CANADA

THE EFFECT OF SOME TEST BAR VARIABLES ON THE MECHANICAL PROPERTIES OF ALUMINUM ALLOYS

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THE EFFECT OF SOME TEST BAR VARIABLES ON THE MECHANICAL PROPERTIES OF ALUMINUM ALLOYS

by

A. Couture* and J. W. Meier**

ABSTRACT

The effect of machining on the tensile properties of aluminum alloy test bars was investigated. Although certain of the differences in ultimate strength and elongation were found to be statistically significant in some cases, they were of the same order as differences that are observed between melts of the same composition.

A comparison of 0.1% and 0.2% yield strength values, obtained on test bars of various aluminum alloys, showed that the linear relationship between these two values is different for most of the alloys investigated.

Similarly, linear relationships between the elongation values used in North America (4D) and in Great Britain (3.5D) were found for the alloys investigated.

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Direction des mines

EFFET DE CERTAINES VARIABLES SUR LES PROPRIÉTÉS MÉCANIQUES D'ÉPROUVETTES EN ALLIAGES D'ALUMINIUM

par

A. Couture* et J. W. Meier**

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RÉSUMÉ

Les auteurs ont étudié l'effet de l'usinage sur les propriétés mécaniques d'éprouvettes en alliages d'aluminium. L'analyse statistique a démontré que l'usinage peut apporter des variations appréciables de la résistance à la rupture et de l'allongement dans certains cas, mais que ces différences sont du même ordre de grandeur que celles que l'on remarque entre différentes coulées du même alliage.

Ils ont établi que la relation entre les limites conventionnelles d'élasticité pour des déformations permanentes de 0.1 et 0.2 p. 100 est linéaire, mais que la droite de correspondance reliant ces deux valeurs peut varier de façon appréciable d'un alliage à l'autre.

De même ils ont déterminé des droites de correspondance entre allongements mesurés sur des distances entre repéres égales à 4 et 3.5 fois le diamètre de l'éprouvette, longueurs utilisées en Amérique du Nord et en Grande-Bretagne.

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INTRODUCTION

Separately-cast test bars are used throughout the foundry industry to assess melt quality and the effect of heat treatment, as well as for research and development work on alloy compositions or heat treatments. It is well known that properties obtained on separately-cast test bars do not represent the properties of production castings of various shapes and sizes.

The full value of melt quality evaluation can be achieved only if the test bars are cast under standardized and strictly controlled conditions. As reported earlier(1,2), there are almost fifty variables that may affect the data obtained from mechanical tests on cast test bars, and these variables relate to alloy composition, melting conditions, casting design, heat treatment, test bar preparation, and certain differences in testing methods.

This report deals only with some aspects of three such variables, namely, the effect of machining on the tensile property values of test bars, and a comparison of yield strengths and elongations used in various countries.

Recent efforts to establish international standards for aluminum casting alloys, undertaken by the International Organization for Standardization (ISO/TC79), showed that alloy properties cannot be specified without a basic agreement on at least some of the more important factors affecting test bar results.

One of the more serious problems in the international use of test bars is the preparation of test bars. Most European countries still specify test bars machined to finished dimensions, whereas North American specifications have, for many years, called for cast-to-shape test bars. There is no doubt that test results depend on the accuracy of dimensional measurements of the cross-section in the gauge length, and that the test results may be affected by the cross-section uniformity and the degree of surface smoothness. Nevertheless, it is known, from long-established and general use of cast-to-shape test bars in North American light alloy foundries, that the slight differences in tensile results are not significant enough to justify costly and time-consuming machining, especially where large numbers of routine tests are made.

Another point of difference is the determination of yield strength. In Great Britain, the yield strength (or proof stress, as it is called there) is defined as the stress that produces, while the load is still applied, a non-proportional extension equal to 0.1% of the gauge length. All other countries use a 0.2% yield strength.

A similar situation exists in the use of different gauge lengths in the determination of elongation values. In North America a gauge length equal to 4 times the gauge diameter (4D) is used, while Great Britain uses 3.5D, France 7.25D, and all other European countries 5D or 10D. International standardization requires agreement in convention, which would also greatly assist research workers who have to compare their results with those of their foreign colleagues.

The present report is divided into three separate parts. The first deals with the effect of machining and, to some extent, test bar size, on the mechanical property values obtained on separately-cast-test bars; the second compares 0.1% and 0.2% yield strength values; and the third correlates elongation values obtained on gauge lengths equal to 3.5 and 4 times the gauge diameter.

PART I: EFFECT OF MACHINING

Survey of Literature

The problem of using cast-to-shape or machined test bars for sand-cast aluminum alloys is not new, as may be seen from the discussion of the subject by Gillett(3) in 1912, more than half a century ago. He stated: "It is plain that improvement due to more accurate measurement of the machined section, or to a straighter pull on the testing machine due to use of threaded grips and ball and socket holders, is not enough to pay for the machining." And this was, and still is, the belief held by the North American aluminum foundries, which use, without any exception, cast-to-shape test bars. In contradiction, however, in most European countries the machining of test bars is mandatory.

Since 1912, the effect of machining on the accuracy of tensile test results has been investigated many times, and numerous publications discuss this problem. Only a few will be mentioned here to review the subject.

Dix and Lyon(4) found that, in Al-Cu alloys (e.g., C4), "the removal of the surface skin from separately-cast test bars results in a reduction of the UTS of 20 to 25%, while the effect of removing the skin or machining the specimens from Al-4Si-3Cu alloy results in practically no reduction in strength."

Archer and Jeffries(5) state that "the skin of the casting usually possesses slightly better structure and properties than the interior on account of the higher degree of chilling" and that, therefore, "both strength and elongation are apt to be slightly lower on machined test bars than on unmachined bars."

Zeerleder(6) says that, if machined test bars are used, the as-cast cross-section before machining should be stated, because the ratio of the machined bar diameter to that of the unmachined casting might considerably affect the results (the more machining the lower the properties).

Rowe(7) investigated the effect of machining on the properties of about 300 separately-cast aluminum alloy test bars and found "the mechanical properties of the cast-to-shape and machined specimens to be practically identical in magnitude and uniformity".

British work(8) on test bars included an investigation on the effect of the amount of machining, comparing three different diameters of machined bars (0.564, 0.505 and 0.437 in.). The tensile test results obtained on Al-10 Mg alloy bars showed that the UTS and the elongation values were very much reduced by the increased machining, but that the scatter of results at any given diameter was not largely affected. Statistical analysis of the test results revealed that the differences between the values obtained for bars of various diameters were highly significant. It was concluded that the effect of machining was first to improve the tensile properties by diminishing the notch effect, and then to cause a reduction as the outer layers of metal were removed. This supports the commonly held view that castings should be made as close to final dimensions as possible, with machining reduced to a minimum.

Howell(9) tested 400 Al-4Cu-2Ni-1.5Mg alloy and 250 Al-4.5Cu-0.8Si alloy bars, of which half were tested as-cast and the other half after machining "just enough to true them up thoroughly". The results presented by him indicate no significant difference in tensile strength and elongation between the as-cast and machined bars.

Roitman and Fridman(10) compared results of micro-tests on a special micro-testing machine with tests of the same material, but with specimens of roughly one order of magnitude larger on the usual machine. The comparison showed higher strength characteristics of micro-specimens, whereby in some steels the plasticity was increased by 30%, and the breaking load by 50%. The explanation of this is the comparatively greater influence of the surface layers on micro-specimens.

Templin and Aber(11) investigated the use of miniature specimens for tensile testing and found that, in a wrought 14S-T alloy, the results "indicated that the bar diameter does not affect the values of UTS, 0.2% YS and elongation, provided that the grain structure is fine".

