OSU
Oregon State
UNIVERSITY

INFORMAL REQUEST FOR PROPOSAL
No. JF165592IP

DATA ACQUISITION SOFTWARE DEVELOPMENT

PROPOSAL DUE DATE AND TIME:

August 6, 2013 (3:00 PM, PT)

OSU Procurement and Contract Services Offices are open from 8:00 am – 12:00 noon and 1:00 pm – 5:00 pm.
Offices are closed during the 12:00 noon – 1:00 pm lunch hour.

SUBMITTAL LOCATION:

Oregon State University
Procurement and Contract Services
644 SW 13th Avenue
Corvallis, Oregon 97333

1.0 GENERAL

1.01 SCHEDULE OF EVENTS

- Issue Date........July 19, 2013
- Pre-Proposal Conference........July 24, 2013 (11:00 am, PT)
- Deadline for Requests for Clarification or Change........July 26, 2013 (4:00 pm, PT)
- Proposal Due Date and Time........August 6, 2013 (3:00 pm, PT)

This Schedule of Events is subject to change. Any changes will be made through the issuance of Written Addenda.

1.02 PRE-PROPOSAL CONFERENCE

A voluntary Pre-Proposal Conference will be held on Wednesday, July 24, 2013, 11:00 am PST at the Radiation Center located at 3451 SW Jefferson Way, Corvallis, Oregon. If you are unable to attend in person but wish to call in, a teleconference number will be available. Please contact the Administrative Contact list in section 1.04 below for the teleconference number.

1.03 ISSUING OFFICE

The Procurement and Contract Services (PaCS) department of Oregon State University (OSU) is the issuing office and is the sole point of contact for this Request for Proposal. Address all concerns or questions regarding this solicitation to the Administrative Contact identified below.

1.04 ADMINISTRATIVE CONTACT

	ADMINISTRATIVE CONTACT	ALTERNATE CONTACT
Name:	James Figgins	Shannon Fanourakis
Title:	Purchasing Analyst III	Purchasing Analyst III
Telephone:	541-737-6995	541-737-3572
Fax:	541-737-2170	541-737-2170
E-Mail:	james.figgins@oregonstate.edu	Shannon.fanourakis@oregonstate.edu

1.05 DEFINITIONS

As used in this solicitation, the terms set forth below are defined as follows:

a. "Addenda" means an addition to, deletion from, a material change in, or general interest explanation of the Request for Proposal.
b. "Exhibits" means those documents which are attached to and incorporated as part of the Request for Proposal.
c. "Proposal" means an offer, binding on the Proposer and submitted in response to the Request for Proposal.
d. "Proposer" means an entity that submits a Proposal in response to the Request for Proposal.
e. "Proposal Due Date and Time" means the date and time specified in the Request for Proposal as the deadline for submitting Proposals.
f. "Request for Proposal" (RFP) means the document issued to obtain Written, competitive Proposals to be used as a basis for making an acquisition or entering into a Contract when price will not necessarily be the predominant award criteria.
g. "Responsible" means an entity that demonstrates their ability to perform satisfactorily under a Contract by meeting the applicable standards of responsibility outlined in OAR 580-061-0130.
h. "Responsive" means a Proposal that has substantially complied in all material respects with the criteria outlined in the Request for Proposal.
i. "Written or Writing" means letters, characters, and symbols inscribed on paper by hand, print, type, or other method of impression intended to represent or convey particular ideas or meanings.

2.0 INTRODUCTION AND BACKGROUND

2.01 INTRODUCTION

Procurement and Contract Services is seeking Responsive Responsible Proposers to submit Proposals for writing and providing Data Acquisition and Control Software for the High Temperature Test Facility (HTTF) located at the Radiation Center at Oregon State University.

2.02 BACKGROUND

The Department of Nuclear Engineering and Radiation Health Physics at Oregon State University (OSU) has a new integral test facility called the High Temperature Test Facility (HTTF), which is a test facility that uses helium gas for the primary coolant. To control, monitor, and log data from the HTTF, control logic must be written in the program LabVIEW and installed on-site at the Radiation Center. A complete set of documentation shall be provided by the vendor to allow the customer to operate and troubleshoot the delivered software package.

2.03 OREGON STATE UNIVERSITY

Founded in 1868, Oregon State University is a comprehensive, research-extensive, public university located in Corvallis. OSU is a member of the Oregon University System and one of only two American universities to hold the Land Grant, Sea Grant, Space Grant and Sun Grant designations. OSU is also the only Oregon institution to hold the Carnegie Foundation's top ranking for research universities, a recognition of the depth and quality of OSU's graduate education and research programs.

Through its centers, institutes, Extension offices and Experiment Stations, OSU has a presence in almost every one of Oregon's 36 counties, including its main campus in Corvallis, the Hatfield Marine Sciences Center in Newport and OSU-Cascades Campus in Bend. OSU offers undergraduate, masters and doctoral degrees through 12 academic colleges enrolling more than 25,000 students from every county in Oregon, every state in the country and more than 90 nations.

3.0 STATEMENT OF WORK

3.01 SAMPLE CONTRACT

A sample contract containing a statement of work and contractual terms and conditions is included at Exhibit A.

4.0 PROPOSER QUALIFICATIONS

4.01 MINIMUM QUALIFICATIONS

In order to qualify as a Responsive Proposer, the Proposer needs to meet the minimum qualifications below. After verification that the minimum qualifications have been met, OSU will award points based on the level of the Proposer's qualifications.

a.) Must have a minimum 5 year work experience using the software LabVIEW and its modules.
b.) Must be able to meet on-site at the Radiation Center on a monthly basis including an initial kick-off meeting and close-out meeting. Key Personnel must be identified.

4.02 PREFERRED QUALIFICATIONS

OSU will award additional points for Proposers able to meet the preferred qualifications below.

a.) Have 8 years work experience or more using the software LabVIEW and its modules.
b.) Previous work experience developing control and data acquisition software for test facilities or comparable projects of this scope.
c.) Familiarity with NQA-1 quality control standards.
d.) Has previous experience working as a test or design engineer.
e.) Proposer is a partner in the National Instruments Alliance..
f.) Has experience working with National Instruments hardware.

5.0 REQUIRED SUBMITTALS AND EVALUATION

5.01 REQUIRED SUBMITTALS

Proposers should submit the following information:

- Description of how the Proposer will meet the requirements laid out in the specifications listed at Exhibit A, Attachment B. At a minimum the Proposer should provide:
  - Implementation Plan, estimated schedule to completion
- Description of how the Proposer meets the minimum qualifications listed in section 4.01. At a minimum the Proposer should provide:
  - Documentation on previous projects showing a minimum of five (5) year experience using LabVIEW software.
  - List of Key Personnel which includes contact information.
  - Location of support/key personnel.
- Detailed information about how the Proposer meets the preferred qualifications detailed in section 4.02 At a minimum to Proposer should provide:
  - Company history showing a minimum of eight (8) years' experience with LabVIEW software.
  - Documentation on previous projects, over the last eight (8) years, performed on control and data acquisition software. Projects should be comparable to this scope of work.
  - Documentation showing experience with National Instruments hardware.
  - Statement stating a clear understanding of NQA-1 quality control standards.
- Complete and itemized pricing of the goods or services requested. A not-to-exceed (NTE) total cost is required. Pricing should show:
  - Software
  - Training
  - Documentation

  NTE Total

  Pricing must be inclusive of all expenses incurred to support time on site until final acceptance by OSU.
- Exhibit B: Certifications fully completed.
- Exhibit C: References fully completed.

5.02 EVALUATION

This is a multistage evaluation. OSU will first review all Proposals to determine Responsiveness. Proposals that do not comply with the instructions or are incomplete may be deemed non-Responsive. Proposer's deemed non-Responsive will be notified in Writing, identifying the reason(s) the Proposal is non-Responsive. The evaluation committee will then perform first stage evaluations on the Written Proposals based on the following evaluation criteria. Points will be given in each criteria and a total score will be determined. The maximum points available for each criterion are identified below.

Evaluation Criteria	Points
Proposal relative to the required Specifications, Section 3.01, Attachment B	15
Proposer's qualifications relative to the minimum qualifications, Section 4.01	20
Proposer's qualifications relative to the preferred qualifications, Section 4.02	30
References	15
Price of the goods or services	20
Total	**100**

OSU may award after the first stage evaluation to the highest ranked Proposer without moving on to the second stage evaluation. If OSU decides to move to a second stage evaluation, the highest ranked Proposers from the first stage evaluation will move to the second stage evaluation. Proposers who are included in the second stage evaluation may be requested to provide additional information about their Proposal through interviews, presentations, requests for best and final Proposals or other methods relevant to the goods or services, in order for the evaluation committee to make a final determination. Points awarded in the first stage evaluation may be carried to the second stage evaluation. Contract will be awarded to the Proposer who in OSU's opinion, best meets the requirements and qualifications of the IRFP and OSU's needs.

5.03 INVESTIGATION OF REFERENCES

OSU reserves the right to investigate and to consider the references and the past performance of any Proposer with respect to such things as its performance or provision of similar goods or services, compliance with specifications and contractual obligations, and its lawful payment of suppliers, subcontractors, and workers. OSU further reserves the right to consider past performance, historical information and facts, whether gained from the Proposal, Proposer interviews, references, OSU or any other source in the evaluation process. OSU may postpone the award or execution of the Contract after the announcement of the notice of intent to award in order to complete its investigation.

6.0 INSTRUCTIONS TO PROPOSERS

6.01 APPLICABLE STATUTES AND RULES

This RFP is subject to the applicable provisions and requirements of the Oregon Revised Statutes, Oregon Administrative Rules, and OSU Policies and Procedures.

6.02 REQUESTS FOR CLARIFICATION OR CHANGE

Requests for clarification or change of the Informal Request for Proposal must be in Writing and submitted to PaCS at least two (2) days before the Proposal Due Date and Time, unless specified otherwise herein. Such requests for clarification or change must include the reason for the Proposer's request. OSU will consider all timely requests and, if acceptable to OSU, amend the Informal Request for Proposal by issuing an Addendum. Envelopes, e-mails or faxes containing requests should be clearly marked as a Request for Clarification or Change and include the RFP Number and Title.

6.03 ADDENDA

Only documents issued as Written Addenda by PaCS serve to change the RFP in any way. No other direction received by the Proposer, written or verbal, serves to change the RFP document. If you have received an Informal Request for Proposal you should consult PaCS, prior to Proposal submittal, to assure that you have not missed any Addenda. Proposers are not required to return Addenda with their Proposal. However, Proposers are responsible for obtaining and incorporating any changes made by Addendum into their final Proposal. Failure to do so may, in effect, make the Proposal non-Responsive, which may cause the Proposal to be rejected.

6.04 PREPARATION AND SIGNATURE

Proposals should be Written and signed in ink by an authorized representative with authority to bind the Proposer. Signature certifies that the Proposer has read, fully understands, and agrees to be bound by the RFP and all Exhibits and Addenda to the RFP.

6.05 PUBLIC RECORD

Upon completion of the Request for Proposal process, information in your Proposal will become subject records under the Oregon Public Records Law. Only those items considered a "trade secret" under ORS 192.50 (2), may be exempt from disclosure. If a Proposal contains what the Proposer considers a "trade secret" the proposer must mark each sheet of information as such. Only bona fide trade secrets may be exempt and only if public interest does not require disclosure.

6.06 SUBMISSION

Proposals must be submitted no later than the Proposal Due Date and Time. Envelopes, faxes, or e-mails containing Proposals should contain the RFP No., RFP Title and the Proposal Due Date and Time. Proposals may be mailed to Oregon State University, Procurement and Contract Services, 644 SW 13th Street, Corvallis, OR 97333-4238, faxed to (541) 737-2170 or e-mailed in PDF format to the individual identified on the first page of this RFP.

6.07 PROPOSALS ARE OFFERS

The Proposal is the Proposer's offer to enter into a Contract pursuant to the terms and conditions specified in the RFP, its Exhibits, and Addenda. The offer is binding on the Proposer for one hundred twenty (120) days, unless otherwise specified herein. OSU's award of the Contract constitutes acceptance of the offer and binds the Proposer.

6.08 RIGHT TO REJECT

OSU may reject, in whole or in part, any Proposal not in compliance with the RFP, Exhibits, and Addenda. OSU may reject all Proposals if it is in the best interest of OSU to do so.

6.09 PROPOSAL PREPARATION COSTS

OSU is not liable for costs incurred by the Proposer during the RFP process.

6.10 AWARDS

OSU reserves the right to make award(s) by individual item, group of items, all or none, or any combination thereof; on a geographical basis and/or on a statewide basis with one (1) or more suppliers. OSU reserves the right to delete any item from the contract when deemed to be in the best interest of OSU.

EXHIBIT A
SAMPLE CONTRACT

OREGON STATE UNIVERSITY
PERSONAL/PROFESSIONAL SERVICES CONTRACT (PPSC)

Department Contract #

This Contract is entered into by and between the State of Oregon acting by and through its Board of Higher Education on behalf of Oregon State University (OSU/Institution) for its (Department) and (Contractor).

Whereas OSU has need of the services which Contractor is competent to provide; now therefore, in consideration of the sum not to exceed $ to be paid at the rate of $ /hour to Contractor by OSU, Contractor agrees to perform between date of last signature and **,** inclusive, the following personal and/or professional services:

Contractor shall not begin work until the Contract is signed by all parties listed below. Unless otherwise specified herein, OSU shall pay only for work performed. Contractor shall submit detailed invoice(s) for work performed to Department for payment. Invoices are paid according the OSU's standard payment terms which are Net 30 days from receipt of correct invoice.

The following attachments are incorporated by this reference and made a part of this contract: Attachment A, OUS Standard Contract Provisions inclusive of Supplemental Special Federal Terms, and ☒ Attachment B; Specifications ☒ Attachment C; Key Personnel

☐ Other Attachments _____, _____, _____.

INSURANCE: the minimum limit is $ Type required: ☐ CGL ☐ AUTO ☐ Professional

THIS CONTRACT SHALL BECOME EFFECTIVE AND BINDING UPON LAST SIGNATURE BY AUTHORIZED REPRESENTATIVES OF THE PARTIES AS PROVIDED HEREIN.

OSU

OSU Department Head Date
(Typed Name):

OSU Contract Officer Date

Department of Justice Date
(Only for contracts over $100,000)

CONTRACTOR

Signature Date
Typed Name:
Address:

Phone:

Banner Vendor ID No.:
U.S. Tax Identification No.:
Contractor is a: (Check One)
☐ Resident U.S. citizen
☐ Resident non-U.S. citizen (Green Card Holder)
☐ Non-U.S. citizen
☐ Partnership
☐ Corporation
☐ Contractor is also a minority group member

OSU VENDOR NO.	FORM PREPARED BY	PREPARER'S ADDRESS	DATE

INDEX CODE	ACCOUNT CODE	ACTIVITY CODE	PAYMENT AMOUNT

Place Bar Code Label Here	All payments and reimbursements made on this contract will be 1099-misc. reportable. *Rev 11-/09*

ATTACHMENT A
DEPARTMENT OF HIGHER EDUCATION STANDARD PERSONAL/PROFESSIONAL SERVICES CONTRACT PROVISIONS

ACCESS TO RECORDS. Contractor shall maintain books, records, documents, and other evidence and accounting procedures and practices sufficient to reflect properly all costs of whatever nature claimed to have been incurred and anticipated to be incurred in the performance of this Contract. The Oregon Board of Higher Education, Oregon Secretary of State, Federal Government, and their duly authorized representatives shall have access to the books, documents, papers, and records of Contractor which are directly pertinent to this Contract for the purpose of making audit, examination, excerpts, and transcripts. Such books and records shall be maintained by Contractor for three years from the date of contract expiration unless a shorter period is authorized in writing. Contractor is responsible for any audit discrepancies involving deviation from the terms of this Contract and for any commitments or expenditures in excess of amounts authorized by Institution.

ASSIGNMENT. Contractor shall not assign or transfer its interest nor delegate its obligation in this Contract without the express written consent of the Institution.

AVAILABILITY OF FUNDS. Institution certifies that sufficient funds are available and authorized for expenditure to finance costs of this Contract within its current biennial appropriation or expenditure limitation, provided, however, that continuation of the Contract, or any extension, after the end of the fiscal period in which it is written, is contingent upon a new appropriation or limitation for each succeeding fiscal period for the purpose of this Contract.

CAPTIONS. The captions or headings in this Contract are for convenience only and in no way define, limit, or describe the scope or intent of any provisions of this Contract.

COMPLIANCE WITH APPLICABLE LAW. Contractor agrees to comply with all federal, state, county, and local laws, ordinances, and regulations applicable to the work to be done under this Contract. Contractor specifically agrees to comply with all applicable requirements of federal and state civil rights and rehabilitation statutes, rules, and regulations. Contractor also shall comply with the Americans with Disabilities Act of 1990 (Pub L No. 101-336), ORS 659.425, and all regulations and administrative rules established pursuant to those laws. Failure or neglect on the part of Contractor to comply with any or all such laws, ordinances, rules, and regulations shall not relieve Contractor of these obligations nor of the requirements of this Contract. Contractor further agrees to make payments promptly when due, to all persons supplying to such Contractor, labor or materials for the prosecution of the work provided in this Contract; pay all contributions or amounts due the Industrial Accident Fund from such contractor incurred in the performance of this Contract; not permit any lien or claim to be filed or prosecuted against the state on account of any labor or material furnished; pay to the Department of Revenue all sums withheld from employees pursuant to ORS 316.167. If Contractor fails or refuses to make any such payments required herein, the appropriate Institution official may pay such claim to such payment. Any payment of a claim in the manner authorized in this section shall not relieve the Contractor or Contractor's surety from obligation with respect to any unpaid claims.

CONFLICT OF INTEREST. Contractor covenants that it presently has no interest and shall not acquire any interest, direct or indirect, which would conflict in any manner or degree with the performance of its services hereunder. Contractor further covenants that in the performance of this Contract no person having any such interest shall be employed.

DUAL PAYMENT. Contractor shall not be compensated for work performed under this Contract from any other entity of the State of Oregon.

EXECUTION AND COUNTERPARTS. This Contract may be executed in several counterparts, each of which shall be an original, all of which shall constitute but one and the same instrument.

GOVERNING LAW. This Contract shall be governed and construed in accordance with the laws of the State of Oregon. Any claim, action, or suit between Institution and Contractor that arises out of or relates to performance of this Contract shall be brought and conducted solely and exclusively within the Circuit Court for Benton County, for the State of Oregon. Provided, however, that if any such claim, action, or suit may be brought only in a federal forum, it shall be brought and conducted solely and exclusively within the United States District Court for the District of Oregon.

HAZARD COMMUNICATION. Contractor shall notify Institution prior to using products containing hazardous chemicals to which Institution employees may be exposed. Products containing hazardous chemicals are those products defined by Oregon Administrative Rules, Chapter 437. Upon Institution's request, Contractor shall immediately provide Material Safety Data Sheets, as required by OAR 437-155-025, for the products subject to this provision.

INDEMNITY, RESPONSIBILITY FOR DAMAGES. Contractor shall be responsible for all damage to property, injury to persons, and loss, expense, inconvenience, and delay which may be caused by, or result from, the conduct of work under this contract, or from any act, omission, or neglect of contractor, its subcontractors, or employees. Contractor shall save, defend, indemnify, and hold harmless the State of Oregon, the State Institution of Higher Education, the Institution, and their officers, agents, employees, and members from all claims, suits, and actions of any nature resulting from or arising out of the activities or omissions of Contractor or its subcontractors, officers, agents, or employees acting under this contract.

INDEPENDENT CONTRACTOR STATUS. The service(s) to be rendered under this Contract are those of an independent contractor. Contractor is not to be considered an agent or employee of Institution for any purpose, and neither Contractor nor any of Contractor's agents or employees are entitled to any of the benefits that Institution provides for its employees. Contractor will be solely and entirely responsible for its acts and for the acts of its agents or employees during the performance of this Contract. If Contractor is providing personal services as an **individual**, (a) Contractor: (1) Is engaged as an independent contractor and will be responsible for any Federal or State taxes applicable to this payment; (2) Will not be eligible for any Federal Social Security, State Workers' Compensation, unemployment insurance, or Public Employees Retirement System benefits from this Contract payment; (3) Is not an officer, employee, or agent of the State as these terms are used in ORS 30.265 and will not be under the direction and control of Institution; (4) Is not currently employed by the Federal Government and the amount charged does not exceed his normal charge for the type of service provided if payment is to be charged against Federal funds; (5) Is not a member of the Oregon Public Employees Retirement System; or (6) if a contributing member of the Oregon Public Employees Retirement System for which contributions to the retirement system must be withheld, Contractor's contribution to the retirement system will be withheld and a corresponding Institution contribution made; and (7) Must furnish Form IRS Form 8233 in duplicate with this Contract if Contractor is a non-resident alien and claims exemption from Federal Withholding tax. (b) The Oregon State Board of Higher Education, acting on behalf of Institution, will report the total amount of all payments to Contractor, including any expenses, in accordance with Federal Internal Revenue Service and State of Oregon Department of Revenue regulations.

INSURANCE. Contractor shall secure at its own expense and keep in effect during the term of this Contract general liability insurance. Insurance policies, which cannot be excess to a self-insurance program, are to be issued by an insurance company authorized to do business in the State of Oregon. The State of Oregon, acting by and through the State Board of Higher Education on behalf of the Institution and their officers and employees shall be included as an additional insured in said insurance policy. If any of the liability insurance is arranged on a "claims made" basis, "tail" coverage will be required at the completion of this Contract for a duration of 24 months.

NOTICES AND REPRESENTATIVES. All notices, certificates, or communications shall be delivered or mailed postage prepaid to the parties at their respective places of business as identified in the signature block of this Contract, unless otherwise designated in writing. Copies of such correspondence shall also be sent to all other Contract signatories.

OVERDUE PAYMENTS. Any charges claimed by the Contractor for payment of an overdue amount shall be in accordance with the provisions of ORS 293.462.

OWNERSHIP OF WORK PRODUCT. All work products or any form of property originated or prepared by Contractor which result from this Contract are the exclusive property of Institution.

SEVERABILITY. If any term or provision of this Contract is declared by a court of competent jurisdiction to be illegal or in conflict with any law, the validity of the remaining terms and provisions shall not be affected, and the rights and obligations of the parties shall be construed and enforced as if the Contract did not contain the particular term or provision held to be invalid.

SUBCONTRACTS AND ASSIGNMENTS. Contractor shall not enter into any subcontracts for any of the work scheduled under this Contract, or assign or transfer any of its interest in this Contract, without obtaining prior written approval from the Institution.

SUCCESSORS IN INTEREST. The provisions of this Contract shall be binding upon and shall inure to the benefit of the parties hereto, and their respective successors and assigns.

TAX COMPLIANCE CERTIFICATION. Contractor hereby certifies, under penalty of perjury, as provided in ORS 305.385(1), that to the best of Contractor's knowledge Contractor is not in violation of any Oregon tax laws named in ORS 305.380(4), including without limitation the state inheritance tax, gift tax, personal income tax, corporation income and excise taxes, amusement device tax, timber taxes, cigarette tax, other tobacco tax, 9-1-1 emergency communications tax, the homeowners and renters property tax relief program and local taxes administered by the Department of Revenue, including the Multnomah County Business Income Tax, Lane Transit District Tax, Tri-Metropolitan Transit District Employer Payroll Tax, and the Tri-Metropolitan District Self-Employment Tax.

TERMINATIONS. This Contract may be terminated at any time by mutual consent of both parties, or by either party upon thirty (30) days' notice in writing and delivered by certified mail or in person to the other party. In addition, the Institution may terminate this Contract effective upon delivery of written notice to Contractor, or at such later date as may be established by the Institution, if (a) Federal or state regulations or guidelines are modified, changed, or interpreted in such a way that the services are no longer allowable or appropriate for purchase under this Contract; or (b) Any license or certificate required by law or regulation to be held by the Contractor to provide the services required by this Contract is for any reason denied, revoked, or not renewed. This Contract may also be terminated by Institution for default (including breach of contract) if (a) Contractor fails to provide services or materials called for by this Contract within the time specified; or (b) Contractor fails to perform any of the other provisions of this Contract, or so fails to pursue the work as to endanger performance of this Contract in accordance with its terms, and after receipt of written notice from Institution, fails to correct such failures within ten days. The rights and remedies of Institution provided in the above clause related to defaults (including breach of contract) by Contractor shall not be exclusive and are in addition to any other rights and remedies provided by law or under this Contract.

TERMINATION DUE TO NONAPPROPRIATION OF FUNDS. If sufficient funds are not provided in future legislatively approved budgets of Institution (or from applicable Federal, state, or other sources) to permit Institution in the exercise of its reasonable administrative discretion to continue this Contract, or if Institution or program for which this Contract was executed is abolished, the Institution may terminate this Contract without further liability by giving Contractor not less than thirty (30) days notice. In determining the availability of funds from the Oregon Legislature for this Contract, Institution may use the budget adopted for it by the Joint Ways and Means Committee of the Oregon Legislative Assembly.

FOREIGN CONTRACTOR. If Contractor is not domiciled in or registered to do business in the State of Oregon, Contractor shall promptly provide to the Oregon Department of Revenue and the Secretary of State, Corporation Division, all information required by those agencies relative to this Contract. Contractor shall demonstrate its legal capacity to perform these services in the State of Oregon prior to entering into this Contract.

FORCE MAJEURE. Neither Institution nor Contractor shall be held responsible for delay or default caused by fire, riot, acts of God, or war where such cause was beyond, respectively, Institution's or Contractor's reasonable control. Contractor shall, however, make all reasonable efforts to remove or eliminate such a cause of delay or default and shall, upon the cessation of the cause, diligently pursue performance of its obligations under this Contract.

WAIVER. The failure of Institution to enforce any provision of this Contract shall not constitute a waiver by Institution of that or any other provision.

APPROVALS. In some instances, another state agency may be required to approve this Contract before any work may commence under this Contract.

RECYCLING. In the performance of this Contract the Contractor shall use, to the maximum extent economically feasible, recycled paper.

WORKERS' COMPENSATION. All employers, including Contractor, that employ subject workers who work under this Contract in the State of Oregon shall comply with ORS 656.017 and provide the required workers' compensation coverage, unless such employers are exempt under ORS 656.126. Contractor shall ensure that each of its subcontractors complies with these requirements.

MERGER. THIS CONTRACT CONSTITUTES THE ENTIRE AGREEMENT BETWEEN THE PARTIES. THERE ARE NO UNDERSTANDINGS, AGREEMENTS, OR REPRESENTATIONS, ORAL OR WRITTEN, NOT SPECIFIED HEREIN REGARDING THIS CONTRACT. NO AMENDMENT, CONSENT, OR WAIVER OF TERMS OF THIS CONTRACT SHALL BIND EITHER PARTY UNLESS IN WRITING AND SIGNED BY ALL PARTIES. ANY SUCH AMENDMENT, CONSENT, OR WAIVER SHALL BE EFFECTIVE ONLY IN THE SPECIFIC INSTANCE AND FOR THE SPECIFIC PURPOSE GIVEN. CONTRACTOR, BY THE SIGNATURE HERETO OF ITS AUTHORIZED REPRESENTATIVE, ACKNOWLEDGES HAVING READ AND UNDERSTOOD THE CONTRACT AND CONTRACTOR AGREES TO BE BOUND BY ITS TERMS AND CONDITIONS.

OREGON STATE UNIVERSITY
REQUEST FOR QUOTE (RFQ)

SUPPLEMENT TO ATTACHMENT A
TERMS AND CONDITIONS

1. *Equal Employment Opportunity*—All contracts shall contain a provision requiring compliance with E.O. 11246, "Equal Employment Opportunity" (30 FR 12319, 12935, 3 CFR, 1964-1965 Comp., p. 339), as amended by E.O. 11375, "Amending Executive Order 11246 Relating to Equal Employment Opportunity," and as supplemented by regulations at 41 CFR part 60, "Office of Federal Contract Compliance Programs, Equal Employment Opportunity, Department of Labor."

2. *Copeland "Anti-Kickback" Act (18 U.S.C. 874 and 40 U.S.C. 276c)*—All contracts and subgrants in excess of $2000 for construction or repair awarded by recipients and subrecipients shall include a provision for compliance with the Copeland "Anti-Kickback" Act (18 U.S.C. 874), as supplemented by Department of Labor regulations (29 CFR part 3, "Contractors and Subcontractors on Public Building or Public Work Financed in Whole or in Part by Loans or Grants from the United States"). The Act provides that each contractor or subrecipient shall be prohibited from inducing, by any means, any person employed in the construction, completion, or repair of public work, to give up any part of the compensation to which he is otherwise entitled. The recipient shall report all suspected or reported violations to the Federal awarding agency.

3. *Rights to Inventions Made Under a Contract or Agreement*—Contracts or agreements for the performance of experimental, developmental, or research work shall provide for the rights of the Federal Government and the recipient in any resulting invention in accordance with 37 CFR part 401, "Rights to Inventions Made by Nonprofit Organizations and Small Business Firms Under Government Grants, Contracts and Cooperative Agreements," and any implementing regulations issued by the awarding agency.

4. *Clean Air Act (42 U.S.C. 7401 et seq.) and the Federal Water Pollution Control Act (33 U.S.C. 1251 et seq.), as amended*—Contracts and subgrants of amounts in excess of $100,000 shall contain a provision that requires the recipient to agree to comply with all applicable standards, orders or regulations issued pursuant to the Clean Air Act (42 U.S.C. 7401 *et seq.*) and the Federal Water Pollution Control Act as amended (33 U.S.C. 1251 *et seq.*). Violations shall be reported to the Federal awarding agency and the Regional Office of the Environmental Protection Agency (EPA).

5. Debarment and Suspension (E.O.s 12549 and 12689)—A contract award with an amount expected to equal or exceed $25,000 and certain other contract awards (see 2 CFR 180.220) shall not be made to parties listed on the government-wide Excluded Parties List System, in accordance with the OMB guidelines at 2 CFR part 180 that implement E.O.s 12549 (3 CFR, 1986 Comp., p. 189) and 12689 (3 CFR, 1989 Comp., p. 235), "Debarment and Suspension." The Excluded Parties List System contains the names of parties debarred, suspended, or otherwise excluded by agencies, as well as parties declared ineligible under statutory or regulatory authority other than E.O. 12549.

ATTACHMENT B

FACILITY SOFTWARE – CONTROL, MONITOR, AND DATA ACQUISITION

OSU-HTTF-SPEC

Department of Nuclear Engineering and Radiation Health Physics

Oregon State University

116 Radiation Center

Corvallis, OR 97331-5902

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Software Requirements for HTTF

1 Scope

This specification document details the software requirements needed for controlling, monitoring, and logging of the High Temperature Test Facility (HTTF). Presented herein are all the requirements to which the software vendor must adhere upon reception of this contract. Vendors shall develop and install a software package in LabVIEW 2012® that will allow for the control, monitoring, and logging of all the instrumentation channels in the HTTF. LabVIEW 2012® is the version already installed on the HTTF's host computer. A complete set of documentation shall be provided by the vendor to allow the customer to operate and troubleshoot the delivered software package based on the requirements described in this document. Additionally, the developer must be available to meet on-site to demonstrate and train how the program is used and designed.

2 General

(A) Purpose – The purpose of the software package is to control, monitor, and log data in the HTTF.

(B) Location – The software will be operated from a desktop work station located in the Advanced Nuclear Systems Engineering Laboratory (ANSEL) building of the Radiation Center at Oregon State University, Corvallis, Oregon, at an elevation of 235 feet above sea level.

3 Facility Overview

The High Temperature Test Facility (HTTF) is a one-quarter height scaled test reactor based on the Modular High Temperature Gas-Cooled Reactor (MHTGR). A process and instrument diagram (P&ID) is appended for reference. The HTTF is an integral test facility that uses helium gas for the primary coolant. Helium is driven by a fan into the reactor core. Once heated, the helium flows through and is cooled in a steam generator before once again reaching the fan. Electrical heater rods are used to represent the heat produced by nuclear fuel. During normal operations, the expected coolant temperature at the outlet of the core is about 687 °C. However, during accident scenarios, the facility is expected to reach a maximum of about 1600 °C along the centerline of the core.

The purpose behind the HTTF is to provide NQA-1 (nuclear quality assurance) experimental data for MHTGR system support codes. Data is to be taken for normal operations and simulated accident conditions.

The Data Acquisition and Control System (DACS) of the HTTF is divided between a Data Acquisition System (DAS) and a Programmable Logic Controller system (PLC). On the DAS, there are 431 instruments, equating to a total of 365 thermocouples, 8 pressure sensors, 10 voltage sensors, and 48 gas concentration instruments. Connected to the PLC, there are 31 4-20 mA analog input process instruments, 19 4-20 mA analog output devices, 30 digital output devices, and 26 digital input devices. For a much more detailed description of the instrumentation placed throughout the facility, refer to the attached Instrumentation Plan.

4 LabView User Interface

4.1 Indicators

The HTTF is divided into several different systems, which will require indicators. These systems include:

- Reactor Pressure Vessel (RPV)
- Reactor Cavity Cooling System (RCCS)
- Inlet/Outlet Duct Rakes
- Reactor Cavity Simulation Tank (RCST)

At the least, a separate tab dedicated to the above systems needs to be on the graphical user interface (GUI). A couple of example tabs are appended after the P&ID, showing the generally expected layout for each screen. All instruments in the RCCS, rakes, and RCST need to have an indicator in these tabs. Crucial instruments in the RPV will also need to be displayed, and a list of these crucial instruments is given in Table 5-3.

