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Effect on the Static Strength of Aluminium Alloy Test Specimens of the Attachment of Thermocouples by a Welding Technique

by

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EFFECT ON THE STATIC STRENGTH OF ALUMINIUM ALLOY TEST SPECIMENS OF THE ATTACHMENT OF THERMOCOUPLES BY A WELDING TECHNIQUE

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SUMMARY

Tensile tests were made on a large number of aluminium alloy test specimens extracted from sheet material to Specifications L.71, L.72, L.73, DTD.687A and DTD.5070 to determine the effect of attaching thermocouple leads to them by a welding technique.

The tests showed that the thermocouple welds had a negligible effect on the proof and ultimate stresses and on Young's Modulus. There was, however, a marked tendency for the specimens to fail at the thermocouple welds with considerable decrease in the elongation at fracture.

The reduction of elongation and failure at the weld suggests that it would be prudent to avoid the welding method of thermocouple attachment for specimens where the measurement of elongation at fracture is required, and for specimens and structural parts subject to fatigue load, but this method is recommended for calibration of other temperature measuring devices, including thermocouples attached by other means.

Replaces R.A.E. Tech. Note No. Structures 345 - A.R.C. 25921

CONTENTS

APPENDICES

TABLES

ILLUSTRATIONS

1 INTRODUCTION

This paper records the results of tests made at the R.A.E. on five aluminium alloy sheet materials to determine the effect on the strength, modulus and elongation values obtained from tensile tests when thermocouple wires are welded to the specimens. The influence of the thermocouple weld on the position of failure is also investigated.

The thermocouple wires are welded independently to the surface of the test specimen*, and this ensures that the junction between these wires is made within the material under test. Thus the junction is not exposed to convection currents as a thermocouple lead on the surface would be and consequently more accurate temperature measurements are obtained.

The tests showed that the thermocouple welds had a negligible effect on the proof and ultimate stresses and on Young's Modulus. There was, however, a marked tendency for the specimens to fail at the thermocouple welds with a considerable decrease in the elongation at fracture.

2 RANGE OF INVESTIGATION

2.1 Materials and specimens

Tensile test specimens (Fig.1) were extracted from 18 SWG aluminium alloy sheet materials to Specifications L.71, L.72, L.73, DTD.687A and DTD.5070. These materials were chosen as being representative of those used in aircraft construction, and include clad and unclad alloys, single and double heat treatment alloys, and aluminium-copper and aluminium-zinc alloys. Extracts from the specifications of the materials are given in Appendix 2.

The number of test specimens was 100 for each of the alloys except L.72, where only 50 were available from the material stock. The large number of specimens was chosen so that a reliable indication of the effect of the welding technique would be obtained. Half the specimens in each material did not have thermocouple wires attached and the other half had thermocouple wires attached by welding. The position of the welded wires is shown in Fig.1 and the charging circuit for the welding apparatus is shown in Fig.2.

The elongation was measured by reference to grid lines lightly marked on the specimen at $\frac{1}{8}$ in. intervals.

2.2 Test technique

The specimens were tested in a 15,000 lb Denison tensile testing machine, and the extensions during test were measured using a Lamb's roller extensometer on a 2 in. gauge length. The failing load and position of fracture of each specimen was noted, the Young's Modulus determined and the elongation measured.

The tests were made at room temperature. This was done because a quick assessment was required of the effects of thermocouple welding and no elevated

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* The method of welding thermocouple wires to the specimen is described in Appendix 1.

temperature testing apparatus was, at that time, readily available. It was reasoned that if the effects at room temperature were found to be small, then the effects would also be small at elevated temperature.

3 RESULTS OF TESTS

Table 1 lists the 0.1%, 0.2% and ultimate tensile stresses, Young's Modulus and elongation for each specimen. Mean values and coefficients of variation are given for each test condition.

Table 2 summarises the mean test values and coefficients of variation and gives, as a percentage, the number of specimens failing at the weld.

4 DISCUSSION OF RESULTS AND CONCLUSIONS

The attachment of thermocouple wires gave a slight increase in the mean values of the 0.1% and 0.2% proof stresses but there was no noticeable effect on Young's Modulus and ultimate tensile stress. Histograms showing the distribution of ultimate tensile stress, for specimens with and without thermocouples attached, are shown in Fig.3. These are for DTD.687A material and are typical of the other materials used and are also typical of the other material strength properties.

For L.72, L.73, DTD.687A and DTD.5070, over 90% of the specimens failed at the weld, and for L.71 material 54% of the specimens failed at the weld. It is noted that L.71 is the only unclad material among those tested; whether this is a sufficient explanation of the different behaviour is not pursued further here since the difference is one of degree and does not affect the main conclusions. Histograms showing the position of fracture, with and without thermocouples attached, are shown in Fig.4 for DTD.687A material (these are also typical for L.72, L.73 and DTD.5070 materials) and in Fig.5 for L.71 material. Subsequent work at elevated temperatures has shown a similar tendency to fracture at the weld of the thermocouple.

The attachment of thermocouple wires gave a reduction of up to 25% in the elongation values; histograms showing the distribution of elongation, with and without thermocouples attached, are shown in Fig.6.

Information from other sources suggests that for steels, the welding of thermocouple wires to test specimens has little or no effect on the position of fracture or the elongation. Inspection of such welds shows that the damage to the surface of the steel specimens is less than that for the aluminium alloy specimens. Attempts to reduce the damage to the aluminium alloy specimens by altering the intensity of the spark discharge and contact pressure between the electrode and the thermocouple wire at the moment of spark discharge, have resulted in unsatisfactory welds. It is doubtful if further development of this method of welding will produce satisfactory welds which have no effect on position of fracture or the elongation of aluminium alloy specimens.

It would be prudent to avoid the welding method of thermocouple attachment for specimens where the measurement of elongation at fracture is required, and for specimens and structural parts subject to fatigue loading. In such cases a method of temperature measurement should be used which does not affect the integrity of the test material, (e.g. clamping, or clipping on of separate thermocouple wires or of a thermocouple bead). The accuracy of the temperature readings must then be checked, and the welded-on thermocouple described in this paper, used side by side with the proposed thermocouple, is recommended as a datum of comparison for such checks.

SYMBOLS

t_1 0.1% proof stress in tension, tons/sq in.

t_2 0.2% proof stress in tension, tons/sq in.

f_t ultimate stress in tension tons/sq in.

E_1 Young's Modulus in tension (initial slope) 10^6 lb/sq in.

E_2 Young's Modulus in tension (second slope) 10^6 lb/sq in.

e elongation in tension per cent

v coefficient of variation per cent $= \frac{100}{\bar{x}} \sqrt{\frac{\Sigma(x - \bar{x})^2}{n - 1}}$

where $\bar{x}$ is the mean value of a group of test results

x is an individual test result in the group

n is number of specimens in the group

APPENDIX 1

ATTACHMENT OF THERMOCOUPLE LEADS TO ALUMINIUM ALLOY SPECIMENS BY A WELDING TECHNIQUE

The insulation was removed for one inch from the end of the lead and the wire thoroughly cleaned using fine emery paper. The bare end of the wire was placed in a spring clip connected to the positive terminal of an 80 volt H.T. battery, the negative terminal of which was in electrical contact with a mercury pool. By touching the tip of the wire on the surface of the pool and slightly withdrawing it an arc was struck and a small spherical bead (approximate diameter 0.025 inch) formed on the end of the wire. In order to inhibit oxidisation of the mercury surface and to reduce the amount of mercury vapour given off, the pool was covered by a shallow layer of transformer oil.

The bead so formed was placed on two thicknesses of oiled tracing paper on the top surface of the specimen, which had been cleaned with carbon tetrachloride. A small steel plunger, weight 1.3 oz, mounted on two guide rods, was placed vertically over the bead. The plunger was connected to the negative terminal of the charging circuit shown in Fig.2, the positive terminal of which was firmly clamped to a portion of the specimen away from the gauge length. The 400 MF capacitor having been charged, the circuit was disconnected from the mains supply and the plunger dropped on to the bead from a height of one foot: the bead was forced through the oiled paper, and the resulting condenser discharge and pressure combined to effect the "welding" of the bead to the specimen.

The main advantage of this method over the resistance welding technique is that an arc is formed at the point of contact of the bead, and hence, the heat developed at the junction is more independent of the resistivities of the adjacent materials.

APPENDIX 2

SPECIFICATION DETAILS OF L.71, L.72, L.73, DTD.687A AND DTD.5070

L.73

Clad aluminium alloy sheet, artificially aged.

Chemical composition:-

Copper	Not less than 3.8% nor more than 4.8%
Magnesium	Not less than 0.55% nor more than 0.85%
Iron	Not more than 1.0%
Silicon	Not less than 0.6% nor more than 0.9%
Manganese	Not less than 0.4% nor more than 1.2%
Aluminium	The remainder

Mechanical properties:-

0.1% proof stress not less than 21 $tons/in^2$.
Ultimate tensile stress not less than 27 $tons/in^2$.
Elongation not less than 8%

DTD.687A

Clad aluminium alloy sheet, artificially aged.

Chemical composition:-

Copper	Not more than 1.5%
Magnesium	Not less than 2.0% nor more than 3.5%
Silicon	Not more than 0.5%
Iron	Not more than 0.5%
Manganese	Not less than 0.3% nor more than 1.0%
Zinc	Not less than 4.5% nor more than 6.5%
Titanium	Not more than 0.3%
Chromium	Not more than 0.5%
Aluminium	The remainder

Mechanical properties:-

0.1% proof stress not less than 27 $tons/in^2$.
Ultimate tensile stress not less than 32 $tons/in^2$.

L.72

Clad aluminium alloy sheet, naturally aged.

Chemical composition:-

Copper	Not less than 3.8% nor more than 4.8%
Iron	Not more than 1.0%
Silicon	Not less than 0.6% nor more than 0.90%

Magnesium	Not less than 0.55% nor more than 0.85%
Manganese	Not less than 0.4% nor more than 1.2%
Aluminium	The remainder

Mechanical properties:-

0.1% proof stress not less than 15 tons/in.^{2}
Ultimate tensile stress not less than 25 tons/in.^{2}
Elongation not less than 15%

DTD.5070

Clad aluminium alloy sheet, artificially aged.

