ENGINEERING OPERATIONS REPORT

Induction Graphitizing Furnace
Acceptance Test Report

Project 143

March 1972
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Approved:

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ABSTRACT

The objective of this report is to document the results of the furnace acceptance test. Evidence of equipment conformance to ANSC Specification AGC 90278A, including amendments contained in ANSC Purchase Order No. OQ136, is given. Testing was completed in accordance to procedures and criteria contained in the ANSC Acceptance Test Plan.
The induction furnace was designed to meet the requirements of ANSC Specification 90278A, Furnace, Vertical, Vacuum-Inert, Induction. The furnace was designed and constructed by the Cragmet Division of the Cheston Company, Rancocas, New Jersey, An Inductotherm Affiliate, under ANSC Purchase Order N-00136. The Buyer was W. J. Carey. R. P. Radtke, Project Engineer, under the supervision of L. A. Shurley, Manager, Nozzle, Pressure Vessel and Skirt Department, was responsible for design, fabrication, installation and activation of the furnace complex. G. W. Haughton provided Quality Assurance surveillance of the fabrication, installation, and activation. Bldg. 2005 facilities were prepared by A. R. McLain, Plant Engineer. The furnace was procured for the fabrication of the NERVA nozzle extension, Project 143h in Contract SNP-1 with the Space Nuclear Systems Operations. The Project was monitored by G. K. Sievers and K. E. Estes, SNSO-C.
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I. INTRODUCTION

The purpose of this report is to document the results of the furnace acceptance test. This equipment was designed for converting carbon forming substances into graphitic structures according to ANSC Specification 90278A, Furnace, Vertical, Vacuum-Inert, Induction, dated 22 May 1970, shown in Appendix B.

Conformance to the specification was verified by joint effort of ANSC Project Engineering and Quality Assurance. Tests were performed in accordance to procedures and criteria in the ANSC Acceptance Test Plan, shown in Appendix A. Discrepancies were recorded on Inspection Report No's 503993, 503994, and 512330, shown in Appendix C. Disposition of all items was completed and duly documented.

All work and activities referred to herein were performed in accordance with ANSC Purchase Order N-00136, awarded to the Cheston Company on 28 September 1970. The ANSC Acceptance Test Plan operations were completed on 24 August 1971.

The Furnace System was accepted by NERVA Engineering Operations, Project 143, on August 30, 1971.
II. SUMMARY

The induction furnace was designed to provide the controlled temperature and environment required for the post-cure, carbonization and graphitization processes for the fabrication of a fibrous graphite NERVA nozzle extension. The furnace is capable of automatically controlled temperature rise rates of 5 to 60°C/hr from 120 to 2750°C. The furnace atmosphere is controllable at 10⁻² mm Hg vacuum to 3 psig nitrogen or argon to 2000°C, and 0 to 3 psig argon to 2750°C. The hot zone dimensions are 11 feet mean diameter and 14 feet long. The length may be extended to 19 feet by redesign of the work load support.

The acceptance testing required six tests and a total operating time of 298 hours. Low Temperature Mode Operations, i.e., 120 to 850°C, were completed in one test run. High Temperature Mode Operations, i.e., 120 to 2750°C, were completed during five tests. The test procedure was contained in the ANSC Acceptance Test Plan. This plan was prepared to demonstrate all performance requirements contained in Section 3 of the furnace specification No. AGC 90278A.

All test data was recorded by Quality Assurance Representatives in the Quality Assurance Log Book. Satisfactory completion of the Acceptance Test Plan was certified by the supplier, and verified by ANSC Quality Assurance. Discrepancies were reported on Inspection Report No's 503993, 503994, and 512330. Satisfactory disposition of all items was completed.

A summary of the furnace performance as compared to specification requirements is shown in Table 1. The performance demonstrated met or exceeded the specification requirements except for the furnace shell temperature. The outer chamber flange temperature reached 85°C at the maximum hot zone temperature of 2695°C. However, the high surface temperature was acceptable since it was within the safe limit of 116°C. This limit was established by the maximum flange O-ring use temperature.

Satisfactory completion of the ANSC Acceptance Test Plan demonstrated that the induction furnace system meets the requirements of ANSC Specification AGC 90278A. The equipment has been accepted by Project Engineering as operational.
TABLE I

Summary of Acceptance Test Performance of Induction Furnace

Specification Requirement

Furnace Performance

Section 3.0

Para No.

1.1 Maximum Temperature, 2750°C

2695°C, within controllability range of ± 55°C.

1.2 Temperature Controllability

1.2.1 ± 5°C at 120°C to 850°C

+ 5°C at 120°C and 700°C.

1.2.2 ± 2% at 850°C to 2750°C

Less than ± 1% at 700°C and 2695°C.

1.3 Temperature Gradient, 100°C maximum at 2750°C

10°C at 2695°C.

1.4 Temperature Rate Controllability

1.4.1 5 to 15°C/hr at 120°C to 850°C

5°C/hr at 120 to 240°C and 15°C/hr at 600°C to 850°C

1.4.2 15 to 60°C/hr at 120°C to 2600°C; 15°C to 60°C/hr at 2600°C to 1500°C

60°C/hr at 2180°C to 2600°C; 15°C/hr at 2695 to 2680; 60°C/hr

2.1 Furnace Atmosphere

2.1.1 Vacuum, 50 microns, maximum

17 microns

2.1.2 Argon or nitrogen 0.1-3.0 SCFM

Argon and nitrogen, less than 1 ppm H₂O. 0.1-10 SCFM to 3.0 psig.

50 microns - 3 psig

2.2 Rate of Evacuation, ambient to 50 microns in 30 minutes, maximum

Ambient to 50 microns in 25 minutes.
<table>
<thead>
<tr>
<th>Specification Requirement</th>
<th>Furnace Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Section 3.0</strong></td>
<td></td>
</tr>
<tr>
<td>Para No.</td>
<td></td>
</tr>
<tr>
<td>2.3 Rate of Back-Fill,</td>
<td>Air, 15 minutes; N\textsubscript{2} or Ar, 10 minutes.</td>
</tr>
<tr>
<td>50 microns to ambient in 20 minutes, maximum</td>
<td></td>
</tr>
<tr>
<td>2.4 Inert Gas Pressure Control,</td>
<td>Manual gas pressure control at 3.0 psig.</td>
</tr>
<tr>
<td>5 to 30 in. Hg</td>
<td></td>
</tr>
<tr>
<td>2.5 Forced Gas Convective Cooling,</td>
<td>2695°C to 200°C in two days at 60°C/hr, maximum.</td>
</tr>
<tr>
<td>2750°C to 200°C in seven days</td>
<td></td>
</tr>
<tr>
<td>at 60°C/hr, maximum</td>
<td></td>
</tr>
<tr>
<td>3.1 Chamber Leak Rate, 1 x 10^{-4} mm Hg/min pressure rise at 75 microns</td>
<td>1 x 10^{-6} mm Hg/min at 75 microns.</td>
</tr>
<tr>
<td>3.2 Water Channel Leak Rate, no leaks at 100 psig</td>
<td>No leaks at 100 psig.</td>
</tr>
<tr>
<td>4.3 Water Temperature, 70°C maximum</td>
<td>61°C, chamber water outlet.</td>
</tr>
<tr>
<td>4.5 Furnace Shell Temperature, 50°C maximum</td>
<td>85°C (flanges).</td>
</tr>
</tbody>
</table>
III. DISCUSSION OF RESULTS

A. GENERAL

Data and observations during the acceptance testing were recorded by Quality Assurance representatives in the Quality Assurance Log Book. Special test equipment included contact pyrometers, optical pyrometers, and bulb thermometers, for temperature measurements. Precision levels and steel tapes were used to measure internal furnace dimensions. Temperature measurement equipment carried current AGC calibration certification numbers.

B. MEANS OF EQUIPMENT PERFORMANCE EVALUATION

The test operation defined by the Acceptance Test Plan was designed to demonstrate furnace performance requirements of ANSC Specification 90278A, Appendix B. Completion of operations activity items was certified by the supplier and satisfactory demonstration to meet the test criteria was verified by the ANSC Quality Assurance Representative. Signatures were affixed to the Acceptance Test Plan.

Furnace operations required by the ANSC Acceptance Test Plan, Appendix A, were performed from 24 July to 24 August 1971. The plan consisted of four sections: Mechanical, Electrical, Safety Interlock, and Performance Operations. The Performance Operations were completed in two phases: Low Temperature Mode, and High Temperature Mode.

The Low Temperature Mode required one furnace run to satisfy the requirements of the acceptance test plan. Five tests were required to complete the High Temperature Mode operations. Prior to performance tests, a run to 2000°C was completed to outgas volatiles, such as water vapor, sulfur, and metal impurities, from the graphite components within the furnace hot zone. Table 2 lists the test schedule and operating durations. The acceptance testing required 298 hours of operation.

Discrepancies were recorded on Inspection Report No's 503993, 503994, and 512330, Appendix C. Disposition of all items was completed by Project Engineering. The furnace system was accepted by NERVA Engineering Operations, Project 143, on August 30, 1971.
### TABLE 2

#### Section IV
Acceptance Test Schedule
(July-August 1971)

<table>
<thead>
<tr>
<th>Test No.</th>
<th>Mode</th>
<th>Dates</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>High Temperature</td>
<td>7/24 thru 7/26</td>
<td>52 hours</td>
</tr>
<tr>
<td>2</td>
<td>Low Temperature</td>
<td>7/29 thru 8/1</td>
<td>56 hours</td>
</tr>
<tr>
<td>3</td>
<td>High Temperature</td>
<td>8/3 thru 8/6</td>
<td>69 hours</td>
</tr>
<tr>
<td>4</td>
<td>High Temperature</td>
<td>8/7 thru 8/8</td>
<td>37 hours</td>
</tr>
<tr>
<td>5</td>
<td>High Temperature</td>
<td>8/11 thru 8/13</td>
<td>52 hours</td>
</tr>
<tr>
<td>6</td>
<td>High Temperature</td>
<td>8/23 thru 8/24</td>
<td>32 hours</td>
</tr>
</tbody>
</table>
The following paragraphs summarize the test results as required per Section 3.1 of Specification AGC 90278B.

C. COMPLIANCE WITH EQUIPMENT SPECIFICATIONS

"Section 3 REQUIREMENTS

3.1 Performance.

3.1.1 Functional Characteristics.
The furnace shall be capable of heating the graphite work load to the maximum operating temperature with the performance requirements described below. The work load shall be as defined in Table I and Figures 1 and 2. The furnace shall be capable of achieving the following performance.

3.1.1.1 Temperature Capability.

3.1.1.1.1 Maximum Temperature.

(a) The furnace shall be capable of operating at a maximum continuous operating temperature of 2200°C, within the useful life requirements of 3.1.2.2.

(b) Option 1 - High Temperature Capability.
The furnace shall be capable of operating at a maximum continuous operating temperature of 2750°C within the useful life requirements of 3.1.2.2."

The required maximum continuous operating temperature of the furnace was 2750°C, Option 1, above. The controllability requirements, Para. 3.1.1.2 below, was plus-minus 55°C. Therefore, a maximum controlled temperature within the range of 2695°C to 2750°C was acceptable.

The maximum furnace temperature was demonstrated in accordance with Test No. A.1.e, Section IV of the Acceptance Test Plan. The maximum furnace temperature, as measured with an L and N optical pyrometer, was 2555°C. A temperature correction, accounting for stem and radiation losses, was required to compute the difference between the true susceptor temperature and optical pyrometer target temperature readout. (The target was a closed-end graphite tube
extending 8 cm into the hot zone from a side sight port.) An oversight or omission of such correction can result in operations at over-design conditions.

The temperature difference was calculated to be 105°C. The analytical thermal model is described in Appendix D. The correction for absorption of radiation by the quartz glass window was 35°C. The total temperature correction was 140°C. Therefore, the maximum corrected furnace temperature attained was 2555°C plus 140°C, or 2695°C. This value satisfied the requirement for maximum controllable furnace temperature.

"3.1.1.1.2 Temperature Controllability.

(a) The furnace temperature shall be controllable within ± 2% of any set point, set between 850°C and the maximum operating temperature.

(b) Option 2 - Low Temperature Control Capability. - The furnace temperature shall be controllable within ± 5°C of any set point, set between 120°C and 850°C. The temperature will be measured on the work load when enclosed within a retort, to be supplied by ANSC."

The temperature controllability requirement in Para (a) of ± 2% was met at 700°C and at 2695°C. The test procedure was given in Para. A.1.a and Para A.1.e of the Acceptance Test Plan. The temperature of 700°C was met in lieu of 850°C because the programed cam controller was inadvertently set at 700°C. This deviation in procedure was reported in Quality Assurance Inspection Report No. 503993, Item 5, and approved by Project Engineering. The lower (700°C vs 850°C) temperature controllability was more difficult because it required greater instrumentation sensitivity.

The range for ± 2% at 700°C is ± 14°C, and 2750°C (maximum attainable temperature) is ± 55°C. The controllability attained at 700°C and 2695°C was ± 5°C. This was within the operators ability to read the temperature print-out. Therefore, the furnace system was well within the temperature controllability requirement of the specification.
The low temperature control capability requirement of $\pm 5^\circ C$, Para. (b) above, was demonstrated at $120^\circ C$, as defined by Para A.2.a of the Test Plan. The range of temperature control at $120^\circ C$ was $\pm 5^\circ C$; thus, the requirement of the specification was met.

"3.1.1.1.3 Temperature Gradient. - The axial temperature gradient shall be within $100^\circ C$ over the length of the susceptor corresponding to position of the work load when the furnace is operating at the maximum temperature capability."

The axial temperature gradient was determined during Test A.1.f of the Test Plan. The furnace temperatures at the top and bottom viewports were measured. The measurements were $2555^\circ C$ on top, and $2545^\circ C$ at the bottom. The temperature correction of $140^\circ C$ gave a $10^\circ C$ axial temperature difference, $2695^\circ C$ minus $2685^\circ C$. Therefore, the axial temperature difference of $10^\circ C$ at the maximum operating temperature satisfied the specification requirement with a $90^\circ C$ positive margin.

