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We encourage feedback from users of these standards so that suggestions can be incorporated into future versions of this document.

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A Flash Radiograph Standard for Nb-Ti Alloys

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Abstract

A standard which will provide a benchmark for assessing the micro-inhomogeneity of Nb-Ti alloys used in the fabrication of high J_c composite superconductors has been prepared.

Introduction

Some degree of coring is inevitable in Nb-Ti alloys due to the large difference in freezing points of the constituents (T_m(Nb)=2740K, T_m(Ti)=1943K). In addition to chemical variations due to coring, inadequate control of the alloy fabrication process can result in Ti-rich “freckles” and Nb-rich inclusions. It has been shown that a high degree of chemical homogeneity is required in Nb-Ti alloys destined for use in high J_c composites[1]. Alloy for use in such demanding applications as the SSC and RHIC accelerator magnets should ideally have no Nb inclusions, a minimal number of “freckles” and a micro-inhomogeneity level of approximately ±1.5wt.%Ti or better. Development of Nb-Ti alloy for such uses has resulted in a “High Homogeneity” grade for superconductor application. The designation of “High Homogeneity” grade for a given melt of alloy is based on the assessment of x-ray density using a flash radiograph of a ~6.4mm thick section of the billet in comparison to a sample sheet of flash radiographs of acceptable and non-acceptable billets provided by Teledyne Wah Chang Albany, TWCA[2]. Although flash radiography is a purely qualitative technique it is preferred to quantitative methods of chemical homogeneity measurement (such as WDS and EDS electron microprobe) because it is economical and provides a rapid assessment of the entire billet cross-section. Small differences in experimental set-up, however, can result in large differences in the sensitivity of the flash radiograph. The Superconducting Super Collider, SSC, requires the purchase of a very large number (>11,000) of "High Homogeneity" Nb-47wt.%Ti billets for manufacture into the multifilamentary superconducting composite wire used to wind the accelerator magnets. In order that the alloy manufacturers have a reference that allows them to standardize radiography parameters and assess micro-homogeneity, a standard Nb-Ti alloy slice has been developed which may be included in flash radiographs of "High Homogeneity" material.

