Carondelet Division
8600 Commercial Blvd. • Pevely, MO 63070 USA
Phone: 636-475-2199 • Fax: 636-479-3399
E-Mail: Charles.Ruud@MetalTek.com

Corrective Action 1671
Carondelet Division
Corrective Action Type NCR
Date 4-10-06 Revised **4-20-06**
CA Originator C. Ruud
Applies to: A-6 Coil

Description of Defect / Non-Conformance

Test bar from zone 1 failed elongation at -320 F. Result was 20% versus a minimum of 32%. The original set of three bars, Z-1, Z-2 and Z-3 were sent for testing. Z-1 failed for elongation, 26% vs 32% minimum and Z-3 failed for elongation 19% vs 32% minimum. All other results were acceptable. Retests were ordered. The second results were similar. Z-1 failed for elongation, 25% vs 32% minimum and Z-3 failed for elongation 13% vs 32% minimum, but broke outside the gauge length. The third set of bars was tested. Z-3 passed and Z-1 failed for elongation, 20% vs 32% minimum, but broke outside the gauge length. All other test results were acceptable. See attached test reports. **A fourth set of 3 test bars were tested. All results were acceptable. See last report. Please note that the identification of these bars was not readable, but it is believed that they came from zones 1, 2 and 3.**

Root Cause

See attached report, with attachments.

Corrective Action

Use A-6 as is.

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Actual Completion Date

Completed 4/20/06.

Signed: C. Ruud

CC: B. Craig, J. Edwards, E.J. Kubick, J. Markham, J. Galaske

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March 9, 2006

CERTIFICATION

Section 1 of 1
WMT&R Report No. 6-23847
P.O. No. 19386
Requisition No. 7580

MetalTek International
The Carondelet Division
8600 Commercial Blvd.
I-55 Industrial Park
Pevely, MO 63070-1528

Attention: Jim Galaske

Subject: All processes, performed upon the material as received, were conducted at WMT&R, Inc. in accordance with the WMT&R Quality Assurance Manual, Rev. 9, dated 4/1/2000.
The following tests were performed on this order: TENSILE

TENSILE RESULTS: ASTM E21-05
Requirements: UTS ksi (Min 95\Max ---) 0.2% YS ksi (Min 72\Max ---) 4D Elong. % (Min 32\Max ---) Modulus Msi (Min 21\Max ---)
SOAK TIME: 5 Minutes
SPEED OF TESTING: 0.003 in./in./min., 0.05 in./min./in.
MATERIAL: 316 S/S
DISPOSITION: Acceptable

Coil No.	Specimen	TestLog Number	Temp. °F	UTS ksi	0.2% YS ksi	Elong %	RA %	Modulus Msi	Ult. Load lbf	0.2% YLD. lbf	Orig. Dia. (in.)	Final Dia. (in.)	4D Orig GL (in.)	4D Final GL (in.)	Orig. Area (sq. in.)	Machine Number	A\U\R
A6	Z2	D18313	-320	163.7	100.1	61	41	28.0	15730	9616	0.3498	0.2698	1.40	2.25	0.09610135	M9	A

A\U\R: A=ACCEPTABLE, U=UNACCEPTABLE, R=REPORT

TENSILE RESULTS: ASTM E21-05
Requirements: UTS ksi (Min 95\Max ---) 0.2% YS ksi (Min 72\Max ---) 4D Elong. % (Min 32\Max ---) Modulus Msi (Min 21\Max ---)
SOAK TIME: 5 Minutes
SPEED OF TESTING: 0.003 in./in./min., 0.05 in./min./in.
MATERIAL: 316 S/S
DISPOSITION: Unacceptable

Coil No.	Specimen	TestLog Number	Temp. °F	UTS ksi	0.2% YS ksi	Elong %	RA %	Modulus Msi	Ult. Load lbf	0.2% YLD. lbf	Orig. Dia. (in.)	Final Dia. (in.)	4D Orig GL (in.)	4D Final GL (in.)	Orig. Area (sq. in.)	Machine Number	A\U\R
A6	Z1	D18312	-320	161.1	108.9	26	30	29.7	15470	10460	0.3497	0.2929	1.40	1.76	0.09604641	M9	U
A6	Z3	D18314	-320	157.5	111.2	19	28	30.9	15140	10690	0.3498	0.2959	1.40	1.67	0.09610135	M9	U