Chemical composition:-

Copper	Not less than 1.8% nor more than 2.7%
Magnesium	Not less than 1.2% nor more than 1.8%
Silicon	Not more than 0.25%
Iron	Not less than 0.9% nor more than 1.4%
Manganese	Not more than 0.2%
Nickel	Not less than 0.8% nor more than 1.4%
Zinc	Not more than 0.1%
Lead	Not more than 0.05%
Tin	Not more than 0.05%
Titanium	Not more than 0.2%
Aluminium	The remainder

Mechanical properties:-

0.1% proof stress not less than 20 tons/in.^{2}
Ultimate tensile stress not less than 25 tons/in.^{2}
Elongation not less than 6%

L.71

Unclad aluminium alloy sheet, artificially aged.

Chemical composition:-

Copper	Not less than 3.8% nor more than 4.8%
Magnesium	Not less than 0.55% nor more than 0.85%
Silicon	Not less than 0.6% nor more than 0.90%
Iron	Not more than 1.0%
Manganese	Not less than 0.4% nor more than 1.2%
Nickel	Not more than 0.2%
Zinc	Not more than 0.2%
Lead	Not more than 0.05%
Tin	Not more than 0.05%
Aluminium	The remainder

Mechanical properties:-

0.1% proof stress not less than 23 tons/in.^{2}
Ultimate tensile strength not less than 28 tons/in.^{2}
Elongation not less than 8%

TABLE 1

Tension test data for L.73 material without thermocouples attached

Specimen No.	Area sq in.	t_1 tons/sq in.	t_2 tons/sq in.	f_t tons/sq in.	$E_1 \times 10^{-6}$ lb/sq in.	$E_2 \times 10^{-6}$ lb/sq in.	e%
1	0.0240	26.10	26.41	29.24	9.85	9.17	11
2	0.0243	25.28	25.77	28.71	10.50	9.25	10
3	0.0239	24.10	24.66	27.88	9.79	9.03	9
4	0.0235	24.85	25.34	28.33	9.99	9.18	9
5	0.0234	24.67	25.38	28.16	10.11	9.42	9
6	0.0241	25.90	26.12	28.71	10.17	9.48	11
7	0.0242	25.70	26.03	28.69	9.82	9.10	10
8	0.0237	24.43	24.86	27.97	9.97	9.19	9
9	0.0236	24.33	24.96	28.15	9.78	9.32	9
10	0.0242	25.51	26.03	29.35	10.23	9.28	9
11	0.0231	24.93	25.49	28.65	10.47	9.88	9
12	0.0243	26.20	26.64	28.84	10.21	9.06	9
13	0.0241	24.54	25.61	28.74	10.25	9.37	9
14	0.0241	25.26	25.89	28.84	10.27	9.39	9
15	0.0236	24.97	25.65	28.81	10.05	9.29	9
16	0.0236	25.76	26.19	29.59	10.65	9.51	9
17	0.0241	25.92	26.30	28.85	10.21	9.04	11
18	0.0240	25.91	26.41	28.98	10.09	9.04	11
19	0.0238	25.24	25.71	28.57	10.27	9.23	8
20	0.0239	25.78	26.17	28.84	9.49	9.18	10
21	0.0239	26.05	26.28	28.90	9.69	8.97	10
22	0.0239	25.57	26.07	28.71	9.47	8.97	10
23	0.0239	25.96	26.52	29.59	9.82	8.95	9
24	0.0238	26.03	26.50	29.07	9.28	9.05	9
25	0.0239	25.64	26.05	29.57	9.20	8.58	10
26	0.0240	26.16	26.72	27.87	9.63	8.79	9
27	0.0240	25.60	26.18	29.19	10.03	9.12	10
30	0.0239	25.81	26.26	28.82	9.30	8.78	9
31	0.0235	24.48	24.97	27.87	9.49	9.12	8
33	0.0240	25.67	26.10	29.02	9.24	8.98	9
34	0.0244	25.04	25.55	28.16	9.63	9.07	9
35	0.0249	24.54	25.04	27.50	9.19	8.70	10
36	0.0244	24.29	24.82	27.76	9.17	8.83	9
37	0.0252	24.31	24.77	27.64	9.38	8.74	9
39	0.0247	23.16	23.70	26.87	9.12	8.79	9
40	0.0259	23.54	24.05	26.91	9.08	8.48	9
41	0.0236	24.36	24.93	27.95	9.35	8.74	9
42	0.0238	26.13	26.54	28.93	9.67	8.99	10
43	0.0242	24.80	25.36	28.37	9.57	8.98	8
44	0.0239	25.29	25.98	29.06	9.81	9.48	9
46	0.0240	25.61	26.19	29.17	9.76	9.03	9
47	0.0241	25.41	25.98	29.00	9.85	9.85	9
48	0.0242	25.40	26.05	29.00	9.58	8.93	8

TABLE 1 (Continued)

Specimen No.	Area sq in.	t_1 tons/sq in.	t_2 tons/sq in.	f_t tons/sq in.	$E_1 \times 10^{-6}$ lb/sq in.	$E_2 \times 10^{-6}$ lb/sq in.	e%
49	0.0235	25.35	25.89	28.67	9.46	8.87	8
50	0.0241	25.28	25.74	28.80	9.83	9.36	9
v%		2.89	2.68	2.24	4.10	4.40	8.51
$\bar{x}$		25.22	25.73	28.58	9.77	9.10	9

TABLE 1 (Continued)

Tension test data for L.73 material with thermocouples attached

Specimen No.	Area sq in.	t_1 tons/sq in.	t_2 tons/sq in.	f_t tons/sq in.	$E_1 \times 10^{-6}$ lb/sq in.	$E_2 \times 10^{-6}$ lb/sq in.	e%
51	0.0240	25.72	26.34	28.82	9.47	8.54	8
52	0.0237	23.99	24.70	27.74	9.55	8.86	7
53	0.0241	25.89	26.40	28.62	9.46	8.56	9
54	0.0238	26.00	26.39	29.02	9.48	8.85	9
55	0.0238	26.35	26.86	29.32	9.48	8.39	8
56	0.0242	25.41	26.06	29.01	9.81	9.07	8
57	0.0238	26.47	27.01	29.44	9.73	8.85	10
58	0.0240	26.08	26.66	29.02	9.52	8.64	9
59	0.0240	25.82	26.23	28.79	9.45	8.50	8
60	0.0240	25.85	26.28	28.85	9.50	8.75	9
61	0.0240	23.91	24.58	27.55	9.36	8.77	8
62	0.0243	25.41	26.07	28.88	9.85	9.13	9
63	0.0236	25.44	26.04	29.08	9.74	9.02	8
64	0.0236	25.49	26.06	28.93	10.20	8.96	8
65	0.0236	25.08	25.78	28.85	10.20	9.21	8
66	0.0237	25.94	26.44	28.74	9.42	8.66	8
67	0.0240	25.96	26.37	28.89	9.43	8.60	9
68	0.0239	25.96	26.37	28.84	9.48	8.71	9
69	0.0240	25.80	26.21	28.81	9.32	8.62	9
70	0.0240	26.18	26.60	29.15	9.50	8.37	9
71	0.0239	26.11	26.56	28.98	9.41	8.83	9
72	0.0239	25.84	26.50	28.82	9.61	8.72	8
73	0.0240	25.83	26.32	28.70	9.29	8.78	9
74	0.0240	26.00	26.47	28.85	9.47	8.81	9
75	0.0240	26.18	26.60	28.96	9.46	8.68	7
76	0.0237	26.37	26.78	29.01	9.71	8.60	8
77	0.0236	25.27	25.97	28.85	9.92	8.99	7
78	0.0239	26.20	26.59	29.19	9.72	8.63	8
79	0.0238	26.03	26.44	28.88	9.38	8.62	9
80	0.0239	25.81	26.22	28.61	9.41	8.39	8
81	0.0239	25.79	26.43	28.84	9.59	8.59	8
82	0.0239	25.73	26.37	28.67	9.33	8.61	8
83	0.0237	26.01	26.61	29.03	9.37	8.68	8
84	0.0241	26.07	26.49	28.64	9.11	8.55	8
85	0.0240	25.82	26.41	28.65	9.52	8.73	8
86	0.0238	26.22	26.69	29.06	9.17	8.39	8
87	0.0238	26.04	26.51	28.93	9.82	8.74	9
88	0.0242	25.51	26.10	29.02	9.71	8.80	7
89	0.0241	25.79	26.29	28.49	9.41	8.61	8
90	0.0234	25.04	25.65	28.67	9.82	8.70	8
91	0.0241	25.41	26.00	29.00	9.96	8.94	6
92	0.0238	26.17	26.59	29.06	9.54	8.64	8
93	0.0238	26.24	26.64	28.96	9.39	8.51	8
94	0.0240	26.19	26.70	28.96	9.72	8.42	9

TABLE 1 (Continued)

Specimen No.	Area sq in.	t_1 tons/sq in.	t_2 tons/sq in.	f_t tons/sq in.	$E_1 \times 10^{-6}$ lb/sq in.	$E_2 \times 10^{-6}$ lb/sq in.	e%
95	0.0242	25.12	25.82	28.70	9.69	8.84	9
96	0.0241	25.37	25.91	28.67	9.70	8.69	8
97	0.0241	26.25	26.68	28.98	9.62	8.52	8
98	0.0238	26.38	26.83	28.91	9.37	8.67	6
99	0.0241	25.94	26.20	28.87	9.34	8.49	9
100	0.0240	25.91	26.54	28.93	9.29	8.57	7
v%		2.09	1.82	1.11	2.82	2.18	10.63
$\bar{x}$		25.79	26.31	28.84	9.56	8.70	8

Percentage of specimens failing at a weld = 94%.