Lissell(12) found, in his work on cast iron, that three factors influence the mechanical property values of a test bar. The first is the section sensitivity, which is related to the section thickness and is responsible for the decrease of the mechanical properties with increasing section thickness. The second is the volume sensitivity of the material related to the geometrical shape of the testbar, the consequence of which is that test bars of different size are not comparable, even if the properties of the metal itself are identical. A smaller test specimen will, due to the influence of volume under stress, have a higher strength than a larger one. The third factor is the "skin effect". It has been found that the strength increases in test specimens machined from a cast bar to gradually diminishing section size, as can be expected from the law of volume sensitivity. Below a certain size, however, the increase of strength is gradually less pronounced and sometimes is transformed into a decrease in strength. This is due to the fact that, in testing, the "skin effect" is characterized by a decrease in strength when the cross-section of the test specimens becomes smaller; thus the effect noted above is due to a combination of those two factors.

Slachta and Mansfield(13) used Al-5Si-1Cu-0.5Mg alloy bars as-cast and after machining. They found that the machined test bars had a slightly higher UTS, but no conclusions could be drawn for the 0.2% YS and the elongation.

Paine and Stewart(14) mention that earlier work on aluminum alloys showed no significant differences in static mechanical properties of specimens cast to 0.565-in. dia. and machined to 0.505-in. dia. for testing, when compared with 0.505-in. dia. specimens tested with the cast surface intact.

Mascré(15) compared tensile test results obtained on three types of test specimens having 13.8 mm (0.54-in.), 3 mm (0.12-in.) and 1.5 mm (0.06-in.) gauge diameters, taken from four aluminum alloys in various states of heat treatment. Generally, the UTS and elongation obtained on the smaller samples were lower than those from the standard-size test bars. The decrease of properties with decreasing bar diameter (the various test bars were machined from the same size test coupons) was attributed to the relatively greater effect of machining marks or defects. The micro-specimens showed a very high scatter of results.

Arnaud and Lefebvre(16) compared tensile strength and elongation of as-cast and machined test bars of six aluminum alloys. In all cases, higher values were obtained on the unmachined bars, but it should be noted that the as-cast bars had a diameter of 13.8 mm (0.54-in.), as compared with the cast diameter of 18 mm (0.71-in.) from which the other bars were machined to 13.8 mm (hence possible "skin effect"). The scatter of elongation results obtained on as-cast specimens was greater than on machined bars.

Form, Ahearn and Wallace(17), in considering the section size and its influence on tensile properties, distinguish between two effects of widely different origin. First, the strength of materials is known to be subject to a purely "geometrical size effect", illustrated by a decrease in fracture strength as the specimen size is increased. This effect is not associated with variations in metallurgical structure, since it occurs in a series of specimens machined from a stock that is homogeneous throughout. The second effect is connected with the size of the casting (not of the specimen) and may be called "metallurgical size effect". Recent studies show that the assumption of a direct relationship between tensile strength and casting size is not necessarily valid, especially when heavy chilling is applied. In many cases, identical strength values may be obtained in castings of widely differing section size. It follows, then, that tensile strength and section size are not simply related to each other for a given cast metal.

Experimental Procedure

Alloy Preparation -

Table 1 presents the specified compositional limits for the aluminum casting alloys used in this investigation. Melts were made from commercial-quality alloy ingots, with the exception of G10 alloy melts, which were prepared from high-purity aluminum (99.99%) and Domal magnesium (99.98%) ingots with additions of a(commercial) Al-Be alloy hardener.

Ingots were melted in a gas-fired furnace, using a silicon carbide crucible and melt sizes of 30 to 40 lb. No solid flux or grain refining additions were used. All melts were degassed with chlorine, nitrogen or a combination of both, at a temperature of 670 to 680 °C (1240 to 1255 °F), until results of the reduced-pressure solidification test indicated gas-free metal. The metal was cast at a temperature of 670 °C (1240 °F) in green sand. Three melts were prepared for G10, SC51 and SG70 alloys, and one melt for the other alloys.

Test Bar Preparation -

All test bars were produced in a cast-to-shape four-test bar mould according to Canadian draft specification CSA H.G.1.5-1954, Figure 1 (similar to U. S. Federal Specification QQ-M-56, p. 6, Figure 1A). The range of chemical compositions of samples taken from test bars is given in Table 2.

For each temper condition, listed in Table 3, twelve cast-to-shape test bars were taken at random from each melt. Two test bars were left unmachined, while the remaining ten specimens were separated in five groups of two bars each and machined to the following diameters: 0.470 to 0.450 (the reduced portion of cast-to-shape test bars was only skinned), 0.438, 0.375, 0.312 and 0.250 in. All machined bars were 5 1/2 in. long and had a 2 1/2 in. reduced section. The elongation was measured on a length equal to four times the diameter of the reduced section. Test bars that had a defect in the fracture surface were replaced if spare bars were available.

Results

Tensile Tests -

Average tensile test results are given in Table 4 and Figures 2 and 3.

All tensile test results obtained in this investigation were analysed by statistical methods. The criterion used to assess the significance of an effect was 5%, i.e., when an effect was so large that the probability of its occurring by chance alone was less than 5%, that effect was said to be significant. In cases where machining had a significant effect on tensile properties, the Multiple Range Test was used to determine which machining levels produced results that were significantly different from the others.

Results given in Table 4, and Figures 2 and 3, are the averages of three tests for C4, S5 and ZG61 alloys and of four to six tests for G10, SC51 and SG70 alloys.

The ultimate tensile strength was significantly affected by machining, in the case of G10, SC51 and SG70 alloys. For alloy G10, the highest strengths were obtained on bars that had received the greatest and least amounts of machining, while the bars with intermediate cuts (0.375-in. dia.) had the lowest strengths. In the SC51 alloy series, the highest values were obtained with the 0.438 and 0.250-in. bars. In alloy SG70, the 0.438-in. bars gave the highest results and the 0.250-in. bars the lowest.

Machining had a significant effect on the yield strength values of G10, S5 and SC51 alloys. In G10 and SC51 alloys, the yield strength results varied essentially in the same manner as the ultimate strength results. In

S5 alloy the yield strengths of 0.312- and 0.250-in. bars were approximately 25% higher than the average of the first four levels.

Significant variations in elongation results were caused by machining in C4, G10 and SG70 alloys. In G10, the highest elongations were obtained on bars with the greatest and least amounts of machining, and the machined bars with the lowest results were the 0.312-in. bars. Machining improved the elongation results of C4 bars consistently up to a maximum of 40% in the 0.250-in. bars when compared to the cast-to-shape ones. In SG70 the lowest values were found in the 0.250-in. bars.

Discussion of Results

As mentioned earlier, all the mechanical property data were analysed by statistical methods as an aid in evaluating the significance of the influence of machining cast-to-shape test bars on tensile test results. Although it was found that machining had a significant effect in several cases, no simple relationship could be established between the degree of machining and any of the tensile properties. The differences due to machining are irregular and, for G10, SC51 and SG70 alloys, generally of the same order as the differences between lots of castings from different melts of the same alloy, even though those melts were prepared essentially in the same manner and their chemical compositions were within or very close to the limits imposed by specifications.

In the statistical tests, differences due to machining, or from melt to melt of the same composition, were tested against the residual error,which is a measure of the variation between specimens of the same group and treatment. In other words, the larger the experimental error the larger a given effect has to be in order to be shown as significant. This explains certain apparent discrepancies between the results presented in Table 4 and the conclusions based on statistical analysis. This analysis was carried out on the individual data and consequently variations from test to test were taken into account, whereas Table 4 presents only the average without considering such variations.

