ATTACHMENT III

Consumers Power Company
Palisades Plant
Docket 50-255

SUMMARY OF FINDINGS RELATIVE TO PALISADES PLANT REACTOR VESSEL MATERIALS

June 14, 1985

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SUMMARY OF FINDINGS RELATIVE TO PALISADES PLANT REACTOR VESSEL MATERIALS

BACKGROUND

Two irradiated reactor vessel surveillance capsules have been removed from the Palisades Plant reactor vessel in conjunction with the plant reactor vessel surveillance program. The first of these capsules was an accelerated capsule which was subjected to a neutron exposure exceeding the maximum then expected for the vessel inner diameter at the end of the vessel lifetime. Capsule and baseline material documentation is contained in References (1 and 2). Recently the second capsule (a wall capsule) was removed and evaluated as documented in Reference (3).

The materials evaluation for the weld specimens in both irradiated capsules reflected large shifts in the 30 Ft lb Charpy energies with respect to the unirradiated specimens. The shifts for both capsule specimens were above those expected based upon the Reference (4) chemistry/shift/ fluence correlations. For the wall capsule, the shift was above the upper limit curve of Reference (4). The dosimetry calculations for the accelerated capsule indicated a fluence lead factor of 17.5. However, the calculated peak wall fluence based upon the accelerated capsule results was consistent with initial design predictions. Dosimetry measurements and calculations for the recently removed wall capsule resulted in an estimated end-of-life (EOL) fluence roughly 50 percent greater than earlier predicted.

The large shifts in 30 Ft lb energy as a function of neutron exposure and the uncertainty in the EOL exposure provided the impetus for Consumers Power Company (CPCo) to initiate a detailed review of the Palisades reactor vessel and surveillance program weld materials and the core power distribution over the last few fuel cycles. The purpose of this review was to define adjusted weld material reference temperatures as well as maximum vessel wall fluence. The characterization of materials and fluence parameters was required for the determination of primary coolant system operating pressure/temperature limits and for an evaluation of the vessel material vulnerability to pressurized thermal shock loadings.

EARLY FABRICATION HISTORY -CE VESSELS

The Palisades Plant reactor vessel was fabricated by Combustion Engineering (CE) in Chattanooga, TN for CE in Windsor, CT under contract 2966. The last two digits of the contract indicate the year of the contract. The Palisades reactor vessel was fabricated in the 1966 to 1968 time frame as were several other vessels. The fabrication history discussion below is essentially that of References (5 and 6) but it is largely repeated here for continuity. The chronology is important because over a period of time different weld procedures were employed.

The very early commercial vessels were made with SA302 Grade B plate and high Mn-Mo weld wire. The weld wire was produced by Reid Avery Company (Raco) and was bought to a Mil B-4 Modified (HiMnMo) specification. The wire came to be known as Raco 3. The welding flux was produced by ARCOS and came to be known as Arcos B5. Pre-1965 vessels such as Big Rock Point were fabricated by CE with the Raco 3/Arcos B5 wire/flux combination. About 1965, nickel was added to the SA 302 Grade B plate specification to improve hardenability. Nickel was added to the weld specification as well. This was initially accomplished by using the very low nickel Raco 3 wire in conjunction with a second wire of pure nickel - typically Nickel 200. The target level of nickel in these Raco 3 + Ni200 weld deposits was 1.00 weight percent (wt%). Such welds were produced with a Linde 1092 flux. Beginning in late 1966, CE ordered subarc wire to a Mil B-4 Modified (MnMoNi) specification that included the targeted amount of nickel and, therefore, eliminated the need for the dual wire feed process. These initial wires were produced with a nickel content required by specification to be within .9 to 1.1 wt%. Later specification requirements for nickel content were reduced to .60 and .80 wt%. The Mil B-4 Modified (MnMoNi) welds were produced with either Linde 1092,0091 or 124 fluxes. In the early 1970's, CE reverted back to the original Mil B-4 specification. These later welds were made with Linde 0091 or 124 fluxes.

