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Procurement of Type 316 Stainless Steel Reference Heat for LMFBR Research and Development Programs

R. J. Beaver W. R. Martin

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Breeder Reactors)

Contract No. W-7405-eng-26

METALS AND CERAMICS DIVISION

PROCUREMENT OF TYPE 316 STAINLESS STEEL REFERENCE HEAT FOR LMFBR RESEARCH AND DEVELOPMENT PROGRAMS

R. J. Beaver and W. R. Martin

JANUARY 1976

OAK RIDGE NATIONAL LABORATORY
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PROCUREMENT OF TYPE 316 STAINLESS STEEL REFERENCE HEAT FOR LMFBR RESEARCH AND DEVELOPMENT PROGRAMS

R. J. Beaver and W. R. Martin

ABSTRACT

Various sizes of plate, sheet, pipe, rounds, and forgings were produced from a 200-ton air-melted heat of type 316 stainless steel, heat 8092297, made by the Republic Steel Corporation. These items were procured by the Union Carbide Nuclear Division and are stockpiled at the Oak Ridge National Laboratory for disbursement as reference material to ERDA contractors responsible for research and development associated with the Liquid Metal Fast Breeder Reactor Program. This reference material is characterized by singular control of chemical composition; specific traceability of items to each ingot cast; and of the highest quality complying with the requirements of the RDT Standard F 2-4T, *Quality Verification Requirements* and the RDT material standards.

The considerations involved in establishing specification requirements for this reference material are presented and the procurement specification, ORNL-MC-316 appended. Processing and inspection activities are described, and traceability of each item to the ingot cast is presented in detail. The specific results obtained as verification of the chemical composition and the mechanical properties are listed for each size of item procured.

INTRODUCTION

In April 1972, ORNL was selected as the stockpile point for the reference heat of type 316 stainless steel to be used in RRD Programs on mechanical property studies and structural tests for elevated-temperature design.[1] A plan was formulated based on the anticipated usage and inventory requirements of five participating organizations.[2] This plan

[1]Letter, H. M. Roth to A. M. Weinberg, "Establishment of 316H Stainless Steel Stockpile," April 12, 1972.

[2]Letter, A. M. Weinberg to R. J. Hart, "Establishment of Type 316 Stainless Steel Stockpile at ORNL," April 26, 1972.

identified the support effort that would be required. The estimated requirements were established and some modifications were made. The finalized requirements are listed in Table 1. This plan included procurement in accordance with the requirements of the RDT Standards. The approach was to (1) establish technical and quality verification requirements, personal contacts with potential suppliers, a detailed specification and request for bids; (2) evaluate the bids and establish the lowest acceptable bidder; (3) determine that the supplier's quality verification program is in compliance with the requirements of the RDT F 2-4T Standard, *Quality Verification Requirements*; (4) approve all quality verification plans and procedures related to the procurement program; (5) establish periodic surveillances of the supplier's progress during the procurement program; (6) witness all pertinent nondestructive testing; (7) review all certification documents and associated test reports, heat-treatment charts, and traceability records for compliance with the technical and quality verification requirements of the specification; and (8) conduct overinspections upon receipt at the ORNL site. The management activities are illustrated by the flow diagram of Appendix A.

PREAWARD ACTIVITIES

After a series of contacts with numerous suppliers of type 316 stainless steel, meetings were established with the interested suppliers: Allegheny Ludlum Steel Corporation, U.S. Steel Corporation, Republic Steel Corporation, and Carpenter Technology Corporation. The objectives of this meeting were to determine limitations on chemical compositions, considerations of melting practices, feasibility of finite traceability from melt to finished product (e.g., Aircraft Identity System) and interest in producing 200 tons of type 316 stainless steel in various product forms to the RDT Standards requirements.

Subsequent to these discussions, a technical review meeting was held on June 7, 1972, with the coordinators and responsible technical representatives.[3] At that time the product list was revamped and the basic technical requirements established. Shortly thereafter the revised procurement plan was issued.[4] A detailed specification was prepared, identified as ORNL-MC-316, and was carefully reviewed by the responsible technical personnel, including the ORNL RDT Standards writer. The RDT Standards were the underlying bases in this procurement and are referenced in the specification. The latest revision of this specification is included in Appendix B. The considerations in developing this specification were as follows:

1. The scope statement that the material was intended for use in research and development programs associated with high-temperature nuclear applications.

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[3]Letter, W. R. Martin to Distribution, "Notes from 316 Stainless Steel Reference Heat Review Meeting on June 5," June 7, 1972.

[4]Letter, A. M. Weinberg to AEC ORO, "Revised Plan for Establishment of Type 316 Stainless Steel Stockpile at ORNL," Aug. 17, 1972.

Table 1. Estimated Allocations for Reference Heat of Type 316 Stainless Steel

Product Form	Size	ORNL		WARD	HEDL	ANL	ANC	Uncommitted Reserve	Total	
		Mechanical Properties	Structural Tests							
		Length[a] or Area[b]	Length or Area	Length or Area	Length or Area	Length or Area	Length or Area	Length or Area	Length or Area	Approximate Weight (lb)
Rounds	1-in. diam	250	1200	40	200	200	110		2000	5,400
	2-in. diam		600	20	200	200	200		1020	11,100
	2 1/2-in. diam		200						200	3,350
	4 1/2-in. diam		200						200	11,000
Plate	1/2 in. (4 × 8 ft)			64	32	32			128	2,700
	5/8 in. (4 × 8 ft)	60	246				10	100	416	10,800
	1 in. (4 × 8 ft)	220	292		16	16		96	640	26,500
	2 in. (4 × 7 ft)	90	232		8	8		174	512	42,500
Sheet	0.064 in. (3 × 8 ft)	200						984	1184	2,900
	1/8 in. (3 × 8 ft)	288							288	1,500
Pipe	2 in. sched 160		200						200	1,500
	2 1/2-in. OD × 0.560-in. wall			150					150	1,600
	4 in. sched 160	100	250					100	450	10,100
	8 in. sched 80	100	250					100	450	19,500
	16 in. sched 30	20							20	1,700
	28-in.-OD × 0.375-in. wall	12						12	24	2,700
Forging	24 × 24 in. × 10,000 lb		2 ea[c]					2 ea[c]		40,000
TOTAL WEIGHT (Approximate)										191,500

[a]Rounds and pipe dimensions in feet.

[b]Plate and sheet dimensions in square feet.

[c]Length or area not applicable.

2. The identity of reference standards with RDT Standards, and, where applicable, the identification of pertinent ASTM standards. All basic and appropriate optional provisions were applied.

3. No modification of the conventional dimensional tolerances established by ASME standards.

4. A restriction in chemistry tolerances. Comparison with the RDT material standards is shown in Table 2. The previous negotiation meetings with the potential suppliers had indicated that these chemistry requirements of the ORNL-MC-316 Specification were reasonable.

Table 2. Comparison of Chemical Compositions

Chemical Element	Contents, wt %	
	RDT Standards	ORNL-MC-316 Rev. 1[a]
C	0.04 to 0.10	0.050 to 0.080
Mn	2.00 max	1.50 to 2.00
P	0.030 max	0.02 to 0.03
S	0.030 max	0.010 to 0.025
Si	0.75 max	0.30 to 0.60
Ni	11.00 to 14.00	13.25 to 13.75
Cr	16.0 to 18.00	16.5 to 17.5
Mo	2.0 to 3.0	2.20 to 2.50
Co	None	0.10 max
Cu	None	0.20 max
N	None	0.05 max
Cb + Ta	b	0.020 max
B	None	0.003 max
Ti	None	0.020 max

[a]For single heat.

[b]The Cb + Ta content shall be not less than ten times the carbon content and not more than 1.00%.

5. The requirement for chemical analyses at intermediate locations on the ingots and after primary breakdown of the semifinished stock for information purposes only.

6. The requirement to test for susceptibility to intergranular attack by using Practice E of ASTM A262.

7. The exercise of the optional provision of RDT M 3-3T requiring transverse tensile tests for pipe 8 in. in diameter and larger.

8. The disallowance of repair of any of the items by welding.

9. The requirement of a specific definition of surface condition relative to defects.

10. The restriction of the solution heat treatment temperature to 1950 ± 50°F.

11. The requirement that the intergranular corrosion test be applied to all pipe regardless of whether or not the pipe was quenched in water.

12. The requirement for liquid penetrant examination of the surfaces of all items except the inside surfaces of pipe and the surfaces of the finished forgings.

13. The requirements for ultrasonic testing of all items including the basic as well as the appropriate optional provisions of the RDT Standards.

14. The requirement that each forging be worked sufficiently during manufacturing to permit ultrasonic inspection at 1 MHz.

15. Requirements for traceability to assure the specific identity of the items to location of the material in the ingot.

Final authorization by the AEC to proceed with procurement was obtained in January 1973 (Ref. 5).

CONTRACT AWARD ACTIVITIES

The request for proposals was initiated in February 1973. After a series of negotiations and rebidding by the five suppliers submitting proposals, Republic Steel was the low bidder and on October 12, 1973, they were released to furnish the order. None of the suppliers were responsive to providing the 16- and 28-in.-diam pipe. Subsequent negotiations were made with Rollmet, Inc., to provide these sizes of pipe on a best efforts basis using forgings produced from the reference heat and provided to Rollmet by ORNL. In the interim it was discovered that the 2 1/2-in.-OD × 5/8-in.-wall pipe could be provided only to a 0.560-in. nominal wall thickness. This change was acceptable to WARD, but ORNL replaced their order of this size pipe with 2 1/2-in.-diam round.

Procurement activities for the 16- and 28-in.-diam pipe were initiated in January 1974. The purchase order was placed in June 1974 for delivery in early 1975. The forgings procured from Republic Steel were shipped in mid-August 1974 to Carlton Forge, the Rollmet subcontractor, for manufacturing the forged rings from which the two sizes were made.

The price per pound offered by Republic Steel varied from $1.63 to $2.00 for the sheet, plate, and rounds manufactured at their Canton-Massillon facilities. The price per pound for the pipe items manufactured for Republic Steel at the Ellwood City Plant of the U.S. Steel averaged $4.48. The cost of the 16- and 28-in.-diam pipe manufactured on a best efforts basis by Rollmet averaged $11.70 per pound.

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[5]Letter, W. D. Adams to W. R. Martin, "Revised Plan for Establishment of Type 316 Stainless Steel Stockpile at ORNL," Jan. 4, 1973.

SUPPLIER ACTIVITIES

Quality Verification Programming

On November 13–14, 1973, the Quality Verification Programming of the Canton-Massillon facilities, Republic Steel, and the Ellwood City Works of U.S. Steel was reviewed by a team that included the ORNL QA Auditor. The review indicated that except for some modifications and additions to the Quality Verification Plans required by the ORNL-MC-316 Specification, the Republic Steel and U.S. Steel Quality Verification Plans were acceptable.[6] The additions and modifications required as a result of this audit were approved by ORNL on December 14, 1973. The Rollmet Quality Verification Plan and associated procedures were submitted in August 1974. Several resubmissions were required, and in December 1974 all of the Rollmet plans and procedures were approved. The approved Quality Verification Plans and associated procedures are summarized in Appendix C.

Production Schedules

The plate, sheet, forging, and bar items were scheduled for June to August 1974 delivery and the pipe (except the 16- and 28-in.-diam pipe) scheduled for delivery by December 1974. Delivery of the bar items and the 2-in. plate was tardy, but delivery by Republic Steel was completed by the end of December 1974.

The 16- and 28-in.-diam pipe produced by Rollmet was scheduled into production upon receipt of the forgings from ORNL in August 1974. Final receipt at ORNL of the finished pipe was April 1975.

The Melt

The type 316 stainless steel reference heat was air melted in a 200-ton electric furnace at Republic Steel's No. 4 Melt Shop of the Steel Division, Canton, Ohio. This heat, 8092297, was made in February 1974 after an initial heat had been attempted in late January but was diverted because of an 0.012 wt % Pb concentration.

Twenty-nine ingots were produced. The pouring sequence was as follows:

Pouring Sequence	Ingot Size (in.)	Approximate Weight (lb)
1	25 × 27	12,000
2	25 × 27	12,000

[6]Letter, R. J. Beaver to Distribution, "Evaluation of QA Programming at Republic Steel Corp. and U.S. Steel Corp. — Type 316 Reference Heat Procurement," Nov. 20, 1973.

Pouring Sequence	Ingot Size (in.)	Approximate Weight (lb)
3	25 × 27	12,000
4	43 octagon	25,390
5	43 octagon	25,390
6	43 octagon	25,390
7	43 octagon	25,390
8	20 × 41	14,670
9	20 × 41	14,670
10	20 × 41	14,670
11	20 × 41	14,670
12	20 × 41	14,670
13	20 × 41	14,670
14	20 × 41	14,670
15	20 × 41	14,670
16	20 × 41	14,670
17	25 × 27	12,000
18	25 × 27	12,000
19	25 × 27	12,000
20	25 × 27	12,000
21	25 × 27	12,000
22	25 × 27	12,000
23	25 × 27	12,000
24	25 × 27	12,000
25	25 × 27	12,000
26	25 × 27	12,000
27	25 × 27	12,000
28	25 × 27	12,000
29	25 × 27	12,000

The ladle analyses, based on the average of samples taken during pouring of ingots 3 and 13, are shown in Table 3. An attempt to obtain a sample during pouring of the last ingot in accordance with the quality verification plan failed.

Identification System

The identity of each ingot was maintained, and all product forms manufactured are traceable to the ingot from which they were produced. The Aircraft Identity System was used as the identification system for traceability. In this system, the alphabetic lettering sequence, A, B, C, etc., represents the location from the top to the bottom of the item being identified. The system is illustrated in Fig. 1. Because of size limitations, rounds 2 1/2 in. in diameter and less were excepted to this system and were simply identified numerically, but traceable to an Aircraft Identified billet from which the rounds were produced. The sheet products were also identified numerically but traceable to location in the ingot.

Table 3. Ladle Analyses of Republic Steel (Heat 8092297)

Chemical Element	Ladle Analyses (wt %)
C	0.057
Cr	17.25
Ni	13.48
Mn	1.86
Si	0.58
P	0.024
S	0.019
Mo	2.34
Co	0.02
Cu	0.10
N	0.030
Cb + Ta	a
Ti	0.02
B	0.0005
Pb	0.003
Sn	0.004

[a]Not detectable at level of 0.01 wt %.

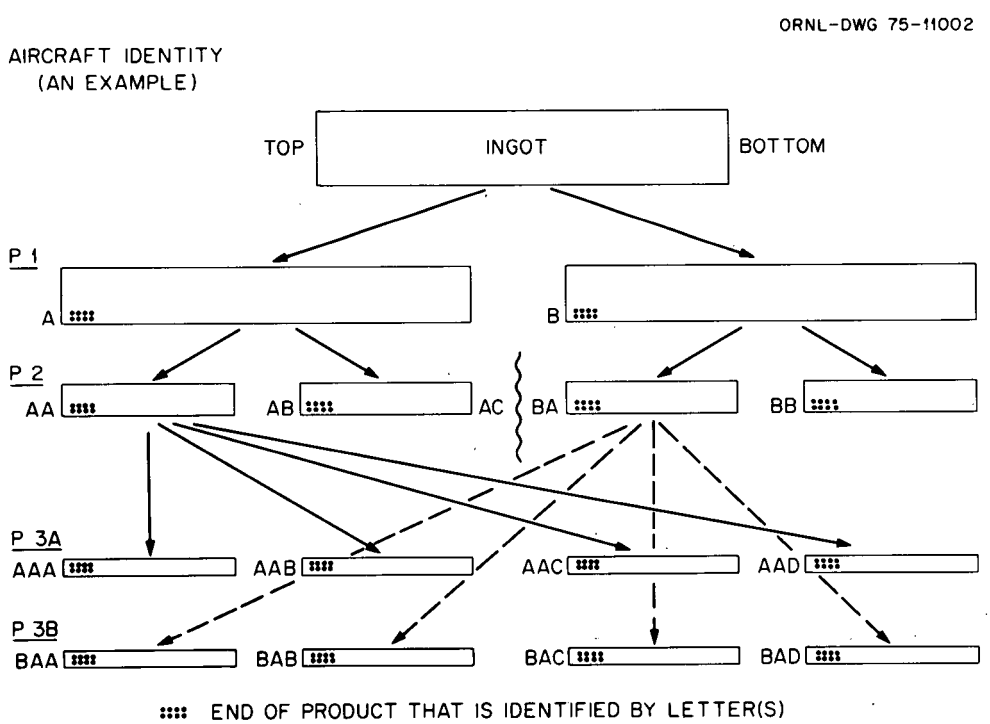

Fig. 1. Aircraft Identity System Used for Traceability of Product Forms.

