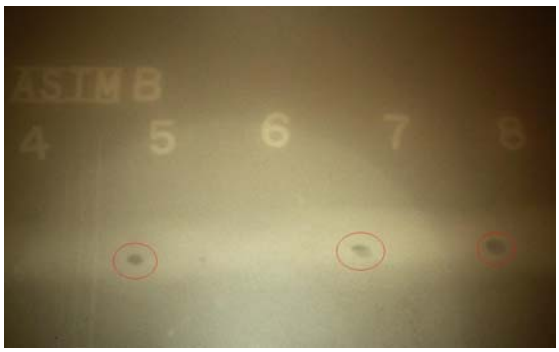
Appendix A
Photographs

Appendix A- Photographs

No. 1- Aluminum bronze pipe test section CH-7. White marks at right indicate bands of ultrasonic thickness test points.

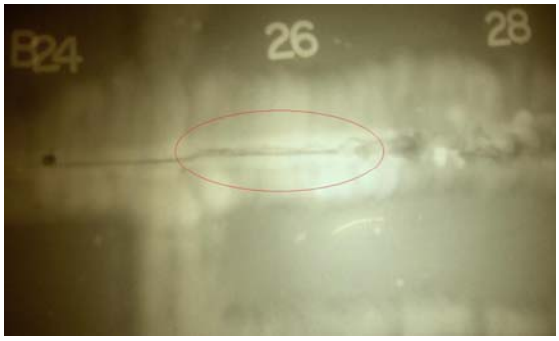
No. 2- Radiography test equipment. Metal box at center is housing for source which is deployed using yellow cable. Film and tape with lead reference numbers are at photo right, Geiger counter at left.



No. 3- Portion of radiograph of weld at CH-10 L1. Dark spots (circled) show porosity.

No. 4- Portion of radiograph of weld at CH-9 C1. Dark spots in a line (circled) indicate incomplete penetration.

No. 5- Portion of radiograph of weld at CH-33B L1. Dark spots in a line (circled) indicate lack of fusion.



No. 6- Portion of radiograph of weld at CH-18 C3, view 20-34. Dark line (circled) is a crack in the weld.

No. 7- Shear-wave ultrasonic testing. The weld is coated with gel couplant and ultrasonic transducers on angled blocks are moved over it. Image on instrument is interpreted by technicians to indicate presence or absence of defects.

No. 8- Seeping leak at repair weld in aluminum bronze pipe in Desalting Building.

No. 9- Seeping leak at original weld in aluminum bronze pipe in Desalting Building.

No. 11- Unwelded joint in the 72-inch header pipe at the Intake Pumping Station. This location was found covered with silt, suggesting that groundwater leaked into the pipe through this joint.

No. 10- Typical cracked circumferential weld in 72-inch header at Intake Pumping Station. The crack is the vertical line from above the ruler. This crack is in the weld between pipe piece nos. 2 and 3.

No. 12- Cracked weld in 54-inch pipe at Wye Vault at the MODE. Crack is the dark vertical line at the tip of the pen. Blue-green copper corrosion products covered the crack.

No. 13- Interior of 30-inch Hydranautics Feed pipe at location CH-19. Blue-green corrosion products are evident below the water line on the longitudinal weld (foreground) and on the circumferential weld (center).

No. 15- Close view of repair weld found under mound of corrosion products in foreground of Photo No. 13. This location is on along the longitudinal weld at the bottom of the pipe.

No. 14- Corrosion pitting on welds in bottom pipe shown in Photo No. 13. Pit at right has been cleaned to show reddish copper color from dealloying. Mound of blue-green corrosion product at left is underlain with the same type of pit.

Appendix B
Summary of Ultrasonic Thickness Gauging of Pipe Wall

Table B-1 - Summary of Ultrasonic Thickness Gauging of Pipe Wall
YDP Aluminum Bronze Pipe

Record Drawing			Pipe Wall Thickness												
CH No.	Pipe Dia	Nominal Required Wall Thickness	Position	Band No.1	Band No. 2	Notes	Band 1 Diff from Ave	Band 2 Diff from Ave	Diff between bands	Band 1 Pass or Fail	Band 2 Pass or Fail	Band 1 Diff from Min	Band 1 Diff from Max	Band 2 Diff from Min	Band 2 Diff from Max
1	30	0.375	A	388	380		1.83	-2.25	0.008	pass	pass				
			B	390	381		3.83	-1.25	0.009	pass	pass				
			C	387	383		0.83	0.75	0.004	pass	pass				
			D	391	383		4.83	0.75	0.008	pass	pass				
			E	387	381		0.83	-1.25	0.006	pass	pass				
			F	380	388		-6.17	5.75	0.008	pass	pass				
		Min	G	387	389		0.83	6.75	0.002	pass	pass				
		0.352	H	385	382		-1.17	-0.25	0.003	pass	pass				
		Max	I	385	380		-1.17	-2.25	0.005	pass	pass				
		0.398	J	386	379		-0.17	-3.25	0.007	pass	pass				
			K	382	381		-4.17	-1.25	0.001	pass	pass				
			L	386	380		-0.17	-2.25	0.006	pass	pass				
2	18	0.4375	A	435	415		0.38	-0.38	0.02	pass	pass				
			B	436	414		1.38	-1.38	0.022	pass	fail			-0.0005	
			C	434	416		-0.63	0.63	0.018	pass	pass				
		Min	D	432	415		-2.63	-0.38	0.017	pass	pass				
		0.4145	E	433	414		-1.63	-1.38	0.019	pass	fail			-0.0005	
		Max	F	435	417		0.38	1.63	0.018	pass	pass				
		0.4605	G	436	416		1.38	0.63	0.02	pass	pass				
			H	436	416		1.38	0.63	0.02	pass	pass				
3	24	0.375	A	303	n/a		-7.63			fail		-0.049		n/a	n/a
			B	327	n/a		16.38			fail		-0.025		n/a	n/a
			C	317	n/a		6.38			fail		-0.035		n/a	n/a
		Min	D	311	n/a		0.38			fail		-0.041		n/a	n/a
		0.352	E	309	n/a		-1.63			fail		-0.043		n/a	n/a
		Max	F	307	n/a		-3.63			fail		-0.045		n/a	n/a
		0.398	G	306	n/a		-4.63			fail		-0.046		n/a	n/a
			H	305	n/a		-5.63			fail		-0.047		n/a	n/a

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YDP Aluminum Bronze Pipe

Record Drawing			Pipe Wall Thickness												
CH No.	Pipe Dia	Nominal Required Wall Thickness	Position	Band No.1	Band No. 2	Notes	Band 1 Diff from Ave	Band 2 Diff from Ave	Diff between bands	Band 1 Pass or Fail	Band 2 Pass or Fail	Band 1 Diff from Min	Band 1 Diff from Max	Band 2 Diff from Min	Band 2 Diff from Max
4	48	0.75	A	750	738		4.58	-5.33	0.012	pass	pass				
			B	744	745		-1.42	1.67	0.001	pass	pass				
			C	743	744		-2.42	0.67	0.001	pass	pass				
			D	744	746		-1.42	2.67	0.002	pass	pass				
			E	749	739		3.58	-4.33	0.01	pass	pass				
			F	749	736		3.58	-7.33	0.013	pass	pass				
		Min	G	739	738		-6.42	-5.33	0.001	pass	pass				
		0.721	H	739	741		-6.42	-2.33	0.002	pass	pass				
		Max	I	743	745		-2.42	1.67	0.002	pass	pass				
		0.779	J	746	750		0.58	6.67	0.004	pass	pass				
			K	750	749		4.58	5.67	0.001	pass	pass				
			L	749	749		3.58	5.67	0	pass	pass				
5	12	0.3125	A	417	425		8.75	25.25	0.008	pass	pass		0.0815		0.0895
			B	411	387		2.75	-12.75	0.024	pass	pass		0.0755		0.0515
			C	409	439		0.75	39.25	0.03	pass	pass		0.0735		0.1035
			D	407	403		-1.25	3.25	0.004	pass	pass		0.0715		0.0675
		Min	E	403	381		-5.25	-18.75	0.022	pass	pass		0.0675		0.0455
		0.2895	F	405	383		-3.25	-16.75	0.022	pass	pass		0.0695		0.0475
		Max	G	407	388		-1.25	-11.75	0.019	pass	pass		0.0715		0.0525
		0.3355	H	407	392		-1.25	-7.75	0.015	pass	pass		0.0715		0.0565
6	18	0.4375	A	418	421		-0.50	-0.63	0.003	pass	pass				
			B	421	422		2.50	0.38	0.001	pass	pass				
			C	416	419		-2.50	-2.63	0.003	pass	pass				
		Min	D	416	423		-2.50	1.38	0.007	pass	pass				
		0.4145	E	419	426		0.50	4.38	0.007	pass	pass				
		Max	F	420	420		1.50	-1.63	0	pass	pass				
		0.4605	G	418	421		-0.50	-0.63	0.003	pass	pass				
			H	420	421		1.50	-0.63	0.001	pass	pass				

Table B-1 - Summary of Ultrasonic Thickness Gauging of Pipe Wall
YDP Aluminum Bronze Pipe

Record Drawing			Pipe Wall Thickness												
CH No.	Pipe Dia	Nominal Required Wall Thickness	Position	Band No.1	Band No. 2	Notes	Band 1 Diff from Ave	Band 2 Diff from Ave	Diff between bands	Band 1 Pass or Fail	Band 2 Pass or Fail	Band 1 Diff from Min	Band 1 Diff from Max	Band 2 Diff from Min	Band 2 Diff from Max
7	18	0.4375	A	435	602		1.75	1.63		pass	pass				0.1415
			B	436	603		2.75	2.63		pass	pass				0.1425
			C	436	601		2.75	0.63		pass	pass				0.1405
			D	432	599		-1.25	-1.38		pass	pass				0.1385
		Min	E	429	598		-4.25	-2.38		pass	pass				0.1375
		0.4145	F	431	600		-2.25	-0.38		pass	pass				0.1395
		Max	G	432	599		-1.25	-1.38		pass	pass				0.1385
		0.4605	H	435	601		1.75	0.63		pass	pass				0.1405
8	20	0.4375	A	432	392		1.75	4.25	0.04	pass	fail			-0.0225	
			B	431	387		0.75	-0.75	0.044	pass	fail			-0.0275	
			C	429	388		-1.25	0.25	0.041	pass	fail			-0.0265	
		Min	D	430	385		-0.25	-2.75	0.045	pass	fail			-0.0295	
		0.4145	E	429	386		-1.25	-1.75	0.043	pass	fail			-0.0285	
		Max	F	431	387		0.75	-0.75	0.044	pass	fail			-0.0275	
		0.4605	G	430	387		-0.25	-0.75	0.043	pass	fail			-0.0275	
			H	430	390		-0.25	2.25	0.04	pass	fail			-0.0245	
9	18	0.3125	A	290	300		-0.08	1.83	0.01	pass	pass				
			B	290	298		-0.08	-0.17	0.008	pass	pass				
			C	291	299		0.92	0.83	0.008	pass	pass				
			D	290	298		-0.08	-0.17	0.008	pass	pass				
			E	291	300		0.92	1.83	0.009	pass	pass				
			F	289	299		-1.08	0.83	0.01	fail	pass	-0.0005			
		Min	G	289	296		-1.08	-2.17	0.007	fail	pass	-0.0005			
		0.2895	H	290	298		-0.08	-0.17	0.008	pass	pass				
		Max	I	290	290		-0.08	-8.17	0	pass	pass				
		0.3355	J	289	299		-1.08	0.83	0.01	fail	pass	-0.0005			
			K	291	300		0.92	1.83	0.009	pass	pass				
			L	291	301		0.92	2.83	0.01	pass	pass				
10															

Table B-1 - Summary of Ultrasonic Thickness Gauging of Pipe Wall
YDP Aluminum Bronze Pipe

Record Drawing			Pipe Wall Thickness												
CH No.	Pipe Dia	Nominal Required Wall Thickness	Position	Band No.1	Band No. 2	Notes	Band 1 Diff from Ave	Band 2 Diff from Ave	Diff between bands	Band 1 Pass or Fail	Band 2 Pass or Fail	Band 1 Diff from Min	Band 1 Diff from Max	Band 2 Diff from Min	Band 2 Diff from Max
11	30	0.4375	A	410	410		-1.08	4.25	0	fail	fail	-0.0045		-0.0045	
			B	413	404		1.92	-1.75	0.009	fail	fail	-0.0015		-0.0105	
			C	412	405		0.92	-0.75	0.007	fail	fail	-0.0025		-0.0095	
			D	412	410		0.92	4.25	0.002	fail	fail	-0.0025		-0.0045	
			E	412	407		0.92	1.25	0.005	fail	fail	-0.0025		-0.0075	
			F	411	408		-0.08	2.25	0.003	fail	fail	-0.0035		-0.0065	
			G	410	402		-1.08	-3.75	0.008	fail	fail	-0.0045		-0.0125	
		Min	H	413	407		1.92	1.25	0.006	fail	fail	-0.0015		-0.0075	
		0.4145	I	414	403		2.92	-2.75	0.011	fail	fail	-0.0005		-0.0115	
		Max	J	407	402		-4.08	-3.75	0.005	fail	fail	-0.0075		-0.0125	
		0.4605	K	409	406		-2.08	0.25	0.003	fail	fail	-0.0055		-0.0085	
			L	410	405		-1.08	-0.75	0.005	fail	fail	-0.0045		-0.0095	
12	16	0.25	A	255	250		-0.13	-1.38	0.005	pass	pass				
			B	254	250		-1.13	-1.38	0.004	pass	pass				
			C	255	253		-0.13	1.63	0.002	pass	pass				
			D	257	252		1.88	0.63	0.005	pass	pass				
		Min	E	255	251		-0.13	-0.38	0.004	pass	pass				
		0.234	F	254	252		-1.13	0.63	0.002	pass	pass				
		Max	G	255	252		-0.13	0.63	0.003	pass	pass				
		0.266	H	256	251		0.88	-0.38	0.005	pass	pass				
13															

Table B-1 - Summary of Ultrasonic Thickness Gauging of Pipe Wall
YDP Aluminum Bronze Pipe

Record Drawing			Pipe Wall Thickness												
CH No.	Pipe Dia	Nominal Required Wall Thickness	Position	Band No.1	Band No. 2	Notes	Band 1 Diff from Ave	Band 2 Diff from Ave	Diff between bands	Band 1 Pass or Fail	Band 2 Pass or Fail	Band 1 Diff from Min	Band 1 Diff from Max	Band 2 Diff from Min	Band 2 Diff from Max
14	30	0.4375	A	436	436		3.92	2.50	0	pass	pass				
			B	435	439		2.92	5.50	0.004	pass	pass				
			C	436	437		3.92	3.50	0.001	pass	pass				
			D	434	435		1.92	1.50	0.001	pass	pass				
			E	433	432		0.92	-1.50	0.001	pass	pass				
			F	431	429		-1.08	-4.50	0.002	pass	pass				
		Min	G	429	425		-3.08	-8.50	0.004	pass	pass				
		0.4145	H	431	429		-1.08	-4.50	0.002	pass	pass				
		Max	I	426	431		-6.08	-2.50	0.005	pass	pass				
		0.4605	J	428	434		-4.08	0.50	0.006	pass	pass				
			K	431	437		-1.08	3.50	0.006	pass	pass				
			L	435	438		2.92	4.50	0.003	pass	pass				
15	30	0.4375	A	425	435		6.00	5.00	0.01	pass	pass				
			B	413	434		-6.00	4.00	0.021	fail	pass	-0.0015			
			C	416	433		-3.00	3.00	0.017	pass	pass				
			D	416	431		-3.00	1.00	0.015	pass	pass				
		Min	E	418	422		-1.00	-8.00	0.004	pass	pass				
		0.4145	F	419	420		0.00	-10.00	0.001	pass	pass				
		Max	G	422	432		3.00	2.00	0.01	pass	pass				
		0.4605	H	423	433		4.00	3.00	0.01	pass	pass				
26	48	0.75	A	685	710		1.42	-0.92	0.025	fail	fail	-0.036		-0.011	
			B	684	711		0.42	0.08	0.027	fail	fail	-0.037		-0.01	
			C	685	712		1.42	1.08	0.027	fail	fail	-0.036		-0.009	
			D	685	711		1.42	0.08	0.026	fail	fail	-0.036		-0.01	
			E	687	711		3.42	0.08	0.024	fail	fail	-0.034		-0.01	
			F	683	713		-0.58	2.08	0.03	fail	fail	-0.038		-0.008	
		Min	G	689	705		5.42	-5.92	0.016	fail	fail	-0.032		-0.016	
		0.721	H	680	710		-3.58	-0.92	0.03	fail	fail	-0.041		-0.011	
		Max	I	687	712		3.42	1.08	0.025	fail	fail	-0.034		-0.009	
		0.779	J	678	714		-5.58	3.08	0.036	fail	fail	-0.043		-0.007	
			K	679	711		-4.58	0.08	0.032	fail	fail	-0.042		-0.01	
			L	681	711		-2.58	0.08	0.03	fail	fail	-0.04		-0.01	

Table B-1 - Summary of Ultrasonic Thickness Gauging of Pipe Wall
YDP Aluminum Bronze Pipe

Record Drawing			Pipe Wall Thickness												
CH No.	Pipe Dia	Nominal Required Wall Thickness	Position	Band No.1	Band No. 2	Notes	Band 1 Diff from Ave	Band 2 Diff from Ave	Diff between bands	Band 1 Pass or Fail	Band 2 Pass or Fail	Band 1 Diff from Min	Band 1 Diff from Max	Band 2 Diff from Min	Band 2 Diff from Max
17	30	0.4375	A	388	398		-0.25	1.00	0.01	fail	fail	-0.0265		-0.0165	
			B	392	398		3.75	1.00	0.006	fail	fail	-0.0225		-0.0165	
			C	393	396		4.75	-1.00	0.003	fail	fail	-0.0215		-0.0185	
			D	392	397		3.75	0.00	0.005	fail	fail	-0.0225		-0.0175	
			E	392	398		3.75	1.00	0.006	fail	fail	-0.0225		-0.0165	
			F	391	398		2.75	1.00	0.007	fail	fail	-0.0235		-0.0165	
		Min	G	390	397		1.75	0.00	0.007	fail	fail	-0.0245		-0.0175	
		0.4145	H	383	399		-5.25	2.00	0.016	fail	fail	-0.0315		-0.0155	
		Max	I	381	398		-7.25	1.00	0.017	fail	fail	-0.0335		-0.0165	
		0.4605	J	378	396		-10.25	-1.00	0.018	fail	fail	-0.0365		-0.0185	
			K	384	394		-4.25	-3.00	0.01	fail	fail	-0.0305		-0.0205	
			L	395	395		6.75	-2.00	0	fail	fail	-0.0195		-0.0195	
18	30	0.4375	A	425	638		-0.25	4.75	0.213	pass	pass				0.1775
			B	428	641		2.75	7.75	0.213	pass	pass				0.1805
			C	426	641		0.75	7.75	0.215	pass	pass				0.1805
			D	421	641		-4.25	7.75	0.22	pass	pass				0.1805
			E	426	631		0.75	-2.25	0.205	pass	pass				0.1705
			F	426	625		0.75	-8.25	0.199	pass	pass				0.1645
		Min	G	428	626		2.75	-7.25	0.198	pass	pass				0.1655
		0.4145	H	427	628		1.75	-5.25	0.201	pass	pass				0.1675
		Max	I	424	628		-1.25	-5.25	0.204	pass	pass				0.1675
		0.4605	J	425	631		-0.25	-2.25	0.206	pass	pass				0.1705
			K	424	633		-1.25	-0.25	0.209	pass	pass				0.1725
			L	423	636		-2.25	2.75	0.213	pass	pass				0.1755
19	30	0.4375	A	401	410		-1.38	1.88	0.009	fail	fail	-0.0135		-0.0045	
			B	400	410		-2.38	1.88	0.01	fail	fail	-0.0145		-0.0045	
			C	399	409		-3.38	0.88	0.01	fail	fail	-0.0155		-0.0055	
			D	401	410		-1.38	1.88	0.009	fail	fail	-0.0135		-0.0045	
		Min	E	403	411		0.63	2.88	0.008	fail	fail	-0.0115		-0.0035	
		0.4145	F	407	405		4.63	-3.13	0.002	fail	fail	-0.0075		-0.0095	
		Max	G	406	404		3.63	-4.13	0.002	fail	fail	-0.0085		-0.0105	
		0.4605	H	402	406		-0.38	-2.13	0.004	fail	fail	-0.0125		-0.0085	