The RPV is additionally divided into different segments, which are:

- Upper Plenum and head
- Upcomer
- Core region
- Lower Plenum
- Metallic Core Support Structure (MCSS)

The core region instruments are divided between a heavily instrumented Primary Sector and less instrumented Secondary and Tertiary Sectors. This is shown in the following figure.

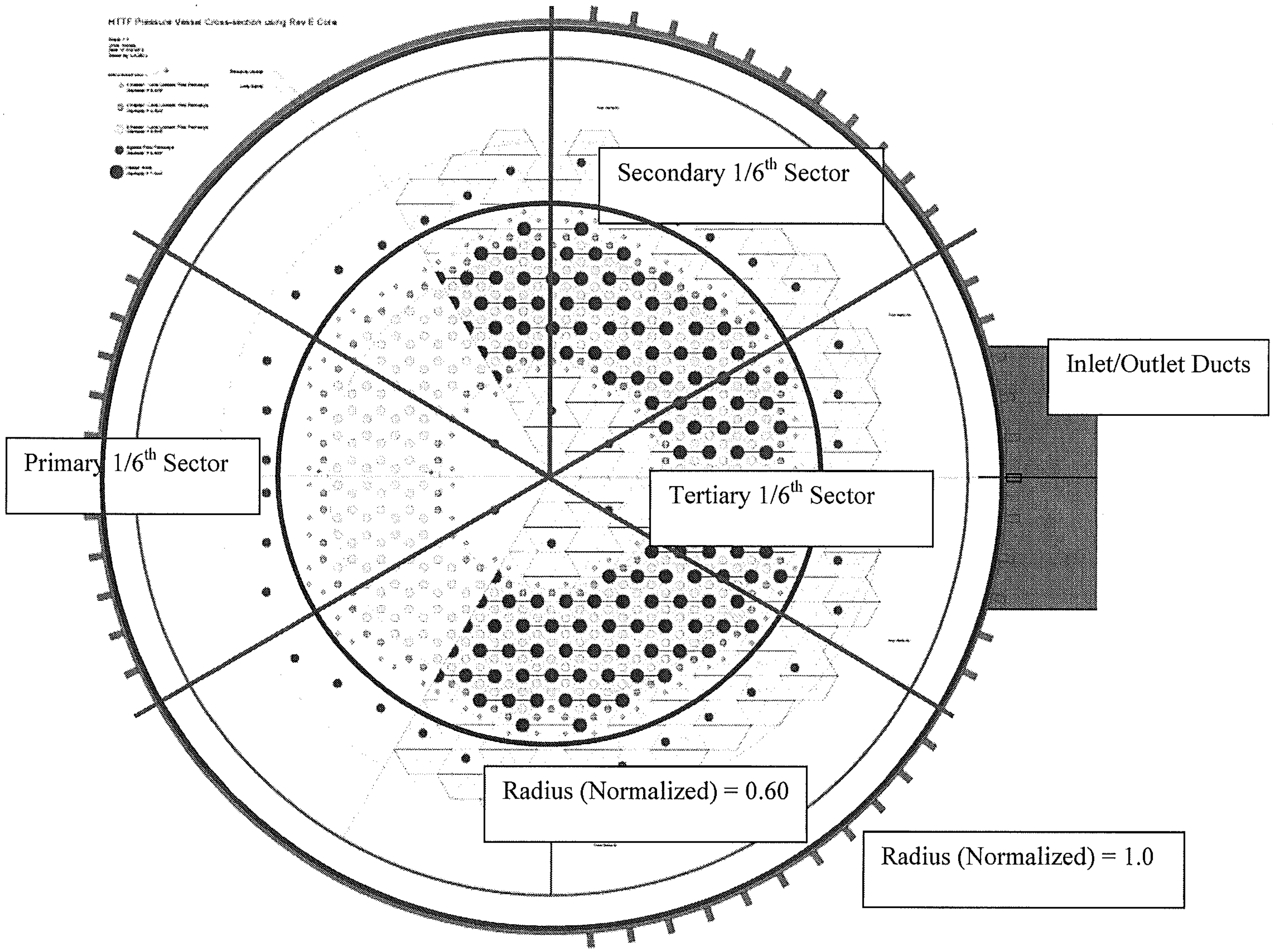


Figure 4-1: HTTF Pressure Vessel Cross Section showing the Instrumented Primary, Secondary, and Tertiary 1/6th Azimuthal Sectors

On the PLC, all process instruments that utilize a 4-20 mA analog input signal need to have an indicator on the graphical user interface (GUI). These PLC instruments are given in the following table and are also shown in the attached P&ID.

Table 4-1: PLC Instruments requiring an Indicator—4-20 mA analog input

Part Number	Instrument Type	Location	Number
Analog Input			
TT-010	Temperature Transmitter	RCCS Storage Tank.	1
TT-801	Temperature Transmitter	RCCS Feed Line	1
TT-100	Temperature Transmitter	Outlet Duct	1
TT-200	Temperature Transmitter	Inlet Duct	1
TT-201	Temperature Transmitter	Circulator Inlet	1
TT-202	Temperature Transmitter	Circulator Outlet	1
TT-532	Temperature Transmitter	RCST Recirculation Outlet	1
TT-602	Temperature Transmitter	Steam Generator Inlet	1
TT-700	Temperature Transmitter	Cooling Water Temperature	1
		TOTAL TTs	**9**
PT-100	Pressure Transmitter	Outlet Duct Pressure	1
PT-200	Pressure Transmitter	Inlet Duct Pressure	1
PT-201	Pressure Transmitter	Circulator Inlet Pressure	1
PT-202	Pressure Transmitter	Circulator Outlet Pressure	1
PT-300	Pressure Transmitter	RCST Recirculation Pressure	1
DPT-500	Differential Pressure Transmitter	RCST Differential	1
PT-601	Pressure Transmitter	Steam Generator Pressure	1
LDP-601	Level Differential Pressure	Steam Generator Level	1
		TOTAL PRESSURE INSTRUMENT	**8**
FT-010	Flow Transmitter	Steam Generator Feed Flow	1
FIT-801	Flow Indicating Transmitter	RCCS Feed Flow Transmitter	1
		TOTAL FITs	**2**
AIT-533	Oxygen Analyzer	RCST Vent	1
AIT-201	Oxygen Analyzer	Primary Loop Oxygen Analyzer	1
		TOTAL ANALYZERS	**2**
KW-101 through KW-110	Power Meter	Heater Rod Bank #1-10	**10**
	TOTAL PROCESS INSTRUMENTATION		**31**

All these aforementioned instruments are crucial for safe operation of the facility.

An "All Data" tab shall also be provided, which tabulates all the instrument measurements in the facility for quick reference. Additionally, there shall be a "Plot" tab that will allow for any instrument to be displayed and plotted on screen.

4.2 Controls

The front panel GUI shall be reminiscent of the attached P&ID. As such, the necessary valves, drives, and relays that need to be controlled on the front panel are included in the following table. These devices utilize a 4-20 mA analog output signal for control

Table 4-2: Necessary Controls on the Front Panel—4-20 mA analog output

Part Number	Instrument Type	Location	Number
Analog Output			
PCV-400	Pressure Control Valve	Primary Circulator Vent Valve	1
PCV-602	Pressure Control Valve	Steam Generator Blowdown	1
LCV-013	Level Control Valve	Steam Generator Level Control Valve	1
FCV-532	Flow Control Valve	RCST Circulation Valve	1
FCV-807	Flow Control Valve	RCCS Pump Outlet	1
		TOTAL VARIABLE POS. VALVES	**5**
VSD-010	Variable Speed Drive	Steam Generator Feed Pump	1
VSD-200	Variable Speed Drive	Primary Side Circulator Pump	1
VSD-501	Variable Speed Drive	RCST Vacuum Pump	1
VSD-801	Variable Speed Drive	RCCS Feed Pump	1
		TOTAL VSD ANALOG CONTROL	**4**
SCR-101 through SCR-110	Silicon Control Rectifiers	Heater Rod Bank #1-10	**10**
	TOTAL mA CURRENT CONTROL		**19**

There are also a list of valves and relays that utilize a digital output signal. These are included in the following table. For the valves listed below, they utilize an air system, shown in the P&ID, to open and close them.

Table 4-3: Necessary Valves and Relays on the Front Panel

Part Number	Instrument Type	Location	Number
Digital Output:			
PCV-010	Solenoid Valve	RCCS Water Tank Pressure	1
PCV-701	Solenoid Valve	Circulator Pressure	1
LCV-010	Solenoid Valve	RCCS Water Tank Level	1
SV-203	Solenoid Valve	Circulator Outlet	1
SV-311	Solenoid Valve	Hot Leg Guillotine Break	1
SV-313	Solenoid Valve	Cold Leg Guillotine Break	1
SV-331	Solenoid Valve	Lower Blowdown Valve	1
SV-332	Solenoid Valve	Blowdown Valve	1
SV-502	Solenoid Valve	Circulator Helium Supply	1
SV-531	Solenoid Valve	Lower RCST Pump Inlet	1
SV-533	Solenoid Valve	RCST Vacuum Pump Vent	1
SV-541	Solenoid Valve	Communication Break Valve	1
SV-551	Solenoid Valve	RCST Gas Supply	1
		TOTAL SOLENOID VALVES	**13**
HOA-010	Hands-Off-Automatic for Variable Speed Drive	Steam Generator Feed Pump	1
HOA-200	Hands-Off-Automatic for Variable Speed Drive	Primary Side Circulator Pump	1
HOA-501	Hands-Off-Automatic for Variable Speed Drive	Vacuum Pump	1
HOA-701	Hands-Off-Automatic	Cooling Water Pump	1
HOA-801	Hands-Off-Automatic for Variable Speed Drive	RCCS Feed Pump	1
		TOTAL HOA	**5**
CR-101 through CR-110	Heater SCR Contactors	Heater Rod Bank #1-10	**10**
ES-002	Emergency Stop		1

ES-003	Emergency Stop		1
		TOTAL EMERGENCY STOP	**2**
	TOTAL DIGITAL OUTPUT SIGNALS		**30**

5 System Operation

The following subsections will detail what happens during startup, normal operations, shutdown, and emergencies.

5.1 Startup Actions

On startup, a login screen needs to appear with the option to access one of three modes: administrative, maintenance, and normal operations. A username/password combination is required to gain access to any of these modes. In this way, only the people who are involved with this project are able to control the facility. At the login screen, the user has the option to enable a recording of the current session, which will allow for future playback, if desired.

The administrative mode allows the user to select who is given access to the control software and also allows for individual password allocation. In administration mode, the user can also define which modes all project members can access. Additionally, the administrative access gives full use of the facility (i.e. all heaters, pumps, valves, etc.) without any alarms or trips engaged.

The maintenance mode turns off the use of heaters and pumps, but it still allows for valve actuation. Users are able to gain access to instrumentation alignment in this mode.

For normal operations mode, full use of the facility is given but with all alarms and trips enabled.

5.2 Runtime Actions

During normal operations, the primary loop consists of a blower that sends helium into the vessel. The gas rises to the upper plenum and goes down through the core. At the core outlet, it mixes in the lower plenum, leaves the vessel, and is cooled in the steam generator before the process is repeated. 10 heater banks controlled by SCRs will regulate the power entering the core. At the controls, the 10 SCRS can be controlled individually (i.e. a different output signal can be sent to each SCR) or uniformly (i.e. they all receive the same signals from the host computer).

There is a pump (P-701) that is feeding cooling water to the primary blower. A switched labeled PSL-701 (pressure-switch-low) measures the pressure behind the pump. If the switch is triggered, control logic is set to trip P-701. Once the cooling water has passed through the blower, two temperature switches (TSH-701a and TSH-701b) measure the temperature of the cooling water. If the temperature gets too high, the switch will trigger, producing an alarm. Alarms will be furthered discussed under Section 5.4.

There is also a water storage tank (labeled T-010 in the P&ID) that provides feed water to two separate pumps. One of these pumps delivers water through the eight panels of the RCCS, which acts as the ultimate heat sink for the facility. The second pump is the main feed pump, which delivers water to the steam generator. There is a switch associated with this storage tank, called LSL-010 (Level-switch-low). When the level in the tank is low, this switch shall automatically toggle LCV-010 (from Table 4-2) to begin filling the tank. The switch is set to trigger whenever the water level goes below 3 inches from the top of the tank.

The three switches in the HTTF are summarized below.

Table 5-1: Digital Input Switches

Part Number	Instrument Type	Location	Number
Digital Input:			
PSL-701	Pressure Switch Low	Circulator Cooling Pressure Low	1
LSL-010.	Level Switch Low	RCCS Water Tank Level Low	1
TSH-701	Temperature Switch High	Circulator High Oil Temperature	1
		TOTAL SWITCHES	**4**

During normal operations, there are also several control loops. An example of a control loop that will require a Proportional-Integral-Differential (PID) controller is for the steam generator. As shown on the P&ID, a level differential pressure instrument (LDP-601) measures the water level in the steam generator. This instrument is tied via the control logic to LCV-013, which is a variable position valve that can change the flow rate of the steam generator feed pump. A PID controller shall be utilized between these two instruments, where LDP-601 is the process variable and LCV-013 is the manipulated variable. A list of loops that will require a PID controller is shown in the following table.

Table 5-2: PID Control Loops

Process Variable	Manipulated Variable	P&ID Label
FT-801	FCV-807	FIC-801
LDP-601	LCV-013	LIC-601
TT-010	LCV-010	TIC-010
TT-532	SV-532	TIC-532
TT-100	SCR-101 through SCR-110	TIC-003
PT-201 and PT-202	VSD-200 and SV-400	PIC-201
TT-201	PCV-602	PIC-602
	TOTAL PID LOOPS	7

There shall also be a tab dedicated to checking for errors. This shall include verifying that the DAQ and PLC chassis and the host computer are communicating properly. An alarm shall trigger if communication between the host computer and the DAQ and PLC chassis is lost. Alarms are given in further detail under Section 5.4.

5.3 Shutdown Actions

During the shutdown process, the software must first check that the facility is in a safe configuration. Otherwise, the user cannot shutdown the software. The safe configuration checks verify that the system pressures are less than 50 psi, system temperatures are less than 200 °F, and the system flow rates are less than 5 gpm. The system must also check that all 10 SCRs and pumps are off.

If any of these checks are not met, the user will be returned to the main control screen. If all checks are satisfied, the software can be shutdown.

5.4 Emergency Stop Actions and Alarms

There are two manually actuated emergency stop buttons located on the facility. An additional emergency stop button must also be on the control screen and accessible at all times.

When any of these three emergency buttons are actuated, the heater rods to the core (i.e. SCRs) need to trip off. Additional alarms and trips, based on the facility's critical instruments, will also be required, and a tentative list of the critical instruments is provided in the Table 5-3.

From these critical instruments, the various alarms can be ascertained, which are listed in Table 5-4. The conditions for which these alarms and trips will trigger can be manually inputted by the user. Whenever an alarm or trip occurs, the border of all screens shall flash red and an alarm tone shall play. In the event of any trips, at the minimum, the SCRs must shut down.

Table 5-3: List of HTTF Critical Instruments

Number	Instrument Type
1	LDP-601
2	PT-601
3	FT-010
4	All core TCs
5	TH-101 through TH-110
6	KW-101 through KW-110
7	PT-202
8	TT-010
9	LSL-010
10	TT-700, TSH-701a, TSH-701b
11	HOA-702
12	PSL-701
13	AIT-202
14	AIT-533
15	FT-801

Table 5-4: List of Required Annunciator

Number	Annunciator Title	Alarm Description	Process Variable for Alarm
1	Steam Generator Water Level	Alarms when steam generator water level is too low or too high	LDP-601
2	Steam Generator Pressure	Alarms when steam generator pressure exceeds operating pressure limits	PT-601
3	Secondary Loop Flow Rate	Alarms when steam generator loop flow rate is greater than the designed flow rate of the steam generator feed pump	FT-010
4	Core Temperature Thermocouples	Alarms when the maximum core thermocouple temperature exceeds operating temperature limits	All core TCs
5	Core Heater Rod Temperatures	Alarms when the maximum heater rod temperature exceeds operating temperature limits	TH-101 through TH-110
6	Core Heater Rod Power	Alarms if maximum heater rod power measurement exceeds heater rod design power	KW-101 through KW-110
7	Blower Outlet Pressure	Alarms if the pressure at the outlet of the blower is too high	PT-202
8	Cooling Water Tank Water Temperature	Alarms if cooling water temperature in cooling tank approaches a state of water saturation	TT-010
9	Cooling Water Tank Water Level	Alarms when the level-switch-low is triggered for the cooling water tank	LSL-010
10	Blower Cooling Water Temperature	Alarms if cooling water temperature is too high	TT-700, TSH-701a, TSH-701b
11	Blower Cooling Water Pump	Alarms if pump providing cooling water to blower shuts off	HOA-702
12	Blower Cooling Water Pump Pressure	Alarms if pressure for the pump providing cooling water to the blower is low	PSL-701
13	Primary Loop Oxygen Concentration	Alarms if primary loop oxygen concentration exceeds facility design limits	AIT-202
14	RCST Fill Loop Oxygen Concentration	Alarms if RCST fill line oxygen concentration exceeds facility design limits	AIT-533
15	RCCS Low Flow Rate	Alarms when RCCS loop flow rate is greater than the designed flow rate of the RCCS feed pump.	FT-801
16	Data Transfer	Alarms when the PLC and/or DAS are unresponsive during data transfer	---

6 Alignment Requirements

All the TCs, GCIs, and process instruments in the facility produce either an analog voltage or current signal. This signal is sent to the modules in the DAS and PLC chassis to be converted to a digital signal, which is read at the host computer. This digital signal is the raw value that the computer then calculates into a practical engineering unit (i.e. Celsius, Pascals, etc.). Engineering values are computed via a linear equation using the raw digital value as the independent variable. The alignment process is performed to determine the slope of the linear equation for each instrument. Since each instrument has a different field range, the slopes will vary between instruments.

All DAS panel instruments and process instruments on the PLC will require alignment. A tab dedicated to instrument alignment shall be in the software.

7 Logging Requirements

Every time a user logs into the software, file folder shall be created in a programmable directory that allows for the storage of files taken during the user's operation of the facility. This folder shall store the following three files types:

i. the *Operations Event Log*;
ii. raw Data Acquisition System (DAS) data; and
iii. all Programmable Logic Controller (PLC) data

Preferentially, the file format of the *Operations Event Log* will be saved and stored as a textual file, and the file formats of the DAS and PLC data will be saved and stored in a csv file format.

The *Operations Event Log* shall immediately begin logging all operations the instant a user has logged in and will stop recording once a session is closed or the user has logged off. The operations event log shall immediately be stored to disk upon termination of a user's session.

For the *Operations Event Log*, the name of the facility operator must be recorded. Additionally, the *Operations Event Log* shall record all the operations performed during any individual user session and be visible from every screen in the graphical user interface (GUI). It shall provide the following three capabilities:

i. All functions and operations performed during a user's login session (i.e. switching tabs or actuating a valve) shall be presented automatically with a description and corresponding time stamp (date and time) in the *Operations Event Log*. These events shall be displayed in black text.

ii. All alarms and errors that occur during a user's login session shall be presented automatically with a description and corresponding time stamp (date and time) in the *Operations Event Log.* These events shall be displayed in red text.

iii. The user shall have the option to manually submit a comment into the log when they double click on open or empty lines of the *operations event log.* A time stamp (with date and time) shall be given for every manually entered user comment. Manual entries shall be displayed in blue text.

The *Operations Event Log* shall have a scroll bar to allow the user to review previous log entries. All events in the *operations event log* shall be fixed and cannot be manipulated in any way. The *operations event log* shall be saved to disk in this form.

The DAS and PLC data files shall begin saving and storing data to disk once a user has logged into the software. These data files shall continuously be written to disk throughout the duration of a user's session and will stop writing when the session has terminated. The software must be able to handle experimental data collection periods between 8-12 hours and have a sampling rate of 1-2 Hz.

Additionally, there shall be a playback feature that allows for review of all the actions performed during a session. The option to record a session shall be available on the Login Screen.

The HTTF control logic should also be flexible enough to allow for possible higher instrumentation channel counts in the future.

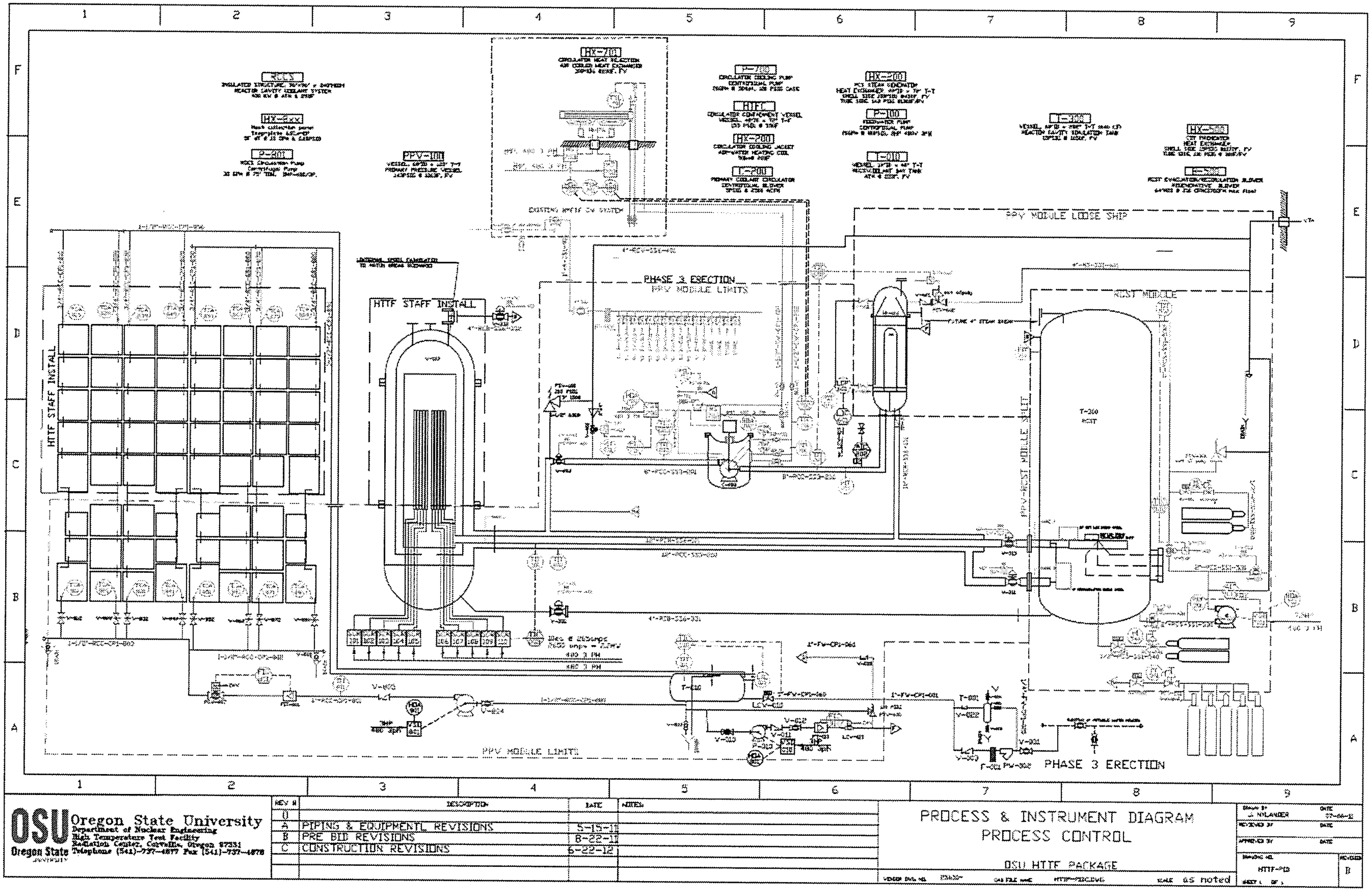
8 List of Appended Documents

Included in the following table is a list of all the appended attachments appropriate to the scope of this document.

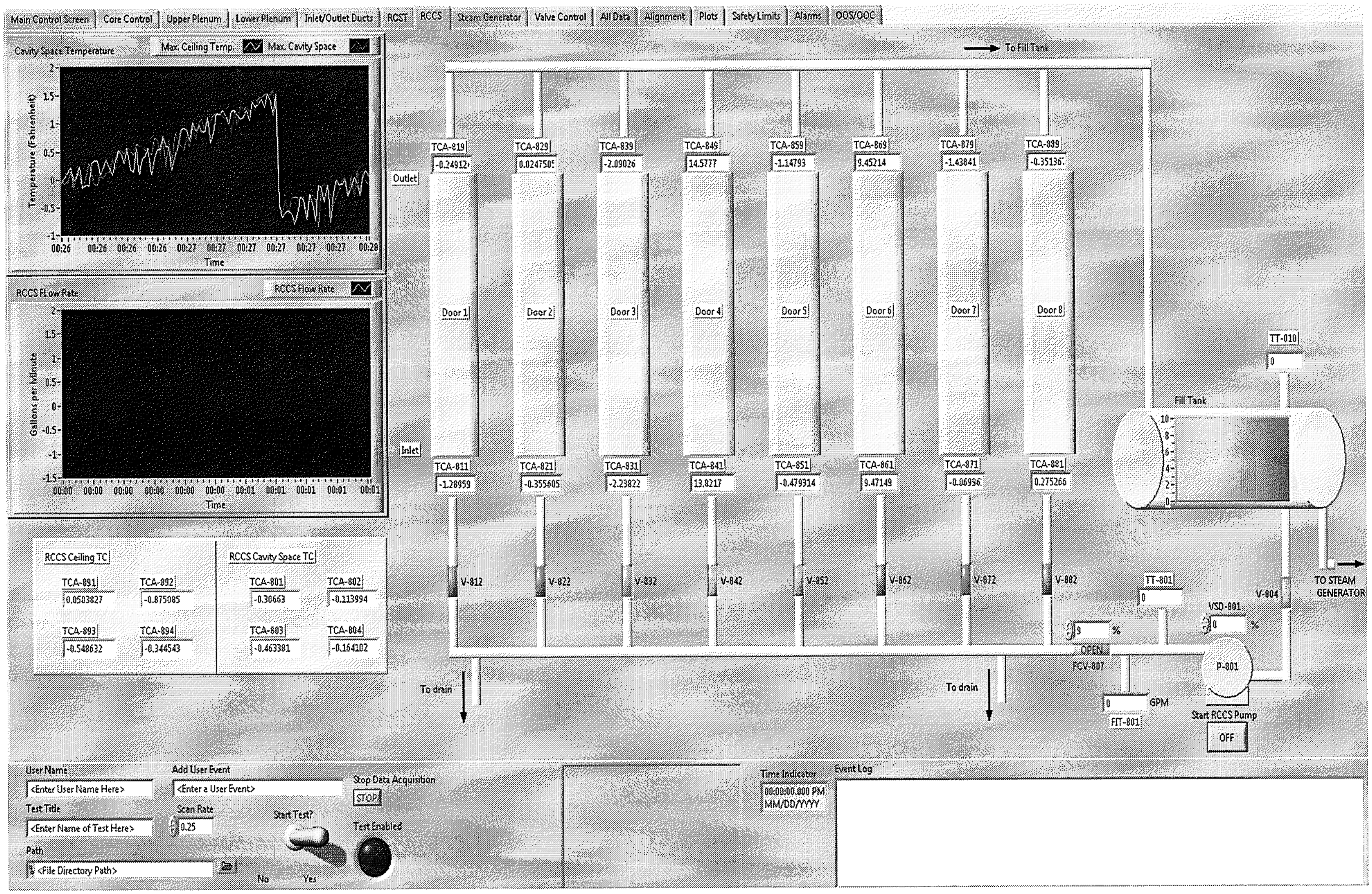
Table 8-1: Appended Documents

Number	Document
1	HTTF Process and Instrumentation Diagram
2	Example GUI screen for RCCS System
3	Example GUI screen for Steam Generator System
4	Example GUI screen for RCST system
5	HTTF Instrumentation Plan

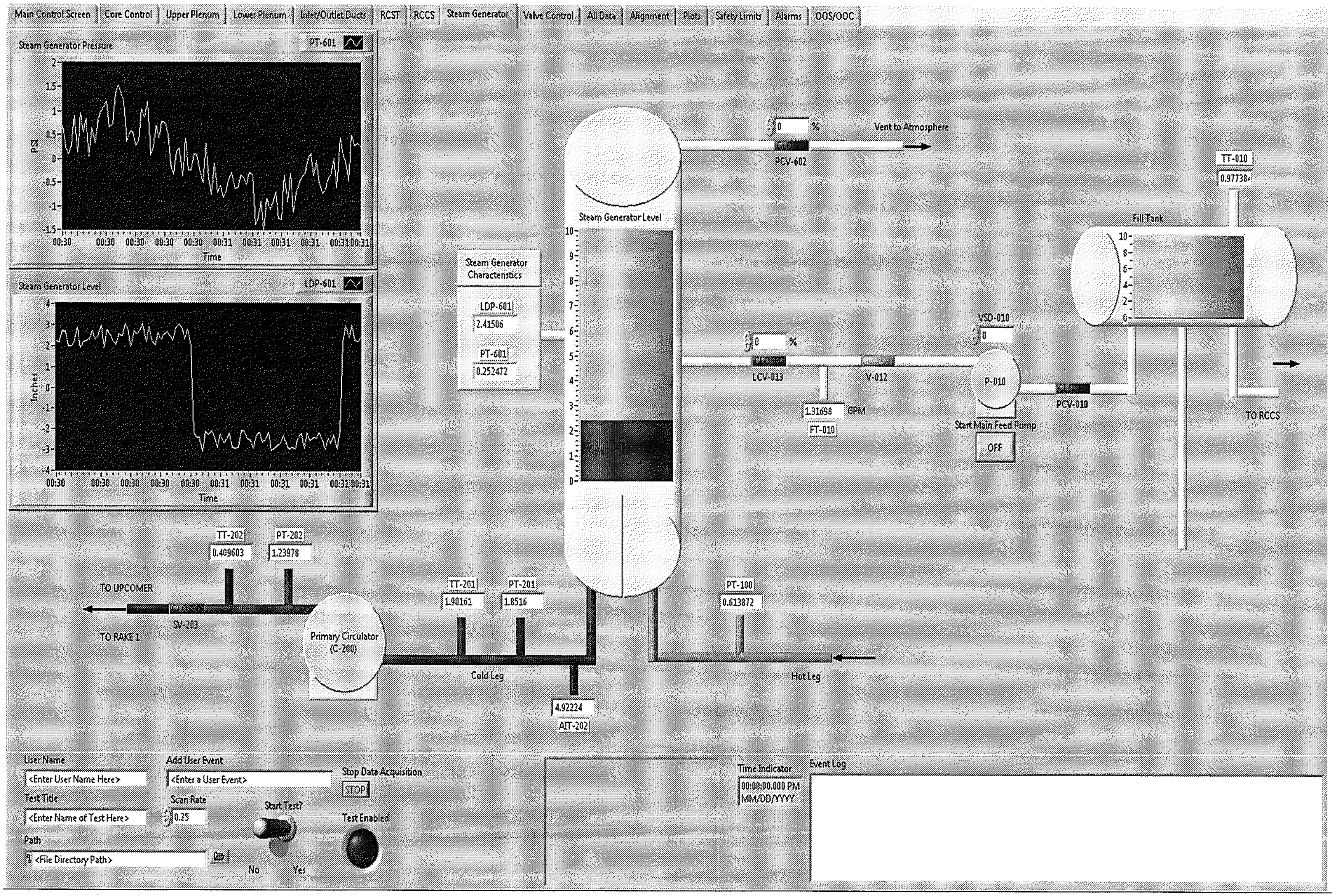
HTTF Process and Instrumentation Diagram:



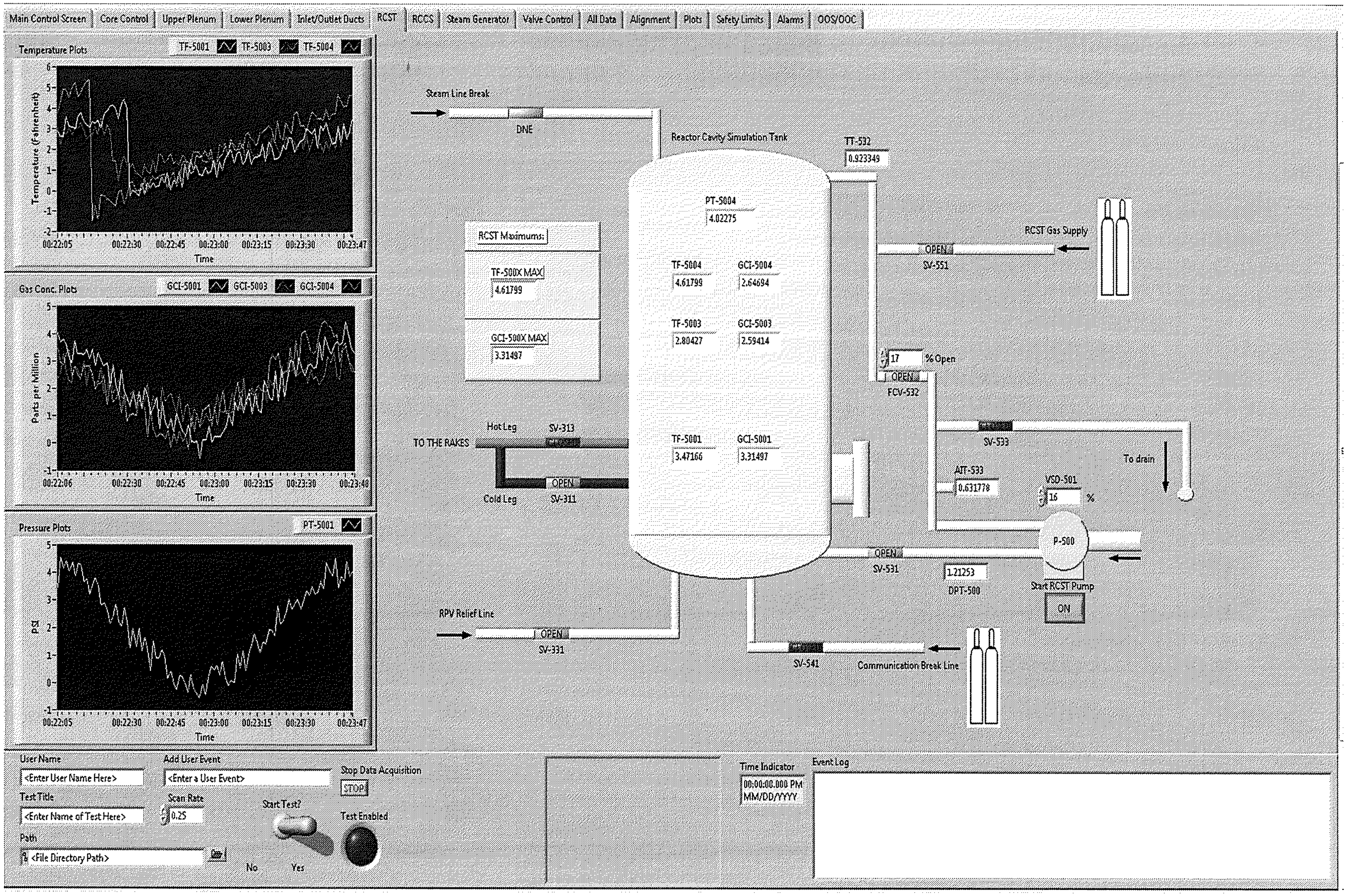
Reactor Cavity Cooling System Screen:



Steam Generator Screen:



Reactor Cavity Simulation Tank Screen:



APPENDIX 1

Instrumentation Plan for the High Temperature Test Facility at Oregon State University

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1 INTRODUCTION

This instrumentation plan describes the instrumentation requirements and design for the Oregon State University (OSU) High Temperature Test Facility (HTTF). This report will outline code validation requirements, HTTF instrumentation design specifications, data acquisition and control system (DACS) design specifications as well as a brief description of the instrumentation to be used in the HTTF.