Tables 1 and 2 are reproduced from Reference (6). Table 1 tends to be ordered from contract date from top to bottom. With that understanding, one can reliably conjecture which heats of wire may be associated with which vessel. The fabrication record for the Palisades Plant reactor vessel is a bit more complicated because it must be considered to be a transitional vessel insofar as weld wire heats and welding procedures are concerned. As will be discussed below, the Palisades reactor vessel contains two heats of Raco 3 wire and two heats of Mil-B4 Modified (produced by ADCOM) wire while the reactor vessel surveillance program reflects a third heat of Raco 3 wire which is not in any of the vessel welds.

VESSEL FABRICATION RECORDS FOR PALISADES

Reference (3) reported the results of chemical analyses by Westinghouse of fractured Charpy specimens from the Palisades Plant surveillance program. The analyses reflected a very strong variation in nickel content across the specimen. The variation was judged inconsistent with the variation expected from welding procedures associated with either HiMnMo or MnMoNi weld wire. It appeared that such a nickel variation could only be expected in Raco 3 welds where the Nickel-200 addition was varied during the dual wire feed process. The chemical analyses suggested that the surveillance weld was not the Mil B-4 Modified wire heat 27204 weld as CE had reported (under contract to CPCo) to the Staff in Reference (7). The original CE surveillance report (Reference (10)) indicated that the surveillance weld was produced with Raco 3/Ni 200 consumables.

CPCo was advised by the EPRI staff to consider a very thorough search of the Palisades reactor vessel and surveillance program records in order to address uncertainties in weld characteristics. A similar search by Baltimore Gas and Electric (BG&E) was judged by BG&E to be very valuable. Therefore, CPCo and CE conducted a detailed search of vessel and surveillance fabrication records to include test reports, weld inspection reports, shop travellers, specifications and weld procedures. References (8 and 9) are documentation reports associated with the findings of CPCo and CE during that search. Records were detailed enough to indicate the date and amounts of the various weld wires which CE received during the 1965 to 1970 time frame. It was also possible to make reasonable estimates of the dates at which many of the wire heats were entirely consumed. Shop travelers clearly associated weld seams with wire heats, fluxes and welding procedures. All records were not perfectly traceable. However, there were no obvious conflicts in the documentation and one could hypothesize the fabrication scenario for the Palisades vessel with reasonable reliability. The records revealed no inconsistencies with regard to previous understandings with regard to the reactor vessel itself. However records clearly indicated that the surveillance weld was made of a Raco 3 wire with the Ni-200 addition and not with the Mil B-4 Modified heat 27204. The surveillance weld was made over a year after the reactor girth weld was finished. Normal CE practice was to use the same consumables for the beltline girth and the surveillance welds. Table 3 provides a record of the consumables used in the beltline and surveillance welds.

Reference (9) provides a very logical summary of the fabrication sequence of the Palisades vessel/surveillance welds. It suggests that the surveillance weld was intended to represent the vessel longitudinal welds. Based upon wire receipt dates, vessel and surveillance weld fabrication sequence and changes in shop welding practices, the use of Mil B-4 (HiMnMo) wire with Ni-200 addition was being phased out in the 1966-1967 time frame and was being replaced by Mil B-4 Modified (MnMoNi) wire with nickel included. The use of Raco 3 heat W5214 in many vessels (Table 4) seems to have depleted the stock by mid-1967. The Raco 3 34B009 wire was available with Raco 3 W5214 for a period of time. However, that wire was exhausted by early 1969. The Mil B-4

Modified 27204 wire from ADCOM Metals Company appears to have been consumed between mid-1967 and early 1968. It can be conjectured that there simply was not enough of the weld wire used in the fabrication of the Palisades vessel (W5214, 34B009 or 27204) remaining in stock to fabricate the surveillance weld. Therefore, a new Raco 3 wire (heat 3277) was special ordered.

