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INTERNATIONAL STANDARDIZATION OF TEST BARS FOR CAST COPPER ALLOYS

by

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PHYSICAL METALLURGY DIVISION

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SUMMARY OF RESULTS

Laboratory and industrial trials of a French standard test bar were undertaken, to compare it with standard North American test bars, and determine its suitability for use with cast copper alloys.

The results suggest that the French design will be satisfactory for alloys other than those with a marked tendency to dross formation.

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INTRODUCTION

In 1963, the Secretariat of ISO/TC26/WG3 proposed the adoption of the French test bar design (AFNOR standard) as an ISO reference bar for cast copper-base alloys.

This bar is illustrated in Figure 1, and it will be seen that it is similar to the "Dow" bar, (Figure 2), which is commonly used for magnesium alloys in North America*, and has been used in these laboratories for copper alloys. Because of the laboratory experience with Dow bars on cast copper alloys, it was thought that the proposed French test bar might be subject to the following defects:-

a) relative insensitivity to melt quality,

b) high scatter of results between bars,

c) high incidence of oxide and dross inclusions on the cope side of the bar when casting alloys such as aluminum bronze and high-tensile brass. (This is a common feature of all unmachined test bars).

It is of interest to note that similar fears were expressed by the British (document ISO/TC26/GT3 N16, February 1964).

This report is a brief account of the work undertaken to examine the performance of the French test bar on copper alloys.

EXPERIMENTAL MELTS

It was realized that the only effective way of assessing the respective merits of test bars was to undertake a large-scale industrial trial with an appropriate analysis of results. However, it was decided initially to conduct a small laboratory investigation as a preliminary survey.

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* According to CSA.HG. 1-1963 and U.S. Federal Specification QQ-M-56.

Three alloys of nominal composition 85% Cu - 5% Sn - 5% Pb - 5% Zn, 88% Cu - 10% Sn - 2% Zn and 57% Cu - 40% Zn - 1% Fe - 1% Al - 0.6% Mn, were chosen as representing leaded red brass (gunmetal), tin bronze, and high-tensile brass (manganese bronze).

These were melted in a high-frequency, lift-coil induction furnace, without flux cover, and half the melt was poured into a French test bar mould, a Dow bar mould and two ASTM keel block moulds (Figure 3), to give four test coupons of each type. This metal was not deoxidized or degassed in any way, and hence must be considered to be of "poor", or at least no better than average, melt quality.

The remaining half melt was returned to the furnace where it was retained at the pouring temperature while being degassed with nitrogen at about 5 litres per minute for fifteen minutes. Small zinc additions were made to compensate for losses, and the tin bronze and leaded red brass were deoxidized with phosphor copper shot to leave a residual 0.01% P. Test bars were then poured as before.

The results of tensile tests on these bars are given in Table 1, each result being the average of four bars.

INDUSTRIAL TRIALS

At this point, the French test bar pattern was transferred to a commercial foundry where it was anticipated that sufficient data could be collected over a period to justify statistical comparison with the North American standard test bar used by the foundry (Figure 4a).

Unfortunately, to conform with their standard testing equipment, the foundry found it necessary to machine the French test bars. Since it was considered that this might invalidate the results, the test was discontinued after a short period. However, the results of the individual industrial tests are given in Table 2.

DISCUSSION OF RESULTS

The results are discussed in relation to the points raised in the introduction:

a) insensitivity to melt quickly. As shown in Table 1, there was relatively good differentiation between good and poor quality melts with regard to ultimate tensile strength and per cent elongation for the French test bar. The similarity of yield strength values is to be expected, because of the nature of the test.

b) high scatter of results between bars. The detailed results, which are not shown, suggest that apart from the high-tensile brass which will be discussed later, the results from the French test bar are relatively free from scatter. (It may be that the pouring temperature of 1150°C (2100°F) was sufficiently high to ensure a columnar structure, although this was unfortunately not checked at the time). However, the foundry conducting the industrial trials commented that the French bar appeared to be more sensitive to pouring temperature than the ASTM full-web bar.

c) inclusions in cast-to-shape bars with alloys of high dross-forming potential. This was confirmed in the laboratory tests with high-tensile brass, where all of the French bars and all but one of the Dow bars showed flaws in the fracture, probably associated with dross inclusions, whereas none of the keel blocks showed these inclusions. This accounts for the relatively low values of ultimate tensile strength and elongation, and suggests that the French bar, in common with other similar cast-to-shape bars, is unsuitable for this class of alloys.