"3.1.1.1.4 Temperature Rate Controllability. -

The rate of temperature increase shall be controlled at 15 to 60$^\circ C$ per hour between $120^\circ C$ and $2600^\circ C$. The rate of temperature increase shall be no less than 60$^\circ C$ per hour between $2545^\circ C$ and $2600^\circ C$. The rate of temperature decrease shall be controllable at 15 to 60$^\circ C$ per hour between the maximum operating temperature and $1500^\circ C$.

(b) Option 2 - Low Temperature Control Capability. -

The rate of temperature increase shall be controllable at 5 to $15^\circ C$ per hour between $120^\circ C$ and $850^\circ C$.

The specification required the rate of temperature rise and decrease to be controllable within defined rate and temperature ranges. The procedures established in the Acceptance Test Plan provided demonstration of the lowest and highest required temperature rates. In general, it is more difficult to demonstrate low heating rates at low temperatures, and high heating rates at high temperatures.
The Acceptance Test Plan, Section IV, High Temperature Mode, Paragraphs A.1.a, A.1.c, and A.1.g required 15°C/hr from 120°C to 240°C, 60°C/hr from 2180°C to 2600°C, and 15°C/hr from 2750°C to 2680°C, and 60°C/hr from 2680°C to 1800°C. Low temperature control testing was completed with a stainless steel retort positioned within the furnace. Paragraph A.2.b defined the low temperature mode test procedure. Heating rates of 5°C/hr from 120°C to 160°C, and 15°C/hr from 600°C to 850°C were required.

The required temperature rates were satisfactorily demonstrated. The High Temperature Mode tests were completed during four furnace runs. All low temperature control tests were successfully completed during a single test. Some difficulty was encountered in meeting the required heating rates because the program cams were not accurately prepared by the supplier. However, the heating rates demonstrated were the rates programed on the cams. A Quality Assurance Inspection Report documented the temperature rate deviations.

Inspection Report No. 503993, Items 5 and 8, identify temperature rate deviations from the rates required by the Acceptance Test Plan. In each case, the furnace temperature followed the programed temperature demanded by the cam. This demonstrated that the furnace was controllable with the accuracy required. Future operation will require more accurately cut cams to achieve the rates desired.

"3.1.1.2 Furnace Atmosphere. -

3.1.1.2.1 Atmospheric Conditions. - The temperature controllability and profile, shall be maintainable with each of the following furnace atmospheres:

(a) Vacuum
(b) Argon or nitrogen
   (1) Flow Rate 0.1 - 3.0 SCFM
   (2) Pressure 50 microns - 3 psig

Vacuum will not be required at temperatures which cause sublimation of carbon."
The furnace atmosphere control system was demonstrated during the acceptance testing. Pressure and flow control was shown at all temperatures and temperature rates. Vacuum was held to less than 50 microns at 400°C and 2000°C. The ultimate vacuum attained was 17 microns at ambient temperature.

Argon and nitrogen flow rates were controllable at 0.1 to 10 SCFM, which is within the 0.1 to 3 SCFM requirement. Inert gas pressure was maintained at 3.0 PSIG during all testing. The inert gas dew point was less than 1 ppm.

"3.1.1.2.2 Rate of Evacuation. - The cold furnace shall be capable of being evacuated of air at ambient conditions to 50 microns in 30 minutes, and being held continuously for a minimum period of fourteen days."

A 50 micron vacuum was attained within 30 minutes, as required by the specification. The shortest pumpdown time was 25 minutes. The procedure for this test was given in Paragraph B.1.a of the Acceptance Test Plan, Section IV.

Regarding 14 days at 50 microns operations - no maintenance required was demonstrated for 14 cumulative days of operations, as opposed to continuous - the later being not practical to execute during Acceptance Tests.

"3.1.1.2.3 Rate of Back-Fill. - The cold furnace shall be capable of being back-filled with air, nitrogen, or argon from fifty microns to ambient pressure in a maximum of twenty minutes."

The rate of back-fill with air was determined to be 50 microns to ambient pressure in 15 minutes. Paragraph B.1.b of the Acceptance Test Plan, Section IV, required back-fill within 20 minutes. Since the inert gas supply is pressurized, back-fill times with argon and nitrogen were less than 15 minutes.

"3.1.1.2.4 Option No. 3, Inert Gas Pressure Control. - The shell pressure shall be controllable at 5 to 30 inches of Hg with argon or nitrogen flowing at two SCFM."

Both argon and nitrogen gas pressures were controlled and recorded during the Acceptance Testing at 3.0 psig as required by Section IV, Paragraphs A.1 and A.2. The flow rate of 3 SCFM was maintained at 3 psig pressure. This test was sufficient to determine acceptability of the inert gas control system at all required pressures and flows.

"3.1.1.2.5 Option No. 4, Forced Gas Convective Cooling. -
The inert gas system shall provide convective cooling sufficient to cool the furnace from 2750°C to 200°C in seven (7) days at a rate not to exceed 60°C in one (1) hour.

"3.1.1.2.5.1 Option 4, Forced Gas Convective Cooling. -
Inert gas shall be circulated through the furnace hot zone to provide convective cooling at temperatures between 800°C and 120°C."

The forced gas convective cooling system provided a marked increase in cooling rates at temperatures below 800°C. The system consisted of a high temperature blower which circulated hot furnace gases through a gas-water heat exchanger.

The performance of this system satisfied the requirements of the specification. Using the procedure of the Acceptance Test Plan, Section IV, Paragraph A.1.h, a two-day cooldown time was demonstrated. When cooling rates up to 200°C/hr were employed, the total cooldown time from 2695°C to 200°C was less than one day. The furnace test was significantly better than required by the specification.

"3.1.1.3 Leak Rates. -

"3.1.1.3.1 Furnace Shell. - The maximum allowable gas leak rate of the furnace shell shall be \(1 \times 10^{-4}\) mm Hg per minute pressure rise when the vacuum system is isolated from the shell, and the pressure within the shell is 75 microns.

"3.1.1.3.2 Cooling Water Channels. - All cooling water channels, including those for the furnace shell, if the ASME Boiler and Pressure Vessel Code is applicable, induction coil, vacuum system, and supply and outlet lines, shall not leak any water when tested at 100 psig."
The furnace shell gas and water channel leak rates were tested during the furnace installation and activation periods according to procedures established in the Acceptance Test Plan and Specification.

The furnace shell gas leak rate was tested as required by Paragraph C.1 of the Acceptance Test Plan, Section IV. The plan referenced Paragraph 4.2.1 of the Specification. The measured shell leak rate was less than $1 \times 10^{-6} \text{ mm Hg/min}$ pressure rise at 75 microns. The leak rate test result met the specified rate of $1 \times 10^{-4} \text{ mm Hg/min}$, maximum with $10^{-2} \text{ mm Hg/min}$ margin.

The integrity of the furnace system coolant channels was demonstrated prior to the first elevated temperature test. The procedure was given in Paragraph 1.2 of the Acceptance Test Plan, Section I. No leaks were visually detected.

During the elevated temperature testing, the test procedure in Paragraph C.4, Section IV, was used. Several leaks were noted and recorded in Inspection Report No. 503993, Items 12 and 18. Item 12 identified water leaks in air release valves on the furnace jacket. The valves were added to the system as a field modification. Release of entrapped air at the top of the jacket allowed increased cooling of the top flange. However, when first installed, the valves leaked water. After the supplier repaired the valves, no leaks were visually detected.

Item 18 describes water leaks observed in the Baltimore Air Coil water cooling tower. The cause of the leaking was determined to be excessive turbulence in the water sump. As a result, water flowed through the fan section to the ground below. The supplier placed baffles in the sump which reduced the turbulence, and prevented all leakage.

"3.1.1.4 Furnace Water Cooling.

"3.1.1.4.1 Capacity. - The cooling water system shall be supplied by the contractor and shall have a capacity sufficient to provide coolant for the induction coil, furnace shell, and vacuum pump as required to meet the requirements of this specification."
The capacity of the cooling water system was selected by the supplier to meet the requirements of the system, and the maximum water outlet temperatures required by the specification. The system selected delivered approximately 360 GPM at 60 psig. The Baltimore Air Coil cooling tower removed up to 85,000 BTU/hr from the recirculating coolant.

Acceptance tests which verified the adequacy of the cooling water system are given below.

"3.1.1.4.2 Backup System. - The cooling system shall be capable of providing for an automatic alternate coolant supply in the event of major component or electrical power failure."

The automatic alternated coolant supply was provided by ANSC. Functionally, the system was shown to provide cooling water in excess of 400 GPM at 60 psig inlet pressure. The test procedure was given in Paragraphs I.3 and I.4 of the Acceptance Test Report, Section I.

The emergency water backup to the normal closed-loop cooling system performed satisfactorily. In the event of a plant power outage, the furnace power would automatically shut off; and, the emergency water supply would safely cool the furnace to ambient temperature.

"3.1.1.4.3 Water Temperature. - The cooling water shall not exceed 70°C at the induction coil and furnace shell outlets when the heating zone is operated continuously at the maximum operating temperature."

The cooling water temperatures were tested according to the procedure listed in Paragraph D.1 of the Acceptance Test Plan, Section IV. The maximum water temperatures measured while the furnace was operating at 2695°C were as follows:
In particular, the maximum induction coil and furnace shell water temperatures were 58°C and 61°C, respectively. These test results were within the specification requirement of 70°C.

"3.1.1.4.4 Water Flow. - All coolant channels shall be protected from blockage by particulate matter (greater than 0.05 inch diameter)."

Both the closed-loop cooling system and emergency water cooling supply have screens which trap all particulate matter greater than 0.05 inch in diameter. When all testing was completed, the screens were checked. No particulate matter was observed.

"3.1.1.4.5 Furnace Shell Cooling. - The outside wall temperature of the furnace shell, including all attached fittings, shall not exceed 50°C when operating continuously at the maximum operating temperature."

The outside wall temperature of the furnace shell was measured at numerous locations during the acceptance testing according to procedures given in Paragraph D.2 of the Acceptance Test Plan, Section IV. The shell flange temperatures exceeded the specification limit of 50° at furnace temperatures in excess of about 1900°C. At 2695°C, the maximum flange temperature was 85°C.
Accordingly, the discrepancy was noted as Item 6 on Inspection Report No. 503993. Final disposition to accept the overtemperature was made. The temperature design limit was found to be 116°C, the maximum O-ring use temperature. Therefore, the 85°C temperature was technically acceptable.

"3.1.2 Operability. - The furnace system shall be capable of being operated within the following requirements.

"3.1.2.1 Maintainability. - No periodic maintenance shall be required within a time period of fourteen days while the furnace is being operated according to the performance requirements of Section 3.1.

"3.1.2.1.1 Maintenance and Repair Cycles. - There shall be no periodic maintenance required on the induction coil or furnace shell.

"3.1.2.1.2 Service and Accessibility. - All components of the furnace which require periodic maintenance shall be accessible for repair. Required ladders, staircases, and platforms shall be provided by the contractor."

The operability requirements of the specification were tested using the procedures in Paragraph E.1 of the Acceptance Test Plan, Section IV. No periodic maintenance was required on any furnace component during fourteen days of operation except for the need to add rust inhibitor to the water supply.

Due to rust in the cooling water, it was necessary to add a chromate rust inhibitor. This maintenance was listed as a discrepancy, and reported as Item 19 of Inspection Report 503993. However, the disposition was to accept this action, since anti-rust water treatment is considered normal maintenance.

"3.1.2.2 Useful Life. - The furnace system will have a minimum useful life of eight years, allocated as follows:

Rated Operating Life
(a) Time 5000 hours, minimum
(b) Thermal Cycles 50, maximum

A thermal cycle shall conform to the performance requirements in Section 3.1, and a maximum hold time of five hours at or below the maximum operating temperature."
The useful life requirement was tested in compliance to procedures established by Paragraph E.2 of the Acceptance Test Plan, Section IV. The total operating time of the furnace system was 298 hours. No significant deterioration of the furnace components was visible after testing was completed.

The useful life of 5000 hours is a design requirement, introduced for the purpose of influencing the design, but it was not expected and not practical to be demonstrated during Acceptance Testing.

D. OTHER REQUIREMENTS

Other requirements, as related to conformance drawings, materials, functionality of safety interlocks, were demonstrated prior to shipment from the manufacturing site or during the Acceptance Testing after installation. Verification of functionality of all items not covered within the Specification Requirements, Section 3.1, can be found in the appropriate sections of Appendix A.

IV. CONCLUSIONS

1. The performance requirements of ANSC Specification No. AGC-90278A, Section 3, were satisfactorily demonstrated using procedures according to the ANSC Acceptance Test Plan.

2. The furnace chamber flange temperature exceeded the maximum temperature limit. However, the higher temperature was acceptable because it was within the safe operating limit.

3. The largest 2750°C induction furnace in the free world is operational.

V. RECOMMENDATIONS

1. The induction furnace should be operated prior to expiration of supplier's guarantee on 25 August 1972.

2. Precautions should be taken when loading or unloading the furnace to prevent damage to the susceptor or work load support.
3. Inspect the Baltimore Air Coil water cooling tower to determine the cause of the 9 psig pressure drop which is in excess of that specified in the supplier's manual.