The HTTF is an integral test facility which has been designed to model the behavior of interest for a Very High Temperature Gas Reactor (VHTR) during the Depressurized Conduction Cooldown (DCC) event. It also has the potential to conduct limited explorations into the progression of the Pressurized Conduction Cooldown (PCC) event and phenomena during normal operations. The facility is scaled 1:4 by height and 1:64 by volume. The maximum core power for the facility is approximately 2.2MW. The core region will be of a modular design to allow for both the prismatic block core and the pebble bed core designs to be tested. However, only the prismatic block design is discussed in this report. Details of the facility scaling are discussed in detail in reference [1].

As stated in reference [1], a correctly scaled integral facility modeling the VHTR that can be used to examine the thermal hydraulic system behavior of the design basis and beyond design basis transients is of significant value. The experimental results obtained in such a program could be used to validate analytical tools and methods being proposed for use with the VHTR. Therefore, it is of importance that the HTTF be instrumented in such a way that the required data is collected to meet its overall goals of phenomena examination and code validation.

A Next Generation Nuclear Plant (NGNP) Phenomena Identification and Ranking Table (PIRT) was completed for the NRC in 2008 [2]. The testing program at the HTTF will provide data for the following three of the six general categories of postulated accident scenarios for the VHTR identified in the NGNP PIRT.

1. Pressurized loss of forced convection (P-LOFC),

2. Depressurized loss of forced convection (D-LOFC),

3. Depressurized loss of forced convection with air ingress,

Because the primary mode of heat removal from the core in the event of a loss of forced convection is through conduction and then radiation through the reactor cavity, the P-LOFC event is often referred to as the PCC event and the D-LOFC event as the DCC event. The D-LOFC involves some sort of reactor coolant system break which allows primary coolant to leak into the reactor cavity. The D-LOFC with air ingress is classified as a separate event because not all break scenarios result in significant air ingress. Several factors influence the amount of air ingress including the location and size of break.

The specific data requirements for each test in the HTTF test matrix are discussed in detail in reference [3]. Reference [3] focuses on the answer to the question "What data should we collect?" The information contained in this Instrumentation Plan will answer the "Where?", "When?" and "How?" the data shall be collected to meet the requirements in the HTTF test matrix.

In addition to the instrumentation used to collect data to achieve the overall goals of the HTTF test program, there will be instrumentation in the HTTF which is primarily used to ensure the safe operation of the test facility. This type of instrumentation shall be termed "Control Instrumentation" and will be discussed in this report. This report will also discuss the DACS which is a personal computer controlled system that is used to control both the collection and storage of the test matrix and control system data as well as electrical and mechanical operation of the test facility.

2 VALIDATION REQUIREMENTS

The data produced by the HTTF has two major uses as discussed above: (1) the examination of the thermal hydraulic system behavior of the VHTR design basis and beyond design basis transients, and (2) the validation of analytical tools and methods being proposed for use with the VHTR. These analytical tools usually take the form of some sort of computer analysis tool. These computer analysis tools can also be broken down into two major categories: (1) system level codes such as RELAP5-3D, MELCOR and AGREE, and (2) computational fluid dynamics (CFD) tools such as STAR-CCM+.

The discussion of the data requirements to support use number 1 above, thermal hydraulic system behavior, is discussed in detail in references [1] and [3]. These documents use the PIRT [2] as the main source of information concerning the development of the thermal hydraulic system behavior in the VHTR.

The hallmark of systems codes is that, in general, they are lumped parameter models which rely on volumes of a finite size in relation to the size of the actual system. The fluid and solid parameters within the volumes of a systems code model are typically averaged in some fashion through the volume and represented as a point value for the purposes of calculation. The volume sizes in these codes are normally much larger than volume sizes found in the use of CFD codes and thus may have some uncertainty built into them as a result of the discretization error. In addition, systems codes may rely heavily on empirical models in areas where the discretized conservation equations for the code fail to produce accurate results. Primarily, the advantage of using these codes is that the computational resources required tend to be much smaller than those required for CFD modeling.

When it comes to code validation, the use of point measuring instruments such as thermocouples, pressure sensors and flow meters, translate very well into use for systems code validation. There is no requirement that the experimental parameters be known in a continuous three dimensional field for comparison with systems code results. As long as the experimental results are collected in areas which are representative of the code model's volume set, the comparison should be rather straight forward.

On the other hand, CFD model results tend to be produced as a fully resolved three dimensional field for the major flow and fluid parameters such as velocity, temperature, pressure and density. There is, typically, no averaging over a finite volume done by the code itself and any such averaging will have to be completed as a post-processing effort. The use of point measuring instruments may therefore be of limited direct value in the validation of CFD models. There is simply not enough information provided by the experimental data to validate the entire three dimensional flow field.

There are several ways in which this limitation in the validation of CFD can be overcome. Firstly, flow visualization techniques can be utilized to collect two and three dimensional flow field information. It may be impractical to collect this visualization information in all areas of a given test facility, but it should be looked at as a potential source of information in those areas where it is anticipated that the CFD models will have difficulty modeling the representative phenomena. Secondly, one may use the point measurement techniques in an experimental facility to see if the CFD code does predict this overall average behavior. If the CFD model fails to predict the point measurements it may indicate that the CFD model is having difficulty with the subject phenomena and geometry and may indicate that further examination is warranted. The opposite is not necessarily true, as an accurate CFD prediction of the point measurement may not indicate that the CFD code is operating properly. It may indicate that the code is having multiple deficiencies that are offsetting one another to produce the measured result. As such, the information provided by these point measurements may not be enough for a complete validation of the CFD code and models but certainly they can be used to further inform their application.

In order to make the most efficient use of the limited instrumentation resources at a test facility, an instrumentation plan should concentrate its most detailed instrumentation to areas (phenomena and geometry) which are expected to be the most challenging for the codes and models that are being validated. One has to be careful not to "recollect" the information that one already has or to collect the data that will "validate" positions with already understood phenomena. However, it is unrealistic that a test facility can collect "all information, everywhere" and thus some thought must go into the placement of the instrumentation. From a glance at the VHTR geometry and the design/beyond design basis accident progression, several areas of the VHTR have been identified as areas of interest, to include the following:

1. Exchange flow in the cross over vessels during the quad break initiator of the D-LOFC,
2. Momentum driven and thermal mixing of gas jets in the lower plenum during normal operations,
3. Momentum driven and thermal mixing of gas plumes in the upper plenum during the natural circulation phase of both the P-LOFC and the D-LOFC, and
4. Core and vessel temperature profiles (radial and axial) during both the P-LOFC and the D-LOFC.

An in depth analysis for the MELCOR code and its validation data requirements has been completed by researchers at Texas A&M University [4]. Table 2-1 outlines the HTTF instrumentation needs required for the validation of MELCOR from this study. Note in this table that not only is data required for the direct validation of the code, but certain information is also necessary to set the boundary conditions for the code transients.

Table 2-1: HTTF Instrumentation Requirements for MELCOR Validation [4]

Parameter	MELCOR	Rationale	MELCOR Calculation Parameter
Core effective thermal conductivity		Given High importance in the NRC PIRT; needed as input data for MELCOR calculations; the effective conductivity predicted by the designers should be verified in initial testing	
Vessel and RCCS emissivities		Given High importance in the NRC PIRT; needed as input data for MELCOR calculations	
Power profile		Given High importance in the NRC PIRT; needed as input data for MELCOR calculations	
Decay heat		Given High importance in the NRC PIRT; needed as input data for MELCOR calculations	
Primary system coolant leakage rate		Needed as boundary condition for MELCOR calculations	
Heat losses		Needed as boundary condition for MELCOR calculations	
Core flow	X	Needed to know flow distribution through the coolant channels	(FL velocity) * (CVH density) * (FL area)
Core coolant bypass flow	X	Given High importance in the NRC PIRT; measurement of this parameter will depend on whether or not the HTTF has a bypass region(s)	(FL velocity) * (CVH density) * (FL area)
Reactor vessel cavity air temperature	X	Given High importance in the NRC PIRT	CVH-TVAP (gas temperature)
Ceramic temperature distribution	X	Can be used to determine ceramic stored energy or "afterheat" in cooldown events	COR component temperatures
Coolant temperature distribution	X	Needed to verify proper heat removal by MELCOR	CVH-TLIQ (liquid temperatures)
RCCS panel surface temperature	X	Must be known to control flow through MELCOR's RCCS to maintain constant temperature BC	HS or REF temperatures
Core barrel inner and outer surface temperatures	X	Radiative heat transfer between the core barrel and RPV could be better characterized with these data	HS or REF temperatures
Reactor pressure vessel inner and outer surface temperatures	X	Radiative heat transfer between the RPV and RCCS panels and between core barrel and RPV could be better characterized with these data	HS or REF temperatures
Core pressure drop	X	Designers must verify that the desired scaled pressure drop has been achieved	Difference of CVH gas pressures
Lower plenum gas concentrations	X	Molecular diffusion and air ingress are given High importance in the NRC PIRT	CVH mass fraction

Parameter	MELCOR	Rationale	MELCOR Calculation Parameter
Outlet plenum flow distribution	X	Given High importance in the NRC PIRT; for MELCOR, knowledge of hot channel locations is needed	(FL velocity) * (CVH density) * (FL area) and CVH-TVAP (gas temperature)
Reactor vessel cavity air concentration	X	Given High importance in the NRC PIRT. Needed for D-LOFC	CVH mass fraction
Duct exchange flow rates	X	Given High importance in the NRC PIRT; for MELCOR, some indication of the flow distribution is needed for D-LOFC	(FL velocity) * (CVH density) * (FL area) For helium outlet flow and air inlet flow

CVH = hydrodynamic control volume within MELCOR spatial nodalization
FL = MELCOR flow path
HS = MELCOR heat structure
REF = MELCOR reflector component

3 DESIGN REQUIREMENTS

The following sections are the design requirements that have been developed for the HTTF instrumentation and the HTTF DACS. The following acronyms will be used throughout:

ANSEL	Advanced Nuclear System Engineering Laboratory
DAQ	Data Acquisition
PLC	Programmable Logic Controller
RCCS	Reactor Cavity Coolant System
RCST	Reactor Cavity Simulation Tank Instrumentation

3.1 General

1. All instrumentation shall be of a size small enough to fit in the Advanced Nuclear Systems Engineering Laboratory (ANSEL) at Oregon State University.

2. All instrumentation shall be of a size to fit in the location of interest. This includes size considerations of inline piping, penetration depths, etc.

3. Instrumentation shall provide for the capability to be calibrated to NQA-1 standards.

4. Where applicable, instrumentation with power requirements shall be delivered by already existing power.

5. Instrumentation shall have output signals that can be read by the DAQ and PLC systems and follow typical industry practices.

6. Instrumentation and wiring shall be constructed of a material that shall not experience significant degradation or corrosion during extended idle periods, even without layup preparation, while residing in the Advanced Nuclear System Engineering Laboratory with expected atmospheric conditions between 20°F-110°F and 0%-100% humidity.

7. All HTTF instrumentation shall be capable of 1000 cycles from atmospheric pressure and room temperature to its operating pressure and temperature and back to atmospheric pressure and room temperature over their lifetime.

8. HTTF instrumentation shall have a test-taking lifetime of at least 1000 hrs in operation.

9. Where applicable, instrumentation shall have the capability of sending an error signal upon failure.

3.2 Primary Pressure Vessel Instrumentation

1. Primary pressure vessel instrumentation shall be installed in a density and location sufficient for the use of the experimental data in the validation of nuclear reactor system and computational fluid dynamics codes.

2. All instrumentation to be used in the HTTF primary pressure vessel shall be able to operate in an environment of helium, nitrogen, argon, carbon dioxide and air.

3. HTTF primary pressure vessel instrumentation shall be of such material construction to withstand maximum temperatures expected to be experienced in the test facility :
    a. Inner radial half of core: 1800 C
    b. Outer radial half of core: 1250 C
    c. Lower Plenum: 1000 C
    d. Upper Plenum: 1600 C
    e. Core Barrel and Upcomers: 1000 C
    f. Pressure Vessel: 800 C

4. HTTF primary pressure vessel instrumentation shall maintain operability at 125% of the primary system operating pressure.

5. Instrumentation wiring shall be of a size to pass through instrumentation ports in the pressure vessel. Wiring shall also be of construction such that operability is maintained considering temperature effects and the wiring routing paths.

6. Thermocouples to be used in the primary pressure vessel shall be capable of measuring temperatures corresponding to temperatures listed above.

7. Pressure sensors to be used in the primary pressure vessel shall have sensitivity sufficient to measure pressure differences corresponding to core natural circulation velocities expected during the natural circulation phase of the Depressurized Conduction Cooldown event.

8. Gas sensor instrumentation shall allow for in-situ, real time gas concentration measurements.

9. Gas sensor instrumentation shall have a 5% accuracy corresponding to local conditions.

3.3 Reactor Cavity Coolant System (RCCS) Instrumentation

1. The RCCS shall be instrumented to measure temperatures, pressures, and flowrates sufficient to calculate energy balances across the RCCS and the individual panel columns. Panel columns are RCCS panels connected in series. Each column is connected to the RCCS inlet and outlet headers.

2. Thermocouples shall be used to measure water temperatures at the inlet and the outlet of individual panel columns. Temperature limits of the thermocouples shall be at least 25% greater than the expected highest RCCS water temperature.

3. Pressure sensors shall be chosen such that the range shall be at least 130% of the normal operating pressure in the RCCS.

4. The flowmeter to be used for the RCCS bulk flow shall be able to operate under the expected RCCS pressures, temperatures, and flowrates. The flowmeter shall be capable of installation in the installed RCCS piping.

5. The maximum flowrate limit for the flowmeter shall correspond to the pump maximum design flowrate.

6. The flowmeter shall be designed to handle water temperatures 25% greater than the expected RCCS high operating water temperature.

3.4 Reactor Cavity Simulation Tank Instrumentation (RCST)

1. RCST instrumentation shall be installed in a density and location sufficient for the determination of the RCST boundary condition prior to the commencement of the Depressurized Conduction Cooldown Event.

2. RCST instrumentation shall be operable in an environment of helium, nitrogen, air, argon and carbon dioxide.

3. RCST instrumentation shall have temperature limits corresponding to the design temperature of the cavity simulation tank.

4. Gas sensor instrumentation shall allow for in-situ, real time gas concentration measurements.

5. Gas sensor instrumentation shall have a 5% accuracy corresponding to local conditions.

3.5 Primary System Instrumentation

1. Primary system instrumentation shall be installed in a density and location sufficient to safely operate and control the HTTF.

2. Primary system gas instrumentation shall be operable in an environment of helium, nitrogen, air, argon, and carbon dioxide.

3. Primary system instrumentation shall have upper pressure ranges of at least 125% of the maximum primary system operating pressure.

4. Thermocouples shall be operable to at least 125% of the maximum primary system operating temperature.

5. Gas sensor instrumentation shall allow for in-situ, real time gas concentration measurements.

6. Gas sensor instrumentation shall have a 5% accuracy corresponding to local conditions.

3.6 Secondary System Instrumentation

1. Secondary system instrumentation shall be installed in a density and location sufficient to control the heat removed from the primary system by the secondary system.

2. Secondary system instrumentation shall have upper pressure ranges of at least 125% of the maximum secondary system operating pressure.

3. Thermocouples shall be operable to at least 125% of the maximum secondary system operating temperature.

3.7 Data Acquisition (DAQ) and Programmable Logic Controller (PLC)

1. The DAQ and PLC hardware chassis and associated components shall be of size for placement in the test-bay near the corresponding instruments.

2. DAQ and PLC hardware chassis shall be of modular design.

3. DAQ and PLC hardware shall perform signal conditioning, digitization, and data acquisition in an integrated design.

4. DAQ and PLC hardware shall be capable of analog output, counter/timers and triggering and synchronization circuitry for data collection, and instrument control.

5. Connection from DAQ and PLC test-bay hardware to control room lab workstations shall be by cable (i.e. copper, fiber-optic).

6. The DAQ and PLC components shall be based on internal buses for connection to control room lab workstations.

7. All DAQ and PLC hardware shall be compatible with a graphical user interface program operated on Windows based workstation.

8. DAQ and PLC shall have real time monitoring.

9. Hardware and connections shall be capable of gigabit bandwidth and microsecond latency.

10. DAQ and PLC channels shall have an accuracy of at least 1.0% of full scale.

11. DAQ and PLC channels shall have sampling rates sufficient for the use of the experimental data in the validation of nuclear reactor system and computational fluid dynamics codes.

12. The DAQ and PLC hardware to be contained in the bay shall be constructed of a material that shall not experience significant degradation or corrosion during extended idle periods, even without layup preparation, while residing in the Advanced Nuclear System Engineering Laboratory with expected atmospheric conditions between 20°F-110°F and 0%-100% humidity.

13. The DAQ and PLC shall use 120 V, 60 hertz power supply.

14. The timing sequence of channel sampling shall be specified and quantified.

15. Channels whose operation can impact the safety of the operators or the integrity of the test facility shall be sampled using a dual modular redundant system.

4 HTTF INSTRUMENTATION

The following table presents the current HTTF instrumentation package. Details of the various instrumentation locations are presented in later sections of this report.

Table 4-1: HTTF Instrumentation Package

Location	Type	Number	Total
THERMOCOUPLES			
Primary 1/6th Core Section, Lower Reflector Block #1, Axial Level 2, 4, 6, and 8 (1 TC each level)	C	5	
Primary 1/6th Core Section, Lower Reflector Block #3	K, C	2	
Primary 1/6th Core Section, Axial Level 1 (9 TC)	C	9	
Primary 1/6th Core Section, Axial Level 3,5,7, and 9 (10 TC each level)	K, C	40	
Primary 1/6th Core Section, Heater Rod TCs	C	10	
Primary 1/6th Core Section, Cold-Junction Compensation	K	21	
Total Core TCs in Primary 1/6th Section	High Temperature: 61 K-type (Low Temp): 26		87
Secondary 1/6th Core Section, Axial Level 1	C	8	
Secondary 1/6th Core Section, Axial Levels 3,5,7, and 9 (9 TC each level)	K, C	36	
Secondary 1/6th Section, Axial Level 10	C	1	
Secondary 1/6th Core Section, Heater Rod TCs	C	10	
Secondary 1/6th Section, Cold-Junction Compensation	K	16	
Total Core TCs in Secondary 1/6th Section	High Temperature: 51 K-type (Low Temp): 20		71
Tertiary 1/6th Core Section, Lower Reflector Block #3	K	1	
Tertiary 1/6th Section, Axial Levels 3, 5, and 7 (9 TC each level)	K, C	27	
Tertiary 1/6th Section, Heater Rod TCs	C	8	
Tertiary 1/6th Section, Cold-Junction Compensation	K	10	
Total Core TCs in Secondary 1/6th Section	High Temperature: 32 K-type (Low Temp): 14		46
Total Core TCs	**High Temperature: 144** **K-type (Low Temp): 60**		**204**
Primary 1/6th Section, Upper Plenum Floor TCs	K	10	
Upper Plenum Shroud and Vessel TCs	K	6	
Control Rod Drive Break TCs	K	2	
Total Upper Plenum Solid TCs (Floor/Shroud/Head)			18
Upper Plenum Gas Thermocouples	K	24	
Total Upper Plenum Gas Thermocouples			24
Total Upper Plenum TCs			**42**
Lower Plenum Gas Temperature TCs	K	32	
Lower Plenum Inlet Gas Temperature TCs	K	12	
Lower Plenum Floor Temperature TCs	K	12	
Total Lower Plenum Gas Thermocouples			56
Lower Plenum Side Reflector TCs	K	2	
Lower Instrumentation Break TCs	K	2	
Lower Head TCs	K	2	
Total Lower Plenum Solid TCs			6
Total Lower Plenum TCs			**62**

Location	Type	Number	Total
Metallic Core Support Structure (MCSS) TCs	K	2	
Total MCSS TCs			**2**
Primary 1/6th Section, Outer Core Barrel TCs, Axial Levels: Lower Reflector Block #3, 3, 5, 7, 10)	K	5	
Primary 1/6th Section, Upcomer TCs, Axial Levels: Lower Reflector Block #3, 3, 5, 7, 10)	K	5	
Primary 1/6th Section, Inner RPV TCs, Axial Levels: 3, 5, 7	K	3	
Primary 1/6th Section, Outer RPV TCs, Axial Levels: Lower Reflector Block #3, 3, 5, 7, 10	K	5	
Total Outer Cylinder TCs			**18**
Outlet Duct TCs in Rake near vessel (Rake 1)	K	3	
Outlet Duct TCs in Rake downstream from vessel (Rake 2)	K	3	
Inlet Duct TCs in Rake near vessel (Rake 1)	K	2	
Inlet Duct TCs in Rake downstream from vessel (Rake 3)	K	2	
Total Inlet/Outlet Duct TCs			**10**
RCCS TCs (2 TCs per door)	K	16	
RCCS Cavity Ceiling	K	4	
RCCS Cavity Space	K	4	
Total RCCS TCs			**24**
Reactor Cavity Simulation Tank (RCST) TCs	K	3	
Total RCST TCs			**3**
TOTAL THERMOCOUPLES	High Temperature: 144 K-type (Low Temp): 221		**365**
PRESSURE INSTRUMENTATION (Taps and Sensors)			
Pressure Taps:			
Core top/bottom (1 tap at the top/ 1 tap at the bottom)			2
Upcomer top			1
Lower Plenum			1
MCSS			1
Upper Plenum			1
Hot Leg Duct			1
Cold Leg Duct			1
Reactor Cavity Simulation Tank			1
TOTAL PRESSURE TAPS			**9**
Pressure Sensors:			
Core Pressure (1 DPT for both taps)	Differential Pressure		1
Upcomer Pressure	Differential Pressure		1
Lower Plenum Pressure	Differential Pressure		1
MCSS	Differential Pressure		1
Upper Plenum	Differential Pressure		1
Hot Leg Duct	Differential Pressure		1
Cold Leg Duct	Static Pressure		1
Reactor Cavity Simulation Tank	Static Pressure		1
TOTAL PRESSURE SENSORS			**8**

Location	Type	Number	Total
VOLTAGE MEASUREMENT			
Primary Side Voltage Measurements for Heater Rod Bank -101, -103, -105, -107, and -109	Voltage Measurement		5
Tertiary Side Voltage Measurements for Heater Rod Bank -102, -104, -106, -108, and -110	Voltage Measurement		5
TOTAL VOLTAGE TAPS			**10**
GAS CONCENTRATION INSTRUMENTS (GCI)			
Primary 1/6th Core Section, Axial Levels 1 through 9 (1 GCI per level)		9	
Secondary 1/6th Core Section, Axial Levels 1,3,5,7, and 9 (1 GCI per level)		5	
Total Core GCIs			**14**
Primary 1/6th Core Section, Upper Plenum Floor GCI		1	
Instrumented Upper Plenum Control Rod Guide Tubes (2 GCI per tube)		6	
High Instrumentation Break GCI		1	
Total Upper Plenum GCIs			**8**
Lower Plenum GCIs at 25% Plenum Height		4	
Lower Plenum GCIs at 75% Plenum Height		4	
Low Instrumentation Break GCI		1	
Total Lower Plenum GCIs			**9**
Primary 1/6th Section, Upcomer GCI, Axial Levels: Lower Reflector #3, 4, 6, and 10 (1 GCI per level)		4	
Total Upcomer GCIs			**4**
Outlet Duct Gas Sensors in Rake near vessel (Rake 1)			3
Outlet Duct Gas Sensors in Rake downstream from vessel (Rake 2)			3
Inlet Duct Gas Sensors in Rake near vessel (Rake 1)			2
Inlet Duct Gas Sensors in Rake downstream from vessel (Rake 3)			2
Total Inlet/Outlet Duct GCIs			**10**
Reactor Cavity Simulation Tank GCIs	3		
Total Reactor Cavity Simulation Tank GCIs			**3**
TOTAL GCIs			**48**
TOTAL HTTF INSTRUMENTATION			**431**

4.1 CORE REGION INSTRUMENTATION

The following four subsections present the thermocouple, pressure sensor, gas concentration instruments (GCI), and heater rod power measurement instrumentation that will be placed in the core region.

4.1.1 Core Thermocouples

Thermocouples will be used to measure radial and axial core thermal profiles for both solid ceramic material and coolant gas temperatures. It is anticipated that temperatures greater than 1250 °C will occur for core regions with a normalized radius less than 0.6. Therefore, thermocouples inside this inner region will be C-type thermocouples as these can handle higher temperatures. Thermocouples in the outer regions (a normalized radius greater than 0.6) will be K-type thermocouples, which have an operable range up to 1250 °C. See Figure 4-1 for a cross section of the core layout.

The core section is divided into 1/6th azimuthal sections, with thermocouples placed in all the core axial levels. However, only three 1/6th sections of the core will be instrumented. As outlined in Table 4-1, one section will contain 87 thermocouples, and it is called the Primary 1/6th Sector. Another section (called the Secondary 1/6th Sector) houses 70 thermocouples in total. All remaining core thermocouples are placed in the Tertiary 1/6th Sector. The Primary Sector is the 1/6th section of the core that is opposite the inlet/outlet gas ducts. The thermocouples are placed at specific radial positions in the Primary Sector, which are outlined in Table 4-2. Thermocouples are located in all levels in the Primary Sector, although some axial levels are less instrumented and do not have thermocouples at all radial positions. Details and figures for each axial level are shown in later sections.

The Secondary Sector is a 1/6th section of the core that is 60° counter-clockwise from the inlet/outlet ducts. This sector is not as highly instrumented as the Primary Sector. For consistency, thermocouples in the Secondary Sector are located in the same radial positions as those in the Primary. Table 4-2 shows these positions.. Further details for thermocouple locations in each sector are shown in Figure 4-9 through Figure 4-11 below.

The Tertiary Sector is the 1/6th section that is in line with the inlet/outlet ducts and is 180° from the Primary Sector. It is the least instrumented of the three sectors. Again, radial positions in the Tertiary Sector correspond to the locations specified in Table 4-2. Additional details on thermocouple locations are provided in later sections.

Table 4-2: Core Thermocouples, Overview of Thermocouple Locations

Location	Measured State	TC Type
Outer Reflector #1 (R=0.850)	Solid	K
Core (R=0.600)	Solid	C
Core (R=0.475)	Solid	C
Core (R=0.365)	Solid	C
Core (R=0.338)	Solid	C
Core Inner Reflector (R=0.18)	Solid	C
Centerline Core (R=0.00)	Solid	C
Center Flow Channel (R=0.493)	Gas	C
Center Flow Channel (R=0.383)	Gas	C
Center Flow Channel (R=0.320)	Gas	C

* R location refers to a normalized radial position where R=1.0 corresponds to the vessel outer radius.

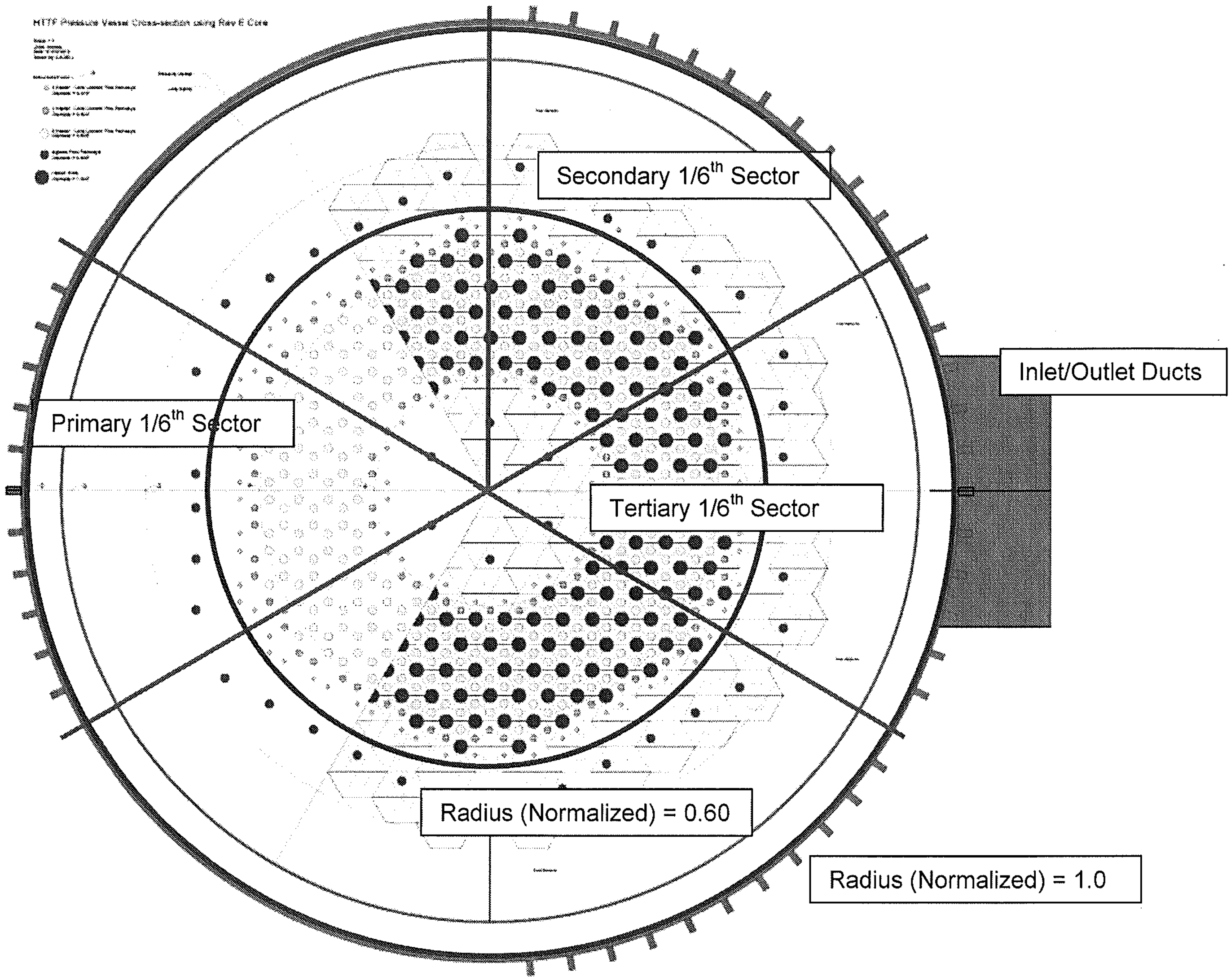

Figure 4-1: HTTF Pressure Vessel Cross Section showing the Instrumented Primary and Secondary 1/6th Sectors

The numbering convention of axial levels corresponds to the top of corresponding core block. Small, horizontal thermocouple channels (shown by green lines in Figure 4-2) will be cast into the top of each ceramic core block through which the thermocouple wiring can run radially outward from the thermocouple placement. The smaller instrumentation channels in the core—for a normalized radius less than 0.85—are ¼ inch thick and deep. Larger instrumentation channels (shown for R>0.85) are ½ inch thick and deep. The instrumentation leads will be collected in a gap between the core blocks and the outer permanent reflector. Figure 4-3 shows an axial layout of the core region with the relative routing of the thermocouple wiring. In the gap between the core blocks and the outer reflector, the TC leads will be directed downward before being brought out of the pressure vessel through an instrumentation bulkhead. The Primary, Secondary, and Tertiary Sectors currently have 7 bulkheads each, but this can be expanded to 11 bulkheads per sector.