It would seem reasonable to assume that under ordinary circumstances, the Raco 3 (heat 3277) as-welded chemistries would be similar to those of other Raco 3 welds. However, Reference (3,9 and 10) imply that the Palisades surveillance weld is chemically uncharacteristic of welds of Raco 3 wire used in vessel fabrication in the 1966-1969 time span. The copper content of the surveillance weld is on the upper end of the published distribution and is more characteristic of the very early Raco 3 welds such as used in the Big Rock Point vessel (1960-61). The variation in copper through the weld thickness (Reference (11)) is also unusually high for this type of consumable. The variation in nickel content may lead one to speculate that wire feed mechanisms for nickel wire which had not been used for over a year may not have been functioning properly. It would appear that the Palisades Raco 3 vessel welds are best represented by other Raco 3 welds made for other vessels and for other surveillance programs at the time of manufacture of the Palisades reactor vessel. The as-deposited reactor vessel welds in the Palisades vessel have not been sampled for chemistry. However, there is a significant data base of chemistries available for other welds made with the same consumables. The data base for the Mil B-4 Modified heat 27204 wire is more limited than that for Raco 3 wire. There appear to be only two reliable ADCOM wire heat 27204 data sources which provide chemistry. These sources (References (12 and

13)) provide similar copper and nickel values to one another and to the Raco 3 summary discussed below.

CHEMISTRY-RACO 3 WELDS

Tables 4 and 5 are essentially extracted from Reference (6). From those Tables, it may be concluded that mean values for Raco 3 welds may be taken as .19 wt% copper and 1.10 wt% nickel. These chemistries constitute mean values appropriate for inclusion in guidelines for determining adjusted reference temperatures. In an EPRI research project with General Electric Co (Reference (14)) as discussed in Reference (6), detailed chemical sampling and mechanical testing were conducted. The NDTT of the Raco W5214/Ni200 surveillance weld was determined to -80°F. Charpy data were in the form of a curve. Triplicate specimen testing as required by the ASME Code (Reference (15)) at NDTT plus 60°F was not conducted, so a RT_{NDT} reference temperature was not explicitly determined. However, it is very clear from an inspection of the Charpy curve that such a triplicate would have met 50 Ft lbs and RT_{NDT} would have been -80°F.

CHEMISTRY - ADCOM HEAT 27204 WELDS

As noted above, the chemistry for the Mil B-4 Modified heat 27204 comes from two sources. Each source has resulted from a record search of the CE Chattanooga facility for the Diablo Canyon reactor vessel/surveillance program fabrication data. Pacific Gas and Electric conducted this search in early 1985. A heat 27204 flange to upper shell girth seam weld on contract

14166 (a Japanese vessel for Westinghouse) provided a copper/nickel data pair of .18/.96 wt%. That record search has also concluded that what was earlier reported as a tandem arc (heats 12008 and 27204) reactor vessel surveillance weld, References (5 and 13), was in fact simply a weld using only the heat 27204 wire. The chemistry for that weld reflects .21 wt% copper and .98 wt% nickel. There are no known drop weight tests on heat 27204 weld wire deposits. Therefore, initial reference temperatures can only be estimated on a statistical basis based upon similar welds. CE test reports for wire heats W5214, 34B009 and 27204 contain triplicate Charpy tests at +10°F. The tests for all three heats indicate that the welds fall within the generic statistical band associate with CE welds for initial RT_{NDT} as reported in Reference (16)

PREDICTED END OF LIFE EXPOSURE

The physics calculations in Reference (3) have been thoroughly reviewed by CPCo. Revised fuel loads and core power distribution have varied the projection of EOL peak vessel wall fluence. The axial peaking factor employed in Reference (3) should be reduced to 1.15 from the 1.20 which has been employed. With this adjustment, the peak vessel inner diameter fluence would be projected to be $5.9 \times 10^{19} n/cm^2$. This value represents the average of measured and calculated numbers. This fluence is essentially the same as that for Calvert Cliffs 1 (Reference (5)) and has been accepted as an accurate, updated value by CPCo. Both Palisades and Calvert Cliffs 1 operate without thermal shields.