4. The existing Tungsten Rhenium thermocouples should be replaced with a heavy duty type.

5. Prior to future operation, conduct a water flow distribution check. Monitor all cooling circuits during subsequent operation.
APPENDIX A

ANSC INDUCTION GRAPHITIZING FURNACE
ACCEPTANCE TEST PLAN AND PROCEDURES

19
INDUCTION GRAPHITIZING FURNACE

ACCEPTANCE TEST PLAN AND PROCEDURES

ANSC PURCHASE ORDER N-00136
CRAEDM DIVISION OF CHERSON CORPORATION
RANOCAS, NEW JERSEY

REVISION "A"

PROCEDURAL AMENDMENT
TO
INDUCTION FURNACE OPERATIONS
APPLICABLE DOCUMENTS

1. AGC SPECIFICATION 90278A, FURNACE, VACUUM - INERT, INDUCTION

2. ANSC PURCHASE ORDER, VER. VACUUM - INERT ATMOSPHERE INDUCTION FURNACE, AND AMENDMENTS TO AGC SPECIFICATION 90278A.

3. CRAGMET DRAWINGS, FURNACE, VACUUM - INERT INDUCTION, NOS. 3086-100-008 THROUGH 3086-914-108.

4. ANSC DRAWINGS, FACILITY PREPARATION FOR GRAPHITIZING FURNACE, NOS. NPE 30-1-70A THROUGH NPE 12-1-71.
<table>
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<tr>
<th>TEST</th>
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</table>
| 11 Tests |                          |                   |              | 1. Determine that operating procedures performed during acceptance testing conform to the Operating Manual. | 1a. The operating procedures in the Operating Manual will be followed for all operations.  
1b. Observe and record any deviation from procedures given in the Operating Manual, except for special procedures given in Operations below. |

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<th>VERIFICATION BY AUSC</th>
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<tr>
<td>A. Work Load</td>
<td>3.3.1.4</td>
<td>3086-200-60A</td>
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<td>Support</td>
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<td>B. Susceptor</td>
<td>Letter Agreement</td>
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<tr>
<td>C. Induction</td>
<td>3.3.1.6.2</td>
<td>3086-490-10H</td>
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<tr>
<td>Heating Coil</td>
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<tr>
<td>D. Thermal</td>
<td>3.3.1.13.1</td>
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<td>Furnace Shell</td>
<td>3.3.1.7.5</td>
<td>3086-200-10A</td>
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<td>3.3.1.4.1</td>
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<td>Vacuum System</td>
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<td>3086-100-44</td>
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### Acceptance Test Plan - Section I - Mechanical Operations

<table>
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<tr>
<th>Component</th>
<th>Specification Paragraph</th>
<th>Drawing Reference</th>
<th>Test Sequence</th>
<th>Criteria</th>
<th>Operation</th>
<th>Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
<td>2. Nitrogen gas supply pressure is 180 psig minimum.</td>
<td>1b. Observe and record inert gas pressure on gauge 70-26.</td>
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<td>3. Emergency Argon gas supply pressure is 200 psig minimum.</td>
<td>2. Repeat Item 1 above.</td>
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<td>4. Dew point of argon gas supply is less than -40°F.</td>
<td>3. Repeat Item 1 above.</td>
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<td>5. Dew point of nitrogen gas is less than -40°F.</td>
<td>4. Measure dew point of inert gas with Beckman Trace Moisture Analyzer, Model 340 (AN7C supplied).</td>
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<td>6. Argon gas flow and pressure in the furnace shell is controllable at 3.0 SCFM.</td>
<td>5. Repeat Item 4 above.</td>
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<tr>
<td>H. Power Supply and Controls</td>
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<tr>
<td>I. Cooling Water (Note: All pressure reducers are to be adjusted during heat-up to thermally balance system)</td>
<td>3086-600-20C</td>
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<td></td>
<td>NPE-30-5-70A</td>
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<td>3086-600-30B</td>
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<td>3086-100-90</td>
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<td>1. Normal water pump No. 30-3 turns on automatically.</td>
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</tbody>
</table>

No mechanical tests required.

1a. Close valve No. 70A-V-1.

1b. Open valves Nos. 30-9, -11, -12, -13, -14 (4 valves to open).

1c. Turn on power to normal water pump No. 30-3.

1d. Open valves No. 70A-V-4 and 30-15 to fill closed loop water system with domestic water.
<table>
<thead>
<tr>
<th>COMPONENT</th>
<th>SPECIFICATION REFERENCE</th>
<th>TEST SEQUENCE</th>
<th>CRITERIA</th>
<th>OPERATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>3086-600-30B</td>
<td>NPE 30-5-70A</td>
<td></td>
<td>2. No leaks in water system (3086-600-30B) that can be visually observed.</td>
<td>1e. Observe that normal pump No. 30-3 turned on when the water level in the hot well, No. 100-90, filled to the lower limit of level indicator switch No. 30-23.</td>
</tr>
<tr>
<td></td>
<td>3086-600-30B</td>
<td></td>
<td></td>
<td>1g. Record water pressure at pump outlet, as measured on gauge No. 30-29, and pressure at gauge No. 70A-9 (P1-5 and -6)</td>
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<td>2. Observe and record locations of any water leak visually detected in system.</td>
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<tr>
<td>3086-500-30</td>
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<td>3a. Turn on normal water pump No. 30-3.</td>
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<td>3b. Open valves Nos. 70A-V-1 and -2, and -6.</td>
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<td>3c. Turn off normal water pump to simulate power outage.</td>
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<td>3d. Adjust No. 70A-PRV-1 pressure regulator to activate valve No. 70A-ECV-1 at first drop in system pressure.</td>
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<td>3e. Repeat 3b, 3c and 3d, as required to properly adjust PRV-1.</td>
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<td>3f. Observe the emergency water pump No.30-3 start up when the water level in the hot well reaches the upper limit of level indicator switch, No. 30-23.</td>
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<td>3g. Measure and record emergency pump outlet pressure at gauge No. TBD, for information only.</td>
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<td>4a. Turn on normal water pump to simulate return to normal power.</td>
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<td>4b. Observe that emergency water supply shuts off automatically.</td>
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<td>5a. Turn on fan motors and water circulating pump motor.</td>
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<td>5b. Observe and record any visible water leaks.</td>
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<td>5c. Record water pressure on gauges, Nos. TBD for information only.</td>
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<td>TEST SEQUENCE</td>
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No mechanical testing required.
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<td>A. Work Load Support</td>
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<td>B. Susceptor</td>
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<td>C. Induction Heating Coil</td>
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<td>F. Vacuum System</td>
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**ACCEPTANCE TEST PLAN**

**SECTION II: ELECTRICAL OPERATION**

1. The following criteria applies to all component tests: No electrical malfunctions, including short circuits, fuse burn-out, breaker disconnect, or other electrical failure.

   No electrical test required.

1. See Section IV.

   1. The coil is electrically insulated. No arcing permitted.

   No electrical test required.

1. Heat sink operates without electrical malfunction.

1. 480V, 3 phase service is available.

   1. Measure and record 3 phase voltage service to motor control center, No. 30-1 with voltmeter.

   2. Motors on mechanical pumps, Nos. 20-1 and "Roots" type blower, No. 44-1, operate without electrical malfunction.

   2a. Trace circuit Nos. 1A, 1B, 1C, 1D, and 1E on Ref. 401-30 and 402-00A to identify and locate electrical components

   2b. Observe, detect, and record electrical malfunctions.

   1. All electrical components shall be demonstrated to perform properly.

   1. See Section IV.

   1a. Connect induction coil to 5000 VDC voltage supply. Verify connection.

   1b. Probe entire coil surface with ground wire.

   1c. Detect by sight and sound arcing through electrical insulation on coil.

   1d. Record location of arc and immediately notify ANSC and Cragmor Project Managers.
### COMPONENT SPECIFICATION DRAWING TEST CRITERIA OPERATION OBSERVATIONS CERTIFICATION VERIFICATION

<p>| All Components | 4.4.1(b) | | | |
|----------------|---------|---------|-------------------------------|---|---|
| <strong>A. Work Load Support</strong> | | | | |
| <strong>B. Susceptor</strong> | | | | |
| <strong>C. Induction Heating Coil</strong> | 3.3.1.6.3 | 3086-490-10G | 1. The following criteria applies to all component tests: No electrical malfunctions, including short circuits, fuse burn-out, breaker disconnect, or other electrical failure. No electrical test required. | | |
| <strong>D. Thermal Insulation</strong> | 3.2.2.1(d) | | | |
| <strong>E. Furnace Shell</strong> | 3.3.1.4.1 | JU02-200-6UA 3086-401-30 | 1. The coil is electrically insulated. No arcing permitted. No electrical test required. | | |
| | | 3086-100-44 3086-401-30 3086-402-00A 3086-600-20C | 2. 480V, 3 phase service is available. | 1b. Observe, detect and record heat sink electrical malfunctions. |
| | | | 2. Motors on mechanical pumps, Nos. 20-1 and &quot;Roots&quot; type blower, No. 44-1, operate without electrical malfunction. | 2a. Trace circuit Nos. 1A, 1B, 1C, 1D, and 1E on Ref. 401-30 and 402-00A to identify and locate electrical components |
| | | | 2b. Observe, detect, and record electrical malfunctions. | 2b. Observe, detect, and record electrical malfunctions. |</p>
<table>
<thead>
<tr>
<th>COMPONENT</th>
<th>SPECIFICATION PARAGRAPH</th>
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<th>TEST SEQUENCE</th>
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<tr>
<td>G. Inert Gas Flow Control System</td>
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<td>No electrical test required.</td>
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<tr>
<td>H. Power Supply</td>
<td>3.3.1.10.1</td>
<td>3086-490-20</td>
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<td>1. Measure and record 3 phase voltage to tripler transformers No. 20-9 with voltmeter.</td>
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<td>2a.</td>
<td>Power supply output.</td>
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<td>2b.</td>
<td>Power supply capacity is 1500 kW min.</td>
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<td>2c.</td>
<td>Power supply operates without electrical malfunction.</td>
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<td>2d.</td>
<td>Silicon rectifier output is variable between 0 and 100 vdc and has a maximum output of 100 amperes.</td>
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<td>3.</td>
<td>No voltage or heating detected on exposed electrically conductive surfaces near the coil power ports. Surfaces 180° during testing.</td>
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<td>3a.</td>
<td>Measure and record voltage to ground on metal surface near the coil power ports No. 40-1.</td>
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<td>3b.</td>
<td>Measure and record temperature of metallic surfaces near the coil power ports.</td>
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</table>
1. Cooling Water
   - 480v, 3 Phase 1, 60 Hz service to Baltimore Air Cell water cooling tower.
   - BAC operates without electrical malfunction.
   - Normal and emergency water pump operates without electrical malfunction.

2. Emergency Water Pump System
   - Emergency water pump is automatically powered by emergency propane generator during a simulated power outage.
   - Level indicator switch operates without electrical malfunction.

3. Instrumentation 3.3.1.2.1(J)
   - Control panel is automatically powered by emergency propane generator during a simulated power outage.
   - Control panel lights are lit when light test switch is turned on.

4. Operations
   - Measure and record 3 phase voltage service to B.A.C. No. 450-30 with a voltmeter.
   - Trace circuit 401-30 to identify and locate electrical components.
   - Observe, detect, and record B.A.C. and malfunctions.
   - Trace circuits 2A and 3C on Dwg 401-30 and 402-00A to identify and locate electrical components.
   - Observe, detect, and record normal and emergency and normal pump motors, Nos. 30-3, malfunction on circuits Nos. 2A and 3C.

5. Observations
   - Same as above.

6. Certification by Craget
   - Signed: T. Craget
   - Signed: R. Craget
   - Signed: T. Craget
   - Signed: R. Craget
   - Signed: T. Craget
### ACCEPTANCE TEST PLAN - SECTION II - ELECTRICAL OPERATION

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<th>TEST SEQUENCE</th>
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<td>3. Two pressure recorders Nos. 10-37 and 10-38, a pressure gauge No. 10-1, are calibrated to within 1% of full scale deflection.</td>
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<td>4. Two temperature recorders, No. 20-4 are accurate to ± 1 mV.</td>
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<tr>
<td></td>
<td></td>
<td>3086-401-20</td>
<td>3086-410-10</td>
<td>5. Two duplex cam time plotters, Nos. 16-23, are accurate to ± TBD mV.</td>
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<thead>
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<th>CRITERIA</th>
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<tbody>
<tr>
<td>3a. Secure vacuum system according to procedure in Operating Manual, Paragraph TBD.</td>
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<tr>
<td>3b. Reduce chamber pressure to 50 microns Hg.</td>
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<tr>
<td>3c. Turn on pressure recorders Nos. 10-37 and 10-38, and adjust readings to pressure measured by vacuum gauge No. 10-1.</td>
</tr>
<tr>
<td>3d. Adjust pressure gauge No. 10-1 as above.</td>
</tr>
<tr>
<td>3e. Read 100, 200, 300, 400, 500, 600, 700, 800, 900, and 1000 microns Hg, and readjust as necessary so that maximum error is within 1% of full scale deflection.</td>
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<thead>
<tr>
<th>OPERATION</th>
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</thead>
<tbody>
<tr>
<td>3a. Secure vacuum system according to procedure in Operating Manual, Paragraph TBD.</td>
</tr>
<tr>
<td>3b. Reduce chamber pressure to 50 microns Hg.</td>
</tr>
<tr>
<td>3c. Turn on pressure recorders Nos. 10-37 and 10-38, and adjust readings to pressure measured by vacuum gauge No. 10-1.</td>
</tr>
<tr>
<td>3d. Adjust pressure gauge No. 10-1 as above.</td>
</tr>
<tr>
<td>3e. Read 100, 200, 300, 400, 500, 600, 700, 800, 900, and 1000 microns Hg, and readjust as necessary so that maximum error is within 1% of full scale deflection.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>OBSERVATIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>3a. Secure vacuum system according to procedure in Operating Manual, Paragraph TBD.</td>
</tr>
<tr>
<td>3b. Reduce chamber pressure to 50 microns Hg.</td>
</tr>
<tr>
<td>3c. Turn on pressure recorders Nos. 10-37 and 10-38, and adjust readings to pressure measured by vacuum gauge No. 10-1.</td>
</tr>
<tr>
<td>3d. Adjust pressure gauge No. 10-1 as above.</td>
</tr>
<tr>
<td>3e. Read 100, 200, 300, 400, 500, 600, 700, 800, 900, and 1000 microns Hg, and readjust as necessary so that maximum error is within 1% of full scale deflection.</td>
</tr>
</tbody>
</table>
## Acceptance Test Plan
### Section III. Safety Interlocks

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<tbody>
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<td>All Systems</td>
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<td>3086-410-10A</td>
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<td>3.1.6.2.1</td>
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<td>3.1.6.2.2</td>
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</table>

### Criteria

1. The following criteria apply to all tests.
   1a. In all instances where known hazards exist and cannot be eliminated, appropriate protective systems shall be employed consistent with established safety codes or standards and/or accepted industrial practices.
   1b. Where it is not possible to preclude the existence or occurrence of a known hazard, reliable devices shall be employed for timely detection of the condition and the generation of an adequate warning signal. Warning signals shall be standardized within like types of systems to minimize the probability of improper personnel reaction to the signal(s).
   1c. Noise levels shall not exceed limits for eight-hour exposure to personnel, as defined in the Walsh-Healy Act 41CFR 50-204. Note: No excessive noise level is anticipated.
   1d. Investigate any condition discovered during