Plate Production

The 1/2- and 5/8-in.-thick plates were produced from 25 × 27 in. ingots 2 and 3. These ingots were bloomed on the 35-in. Canton blooming mill to 18 × 4 in. blooms. Each bloom was cut into three sections, identified as A, B, and C, respectively. Plates were hot rolled on the South Works Plate Mill to approximately 4 ft wide × 8 ft long. This operation required rolling in a direction transverse to the original direction of the previous blooming operation.

The 1- and 2-in.-thick plates were processed similarly except that the ingot size was 20 × 41 in. and was bloomed to 34 × 5 in. slabs. In these plate sizes one section cut from the bloom constituted one plate rolled to size.

The Aircraft Identity and traceability of the plates accepted are identified in Table 4.

All sizes of plates were solution annealed at 1950 ± 50°F.

Table 4. Traceability and Identification of Plates Produced from Republic Steel Heat 8092297 and Presented for ORNL Acceptance

Plate Identity							
1/2-in.-Thick Ingot 2		5/8-in.-Thick Ingots 2 and 3		1-in.-Thick Ingots 9, 10, 11, 13, 14		2-in.-Thick Ingots 9, 10, 11, 12, 14, 15, 16	
Bloom	Plate	Bloom	Plate	Bloom	Plate	Bloom	Plate
2A	2AB		2BA	9A	9A	9D	9D
	2AC	2B	2BB	9B	9B	9E	9E
			2BC	9C	9C		
2B	2CA					10D	10D
	2CB	2C	2CC	10A	10A		
				10B	10B		
			3AA	10C	10C	11D	11D
		3A	3AB			11E	11E
			3AC	11A	11A		
				11B	11B	12A	12A
			3BA	11C	11C	12B	12B
		3B	3BB			13C	12C
			3BC	13A	13A	12D	12D
				13B	13B		
			3CA	13C	13C	14A	14A
		3C	3CB	13D	13D		
			3CC	13E	13E	15A	15A
				13F	13F	15B	15B
						15C	15C
				14B	14B	15D	15D
				14C	14C		
				14D	14D		
				14E	14E	16C	16C
				14F	14F	16D	16D

Sheet Production

Both the 0.125- and 0.060-in.-thick sheet were produced from ingot 8, 20 × 41 in. in size, which was bloomed on the Canton 35-in. mill to 37 1/2 × 5 3/4 in. This slab was hot rolled on the Cleveland 84-in. strip mill to 0.250 × 38 in. Subsequent to annealing, this "hot band" was cold rolled on the 54-in. reversing mill at the Enduro Works to 0.125-in. gage, and then solution annealed at 1950 ± 50°F (bright annealing). After cutting the coil into sheets, the sheets were stretcher leveled and squared by shearing.

The identity system approved for the sheet deviated from the Aircraft Identity System in that each sheet was numerically identified sequentially. Throughout all operations the traceability was personally monitored by Republic Steel's product metallurgist, who assured that the numerical order represented portions of material from the ingot in a sequence from top to bottom. The initial 196-in. length of 0.125-in. sheet from the reversing mill was removed as scrap prior to identifying the sheet numerically. Twenty 0.125-in.-thick sheets were cut from the 0.125-in.-thick coil and identified sequentially 1 through 20.

The 0.125-in.-thick band was cold rolled to 0.060-in. thickness on the same reversing mill, solution annealed, stretcher leveled, and squared using the same processing used in producing the 0.125-in.-thick sheet. The sheets cut from this 0.060-in.-thick coil were identified sequentially 20 through 88. The last 196 in. of the coil was removed as scrap. The identity of the sheets presented for inspection is shown in Table 5.

Table 5. Traceability and Identification of Sheets[a] Produced from Republic Steel Heat 8092297 and Presented for ORNL Acceptance

0.125-in. Sheet Identity	
2	15
9	16
10	17
11	18
12	19
14	20

0.060-in. Sheet Identity			
38	50	62	75
39	51	63	77
40	52	64	78
41	53	65	79
42	54	66	80
43	55	67	81
44	56	69	82
45	57	70	83
46	58	71	84
47	59	72	85
48	60	73	86
49	61	74	87
			88

[a]All sheets traceable to 0.250-in.-thick "hot bands" 8368-4030. "Hot band" traceable to 37 1/2 × 5 3/4 in. slab bloomed from ingot 8. Numerical sequence represents location in ingot from top proceeding to bottom.

Production of Rounds

All rounds were produced from 25 × 27 in. ingots, bloomed to 9 × 7 3/4 in. on the 35-in. Canton mill, cut into Aircraft Identified multiples, and hot rolled on the 18-in. Massillon mill through a series of intermediate breakdowns to slightly above final product diameter. All rounds were solution annealed at 1950 ± 50°F and subsequently straightened. Turning and grinding to final size was done by the Union Drawn Division. The identities of the rounds are listed in Table 6. The only size with individual Aircraft Identity was the 4 1/2-in.-diam round. All 1-in.-diam-rounds were given the same numerical identity traceable to the Aircraft Identified reroll billet from which they were produced. The 2-in.-diam and 2 1/2-in.-diam rounds were numerically identified in sequence traceable to the reroll billet from which they were produced, with the "X" in the identity indicating the round cut from the bottom half of the round produced from the reroll billet.

Rounds 1 in. in Diameter

The 1-in.-diam rounds were hot rolled from ingot 26. Three 9 × 7 3/4 in. blooms were produced: 26A, 26B, and 26C. Subsequent cutting produced multiples 26AA, 26AB, 26BA, 26BB, 26CA, and 26CB. The 9 × 7 3/4 in. blooms were hot rolled to 4 × 4 in. reroll billets identified as 26AAA, 26ABA, 26BAA, 26BBA, and 26CAA (26CB was diverted to the 2-in.-diam bar production).

Rounds 2 in. in Diameter

The 2-in.-diam rounds are traceable to ingots 24, 25, and 26. Three 9 × 7 3/4 in. blooms were produced from ingot 25: 25A, 25B, and 25C. Subsequent cutting produced multiples 25AA, 25AB, 25BA, 25BB, 25CA, and 25CB. Multiple 26CB (from ingot 26) and 24CA and 24CB (from ingot 24) were added to this production. These multiples were hot rolled to 5 3/4-in. reroll billets identified as 24CAA, 24CBA, 25AAA, 25ABA, 25BAA, 25BBA, 25CAA, 25CBA, and 26CBA.

Rounds 2 1/2 in. in Diameter

The 2 1/2-in.-diam rounds are traceable to ingot 24. Three 9 × 7 3/4 in. blooms were produced, 24A, 24B, and 24C. Subsequent cutting produced multiples 24AA, 24AB, 24BA, 24BB, 24CA, and 24CB (24CA and 24CB were diverted to the 2-in.-round production). The 9 × 7 3/4 in. multiples were hot rolled to 5 3/4 in. square reroll billets producing 24AAA, 24ABA, 24BAA, and 24BBA.

Rounds 4 1/2 in. in Diameter

The 4 1/2-in.-diam rounds are traceable to ingots 20 and 23. Seven 9 × 7 3/4 in. blooms were produced, 20A, 20B, 20C, 20D, 23A, 23B, 23C,

Table 6. Traceability and Identification of Rounds Produced from Republic Steel Heat 8092297 and Presented for ORNL Acceptance

1-in.-Diam Ingot 26				
Bloom	Bloom Multiple	Reroll Billet	Number of Rounds	Identity of Rounds
26A	26AA	26AAA	38	All 1s
	26AB	26ABA	36	All 2s
26B	26BA	26BAA	32	All 3s
	26BB	26BBA	36	All 4s
26C	26CA	26CAA	33	All 5s

2-in.-Diam Ingots 24, 25, 26				
Bloom	Bloom Multiple	Reroll Billet	Number of Rounds	Identity of Rounds
24C	24CA	24CAA	10	1, 1X 2, 2X 3, 3X 4, 4X 5, 5X
	24CB	24CBA	10	10, 10X 11, 11X 12, 12X 13, 13X 14, 14X
25A	25AA	25AAA	7	20 21, 21X 22, 22X 23X 24X
	25AB	25ABA	10	30, 30X 31, 31X 32, 32X 33, 33X 34, 34X
25B	25BA	25BAA	10	40, 40X 41, 41X 42, 42X 43, 43X 44, 44X
	25BB	25BBA	8	50, 50X 51X 52, 52X 53 54X 55
25C	25CA	25CAA	10	60, 60X 61, 61X 62, 62X 63, 63X 64, 64X
	25CB	25CBA	11	70, 70X 71, 71X 72, 72X 73, 73X 74, 74X 75
26C	26CB	26CBA	10	80, 80X 81, 81X 82, 82X 83, 83X 84, 84X

2 1/2-in.-Diam Ingot 24				
Bloom	Bloom Multiple	Reroll Billet	Number of Rounds	Identity of Rounds
24A	24AA	24AAA	5	1, 1X 2, 2X 3X
	24AB	24ABA	1	10X
24B	24BA	24BAA	5	20, 20X 21 22 23
	24BB	24BBA	7	30, 30X 31, 31X 32, 32X 33

4 1/2-in.-Diam Ingots 20 and 23		
Bloom	Bloom Multiple	Identity of Rounds
20C	20CA	20CAA 20CAB
	20CB	20CB
20D	20DA	20DAA[a] 20DAB
23A	23AA	23AAA 23AAB
	23AB	23AB
23B	23BA	23BAA 23BAB
	23BB	23BB
23C	23CA	23CAA 23CAB
	23CB	23CB
23D	23DA	23DAA 23DAB
	23DB	23DB

[a]Cut into two short pieces.

and 23D. (Blooms 20A and 20B were diverted to other applications.) The remaining 9 × 7 3/4 in. blooms were hot rolled to 4 3/4-in.-diam rounds, and Aircraft Identified.

Pipe Production

All pipe items except the 16- and 28-in.-diam pipe were produced at the Ellwood City Works of U.S. Steel, the subcontractor selected by the Republic Steel. Rounds of the appropriate diameters required by U.S. Steel were provided by Republic Steel from heat 8092297. Seamless pipe was produced using the Mannesman process in which the round, after being heated to temperature, is squeezed between rotating rolls while being rotated at high speed and drawn through the mill over a piercing point located between the rolls. Subsequent to the piercing operation the pipe is reduced either by plug rolling and reeling or bar rolling and sizing. All pipe was solution annealed at 1950 ± 50°F.

The rounds provided to U.S. Steel for all except the 8-in. sched 80 pipe were produced from ingots 20, 21, 22, and 27. These ingots were hot rolled on the 35-in. Canton mill to 9 × 7 3/4 in. blooms, and, in the case of the rounds for the 2-in. sched 160 pipe, to 8 × 6 3/4 in. blooms. Subsequently these blooms were hot rolled to the appropriate diameter on the 18-in. Massillon mill and turned at the Union Drawn Division to the following final sizes required by U.S. Steel:

3 1/2-in.-diam round for 2-in. sched-160 pipe
3 3/4-in.-diam round for 2 1/2-in.-OD × 0.560-in.-wall pipe
4 1/2-in.-diam round for 4-in. sched-160 pipe

The 8-in.-diam rounds required by U.S. Steel for the 8-in. sched 80 pipe were produced from ingots 1, 17, 18, and 19. These ingots were hot rolled into 24 × 15 in. blooms on the Canton 35-in. mill, hot forged into 8 1/2-in.-diam rounds at the South Works, and turned to final size at the Union Drawn Division.

As shown in Table 7, each round was identified with its Aircraft Identity traceable to the ingot from which it was produced. One length of pipe was produced from one Aircraft Identified round, and each length of pipe is identified in the recurring markings with the Aircraft Identity of the round from which it was produced. The 16-in. sched 30 pipe and the 28-in.-OD × 0.375-in.-wall pipe were produced at Rollmet by roll extrusion, a reduction process at room temperature that involves intermediate annealing. The 16-in. sched 30 pipe was produced by external roll extrusion in which the die ring works the material from the outside, increasing the length and decreasing the thickness while maintaining constant inside diameter. The 28-in.-diam × 0.375-in.-wall pipe was produced by internal roll extrusion in which solid rollers inserted within the forged ring apply pressure on the internal surfaces, while a tight-fitting external die ring maintains the outside diameter within very close tolerances.

Table 7. Traceability and Identification of Pipe Produced from Republic Steel Heat 809227 and Presented to ORNL for Acceptance

2-in. Sched 160 Ingot 27			2 1/2-in. OD × 0.560-in. Wall Ingot 20			4-in. Sched 160 Ingots 21 and 22			8-in. Sched 80 Ingots 1, 17, 18, 19	
Bloom	Hot Rolled Round	Finished Pipe	Bloom	Hot Rolled Round	Finished Pipe	Bloom	Hot Rolled Round	Finished Pipe	Forged Round	Finished Pipe
27A	27AA	27AAA 27AAB 27AAC[a] 27AAD	20A	20AA	20AAA 20AAB	21A	21AA	21AAA 21AAB	1A	1A
				20AB	20ABA 20ABB		21AB	21ABA 21ABB	1B	1BA 1BB
	27AB	27ABA 27ABB 27ABC 27ABD		20AC	20ACA 20ACB	21B	21BA	21BAA 21BAB	1C	1CA 1CB
				20AD	20ADA 20ADB		21BB	21BBA 21BBB	1D	1DA 1DB
27B	27BA	27BAA 27BAB 27BAC 27BAD	20B	20BA	20BAA 20BAB	21C	21CA	21CAA 21CAB	17A	17A
				20BB	20BBA 20BBB		21CB	21CBA 21CBB	17B	17BA[a] 17BB
	27BB	27BBA 27BBB 27BBC 27BBD		20BC	20BCA 20BCB	21D	21DA	21DAA 21DAB	17C	17CA 17CB[a]
					20BDA		21DB	21DBA 21DBB	17D	17DA 17DB
						22A	22AA 22AB	22AAB 22ABA 22ABB	18A	18AA 18AB[a]
						22B	22BA	22BAA 22BAB	18B	18BA 18BB
							22BB	22BBA 22BBB	18C	18CA 18CB
						22C	22CA	22CAA 22CAB	18D	18DA 18DB
							22CB	22CBA 22CBB	19A	19A[a]
						22D	22DA	22DAA 22DAB	19B	19BA
							22DB	22DBA 22DBB	19C	19CA 19CB
									19D	19DA 19DB

[a]Cut into two pieces.

Forgings 4BA, 4BB, 5AB, 5BA, and 5BB produced by Republic Steel were shipped to Carlton Forge, the Rollmet subcontractor, for manufacturing the pipe blanks. These blanks were fabricated by piercing and forging to a size slightly in excess of the size of the final machined blanks listed as follows:

Final Pipe	Machined Blank
16-in.-diam	18.25 in. OD × 15.10 in. ID × 78 in.
28-in.-diam	28.00 in. OD × 25.25 in. ID × 56 in.

The identity and traceability of these pipes are listed in Table 8.