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Record Drawing			Pipe Wall Thickness												
CH No.	Pipe Dia	Nominal Required Wall Thickness	Position	Band No.1	Band No. 2	Notes	Band 1 Diff from Ave	Band 2 Diff from Ave	Diff between bands	Band 1 Pass or Fail	Band 2 Pass or Fail	Band 1 Diff from Min	Band 1 Diff from Max	Band 2 Diff from Min	Band 2 Diff from Max
20	16	0.25	A	248	250		0.13	0.00	0.002	pass	pass				
			B	247	252		-0.88	2.00	0.005	pass	pass				
			C	249	250		1.13	0.00	0.001	pass	pass				
			D	248	249		0.13	-1.00	0.001	pass	pass				
		Min	E	246	251		-1.88	1.00	0.005	pass	pass				
		0.234	F	248	250		0.13	0.00	0.002	pass	pass				
		Max	G	250	248		2.13	-2.00	0.002	pass	pass				
		0.266	H	247	250		-0.88	0.00	0.003	pass	pass				
21	24	0.375	A	373	369		0.92	1.75	0.004	pass	pass				
			B	374	370		1.92	2.75	0.004	pass	pass				
			C	374	368		1.92	0.75	0.006	pass	pass				
			D	372	365		-0.08	-2.25	0.007	pass	pass				
			E	376	363		3.92	-4.25	0.013	pass	pass				
			F	370	366		-2.08	-1.25	0.004	pass	pass				
		Min	G	365	373		-7.08	5.75	0.008	pass	pass				
		0.352	H	366	359		-6.08	-8.25	0.007	pass	pass				
		Max	I	366	370		-6.08	2.75	0.004	pass	pass				
		0.398	J	378	365		5.92	-2.25	0.013	pass	pass				
			K	376	370		3.92	2.75	0.006	pass	pass				
			L	375	369		2.92	1.75	0.006	pass	pass				
22	24	0.375	A	361	367		-0.50	2.13	0.006	pass	pass				
			B	359	365		-2.50	0.13	0.006	pass	pass				
			C	359	363		-2.50	-1.88	0.004	pass	pass				
			D	362	366		0.50	1.13	0.004	pass	pass				
		Min	E	363	363		1.50	-1.88	0	pass	pass				
		0.352	F	361	364		-0.50	-0.88	0.003	pass	pass				
		Max	G	364	365		2.50	0.13	0.001	pass	pass				
		0.398	H	363	366		1.50	1.13	0.003	pass	pass				

Table B-1 - Summary of Ultrasonic Thickness Gauging of Pipe Wall
YDP Aluminum Bronze Pipe

Record Drawing			Pipe Wall Thickness												
CH No.	Pipe Dia	Nominal Required Wall Thickness	Position	Band No.1	Band No. 2	Notes	Band 1 Diff from Ave	Band 2 Diff from Ave	Diff between bands	Band 1 Pass or Fail	Band 2 Pass or Fail	Band 1 Diff from Min	Band 1 Diff from Max	Band 2 Diff from Min	Band 2 Diff from Max
23	36	0.5625	A	533	546		-7.13	-1.50	0.013	fail	pass	-0.0005			
			B	543	544		2.88	-3.50	0.001	pass	pass				
			C	546	548		5.88	0.50	0.002	pass	pass				
			D	539	547		-1.13	-0.50	0.008	pass	pass				
		Min	E	540	554		-0.13	6.50	0.014	pass	pass				
		0.5335	F	546	553		5.88	5.50	0.007	pass	pass				
		Max	G	536	543		-4.13	-4.50	0.007	pass	pass				
		0.5915	H	538	545		-2.13	-2.50	0.007	pass	pass				
24	36	0.5625	A	546	554		2.58	2.42	0.008	pass	pass				
			B	547	558		3.58	6.42	0.011	pass	pass				
			C	547	554		3.58	2.42	0.007	pass	pass				
			D	547	550		3.58	-1.58	0.003	pass	pass				
			E	546	548		2.58	-3.58	0.002	pass	pass				
			F	537	548		-6.42	-3.58	0.011	pass	pass				
		Min	G	535	547		-8.42	-4.58	0.012	pass	pass				
		0.5335	H	537	548		-6.42	-3.58	0.011	pass	pass				
		Max	I	540	548		-3.42	-3.58	0.008	pass	pass				
		0.5915	J	545	549		1.58	-2.58	0.004	pass	pass				
			K	548	557		4.58	5.42	0.009	pass	pass				
			L	546	558		2.58	6.42	0.012	pass	pass				
25	36	0.5625	A	541	574		-9.50	4.50	0.033	pass	pass				
			B	546	575		-4.50	5.50	0.029	pass	pass				
			C	550	573		-0.50	3.50	0.023	pass	pass				
			D	554	570		3.50	0.50	0.016	pass	pass				
		Min	E	551	560		0.50	-9.50	0.009	pass	pass				
		0.5335	F	555	565		4.50	-4.50	0.01	pass	pass				
		Max	G	553	567		2.50	-2.50	0.014	pass	pass				
		0.5915	H	554	572		3.50	2.50	0.018	pass	pass				

Table B-1 - Summary of Ultrasonic Thickness Gauging of Pipe Wall
YDP Aluminum Bronze Pipe

Record Drawing			Pipe Wall Thickness												
CH No.	Pipe Dia	Nominal Required Wall Thickness	Position	Band No.1	Band No. 2	Notes	Band 1 Diff from Ave	Band 2 Diff from Ave	Diff between bands	Band 1 Pass or Fail	Band 2 Pass or Fail	Band 1 Diff from Min	Band 1 Diff from Max	Band 2 Diff from Min	Band 2 Diff from Max
16	30	0.4375	A	410	415		2.80	4.75	0.005	fail	pass	-0.0045			
			B	407	411		-0.20	0.75	0.004	fail	fail	-0.0075		-0.0035	
			C	402	407		-5.20	-3.25	0.005	fail	fail	-0.0125		-0.0075	
			D	400	400		-7.20	-10.25	0	fail	fail	-0.0145		-0.0145	
			E	399	415		-8.20	4.75	0.016	fail	pass	-0.0155			
			F	402	411		-5.20	0.75	0.009	fail	fail	-0.0125		-0.0035	
		Min	G	407	410		-0.20	-0.25	0.003	fail	fail	-0.0075		-0.0045	
		0.4145	H	n/a	n/a							n/a	n/a	n/a	n/a
		Max	I	n/a	n/a							n/a	n/a	n/a	n/a
		0.4605	J	415	n/a		7.80			pass				n/a	n/a
			K	417	n/a		9.80			pass				n/a	n/a
			L	413	413		5.80	2.75	0	fail	fail	-0.0015		-0.0015	
27	48	0.75	A	727	734		0.58	-7.08	0.007	pass	pass				
			B	717	755		-9.42	13.92	0.038	fail	pass	-0.004			
			C	715	731		-11.42	-10.08	0.016	fail	pass	-0.006			
			D	711	732		-15.42	-9.08	0.021	fail	pass	-0.01			
			E	718	748		-8.42	6.92	0.03	fail	pass	-0.003			
			F	728	744		1.58	2.92	0.016	pass	pass				
		Min	G	730	740		3.58	-1.08	0.01	pass	pass				
		0.721	H	728	749		1.58	7.92	0.021	pass	pass				
		Max	I	733	738		6.58	-3.08	0.005	pass	pass				
		0.779	J	739	722		12.58	-19.08	0.017	pass	pass				
			K	732	750		5.58	8.92	0.018	pass	pass				
			L	739	750		12.58	8.92	0.011	pass	pass				
28	18/24	0.3125/0.375	A	323	377	Band number 2 on	1.50	0.58		pass	pass				
			B	321	378	reducer	-0.50	1.58		pass	pass				
			C	318	377		-3.50	0.58		pass	pass				
			D	315	375		-6.50	-1.42		pass	pass				
			E	314	374		-7.50	-2.42		pass	pass				
			F	321	373		-0.50	-3.42		pass	pass				
		Min	G	324	378		2.50	1.58		pass	pass				
		0.2895/0.352	H	324	376		2.50	-0.42		pass	pass				
		Max	I	324	378		2.50	1.58		pass	pass				
		0.3355/0.398	J	323	371		1.50	-5.42		pass	pass				
			K	325	380		3.50	3.58		pass	pass				
			L	326	380		4.50	3.58		pass	pass				

Table B-1 - Summary of Ultrasonic Thickness Gauging of Pipe Wall
YDP Aluminum Bronze Pipe

Record Drawing			Pipe Wall Thickness												
CH No.	Pipe Dia	Nominal Required Wall Thickness	Position	Band No.1	Band No. 2	Notes	Band 1 Diff from Ave	Band 2 Diff from Ave	Diff between bands	Band 1 Pass or Fail	Band 2 Pass or Fail	Band 1 Diff from Min	Band 1 Diff from Max	Band 2 Diff from Min	Band 2 Diff from Max
29	12	0.25	A	427	418		12.75	-0.63	0.009	pass	pass		0.161		0.152
			B	421	422		6.75	3.38	0.001	pass	pass		0.155		0.156
			C	411	419		-3.25	0.38	0.008	pass	pass		0.145		0.153
			D	414	416		-0.25	-2.63	0.002	pass	pass		0.148		0.15
		Min	E	412	416		-2.25	-2.63	0.004	pass	pass		0.146		0.15
		0.234	F	412	418		-2.25	-0.63	0.006	pass	pass		0.146		0.152
		Max	G	409	420		-5.25	1.38	0.011	pass	pass		0.143		0.154
		0.266	H	408	420		-6.25	1.38	0.012	pass	pass		0.142		0.154
30															
31	30	0.375	A	430	428		4.75	5.83	0.002	pass	pass		0.032		0.03
			B	426	422		0.75	-0.17	0.004	pass	pass		0.028		0.024
			C	428	420		2.75	-2.17	0.008	pass	pass		0.03		0.022
			D	429	415		3.75	-7.17	0.014	pass	pass		0.031		0.017
			E	415	415		-10.25	-7.17	0	pass	pass		0.017		0.017
			F	405	410		-20.25	-12.17	0.005	pass	pass		0.007		0.012
		Min	G	427	405		1.75	-17.17	0.022	pass	pass		0.029		0.007
		0.352	H	429	430		3.75	7.83	0.001	pass	pass		0.031		0.032
		Max	I	430	433		4.75	10.83	0.003	pass	pass		0.032		0.035
		0.398	J	430	427		4.75	4.83	0.003	pass	pass		0.032		0.029
			K	426	430		0.75	7.83	0.004	pass	pass		0.028		0.032
			L	428	431		2.75	8.83	0.003	pass	pass		0.03		0.033
32	30	0.375	A	401	390		3.42	-3.83	0.011	pass	pass		0.003		
			B	400	391		2.42	-2.83	0.009	pass	pass		0.002		
			C	402	392		4.42	-1.83	0.01	pass	pass		0.004		
			D	400	400		2.42	6.17	0	pass	pass		0.002		0.002
			E	402	402		4.42	8.17	0	pass	pass		0.004		0.004
			F	401	402		3.42	8.17	0.001	pass	pass		0.003		0.004
		Min	G	398	398		0.42	4.17	0	pass	pass				
		0.352	H	388	388		-9.58	-5.83	0	pass	pass				
		Max	I	390	390		-7.58	-3.83	0	pass	pass				
		0.398	J	391	391		-6.58	-2.83	0	pass	pass				
			K	398	391		0.42	-2.83	0.007	pass	pass				
			L	400	391		2.42	-2.83	0.009	pass	pass		0.002		

Table B-1 - Summary of Ultrasonic Thickness Gauging of Pipe Wall
YDP Aluminum Bronze Pipe

Record Drawing			Pipe Wall Thickness												
CH No.	Pipe Dia	Nominal Required Wall Thickness	Position	Band No.1	Band No. 2	Notes	Band 1 Diff from Ave	Band 2 Diff from Ave	Diff between bands	Band 1 Pass or Fail	Band 2 Pass or Fail	Band 1 Diff from Min	Band 1 Diff from Max	Band 2 Diff from Min	Band 2 Diff from Max
33	16	0.25	A	250	250		1.08	2.75	0	pass	pass				
			B	249	247		0.08	-0.25	0.002	pass	pass				
			C	248	246		-0.92	-1.25	0.002	pass	pass				
			D	247	245		-1.92	-2.25	0.002	pass	pass				
			E	248	246		-0.92	-1.25	0.002	pass	pass				
			F	248	248		-0.92	0.75	0	pass	pass				
		Min	G	248	250		-0.92	2.75	0.002	pass	pass				
		0.234	H	249	247		0.08	-0.25	0.002	pass	pass				
		Max	I	250	245		1.08	-2.25	0.005	pass	pass				
		0.266	J	251	246		2.08	-1.25	0.005	pass	pass				
			K	249	248		0.08	0.75	0.001	pass	pass				
			L	250	249		1.08	1.75	0.001	pass	pass				
33B	16	0.25	A	258	242		4.38	-4.38	0.016	pass	pass				
			B	252	243		-1.63	-3.38	0.009	pass	pass				
			C	253	248		-0.63	1.63	0.005	pass	pass				
			D	252	246		-1.63	-0.38	0.006	pass	pass				
		Min	E	251	250		-2.63	3.63	0.001	pass	pass				
		0.234	F	255	251		1.38	4.63	0.004	pass	pass				
		Max	G	260	245		6.38	-1.38	0.015	pass	pass				
		0.266	H	248	246		-5.63	-0.38	0.002	pass	pass				
34															
35															
36															
37															

Table B-1 - Summary of Ultrasonic Thickness Gauging of Pipe Wall
YDP Aluminum Bronze Pipe

Record Drawing			Pipe Wall Thickness												
CH No.	Pipe Dia	Nominal Required Wall Thickness	Position	Band No.1	Band No. 2	Notes	Band 1 Diff from Ave	Band 2 Diff from Ave	Diff between bands	Band 1 Pass or Fail	Band 2 Pass or Fail	Band 1 Diff from Min	Band 1 Diff from Max	Band 2 Diff from Min	Band 2 Diff from Max
38	42	0.25	A	278	270		4.75	1.17	0.008	pass	pass		0.012		0.004
			B	275	270		1.75	1.17	0.005	pass	pass		0.009		0.004
			C	272	271		-1.25	2.17	0.001	pass	pass		0.006		0.005
			D	271	268		-2.25	-0.83	0.003	pass	pass		0.005		0.002
			E	274	270		0.75	1.17	0.004	pass	pass		0.008		0.004
			F	272	268		-1.25	-0.83	0.004	pass	pass		0.006		0.002
		Min	G	267	265		-6.25	-3.83	0.002	pass	pass		0.001		
		0.234	H	269	263		-4.25	-5.83	0.006	pass	pass		0.003		
		Max	I	270	265		-3.25	-3.83	0.005	pass	pass		0.004		
		0.266	J	278	271		4.75	2.17	0.007	pass	pass		0.012		0.005
			K	276	274		2.75	5.17	0.002	pass	pass		0.01		0.008
			L	277	271		3.75	2.17	0.006	pass	pass		0.011		0.005
39	54	0.25	A	241	244		-7.25	-7.13	0.003	pass	pass				
			B	257	252		8.75	0.88	0.005	pass	pass				
			C	250	256		1.75	4.88	0.006	pass	pass				
			D	258	251		9.75	-0.13	0.007	pass	pass				
		Min	E	245	251		-3.25	-0.13	0.006	pass	pass				
		0.234	F	243	252		-5.25	0.88	0.009	pass	pass				
		Max	G	250	252		1.75	0.88	0.002	pass	pass				
		0.266	H	242	251		-6.25	-0.13	0.009	pass	pass				
40	3.5	0.25	A	381	388		-11.38	-7.38	0.007	pass	pass		0.115		0.122
			B	389	396		-3.38	0.63	0.007	pass	pass		0.123		0.13
			C	394	385		1.63	-10.38	0.009	pass	pass		0.128		0.119
			D	401	394		8.63	-1.38	0.007	pass	pass		0.135		0.128
		Min	E	392	417		-0.38	21.63	0.025	pass	pass		0.126		0.151
		0.234	F	409	396		16.63	0.63	0.013	pass	pass		0.143		0.13
		Max	G	382	393		-10.38	-2.38	0.011	pass	pass		0.116		0.127
		0.266	H	391	394		-1.38	-1.38	0.003	pass	pass		0.125		0.128
41	3.5	0.25	A	419	416		9.00	8.00	0.003	pass	pass		0.153		0.15
		Min	B	406	409		-4.00	1.00	0.003	pass	pass		0.14		0.143
		0.234	C	406	400		-4.00	-8.00	0.006	pass	pass		0.14		0.134
		Max	D	409	407		-1.00	-1.00	0.002	pass	pass		0.143		0.141
		0.266													

Table B-1 - Summary of Ultrasonic Thickness Gauging of Pipe Wall
YDP Aluminum Bronze Pipe

Record Drawing			Pipe Wall Thickness												
CH No.	Pipe Dia	Nominal Required Wall Thickness	Position	Band No.1	Band No. 2	Notes	Band 1 Diff from Ave	Band 2 Diff from Ave	Diff between bands	Band 1 Pass or Fail	Band 2 Pass or Fail	Band 1 Diff from Min	Band 1 Diff from Max	Band 2 Diff from Min	Band 2 Diff from Max
42	30	0.25	A	287	250		5.00	4.67	0.037	pass	pass		0.021		
			B	290	236		8.00	-9.33	0.054	pass	pass		0.024		
			C	286	238		4.00	-7.33	0.048	pass	pass		0.02		
			D	280	243		-2.00	-2.33	0.037	pass	pass		0.014		
			E	279	247		-3.00	1.67	0.032	pass	pass		0.013		
			F	276	236		-6.00	-9.33	0.04	pass	pass		0.01		
		Min	G	283	236		1.00	-9.33	0.047	pass	pass		0.017		
		0.234	H	280	241		-2.00	-4.33	0.039	pass	pass		0.014		
		Max	I	279	252		-3.00	6.67	0.027	pass	pass		0.013		
		0.266	J	277	257		-5.00	11.67	0.02	pass	pass		0.011		
			K	282	257		0.00	11.67	0.025	pass	pass		0.016		
			L	285	251		3.00	5.67	0.034	pass	pass		0.019		
43	30	0.25	A	241	251		-4.38	2.63	0.01	pass	pass				
			B	249	249		3.63	0.63	0	pass	pass				
			C	252	245		6.63	-3.38	0.007	pass	pass				
			D	254	249		8.63	0.63	0.005	pass	pass				
		Min	E	242	249		-3.38	0.63	0.007	pass	pass				
		0.234	F	242	250		-3.38	1.63	0.008	pass	pass				
		Max	G	241	245		-4.38	-3.38	0.004	pass	pass				
		0.266	H	242	249		-3.38	0.63	0.007	pass	pass				
44	24	0.25	A	255	245		-0.13	2.63	0.01	pass	pass				
			B	257	243		1.88	0.63	0.014	pass	pass				
			C	255	242		-0.13	-0.38	0.013	pass	pass				
			D	256	239		0.88	-3.38	0.017	pass	pass				
		Min	E	253	240		-2.13	-2.38	0.013	pass	pass				
		0.234	F	254	244		-1.13	1.63	0.01	pass	pass				
		Max	G	256	242		0.88	-0.38	0.014	pass	pass				
		0.266	H	255	244		-0.13	1.63	0.011	pass	pass				

Table B-1 - Summary of Ultrasonic Thickness Gauging of Pipe Wall
YDP Aluminum Bronze Pipe

Record Drawing			Pipe Wall Thickness												
CH No.	Pipe Dia	Nominal Required Wall Thickness	Position	Band No.1	Band No. 2	Notes	Band 1 Diff from Ave	Band 2 Diff from Ave	Diff between bands	Band 1 Pass or Fail	Band 2 Pass or Fail	Band 1 Diff from Min	Band 1 Diff from Max	Band 2 Diff from Min	Band 2 Diff from Max
45	14	0.25	A	255	256		2.33	1.67	0.001	pass	pass				
			B	254	256		1.33	1.67	0.002	pass	pass				
			C	255	255		2.33	0.67	0	pass	pass				
			D	251	256		-1.67	1.67	0.005	pass	pass				
			E	250	250		-2.67	-4.33	0	pass	pass				
			F	251	254		-1.67	-0.33	0.003	pass	pass				
		Min	G	251	253		-1.67	-1.33	0.002	pass	pass				
		0.234	H	254	254		1.33	-0.33	0	pass	pass				
		Max	I	252	253		-0.67	-1.33	0.001	pass	pass				
		0.266	J	253	255		0.33	0.67	0.002	pass	pass				
			K	253	255		0.33	0.67	0.002	pass	pass				
			L	253	255		0.33	0.67	0.002	pass	pass				
46A	8.625	0.25	A	417	417		2.63	2.13	0	pass	pass		0.151		0.151
			B	416	419		1.63	4.13	0.003	pass	pass		0.15		0.153
			C	413	418		-1.38	3.13	0.005	pass	pass		0.147		0.152
			D	398	397		-16.38	-17.88	0.001	pass	pass		0.132		0.131
		Min	E	416	412		1.63	-2.88	0.004	pass	pass		0.15		0.146
		0.234	F	418	417		3.63	2.13	0.001	pass	pass		0.152		0.151
		Max	G	417	419		2.63	4.13	0.002	pass	pass		0.151		0.153
		0.266	H	420	420		5.63	5.13	0	pass	pass		0.154		0.154
46B	10	0.3125	A	254	253		-5.00	-11.90		fail	fail	-0.0355		-0.0365	
			B	255	254		-4.00	-10.90		fail	fail	-0.0345		-0.0355	
			C	258	254		-1.00	-10.90		fail	fail	-0.0315		-0.0355	
			D	264	269		5.00	4.10		fail	fail	-0.0255		-0.0205	
			E	264	273		5.00	8.10		fail	fail	-0.0255		-0.0165	
		Min	F	261	275		2.00	10.10		fail	fail	-0.0285		-0.0145	
		0.2895	G	260	275		1.00	10.10		fail	fail	-0.0295		-0.0145	
		Max	H	256	270		-3.00	5.10		fail	fail	-0.0335		-0.0195	
		0.3355	I	n/a	262			-2.90			fail			-0.0275	
			J	n/a	264			-0.90			fail			-0.0255	

Table B-1 - Summary of Ultrasonic Thickness Gauging of Pipe Wall
YDP Aluminum Bronze Pipe