Axial level 10 thermocouples correspond to the top of the heated core. The top of Lower Reflector #3 corresponds to the bottom of the heated core. These sets of thermocouples measure the inlet and outlet temperatures of the core. Thermocouples in the bottom lower reflector block (Lower Reflector #1 in **Error! Reference source not found.**) yield temperatures midway between the outlet of the core and the lower plenum. TCs at the top of the Upper Reflector #2 block represent the Upper Plenum floor TCs. While not listed here in the core detail, there are thermocouples also at the floor of the upper plenum. These thermocouples along with the axial level 10 thermocouples characterize temperature changes across the upper reflector.

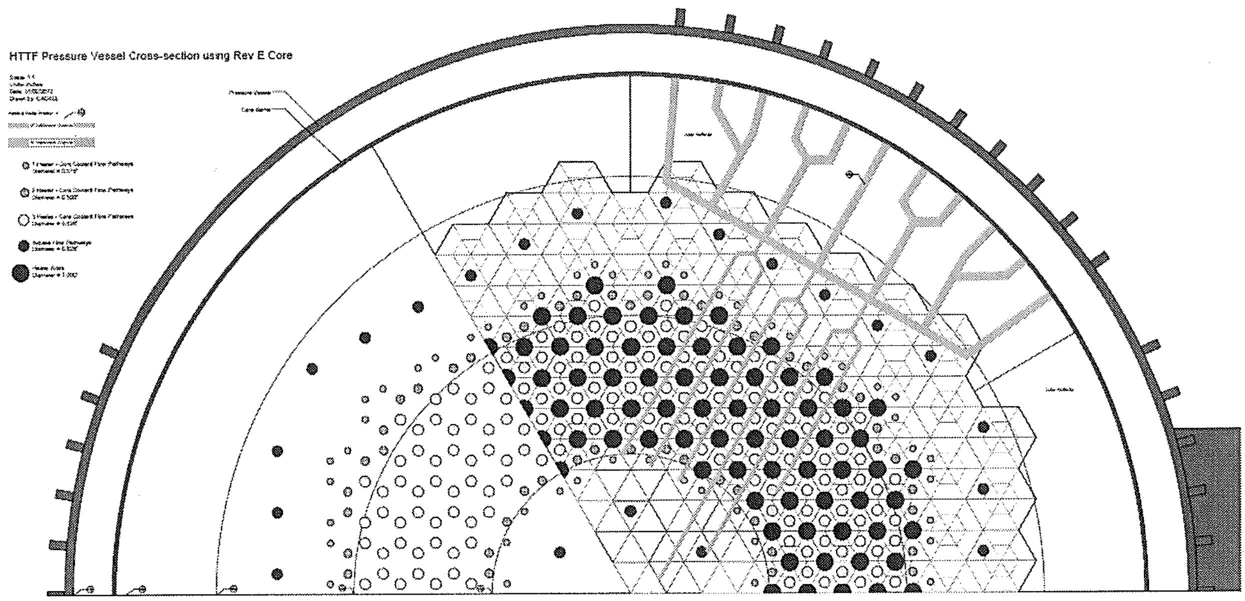

Figure 4-2: HTTF Pressure Vessel Cross Section Thermocouple Placement: Green lines show horizontal TC channel cast into the top of each ceramic core block

Instrumentation channels are also cast into the outer reflector. Figure 4-3 shows the axial levels where outer reflector channels have been cast (i.e. on the Lower Reflector #3; Levels 3, 5, 7 and 9; and on the Upper Plenum Floor). Thermocouples in the outer reflector will have their leads be brought radially inward to the instrumentation gap, down the gap between the core blocks and the outer reflector, and finally directed out the vessel via an instrumentation bulkhead. Relative instrumentation wiring for the outer reflector is also shown in the figure below.

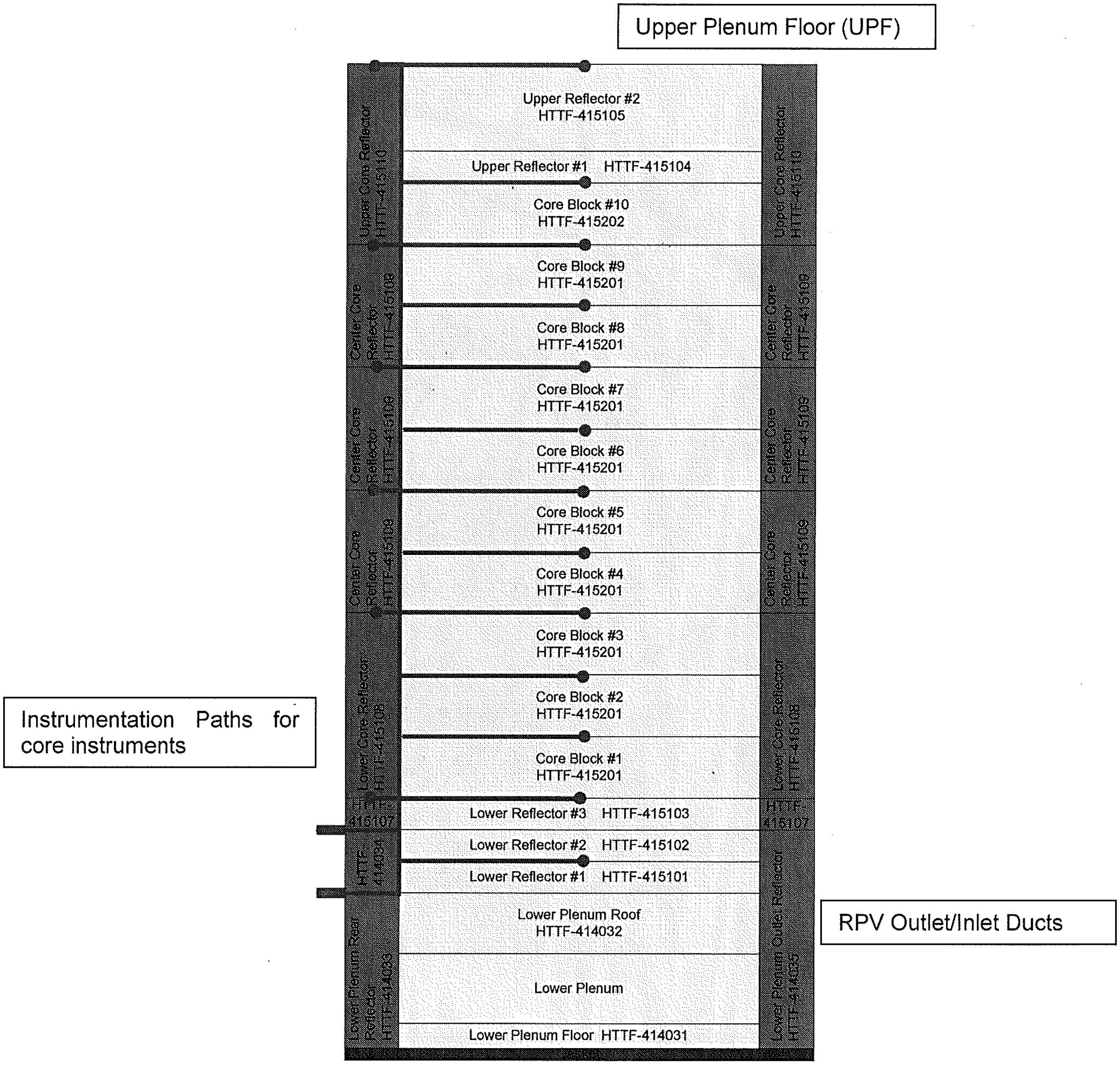

Figure 4-3: Axial Cross-Sectional Diagram of the Ceramic Component Orientation within the HTTF RPV (Drawn to Scale): Red lines indicate core instrumentation wiring.

To acquire the best data for the C-type thermocouples, a cold-junction compensation (CJC) thermocouple will be placed in the instrumentation voids between the core blocks and the outer reflector. This cold-junction compensation thermocouple will serve both the function of another core temperature TC and a voltage compensation for the C-type TCs in the core region. There are three instrumented voids which refer to the three "tuning forks" in the core molds. For clarity, the following figure points out the "tuning forks." Void #1 refers to the leftmost "tuning fork," Void #2 is the middle fork, and Void #3 is the rightmost fork. The following figures will show which voids have CJC TCs in the Primary, Secondary, and Tertiary Sectors. Cold-junction compensation TCs will be depicted by a blue circle.

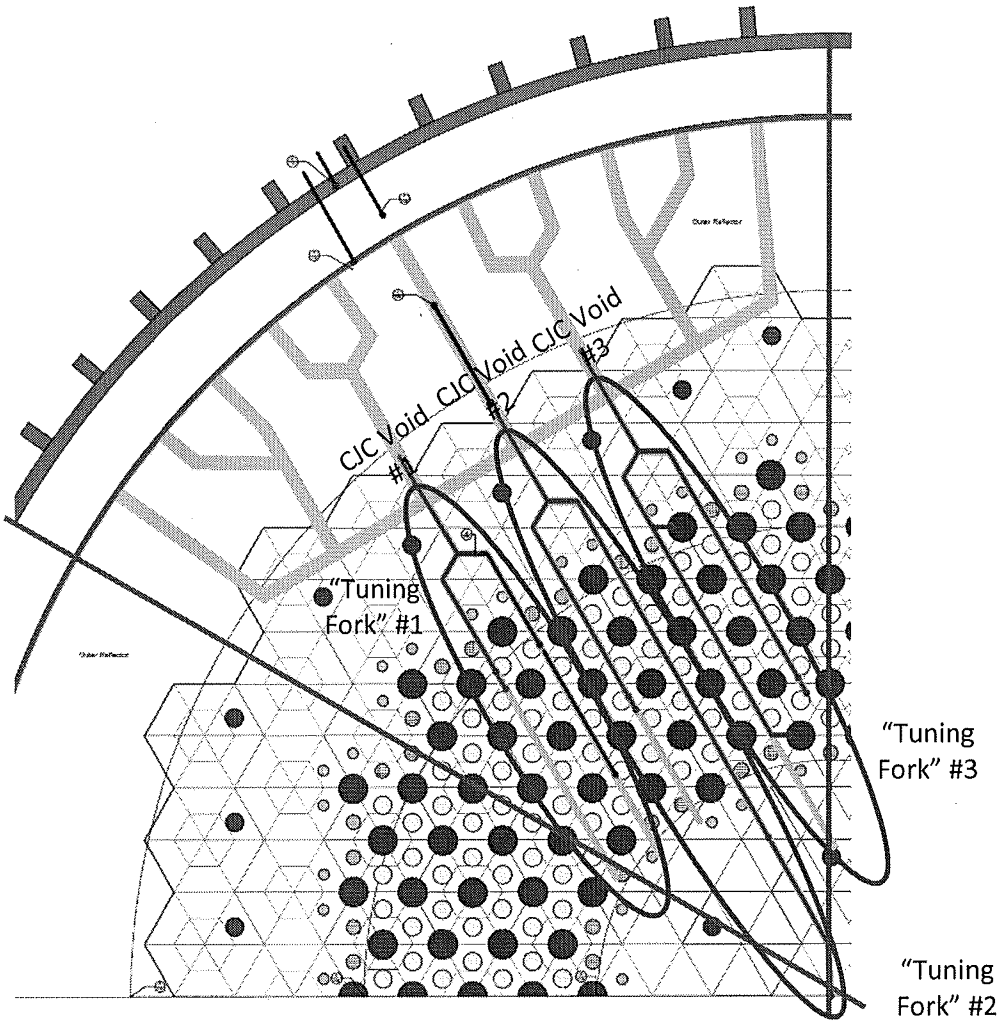

Figure 4-4: General Core Block Assembly showing Instrumented CJC Voids and "Tuning Forks"

4.1.1.1 Primary Sector Core Thermocouples

In the Primary core section instrumentation package, thermocouples are spread out over all axial levels with a higher density of thermocouples placed in axial levels 1, 3, 5, 7 and 9. Axial level 10 is not instrumented on the Primary Sector due to limited accessibility from the heater banks. Instead, axial level 10 is instrumented on the Secondary Sector. Greater detail of the Secondary Sector and Tertiary Sectors will be given later.

On every instrumented axial level in the Primary Sector, there is at least 1 ceramic temperature thermocouple measure the centerline temperature of the core. The Lower Reflector Block #1, and axial levels 2, 4, 6, 8 are the only levels that have this centerline temperature thermocouple. On these levels, there is also 1 CJC TC for the centerline C-type TCs, which will be routed through Void #2. The CJC thermocouple is denoted by a blue circle. Thermocouples on these levels are shown in the following figure.

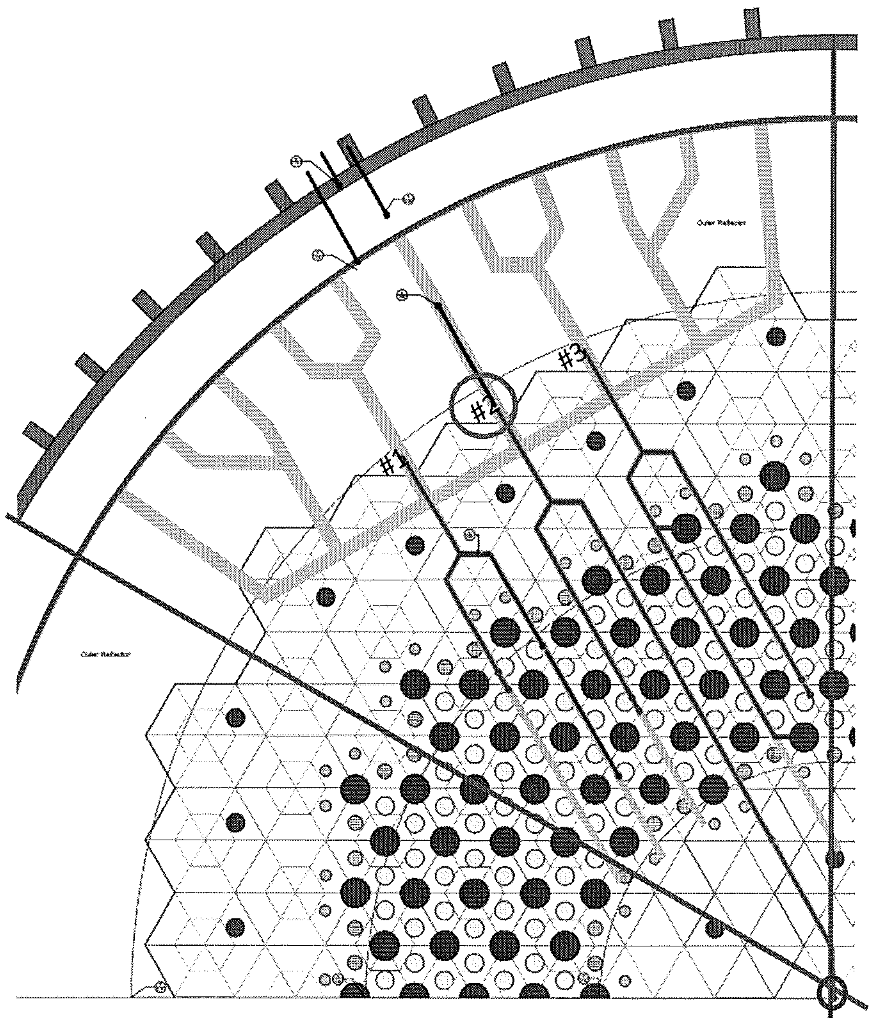

Figure 4-5: Primary 1/6th Sector Thermocouples for Lower Reflector #1, and Axial Levels 2, 4, 6, and 8

Ceramic Temperature TCs: O

K-type Cold-Junction Compensation TCs: O

Lower Reflector #3 has 3 TCs due to limited access from the heater rod banks. To accommodate the heater banks, Lower Reflector #3 was required to have a unique mold shape with instrumentation channels cast differently than for the core blocks. On this level, there is the centerline temperature thermocouple, and 1 outer reflector TC (R=0.85). These thermocouples are depicted by purple circles in the figure below. One CJC TC is located in Void #3 to accommodate the C-type TC.

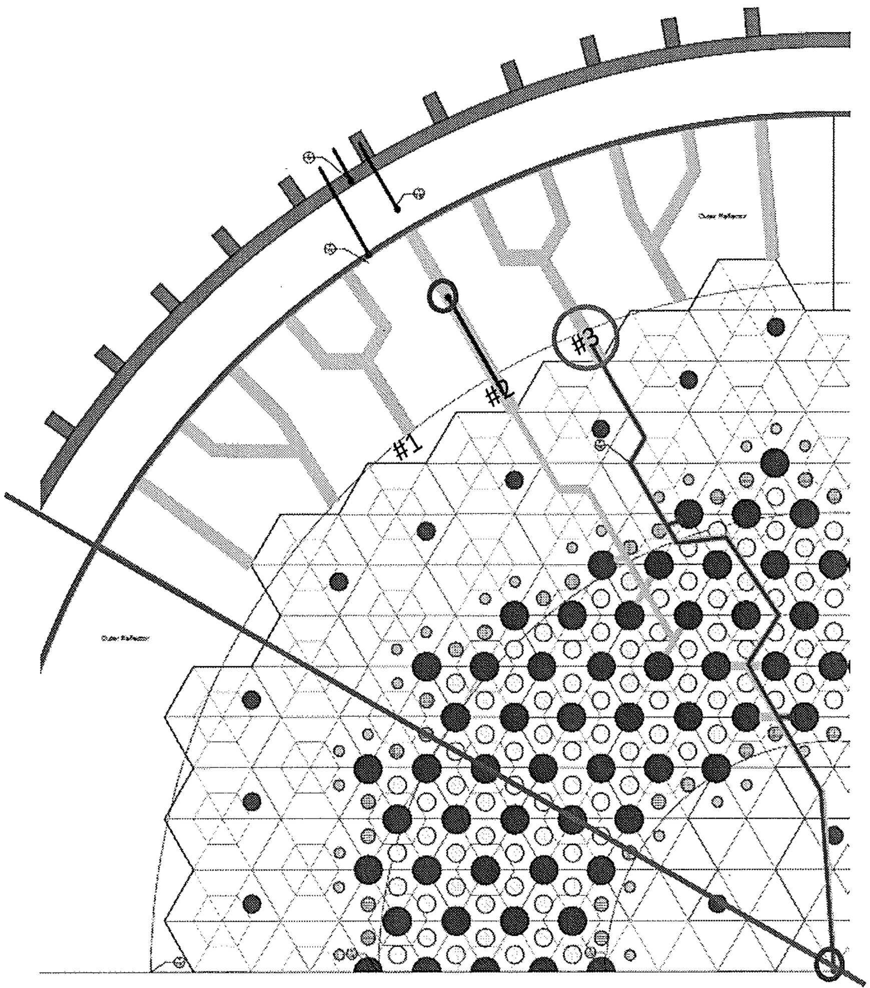

Figure 4-6: Primary 1/6th Sector Thermocouples for Lower Reflector Block #3

Ceramic Temperature TCs: O

K-type Cold-Junction Compensation TCs: O

Axial Level 1 is the next most heavily instrumented level with 14 TCs, consisting of: 3 gas temperature TCs (black circles), 6 ceramic temperature TCs (purple circles), 3 CJC TCs (blue circles). Positions are shown in the figure below and correspond to radial positions presented in Table 4-2. The outer reflector TC is not included on this level due to no accessibility from the outer reflector blocks (refer to Figure 4-3). Since there are C-type TCs over three separate tuning forks, there are also 3 CJC TCs on each of these levels. The following figure shows the radial locations of all these thermocouples.

In addition to these thermocouples, there are also two heater rod thermocouples. The heater rods are annular shaped, and the instrumented heater rods will have thermocouples in the inner heater wall. Instrumented heater rods are denoted by filled green circles. These heater rods were selected to be instrumented because they coincide with the core voltage measurements. Core voltage measurements are discussed under Section 4.1.4.

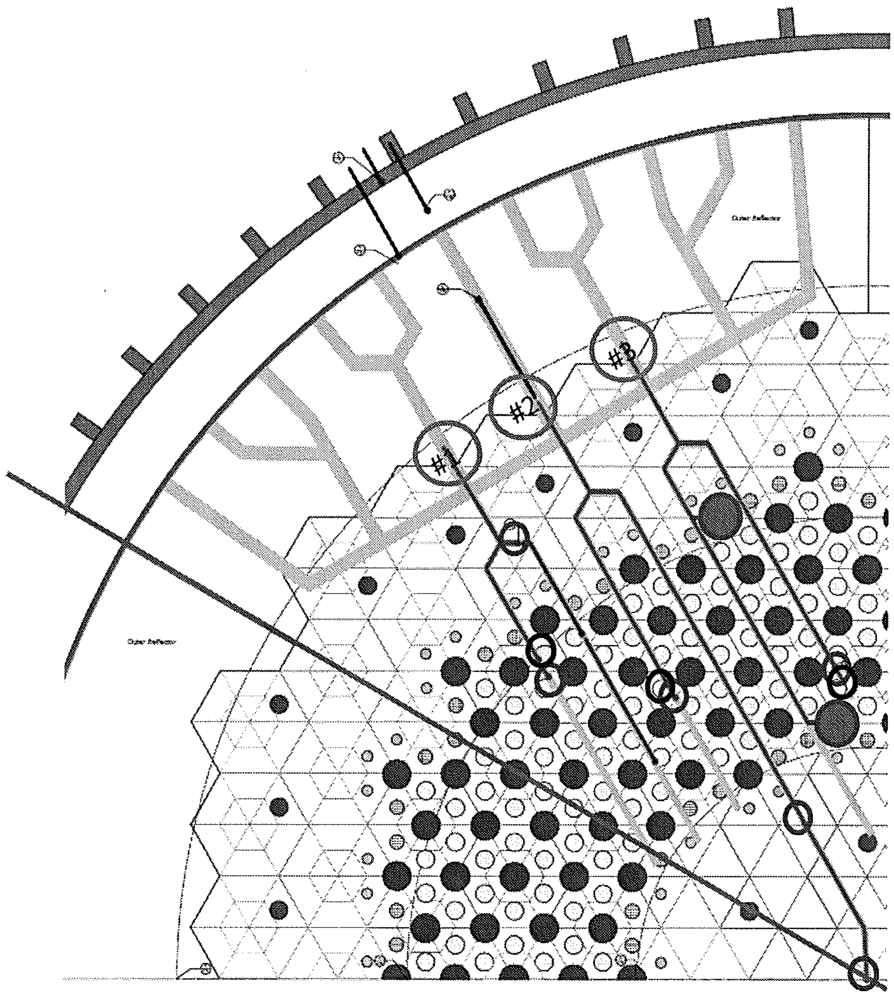

Figure 4-7: Primary 1/6th Sector Thermocouples for Axial Level 1

Ceramic Temperature TCs:

Gas Coolant Channel TCs:

K-type Cold-Junction Compensation TCs:

Instrumented Heater Rod:

In the Primary Sector, the Axial Levels 3, 5, 7 and 9 have the most instrumentation. These levels have 15 total thermocouples per level. They are in the radial positions shown in Table 4-2. Three CJC thermocouples are needed in all three voids, and these levels also have two heater rod instrumented to measure temperature.

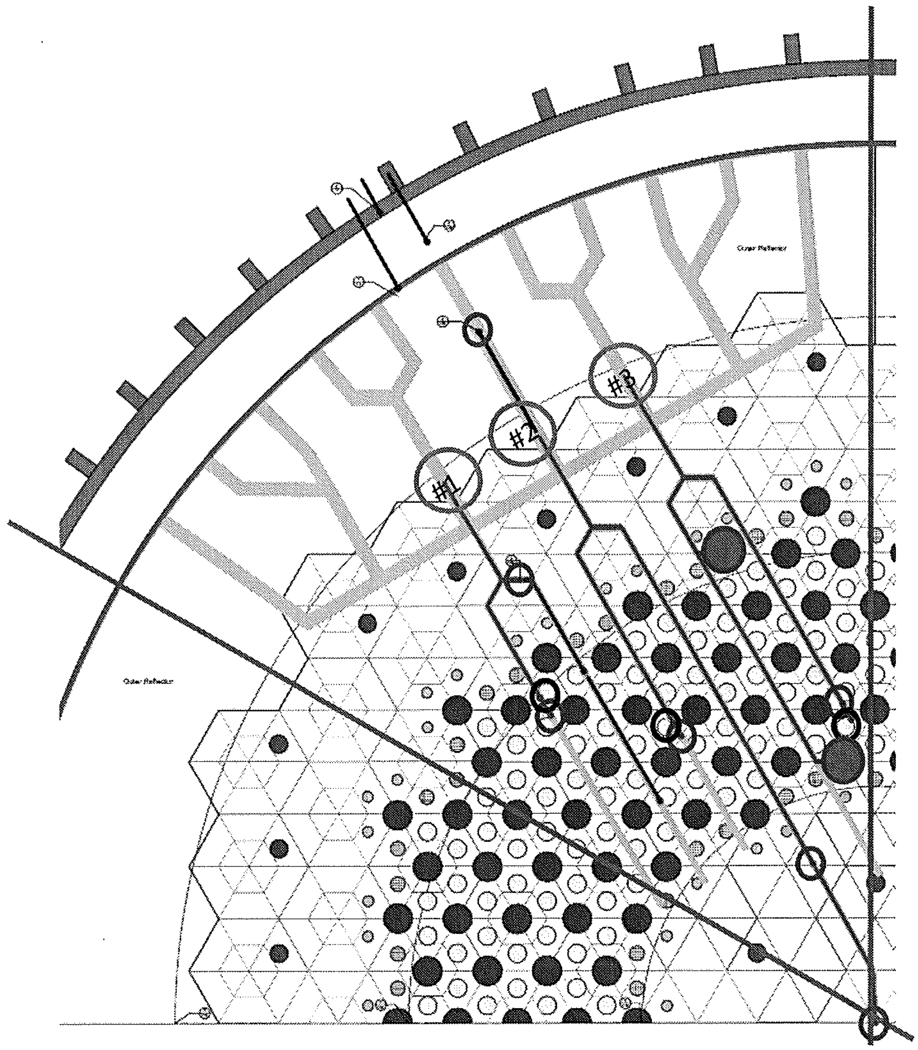

Figure 4-8: Primary 1/6th Sector Thermocouples for Axial Levels 3, 5, 7, and 9

Ceramic Temperature TCs:

Gas Coolant Channel TCs:

K-type Cold-Junction Compensation TCs:

Instrumented Heater Rod:

4.1.1.2 Secondary Sector Core Thermocouples

While the above figures detail where the thermocouples will be placed in the Primary Sector, there are additional thermocouples in the partially instrumented Secondary and Tertiary Sectors. In the Secondary Sector, which is the 1/6th section 60° counterclockwise from the inlet/outlet ducts, there are thermocouples placed in the same radial positions as those detailed in Table 4-2. These thermocouples are placed at axial levels 1, 3, 5 (core axial midplane), 7, 9, and 10.

On Axial Level 10, there is no access for instrumentation through the Primary Sector due to the heater banks. As such, the centerline temperature TC for axial level 10 has to have its one centerline TC routed through the Secondary Sector bulkheads. Due to the heater rod banks, the axial level 10 block has a unique mold shape to accommodate the heater banks; and as such, has different instrumentation channels than the other core blocks. The following figure shows how the instrumentation channels are cast and how the centerline thermocouple will be routed. 1 CJC TC is needed in this level, and it is located in Void #3.

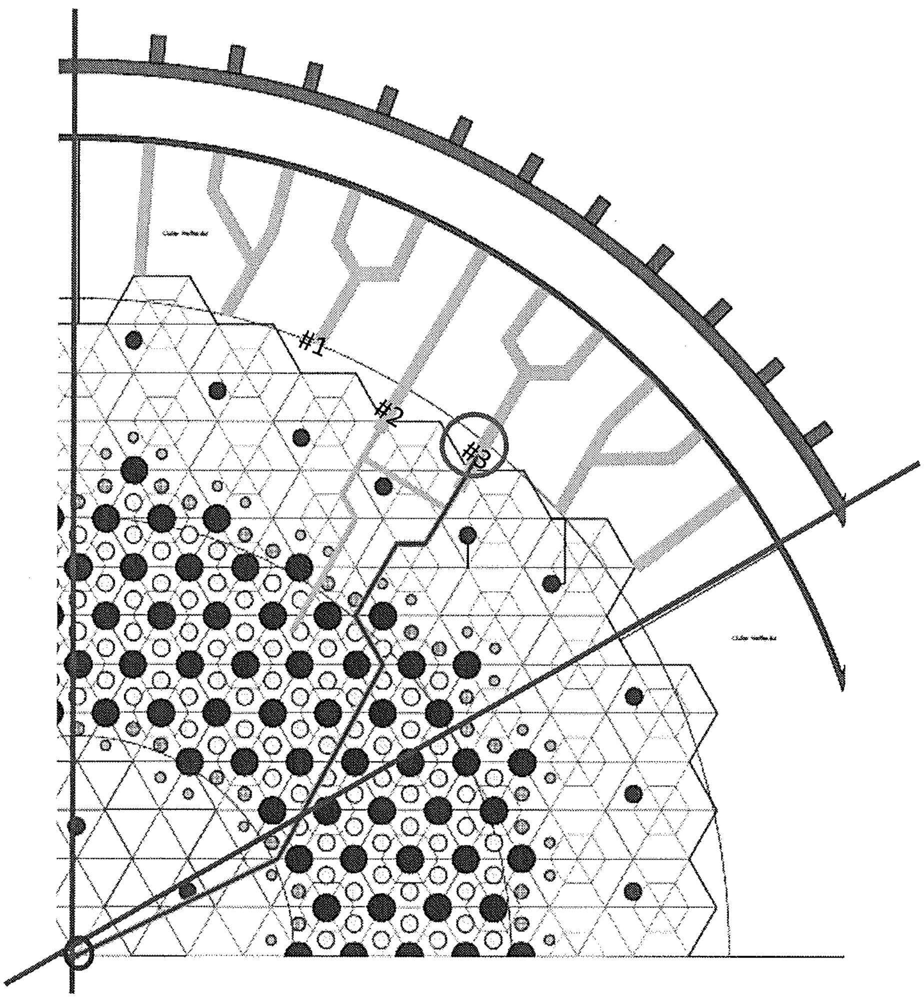

Figure 4-9: Secondary 1/6th Sector Thermocouples for Axial Level 10

Ceramic Temperature TCs: O

K-type Cold-Junction Compensation TCs: O

Axial Level 1 in the Secondary Sector has 13 thermocouples: 3 gas coolant channel TCs, 5 ceramic temperature TCs, 2 heater rod TCs, and 3 CJC TCs in Voids #1 through #3. Radial positions correspond to those in the Primary Sector.