Table 8. Traceability and Identification of 16-in. Sched 30 and 28-in.-OD × 0.375-Wall Pipe Produced by Rollmet from Forgings Made from Republic Steel Heat 8092297 Supplied by ORNL

Rollmet Identity	Traceable to Section of Forging	Traceable to Forging	Traceable to Ingot
	16-in. Sched 30 Pipe		
CF-001-1A	4BA	4B	4
CF-001-1B	4BA	4B	4
CF-002-1A	4BB	4B	4
CF-002-1B	4BB	4B	4
	28-in.-OD × 0.375-in.-Wall Pipe		
CF-003	5AB	5A	5
CF-004	5BA	5B	5
CF-005	5BB	5B	5

Forging Production

The 24 × 24 in. forgings were produced from 43-in. octagon ingots 4, 5, and 7. Forging was done at the South Works Forge Shop. The ground ingot was initially forged by drawing to 34 × 34 in., ground again, and drawn to 24 × 24 in., solution annealed at 1950°F, and machined. During ultrasonic examination of forgings 4A, 4B, 5A, and 5B, no response was obtained. This condition was attributed to extensive dendritic structure in the central region and coarse-grained structure (ASTM 1 and 2) in the other regions. Ingot 7 was upset forged, drawn, and annealed at 1950°F but again no response was observed during ultrasonic examination. The condition was attributed to coarse grains.

The Aircraft Identification and traceability of these forgings are shown in Table 9.

Table 9. Traceability and Identification of Forgings Produced from Republic Steel Heat 8092297 and Presented for ORNL Acceptance

Aircraft Identification	Traceable to Forging	Traceable to Ingot
4A	4A	4
4BA	4B	4
4BB	4B	4
5AA	5A	5
5AB	5A	5
5BA	5B	5
5BB	5B	5
7A	7A	7
7B	7B	7

VERIFICATION OF SPECIFICATION REQUIREMENTS

Quality Verification Plans (QVP) prepared in sufficient detail were the bases for assuring compliance to the requirements of the ORNL-MC-316 Specification. These Quality Verification Plans were reviewed by a member of the staff of the ORNL Quality Assurance Director and the Quality Assurance Coordinators of the Finance Materials Division and the Metals and Ceramics Division. Each QVP was approved by the Quality Assurance Coordinator of the Metals and Ceramics Division, who also acted as the Authorized Technical Representative. Inspections by ORNL inspectors were limited to witnessing all ultrasonic examinations for internal quality, liquid penetrant examinations for external quality wherever possible, and random overchecks of dimensional requirements while witnessing the non-destructive examinations. The acceptability of all other verifications to the specification requirements was based on the detail in the QVPs and the subsequent certifications and test reports.

Periodic surveillance during the production of the items was conducted by the Authorized Technical Representative for the purpose of

witnessing the progress being achieved and observing the implementation of the Aircraft Identification System.[7–11]

Chemistry

An important aspect of this procurement was the fact that all items produced were produced from a single 200-ton melt. Therefore chemical variations among the items produced should be minimal. Comparison of results with respect to chemical variations among the participants in this research and development effort should not be a negative factor. To support this thesis, in addition to the check analyses normally required for each lot of the various product forms, 52 independent check analyses at intermediate stages of production were obtained. These data are listed in Appendix D, and may be compared with the check analyses of the final products, identified in subsequent sections of this report.

Verification of Internal Quality

A most important technical aspect in procurement of the type 316 stainless reference heat is the assurance of the internal quality of the items procured. Therefore, all of the basic ultrasonic examination provisions of the RDT Standards were exercised, including appropriate optional provisions as identified in Table 4 (for bar, sheet, and plate material) and paragraph 6.8 of the Ordering Data (for pipe) of the ORNL-MC-316 Specification. Specific procedures were detailed by the supplier of ultrasonic examination services, and approved by the ORNL Inspection Engineering Department. All examinations were witnessed by a qualified inspector of the ORNL Inspection Engineering Department as additional assurance that the examinations were conducted in accordance with the approved procedures. The results of these inspections indicate that high-quality items were produced.

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[7]Letter, R. J. Beaver to Distribution, "Surveillance at Republic Steel on March 27–28, 1974," March 29, 1974.

[8]Letter, R. J. Beaver to Distribution, "Surveillance of Republic Steel on April 30 and May 1," May 3, 1974.

[9]Letter, R. J. Beaver to Distribution, "Type 316 Stainless Reference Heat Procurement," July 11, 1974.

[10]Letter, R. J. Beaver to Distribution, "Surveillance at U.S. Steel, Ellwood City Plant on Aug. 27, 1974," Aug. 29, 1974.

[11]Letter, R. J. Beaver to Distribution, "Surveillance of Carlton Forge and Rollmet, Inc., on Oct. 28–30, 1974," Nov. 5, 1974.

Verification of Surface Quality

To better define the surface quality requirements, paragraph 6.12, ordering data was added to the ORNL-MC-316 Specification to avoid controversy over the interpretation of "good workmanship" commonly referred to in many of the ASTM material standards. Except for the inside surface of pipe and the surfaces of forgings the acceptance criteria of RDT F 3-37 for liquid penetrant examination was applied. These criteria created additional quality control provisions on the part of the supplier (grinding of bars and plates and honing of pipe) to assure compliance to the acceptance criteria. Except for isolated pits in some sheet material, the surfaces of the items complied with the defined defect limitations. Localized regions may be observed where grinding was done on some items to remove defects, but this is an acceptable practice used in removal of and exploration of the depth of surface defects. Verification of the surface condition of the inside surfaces of pipe was based entirely on the results of the acceptance criteria and the intensity of the types of ultrasonic examinations exercised in verification of the quality of the pipe.

Deviations and Noncompliances

Deviations to the Specification (changes prior to implementation) and noncompliances to the requirements were reported on ORNL Deviation Request and Nonconformance Request Forms, illustrated in Figs. 2, 3, and 4, respectively. The Supplier Nonconformance Request Forms were provided to Republic Steel for their use. Several reports were generated during this procurement and are summarized in Appendix E. All requests were approved by the Project Leader and the Quality Assurance Coordinator of the Metals and Ceramics Division.

Verification Results of Bar Items

The inspection and test results for the 1-, 2-, 2 1/2-, and 4 1/2-in.-diam bars are attached to the Republic Steel Certificates of Tests identified by control cards 50952, 50955, 50957, and 50959, respectively. These data are maintained in the Material Control File of the ORNL Finance and Materials Division.

Table 10 lists the results of the check analyses for verification of the product chemistry. The certified results of the mechanical properties tests are listed in Table 11.

All bars were certified to have been solution heat treated at 1950 ± 50°F, verified by submitted heat treat charts, and were also certified as resistant to intergranular attack on the basis of acceptable test results to Practice E of ASTM A262.

DEVIATION REQUEST
OAK RIDGE NATIONAL LABORATORY

DEVIATION NO.	
DIVISION	

QA PROGRAM

TYPE: ☐ MATERIAL ☐ PART ☐ SYSTEM ☐ ASSEMBLY

PROJECT TITLE		PROGRAM
ITEM NAME	QUALITY LEVEL	SPECIFICATION
DRAWING NO.	SHOP ORDER	WORK/PURCHASE ORDER

DESCRIPTION OF DEVIATION

NAME	TITLE	DATE

JUSTIFICATION AND LIMITATIONS

NAME	TITLE	DATE

APPROVED BY:	PROJECT LEADER	DATE	OTHER	DATE
	LEAD DESIGNER	DATE	OTHER	DATE
	ITEM USER	DATE	QAC	DATE

UCN-5458A
(3 2-74)

Fig. 2a. Reproduction of ORNL Deviation Request.

INSTRUCTIONS FOR USE

1. For each proposed deviation, the Project Leader (PL) or person(s) delegated by the PL shall complete the Description of Deviation portion of this form and shall sign and date this portion on completion at the indicated place.

2. The Deviation Request (DR) Continuation Sheet shall be used as necessary to adequately explain Step 1.

3. Upon evaluation by management of the correctness and completeness of Steps 1 and 2, the PL or his designee shall complete the portion, Justification and Limitations in the necessary detail, and shall sign and date this portion.

4. The DR Continuation Sheet shall be used as necessary to adequately explain Step 3.

5. The portion, Approved By, requires signature of all personnel substantially participating in the approval of the deviation, giving date and their title.

6. Each DR(s), where the deviation results in a design or engineering change, requires the signature of the Lead Designer with the date of such signature.

7. All DR's require the signature of the person using the final item or responsible for its performance in service, or the signature of his supervisor; unless such authority is specifically delegated by the QA Program Plan or QA Program Index to management responsible for manufacture.

8. The DR and each attached DR Continuation Sheet shall be signed and dated at the appropriate places.

9. The QAC shall, upon satisfactory completion of the information required on the DR, sign and date the DR.

Fig. 2b. Instructions for Use of ORNL Deviation Request.

UNION CARBIDE CORPORATION - NUCLEAR DIVISION
OAK RIDGE NATIONAL LABORATORY

SUPPLIER NONCONFORMANCE REPORT NO. _____

DATE OF SNR

TO: Union Carbide Corporation - Nuclear Division
P.O. Box M, Oak Ridge, Tennessee 37830
_____ Purchasing Division

ATTN: _____ CONTRACT ADMINISTRATOR

FROM: Supplier (and Address)

TYPE: ☐ Material ☐ Part ☐ Subassembly ☐ Final Assembly ☐ Other _____

ITEM NAME & SERIAL NUMBER(S)	DWG./SPEC. NO. & REV.	P.O./SUBCONTRACT NO.
PROJECT NAME	QTY. N/C ITEMS	RELATED SNR'S

DESCRIPTION OF NONCONFORMING CONDITION(S)

IDENTIFY REQUIREMENT(S) VIOLATED

INSPECTOR OR ORIGINATOR _____ DATE _____ ORNL SITE INSPECTOR _____ DATE _____

RECOMMENDED DISPOSITION

☐ Accept as is ☐ Rework

☐ Repair ☐ Reject

ATTACHMENTS: (LIST)

REMEDIAL ACTION & JUSTIFICATION

CAUSE, AND CORRECTIVE ACTION, WITH SCHEDULE

SUPPLIER APPROVALS

ENGINEERING _____ DATE _____ QUALITY ASSURANCE _____ DATE _____

ANSWER REQUIRED BY _____ DATE _____

ORNL APPROVALS

SUPPLIER'S DISPOSITION IS: ☐ Approved ☐ Disapproved ☐ Conditionally Approved as per Attachment

Minor or Incidental SNR ☐ Yes ☐ No

SNR Affects Receiving Inspection or Installation ☐ Yes ☐ No

PROJECT LEADER _____ DATE _____ QUALITY ASSURANCE _____ DATE _____

DISPOSITION ACTION

QTY. ACC.	QTY. REJ.	NEW SNR(S)	SUPPLIER'S INSPECTOR'S OR ORNL SITE INSPECTOR'S SIGNATURE	SUPPLIER'S QA
			_____ DATE	_____ DATE

The issuance and acceptance of this request in no way limits or affects the warranty provisions of the order. This request shall not establish a a precedent or obligation to accept existing or future items not conforming to all provisions of the contract.

UCN-10816
(3 8-73)

Fig. 3a. Reproduction of Supplier Nonconformance Report.

INSTRUCTION FOR USE

1. On report of a nonconformance, the appropriate management at the supplier's place of business shall complete the information on the addressee and sender, type of nonconformance, quantity of items involved, and the identification information required.

2. The responsible supplier technical management shall identify the technical requirements of the contract violated by the nonconformance, such as violation of engineering drawing dimensions, specifications, codes and standards, process procedures, the QA verification plan, etc.

3. The responsible supplier technical management shall describe the nonconformance by identifying the condition that causes the item to depart from the requirements of the contract.

4. The supplier shall request the ORNL site inspector (if one is assigned) to initial the SNR at the indicated space which initials attest that the ORNL site inspector has reviewed supplier's actions in complying with instructions 1, 2 and 3.

5. The responsible supplier technical management shall propose a disposition of the item, and detail the remedial actions or facts to validate such disposition and justify that such actions or facts are consistent with the recommended disposition.

6. The responsible supplier technical management shall report what actions or situations caused the nonconformance, the corrective action applied, or to be applied, to prevent reoccurrences, and the date upon which corrective action is to be completed.

7. Additional documents related to or explaining in more detail the subject matter required by any heading on this SNR form shall be attached to the SNR and listed under attachments.

8. The supplier shall ensure that appropriate supplier approvals and descriptions (instructions 1, 2 and 3) are made by signature with dates, and that the date that ORNL is requested to return the SNR to the supplier is stated.

9. ORNL management shall complete the ORNL approval portion and return the SNR via the contract administrator to the supplier within the time period agreed on.

10. The supplier shall complete the disposition action by recording the disposition of items affected by the SNR to which the ORNL site inspector (if one is assigned) shall attest by his signature, and otherwise by the signature of the supplier's designated quality control or inspection personnel. The supplier's QA manager or his authorized designee shall review the disposition for compliance to authorized disposition actions and indicate approval by signing the SNR.

11. Completed SNR's shall be retained as directed by provisions of the contract.

Fig. 3b. Instruction for Use of Supplier Nonconformance Report.

OAK RIDGE NATIONAL LABORATORY
NONCONFORMANCE REPORT

NCR NO.	
DIVISION	

QA PROGRAM

TYPE: ☐ MATERIAL ☐ PART ☐ SYSTEM ☐ ASSEMBLY

PROJECT TITLE PROGRAM

ITEM NAME	QUALITY LEVEL	SPECIFICATION
DRAWING NO.	SHOP ORDER	WORK / PURCHASE ORDER

DESCRIPTION AND CAUSE OF NONCONFORMANCE

NAME	TITLE	DATE

PROPOSED REMEDY AND JUSTIFICATION

PROPOSED DISPOSITION: ☐ USE UNCORRECTED ☐ REPAIR ☐ REWORK ☐ REJECT

NAME	TITLE	DATE

DISPOSITION:	☐ USE UNCORRECTED ☐ REPAIR ☐ REWORK ☐ REJECT		CORRECTIVE ACTION REPORT ☐ YES ☐ NO	
APPROVED BY:	PROJECT LEADER	DATE	OTHER	DATE
	LEAD DESIGNER	DATE	OTHER	DATE
	ITEM USER	DATE	QAC	DATE

☐ APPROVED DISPOSITION COMPLETED

NAME TITLE DATE

UCN-10077
(3 3-74)

Fig. 4a. Reproduction of ORNL Nonconformance Report.

INSTRUCTIONS FOR USE

1. On report of a nonconformance the Project Leader or person(s) delegated by the Project Leader shall fill in the initial portion of this form and complete the Description and Cause of Nonconformance portion as soon as possible.

2. If the cause of the nonconformance is not immediately determinable, the Project Leader or his designee(s) shall upon completion of the quality control or quality assurance measures necessary to determine the cause promptly complete this portion. The Project Leader or his designee shall sign and date this portion on completion at the indicated place.

3. Upon evaluation by management of the remedial action necessary to dispose of the item and the justification for such action, the Project Leader or his designee(s) shall complete the portion, Proposed Remedy and Justification, detailing actions to be applied to the item and the reasons the remedy will make the item adequate for the intended use. The recommended disposition shall be indicated in this portion. The Project Leader or his designee shall sign and date this portion on completion.

4. The NCR Continuation Sheet shall be used as necessary to adequately explain Steps 1, 2, and 3.

5. The technical review committee shall complete the portion, Disposition and Corrective Action Report, by checking the appropriate box indicating the decision of the technical review committee.

6. The portion, Approved By, requires the signature of the Project Leader or his designee and all personnel substantially participating in the evaluation of the nonconformance, recommending disposition, and/or requiring a corrective action report, giving date and title.

