ELECTRIC POWER RESEARCH INSTITUTE

Alloy 690 Metallurgical Characterization

EPRI/MRP Mitigation & Testing ITG
November 10-11, 2008

Eric Willis
Sr. Project Manager WRTC

Alloy 690 Metallurgical Characterization

- Banding has been shown to significantly increase the CGR in Alloy 690
- Banding can be defined as:
  - Inhomogenities in grain size and MC carbide distribution
  - Large variation in grain boundary carbide decoration, stringers or sheets of oxide, and carbo-nitride inclusions
- Survey to determine if banding structures are present in Alloy 690 material product forms used for fabrication of CRDM penetrations
- Banding in other Alloy 690 product forms (plates and billets) is being examined
- This is work-in-progress
  - 9 samples have been examined with optical microscopy
  - Quantitative metallography is being used to quantify degree of banding in each heat of Alloy 690
  - Additional samples of Alloy 690 are being obtained
    - Extrusions
    - Billets

© 2008 Electric Power Research Institute, Inc. All rights reserved.

Alloy 690 Sample Set

Sample No.	Application	Heat No.	Form & Size (in.)	Melting Practice	Primary Hot Working	Annealing	TT
1	CRDM at Oconee NPP	WIN 415	4.3 OD x 2.3 ID pipe	Electric Arc + ESR	Forged Extruded	1100C	720C for 10hrs
2	CRDM in Westinghouse replacement heads	D272007-A01-2	4.41 OD x 2.33 ID pipe	AOD or VOD	Extruded	1075C for 30 min Water quenched	700C for 15hrs
3	CRDM in Westinghouse replacement heads	D272007-A02-1	4.41 OD x 2.33 ID pipe	AOD or VOD	Extruded	1075C for 30 min Water quenched	700C for 15hrs
4	Production heat	NX8244 HK11	1 x 4 x 5”Plate	Not listed in CMTR	Hot rolled	982C/1hr A.C.	727C
5	Production heat	X58K-3/ 75176-A	6.8 OD. billet	VIM+ ESR	Press + rotary forge	1029C/4 hr Water quenched	727C for 5hr
6	Production heat	NX8244 HK14	Billet slice half moon	Not listed in CMTR	Commercially forged	1025C/1hr A.C.	727C

© 2008 Electric Power Research Institute, Inc. All rights reserved.

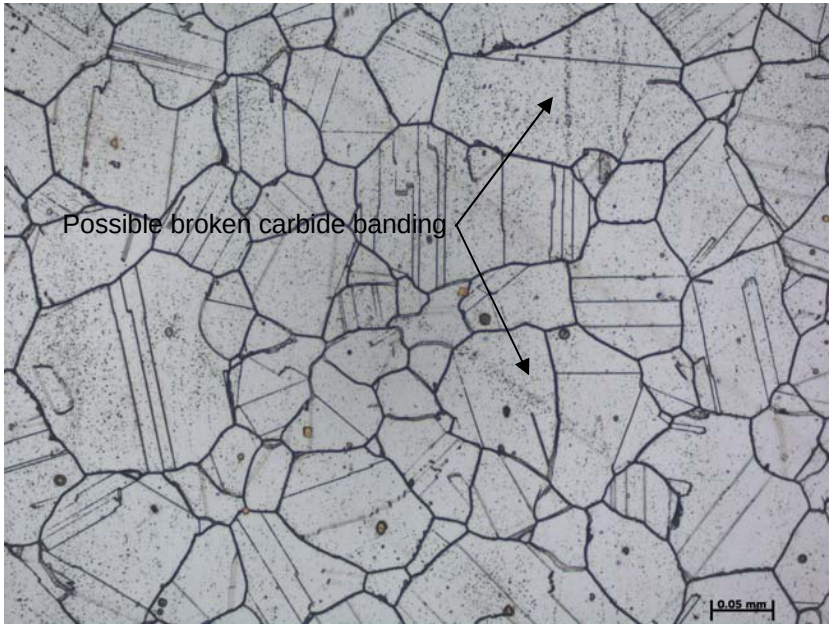
Alloy 690 Sample Set

Sample No.	Application	Heat No.	Form & Size (in.)	Melting Practice	Primary Hot Working	Annealing	TT
7	Production heat	NX8541HK131	Rod 3ft long ¾in diameter		Forged		
8	CEDM from Calvert Cliff NPP	RE242	4-1/4”OD X 2-1/6ID (107.5 mm OD. X 52.39 ID.)	Electric Arc Furnace +ESR	Forged Extruded	1140C quenched	716C for 10hrs
9	CRDM material supplied for to EPRI for Research	WQ 787		Electric Arc Furnace +ESR	Forged Extruded	1040/1060C	715C for 6hrs Air cooled