A\U\R: A=ACCEPTABLE, U=UNACCEPTABLE, R=REPORT

Matthew Wojton 3-9-06
Roy E. Starr\Matt Wojton
Technical Services Manager\ Tensile Supervisor
March 9, 2006

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Accredited Nadcap Materials Testing Laboratory

April 3, 2006

CERTIFICATION

WMT&R Report No. 6-25662
P.O. No. 19386
Requisition No. 7580

MetalTek International
The Carondelet Division
8600 Commercial Blvd.
I-55 Industrial Park
Pevely, MO 63070-1528

Attention: Jim Galaske

Subject: All processes, performed upon the material as received, were conducted at WMT&R, Inc. in accordance with the WMT&R Quality Assurance Manual, Rev. 9, dated 4/1/2000.
The following tests were performed on this order: TENSILE

TENSILE RESULTS: ASTM E21-05

Requirements: UTS ksi (Min 95\Max —) 0.2% YS ksi (Min 72\Max —) 4D Elong. % (Min 32\Max —) Modulus Msi (Min 21\Max —)

SOAK TIME: 5 Minutes

SPEED OF TESTING: 0.003 in./in./min., 0.05 in./min./in.

MATERIAL: Metaltek CF8MNMnMOD

DISPOSITION: Acceptable

Coil No.	Specimen	TestLog Number	Temp. °F	UTS ksi	0.2% YS ksi	Elong %	RA %	Modulus Msi	Ult. Load lbf	0.2% YLD. lbf	Orig. Dia. (in.)	Final Dia. (in.)	4D Orig GL (in.)	4D Final GL (in.)	Orig. Area (sq. in.)	Machine Number	A\U\R
A6	Z2	D[illegible]	-3[illegible]0	166.2	99.8	58	44	25.3	16120	9677	0.35[illegible]4	0.2622	1.40	2.2[illegible]	0.09698250	M9	A

A\U\R: A=ACCEPTABLE, U=UNACCEPTABLE, R=REPORT

TENSILE RESULTS: ASTM E21-05

Requirements: UTS ksi (Min 95\Max —) 0.2% YS ksi (Min 72\Max —) 4D Elong. % (Min 32\Max —) Modulus Msi (Min 21\Max —)

SOAK TIME: 5 Minutes

SPEED OF TESTING: 0.003 in./in./min., 0.05 in./min./in.

MATERIAL: Metaltek CF8MNMnMOD

DISPOSITION: Unacceptable

Coil No.	Specimen	TestLog Number	Temp. °F	UTS ksi	0.2% YS ksi	Elong %	RA %	Modulus Msi	Codes	Ult. Load lbf	0.2% YLD. lbf	Orig. Dia. (in.)	Final Dia. (in.)	4D Orig GL (in.)	4D Final GL (in.)	Orig. Area (sq. in.)	Machine Number	A\U\R
A6	Z1	D30718	-320	166.1	106.1	25	26	27.6	—	16050	10450	0.3506	0.3024	1.40	1.75	0.09665160	M9	U
A6	Z3	D30720	-320	129.7	105.2	13	19	27.9	D	12540	10170	0.3506	0.3153	1.40	1.58	0.09665160	M9	U

A\U\R: A=ACCEPTABLE, U=UNACCEPTABLE, R=REPORT

Requirements provided by MetalTek International

D - Ruptured outside middle half of gage length.

Roy E. Starr/Matt Wojton
Technical Services Manager / Tensile Supervisor

4-3-06
April 3, 2006

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April 10, 2006

CERTIFICATION

Section 1 of 1
WMT&R Report No. 6-26780
P.O. No. 19386
Requisition No. 7580

MetalTek International
The Carondelet Division
8600 Commercial Blvd.
I-55 Industrial Park
Pevely, MO 63070-1528

Attention: Jim Galaske

Subject: All processes, performed upon the material as received, were conducted at WMT&R, Inc. in accordance with the WMT&R Quality Assurance Manual, Rev. 9, dated 4/1/2000.
The following tests were performed on this order: TENSILE

