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DSTL, DSIR 23/27631, 8 Sep 2009

S & T Memo. No. 12/57

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DTD. 166 - TYPE AUSTENITIC CHROMIUM - NICKEL STEEL SHEET: A SUMMARY OF PROPERTIES

REPORT OF WORK CARRIED OUT BY BRISTOL AIRCRAFT LTD.

FOR MINISTRY OF SUPPLY

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DTD.166-TYPE AUSTENITIC CHROMIUM-NICKEL STEEL SHEET: A SUMMARY OF PROPERTIES

00. INTRODUCTION

This report summarises the properties of the stabilised 18% chromium/8% nickel stainless steel sheet materials chosen by Bristols for structural applications. The major characteristics influencing this selection were the weldability (in particular to FV.448, a 12% chromium type steel) and the high strength.

The material is basically Firth-Vickers steel FDP (which conforms to specification DTD.166, recently superseded by S.520) modified by various special Bristol requirements. The factors which have led to the formulation of these special requirements are outlined herein.

Messrs. Fairey Aviation Co. Ltd. have also chosen this material for structural applications and, with their agreement, this report has been extended to include comments on their experience.

Note: All results quoted in this report have been obtained using material supplied by Firth-Vickers (Stainless Steel) Ltd. Figures 1-11 are based on results obtained by Bristols (or supplied to them by Firth-Vickers) and Figure 12 is based on results obtained by Faireys.

01. CHEMICAL COMPOSITION

The material is of the 18% chromium 8% nickel stabilised austenitic type. The specified chemical composition is given in Table 1 attached, together with those for the now obsolete DTD.166 and for S.520 (the nearest equivalents in national specifications).

02. GRADES USED

02.01 By Bristol Aircraft Ltd.

Bristol specifications have been prepared for 4 grades of DTD.166-type material, as follows:-

Application	Specification No.	Min. Spec. Properties				Comments
		E_c	t_1	f_t	e	
Purchase from Firth-Vickers	BAC.A.1038	-	42	58-68	15	Requires conversion by User to 1021, 22 or 61
Aircraft use	BAC.A.1021	27.0	48	64	6	)Properties)after heat)treatment by)User
	BAC.A.1061	-	45	60	6	
Non-aircraft use (e.g. models)	BAC.A.1022	-	42	56	15	Does not require heat treatment
DTD.166 and S.520 (ref. only)		-	40-50	52-70	15	Not used

Thus BAC.A.1021 covers the high grade aircraft material, and BAC.A.1061 the material for use where modulus is less critical. The special requirements in these BAC.A. specifications are summarised in Table 2 attached.

An important feature to be noted is that many of the special requirements cannot be checked by the material supplier, but only by the user (e.g. puddle-weldability; compression modulus). The user, therefore, is driven to creating an internal checking and re-identification procedure not encountered with most other materials.

.02.02. By Fairey Aviation Co. Ltd.

A Fairey specification (FSIS.183) has been prepared to cover "Higher Property Level Material", with the following properties:-

t_p : 60 tons/in^2 min.

f_t : 65 tons/in^2 min.

e : 5% min.

these higher properties are obtained on strip-rolled material by cold work. This specification covers both purchase and use. Mechanical properties are checked by longitudinal testing; there is no modulus testing, modulus recovery treatment or demonstration of weldability.

DTD.166 material without special strength requirements is also used by Faireys, and is called "Lower Property Level Material".

Note: It is considered by both Bristols and Faireys that it is not desirable to use the DTD.166/S.520 specifications without additional controls as material to these 'national' specifications can show large variations in properties.

03. METHOD OF MANUFACTURE

DTD.166 specification permits manufacture either by single sheet-rolling or by continuous strip-rolling; the relative advantages of these two processes are as follows:

Strip-rolling compared with sheet-rolling	
Advantages	Disadvantages
1. Higher strength attainable (at corresponding loss of elongation)	1. Large minimum quantity (9000 lb. normally; 5000-7000 lb. specially); hence strip-rolled material for test purposes not available unless this quantity is being produced for other applications.
2. No length limitation for sheet widths up to 40" (or up to 36" with edge trimming to achieve tighter thickness tolerances).	2. The stress-strain curve is always very flat, and stretch forming therefore impossible.
3. Closer thickness tolerances attainable.	3. Oxidation of outcropping titanium stringers gives longitudinal defects instead of curved 'shell' mark defects; this would not be relevant if niobium were used instead of titanium for stabilisation.
4. Flatness standard probably superior.	

The advantages of strip-rolling have been considered by Bristols and by Faireys to outweigh the disadvantages, and sheet-rolling has therefore been eliminated from the relevant "BAC.A." and "FSIS" specifications.

04. THICKNESS TOLERANCES

As a given excess thickness an steel gives three times the excess weight of that in aluminium alloy, close thickness control is very desirable.

For strip-rolled BAC.A.1038, edge trimming (2" each side) enables a much more uniform sheet to be used. Means and 90% probability ranges (applicable as thickness distributions were generally Gaussian) are shown in Figure 1 for about 2500 results covering 5 thicknesses, and it can be seen that the desired range after trimming is not unrealistic if small percentages outside can be accepted.

05. MECHANICAL PROPERTIES "AS-DELIVERED"

(a) Strengths Achieved

The strength achieved is primarily a function of the amount of cold work during rolling, although it can also be affected by variations in chemical composition within the specified range. The relation between t_1, f_t and e% is given in Figure 3; the wider scatter in sheet-rolled materials is probably associated with:-

(i) The variation in the forms of stress-strain curves obtainable from sheet-rolled material (see Figure 2), and

(ii) the wider range of delivery dates for the sheet-rolled material actually tested, and the expectation therefore of greater variations in chemical composition between different specimens.