TABLE 1 (Continued)

Tension test data for DTD.687A material without thermocouples attached

Specimen No.	Area sq in.	t_1 tons/sq in.	t_2 tons/sq in.	f_t tons/sq in.	$E_1 \times 10^{-6}$ lb/sq in.	$E_2 \times 10^{-6}$ lb/sq in.	e%
1	0.0239	29.44	30.00	33.19	8.80	8.41	11
2	0.0239	29.43	30.16	33.30	8.93	8.43	14
3	0.0238	27.69	28.64	32.28	8.95	8.42	11
4	0.0241	27.74	28.75	32.47	8.99	8.61	13
5	0.0240	30.00	29.00	32.82	8.83	8.46	14
6	0.0240	27.68	28.78	32.44	9.20	8.85	14
7	0.0238	29.32	30.04	33.01	9.56	8.48	13
8	0.0240	27.99	28.77	32.49	9.02	8.50	11
9	0.0237	27.74	28.76	32.72	9.00	8.53	11
10	0.0240	29.54	30.26	33.56	9.28	8.83	12
11	0.0237	29.44	30.20	33.37	9.20	8.47	11
12	0.0238	28.01	28.70	32.27	9.07	8.37	11
13	0.0239	27.84	28.77	32.55	8.93	8.38	13
14	0.0237	29.81	30.38	34.11	9.09	8.66	12
15	0.0240	29.35	30.02	32.90	8.78	8.43	13
16	0.0240	29.54	30.19	33.04	8.97	8.46	14
17	0.0238	29.42	30.00	32.86	9.01	8.52	14
18	0.0239	29.17	29.84	32.61	8.98	8.62	11
19	0.0240	27.72	28.65	31.96	8.80	8.46	12
20	0.0240	29.52	30.11	32.97	9.23	8.39	11
21	0.0236	27.81	28.76	32.28	9.68	8.51	12
22	0.0237	28.08	28.95	32.65	9.10	8.78	10
23	0.0240	27.86	28.67	32.06	8.82	8.52	13
24	0.0236	27.93	28.84	32.25	8.81	8.18	12
25	0.0238	29.59	30.08	32.78	8.91	8.52	11
26	0.0240	29.67	30.31	33.40	9.19	8.49	11
27	0.0235	29.69	30.34	33.21	9.23	8.66	11
28	0.0238	27.61	28.51	32.04	9.07	8.68	12
29	0.0238	27.71	28.61	32.13	9.28	8.64	11
30	0.0241	27.85	28.86	32.17	9.06	8.52	11
31	0.0240	27.85	28.68	31.93	9.00	8.44	11
32	0.0239	27.97	28.72	32.03	9.03	8.54	13
33	0.0240	29.61	30.13	32.89	8.97	8.28	14
34	0.0240	27.79	28.70	32.00	8.78	8.35	12
35	0.0240	29.50	30.11	33.12	9.15	8.80	13
36	0.0240	27.77	28.42	31.78	9.15	8.42	11
37	0.0240	27.12	28.07	31.78	8.90	8.59	13
38	0.0240	28.05	29.08	32.24	8.91	8.56	12
39	0.0241	27.85	28.59	32.03	9.27	8.13	11
40	0.0238	27.56	28.48	31.74	9.04	8.64	11
41	0.0237	27.63	28.67	32.05	9.05	8.34	11
42	0.0238	27.71	28.57	32.03	8.89	8.46	13
43	0.0240	29.78	30.37	33.23	9.23	8.73	13

TABLE 1 (Continued)

Specimen No.	Area sq in.	t_1 tons/sq in.	t_2 tons/sq in.	f_t tons/sq in.	$E_1 \times 10^{-6}$ lb/sq in.	$E_2 \times 10^{-6}$ lb/sq in.	e%
44	0.0238	27.69	28.46	32.05	9.00	8.60	11
45	0.0239	29.52	30.14	33.18	9.11	8.63	11
46	0.0239	29.60	30.27	32.96	9.29	8.52	14
47	0.0240	29.68	30.26	33.27	9.34	8.69	13
48	0.0238	27.37	28.33	31.82	9.02	8.37	11
49	0.0237	29.44	30.14	32.77	9.11	8.45	12
50	0.0240	29.47	30.15	32.96	9.33	8.33	14
v%		3.22	2.63	1.72	2.09	1.76	9.75
$\bar{x}$		28.58	29.33	32.60	9.07	8.51	12

TABLE 1 (Continued)

Tension test data for DTD.687A material with thermocouples attached

Specimen No.	Area sq in.	t_1 tons/sq in.	t_2 tons/sq in.	f_t tons/sq in.	$E_1 \times 10^{-6}$ lb/sq in.	$E_2 \times 10^{-6}$ lb/sq in.	e%
51	0.0239	27.78	28.76	31.99	8.84	8.20	7
52	0.0235	30.00	30.74	33.05	9.31	8.46	8
53	0.0238	29.94	30.71	33.46	9.29	8.66	10
54	0.0238	29.90	30.54	33.10	9.28	8.38	9
55	0.0241	29.81	30.38	32.98	9.18	8.36	8
56	0.0237	29.93	30.51	33.98	9.06	8.37	9
57	0.0240	28.22	29.00	32.26	9.10	8.44	8
58	0.0239	27.77	28.82	31.97	8.95	8.60	8
59	0.0240	28.05	29.04	32.39	9.14	8.56	9
60	0.0240	27.99	28.95	32.17	9.16	8.61	9
61	0.0241	28.36	29.27	32.61	8.88	8.49	11
62	0.0240	28.09	28.96	32.08	8.92	8.46	8
63	0.0239	27.99	28.77	32.14	9.18	8.56	9
64	0.0239	29.95	30.64	33.45	9.03	8.45	8
65	0.0239	29.84	30.53	33.08	9.09	8.37	8
66	0.0241	28.44	29.16	32.39	9.14	8.38	9
67	0.0240	29.72	30.43	32.78	9.10	8.66	8
68	0.0240	30.12	30.80	33.33	9.38	8.68	8
69	0.0240	27.73	28.67	31.83	8.89	8.43	9
70	0.0238	28.12	28.96	32.27	9.17	8.64	8
71	0.0240	28.03	28.94	32.23	9.00	8.50	8
72	0.0241	27.74	28.79	32.06	9.01	8.54	8
73	0.0239	29.90	30.47	32.56	9.15	8.48	6
74	0.0239	30.09	30.73	33.42	9.36	8.48	10
75	0.0237	28.12	28.99	32.32	9.13	8.52	8
76	0.0238	29.76	30.43	32.86	9.09	8.61	9
77	0.0237	28.01	28.97	32.50	9.36	8.72	8
78	0.0240	27.96	28.85	32.13	8.99	8.38	9
79	0.0239	28.18	29.12	32.46	8.98	8.58	9
80	0.0238	28.10	28.95	32.38	8.75	8.57	10
81	0.0238	28.12	28.95	32.12	9.14	8.59	7
82	0.0240	27.86	28.66	31.77	8.92	8.50	8
83	0.0243	28.07	28.70	32.04	9.03	8.60	10
84	0.0238	30.07	30.65	33.47	9.33	8.64	11
85	0.0240	28.03	28.98	32.23	8.97	8.78	8
86	0.0240	27.79	28.66	31.97	8.90	8.18	10
87	0.0238	30.03	30.73	33.02	9.17	8.33	9
88	0.0238	27.88	28.83	31.98	9.15	8.67	8
89	0.0239	28.01	29.08	32.23	9.15	8.76	7
90	0.0240	27.73	28.70	32.25	8.77	8.48	11
91	0.0238	29.62	30.32	32.93	8.96	8.57	9
92	0.0238	29.89	30.68	33.01	9.11	8.59	8
93	0.0237	29.82	30.53	33.26	9.06	8.39	11

TABLE 1 (Continued)

Specimen No.	Area sq in.	t_1 tons/sq in.	t_2 tons/sq in.	f_t tons/sq in.	$E_1 \times 10^{-6}$ lb/sq in.	$E_2 \times 10^{-6}$ lb/sq in.	e%
94	0.0238	27.86	28.79	32.20	9.03	8.58	9
95	0.0241	30.12	30.77	33.43	9.19	8.87	9
96	0.0241	30.19	30.79	33.13	9.04	8.47	8
97	0.0238	30.14	30.76	33.25	9.08	8.58	8
98	0.0241	29.82	30.58	33.28	9.22	8.89	9
99	0.0241	29.81	30.47	33.25	9.04	8.58	11
100	0.0237	29.93	30.53	32.77	9.03	8.22	7
v%		3.32	2.90	0.52	1.54	1.76	12.73
$\bar{x}$		28.89	29.68	32.63	9.08	8.53	9

Percentage of specimens failing at a weld = 96%.