7. Where the nonconformance results in a violation of design requirements and the disposition recommended is Use Uncorrected or Repaired, the approval of the Lead Designer is required by his signature with date.

8. All NCR's pertaining to items manufactured, fabricated, or assembled at ORNL, require the signature of the person using the final item or responsible for its performance in service, or the signature of his supervisor; unless such authority is specifically delegated by the QA Program Index to management responsible for manufacture, fabrication, or assembly.

9. The NCR and each attached NCR Continuation Sheet shall be signed and dated at the appropriate places.

10. The QAC shall, upon satisfactory completion of all required QA actions, sign and date the NCR.

11. A copy of the NCR completed to this stage shall be transmitted to the personnel who are to accomplish the approved disposition, and upon completion, the responsible person shall check the box Approved Disposition Completed, sign, give title, date the copy, and return it to the project.

Fig. 4b. Instructions for Use of ORNL Nonconformance Report.

Table 10. Chemistry Results of Bar Products Type 316 Stainless Steel Republic Steel Heat 8092297

Chemical Element	ORNL-MC-316 Specification (wt %)	Concentration, wt %			
		1-in. Round	2-in. Round	2 1/2-in. Round	4 1/2-in. Round
C	0.050 to 0.080	0.060	0.051	0.054	0.063
Mn	1.50 to 2.00	1.85	1.87	1.86	1.85
P	0.02 to 0.03	0.024	0.030	0.024	0.022
S	0.01 to 0.025	0.019	0.018	0.019	0.020
Si	0.30 to 0.60	0.58	0.53	0.60	0.57
Cu	0.20 max	0.09	0.09	0.08	0.07
Ni	13.25 to 13.75	13.70	13.45	13.50	13.45
Cr	16.5 to 17.5	17.10	17.28	17.19	16.80
Mo	2.20 to 2.50	2.35	2.32	2.34	2.33
Ti	0.020 max	0.01	0.02	0.02	0.02
Co	0.10 max	0.02	0.02	0.02	0.02
N	0.05 max	0.032	0.030	0.030	0.030
B	0.003 max	0.0005	0.0005	0.0005	0.0005
Cb + Ta	0.020 max	<0.01	<0.01	<0.01	<0.01
Al	Not Required	0.023			

Table 11. Certified Results of Mechanical Properties of Bar Items Produced by Republic Steel Type 316 Stainless Steel Heat 8092297

Bar Size, Diam (in.)	Identity Number	Yield Point (psi)	Tensile Strength (psi)	Elongation (%)	Reduction in Area (%)	Hardness (Brinell)
1	26AAA	33,600	78,800	60	75.0	131
2	25AAA	31,200	78,700	60	76.2	131
2 1/2	24AAA	32,700	79,200	56	76.4	131
4 1/2	23AA	31,500	75,000	56.5	77.8	137

Ultrasonic inspections were conducted during the period of October 9 to 18, 1974, and were witnessed by the ORNL inspector.[12] Ultrasonic defects were found in portions of the following rounds:

Diameter	Identity
2 in.	1, 10, 20, 64, 80X, and 84X
2 1/2 in.	20
4 1/2 in.	20DAB

These defective regions were removed creating rounds shorter than the specified length. The 4 1/2 in.-diam round, 20DAA, had been cut into two pieces at Republic Steel prior to ultrasonic inspection creating lengths shorter than specified. All rounds with lengths shorter than specified were approved for acceptance by Supplier Nonconformance Report 51.

The liquid penetrant examinations of the rounds were not witnessed by the ORNL inspector. The CONAM Industries certificate serves as evidence of the inspection results.

Verification Results of Plate Items

The inspection and test results for the 1/2-, 5/8-, 1-, and 2-in.-thick plate products are attached to the Republic Steel Certificate of Tests identified by control cards 3763, 3764, 3765, and 3767, respectively. These data are maintained in the Material Control File of the ORNL Finance and Materials Division.

Table 12 lists the results of the check analyses for verification of the product chemistry. The certified results of the mechanical properties tests are listed in Table 13.

All plates were certified to have been solution heat treated at 1950 ± 50°F, verified by submitted heat treat charts, and were also certified as resistant to intergranular attack on the basis of acceptable test results to Practice E of ASTM A262.

Ultrasonic and liquid penetrant inspections were conducted for the 1/2-, 5/8-, and 1-in. plates during the period August 5 to 16, 1974, and for the 2-in. plate during the period September 10 to 19, 1974. These inspections were witnessed by the ORNL inspector.[13,14] All 1/2-, 5/8-, and 1-in. plates met the requirements of the ultrasonic and liquid

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[12]Letter, C. E. Childress to R. J. Beaver, "Inspection of Type 316 Stainless Steel Materials at CONAM Inspection, Inc., Columbus, Ohio, Purchase Order 73X-27198V, Inspection Request 11712," Oct. 30, 1974.

[13]Letter, C. E. Childress to R. J. Beaver, "Inspection of Type 316 Stainless Steel Materials at CONAM Inspection, Inc., Columbus, Ohio, Purchase Order 73X-27198V, Inspection Request 11712," Aug. 6, 1974.

[14]Letter, C. E. Childress to R. J. Beaver, "Inspection of Type 316 Stainless Steel Materials at CONAM Inspection, Inc., Columbus, Ohio, Purchase Order 73X-27198V, Inspection Request 11712," Sept. 26, 1974.

Table 12. Chemistry Results of Plate Products Type 316 Stainless Steel
Republic Steel Heat 8092297

Chemical Element	ORNL-MC-316 Specification (wt %)	Concentration, wt %								
		1/2-in. Plate	5/8-in. Plate	1-in. Plate			2-in. Plate			
				Lot 13A	Lot 9A	Lot 14C	Lot 661 (Pos. 16B)	Lot 661 (Pos. 10D)	Lot 676 (Pos. 14A)	Lot 676 (Pos. 15A)
C	0.050 to 0.080	0.060	0.060	0.059	0.060	0.059	0.065	0.062	0.063	0.064
Mn	1.50 to 2.00	1.88	1.88	1.84	1.86	1.86	1.83	1.85	1.82	1.82
P	0.02 to 0.03	0.024	0.023	0.024	0.024	0.024	0.022	0.023	0.022	0.024
S	0.01 to 0.025	0.020	0.020	0.018	0.018	0.018	0.018	0.020	0.018	0.020
Si	0.30 to 0.60	0.61	0.62	0.58	0.57	0.57	0.58	0.58	0.57	0.58
Cu	0.20 max	0.08	0.08	0.10	0.10	0.10	0.08	0.08	0.08	0.08
Ni	13.25 to 13.75	13.40	13.40	13.40	13.45	13.45	13.30	13.40	13.30	13.35
Cr	16.5 to 17.5	17.30	17.30	17.15	17.15	17.15	17.01	17.10	16.90	17.15
Mo	2.20 to 2.50	2.34	2.34	2.34	2.34	2.34	2.29	2.30	2.34	2.32
Ti	0.020 max	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Co	0.10 max	9,92	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01
N	0.05 max	0.032	0.034	0.032	0.033	0.031	0.031	0.031	0.033	0.032
B	0.003 max	0.0005	0.0005	0.0005	0.0006	0.0005	0.0006	0.0005	0.0006	0.0005
Cb + Ta	0.020 max	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

Table 13. Certified Results of Mechanical Properties of Plate Items Produced by Republic Steel Type 316 Stainless Steel Heat 8092297

Plate Thickness (in.)	Lot Number	Test Location (Plate Number)	Yield Point (psi)	Tensile Strength (psi)	Elongation (%)	Reduction in Area (%)	Hardness	
							Rockwell B	Brinell
1/2	391	2AB	35,000	80,300	54.0	72.1	84	
1/8	403	3BA	46,000	82,300	52.0	72.5	81	
1	465	13A	46,000	82,000	50.0	68.2		137
1	596	9A	42,000	81,000	50.0	67.5		137
1	508	14C	43,000	81,500	50.0	68.2		137
2	661	16B	37,500	78,000	55.0	68.2		143
2	676	14A	38,000	77,500	56.5	68.2		143

penetrant examinations. During ultrasonic examination of the 2-in. plates 15D, 16B, 10E, and 11E, the back reflection could not be maintained in specific identified regions of the plates. In two of these plates (15D and 11E) the effect was quite limited and isolated. These plates were approved for acceptance by Supplier Nonconformance Report 50.

Dimensional inspections of plates revealed several noncompliances in the thickness requirements where localized regions of limited area had been ground slightly under the allowable thicknesses. These deviations were considered quite minor and the following plates were approved for acceptance by the following identified Supplier Nonconformance Reports (SNR):

Thickness, in.	Identity	Report
1/2	2CA	SNR 13
5/8	2BC	SNR 14
	2BA	SNR 15
	3CA	SNR 16
	3BA	SNR 17
1	14F	SNR 18
	13C	SNR 19
2	10D	SNR 26
	16D	SNR 26
	9D	SNR 26
	16C	SNR 26
	10E	SNR 26
	11E	SNR 26
	14A	SNR 26
	15B	SNR 26

While machining one of the 2-in. plates, 12C, a region 15-in.-long × 1/4-in.-thick failed to "clean up" and the plate was approved for acceptance by Supplier Nonconformance Report 11.

Verification Results of Sheet Items

The inspection and test results for the 0.060- and 0.125-in.-gage sheet products are attached to the Republic Steel Certificate of Tests, identified by control card 3772 and 3773, respectively. These data are maintained in the Material Control File of the ORNL Finance and Materials Division.

Table 14 lists the chemistry results for the 0.060- and 0.125-in. gage products, and also the 0.250-in. gage coil from which these products were produced. Certified results of mechanical properties tests are listed in Table 15.

All sheets were certified to have been solution heat treated at 1950 ± 50°F, verified by photographs of the furnace charts, and were also certified as resistant to intergranular attack on the basis of acceptable test results to Practice E of ASTM A262.

Table 14. Chemistry Results of Sheet Products Type 316 Stainless Steel Republic Steel Heat 8092297

Chemical Element	ORNL-MC-316 Specification Concentration (wt %)	Concentration, wt %	
		0.060-in. Gage	0.125-in. Gage
C	0.050 to 0.080	0.060	0.058
Mn	1.50 to 2.00	1.86	1.82
P	0.02 to 0.03	0.023	0.023
S	0.01 to 0.025	0.018	0.019
Si	0.30 to 0.60	0.60	0.58
Cu	0.20 max	0.08	0.10
Ni	13.25 to 13.75	13.50	13.35
Cr	16.5 to 17.5	17.35	17.05
Mo	2.20 to 2.50	2.34	2.33
Ti	0.020 max	<0.01	0.01
Co	0.10 max	0.02	0.02
N	0.05 max	0.032	0.035
B	0.003 max	0.0005	0.0004
Cb + Ta	0.020 max	<0.01	<0.01

Table 15. Certified Results of Mechanical Properties of Sheet Items Produced by Republic Steel Type 316 Stainless Steel Heat 8092297

Identity	Sheet Size (gage)	Yield Point (psi)	Tensile Strength (psi)	Elongation (%)	Hardness (Rockwell B)
8368-4031	0.060	48,700	86,500	46	82
8368-4030	0.125	49,010	85,190	50	81

Ultrasonic and liquid penetrant inspections were conducted during the period August 5–16, 1974. The ultrasonic inspections were witnessed by the ORNL inspector.[15] All items met the requirements of the ultrasonic examinations.

The liquid penetrant examination revealed that several plates (especially the 0.060-in.-gage) contained isolated pits, generally one per sheet, which exceeded the 5% allowable depth limit. These defects were attributed to dirt or slivers. Because of the isolated nature of these defects, these noncompliances were approved for acceptance by the following Supplier Nonconformance Reports:

SNR Report	Sheet Number	Gage, in.
24	15	0.125
25	19	0.125
27	43	0.060
28	47	0.060
29	49	0.060
30	50	0.060
31	51	0.060
32	52	0.060
33	53	0.060
34	54	0.060
35	55	0.060
36	59	0.060
37	60	0.060
38	61	0.060
39	63	0.060
40	65	0.060
41	70	0.060
42	71	0.060
43	75	0.060
44	78	0.060
45	80	0.060
46	81	0.060
47	82	0.060
48	85	0.060

Verification Results of Pipe Items Produced by U.S. Steel Under Subcontract with Republic Steel

The inspection and test results for the pipe items produced for Republic Steel by U.S. Steel are attached to the Republic Steel Certificate of Tests identified by control cards 3776, 3777, 3779, and

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[15]Letter, C. E. Childress to R. J. Beaver, "Inspection of Type 316 Stainless Steel Materials at CONAM Inspection, Inc., Columbus, Ohio, Purchase Order 73X-27198V, Inspection Request 11712," Aug. 21, 1974.

3782 for the 2-in. diam, 2 1/2-in. diam, 4-in. diam, and 2-in. diam, respectively. These data are maintained in the Material Control File of the ORNL Finance and Materials Division.

Table 16 lists the results of the check analyses for verification of product chemistry. The certified results of the mechanical properties tests are listed in Table 17.

All pipe was certified to have been solution annealed at 1950 ± 50°F, verified by submitted heat treat charts, and were also certified as resistant to intergranular attack on the basis of acceptable test results to Practice E of ASTM A262.

Ultrasonic inspections were conducted during the period December 3–13, 1974, and were witnessed by the ORNL inspector.[16] All items presented, except some of the 8-in. sched 80 pipe were acceptable to the requirements of the ultrasonic examination. In the case of the 8-in. sched 80 pipe, a rejectable region from the center of 19A had to be removed, leaving 2 pieces (one 16 ft, 7 in. long and the other 6 ft, 5 in. long). Rejectable regions at both ends of 19DB were removed leaving a piece 9 ft, 9 in. long. The outside diameter of 17CB in the central region was undersize this region removed, providing two pieces (one was 9 ft, 8 in. long; the other was 6 ft, 4 in. long). The outside diameter of 18AB in the central region was undersize this region removed, providing two pieces (one was 5 ft, 1 in.; the other was 6 ft, 6 in.). A region rejectable by ultrasonic examination was removed from the central region of 17BA, providing two acceptable pieces (one was 5 ft long; the other was 6 ft, 1 in. long). Item 19BB was rejected in entirety by the requirements of the ultrasonic examination. All of the items with lengths less than the specified requirement of 12 ft were approved for acceptance by Supplier Nonconformance Report 52. Included were the items identified above; 19CB and 1BB of 8-in. sched 80 pipe; 27AAC (2 pieces) of 2-in. sched 160 pipe; 20ABB of 2 1/2-in.-OD × 0.375-in.-wall pipe; and 21ABB of 4-in. sched 160 pipe.

The tested flattening test specimens were mislaid by U.S. Steel, and the tested specimens were not available for submission to ORNL as required by the Specification.

Verification of Results of the 16-in. Sched 30 and 28-in.-OD × 0.375-in.-Wall Pipe Produced by Rollmet Under Contract to ORNL

The inspection and tests results for the 16-in. sched 30 and the 28-in.-OD × 0.375-in.-wall pipe products are attached to Rollmet delivery tickets 1489, 1490, 1491, and 1492 (for the 16-in. sched 30 pipe), and 1493, 1494, and 1495 (for the 28-in.-OD × 0.375-in.-wall pipe). These data are maintained in the Material Control File of the ORNL Finance and Materials Division.

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[16]Letter, C. E. Childress to R. J. Beaver, "Ultrasonic Inspection of Type 316 Stainless Steel Pipe and Tubing at U.S. Steel, Ellwood City, Pa., Plant, Purchase Order 73X-27198V, Inspection Request 11712," Dec. 18, 1974.