Record Drawing			Pipe Wall Thickness												
CH No.	Pipe Dia	Nominal Required Wall Thickness	Position	Band No.1	Band No. 2	Notes	Band 1 Diff from Ave	Band 2 Diff from Ave	Diff between bands	Band 1 Pass or Fail	Band 2 Pass or Fail	Band 1 Diff from Min	Band 1 Diff from Max	Band 2 Diff from Min	Band 2 Diff from Max
47	24	0.25	A	282	272		0.42	1.25	0.01	pass	pass		0.016		0.006
			B	282	272		0.42	1.25	0.01	pass	pass		0.016		0.006
			C	281	268		-0.58	-2.75	0.013	pass	pass		0.015		0.002
			D	278	264		-3.58	-6.75	0.014	pass	pass		0.012		
			E	277	265		-4.58	-5.75	0.012	pass	pass		0.011		
			F	275	262		-6.58	-8.75	0.013	pass	pass		0.009		
		Min	G	274	275		-7.58	4.25	0.001	pass	pass		0.008		0.009
		0.234	H	285	272		3.42	1.25	0.013	pass	pass		0.019		0.006
		Max	I	286	273		4.42	2.25	0.013	pass	pass		0.02		0.007
		0.266	J	288	274		6.42	3.25	0.014	pass	pass		0.022		0.008
			K	286	277		4.42	6.25	0.009	pass	pass		0.02		0.011
			L	285	275		3.42	4.25	0.01	pass	pass		0.019		0.009
48	18/14	0.3125/0.25	A	292	262	Don't know which band	1.67	1.67				n/a	n/a	n/a	n/a
			B	291	261	is for which thickness	0.67	0.67				n/a	n/a	n/a	n/a
			C	289	262		-1.33	1.67				n/a	n/a	n/a	n/a
			D	290	263		-0.33	2.67				n/a	n/a	n/a	n/a
			E	291	259		0.67	-1.33				n/a	n/a	n/a	n/a
			F	289	259		-1.33	-1.33				n/a	n/a	n/a	n/a
		Min	G	288	258		-2.33	-2.33				n/a	n/a	n/a	n/a
		0.2895/0.234	H	289	258		-1.33	-2.33				n/a	n/a	n/a	n/a
		Max	I	291	261		0.67	0.67				n/a	n/a	n/a	n/a
		0.3355/0.266	J	291	262		0.67	1.67				n/a	n/a	n/a	n/a
			K	292	260		1.67	-0.33				n/a	n/a	n/a	n/a
			L	291	259		0.67	-1.33				n/a	n/a	n/a	n/a

Table B-1 - Summary of Ultrasonic Thickness Gauging of Pipe Wall
YDP Aluminum Bronze Pipe

Record Drawing			Pipe Wall Thickness												
CH No.	Pipe Dia	Nominal Required Wall Thickness	Position	Band No.1	Band No. 2	Notes	Band 1 Diff from Ave	Band 2 Diff from Ave	Diff between bands	Band 1 Pass or Fail	Band 2 Pass or Fail	Band 1 Diff from Min	Band 1 Diff from Max	Band 2 Diff from Min	Band 2 Diff from Max
49	30	0.25	A	256	257		2.50	2.67	0.001	pass	pass				
			B	255	256		1.50	1.67	0.001	pass	pass				
			C	261	256		7.50	1.67	0.005	pass	pass				
			D	252	251		-1.50	-3.33	0.001	pass	pass				
			E	258	258		4.50	3.67	0	pass	pass				
			F	247	256		-6.50	1.67	0.009	pass	pass				
		Min	G	246	252		-7.50	-2.33	0.006	pass	pass				
		0.234	H	249	252		-4.50	-2.33	0.003	pass	pass				
		Max	I	252	250		-1.50	-4.33	0.002	pass	pass				
		0.266	J	256	259		2.50	4.67	0.003	pass	pass				
			K	258	251		4.50	-3.33	0.007	pass	pass				
			L	252	254		-1.50	-0.33	0.002	pass	pass				
50	16	0.25	A	244	244		-7.63	-5.00	0	pass	pass				
			B	259	261		7.38	12.00	0.002	pass	pass				
			C	260	252		8.38	3.00	0.008	pass	pass				
			D	251	242		-0.63	-7.00	0.009	pass	pass				
		Min	E	250	255		-1.63	6.00	0.005	pass	pass				
		0.234	F	248	244		-3.63	-5.00	0.004	pass	pass				
		Max	G	252	248		0.38	-1.00	0.004	pass	pass				
		0.266	H	249	246		-2.63	-3.00	0.003	pass	pass				
51	54	0.25	A	283	259		11.13	7.88	0.024	pass	pass		0.017		
			B	279	261		7.13	9.88	0.018	pass	pass		0.013		
			C	269	252		-2.88	0.88	0.017	pass	pass		0.003		
			D	270	262		-1.88	10.88	0.008	pass	pass		0.004		
		Min	E	273	243		1.13	-8.13	0.03	pass	pass		0.007		
		0.234	F	269	245		-2.88	-6.13	0.024	pass	pass		0.003		
		Max	G	265	243		-6.88	-8.13	0.022	pass	pass				
		0.266	H	267	244		-4.88	-7.13	0.023	pass	pass		0.001		

Table B-1 - Summary of Ultrasonic Thickness Gauging of Pipe Wall
YDP Aluminum Bronze Pipe

Record Drawing			Pipe Wall Thickness												
CH No.	Pipe Dia	Nominal Required Wall Thickness	Position	Band No.1	Band No. 2	Notes	Band 1 Diff from Ave	Band 2 Diff from Ave	Diff between bands	Band 1 Pass or Fail	Band 2 Pass or Fail	Band 1 Diff from Min	Band 1 Diff from Max	Band 2 Diff from Min	Band 2 Diff from Max
52	36	0.25	A	303	280		15.50	1.50	0.023	pass	pass		0.037		0.014
			B	287	271		-0.50	-7.50	0.016	pass	pass		0.021		0.005
			C	284	270		-3.50	-8.50	0.014	pass	pass		0.018		0.004
			D	286	282		-1.50	3.50	0.004	pass	pass		0.02		0.016
		Min	E	291	283		3.50	4.50	0.008	pass	pass		0.025		0.017
		0.234	F	285	283		-2.50	4.50	0.002	pass	pass		0.019		0.017
		Max	G	281	280		-6.50	1.50	0.001	pass	pass		0.015		0.014
		0.266	H	283	279		-4.50	0.50	0.004	pass	pass		0.017		0.013
53	20	0.3125	A	300	302		-1.13	-0.13	0.002	pass	pass				
			B	302	303		0.88	0.88	0.001	pass	pass				
			C	304	304		2.88	1.88	0	pass	pass				
			D	302	302		0.88	-0.13	0	pass	pass				
		Min	E	299	301		-2.13	-1.13	0.002	pass	pass				
		0.2895	F	301	300		-0.13	-2.13	0.001	pass	pass				
		Max	G	298	302		-3.13	-0.13	0.004	pass	pass				
		0.3355	H	303	303		1.88	0.88	0	pass	pass				
54	30	0.25	A	257	257		-3.38	0.75	0	pass	pass				
			B	262	261		1.63	4.75	0.001	pass	pass				
			C	264	260		3.63	3.75	0.004	pass	pass				
			D	264	258		3.63	1.75	0.006	pass	pass				
		Min	E	262	253		1.63	-3.25	0.009	pass	pass				
		0.234	F	259	251		-1.38	-5.25	0.008	pass	pass				
		Max	G	258	250		-2.38	-6.25	0.008	pass	pass				
		0.266	H	257	260		-3.38	3.75	0.003	pass	pass				
55	30	0.4375	A	420	425		-0.25	6.13	0.005	pass	pass				
			B	420	420		-0.25	1.13	0	pass	pass				
			C	413	421		-7.25	2.13	0.008	fail	pass	-0.0015			
			D	428	420		7.75	1.13	0.008	pass	pass				
		Min	E	421	424		0.75	5.13	0.003	pass	pass				
		0.4145	F	420	407		-0.25	-11.88	0.013	pass	fail			-0.0075	
		Max	G	422	415		1.75	-3.88	0.007	pass	pass				
		0.4605	H	418	419		-2.25	0.13	0.001	pass	pass				

Table B-1 - Summary of Ultrasonic Thickness Gauging of Pipe Wall
YDP Aluminum Bronze Pipe

Record Drawing			Pipe Wall Thickness												
CH No.	Pipe Dia	Nominal Required Wall Thickness	Position	Band No.1	Band No. 2	Notes	Band 1 Diff from Ave	Band 2 Diff from Ave	Diff between bands	Band 1 Pass or Fail	Band 2 Pass or Fail	Band 1 Diff from Min	Band 1 Diff from Max	Band 2 Diff from Min	Band 2 Diff from Max
56	16	0.25	**A**	269	251		14.25	0.63	0.018	pass	pass		0.003		
			B	255	250		0.25	-0.38	0.005	pass	pass				
			C	253	249		-1.75	-1.38	0.004	pass	pass				
			D	254	248		-0.75	-2.38	0.006	pass	pass				
		Min	**E**	252	249		-2.75	-1.38	0.003	pass	pass				
		0.234	**F**	253	250		-1.75	-0.38	0.003	pass	pass				
		Max	**G**	251	254		-3.75	3.63	0.003	pass	pass				
		0.266	**H**	251	252		-3.75	1.63	0.001	pass	pass				

799 Pass assuming a thicker plate is acceptable
149 Fail
20 Probable sections with thicker plate

Appendix C
Standard Specification for Welded Copper-Alloy Pipe

Designation: B 608 – 88

Standard Specification for Welded Copper-Alloy Pipe[1]

This standard is issued under the fixed designation B 608; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers arc-welded copper-alloy pipe for brackish water or seawater piping systems. A number of nondestructive tests and inspections are contained in the section of Supplementary Requirements. When these are required, the appropriate supplementary requirements must be specified in the purchase order or contract.

1.2 The following four alloys are covered:

Copper Alloy UNS Number[2]	Nominal Composition, %				
	Cu	Ni	Al	Fe	Sn
C61300	90.5	...	6.7	2.5	0.3
C61400	90.5	...	7.0	2.5	...
C70600	90.0	10.0	...	...	...
C71500	70.0	30.0	...	...	...

1.3 Although no restriction is placed on the size of pipe that may be furnished under this specification, commercial usage is normally limited to nominal sizes 4 in. (101 mm) and larger in diameter.

1.4 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

2. Referenced Documents

2.1 The following documents, of the issue in effect on the date of material purchase, form a part of this specification to the extent referenced herein:

2.1.1 *ASTM Standards:*

B 169 Specification for Aluminum Bronze Plate, Sheet, Strip, and Rolled Bar[3]

B 402 Specification for Copper-Nickel Alloy Plate and Sheet for Pressure Vessels[3]

E 8 Test Methods of Tension Testing of Metallic Materials[4]

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specification[5]

E 54 Methods for Chemical Analysis of Special Brasses and Bronzes[6]

E 55 Practice for Sampling Wrought Nonferrous Meta and Alloys for Determination of Chemical Composition

E 62 Methods for Chemical Analysis of Copper an Copper Alloys (Photometric Method)[6]

E 75 Methods for Chemical Analysis of Copper-Nick and Copper-Nickel-Zinc Alloys[6]

E 190 Method for Guided Bend Test for Ductility o Welds[8]

E 527 Practice for Numbering Metals and Alloys (UNS)

2.1.2 *AWS Standards:*

A 5.7 Copper and Copper-Alloy Arc-Welding Electrodes

A 5.7 Copper and Copper-Alloy Welding Rods

2.1.3 *ASME Standards:*

Section III, Division 1, Boiler and Pressure Vessel Cod Nuclear Power Plant Components[11]

Section V, Boiler and Pressure Vessel Code, Nondestru tive Examination[11]

Section VIII, Division 1, Boiler and Pressure Vessel Cod Pressure Vessels[11]

Section IX, Boiler and Pressure Vessel Code, Weldi Qualifications[11]

3. Definitions

3.1 *arc welding*—a group of welding processes where coalescence is produced by heating with an arc or arcs, wi or without the application of pressure and with or witho the use of filler metal.

3.2 *as-welded condition*—a condition created as a result forming annealed sheet or plate into tubular form a welding without subsequent heat treatment or cold work.

3.3 *base metal*—the sheet or plate from which the pipe formed.

3.4 *portion size*—the number of lengths of pipe to be us for a specific test.

3.5 *sample*—the final form of a material submitted chemical analysis (drillings, millings, etc.) or a prepared t specimen to be used for mechanical testing.

3.6 *weld reinforcement*—the portion of the welded jo which extends beyond the inner and outer surface of the b metal of the welded pipe.

4. Ordering Information

4.1 Orders for material under this specification sh include the following information:

[1] This specification is under the jurisdiction of ASTM Committee B-5 on Copper and Copper Alloys and is the direct responsibility of Subcommittee B05.04 on Pipe and Tube.

Current edition approved Feb. 26, 1988. Published April 1988. Originally published as B 608 – 76. Last previous edition B 608 – 86.

[2] The UNS system for copper and copper alloys (see Practice E 527) is a simple expansion of the former standard-designation system accomplished by the addition of a prefix "C" and a suffix "00." The suffix can be used to accommodate composition variations of the base alloy.

[3] *Annual Book of ASTM Standards*, Vol 02.01.

[4] *Annual Book of ASTM Standards*, Vols 02.02 and 03.01.

[5] *Annual Book of ASTM Standards*, Vol 14.02.

[6] *Annual Book of ASTM Standards*, Vol 03.05.

[7] *Annual Book of ASTM Standards*, Vols 02.01 and 03.05.

[8] *Annual Book of ASTM Standards*, Vol 03.01.

[9] *Annual Book of ASTM Standards*, Vols 01.01 and 02.01.

[10] Available from the American Welding Society, 2501 North West 7t Miami, FL 33125.

[11] Available from the American Society of Mechanical Engineers, 345 East St., New York, NY 10017.

4.1.1 Quantity.
4.1.2 Copper Alloy UNS No. (Section 1).
4.1.3 Nominal diameter (Section 10) or special outside diameter.
4.1.4 Pressure class (Section 10) or special wall thickness.
4.1.5 Unit length (Section 10).
4.1.6 ASTM Specification B 608.
4.1.7 Optional (see Supplementary Requirements).

5. Materials and Manufacture

5.1 The pipe shall be made from annealed copper-alloy sheet or plate that conforms to the requirements of Specifications B 169 or B 402 except as amended herein.

5.2 Welded joints shall be made either manually or automatically by an arc welding process.

5.3 Filler metal, if used in an arc-welding process, shall conform to one of the following specifications and classifications shown for each base metal:

Base Metal Copper Alloy UNS Number	Filler Metal AWS Specification A5.6	A5.7
C61300	ECuAl-A2	ERCuAl-A2
C61400	ECuAl-A2	ERCuAl-A2
C70600	ECuNi	ERCuNi
C71500	ECuNi	ERCuNi

5.4 Welding procedures and welding operators shall be qualified in accordance with the *ASME Boiler and Pressure Vessel Code*, Section IX.

5.5 Each length of pipe may contain more than one longitudinal welded joint.

5.5.1 The welded joint shall be a full-penetration weld and may have a reinforcing bead on each side; such reinforcement shall not be more than 1/16 in. (1.6 mm) per side measured in the radial direction.

5.5.2 At no place shall the thickness of the weld section be less than the thickness of the adjacent base metal.

5.5.3 The contour of the weld bead shall be smooth, having no sharp valley or groove at the weld center or edges.

5.5.4 Smooth concavity of the weld bead contour is acceptable provided the minimum weld bead thickness is not less than the thickness of the adjacent base metal.

5.5.5 Any offset of base metal edges at a weld that is within the tolerance of 10.2.7 shall be faired at a 3 to 1 minimum taper over the width of the finished weld, or if necessary, by adding additional weld metal beyond what would otherwise be the edge of the weld. Such build-up welding shall be performed in accordance with the requirements of 5.4.

5.5.6 Weld reinforcement may be removed at the option of the manufacturer or when specified by the purchaser as Supplementary Requirement S7.

5.6 Weld defects shall be repaired by removal to sound metal and rewelding. A repaired weld shall meet all requirements of an original weld.

5.7 Base metal defects such as slivers, inclusions or laps shall be repaired by removal to sound metal. Build-up welding shall be performed when such removal reduces the wall thickness below the minimum allowed by the specification. Such build-up welding shall be performed in accordance with the requirements of 5.4. The thickness of the repaired section shall meet the requirements of a welded joint.

5.8 Pipe shall be furnished in the as-welded condition (Section 3).

6. Chemical Composition

6.1 The pipe material shall conform to the chemical requirements specified in Table 1.

6.2 These specification limits do not preclude the presence of other elements. Limits for unnamed elements may be established by agreement between manufacturer or supplier and purchaser.

6.2.1 For copper alloys in which copper is specified as the remainder, copper may be taken as the difference between the sum of all the elements analyzed and 100 %.

6.2.1.1 When all the elements in Table 1 are analyzed, their sum shall be as shown in the following table.

Copper Alloy UNS No.	Copper Plus Named Elements, % min
C61300	99.8
C61400	99.5
C70600	99.5
C71500	99.5

7. Mechanical Properties

7.1 The pipe shall be capable of (Note 1) meeting the requirements of a transverse tension test, taken across any weld, as shown in Table 2. Tension specimen failure may occur in either the base metal or the weld metal.

8. Guided-Bend Test

8.1 Pipe shall be capable of (Note 1) meeting the requirements of a transverse face and root guided-bend test taken with the weld in the center of the bend specimen.

NOTE 1—The term "capable of" as used in this specification means that the test is not mandatory under the terms of this specification unless definitely specified in the purchase order; however, should subsequent testing by the procuring activity establish that the material does not meet these requirements, the material will be rejected.

8.2 After bending, the guided-bend specimens shall have no open defects exceeding 0.125 in. (3.18 mm) measured in any direction on the convex surface of the specimen except that cracks originating from the corners of the specimen shall not be considered.

9. Hydrostatic Test

9.1 Pipe shall be capable of (Note 1) withstanding, without showing weakness, defects or leakage, an internal hydrostatic pressure, determined by the following equation for thin hollow cylinders under tension, which will produce in the pipe wall a theoretical fiber stress of 7000 psi (48 MPa):

$$P = 2St/(D - 0.8t)$$

where:
P = hydrostatic pressure, psi (or MPa),
t = nominal wall thickness, in. (or mm),
D = outside diameter, in. (or mm), and
S = pipe wall fiber stress, psi (or MPa).

9.2 No pipe size need be tested at a hydrostatic pressure greater than 1000 psi (6900 kPa).

9.3 The hydrostatic leak test shall be made on each length of pipe when specified by the purchaser as Supplementary Requirement S4.

10. Dimensions and Permissible Variations

10.1 *Dimensions:*

10.1.1 Pipe diameter shall be specified as a nominal

TABLE 1 Chemical Requirements

Copper Alloy UNS Number	Composition, %										
	Copper[A]	Nickel incl Cobalt	Aluminum	Lead, max	Iron	Zinc, max	Manganese, max	Sulfur, max	Phosphorus, max	Carbon, max	Tin
C61300[B]	remainder	0.15 max	6.0–7.5	0.01	2.0–3.0	0.10	0.20	...	0.015	...	0.20–0.50
C61400	remainder	...	6.0–8.0	0.01	1.5–3.5	0.20	1.0	...	0.015	...	...
C70600	remainder	9.0–11.0	...	0.02	1.0–1.8	0.50	1.0	0.02	0.02	0.05	...
C71500	remainder	29.0–33.0	...	0.02	0.4–1.0	0.50	1.0	0.02	0.02	0.05	...

[A] Silver counting as copper.
[B] "When the product is for subsequent welding applications and is so specified by the purchaser, chromium shall be 0.05 % max, cadmium 0.05 % max, zinc 0.05 % max and zirconium 0.05 % max."

TABLE 2 Transverse Tensile Strength Requirements[A]

Copper Alloy UNS Number	Tensile Strength, min, psi (MPa)[B]
C61300	70 (485)
C61400	70 (485)
C70600	40 (275)
C71500	50 (345)

[A] See Supplementary Requirement S2.
[B] See Appendix X1.

diameter in inches as shown in Tables 3, 4, or 5.

10.1.2 Pipe wall thickness shall be that shown in Tables 3, 4, or 5 for the diameter and pressure class specified.

10.1.3 If a pipe outside diameter or wall thickness, not specified in Tables 3, 4, or 5 is desired, the diameter and the wall thickness shall be specified in decimal fractions of an inch.

10.1.4 Pipe shall be furnished in 12-ft (3.66-m) lengths unless otherwise specified.

10.1.5 Circumferential welds, of the same quality as the longitudinal welds, may be used to create pipe lengths that are ordered longer than 12 ft (3.66 m).

10.2 *Permissible Variations:*

10.2.1 *Outside Diameter*—The average outside diameter shall not vary from the specified outside diameter by more than the tolerances specified in Table 6.

10.2.2 *Roundness*—The difference between the major and minor outside diameter at any pipe cross section shall not be greater than the differences specified in Table 7.

10.2.3 *Wall Thickness*—The wall thickness at any point of the pipe shall not vary from the specified wall thickness by more than the tolerances specified in Table 8.

10.2.4 *Length*—The length of any pipe shall be the specified length plus or minus 0.500 in. (13 mm).

10.2.5 *Straightness*—The maximum curvature (depth of arc), when measured as a deviation from a straightedge 10 ft (3.05 m) in length, shall not exceed 0.5 in. (13 mm).

10.2.6 *Squareness of Cut*—The departure from squareness of the end of any pipe shall not exceed 0.016 in./in. (0.016 mm/mm) of outside diameter.

10.2.7 *Offset*—Radial misalignment of two edges to be butt welded shall not exceed the offset tolerances specified in Table 9.

11. Workmanship, Finish, and Appearance

11.1 Roundness, straightness, ovality, uniformity of contour, and condition of the inner and outer surfaces of the pipe shall be such as to make it suitable for the intended application.