TABLE 1 (Continued)

Tension test data for L.72 material without thermocouples attached

Specimen No.	Area sq in.	t_1 tons/sq in.	t_2 tons/sq in.	f_t tons/sq in.	$E_1 \times 10^{-6}$ lb/sq in.	$E_2 \times 10^{-6}$ lb/sq in.	e%
1	0.0237	19.78	19.93	27.63	9.96	9.66	21
2	0.0241	19.94	20.05	27.97	9.83	9.05	23
3	0.0238	19.96	20.11	28.18	10.27	9.20	21
4	0.0241	19.64	19.92	27.79	10.20	10.20	21
5	0.0238	19.75	19.88	27.97	9.93	9.06	21
6	0.0238	19.79	19.92	29.67	9.82	9.20	21
7	0.0237	19.95	20.00	28.09	10.28	9.91	20
8	0.0238	19.83	19.94	28.14	10.18	9.27	22
9	0.0236	19.52	19.94	28.56	9.60	9.08	23
10	0.0237	19.74	19.99	28.12	10.05	9.45	23
11	0.0239	19.47	19.84	27.88	10.19	9.52	21
12	0.0238	19.49	19.62	27.66	9.59	9.03	23
13	0.0237	19.99	20.07	27.67	9.92	9.03	21
14	0.0237	19.24	19.52	27.48	9.57	9.03	21
15	0.0237	19.33	19.57	27.64	9.45	8.95	21
16	0.0239	20.10	20.25	27.52	9.30	8.67	23
17	0.0241	19.36	19.60	27.27	9.44	9.44	21
18	0.0237	19.48	19.78	27.58	9.47	9.08	22
19	0.0237	19.63	19.82	27.71	9.79	8.95	23
20	0.0240	19.33	19.49	27.46	9.35	8.89	21
21	0.0238	19.81	19.98	27.78	9.29	8.99	19
22	0.0235	19.91	20.16	27.98	9.57	9.18	20
23	0.0238	19.55	19.83	27.78	10.02	9.41	21
24	0.0238	19.43	19.58	27.35	9.27	8.90	21
25	0.0238	19.51	19.73	27.69	9.56	9.56	21
v%		1.27	1.01	1.72	3.38	3.79	5.14
$\bar{x}$		19.66	19.86	27.86	9.76	9.23	21

TABLE 1 (Continued)

Tension test data for L.72 material with thermocouples attached

Specimen No.	Area sq in.	t_1 tons/sq in.	t_2 tons/sq in.	f_t tons/sq in.	$E_1 \times 10^{-6}$ lb/sq in.	$E_2 \times 10^{-6}$ lb/sq in.	e%
26	0.0238	19.85	20.04	28.21	9.67	9.39	20
27	0.0236	19.29	19.48	27.87	9.60	9.09	21
28	0.0236	19.59	20.03	27.59	9.59	8.99	16
29	0.0236	20.09	20.30	28.53	9.50	8.97	18
30	0.0238	19.85	19.96	27.91	9.46	8.96	15
31	0.0237	19.97	20.25	28.31	9.48	8.95	21
32	0.0238	19.87	20.04	27.31	9.56	8.84	14
33	0.0238	20.02	20.26	27.82	9.69	8.88	15
34	0.0238	19.53	19.83	27.46	9.53	8.96	14
35	0.0238	19.57	19.83	27.76	9.46	8.87	16
36	0.0238	19.98	20.16	27.71	9.58	8.79	15
37	0.0236	20.06	20.29	27.87	9.60	9.06	16
38	0.0237	20.02	20.21	27.82	9.69	8.80	16
39	0.0237	19.76	19.96	27.80	9.53	9.09	14
40	0.0238	19.59	19.85	27.37	9.62	9.07	16
41	0.0238	19.94	20.20	27.84	9.86	9.02	17
42	0.0238	19.89	20.05	27.73	9.42	9.15	17
43	0.0238	20.00	20.22	28.03	9.60	9.18	18
44	0.0239	19.75	19.84	27.65	9.08	9.08	18
45	0.0237	19.87	20.00	27.70	9.31	8.95	19
46	0.0237	19.63	19.72	27.44	9.66	9.04	16
47	0.0238	19.89	20.02	27.39	9.53	9.22	16
48	0.0238	19.55	19.74	27.74	9.88	9.07	18
49	0.0238	19.61	19.85	27.63	9.51	9.07	17
50	0.0239	19.84	20.03	27.92	9.49	9.12	17
v%		1.01	1.00	1.04	1.67	1.44	11.65
$\bar{x}$		19.80	20.01	27.78	9.56	9.02	17

Percentage of specimens failing at a weld = 96%.

TABLE 1 (Continued)

Tension test data for DTD.5070 material without thermocouples attached

Specimen No.	Area sq in.	t_1 tons/sq in.	t_2 tons/sq in.	f_t tons/sq in.	$E_1 \times 10^{-6}$ lb/sq in.	$E_2 \times 10^{-6}$ lb/sq in.	e%
1	0.0236	23.86	24.03	26.22	10.23	9.21	8
2	0.0238	23.59	23.98	25.85	10.31	9.11	6
3	0.0238	23.68	23.98	27.39	10.17	8.96	6
4	0.0237	23.58	24.07	25.84	10.17	9.08	8
5	0.0239	22.82	23.15	25.25	10.10	9.57	8
6	0.0238	22.42	22.55	25.32	10.08	9.39	8
7	0.0240	23.43	23.52	25.57	10.04	8.93	8
8	0.0238	23.35	23.69	25.68	10.32	9.43	8
9	0.0241	23.21	23.34	27.34	10.29	9.48	8
10	0.0239	23.56	23.92	25.84	10.33	9.52	8
11	0.0238	22.57	22.92	25.21	10.37	9.77	7
12	0.0239	23.44	23.73	25.76	10.11	9.58	6
13	0.0241	22.28	22.58	24.99	10.38	9.07	8
14	0.0235	23.90	24.07	26.16	10.45	9.67	6
15	0.0235	22.76	23.16	25.43	10.16	9.80	8
16	0.0239	23.11	23.29	25.34	10.47	10.47	9
17	0.0237	23.73	23.95	25.82	10.37	9.48	9
19	0.0240	22.67	22.81	25.08	10.22	9.30	8
20	0.0237	23.73	23.94	27.85	10.21	9.23	8
21	0.0239	23.92	24.51	25.34	10.19	9.16	6
22	0.0240	22.36	22.51	25.00	9.86	9.20	6
23	0.0237	22.41	22.64	24.94	10.03	9.12	8
24	0.0239	22.93	23.19	25.41	9.91	9.60	7
25	0.0238	22.94	23.60	25.66	9.99	9.35	8
26	0.0238	23.14	23.65	25.45	9.92	9.06	8
27	0.0238	22.94	23.62	25.25	9.90	9.23	9
29	0.0239	22.85	23.23	25.21	10.19	9.08	8
30	0.0238	23.22	23.93	25.39	10.02	9.06	8
31	0.0238	22.80	23.10	25.24	9.93	8.95	9
32	0.0238	22.58	22.83	24.89	10.22	9.85	10
33	0.0240	22.55	23.11	25.05	10.11	9.79	6
34	0.0239	22.54	23.05	24.88	10.38	9.04	10
35	0.0238	22.88	23.23	25.22	10.02	9.71	10
36	0.0241	22.60	23.01	24.90	10.20	8.86	10
37	0.0241	22.19	22.64	24.80	10.38	9.00	9
39	0.0239	23.51	23.81	25.51	10.20	9.21	9
40	0.0236	23.24	23.50	25.52	10.03	8.83	11
41	0.0237	23.11	23.60	24.94	10.03	9.23	9
42	0.0237	22.45	22.98	24.94	10.13	9.08	9
44	0.0239	22.88	23.12	25.28	9.98	8.84	9
45	0.0238	22.94	22.98	25.14	10.13	9.64	10
46	0.0239	22.44	22.83	24.85	9.91	9.20	9
47	0.0240	21.95	22.56	24.63	9.78	9.16	11

TABLE 1 (Continued)

Specimen No.	Area sq in.	t_1 tons/sq in.	t_2 tons/sq in.	f_t tons/sq in.	$E_1 \times 10^{-6}$ lb/sq in.	$E_2 \times 10^{-6}$ lb/sq in.	e%
48	0.0237	22.94	23.24	25.39	9.64	9.04	9
49	0.0240	22.96	23.04	24.97	10.17	9.10	10
50	0.0238	23.20	23.53	25.54	9.66	9.14	10
v%		2.17	2.14	2.59	1.88	3.55	16.88
$\bar{x}$		23.00	23.34	25.46	10.12	9.30	8

TABLE 1 (Continued)

Tension test data for DTD.5070 material with thermocouples attached

Specimen No.	Area sq in.	t_1 tons/sq in.	t_2 tons/sq in.	f_t tons/sq in.	$E_1 \times 10^{-6}$ lb/sq in.	$E_2 \times 10^{-6}$ lb/sq in.	e%
51	0.0237	23.68	24.14	25.74	10.15	9.37	6
52	0.0240	22.74	23.13	25.20	9.88	9.02	6
53	0.0238	23.81	24.31	25.89	9.86	8.79	6
54	0.0238	23.59	23.96	25.61	9.93	9.10	6
55	0.0240	23.39	23.85	25.77	10.17	9.50	5
56	0.0235	23.11	23.53	26.24	10.05	9.18	7
57	0.0238	23.62	24.05	25.66	9.77	9.12	3
58	0.0236	23.23	23.62	25.68	9.84	9.30	6
59	0.0240	23.10	23.31	25.45	9.60	8.89	6
60	0.0236	23.78	24.16	25.83	9.85	9.08	5
61	0.0236	23.82	24.18	25.96	10.22	9.16	6
62	0.0238	23.58	24.01	25.96	9.86	9.08	6
63	0.0239	23.34	23.60	25.56	9.91	9.16	6
64	0.0235	23.63	24.05	25.84	10.03	9.16	6
65	0.0236	23.54	24.01	25.73	9.68	9.08	5
66	0.0238	23.55	24.02	25.86	9.66	9.21	6
67	0.0239	23.30	23.75	25.71	9.73	9.20	8
68	0.0238	23.64	24.03	25.81	9.73	8.86	6
69	0.0237	23.40	23.80	25.48	10.05	9.14	5
70	0.0237	23.52	23.92	25.62	9.85	8.90	6
71	0.0238	22.93	23.35	25.43	9.70	9.21	6
72	0.0240	22.57	22.87	25.07	9.79	9.21	6
73	0.0238	23.57	23.98	25.95	9.93	9.29	5
74	0.0241	22.84	23.27	25.20	9.78	9.16	5
75	0.0236	23.63	24.07	25.85	9.68	9.24	5
76	0.0235	23.62	24.04	25.96	10.05	9.37	6
77	0.0236	23.47	23.86	25.72	9.68	9.15	4
78	0.0235	23.79	24.17	25.93	9.78	9.21	6
79	0.0235	23.98	24.36	26.04	9.87	9.21	6
80	0.0237	22.63	23.04	25.21	9.74	9.02	5
81	0.0241	22.97	23.36	25.38	10.01	9.12	6
82	0.0234	23.86	24.26	26.02	9.85	9.31	6
83	0.0237	22.95	23.42	25.29	9.57	9.14	7
84	0.0237	22.68	23.09	25.24	9.85	9.04	6
85	0.0241	22.72	23.02	25.00	9.81	8.88	5
86	0.0239	22.89	23.36	25.34	9.82	8.97	6
87	0.0239	23.01	23.40	25.44	9.77	9.19	6
88	0.0236	23.67	24.07	25.88	9.94	9.12	5
89	0.0238	23.57	24.02	26.14	10.21	9.41	6
90	0.0237	23.01	23.38	25.36	9.92	9.06	6
91	0.0236	23.79	24.19	26.06	9.92	9.30	6
92	0.0238	22.91	23.30	25.29	9.77	9.08	5
93	0.0235	23.19	23.59	25.86	10.19	9.49	5