Furthermore, there are a number of cases where, although the influence of machining proved to be significant from a statistical point of view, such an effect is difficult to explain on any rational basis. This is particularly true of the cases where results vary in an up-and-down manner without following a definite pattern. Although such differences may be real and explainable by variations in microstructure, chemical composition, etc., their significance from an engineering point of view is difficult to assess, as it appears practically impossible, after these limited tests, to predict how, and to what extent, machining will affect tensile test values in a particular case. However, the results reported in this investigation show that one should be aware of the possibility of appreciable variations in tensile test data caused only by using test pieces of different sizes.

PART II: YIELD STRENGTH

Background

Yield strength (or proof stress, as it is termed in Great Britain) is the most important design criterion of non-ferrous alloys and it is, therefore, necessary to convert yield strength results determined and reported according to the particular specified permanent set. In order to permit comparison of test results given in British papers and reports with those obtained in North American practice, and to have some comparative data for discussions at ISO/TC79 meetings, an attempt was made to find a relationship between 0.1% and 0.2% yield strength values for six aluminum alloys.

Materials and Procedures

The data analysed in this investigation were obtained from tensile test bars used in the evaluation of other factors, namely: the effect of casting temperature and holding time, reported earlier(2), and the effect of machining, covered in Part I of this report. In most of these cases, only the 0.2% yield strength values were reported, although both the 0.2 and 0.1% yield strengths were measured.

The ranges of results of chemical analyses from the melts used in this investigation are presented in Table 5. These indicate that the tests were carried out on material that had a chemical composition lying within or very close to the limits imposed by specifications (Table 1).

Although most heat-treated test bars were subjected to the standard heat treatments described in Table 3, some of the high yield strength values were obtained by altering the ageing treatment.

Results

Figures 4, 5 and 6 present all the individual data studied in the course of this investigation. A total of 908 pairs of data were available and the number of test bars from each alloy is given in the second column of Table 6.

These data were analysed separately for each alloy by means of statistical methods, in order to determine the type of relationship that exists between 0.1 and 0.2% yield strength values and the equation of the curve representing that relationship. In all cases it was found that the relationship existing between 0.1 and 0.2% yield strength values could be represented satisfactorily by a straight line over the range of results investigated. The equations of the regression lines of 0.1% yield strength on 0.2% yield strength are given in the fifth column of Table 6 and are represented by the solid lines of Figures 4, 5 and 6.

Additional statistical tests were carried out in order to determine if two or more curves could be pooled, i.e., if the relationship for one alloy was essentially the same as that for another or other alloys. It was found that the relationship differed significantly from alloy to alloy, with the exception of SC51-T6 and SG70-T6 alloys where results were plotted as a single line (Figure 6). The level of significance used in this work was 5%, i.e., when an effect or difference of the magnitude found in these tests would arise by chance alone in less than 5 cases out of 100, such an effect or difference was considered to be significant.

Discussion of Results

Examination of the equations shown in the fifth column of Table 6 indicates that the ratio of 0.2% yield strength to 0.1% yield strength results varies with the yield strength level considered. The equations being of the type $y = a + bx$, the ratio x/y is constant only if "a" equals zero. The "a" factor has no physical significance, because the equations obtained are valid only for the range of values investigated.

The dotted lines of Figures 4, 5 and 6 are the 95% confidence limits for a single prediction of the 0.1% yield strength from a given 0.2% yield strength value. These limits are given in the last two columns of Table 6 for typical 0.2% yield strength values. The limits are shown as straight lines, although the band should be wider at both ends; however, for the range of 0.2% yield strength investigated, these differences are imperceptible on the scale used for these figures. These limits should not be extrapolated to values not covered by the present tests.

PART III: ELONGATION

Background

This study was undertaken to compare elongation values based on a gauge length equal to four gauge diameters (4D, as used in North America) with those based on a gauge length equal to 4 times the square root of the gauge section area (or 3.5D, as used in Great Britain).

It is known, from numerous papers published in the past 50 years (e.g.,(18, 19)), that elongation values can be directly compared only if measured on test specimens having an identical gauge length-to-diameter ratio. Unfortunately, these two ratios are not identical in the above case.

In 1955, Mascré(20) compared elongations measured on gauge lengths used in France (7.25D) and those proposed by ISO/TC70 for international standardization (5D) for four aluminum casting alloys. He concluded that there are no significant differences between the two elongation values. The author studied rather low elongation values (3-7%) and claimed that the differences between the minimum specified values are less than 5% of the elongation value, which is less than the experimental scatter of results. (This is certainly not true for aluminum alloys having higher elongations -- e.g. Al-10 Mg, high-purity Al-7 Si-0.3 Mg, and Al-5 Si, where the differences may raise to 10-20 (or more) % of the elongation values.)

It seems to be useful to repeat the conclusions reached by Howell(9) in his study of elongation determinations on light alloys:

> "These tests show that with straight test bars, carefully prepared and carefully tested following a good testing technique, elongation values determined by two experienced individuals on the same test bar are very likely to differ by 0.5% in 2 in. Without such careful attention to details, values would not agree this closely. ..... Specifications now require that elongation in 2 in. be measured to 0.5% in 2 in., and these tests indicate quite definitely that it would be unreasonable to expect such values to be determined any more closely."

Materials and Procedures

The test bars used in this study were taken from various investigations carried out in these laboratories and were, therefore, in various temper conditions, including some overaged specimens used in the yield strength study described in Part II of this report. The chemical composition of these bars was within the specified limits (see Table 1). Each pair of elongation values was obtained on the same test bar, marked both for 3.5D and 4D gauge lengths.

Results

The number of test bars used for each alloy is shown in the second column of Table 7, and the individual data for alloys G10 and S5 in Figures 7 and 8. The results for alloy SG70 were not plotted, because, the elongation values being relatively low and the number of test bars large (191), single points would have represented several results and such a graph would be more misleading than helpful.

The average elongation values measured on gauge lengths equal to 4 diameters and to 4 times the square root of the area (3.5D) are shown in the third and fourth columns of Table 7. It will be noticed that the results for G10-T4 alloy are much lower than those normally produced at these laboratories. This is because many test bars used in this investigation were cast at very high temperatures in order to study the effect of casting temperature and holding time on mechanical properties(2) and, in the case of G10 alloy, overheating had a disastrous effect on elongation.

The data presented in this study were statistically analysed, in the manner described in Part II of this report, on yield strength. It was found that the relationship between elongation values measured on gauge lengths equal to 4 diameters and to 4 times the square root of area could be represented satisfactorily by a straight line for the three alloys investigated, and that the relationship varied significantly from one alloy to the other. The equations of the straight lines appear in the fifth column of Table 7 and the relationships are illustrated by the heavy lines of Figures 7 and 8. The light lines were drawn at 45° in order to indicate the deviations between the two measurements.

The relationships between elongations of 3.5 and 4D are subject to the same criticisms as those established for yield strength insofar as the intercept values are concerned. The intercepts are small in the cases under consideration and, for reasons previously elaborated, they have no practical meaning.

CONCLUSIONS

1. Although the analysis of results relating to different amounts of machining showed that some differences in UTS and elongation are statistically significant, these differences were found to be of the same order as differences between melts of the same composition. From an engineering point of view, therefore, it is evident that, with few exceptions, the tensile test results obtained on as-cast and machined test bars were substantially identical.

2. The relationships between 0.1% and 0.2% yield strength values, and between elongation values measured on gauge lengths equal to 3.5 and 4 diameters, can be represented by straight lines, the slopes of which vary significantly from one composition to another for the alloys used in this investigation.

3. The results obtained in this study indicate the advisability of specifying both the type of yield strength to be reported and the gauge length on which the elongation should be measured, because, in certain cases, the use of one rather than the other may result in the acceptance or rejection of products for which the opposite decision would otherwise have been taken.