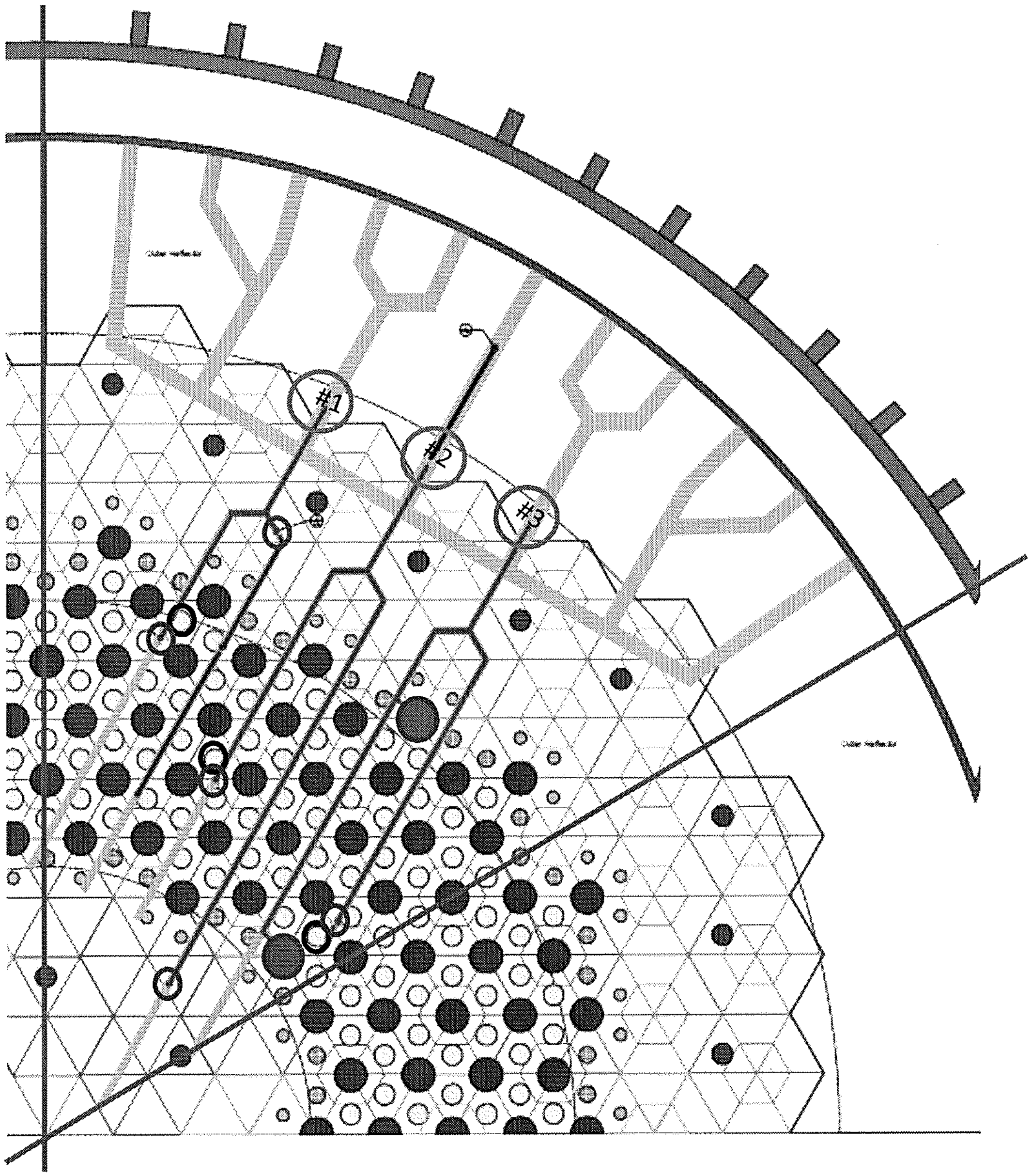

Figure 4-10: Secondary 1/6th Sector Thermocouples for the Axial Level 1

Gas Coolant Channel TCs: O

Ceramic Temperature TCs: O

K-type Cold-Junction Compensation TCs: O

In the Secondary Sector, axial levels 3, 5, 7, and 9 have the most instrumentation with 14 TCs. Like for Axial Level 1, there are 3 gas coolant channel thermocouples, shown by black circles in the figure below. There 6 ceramic temperature thermocouples (depicted by purple) per level. An additional two thermocouples are for heater rod temperature measurements. Three CJC thermocouples are needed in all voids.

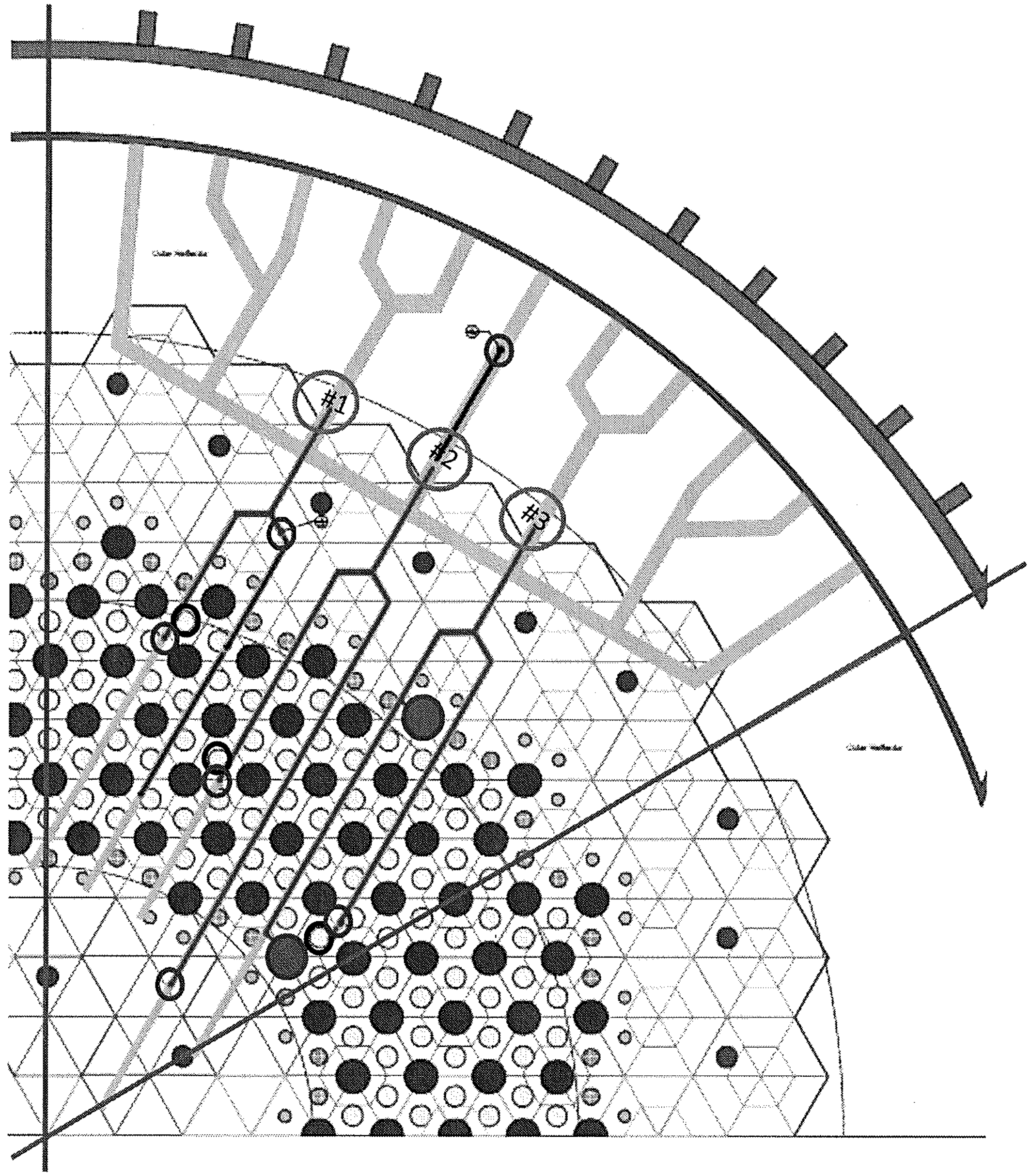

Figure 4-11: Secondary 1/6th Sector Thermocouples for Axial Levels 3, 5, 7, and 9

Ceramic Temperature TCs:

Gas Coolant Channel TCs:

K-type Cold-Junction Compensation TCs:

Instrumented Heater Rod:

4.1.1.3 Tertiary Sector Core Thermocouples

The following two figures will outline the thermocouple package in the Tertiary Sector. The Tertiary Sector is the 1/6th core section directly in-line with the inlet/outlet ducts, and it is located 180° from the Primary Sector.

Lower Reflector Block #3 has just 1 TC at the outer reflector. No CJC TC is necessary on this level since the outer reflector TC is K-type.

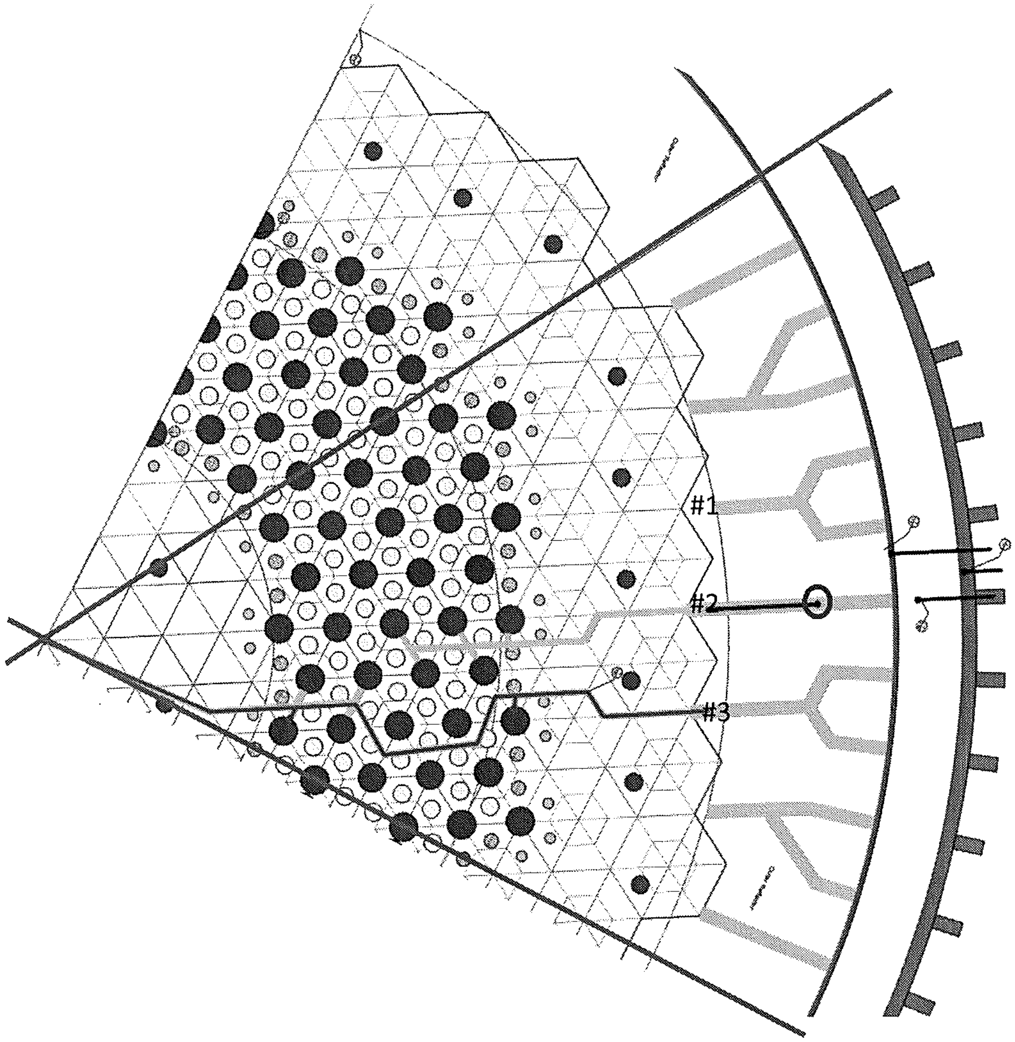

Figure 4-12: Tertiary 1/6th Sector Thermocouples for Lower Reflector Block #3

Ceramic Temperature TCs: O

Axial Level 1 has 3 TCs on it, which are the two heater rod temperature thermocouples and a CJC TC located in Void #3.

Axial Levels 3, 5, and 7 have the most instrumentation with 14 thermocouples in total. Radial locations correspond exactly to those presented in Figure 4-11 above.

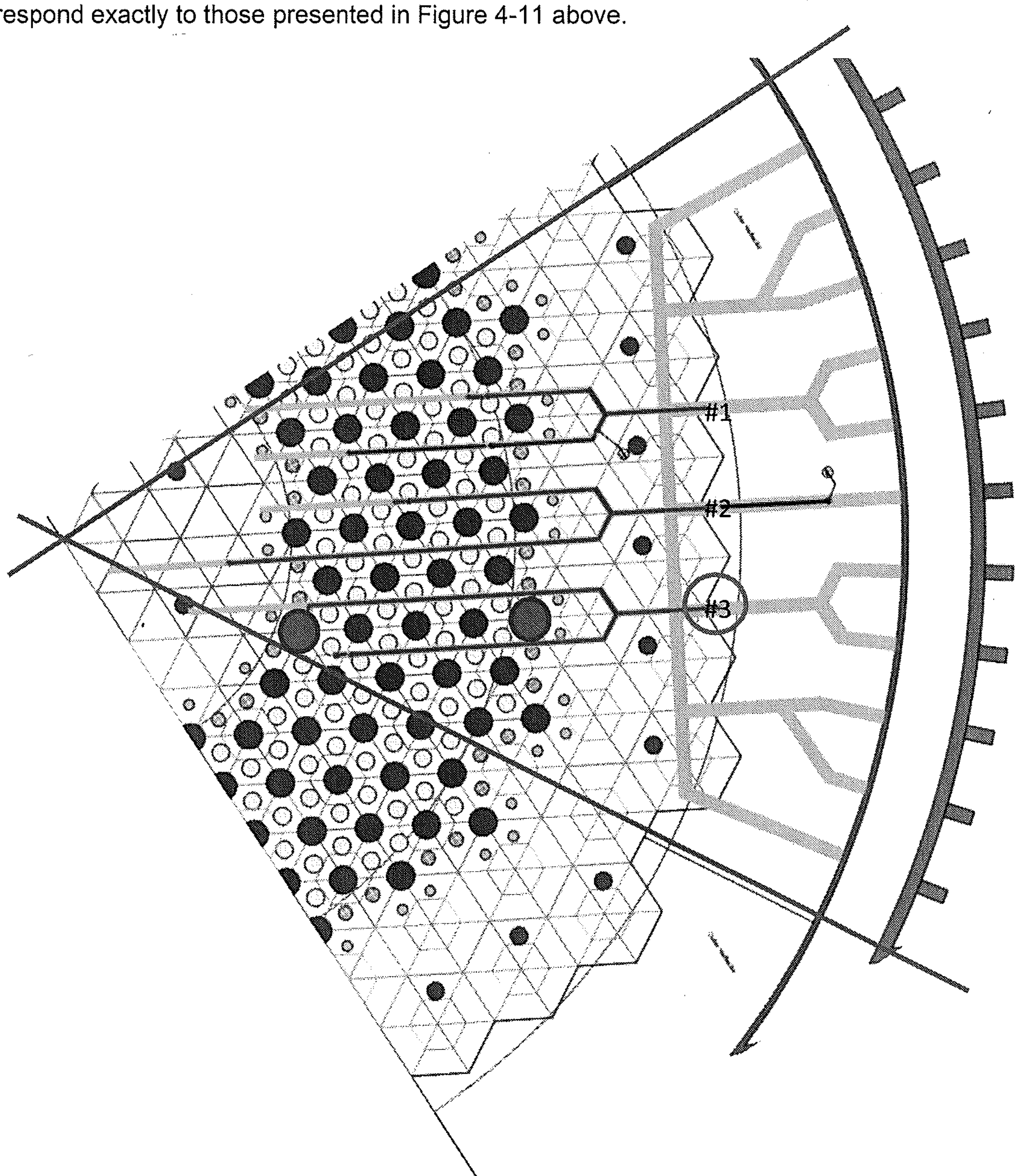

Figure 4-13: Tertiary 1/6th Sector Thermocouples for Axial Levels 1

K-type Cold-Junction Compensation TCs:

Instrumented Heater Rod:

Axial levels 3, 5, and 7 have the most instrumentation with 14 thermocouples in total. Radial locations correspond exactly to those presented in Figure 4-11 above.

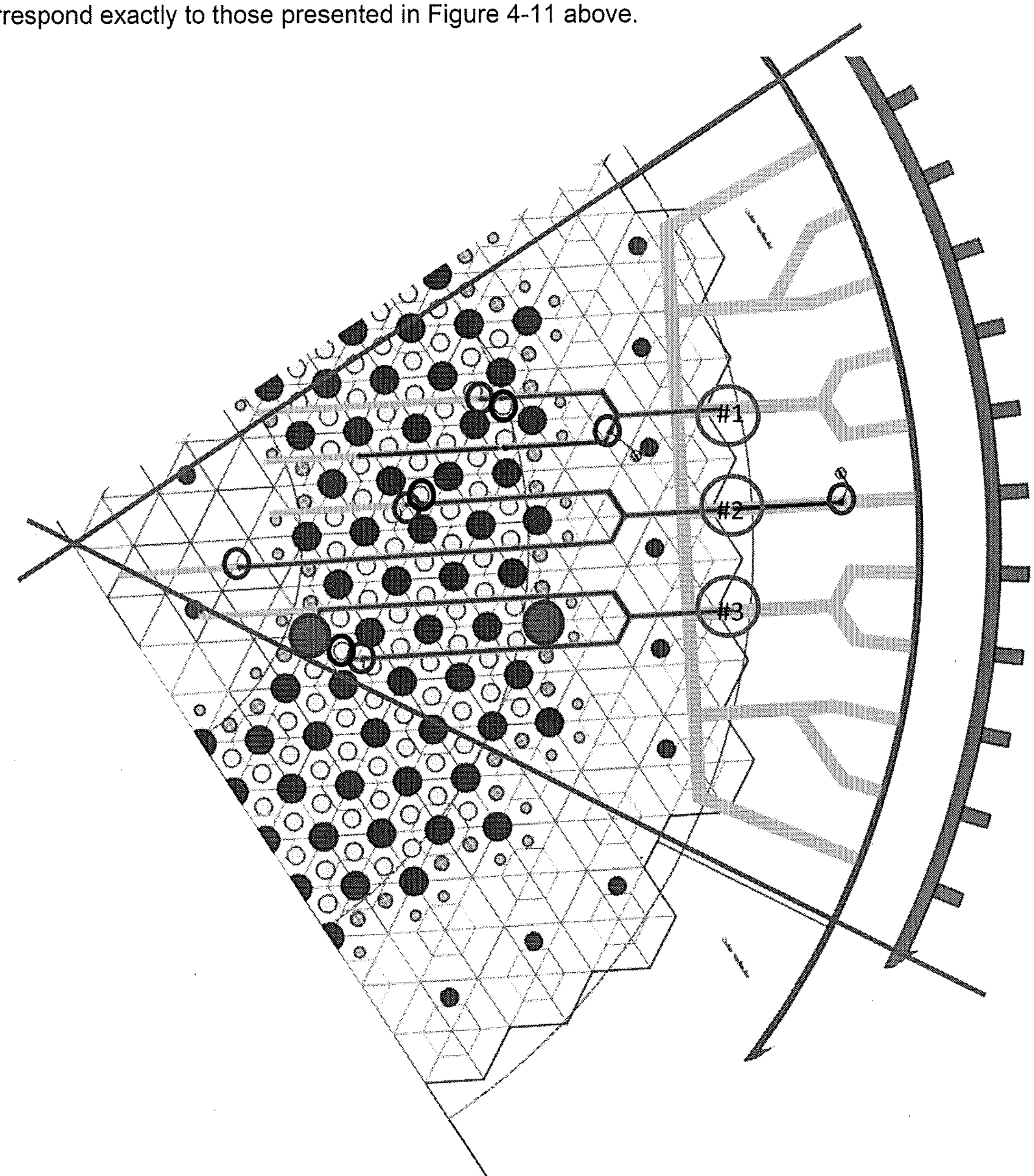

Figure 4-14: Tertiary 1/6th Sector Thermocouples for Axial Levels 3, 5, and 7

Ceramic Temperature TCs:

Gas Coolant Channel TCs:

K-type Cold-Junction Compensation TCs:

Instrumented Heater Rod:

To summarize the numbers of CJC TCs in the core, the following table shows their locations.

Table 4-3: Cold-Junction Compensation Thermocouple Locations

Axial Level	Location	# of CJC TCs	TC Type
Primary Sector CJC TCs			
LR #1	Void #2	1	K
LR #3	Void #3	1	K
Level 1	Void #1; Void #2; Void #3	3	K
Level 2	Void #2	1	K
Level 3	Void #1; Void #2; Void #3	3	K
Level 4	Void #2	1	K
Level 5	Void #1; Void #2; Void #3	3	K
Level 6	Void #2	1	K
Level 7	Void #1; Void #2; Void #3	3	K
Level 8	Void #2	1	K
Level 9	Void #1; Void #2; Void #3	3	K
Level 10	N/A	0	---
	TOTAL PRIMARY CJC TCs:	**21**	
Secondary Sector CJC TCs			
LR #1	N/A	0	---
LR #3	N/A	0	---
Level 1	Void #1; Void #2; Void #3	3	K
Level 2	N/A	0	---
Level 3	Void #1; Void #2; Void #3	3	K
Level 4	N/A	0	---
Level 5	Void #1; Void #2; Void #3	3	K
Level 6	N/A	0	---
Level 7	Void #1; Void #2; Void #3	3	K
Level 8	N/A	0	---
Level 9	Void #1; Void #2; Void #3	3	K
Level 10	Void #3	1	K
	TOTAL SECONDARY CJC TCs:	**16**	
Tertiary Sector CJC TCs			
LR #1	**N/A**	0	---
LR #3	N/A	0	---
Level 1	Void #3	1	K
Level 2	**N/A**	0	---

Level 3	Void #1; Void #2; Void #3	3	K
Level 4	**N/A**	0	---
Level 5	Void #1; Void #2; Void #3	3	K
Level 6	**N/A**	0	---
Level 7	Void #1; Void #2; Void #3	3	K
Level 8	**N/A**	0	---
Level 9	N/A	0	---
Level 10	**N/A**	0	---
	TOTAL TERTIARY CJC TCs:	**10**	
	TOTAL CJC TCs in VESSEL:	**47**	

4.1.2 Core Pressure Instruments

One coolant channel in the primary sector will be instrumented with a differential pressure transmitter (DPT) corresponding to upper and lower position pressure taps. Two vertical positions will be used for these instruments. The high position corresponds to above the orifice plate immediately below the upper plenum floor. The low position will be at the bottom of the core. Refer to the following figure for this location. To measure the pressure through the core, a differential pressure transmitter will be utilized. An overview of the pressure instrument locations is provided in Figure 4-39.

All pressure transmitters produce an analog out signal of 4-20 mA—4 mA pertaining the minimum range of the instrument and 20 mA for the maximum. This signal is picked up and recorded by the DAQ system. Refer to Table 5-1 for an overview of the number of 4-20 mA output instruments there are in the HTTF.

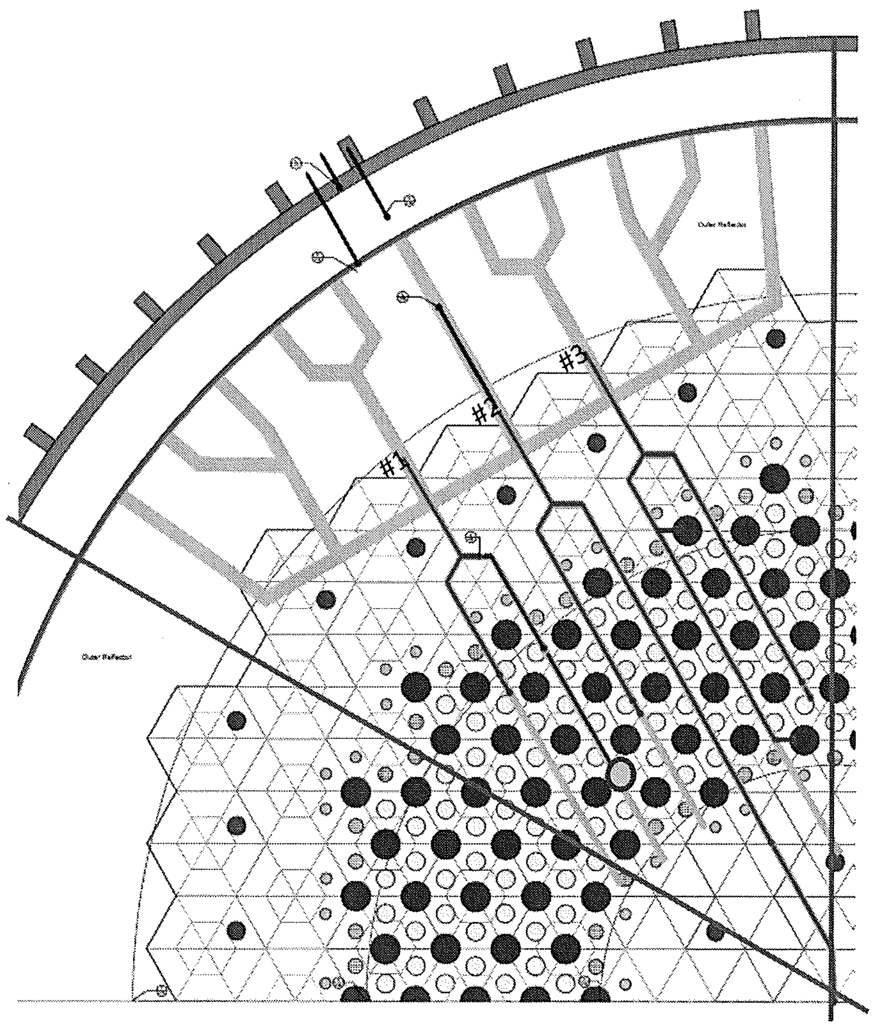

Figure 4-15: Differential Pressure Transmitter Location at Core Top and Bottom

4.1.3 Core Gas Concentration Instruments

Gas concentration instruments (GCI) measure the ratio of working to break gas, and they will be used in the Primary and Secondary Sectors of the core. In the Primary Sector, axial levels 1 through 9 and the Upper Plenum Floor are all instrumented with 1 GCI. However, GCI locations alternate between levels. For odd-numbered axial levels, the GCI measures the gas concentration for a coolant channel at normalized R=0.33. For the even-numbered axial levels and the upper plenum floor, a coolant channel at normalized R=0.485 is instrumented with a GCI. The following two figures detail the locations of these GCIs. The instrumented channel is denoted by a filled purple circle. Note that, like the thermocouple channels, these sensor wires are routed through a small, horizontal channel that is cast in the ceramic core blocks. (Refer back to Figure 4-3 for a relative depiction of instrumentation wiring into the core.) The sensor channel is depicted by a red line in the core figure below.

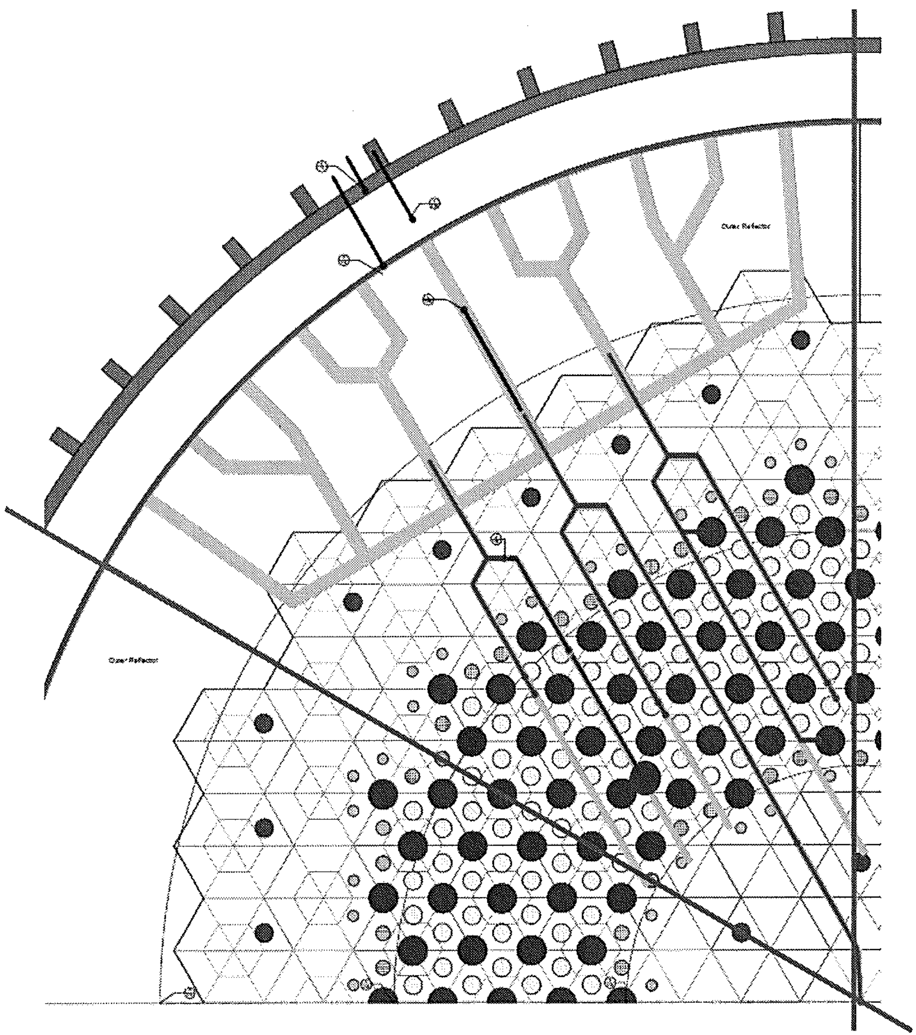

Figure 4-16: Primary 1/6th Section Gas Instruments in Instrumented Coolant Channel at Axial Levels 1, 3, 5, 7, and 9 ●

For the even-numbered axial levels, this location is shown below, resulting in 5 GCIs total at this channel.

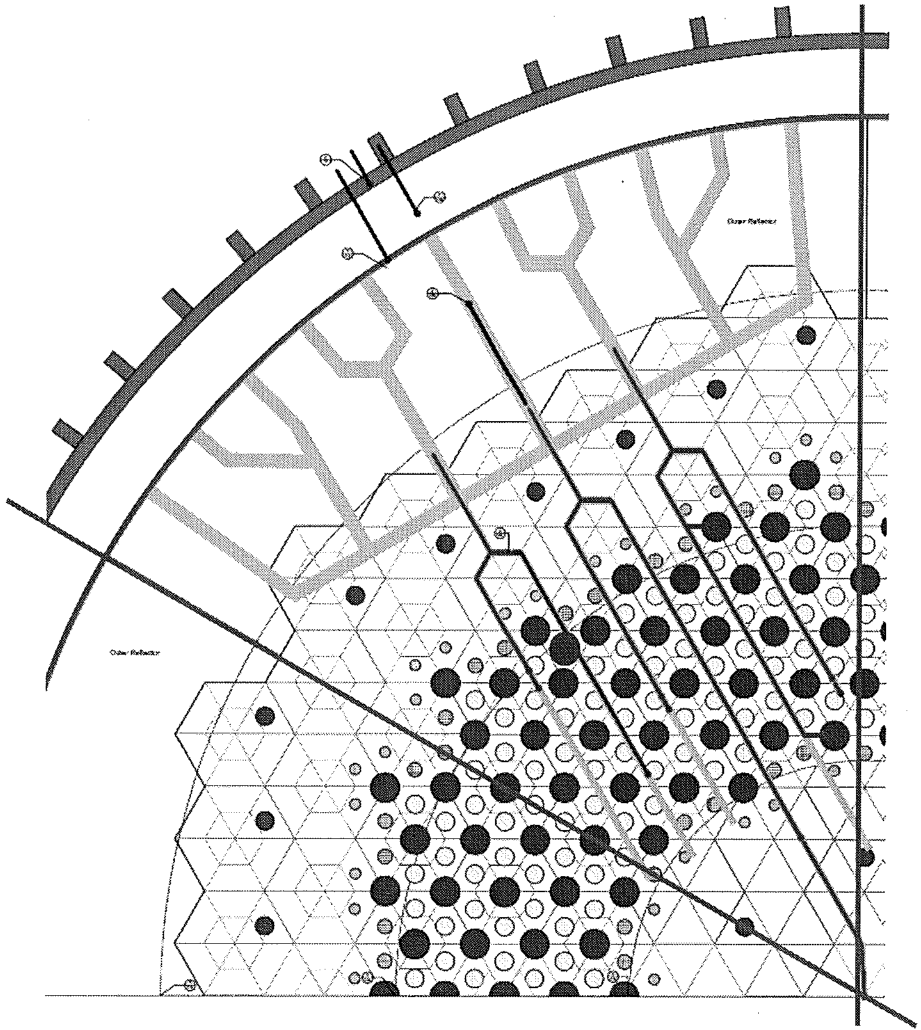

Figure 4-17: Primary 1/6th Section Gas Instruments in Instrumented Coolant Channel at Axial Levels 2, 4, 6, 8, and the Upper Plenum Floor ●

In the Secondary Sector, the GCI arrangement is identical to the odd-numbered axial level arrangement in the Primary Sector. Five GCIs are located in the coolant channel at the normalized R=0.33. The following figure shows this location.