2. All control panel lights are lit when tested.

3. Water trouble light turns on and horn sounds during simulated cooling water pressure loss.

### Operation

1. Perform a test to determine whether an unsafe condition exists and record results.
   2b. Observe and record any lights not lit and on control panel No. 302-10, compartment "A".
   2c. Push light test buttons on the control panel, compartment "B".
   2d. Observe and record any lights not lit on Section 7.
   1a. Turn on normal water pump No. 30-3.
   1b. Open valves Nos. 30-9.
   1d. Throttle valves No. 30-9 at 2nd level to induce water pressure loss.
   1e. Observe all pressure gauges No. 30-12 at the 2nd level module and record pressures when alarm is sounded.
   1f. Observe that light Nos. 150, 151, 152, 160, 161, 164, and 165 turn on and horn sounds.
<table>
<thead>
<tr>
<th>SYSTEM</th>
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<th>DRAWING REFERENCE</th>
<th>TEST SEQUENCE</th>
<th>CRITERIA</th>
<th>OPERATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>3086-600-20</td>
<td></td>
<td></td>
<td></td>
<td>2. Water trouble lights turn on and horn sounds during simulated water flow failure.</td>
<td>1a. Repeat 1b through 1f at 3rd level module valve and gauges.</td>
</tr>
<tr>
<td>3086-600-30</td>
<td></td>
<td></td>
<td></td>
<td>3. Horn sounds during simulated cooling water overtemperature for each temperature switch.</td>
<td>2a. Turn on normal pump No. 30-3.</td>
</tr>
<tr>
<td></td>
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<td>4. The heat sink is automatically closed during a simulated overtemperature of the bottom shell jacket water temperature switch.</td>
<td>2b. Open valves No. 30-9.</td>
</tr>
<tr>
<td>3086-610-10A</td>
<td></td>
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<td></td>
<td>5. Water trouble lights turn on and horn sounds during simulated water leak inside shell and heat exchanger.</td>
<td>2c. Push reset button PB-167.</td>
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<tr>
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<td></td>
<td>2e. Observe that light Nos. 150, 151, 152, 160, 161, 164 and 165 turn on and horn sounds.</td>
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<td>2f. Push button PB-168 to silence alarm.</td>
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<td>3a. Adjust all temperature limit switches No. 30-47, one at a time, to a setting at which the alarm will sound.</td>
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<td>3b. Observe that each switch when adjusted will sound the horn.</td>
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<td>4a. Open the heat sink.</td>
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<td>4b. Adjust temperature limit switch No. 30-47 to a setting at which the heat sink is observed to close.</td>
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<td>5a. &quot;Jumper&quot; water leak switches Nos. 74D in shell and heat exchanger.</td>
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<td>5b. Observe that lights 154 and 156 turn on and listen for the trouble horn.</td>
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<td>6a. Turn on emergency water pump No. 30-3.</td>
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<td>6b. Observe trouble light No. 157 turns on and horn sounds.</td>
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<td>SYSTEM</td>
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<td>TEST SEQUENCE</td>
<td>CRITERIA</td>
<td>OPERATION</td>
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<tr>
<td>B. Vacuum System</td>
<td>3068-600-20</td>
<td>3068-410-10A</td>
<td></td>
<td>1. During vacuum operation, main vacuum valve closes automatically, trouble light turns on and horn sounds when chamber pressure rises above 20 ± 2 mm Hg vacuum.</td>
<td>1a. Open main vacuum valve No. 20-4, with chamber pressure at less than 20 mm Hg pressure. Measure pressure with gauge No. 10-2.</td>
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<td>1b. Set switch No. 10-PB15B on automatic.</td>
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<td>1c. Increase chamber pressure by introducing inert gas at 1 SCFM.</td>
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<td>1d. Record pressure at which valve is heard to &quot;slam&quot; shut.</td>
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<td>1e. Observe that light No. 166 turns on and horn sounds.</td>
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<td>2a. Secure furnace lid for greater than 3 psig release pressure.</td>
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<td>2b. Increase chamber pressure to 3-4 psig by introducing inert gas at 1 SCFM.</td>
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<td>2c. Observe that fault light No. 163 turns on and horn sounds.</td>
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<td>3a. Turn on gas cooling fan.</td>
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<td>3b. Adjust temperature limit switch No. 760 to a setting at which the fan is heard to shut off.</td>
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<td>3c. Observe that light No. 162 turns on, and horn is heard.</td>
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<td>1a. Push the test button below each trouble light on control panel 410-10, Compart-</td>
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<td>ment B.</td>
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<td>1b. Observe that all lights operate.</td>
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<td></td>
<td>2a. Open and close each door on power supply cabinets located on 2nd and 3rd level.</td>
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<td></td>
<td>2b. Observe that the door interlock light No. 10-7 and light 10-15 are lit, and horn sounds when each door is opened.</td>
</tr>
</tbody>
</table>

. Power Supply | 3068-410-10 |

<p>| | | | | | 1. Power supply trouble lights turn on when tested. |
| | | | | | 2. &quot;Door Interlock&quot; and &quot;Induction off&quot; trouble lights turn on, and horn sounds when cabinet doors are opened. |</p>
<table>
<thead>
<tr>
<th>SYSTEM</th>
<th>SPECIFICATION PARAGRAPH</th>
<th>DRAWING REFERENCE</th>
<th>TEST SEQUENCE</th>
<th>CRITERIA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3086-600-20</td>
<td></td>
<td></td>
<td>1. &quot;Loss of continuity&quot; and &quot;induction off&quot; lights turn on, and horn sounds during a simulated thermocouple failure.</td>
</tr>
<tr>
<td></td>
<td>3086-410-10</td>
<td></td>
<td></td>
<td>2. Observe that lights 10-153 and 10-155 are turned on and horn sounds.</td>
</tr>
<tr>
<td></td>
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<td></td>
<td></td>
<td>3. &quot;Cabinet water pressure&quot; and &quot;induction off&quot; trouble lights turn on, and horn sounds when water is shut off.</td>
</tr>
<tr>
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<td></td>
<td>4. &quot;Tripler overtemperature&quot; and &quot;induction off&quot; trouble lights turn on, and horn sounds when water is over TBD °C.</td>
</tr>
<tr>
<td></td>
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<td></td>
<td>5. &quot;Line overload&quot; and &quot;induction off&quot; lights turn on and horn sounds when line is overloaded.</td>
</tr>
<tr>
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<td></td>
<td>6. &quot;Overpower&quot; and &quot;induction off&quot; lights turn on, and horn sounds when output is more than 1750 kw.</td>
</tr>
<tr>
<td></td>
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<td></td>
<td>7. &quot;Overvoltage&quot; and &quot;induction off&quot; lights turn on, and horn sounds when voltage is over 600v.</td>
</tr>
<tr>
<td></td>
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<td></td>
<td>8. &quot;Ground leak&quot; and &quot;induction off&quot; lights turn on and horn sounds when a coil to ground short is simulated.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>OPERATION</th>
<th>OBSERVATIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>3a. Shut off and turn on valves 30-14 on the 2nd and 3rd level.</td>
<td></td>
</tr>
<tr>
<td>3b. Observe that water pressure light 10-7 and light 10-155 are lit, and horn sounds when each valve is turned on.</td>
<td></td>
</tr>
<tr>
<td>4. Test TBD.</td>
<td></td>
</tr>
<tr>
<td>5. Test TBD.</td>
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<tr>
<td>6. Test TBD.</td>
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<tr>
<td>7. Test TBD.</td>
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<tr>
<td>8. Test TBD.</td>
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<thead>
<tr>
<th>CERTIFICATION BY CHAPIN</th>
<th>VERIFICATION BY ASSOC</th>
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<tbody>
<tr>
<td></td>
<td>7/1/71</td>
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<td>7/1/71</td>
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</tbody>
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FUNCTIONAL CHARACTERISTIC | SPECIFICATION PARAGRAPH | DRAWING REFERENCE | TEST SEQUENCE | CRITERIA | OPERATION | OBSERVATIONS | CERTIFICATION BY CRASHTEK | VERIFICATION BY ANSC
--- | --- | --- | --- | --- | --- | --- | --- | ---
Tests | 4.4.1(d) | 306-401-20A | 3.1.1 | 1. The following criteria applies to all tests: 1a. Performance is to be met within the normal design ratings of all equipment. 1b. The furnace heats the graphite work load to the maximum operating temperature (2750°C) with the performance requirements described below. (Note: Do not exceed 2750°C at any time.) | The furnace operating procedures in the Operating Manual will be followed for all operations performed. | Data sheets | J. Schmitz | 6/7/71
Temperature Capability | 3.1.1.1 | 306-410-10A | 3.1.1.4 | 1. High Temperature Mode 1a. The rate of temperature increase is controllable at 15 to 60°C per hour between 120°C and 2600°C. For this test, the rate is 15 to 2°C per hour between 120°C to 240°C, and during capacitance switching operations. | 1. High Temperature Test 1a1. Position the graphite simulated work load in the furnace according to Drawing No. T-1050171. 1a2. Prepare furnace for temperature cycling in an argon atmosphere, 3 psig and 3 SCFM. 1a3. Manually control temperature from room temperature to 120°C at 180°C per hour. 1a4. Automatically control heating rate of 15°C per hour from 120°C to 240°C. 1a5. Then, calculate and record actual rates of temperature change at 15 minute intervals. Required information is on recorder No. 20-1. 1a6. Manually control heating rate at 200°C per hour, maximum, from 240°C to within approximately 20°C of the temperature where capacitance switching was required during Electrical Operations, Paragraph 11.6.2 above. 1a7. Then control the rate of temperature rise at 15°C per hour until the capacitance switch is completed, and one hour thereafter. Note: Should the temperature reach 850°C, proceed to Operation 1b1, and then complete 1a7. 1a8. Then, calculate and record actual rates of temperature change at 15 minute intervals. | Log Page 102 | J. Schmitz | 7/6/71
Log Page 230 | J. Schmitz | 6/7/71
Log Page 145 | J. Schmitz | 7/6/71
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<td>3.1.1.1.2</td>
<td>3086-401-20A</td>
<td></td>
<td>1b, 1c, 1d</td>
</tr>
</tbody>
</table>

**CRITERIA**

1b. The furnace temperature shall be controllable within ±2% of any set point, set between 850°C and 2750°C. For this test, the controllability is determined at 850°C ± 9°C, set point temperature.

1c. The rate of temperature increase shall be controllable at 15 to 60°C per hour between 120°C and 2600°C. For this test, the rate is 20°C per hour between 2180 and 2600°C.

1d. For information only, determine rate of temperature increase above 2600°C.

1e. The furnace temperature shall be controllable within ±2% of any set point, set between 850°C and 2750°C. For this test, the controllability is determined at 2750°C, set point temperature.

1f. The axial temperature gradient is within 100°C.

**OPERATION**

1b1. Manually change temperature to 850°C ± 9°C, as required, and automatically maintain this set point temperature for 30 minutes.

1b2. Calculate and record the temperature controllability and report in percent of set point. Required information is on recorder 20-7.

1c1. Manually control temperature at approximately 200°C per hour between the current temperature and 2100 ± 20°C.

1c2. Automatically control the rate of temperature rise at 60°C per hour to 2600°C.

1c3. Then, calculate and record actual rates of temperature change at 15 minute intervals. Required information is on recorder No. 20-3.

1d1. Automatically control temperature from 6500 to 2750°C at 60°C per hour.

1d2. Measure with manual optical pyrometer and record temperatures at all viewpoints every 15 minutes.

1d3. Calculate and record the rate of temperature rise.

1e1. Manually adjust the temperature to 2750°C, maximum, and automatically maintain this set point temperature for 5 hours.

1e2. Measure and record the top, middle and bottom viewpoint temperature every 15 minutes with manual optical pyrometers.

1e3. Calculate and record the temperature controllability during 1e2 and report as ±2% of set point temperature.

1f. Concurrently with operation 1e, calculate and record the top to bottom viewpoint temperature gradients.
1g. The rate of temperature decreases shall be controllable at 15 to 60 °C per hour between 2750 and 1500°C. For this test, the rate of decrease is 15° ± 2°C per hour between 2750 and 2550°C, and 60° ± 6°C per hour between 2690°C and 1800°C.

1h. The forced gas cooling system is sufficient to enable the furnace to cool from 2750°C to 200°C within seven days at a rate not to exceed 60°C per hour.
2. Low Temperature Mode

2a. The furnace temperature is controllable within ±5°C of any set point, set between 120°C and 850°C. For this test, the temperature is controllable at ±5°C of 120°C ± 5°C, set point.

2b. The rate of temperature increase is controllable at 5 to 15°C per hour between 120 and 850°C. For this test, the rate is controllable at 5° ± 2°C per hour between 120 and 160°C, and 15° ± 2°C between 600 and 850°C.

2. Low Temperature Test

2a1. Place simulated work load Dwg. No. T-1050171 in retort, connect retort control system, and position retort in furnace.

2a2. Maintain nitrogen furnace atmosphere at 3 psig and 3 SCFM.

2a3. Adjust retort pressure differential switch No. TBD at 0.2 lbs above the operating pressure differential. Set retort alarm switch No. TBD on automatic.

2a4. Manually control retort temperature from room temperature to 120°C ± 5°C at TBD °C per hour.

2a5. Automatically control the retort set point temperature at 120°C for 30 minutes. Record the temperature on recorder 20-3 every 5 minutes.

2a6. Calculate and record the temperature deviation. Report as ±°C temperature range about the set point.

2b1. Automatically control the rate of retort temperature rise at 5°C per hour between 120°C and 160°C.

2b2. Then, calculate and record actual rates of temperature at 15 minute intervals. Required information is on recorder No. 20-3.

2b3. Manually control the rate of temperature rise between 160 and 600°C at 200°C per hour, maximum (Inf. only).
### ACCEPTANCE TEST PLAN - SECTION IV - PERFORMANCE

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<th>DRAWING REFERENCE</th>
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</tr>
</thead>
</table>

#### 3.1.1.2

2c. The furnace temperature is controllable within ±5°C of any set point, set between 120°C and 850°C. For this test, the temperature is controllable at ±5°C of 850°C ±5°C, set point.

2d. Determine cooling rate for information only.

#### B. Furnace Atmosphere

<table>
<thead>
<tr>
<th>3.1.1.2.2</th>
<th>3086-410-10</th>
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</table>

1. **Vacuum System**

1a. The cold furnace is evacuated of air at ambient conditions to 50 microns in 30 minutes.