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AC:JWM:(PES):vb

TABLE 1

Chemical Composition of Aluminum Alloy Castings* (%)

Alloy ** Designation	Cu	Fe	Mg	Mn	Si	Ti	Zn	Cr
C4	4.0-5.0	1.0	0.03	0.30	1.2	0.20	0.10	-
G10	0.10	0.30	9.5 -10.6	0.10	0.20	0.10	0.10	-
S5	0.10	0.80	-	0.10	4.5-6.0	0.20	0.10	-
SC51	1.0-1.5	0.60	0.40-0.60	0.30	4.5-5.5	0.20	0.10	-
SG70	0.20	0.50	0.20-0.40	0.10	6.5-7.5	0.20	0.10	-
ZG61	0.30	1.0	0.50-0.70	0.30	0.25	0.10-0.30	5.0-6.00	0.40-0.60

Unless range is shown, single values are the maximum amounts permitted.

* According to CSA Specification HA.9-1958.
** According to CSA Code H.1.1.-1958.

TABLE 2

Ranges of Analytical Results (%)

Alloy ** Designation	Cu	Fe	Mg	Mn	Si	Ti	Zn	Cr
C4**	4.69	0.38	-	-	0.76	0.12	-	-
G10	-	0.01-0.02	10.34-10.75	-	0.01-0.02	0.08-0.09	-	-
S5**	-	0.26	-	-	4.99	0.08	-	-
SC51	1.32-1.34	0.27-0.31	0.53-0.55	-	4.93-4.97	0.12-0.13	-	-
SG70	-	0.32-0.34	0.31-0.34	-	6.88-7.25	0.13-0.15	-	-
ZG61**	0.15	0.49	0.64	0.05	0.21	0.15	5.37	0.47

* According to CSA Code H.1.1.-1958.

** Only one melt was used for C4, ZG61 and S5 alloys.

TABLE 3

Heat Treatments Used, and Properties Specified for Separately-Cast Test Bars*

Alloy ** Designation	Solution Treatment			Ageing Treatment			Minimum		
	Temperature, °C	°F	Time, hr	Temperature, °C	°F	Time, hr	UTS, kpsi	0.2% YS, kpsi	El, % in 2 in.
C4-T6	515	960	16	160	320	4	32	20	3
G10-T4	435	815	20	-	-	-	42	22	12
S5-F	-	-	-	-	-	-	17	-	3
SC51-T6	525	975	16	160	320	4	32	20	2
SG70-T6	535	995	16	160	320	4	30	20	3
ZG61-F	-	-	-	Room		21 days	32	22	3

* According to CSA Specification HA.9-1958.

** According to CSA Codes H.1.1.-1958 and H.1.2.-1958.

TABLE 4

Effect of Machining on Tensile Properties of Separately-Cast Test Bars of Some Aluminum Casting Alloys

Alloy ** Designation	Property	Cast-to-Shape 0.505 in.	Machined diameters, inches				
			0.470 - 0.450	0.438	0.375	0.312	0.250
C4-T6	UTS*	46.2	46.7	47.5	47.1	48.0	47.5
	YS*	30.0	30.0	30.6	31.3	30.0	29.5
	El*	7	6.5	7	8	8.5	10
G10-T4	UTS	54.0	56.1	55.2	53.4	54.7	55.6
	YS	27.1	29.8	28.7	27.8	28.8	28.3
	El	35	39	37.5	38	35.5	38.5
S5-F	UTS	21.4	21.7	21.5	21.4	21.1	21.7
	YS	7.7	8.6	8.0	7.7	10.1	10.1
	El	17	20	17	18.5	12	18.5
SC51-T6	UTS	42.0	42.6	43.6	42.2	42.7	43.3
	YS	36.3	37.1	37.6	36.6	37.4	37.5
	El	2.5	2.5	3	2.5	3	3
SG70-T6	UTS	35.9	37.2	38.1	37.3	37.0	35.8
	YS	28.5	29.1	29.9	30.0	30.4	29.2
	El	3.5	3	3	3.5	3.5	2.5
ZG61-F	UTS	38.5	38.1	37.3	36.4	36.8	36.0
	YS	29.5	30.0	27.5	30.0	30.3	29.7
	El	5	5	5.5	4	4.5	4.5

* UTS - Ultimate Tensile Strength, kpsi; YS - 0.2% Yield Strength, kpsi; Elongation, % in 4 times the test bar diameter.

** According to CSA Codes H.1.1.-1958 and H.1.2.-1958.

TABLE 5

Ranges of Analytical Results (%)

Alloy * Designation	Cu	Fe	Mg	Si	Ti	Zn	Cr
C4**	4.62-4.82	0.15-0.38	-	0.46-0.78	0.10-0.12	-	-
G10**	-	0.01-0.17	10.09-10.75	0.01-0.10	0.01-0.09	-	-
S5	-	0.25-0.27	-	4.88-5.00	0.08-0.09	-	-
SC51	1.23-1.34	0.27-0.35	0.45-0.55	4.93-5.15	0.11-0.13	-	-
SG70	-	0.25-0.34	0.30-0.35	6.78-7.55	0.13-0.17	-	-
ZG61	0.15-0.19	0.44-0.49	0.64-0.75	-	0.12-0.16	5.22-5.68	0.27-0.47

* According to CSA Code H.1.1.-1958.

** A few melts of this alloy were prepared from high-purity materials and, consequently have lower impurity contents than those prepared from commercial ingots.

TABLE 6

Relationship and Comparison Between 0.1 and 0.2% Yield Strength Data

Alloy Designation *	Number of Specimens	Average, kpsi		0.1% Yield Strength equals	Typical Yield Strength**, kpsi		
		0.2% YS	0.1% YS		Typical 0.2% YS	Limits for 0.1% YS	
						Lower	Upper
C4-T6	209	30.6	27.8	0.48 + 0.89 0.2% YS	28	24.0	26.9
G10-T4	155	27.2	25.0	5.45 + 0.72 0.2% YS	26	23.0	25.3
S5-F	137	7.5	6.4	-0.03 + 0.85 0.2% YS	8	6.4	7.2
SC51-T6	159	33.5	29.8	-0.84 + 0.91 0.2% YS	34	28.5	32.0
SG70-T6	90	29.3	26.1	-0.59 + 0.91 0.2% YS	30	24.8	28.4
ZG61-F	158	25.9	23.1	5.11 + 0.70 0.2% YS	25	21.4	23.6

* According to CSA Codes H.1.1.-1958.