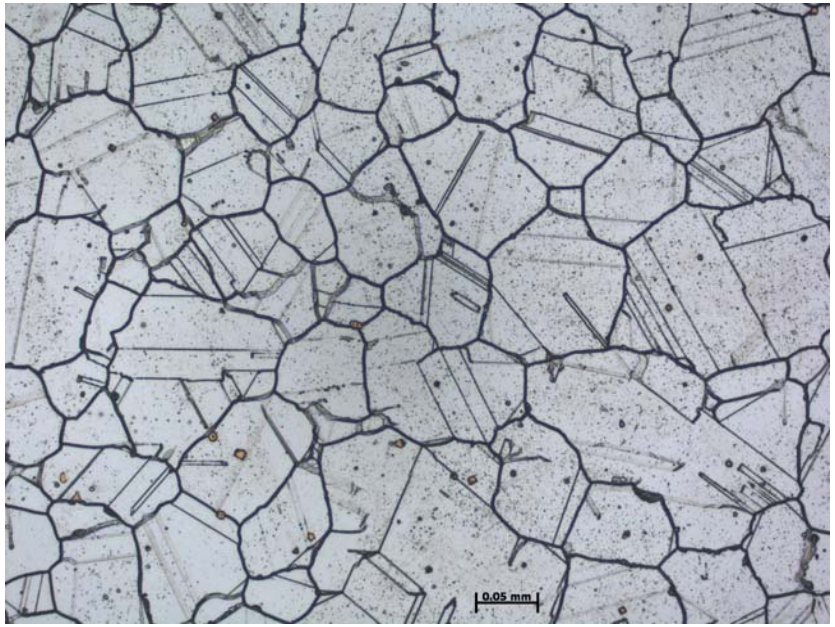
© 2008 Electric Power Research Institute, Inc. All rights reserved.

Alloy 690 Microstructure Sample 1 (Extrusion)

Aubert & Duval, Alloy 690 (Heat WIN 415)



Longitudinal direction



Transverse direction

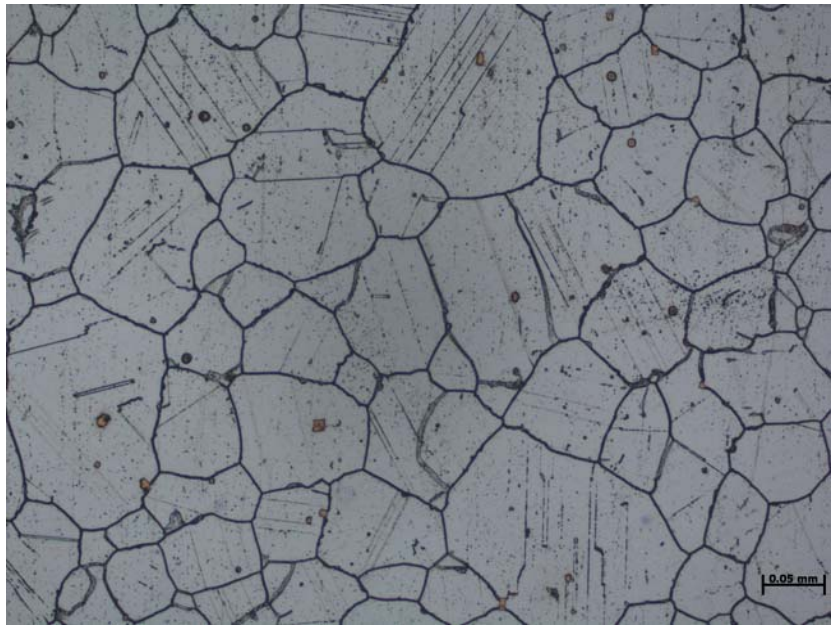
Magnification 200X, Electrolytic nital

© 2008 Electric Power Research Institute, Inc. All rights reserved.