It might also be mentioned that compared to the standard machined-to-size North American test bar, the French bar gives higher yield strength and ultimate tensile strength values for the laboratory tests on the leaded red brass and tin bronze. Similarly, all values, particularly elongation and ultimate tensile strength, are lower for the French bar with high-tensile brass, because of the inclusion problem. While it is appreciated that test bar philosophy requires that the test bar represent melt quality, not the properties of castings made from the melt, the wide differences in properties which can be obtained by testing the same melt with different test bars could cause difficulty and misunderstanding when comparing national and international standards for material or acceptance procedures.

CONCLUSIONS

On the basis of the limited experimental and production trials, it is suggested that the French test bar would be satisfactory as an international standard for tin bronzes, leaded red brasses (gunmetals) and other copper alloys with similar solidification characteristics. A proviso might be added that the pouring temperature may be critical, and that the relationship between national and international standards may need careful consideration in view of the widely different properties to be expected from the same melt, using different types of test bar.

It is considered that the French test bar is not satisfactory for high-tensile brass (manganese bronze), aluminium bronze, and similar alloys, because of the high incidence of dross inclusions in the gauge length. For this class of alloys it is considered that a more massive machined-to-size test casting is essential to ensure that inclusions are completely eliminated from the gauge length.

ACKNOWLEDGEMENTS

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JOE:AC:lc

TABLE 1

Results of Experimental Metals* using Three Different Test Bars (Mean of 4 Results)

	"Good" Melt Quality					"Poor" Melt Quality				
Type of Test Bar	UTS kpsi	0.2% YS kpsi	0.5% YS kpsi	% El. in 4D	% El. in 5D	UTS kpsi	0.2% YS kpsi	0.5% YS kpsi	% El. in 4D	% El. in 5D
Alloy 85-5-5-5 (85.5 Cu-4.8 Sn-5.0 Pb-4.2 Zn)										
Dow	39.0	17.2	18.2	34	33	33.2	16.8	17.4	19	18
French	37.6	16.2	16.8	32	32	30.4	15.9	16.8	16	15
ASTM Keel Block	31.9	13.9	14.8	34	33	31.3	13.9	16.6	33	32
Specified Properties (1)										
	30.0 min		14.0 min	20.0 min						
Alloy 88-10-2 (87.0 Cu-10.66 Sn-2.1 Zn-0.13 Pb)										
Dow	49.7	22.1	23.0	29	26	43.6	21.6	22.6	17	15
French	47.9	21.2	22.2	28	26	44.5	21.9	23.4	19	18
ASTM Keel Block	43.6	18.6	19.6	36	34	38.0	17.4	18.2	27	27
Specified Properties (2)										
	40.0 min		18.0 min	20.0 min						
High-Tensile Brass (Manganese Bronze) 56.7 Cu-39.8 Zn-1.0 Fe-1.0 Al-0.6 Mn-0.3 Sn										
Dow	83.8	37.0	38.1	15	14	78.2	37.0	37.7	12	12
French	75.2	35.9	36.7	11	9	70.1	35.7	35.7	10	8
ASTM Keel Block	85.0	39.9	40.8	25	24	82.7	34.7	35.9	26	25
Specified Properties (3)										
	65.0 min		25.0 min	20 min						

* All material melted in lift-coil induction furnace, and cast at 1150°C (2100°F) except for high-tensile brass (manganese bronze), which was cast at 1025°C (1875°F). "Poor" melt quality represents straight forward melting without fluxing, deoxidation or degassing. "Good" melt quality is same material which has been degassed with nitrogen, and, in the case of the tin-bearing alloys, deoxidized to leave a residual 0.01%P.