Description of Standard

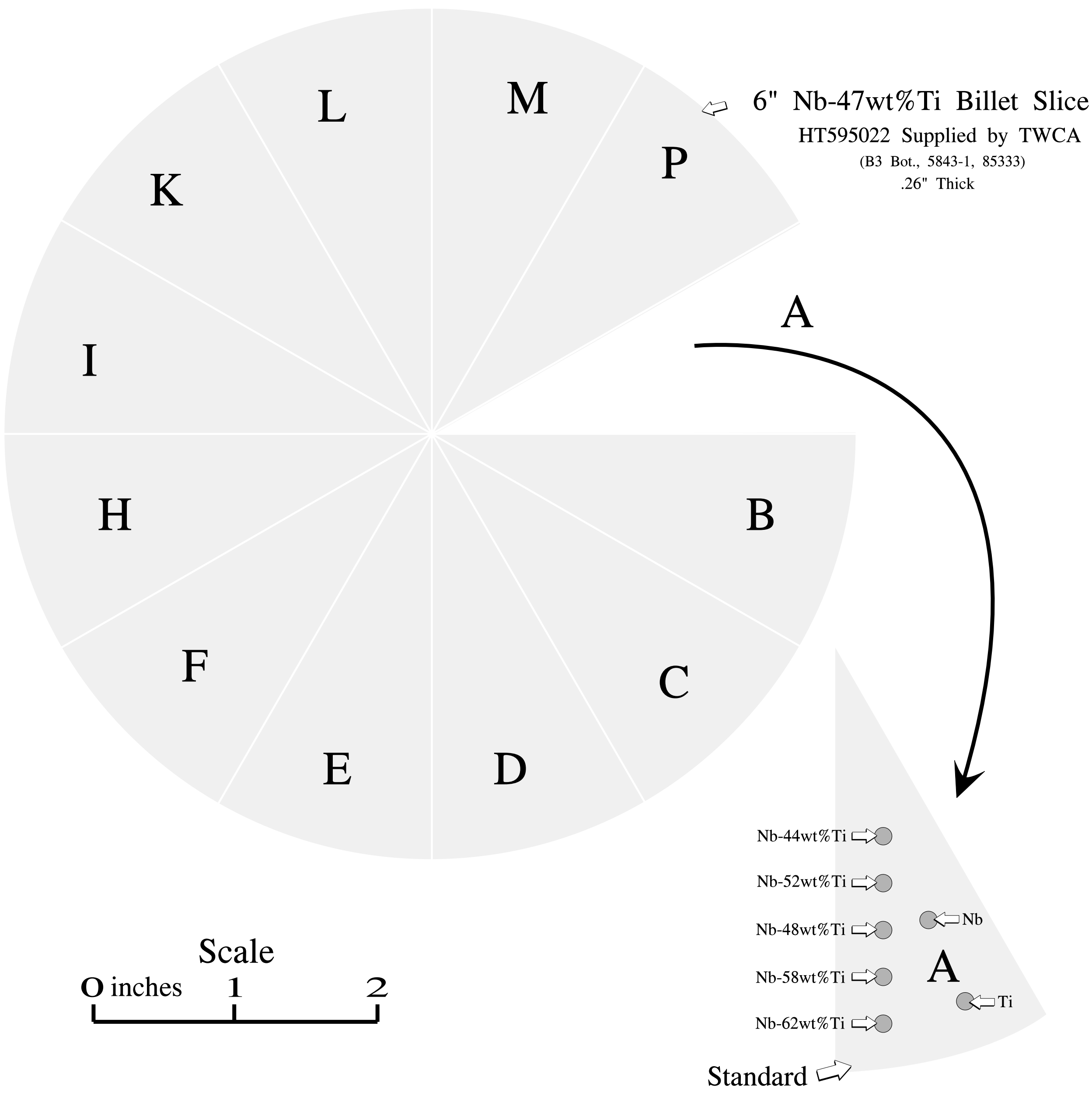

Figure 1 Schematic Illustration of Nb-Ti Flash Radiograph Standards.

A typical "High Homogeneity" billet slice (Nb-46wt.%Ti) was provided by TWCA and was cut into 12 equal "Standard" segments. Into each segment 3mm diameter high homogeneity grade alloy cores of known composition (Table I) varying from Nb-44wt.%Ti to Nb-62wt.%Ti were inserted. In addition to the alloy cores both Nb and Ti samples were introduced into the segments. The arrangement of cores within the standards is illustrated in Figure 1. The front and back faces of the individual standards were subsequently ground to a smooth finish. The final thicknesses of the standards are listed in Table II. Sufficient flash radiographs of the assembled samples (Fig. 2) were taken by TWCA to provide an original flash radiograph with each standard.

Use of Standard

Operators should be familiar with the ASTM Standard Recommended Practice for Radiographic Testing (E94). It is expected that the guidelines for good radiographic practice given in E94 will be followed. It is recommended that a technique log be maintained that contains the information suggested in E94 section 13 (see Table III). The SSC standard is quite different to a penetrameter in that it is designed to be close to 100% of the specimen thickness rather than 2% and rather than using holes the SSC Flash Radiograph uses cores of standard compositions. Thus the contrast range can be more closely controlled to the optimum for the Nb-Ti alloy. The specimen thickness must, however, be as close as possible to that of the standard in order to obtain the maximum benefit. The

Table I Composition of Standard Slice and Inserts

Sample	Slice	Nb-44wt.%Ti	Nb-48wt.%Ti	Nb-52wt.%Ti	Nb-58wt.%Ti	Nb-62wt.%Ti
Wt.%Ti	46.0	43.5	47.8	52.4	57.8	62.3
At.%Ti	62.3	59.9	64.0	68.1	72.7	76.2
Avg. At. Number	29.2	29.6	28.8	28.1	27.2	26.5
Last Anneal Diam.	n.a.	41mm	38mm	41mm	38mm	38mm
ρ(g/cm^3)	6.08*	6.02	6.01*	5.77	5.67	5.52
Element	Impurity Concentration, ppm.					
Al	<25	<25	32	<25	<25	30
C	55	40	70	34	50	60
Cr	<50	<50	<50	<50	<50	<50
Cu	<10	12	<10	<10	45	12
Fe	<50	<50	72	<50	74	92
H	<5	16	20	<5	21	48
N	45	23	40	30	20	8
Ni	<25	<25	<25	<25	<25	<25
O	608	690	570	608	680	620
Si	<100	<100	<100	<100	<100	<100
Sn	-	<40	<40	<40	<40	<40
Ta	980	1310	480	550	540	520

*=extrapolated value

Table II Composition of Standard Slice and Inserts

Standard Section	Standard Thickness, mm				Standard Thickness, inches			
	Outer	Center	Inner	Average	Outer	Center	Inner	Average
A	6.18	6.17	6.11	6.15	0.243	0.243	0.241	0.242
B	6.31	6.28	6.24	6.28	0.248	0.247	0.246	0.247
C	6.17	6.20	6.21	6.19	0.243	0.244	0.244	0.244
D	6.23	6.24	6.25	6.24	0.245	0.246	0.246	0.246
E	6.27	6.28	6.27	6.27	0.247	0.247	0.247	0.247
F	6.15	6.14	6.13	6.14	0.242	0.242	0.241	0.242
H	6.24	6.25	6.25	6.25	0.246	0.246	0.246	0.246
I	6.20	6.21	6.21	6.21	0.244	0.244	0.244	0.244
K	6.18	6.20	6.23	6.20	0.243	0.244	0.245	0.244
L	6.12	6.16	6.20	6.16	0.241	0.243	0.244	0.243
M	6.21	6.23	6.23	6.22	0.244	0.245	0.245	0.245
P	6.25	6.24	6.23	6.24	0.246	0.246	0.245	0.246
Average	6.21	6.22	6.21	6.21	0.244	0.245	0.245	0.245
Std. Dev.	0.05	0.04	0.05	0.05	0.002	0.002	0.002	0.002

thickness of the sample should be measured at a minimum of three equally spaced positions around the slice and recorded on or with the film. If the standard is much thicker than that normally used by the alloy manufacturer the standard could be machined to match the standard slice thickness used. The advantage of this would be to allow easy comparison with older samples without re-grinding each one. The relative intensities provided by the different alloy compositions within the standard should still be valid. The primary disadvantage will be that this is an irreversible step for the standard and there is a limited number of these standards.