TABLE 3 Standard Sizes and Wall Thickness
Copper Alloy UNS Nos. C61300 and C61400

Inch-Pound Units, Thickness, in.						
Diameter, in.		Pressure Class, psi[A]				
Nominal	Outside	50	75	100	150	200
4	4.50	0.094	0.094	0.094	0.094	0.094
5	5.563	0.094	0.094	0.094	0.094	0.094
6	6.625	0.094	0.094	0.094	0.094	0.094
8	8.625	0.094	0.094	0.094	0.094	0.094
10	10.75	0.094	0.094	0.094	0.125	0.125
12	12.75	0.094	0.094	0.094	0.125	0.165
14	14.00	0.125	0.125	0.125	0.125	0.165
16	16.00	0.125	0.125	0.125	0.134	0.187
18	18.00	0.125	0.125	0.125	0.165	0.187
20	20.00	0.125	0.125	0.125	0.165	0.250
24	24.00	0.125	0.125	0.134	0.187	0.250
30	30.00	0.134	0.134	0.165	0.250	0.312
36	36.00	0.134	0.165	0.187	0.312	0.375
42	42.00	0.187	0.187	0.250	0.312	0.437
48	48.00	0.187	0.187	0.250	0.375	0.437
SI Units, Thickness, mm						
Diameter, in.		Pressure Class, kPa[A]				
Nominal	Outside	345	517	689	1034	1379
4	4.50	2.38	2.38	2.38	2.38	2.38
5	5.563	2.38	2.38	2.38	2.38	2.38
6	6.625	2.38	2.38	2.38	2.38	2.38
8	8.625	2.38	2.38	2.38	2.38	2.38
10	10.75	2.38	2.38	2.38	3.18	3.18
12	12.75	2.38	2.38	2.38	3.18	4.19
14	14.00	3.18	3.18	3.18	3.18	4.19
16	16.00	3.18	3.18	3.18	3.40	4.76
18	18.00	3.18	3.18	3.18	4.19	4.76
20	20.00	3.18	3.18	3.18	4.76	6.35
24	24.00	3.18	3.18	3.40	4.76	6.35
30	30.00	3.40	3.40	4.19	6.35	7.94
36	36.00	3.40	4.19	4.76	7.94	9.53
42	42.00	4.76	4.76	6.35	7.94	11.1
48	48.00	4.76	4.76	6.35	9.53	11.1

[A] Pressure ratings apply to any design temperature not exceeding 350°F (176°C). Pressure ratings are calculated for each size and pressure class based on a corrosion allowance of 0.020 in. (0.508 mm), a weld efficiency of 70 %, and the thickness tolerances shown in Table 8.

11.2 Pipe shall be free of all imperfections not consistent with best commercial practice. Repaired areas conforming to 5.7 shall be acceptable.

12. Sampling

12.1 When Supplementary Requirements are specified, the lot size, portion size, and selection of samples shall be as follows:

TABLE 4 Standard Sizes and Wall Thickness
Copper Alloy UNS No. C70600

Inch-Pound Units, Thickness, in.						
Diameter, in.		Pressure Class, psi[A]				
Nominal	Outside	50	75	100	150	200
4	4.50	0.094	0.094	0.094	0.094	0.109
5	5.563	0.094	0.094	0.094	0.094	0.125
6	6.625	0.094	0.094	0.094	0.109	0.134
8	8.625	0.094	0.094	0.094	0.148	0.165
10	10.75	0.094	0.094	0.125	0.165	0.250
12	12.75	0.094	0.125	0.134	0.187	0.250
14	14.00	0.125	0.125	0.148	0.250	0.250
16	16.00	0.125	0.125	0.165	0.250	0.312
18	18.00	0.125	0.148	0.187	0.250	0.312
20	20.00	0.125	0.148	0.187	0.312	0.375
24	24.00	0.134	0.187	0.250	0.312	0.437
30	30.00	0.148	0.250	0.312	0.437	0.500
36	36.00	0.187	0.250	0.312	0.500	0.625
42	42.00	0.250	0.312	0.375	0.562	0.687
48	48.00	0.250	0.312	0.437	0.625	0.812
SI Units Thickness, mm						
Diameter, in.		Pressure Class, kPa[A]				
Nominal	Outside	345	517	689	1034	1379
4	4.50	2.38	2.38	2.38	2.38	2.77
5	5.563	2.38	2.38	2.38	2.38	3.18
6	6.625	2.38	2.38	2.38	2.77	3.40
8	8.625	2.38	2.38	2.38	3.76	4.19
10	10.75	2.38	2.38	3.18	4.19	6.35
12	12.75	2.38	3.18	3.40	4.76	6.35
14	14.00	3.18	3.18	3.76	6.35	6.35
16	16.00	3.18	3.18	4.19	6.35	7.94
18	18.00	3.18	3.76	4.76	6.35	7.94
20	20.00	3.18	3.76	4.76	7.94	9.53
24	24.00	3.40	4.76	6.35	7.94	11.1
30	30.00	3.76	6.35	7.94	11.1	12.7
36	36.00	4.76	6.35	7.94	12.7	15.9
42	42.00	6.35	7.94	9.53	14.3	17.5
48	48.00	6.35	7.94	11.1	15.9	20.6

[A] Pressure ratings apply to any design temperature not exceeding 150°F (65°C). Pressure ratings are calculated for each size and pressure class based on a corrosion allowance of 0.020 in. (0.508 mm), a weld efficiency of 70 %, and the thickness tolerances shown in Table 8.

TABLE 5 Standard Sizes and Wall Thicknesses
Copper Alloy UNS No. C71500

Inch-Pound Units, Thickness, in.						
Diameter, in.		Pressure Class, psi[A]				
Nominal	Outside	50	75	100	150	200
4	4.50	0.094	0.094	0.094	0.094	0.094
5	5.563	0.094	0.094	0.094	0.094	0.109
6	6.625	0.094	0.094	0.094	0.094	0.125
8	8.625	0.094	0.094	0.094	0.125	0.148
10	10.75	0.094	0.094	0.125	0.148	0.165
12	12.75	0.094	0.094	0.125	0.165	0.250
14	14.00	0.125	0.125	0.125	0.187	0.250
16	16.00	0.125	0.125	0.148	0.187	0.250
18	18.00	0.125	0.125	0.165	0.250	0.312
20	20.00	0.125	0.134	0.165	0.250	0.312
24	24.00	0.125	0.165	0.187	0.312	0.375
30	30.00	0.134	0.187	0.250	0.375	0.437
36	36.00	0.165	0.250	0.312	0.437	0.500
42	42.00	0.187	0.250	0.312	0.437	0.625
48	48.00	0.187	0.312	0.375	0.500	0.687
SI Units, Thickness, mm						
Diameter, in.		Pressure Class, kPa[A]				
Nominal	Outside	345	517	689	1034	1379
4	4.50	2.38	2.38	2.38	2.38	2.38
5	5.563	2.38	2.38	2.38	2.38	2.77
6	6.625	2.38	2.38	2.38	2.38	3.18
8	8.625	2.38	2.38	2.38	3.18	3.76
10	10.75	2.38	2.38	3.18	3.76	4.19
12	12.75	2.38	2.38	3.18	4.19	6.35
14	14.00	3.18	3.18	3.18	4.76	6.35
16	16.00	3.18	3.18	3.76	4.76	6.35
18	18.00	3.18	3.18	4.19	6.35	7.94
20	20.00	3.18	3.40	4.19	6.35	7.94
24	24.00	3.18	4.19	4.76	7.94	9.53
30	30.00	3.40	4.76	6.35	9.53	11.1
36	36.00	4.19	6.35	7.94	11.1	12.7
42	42.00	4.76	6.35	7.94	11.1	15.9
48	48.00	4.76	7.94	9.53	12.7	17.5

[A] Pressure ratings apply to any design temperature not exceeding 150°F (65°C). Pressure ratings are calculated for each size and pressure class based on a corrosion allowance of 0.020 in. (0.508 mm), a weld efficiency of 70 %, and the thickness tolerances shown in Table 8.

12.1.1 *Lot Size*—A lot shall consist of the following quantity, or fraction thereof, of pipe of the same diameter and wall thickness manufactured at the same time:

Outside Diameter, in. (mm)	Lot Size, ft (m)
Up to 10.750 (273), incl	1000 (305)
Over 10.75 to 24 (273 to 610), incl	500 (152)
Over 24 to 36 (610 to 914), incl	200 (61.0)
Over 36 to 48 (914 to 1220), incl	100 (30.5)
Over 48 (1220)	50 (15.2)

12.1.2 *Portion Size*—When a Supplementary Requirement specifies that the number of lengths of pipe to be tested is based on a "per lot" basis, the portion size shall be determined from 12.1.1 and the Supplementary Requirement. Otherwise, the portion size shall be as stated directly in each Supplementary Requirement.

12.1.3 *Selection of Samples*—When more than one length of pipe is required to be used for a specific test, each sample shall be taken from a separate length of pipe.

TABLE 6 Average Outside Diameter[A] Tolerances, in. (mm)

Specified Outside Diameter	Tolerance, plus and minus
Up to 8.625 (219), incl	0.031 (0.79)
Over 8.625 to 18 (219 to 457), incl	0.063 (1.6)
Over 18 to 30 (457 to 762), incl	0.094 (2.4)
Over 30 to 48 (762 to 1220), incl	0.125 (3.2)
Over 48 (1220)	0.3 %

[A] The average outside diameter of a pipe is the outside circumference at any one cross section of the pipe divided by 3.1416.

TABLE 7 Roundness[A] Requirements

Specified Outside Diameter, in. (mm)	Roundness, %[A]
Up to 8.625 (219), incl	3.0
Over 8.625 to 18 (219 to 457), incl	2.5
Over 18 to 24 (457 to 610), incl	2.0
Over 24 to 48 (610 to 1220), incl	1.5
Over 48 (1220)	1.0

[A] The roundness of a pipe is the difference between the major and minor outside pipe diameter, as determined at any one cross section, divided by the specified outside diameter and expressed in percent.

13. Number of Tests and Retests

13.1 *Chemical Analysis*—When chemical analysis is required by Supplementary Requirement S1, samples for chemical analysis shall be taken in accordance with Practice E 55. Drillings, millings, etc., shall be taken in approximately equal weight from each of the sample pieces selected in

TABLE 8 Wall Thickness Tolerances,[A] in. (mm)

Specified Wall Thickness	Tolerance, plus and minus
Up to 0.094 (2.38), incl	0.010 (0.25)
Over 0.094 to 0.134 (2.38 to 3.40), incl	0.014 (0.36)
Over 0.134 to 0.250 (3.40 to 6.35), incl	0.016 (0.41)
Over 0.250 to 0.500 (6.35 to 12.7), incl	0.023 (0.58)
Over 0.500 to 0.750 (12.7 to 19.1), incl	0.029 (0.74)
Over 0.750 to 1.000 (19.1 to 25.4), incl	0.037 (0.94)
Over 1.000 (25.4)	0.045 (1.10)

[A] Maximum deviation at any point.

TABLE 9 Weld Offset Tolerances, in. (mm)

Specified Wall Thickness (*t*)	Radial Offset Longitudinal Circumferential	
	Weld	Weld
Up to 0.125 (3.18), incl	¼ *t*	¼ *t*
Over 0.125 to 0.250 (3.18 to 6.35), incl	0.032 (0.81)	0.032 (0.81)
Over 0.250 to 0.375 (6.35 to 9.53), incl	0.047 (1.20)	0.047 (1.20)
Over 0.375 to 0.500 (9.53 to 12.7), incl	0.063 (1.60)	0.063 (1.60)
Over 0.500 to 0.750 (12.7 to 19.1), incl	0.063 (1.60)	0.094 (2.40)
Over 0.750 (19.1)	0.094 (2.40)	0.125 (3.20)

accordance with S1.1 and combined into one composite sample. The minimum weight of the composite sample that is to be divided into three equal parts shall be 150 g.

13.2 *Other Tests*—For other tests, test specimens shall be taken from the number of lengths of pipe as required by 12.1.2 and 12.1.3.

13.3 *Retests:*

13.3.1 If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

13.3.2 If the results of any test made to determine chemical analysis or mechanical properties fail to meet the specified limits, this test shall be repeated on each of two additional specimens taken from different pieces within the same lot and the results of both of these tests shall comply with the specified requirements.

14. Test Specimens

14.1 Tension test specimens shall conform to the requirements of Test Specimens section and Fig. 15, Standard Tension Test Specimen for Cast Iron, of Methods E 8.

14.2 Tension test results on material covered by this specification are not seriously affected by variations in speed of testing. A considerable range of testing speed is permissible; however, the rate of stressing to the yield strength should not exceed 100 000 psi/min (11.49 MPa/s). Above the yield strength, the movement per minute of the testing machine head under load should not exceed 0.5 in./in. (0.5 mm/mm) of gage length (or distance between grips for full-section specimens).

15. Test Methods

15.1 The properties enumerated in this specification shall, in case of disagreement, be determined in accordance with the following applicable ASTM methods:

Test	ASTM Designation[A]
Chemical Analysis	E 54 or E 75
Tension Test	E 8
Guided-Bent Test	E 190

[A] See Section 2 of this specification.

16. Significance of Numerical Limits

16.1 For purposes of determining compliance with the specified limits for requirements of the properties listed in the following table, an observed value or a calculated value shall be rounded as indicated in accordance with the rounding method of Recommended Practice E 29.

Property	Rounded Unit for Observed or Calculated Value
Chemical composition	nearest unit in the last right-hand place of figures of the specified limit
Tensile strength	nearest 1 ksi (nearest 5 MPa)

17. Inspection

17.1 The manufacturer shall inspect and make necessary tests to verify that the pipe furnished conforms to the requirements of this specification.

17.2 If in addition the purchaser elects to perform his own inspection, the manufacturer shall afford the inspector all reasonable facilities to satisfy him that the pipe furnished conforms to the requirements of this specification. All tests and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere with the operation of the works. When automated finishing and inspection equipment is available at a facility, purchaser and manufacturer or supplier may by mutual agreement accomplish the final inspection simultaneously.

18. Rejection and Rehearing

18.1 Material that fails to conform to the requirements of this specification may be rejected. Rejection should be reported to the manufacturer or supplier promptly and in writing. In case of dissatisfaction with the results of the test the manufacturer or supplier may make claim for a rehearing.

18.2 Radiographic or liquid penetrant examination performed by the purchaser shall not be a basis for rejection unless those examinations were specified as supplementary requirements at the time of ordering.

19. Certification

19.1 When specified on the purchase order, the manufacturer shall furnish to the purchaser a certificate stating that each lot has been sampled, tested, and inspected in accordance with this specification and has met the requirements herein.

19.2 When material is specified to meet the requirements of *ASME Boiler and Pressure Vessel Code*, the certification requirement of 19.1 is mandatory.

20. Mill Test Report

20.1 When specified on the purchase order, the manufacturer shall furnish to the purchaser a test report showing results of tests required by the specification.

21. Packaging and Package Marking

21.1 Pipe shall be prepared for shipment in such manner as to ensure acceptance by common carrier for transportation and to afford protection from the normal hazards of transportation.

21.2 Each length of pipe shall be marked with the specification number, copper alloy number, nominal size

sure class, and the name or trademark of the manufac-

1.2.1 If a nonstandard size or wall thickness has been specified, the marking shall contain the exact outside diameter and wall thickness in inches instead of the nominal diameter and pressure class.

SUPPLEMENTARY REQUIREMENTS FOR PIPE REQUIRING SPECIAL CONSIDERATION

Supplementary requirements shall not apply unless specified in the order, in which event, the specified tests shall be made by the manufacturer as a part of the order.

Chemical Analysis

1.1 A chemical analysis shall be made from one length of representing base metal. Chemical analysis shall con- to the requirements of Section 6. Lot size shall be ermined from 12.1.1.

1.2 Individual lengths failing to conform chemically to tion 6 shall be rejected. Retesting is required in accord- with 13.3.3.

Transverse Tension Test

2.1 One transverse tension test specimen per lot shall be en across the welded joint.

2.1.1 The test specimen shall be of the full thickness of base metal and shall be taken from the end of the shed pipe and flattened cold and machined to test sample nensions.

2.1.2 As an alternative, the test specimen may be taken m a test plate of the same material as the pipe which has n attached to the end of the pipe and welded as a longation of the longitudinal seam.

2.2 The tension test shall be performed in accordance h Method E 8.

2.3 The tension test shall meet the requirements of tion 7.

Transverse Guided-Bend Test

3.1 Two transverse bend test specimens shall be taken m the pipe with the welded joint in the approximate ter of the specimens.

3.1.1 The test specimens shall be of the full thickness of base metal and shall be taken from the end of the shed pipe and flattened cold and cut to test sample nensions.

3.2 Transverse guided-bend testing shall be performed in ordance with Method E 190.

3.2.1 One transverse root bend test and one transverse e bend test shall be made.

3.2.1.1 For pipe that has been welded from both sides, the inside weld surface will be considered as the weld root.

S4. Hydrostatic Test

S4.1 Each length of pipe shall be tested hydrostatically at a pressure as specified in 9.1.

S4.2 Hydrostatic pressure shall be held for sufficient time to allow examination of the entire length of a weld seam.

S4.3 This supplementary requirement is not recommended for outside diameters greater than 24 in. (610 mm).

S5. Radiographic Examination

S5.1 The number of pipe lengths to be examined by radiography shall be specified by the purchaser.

S5.2 All welded joints in any individual length of pipe shall be radiographed completely.

S5.3 Radiographic procedure and acceptance criteria shall conform to the *ASME Boiler and Pressure Vessel Code*, Section III, Division 1, or Section VIII, Division 1, as specified.

S6. Liquid Penetrant Examination

S6.1 All welded joints in all lengths of pipe shall be liquid penetrant examined to the extent specified in either S6.1.1 or S6.1.2.

S6.1.1 The outside surface of the welded joint shall be liquid penetrant examined.

S6.1.2 Both the outside and inside surfaces of the welded joint shall be liquid penetrant examined.

S6.2 Liquid penetrant examination procedure and acceptance criteria shall conform to the *ASME Boiler and Pressure Vessel Code*, Section III, Division 1, or Section VIII, Division 1, as specified.

S7. Weld Reinforcement Removal

S7.1 Weld reinforcement shall be removed completely from the inside and outside surfaces of the welded joint.

S7.1.1 Weld thickness shall not be less than as specified in 10.2.3 after removal of reinforcement.

S7.2 This requirement applies to longitudinal welds only.

Appendix D
Summary of Radiographic Test of Welds

Table D-1 - Summary of Radiographic Tests of Welds
YDP Aluminum Bronze Pipe

Weld No.	View	Diameter	Wall Thk	Date of RT 2006	Meets Qual. Req.	Fails Qual. Req.	Crack	Lack of Fusion	Incomplete Penetration	Porosity	Inclusion	Undercutting	Other	Remarks
CH1 C2	0-14	30	7/16	1-Jun		X		X						
CH1 C2	14-28	30	7/16	1-Jun	✓									
CH1 L1	0-14	30	7/16	1-Jun	✓									
CH2 L1	0-14	20	7/16	1-Jun		X			X	X				
CH3 L1	0-14	24	3/8	2-Jun		X		X		X				
CH4 C3	0-14	48	0.75	1-Jun		X				X				
CH4 C3	14-28	48	0.75	1-Jun		X				X				
CH4 L3	0-14	48	0.75	1-Jun	✓									
CH5 C1	0-14	12	7/16	2-Jun		X		X		X				
CH6 C1	0-14	18	7/16	2-Jun		X			X	X				
CH6 L2	0-14	18	7/16	2-Jun		X				X				
CH7 C1	0-14	20	7/16	1-Jun		X			X	X				
CH7 C3	10-24	20	7/16	1-Jun		X		X	X					
CH7 L1	10-24	20	7/16	1-Jun		X			X	X				
CH8 L1	0-14	20	7/16	1-Jun		X		X						
CH9 C1	10-22	20	3/8	31-May		X			X					
CH9 L1	0-14	20	3/8	31-May		X			X					
CH10 C1	52-66	30	7/16	30-May		X			X					
CH10 C1	66-80	30	7/16	30-May		X			X	X				
CH10 L1	0-14	30	7/16	30-May		X				X				
CH11 C1	0-14	30	3/8	1-Jun		X			X	X				
CH11 C1	14-28	30	3/8	1-Jun		X			X	X				
CH11 L1	0-14	30	3/8	1-Jun		X		X		X				
CH12 C1	0-14	16	3/8	1-Jun		X			X	X				
CH12 L1	0-14	16	3/8	1-Jun		X		X	X	X				
CH13	LEVEE CROSSING, NO ACCESS													
CH14	NO RADIOGRAPHY; SHEAR WAVE UT ONLY													
CH15C1	14-28	30	3/8	6-Jun		X			X	X				
CH16	NO RADIOGRAPHY (CONCRETE ENCASED); X UT WALL ONLY													
CH17 Cl	0-14	30	0.5	15-Jun		X		X		X				
CH17 C1	14-28	30	0.5	15-Jun		X		X		X				
CH18 C3	6-20	30	7/16	31-May		X				X				
CH18 C3	20-34	30	7/16	31-May		X	X		X	X				
CH18 C4	0-14	30	5/8	31-May		X		X		X				
CH18 C4	14-28	30	5/8	31-May		X		X		X				
CH18 C5	0-14	30	5/8	31-May		X		X		X				
CH18 C5	14-24	30	5/8	31-May		X		X		X				
CH18 L6	0-14	30	5/8	31-May		X				X				
CH19 C1	0-14	30	7/16	8-Jun		X		X	X	X				
CH19 C1	14-28	30	7/16	8-Jun		X		X						
CH19L2	0-14	30	7/16	8-Jun		X		X		X				