Table 16. Chemistry Results of Pipe Products Produced for Republic Steel by U.S. Steel Type 316 Stainless Steel Republic Steel Heat 8092297

Lot Number	Identity	Concentration, wt %														
		C	Mn	P	S	Si	Cu	Ni	Cr	Mo	Al	Ti	Cb + Ta	B	Co	N
ORNL-MC-316 Spec.		0.050–0.080	1.50–2.00	0.02 to 0.03	0.01 to 0.025	0.30 to 0.60	0.20 max	13.25 to 13.75	16.5 to 17.5	2.20 to 2.50	Not Req'd	0.020 max	0.020 max	0.003 max	0.10 max	0.05 max
							2-in. Sched 160									
191	27BAA	0.070	1.87	0.025	0.019	0.57	0.10	13.55	17.05	2.35	0.015	0.02	<0.01	0.0005	<0.01	0.032
	BAA-T	0.070	1.87	0.027	0.018	0.56	0.10	13.48	17.05	2.35	0.014	0.02	<0.01	0.0005	<0.01	0.032
191	27BBC	0.067	1.87	0.026	0.019	0.56	0.10	13.50	17.00	2.35	0.013	0.02	<0.01	0.0005	<0.01	0.032
	BBC-T	0.67	1.87	0.026	0.018	0.56	0.10	13.50	17.00	2.35	0.013	0.02	<0.01	0.0005	<0.01	0.031
							2 1/2-in.-OD × 0.560-in.-Wall									
190	20BAB	0.063	1.87	0.028	0.018	0.55	0.10	13.55	17.00	2.35	0.014	0.02	<0.01	0.0005	<0.01	0.031
	BAB-T	0.062	1.87	0.025	0.018	0.56	0.10	13.48	17.00	2.35	0.014	0.02	<0.01	0.0005	<0.01	0.031
190	20ABB	0.065	1.87	0.028	0.018	0.56	0.10	13.55	17.05	2.35	0.013	0.02	<0.01	0.0005	<0.01	0.031
	ABB-T	0.65	1.87	0.026	0.018	0.56	0.10	13.55	17.05	2.35	0.014	0.02	<0.01	0.0005	<0.01	0.032
							4-in. Sched 160									
189	22CBA	0.062	1.86	0.024	0.018	0.58	0.10	13.55	17.10	2.34	0.017	0.02	<0.01	0.0005	<0.01	0.031
	CBA-T	0.064	1.86	0.024	0.018	0.59	0.10	13.60	17.10	2.34	0.017	0.02	<0.01	0.0005	<0.01	0.031
189	22CBB	0.061	1.86	0.024	0.018	0.58	0.10	13.55	17.15	2.34	0.016	0.02	<0.01	0.0005	<0.01	0.031
	CBB-T	0.062	1.86	0.024	0.018	0.58	0.10	13.55	17.10	2.34	0.016	0.02	<0.01	0.0005	<0.01	0.031
189	22DAB	0.061	1.86	0.023	0.018	0.58	0.10	13.55	17.10	2.34	0.015	0.02	<0.01	0.0005	<0.01	0.31
		0.062	1.86	0.024	0.018	0.58	0.10	13.55	17.15	2.34	0.016	0.02	<0.01	0.0005	<0.01	0.032
189	21DBA	0.063	1.86	0.023	0.018	0.59	0.10	13.50	17.15	2.34	0.015	0.02	<0.01	0.0005	<0.01	0.031
	DBA-T	0.065	1.86	0.023	0.018	0.57	0.10	13.55	17.20	2.34	0.015	0.02	<0.01	0.0005	<0.01	0.032
							8-in. Sched 80									
188	12CA	0.065	1.86	0.026	0.018	0.58	0.10	13.50	17.10	2.32	0.017	0.02	<0.01	0.0004	<0.01	0.032
	CA-T	0.063	1.86	0.027	0.018	0.57	0.11	13.50	17.10	2.34	0.014	0.02	<0.01	0.0005	<0.01	0.032
188	19CB	0.066	1.86	0.026	0.018	0.56	0.10	13.50	17.10	2.33	0.015	0.02	<0.01	0.0004	<0.01	0.031
	CB-T	0.068	1.86	0.028	0.018	0.58	0.10	13.50	17.15	2.35	0.014	0.02	<0.01	0.0005	<0.01	0.031
187	18DA	0.066	1.87	0.027	0.018	0.56	0.11	13.50	17.09	2.33	0.014	0.01	<0.01	0.0004	<0.01	0.032
	DA-T	0.063	1.86	0.027	0.018	0.57	0.10	13.50	17.07	2.32	0.015	0.02	<0.01	0.0004	<0.01	0.032
187	17BA	0.062	1.86	0.027	0.018	0.58	0.10	13.50	17.18	2.33	0.015	0.02	<0.01	0.0004	<0.01	0.031
	BA-T	0.061	1.85	0.026	0.018	0.56	0.11	13.48	17.20	2.33	0.015	0.02	<0.01	0.0005	<0.01	0.031

Table 17. Certified Results of Mechanical Properties of Pipe Items Produced for Republic Steel by U.S. Steel Type 316 Stainless Steel Republic Steel Heat 8092297

Lot Number	Identity	Yield Point (psi)	Tensile Strength (psi)	Elongation (%)
		2-in. Sched 160		
191	27BAA	46,716	82,865	65
191	27BBC	52,961	86,904	70
		2 1/2-in.-OD × 560-in.-Wall		
190	20BAB	39,828	82,720	55
190	20ABB	36,764	82,107	60
		4-in. Sched 160		
189	22CBB	51,689	85,913	67
189	22CBA	45,390	83,806	66
189	21DBA	47,790	84,018	68
189	22DAB	42,372	84,745	68
		8-in. Sched 80		
188	19CB	44,857	81,156	68
188	1CA	46,535	82,614	68
187	18DA	46,084	82,156	666
187	17BA	48,057	80,785	69

The chemical check analyses of the 16- and 28-in.-diam pipe are listed in Table 18 and may be compared with Republic Steel's check analyses of the forgings from which the pipe was manufactured. The nickel concentration reported by Rollmet is slightly less than the limit established by the ORNL-MC-316 Specification. Check analyses by ORNL, however, supports the Republic Steel check analyses of the forgings supplied to Rollmet leaving no doubt that the pipe furnished to ORNL by Rollmet was manufactured from the forgings produced from Republic Steel Heat 8092297.

The certified results of the mechanical properties test are listed in Table 19.

All pipe was certified to have been solution annealed at 1950 ± 50°F, verified by submitted heat treat charts, and were also certified as resistant to intergranular attack on the basis of acceptable test results to Practice E of ASTM A262.

Ultrasonic and liquid penetrant inspections were conducted during the period March 31 through April 9, 1975. These inspections were witnessed by the ORNL inspector.[17] All pipe produced, except the 16-in. sched 30 pipe

[17]Letter, C. E. Childress to R. J. Beaver, "Inspection of the 16- and 28-Inch Diameter, Type 316 Stainless Steel Pipe, Extruded by Rollmet, Inc., Santa Ana, Calif., Purchase Order 73X-27198V, Inspection Request 11712," April 14, 1975.

Table 18. Comparison of Chemistry Results of Pipe Products Produced by Rollmet Under Contract to ORNL Type 316 Stainless Steel Republic Steel Heat 8092297

Identity	Concentration, wt %														
	C	Mn	P	S	Si	Cu	Ni	Cr	Mo	Al	Ti	Cb + Ta	B	Co	N
Republic Steel Forgings															
4B	0.061	1.81	0.026	0.016	0.61	0.08	13.35	17.10	2.34	0.016	<0.01	<0.01	0.0006	0.01	0.031
5B	0.061	1.84	0.026	0.016	0.59	0.08	13.35	17.10	2.34	0.016	<0.01	<0.01	0.0006	0.01	0.031
Rollmet 16-in. Sched 30															
CF002-1A	0.065	1.75	0.02	0.01	0.60	0.05	12.80	17.50	2.30		<0.05	<0.05	<0.001		
CF001-1A	0.065	1.81	0.014	0.013	0.58	0.14	12.85	17.50	2.41		0.01	0.01	<0.01		
CF001-1B	0.06	1.75	0.015	0.013	0.60	0.14	12.95	17.50	2.37		0.01	0.01	<0.001		
CF001-1B	0.06	1.75	0.015	0.013	0.60	0.14	12.95	17.50	2.37		0.01	0.01	<0.001		
Rollmet 28-in. OD 0.560-in. Wall															
CF005	0.065	1.77	0.02	0.014	0.57	0.05	12.65	17.18	2.18		<0.05	<0.05	<0.01		
CF003	0.07	1.78	0.02	0.012	0.55	0.05	12.70	17.20	2.20		<0.05	<0.05	<0.01		
CF004	0.065	1.84	0.015	0.014	0.58	0.13	12.80	17.40	2.37		0.01	<0.01	<0.001		
ORNL Check Analyses															
CF 002-1A	0.064	1.75	0.020	0.018	0.65	0.04	13.5	17.5	2.38		<0.01	<0.05	0.0003	0.05	
CF 004-G	0.066	1.6	0.022	0.019	0.62	0.03	13.3	16.8	2.38		<0.01	<0.05	0.0015	0.03	

Table 19. Certified Results of Mechanical Properties of the 16-in. Sched 30 and 28 × 0.375-in. Wall Pipe Produced by Rollmet for ORNL Type 316 Stainless Steel Republic Steel Heat 8092297

Identity	Yield Point (psi)	Tensile Strength (psi)	Elongation (%)	Reduction in Area (%)
		16-in. Sched 30		
CF001-1A	40,850	82,200	48.4	68.3
CF001-AG	40,300	83,000	54.7	66.0
CF001-1B	42,650	83,350	51.6	53.4
CF001-1BG	36,900	82,050	54.7	67.0
CF002-1B	38,600	82,350	65.0	79.7
CF002-1BG	39,450	81,650	56.0	76.5
CF002-1A	38,150	81,250	53.0	75.1
CF002-1AG	36,350	81,600	60.0	78.9
		28-in.-OD × 0.375-in.-Wall		
CF-003	38,050	81,700	61.0	76.1
CF-003G	37,450	81,250	56.0	78.1
CF-004	40,400	81,250	56.3	63.9
CF-004G	38,450	80,750	56.3	65.9
CF-005	36,400	81,400	60.0	78.3
CF-005G	37,400	82,100	56.0	74.4

identified as CF-002-1B, were acceptable to the requirements of the ultrasonic examination. This item was not acceptable to the specification requirement for ovality and was rejected for the intended application prior to ultrasonic examination.

Liquid penetrant examination revealed defects in the 16-in. sched 30 pipe items identified as CF-001-1B and CF-001-1A. These defects are in identifiable isolated regions, and they can be removed to produce pieces of the following approximate lengths:

CF-001-1B — 14, 50, and 25 in.
CF-001-1A — 72 and 36 in.

Since item CF-002-1A was completely acceptable, six pieces of completely acceptable pipe consisting of 26.4 ft are available.

All of the 28-in.-OD × 0.375-in.-wall pipe was completely acceptable and therefore 36 ft of this size are available.

Verification Results of Forging Items

The inspection and test results for the forgings are attached to the Republic Steel Certificate of Tests identified by control card 3783. These data are maintained in the Material Control file of the ORNL Finance and Materials Division. Table 20 lists the results of check analyses for verification of product chemistry. The certified results of the mechanical properties tests are listed in Table 21.

Attempts to ultrasonically inspect forgings 4 and 5 were unsuccessful because back reflection could not be established. These forgings were approved for acceptance by Supplier Nonconformance Report 12 on the basis of the Republic Steel guarantees that items made from these forgings will be free of internal defects as determined by the appropriate ultrasonic examination requirements of the ORNL-MC-316 Specification. Although forging 7 was upset forged 30% prior to drawing, an attempt to ultrasonically inspect this forging was unsuccessful because back reflection could not be established. The forging was approved for acceptance by Supplier Nonconformance Report 49 on the basis of the same Republic Steel guarantee that was applied to forgings 4 and 5. As a matter of record, forgings 4 and 5 represented the material from which the 16-in. sched 30 and 28 × 0.375 in. wall pipe was produced at Rollmet. Ultrasonic testing of these pipe items did not reveal any internal defects.

PROBLEMS ENCOUNTERED DURING PROCUREMENT

Procurement of the items for the reference type 316 stainless steel heat progressed relatively smoothly but some problems were encountered. These problems are considered minor but are reported in the interest of improving specifications and quality assurance actions for the benefit of future procurements of this nature.

The only difficulty with the specification requirements was the requirement for measurement of the actual strain rate during tensile testing. Prior to approval of the quality verification plan, a deviation of this requirement was granted to allow the test to be based on the commonly accepted free-running crosshead speed. A minor deviation to the ASTM Standard referenced in the specification was permitted by eliminating metal-stamping identification on plate surfaces. This change was permitted in the interest of avoiding damage to the surfaces by the metal stamping and because each plate has an Aircraft Indentity number stamped near one end in addition to recurring ink markings on each plate.

A minor problem was encountered in localized violations of the minimum thickness allowed for plates. These noncompliances were created during grinding of the surfaces to obtain a surface condition amenable to inspection to the surface defect requirements of the specification as determined by liquid penetrant examination. These violations were in the vicinities of the ends and edges where the thickness requirements were verified with micrometers, the commonly accepted ASTM practice. The thickness of the entire plate is based on the assumption that this verification practice is acceptable. In the future, considerations should be

Table 20. Chemistry Results of the 24 × 24 in. Forgings
Type 316 Stainless Steel Republic Steel Heat 8092297

Identity	Concentration, wt %														
	C	Mn	P	S	Si	Cu	Ni	Cr	Mo	Al	Ti	Cb + Ta	B	Co	N
ORNL-MC-316 Spec.	0.50–0.80	1.50–2.00	0.02–0.03	0.01–0.025	0.30–0.60	0.20 max	13.25–13.75	16.5–17.5	2.20–2.50	Not Req'd	0.020 max	0.020 max	0.003 max	0.10 max	0.05 max
No. 4	0.061	1.81	0.026	0.016	0.61	0.08	13.35	17.10	2.34	0.016		<0.01	0.006	0.01	0.031
No. 5	0.061	1.84	0.026	0.016	0.59	0.08	13.35	17.10	2.34	0.016		<0.01	0.006	0.01	0.031
No. 7	0.067	1.85	0.024	0.017	0.59	0.08	13.45	17.25	2.35	0.013		<0.01	0.005	0.01	0.032

Table 21. Certified Results of Mechanical Properties of the 24 × 24 in. Forgings Type 316 Stainless Steel Republic Steel Heat 8092297

Identity	Yield Point (psi)	Tensile Strength (psi)	Elongation (%)	Reduction in Area (%)	Hardness (Brinell)
4B	35,000	33,000	58.0	70.5	137
5B	33,000	70,000	54.0	63.4	137
7	35,100	73,300	47.0	51.7	163

given to the advisability of using vidigage techniques for verification of the thickness of ground plates.

A problem that occurred with the sheet items was the presence of pitted regions, detected by liquid penetrant inspection, that necessitated considerable localized grinding. These sheet items were considered by Republic Steel as representative of their high-quality sheet and an inference exists that the liquid penetrant acceptance criteria of RDT F 3-37 for sheet may be unduly severe. Nevertheless, the liquid penetrant examination did reveal pits that could not be ground away without violating the ASTM minimum thickness requirement. Approximately 35% of the sheet items approved for acceptance had isolated pits that were not removed. These pits were attributed to dirt and slivers that occurred during rolling operations.

A problem occurred in the 24 × 24 in. forgings and to a minor degree with the 2-in. plates wherein during ultrasonic examination no back reflection was obtained. The first two forgings made (4 and 5) had been drawn from a 43-in. octagon ingot to the 24 × 24 in. forgings, a 2.3-to-1 reduction in area. The third forging (7) was upset forged prior to drawing to obtain better grain refinement but to no avail insofar as ultrasonic response was concerned. Failure to obtain back reflection in the case of the forgings as well as some of the 2-in. plate was attributed to the coarseness of the grains.