TABLE 1 (Continued)

Specimen No.	Area sq in.	t_1 tons/sq in.	t_2 tons/sq in.	f_t tons/sq in.	$E_1 \times 10^{-6}$ lb/sq in.	$E_2 \times 10^{-6}$ lb/sq in.	e%
94	0.0238	22.98	23.39	25.48	9.77	8.79	6
95	0.0237	23.15	23.54	25.62	9.85	9.01	6
96	0.0238	23.19	23.62	25.48	9.77	9.20	6
97	0.0238	22.91	23.43	25.40	9.95	9.12	5
98	0.0235	23.59	24.15	26.18	9.86	9.05	5
99	0.0240	22.47	22.82	25.00	9.91	8.86	6
100	0.0235	23.18	23.56	25.65	9.98	9.08	6
v%		1.67	1.73	1.21	1.52	1.75	12.67
$\bar{x}$		23.30	23.71	25.64	9.87	9.13	6

Percentage of specimens failing at a weld = 100%

TABLE 1 (Continued)

Tension test data for L.71 material without thermocouples attached

Specimen No.	Area sq in.	t_1 tons/sq in.	t_2 tons/sq in.	f_t tons/sq in.	$E_1 \times 10^{-6}$ lb/sq in.	$E_2 \times 10^{-6}$ lb/sq in.	e%
1	0.0244	25.13	26.11	29.76	10.42	10.42	8
2	0.0249	25.28	26.00	29.62	10.25	10.25	9
3	0.0249	24.89	25.59	29.01	10.47	10.47	9
4	0.0245	25.15	25.91	29.66	10.25	9.69	10
5	0.0243	25.37	26.10	29.82	10.27	9.71	10
7	0.0245	24.62	25.44	29.24	10.31	9.94	8
8	0.0245	24.58	25.46	29.15	10.25	10.25	8
9	0.0246	24.52	25.72	28.89	10.04	9.50	4
10	0.0246	25.57	26.24	29.87	10.29	9.76	9
11	0.0243	25.65	26.40	30.14	10.06	9.38	10
12	0.0245	25.02	25.84	29.68	10.23	9.59	10
13	0.0246	25.46	26.15	30.31	10.08	9.65	10
14	0.0245	24.40	25.22	28.08	9.90	9.38	5
15	0.0245	25.51	26.06	29.02	10.14	9.82	4
16	0.0245	25.80	26.60	29.97	10.23	10.23	9
17	0.0245	24.59	25.46	30.55	10.38	10.02	4
18	0.0244	24.07	25.24	27.75	10.23	9.63	4
19	0.0244	25.10	25.92	29.89	10.12	9.69	9
20	0.0244	25.30	26.03	30.00	10.25	9.88	9
21	0.0248	25.18	25.89	29.74	10.12	9.80	3
22	0.0245	24.83	25.56	28.67	10.06	9.67	4
23	0.0246	25.38	26.05	29.71	10.15	9.59	11
24	0.0245	25.28	26.00	29.75	10.10	10.10	8
25	0.0245	25.30	26.04	28.99	10.31	9.90	7
26	0.0247	25.03	25.72	29.71	10.12	9.61	10
27	0.0243	25.39	26.12	29.97	10.19	9.79	9
28	0.0245	24.94	25.74	29.72	10.06	9.52	10
29	0.0245	24.93	25.69	29.88	10.38	9.76	10
30	0.0249	25.05	25.75	29.55	10.17	9.50	9
31	0.0245	24.27	25.04	27.95	10.04	9.65	3
32	0.0244	25.24	26.35	28.33	10.17	9.69	1
33	0.0248	24.16	24.91	27.43	9.80	9.80	4
34	0.0245	24.97	25.71	27.90	10.19	9.59	4
35	0.0246	24.54	25.39	29.40	10.12	10.12	10
36	0.0245	24.73	25.60	29.24	10.49	9.78	6
37	0.0246	24.86	25.61	27.68	10.25	9.69	1
38	0.0245	24.43	25.20	27.61	9.98	9.67	3
39	0.0251	24.56	25.31	28.09	9.86	9.55	6
40	0.0246	24.99	25.70	30.05	10.12	9.54	10
41	0.0246	25.34	25.99	29.69	10.25	9.84	8
42	0.0246	25.26	26.08	28.35	10.00	9.65	4
43	0.0246	24.83	25.63	29.69	10.17	10.17	9
44	0.0246	25.26	25.97	29.84	10.21	9.36	10

TABLE 1 (Continued)

Specimen No.	Area sq in.	t_1 tons/sq in.	t_2 tons/sq in.	f_t tons/sq in.	$E_1 \times 10^{-6}$ lb/sq in.	$E_2 \times 10^{-6}$ lb/sq in.	e%
45	0.0246	25.77	26.44	30.14	10.06	9.52	10
46	0.0243	25.41	26.18	29.90	10.10	9.64	5
47	0.0248	24.54	25.31	27.38	9.94	9.70	3
48	0.0243	25.52	26.35	30.33	10.27	9.98	9
49	0.0248	24.49	25.33	28.10	10.02	10.02	4
50	0.0247	24.91	25.65	29.60	10.25	9.92	8
v%		1.68	1.47	2.98	1.38	2.66	41.14
$\bar{x}$		25.01	25.79	29.24	10.12	9.78	7

TABLE 1 (Continued)

Tension test data for L.71 material with thermocouples attached

Specimen No.	Area sq in.	t_1 tons/sq in.	t_2 tons/sq in.	f_t tons/sq in.	$E_1 \times 10^{-6}$ lb/sq in.	$E_2 \times 10^{-6}$ lb/sq in.	e%
51	0.0246	25.74	26.48	29.91	10.25	9.96	8
52	0.0248	25.46	26.05	29.39	10.36	9.59	5
53	0.0248	25.60	26.33	29.15	10.23	9.41	5
54	0.0245	24.89	25.75	29.05	10.16	9.58	6
55	0.0245	25.13	25.87	28.28	10.12	9.58	4
56	0.0248	25.00	25.85	29.52	10.21	9.92	8
57	0.0245	25.08	25.86	29.37	10.14	9.82	8
58	0.0247	25.50	26.04	29.24	10.00	9.32	8
59	0.0248	25.03	25.82	28.60	9.94	9.55	6
60	0.0247	24.76	25.47	28.56	10.08	9.43	6
61	0.0247	25.38	26.10	29.21	10.21	9.76	5
62	0.0245	25.26	26.09	28.75	10.08	9.50	4
63	0.0245	25.13	25.90	28.73	10.27	9.59	5
64	0.0245	24.81	25.58	27.90	10.18	9.86	4
65	0.0248	24.84	25.63	28.87	10.21	9.42	5
66	0.0248	25.15	25.89	28.80	10.25	9.84	7
67	0.0245	25.31	26.22	29.75	10.14	9.82	6
68	0.0246	25.23	26.08	29.34	10.23	9.48	7
69	0.0245	25.64	26.31	29.53	10.23	9.10	7
70	0.0245	25.10	25.86	29.46	10.23	9.67	7
71	0.0245	24.73	25.64	28.04	10.14	9.45	4
72	0.0245	24.87	25.64	28.72	10.38	9.50	6
73	0.0245	25.86	26.53	29.99	10.21	9.29	8
74	0.0248	25.08	25.92	28.91	10.25	9.80	6
75	0.0246	25.59	26.46	29.76	10.29	9.96	10
76	0.0246	24.96	25.72	28.91	10.32	9.86	4
77	0.0246	24.71	25.43	28.44	10.19	9.34	4
78	0.0249	25.25	25.98	29.30	10.25	9.24	5
79	0.0245	24.93	25.82	28.99	10.23	9.38	8
80	0.0246	25.74	26.50	29.76	10.17	9.50	7
81	0.0246	24.76	25.58	28.11	10.15	9.45	4
82	0.0249	24.92	25.77	29.12	10.08	9.53	6
83	0.0243	25.69	26.46	29.91	10.25	9.81	8
84	0.0245	25.59	26.22	29.75	10.49	9.03	8
85	0.0247	24.70	25.57	28.40	10.01	9.70	5
86	0.0248	25.58	26.21	29.87	10.27	9.20	6
87	0.0245	25.30	26.08	29.61	10.23	9.56	6
88	0.0248	24.40	25.13	27.99	10.23	9.40	5
89	0.0246	25.01	25.84	28.75	10.25	9.88	5
90	0.0245	25.82	26.59	30.11	10.31	9.56	7
91	0.0246	24.85	25.72	28.55	10.27	9.37	5
92	0.0251	24.92	25.63	28.39	10.09	9.42	5
93	0.0245	25.51	26.28	29.43	10.29	9.76	6

TABLE 1 (Continued)

Specimen No.	Area sq in.	t_1 tons/sq in.	t_2 tons/sq in.	f_t tons/sq in.	$E_1 \times 10^{-6}$ lb/sq in.	$E_2 \times 10^{-6}$ lb/sq in.	e%
94	0.0248	25.43	26.19	29.55	10.23	9.90	8
95	0.0249	25.44	26.21	29.05	10.17	9.42	5
96	0.0248	24.87	25.61	28.17	10.14	9.41	8
97	0.0245	25.13	25.93	28.94	10.33	9.69	7
98	0.0245	24.96	25.67	28.50	10.25	9.32	6
99	0.0247	25.90	26.55	29.86	10.12	9.65	8
100	0.0248	25.13	25.87	28.89	10.02	9.55	5
v%		1.43	1.27	2.03	0.88	2.41	25.00
$\bar{x}$		25.19	25.96	29.06	10.20	9.56	6

Percentage of specimens failing at a weld = 54%.