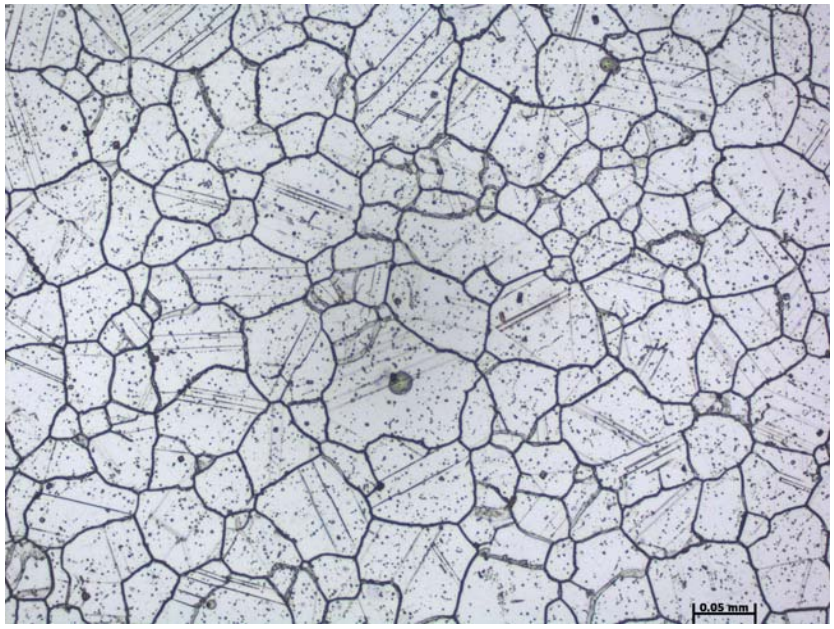
ELECTRIC POWER RESEARCH INSTITUTE

Alloy 690 Microstructure Sample 2 (Extrusion)

Sumitomo, Alloy 690 (Heat D272007-A01-2),



Longitudinal direction



Transverse direction

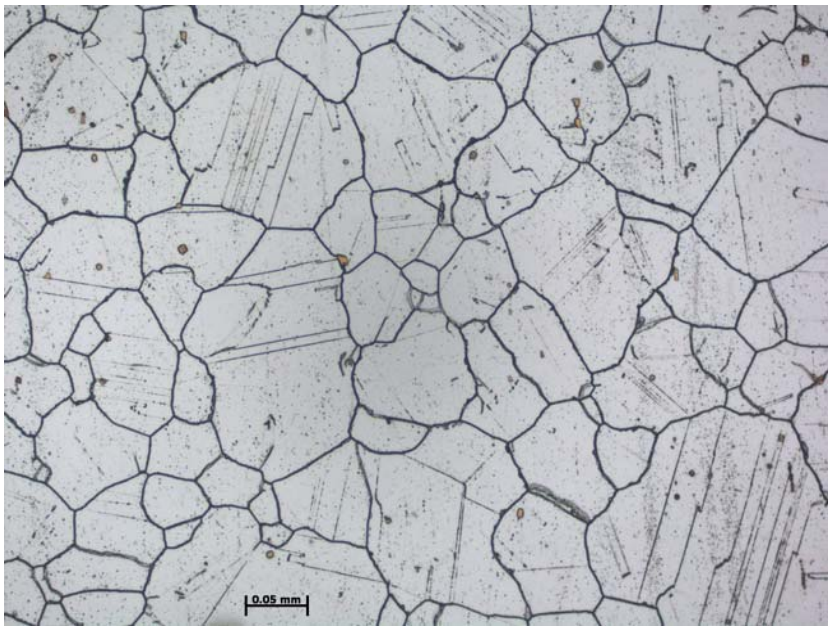
Magnification 200X, Electrolytic nital

© 2008 Electric Power Research Institute, Inc. All rights reserved.

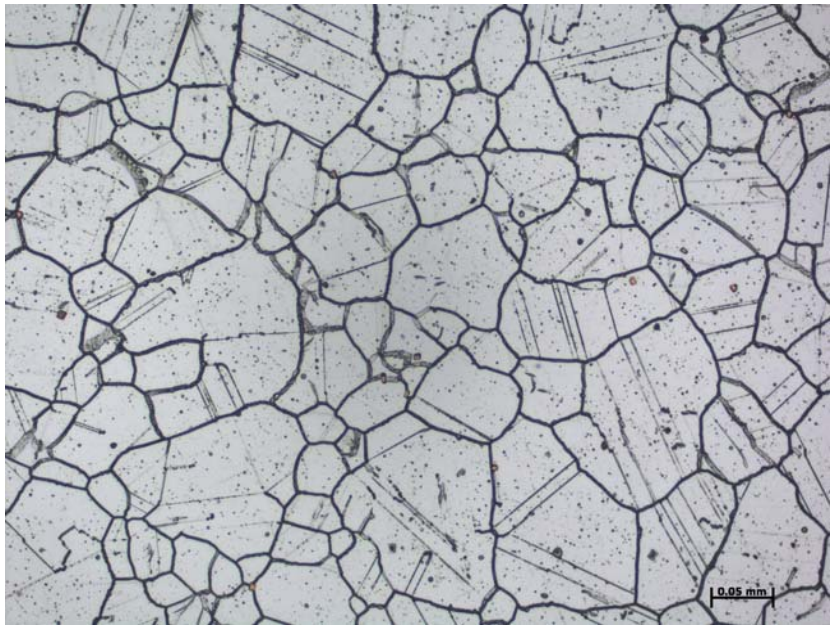
ELECTRIC POWER RESEARCH INSTITUTE

Alloy 690 Microstructure Sample 3 (Extrusion)