(b) Directional Variations

As DTD.166-type materials are cold-worked, it would be expected that there would be some directional variation of properties. As can be seen from Figure 4, this variation does occur (particularly with strip-rolled material), being most marked in E, E_c and c_1 and less marked in t_1 and f_t. It is important to note that, contrary to aluminium alloys, it is the longitudinal direction which is the weaker (hence the need for longitudinal testing).

(c) Compression/Tension Relationship

From Figure 5 it can be seen that longitudinally c_1 is markedly lower than t_1, although E_c and E are similar (transversely, tension and compression properties are similar).

(d) Effects of Cold Work

Preliminary tests on sheet-rolled material show that transverse E drops to the level of longitudinal E with 1% prestrain or more (less than 1% might be sufficient), with a corresponding increase in t_1; they also show that longitudinal c_1 drops by some 30% with 2% prestrain or more. These tests were regarded as showing a considerable Bauschinger effect, and the need to include forming effects when considering design strengths.

(e) Effects of Straining Rate

It has been shown that variation of straining rate within the range likely to be encountered in normal laboratory work does not affect test results.

(f) Properties at Elevated Temperature

Test data are inadequate at present, but drops at 200°C of 15-20% in t_1 and f_t have been obtained; drops in E are not yet well established (due to testing difficulties) but are probably less than in strength.

Heating at 200°C for up to 10 hours gave an increase in t_1 but no change in other room temperature ('recovery') properties.

(g) Bearing/Tension Relationship

There is some evidence to suggest that the proof bearing stress of DTD.166-type materials is about 1.8 times the proof tensile stress, which is higher than the factor of 1.5 normally assumed when no test data are available. However, considerable scatter was obtained on the tests (1.55 to 2.22) so 1.5 would appear to be realistic for design purposes.

(h) Fatigue Properties

The results of longitudinal fatigue tests are shown in Figure 12. The results obtained were as follows:-

Material	Long Surface Finish Micro-in.		Endurance Limit at 10^6 cycles tons/in^2	Endurance Ratio
	As Delivered	After Polishing		
"Lower Property Level"	4/4½	1/1½	27.1	0.521
"Higher Property Level"	3½	2½	33.3	0.514

The transverse surface finish of the specimens (i.e. resulting from longitudinal markings) was generally about 1½ micro-in. greater than the longitudinal value.

06. MECHANICAL PROPERTIES AFTER "MODULUS RECOVERY" HEAT TREATMENT

(a) Effect on Mechanical Properties

Heat treatment of DTD.166-type materials in the range 400/550°C produces an increase in mechanical strength and stiffness with sometimes a loss in ductility. The effect is due to a precipitation-type mechanism, and the treatment has been variously described as:-

Precipitation treatment,
Modulus Recovery treatment, or
High Temperature stress-relieving.

These descriptions are synonymous, and the second is favoured at Bristol.

The improvement in moduli and strength due to this type of treatment is marked, and may be accompanied by some reduction in elongation. Information is available on the effects of the following 5 treatments:-

(i) 590°C for 4 hours ; moduli and strengths are improved nearly as much as for (ii), (iii) and (v) treatments, with increased elongation, suggesting that the temper softening range is commencing at this temperature.

(ii) 550°C for 4 hours : moduli and strengths are significantly improved (see Figures 6 and 7) without reduction in elongation.

(iii) 525°C for 4 hours : although elongations tend to be slightly lower with this treatment than with (ii), the difference is not significant, so that in Figures 6 and 7 this treatment has not been differentiated from (ii).

(iv) 500°C : there is evidence that the maximum strength increase, accompanied by the maximum reduction in elongation, occurs at 500°C, and that this temperature should be avoided.

(v) 450°C for 2 hours : moduli and proof strengths are improved as for (ii) and (iii), but ultimate strengths tend to be somewhat higher and elongations to be somewhat lower (see Figures 6 and 7), than for (ii) and (iii).

It may also be noted that the improvements in moduli and strength were more marked in strip-rolled than in sheet-rolled material and that the large reductions in elongation appear to be confined to sheet-rolled material.

The relation between t_1, f_t and e% after "Modulus-Recovery" is shown in Figure 8, and compared with the As-delivered properties (see Figure 3) there is again a general improvement in characteristics, particularly for strip-rolled material. It is possible that variations in chemical composition rather than the rolling method used, was responsible for the effects noted in this and the previous paragraph.

Properties in the As-delivered condition have been regarded by this Company as inadequate for structural use, and "Modulus Recovery" has been required for all material both to achieve the higher strengths and stiffnesses and to achieve less directional and compression/tension variations (see below). Experience to date suggests that the final properties being achieved are satisfactory.

"Modulus Recovery" must follow all forming operations other than distortion correction.

The colour of sheets after "Modulus Recovery" varies from yellow-brown to blue-brown, the blue trend increasing with increasing "Modulus Recovery" temperature and with lack of degreasing

(b) Effect on Directional Variations

From Figure 9 it can be seen that, although the material is still significantly directional, the variation is less marked than in the As-delivered condition (Figure 4).

(c) Effect on Compression/Tension Relationship

From Figure 10 it can be seen that the differences between compression and tension properties are much smaller than in the As-delivered condition (Figure 5).

(d) Scatter of Properties within a Sheet

Extensive tests within a sheet have shown that the Coefficients of Variation on tension and compression moduli in the longitudinal and transverse directions vary from 1¼% to 3%, so that individual testing of sheets is a satisfactory means of control. The Coefficient of Variation on DPN numbers varied from 1½% to 2½%; the direction of indentation affects DPN values in the same sense as direction of loading affects f_t values.

(e) Effects of Prestrain prior to "Modulus Recovery"

Tests on material given 3% tensile prestrain followed by a "Modulus Recovery" treatment have shown that the need to include forming effects when considering design strengths is not fully eliminated by introducing "Modulus Recovery":-

(i) longitudinal prestrain. Including the prestrain has little effect on the longitudinal tension or compression properties after "Modulus Recovery".