Minor deficiencies occurred that did not have any adverse technical effect, but did create inconveniences. These include (1) CONAM Industries inadvertence in identifying the improper Republic Steel heat number on all bar items, thus necessitating complete remarking by CONAM at the ORNL site; (2) CONAM Industries inadvertence in improper recurring ink markings on the 2-in. plate, thus necessitating complete remarking by electrochemical etching at the ORNL site; (3) U.S. Steel's inadvertence in mislaying material to be transfered to Republic Steel for product analyses (including tested flattening specimens), thus necessitating removal of sections from specific pipe items at the ORNL site for use in determining product chemical analyses; and (4) U.S. Steel's inadvertence in identification of 8-in. sched 80 pipe item 19BA as 17DB, thus necessitating corrections at the ORNL site.

CONCLUSIONS

1. The procurement of the type 316 stainless steel reference heat was implemented in accordance with the requirements of RDT F 2-4T in which quality verification plans and inspection and test procedures were presented by the suppliers and approved by ORNL.

2. Based on extensive chemical analyses of semifinished material and finished products, the variation in the chemistry of the items procured are as follows.

Chemical Element	Range in Concentration (wt %)
C	0.051 to 0.071
Mn	1.81 to 1.89
P	0.020 to 0.028
Si	0.53 to 0.61
Ni	13.35 to 13.75
Cr	16.80 to 17.30
Mo	2.32 to 2.36
Cu	0.07 to 0.11
Co	0.01 to 0.02
B	0.0004 to 0.0006
Ti	<0.01 to 0.02
Cb + Ta	<0.01
Al	0.015 to 0.018
Pb	0.003
Sn	0.004
N	0.029 to 0.035

3. Based on the certified results of tensile tests of the solution-annealed items, the range in the tensile properties is as follows:

Ultimate Tensile Strength, psi	78,000 to 86,900
Yield Strength, psi	31,000 to 53,000
Elongation, %	50 to 70

4. Based on the intensive coordination of the Republic Steel product metallurgist and periodic surveillance of the ORNL Quality Assurance Coordinator of the Metals and Ceramics Division, each item received is traceable to specific location in ingots produced.

5. The internal quality of all items has been verified to the acceptance criteria of the RDT Standards by ultrasonic examinations witnessed by a representative of the ORNL Inspection Engineering Department.

6. The surface quality of all items determined by liquid penetrant examination complies with the ORNL-MC-316 Specification requirements except isolated pits on some sheet material that was approved for acceptance. The inside surfaces of pipe are assumed to be acceptable based

on the ultrasonic acceptance criteria of the ORNL-MC-316 Specification and the types of ultrasonic examination applied.

7. All items were solution annealed at 1950 ± 50°F based on submitted heat treatment charts and certifications to intergranular corrosion tests of ASTM A262, Practice E.

ACKNOWLEDGMENTS

We thank our associates at ORNL for their assistance in the implementation of a successful procurement of this reference type 316 stainless steel heat of materials for LMFBR research and development programs: H. E. McCoy, D. A. Canonico, and P. Patriarca of the Metals and Ceramics Division for their comments in the establishment of the requirements of the ORNL-MC-316 Specification; R. M. Fuller, the RDT Standards writer, and K. K. Klindt and R. C. Hudson of the Inspection Engineering Department for their assistance in establishing the quality verification requirements; W. O. Graves and S. S. Croft of the Finance and Materials Division in the establishment of the Management Plan; the assistance of K. K. Klindt and C. K. McGlothlan, the ORNL QA Auditor, and S. S. Croft in auditing the quality assurance programming at the Republic Steel Corporation and the U.S. Steel Corporation; and the assistance of C. E. Childress of the Inspection Engineering Department in witnessing nondestructive inspections.

We especially appreciate the efforts of A. F. Johnson of the UCC-ND Procurement Office in his assistance in establishing potential suppliers of the reference heat and in his administration of the procurement contract.

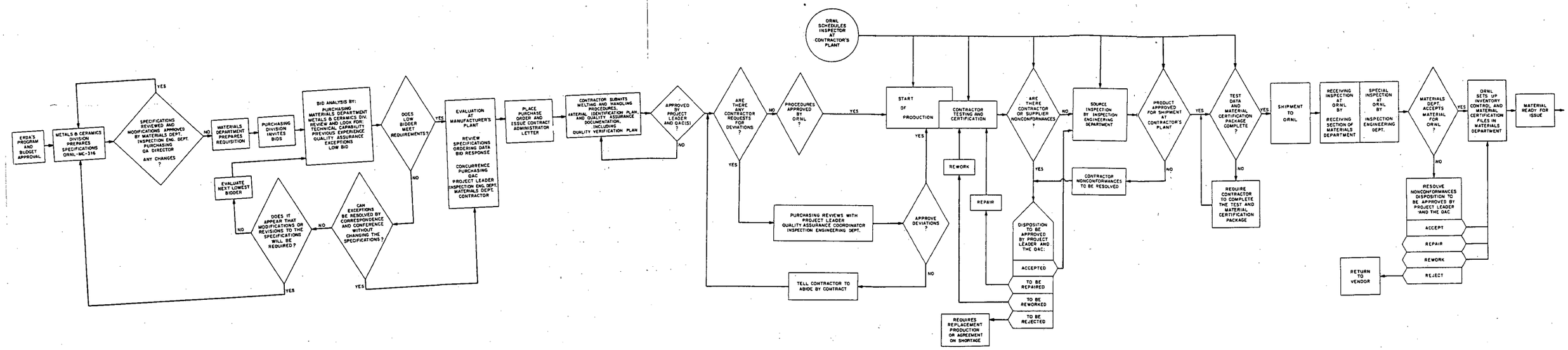
We acknowledge the interest, cooperation and efforts of the Republic Steel Corporation, especially those of J. A. Odar, Keith Davis, and R. G. Garver, in the production of this reference heat of material, applying the requirements of the ORNL-MC-316 Specification, RDT Material Standards and the RDT Quality Verification Standard, RDT F 2-4T. For the same reasons we acknowledge the efforts of the staff of Rollmet, Inc., in their interest and cooperation in producing 16- and 28-in.-diam pipe under the jurisdiction of the ORNL-MC-316 Specification, the RDT material standard and the RDT Quality Verification Standard.

The typing and preparation of this report for reproduction was accomplished by Stephanie Davison under the direction of Meredith Hill, and we commend them for a job well done.

APPENDIX A

MANAGEMENT FLOW CHART

ORNL-DWG 73-7583R



FLOW DIAGRAM OF PROCUREMENT OF MATERIAL
Specification ORNL—MC-316

Req: C-0918-73

APPENDIX B

SPECIFICATION

ORNL-MC-316, Rev. 1

SPECIFICATION FOR TYPE 316 AUSTENITIC STAINLESS STEEL PRODUCT FORMS FOR RDT RESEARCH AND DEVELOPMENT PROGRAM

July 25, 1973

OAK RIDGE NATIONAL LABORATORY

OPERATED BY

UNION CARBIDE CORPORATION

NUCLEAR DIVISION

POST OFFICE BOX X

OAK RIDGE, TENNESSEE 37830

1. SCOPE

This specification establishes the requirements for type 316 austenitic stainless steel pipe, bar, plate, sheet, and forging intended for use in research and development programs associated with high-temperature nuclear applications.

2. APPLICABLE DOCUMENTS (R)

The following standards and specifications and their references are part of this specification except as modified or supplemented by this specification.

2.1 AEC-RDT Standards (R)

RDT M2-2T (May 1973)	— Stainless and Low Alloy Steel Forgings
RDT M3-3T (January 1972)	
Amendment 1 (July 1972)	
Amendment 2 (December 1972)	
Amendment 3 (April 1973)	— Austenitic Stainless Steel Pipe
RDT M5-1T (January 1972)	
Amendment 1 (July 1972)	
Amendment 2 (April 1973)	— Stainless Steel Plate, Sheet, and Strip
RDT M7-3T (August 1972)	
Amendment 1 (April 1973)	— Stainless Steel Bars and Shapes
RDT F2-4T (October 1969)	
Amendment 1 (October 1971)	— Quality Verification Program Requirements
RDT F3-6T (July 1971)	
Amendment 1 (April 1972)	— Nondestructive Examination
RDT F3-37T (July 1971)	
Amendment 1 (April 1972)	
Amendment 2 (November 1972)	
Amendment 3 (April 1973)	— Special Requirements for Metal Products

2.2 American Society for Testing and Materials

A 388-64, Ultrasonic Testing and Inspection of Heavy Steel Forgings
A 8-69, Standard Methods for Tension Testing of Metallic Materials
E 29-67, Recommended Practice for Indicating Which Places of Figures Are to Be Considered Significant in Specified Limiting Values

3. TECHNICAL REQUIREMENTS

3.1 Scope. The product technical requirements shall be in accordance with all of the requirements of the applicable referenced RDT standards, and the additional requirements given in Sect. 6, Ordering Data.

3.2 Dimensions. Tolerances shall be in accordance with the applicable reference RDT Standards.

3.3 Chemical Composition. Each finished product shall conform to the chemical composition requirements of 6.1, Ordering Data. Ingots and the product in the semifinished condition after primary breakdown shall be analyzed and the results, including sample location, shall be reported to the Company for information purposes only.

3.4 Corrosion Resistance. Freedom from intergranular attack shall be in accordance with 6.11, Ordering Data.

3.5 Cleaning. The finished products shall conform to the requirements of the applicable referenced RDT standards that preclude contamination (such as excess oxide, metallic particles, oil, grease, lubricants, residual cleaning compounds, dirt, and chips).

3.6 Mechanical Properties

3.6.1 Tensile Properties. The tensile properties of the finished products shall comply with the tensile property requirements of the applicable referenced RDT standards and the additional requirements of 6.2, Ordering Data.

3.6.2 Ductility and Soundness. Each lot of pipe shall be proven ductile and sound by compliance to the flattening tests of the applicable referenced RDT standards.

3.6.3 Hydrostatic Pressurization. The finished pipe shall be hydrostatically tested in accordance with the applicable referenced RDT standards. Each pipe shall be pressurized prior to dimensional and nondestructive testing, but after all heat treating and straightening operations have been completed.

3.7 Surface Requirements

3.7.1 Surface Condition. The finished surfaces shall be free of oxide and shall be limited to defects in accordance with 6.12, Ordering Data.

3.7.2 Surface Texture. The surface texture of each finished product shall comply with 6.3, Ordering Data.

3.7.3 Repair. No bar, plate, sheet, or forging shall be repaired by welding in compliance with 6.4, Ordering Data. Pipe is excluded from repair by the referenced RDT standard.

3.8 Nondestructive Testing Requirements. All products shall be examined nondestructively in accordance with the following requirements, and shall comply with the applicable acceptance criteria.

3.8.1 Liquid Penetrant Examination. The finished surfaces of each bar shall be examined by liquid penetrant inspection in accordance with the requirements of RDT M 7-3. Except for the surfaces of the forging and the inside surfaces of pipe, the surfaces of the other products shall be examined by liquid penetrant inspection in accordance with 6.5, Ordering Data.

3.8.2 Ultrasonic Examination

(a) Plate and Sheet. Each finished plate 3/16 in. and greater in thickness shall be examined for internal and external defects using test equipment capable of longitudinal wave ultrasonic inspection in accordance with the referenced RDT standards. Plates 2 in. or less in thickness and sheets less than 3/16 in. thick shall be examined using test equipment in accordance with the referenced RDT standards and 6.6, Ordering Data.

(b) Bars and Forging. Each finished forging shall be examined for internal and external defects using ultrasonic equipment capable of longitudinal wave ultrasonic inspection in accordance with the referenced RDT standards. Each finished bar shall be examined for internal and external defects using ultrasonic equipment capable of longitudinal wave ultrasonic inspection in accordance with the referenced RDT standards and to angle beam ultrasonic inspection in accordance with 6.7, Ordering Data.

(c) Pipe. Each finished pipe shall be examined for internal and external defects using ultrasonic testing equipment in accordance with the 6.8, Ordering Data.

3.9 Processes

3.9.1 Manufacture

(a) Melting. Melting processes shall comply with the applicable referenced RDT standards.

(b) Working. Each forging shall be worked sufficiently during manufacturing to permit ultrasonic inspection at 1 Mhz.

(c) Handling. Handling procedures during manufacture shall be in accordance with the requirements of the referenced RDT standards.

(d) Heat Treating. All products shall be heat treated in accordance with 6.13, Ordering Data.

(e) Cleanliness. Precautions shall be taken during manufacture to assure cleanliness in accordance with the requirements of the applicable referenced RDT standards. Lubricants on surfaces of product during heat treatment are considered deleterious and care shall be exercised to assure that all lubricants are removed from all surfaces of each product prior to any heat treatment.

3.9.2 Identification

The material shall be marked and processed in a manner that shall insure individual product identity and traceability in accordance with RDT F2-4, Sect. 4, and traceability back to the location of the material in the ingot in accordance with 6.9, Ordering Data.

4. QUALITY ASSURANCE PROVISIONS

4.1 Quality Assurance Program Requirements. The Seller shall plan, establish, implement, and maintain a documented quality assurance program that fulfills all requirements of RDT F2-4 and any additional quality assurance requirements of the contract.

4.2 Quality Assurance Documentation. The Seller is responsible for the preparation of all quality assurance documentation required by the applicable sections of RDT F2-4. The documents identified in Table 2 shall be submitted to the Company for the applicable purposes at the indicated time. The granting of process or procedural approvals by the Company shall not be construed to relieve the Seller in any way or to any extent from the full responsibility for delivering items conforming with all requirements of this specification.

4.3 Records. Records traceable through complete fabrication and sequence of operations from melt through working, annealing, and finishing operations shall be maintained for each lot. The Seller shall supply such information with his test reports on all delivered items. (R)

4.4 Responsibility. In accordance with RDT F2-4, Section 1.4, the Seller shall be responsible for the performance of all tests and inspections required prior to submission to the Company of any of the products for acceptance. The performance of such tests and inspections does not limit the right of the Company to conduct such other tests and inspections as the Company deems necessary to assure that all items are in conformance with all requirements of this specification. Except as otherwise specified, the Seller may use either his or any commercial laboratory acceptable to the Company. Records of all tests and examinations shall be kept complete and shall be supplied to the Company.

4.5 Inspection Requirements. Inspection requirements are listed in Table 3. Where "lot qualification" is listed as the inspection plan or type, the lot shall be accepted only when all of the required number of samples meet the referenced requirement. Where sampling plan criterion is listed, the Seller shall establish the sampling plan and obtain the Company's approval.

Table 2. Documentation Submittal Requirements

Item	Description	Reference Paragraph of RDT F2-4	Reference Paragraph of RDT F3-6	Reference Paragraph of ORNL Specification	Submit to Company for Approval	Submit to Company for Information	Time of Submittal to Purchaser
1	Planning	2.1			X		Before order is placed.
1.1	Quality verification plan	2.1.1			X		Before order is placed.
1.2	Sampling plan	2.1.2			X		Before order is placed.
1.3	Audit plan	10			X		Before order is placed.
1.4	Personnel	2.2			X		Before order is placed.
1.5	Identification and marking	4		3.9.2	X		Before order is placed.
1.6	Purchased items	5.1			X		Before order is placed.
1.7	In-process inspection	5.2.1			X		Before order is placed.
1.8	Completed item inspection	5.2.2			X		Before order is placed.
1.9	Tests	5.3			X		Before order is placed.
1.10	Inspection procedures, instructions, and check lists	3.1	1.		X		Before order is placed.
1.11	Technical data	3.2			X		Before order is placed.
1.12	Records	3.3			X		Before order is placed.
1.13	Tests	5.3			X		Before order is placed.
1.14	Inspection and test status	5.4			X		Before order is placed.
1.15	Certification	5.5			X		With items submitted for acceptance.
1.16	Equipment calibration and control	6				X	Before order is placed.
1.17	Control of nonconforming items	7			X		Before order is placed.
1.18	Corrective action	8			X		As appropriate.
1.19	Protection	9			X		Before order is placed.
2	Melting processes			3.9.1(a)	X		Before order is placed.
3	Handling			3.9.1(c)	X		Before order is placed.
4	Heat treating			3.9.1(d)		X	30 days prior to production.
5	Cleanliness			3.9.1(c)		X	30 days prior to production.
6	Nondestructive test procedures			3.8	X		Before order is placed.
7	Packaging			5.1		X	Before order is placed.
8	Marking for shipment			5.2		X	Before order is placed.
9	Analytical Chemistry procedures			4.5.2	X		Before order is placed.