Sumitomo, Alloy 690 (Heat D272007-A02-1),



Longitudinal direction



Transverse direction

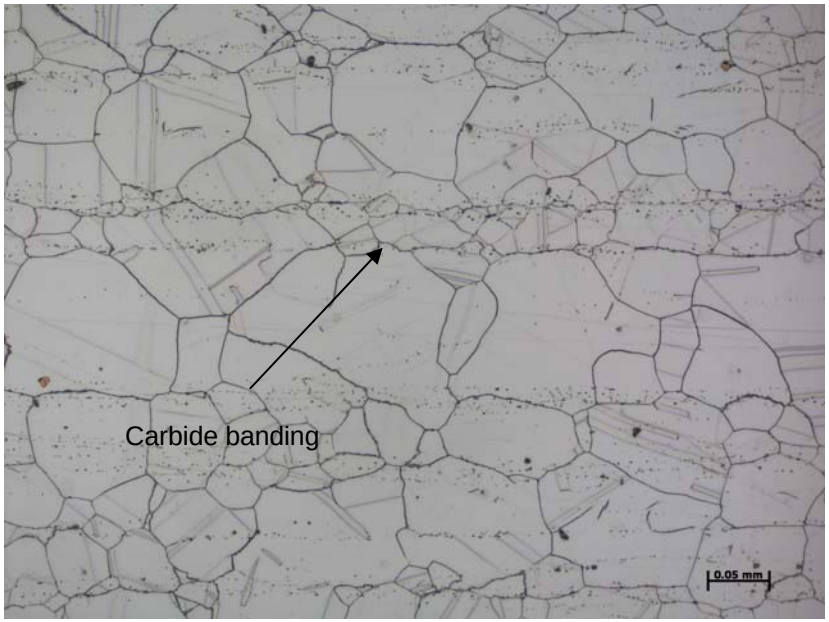
Magnification 200X, Electrolytic nital

© 2008 Electric Power Research Institute, Inc. All rights reserved.

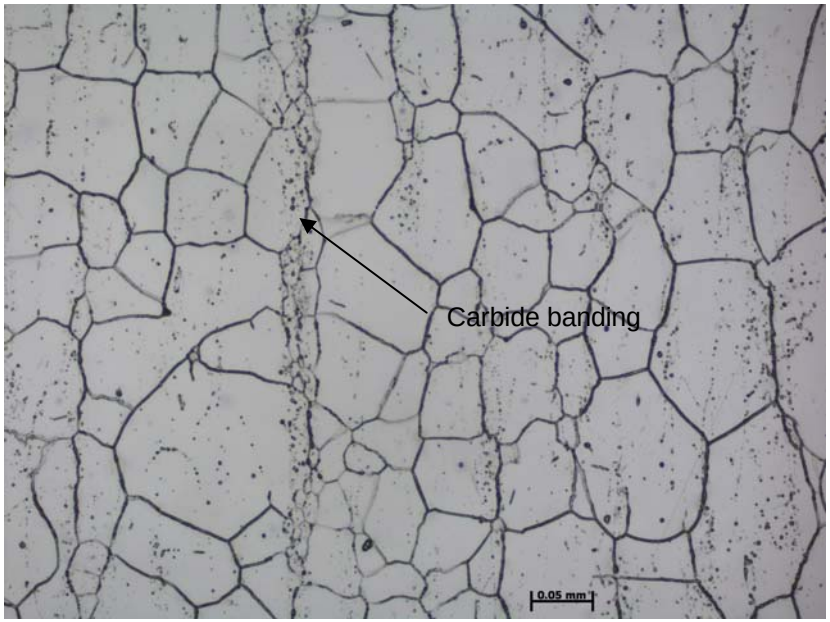
ELECTRIC POWER RESEARCH INSTITUTE

Alloy 690 Microstructure Sample 4 (1in. (t) Plate)