(ii) transverse prestrain. Including the prestrain has little effect on the transverse compression properties after "Modulus Recovery", but the effect on the transverse tension properties is approximately to double the increases in t_1 and f_t due to "Modulus Recovery", apparently without impairing the elongation (compare Figure 11 with Figures 3 and 8).

(f) Effects of Low Temperature Treatment Prior to "Modulus Recovery"

There is some evidence to suggest that a low temperature treatment at, say, -50°C will increase the effect of a subsequent "Modulus Recovery" treatment, but it is not conclusive.

(g) Effect on Distortion

In thicker parts (16 swg., say) the distortion produced by "Modulus Recovery" is small. In thinner parts (22 swg., say), however, distortion is sufficient to require subsequent correction if serious assembly stresses are to be avoided; the effect of this correction on properties is removed by applying a second "Modulus Recovery" treatment (this second treatment usually produces some further distortion which this Company would correct without further "Modulus Recovery", accepting any resultant loss in property).

07. FORMING

07.01 At Bristol Aircraft Ltd.

Stretch-forming was originally selected on the basis of some satisfactory operations on sheet-rolled material at the lower end of the DTD.166 strength range. However, despite extensive development trials, stretch-forming of strip-rolled material and the majority of sheet-rolled material subsequently proved impractical; this seems explicable in terms of the shapes of the stress-strain curves to failure (see Figure 2), the 'flat top' types not permitting stretch-forming.

Farnham rolling followed by wheeling has been used successfully for forming severe single curvatures (also including slight reflex double curvatures) and does not seem to produce much change in properties. To avoid minor surface damage of the rolls which might later imprint on soft surfaces (of, e.g. aluminium alloys) it has been found satisfactory to Farnham roll DTD.166-type materials between aluminium alloy sheets which protect the rolls.

Bend radii down to 2t have been produced by "rubber bolster" press forming, and by using female rubber dies in brake press forming, provided special care is exercised on tool design. Section rolling down to 2t has also been successful but only so far on a laboratory scale and has not yet been proved as a production process. Dimples can also be produced in the material, but again need special tool development.

When DTD.166-type materials are worked to hardnesses in excess of 350/370 DPN (as could occur in dimpling), stress-corrosion troubles are thought to be liable to occur; to avoid these possible troubles, a stress-relief (which is provided by the "Modulus Recovery" treatments) is considered to be most advisable.

07.02 At Fairey Aviation Co. Ltd.

The use of matched tools on a power press has been found necessary for producing details such as flanged ribs, but the finish is not suitable for subsequent spot welding. Normal rubber press forming techniques were inadequate for forming the material, and hand forming was not practicable in material thicker than 20 swg.

08. WELDABILITY

08.01 Puddle Welding

The "puddle welding" process has been developed by Bristols for welding through DTD.166-type materials either into DTD.166-type or into FV.448-type materials (see para. 00 : Introduction). It is an argon-arc process using a tungsten electrode but not involving pressure; there is full penetration of the upper sheet by the weld pool, and partial penetration of the lower sheet (it may be used also for welding more than 2 sheets). The gap between the sheets at time of welding must be restricted, as increased gaps result in reduced strength; gaps of no more than 0.002 inches have been required by Bristols, and they necessitate both accurate forming before welding and stiff jigs with power-holding. Individual welds are used rather than continuous runs, to reduce distortions.

"Puddle welds" have shown good shear strength and consistency and tension strengths of the same order. There appears to be considerable energy absorption at failure, when the weld nugget is generally pulled out from a sheet. Heat treatment after welding has not been considered necessary.

Inspection of welds by radiography is often difficult, due to:-

(i) accessibility problems, and

(ii) difficulties of interpretation - e.g. cracks can be detected but inadequate penetration is not shown up.

It has been found, however, that visual examination of the back of the weld provides an excellent means of identifying bad welds (the back of the weld shows coloured zones produced by oxide films of varying thickness); a reweld procedure has been developed to permit repair.

One batch of sheet-rolled DTD.166-type material was found to exhibit abnormal welding characteristics; tests on several hundred other sheet-rolled and strip-rolled batches have not reproduced this condition (neither have batches specially manufactured to check extremes of chemical composition). However, all material is now checked on receipt to ensure normal welding characteristics.

08.02 Spot Welding

Test data have been obtained by Faireys on the spot welding of both the "Lower Property Level Material" (DTD.166) and the "Higher Property Level Material" (FSIS.183). Although the interpretation of the results is, as they emphasise, complicated by variations in the welding process, the following conclusions have been drawn:-

(a) Although P_s/t of about 35,000 lb./in. was obtained with DTD.166, only 20,000/25,000 lb./in. was obtained with FSIS.183.

(b) Tension strengths were slightly higher than shear strengths.

(c) The presence of a spot weld reduced the static proof and ultimate strengths of the basic sheet materials by up to 10%, and the endurance limit at 10×10^6 cycles by some 10% to 20%.

(d) Shear tests in fatigue $P (1 \pm \frac{1}{2})$ produced failure at 10×10^6 cycles when P = 9% mean static failing load in DTD.166 and 15% mean static failing load in FSIS.183.

(e) More limited evidence suggests that tension tests in fatigue $P (1 \pm \frac{1}{2})$ produced failure at 10 x 10 cycles when P was about 2% to 4% of the mean static failing load.

09. CORROSION RESISTANCE

At worst only slight local pitting was found by Faireys when samples of DTD.166 material were exposed for 150 days either to local industrial atmosphere or to twice-daily intermittent salt spray corrosion conditions.

10. CONCLUSION

Although further information is still required for all the implications of the use of DTD.166-type sheet materials for aircraft structural uses to be fully evaluated, present data suggest that these materials may have considerable advantages for certain types of application.