Table D-1 - Summary of Radiographic Tests of Welds
YDP Aluminum Bronze Pipe

Weld No.	View	Diameter	Wall Thk	Date of RT 2006	Meets Qual. Req.	Fails Qual. Req.	Crack	Lack of Fusion	Incomplete Penetration	Porosity	Inclusion	Undercutting	Other	Remarks
CH20 C1	0-14	16	3/8	31-May		X			X					
CH20 L1	0-14	16	3/8	31-May		X			X	X				
CH21	NO RADIOGRAPHY; SHEAR WAVE UT ONLY													
CH22 C1	0-14	24	0.375	5-Jun		X			X	X				
CH22 C1	14-28	24	0.375	5-Jun		X			X	X				
CH22 L3	0-14	24	0.375	5-Jun		X			X	X				
CH23 C4	0-14	36	9/16	6-Jun		X		X	X	X				
CH23 C4	14-28	36	9/16	6-Jun		X		X						
CH23 L5	0-14	36	9/16	6-Jun		X							X	Linear indication on base metal surface
CH24 CI	0-14	36	5/8	8-Jun		X			X	X				
CH24 CI	14-28	36	5/8	8-Jun		X			X	X				
CH24 L1	0-14	36	5/8	8-Jun		X				X				
CH25 C1	14-28	36	9/16	6-Jun		X			X	X				
CH26	NOT USED (CONCRETE ENCASED); X UT WALL ONLY													
CH27 C1	0-14	48	3/4	31-May		X			X	X	X			
CH27 C1	14-28	48	3/4	31-May		X			X	X				
CH27 L2	0-14	48	3/4	31-May	✓									
CH28 C1	6-22	20	0.375	30-May		X		X	X	X				
CH28 C1	22-36	20	0.375	30-May		X		X		X				
CH28 C1	46-0	20	0.375	30-May		X		X	X	X				
CH28 L1	0-15	20	0.375	30-May		X			X	X				
CH28 L2	0-15	20	0.375	30-May		X			X	X				
CH28 L3	0-5	20	0.375	30-May		X			X	X				
CH28 C2	55-70	24	0.5	30-May		X		X		X				
CH29 C1	0-14	12	7/16	31-May		X				X				
CH 30	LEVEE CROSSING, NO ACCESS													
CH31 C1	28-42	30	7/16	1-Jun	✓									
CH31 C1	42-56	30	7/16	1-Jun		X			X					
CH31 L1	0-14	30	7/16	1-Jun		X		X		X				
CH32 C1	62-76	30	7/16	1-Jun		X		X						
CH32 C1	76-92	30	7/16	1-Jun	✓									
CH32 L1	0-14	30	7/16	1-Jun		X			X	X				
CH32 L1	14-28	30	7/16	1-Jun		X				X				
CH33 C4	0-14	16	3/8	1-Jun		X				X				
CH33 L3	0-10	16	3/8	1-Jun		X			X					
CH33B C1	0-14	16	3/8	1-Jun		X		X	X	X				
CH33B L1	0-14	16	3/8	1-Jun		X		X						
CH34	NOT USED (REPLACED BY 33B ABOVE)													
CH35	LEVEE CROSSING, NO ACCESS													
CH36	LEVEE CROSSING, NO ACCESS													
CH37	NO RADIOGRAPHY; CONCRETE ENCASED													

Table D-1 - Summary of Radiographic Tests of Welds
YDP Aluminum Bronze Pipe

Weld No.	View	Diameter	Wall Thk	Date of RT 2006	Meets Qual. Req.	Fails Qual. Req.	Crack	Lack of Fusion	Incomplete Penetration	Porosity	Inclusion	Undercutting	Other	Remarks
CH38 C1	0-14	42	0.375	1-Jun		X			X	X				
CH38 C1	14-28	42	0.375	1-Jun		X			X	X				
CH38 L1	0-14	42	0.375	1-Jun		X		X						
CH39A L1	0-14	54	3/8	7-Jun	✓									
CH39A L1	14-28	54	3/8	7-Jun	✓									
CH39A L2	0-8	54	3/8	7-Jun		X		X						
CH39A L3	0-14	54	3/8	7-Jun		X			X	X				
CH39B C1	0-14	54	3/8	8-Jun		X	X	X	X	X				
CH39B C1	14-28	54	3/8	8-Jun		X	X	X	X	X				
CH39B C2	0-14	54	3/8	8-Jun		X	X	X	X	X				
CH39B C2	14-28	54	3/8	8-Jun		X	X	X	X	X				
CH40 C1	4-8	3	0.375	30-May		X				X				
CH40 C1	8-0	3	0.375	30-May	✓									
CH41CI	0-4	3.5		5-Jun		X		X						
CH42 C1	0-14	30	0.375	2-Jun		X			X	X				
CH42 C1	14-28	30	0.375	2-Jun		X			X	X				
CH42 C2	0-14	30	0.375	2-Jun	✓									
CH42 C2	14-28	30	0.375	2-Jun		X	X		X					
CH42 L2	0-14	30	0.375	2-Jun		X			X					
CH42 C2	0-14	30	0.375	2-Jun	✓									
CH43 L1	0-14	30	0.25	15-Jun		X			X	X				
CH44L1	0-14	24	0.375	5-Jun		X		X						
CH44L1	14-28	24	0.375	5-Jun		X		X						
CH45 C5	24-0	10	3/8	31-May		X	X							
CH45 C6	0-12	10	3/8	31-May		X		X						
CH45 C6	22-34	10	3/8	31-May		X			X					
CH46A C1	0-11	12	1/2	31-May		X			X					
CH46B T1	0-8	12	0.375	31-May		X				X				
CH46B T2	0-8	12	0.375	31-May		X				X				
CH47 C1	42-56	30	3/8	30-May		X		X	X	X				
CH47 C1	56-70	30	3/8	30-May		X	X	X	X	X				
CH47 C2	8-22	24	3/8	30-May		X	X	X	X	X				
CH47 L1	0-14	24	3/8	30-May		X			X	X				
CH47 L2	0-16	24	3/8	30-May		X			X					
CH48 C1	0-14	20	3/8	31-May		X			X					
CH48 C2	4-18	14	3/8	31-May		X			X	X			X	LACK OF FILL
CH48 L2	0-8	14	3/8	31-May		X			X	X				

Table D-1 - Summary of Radiographic Tests of Welds
YDP Aluminum Bronze Pipe

Weld No.	View	Diameter	Wall Thk	Date of RT 2006	Meets Qual. Req.	Fails Qual. Req.	Crack	Lack of Fusion	Incomplete Penetration	Porosity	Inclusion	Undercutting	Other	Remarks
CH49 C1	14-28	30	3/8	31-May		X			X					
CH49 C1	28-42	30	3/8	31-May		X		X						
CH49 L1	20-36	30	3/8	31-May		X			X					
CH49 L1	36-50	30	3/8	31-May	✓									(VERIFY)
CH50 C1	0-14	16	3/8	31-May		X			X	X				
CH50 L1	0-14	16	3/8	31-May		X			X	X				
CH51 C1	0-14	54	3/8	6-Jun		X		X						
CH51 C1	14-28	54	3/8	6-Jun		X			X	X				
CH51 L1	0-14	54	3/8	6-Jun		X		X						
CH52 C1	0-14	20	3/8	6-Jun		X	X	X						
CH52 C1	14-28	20	3/8	6-Jun	✓									
CH52 L1	0-14	20	3/8	6-Jun		X		X						
CH53 C1	0-14	36	3/8	6-Jun		X		X	X					
CH53 L1	0-14	36	3/8	6-Jun		X			X	X				
CH54 C1	0-14	30	5/8	7-Jun		X		X	X	X				
CH54 C1	14-28	30	5/8	7-Jun		X		X	X	X				
CH54 L1	0-14	30	5/8	7-Jun		X		X	X	X				
CH55 C1	0-14	30	7/16	7-Jun		X			X	X				
CH55 C1	14-28	30	7/16	7-Jun		X			X	X				
CH55 L1	0-14	30	7/16	7-Jun		X			X	X				
CH56 C1	0-14	16	3/8	7-Jun		X		X	X	X				
CH56 L1	0-14	16	3/8	7-Jun		X		X	X	X				
CH57 C1	0-14	30	3/8	8-Jun		X			X	X				
CH57 C1	14-28	30	3/8	8-Jun		X			X	X				
CH57 L1	0-8	30	3/8	8-Jun	✓									
COUNT					14	120	10	50	75	85	1	0	2	
Pass Rate					10%	90%								
Reason for Failure							8%	42%	63%	71%				
Test Piece (panels cut for metallography)														
C1	0-14	18	3/8	7-Jun		X	X		X					
L1	0-14	18	3/8	7-Jun		X			X	X				
C3	0-12	18	3/8	7-Jun		X		X	X	X				
Abbreviations and notes														
CH = CH2M HILL test section (numbered 1-x)														
C = Circumference weld (numbered 1-x in test section)														
L = Longitudinal weld (numbered 1-x in test section)														
View = length of radiographed weld in inches														
Data taken from Phoenix National Laboratories radiographic analysis reports														

Appendix E
ASME B31.3—Chapter IV Inspection, Examination, and Testing

Chapter VI
Inspection, Examination, and Testing

340 INSPECTION

340.1 General

This Code distinguishes between examination (see para. 341) and inspection. Inspection applies to functions performed for the owner by the owner's Inspector or the Inspector's delegates. References in this Code to the "Inspector" are to the owner's Inspector or the Inspector's delegates.

340.2 Responsibility for Inspection

It is the owner's responsibility, exercised through the owner's Inspector, to verify that all required examinations and testing have been completed and to inspect the piping to the extent necessary to be satisfied that it conforms to all applicable examination requirements of the Code and of the engineering design.

340.3 Rights of the Owner's Inspector

The owner's Inspector and the Inspector's delegates shall have access to any place where work concerned with the piping installation is being performed. This includes manufacture, fabrication, heat treatment, assembly, erection, examination, and testing of the piping. They shall have the right to audit any examination, to inspect the piping using any examination method specified by the engineering design, and to review all certifications and records necessary to satisfy the owner's responsibility stated in para. 340.2.

340.4 Qualifications of the Owner's Inspector

(a) The owner's Inspector shall be designated by the owner and shall be the owner, an employee of the owner, an employee of an engineering or scientific organization, or of a recognized insurance or inspection company acting as the owner's agent. The owner's Inspector shall not represent nor be an employee of the piping manufacturer, fabricator, or erector unless the owner is also the manufacturer, fabricator, or erector.

(b) The owner's Inspector shall have not less than 10 years experience in the design, fabrication, or inspection of industrial pressure piping. Each 20% of satisfactorily completed work toward an engineering degree recognized by the Accreditation Board for Engineering and Technology (Three Park Avenue, New York, NY 10016) shall be considered equivalent to 1 year of experience, up to 5 years total.

(c) In delegating performance of inspection, the owner's Inspector is responsible for determining that a person to whom an inspection function is delegated is qualified to perform that function.

341 EXAMINATION

341.1 General

Examination applies to quality control functions performed by the manufacturer (for components only), fabricator, or erector. Reference in this Code to an examiner is to a person who performs quality control examinations.

341.2 Responsibility for Examination

Inspection does not relieve the manufacturer, the fabricator, or the erector of the responsibility for:

(a) providing materials, components, and workmanship in accordance with the requirements of this Code and of the engineering design [see para. 300(b)(3)]

(b) performing all required examinations

(c) preparing suitable records of examinations and tests for the Inspector's use

341.3 Examination Requirements

341.3.1 General. Prior to initial operation each piping installation, including components and workmanship, shall be examined in accordance with the applicable requirements of para. 341. The type and extent of any additional examination required by the engineering design, and the acceptance criteria to be applied, shall be specified. Joints not included in examinations required by para. 341.4 or by the engineering design are accepted if they pass the leak test required by para. 345.

(a) For P-Nos. 3, 4, and 5 materials, examination shall be performed after completion of any heat treatment.

(b) For a welded branch connection the examination of and any necessary repairs to the pressure containing weld shall be completed before any reinforcing pad or saddle is added.

341.3.2 Acceptance Criteria. Acceptance criteria shall be as stated in the engineering design and shall at least meet the applicable requirements stated below, in para. 344.6.2 for ultrasonic examination of welds, and elsewhere in the Code.

(a) Table 341.3.2 states acceptance criteria (limits on imperfections) for welds. See Fig. 341.3.2 for typical weld imperfections.

(b) Acceptance criteria for castings are specified in para. 302.3.3.

341.3.3 Defective Components and Workmanship. An examined item with one or more defects (imperfections of a type or magnitude exceeding the acceptance criteria of this Code) shall be repaired or replaced; and the new work shall be reexamined by the same methods, to the same extent, and by the same acceptance criteria as required for the original work.

341.3.4 Progressive Sampling for Examination. When required spot or random examination reveals a defect:

(a) two additional samples of the same kind (if welded or bonded joints, by the same welder, bonder, or operator) shall be given the same type of examination

(b) if the items examined as required by (a) above are acceptable, the defective item shall be repaired or replaced and reexamined as specified in para. 341.3.3, and all items represented by these two additional samples shall be accepted, but

(c) if any of the items examined as required by (a) above reveals a defect, two further samples of the same kind shall be examined for each defective item found by that sampling

(d) if all the items examined as required by (c) above are acceptable, the defective item(s) shall be repaired or replaced and reexamined as specified in para. 341.3.3, and all items represented by the additional sampling shall be accepted, but

(e) if any of the items examined as required by (c) above reveals a defect, all items represented by the progressive sampling shall be either:

(1) repaired or replaced and reexamined as required, or

(2) fully examined and repaired or replaced as necessary, and reexamined as necessary to meet the requirements of this Code

341.4 Extent of Required Examination

341.4.1 Examination Normally Required. Piping in Normal Fluid Service shall be examined to the extent specified herein or to any greater extent specified in the engineering design. Acceptance criteria are as stated in para. 341.3.2 and in Table 341.3.2, for Normal Fluid Service unless otherwise specified.

(a) *Visual Examination.* At least the following shall be examined in accordance with para. 344.2:

(1) sufficient materials and components, selected at random, to satisfy the examiner that they conform to specifications and are free from defects.

(2) at least 5% of fabrication. For welds, each welder's and welding operator's work shall be represented.

(3) 100% of fabrication for longitudinal welds, except those in components made in accordance with a listed specification. See para 341.5.1(a) for examination of longitudinal welds required to have a joint factor E_j of 0.90.

(4) random examination of the assembly of threaded, bolted, and other joints to satisfy the examiner that they conform to the applicable requirements of para. 335. When pneumatic testing is to be performed, all threaded, bolted, and other mechanical joints shall be examined.

(5) random examination during erection of piping, including checking of alignment, supports, and cold spring.

(6) examination of erected piping for evidence of defects that would require repair or replacement, and for other evident deviations from the intent of the design.

(b) *Other Examination*

(1) Not less than 5% of circumferential butt and miter groove welds shall be examined fully by random radiography in accordance with para. 344.5 or by random ultrasonic examination in accordance with para. 344.6. The welds to be examined shall be selected to ensure that the work product of each welder or welding operator doing the production welding is included. They shall also be selected to maximize coverage of intersections with longitudinal joints. When a circumferential weld with an intersecting longitudinal weld(s) is examined, at least the adjacent 38 mm ($1\frac{1}{2}$ in.) of each intersecting weld shall be examined. In-process examination in accordance with para. 344.7 may be substituted for all or part of the radiographic or ultrasonic examination on a weld-for-weld basis if specified in the engineering design or specifically authorized by the Inspector.

(2) Not less than 5% of all brazed joints shall be examined by in-process examination in accordance with para. 344.7, the joints to be examined being selected to ensure that the work of each brazer making the production joints is included.

(c) *Certifications and Records.* The examiner shall be assured, by examination of certifications, records, and other evidence, that the materials and components are of the specified grades and that they have received required heat treatment, examination, and testing. The examiner shall provide the Inspector with a certification that all the quality control requirements of the Code and of the engineering design have been carried out.

341.4.2 Examination — Category D Fluid Service. Piping and piping elements for Category D Fluid Service as designated in the engineering design shall be visually examined in accordance with para. 344.2 to the extent necessary to satisfy the examiner that components, materials, and workmanship conform to the requirements of this Code and the engineering design. Acceptance criteria are as stated in para. 341.3.2 and in Table

(04)

Table 341.3.2 Acceptance Criteria for Welds and Examination Methods for Evaluating Weld Imperfections

Criteria (A to M) for Types of Welds and for Service Conditions [Note (1)]										Weld Imperfection	Examination Methods			
Normal and Category M Fluid Service			Severe Cyclic Conditions			Category D Fluid Service								
Type of Weld			Type of Weld			Type of Weld								
Girth, Miter Groove & Branch Connection [Note (4)]	Longitudinal Groove [Note (2)]	Fillet [Note (3)]	Girth, Miter Groove & Branch Connection [Note (4)]	Longitudinal Groove [Note (2)]	Fillet [Note (3)]	Girth and Miter Groove	Longitudinal Groove [Note (2)]	Fillet [Note (3)]	Branch Connection [Note (4)]		Visual	Radiography	Magnetic Particle	Liquid Penetrant
A	A	A	A	A	A	A	A	A	A	Crack	✓	✓	✓	✓
A	A	A	A	A	A	C	A	N/A	A	Lack of fusion	✓	✓	. . .	. . .
B	A	N/A	A	A	N/A	C	A	N/A	B	Incomplete penetration	✓	✓	. . .	. . .
E	E	N/A	D	D	N/A	N/A	N/A	N/A	N/A	Internal porosity	. . .	✓	. . .	. . .
G	G	N/A	F	F	N/A	N/A	N/A	N/A	N/A	Internal slag inclusion, tungsten inclusion, or elongated indication	. . .	✓	. . .	. . .
H	A	H	A	A	A	I	A	H	H	Undercutting	. . .	✓	. . .	. . .
A	A	A	A	A	A	A	A	A	A	Surface porosity or exposed slag inclusion [Note (5)]	✓	. . .	. . .	. . .
N/A	N/A	N/A	J	J	J	N/A	N/A	N/A	N/A	Surface finish	✓	. . .	. . .	. . .
K	K	N/A	K	K	N/A	K	K	N/A	K	Concave root surface (suck up)	✓	✓	. . .	. . .
L	L	L	L	L	L	M	M	M	M	Weld reinforcement or internal protrusion	✓	. . .	. . .	. . .

GENERAL NOTES:

(a) Weld imperfections are evaluated by one or more of the types of examination methods given, as specified in paras. 341.4.1, 341.4.2, 341.4.3, and M341.4, or by the engineering design.

(b) "N/A" indicates the Code does not establish acceptance criteria or does not require evaluation of this kind of imperfection for this type of weld.

(c) Check (✓) indicates examination method generally used for evaluating this kind of weld imperfection.

(d) Ellipsis (. . .) indicates examination method not generally used for evaluating this kind of weld imperfection.

(04)

Criterion Value Notes for Table 341.3.2

Criterion Symbol	Criterion Measure	Acceptable Value Limits [Note (6)]
A	Extent of imperfection	Zero (no evident imperfection)
B	Depth of incomplete penetration	≤ 1 mm (1/32 in.) and ≤ $0.2\overline{T}_w$
	Cumulative length of incomplete penetration	≤ 38 mm (1.5 in.) in any 150 mm (6 in.) weld length
C	Depth of lack of fusion and incomplete penetration	≤ $0.2\overline{T}_w$
	Cumulative length of lack of fusion and incomplete penetration [Note (7)]	≤ 38 mm (1.5 in.) in any 150 mm (6 in.) weld length
D	Size and distribution of internal porosity	See BPV Code, Section VIII, Division 1, Appendix 4
E	Size and distribution of internal porosity	For $\overline{T}_w$ ≤ 6 mm (1/4 in.), limit is same as D For $\overline{T}_w$ > 6 mm (1/4 in.), limit is 1.5 × D
F	Slag inclusion, tungsten inclusion, or elongated indication	
	Individual length	≤ $\overline{T}_w/3$
	Individual width	≤ 2.5 mm (3/32 in.) and ≤ $\overline{T}_w/3$
	Cumulative length	≤ $\overline{T}_w$ in any $12\overline{T}_w$ weld length
G	Slag inclusion, tungsten inclusion, or elongated indication	
	Individual length	≤ $2\overline{T}_w$
	Individual width	≤ 3 mm (1/8 in.) and ≤ $\overline{T}_w/2$
	Cumulative length	≤ $4\overline{T}_w$ in any 150 mm (6 in.) weld length
H	Depth of undercut	≤ 1 mm (1/32 in.) and ≤ $\overline{T}_w/4$
I	Depth of undercut	≤ 1.5 mm (1/16 in.) and ≤ [$\overline{T}_w/4$ or 1 mm (1/32 in.)]
J	Surface roughness	≤ 500 min. *Ra* per ASME B46.1
K	Depth of root surface concavity	Total joint thickness, incl. weld reinf., ≥ $\overline{T}_w$
L	Height of reinforcement or internal protrusion [Note (8)] in any plane through the weld shall be within limits of the applicable height value in the tabulation at right, except as provided in Note (9). Weld metal shall merge smoothly into the component surfaces.	For $\overline{T}_w$, mm (in.) → Height, mm (in.) ≤ 6 (1/4) → ≤ 1.5 (1/16) > 6 (1/4), ≤ 13 (1/2) → ≤ 3 (1/8) > 13 (1/2), ≤ 25 (1) → ≤ 4 (5/32) > 25 (1) → ≤ 5 (3/16)
M	Height of reinforcement or internal protrusion [Note (8)] as described in L. Note (9) does not apply.	Limit is twice the value applicable for L above

Notes follow on next page

Table 341.3.2 Acceptance Criteria for Welds and Examination Methods for Evaluating Weld Imperfections (Cont'd)

NOTES:

(1) Criteria given are for required examination. More stringent criteria may be specified in the engineering design. See also paras. 341.5 and 341.5.3.