Special Metals, Alloy 690 (Heat NX8244 HK11),



Longitudinal direction



Transverse direction

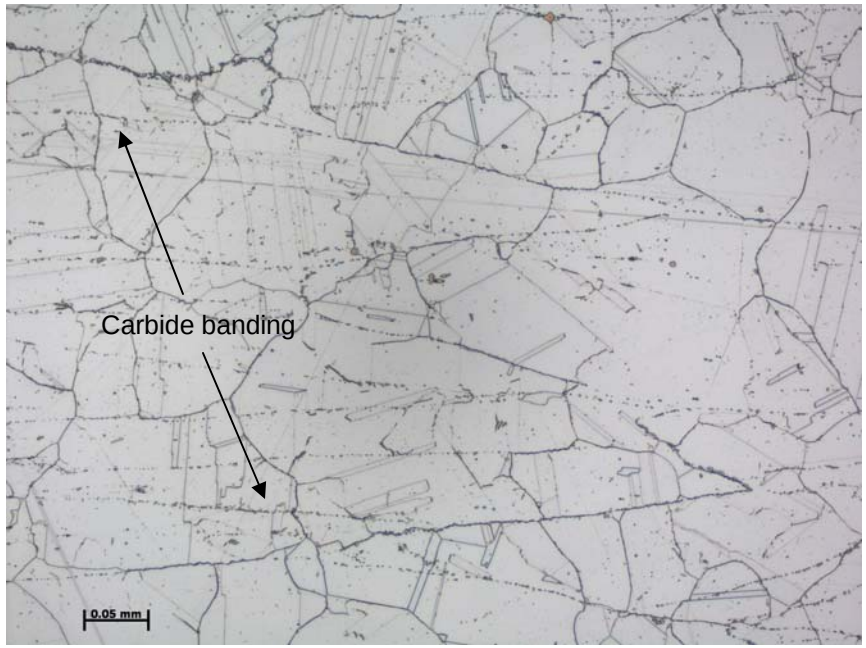
Magnification 200X, Electrolytic nital

© 2008 Electric Power Research Institute, Inc. All rights reserved.

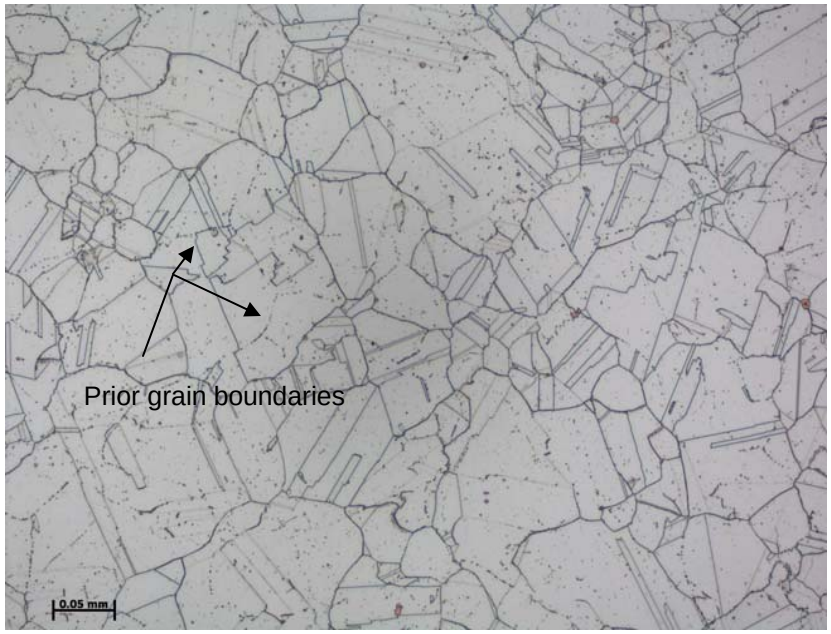
ELECTRIC POWER RESEARCH INSTITUTE

Alloy 690 Microstructure Sample 5 (6.7 in. dia. Billet)

Allvac, Alloy 690 (Heat X58K-3/75176-A B5-B-3),



Longitudinal direction



Transverse direction

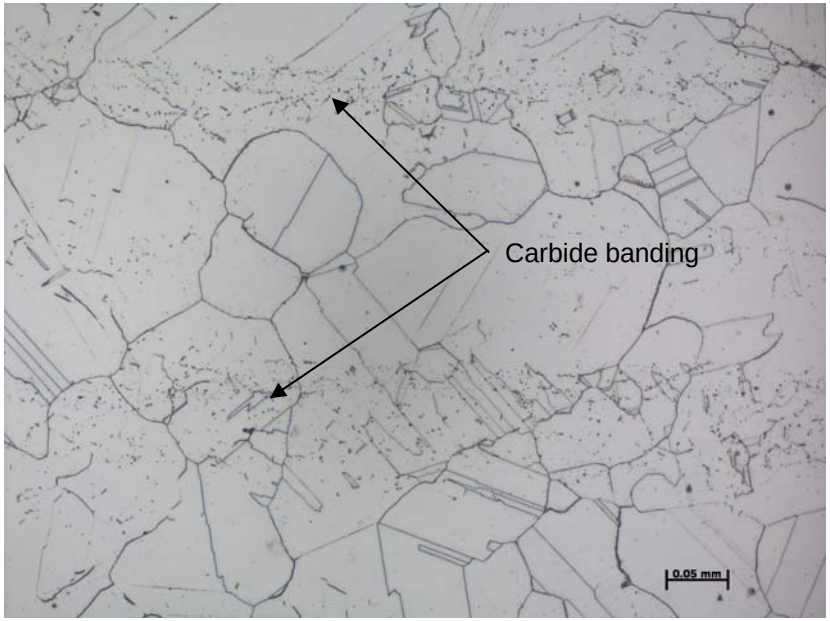
Magnification 200X, Electrolytic nital

© 2008 Electric Power Research Institute, Inc. All rights reserved.