DAMAGE FORECASTING

In order to address the Pressurized Thermal Shock concern, the NRC has posed a "PTS Rule" (Reference (17)). The EOL RT_{NDT} is:

$$RT_{NDT_{EOL}} = RT_{NDT_{initial}} + \Delta RT_{NDT} + 2\sqrt{\sigma^2 initial + \sigma^2 shift}$$

$$\Delta RT_{NDT} = [\ -10 + 470\ Cu + 350\ CuNi]\ \left[\frac{\phi\ (t)}{10^{19}}\right]^{.27}$$

Where:

- Cu = Copper wt%
- Ni = Nickel wt%
- ϕ (t) = Neutron Fluence
- σ shift = 24°F
- σ initial = 17°F or any lower justified value

LONGITUDINAL WELD

Employing .19wt% for copper, 1.10wt% nickel, $5.9\times10^{19} n/cm^2$ for fluence and considering the generic mean $RT_{NDT_{initial}}$ of -56°F from Reference (16):

$$RT_{NDT_{EOL}} = -56 + 246 + 2\sqrt{17^2 + 24^2}$$

$$= 249°F$$

GIRTH WELD

Employing .21 wt% for copper, .98 wt% for nickel from Reference (13), $5.9 \times 10^{19} n/cm^2$ for fluence and the generic mean $RT_{NDT_{initial}}$ of -56°F:

$$RT_{NDT_{EOL}} = -56 + 260 + 2\sqrt{17^2 + 24^2}$$

$$= 263°F$$

ASSESSMENT

Based upon the PTS Rule evaluation procedures, the Palisades Plant welds will not exceed the screening limits. For the longitudinal weld, the $RT_{NDT_{EOL}}$ is conservatively evaluated as 249°F which is below the screening limit of 270°F. For the girth weld, the $RT_{NDT_{EOL}}$ is determined to be 263°F which is below the screening limit of 300°F. Therefore, Palisades reactor vessel need not be affected by PTS considerations.

OVERALL CONCLUSION

A detailed review of reactor vessel fabrication and reactor vessel surveillance irradiation data has been conducted in order for CPCo to predict more accurately the Palisades Plant reactor vessel weld material properties over the vessel lifetime.

The detailed review of the reactor vessel fabrication records confirmed that the previously reported vessel information was correct. This review revealed that the welds in the Palisades vessel were made with same materials and procedures and in the same time frame as the welds in other vessels and in other reactor vessel surveillance programs. However, the review confirmed some inconsistencies regarding the Palisades surveillance material

The Palisades Plant reactor surveillance weld material differs from the welds in the vessel itself. Although the weld was from the same supplier as for the longitudinal vessel welds, the heat of wire was different, the surveillance weld was made about two years after the longitudinal vessel welds and the weld chemistries and the through-thickness variations of the copper and nickel were not consistent with other Raco 3 welds of the Palisades reactor vessel vintage.

In view of the above, it has been concluded that surveillance and weld deposit data from other sources would more realistically reflect both the chemical and mechanical properties of the Palisades Plant reactor vessel welds. The chemical properties from a reasonably large data base has been used to determine chemistries for the Palisades vessel longitudinal welds. A more limited, but reliable, data base has been employed for the vessel girth welds. These data bases integrated into the PTS Rule formulation imply no PTS concerns. Those same data can be applied to the development of primary coolant system pressure/temperature limits.

REFERENCES

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3. Kunka, M.K. and C.A. Cheney, "Analysis of Capsules T-330 and W-290 from the Consumers Power Company Palisades Reactor Vessel Radiation Surveillance Program," WCAP-10637, September, 1984.

4. U.S. NRC Regulatory Guide 1.99 Rev 1, " Effects of Residual Elements on Predicted Radiation Damage to Reactor Vessel Materials", Office of Standards Development, U S Nuclear Regulatory Commission, April, 1977.

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11. Letter from E.D. Foreman (Anamet Laboratories) to T Griesbach (EPRI), "One Welded Plate for Chemical Analysis of the Weld Metal", April 24, 1985.

12. Letter W.C. Ham (Pacific Gas and Electric) to J B Toskey (CPCo), Transmittal of Combustion Engineering Test Reports, April 3, 1985.

13. Mager T.R.et al, "Pacific Gas and Electric Diablo Canyon Unit 1 Reactor Vessel Radiation Surveillance Program", WCAP-8465, January 1975.