Table 3. Quality Conformance Inspection

Item	Characteristic	Specification Requirement	Type	Reference Test Method
4.5.1	Dimensions, product			
	(a) Length, width, thickness of all products	3.2	Commercial practice.	Standard gaging.
	(b) Diameter of pipe	3.2	Commercial practice.	Standard gaging.
	(c) Wall thickness of pipe	3.2	Commercial practice.	Standard gaging.
	(d) Straightness of pipe, and bars	3.2	Commercial practice.	Standard gaging.
	(e) Flatness and camber of plate and sheet	3.2	Commercial practice.	Standard gaging.
4.5.2	Chemical composition			
	(a) Ingots	3.3	Seller plan as approved by the Company.	Chemical analyses: ASTM standards proposed by Seller and approved by the Company.
	(b) Semifinished product after primary breakdown	3.3	Seller plan as approved by the Company.	Chemical analyses: ASTM standards proposed by Seller and approved by the Company.
	(c) Finished product	3.3	In accordance with applicable referenced RDT standards.	Chemical analyses: ASTM standards proposed by Seller and approved by the Company.
4.5.3	Corrosion resistance	3.4	Tests of representative samples in accordance with the applicable referenced RDT standards.	Corrosion resistance shall be determined where applicable in accordance with ASTM A-262, Practice E.
4.5.4	Cleanliness	3.4	All surfaces.	Visual.
4.5.5	Tensile properties	3.6.1	Tests of representative samples selected in accordance with the applicable referenced standard. Transverse tension tests of pipe 8 in. diam and greater shall be required in accordance with 6.2, Ordering Data.	Tensile properties shall be determined using methods described in ASTM A-370. Gage length for pipe and tubing shall be consistent with that recommended in ASTM A-370, Supplement II. Location of specimens and gage length for solid specimens shall be consistent with ASTM E8. The strain rate throughout the tests shall be 0.05 in./in./min.

Table 3. (Continued)

Item	Characteristic	Specification Requirement	Type	Reference Test Method
4.5.6	Ductility and soundness[a]	3.6.2	Tests of a minimum of two pipes per lot.	The pipe shall be subjected to the flattening test in ASTM A-530, Paragraph 4.
4.5.7	Hydrostatic pressurization	3.6.3	Each pipe.	Pipe and tubing shall be tested in accordance with the applicable referenced RDT standards. If any pipe or tube shows leaks during the hydrostatic tests, it shall be rejected.
4.5.8	Surface condition	3.7.1	Entire surfaces.	Visual examination and liquid penetrant inspection where required.
4.5.9	Surface texture	3.7.2	Entire surfaces.	Visual examination.
4.5.10	Repair	3.7.3	Entire surfaces.	No repairs allowed.
4.5.11	Liquid penetrant examination	3.8.1	Entire surfaces except inside surface of pipe and the surfaces of the forging product.	All surfaces shall be subjected to a liquid penetrant method which complies with Sect. 4 of RDT F3-6 to the acceptance criteria in the applicable sections of RDT F3-37.
4.5.12	Ultrasonic examination of finished products (a) Plate and sheet	3.8.2	All material.	All plates shall be examined for internal and external defects with test equipment capable of longitudinal and angle-beam ultrasonic inspection in accordance with the provisions of RDT 3-6, Sect. 7, to the acceptance criteria of RDT F3-37, Sect. 5.1.1(a) and 5.1.1(b). Sheets less than 3/16 in. thick shall be examined for internal and external defects with equipment capable of angle-beam ultrasonic inspection in accordance with 6.6, Ordering Data.

Table 3. (Continued)

Item	Characteristic	Specification Requirement	Type	Reference Test Method
	(b) Forgings and bars		All material.	Each forging and bar shall be examined for internal and external defects with ultrasonic test equipment calibrated with the flat bottom hole standards for longitudinal wave calibration, in accordance with the applicable standards of RDT F3-6, Sect. 9. The levels of the reference standards in relation to diameters and thicknesses is as follows: Level 2 for diameters and thicknesses 1/2 through 3 in. and Level 4 for diameters and thicknesses greater than 3 in. in accordance with the requirements of RDT F3-6, Sect. 9 and RDT F3-37, 5.1.2(a). Acceptance criteria shall be in accordance with RDT F3-37, 5.1.2(a) (1) and RDT 5.1.2(a) (2) as related to the applicable diameter and thickness. Each bar shall also be examined for internal and external defects with equipment capable of ultrasonic angle-beam examination in accordance with the requirements of 6.7, Ordering Data.
	(c) Pipe	3.7.2	All material.	Each pipe shall be examined for internal and external defects using ultrasonic test equipment in accordance with the requirements of 6.8, Ordering Data.

Table 3. (Continued)

Item	Characteristic	Specification Requirement	Type	Reference Test Method
4.5.13	Melting	3.8.1(a)	Certification.	Melter's records.
	Handling	3.8.1(b)	Certification.	Seller's records.
	Heat treating	3.8.1(c)	Certification.	The Seller's heat treating equipment and temperature controlling devices shall be calibrated in accordance with the Seller's procedures.
	Cleanliness during manufacture	3.8.1(d)	Certification.	Seller's records.
4.5.14	Identification	3.8.2	Certification.	Seller's records.

[a]All tested samples shall be submitted to the Company. Each tested sample shall be identified with a number identical to the pipe or tube from which it was taken.

5. PREPARATION FOR DELIVERY

5.1 Packaging. The respective products except the forging shall be boxed in accordance with the requirements of the applicable referenced RDT standards in a manner that shall assure delivery of clean, undamaged material.

5.2 Marking for Shipment. Each bundle or packing box shall be legibly and conspicuously marked in accordance with the requirements of 6.10, Ordering Data.

6. ORDERING DATA

6.1 Chemical Composition. The finished product shall conform to the following chemical composition requirements. (R)

	Composition, wt %	
	From Multiple Heats	From a Single Heat
C	0.060 to 0.080	0.050 to 0.080
Cr	16.5 to 17.0	16.5 to 17.5
Ni	13.25 to 13.75	13.25 to 13.75
Mn	1.50 to 1.75	1.50 to 2.00
Si	0.30 to 0.60	0.30 to 0.60
P	0.02 to 0.03	0.02 to 0.03
S	0.015 to 0.025	0.010 to 0.025
Mo	2.20 to 2.50	2.20 to 2.50
Co	0.10 max	0.10 max
Cu	0.20 max	0.20 max
N	0.05 max	0.05 max
Cb + Ta	0.020 max	0.020 max
Ti	0.020 max	0.020 max
B	0.001 max	0.003 max

Check analyses of pipe shall be obtained from a minimum of two pipes per lot. Analyses shall also be made at intermediate locations on ingots and after primary breakdown on semifinished stock for information purposes to the Company using a plan submitted by the Seller for approval by the Company. Chemical analytical procedures shall comply with the requirements of the applicable ASTM standards.

6.2 Transverse Tension Tests. Transverse tension tests shall be made from both ends of each length of pipe 8 in. diam and over in nominal diameter. If the specimen from either end of any length fails to conform to the tensile properties specified in RDT M3-3T, that length shall be rejected.

6.3 Surface Texture. Preparation of surfaces shall be as indicated in Sect. 4.6 of RDT F3-6T in order to permit liquid penetrant inspection for surface condition where required, and in order to permit ultrasonic inspection in accordance with the referenced RDT standards and this specification.

6.4 Repair. No bar, plate, sheet, or forging shall be repaired by welding.

6.5 Liquid Penetrant Inspection. Liquid penetrant examination of the outside surfaces of plates and sheets, and the outside surfaces of pipe shall be performed in accordance with RDT F3-6, Sect. 4 to the applicable acceptance criteria of RDT F3-37.

6.6 Ultrasonic Inspection of Sheet. Each sheet less than 3/16 in. in thickness shall be examined by angle-beam ultrasonic inspection in accordance with the optional provision of RDT M5-1.

6.7 Ultrasonic Inspection of Bars. Each finished bar shall be inspected for internal and external defects by circumferential angle-beam ultrasonic examination. This examination shall be performed by relating the angle-beam ultrasonic inspection procedures described in ASTM A-388 to solid bars. For all bars, except those 4 1/2 in. diam, the ultrasonic equipment shall be calibrated using standards containing a 1/32-in. hole drilled to a depth of 3/4 in. into the end of the standard parallel to the axis and at a distance one-fourth of the diameter from the axis. For the 4 1/2-in.-diam bars, the diameter of the hole shall be 1/16 in. The ultrasonic equipment shall also be calibrated for all bars using standards containing a notch, 1% of the applicable diameters in depth by 1 in. long cut parallel to the longitudinal axis. Bars containing discontinuities producing indications with an amplitude equal to or greater than that produced by the referenced hole or notch shall be rejected.

6.8 Ultrasonic Inspection of Pipe. Each finished pipe shall be ultrasonically inspected for internal and external defects with the application of longitudinal notches in accordance with the optional provision of RDT M 3-3, Amendment 1, page 8, Sect. 4.

The ultrasonic examination shall also include inspection with the application of transverse notches in accordance with the provisions of RDT F 3-37, Sect. 5.1.5.(a) (2) with the exception that the calibration level is S-4.

The ultrasonic examination shall also include procedures for inspection of laminar defects and any condition that causes 90% loss of back reflection shall be cause for rejection.

6.9 Identification. The identification of the material for each product shall include identification traceable from the location in the ingot through each manufacturing sequence to the finished product.

6.10 Marking for Shipment. In addition to compliance with the referenced applicable RDT standards, each package, whether bundle or box, shall be legibly and conspicuously marked with the following data:

- Purchase Order Number
- Name of Manufacturer
- Grade
- Size
- Part Number
- Lot Number
- Number of Pieces in Container
- Number of Feet (or Pieces) in Lot
- Gross, Net, and Tare Weights

6.11 Corrosion Resistance. If the products are cooled after heat treatment at the solution annealing temperature by means other than quenching in water, tests for each heat treating lot as defined by the applicable referenced RDT standards shall be conducted in accordance with Practice E of ASTM A-262. The number of corrosion tests shall not be less than the number of tensile tests required, pipe transverse tests excepted.

6.12 Surface Condition. The surfaces of all finished products, except the forging, shall be free of cracks and surface checks, and shall be limited to other defects as follows:

(a) The size shall comply with the acceptance criteria of Sects. 5.1.1(d), 5.1.2(c), and 5.1.5(c) of RDT F3-37 for plate and sheet, bars, and pipe, respectively.

(b) Scabs, seams, laps, tears, or slivers no deeper than 5% of the nominal thickness are acceptable.

(c) Mechanical marks or abrasions and pits are acceptable if they do not exceed 5% of the nominal thickness, except where 5% of the nominal thickness exceeds 1/16 in.

(d) All defects shall be explored for depth. Those that do not comply with the acceptance criteria can be removed by grinding or machining, provided removal at the point of grinding or machining does not cause a noncompliance of the minimum thickness requirements.

The finished surfaces of the forging shall have no defects of a nature or degree that will be detrimental to the stamping, forming, machining, or fabrication of finished parts.

6.13 Heat Treating. Each product shall be solution treated at the same nominal solution treatment temperature. The solution treatment shall consist of heating the material at a temperature of 1950°F ± 50°F and quenching in water or rapidly cooling by other means. Equipment shall be calibrated in accordance with the Seller's procedures that are reviewed by the Company prior to use.

6.14 Intergranular Corrosion Test. Each lot of pipe, whether quenched in water or cooled by other means, shall be tested to demonstrate freedom from intergranular attack by performing an intergranular corrosion test in accordance with ASTM A262, Practice E. Specimens for the intergranular corrosion test shall be taken from the same location(s) as specified for mechanical test specimens. (N)

APPENDIX C

SUMMARY OF QUALITY VERIFICATION PLANS AND INSPECTION PROCEDURES

Republic Steel Corp.

Steel Division (General)

Thirty two pages of text with nine attachments identifying and describing control of (1) melting and fabricating activities; (2) certification of tests; (3) Aircraft Identity System; (4) chemical analyses; (5) mechanical test equipment; (5) annealing; and (6) temperature measuring equipment.

Union Drawn Division (Bar Items, including rounds for pipe production by U.S. Steel Corp.)

Eleven pages of text with eight attachments identifying and describing the (1) work orders; (2) quality check-off report; (3) Aircraft Identity System; (4) nonconformance tagging and reporting; and (5) process outlines.

South Division (Plates and forging items)

A Quality Control Manual consisting of 13 pages of text; an attached quality verification plan for the items; 29 exhibits describing process detail, records, and traceability; three standard operating procedures for controlling annealing and one standard operating procedure for polishing plates.

Enduro Division (Sheet)

A quality verification plan consisting of 18 pages of text and 10 exhibits exemplifying records used in controlling the work and recording data.

CONAM (nondestructive examination subcontractor for Republic Steel product forms)

Immersion Ultrasonic Procedure for Bars (408-UT-324)

Ultrasonic Inspection for Shear Wave
Inspection of Plate (408-UT-325)

Marking and Packaging Procedure (408-QC-328)

Ultrasonic Procedure for Shear Wave Inspection of Sheet (408-UT-329)

Liquid Penetrant Inspection for Round, Multisided, Square Bar, Plate and Sheet (408-PT-330)

Ultrasonic Procedure for Longitudinal Wave Inspection of Forgings (408-UT-331)

U.S. Steel Corp — Gary Ellwood City Works

A Quality Verification Plan consisting of a text of three pages, with attachments describing the following procedures.

Bale Numbering Procedure

Cleaning and Pickling Procedure

Visual Inspection Procedure

Hydrostatic Testing Procedure

Standard Practice for Qualification and Certification of Personnel Conducting or Supervising Nondestructive Testing

Discrepant Material Control

Tool, Test Equipment and Gage Control

Production Sequence (300 Series Stainless)

Internal Audit Procedure

Annealing Procedure for Austenitic Stainless Steel

Packaging Procedures for Stainless Tubing

Ultrasonic Inspection Procedure

Ultrasonic Inspection Reference Standard

Ultrasonic Testing Report

Quality Verification Plan

Liquid Penetrant Inspection Procedure

Rollmet, Inc., Santa Ana, Calif. (16- and 28-in.-diam pipe)

A Quality Verification Plan (RP-ORNL-MC-316) consisting of 46 pages of text, and the following quality verification procedures.