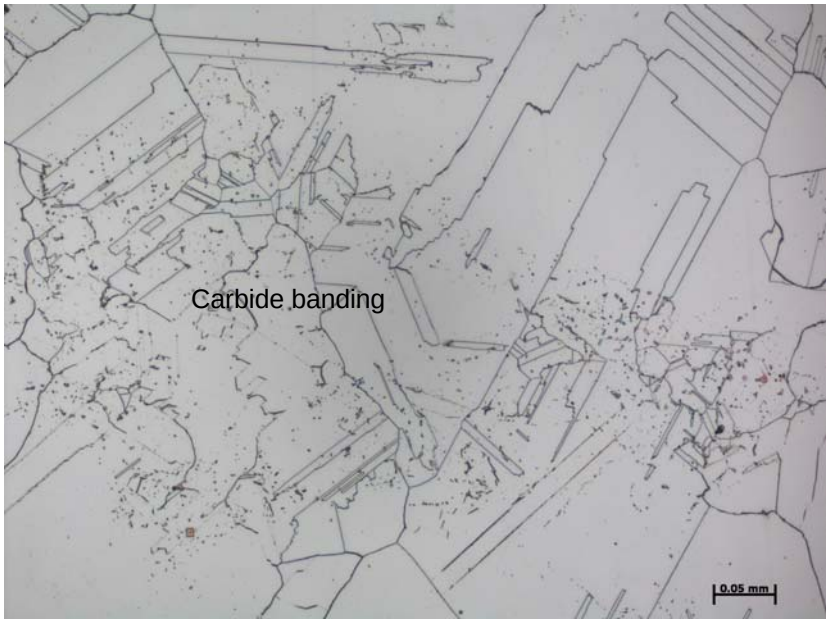
ELECTRIC POWER RESEARCH INSTITUTE

Alloy 690 Microstructure Sample 6 (8 in. dia. Billet)

Special Metals, Alloy 690 (Heat NX8244 HK14),



Longitudinal direction



Transverse direction

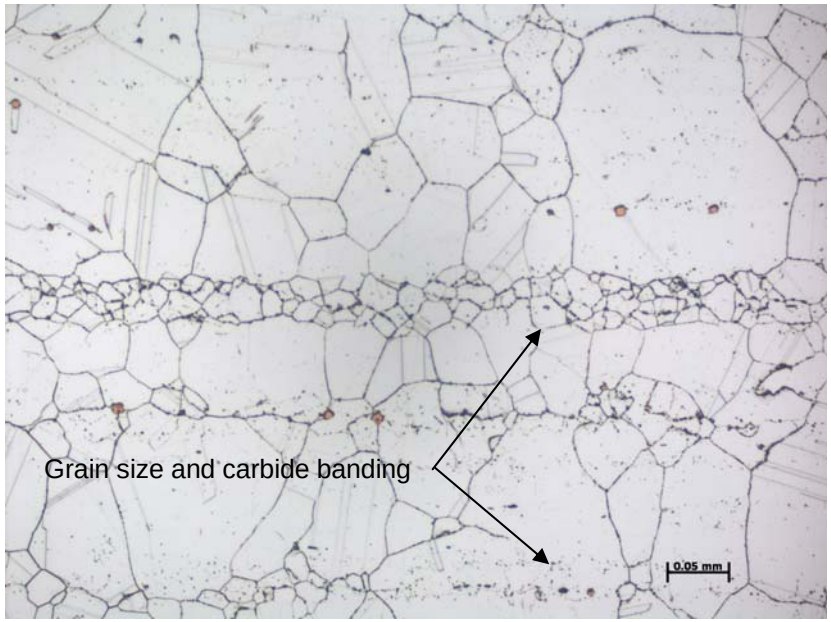
Magnification 200X, Electrolytic nital

© 2008 Electric Power Research Institute, Inc. All rights reserved.

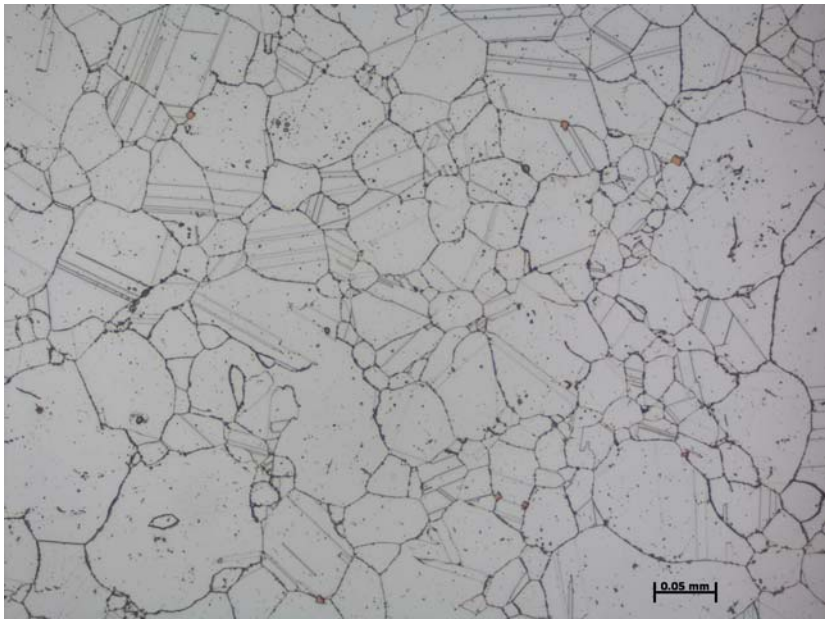
ELECTRIC POWER RESEARCH INSTITUTE

Alloy 690 Microstructure Sample 7 (¾” dia. Rod)