TABLE 1

CHEMICAL COMPOSITION OF DTD.166-TYPE MATERIALS

Element	Content : %					
	DTD.166B		S.520 and FSIS.183		BAC.A.1038	
	Min.	Max.	Min.	Max.	Min.	Max.
Carbon	-	0.25	-	0.16	-	0.15
Chromium	12.00	-	16.0	20.0	17.0	19.0
Nickel	6.0	20.0	7.0	12.0	7.0	10.0
Silicon	0.20	-	0.20	-	0.20	1.0
Manganese	-	1.00	-	1.0	-	1.0
Sulphur	-	0.05	-	0.045	-	0.045
Phosphorus	-	0.05	-	0.045	-	0.045
Titanium	optional	-	5 x C*	-	5 x C	-
Niobium	optional	-	10 x C*	-	-	-
Tungsten	optional	-	optional	-	-	-
Molybdenum	optional	-	optional	-	-	-
Tantalum	-	-	optional	-	-	-
Copper	optional	-	optional	-	-	-
Vanadium	optional	-	optional	-	-	-

* In S.520 the titanium and niobium additions are alternatives.

Notes

1. It has been suggested by Firth-Vickers that manganese contents of all DTD.166-type materials should be increased from 1% to 2% max. It is considered that this change (which could permit a reduction in nickel content) should not cause much change in mechanical properties, other than increasing the t_1/f_t ratio in the heavily cold-worked condition. Bristols, however, resisted the proposal for special applications because of the volume of check testing involved. Another user also resisted the proposal because, in applications where contact with hydrogen peroxide might occur, the higher manganese content might be unacceptable.

2. So far as is known, niobium has only recently been used extensively in this country instead of titanium for stabilising DTD.166-type materials against weld decay. However, Firth-Vickers are intending to use niobium instead of titanium in the future for general manufacture because of the improvement in surface finish which would result; it is expected that this would not result in any changes in basic mechanical properties, but the response of niobium-stabilised material to "Modulus Recovery" is not known. It is believed that attempts in the U.S.A. some years ago to use niobium instead of titanium led to some form of trouble but no direct evidence has been found.

TABLE 2

SPECIAL REQUIREMENTS IN BAC.A. SPECIFICATIONS FOR DTD.166-TYPE MATERIAL

Application	Specification	Special Requirements
Purchase from Firth-Vickers	BAC.A.1038	1. Chemical composition restricted to selected manufacturers' range. 2. Only strip-rolled; sheet rolling prohibited. 3. Close thickness tolerance control. 4. High mechanical properties. 5. Elongation values to be obtained for material 12 swg. and thinner. 6. Blank material required with each "parcel" for subsequent testing by user.
Aircraft use	BAC.A.1021	1. Conversion from BAC.A.1038 only. 2. Additional thickness tolerance control. 3. Material requires "Modulus Recovery" heat treatment (one of two types to be selected) after major forming but before assembly; specimens for checking properties after heat treatment extracted longitudinally. 4. E_c requirement after "Modulus Recovery". 5. Higher t_1 and f_t requirements after "Modulus Recovery" ($t_1/f_t = \frac{3}{4}$ = aircraft proof/ultimate ratio). 6. 6% elongation requirement after "Modulus Recovery". 7. Puddle-weldability demonstrated by shear and prising tests.
	BAC.A.1061	All requirements of BAC.A.1021 except '4'
Non-aircraft use (e.g. models)	BAC.A.1022	1. Conversion from BAC.A.1038 only. 2. Puddle-weldability demonstration by shear and prising tests

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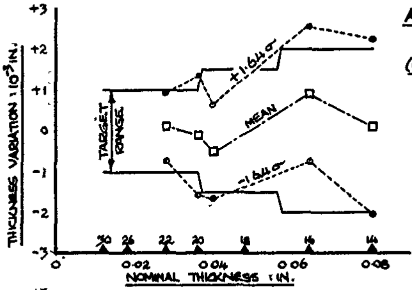
FIG. No. 1

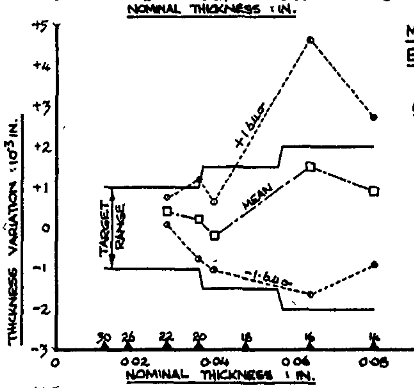
THICKNESS VARIATIONS ACHIEVED IN BACA 1038

NOTE: BACA 1038 SPECIFIES STRIP-ROLLING ONLY, AND A VERY CLOSE TARGET RANGE FOR THICKNESS WHICH IS APPLICABLE AFTER 2" HAVE BEEN SLIT FROM EACH EDGE OF THE STRIP

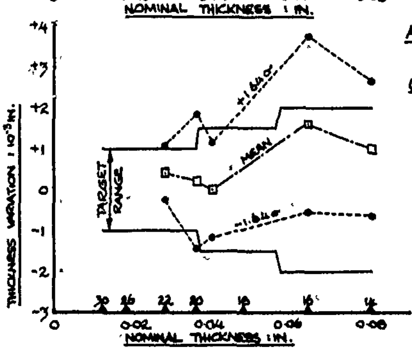
ALL RESULTS ARE FROM STRIP-ROLLED SHEETS 24"/36" WIDE



AT EDGE OF SHEET (1147 RESULTS)



MID-WAY BETWEEN EDGE & CENTRE OF SHEET (842 RESULTS)



AT CENTRE OF SHEET (562 RESULTS)