Specified Properties

(1) CSA Standard HC9-1962, alloy ZP55-SC, and ASTM B145-63, alloy 4A.
(2) CSA Standard HC9-1962, alloy TZ102-SC, and ASTM B143-61, alloy 1A.
(3) CSA Standard HC9-1962, alloy ZF391-SC, and ASTM B147-63, alloy 8A.

TABLE 2

Results of Industrial Trials of Two Test Bar Designs

	French Test Bar*			ASTM Full-Web Bar		
	UTS kpsi	0.5% YS kpsi	% El. 4D	UTS kpsi	0.5% YS kpsi	% El. 4D
	Alloy 85-5-5-5 (85 Cu-5 Sn-5 Pb-5Zn)					
		Pouring Temperature 1120°C (2050°F)				
	34.3	21.8	20.5	37.8	20.4	32.0
	33.2	21.4	21.0	36.3	19.6	28.0
	34.3	20.9	16.0**	38.4	21.1	30.5
Mean	33.9	21.4	20.5	37.5	20.4	30.0
		Specified Properties (1)		30.0 min	14.0 min	20.0 min
	Alloy 88-10-2 (88 Cu-10 Sn-2Zn)					
		Pouring Temperature 1150°C (2100°F)				
	47.0	23.4	20.5	49.0	21.8	28.0
	46.7	23.2	19.5	50.4	22.4	31.0
	46.8	22.8	20.0	49.9	22.6	29.0
	47.4	23.7	19.5	47.6	21.8	27.5
Mean	47.0	23.3	20.0	49.2	22.2	29.0
		Pouring Temperature 1205°C (2200°F)				
	45.6	22.5	26.0	46.4	21.0	26.0
	44.8	21.9	27.0	47.0	21.4	28.0
	44.2	23.6	24.0	47.1	20.9	29.5
Mean	44.8	23.2	25.5	46.8	21.5	28.5
	44.9	22.8	25.5	46.8	21.2	28.0
		Pouring Temperature 1260°C (2300°F)				
	42.8	21.1	21.5	No bars poured at this temperature		
	42.1	21.5	18.0**			
	40.8	20.8	17.5**	Specified Properties (2)		
	42.1	21.4	22.0			
Mean	41.9	21.2	21.5	40.0 min	18.0 min	20.0 min

(cont'd)....

TABLE 2

Results of Industrial Trials of Two Test Bar Designs (concl'd)

	Alloy 88-8-4 (88 Cu-8 Sn-4Zn)					
		Pouring Temperature 1150°C (2100°F)				
	44.5	22.1	19.5	46.3	21.6	32.5
	43.9	21.8	18.0	47.6	21.6	32.0
	43.8	22.7	17.0**	45.4	22.1	29.0
	44.6	22.9	20.0	45.9	20.9	30.5
Mean	44.2	22.4	19.0	46.3	21.5	31.0
		Pouring Temperature 1205°C (2200°F)				
	42.7	22.8	24.5	44.4	20.8	28.5
	41.8	22.4	17.0**	45.0	21.4	25.0
	42.3	21.9	25.0	44.2	21.2	27.0
	42.0	22.1	24.5	43.1	21.5	24.0**
Mean	42.2	22.3	26.5	44.2	21.2	26.5
		Pouring Temperature (1260°C (2300°F)				
	40.2	20.7	20.0	No bars poured at this temperature		
	39.6	20.5	19.0			
	39.3	21.2	18.5	Specified Properties (3)		
	40.8	19.8	19.5			
Mean	40.0	20.6	19.5	40.0 min	18.0 min	20.0 min
	Alloy 80-10-10 (80 Cu-10 Sn-10Pb)					
	–	Pouring Temperature 1120°C (2050°F)				
	28.3	20.3	12.0	30.4	19.5	16.5
	30.0	20.2	14.0	29.8	20.1	16.0
	30.2	20.1	8.5	29.3	19.1	13.5
Mean	29.5	20.2	11.5	29.8	19.6	15.5
		Specified Properties (4)		25.0 min	12.0 min	8.0 min

* All French test bars machined to size before testing.