14. Draft Report, "Fracture Toughness of Reactor Vessel Steel Welds", General Electric, EPRI Contract RP2180-6, November 1983.

15. American Society of Mechanical Engineers Boiler and Pressure Vessel Code, Section III, Article NB-2331, Materials for Vessels, 1983 edition.

16. "Evaluation of Pressurized Thermal Shock Effects due to Small Break LOCA's with Loss of Feedwater for the Combustion Engineering NSSS", CEN-189, CE Power Systems, December 1981

17. "Proposed Pressurized Thermal Shock Rule", US NRC. SECY-83-288, July 15, 1983.

TABLE 1

VESSELS FABRICATED BY C-E WITH
RACO 3 HIGH Mn-Mo WIRE

Humboldt Bay	(BWR)	USA
Zorita	(PWR)	Spain
Big Rock Point	(BWR)	USA
Tarapur	(BWR)	India
Connecticut Yankee	(PWR)	USA
San Onofre	(PWR)	USA
Robinson 2 *	(PWR)	USA
Millstone*	(BWR)	USA
Indian Point 2 *	(PWR)	USA
Indian Point 3 *	(PWR)	USA
Salem 1 *	(PWR)	USA
Palisades *	(PWR)	USA

*Ni 200 added

TABLE 2

HEATS OF RACO 3 HIGH Mn-Mo WIRE
USED BY C-E

Heat Number	Date Available
9565	9-61
86054B	3-64
1248	12-64
W5214	9-65
39B196	12-66
34B009	1-67

TABLE 3

CONSUMABLES USED IN THE
PALISADES REACTOR VESSEL BELTLINE AND
SURVEILLANCE WELDS

Intermediate Shell Longitudinal Seams (2-112A/C)	Raco 3 W5214 3/16" w/Ni200 N 7753A 1/16" Linde 1092 Lot 3617
Lower Shell	Raco 3 W5214 3/16" or Raco 3 34B009 3/16"
Longitudinal Seams (3-112A/C)	w/Ni200 N 7753A 1/16 Linde 1092 Lot 3692
Intermediate/Lower Shells Girth Weld (9-112)	Mil B-4 Mod (MnMoNi) Heat 27204 3/16" Linde 1092 Lot 3714
Surveillance Weld	Raco 3 3277 linde 1092 lot 3833 Ni-200 N-0591A (face weld only) E8018 Electrode HADH (back weld, base metal repair.

TABLE 4

COPPER MEASUREMENTS ON RACO 3 WELDMENTS MADE BY C-E

Plant	Weld	Heat No.	Cu. Content (x)[1] Wt%
Humboldt	Surv.	?	0.22(6)
Zorita	Surv.	1248	0.22
Big Rock Point	Surv.	?	0.26(3)
Tarapur	Surv.	?	0.16(5)
Conn. Yankee	Surv.	9565/86054B	0.22
San Onofre	Surv.	?	0.19
Millstone 1	Surv.	W5214	0.19(13)
IP 2	Surv.	W5214	0.20(4)
IP 3	Surv.	W5214	0.15
Salem 1	Surv.	39B196	0.16
IP 3	Long Seam	W5214	0.15(3)
Lab Record	Weld Deposit	W5214	0.20
Lab Record	Weld Deposit	34B009	0.15
Robinson	Head Weld 1	34B009	0.19(4)
Robinson	Head Weld 2	W5214	0.16(4)

[1]average of X measurements

TABLE 5

NICKEL CONTENT OF RACO 3+Ni 200/LINDE 1092 WELDMENTS

Plant	Weld	Ni 300 Heat Number	Ni Content Wt%
Millstone 1	Surv.	N7753A	0.98(13)[1]
Salem 1	Surv.	N7753A	1.26
IP3	Surv.	N7753A	1.02
IP3	Long Seam	N7753A	1.09(3)
IP2	Surv.	N7753A	1.15(4)
Lab Records (C-E)		N7753A	1.09(5)
Robinson	Head 2	?	0.99(4)

[1]indicated multiple measurements

ADDENDUM

The chemical analysis transmitted was conducted on a through-thickness section of the Palisades Plant reactor vessel surveillance program archival material. The particular section transmitted to Anamet is depicted as the HAZ-metal-piece 3 section on CE Drawing 2966-E-2988 Rev 3. The drawing is copied in Reference (10).