2. The cold furnace is back-filled with air from 50 microns to ambient pressure in 20 minutes, maximum.

#### OPERATION

2b4. Automatically control the rate of retort temperature rise at 15°C per hour between 600 and 850°C. Monitor the susceptor temperature and do not allow the susceptor temperature to exceed 950°C. (This may be in lieu of attaining an 850°C retort temperature.)

2b5. Then, calculate and record actual rates of temperature at 15 minute intervals. Required information is on recorder No. 20-3.

2c1. Manually adjust the retort temperature at 800 ±5°C, and automatically maintain the set point temperature for 30 minutes. Record retort temperature on recorder No. 20-3 every 5 minutes.

2c2. Calculate and record the temperature deviation. Report as ±°C temperature range about the set point.

2d1. Manually control temperature, and heat sink and forced gas convective cooling system to cool down to 200°C at 60°C per hour, maximum.

2d2. Then, calculate and record actual rates of temperature change at 15 minute intervals. Required information is on recorder No. 20-3.

#### OBSERVATIONS

<table>
<thead>
<tr>
<th>BY CRESMET</th>
<th>VERIFICATION BY ANSC</th>
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</table>

#### 1. Rate of Evacuation Test

1a. Secure vacuum system and pump down chamber.

1a2. Clock and record every 5 minutes time to reduce shell pressure to 50 microns. Measure pressure on gauge No. 10-2.

2. Rate of back-fill test.

2a1. After above, open furnace air release valve No. 180.

2a2. Clock and record every 5 minutes time to increase shell pressure to ambient conditions. Measure pressure on gauge No. 10-2.
<table>
<thead>
<tr>
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<th>SPECIFICATION REFERENCE</th>
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<th>VERIFICATION BY ANSIC</th>
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1. The shell helium gas leak rate is $1 \times 10^{-6}$ mm Hg per minute pressure rise at 75 microns.
2. The shell helium gas leak rate is $1 \times 10^{-4}$ mm Hg per minute pressure decay at 5 psig.
3. The induction coil helium gas leak rate is $3 \times 10^{-6}$ std cc per second, maximum, at 1 micron Hg coil pressure, or less.
4. No leaks in water system visually detected when in operation.
5. The furnace cooling water temperature is not greater than 70°C at the induction coil and furnace shell outlet.

1. Complete shell leak rate test as per specification, paragraph 4.2.1 (a, b, c).
2. Complete shell leak rate test as per specification, paragraph 4.2.1 (d, e).
3. Complete induction coil leak test as per specification, paragraph 4.2.2. The furnace shell or coil may be filled with helium in lieu of use of a plastic shroud.
4. Visually observe water leaks during Mechanical Operations Test No. 1.1.2.

1. Cooling water temperature test.
   1a. Set the induction coil and shell outlet temperature limit switches, Nos. 30-21, at 70°C and record time and location when overtemperature alarm No. TBD is activated.
   1b. Read and record the outlet water temperatures of all gauges Nos. 30-21.
2. Chamber Temperature Test
   2a. Continuously measure outside chamber temperature at random locations with a contact pyrometer during performance testing.
   2b. Record temperature and location of temperatures detected in excess of 50°C.

1. Observe and record maintenance required during all acceptance testing.
2. Visually inspect and record condition of furnace components, Specification Paragraph 3.2.2.1, before and after each furnace operation.
APPENDIX B

ANSC SPECIFICATION NO. AGC 90278B,
FURNACE, VERTICAL, VACUUM-INERT, INDUCTION,
dated 22 May 1970

44
AEROJET NUCLEAR SYSTEMS COMPANY
A DIVISION OF AEROJET-GENERAL CORPORATION
CODE IDENT. NO. 05024
SPECIFICATION AGC-90278B

FURNACE, VERTICAL, VACUUM - INERT, INDUCTION

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Authorized for Release:

J. H. Yetto, Supervisor
ANSC Specifications & Standards
Section 1. SCOPE

1.1 Scope.- This specification establishes the performance and qualification requirements for equipment identified as a vertical vacuum inert atmosphere induction furnace system.

1.2 Options.- Optional designs covered under this specification include the following:

(a) Option 1 - High Temperature Capability System
(b) Option 2 - Low Temperature Control Capability System
(c) Option 3 - Inert Gas Pressure Control System
(d) Option 4 - Forced Gas Convective Cooling System

Stipulation of a specific option includes all requirements listed in the specification under that option designation.

Section 2. APPLICABLE DOCUMENTS

2.1 Government Documents.- The following documents form a part of this specification to the extent specified herein. The issue used shall be that controlled by the latest approved contractor's controlled documents list. When the requirements of this specification and subsidiary documents are in conflict the following precedence shall apply:

(a) This Specification.
(b) Document referenced herein.
(c) Documents subsidiary to those referenced herein.
SPECIFICATIONS

Federal
QQ-A-200  Aluminum Alloy Extruded Bar, Rod, and Shapes
QQ-A-225  Aluminum Alloy Rolled Bar, Rod, and Shapes
QQ-S-766  Stainless Steel Plate and Sheet

Military
MIL-P-27401  Nitrogen
MIL-A-18455  Argon

STANDARDS

Military
MIL-STD-1472  Human Engineering Design Criteria for Military Systems Equipment and Facilities

PUBLICATIONS

NASA
NHB 1700.1  NASA Safety Manual

2.2 Technical Society Documents.- The following documents form a part of this specification to the extent specified herein. The issue used shall be that controlled by the latest approved contractor's controlled document list. When the requirements of this specification and subsidiary documents are in conflict, the following precedence shall apply:

(a) This Specification.
(b) Document referenced herein.
(c) Documents subsidiary to those referenced herein.
American Society of Mechanical Engineers

ASME Boiler and Pressure Vessel Code

American Society for Testing and Materials Standards

A193-68  Alloy-Steel Bolting Materials for High Temperature Service
A194-68  Carbon and Alloy Steel Nuts for Bolts for High Pressure and High Temperature Service
A240-67  Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Fusion-Welding Unfired Pressure Vessels
A276-67  Hot Rolled and Cold Finished Stainless and Heat Resistant Steel Bars
A312-64  Seamless and Welded Austenitic Stainless Steel Pipe

American Society of Heating and Ventilating Engineers

ASHVE Manual

American National Standards (ANSI)

B2.1-1960  Pipe Threads
B16.5-1961  Steel Pipe Flanges and Flanged Fittings
B31.1-1955  Code for Pressure Piping
            and Addenda

Other Publications

41CFR 50-204  Walsh-Healy Act
NFPA    National Fire Code
NEC     National Electrical Code
2.3 Aerojet Nuclear Systems Company Documents. - The following documents form a part of this specification to the extent specified herein. The issue used shall be that controlled by the latest approved contractor's controlled documents list. When the requirements of this specification and subsidiary documents are in conflict, the following precedence shall apply:

(a) This Specification.
(b) Document referenced herein.
(c) Documents subsidiary to those referenced herein.

DRAWINGS

SPE 14-1-70 Building 20005 Heat Treat Facility Description

Section 3. REQUIREMENTS

3.1 Performance.-

3.1.1 Functional Characteristics.- The furnace shall be capable of heating the graphite work load to the maximum operating temperature with the performance requirements described below. The work load shall be as defined in Table I and Figures 1 and 2. The furnace shall be capable of achieving the following performance.

3.1.1.1 Temperature Capability.-

3.1.1.1.1 Maximum Temperature.-

(A) The furnace shall be capable of operating at a maximum continuous operating temperature of 2200°C, within the useful life requirements of 3.1.2.2.
(b) Option 1 - High Temperature Capability - The furnace shall be capable of operating at a maximum continuous operating temperature of 2750°C, within the useful life requirements of 3.1.2.2.

3.1.1.1.2 Temperature Controllability -

(a) The furnace temperature shall be controllable within ±2% of any set point, set between 850°C and the maximum operating temperature.

(A) (b) Option 2 - Low Temperature Control Capability - The furnace temperature shall be controllable within ±5°C of any set point, set between 120°C and 850°C. The temperature will be measured on the work load when enclosed within a retort, to be supplied by ANSC.

3.1.1.1.3 Temperature Gradient - The axial temperature gradient shall be within 100°C over the length of the susceptor corresponding to position of the work load when the furnace is operating at the maximum temperature capability.

3.1.1.1.4 Temperature Rate Controllability -

(B) (a) The rate of temperature increase shall be controlled at 15 to 60°C per hour between 120°C and 2600°C. The rate of temperature increase shall be no less than 60°C per hour between 2540°C and 2600°C. The rate of temperature decrease shall be controllable at 15 to 60°C per hour between the maximum operating temperature and 1500°C.

(b) Option 2 - Low Temperature Control Capability - The rate of temperature increase shall be controllable at 5 to 15°C per hour between 120°C and 850°C.

3.1.1.2 Furnace Atmosphere -

(A) 3.1.1.2.1 Atmospheric Conditions - The temperature controllability and profile, shall be maintainable with each of the following furnace atmospheres:

(a) Vacuum 50 microns, maximum

(b) Argon or nitrogen

(1) Flow Rate 0.1 - 3.0 SCFM

(2) Pressure 50 microns - 3 psig

(A) Vacuum will not be required at temperatures which cause sublimation of carbon.

6 Rev. B
3.1.1.2.2 Rate of Evacuation. - The cold furnace shall be capable of being evacuated of air at ambient conditions to 50 microns in 30 minutes, and being held continuously for a minimum period of fourteen days.

3.1.1.2.3 Rate of Back-Fill. - The cold furnace shall be capable of being back-filled with air, nitrogen, or argon from fifty microns to ambient pressure in a maximum of twenty minutes.

(A) 3.1.1.2.4 Option No. 3, Inert Gas Pressure Control. - The shell pressure shall be controllable at 5 to 30 inches of Hg with argon or nitrogen flowing at two SCFM.

(B) 3.1.1.2.5 Option No. 4, Forced Gas Convective Cooling. -

(a) The inert gas system shall provide convective cooling sufficient to cool the furnace from 2750°C to 200°C in seven (7) days at a rate not to exceed 60°C in one (1) hour.

(b) Inert gas shall be circulated through the furnace hot zone to provide convective cooling at temperatures between 880°C and 120°C.

3.1.1.3 Leak Rates. -

3.1.1.3.1 Furnace Shell. - The maximum allowable gas leak rate of the furnace shell shall be $1 \times 10^{-4}$ mm Hg per minute pressure rise when the vacuum system is isolated from the shell, and the pressure within the shell is 75 microns.

(A) 3.1.1.3.2 Cooling Water Channels. - All cooling water channels, including those for the furnace shell, if the ASME Boiler and Pressure Vessel Code is applicable, induction coil, vacuum system, and supply and outlet lines, shall not leak any water when tested at 100 psig.

3.1.1.4 Furnace Water Cooling. -
3.1.1.4.1 **Capacity.**— The cooling water system shall be supplied by the contractor and shall have a capacity sufficient to provide coolant for the induction coil, furnace shell, and vacuum pump as required to meet the requirements of this specification.

3.1.1.4.2 **Backup System.**— The cooling system shall be capable of providing for an automatic alternate coolant supply in the event of major component or electrical power failure.

3.1.1.4.3 **Water Temperature.**— The cooling water shall not exceed 70°C at the induction coil and furnace shell outlets when the heating zone is operated continuously at the maximum operating temperature.

3.1.1.4.4 **Water Flow.**— All coolant channels shall be protected from blockage by particulate matter (greater than 0.05 inch diameter).

3.1.1.4.5 **Furnace Shell Cooling.**— The outside wall temperature of the furnace shell, including all attached fittings, shall not exceed 50°C when operating continuously at the maximum operating temperature.

3.1.2 **Operability.**— The furnace system shall be capable of being operated within the following requirements.

3.1.2.1 **Maintainability.**— No periodic maintenance shall be required within a time period of fourteen days while the furnace is being operated according to the performance requirements of Section 3.1.

3.1.2.1.1 **Maintenance and Repair Cycles.**— There shall be no periodic maintenance required on the induction coil or furnace shell.

3.1.2.1.2 **Service and Accessibility.**— All components of the furnace which require periodic maintenance shall be accessible for repair. Required ladders, staircases, and platforms shall be provided by the contractor.
3.1.2.2 Useful Life.- The furnace system will have a minimum useful life of eight years, allocated as follows:

Rated Operating Life
(a) Time 5000 hours, minimum
(b) Thermal Cycles 50, maximum

(A) A thermal cycle shall conform to the performance requirements in Section 3.1, and a maximum hold time of five hours at or below the maximum operating temperature.

3.1.2.3 Environmental.-

3.1.2.3.1 Natural.- The water available for furnace system cooling has a hardness value of 30 ± 5 ppm as calcium carbonate, CaCO₃.

3.1.2.3.2 Induced.- The inert gases available for the furnace system atmosphere have the following impurities.

(a) Nitrogen as specified in MIL-P-27401 (99.997% N₂)
(b) Argon as specified in MIL-A-18455B (99.998% Ar)

The furnace interior, including the shell, induction coil, and vacuum system, will be exposed to an atmosphere consisting of argon, nitrogen, hydrogen, methane, carbon dioxide, carbon monoxide, and particulate carbon. The quantity of gases to be released by the work load are given in Figure 2.

3.1.2.4 Human Performance.- The furnace system controls will provide the operator with a procedure which meets the standards as given in MIL-STD-1472.
3.1.2.4 Safety. - All components, appurtenances, support equipment, etc., shall be designed and operated so that no single failure or credible combination of errors, malfunctions or accidents can cause personnel injury, and/or serious facility damage or work load loss. This philosophy requires the use of a formal hazards analysis which results in a categorization of potential hazards and documents the analysis and proposed procedures to reduce any undue consequences to acceptable levels. The hazards analysis technique is further described in Section 3.1.2.5.2.2(a).