TENSILE RESULTS: ASTM E21-05
Requirements: UTS ksi (Min 95\Max ---) 0.2% YS ksi (Min 72\Max ---) 4D Elong. % (Min 32\Max ---) Modulus Msi (Min 21\Max ---)
SOAK TIME: 5 Minutes
SPEED OF TESTING: 0.003 in./in./min., 0.05 in./min./in.
MATERIAL: Metaltek CF8MNMnMOD

DISPOSITION: Acceptable

Coil No.	Specimen	TestLog Number	Temp. °F	UTS ksi	0.2% YS ksi	Elong %	RA %	Modulus Msi	Ult. Load lbf	0.2% YLD. lbf	Orig. Dia. (in.)	Final Dia. (in.)	4D Orig GL (in.)	4D Final GL (in.)	Orig. Area (sq. in.)	Machine Number	A\U\R
A6	Z2	D38883	-320	165.8	100.8	36	31	28.6	16070	9774	0.3513	0.2923	1.40	1.90	0.09692731	M9	A
A6	Z3	D38884	-320	160.9	93.7	44	41	25.5	15540	9049	0.3507	0.2686	1.40	2.02	0.09659650	M9	A

A\U\R: A=ACCEPTABLE, U=UNACCEPTABLE, R=REPORT

TENSILE RESULTS: ASTM E21-05
Requirements: UTS ksi (Min 95\Max ---) 0.2% YS ksi (Min 72\Max ---) 4D Elong. % (Min 32\Max ---) Modulus Msi (Min 21\Max ---)
SOAK TIME: 5 Minutes
SPEED OF TESTING: 0.003 in./in./min., 0.05 in./min./in.
MATERIAL: Metaltek CF8MNMnMOD

DISPOSITION: Unacceptable

Coil No.	Specimen	TestLog Number	Temp. °F	UTS ksi	0.2% YS ksi	Elong %	RA %	Modulus Msi	Codes	Ult. Load lbf	0.2% YLD. lbf	Orig. Dia. (in.)	Final Dia. (in.)	4D Orig GL (in.)	4D Final GL (in.)	Orig. Area (sq. in.)	Machine Number	A\U\R
A6	Z1	D38882	-320	134.7	100.2	20	23	26.0	D	13030	9700	0.3510	0.3084	1.40	1.68	0.09676184	M9	U

A\U\R: A=ACCEPTABLE, U=UNACCEPTABLE, R=REPORT

Requirements provided by MetalTek International
D - Ruptured outside middle half of gage length.

Matthew Wojton 4-10-06
Roy E. Starr\Matt Wojton
Technical Services Manager\ Tensile Supervisor
April 10, 2006

Addendum to CA 1671
Effect of Solidification Microstructure on Tensile Properties of Stellaloy
J. Edwards and C. Ruud, MetalTek International

Overview

The development of "Stellaloy" by MetalTek International commenced in 2003 with the modification of the base 316 material primarily for magnetic permeability requirements. Initial results demonstrated that this material is extremely robust mechanically at both ambient and cryogenic temperature ranges. Tensile properties gathered from integrally cast test specimens poured with the modules have shown variability. While most have far exceeded the specification minima, outliers have shown to demonstrate reduced elongation.

Background

Initial tests on the C5 casting showed that the elongation was lower in test bars associated with Zone1 than in other areas of the casting. Repeat tests showed the same result (Table I). Based on this result, the microstructure of the test specimen was examined and characterized compared to other test bars integral to the same modular coil casting. Results are shown in figures Lab report 05M1167, Figures 1, 2 and 3.

Similarly, testing of the A6 casting has shown a lower elongation in the test specimens associated with Zone 1. Testing was repeated in specimens from the same zone with reproducible results (25-26% elongation at 77K), although one test demonstrated a 20% elongation with breakage outside the gauge. Results of this test are shown in Table II and associated microstructures in Figures contained in WMTR#6-26780.

The tensile test variation seems to demonstrate correlation to microstructure with finer grains and heavily dendritic structures showing lower elongation. Other properties are generally well above specification for both samples.

The attached test specimens from the production coils are machined to a 0.350" diameter ("sub size" or SS) bar. The strain rate on the production components is 0.003 in/in/min to yield and 0.05 in/min/in to fracture.