NOTE: WITH A GAUSSIAN DISTRIBUTION THE ±1·64σ RANGE CONTAINS 90% OF ALL RESULTS

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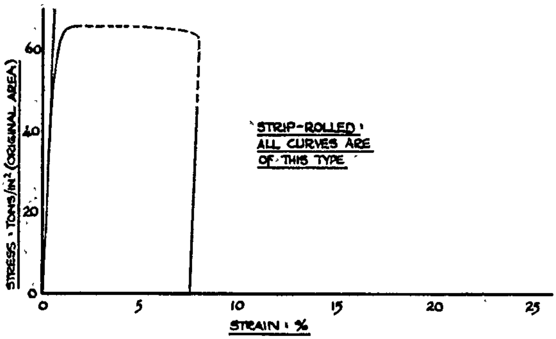
FIG. No. 2

TYPICAL STRESS/STRAIN CURVES TO FAILURE FOR DTD.166-TYPE MATERIALS IN TENSION

CONDITION : AS DELIVERED

DIRECTION : LONGITUDINAL



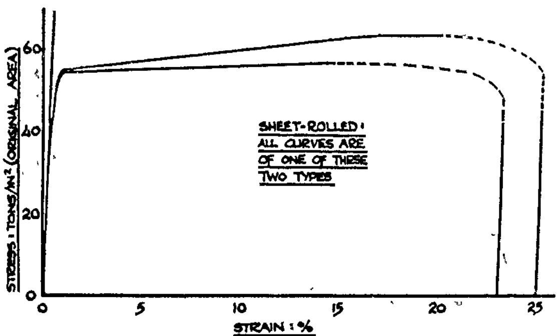


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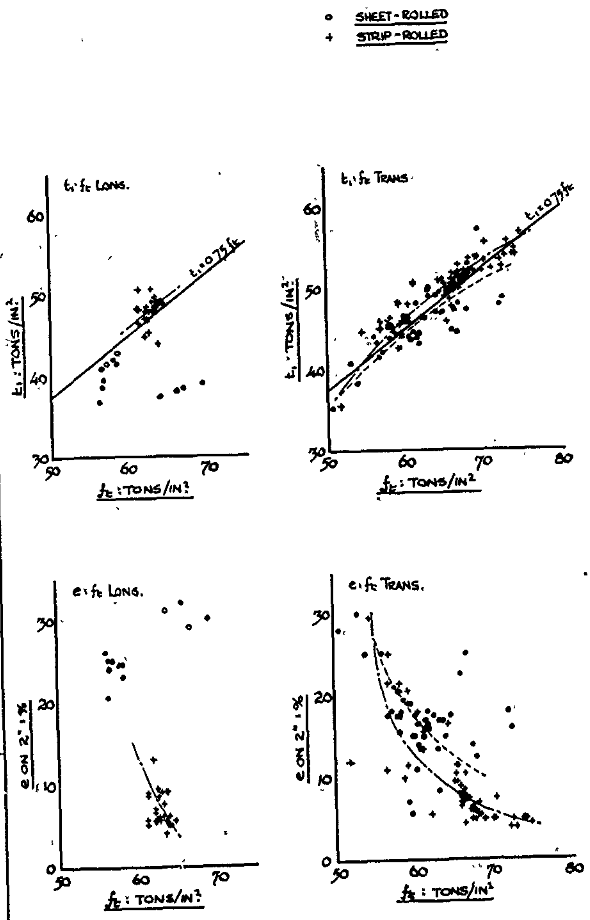
FIG. No. 3

TENSION PROPERTIES OF DTD 166-TYPE MATERIALS

CONDITION : AS DELIVERED



NOTE : WHERE LINES ARE DRAWN IN THESE GRAPHS THEY ARE ONLY INTENDED TO INDICATE GENERAL TRENDS

EACH POINT REPRESENTS AN INDIVIDUAL TEST RESULT

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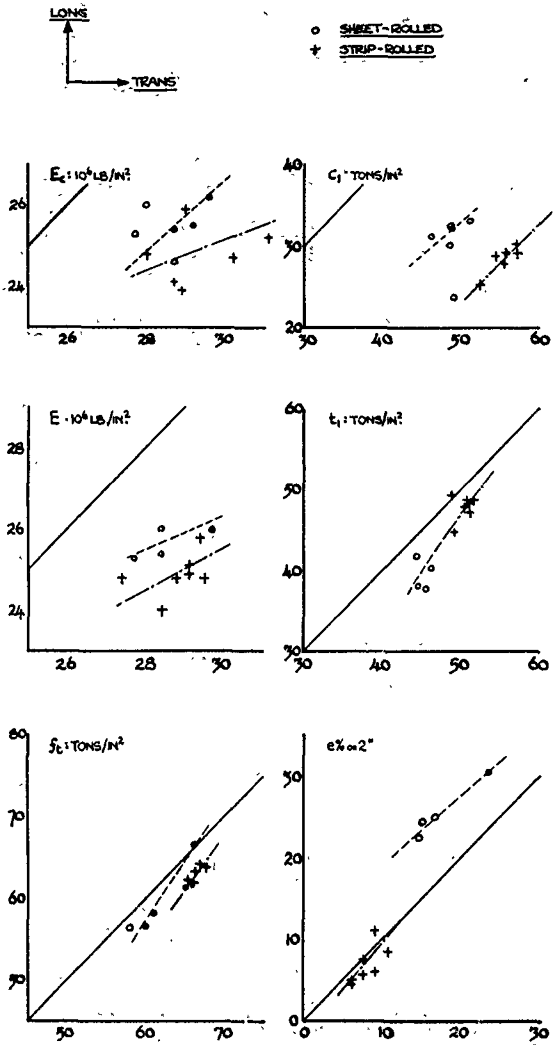
FIG. No. 4