Flash radiographic facilities normally allow for the simultaneous image taking of two adjacent 15cm billet sections with the point x-ray source centrally located above and between the specimens. It is proposed that for consistency the standard is positioned either between the billets (i.e. directly under the x-ray source) or as close to the center-point as possible while still positioned so that it's image appears on the same film as the alloy in question.

Acknowledgments

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References

1 D. C. Larbalestier, A. W. West, W. Starch, W. H. Warnes, P. J. Lee, W. K. McDonald, P. O'Larey, K. C. Hemachalam, B. A. Zeitlin, R. M. Scanlan and C. E. Taylor, "High critical current densities in industrial scale composites made from high homogeneity Nb46.5Ti," IEEE Trans. MAG-21, 269, 1985.

2 Standards for Homogenized Nb-Ti Alloys, published by Teledyne Wah Chang-Albany, Albany Oregon, U.S.A, 1984.

Table III A Sample Technique Log for SSC Billet Flash Radiographs

ASTM E94 Reference	Description	Comment
13.2.1*	Billet I. D.	
13.2.2*	Average Slice Thickness	
13.2.3	Source or focus-film distance	
13.2.4	Film type	
13.2.5	Film density	
13.2.6	Screen type and thickness	
13.2.7	Isotope or X-ray machine identification	
13.2.8	Curie or milliampere minutes	
N.A.	Standard identification	
13.2.11*	Standard thickness	
13.2.12	Special masks or filters	
13.2.13	Collimator of field limitation device	

* = equivalent to

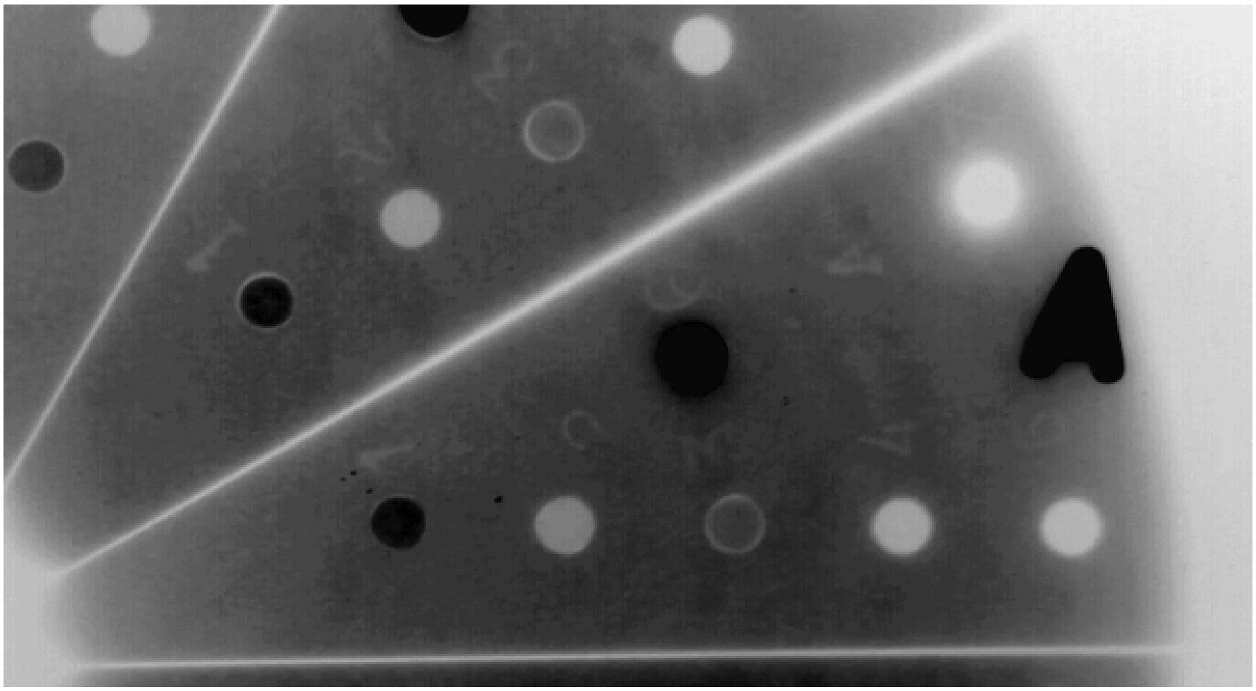

Figure 2 Photo-Positive of Flash-Radiograph of Nb-Ti Flash-Radiograph Standards