Special Metals, Alloy 690 (Heat NX8541 HK131),



Longitudinal direction



Transverse direction

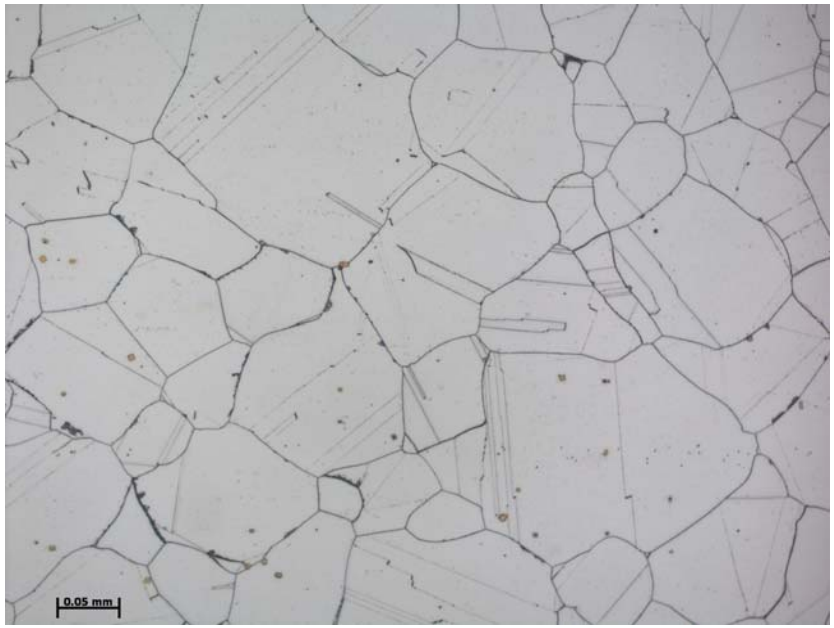
Magnification 200X, Electrolytic nital

© 2008 Electric Power Research Institute, Inc. All rights reserved.

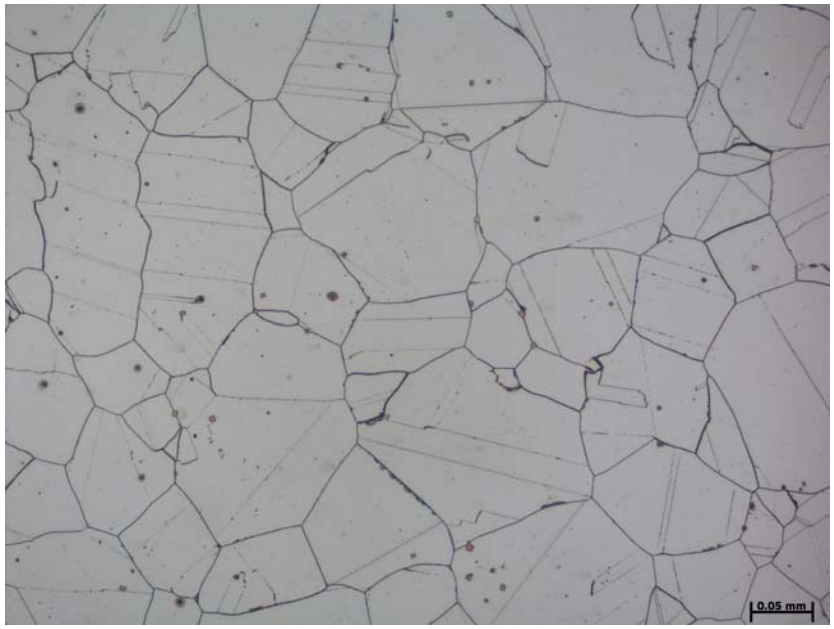
ELECTRIC POWER RESEARCH INSTITUTE

Alloy 690 Microstructure Sample 8 (Extrusion)