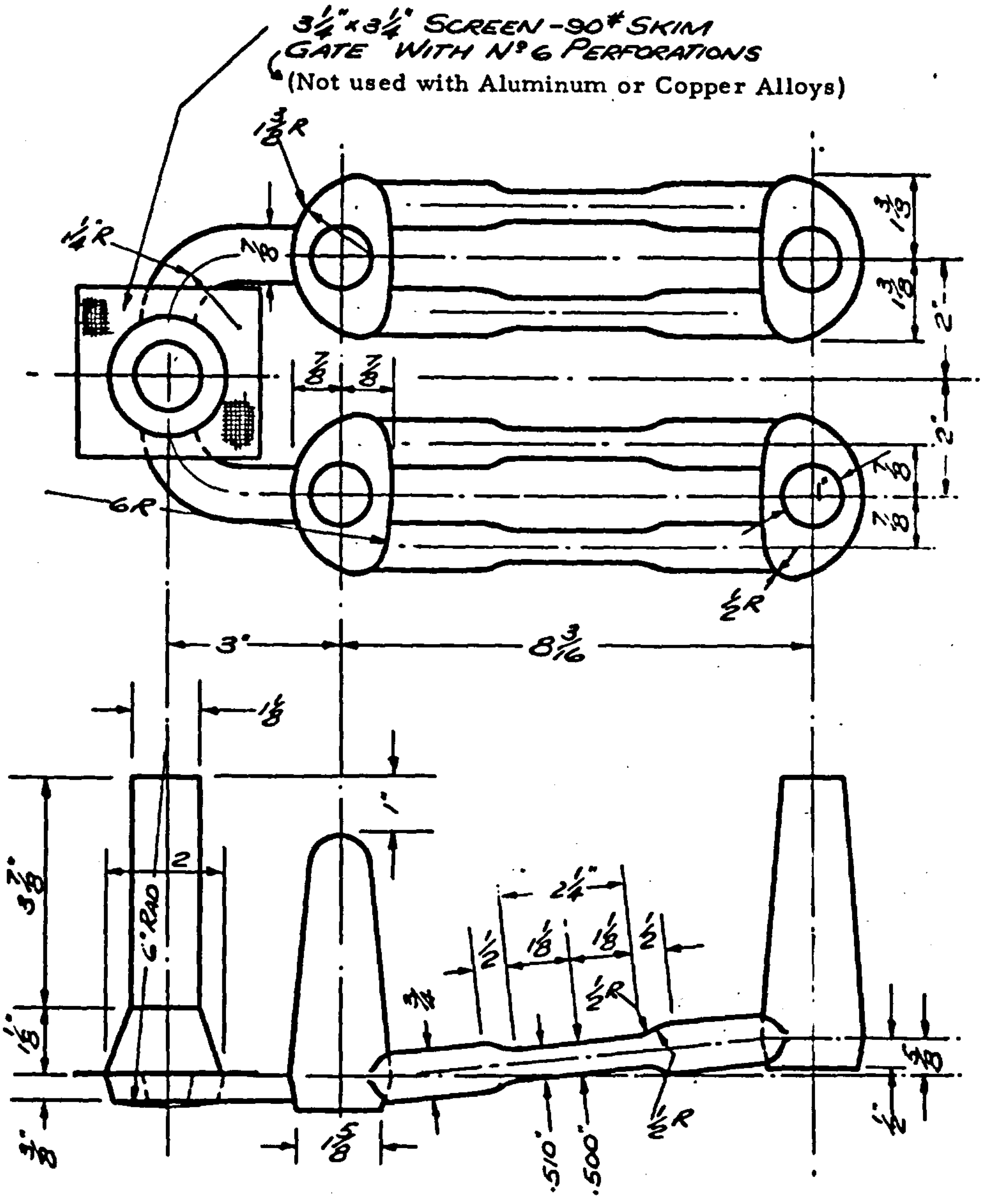
** As obtained from test bars cast-to-shape in the Experimental Foundry of the Mines Branch.

TABLE 7

Relationship and Comparison Between Elongation Values Measured in 4D and 3.5D

Alloy * Designation	Number of Specimens	Average Elongation, %		Elongation 4D equals
		3.5D	4D	
G10-T4	120	16.0	14.6	0.28 + 0.89 El 3.5D
S5-F	171	12.7	11.9	-0.11 + 0.94 El 3.5D
SG70-T6	191	3.3	2.6	0.18 + 0.74 El 3.5D

* According to CSA Codes H.1.1.-1958 and H.1.2.-1958.



(Not used with Aluminum or Copper Alloys)

Figure 1. Test Bar Design According to CSA Draft Specification CSA.HG.1.-1958 (U.S. Federal Specification QQ-M-56).

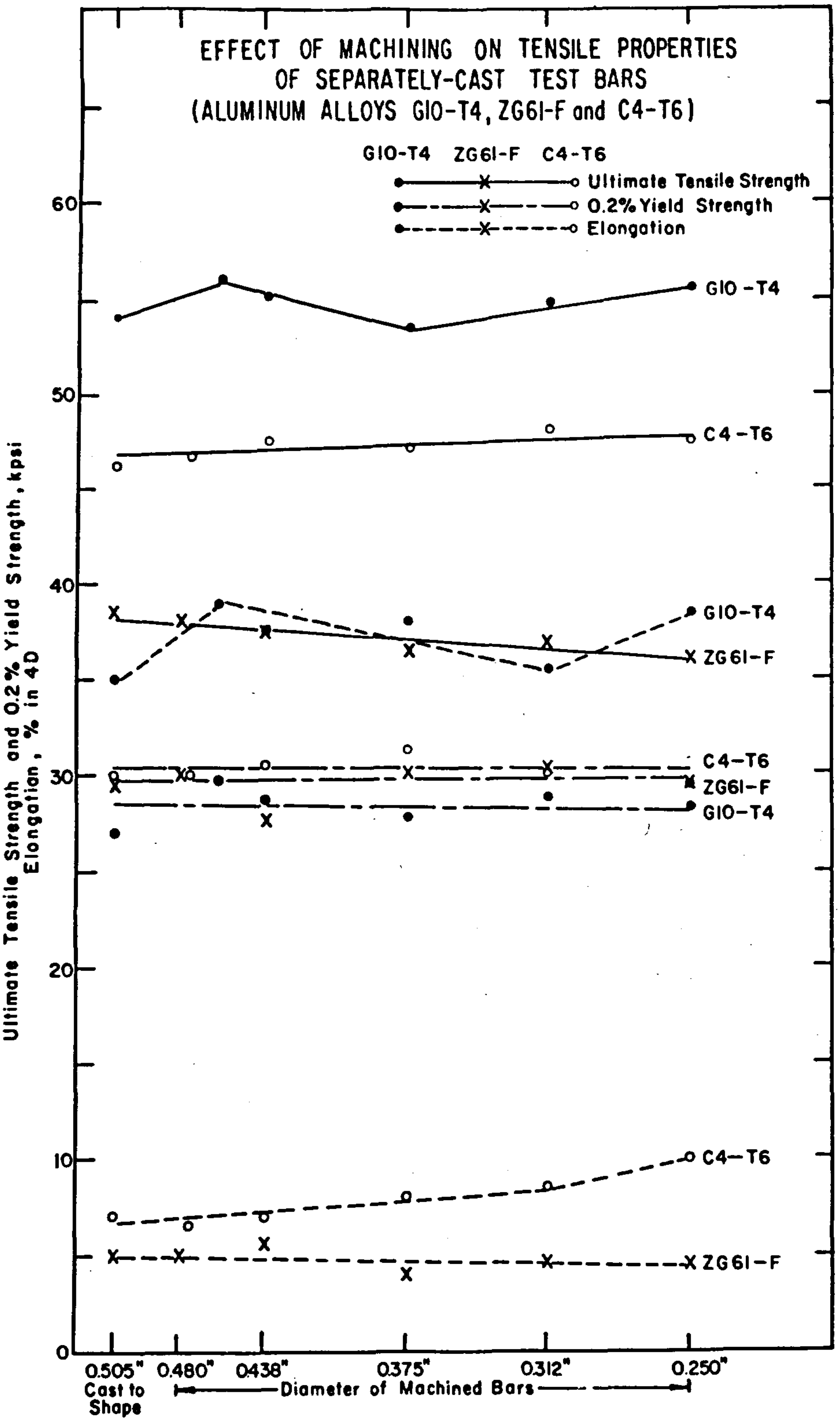


Figure 2. Effect of Machining on Tensile Properties of Separately-Cast Test Bars. (Aluminum alloys G10-T4, ZG61-F and C4-T6).