TABLE 2

Summary of mean test values and coefficients of variation

Material		n	t_1	t_2	f_t	E_1	E_2	e	Peroentage failing at weld
L.73 without thermocouple	$\bar{x}$	45	25.2	25.7	28.6	9.8	9.1	9	-
	v	45	2.9	2.7	2.2	4.1	4.4	8.5	-
L.73 with thermocouple	$\bar{x}$	50	25.8	26.3	28.8	9.6	8.7	8	94
	v	50	2.1	1.8	1.1	2.8	2.2	10.6	-
DTD.687A without thermocouple	$\bar{x}$	50	28.6	29.3	32.6	9.1	8.5	12	-
	v	50	3.2	2.6	1;7	2.1	1.8	9.7	-
DTD.687A with thermocouple	$\bar{x}$	50	28.9	29.7	32.6	9.1	8.5	9	96
	v	50	3.3	2.9	0.5	1.5	1.8	12.8	-
L.72 without thermocouple	$\bar{x}$	25	19.7	19.9	27.9	9.8	9.2	21	-
	v	25	1.3	1.0	1.7	3.4	3.8	5.1	-
L.72 with thermocouple	$\bar{x}$	25	19.8	20.0	27.8	9.6	9.0	17	96
	v	25	1.0	1.0	1.0	1.7	1.4	11.6	-
DTD.5070 without thermocouple	$\bar{x}$	46	23.0	23.3	25.5	10.1	9.3	8	-
	v	46	2.2	2.1	2.6	1.9	3.5	16.9	-
DTD.5070 with thermocouple	$\bar{x}$	50	23.3	23.7	25.6	9.9	9.1	6	100
	v	50	1.7	1.7	1.2	1.5	1.7	12.7	-
L.71 without thermocouple	$\bar{x}$	49	25.0	25.8	29.2	10.1	9.8	7	-
	v	49	1.7	1.5	3.0	1.4	2.7	41.1	-
L.71 with thermocouple	$\bar{x}$	50	25.2	26.0	29.1	10.2	9.6	6	54
	v	50	1.4	1.3	2.0	0.9	2.4	25.0	-

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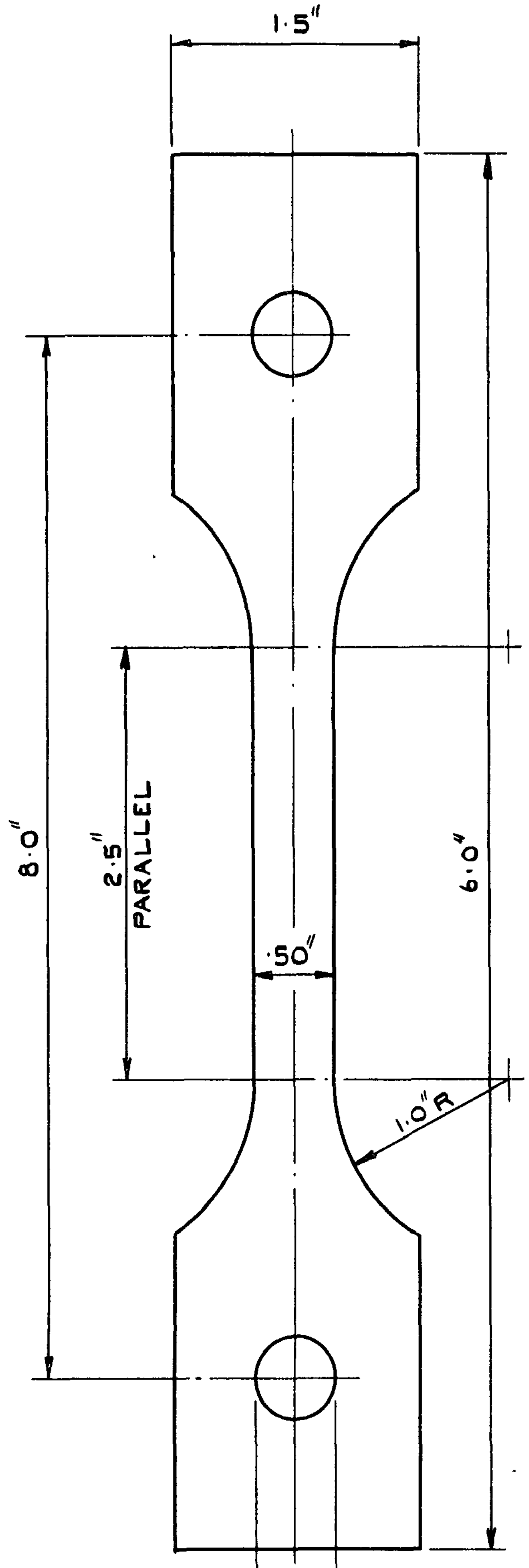
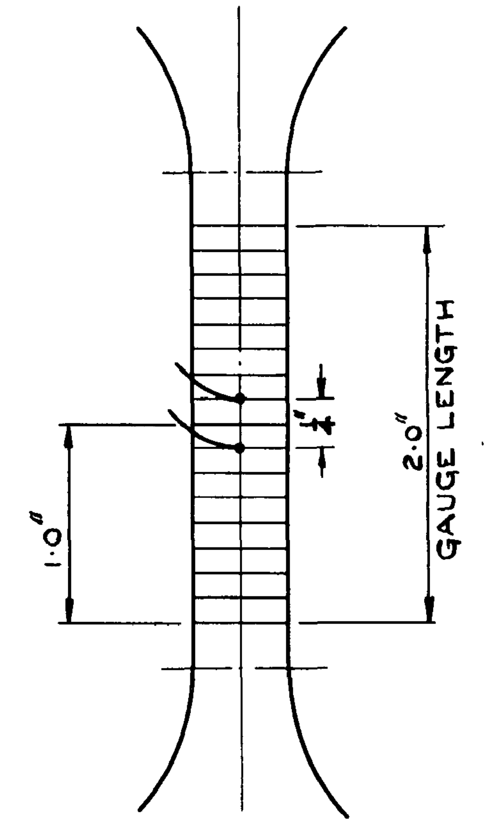


THICKNESS = 16 S.W.G.



POSITION OF THERMOCOUPLE BEADS.

FIG. 1. TEST SPECIMEN.

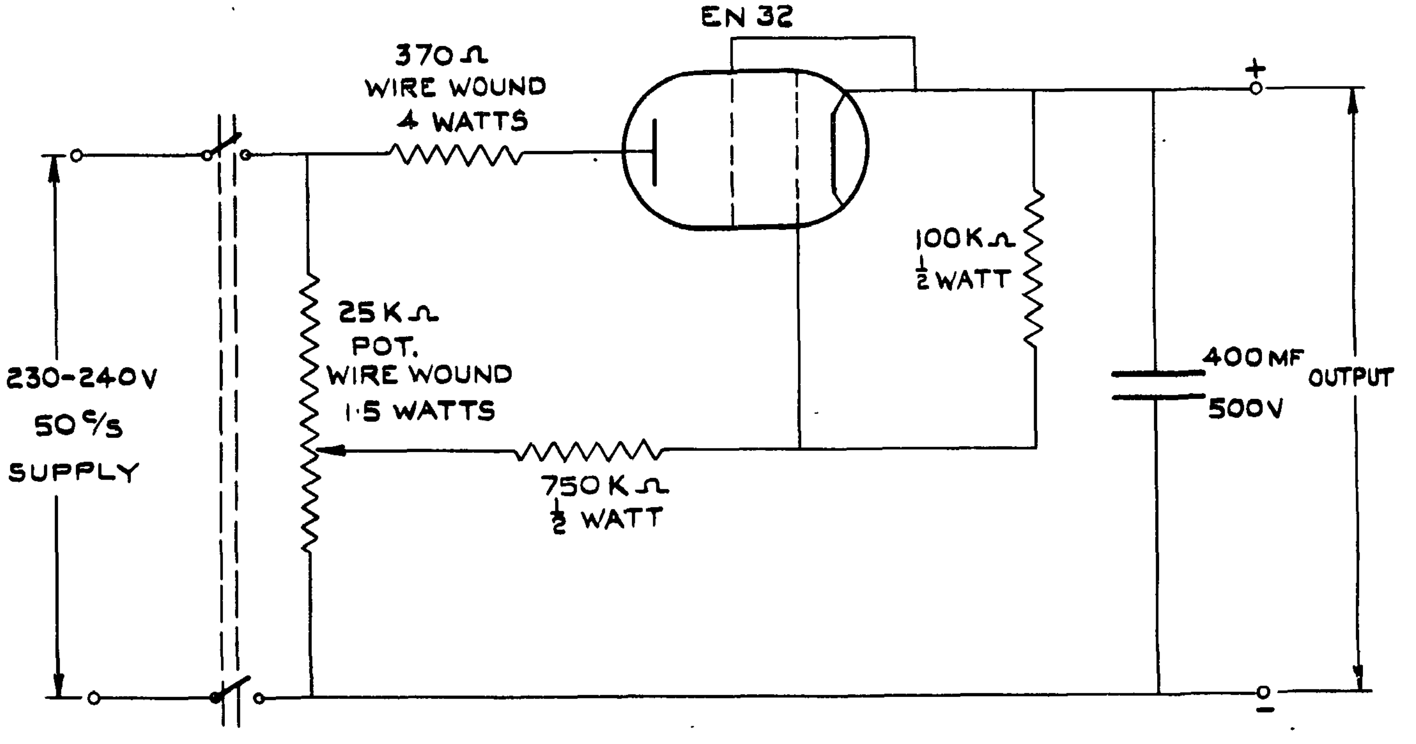


FIG. 2. CHARGING CIRCUIT FOR "WELDING" APPARATUS.