** Denotes flaw in fracture.

Specified Properties

(1) CSA Standard HC9-1962, alloy ZP55-SC, and ASTM B145-63, alloy 4A.
(2) CSA Standard HC9-1962, alloy TZ102-SC, and ASTM B143-61, alloy 1A.
(3) CSA Standard HC9-1962, alloy TZ84P-SC and ASTM B143-61, alloy 1B.
(4) CSA Standard HC9-1962, alloy PT1010-SC and ASTM B144-52, alloy 1B.

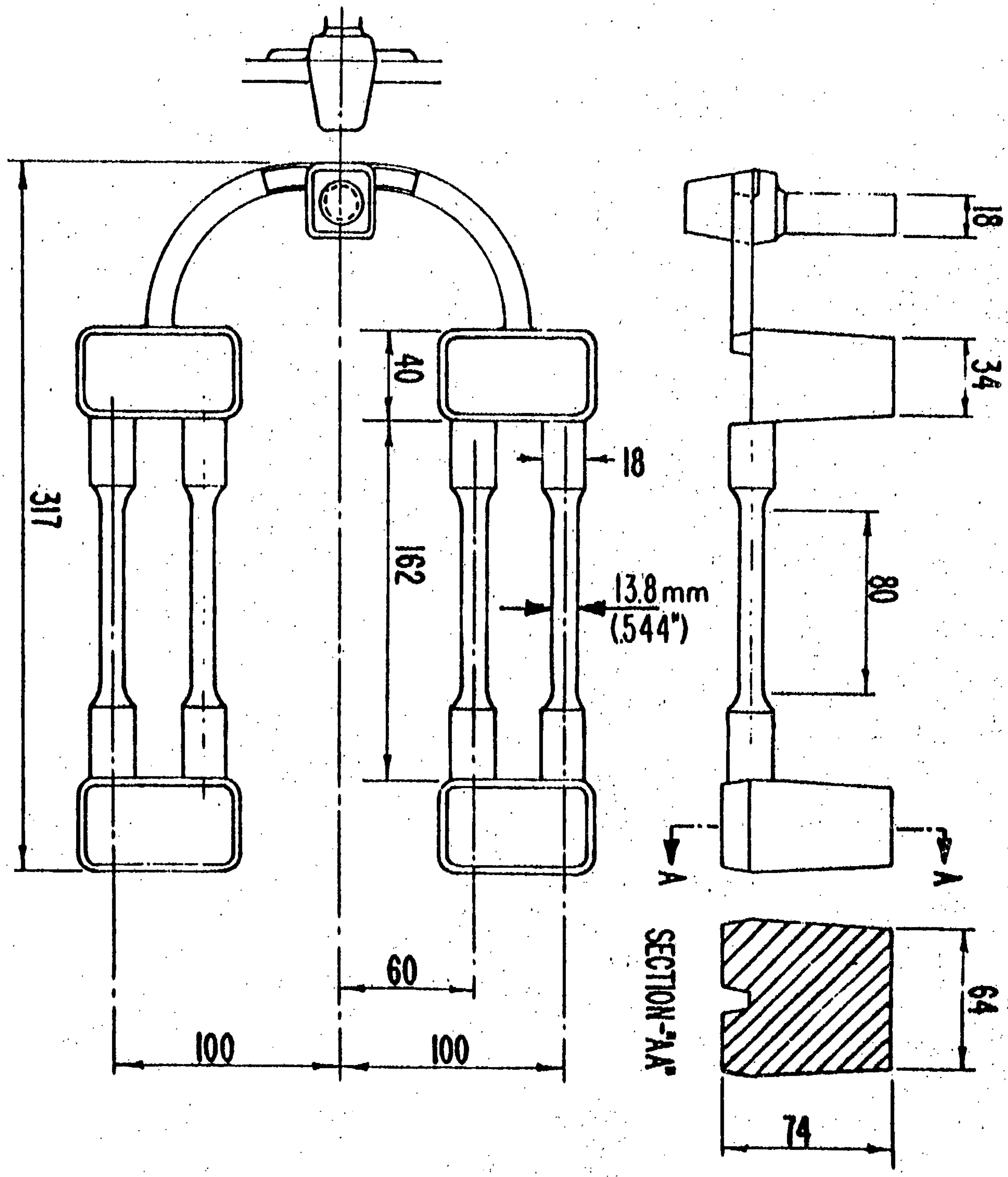


Figure 1. - French Test Bar (NF A 57-702, type B). Dimensions in mm.