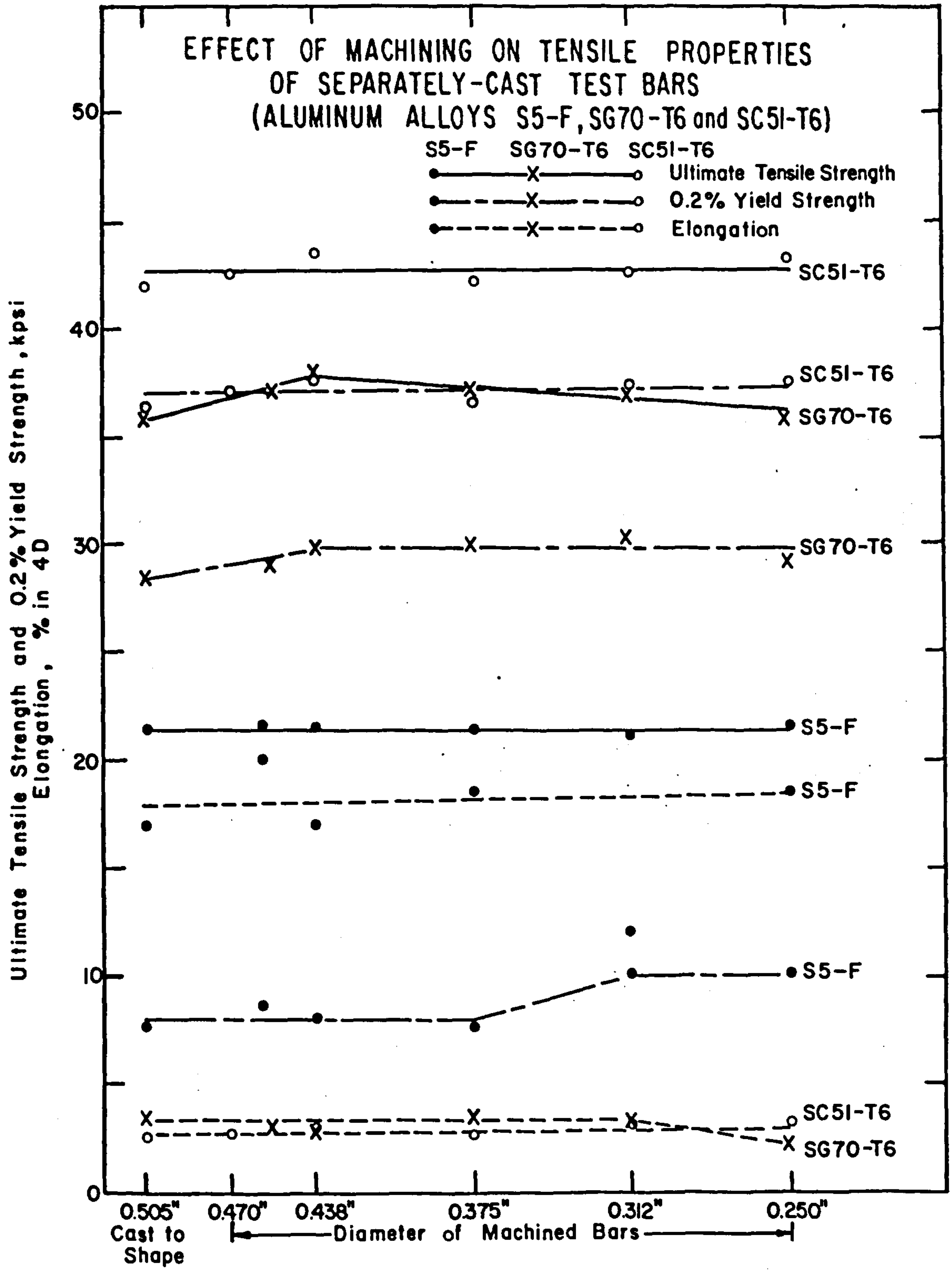


Figure 3. Effect of Machining on Tensile Properties of Separately-Cast Test Bars. (Aluminum Alloys S5-F, SG70-T6 and SC51-T6).

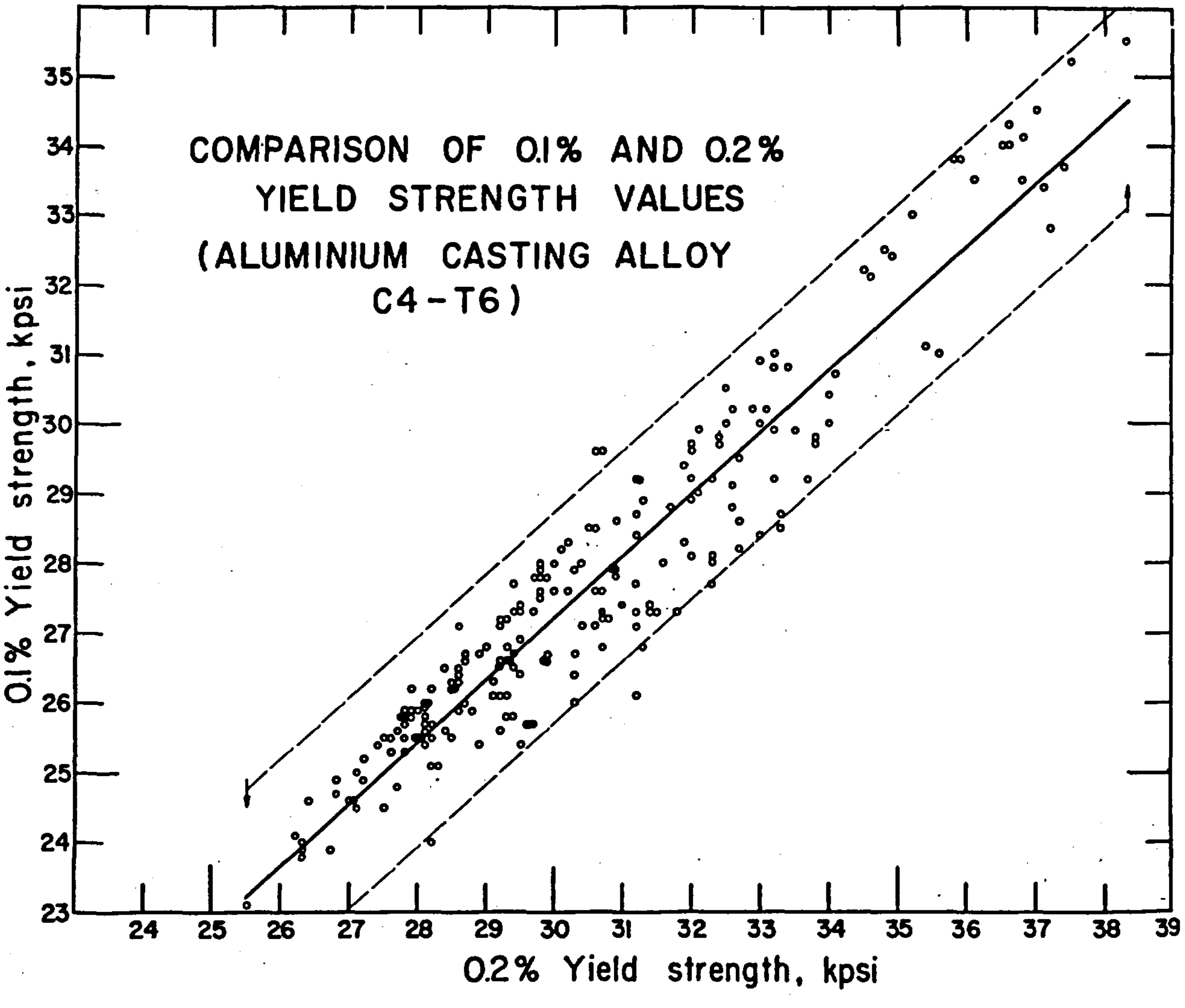


Figure 4. Comparison of 0.1% and 0.2% Yield Strength Values. (Aluminum Casting Alloy C4-T6).