(2) Longitudinal groove weld includes straight and spiral seam. Criteria are not intended to apply to welds made in accordance with a standard listed in Table A-1 or Table 326.1. Alternative Leak Test requires examination of these welds; see para. 345.9.

(3) Fillet weld includes socket and seal welds, and attachment welds for slip-on flanges, branch reinforcement, and supports.

(4) Branch connection weld includes pressure containing welds in branches and fabricated laps.

(5) These imperfections are evaluated only for welds ≤ 5 mm ($^3/_{16}$ in.) in nominal thickness.

(6) Where two limiting values are separated by "and," the lesser of the values determines acceptance. Where two sets of values are separated by "or," the larger value is acceptable. T_w is the nominal wall thickness of the thinner of two components joined by a butt weld.

(7) Tightly butted unfused root faces are unacceptable.

(8) For groove welds, height is the lesser of the measurements made from the surfaces of the adjacent components; both reinforcement and internal protrusion are permitted in a weld. For fillet welds, height is measured from the theoretical throat, Fig. 328.5.2A; internal protrusion does not apply.

(9) For welds in aluminum alloy only, internal protrusion shall not exceed the following values:
(a) for thickness ≤ 2 mm ($^5/_{64}$ in.): 1.5 mm ($^1/_{16}$ in.);
(b) for thickness > 2 mm and ≤ 6 mm ($^1/_4$ in.): 2.5 mm ($^3/_{32}$ in.).
For external reinforcement and for greater thicknesses, see the tabulation for Symbol L.

341.3.2, for Category D fluid service, unless otherwise specified.

341.4.3 Examination — Severe Cyclic Conditions. Piping to be used under severe cyclic conditions shall be examined to the extent specified herein or to any greater extent specified in the engineering design. Acceptance criteria are as stated in para. 341.3.2 and in Table 341.3.2, for severe cyclic conditions, unless otherwise specified.

(a) Visual Examination. The requirements of para. 341.4.1(a) apply with the following exceptions.

(1) All fabrication shall be examined.

(2) All threaded, bolted, and other joints shall be examined.

(3) All piping erection shall be examined to verify dimensions and alignment. Supports, guides, and points of cold spring shall be checked to ensure that movement of the piping under all conditions of startup, operation, and shutdown will be accommodated without undue binding or unanticipated constraint.

(b) Other Examination. All circumferential butt and miter groove welds and all fabricated branch connection welds comparable to those shown in Fig. 328.5.4E shall be examined by 100% radiography in accordance with para. 344.5, or (if specified in the engineering design) by 100% ultrasonic examination in accordance with para. 344.6. Socket welds and branch connection welds which are not radiographed shall be examined by magnetic particle or liquid penetrant methods in accordance with para. 344.3 or 344.4.

(c) In-process examination in accordance with para. 344.7, supplemented by appropriate nondestructive examination, may be substituted for the examination required in (b) above on a weld-for-weld basis if specified in the engineering design or specifically authorized by the Inspector.

(d) Certification and Records. The requirements of para. 341.4.1(c) apply.

341.5 Supplementary Examination

Any of the methods of examination described in para. 344 may be specified by the engineering design to supplement the examination required by para. 341.4. The extent of supplementary examination to be performed and any acceptance criteria that differ from those in para. 341.3.2 shall be specified in the engineering design.

341.5.1 Spot Radiography

(a) Longitudinal Welds. Spot radiography for longitudinal groove welds required to have a weld joint factor E_j of 0.90 requires examination by radiography in accordance with para. 344.5 of at least 300 mm (1 ft) in each 30 m (100 ft) of weld for each welder or welding operator. Acceptance criteria are those stated in Table 341.3.2 for radiography under Normal Fluid Service.

(b) Circumferential Butt Welds and Other Welds. It is recommended that the extent of examination be not less than one shot on one in each 20 welds for each welder or welding operator. Unless otherwise specified, acceptance criteria are as stated in Table 341.3.2 for radiography under Normal Fluid Service for the type of joint examined.

(c) Progressive Sampling for Examination. The provisions of para. 341.3.4 are applicable.

(d) Welds to Be Examined. The locations of welds and the points at which they are to be examined by spot

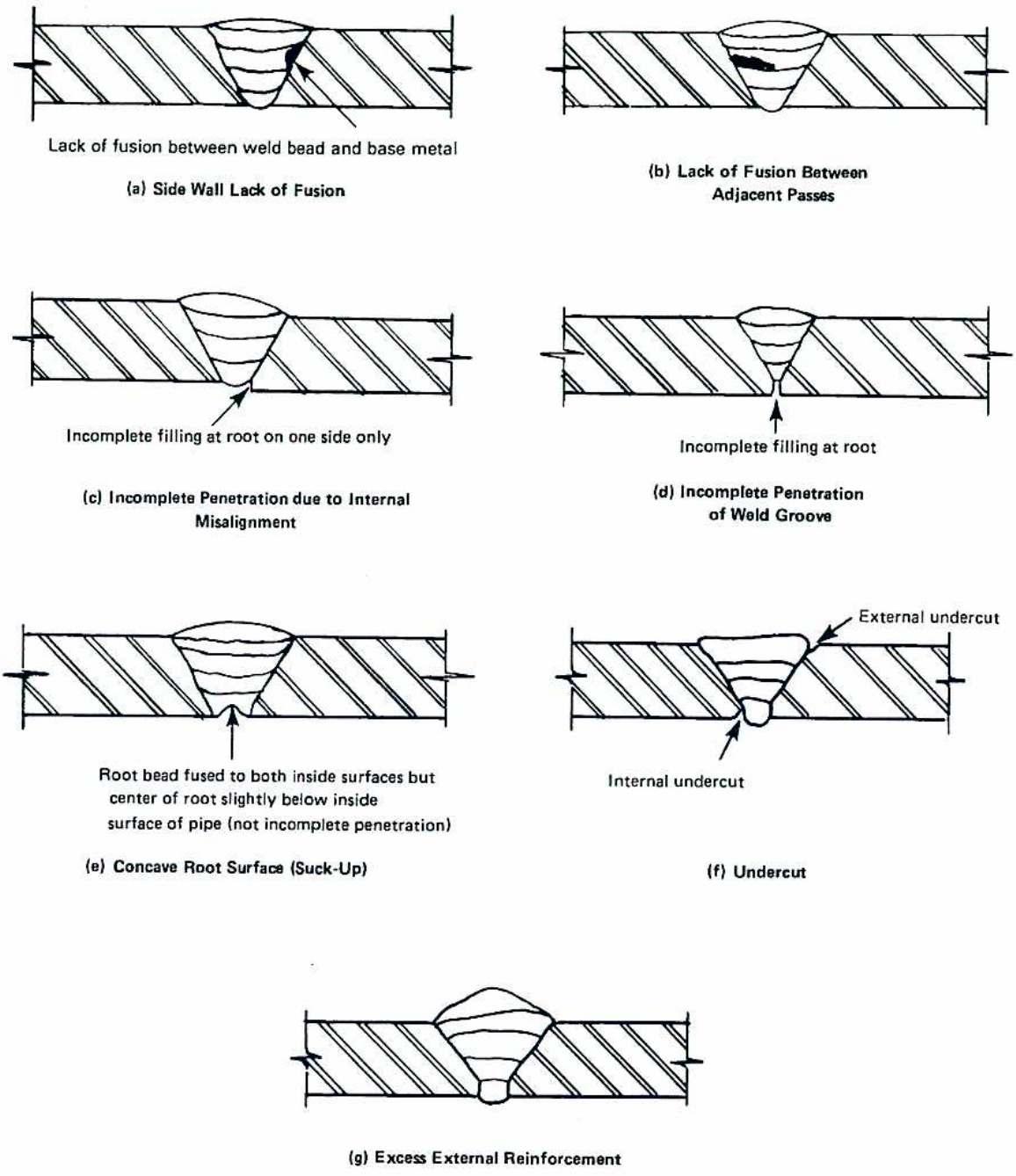


Fig. 341.3.2 Typical Weld Imperfections

radiography shall be selected or approved by the Inspector.

341.5.2 Hardness Tests. The extent of hardness testing required shall be in accordance with para. 331.1.7 except as otherwise specified in the engineering design.

341.5.3 Examinations to Resolve Uncertainty. Any method may be used to resolve doubtful indications. Acceptance criteria shall be those for the required examination.

342 EXAMINATION PERSONNEL

342.1 Personnel Qualification and Certification

Examiners shall have training and experience commensurate with the needs of the specified examinations.[1] The employer shall certify records of the examiners employed, showing dates and results of personnel qualifications, and shall maintain them and make them available to the Inspector.

342.2 Specific Requirement

For in-process examination, the examinations shall be performed by personnel other than those performing the production work.

343 EXAMINATION PROCEDURES

Any examination shall be performed in accordance with a written procedure that conforms to one of the methods specified in para. 344, including special methods (see para. 344.1.2). Procedures shall be written as required in the BPV Code, Section V, Article 1, T-150. The employer shall certify records of the examination procedures employed, showing dates and results of procedure qualifications, and shall maintain them and make them available to the Inspector.

344 TYPES OF EXAMINATION

344.1 General

344.1.1 Methods. Except as provided in para. 344.1.2, any examination required by this Code, by the engineering design, or by the Inspector shall be performed in accordance with one of the methods specified herein.

344.1.2 Special Methods. If a method not specified herein is to be used, it and its acceptance criteria shall be specified in the engineering design in enough detail to permit qualification of the necessary procedures and examiners.

[1] For this purpose, SNT-TC-1A, Recommended Practice for Nondestructive Testing Personnel Qualification and Certification, may be used as a guide.

344.1.3 Definitions. The following terms apply to any type of examination:

100% examination: complete examination of all of a specified kind of item in a designated lot of piping[2]

random examination:[3] complete examination of a percentage of a specified kind of item in a designated lot of piping[2]

spot examination:[3] a specified partial examination of each of a specified kind of item in a designated lot of piping,[2] e.g., of part of the length of all shop-fabricated welds in a lot of jacketed piping

random spot examination:[3] a specified partial examination of a percentage of a specified kind of item in a designated lot of piping[2]

344.2 Visual Examination

344.2.1 Definition. Visual examination is observation of the portion of components, joints, and other piping elements that are or can be exposed to view before, during, or after manufacture, fabrication, assembly, erection, examination, or testing. This examination includes verification of Code and engineering design requirements for materials, components, dimensions, joint preparation, alignment, welding, bonding, brazing, bolting, threading, or other joining method, supports, assembly, and erection.

344.2.2 Method. Visual examination shall be performed in accordance with the BPV Code, Section V, Article 9. Records of individual visual examinations are not required, except for those of in-process examination as specified in para. 344.7.

344.3 Magnetic Particle Examination

Examination of castings is covered in para. 302.3.3. Magnetic particle examination of welds and of components other than castings shall be performed in accordance with BPV Code, Section V, Article 7.

344.4 Liquid Penetrant Examination

Examination of castings is covered in para. 302.3.3. Liquid penetrant examination of welds and of components other than castings shall be performed in accordance with BPV Code, Section V, Article 6.

[2] A designated lot is that quantity of piping to be considered in applying the requirements for examination in this Code. The quantity or extent of a designated lot should be established by agreement between the contracting parties before the start of work. More than one kind of designated lot may be established for different kinds of piping work.

[3] Random or spot examination will not ensure a fabrication product of a prescribed quality level throughout. Items not examined in a lot of piping represented by such examination may contain defects which further examination could disclose. Specifically, if all radiographically disclosable weld defects must be eliminated from a lot of piping, 100% radiographic examination must be specified.

344.5 Radiographic Examination

344.5.1 Method. Radiography of castings is covered in para. 302.3.3. Radiography of welds and of components other than castings shall be performed in accordance with BPV Code, Section V, Article 2.

344.5.2 Extent of Radiography

(a) 100% Radiography. This applies only to girth and miter groove welds and to fabricated branch connection welds comparable to Fig. 328.5.4E, unless otherwise specified in the engineering design.

(b) Random Radiography. This applies only to girth and miter groove welds.

(c) Spot Radiography. This requires a single exposure radiograph in accordance with para. 344.5.1 at a point within a specified extent of welding. For girth, miter, and branch groove welds the minimum requirement is

(1) for sizes ≤ DN 65 (NPS 2½), a single elliptical exposure encompassing the entire weld circumference

(2) for sizes > DN 65, the lesser of 25% of the inside circumference or 152 mm (6 in.)

For longitudinal welds the minimum requirement is 152 mm (6 in.) of weld length.

344.6 Ultrasonic Examination

344.6.1 Method. Examination of castings is covered in para. 302.3.3; other product forms are not covered. Ultrasonic examination of welds shall be performed in accordance with BPV Code, Section V, Article 5, except that the alternative specified in (a) and (b) below is permitted for basic calibration blocks specified in T-542.2.1 and T-542.8.1.1.

(a) When the basic calibration blocks have not received heat treatment in accordance with T-542.1.1(c) and T-542.8.1.1, transfer methods shall be used to correlate the responses from the basic calibration block and the component. Transfer is accomplished by noting the difference between responses received from the same reference reflector in the basic calibration block and in the component and correcting for the difference.

(b) The reference reflector may be a V-notch (which must subsequently be removed), an angle beam search unit acting as a reflector, or any other reflector which will aid in accomplishing the transfer.

(c) When the transfer method is chosen as an alternative, it shall be used, at the minimum

(1) for sizes ≤ DN 50 (NPS 2), once in each 10 welded joints examined

(2) for sizes > DN 50 and ≤ DN 450 (NPS 18), once in each 1.5 m (5 ft) of welding examined

(3) for sizes > DN 450, once for each welded joint examined

(d) Each type of material and each size and wall thickness shall be considered separately in applying the transfer method. In addition, the transfer method shall be used at least twice on each type of weld joint.

(e) The reference level for monitoring discontinuities shall be modified to reflect the transfer correction when the transfer method is used.

344.6.2 Acceptance Criteria. A linear-type discontinuity is unacceptable if the amplitude of the indication exceeds the reference level and its length exceeds:

(a) 6 mm (¼ in.) for $\overline{T}_w \le 19$ mm (¾ in.)

(b) $\overline{T}_w/3$ for 19 mm < $\overline{T}_w \le 57$ mm (2¼ in.)

(c) 19 mm for $\overline{T}_w > 57$ mm

344.7 In-Process Examination

344.7.1 Definition. In-process examination comprises examination of the following, as applicable:

(a) joint preparation and cleanliness

(b) preheating

(c) fit-up, joint clearance, and internal alignment prior to joining

(d) variables specified by the joining procedure, including filler material

(1) (for welding) position and electrode

(2) (for brazing) position, flux, brazing temperature, proper wetting, and capillary action

(e) (for welding) condition of the root pass after cleaning — external and, where accessible, internal — aided by liquid penetrant or magnetic particle examination when specified in the engineering design

(f) (for welding) slag removal and weld condition between passes

(g) appearance of the finished joint

344.7.2 Method. The examination is visual, in accordance with para. 344.2, unless additional methods are specified in the engineering design.

345 TESTING

345.1 Required Leak Test

Prior to initial operation, and after completion of the applicable examinations required by para. 341, each piping system shall be tested to ensure tightness. The test shall be a hydrostatic leak test in accordance with para. 345.4 except as provided herein.

(a) At the owner's option, a piping system in Category D fluid service may be subjected to an initial service leak test in accordance with para. 345.7, in lieu of the hydrostatic leak test.

(b) Where the owner considers a hydrostatic leak test impracticable, either a pneumatic test in accordance with para. 345.5 or a combined hydrostatic-pneumatic test in accordance with para. 345.6 may be substituted, recognizing the hazard of energy stored in compressed gas.

(c) Where the owner considers both hydrostatic and pneumatic leak testing impracticable, the alternative specified in para. 345.9 may be used if both of the following conditions apply:

(1) a hydrostatic test would damage linings or internal insulation, or contaminate a process which would be hazardous, corrosive, or inoperative in the presence of moisture, or would present the danger of brittle fracture due to low metal temperature during the test; and

(2) a pneumatic test would present an undue hazard of possible release of energy stored in the system, or would present the danger of brittle fracture due to low metal temperature during the test.

345.2 General Requirements for Leak Tests

Requirements in para. 345.2 apply to more than one type of leak test.

345.2.1 Limitations on Pressure

(a) *Stress Exceeding Yield Strength.* If the test pressure would produce a nominal pressure stress or longitudinal stress in excess of yield strength at test temperature, the test pressure may be reduced to the maximum pressure that will not exceed the yield strength at test temperature. [See paras. 302.3.2(e) and (f).]

(b) *Test Fluid Expansion.* If a pressure test is to be maintained for a period of time and the test fluid in the system is subject to thermal expansion, precautions shall be taken to avoid excessive pressure.

(c) *Preliminary Pneumatic Test.* A preliminary test using air at no more than 170 kPa (25 psi) gage pressure may be made prior to hydrostatic testing to locate major leaks.

345.2.2 Other Test Requirements

(a) *Examination for Leaks.* A leak test shall be maintained for at least 10 min, and all joints and connections shall be examined for leaks.

(b) *Heat Treatment.* Leak tests shall be conducted after any heat treatment has been completed.

(c) *Low Test Temperature.* The possibility of brittle fracture shall be considered when conducting leak tests at metal temperatures near the ductile-brittle transition temperature.

345.2.3 Special Provisions for Testing

(a) *Piping Subassemblies.* Piping subassemblies may be tested either separately or as assembled piping.

(b) *Flanged Joints.* A flanged joint at which a blank is inserted to isolate other equipment during a test need not be tested.

(c) *Closure Welds.* The final weld connecting piping systems or components which have been successfully tested in accordance with para. 345 need not be leak tested provided the weld is examined in-process in accordance with para. 344.7 and passes with 100% radiographic examination in accordance with para. 344.5 or 100% ultrasonic examination in accordance with para. 344.6.

345.2.4 Externally Pressured Piping. Piping subject to external pressure shall be tested at an internal gage pressure 1.5 times the external differential pressure, but not less than 105 kPa (15 psi).

345.2.5 Jacketed Piping

(a) The internal line shall be leak tested on the basis of the internal or external design pressure, whichever is critical. This test must be performed before the jacket is completed if it is necessary to provide visual access to joints of the internal line as required by para. 345.3.1.

(b) The jacket shall be leak tested in accordance with para. 345.1 on the basis of the jacket design pressure unless otherwise specified in the engineering design.

345.2.6 Repairs or Additions After Leak Testing. If repairs or additions are made following the leak test, the affected piping shall be retested, except that for minor repairs or additions the owner may waive retest requirements when precautionary measures are taken to assure sound construction.

345.2.7 Test Records. Records shall be made of each piping system during the testing, including:

(a) date of test

(b) identification of piping system tested

(c) test fluid

(d) test pressure

(e) certification of results by examiner

These records need not be retained after completion of the test if a certification by the Inspector that the piping has satisfactorily passed pressure testing as required by this Code is retained.

345.3 Preparation for Leak Test

345.3.1 Joints Exposed. All joints, welds (including structural attachment welds to pressure-containing components), and bonds shall be left uninsulated and exposed for examination during leak testing, except that joints previously tested in accordance with this Code may be insulated or covered. All joints may be primed and painted prior to leak testing unless a sensitive leak test (para. 345.8) is required. (04)

345.3.2 Temporary Supports. Piping designed for vapor or gas shall be provided with additional temporary supports, if necessary, to support the weight of test liquid.

345.3.3 Piping With Expansion Joints

(a) An expansion joint that depends on external main anchors to restrain pressure end load shall be tested in place in the piping system.

(b) A self-restrained expansion joint previously shop-tested by the manufacturer [see Appendix X, para. X302.2.3(a)] may be excluded from the system under test, except that such expansion joints shall be installed in the system when a sensitive leak test in accordance with para. 345.8 is required.

(c) A piping system containing expansion joints shall be leak tested without temporary joint or anchor restraint at the lesser of

(1) 150 % of design pressure for a bellows-type expansion joint, or

(2) the system test pressure determined in accordance with para. 345

In no case shall a bellows-type expansion joint be subjected to a test pressure greater than the manufacturer's test pressure.

(d) When a system leak test at a pressure greater than the minimum test pressure specified in (c), or greater than 150% of the design pressure within the limitations of para. 345.2.1(a) is required, bellows-type expansion joints shall be removed from the piping system or temporary restraints shall be added to limit main anchor loads if necessary.

345.3.4 Limits of Tested Piping. Equipment which is not to be tested shall be either disconnected from the piping or isolated by blinds or other means during the test. A valve may be used provided the valve (including its closure mechanism) is suitable for the test pressure.

345.4 Hydrostatic Leak Test

(04) **345.4.1 Test Fluid.** The fluid shall be water unless there is the possibility of damage due to freezing or to adverse effects of water on the piping or the process (see para. F345.4.1). In that case another suitable nontoxic liquid may be used. If the liquid is flammable, its flash point shall be at least 49°C (120°F), and consideration shall be given to the test environment.

345.4.2 Test Pressure. Except as provided in para. 345.4.3, the hydrostatic test pressure at any point in a metallic piping system shall be as follows:

(a) not less than $1\frac{1}{2}$ times the design pressure;

(b) for design temperature above the test temperature, the minimum test pressure shall be calculated by Eq. (24), except that the value of S_T/S shall not exceed 6.5:

$$P_T = \frac{1.5\,PS_T}{S} \qquad (24)$$

where

P = internal design gage pressure
P_T = minimum test gage pressure
S = stress value at design temperature (see Table A-1)
S_T = stress value at test temperature

(c) if the test pressure as defined above would produce a nominal pressure stress or longitudinal stress in excess of the yield strength at test temperature, the test pressure may be reduced to the maximum pressure that will not exceed the yield strength at test temperature. [See paras. 302.3.2(e) and (f).] For metallic bellows expansion joints, see Appendix X, para. X302.2.3(a).