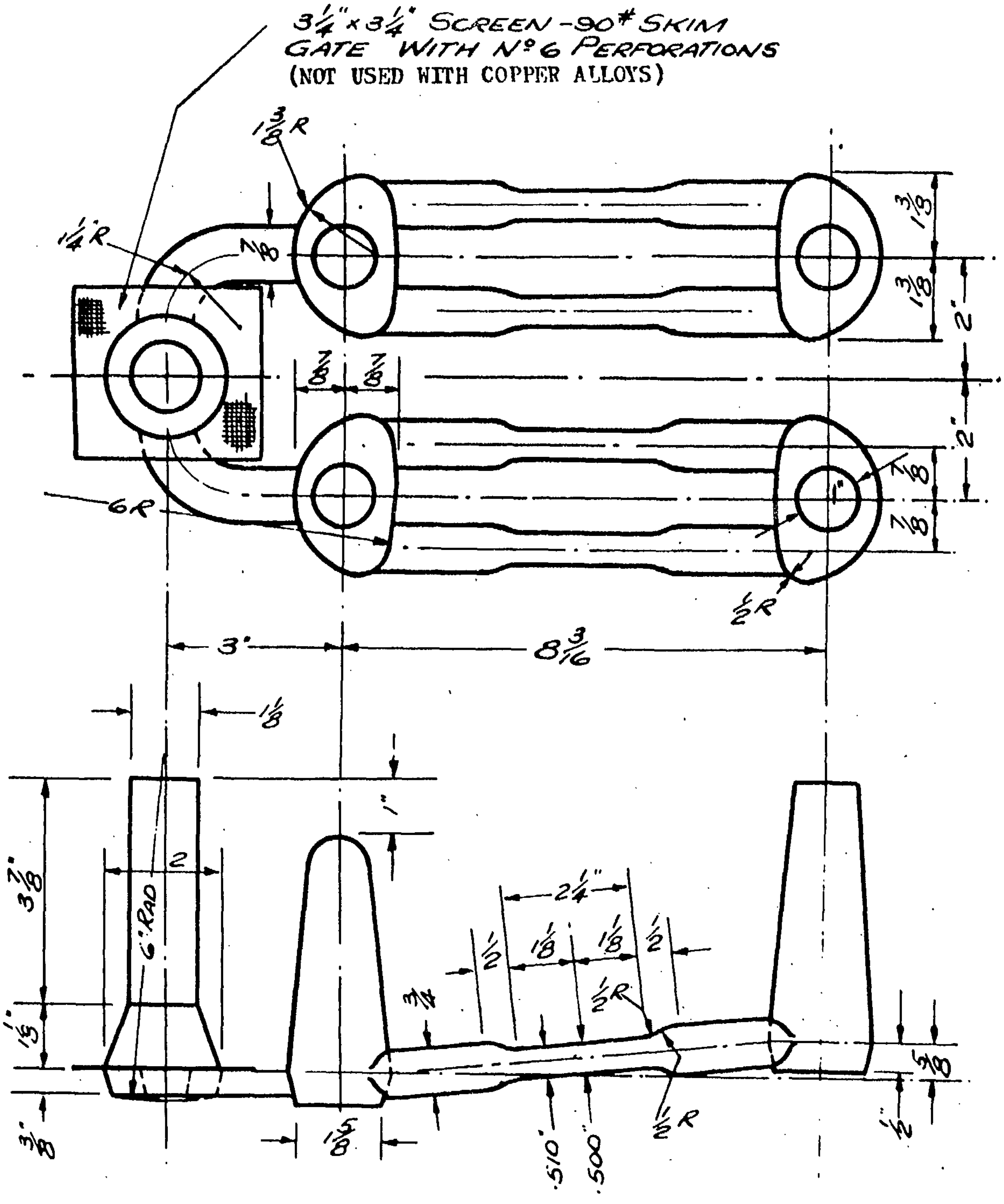
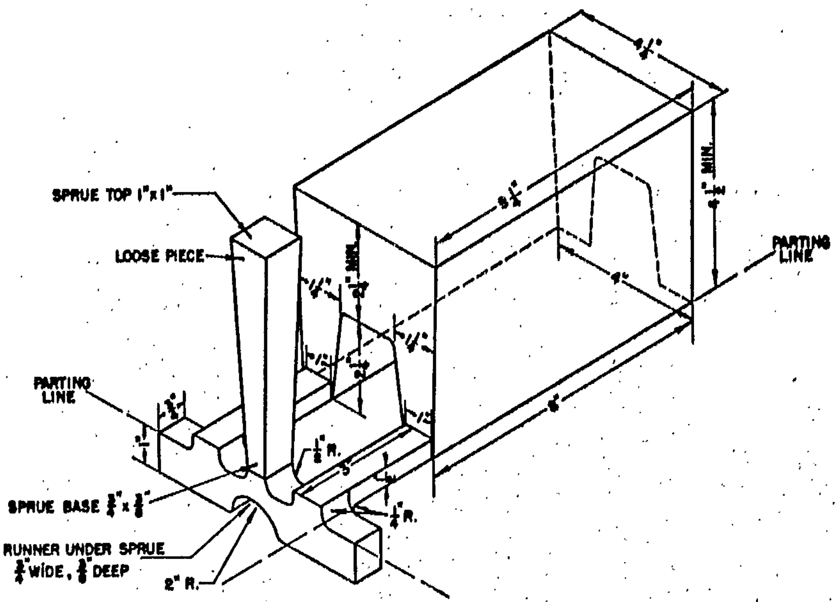