RPB 6020-1	Liquid Penetrant Inspection Procedure
RPB-ORNL-6021	Ultrasonic Inspection Procedure
RPB 6030	Cleaning Procedure
RPB 6040	Receiving, Storage, and Shipping
RPB 6050	Flattening Procedure
RPB-ORNL-6070	Annealing Procedure
RPB-ORNL-6080	Surface Preparation (Grinding)
RPB-6090	Hydrostatic Test Procedure

APPENDIX D

CHEMICAL ANALYSES OF SEMIFINISHED PRODUCTS AT INTERMEDIATE STAGES OF PRODUCTION TYPE 316 STAINLESS STEEL REPUBLIC STEEL HEAT 8092297

Chemical Analyses of Semifinished Products at Intermediate Stages of Production Type 316 Stainless Steel Republic Steel Heat 8092297

Ingot Position	Semifinished Size (in.)	C	Mn	P	S	Si	Ti	Cu	Ni	Cr	Sn	Mo	Pb	Al	Co	B	N
1A	8 1/2 diam	0.063	1.86	0.024	0.019	0.58	0.00	0.10	13.45	17.20		2.35		0.015	0.01	0.0006	0.032
1E		0.059	1.86	0.024	0.018	0.57	0.00	0.09	13.50	17.12		2.36		0.016	0.01	0.0006	0.031
2A	18 × 4	0.056	1.87	0.024	0.017	0.59	0.01	0.09	13.50	17.13	0.004	2.34	0.003	0.016	0.02	0.0005	0.033
2C		0.066	1.88	0.023	0.019	0.59	0.01	0.09	13.40	17.30	0.004	2.35	0.003	0.015	0.02	0.0006	0.033
3A	18 × 4	0.065	1.89	0.024	0.019	0.59	0.01	0.09	13.40	17.28	0.004	2.34	0.003	0.016	0.02	0.0005	0.033
3C		0.066	1.89	0.024	0.019	0.60	0.01	0.09	13.55	17.25	0.004	2.35	0.003	0.015	0.02	0.0005	0.034
8T	37 1/2 × 5 3/4	0.060	1.86	0.023	0.018	0.60	0.01	0.09	13.45	17.15	0.004	2.32	0.003	0.016	0.02	0.0005	0.034
8B		0.059	1.88	0.024	0.018	0.58	0.01	0.09	13.46	17.30	0.004	2.35	0.003	0.015	0.02	0.0006	0.032
8	0.250 gage	0.068	1.84	0.023	0.020	0.59	0.00	0.10	13.45	17.10					0.02		
9T	34 × 5	0.060	1.86	0.023	0.019	0.60	0.01	0.09	13.50	17.15	0.004	2.34	0.003	0.015	0.02	0.0005	0.033
9B		0.062	1.88	0.024	0.019	0.58	0.01	0.09	13.50	17.25	0.004	2.35	0.003	0.014	0.02	0.0006	0.035
10T	34 × 5	0.061	1.88	0.024	0.018	0.58	0.01	0.09	13.50	17.15	0.004	2.34	0.003	0.016	0.02	0.0006	0.033
10B		0.066	1.89	0.023	0.019	0.59	0.01	0.09	13.48	17.25	0.004	2.35	0.003	0.015	0.02	0.0006	0.033
11T	34 × 5	0.059	1.87	0.024	0.018	0.59	0.01	0.09	13.50	17.15	0.004	2.34	0.003	0.015	0.02	0.0005	0.033
11B		0.064	1.88	0.024	0.018	0.58	0.01	0.09	13.50	17.15	0.004	2.35	0.003	0.016	0.02	0.0006	0.032
12T	34 × 5	0.062	1.88	0.023	0.018	0.60	0.01	0.09	13.50	17.20	0.004	2.35	0.003	0.016	0.02	0.0005	0.033
12B		0.066	1.88	0.024	0.019	0.58	0.01	0.09	13.50	17.18	0.004	2.35	0.003	0.015	0.02	0.0006	0.033
13T	34 × 5	0.062	1.87	0.024	0.018	0.60	0.01	0.09	13.55	17.20	0.004	2.34	0.003	0.016	0.02	0.0006	0.035
13B		0.065	1.88	0.023	0.018	0.58	0.01	0.09	13.50	17.20	0.004	2.34	0.003	0.015	0.02	0.0006	0.033
14T	34 × 5	0.062	1.88	0.024	0.018	0.60	0.01	0.09	13.55	17.20	0.004	2.35	0.003	0.015	0.02	0.0005	0.032
14B		0.061	1.88	0.024	0.018	0.58	0.01	0.09	13.55	17.25	0.004	2.35	0.003	0.015	0.02	0.0005	0.032
15T	34 × 5	0.060	1.88	0.024	0.018	0.59	0.01	0.09	13.50	17.20	0.004	2.35	0.003	0.015	0.02	0.0006	0.034
15B		0.064	1.89	0.024	0.019	0.59	0.01	0.09	13.45	17.30	0.004	2.35	0.003	0.015	0.02	0.0005	0.034
16T	34 × 5	0.060	1.87	0.023	0.018	0.59	0.01	0.09	13.50	17.18	0.004	2.34	0.003	0.016	0.02	0.0006	0.032
16B		0.063	1.89	0.024	0.019	0.58	0.01	0.09	13.53	17.30	0.004	2.35	0.003	0.015	0.02	0.0006	0.032
17A	8 1/2 diam	0.063	1.86	0.024	0.018	0.58	0.00	0.10	13.50	17.20		2.34		0.015	0.01	0.0005	0.030
17E		0.060	1.86	0.027	0.019	0.57	0.00	0.08	13.45	17.17		2.33		0.017	0.01	0.0006	0.031
18A	8 1/2 diam	0.062	1.86	0.022	0.019	0.58	0.00	0.09	13.60	17.17		2.37		0.016	0.01	0.0005	0.032
18E		0.063	1.84	0.024	0.020	0.57	0.00	0.08	13.30	17.05		2.32		0.016	0.01	0.0005	0.030
19A	8 1/2 diam	0.061	1.84	0.025	0.020	0.59	0.00	0.08	13.30	17.10		2.33		0.016	0.01	0.0005	0.032
19E		0.063	1.85	0.024	0.018	0.58	0.00	0.10	13.45	17.20		2.34		0.015	0.01	0.0006	0.031
20A	9 × 7 3/4	0.062	1.87	0.024	0.018	0.59	0.01	0.09	13.55	17.15	0.004	2.35	0.003	0.015	0.02	0.0005	0.033
20E		0.061	1.89	0.025	0.019	0.59	0.01	0.09	13.50	17.25	0.004	2.35	0.003	0.015	0.02	0.0005	0.032
20AA	4 in. Round	0.060	1.86	0.020	0.018	0.56	0.02	0.08	13.45	17.19		2.36		0.015	0.01	0.0006	0.032
21A	9 × 7 3/4	0.064	1.88	0.024	0.019	0.58	0.01	0.09	13.57	17.20	0.004	2.35	0.003	0.015	0.02	0.0006	0.033
21E		0.064	1.88	0.024	0.019	0.58	0.01	0.09	13.45	17.25	0.004	2.34	0.003	0.016	0.02	0.0006	0.031
21AA	4 3/4 in. Round	0.068	1.84	0.023	0.019	0.57	0.02	0.08	13.40	17.05		2.33		0.17	0.02	0.0006	0.030
22A	9 × 7 3/4	0.061	1.88	0.024	0.019	0.59	0.01	0.09	13.44	17.20	0.004	2.35	0.003	0.015	0.02	0.0006	0.032
22E		0.062	1.88	0.023	0.019	0.59	0.01	0.09	13.47	17.20	0.003	2.35	0.003	0.016	0.02	0.0005	0.031
23A	9 × 7 3/4	0.061	1.88	0.024	0.019	0.58	0.01	0.09	13.50	17.25	0.004	2.35	0.003	0.015	0.02	0.0005	0.031
23E		0.063	1.89	0.024	0.019	0.58	0.01	0.09	13.50	17.25	0.004	2.35	0.003	0.016	0.02	0.0005	0.032
23AA	4 3/4 in. Round	0.062	1.86	0.023	0.019	0.59	0.00	0.10	13.35	17.15		2.34		0.015	0.02	0.0005	0.032
24A	9 × 7 3/4	0.059	1.88	0.024	0.019	0.58	0.01	0.09	13.40	17.25	0.004	2.35	0.003	0.016	0.02	0.0006	0.032
24D		0.058	1.89	0.024	0.018	0.58	0.01	0.09	13.55	17.30	0.004	2.35	0.003	0.017	0.02	0.0006	0.032
24AAA	2 1/2 in. Round	0.061	1.84	0.023	0.019	0.58	0.00	0.09	13.60	17.10		2.35		0.023	0.02	0.0006	0.032
25A	9 × 7 3/4	0.060	1.87	0.024	0.019	0.59	0.01	0.09	13.48	17.20	0.004	2.35	0.003	0.018	0.02	0.0006	0.032
25D		0.059	1.88	0.023	0.018	0.58	0.01	0.09	13.50	17.25	0.004	2.34	0.003	0.017	0.02	0.0005	0.032
25AAA	2 1/6 in. Round	0.063	1.86	0.025	0.018	0.57	0.01	0.09	13.46	17.10		2.34		0.018	0.02	0.0005	0.029
26A	9 × 7 3/4	0.061	1.88	0.025	0.019	0.59	0.01	0.09	13.55	17.25	0.004	2.35	0.003	0.018	0.02	0.0006	0.031
26D		0.060	1.89	0.024	0.018	0.60	0.01	0.09	13.55	17.30	0.004	2.35	0.003	0.015	0.02	0.0005	0.032
27A	8 × 6 3/4	0.062	1.88	0.024	0.019	0.59	0.01	0.09	13.46	17.25	0.004	2.35	0.003	0.018	0.02	0.0006	0.033
27F		0.064	1.88	0.024	0.018	0.58	0.01	0.09	13.50	17.15	0.004	2.35	0.003	0.017	0.02	0.0006	0.032
27AA	3 5/8 in. Round	0.060	1.85	0.020	0.019	0.60	0.02	0.09	13.40	17.15		2.35		0.020	0.02	0.0005	0.031

APPENDIX E

SUMMARY OF DEVIATIONS AND NONCONFORMANCE REPORTS

SUPPLIER NONCONFORMANCE REPORTS

SNR No.	Item	Description
1	The Melt	Average ladle analysis based on two rather than 3 samples.
2 through 10	2-in.-Thick Plate	Disapproved out-of-flatness condition items reworked by pressing to obtain required flatness.
11	2-in.-Thick Plate	Slight region on edge failed to clean up during machining.
12	24 × 24-in. Forgings (No. 4 and 5)	Unable to ultrasonically inspect because no back reflection could be obtained.
13	0.500-in. Plate (2CA)	One localized region at end was 0.005 in. below allowable thickness.
14	0.625-in. Plate (2BC)	One localized region near end 0.002 in. below allowable thickness.
15	0.625-in. Plate (2BA)	One localized region near end 0.002 in. below allowable thickness.
16	0.625-in. Plate (3CA)	One localized region near end 0.002 in. below allowable thickness.
17	0.625-in. Plate (3BA)	One localized region at corner 0.016 in. below allowable thickness.
18	1-in.-Thick Plate (14F)	Three localized regions near ends, 0.001, 0.005, and 0.019 in. below allowable thickness.
19	1-in.-Thick Plate (13C)	One localized region near end, 0.001 in. below allowable thickness.
20 and 21		Cancelled.
22	2-in.-Diam Bar (No. 62X)	Length shorter than specified (9 ft, 1 in.).

SUPPLIER NONCONFORMANCE REPORTS (Continued)

SNR No.	Item	Description
23	2 1/2-in.-Diam Bar (No. 1 and 31)	Lengths shorter than specified (9 ft, 10 in.).
24	0.125 in. gage sheet (No. 15)	One pit with depth deeper than 5% of thickness.
25	0.125 in. gage Sheet (No. 19)	One pit with depth deeper than 5% of thickness.
26	2-in.-Thick Plate	No. 15B below minimum thickness at one corner. No. 14A below minimum thickness near one end. No. 10D below minimum thickness near one end. No. 16D below minimum thickness near one end. No. 9D below minimum thickness near one end. No. 16C below minimum thickness at one corner. No. 10E below minimum thickness near one end. No. 11E below minimum thickness at two corners.
27	0.060-in. Gage Sheet (No. 43)	One pit deeper than 5% of thickness.
28	0.060-in. Gage Sheet (No. 47)	One pit deeper than 5% of thickness.
29	0.060-in. Gage Sheet (No. 49)	One pit deeper than 5% of thickness.
30	0.060-in. Gage Sheet (No. 50)	One pit deeper than 5% of thickness.
31	0.060-in. Gage Sheet (No. 51)	Two pit deeper than 5% of thickness.
32	0.060-in. Gage Sheet (No. 52)	Six pit deeper than 5% of thickness.
33	0.060-in. Gage Sheet (No. 53)	One pit deeper than 5% of thickness.
34	0.060-in. Gage Sheet (No. 54)	One pit deeper than 5% of thickness.
35	0.060-in. Gage Sheet (No. 55)	Two pit deeper than 5% of thickness.
36	0.060-in. Gage Sheet (No. 59)	Two pit deeper than 5% of thickness.
37	0.060-in. Gage Sheet (No. 60)	Two pit deeper than 5% of thickness.
38	0.060-in. Gage Sheet (No. 61)	One pit deeper than 5% of thickness.
39	0.060-in. Gage Sheet (No. 63)	One pit deeper than 5% of thickness.
40	0.060-in. Gage Sheet (No. 65)	Two pit deeper than 5% of thickness.
41	0.060-in. Gage Sheet (No. 70)	One pit deeper than 5% of thickness.
42	0.060-in. Gage Sheet (No. 71)	One pit deeper than 5% of thickness.
43	0.060-in. Gage Sheet (No. 75)	One pit deeper than 5% of thickness.
44	0.060-in. Gage Sheet (No. 78)	Thirteen pits along one edge deeper than 5% of thickness.
45	0.060-in. Gage Sheet (No. 80)	Three pits with depth deeper than 5% of thickness.
46	0.060-in. Gage Sheet (No. 81)	Seven pits along one edge; four other scattered pits deeper than 5% of thickness.

SUPPLIER NONCONFORMANCE REPORTS (Continued)

SNR No.	Item	Description
47	0.060-in. Gage Sheet (No. 82)	Fourteen pits along one edge deeper than 5% of thickness.
48	0.060-in. Gage Sheet (No. 85)	One pit deeper than 5% of thickness.
49	24 × 24-in. Forging (No. 7)	Unable to ultrasonically inspect because no back reflection could be obtained.
50	2-in.-Thick Plates (11E, 15D, 10E, 16B)	Unable to ultrasonically inspect in localized regions because no back reflection could be obtained.
51	Bars	Lengths shorter than specified. For 2-in. diam No. 64, 20, 10, 84X, 80X, and 1. For 4 1/2-in. diam No. 20DAB and two pieces of No. 20DAA. For 2 1/2-in. diam No. 20.
52	Pipe	Lengths shorter than specified. For 2-in. sched 160, two pieces of No. 27AAC. For 2 1/2-in. OD × 0.560 in. wall, No. 20ABB. For 4-in. sched 160, No. 21ABB. For 8-in. sched 80, No. 19A, 19DB, 19CB, 17CB, 1BB; two pieces of No. 18AB and 2 pieces of No. 17BA.
53	Pipe	U.S. Steel inadvertencies in mislaying tested flattening specimens and material for chemical check analyses by Republic Steel.

ORNL NONCONFORMANCE REPORTS

NCR No.	Item	Description
1	Bars	At ORNL receiving inspection, the heat number on the recurring identification was erroneously identified. This inadvertence was corrected by CONAM at the ORNL site.
2	2-in.-Thick Plate	At ORNL receiving inspection, the identification in the recurring markings was erroneous. This error was corrected by ORNL by erasing the ink markings and replacing correct identification using electrochemical etch recurring markings.
3	8-in. Sched 80 Pipe	At ORNL receiving inspection, pipe item marked 17DB was found misidentified. This identity was erased and replaced with No. 19BA.

ORNL DEVIATION REPORTS

Deviation No.	Item	Description
1	Tensile Testing	The ORNL-MC-316 Specification was modified to allow the free-running crosshead speed to be a measure of the strain rate.
2	Plates	The ASTM requirements to metal die-stamp identification on surfaces of plates exceeding 1/4-in. thickness was eliminated in lieu of metal-stamped Aircraft Identity number at the end of plates and the recurring identification ink markings on plates.

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