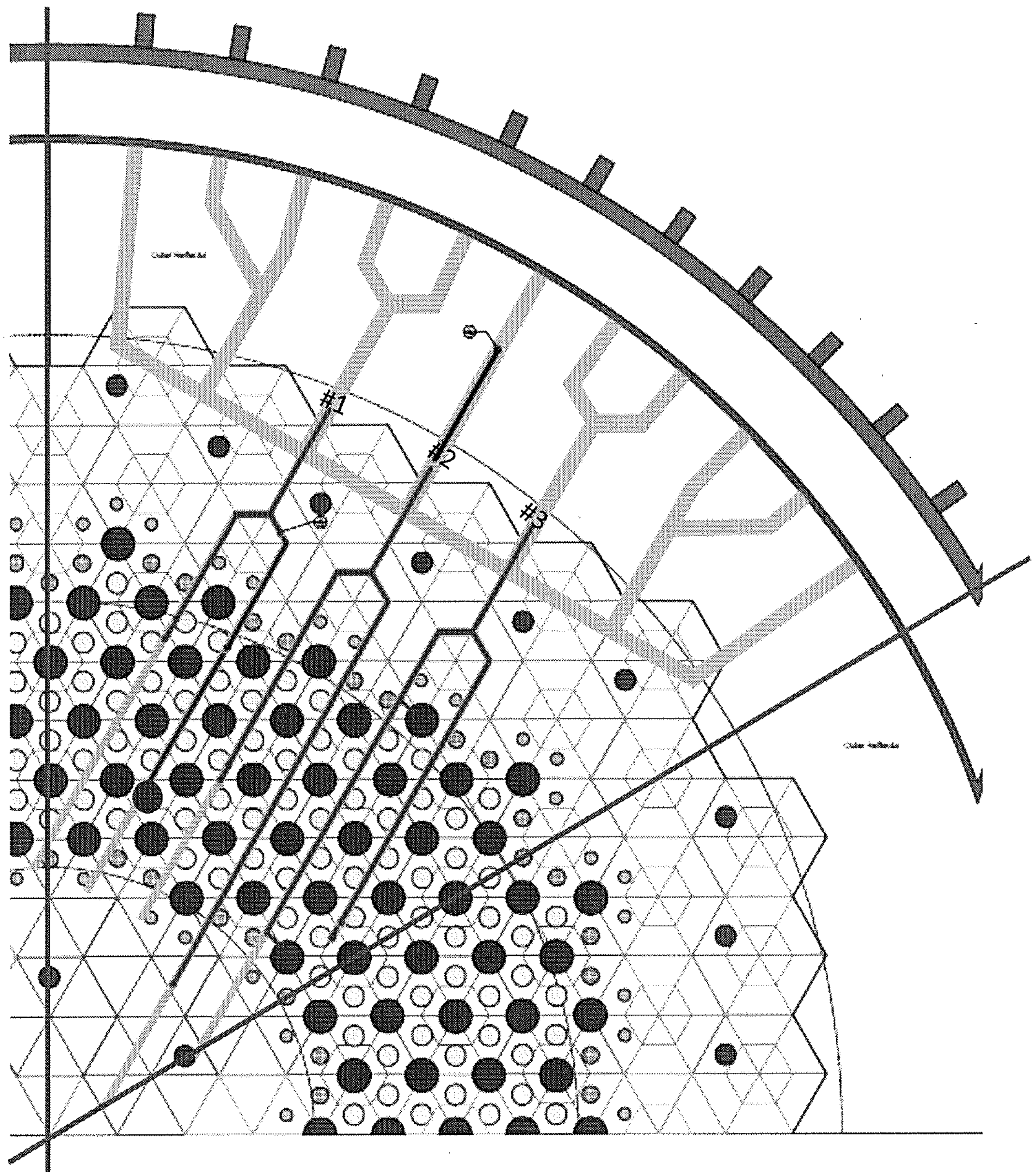

Figure 4-18: Secondary 1/6th Section Gas Instruments in Instrumented Coolant Channel at Axial Levels 1, 3, 5, 7, and 9

GCI instruments produce an analog voltage signal between -20 and 20 mV. This signal is in turn recorded and processed at the DAQ system. Table 5-1 provides a summary of the number of GCI signals the DAQ system is expected to handle.

4.1.4 Heater Rod Power Measurements

Measurements will be taken to characterize power output of the electric heater rods. This includes both current and voltage measurements. There are 210 electric heater rods controlled by 10 silicon-controlled rectifiers (SCRs). Seven Individual heater rods are connected in series to form a leg. Three legs make up the wye configuration for each SCR to utilize the 3-phase 480 VAC service available.

Voltage measurements will be made across two heater rods connected in series. There will be 10 total core voltage taps (1 tap per heater bank). Five core voltage taps are located in the Primary Sector, and the remaining five are in the Tertiary. One current measurement will be output from each of the SCRs.

4.2 UPPER PLENUM and UPPER HEAD REGION

This section details the thermocouple, pressure sensor, and gas concentration instrument instrumentation configuration in the facility's upper plenum and upper head region.

4.2.1 Upper Plenum Thermocouples

Thermocouples will be used in the upper plenum to give a basic thermal map of the gases. Thermocouples will be routed out of the plenum volume through the control rod guide tubes at different axial heights.

A total of 42 thermocouples will be used in the upper plenum and upper head region. Of these thermocouples, 24 TCs will be used to measure gas temperatures, 3 TCs will be used to measure the upper plenum shroud temperature, 3 TCs will be used to measure the upper head temperature, 10 TCs will be used to measure the upper plenum floor, and 2 TCs will be for control rod break lines. Refer to Figure 4-19 for a breakdown of the height locations of these thermocouples in the upper plenum. Locations and quantities are summarized in the table and figures below.

Solid material temperature thermocouples (denoted by purple circles in Figure 4-19) will measure the pressure vessel head and shroud temperatures. Six thermocouples will be placed at 3 different heights in the upper plenum corresponding to 33%, 66%, and the Upper Plenum Top. At each height, the shroud and vessel head temperatures will be measured. The percentage height always refers to percentage of the full plenum height at the center. Table 4-4 outlines the upper plenum thermocouple package.

Gas temperature thermocouples (denoted by black circles in Figure 4-19) will be routed through the guide tubes. In the upper plenum, the gas thermocouples will be placed at 33% and 66% the plenum height.

The gas thermocouple leads will run from the thermocouple junction up through the center of the guide tube and out of the vessel through the upper head. The thermocouples measuring solid material temperatures in the upper plenum shroud and vessel upper head will be routed out, similarly, through bulkheads in the upper head.

The control rod drive break line between the upper plenum of the pressure vessel and the Reactor Cavity Simulation Tank (RCST) contains 2 thermocouples equally spaced in the piping between vessels.

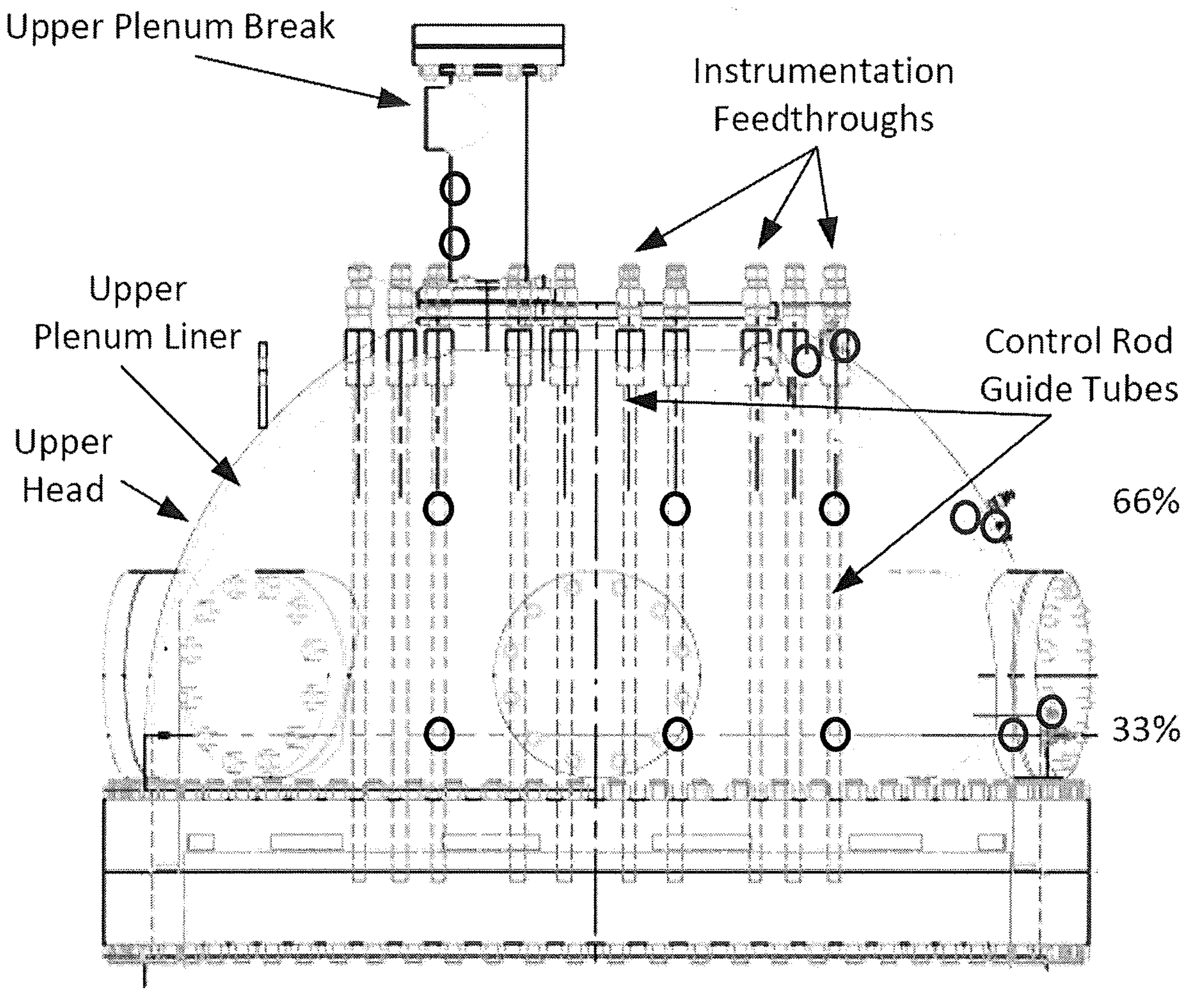

Figure 4-19: Relative Upper Plenum TC Locations (Not all Gas Temperature TCs are shown)

Solid Material Temperature TCs: O

Gas Temperature TCs: O

For the 24 gas temperature thermocouples in the upper plenum, there are 12 instrumented control rod drive tubes. The following figure shows a top-down view of the upper head, and the instrumented control rod drive tubes are circled in black. In the figure below, arrows point to the upper plenum head and shroud TC taps, which are also indicated by a purple circle. Two thermocouple taps exist at each purple circle. These taps exist over the Primary 1/6th Core Sector.

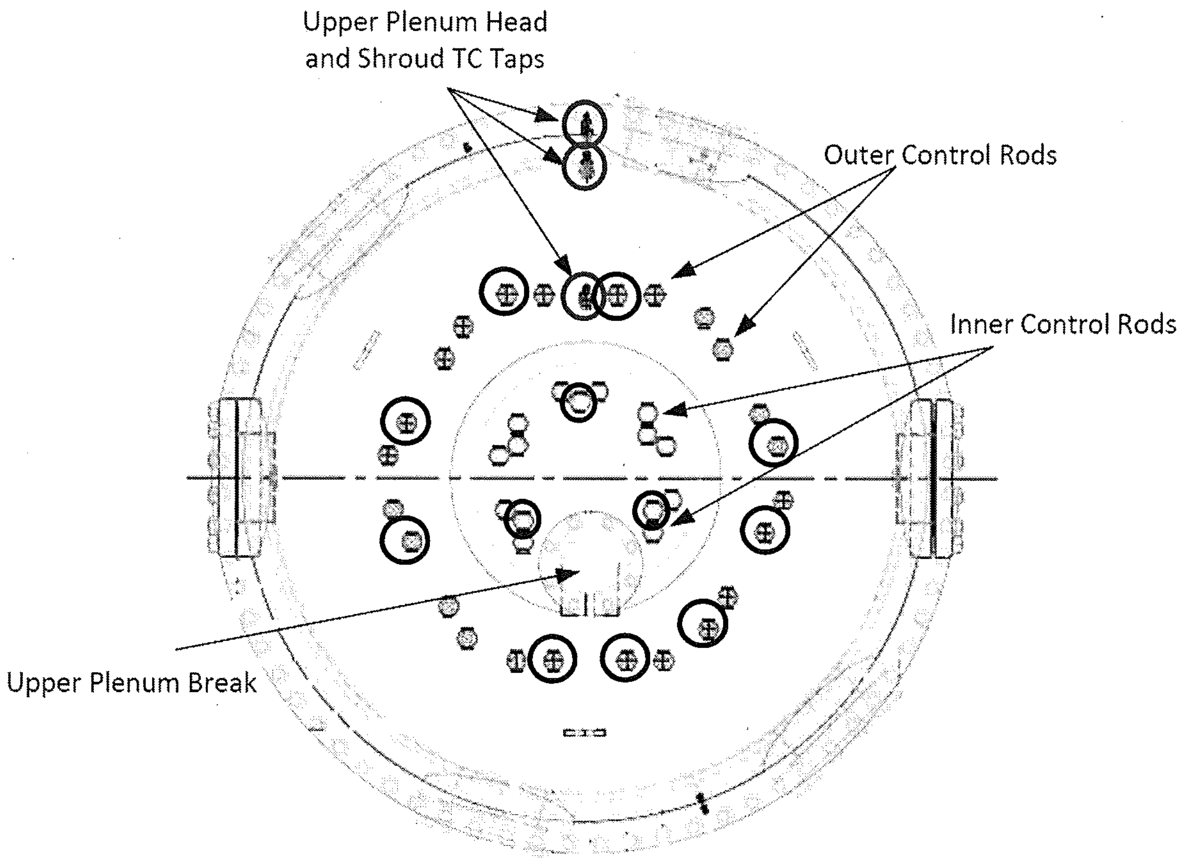

Figure 4-20: Relative Upper Plenum TC Locations (Not all Gas Temperature TCs are shown)
Solid Material Temperature TCs: O

Gas Temperature TCs: O

For the upper plenum floor, there are 10 thermocouples that will be dedicated to measuring gas temperatures, centerline and solid temperatures. All thermocouples are located in the same radial positions listed under Table 4-2 and located in the Primary Sector. Three thermocouples will be placed to measure gas coolant channel temperatures (depicted by black circles). Seven thermocouples will be used to measure the ceramic temperature thermocouples, shown in purple. Note there are no CJC TCs in the upper plenum floor since all floor TCs here are K-type. See Figure 4-21 for a view of the upper plenum floor instrumentation. Table 4-4 below will also summarize the entire upper plenum thermocouple package.

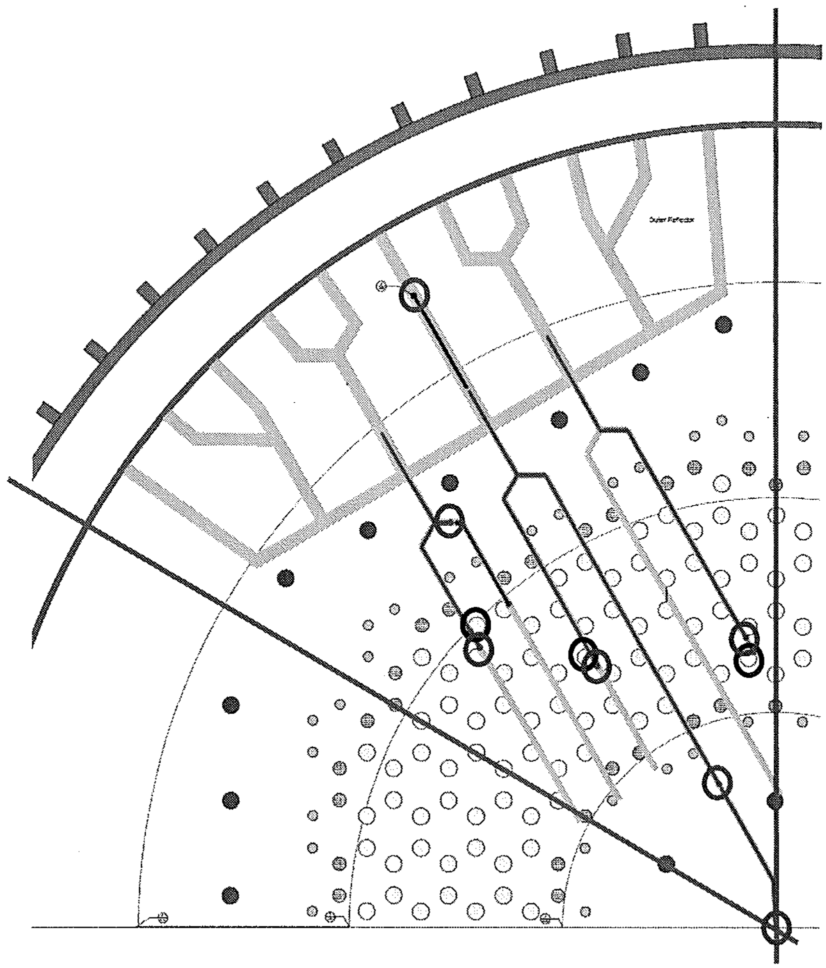

Figure 4-21: Upper Plenum Floor Thermocouple Placement

K-type Solid Material Temperature TCs: O

K-type Gas Coolant Channel TCs: O

Table 4-4: Upper Plenum Thermocouples (Gas, Material, and Control Rod Break Line TCs)

Part Number	Location	Measured State	TC Type
	Primary $1/6^{th}$ Sector		
Upper Plenum Floor:			
	Plenum Floor, Outer Reflector (R=0.85)*	Solid	K
	Plenum Floor (R=0.600)	Solid	K
	Plenum Floor (R=0.475)	Solid	K
	Plenum Floor (R=0.365)	Solid	K
	Plenum Floor (R=0.338)	Solid	K
	Plenum Floor, Inner Reflector (R=0.18)	Solid	K
	Plenum Floor, Centerline (R=0.00)	Solid	K
	Plenum Floor, Gas Channel (R=0.493)	Gas	K
	Plenum Floor, Gas Channel (R=0.383)	Gas	K
	Plenum Floor, Gas Channel (R=0.320)	Gas	K
Gas Temperature Thermocouples:			
	Gas Channel 1, H=33%**	Gas	K
	Gas Channel 1, H=66%	Gas	K

	Gas Channel 2, H=33%	Gas	K
	Gas Channel 2, H=66%	Gas	K
	Gas Channel 3, H=33%	Gas	K
	Gas Channel 3, H=66%	Gas	K
	Gas Channel 4, H=33%	Gas	K
	Gas Channel 4, H=66%	Gas	K
	Gas Channel 5, H=33%	Gas	K
	Gas Channel 5, H=66%	Gas	K
	Gas Channel 6, H=33%	Gas	K
	Gas Channel 6, H=66%	Gas	K
	Gas Channel 7, H=33%	Gas	K
	Gas Channel 7, H=66%	Gas	K
	Gas Channel 8, H=33%	Gas	K
	Gas Channel 8, H=66%	Gas	K
	Gas Channel 9, H=33%	Gas	K
	Gas Channel 9, H=66%	Gas	K
	Gas Channel 10, H=33%	Gas	K
	Gas Channel 10, H=66%	Gas	K
	Gas Channel 11, H=33%	Gas	K
	Gas Channel 11, H=66%	Gas	K
	Gas Channel 12, H=33%	Gas	K
	Gas Channel 12, H=66%	Gas	K
Upper Plenum Shroud, Vessel, and Break TCs:			
	2 Wall TCs: H=33%	Solid	K
	2 Wall TCs: H=66%	Solid	K
	2 Wall TCs: Upper Plenum Top	Solid	K
	2 Control Rod Break Line TCs	Gas	K
		Total thermocouples in upper plenum:	42

* R refers to a projected radius of the upper plenum shroud or upper head respectively. R=1.0 corresponds to the radius of each component respectively.

** H refers to a normalized height location in the upper plenum. H=1.0 is the height from the top of the upper plenum floor to the upper plenum shroud for the inner ring guide tubes.

4.2.2 Upper Plenum Pressure Sensors

One pressure tap will be placed at the top of the upper plenum. This pressure tap is connected to a differential pressure transducer, with its reference line being a pressure tap at the vessel inlet (i.e. cold leg). Refer to Figure 4-39 for an overview of all pressure tap locations in the vessel.

4.2.3 Upper Plenum Gas Concentration Instruments

Gas instruments will be routed similarly to the thermocouples through control rod guide tubes. Three control rod guide tubes will be instrumented with GCIs. In each control rod guide tube, two gas concentration instruments will be placed at H=33% and H=66% the upper plenum height. The following figure outlines which control rod guide tubes are instrumented with gas concentration sensors. Red circles denote approximate sensor locations. GCIs will be positioned on the outside of the control rod tubes; wires will run up through the tube and out the vessel.

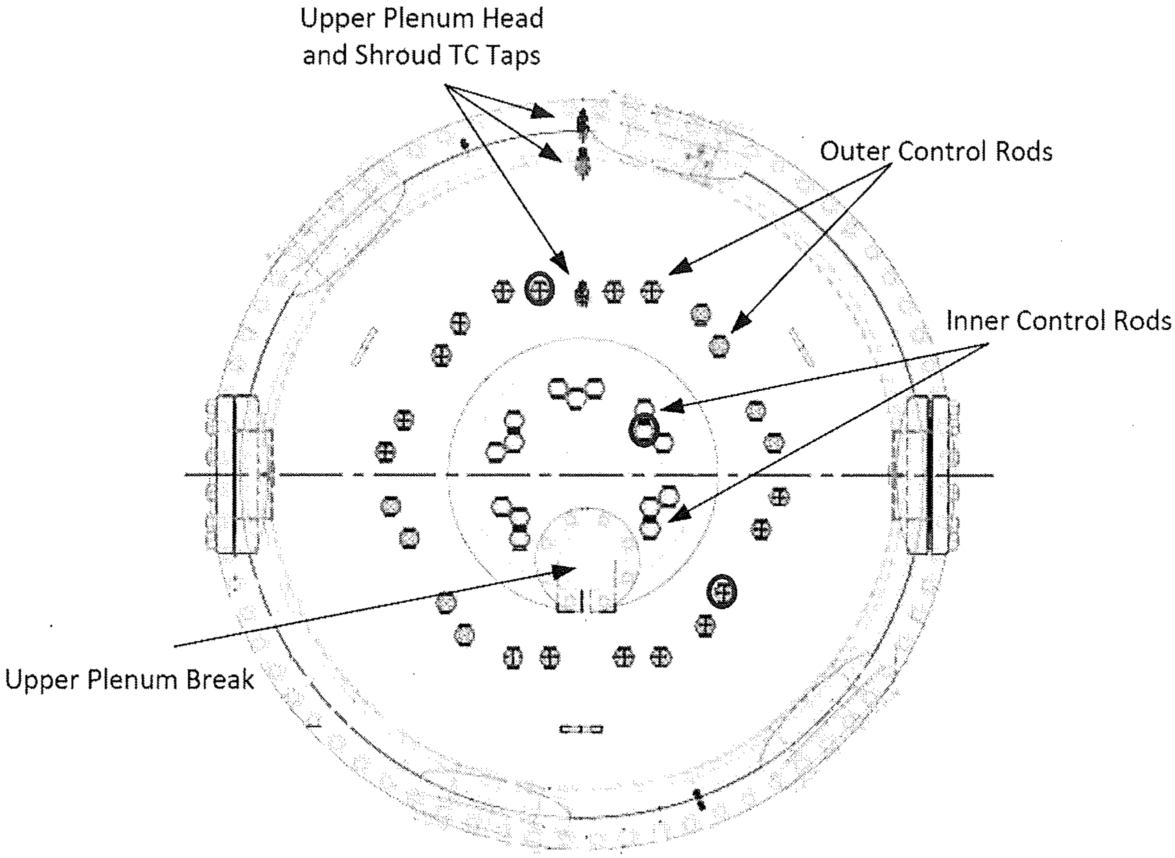

Figure 4-22: Upper Plenum GCI Locations
Instrumented Control Rod Guide Tube (2 GCIs per guide tube at 33% and 66% Upper Plenum Height: O

Two instrumented guide tubes are in the outer ring of control rods whereas only one of the inner ring guide tubes is instrumented. In addition, one gas sensor will be located in the control rod break line between the pressure vessel and the Reactor Cavity Simulation Tank at a position corresponding to a break line thermocouple.

4.3 LOWER PLENUM and LOWER HEAD

The lower plenum thermocouple, pressure sensor, and gas concentration sensor instrumentation configuration is discussed in this section.

4.3.1 Lower Plenum Thermocouples

Lower plenum thermocouples can be categorized by three types: gas thermocouples at distinct plenum heights, ceramic temperature thermocouples in the lower plenum floor, and gas thermocouples at the exit of the transition block. The gas thermocouples will be placed in the lower plenum much in the same way as the upper plenum. These will be routed through the center of specific ceramic support rods where the junctions will protrude out of the support rods to measure the gas temperature. The relative wiring for the lower plenum is shown in the figure below. Thermocouples at different heights of the support columns will be useful for both mixing studies and for the air ingress experiment due to the colder gas temperature of the ingressed gas.

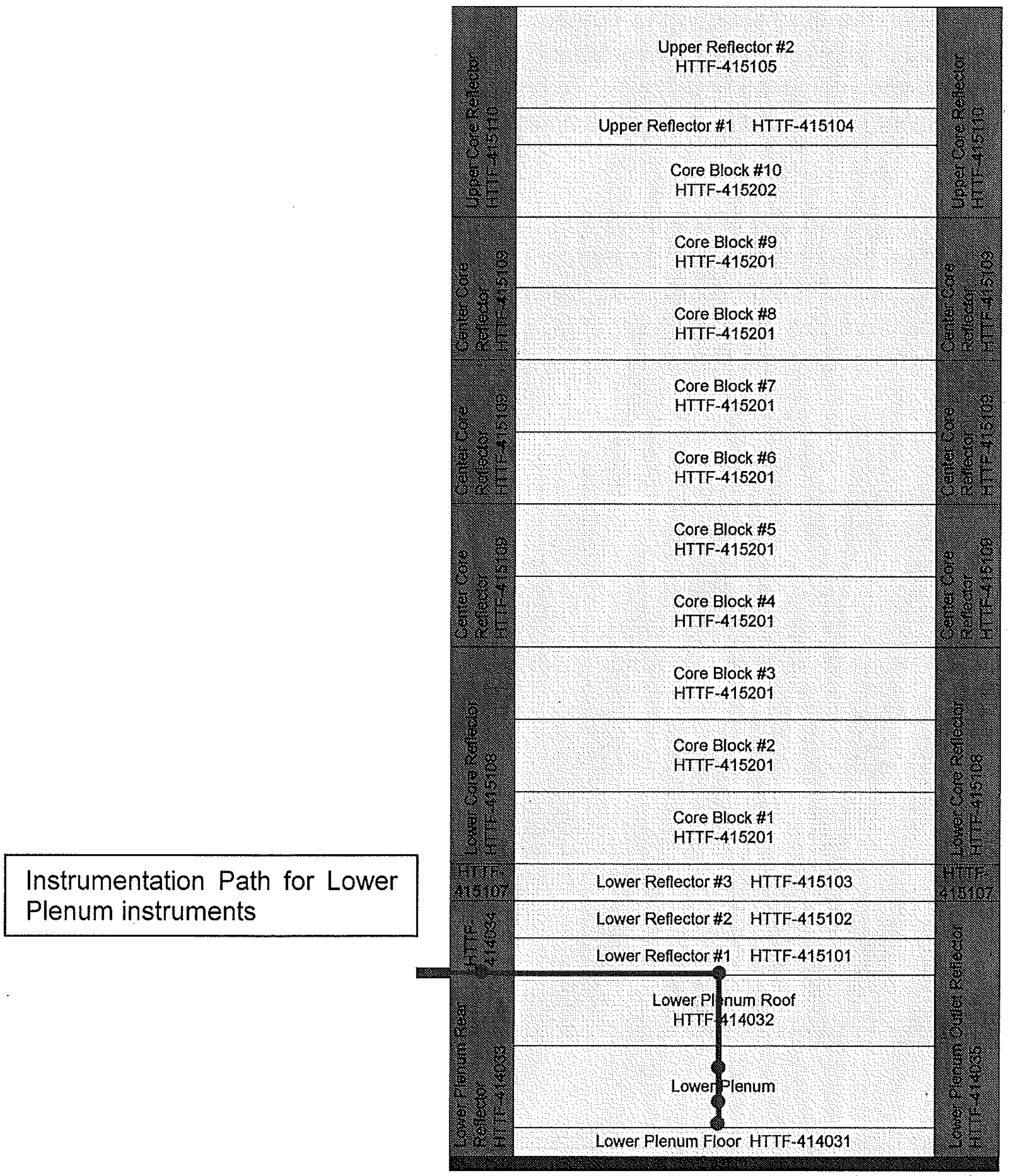

Figure 4-23: Axial Cross-Sectional Diagram of the Ceramic Component Orientation within the HTTF RPV (Drawn to Scale): Red lines indicate lower plenum instrumentation wiring

The instrumentation bulkheads for the lower plenum are on the side of the vessel that is opposite the inlet/outlet ducts. These bulkheads are also located 8 inches below the instrumentation bulkheads used for the core instrument wires in the Primary Sector.

There are a total of 163 lower plenum support posts, although only 16 of them are catered for thermocouples. In these 16 columns, two voids are present in the molds, which allow for thermocouple junctions to protrude into the plenum at 25% and 75% the lower plenum height. These voids are one one-quarter of an inch in diameter, and for reference, the K-type thermocouple has a diameter of one-eighth of an inch. All of these 16 columns will be instrumented with thermocouples at these two elevations.

There are a total of 62 thermocouples in the lower plenum, and they are all K-type. 58 of these thermocouples are routed out through the bulkheads in the Primary Sector (and shown schematically in Figure 4-23 above). The two primary phenomena to be characterized by lower plenum thermocouples are air ingress behavior, and jet mixing and impingement behavior. To characterize air ingress, stratified flow and gas temperatures, TCs are placed at 16 locations corresponding to the TC void posts described in the previous paragraph.

At 12 of these columns, in addition to the two gas temperature thermocouples at 25% and 75% the lower plenum height, there are also a lower plenum inlet gas temperature thermocouple and a lower plenum floor thermocouple. These twelve groups of thermocouples are called jet characterization thermocouples as they measure the temperature from the inlet to roof of a single jet. There are, thus, 48 jet characterization thermocouples, in total, and the following figure details how the jet characterization thermocouples are arranged.

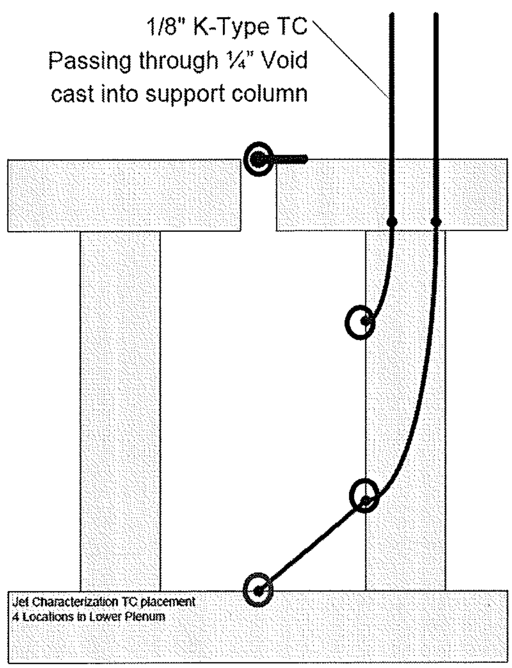

Figure 4-24: Elevation Layout for Jet Characterization TCs (Jet Inlet, 25% and 75% Plenum Height, and two below Jet Plenum Floor)

Gas Temperature Thermocouples (Plenum Inlet, and at 25% and 75% Plenum Height) TCs: O

Lower Plenum Solid Material Thermocouple (Lower Plenum Floor): O

The remaining 2 TCs to be routed out the Primary Sector bulkheads read reflector material temperatures. The following figure will show the locations of these 58 TCs in the lower plenum, and Table 4-5 summarizes the lower plenum thermocouples.