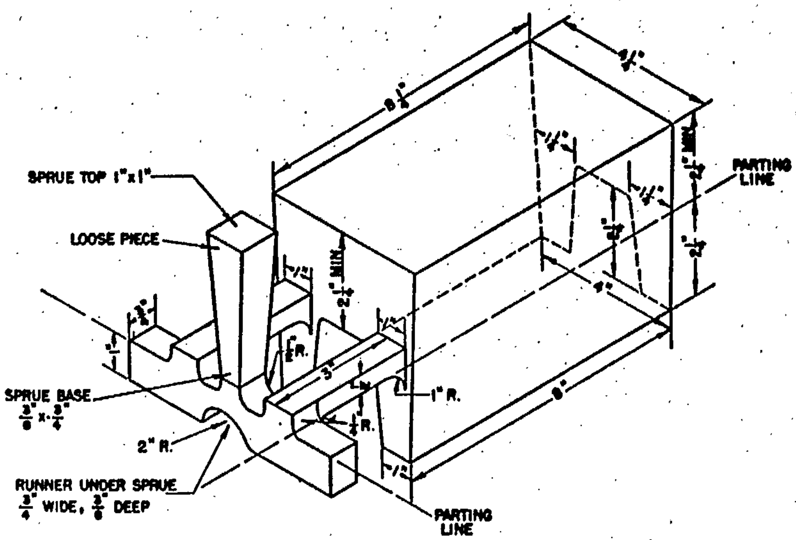