3.1.2.5.1 Documents. - The following documents shall be used as stated to aid in achieving safety goals.

(a) The following documents shall be complied with:

(1) Walsh-Healy Act, 41 CFR 50-204
(2) National Fire Code (NFPA)
(3) Current Threshold Limit Values, American Conference of Government Industrial Hygienist
(4) National Electric Code (NEC)

(b) The following documents may be used as a guide:

(1) American Society of Heating and Ventilating Engineers Manual
(2) NASA Safety Manual NHB-1700.1 (V 1)

3.1.2.5.2 Requirements.

3.1.2.5.2.1 General Requirements. - The following safety requirements, listed in order of preference, shall be applied to the designs:

(a) Protective Systems - In all instances where known hazards exist and cannot be eliminated, appropriate protective systems shall be employed consistent with established safety codes or standards and/or accepted industrial practices.
(b) **Warning Devices.**—Where it is not possible to preclude the existence or occurrence of a known hazard, reliable devices shall be employed for timely detection of the condition and the generation of an adequate warning signal. Responses to warning signals shall be delineated in emergency plans. Warning signals shall be standardized within like types of systems to minimize the probability of improper personnel reaction to the signal(s).

(c) **Special Procedures.**—Where it is not possible to reduce the magnitude of existing or potential hazards through design, protective systems, or the use of warning devices, appropriate emergency procedures shall be developed.

3.1.2.5.2.2 **Special Requirements.**

(a) The contractor shall prepare and submit with his proposal, a preliminary hazards analysis and the hazard analysis procedure he intends to use during the contract period. A final hazards report shall accompany the detail drawings, etc. required for ANSC Engineering Department approval by Paragraph 6.3. The following hazard category definitions will be used in the analysis.

**Category I** - Negligible. Condition(s) such that personnel error, environment, design characteristics, procedural deficiencies or subsystem or component malfunction will not result in damage or personnel injury.

**Category II** - Marginal. Condition(s) such that environment, personnel error, design characteristics, procedural deficiencies, or subsystem or component malfunction can be counteracted or controlled without major damage or any injury to personnel.

**Category III** - Critical. Condition(s) such that environment, personnel error, design characteristics, procedural deficiencies, or subsystem or component malfunction will cause major equipment damage or personnel injury, or will result in a hazard requiring immediate corrective action for personnel or system survival.
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**Category IV - Catastrophic.** Condition(s) such that environment, personnel error, design characteristics, procedural deficiencies, or subsystem or component malfunction will severely degrade system performance and cause subsequent system loss, or death or severe injuries to personnel.

(b) Category III or IV hazard conditions shall be precluded from designs to the maximum practical extent. Any design which includes a Category III or Category IV hazard condition which cannot be eliminated will require review by ANSC. The analysis of Category III or Category IV hazard conditions will be documented together with a proposed procedure for reducing the consequences of the hazard to an acceptable level.

(c) The furnace design shall preclude the accumulation of a mixture of combustible gases which can lead to explosion/fire during operations. Where it is not possible to prevent the occurrence of an explosive atmosphere, ignition sources in the affected area shall be eliminated or protection against ignition otherwise provided.

(d) The furnace/facility design shall preclude the accumulation of inert/toxic gases in the operating area. Reliable devices shall be utilized for timely detection of the condition and generation of an adequate warning signal perceptible by personnel without entering the pit.

(e) The Walsh-Healy Act 41CFR 50-204 shall be followed in meeting the environmental conditions given below.

1. Fresh air shall be supplied to the pit operating area. An oxygen concentration of 20% per volume air shall be maintained at all times.

2. Thermal environment shall be compatible with the facility ventilation capability to provide a personnel working environment in the comfort range as defined in "Heating, Ventilating and Air Conditioning Guide (ASHVE)."
(3) Noise levels shall not exceed limits for eight-hour exposure to personnel.

(4) Illumination shall be adequate for personnel to perform their work efficiently in the operating areas.

(f) The furnace system shall be fail safe, so if there is water failure, power failure, or a vacuum failure, the system will sound an alarm and automatically shut itself down in a safe manner to protect the equipment and work load. The fail safe system shall be monitored by the operator and it shall be possible to detect any fail safe circuit malfunction.

3.2 System Definition.

3.2.1 Interface Requirements.- The furnace system described in this specification shall be physically, mechanically, and functionally suitable for operation with the Sacramento AGC Physical Plant as described below.

3.2.1.1 Schematic Arrangement.- The physical interface relationships of the furnace system and the AGC Physical Plant shall be in accordance with the description of the AGC Building 20005, Heat Treat Facility given in drawing SPE-14-1-70.

3.2.1.2 Detailed Interface Definition.- The mechanical and functional interface relationships of the furnace system shall be in accordance with the following subparagraphs:

(A) 3.2.1.2.1 Mechanical Interfaces.-

(A) 3.2.1.2.1.1 Pit Area.- The furnace shell and vacuum system shall be installed by the contractor in the pit shown in drawing SPE-14-1-70. The existing available pit area can be enlarged to 18.5 feet square by relocation of a concrete beam. Additional space of 9 by 18.5 feet, adjacent to the pit cell, is available to the furnace Contractor.
3.2.1.2.1.2 Sump Location.- The sump located at the bottom of the pit shall remain and will not interface with the proposed furnaces.

3.2.1.2.1.3 Gas Generator.- The existing gas generators are surplus equipment and may be moved by the contractor.

3.2.1.2.2 Functional Interfaces.- The service and utilities available for use by the furnace system are as follows:

3.2.1.2.2.1 Fluid.- Water, nitrogen, and argon will be available as located in drawing SPE-14-1-70. Capacities available are as follows:

- (a) Water: 500-1000 GPM at 80 psi
- (b) Steam: 75-100 BHP at 90 psi (located 600 feet from site)
- (c) Nitrogen: 2000 SCFH continuous, 4000 SCFH for one (1) hour at 4 psi
- (d) Argon: 10,000 SCFM at 50 psi
- (e) Compressed Air: 200-250 CFM at 80 psi (not dry)

3.2.1.2.2.2 Electrical.-

3.2.1.2.2.2.1 Power Availability.- Power will be available as located in drawing SPE-14-1-70. Capacities available are as follows:

- (a) Two (2) each - 12 KV/480V, 1000 KVA 3 Ø transformers.
- (b) 12K/480V, 100 KVA, 3 Ø transformer.
- (c) Two (2) each - 12 KV, 2000 KVA 3 Ø feeders.

Electrical components shall be designed to a power factor rating of 0.90 minimum. Available three phase power shall maintain a balanced load to within 15 percent.
3.2.2.2.2 Power Switching Panel.- The facility power switching panel is identified and shall remain in service. The contractor shall use or modify the available breakers, as required.

3.2.2 Component Identification.-

3.2.2.1 Engineering Component List.- Design of the furnace system shall include the following engineering components. Each component shall be supplied and installed by the contractor. When installed, the components shall be mutually compatible to perform as required in Section 3.1.

(a) Work Load Support
(b) Susceptor
(c) Induction Heating Coil
(d) Thermal Insulation
(e) Furnace Shell
(f) Vacuum System
(g) Inert Gas Flow Control System
(h) Power Supply and Controls
(i) Water Cooling Tower
(j) Instrumentation, Controls, and Control Cubicle

3.3 Design and Construction.- The design, construction and installation of the furnace system shall be provided by the contractor, and shall conform to the following requirements.

3.3.1 General Design Features.-

3.3.1.1 Structural Criteria.- Structural design features shall be consistent with performance requirements specified herein.

(A) 3.3.1.2 Weight.- The weights of the work load components shall be as follows:
AGC-90278

(a) Bulk Graphite Support 6000 lbs, maximum
(b) Fibrous Graphite 600 lbs
(c) Option 2, Low Temperature Control Capability
   (1) Steel Retort 3000 lbs
   (2) Bulk Graphite or Steel Support 6000 lbs, maximum

3.3.1.3 Configuration.- The configuration of the work load is defined in Figure 1.

3.3.1.4 Work Load Support.-

(a) The work load support shall be capable of maintaining the position of the work load within ± one inch, axially and diametrically, during the thermal operating cycle.

(b) Heat Sinks.- Retractable heat sinks incorporated in the workload support shall be capable of increasing the furnace cooling rate.

3.3.1.5 Susceptor.- The susceptor shall be assembled and disassembled from the furnace shell vertically employing an overhead five-ton crane.

3.3.1.6 Induction Heating Coil.-

3.3.1.6.1 Assembly and Disassembly.- The induction coil shall be mounted vertically in the furnace shell, and shall be removed vertically employing a five-ton crane.

3.3.1.6.2 Coil Movement.- The coil shall be supported in such a manner that the coil centerline shall be held within ± one inch of the furnace shell centerline.

3.3.1.6.3 Electrical Insulation.- The coil shall be electrically insulated to prevent arcing.

3.3.1.6.4 Sight Port Pass-Throughs.- A minimum of three sight port pass-throughs shall be provided on the coil to allow optical pyrometric measurement on the susceptor.
3.3.1.6.5 **Coil Size.**—The induction heating coil shall have a copper wall thickness of 0.25 inch, minimum.

3.3.1.6.6 **Coil Support.**—The induction heating coil shall be supported on the outside circumference by vertical columns which are spaced on 23 inch maximum centers.

3.3.1.7 **Furnace Shell.**

3.3.1.7.1 **Type.**—The furnace shell shall be a cylindrical vessel with a flanged main closure.

3.3.1.7.2 **Main Closure.**—The main closure shall be operated with a twenty-ton gantry crane, to be provided by ANSC, and secured with a quick acting spring loaded clamping device which allows gas to escape in the event of shell overpressure.

3.3.1.7.3 **Access Ports.**

(a) Access ports shall be provided for required sight ports, inert gas and air inlet, outlet, vacuum line, thermocouple leads, pressure gauges, and power feed-throughs.

(b) **Option 2 - Low Temperature Control Capability.**—All ports specified and in addition, one inlet and one outlet port to provide two SCFM of argon, nitrogen or air flow at three psig pressure, and two thermocouple lead ports.

3.3.1.7.4 **Sight Ports.**—Sight glass viewports shall be located on the furnace shell so that optical pyrometer measurements can be made on three equally spaced locations on the susceptor corresponding to the top, center, and bottom of the work load. Additional sight ports may be provided by the contractor. The interior of the sight port glass shall be free of deposits during normal operation. The contractor shall consider employing inert gas flushing and ball valve closure.
3.3.1.7.5 Pressure Relief.- A relief valve for vacuum or pressure operation shall be provided to relieve pressure at five psig. Corrosion resistant rupture disc assemblies will be provided to relieve pressure greater than eight psig at ambient temperature. The pressure relief system shall be capable of handling the maximum gas overpressure and flow conditions, and the discharge gas shall be vented to the atmosphere in a safe manner.

3.3.1.7.6 Shell Construction.- The furnace shell shall be of double wall construction, water cooled throughout, and shall meet the performance requirements of paragraphs 3.1.1.4.

3.3.1.7.7 High Intensity Filters.- Sight glass view ports shall be equipped with removable optical filters.

3.3.1.8 Vacuum System.- The vacuum system shall be equipped with a suitable low impedance filter to protect the vacuum pumps from the furnace atmosphere, which consists, in part, of particulate graphite powder.

3.3.1.9 Inert Gas Flow System, Option No. 4, Forced Gas Convective Cooling.-

(a) Gas shall be circulated through the hot zone with a regenerative gas recirculation type system which includes a high temperature fan and water cooled heat exchanger.

(b) Inert Gas Purge.- When required in the event of an emergency, the inert gas flow system shall provide a rapid purge of the furnace.

3.3.1.10 Power Supply.- The contractor shall provide a power supply with sufficient capacity to meet the performance requirements in Section 3.1.

3.3.1.11 Water Cooling Tower.- The contractor shall provide a water cooling tower with sufficient capacity to meet the performance requirements in Section 3.1.

3.3.1.12 Instrumentation, Controls, and Control Cubicle.-
3.3.1.12.1 Control Cubicle.- One enclosed control cubicle containing all measurement, metering, recording, programming, switching, operating control equipment, and etc., shall be provided by the contractor.

3.3.1.12.2 Control Duality.- Switching shall be provided in this control cubicle to permit selective operation of this furnace and a proposed second furnace to be installed adjacent to this unit at a later date.

3.3.1.12.3 Temperature Measurement and Instrumentation.- The temperature shall be continuously and automatically controlled, programmed, and permanently recorded at any one of three locations equally spaced on the susceptor. The locations on the susceptors shall correspond to the top, center, and bottom of the axial work load when positioned within the susceptor.

(a) Controllers.-

(1) Low and middle range temperature controllers shall operate with thermocouples.

(2) A high temperature controller shall operate with a minimum of three radiation pyrometers.

(b) Control Modes.- The controllers shall be capable of manual, set point, and program operating modes which meet the performance requirements of Section 3.1.

(1) Manual Mode.- The manual mode shall be capable of at least 28 coarse power range changes to the full power rating, and of infinite control between these ranges.

(2) Setpoint Mode.- The setpoint mode shall be capable of automatically maintaining a predetermined power level.

(3) Programmer Mode.- The programmer mode shall be capable of continuously and automatically controlling a predetermined temperature or power profile for each of three temperature ranges: low, middle, and high.
(c) **Overtemperature Limiting.** - The deviation between the power and temperature profiles shall be limited to a predetermined span to prevent temperature overshoot.

3.3.1.12.4 **Pressure Measurement and Instrumentation.** - Gas pressure shall be measured at a minimum of two positions on the chamber and at appropriate positions on each vacuum pump. Cooling water pressure shall be measured.

3.3.1.12.5 **Flow Rate Measurement and Instrumentation.** - The flow rates of nitrogen and argon shall be measured and controllable.

3.3.1.12.6 **Option No. 3, Inert Gas Pressure Control.** - The furnace shell pressure shall be automatically controlled, and permanently recorded.

3.3.2 **Selection of Specifications and Standards.** - Standards and Specifications shall be selected by the contractor from paragraph 3.3.3.1.

3.3.3 **Materials, Parts, and Processes.** - Materials shall be new and shall conform to the requirements in referenced specifications.

3.3.3.1 **Applicable Specifications.** - The following material types shall be purchased with certification to the appropriate specifications.

(a) Aluminum
QQ-A-20
QQ-A-250

(b) Copper
QQ-C-576
3.3.3.2 Furnace System Component Material Selection. - Materials of construction shall be selected by the contractor and shall meet the following construction requirements.

3.3.3.2.1 Induction Heating Coil. - Materials of construction shall be resistant to corrosion from the furnace system environment and the coil shall have suitable electrical properties which prevent arcing during operation.

3.3.3.2.2 Susceptor. - Materials of construction considered by the contractor shall include bulk graphite and fibrous carbon. The latter proposed material may be procured from several sources including Rohr, Riverside, California; Hitco, Gardena, California; and Carbon Products Division, Union Carbide, Niagara Falls, New York.