Valinox, Alloy 690 (Heat RE242),



Longitudinal direction



Transverse direction

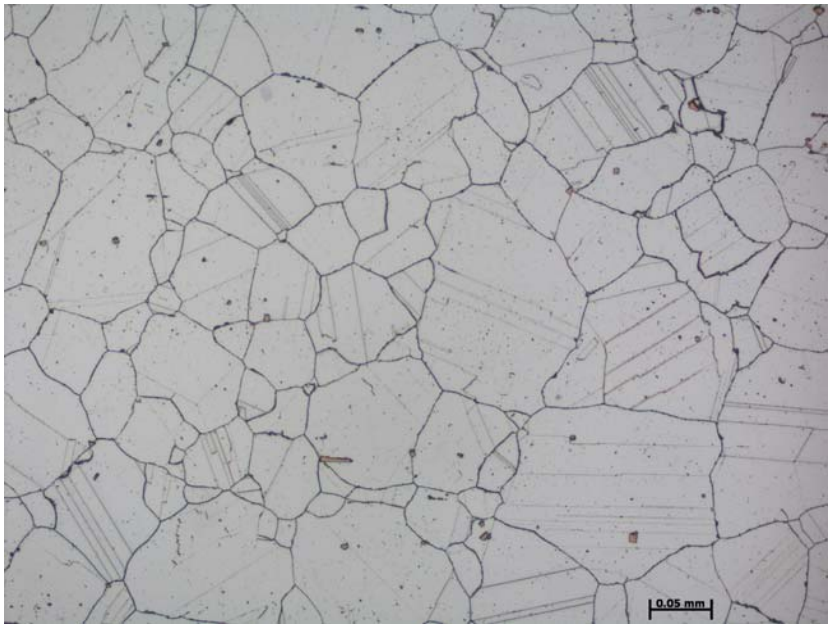
Magnification 200X, Electrolytic nital

© 2008 Electric Power Research Institute, Inc. All rights reserved.

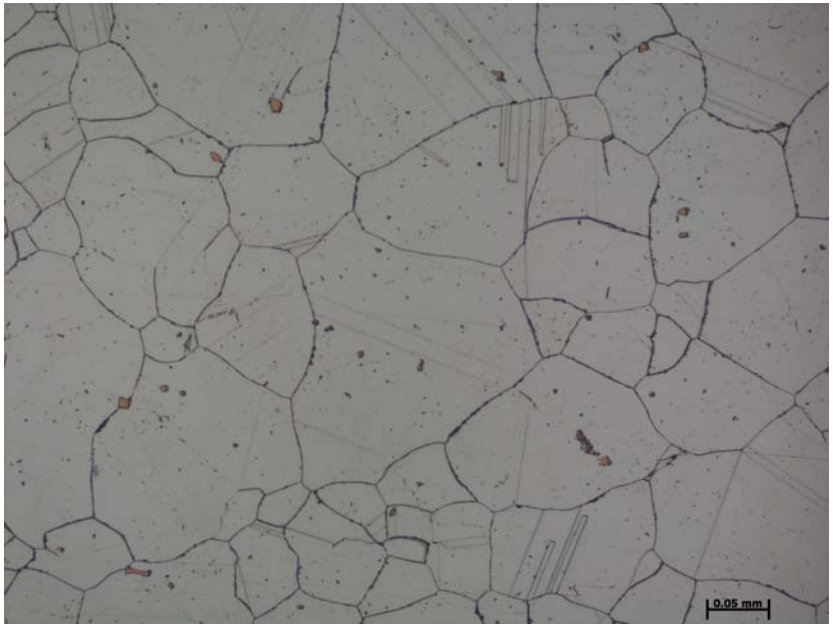
ELECTRIC POWER RESEARCH INSTITUTE

Alloy 690 Microstructure Sample 9 (Extrusion)

Valinox, Alloy 690 (Heat WQ 787),



Longitudinal direction



Transverse direction

Magnification 200X, Electrolytic nital

© 2008 Electric Power Research Institute, Inc. All rights reserved.

ELECTRIC POWER RESEARCH INSTITUTE

Preliminary Conclusions

- Additional Phases found in the Alloy 690
  - $M_{23}C_6$
  - Ti[C,N]
- Inclusions identified
  - TiN
  - MgO encapsulated with TiN
- Preliminary examination showed no banded structures in the 5 heats of extruded Alloy 690 material
- Preliminary examination showed that banded structures were present in 4 heats of Alloy 690 in the following product form
  - 2-Billets,
  - 1-Plate
  - 1-Rod
- Extrusions for CRDMs are typically produced from sections of billets and it appears that the extrusion process may break up the banded structures if present, but additional investigation is required to confirm this theory

© 2008 Electric Power Research Institute, Inc. All rights reserved.

Future Work

- Four additional heats of Alloy 690 extruded tubing are being shipped to EPRI for examination
- Effort is being made to obtain additional billet stock used to fabricate CRDM extrusions
  - This will be used to determine the effect of the extrusion process on banding that may be present in the billet product form.
- The entire sample set will be examined using quantitative image analysis to quantify the level of banding in heat of Alloy 690

© 2008 Electric Power Research Institute, Inc. All rights reserved.