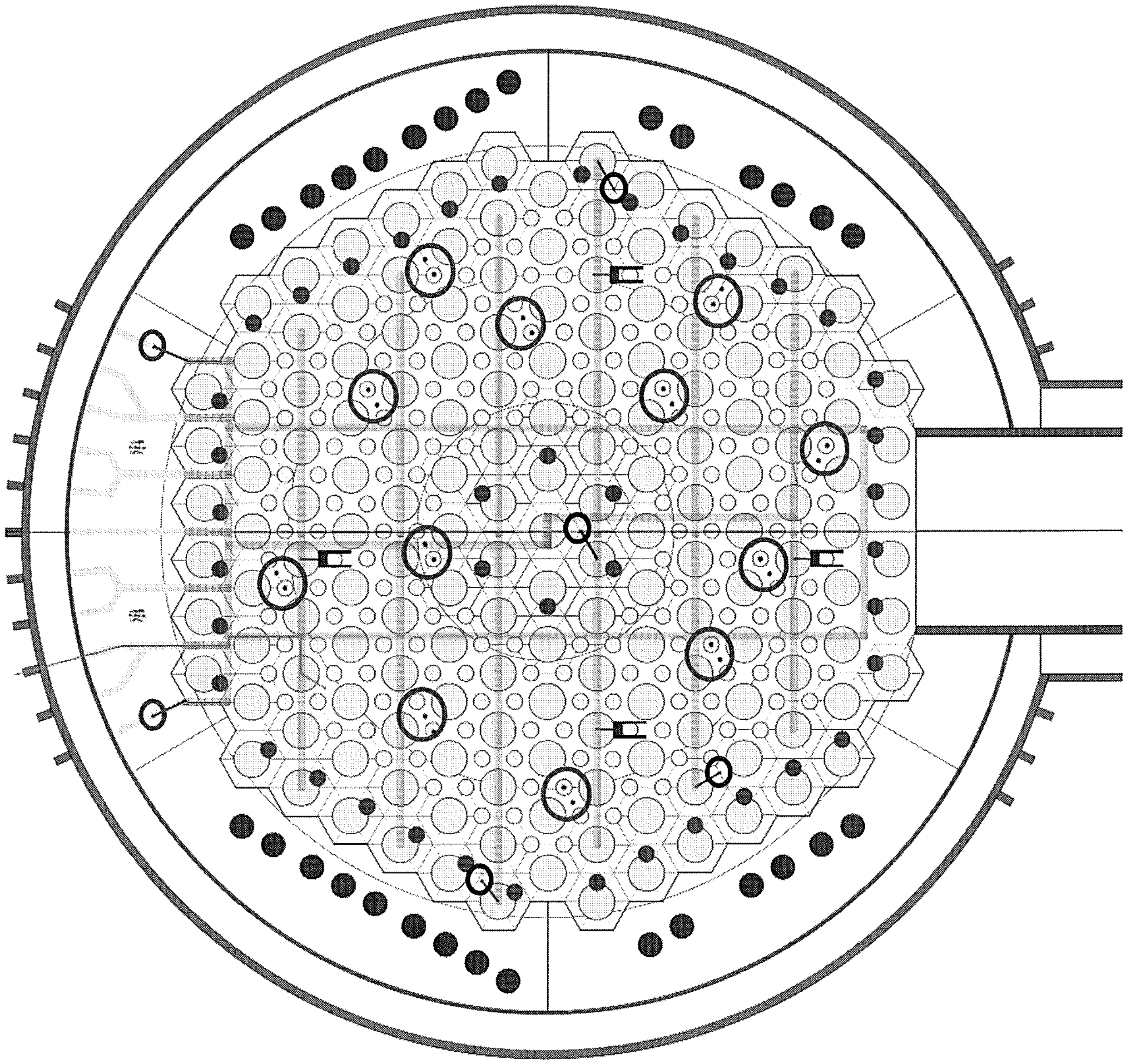

Figure 4-25: Lower Plenum Thermocouple Locations

Reflector Temperature TCs: O

Lower Plenum Height Gas TCs (25% and 75% Heights—2 TCs per circle): O

Jet Characterization and Lower Plenum Floor TCs (4 TCs per circle): O

Table 4-5: Lower Plenum Thermocouples.

Part Number	Location	Model
	All Lower Plenum TCs	K
	Lower Plenum Gas TCs	32
	Lower Plenum Inlet Gas TCs	12
	Lower Plenum Floor TCs	12
	Lower Plenum Side Reflector TCs	2
Total TCs in lower plenum		58

4.3.2 Lower Plenum Pressure Taps

One pressure tap will be placed in the lower plenum, located near the edge of the lower plenum on the side opposite the inlet/outlet ducts. This pressure tap will be connected to a DPT with it reference line being the vessel inlet pressure. Figure 4-26 below shows the location of this pressure tap (depicted by an orange circle).

4.3.3 Lower Plenum Gas Concentration Instruments

Gas sensors will be placed in the lower plenum similarly to the thermocouples—through support rods. Each instrumented rod will have a low and high elevation position at 25% and 75% the lower plenum height. Four support columns will be instrumented for a total of 8 sensors. Figure 4-26 shows the configuration below (depicted by red circles). Figure 4-27 shows the height layout of the gas sensors and the gas temperature TCs in the lower plenum, at 25% and 75% the lower plenum height.

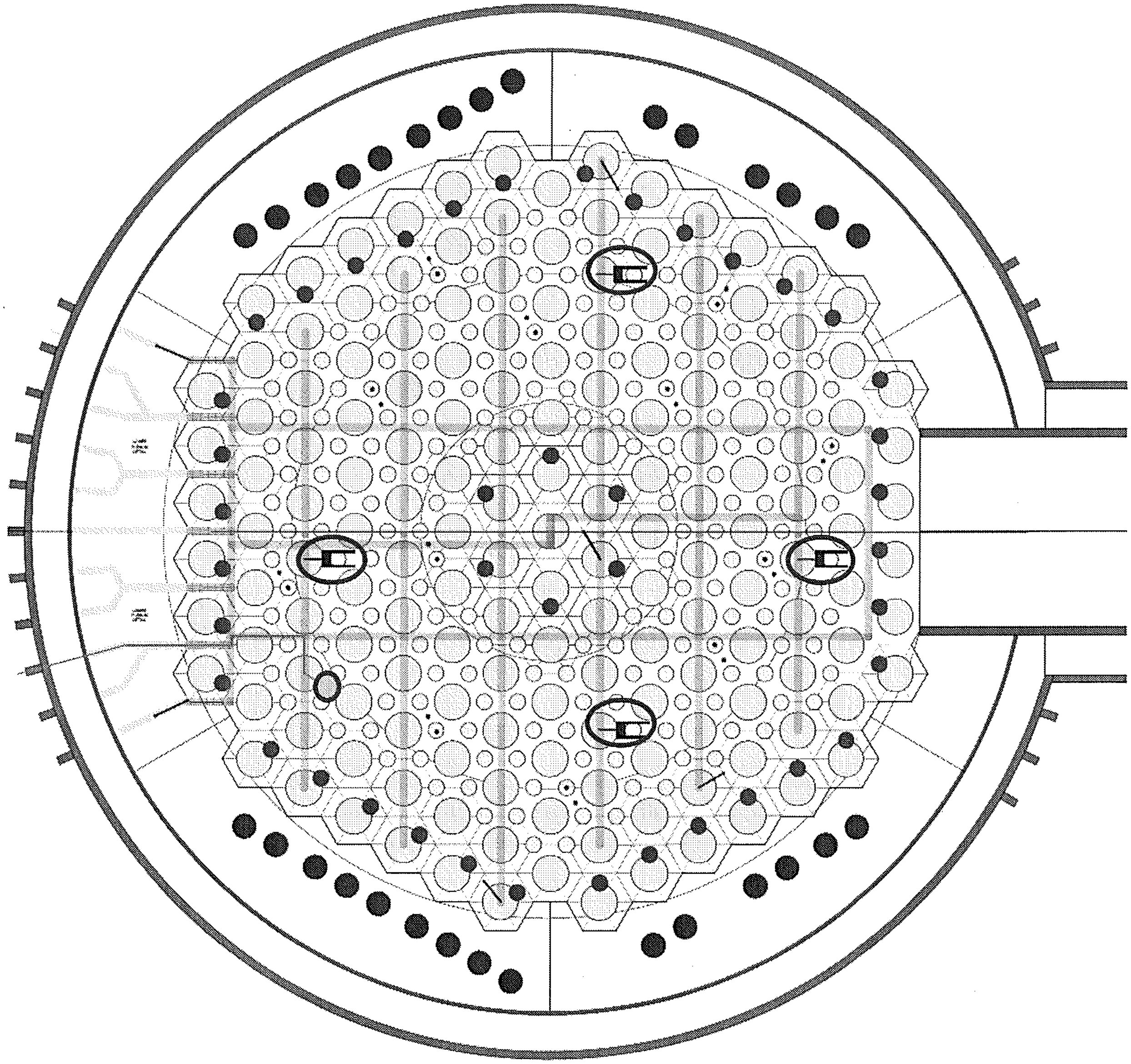

Figure 4-26: Lower Plenum Gas Sensor and Pressure Tap Locations

GCI Locations (2 per circle at 25% and 75% Lower Plenum Height): O

Static Pressure Tap: O

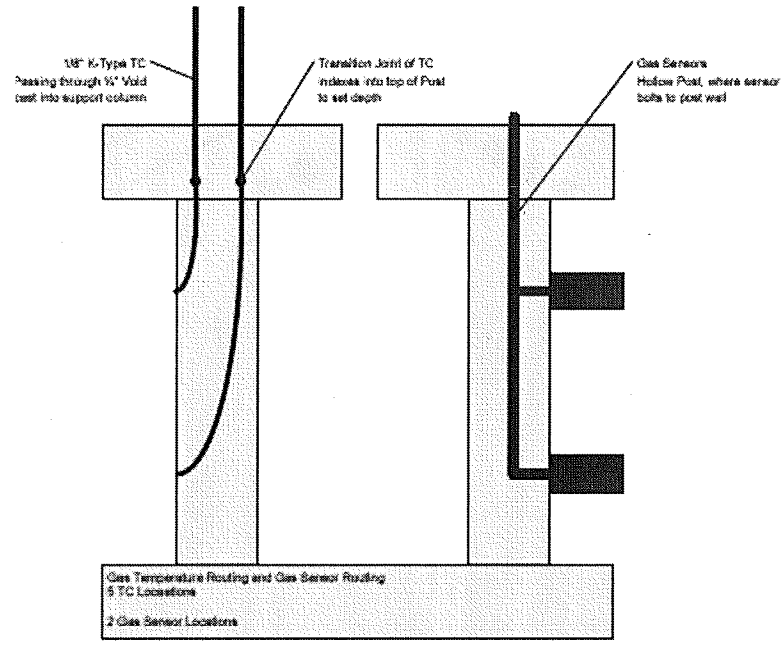

Figure 4-27: Elevation Layout for Gas Sensors and Gas Temperature TCs (at 25% and 75% the Lower Plenum Height)

4.3.4 Lower Head Instrumentation

The lower head instrumentation breakline will contain two thermocouples in the line between the pressure vessel and RCST. These thermocouples will be evenly spaced between the vessels. This line will also contain one GCI at a location corresponding to a break line thermocouple. Two thermocouples will also measure the lower head temperature.

4.3.5 Metallic Core Support Structure Instrumentation

In the Metallic Core Support Structure (MCCS), there are two K-type TCs. These TCs are important for the safety of the facility, because they measure the structures temperature.

There is also 1 pressure tap in the MCCS, which is dedicated to a single DPT instrument for pressure measurement. This tap is connected to a tap at the inlet of the vessel, and Figure 4-39 shows an overview of all the pressure instruments on the vessel.

4.4 CYLINDRICAL SECTIONS (Including Upcomer, Core Barrel, Outer Vessel Wall)

This section details the thermocouple, pressure sensor, and gas sensor instrumentation configuration in the cylindrical section of the vessel.

4.4.1 Cylindrical Section Thermocouples

Upcomer gas temperatures, core barrel, and vessel wall temperatures will be measured along the axial length of the pressure vessel. These thermocouples in the cylinder correspond to the Primary Sector at the Lower Reflector Block #3, and at axial levels 3, 5, 7 and axial level 10. Table 4-6 outlines the cylindrical section thermocouple package.

Lower Reflector Block #3 and axial level 10 contain three thermocouples each. These correspond to the outer core barrel TC (denoted by a pink circle in Figure 4-28), an outer reactor vessel TC (denoted by a purple circle in Figure 4-28), and an upcomer thermocouple, which is shown in yellow in the figure below.

Cylindrical section thermocouples enter the upcomer via bulkheads on the reactor vessel. A 1/8" bulkhead is located at axial levels Lower Reflector #3, 3, 5, 7, and 10. The size of this bulkhead can accommodate both the upcomer TC and the outer core barrel TC. Thermocouples will be inserted into these bulkheads. The upcomer TC will be placed halfway between the vessel wall and the core barrel.

At axial levels 3, 5, and 7, there is another 1/8" bulkhead which will be used for the inner reactor vessel temperature reading. At these levels, a TC will be inserted to the upcomer and placed against the wall. On all instrumented levels (Lower Reflector #3, 3, 5, 7, and 10), there is outer reactor vessel TC, but no bulkhead is required for the placement of this thermocouple. The inner and outer thermocouples on the reactor pressure vessel wall will be used for heat flux calculations.

Table 4-6: Cylindrical sections thermocouples.

Part Number	Location	TC Type
	All Cylindrical Section TCs	K
	Total TCs on axial levels Lower Reflector #3 and 10	6
	Total TCs on axial levels 3, 5 and 7	12
	Total cylindrical section TCs	18

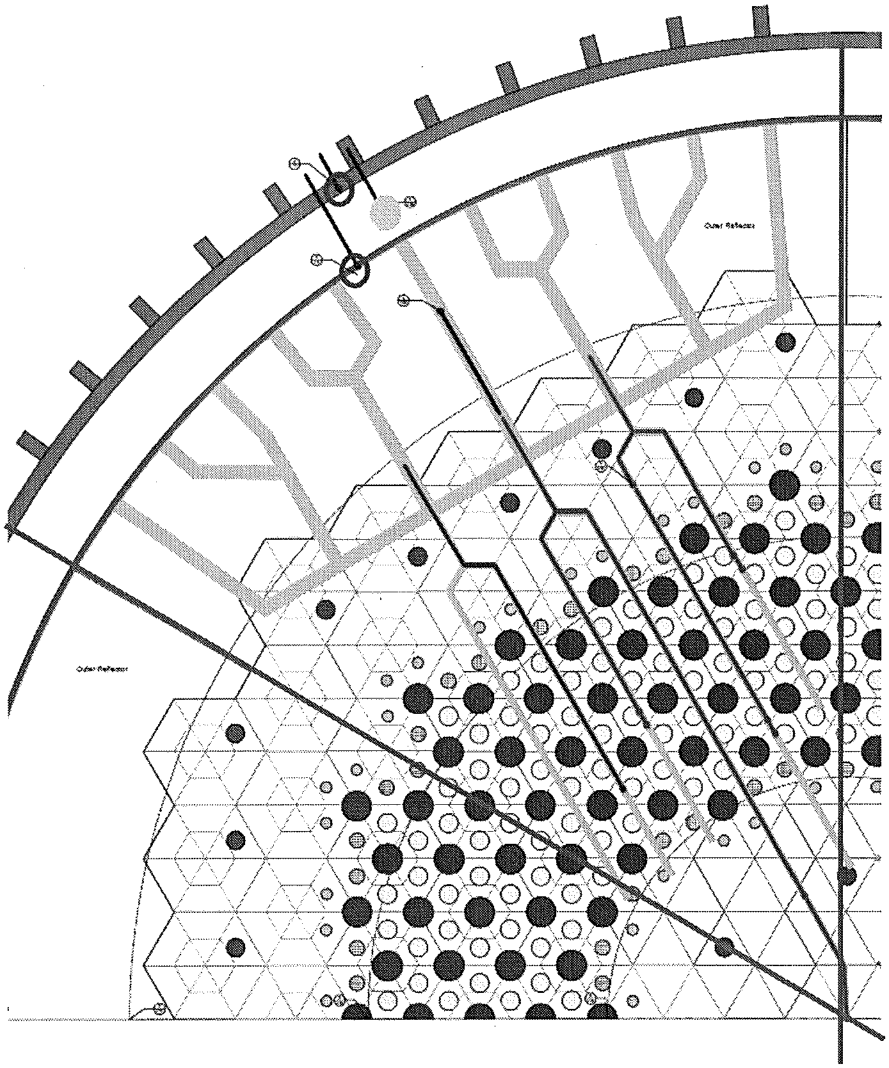

Figure 4-28: Primary 1/6th Sector Cylindrical Section Thermocouples on Lower Reflector #3 and Axial Level 10

Upcomer Temperature TCs:

Outer Core Barrel TCs:

Outer Reactor Vessel TCs:

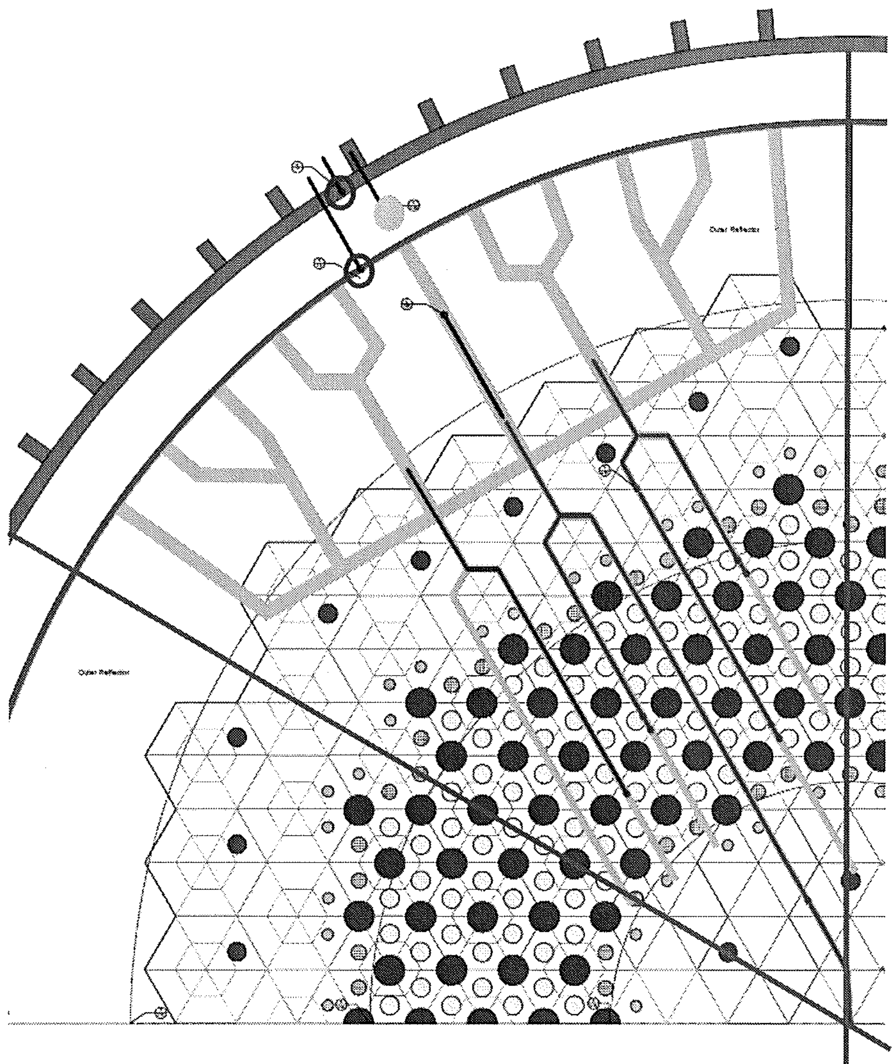

Figure 4-29: Primary 1/6th Sector Cylindrical Section Thermocouples on Axial Levels 3, 5, and 7

Upcomer Temperature TCs:

Outer Core Barrel TCs:

Inner/Outer Reactor Vessel TCs (2 TCs per circle):

4.4.2 Cylindrical Section Pressure Taps

There will be a pressure tap in the Primary Sector at the top of the upcomer annulus. This pressure tap is connected to a DPT with its reference line being the pressure tap at the vessel inlet.

4.4.3 Cylindrical Section Gas Concentration Instruments

Four gas sensors will be used at various heights of the upcomer in the Primary Sector corresponding to axial levels Lower Reflector Block #3, 4, 6, and 10. Figure 4-30 shows the radial location of where these sensors will be placed in the upcomer, denoted by a yellow circle.

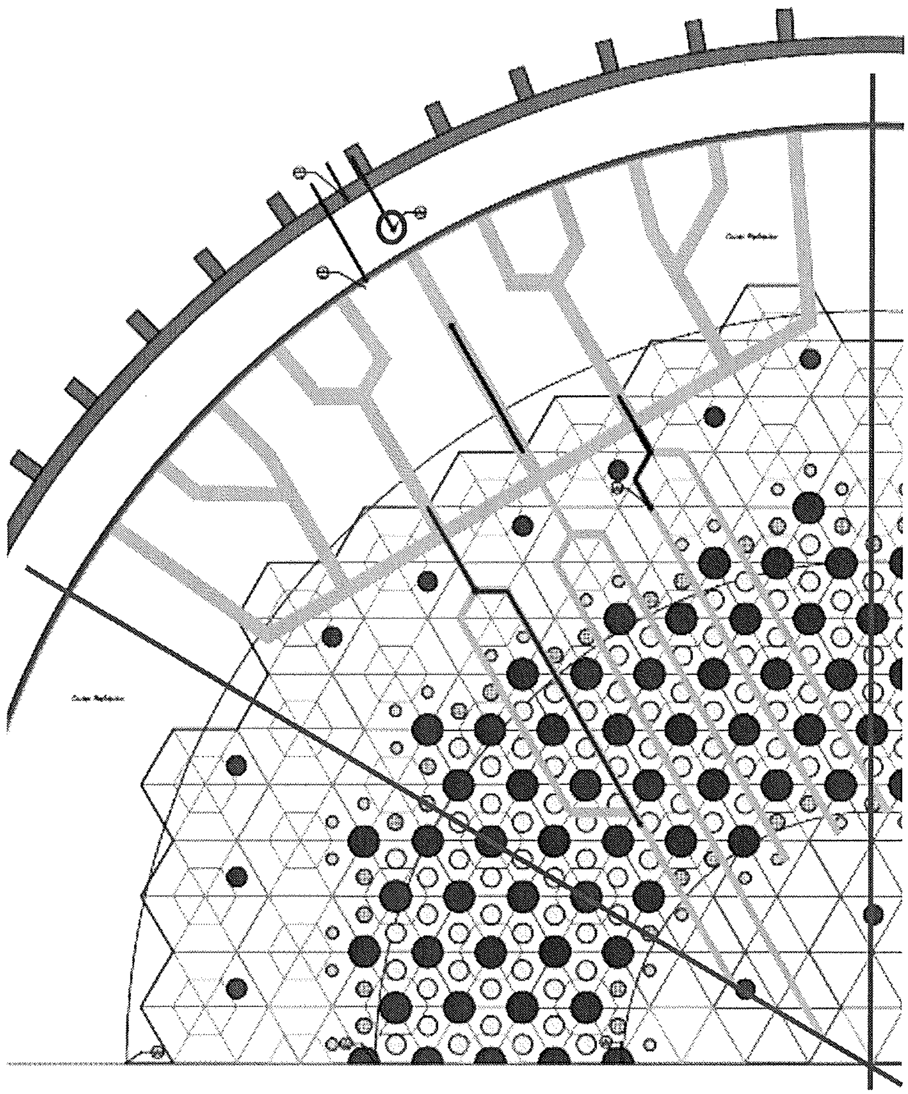

Figure 4-30: Primary 1/6th Section Upcomer Gas Sensor Location (4 sensors in this location)

Upcomer Gas Sensors: O

Similar to the TCs, an instrumentation bulkhead is located at axial levels Lower Reflector #3, 4, 6, and 10 to accommodate the wires for the gas sensors.

4.5 INLET/OUTLET DUCT INSTRUMENTATION

This section discusses the thermocouple, gas concentration sensor, and pressure sensor instrumentation in the inlet/outlet ducts.

The inlet and outlet ducts will be instrumented to acquire data for the air ingress phase of the DCC event. This will include three crossover duct rakes, with one rake at the entrance of the pressure vessel and the other two rakes downstream of the pressure vessel inside the Reactor Cavity Simulation Tank (RCST). Instrumentation is brought into the inlet and outlet ducts via these three rakes. The rakes include bulkheads for TC and pressure tap inserts, and a three-inch opening for plate type gas concentration sensors.

Rake 1 is nearest the pressure vessel, and it has instrumentation ports that penetrate into both the inlet and outlet ducts for thermocouples, pressure instruments, and gas concentration instruments.

Rakes 2 and 3 are downstream of the vessel inside the RCST. In the RCST, Rake 2 penetrates into the hot leg (outlet duct), and Rake 3 penetrates into the cold leg (inlet duct).

4.5.1 Thermocouples

Rake 1 at the entrance to the pressure vessel has 5 thermocouples aligned vertically in the ducts. Three thermocouples are in the hot leg (inner circle) where two are in the cold leg (outer circle).

Rake 2 for the hot leg has 3 thermocouples; and Rake 3 for the cold leg has 2 TCs. The three figures below show the thermocouple configuration. All thermocouples in this region will be K-type. The duct thermocouple package is outlined in Table 4-7.

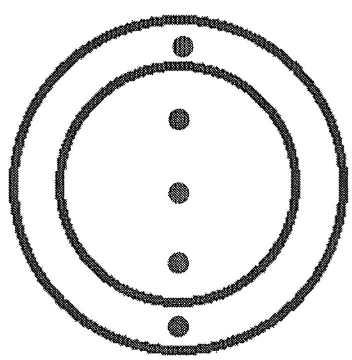

Figure 4-31: TC Locations in Rake 1

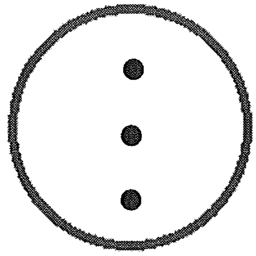

Figure 4-32: TC Locations in Rake 2 (Hot Leg)

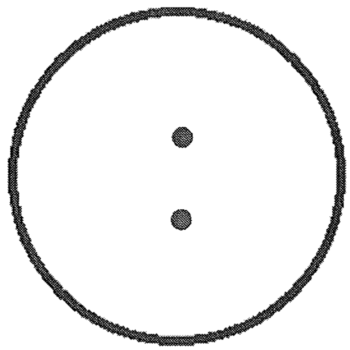

Figure 4-33: TC Locations in Rake 3 (Cold Leg)

Table 4-7: Duct thermocouples

Part Number	Location	Number
Rake 1	Hot Duct TC Rake, near vessel	3
Rake 2	Hot Duct TC rake, away from vessel	3
Rake 1	Cold Duct vertical TC, near vessel	2
Rake 3	Cold Duct vertical TC, away from vessel	2
	Total Duct TCs	10

4.5.2 Gas Concentration Instruments

GCIs will be placed in the ducts at the same vertical positions as the TCs in the three rakes, resulting in 5 sensors near the entrance, 3 sensors in Rake 2, and 2 sensors in Rake 3. The gas concentration instruments inserts are represented, conceptually, by the following two figures.

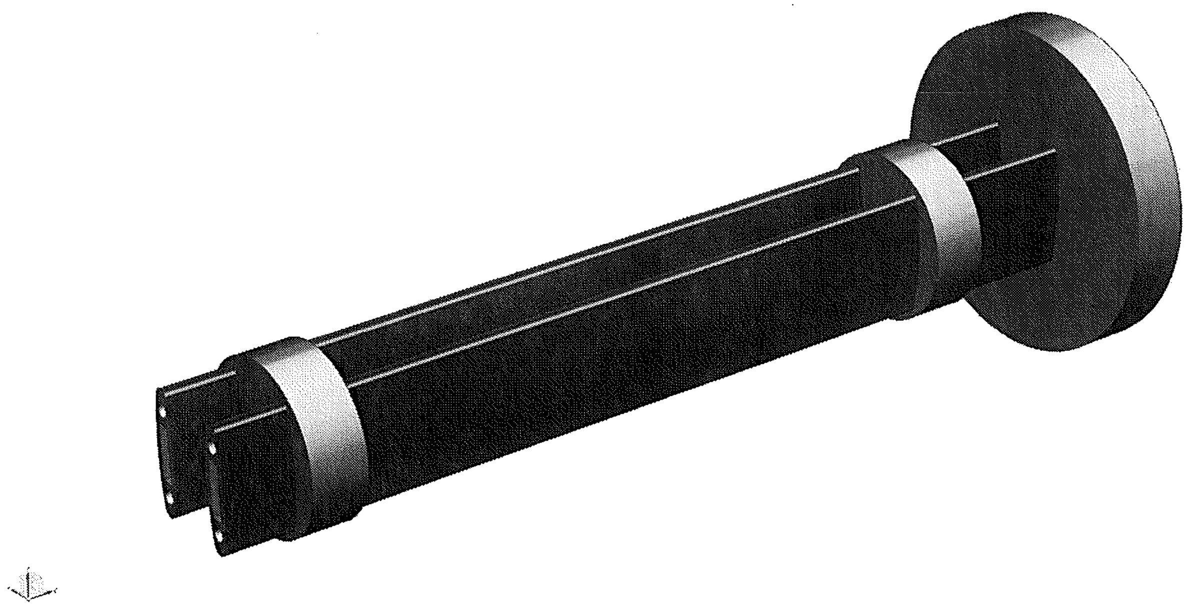

Figure 4-34: Rake Gas Concentration Instrumentation (GCI) Insert

The blue rectangles represent the plate-type GCI. The plate-type GCI requires 2 plates to make a capacitive reading on the gas concentrations. As can be seen, there are a total of 10 plates, resulting in 5 GCIs. The red airfoil shows the support structure for the GCI insert.

The insert is placed in a 3 inch opening at the rakes. A conceptual representation of the rake insert inside the cross-duct is shown below. For note, this would be similar to the insert placed in Rake 1, where the inlet/outlet ducts are concentric.

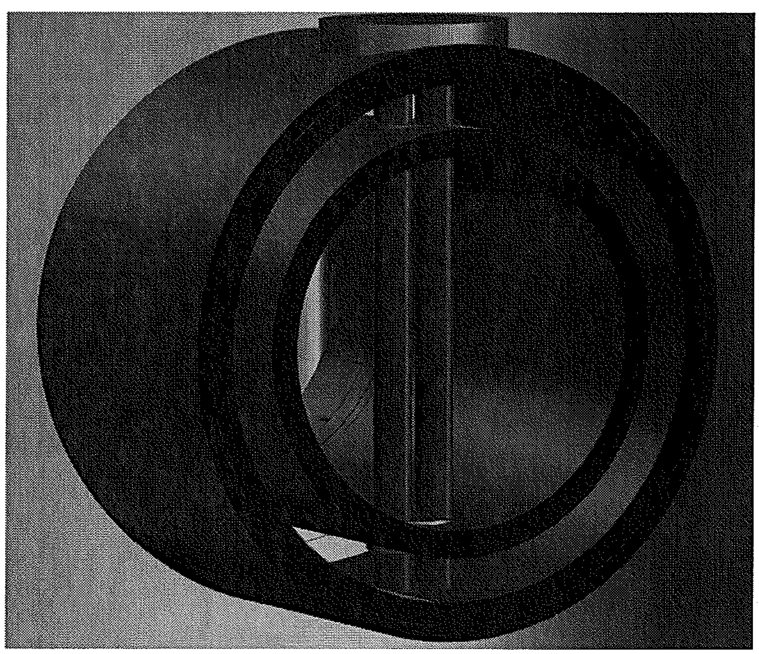

Figure 4-35: Rake GCI Insert Placed in Rake 1

Gas concentration sensors will be placed in the ducts at the same downstream position as the TCs. At each of these locations, 3 gas concentration sensors will be used in the hot duct, and 2 in the cold duct. This is shown in the figures below. The duct gas concentration sensor package is outlined in Table 4-8.

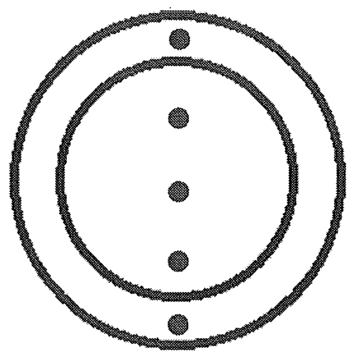

Figure 4-36: GCI Locations in Rake 1

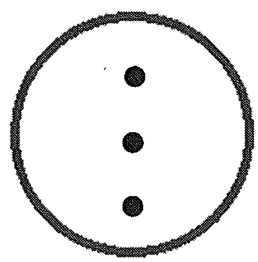

Figure 4-37: GCI Locations in Rake 2 (Hot Leg)

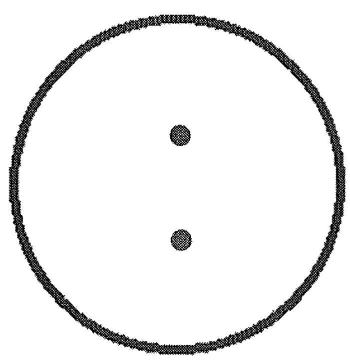

Figure 4-38: GCI Locations in Rake 3 (Cold Leg)

Table 4-8: Duct gas concentration sensors

Part Number	Location	Number
Rake 1	Hot Duct GCI, near vessel	3
Rake 2	Hot Duct GCI, away from vessel	3
Rake1	Cold Duct gas sensors near vessel	2
Rake 3	Cold Duct gas sensor away from vessel	2
	Total Duct Gas Sensors	10

4.5.3 Pressure Taps

The hot leg and cold leg will each have one pressure tap near the rake closest to the vessel (Rake 1). The hot leg pressure tap is connected to a DPT that uses the cold leg pressure as the reference line. In addition, there will be a pressure tap in the Metallic Core Support Structure (MCSS) that will be connected to a differential pressure sensor that uses the cold leg inlet pressure as the reference line.

The cold leg pressure tap will be connected to a static pressure sensor to provide a baseline system pressure. This tap also provides the reference pressure used for the DPTs at the MCSS, top of the upcomer, top of the Upper Plenum, the lower plenum, and the hot leg (resulting in 5 DPT instruments, excluding the 1 core DPT instrument).

4.6 REACTOR VESSEL PRESSURE INSTRUMENT OVERVIEW

In summary, the HTTF Reactor Pressure Vessel (RPV) has 8 pressure taps, which are connected to 7 pressure instruments. Six of these are differential pressure transmitters, and one is a static pressure transmitter.