DIRECTIONAL VARIATION OF TENSION & COMPRESSION PROPERTIES OF DTD.166-TYPE MATERIALS

CONDITION: AS DELIVERED



NOTE: LINES DRAWN IN THESE GRAPHS ARE ONLY INTENDED TO INDICATE GENERAL TRENDS

EACH POINT REPRESENTS MEAN RESULTS FOR A SHEET

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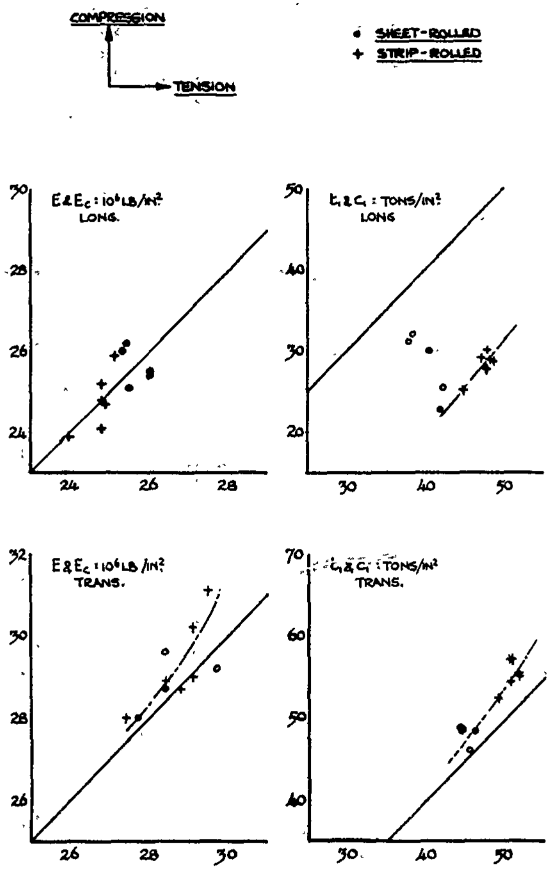
16027.P.

FIG. No. 5

RELATION BETWEEN COMPRESSION & TENSION PROPERTIES OF DTD166-TYPE MATERIALS

CONDITION : AS DELIVERED.



NOTE : WHERE LINES ARE DRAWN IN THESE GRAPHS THEY ARE ONLY INTENDED TO INDICATE GENERAL TRENDS.

EACH POINT REPRESENTS MEAN RESULTS FOR A SHEET

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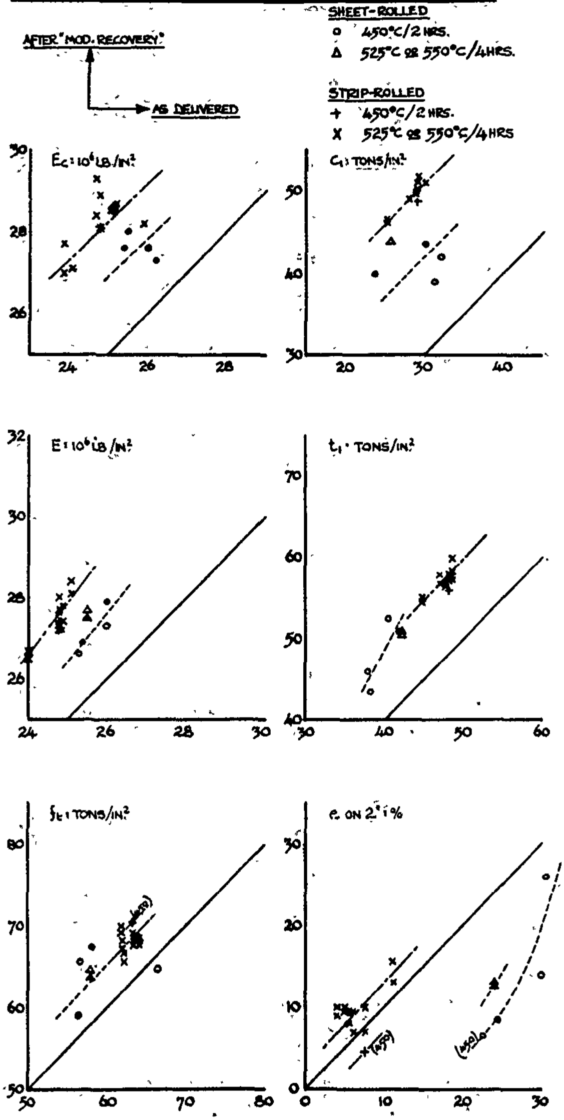
FIG. No. 6

EFFECTS OF "MODULUS RECOVERY" HEAT-TREATMENT ON LONG^{L} PROPERTIES OF DTD.166-TYPE MATERIALS



NOTE: LINES DRAWN IN THESE GRAPHS ARE ONLY INTENDED TO INDICATE GENERAL TRENDS.
EACH POINT REPRESENTS MEAN RESULTS FOR A SHEET.

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FIG. No. 7

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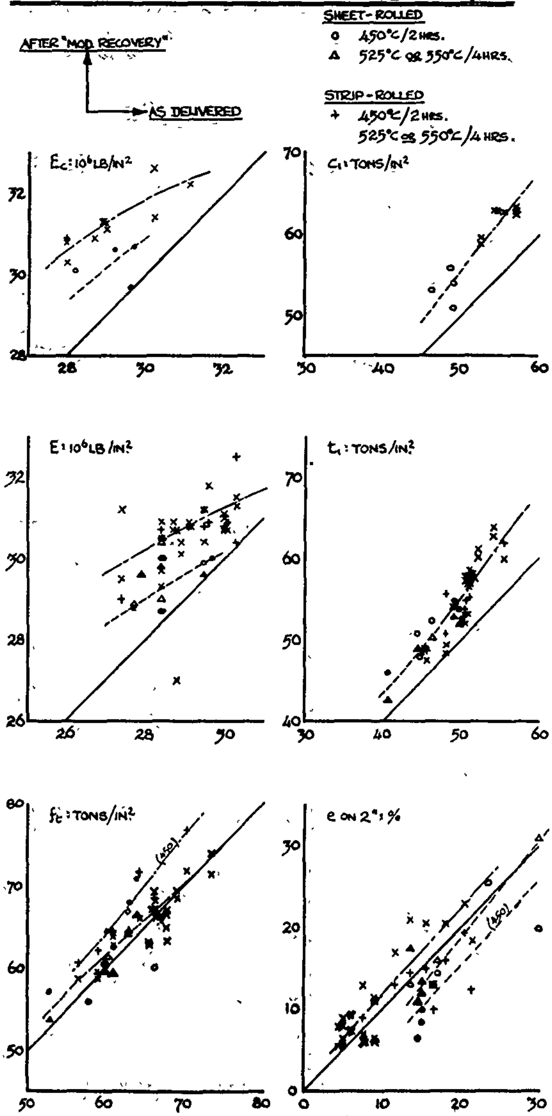
EFFECTS OF "MODULUS RECOVERY" HEAT-TREATMENT ON TRANSE PROPERTIES OF DTD.166-TYPE MATERIALS



