2":

Y	Y	Y	Y	Y	Y	Y	Y
3.5	3.0	1.5	1.5	2.0	1.0	2.0	
3.5	2.0	1.5	1.0	2.5	3.0		
3.5	3.0	2.5	2.0	3.0	2.0		
2.5	3.5	2.0	1.5	2.5	2.5		
2.5	2.0	2.0	3.5	2.5	2.0		$\bar{Y} = 2.4$
3.0	3.0	2.5	1.0	2.5	2.5		
2.0	2.5	2.5	2.5	2.5	3.0		
3.5	2.0	1.5	2.0	3.5	2.5		
3.0	2.5	1.0	2.5	2.0	2.5		
2.0	1.5	1.5	2.0	3.5	2.5		
3.0	2.0	1.0	2.0	3.5	1.5		
3.0	2.5	2.0	2.0	2.0	2.5		
3.5	1.5	3.0	3.5	3.5	2.0		
2.5	3.5	2.0	2.0	3.5	2.5		
4.5	2.5	2.0	2.0	3.5	2.0		
2.0	2.0	2.0	2.0	1.5	3.5		

A47.3 Intensity-2 Test Specimens - Y values are in % in 2":

Y	Y	Y	Y	Y	Y	Y	Y
4.5	4.5	1.0	2.5	3.0	2.0	2.0	1.5
4.0	3.5	4.0	2.5	1.5	1.0	4.0	2.0
3.5	3.0	1.5	3.0	1.5	3.0	2.0	3.5
3.5	4.0	2.0	3.5	1.5	2.5	3.0	2.5
2.5	2.5	2.0	2.5	1.5	3.0	3.0	2.0
4.5	3.0	3.0	3.0	2.0	2.0	3.0	1.5
							$\bar{Y} = 2.1$

A47.4 Intensity-3 Test Specimens - Y values are in % in 2":

Y	Y	Y	Y	Y	Y	Y
3.0	2.5	2.5	3.0	1.5	2.0	1.0
4.0	2.0	1.5	2.5	2.0	1.0	2.0
3.5	3.0	1.0	2.0	2.5	2.0	2.0
4.0	2.5	2.5	1.5	1.0	2.0	2.5
						$\bar{Y} = 2.3$

A47.5 Intensity-4 Test Specimens - Y values are in % in 2":

Y	Y	Y	Y	Y
5.0	5.0	2.0	2.5	1.5
4.0	3.5	1.5	3.0	1.5

$\bar{Y} = 3.0$

Contrails

APPENDIX A

A47.6 Intensity-5 Test Specimens - Y values are in % in 2":

\bar{Y} 1.0 2.0	\bar{Y} 2.0 3.0	\bar{Y} 1.5 2.0	\bar{Y} 1.0 1.5	\bar{Y} 5.0	$\bar{Y} = 2.1$
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A47.7 Intensity-6 Test Specimens - Y values are in % in 2":

\bar{Y} 2.5	\bar{Y} 1.5	\bar{Y} 3.0	\bar{Y} 1.5	\bar{Y} 1.0	\bar{Y} 2.5	$\bar{Y} = 2.0$
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A47.8 Intensity-7-and-Higher Test Specimens, Averaging 7.4 -
Y values are in % in 2":

<u>Y (Intensity 7)</u>	<u>Y (Intensity 8)</u>
2.0	2.5
1.5	3.0
1.0	2.0
1.5	$\bar{Y} = 1.8$

A48. MODULUS-OF-ELASTICITY TEST DATA - IMPERFECTION: POROSITY -
0.6"-THICK MATERIAL

A48.1 Control Test Specimens (no defects)

Data for control test specimens was presented in para-
graph A40.1.

A48.2 Intensity-1 Test Specimens - Y values are in 10^6 psi:

\bar{Y} 26.3	\bar{Y} 29.6	\bar{Y} 28.8	\bar{Y} 26.5	\bar{Y} 30.7	\bar{Y} 26.7
33.3	27.5	27.5	25.6	28.4	26.2
31.3	29.1	29.6	26.4	26.3	
31.5	32.3	29.3	28.6	27.2	
29.3	29.8	28.3	27.3	29.9	
26.8	30.5	27.8	28.3	28.3	
32.1	32.0	28.5	26.7	30.6	
27.8	27.4	25.8	27.5	29.0	
28.5	30.0	29.5	25.3	28.0	
28.7	27.2	29.3	25.5	27.0	$\bar{Y} = 28.4$
29.8	27.0	26.4	25.2	28.1	
28.9	26.9	31.4	27.6	32.3	
27.8	29.5	31.3	27.3	28.9	
28.7	28.9	28.1	28.3	25.1	
31.0	26.8	29.4	27.8	28.5	
26.8	29.0	26.1	29.3	26.8	
31.5	30.2	28.8	26.5	26.7	
30.5	28.7	25.6	26.4	26.6	
26.3	26.7	29.0	28.1	30.0	
30.7	32.0	26.5	27.3	27.3	

Contrails

APPENDIX A

A48.3 Intensity-2 Test Specimens - Y values are in 10^6 psi:

Y	Y	Y	Y	Y	Y	Y
27.8	26.8	28.1	29.9	27.3	35.8	28.2
31.1	35.8	30.3	33.1	28.3	29.7	
31.5	35.3	30.2	28.5	27.6	27.3	
28.2	26.0	30.7	28.7	25.5	31.3	
27.3	27.5	27.7	33.0	27.3	27.1	
28.8	29.0	27.9	26.9	33.8	29.4	
29.8	30.2	28.8	27.4	27.7	32.1	$\bar{Y} = 29.4$