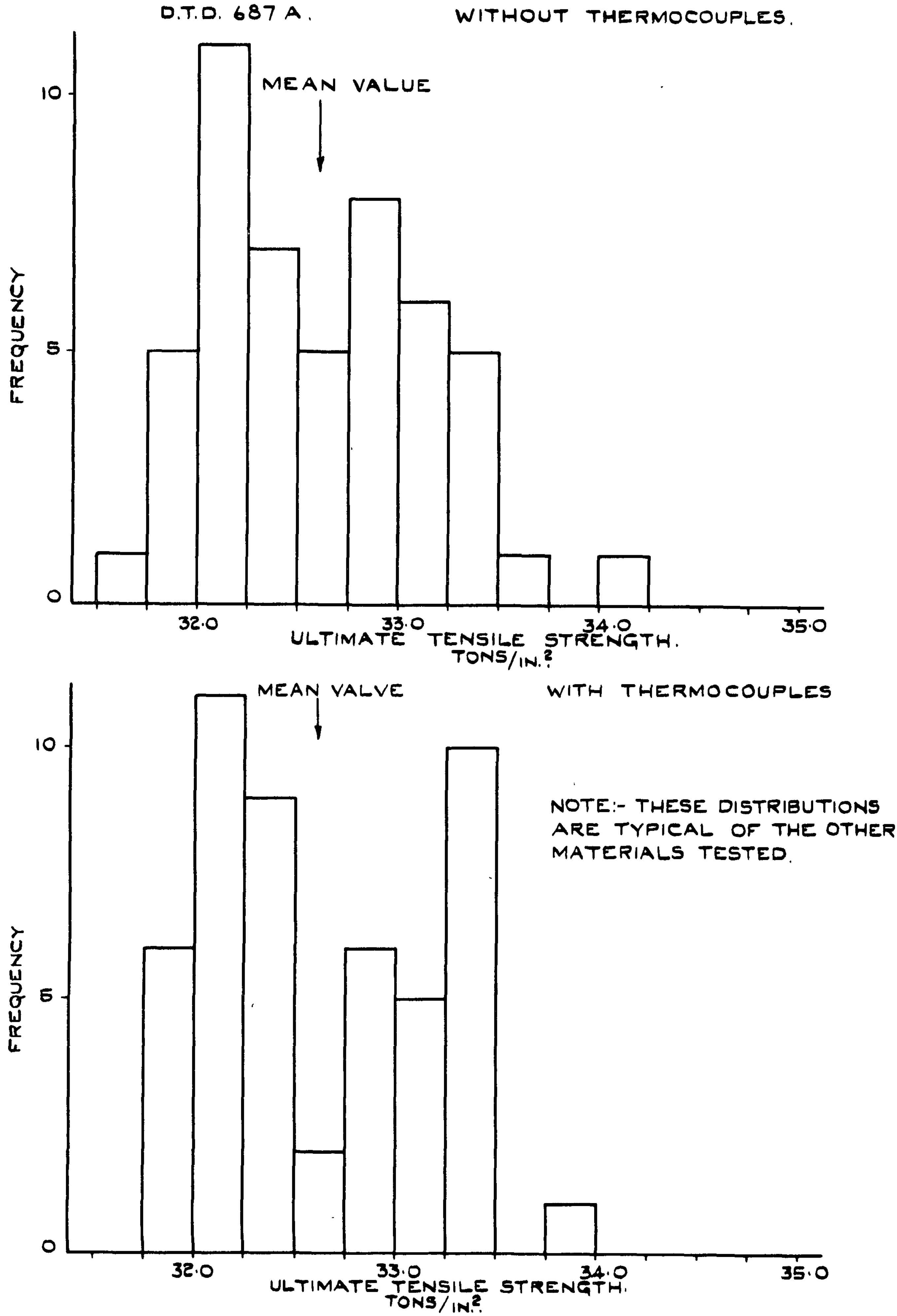


FIG. 3. DISTRIBUTION OF ULTIMATE TENSILE STRENGTH VALUES.

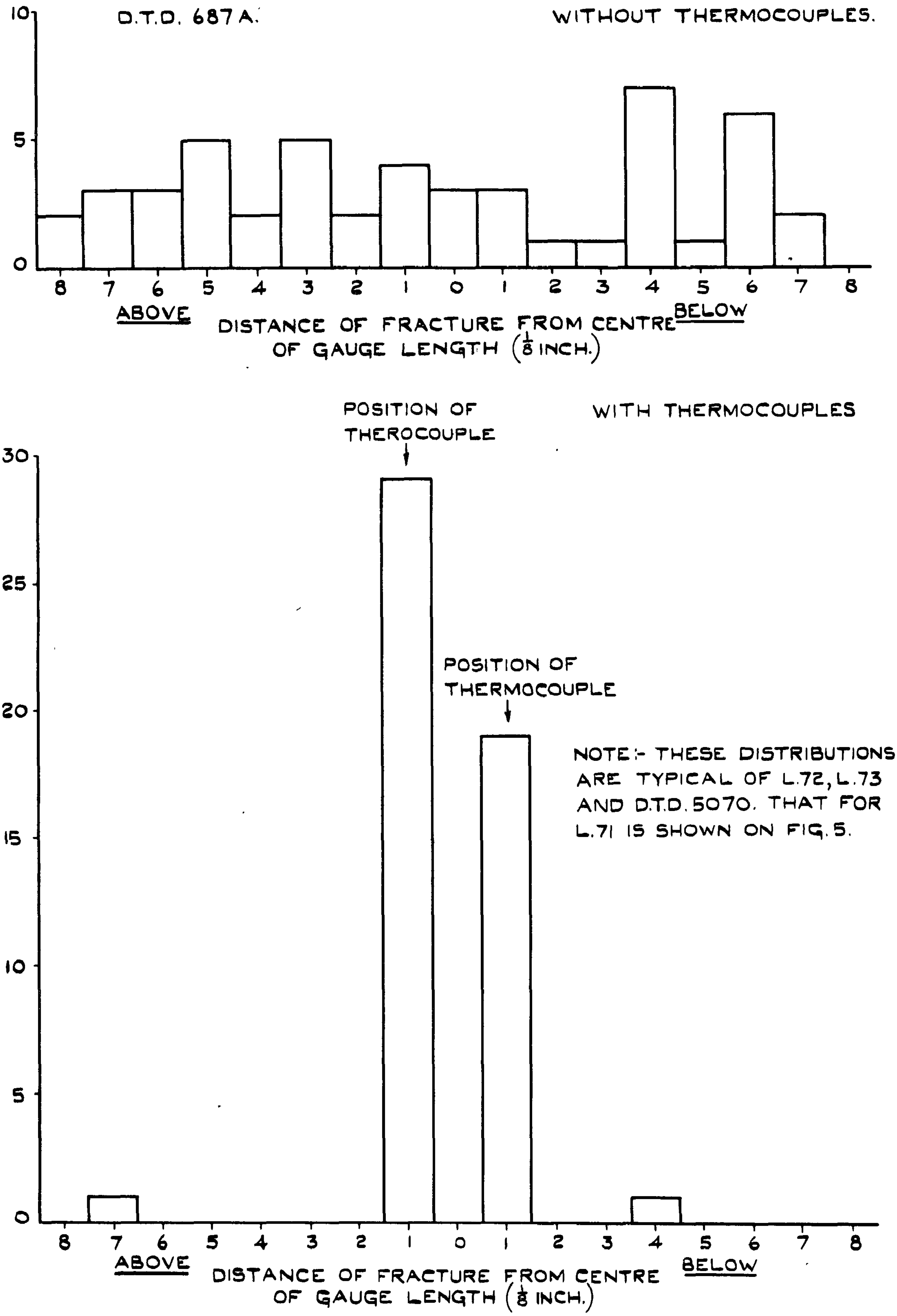
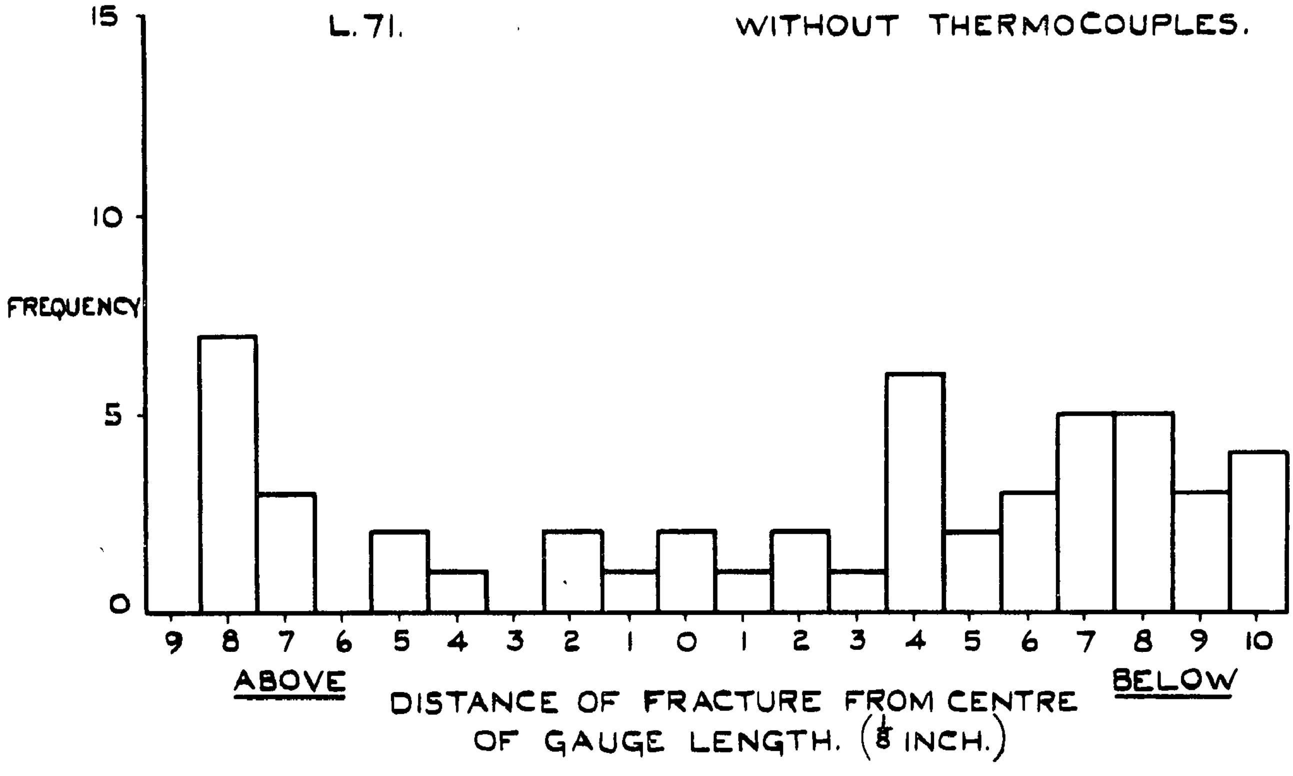


FIG. 4. DISTRIBUTION OF POSITION OF FRACTURE.