NOTE: LINES DRAWN IN THESE GRAPHS ARE ONLY INTENDED TO INDICATE GENERAL TRENDS.

EACH POINT REPRESENTS MEAN RESULTS FOR A SHEET

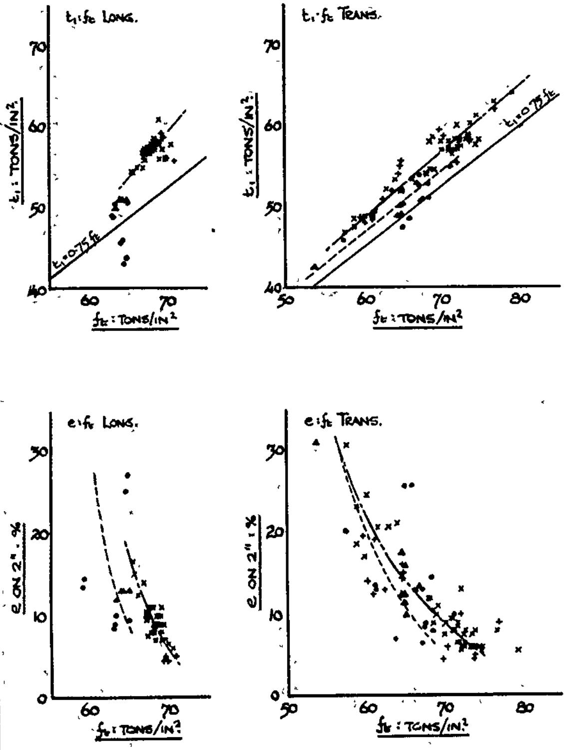
FIG. No. 8

TENSION PROPERTIES OF DTD.166-TYPE MATERIALS

CONDITION: "MODULUS RECOVERY" HEAT-TREATED

SHEET-ROLLED
- ○ 450°C/2 HRS
- △ 525°C or 550°C/4 HRS

STRIP-ROLLED
- + 425°C/2 HRS
- × 525°C or 550°C/4 HRS.



NOTE: WHERE LINES ARE DRAWN IN THESE GRAPHS THEY ARE ONLY INTENDED TO INDICATE TRENDS

EACH POINT REPRESENTS AN INDIVIDUAL TEST RESULT

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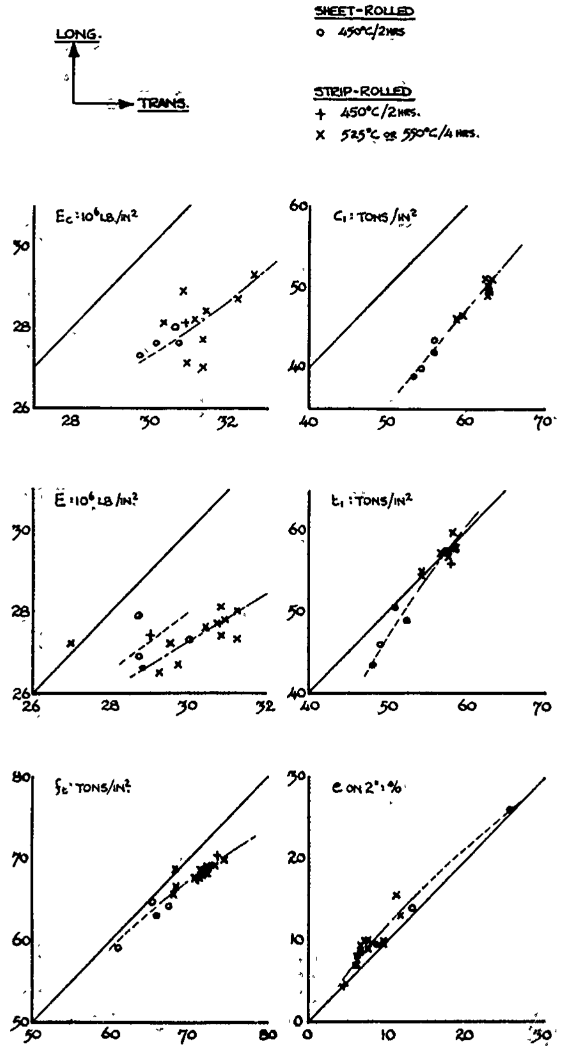
57/22/1 ISSUE 3	DTD.166-TYPE SHEET MATERIALS	10/1958			BRISTOL AIRCRAFT LIMITED ENGINEERING DEVELOPMENT LABORATORY

FIG. No. 9

DIRECTIONAL VARIATION OF TENSION & COMPRESSION PROPERTIES OF DTD.166-TYPE MATERIALS

CONDITION : "MODULUS RECOVERY" HEAT-TREATED.