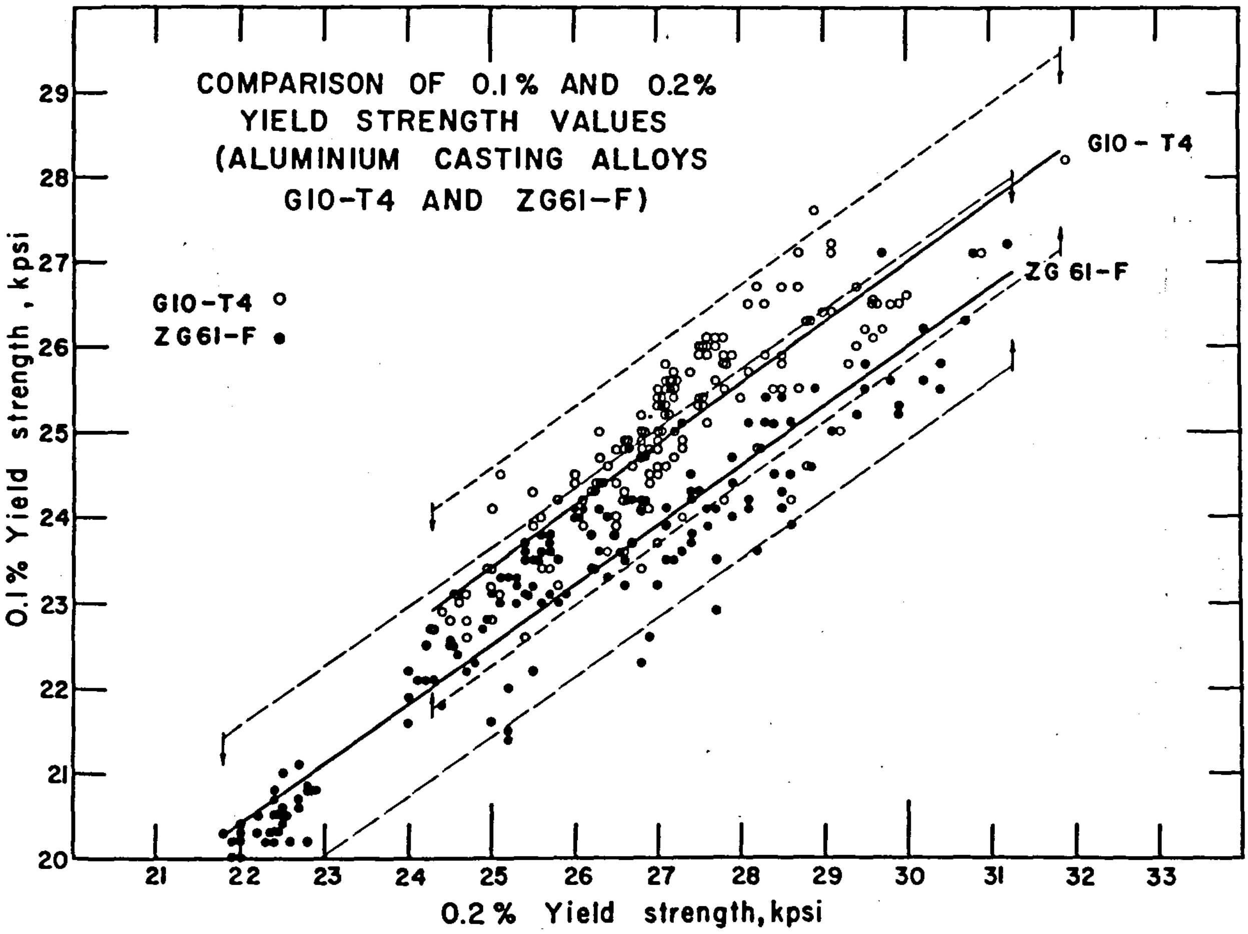


Figure 5. Comparison of 0.1% and 0.2% Yield Strength Values. (Aluminum Casting Alloys G10-T4 and ZG61-F).

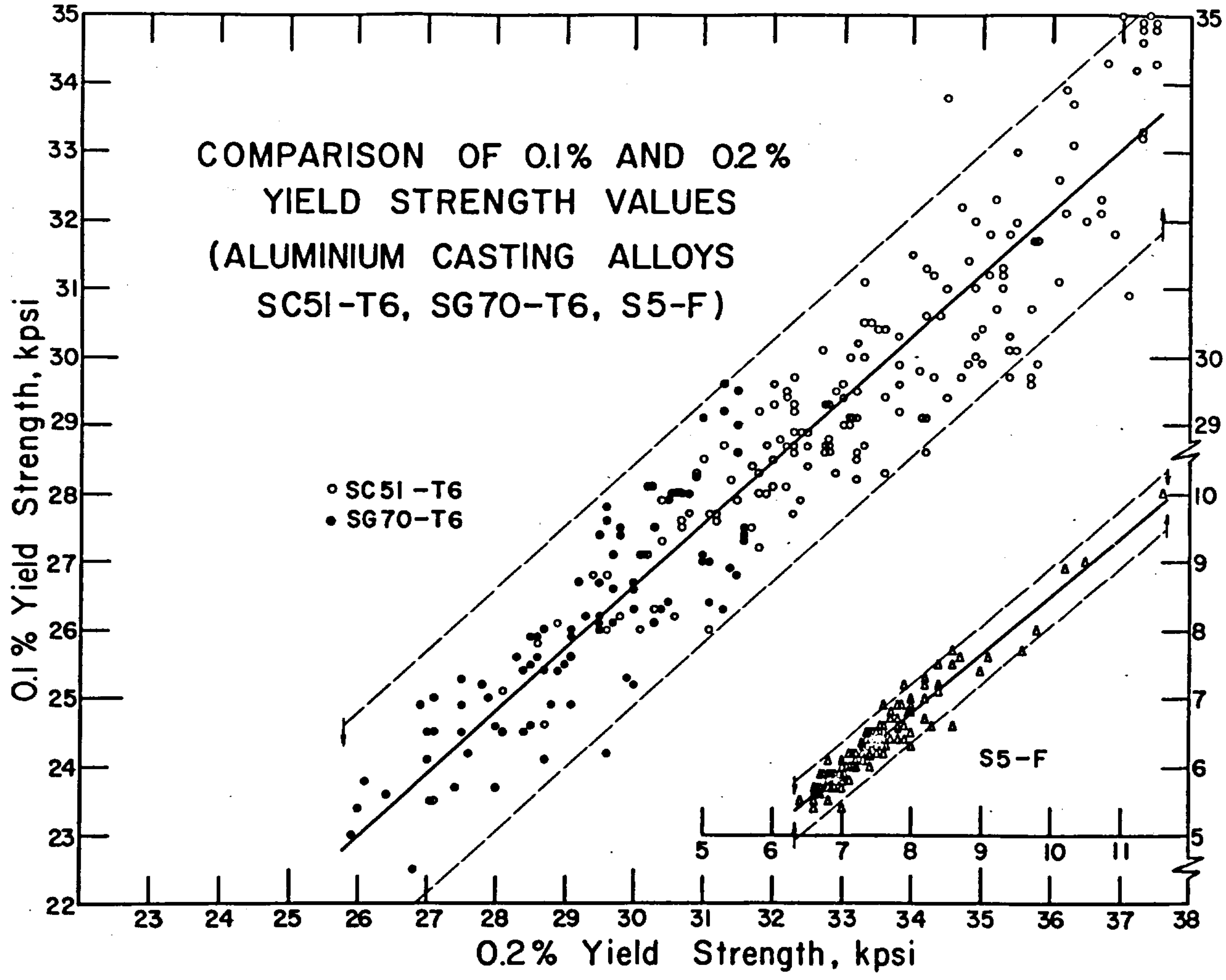


Figure 6. Comparison of 0.1% and 0.2% Yield Strength Values. (Aluminum Casting Alloys SC51-T6, SG70-T6, S5-F).