Figure 2. -"Dow" test bar. (CSA HQ1-1963 and US Federal Specification QQ-M-56)



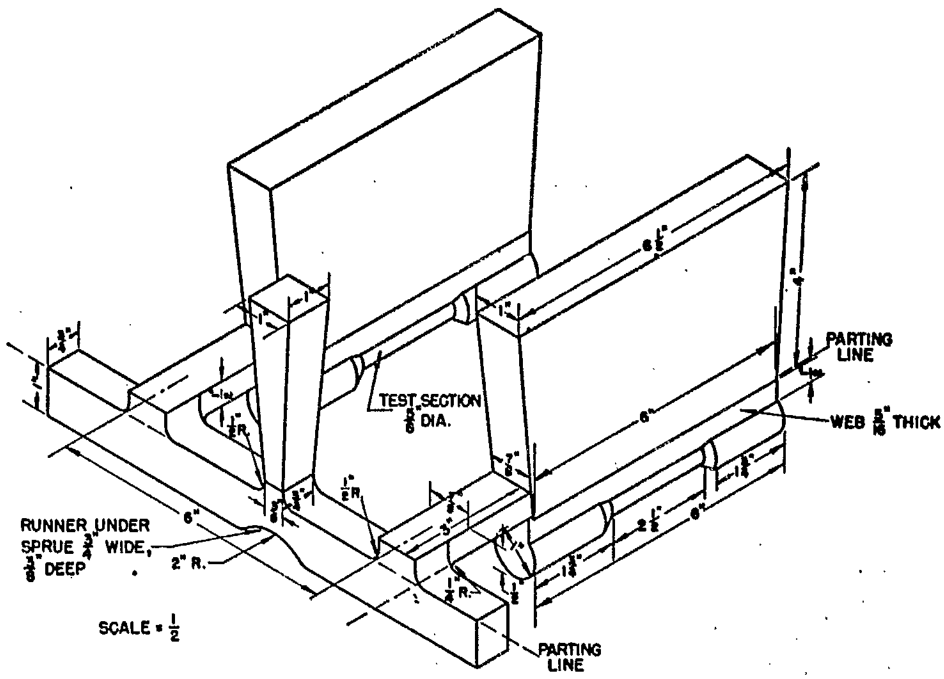
(*a*) Bottom Gating



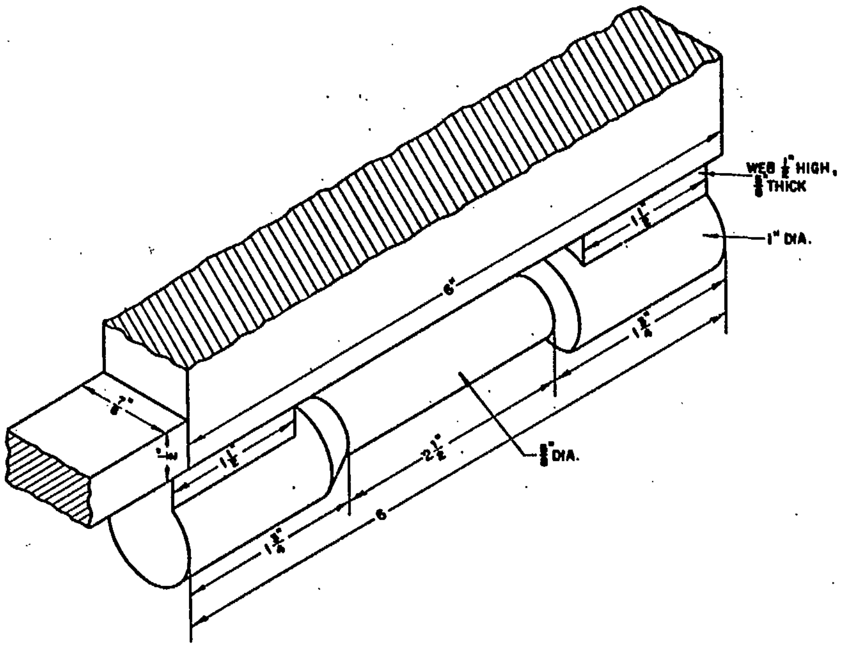
(*b*) Top Gating

NOTE.—Where this type of test bar design is used, bottom gating is recommended for alloys, such as aluminum bronze, where turbulence and oxidation are factors.

Figure 3. - Double keel block test bar. (ASTM B208-58 Figure 1).



-(*a*) Gating Design for Double Vertical Full-Web or Grip-Web Type Bars (Full-Web Bars Being Cast).



(*b*) Design of the Vertical Grip-Web Bar (Gating and Risering System as in (*a*)).

<u>Figure 4.</u> - Double vertical full-web and grip-web type test bars. (ASTM B 208-58 Figure 2).