A piece suitable for analysis was slabbed off the block and subjected to emission spectrograph evaluation. Ten evaluation points essentially equidistant across the 8.625 inch section thickness were considered on either side of the slab. The variation in wt% of copper and especially nickel across the section thickness is judged to be very high. The values of copper and nickel wt% were not unexpected based upon the surveillance program documentation and fabrication records. The chemistries do not reflect the chemistries of the reactor vessel welds.

For information, it is possible to average the chemistries from the Anamet report and estimate mean reference temperature shifts based upon Regulatory Guide 1.99 Rev 2 - an update of Reference (4). These mean shifts can then be compared with measured shifts for the surveillance capsules which are reported in References (2 and 3)

The average copper and nickel weight percents across the section thickness are .25% for copper and 1.12% for nickel. Per Regulatory Guide 1.99 Rev 2, the weld chemistry factor is determined to be 260°F. The accelerated capsule (A-240) sustained a neutron exposure of $4.6 \times 10^{19} n/cm^2$ > 1MEV. The wall capsule (W-290) sustained an exposure of $1.09 \times 10^{19} n/cm^2$ > 1MEV. Per the Regulatory Guide, the associated fluence factors are 1.02 for the wall capsule and 1.39 for the accelerated capsule.

Taking the product of these factors, a mean predicted reference temperature shift may be determined per the Regulatory Guide 1.99 Rev 2 correlation. These shifts are predicted to be 266°F for the wall capsule and 360°F for the accelerated capsule. The actual measured shifts were 290°F for the wall capsule and 350°F for the accelerated capsule.

It may or may not be appropriate to employ the standard deviation of 28°F as statistically appropriate for such data. The applicability of the 28°F as prescribed in the Regulatory Guide depends upon what the uncertainty is assumed to be based on. However, the measured 30 Ft lb shift in the Charpy curve is slightly less than a standard deviation above the mean predicted shift for the wall capsule. The measured shift is less than a standard deviation below the mean predicted shift for the accelerated capsule. Therefore, the surveillance program associated with the Palasades Plant includes fluence/shift data pair which are approximated by the correlations of Regulatory Guide 1.99 Rev 2. However, the surveillance weld material does not reflect the material properties of the reactor vessel welds.

LABORATORY CERTIFICATE

Anamet Laboratories, Inc.

ANALYTICAL
CHEMICAL
METALLURGICAL

2827 SEVENTH STREET • BERKELEY, CALIFORNIA 94710 • (415) 841-5771

HIGH TEMPERATURE
APPLIED RESEARCH
PHYSICAL TESTING

April 30, 1985

LABORATORY NUMBER: 485.326

SUBJECT: One Welded Plate for Chemical Analysis of the Weld Metal

MARK: 9" Thick Plate
Palisades Surveillance Block
Inside to Outside - Side 1
Inside to Outside - Side 2

DATE SUBMITTED: April 24, 1985

REPORT TO: Electric Power Research Institute
3412 Hillview Avenue
P.O. Box 10412
Palo Alto, California 94303
Attn: Tim Griesbach

CHEMICAL ANALYSIS
(Emission Spectrograph)

Inside to Outside-Side 1:		No. 1	No. 2	No. 3	No. 4
Carbon	(C)	0.10%	0.09%	0.09%	0.12%
Chromium	(Cr)	0.07%	0.07%	0.06%	0.10%
Copper	(Cu)	0.26%	0.27%	0.26%	0.23%
Manganese	(Mn)	1.16%	1.11%	1.15%	1.34%
Molybdenum	(Mo)	0.48%	0.49%	0.48%	0.45%
Nickel	(Ni)	1.25%	0.98%	1.27%	1.09%
Phosphorus	(P)	0.013%	0.014%	0.014%	0.012%
Silicon	(Si)	0.27%	0.26%	0.24%	0.22%
Sulfur	(S)	0.012%	0.011%	0.011%	0.012%