345.4.3 Hydrostatic Test of Piping With Vessels as a System [4]

(a) Where the test pressure of piping attached to a vessel is the same as or less than the test pressure for the vessel, the piping may be tested with the vessel at the piping test pressure.

(b) Where the test pressure of the piping exceeds the vessel test pressure, and it is not considered practicable to isolate the piping from the vessel, the piping and the vessel may be tested together at the vessel test pressure, provided the owner approves and the vessel test pressure is not less than 77% of the piping test pressure calculated in accordance with para. 345.4.2(b).

345.5 Pneumatic Leak Test

345.5.1 Precautions. Pneumatic testing involves the hazard of released energy stored in compressed gas. Particular care must therefore be taken to minimize the chance of brittle failure during a pneumatic leak test. Test temperature is important in this regard and must be considered when the designer chooses the material of construction. See para. 345.2.2(c) and Appendix F, para. F323.4.

345.5.2 Pressure Relief Device. A pressure relief device shall be provided, having a set pressure not higher than the test pressure plus the lesser of 345 kPa (50 psi) or 10% of the test pressure.

345.5.3 Test Fluid. The gas used as test fluid, if not air, shall be nonflammable and nontoxic.

345.5.4 Test Pressure. The test pressure shall be 110% of design pressure.

345.5.5 Procedure. The pressure shall be gradually increased until a gage pressure which is the lesser of one-half the test pressure or 170 kPa (25 psi) is attained, at which time a preliminary check shall be made, including examination of joints in accordance with para. 341.4.1(a). Thereafter, the pressure shall be gradually increased in steps until the test pressure is reached, holding the pressure at each step long enough to equalize piping strains. The pressure shall then be reduced to the design pressure before examining for leakage in accordance with para. 345.2.2(a).

345.6 Hydrostatic-Pneumatic Leak Test

If a combination hydrostatic-pneumatic leak test is used, the requirements of para. 345.5 shall be met, and the pressure in the liquid filled part of the piping shall not exceed the limits stated in para. 345.4.2.

345.7 Initial Service Leak Test

This test is applicable only to piping in Category D Fluid Service, at the owner's option. See para. 345.1(a).

[4] The provisions of para. 345.4.3 do not affect the pressure test requirements of any applicable vessel code.

345.7.1 Test Fluid. The test fluid is the service fluid.

345.7.2 Procedure. During or prior to initial operation, the pressure shall be gradually increased in steps until the operating pressure is reached, holding the pressure at each step long enough to equalize piping strains. A preliminary check shall be made as described in para. 345.5.5 if the service fluid is a gas or vapor.

345.7.3 Examination for Leaks. In lieu of para. 345.2.2(a), it is permissible to omit examination for leakage of any joints and connections previously tested in accordance with this Code.

345.8 Sensitive Leak Test

The test shall be in accordance with the Gas and Bubble Test method specified in the BPV Code, Section V, Article 10, or by another method demonstrated to have equal sensitivity. Sensitivity of the test shall be not less than 10^{-3} atm·ml/sec under test conditions.

(a) The test pressure shall be at least the lesser of 105 kPa (15 psi) gage or 25% of the design pressure.

(b) The pressure shall be gradually increased until a gage pressure the lesser of one-half the test pressure or 170 kPa (25 psi) is attained, at which time a preliminary check shall be made. Then the pressure shall be gradually increased in steps until the test pressure is reached, the pressure being held long enough at each step to equalize piping strains.

345.9 Alternative Leak Test

The following procedures and leak test method may be used only under the conditions stated in para. 345.1(c).

345.9.1 Examination of Welds. Welds, including those used in the manufacture of welded pipe and fittings, which have not been subjected to hydrostatic or pneumatic leak tests in accordance with this Code, shall be examined as follows.

(a) Circumferential, longitudinal, and spiral groove welds shall be 100% radiographed in accordance with para. 344.5 or 100% ultrasonically examined in accordance with para. 344.6.

(b) All welds, including structural attachment welds, not covered in (a) above, shall be examined using the liquid penetrant method (para. 344.4) or, for magnetic materials, the magnetic particle method (para. 344.3).

345.9.2 Flexibility Analysis. A flexibility analysis of the piping system shall have been made in accordance with the requirements of para. 319.4.2 (b), if applicable, or (c) and (d).

345.9.3 Test Method. The system shall be subjected to a sensitive leak test in accordance with para. 345.8.

346 RECORDS

346.2 Responsibility

It is the responsibility of the piping designer, the manufacturer, the fabricator, and the erector, as applicable, to prepare the records required by this Code and by the engineering design.

346.3 Retention of Records

Unless otherwise specified by the engineering design, the following records shall be retained for at least 5 years after the record is generated for the project:

(a) examination procedures

(b) examination personnel qualifications

Appendix F
Metallurgical Evaluation of Welded Pipe Samples

Preliminary Report
Metallurgical Evaluation of Welded Pipe Samples
Yuma Desalting Plant

16 August 2006

Prepared by James F. Jenkins, P.E.

Metallurgical Evaluation of Welded Pipe Samples Yuma Desalting Plant

Introduction

Three welded pipe samples were removed from a pipe section found in the “bone yard” of the Yuma desalting plant. The welded pipe samples were “repair welded” to determine if there were metallurgical problems associated with the rewelding of previously welded pipe. The repair welding consisted of both repairs of small weld defects in the original weld and “butter welding” representing the repair of a larger defect. The welding repairs were performed by YDP contractor personnel using the same techniques and materials that have been previously used to repair weld defects at the YDP.

The pipe section was cut into three pieces for shipment to the author.

The samples were marked to identify sections for metallographic analysis. The marked sections are shown in Figures 1 through 3.

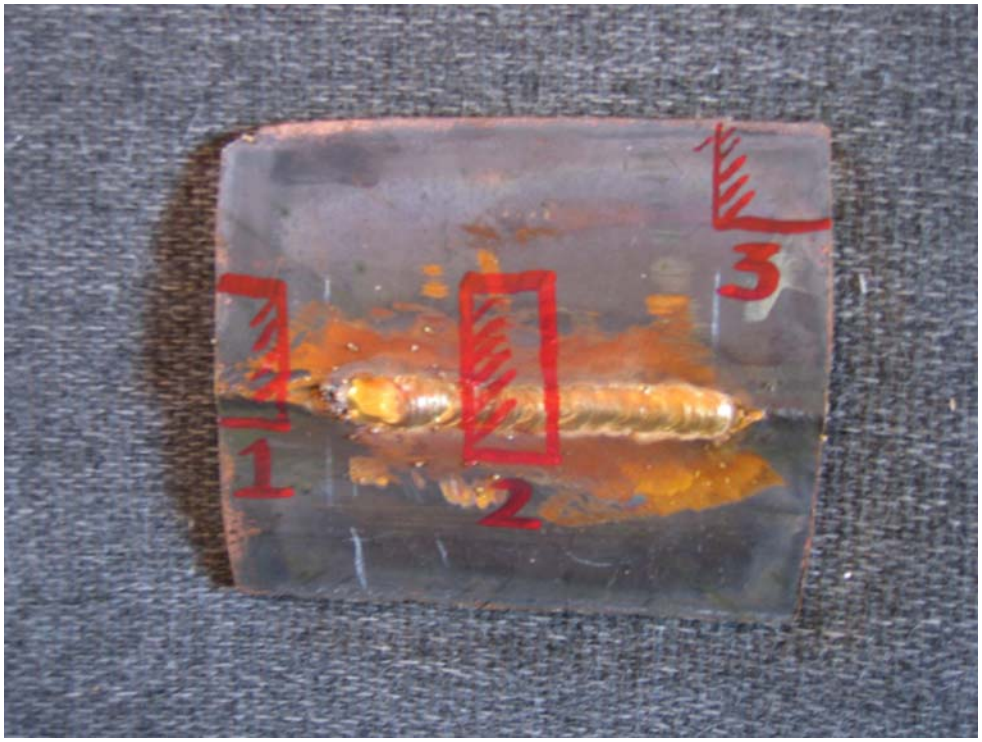


Figure 1. Pipe sample marked for metallurgical sample removal.

Figure 2. Pipe sample marked for metallurgical sample removal.

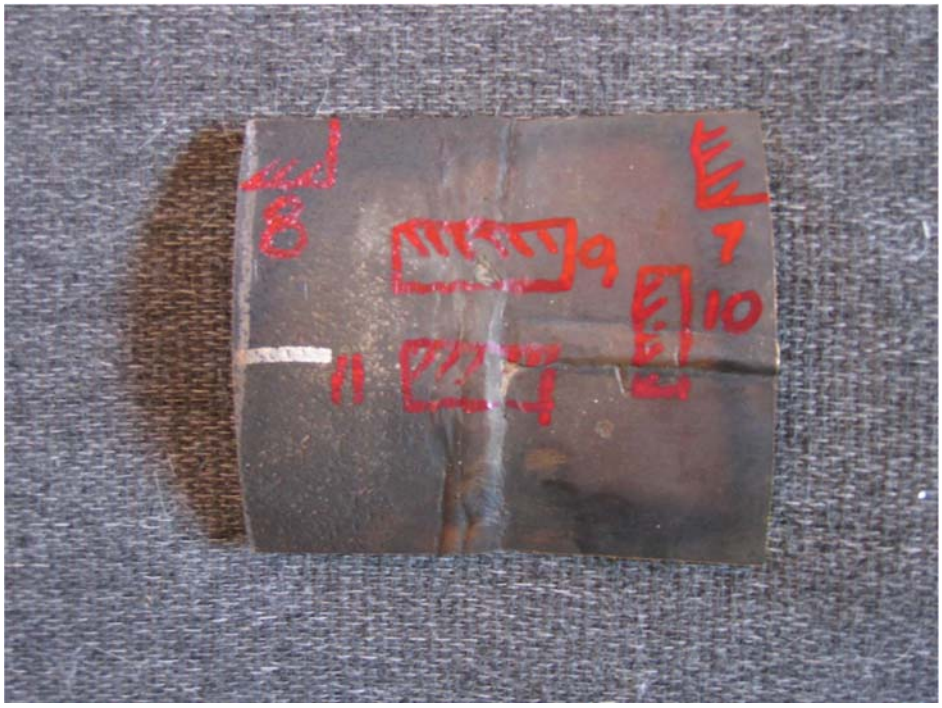


Figure 3. Pipe sample marked for metallurgical sample removal.

The metallurgical samples were removed from the pipe samples by sawing.

The situations that the metallurgical samples represent are given in Table 1.

Sample Number	Description of Situation
1	Section across original girth weld
2	Section across weld repair of original longitudinal seam weld
3	Base metal away from welds – wrought material
4	Section across weld repair of original girth weld
5	Edge of repair “butter weld” perpendicular to girth weld
6	Section of repair “butter weld” from one side of girth weld to other side of girth weld
7	Base metal (thinner material)
8	Base metal (thicker material, possibly cast)
9	Section across original girth weld at change of pipe thickness
10	Section across original girth weld, thinner material
11	Section across longitudinal weld in thinner material and girth weld between thicker and thinner material.

Note: Samples 1 – 3 are from a single pipe section
Samples 4-6 are from a single pipe section
Samples 7 – 11 are from a single pipe section

Table 1. Description of Metallographic Sample Situations

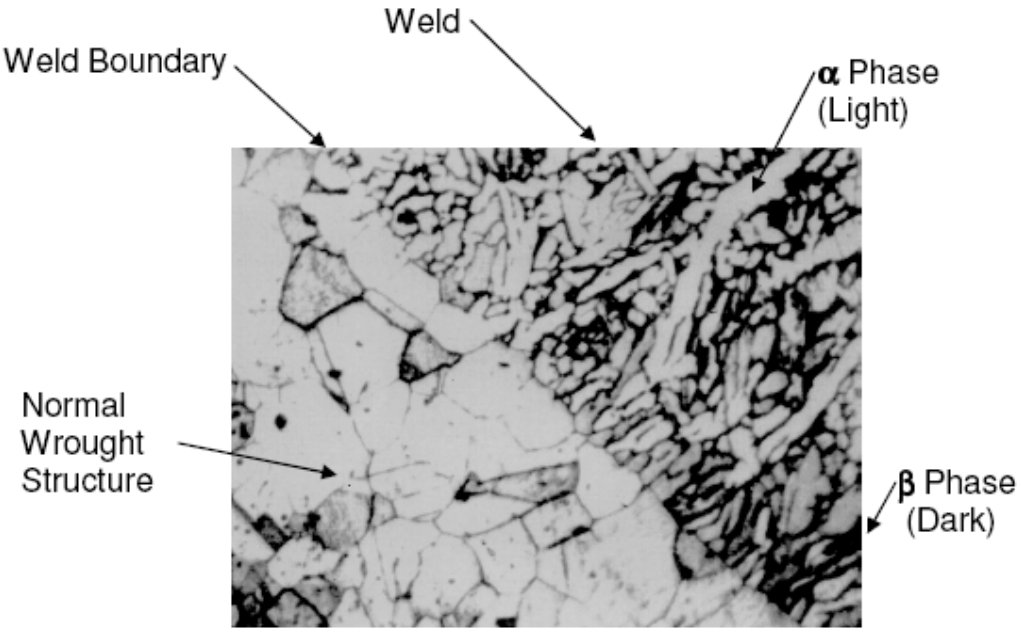
On the metallurgical samples the edge that is cross hatched indicated the surface to be polished and examined.

Examination of Metallurgical Samples

The metallurgical samples were polished using abrasive papers, six micron diamond paste and levigated alumina in accordance with standard metallographic procedures. The samples were not mounted so that the entire surface of the larger samples could be examined.

The samples were etched using Grard’s Number 1 solution (5 parts $FeCl_3$, 10 Parts HCl, 100 parts H_2O). This solution both etches the surface and darkens the ß (beta) phase of aluminum bronze if present.

The samples were examined at magnifications of 100 X and 500 X. Significant amounts of beta phase were found in only one sample that was “butter welded.” The beta phase is very brittle which does not allow for welding. Because of this, the original weld nugget should be completely removed prior to repair welding in order to eliminate the beta phase.

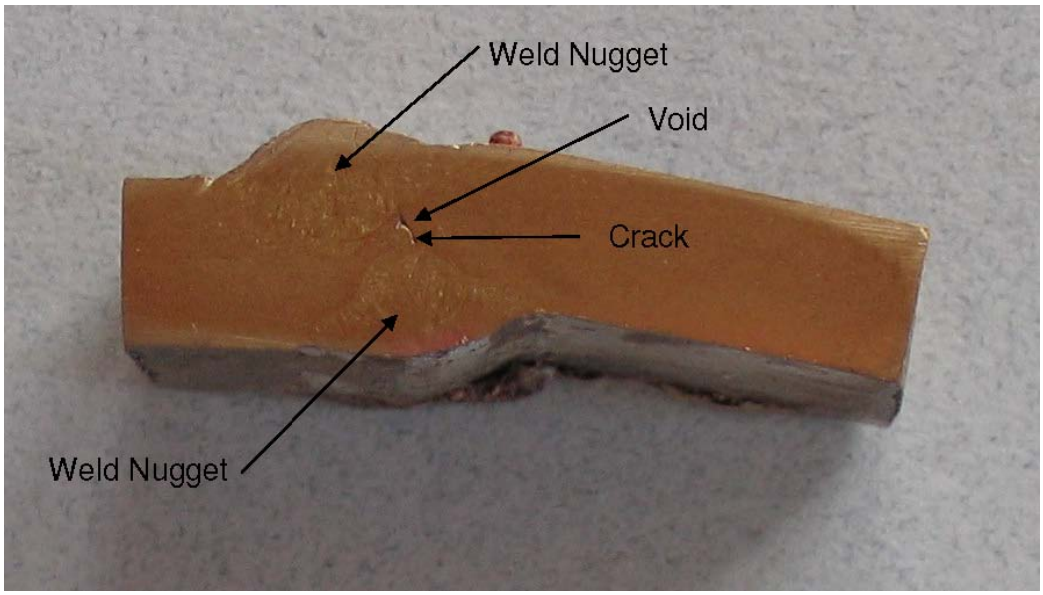


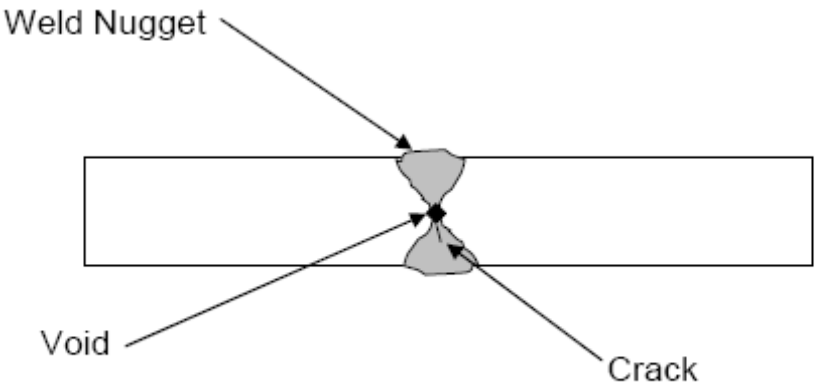
Micrograph - 500 X
Weld on Wrought Aluminum Bronze - Yuma Desalting Plant

There were significant welding defects in seven of the eight samples where welds were present. The three samples that were taken from unwelded portions of the pipe showed normal microstructure for the thinner wrought material and normal microstructure for the thicker cast material.

The weld defects included lack of fusion, incomplete penetration, cracking, and voids. There was corrosion associated with the weld defects in some samples.

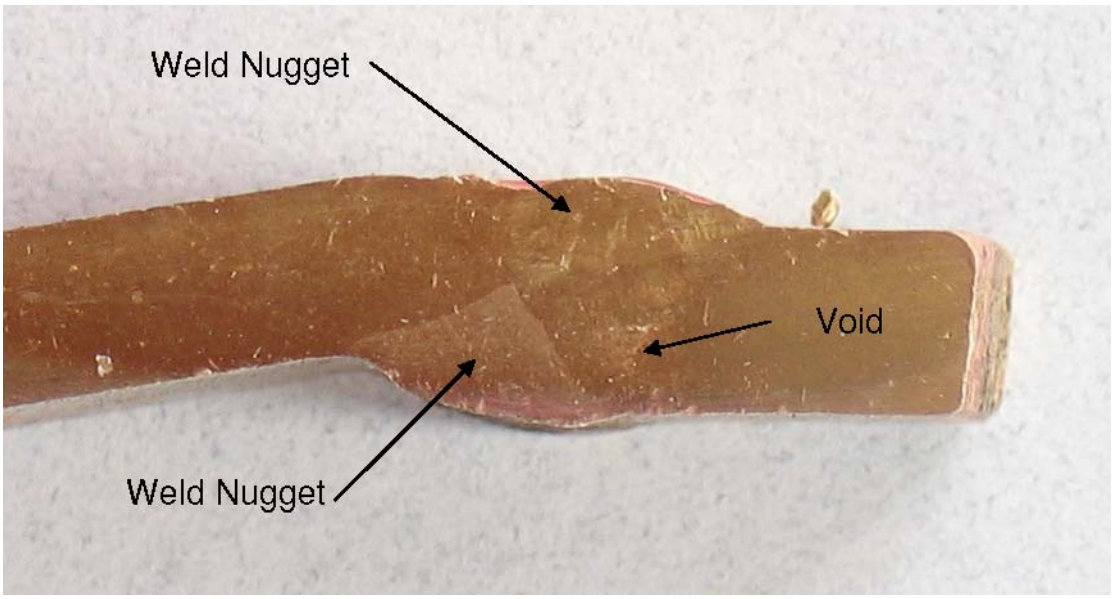
A description of the condition of the samples and photos of the weld defects are given below.

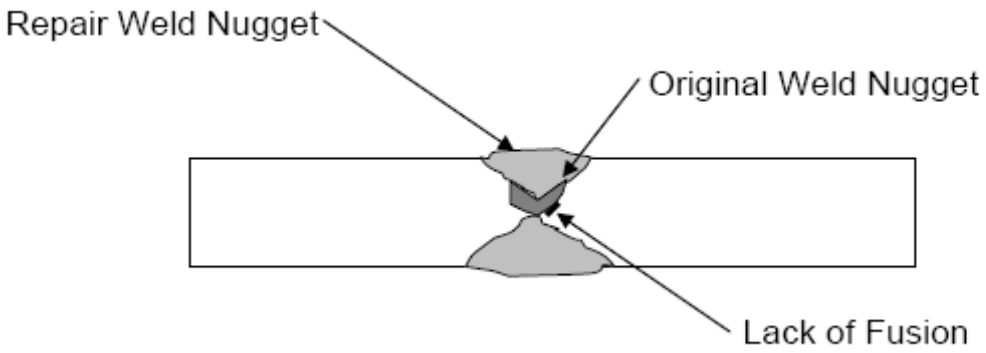




Sample #1 - Section across original girth weld.