3.3.3.2.3 Thermal Insulation. - Materials of construction shall be capable of providing the required useful life and maintainability in this specification. The contractor shall consider all candidate materials including lampblack, carbon blocks, granular carbon, and carbon and graphite felt.

3.3.3.2.4 Furnace Shell. - Materials of construction for the interior walls, port flanges, common size nuts and bolts, and nozzles shall be resistant to corrosion by the furnace system environment.
Section 4. QUALITY ASSURANCE

4.1 Supplier Responsibility. - The contractor shall prepare and submit with his proposal, a complete and concise description of a Quality Assurance Program the contractor proposes to utilize to assure compliance with the provisions of this specification.

4.2 Exceptions. - The contractor's Quality Assurance Program shall be based on compliance with SNPO-C-4 with the following exceptions.

(a) Part I - System Requirements. -

9.4 Evaluation
12.3 Sampling Plans
12.4 Statistical Quality Control Charts
14B.2 Monthly Quality Status Report
15.2 Audit Reports and Corrective Action

(b) Appendix B - Quality Assurance Documentation Cross-Reference Index. - Referenced in Paragraph 22

2. The Contractor shall submit the following for review:

(d) Results of Special Measuring and Test Equipment Evaluations Part I, 9.4
(e) Special Sampling Plans; Application of Sampling Part I, 12.3
(i) Temporary Storage of End Items Part II, 1.3.6

3. The Contractor shall submit the following for information:

(a) Monthly Quality Status Report Part I, 14B.2
(b) Quarterly Summaries of Quality Program Performance Audits Part I, 15.2
4.3 Special Acceptance Tests.

4.3.1 Furnace Shell.— A leak rate and pressure test shall be performed on the furnace shell using the following methods:

(a) Evacuate the furnace shell to 50 microns pressure, having back-filled with helium three times.

(b) Seal-off the furnace shell and measure the leak rate.

(c) Maximum leak rate shall be $1 \times 10^{-4}$ mm Hg per minute pressure, rise at 75 microns pressure.

(d) Pressurize furnace shell with helium at the contractor's design pressure.

(e) Seal-off the furnace shell, measure the leak rate, and record.

4.3.2 Induction Heating Coil.— A leak rate test shall be performed on the coil at the contractor's plant using the following method.

(a) Air pressure of 100 psig will be applied to the coil. Leaks will be detected by applying a soap solution, MIL-L-25567 on all joints. All leaks detected will be eliminated.

(b) Evacuate the coil to one micron absolute pressure or less.

(c) Place a plastic shroud over the coil and fill with helium.

(d) With a calibrated mass spectrometer leak detector, observe the leakage rate for five minutes.

(e) Maximum leak rate shall be $1 \times 10^{-6}$ std cc/sec or less.
Section 6. NOTES

6.1 Facility Description.- The furnace will be installed by the contractor at ANSC Sacramento Facility as defined in drawing SPE-14-1-70 and utilizing the following additional information:

(a) A wall may be built in the pit to isolate the furnace area.

(b) This facility does experience electrical power outages at indeterminate periods of time.

(c) The emergency power generator, located in AGC Building 20005, may be used by the Contractor, manual operation activates the propane, 75KW at 480 volt, generator.

(d) The main water supply is driven by pumps with an independent emergency backup power source.

6.2 Contractor Inspection.- ANSC and/or U. S. Government personnel reserve the right to inspect any of all of the work included in this order at the supplier's plant during fabrication at the contractor's or subcontractor's plant.

6.3 Drawings.- Two sets of detail drawings, descriptions, and a complete bill of materials will be submitted to the ANSC Engineering Department for approval prior to initiation of fabrication or procurement of any component of the furnace and its accessory equipment. Approval of components will not relieve the contractor of his obligation to supply a furnace and accessory equipment in strict conformance with the requirements of the application on
this specification. Three sets of assembly and detail drawings, wiring diagrams, and a complete bill of materials will be required prior to delivery and installation of the furnace and all accessory components. One set of reproducible drawings will be required upon ANSC acceptance of the furnace.

6.4 Operating Manuals.- Six complete sets of operating manuals describing operating, safety, maintenance procedures and parts list will be provided upon ANSC acceptance of the furnace.

6.5 Operating Performance Acceptance.- The contractor will provide a minimum of one operator and one engineer to initiate complete operation of the furnace and to demonstrate the required performance specifications to the satisfaction of ANSC.

6.6 Training.- During a maximum two-week period, and ANSC operator and engineer will be trained in the operation of the furnace.

6.7 Presentation.- A one-day presentation of the proposal in Cleveland, Ohio will be required of the bidder.

6.8 Option 2 - Low Temperature Control Capability.- This feature will be used at a maximum temperature of 850°C.
## TABLE 1

**PHYSICAL PROPERTIES OF AG-CARB FIBROUS GRAPHITE**

<table>
<thead>
<tr>
<th>Property</th>
<th>TEMPERATURE, °F</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RT</td>
</tr>
<tr>
<td><strong>Electrical Resistivity, ohm-cm x 10^{-4}</strong></td>
<td>13-16</td>
</tr>
<tr>
<td><strong>Thermal Conductivity, BTU/hr/ft²/°F/ft</strong></td>
<td></td>
</tr>
<tr>
<td>Hoop</td>
<td>--</td>
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<tr>
<td>Radial</td>
<td>--</td>
</tr>
<tr>
<td><strong>Thermal Expansion, in/in x 10^{-3}</strong></td>
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</tr>
<tr>
<td>Hoop</td>
<td>--</td>
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<tr>
<td>Radial</td>
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</tr>
<tr>
<td><strong>Tensile Strength, ksi</strong></td>
<td></td>
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<tr>
<td>Hoop</td>
<td>11</td>
</tr>
<tr>
<td><strong>Compressive Strength, ksi</strong></td>
<td></td>
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<tr>
<td>Radial</td>
<td>10</td>
</tr>
<tr>
<td><strong>Flexure Strength, ksi</strong></td>
<td></td>
</tr>
<tr>
<td>Hoop</td>
<td>16-20</td>
</tr>
<tr>
<td><strong>Density, gm/cc</strong></td>
<td>1.45 ± 0.5</td>
</tr>
</tbody>
</table>
NOTE: WORK LOAD WEIGHTS

1. FIBROUS GRAPHITE 600 LBS
2. BULK GRAPHITE 6000 LBS
3. STEEL RETORT 3000 LBS (OPTIONAL)

INDUCTION FURNACE WORK LOAD SCHEMATIC

FIGURE 1
WORK PIECE GASSING, LITERS/MIN

\( \text{H}_2, \text{CH}_4, \text{CO}, \text{CO}_2 \)

GAS RELEASE FROM WORK PIECE IN PROPOSED VACUUM INDUCTION FURNACE

FIGURE 2
APPENDIX C

ANSC INDUCTION FURNACE INSPECTION REPORT NO'S
503993, 503994, and 512330

73
**INSPECTION REPORT**

**No. 503993**

<table>
<thead>
<tr>
<th>ITEM S/N</th>
<th>260-5</th>
<th>AGC-90278A</th>
<th>Induction Furnace</th>
</tr>
</thead>
</table>

**Inspection Criteria**

- Accept. Test:

---

Cragmet Div. of Cheston Corp.

N-20136

**18. Discrepancy or Non-conformance**

Per Purchase Order N-00136, AGC Spec. 90278A - the amendments to same, and the acceptance test plan consisting of Section I Mechanical Operation, Section II Electrical Operation, Section III Safety Interlocks and Section IV Performance. The following discrepancies and nonconformances are hereby noted:

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**29. Corrective Action**

Action to prevent recurrence:  
Effectiveness:  

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AEROJET-GENERAL CORPORATION

INSPECTION REPORT - Cont. Sheet

| NO. 503993 |
| PAGE 2 OF 9 |

Induction Furnace

Section I, Page 3, F. 4. Contractor did not demonstrate that the vacuum, mechanical pumps had the capabilities of pulling a vacuum to 10 microns.

Section I, Page 6, 6b, 8b, 9b, 10b & 11b. Measure water flow and record flow rate on Pumps Nos. 30-VP-1, 30-VP-2, 30-VP-3, 30-VP-4 & 30B-BL. Measure and record flow rate in middle, top and bottom furnace shells, not completed by contractor.

Section II, Page 8, H. 2. d. Demonstrate that the silicon rectifier output is variable between 0 & 100 Vdc and has a maximum output of 100 amperes. Section II, Page 10, J. 3. through 3e. Demonstrate that the two pressure recorders Nos. 10-37 and pressure gauge No. 10-1 are calibrated to within 1% of full scale deflection.

1. Accept. The 10 micron valve is the ultimate minimum operating pressure for the vacuum pumps. The capability demonstrated was 17 microns, which is adequate to meet the requirements of the ANSC Spec No. AGC 90278A, Para 3.1.1.2.1.

2. Accept. ANSC will make the required measurements.

3a. Accept. The silicon rectifier has a name plate rating of 100 Vdc. The control circuit requires a maximum 36 volt output. The voltage range of 0-36 volts was demonstrated, and is satisfactory to meet the performance requirements of the Specification.

3b. Preliminary Disposition - Supplier shall show calibration of the listed gauges. The Stokes McLeod gauge requires certification of calibration.

**Table:**

<table>
<thead>
<tr>
<th>CHAR/ITEM NO</th>
<th>CHAR OF CHAR</th>
<th>OCCUR</th>
<th>LIST IN ORDER</th>
<th>KG: PCS,</th>
<th>Dwg/SPEC, RES:</th>
<th>ITEM IDENT</th>
<th>21. PRELIM. DECISION</th>
<th>REVIEW DECISIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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<tr>
<td>Section I, Page 3, F. 4. Contractor did not demonstrate that the vacuum, mechanical pumps had the capabilities of pulling a vacuum to 10 microns.</td>
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<td></td>
<td></td>
</tr>
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<td>Section II, Page 8, H. 2. d. Demonstrate that the silicon rectifier output is variable between 0 &amp; 100 Vdc and has a maximum output of 100 amperes. Section II, Page 10, J. 3. through 3e. Demonstrate that the two pressure recorders Nos. 10-37 and pressure gauge No. 10-1 are calibrated to within 1% of full scale deflection.</td>
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</tbody>
</table>
### Section III, Page 13, B, 1.

**Contractor did not demonstrate that closure was demonstrated at a pressure of 35 microns.**

*The main vacuum valve closes automatically, trouble light turns on and horn sounds, when chamber pressure rises above 20 \( \pm \) Hg Vacuum.*

### Section IV, Page 16, A, 1b.

**Contractor need to demonstrate that controllability was demonstrated at 700°C.**

*This temperature is acceptable in lieu of 850°C because it is a more difficult holding temperature for this equipment.*

### Section IV, Page 17, 1g, 1g1, 1g3, 1h3, 1h5.

**Contractor has not completed this part of the temperature capability tests.**

*The rate is established to decrease 15° \( \pm \forearm 2°C \) per hour, between 2750 and 2680°C and 50° \( \pm \forearm 6°C \) per hour between 2680° and 1800°C.*

### Section IV, Page 20, D, 2.

**Furnace cooling section is not complete.**

*Contractor must demonstrate that cooling is sufficient and that the furnace shells, flanges and all attached fittings shall not exceed 63°C on the top flange and 85°C on the bottom flange. These temperatures are acceptable because the furnace was...*
Reference Section IV, Para. 1a, Page 15. Mechanical Vacuum Pumps. Contractor has operated all 4 pumps above the manufacturer's recommended amperage rating, and has at numerous times operated all 4 pumps without proper oil level, being evident in pump bases. Piping changes on exhaust system, installation of baffles in tees and oil equalizing piping system need drawing changes.

7. Preliminary Disposition. The mechanical pump motor amperes exceeded the manufacturer's rating. The furnace supplier shall certify that the manufacturer's warranty was not voided and warranty to one year from date of out-of-spec operation. Supplier shall make drawing revision, as described in Item 15A below.

Reference Section II, Para. J. 5, Page 10. Duplex Cam Time Plotters - due to faulty or wrong cut cams on 10-23 Honeywell duplex temperature controllers, the controllers do not perform or control temperature decrease at 60°C per hour, as called out per Acceptance Test Procedure.

8. Accept. Furnace temperature followed temperature value demanded by cam controller within required accuracy. Future operation will require more accurately cut cams.
<table>
<thead>
<tr>
<th>CHAR/ ITEM NO.</th>
<th>CLASS/ CHAR.</th>
<th>OCCUR</th>
<th>LIST IN ORDER. NO: PCS. - DWG/ SPEC. - REQ. INSPECTION RES. - ITEM IDENT.</th>
<th>21. PRELIM. DECISION</th>
<th>REVIEW DECISIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td></td>
<td></td>
<td>Reference Section IV, Para. E. 2.</td>
<td>9. Accept. Graphite felt was repaired and replaced satisfactorily by the supplier.</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td></td>
<td></td>
<td>Reference (Section I, Para. bl, Page 2) Cragnet Tool No. 3086, &quot;Workload Base &amp; Measuring Tool&quot;. Contractor did not supply proper measuring tool for vertical alignment of the coils, susceptor or lower 42&quot; work support rings.</td>
<td>10. Accept. Alternate methods of measurement were used to assure acceptable alignment.</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td></td>
<td></td>
<td>Contractor did on numerous times overload the limitations on ANSC Power Sub-Station, passing the red line of amperes allowed.</td>
<td>11. Accept. Overload conditions were reviewed by ANSC Plant Engineering. The amount of overload was within the operating capability of the sub-station.</td>
<td></td>
</tr>
</tbody>
</table>
**INSPECTION REPORT - Cont. Sheet**

<table>
<thead>
<tr>
<th>NO.</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>13</td>
<td>Reference Dwg. No. 3086-300-21 - Sight Port, Graphite parts detail. Contractor must align &amp; adjust sight port tubes. Following all temperature furnace runs, the sight tubes were misaligned, making it impossible to obtain accurate temperature reading for subsequent runs.</td>
</tr>
<tr>
<td>14</td>
<td>Preliminary Disposition. Supplier shall provide certifications as noted. AISC shall replace pump gauge.</td>
</tr>
</tbody>
</table>

**REVIEW DECISIONS**

- 12. Accept. Supplier has repaired valve.
- 13. Accept. Supplier has aligned sight port tubes. This condition will become less noticeable in future runs as settling of the graphite felt is completed.
- 14. Preliminary Disposition. Supplier shall provide certifications as noted. AISC shall replace pump gauge.
The following drawings must be upgraded by the contractor to show in detail changes in regards to the 'as built' configuration.