Inside to Outside-Side 1:		No. 5	No. 6	No. 7	No. 8
Carbon	(C)	0.10%	0.09%	0.08%	0.09%
Chromium	(Cr)	0.06%	0.05%	0.05%	0.05%
Copper	(Cu)	0.27%	0.23%	0.22%	0.22%
Manganese	(Mn)	1.24%	1.19%	1.16%	1.12%
Molybdenum	(Mo)	0.48%	0.46%	0.47%	0.48%
Nickel	(Ni)	0.90%	1.18%	1.28%	1.27%
Phosphorus	(P)	0.014%	0.012%	0.012%	0.012%
Silicon	(Si)	0.22%	0.25%	0.26%	0.27%
Sulfur	(S)	0.012%	0.013%	0.013%	0.013%

Anamet Laboratories, Inc.
2827 SEVENTH STREET • BERKELEY, CALIFORNIA 94710

Lab. No. 485.326

CHEMICAL ANALYSIS
(Emission Spectrograph)

Inside to Outside-Side 1:		No. 9	No. 10
Carbon	(C)	0.09%	0.10%
Chromium	(Cr)	0.06%	0.08%
Copper	(Cu)	0.28%	0.22%
Manganese	(Mn)	1.17%	1.16%
Molybdenum	(Mo)	0.50%	0.46%
Nickel	(Ni)	1.02%	1.10%
Phosphorus	(P)	0.014%	0.012%
Silicon	(Si)	0.26%	0.26%
Sulfur	(S)	0.011%	0.012%

Inside to Outside-Side 2:		No. 1	No. 2	No. 3	No. 4
Carbon	(C)	0.10%	0.11%	0.10%	0.13%
Chromium	(Cr)	0.07%	0.07%	0.06%	0.10%
Copper	(Cu)	0.27%	0.28%	0.27%	0.23%
Manganese	(Mn)	1.11%	1.11%	1.14%	1.32%
Molybdenum	(Mo)	0.50%	0.52%	0.51%	0.47%
Nickel	(Ni)	1.22%	0.94%	1.18%	0.89%
Phosphorus	(P)	0.015%	0.015%	0.015%	0.012%
Silicon	(Si)	0.28%	0.27%	0.27%	0.27%
Sulfur	(S)	0.012%	0.013%	0.012%	0.013%

Inside to Outside-Side 2:		No. 5	No. 6	No. 7	No. 8
Carbon	(C)	0.10%	0.10%	0.09%	0.09%
Chromium	(Cr)	0.06%	0.06%	0.05%	0.05%
Copper	(Cu)	0.27%	0.26%	0.21%	0.22%
Manganese	(Mn)	1.22%	1.18%	1.11%	1.14%
Molybdenum	(Mo)	0.49%	0.49%	0.47%	0.47%
Nickel	(Ni)	0.92%	1.15%	1.29%	1.31%
Phosphorus	(P)	0.014%	0.011%	0.013%	0.012%
Silicon	(Si)	0.22%	0.26%	0.25%	0.26%
Sulfur	(S)	0.013%	0.013%	0.013%	0.013%

LABORATORY CERTIFICATE

Anamet Laboratories, Inc.

2827 SEVENTH STREET • BERKELEY, CALIFORNIA 94710

Lab. No. 485.326

CHEMICAL ANALYSIS
(Emission Spectrograph)

Inside to Outside-Side 2:		No. 9	No. 10
Carbon	(C)	0.10%	0.10%
Chromium	(Cr)	0.06%	0.06%
Copper	(Cu)	0.27%	0.23%
Manganese	(Mn)	1.15%	1.18%
Molybdenum	(Mo)	0.48%	0.44%
Nickel	(Ni)	1.02%	1.12%
Phosphorus	(P)	0.014%	0.012%
Silicon	(Si)	0.26%	0.28%
Sulfur	(S)	0.012%	0.013%

Note: Location 4 is the root of the weld.

These tests were performed in accordance with the purchase order.

Respectfully submitted,

ANAMET LABORATORIES, INC.

By E. A. Foreman

E. A. Foreman
Manager, Quality Control

3c/jw