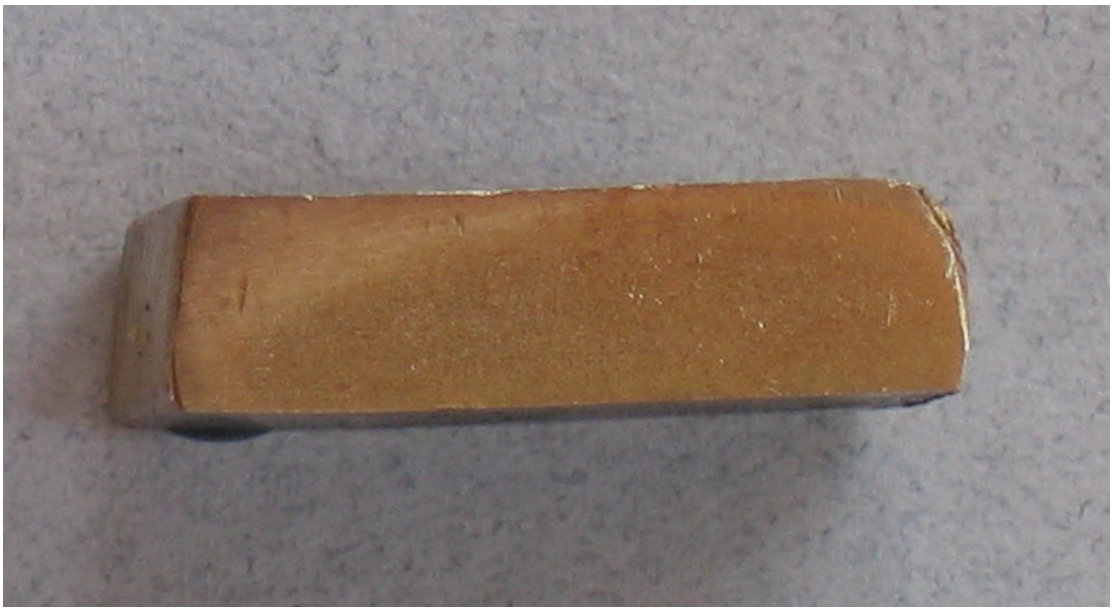
This sample exhibited lack of fusion that created a void and cracking associated with the void.





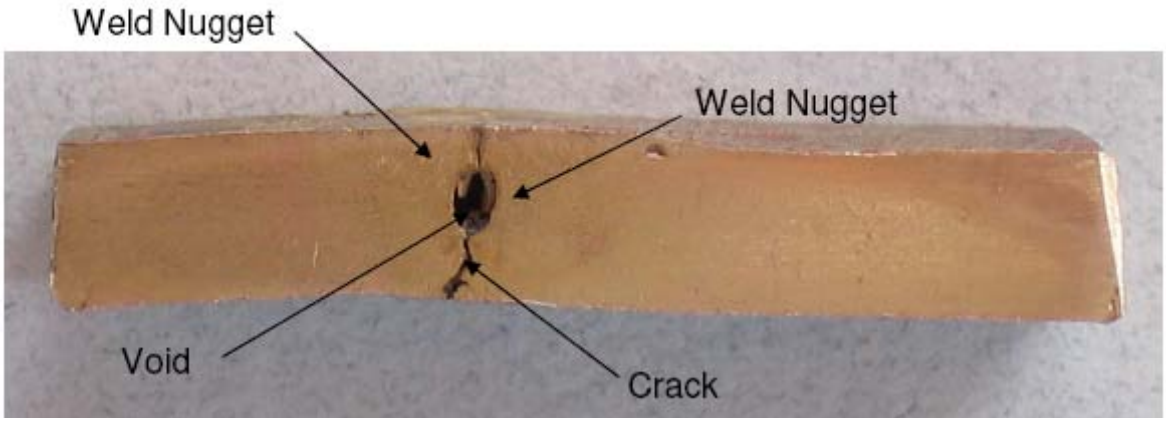
Sample #2 – Section across weld repair of original longitudinal seam weld

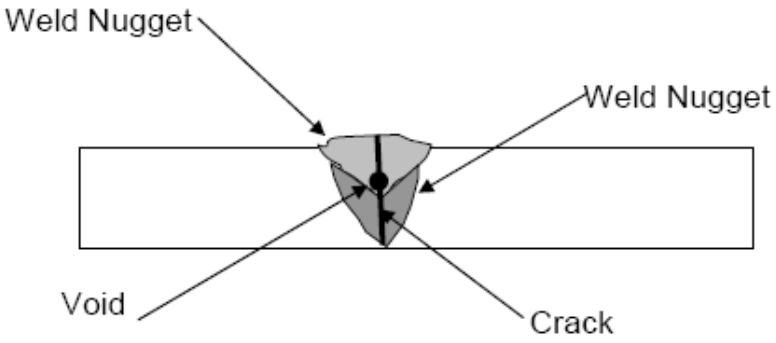
This samples exhibited lack of fusion between the original weld and the base material that was not corrected by the repair weld. The repair weld did not reach the depth of the lack of fusion



Sample #3 – Base metal away from welds – wrought material

This sample showed normal microstructure for wrought aluminum bronze.



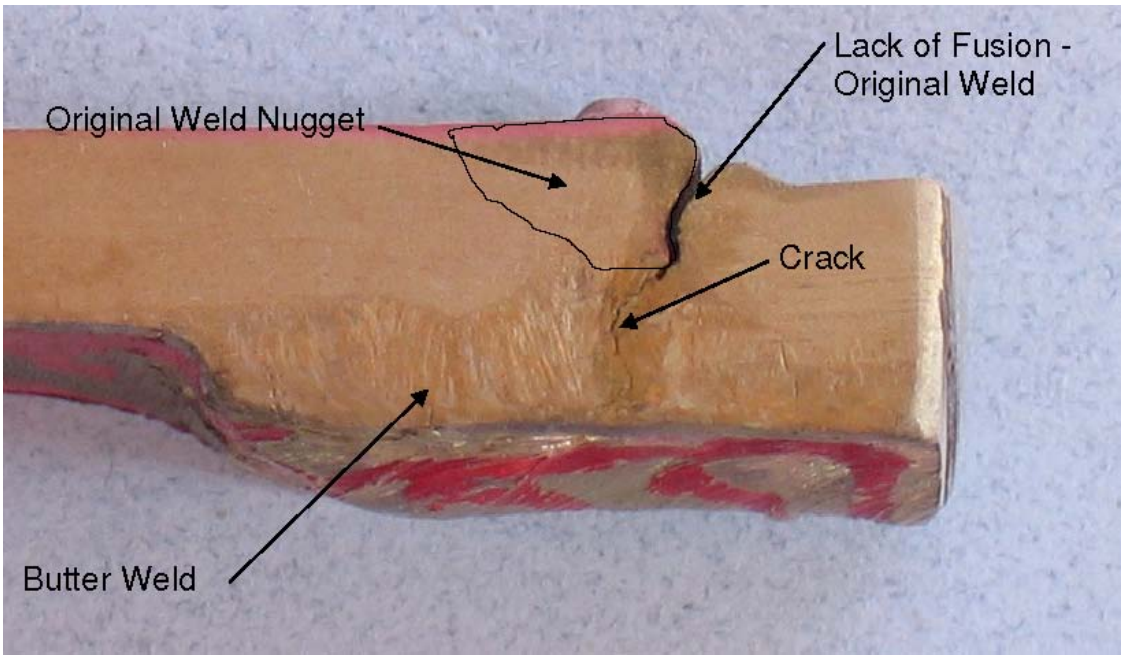


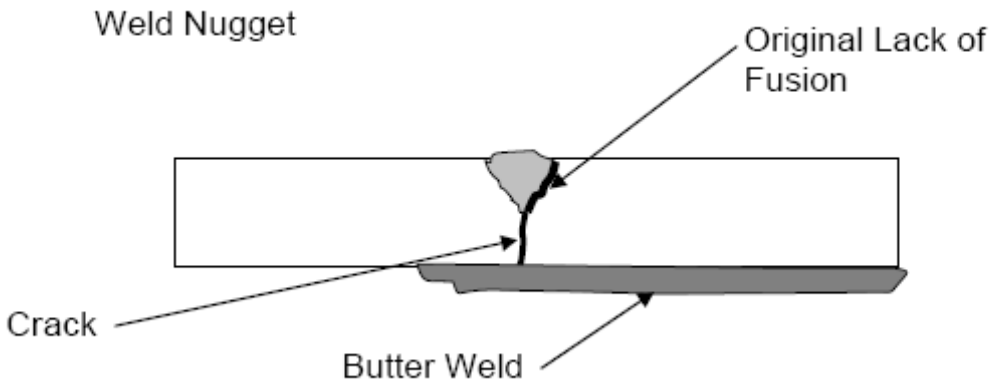
Sample #4 – Section across weld repair of original girth weld

This sample had a large void near the center of the second pass weld with a crack through the sample crossing the void.

Sample #5 – Edge of repair “butter weld” perpendicular to girth weld

This sample had no noticeable defects. There was complete fusion between the “butter weld” and the underlying material. The underlying material was not previously welded at the area sectioned.





Sample #6 – Section of repair “butter weld” from one side of girth weld to other side of girth weld

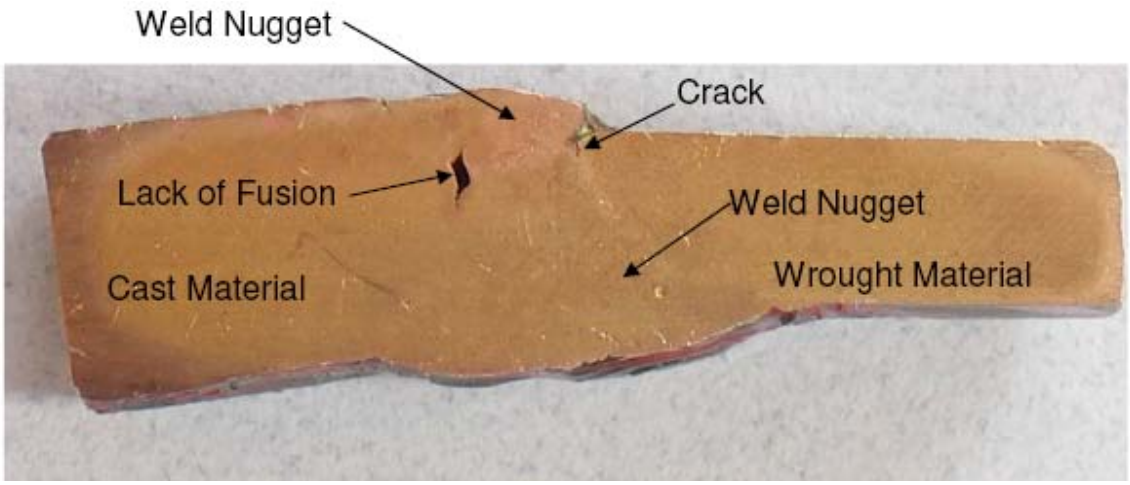
This section had lack of fusion on the original weld and a crack originating at the root of the incomplete fusion that penetrated the “butter weld” through the sample.

Sample #7 – Base metal (thinner material)

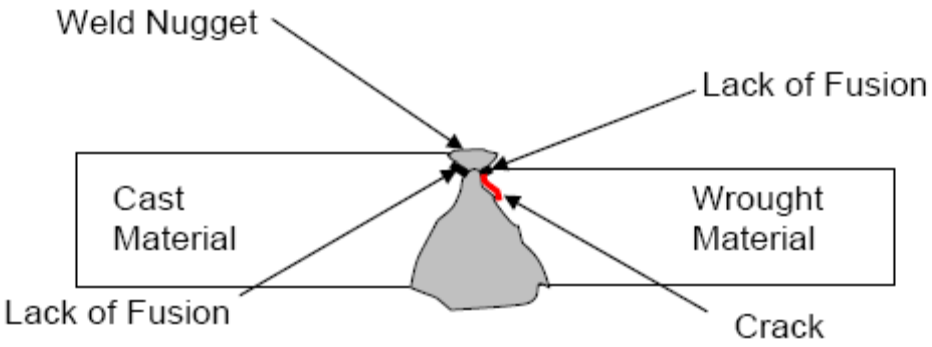
This sample showed normal microstructure for wrought aluminum bronze.

Sample #8 – Base metal (thicker material, possibly cast)

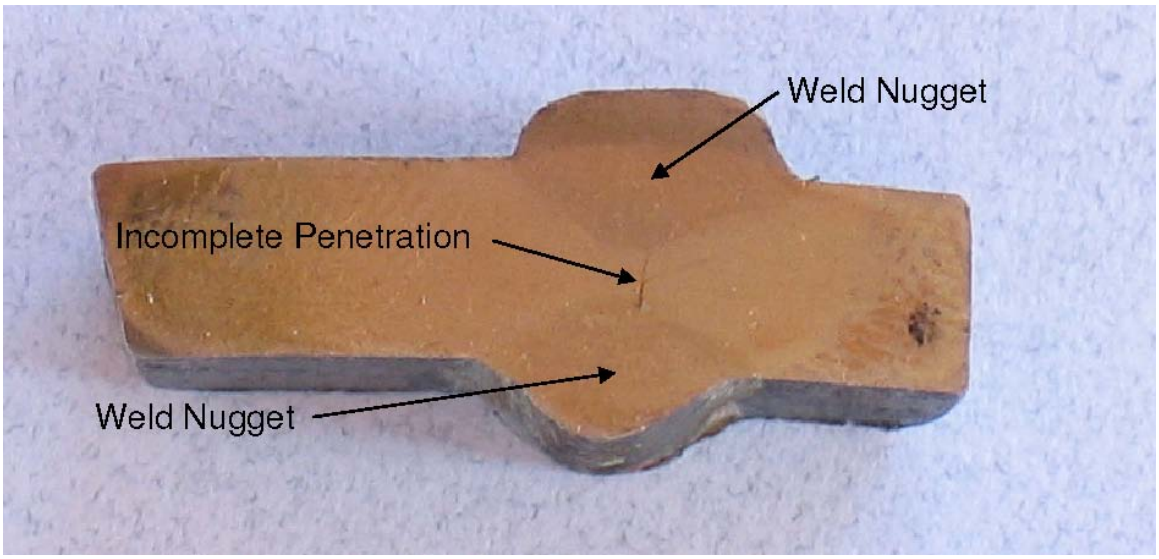
This sample showed normal microstructure for cast aluminum bronze.

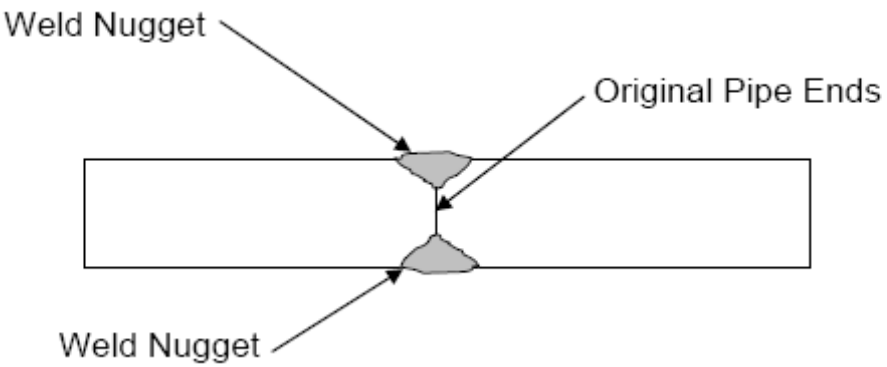


Sample #9 – Section across original girth weld at change of pipe thickness



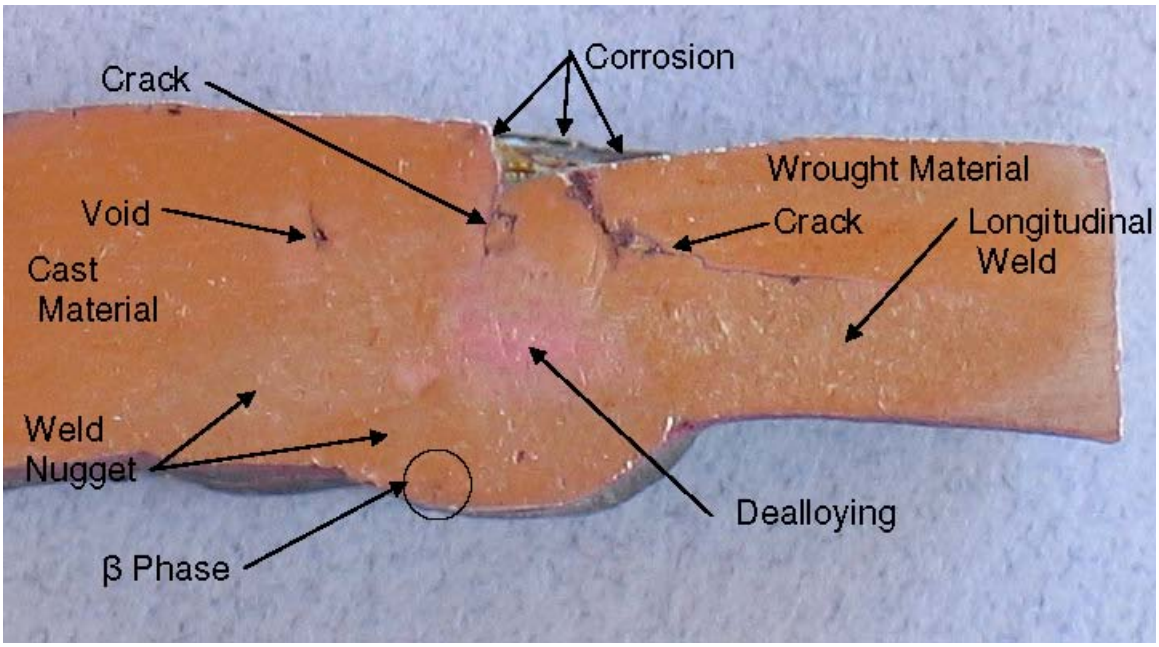
This section had lack of fusion on the original weld and a crack originating at the root of the incomplete fusion. There were also several areas of corrosion on the interior of the pipe.

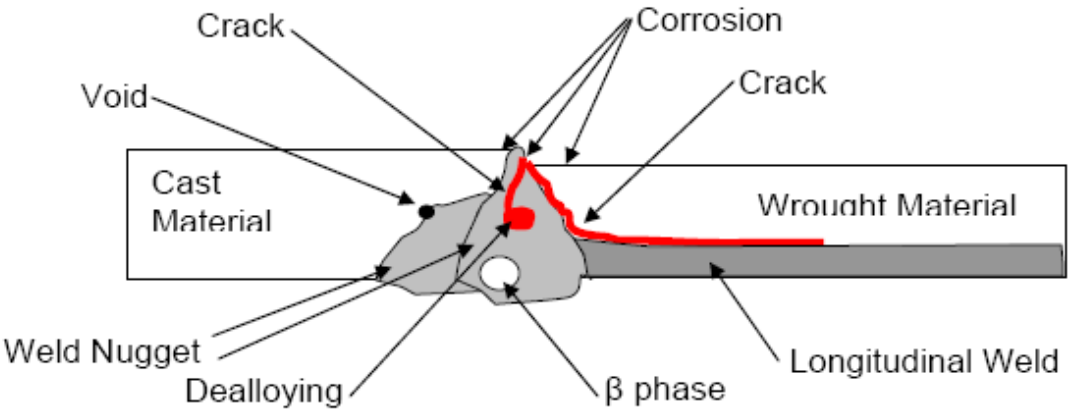




Sample # 10 -Section across original girth weld, thinner material

This sample showed lack of penetration in the original girth weld.





Sample # 11 -Section across longitudinal weld in thinner material and girth weld between thicker and thinner material.

This sample showed lack of fusion, a void, cracking, dealloying in many of the cracks, indicating that the cracks have existed for an extended period, probably from the time of original fabrication, dealloying, lack of fusion and cracking.

Conclusions

Many defects in original welds were found. With one exception, repair welding was not successful in correcting the original defects, introduced new defects, or both.

TEST REPORT
"Customer Supplied Sample (s)"

ATLASLABS@WORLDNET.ATT.NET

ATLAS
TESTING LABORATORIES, INC.

6929 EAST SLAUSON AVENUE • LOS ANGELES, CA 90040 • 323-722-8810 FAX 323-888-1493

PC
JAMES F. JENKINS P.E.
ATTN: JAMES
329 DRAKE ST.
CAMBRIA, CA. 93428

DATE: 04/03/07
ATL# 736375
MAT'L: C95200
SPEC.: CUST. REQ.

ID: CAST

CHEMICAL ANALYSIS: (% BY WEIGHT)

ELEMENTS	MIN. REQ.	MAX. REQ.	RESULTS
Copper	86.0	-	87.5
Iron	2.5	4.0	3.0
Aluminum	8.5	9.5	9.5

METHOD: ASTM-E-1086/94(05)MOD. ATE# 202 STDS: CLAX E1 CDA 954

REMARKS: Conforms to customer requirements.

Respectfully submitted,

Quality Control

TEST REPORT
"Customer Supplied Sample (s)"

ATLASLABS@WORLDNET.ATT.NET

ATLAS TESTING LABORATORIES, INC.

6929 EAST SLAUSON AVENUE • LOS ANGELES, CA 90040 • 323-722-8810 FAX 323-888-1495

PC
JAMES F. JENKINS P.E.
ATTN: JAMES
329 DRAKE ST.
CAMBRIA, CA. 93428

DATE: 04/03/07
ATL# 736375
MAT'L: C61300
SPEC.: CUST. REQ.

ID: WROUGHT WELDING

CHEMICAL ANALYSIS: (% BY WEIGHT)

ELEMENTS	MIN. REQ.	MAX. REQ.	RESULTS
Tin	0.20	0.50	0.37
Lead	-	0.01	0.01
Zinc	-	0.05	0.03
Iron	2.0	3.0	2.4
Nickel + Cobalt	-	0.15	0.02
Phosphorus	-	0.15	<0.01
Aluminum	6.0	7.0	6.1
Silicon	-	0.10	0.02
Chromium	-	0.05	<0.01
Manganese	-	0.20	0.01
Cadmium	-	0.05	<0.01
Zirconium	-	0.05	<0.01
Copper	Remainder		Remainder

METHOD: ASTM-E-415/99a ATE# 202 STDS: CLAX C-13 CDA 613, C
METHOD: ASTM-E-1097-03 ATE# 109 STDS: SYNTHETIC AQUEOUS STD CD, CR & ZR.

REMARKS: Conforms to customer requirements.

Respectfully submitted,