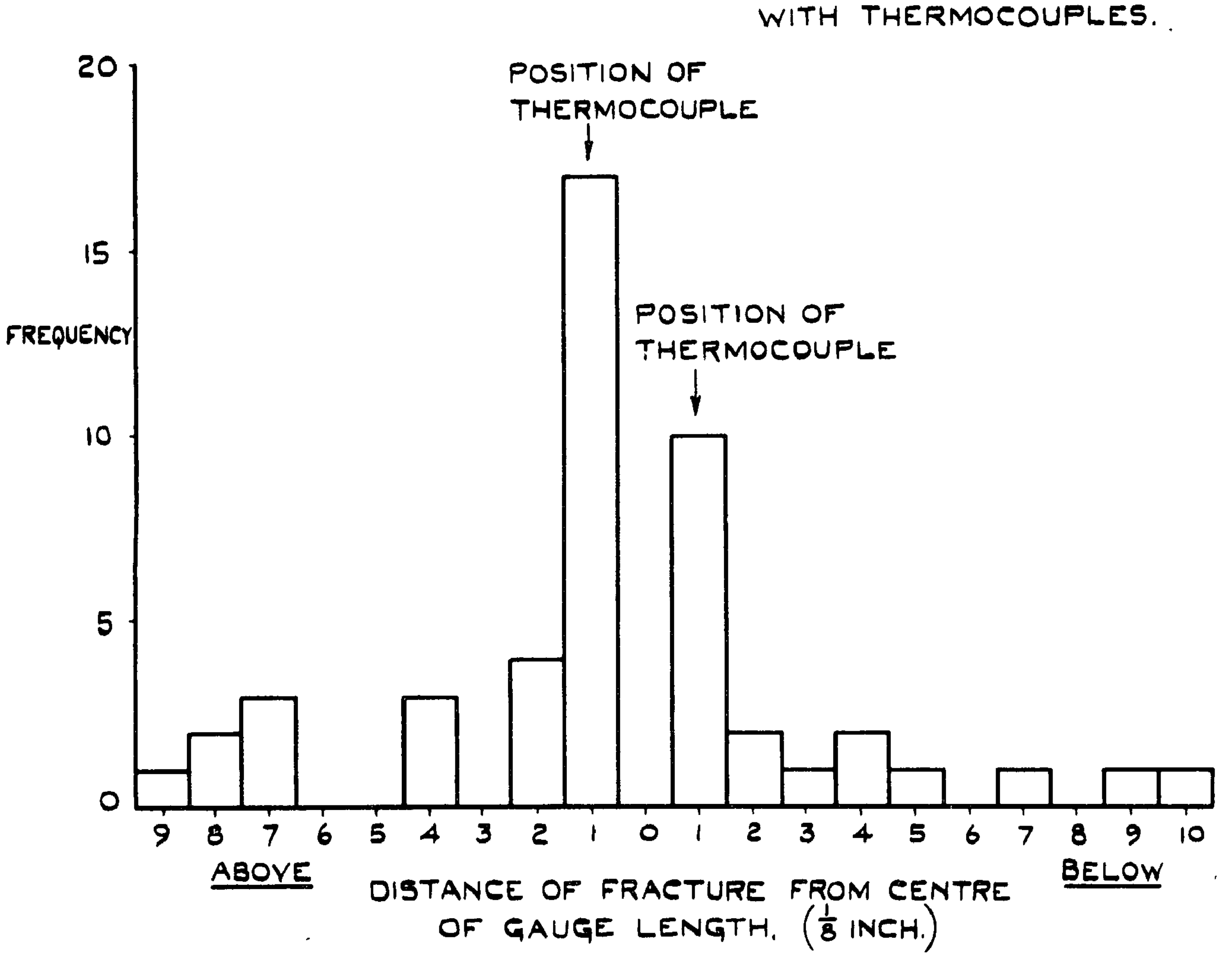


FIG.5. DISTRIBUTION OF POSITION OF FRACTURE.

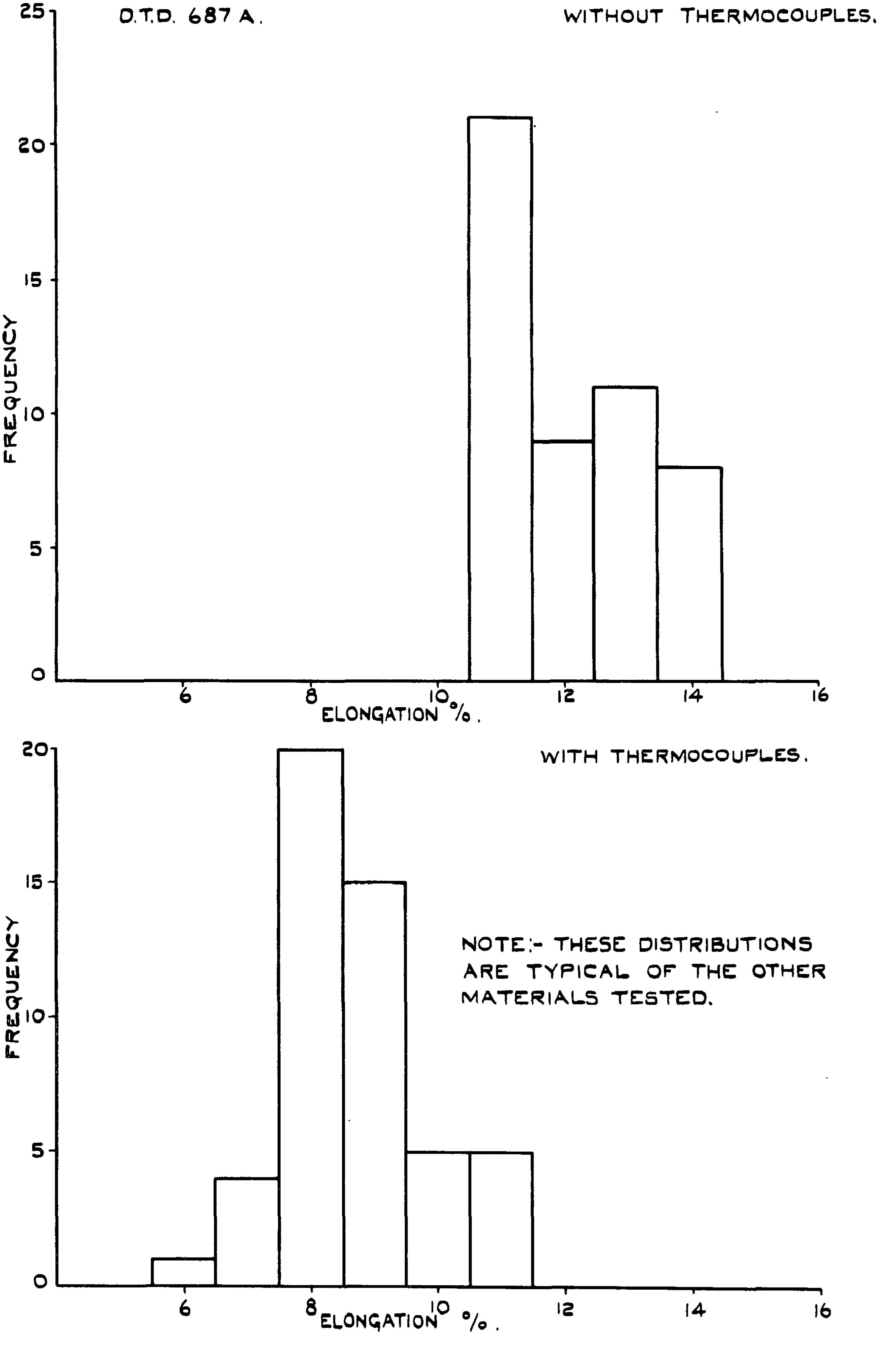


FIG. 6. DISTRIBUTION OF ELONGATION VALUES.

A.R.C. C.P. No. 790

669.715 :
621.415 :
621.791 :
620.172.2

EFFECT ON THE STATIC STRENGTH OF ALUMINIUM ALLOY TEST SPECIMENS OF THE ATTACHMENT OF THERMOCOUPLES BY A WELDING TECHNIQUE. Wright, D.F. and Acheson, G.F. January 1964.

Tensile tests were made on a large number of aluminium alloy test specimens extracted from sheet material to Specifications L.71, L.72, L.73, DTD.687A and DTD.5070 to determine the effect of attaching thermocouple leads to them by a welding technique.

The tests showed that the thermocouple welds had a negligible effect on the proof and ultimate stresses and on Young's Modulus. There was, however, a marked tendency for the specimens to fail at the thermocouple welds with considerable decrease in the elongation at fracture.

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The reduction of elongation and failure at the weld suggests that it would be prudent to avoid the welding method of thermocouple attachment for specimens where the measurement of elongation at fracture is required, and for specimens and structural parts subject to fatigue load, but this method is recommended for calibration of other temperature measuring devices, including thermocouples attached by other means.

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