A. DWG. 3086-100-50 & 3086-600-20 Mechanical Pumps Vacuum, -Stokes, Installation of pump oil by-pass lines at pumps base. Installation of Tee & Baffle in exhaust lines.


C. DWG. 3086-100-20, Sheet 1, Argon System, Emergency. Contractor field decision to change direction and configuration of Argon Emergency Flow System Piping.

D. DWG. 3086-200-10, Graphite Felt Insulation. Contractor field decision to change method of felt installation, from lapped vertical installation to 6" & 7" rolled felt configuration.

E. DWG. 3086-600-10E, Furnace Top Lid, Water Coolant. Contractor change of design from blow-out disks to steel stand pipes at top lid and furnace bottom section.
<table>
<thead>
<tr>
<th>CHRN/ITEM NO.</th>
<th>ISSG OF CHAR</th>
<th>OCCUR</th>
<th>LIST IN ORDER, NO.</th>
<th>REQ. DWG/SPEC.</th>
<th>REQ. INSPECTION RES.</th>
<th>ITEM IDENT.</th>
</tr>
</thead>
<tbody>
<tr>
<td>F. DWG. 3086-200-41 (Detail A)</td>
<td>Vacuum Chamber Weldment detail. Contractor field design change, installation of three air release valves at the flange area, of all three furnace spools - top flange area.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>G: DWG. 3086-300-21, Sight Port Graphite Parts Detail.</td>
<td>Contractor field decision to redesign and install a new configuration of top lid sight port.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>H: DWG. 3086-600-30, Water Schematic &amp; DWG. 3086-100-82, contractor field decision and redesign of larger coolant lines from furnace shells to drain.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I. DWG. 3086-200-10, Vacuum Furnace Assembly. Contractor field decision to install transite boarding around top of inside furnace, between induction coils and furnace wall.</td>
<td></td>
<td></td>
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</tbody>
</table>

**Section IV Page 16, A. Idl.**

Contractor did not demonstrate that the furnace was automatically temperature controlled from 2600 to 2750°C per hour.

16. Accept. The specification does not require automatic temperature controllability between 2500°C and 2750°C. The supplier manually controlled the temperature from corrected readings of 2600°C to 2690°C. This maximum temperature achieved is acceptable because it meets the temperature...
<table>
<thead>
<tr>
<th>CHN/ITEM No.</th>
<th>LIST IN ORDER, NO:</th>
<th>DWG/SPEC</th>
<th>REQ HISP, RES.</th>
<th>ITEM IDENT.</th>
<th>21 PRELIM DECISION</th>
<th>REVIEW DECISIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>17</td>
<td>Section IV, Page 16, 1el</td>
<td>Contractor did not demonstrate that the furnace temperature can be manually adjusted to 2750°C, maximum, and automatically maintain this set point temperature for 5 hours.</td>
<td>controllability requirements of Spec 90278A. Para 3.1.1.1.2 requires controllability of +2% *(temperature correction method referenced below).</td>
<td>17. Accept. As stated above, the maximum temperature demonstrated met the requirements of the specification. Set point temperature control was within the temperature range of 2670°C to 2695°C, which is acceptable.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>Section I, Page 5, L 5</td>
<td>Contractor has not demonstrated that the Baltimore air cooling tower operates without visible water leakage.</td>
<td></td>
<td>18. Accept. Supplier has reworked the cooling tower and has eliminated all water leakage.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>Section IV, Page 20 1a, 1b &amp; 2.</td>
<td>Due to large rust formation in the furnace shell inner walls and piping, rust inhibitor must be added to the system. Contractor has failed to demonstrate that periodic maintenance is not required during any 14 day operating cycle.</td>
<td>19. Accept. Anti-rust water treatment is considered normal maintenance, and will be provided by AISI during future furnace operation.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Temperature Measurement Correction*

2. Target Emissivity -
<table>
<thead>
<tr>
<th>CHAR/ITEM NO</th>
<th>CLASS OF CHAR</th>
<th>OCCUR</th>
<th>LIST IN ORDER, NO./PCS.</th>
<th>REVIEWS/REV.</th>
<th>REVIEW DECISIONS</th>
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<tbody>
<tr>
<td>21 PRELIM. DECISION</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

b. Rudy, E, Pirini Furnace for the Precise Determination of the Melting Temperature of Refractory Substances.

During the operation of painting the Induction Furnace, the painting crews broke loose the Crane #676 Air bleed valve to the middle furnace spool weldment, (Ref. DWG. 3086-200-41, Detail A.) Visual inspection reveals that the installation of the 1/2" N.P.T. Nipple which supports the valve was of poor workmanship. The nipple was supported by only three threads and the tapped 1/2" threaded hole was irregular with the threads being shallow. It should also be noted that this particular furnace...
shell has lost a considerable amount of specially treated water, all from the top spool weldment and to the top level of the center spool. Top and center spools are linked together by a common water coolant line.
1. Accept. Supplier's plan was rejected and supplier was directed to meet requirements of AMSC Acceptance Plan.

Per Purchase Order, Paragraph 8

Furnace System start up.

The Seller has completed a preliminary system check as required by sub paragraph 1 in accordance with the Sellers submitted activation and acceptance plan. Section 1 Activate Water System and Section 2 Activate Pumping System. The following conditions are reported:

1) The preliminary system check was run without AMSC approval of the Seller's plan.
The following unplanned events on actions are reported for record and evaluation:

During the activation of the pumping system while pumping down the chamber, the oil levels in vacuum pump 1 & 2 were unstable, resulting in oil flowing from one pump to another through the venting system allowing one or the other pump's oil supply to become depleted to below recommended oil level.

The Seller attributed the condition to back pressure at the 15 foot level manifold, and the need for baffles in the T joint connecting pumps and vent system.

3) Supplier fabricated and installed baffles in the T section which is not in accordance with the Seller's drawing as approved by ANSC.

The Seller states that the back pressure is caused by ANSC's vent system and recommends modification.

4) The pit is in an unsafe condition as a result of oil being spilled during the Seller's draining and refilling of the vacuum pump oil system. The bottom of the pit is covered with oil, stairways and platforms have been made slick with oil as a result of tracking, oil was washed down the drain which is in violation of safety regulations, the area had an excessive amount of oil.

2. Accept. The oil transfer from one pump to the other was corrected by connecting a common line between the oil sumps of each pump, so that the oil would seek a common level. Baffles were placed at the pump T-joint inlet to reduce pump oil transfer between sister pumps.

3. Preliminary Acceptance. The baffles were installed upon the recommendation of the pump manufacturer to help prevent oil transfer between sister pumps. This repair is acceptable. The supplier will revise Dwg. No. 3085-100-50 and 3086-600-20 accordingly. The ANSC vent system was enlarged as recommended by the pump manufacturer.

4. Accept. ANSC had the pit area cleaned. Safety declared the area acceptable.
SECTION 3, FIELD SERVICES:

On 6-23-71 the Seller was preparing to perform operations initially to activate the pumps with one engineer available. The purchase order requires the Seller's services of one operator and one engineer to initiate complete operation of the furnace, etc.

Accept. The supplier was informed of the need for additional personnel and met the requirement to provide two operating personnel.
APPENDIX D

THERMAL ANALYSIS

FOR

INDUCTION FURNACE

TEMPERATURE MEASUREMENT CORRECTIONS

88
TO: O. J. Demuth  
FROM: D. T. Buchanan  
SUBJECT: Temperature Measurement in Inert Induction Furnace (Including Detailed Target Analysis)


REFERENCES:  
(c) Union Carbide Form CCP-3713 "Effective Thermal Conductivity for Carbon & Graphite Felts", Page 8, dated 9-30-1970
(d) Cragmat Corporation Drawing 3080-300-20, "Sight Port Assembly with Thermocouple Unit", dated 3-19-1971

INTRODUCTION:

This memorandum supersedes Reference (a) and replaces it in its entirety.

SUMMARY:

A thermal analysis was conducted to estimate the effect of the specific load on susceptor temperature within the induction furnace for testing the graphite skirt extension. A one-dimensional analysis indicated that the load consisting of three 2200 lb "candle sticks" will track the susceptor temperature within 2°F at furnace temperatures in excess of 3800°F with a constant susceptor power input of 1500 KW. Therefore, it was concluded that there is no effect of load on susceptor temperature at a given input power near steady-state conditions.
A simple thermal analysis was conducted of the target device which penetrates the furnace insulation and is viewed by a pyrometer. The analysis predicts target temperatures approximately 170 to 185°F below the susceptor and load temperatures.

ANALYSES:

A one-dimensional thermal model of the furnace was coded for the E12901 "Thermal Analyzer" program. The load was input as a single capacitance node with thermal radiation exchange with the susceptor and inner insulation surface. The capacitance of the load was based on a weight of 6600 lbs of graphite with temperature-dependent thermal capacitance as taken from Reference (b). The thermal radiation exchange between the susceptor and the load was based on the surface area of the three 16 in. diameter "candle sticks", each 113 in. high with a shape factor of 1.0 from the susceptor to the load. The susceptor was also input as a single node with a mass of 8000 lbs with its thermal capacitance from Reference (b).

Because of the wide variation in temperature through the insulation a single node approach would have produced a gross error in the thermal capacitance. Therefore, six capacitance nodes representing 333 lbs of insulation each were input with an additional outer surface node held constant at 200°F. This approach presented a problem in selecting the correct thermal conductivity because the data provided in Reference (c) is mean conductivity based on the hot side temperature. Therefore, the conductivity from Reference (c) was adjusted percentage wise to give the specified steady state susceptor and load temperature. This method assured that the total heat loss from the furnace at the specified temperature of 4930°F (2720°C) is approximately correct.

A twelve hour transient thermal analysis was then run with a susceptor heating rate of 1.5 MW. This heating rate accounts for losses in the coil; it is assumed that approximately 1.75 MW are required at the coil to produce a 1.5 MW heat rate at the susceptor. This transient analysis indicated that the load will follow the susceptor temperature within 2°F for temperatures above 3800°F where the temperature rise rate is approximately 250°F/hr.

A simple thermal heat balance of the target used to measure the furnace temperature with a pyrometer was conducted. It was assumed that the target tube as shown on Reference (d) protrudes approximately 3-1/2 inches beyond the
inner insulation surface. The net radiation exchange between the furnace and the outer surface area of that portion of the target which protrudes into the furnace was balanced with heat losses due to stem conduction and thermal radiation to the 200°F sink outside of the insulation. This energy balance was developed as follows:

\[ Q_{\text{in}} = A \alpha \sigma \left( T_f \right)^4 - T_l \]  

(1)

where

- \( Q_{\text{in}} \) = net heat received by target, Btu/sec
- \( A \) = outer surface of target tube which extends into furnace, in.\(^2\)
- \( \alpha \) = absorptivity of target tube (0.95), dimensionless
- \( \sigma \) = Stefan-Boltzmann constant, Btu/in.\(^2\)-sec-°R\(^4\)
- \( T_f \) = furnace temperature (5390°F)
- \( T_l \) = target temperature, °R

Similarly:

\[ Q_{\text{out}} = A_T \varepsilon_e \sigma \left( T_l \right)^4 - (T_l - 200) A_c k/x \]  

(2)

where

- \( Q_{\text{out}} \) = heat loss from target, Btu/sec
- \( A_T \) = target area, in.\(^2\)
- \( \varepsilon_e \) = effective emissivity of target, dimensionless
- \( A_c \) = cross sectional area of graphite material of target tube/in.\(^2\)
- \( k \) = conductivity of graphite, Btu/in.-sec-°R
- \( x \) = thickness of insulation, in.

Since the heat loss must equal the net radiation absorbed from the furnace by the target tube, Equation (1) was set equal to Equation (2)

\[ A \alpha \sigma \left( 5390 \right)^4 - T_l \]  

\[ = A_T \varepsilon_e \sigma \left( T_l \right)^4 - (T_l - 200) A_c k/x \]

and solved for \( T_l \).
The inner and outer surfaces of the insulation through which the target tube passes were assumed to be 4930°F (5390°R) and 200°F respectively. It was therefore estimated that the heat exchange between the target tube and insulation will be minimal and could be neglected considering the preliminary nature of this analysis.

Assuming effective emissivities of .95 and .85, the target temperature errors \( (T_F - T_T) \) were estimated to be 170 and 185°F respectively using the above expression.

CONCLUSIONS:

The above analysis was based on an assumed maximum obtainable furnace temperature of 2720°C and was not intended to determine the steady-state furnace temperature. The transient analysis was conducted to determine the temperature lag of the load surface compared with the susceptor, and to determine if this lag could significantly influence susceptor temperature.

It was speculated that because of the lower surface-to-mass ratio of the "candle sticks" compared to the prototype skirt extension, a load temperature lag and therefore an effect of load on the susceptor temperature might be introduced; this analysis shows that such is not the case. As the load and the susceptor are at essentially the same temperature above 2800°F (1538°C) there should be no error introduced from this source, and the use of candle sticks in place of the prototype skirt extension should have minimal effect on the furnace performance.

The energy radiated from the inner surface area of the target tube will exit through the open end to the 200°F sink or strike the inner surface of the tube. That radiant energy striking the inner surface will either be reflected, re-radiated or conducted to the 200°F sink. Therefore, for the purpose of radiation calculations, the approximation was made that the tube appears as a disk having the I.D. of the tube, and located at the outer end of the tube.

This phenomenon results in the "equivalent" disk having an effective emissivity approaching unity (fairly independent of the tube length or material emissivity). However, if the diameter of the tube is increased, the ratio of emitting target area to the area of the tube receiving radiation from the furnace

will be increased, resulting in a greater target temperature error.

The analysis on the target tube indicates that the target, due to heat losses through stem conduction and thermal radiation, is approximately 175°F lower than the load and susceptor temperature. It is recommended that a more accurate thermal analysis of the target be conducted to allow for a correction in the measurement or that a more accurate method of temperature measurement be devised.

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APPENDIX E

TEMPERATURE CORRECTION

FOR

EMISSIVITY AND ABSORPTION OF QUARTZ GLASS