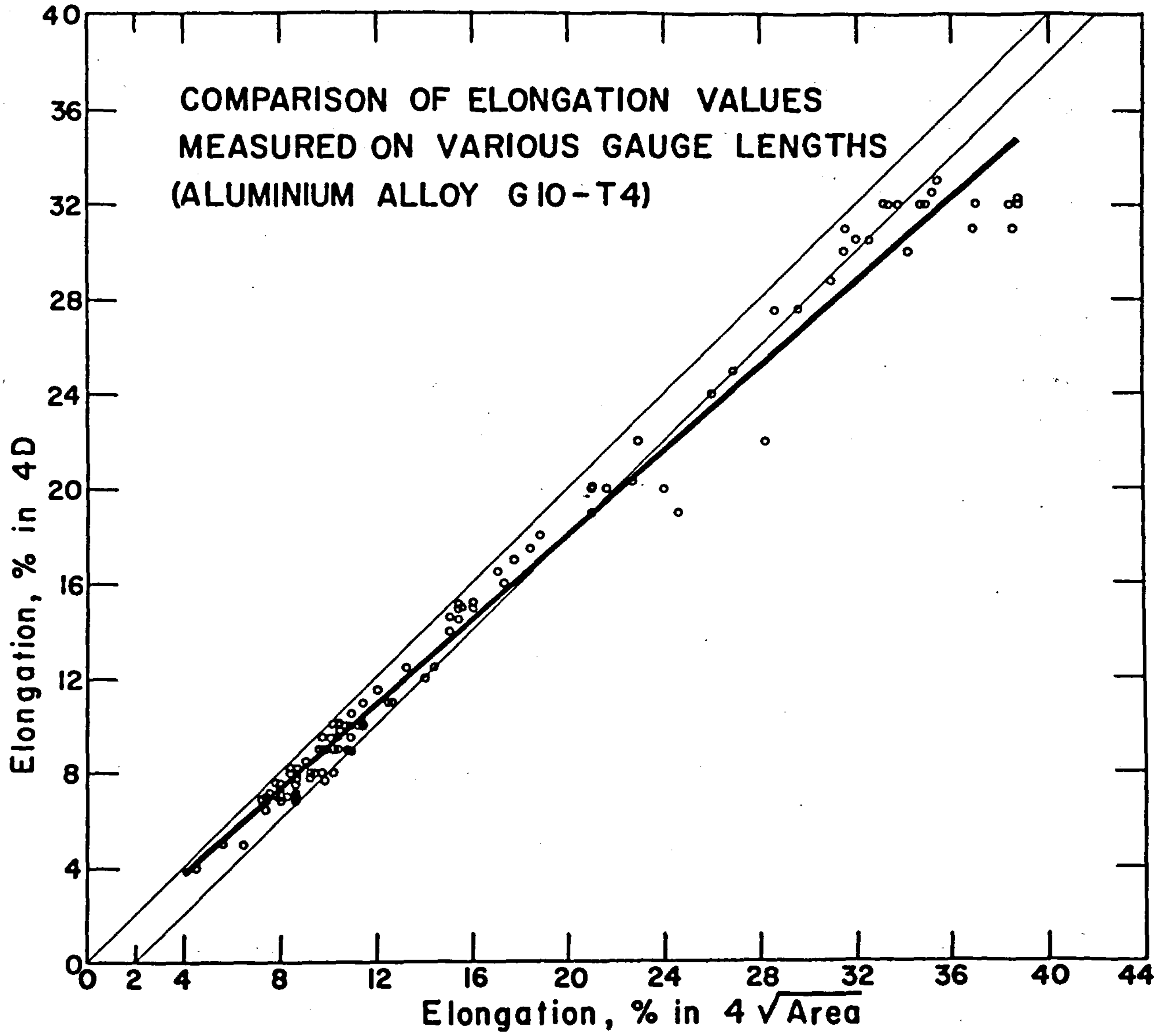


Figure 7. Comparison of Elongation Values Measured on Various Gauge Lengths. (Aluminum Alloy G10-T4).

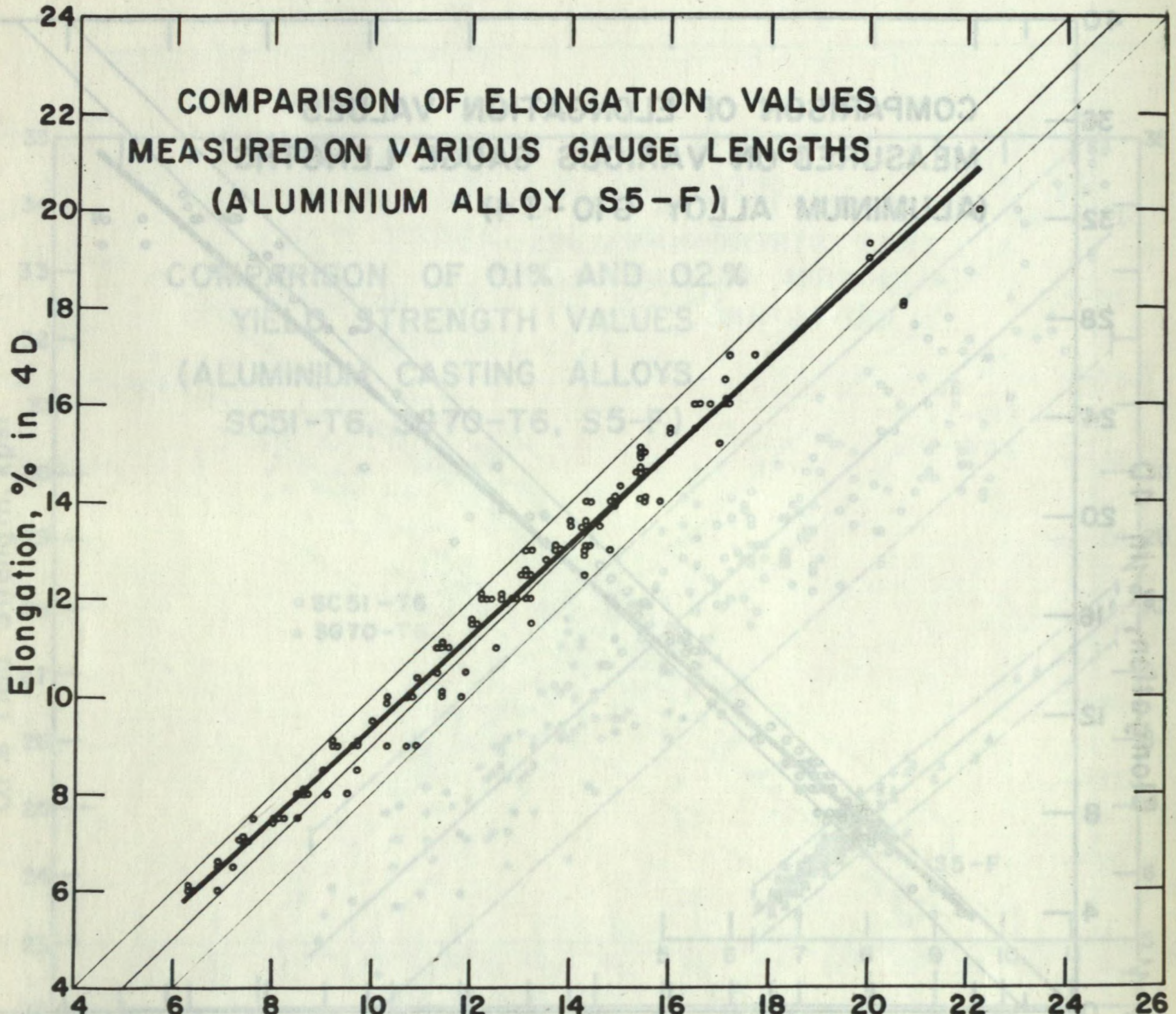


Figure 8. Comparison of Elongation Values Measured on Various Gauge Lengths. (Aluminum Alloy S5-F).