A48.4 Intensity-3 Test Specimens - Y values are in 10^6 psi:

Y	Y	Y	Y	Y	Y
30.3	29.1	29.5	28.3	30.6	31.9
32.0	29.0	32.2	29.8	28.7	
26.4	26.4	26.2	26.7	27.8	
27.5	28.2	27.7	26.9	29.6	
22.8	29.7	31.7	32.3	32.8	$\bar{Y} = 29.0$

A48.5 Intensity-4 Test Specimens - Y values are in 10^6 psi:

Y	Y	Y	Y	Y
27.4	33.0	29.5	25.0	24.7
27.5	27.8	30.1	26.2	27.1

A48.6 Intensity-5 Test Specimens - Y values are in 10^6 psi:

Y	Y	Y	Y	Y	Y
31.4	31.2	25.8	28.8	33.2	28.6
32.7	29.5	32.6	27.0	28.9	31.1

A48.7 Intensity-6 Test Specimens - Y values are in 10^6 psi:

Y	Y	Y	Y	
30.0	30.8	29.1	27.9	$\bar{Y} = 29.5$

A48.8 Intensity-7 Test Specimens - Y values are in 10^6 psi:

Y	Y	Y	Y	Y
28.0	26.7	27.3	28.6	26.1

A48.9 Intensity-8 Test Specimens - Y values are in 10^6 psi:

Y	Y	
29.3	24.9	$\bar{Y} = 27.1$

Contrails

CORRELATION OF TENSILE PROPERTIES
OF STEEL CASTINGS AND MATERIAL
IMPERFECTIONS, AS DETERMINED
BY RADIOGRAPHY

APPENDIX B - EQUIPMENT

WADD TR 60-450

Contrails

Contracts

APPENDIX B

B. EQUIPMENT

Equipment used by the Pacific Alloy Corporation and Convair, San Diego, in conducting this project follows:

B1. Pacific Alloy Corporation Equipment:

B1.1 For Melting -

Ajax Electrothermic Corporation - Induction-Melting Furnace - 850 lbs. capacity.

Motor Generator Set - 175 KVA, 960 cycles.

Kenney Pump Division, New York Air Brake Co. - Furnace-Degassing Equipment - 25 hp., maximum vacuum 1 mm Hg.

B1.2 For Temperature Determinations of the Melt -

Leeds and Northrup Immersion Potentiometer with platinum/platinum-rhodium thermocouple.

Leeds and Northrup Optical Pyrometer - Catalog No. 8821.

B1.3 Annealing Furnaces -

Two Alpine, Model VHS-100 (1900 F maximum temperature).

B1.4 For Humidity Determinations -

Sling psychrometer. Manufactured by Genco.

B1.5 For Molding -

Shell molds containing commercial-purity zircon sand and Bakelite resin.

B1.6 X-ray-

260 KV McCurtain Engineering X-ray, with 2.5 mm focal-spot size, 42-inch focal length, and tungsten target.

Eastman type-M film.

Pacific Alloy Corp. X-ray Laboratory received Air Force certification on October 30, 1956 and was recertified July 10, 1959 with new personnel.

Controls

APPENDIX B

B1.7 For Chemical and Physical Foundry Tests-

Atlas Testing Laboratory (An Air Force-approved facility)
1225 East 63rd Street
Los Angeles 1, California

B2. Convair Equipment:

B2.1 For Hardness Testing -

Wilson Rockwell Tester - Model 4-JRPL.

B2.2 For Tensile Testing -

Super L. Tinium Olsen Electronic Tester (60,000 lbs) with an Olsen strain-rate pacer and recorder.

Southwark Tester with Baldwin (Model MA1B) stress-strain recorder and an O. S. Peters' strain-rate pacer.

Tinius Olsen Test Machine (200,000 lbs) with Tinius Olsen strain pacer and recorder.

B2.3 For Metallography -

Buehler mounting and polishing equipment.

Bausch and Lomb Balphat Metallograph and 3D stereomicroscope

Disa Electropol Electric Polisher - Model 53A

B2.4 For Chemical Analysis -

Wet chemical-laboratory equipment.

B2.5 Machine Shop (Laboratory & Production) -

Full spectrum of metal processing equipment.

B2.6 X-ray

Picker X-ray Machine - 260 KV, 3.5 mm focal-spot size.

Kelchet Viewer - Type G-1.

Picker X-ray Viewer (23" x 56")

G. E. Model BY Type-I Viewer

Eastman film - Type M for 0.1", 0.2" and 0.3" material
Eastman film - Type AA for 0.6" material

Controls

APPENDIX B

B2.7 For Steel -

B2.7.1 Solution-Heat-Treat Furnaces -

General Electric with Leeds and Northrup controls and recording equipment - 50.25 KW, 2000 F maximum temperature. Furnace is supplied with saturated exotherm gas from a G. E. Neutralene Producer with 1000 cu. ft. per hour, low ratio.

B2.7.2 Tempering Furnaces -

Lindberg - 18 KW - Type 202418 - 230, 3-phase volts, 1250 F maximum temperature with Wheelco Capacalog controller and recorder.

C. I. Hayes Co., Inc. Electric Furnace - Type LRF 303.

Industrial Systems Furnace - No. 52-62, 440 volts, 3 phase, 60 cycles.