Analysis

The test specimens are attached to metal feeders ("risers") in the modular coil casting mold. The attachment of these test specimens is largely determined by convenience due to accessibility of the feeder and orientation to a natural interface between mold components (cope, drag, and cores). Metal is introduced into the mold through a series of ceramic tubes from any of 3 ladles and mixes naturally upon entry into the mold cavity.
Attached test specimens are filled by the molten metal at different temperatures and at different elapsed time from mold filling onset. The combination of elapsed time and geometric location of the attached specimens results in a range of solidification structures based on the superheat of the metal entering the specimen as well as the rate of heat extraction from the metal through the sand wall due to mold temperature surrounding the specimen (Table III). In general, cooler metal temperatures favor multiple nucleation sites while cooler mold temperatures promote nucleation at an accelerated rate on the mold

surface. Hotter metal temperatures result in fewer nucleation sites and more growth of individual grains during solidification.

Results

1. The properties measured from attached test specimens vary; however, exceed the specification minima in most cases.
2. Isolated test bars have shown depressed elongation values of approximately 25-29%. Microstructural analysis of these test bars demonstrate that the microstructure is generally fine grained and may or may not contain heavily dendritic structure.
3. Test bar structure is the result of solidification physics of the test material and not associated with physical differences of Zone location.
4. Stellaloy continues to test well across a variety of microstructures at both 77K and RT.

Table III	High Metal Temperature	Low Metal Temperature
High Mold Temperature	Little incentive for nucleation and low thermal gradients. Large columnar grains.	Multiple nucleation sites within material, but little thermal gradient to mold. Creates finely dispersed equiaxed structure within metal with little correlation to mold wall.
Low Mold Temperature	Strong dendritic structure with multiple mold surface nucleation sites. Relatively “fine” appearance of closely spaced dendrites.	Multiple nucleation sites with primary sites on mold walls. Intraspecimen nucleation as solidification progresses. Broken dendritic with equiaxed.

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Accredited Nadcap Materials Testing Laboratory

April 19, 2006

CERTIFICATION

Section 1 of 1

WMT&R Report No. 6-27410
P.O. No. 19386
Requisition No. 7580

MetalTek International
The Carondelet Division
8600 Commercial Blvd.
I-55 Industrial Park
Pevely, MO 63070-1528

Attention: Jim Galaske

Subject: All processes, performed upon the material as received, were conducted at WMT&R, Inc. in accordance with the WMT&R Quality Assurance Manual, Rev. 9, dated 4/1/2000.
The following tests were performed on this order: MICRO and TENSILE

TENSILE RESULTS: ASTM E21-05

Requirements: UTS ksi (Min 95\Max ---) 0.2% YS ksi (Min 72\Max ---) 4D Elong. % (Min 32\Max ---) Modulus Msi (Min 21\Max ---)

SOAK TIME: 5 Minutes

SPEED OF TESTING: 0.003 in./in./min., 0.05 in./min./in.

MATERIAL: Metaltek CF8MNMnMOD

DISPOSITION: Acceptable

Coil No.	Specimen	TestLog Number	Temp. °F	UTS ksi	0.2% YS ksi	Elong %	RA %	Modulus Msi	Ult. Load lbf	0.2% YLD. lbf	Orig. Dia. (in.)	Final Dia. (in.)	4D Orig GL (in.)	4D Final GL (in.)	Orig. Area (sq. in.)	Machine Number	A\U\R
A6	Z1	D43605	-320	167.3	95.8	64	65	25.8	16150	9252	0.3506	0.2082	1.40	2.30	0.09654142	M9	A
A6	Z2	D43606	-320	167.1	97.0	54	80	24.8	16180	9394	0.3511	0.1585	1.40	2.15	0.09681698	M9	A
A6	Z3	D43607	-320	189.4	116.2	51	44	31.7	18300	11220	0.3507	0.2620	1.40	2.12	0.09659650	M9	A

A\U\R: A=ACCEPTABLE, U=UNACCEPTABLE, R=REPORT

Requirements provided by MetalTek International

Roy E. Starr\Matt Wojton
____ Technical Services Manager\✓ Tensile Supervisor

4-19-06

April 19, 2006