NOTE : LINES DRAWN IN THESE GRAPHS ARE ONLY INTENDED TO INDICATE GENERAL TRENDS

EACH POINT REPRESENTS MEAN RESULTS FOR A SHEET

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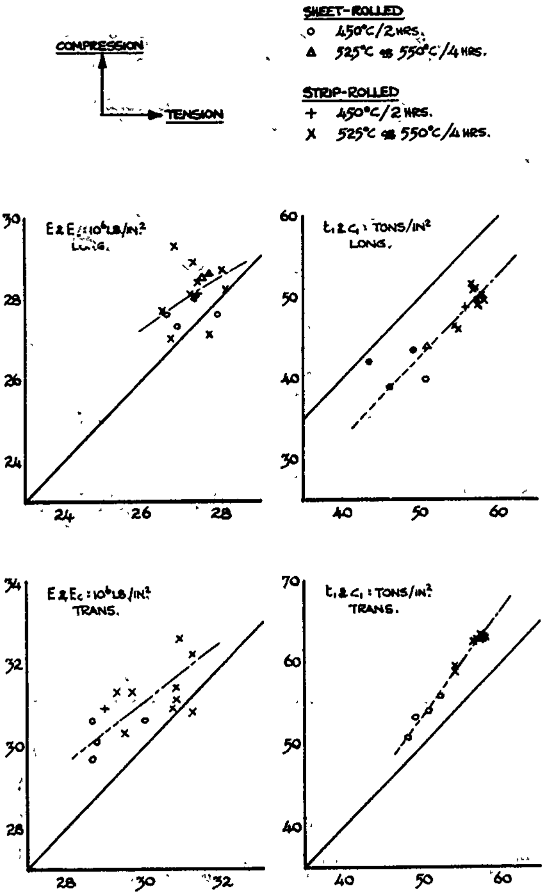
2.15027.B.

FIG. No. 10

RELATION BETWEEN COMPRESSION & TENSION PROPERTIES OF DTD.166-TYPE MATERIALS

CONDITION: "MODULUS RECOVERY" HEAT-TREATED.



NOTE: WHERE LINES ARE DRAWN IN THESE GRAPHS THEY ARE ONLY INTENDED TO INDICATE GENERAL TRENDS.

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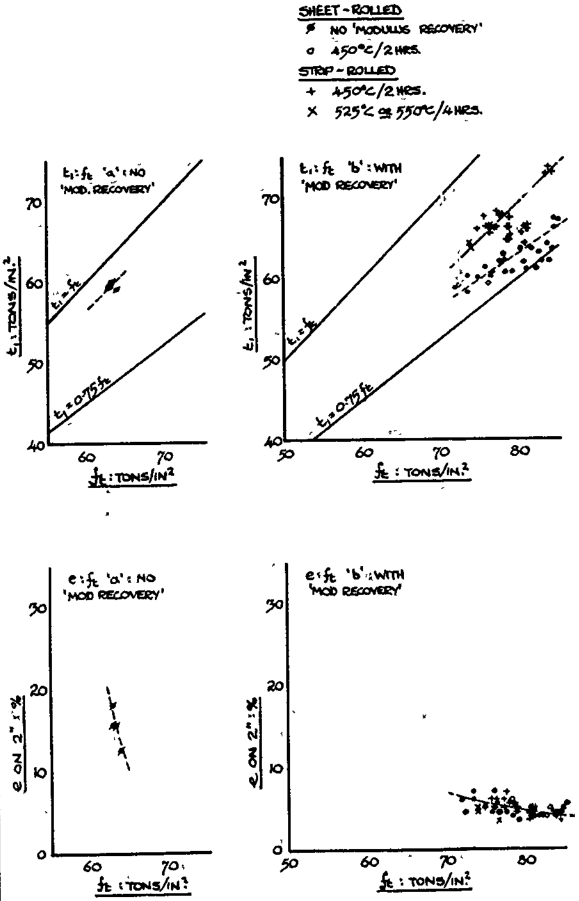
FIG. No. 11

TRANSVERSE TENSION PROPERTIES OF DTD.166-TYPE MATERIALS AFTER 3% TRANSVERSE PRESTRAIN

CONDITION: 'a': PRESTRAINED & TESTED

'b': PRESTRAINED, 'MODULUS RECOVERED' & TESTED



NOTE: LINES DRAWN IN THESE GRAPHS ARE ONLY INTENDED TO INDICATE GENERAL TRENDS

EACH POINT REPRESENTS AN INDIVIDUAL TEST RESULT.

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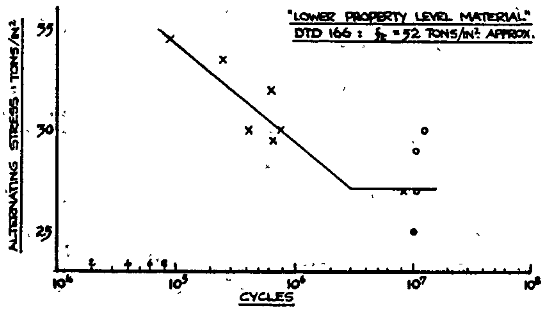
FIG. No. 12

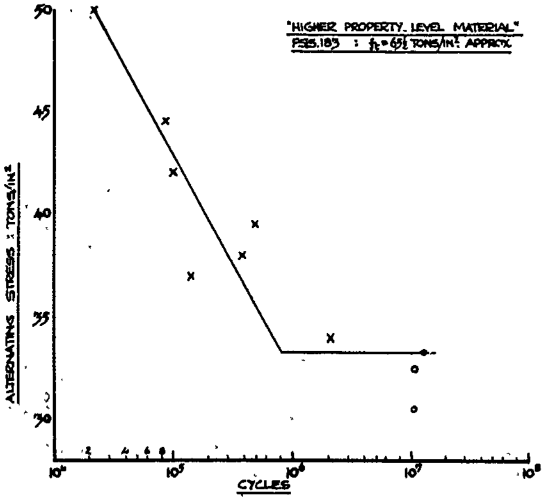
LONGITUDINAL REVERSE BEND S/N CURVES FOR DTD.166-TYPE MATERIALS

CONDITION : AS DELIVERED.

× SPECIMEN FAILED
o SPECIMEN UNBROKEN

STRIP - ROLLED





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