One DPT measures the core pressure drop and requires a pressure tap at the top and bottom of the core. There is one pressure tap in the inlet and outlet ducts of the vessel. The inlet duct (cold leg) pressure tap is connected to a static pressure transmitter. This PT serves as a baseline for the pressure gradients throughout the core. As such, the outlet duct (hot leg) pressure is connected to a DPT. This pressure tap is also connected to the pressure taps at the top of the upcomer, the upper plenum, lower plenum, and MCSS. The following figure shows how these DPTs are to be placed in the HTTF RPV.

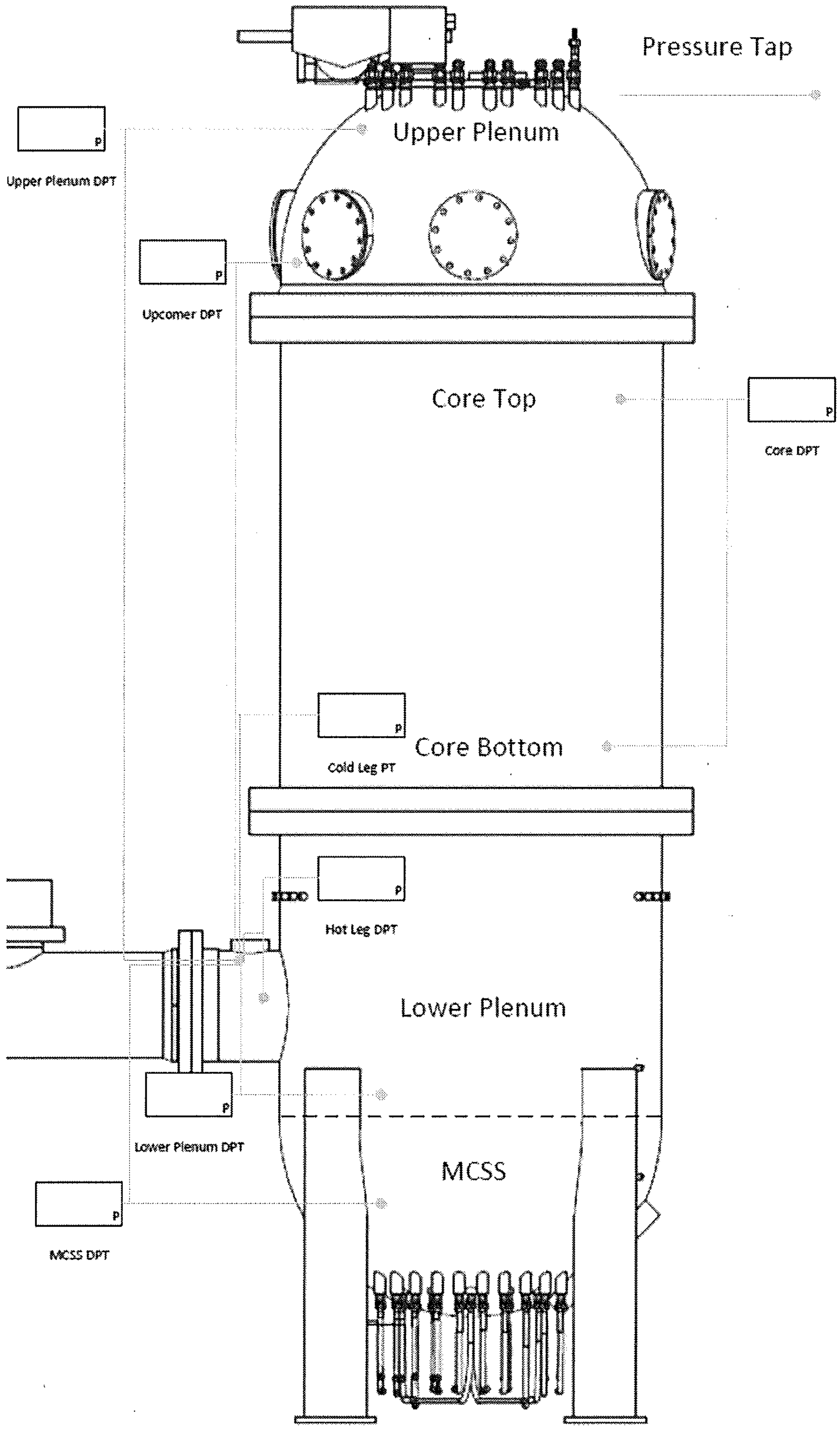

Figure 4-39: Pressure Instrument Placement in the RPV

4.7 REACTOR CAVITY COOLING SYSTEM (RCCS) INSTRUMENTATION

This section discusses the thermocouple and pressure sensor configuration for the RCCS.

4.7.1 Thermocouples

Temperatures will be measured at the RCCS water storage tank, the RCCS pump outlet, RCCS doors, the cavity between the vessel and the doors, and the RCCS ceiling. Thermocouples will be used to measure temperatures at the inlet and outlet of the RCCS doors, and in the cavity ceiling and space. For these areas, K-type thermocouples will be used. The RCCS thermocouple package is outlined in Table 4-9.

Table 4-9: RCCS Thermocouple Package

Part Number	Location	Number
	Water Measurement between panes	
	TCs per door	2
	# of RCCS Doors	8
	RCCS Cavity Ceiling and Space	
	RCCS Cavity Space TCs	4
	RCCS Cavity Ceiling TCs	4
Total RCCS Thermocouples		**24**

The figure below shows how two RCCS doors (doors 2 and 3) are instrumented with thermocouples.

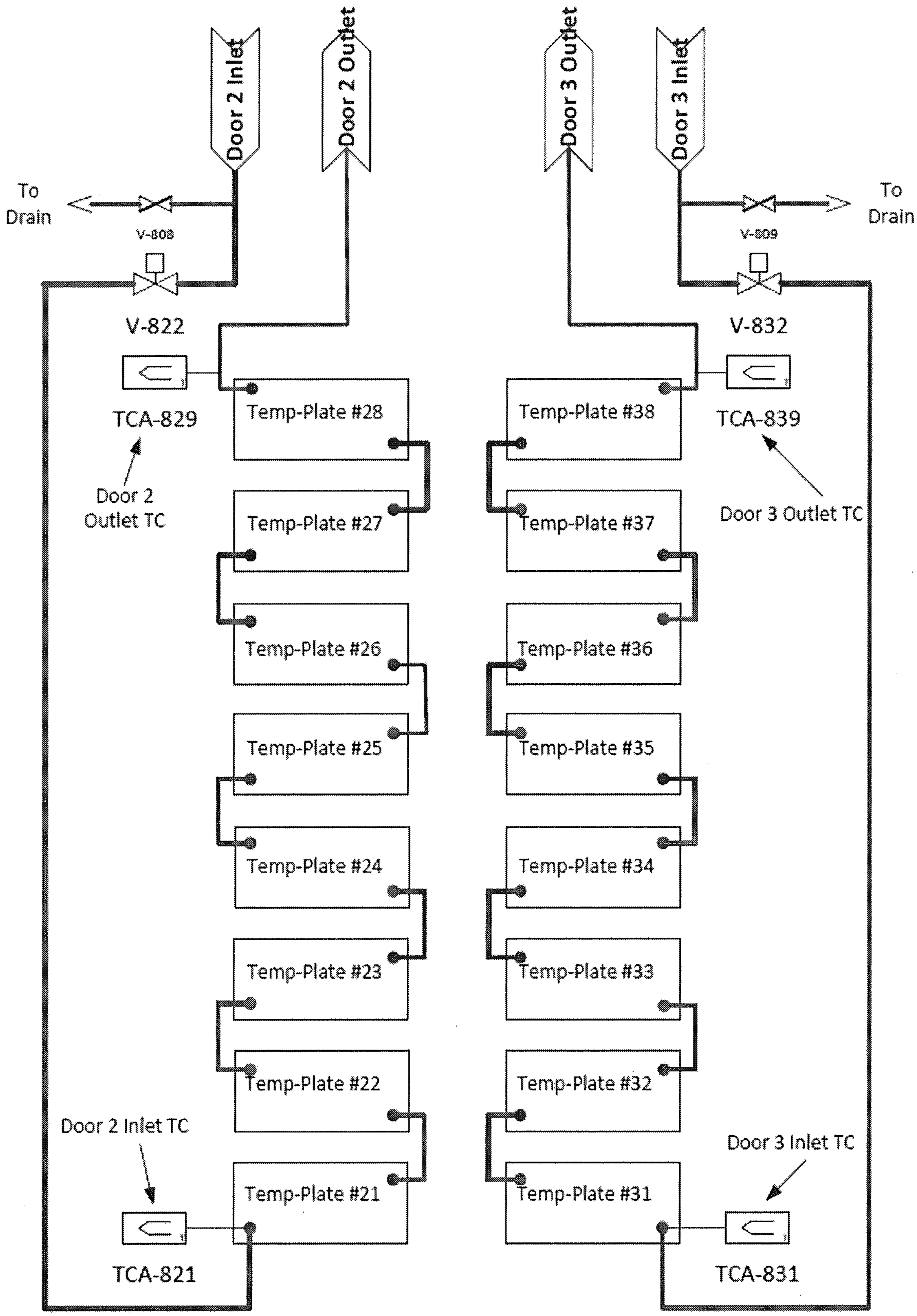

Figure 4-40: RCCS Door TC Placement for Doors 2 and 3

4.8 REACTOR CAVITY SIMULATION TANK

The Reactor Cavity Simulation Tank (RCST) will be instrumented with thermocouples, a pressure tap, and gas sensors. Three thermocouples will be used in the RCST. They will be positioned in vertical alignment at the centerline of the tank at axial levels corresponding to the vessel's lower head, middle plane, and upper head. Three gas sensors will be used at the same three positions of the thermocouples. One pressure tap will measure static pressure in the RCST.

The following table will specify the locations of all the RCST instrumentation taps. The axial refers to the inches from the bottom of the RCST support legs. For note, the azimuthal angle refers to a counter-clockwise rotation, and the following figure shows the top-down view of the RCST (with azimuthal references).

Table 4-10: RCST Instrumentation Tap Locations

Instrument Tap	Axial (inches)	Azimuthal (Degrees)	Azimuthal (radians)
Temperature Taps:			
TC Tap Lower Head	33	150	2.617994
TC Tap Middle Plane	138.125	150	2.617994
TC Tap Upper Head	207.25	150	2.617994
GCI Taps:			
GCI Tap Lower Head	34.5	150	2.617994
GCI Tap Middle Plane	139.625	150	2.617994
GCI Tap Upper Head	208.75	150	2.617994
Pressure Tap:			
Pressure Tap Upper Head	33	150	2.617994

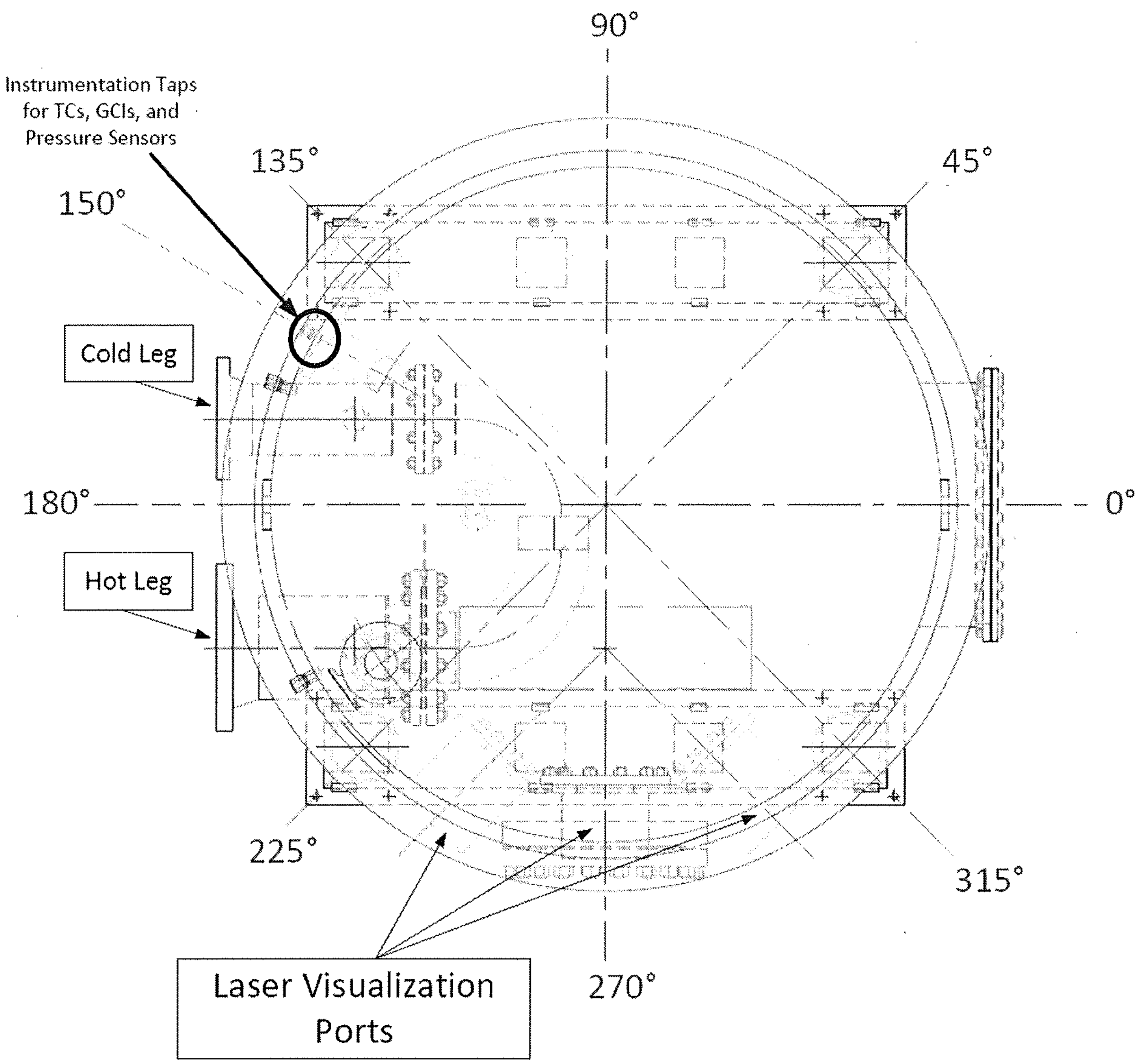

Figure 4-41: Top-down Orientation of RCST Features

4.9 PROCESS INSTRUMENTATION AND CONTROL

There are a number of instruments that will be installed at the HTTF for process control purposes and which will not necessarily be part of the test matrix data for phenomena investigation and code validation. Figure 4-42 shows the Process and Instrumentation Diagram which describes the process instrumentation layout.

The following table labels the name and function of each instrument in the Process and Instrumentation Diagram. Among the process instrumentation, there are temperature transmitters (TTs), pressure transmitters (PTs), level differential pressure transmitters (LDPs) and differential pressure transmitters (DPTs), flow transmitters (FTs), and gas analyzers (AITs). A 4-20 mA current signal is produced from each of these instruments, and it is read via an analog current input module in the HTTF Programmable Logic Controller (PLC) panel.

Additionally, there are also process control instruments. To control the power output to the ten heater rod banks in the core, silicon control rectifiers (SCRs) will be used. Analog current output modules in the HTTF PLC panel send a 4-20 mA signal to the SCRs. The SCRs then regulate the power that is given to the heater rod banks. As there are ten heater banks, there are 10 SCRs. Additionally, there are various valves through the facility that are variable position, requiring a 4-20 mA signal from the user to variably open and close them. Also, a 4-20 mA signal is used to vary the speeds in the facility's pumps and circulators, allowing for control of the flow rates. Table 4-11 and Table 4-12 discuss the instrumentation that requires analog current input and output, respectively.

Table 4-11: P&ID Instrumentation – Analog Current Input

Part Number	Instrument Type	Location	Number
Analog Input			
TT-010	Temperature Transmitter	RCCS Storage Tank.	1
TT-801	Temperature Transmitter	RCCS Feed Line	1
TT-100	Temperature Transmitter	Outlet Duct	1
TT-200	Temperature Transmitter	Inlet Duct	1
TT-201	Temperature Transmitter	Circulator Inlet	1
TT-202	Temperature Transmitter	Circulator Outlet	1
TT-532	Temperature Transmitter	RCST Recirculation Outlet	1
TT-602	Temperature Transmitter	Steam Generator Inlet	1
TT-700	Temperature Transmitter	Cooling Water Temperature	1
		TOTAL TTs	**9**
PT-100	Pressure Transmitter	Outlet Duct Pressure	1
PT-200	Pressure Transmitter	Inlet Duct Pressure	1
PT-201	Pressure Transmitter	Circulator Inlet Pressure	1
PT-202	Pressure Transmitter	Circulator Outlet Pressure	1
PT-300	Pressure Transmitter	RCST Recirculation Pressure	1
DPT-500	Differential Pressure Transmitter	RCST Differential	1
PT-601	~~Pressure Transmitter~~	~~Steam Generator Pressure~~	1
LDP-601	Level Differential Pressure	Steam Generator Level	1
		TOTAL PRESSURE INSTRUMENT	**8**
FT-010	Flow Transmitter	Steam Generator Feed Flow	1
FIT-801	Flow Indicating Transmitter	RCCS Feed Flow Transmitter	1
		TOTAL FITs	**2**
AIT-533	Oxygen Analyzer	RCST Vent	1
AIT-201	Oxygen Analyzer	Primary Loop Oxygen Analyzer	1
		TOTAL ANALYZERS	**2**
KW-101 through KW-110	Power Meter	Heater Rod Bank 1-10	**10**
TOTAL PROCESS INSTRUMENTATION			**31**

Table 4-12: P&ID Instrumentation – Analog Current Output

Part Number	Instrument Type	Location	Number
Analog Output			
PCV-400	Pressure Control Valve	Primary Circulator Vent Valve	1
PCV-602	Pressure Control Valve	Steam Generator Blowdown	1
LCV-013	Level Control Valve	Steam Generator Level Control Valve	1
FCV-532	Flow Control Valve	RCST Circulation Valve	1
FCV-807	Flow Control Valve	RCCS Pump Outlet	1
		TOTAL VARIABLE POS. VALVES	**5**
VSD-010	Variable Speed Drive	Steam Generator Feed Pump	1
VSD-200	Variable Speed Drive	Primary Side Circulator Pump	1
VSD-501	Variable Speed Drive	RCST Vacuum Pump	1
VSD-801	Variable Speed Drive	RCCS Feed Pump	1
		TOTAL VSD ANALOG CONTROL	**4**
SCR-101 through SCR-110	Silicon Control Rectifiers	Heater Rod Bank #1-10	**10**
	TOTAL mA CURRENT CONTROL		**19**

The above instruments coincide with the Process and Instrumentation diagram for Figure 4-42. In addition to the instruments mentioned in Table 4-11 and 4-12, there are other controllers that are used in the HTTF PLC panel. Besides the analog current input and output modules, there are also digital input/output modules. The digital output modules produce a signal that is used to actuate valves and relays while the digital input modules are used to verify a valve or relay's ON/OFF status. Digital input modules, alternatively, are to provide feedback to the host that relays, switches, and valves are either opened or closed.

The following tables will outline the remaining process instrumentation that will be used to control solenoid valves, contactors, and various switches, all of which utilize digital input or output signals.

Table 4-13: PLC Digital Output Instrumentation

Part Number	Instrument Type	Location	Number
Digital Output:			
PCV-010	Solenoid Valve	RCCS Water Tank Pressure	1
PCV-701	Solenoid Valve	Circulator Pressure	1
LCV-010	Solenoid Valve	RCCS Water Tank Level	1
SV-203	Solenoid Valve	Circulator Outlet	1
SV-311	Solenoid Valve	Hot Leg Guillotine Break	1
SV-313	Solenoid Valve	Cold Leg Guillotine Break	1
SV-331	Solenoid Valve	Lower Blowdown Valve	1
SV-332	Solenoid Valve	Blowdown Valve	1
SV-502	Solenoid Valve	Circulator Helium Supply	1
SV-531	Solenoid Valve	Lower RCST Pump Inlet	1
SV-533	Solenoid Valve	RCST Vacuum Pump Vent	1
SV-541	Solenoid Valve	Communication Break Valve	1
SV-551	Solenoid Valve	RCST Gas Supply	1
		TOTAL SOLENOID VALVES	**13**
HOA-010	Hands-Off-Automatic for Variable Speed Drive	Steam Generator Feed Pump	1
HOA-200	Hands-Off-Automatic for Variable Speed Drive	Primary Side Circulator Pump	1
HOA-501	Hands-Off-Automatic for Variable Speed Drive	Vacuum Pump	1
HOA-701	Hands-Off-Automatic	Cooling Water Pump	1
HOA-801	Hands-Off-Automatic for Variable Speed Drive	RCCS Feed Pump	1
		TOTAL HOA	**5**
CR-101 through CR-110	Heater SCR Contactors	Heater Rod Bank #1-10	**10**
ES-002	Emergency Stop		1
ES-003	Emergency Stop		1
		TOTAL EMERGENCY STOP	**2**
	TOTAL DIGITAL OUTPUT SIGNALS		**30**

Table 4-14: PLC Digital Input Instrumentation

Part Number	Instrument Type	Location	Number
Digital Input:			
PSL-701	Pressure Switch Low	Circulator Cooling Pressure Low	1
LSL-010.	Level Switch Low	RCCS Water Tank Level Low	1
TSH-701	Temperature Switch High	Circulator High Oil Temperature	1
		TOTAL SWITCHES	**3**
XSO-203	Position Switch Closed/Open	Circulator Outlet	1
XSC-311	Position Switch Closed/Open	Hot Leg Guillotine Break	1
XSC-313	Position Switch Closed/Open	Cold Leg Guillotine Break	1
XSC-331	Position Switch Closed/Open	Lower Blowdown Valve	1
XSC-332	Position Switch Closed/Open	Upper Blowdown Valve	1
XSC-531	Position Switch Closed/Open	Lower RCST Pump Inlet	1
XSC-533	Position Switch Closed/Open	RCST Vacuum Pump Vent	1
		TOTAL POSITION SWITCHES	**7**
MC-010	Contractor for Variable Speed Drive Feedback	Steam Generator Feed Pump	1
MC-200	Contractor for Variable Speed Drive Feedback	Primary Side Circulator Pump	1
MC-501	Contractor for Variable Speed Drive Feedback	Vacuum Pump	1
MC-801	Contractor for Variable Speed Drive Feedback	RCCS Feed Pump	1
		TOTAL VSD FEEDBACK	**4**
MC-101 through MC-110	Heater SCR Contactors Feedback	Heater Rod Bank #1-10	**10**
ES-002	Emergency Stop Feedback		1
ES-003	Emergency Stop Feedback		1
		TOTAL EMERGENCY STOP	**2**
	TOTAL DIGITAL INPUT SIGNALS		**26**

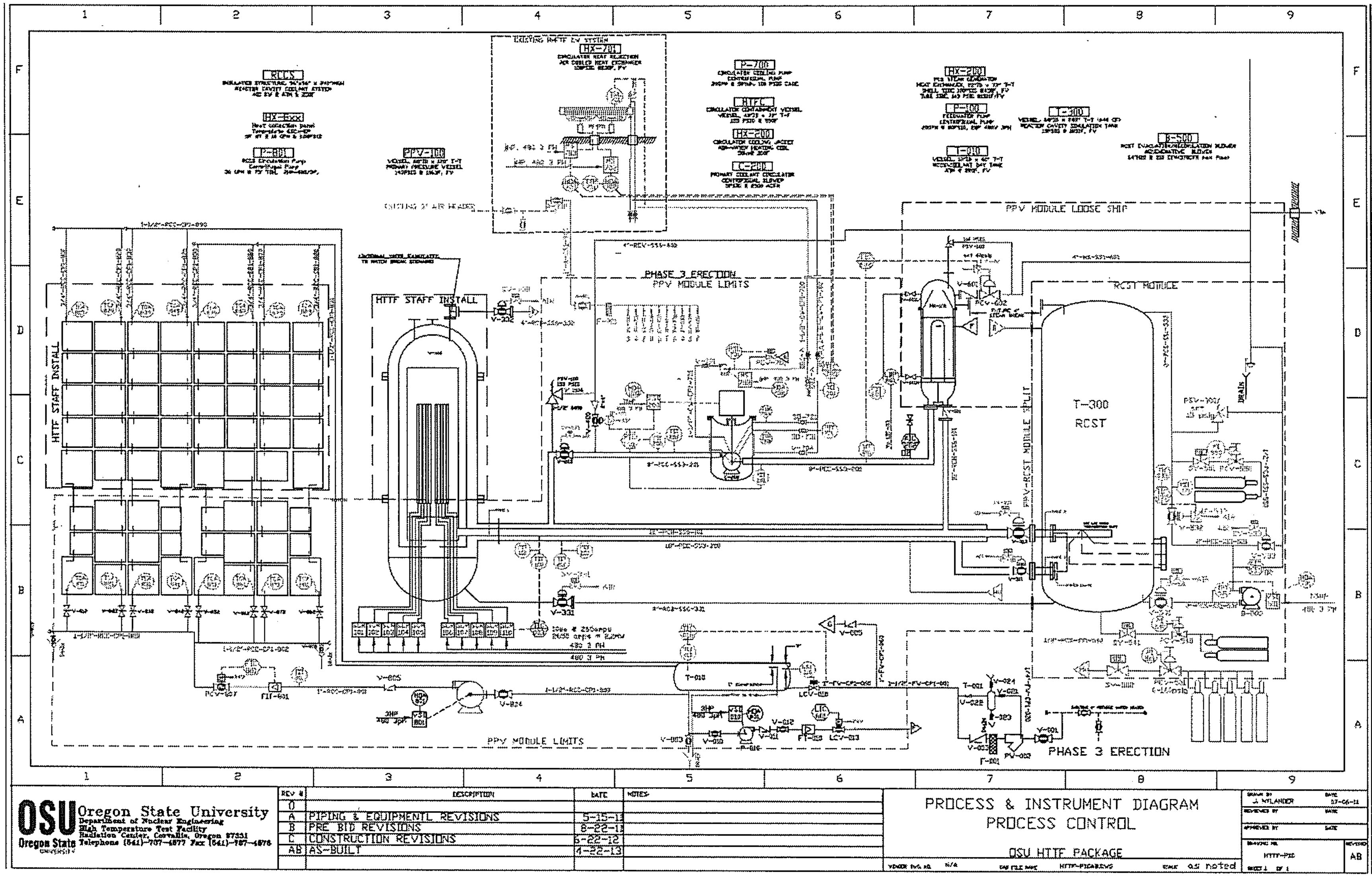

Figure 4-42: HTTF Process and Instrumentation Diagram

5 DATA ACQUISITION AND CONTROL SYSTEM (DACS)

5.1 HTTF SYSTEM REQUIREMENTS

The Data Acquisition and Control System consists of both the Data Acquisition (DAQ) system and the Programmable Logic Control (PLC) system.

The HTTF system must be able to handle the following number of instrument channels at the minimum:

Table 5-1: Quantification of Instrument Channel Types

Channel Type	Number of Channels
Thermocouple Channels	365
4-20 mA Analog Input	49
4-20 mA Analog Output	19
±20 mV Analog Input	48
24 VDC Digital Input	26
24 VDC Digital Output	30

Additionally, the HTTF must be able to handle experimental data collection periods between 8-12 hours and have a sampling rate of 100 Hz to 1 kHz.

The following sections will describe how the HTTF DACS is configured.

5.1 DACS SYSTEM OVERVIEW

The HTTF will use a real-time master controller system for data acquisition and programmable logic control of the HTTF. The facility operator will use a host computer that is connected to the master controller. The host computer will have a commercial software program configured for the control and data acquisition of the HTTF. Figure 5-1 shows a simple diagram on how the DAQ and PLC systems are connected to the host computer. Master controllers daisy-chained to expansion chassis receive the data from the facility's instruments (signal wiring is shown in blue). A daisy-chain is where multiple devices are wired together in sequence. Ethernet cables (shown in green) chain the master controllers to a network switch located on the facility mezzanine in the west side of the ANSEL building. From the network switch, a network server receives the data taken from the switch, and data is also sent to the HTTF DACS host computer. From the host computer, test data, logs, and configuration files can also be viewed and printed.

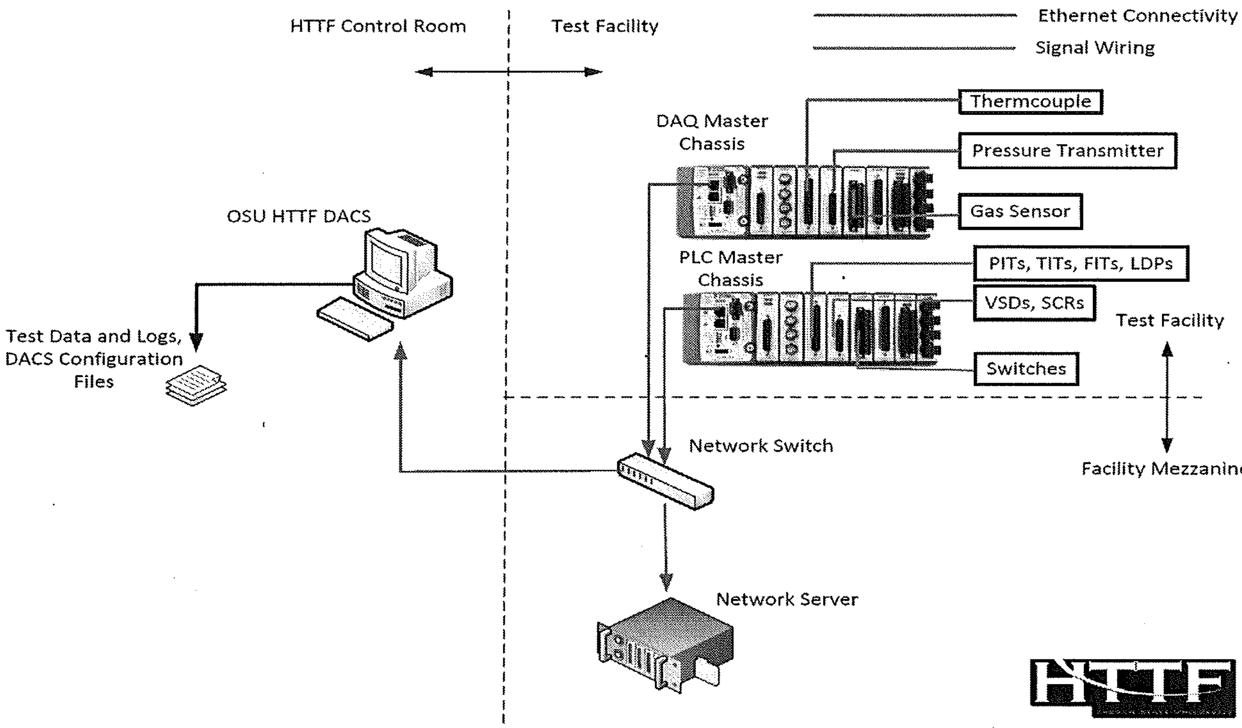

Figure 5-1: DAQ and PLC Connectivity

The real time master controller will be able to be programmed before experiment runs such that no active control is needed from the user on the host computer during the experiment. The system safety measures will be programmed into the master controller to ensure that in the case of disconnect between the host computer and the master controller, system safety measures and data acquisition are preserved.

The master controller will be connected to expansion chassis by Ethernet or a comparable physical data bus. These expansion chassis are where the individual instrument modules will be contained, such as thermocouple modules, current input/output, and digital input/output modules. The following figures will detail how the master controllers are connected to their appropriate expansion chassis. Details will also be given on the module types used in the facility for data acquisition and control. The use of expansion chassis lends the flexibility of locating these chassis in the test facility near their associated instruments. Additionally, using multiple expansion chassis also provides flexibility to expand the data acquisition system at a later time if needed by simply adding more chassis with the respective needed modules.

The HTTF master controller and expansion chassis are contained in four separate panels. As shown in Figure 5-2, two panels are located near the Primary Side of the RPV. As the Primary Sector has a majority of the instruments for data acquisition, these are the DAS panel, containing the DAQ master controller and three chassis, one of which complements the real-time master controller as a master chassis. These two panels are allocated as Panel-4A and Panel-4B. Almost all of the core thermocouples are wired into Panel-4A, which houses the master chassis (DAS-4) and one slave chassis (DAS-4B). The lower plenum thermocouples and some of the Secondary Sector TCs are wired into Panel-4B. Another slave chassis, labeled DAS-4D, is located in this panel, which is daisy-chained back to the master controller in Panel-4B.

A third panel (Junction Box 5) is located near the upper plenum, and it will contain an expansion chassis that receives data from the upper plenum thermocouples, gas sensors, and RCCS ceiling thermocouples. An Ethernet cable (shown in orange in Figure 5-2) will link the expansion chassis back to the DAQ master controller in the DAS panel. Red lines show a relative representation of how instruments are connected to the various chassis.

The fourth panel is located near the Secondary Side of the RPV. This is the PLC panel, which contains the PLC master controller and two chassis. Like for the DAS panel, one of these expansion chassis complements the master controller. Although fewer instruments are required on the secondary side, one of the expansion chassis in the PLC panel is daisy-chained back to the DAQ master controller in the DAQ panel via an Ethernet cable. The PLC master controller has one expansion chassis connected to it, which allows for control of process instrumentation (PTs, TTs, FITs, LDPs, etc.) and control instrumentation (VSDs, SCRs, Switches, etc.).

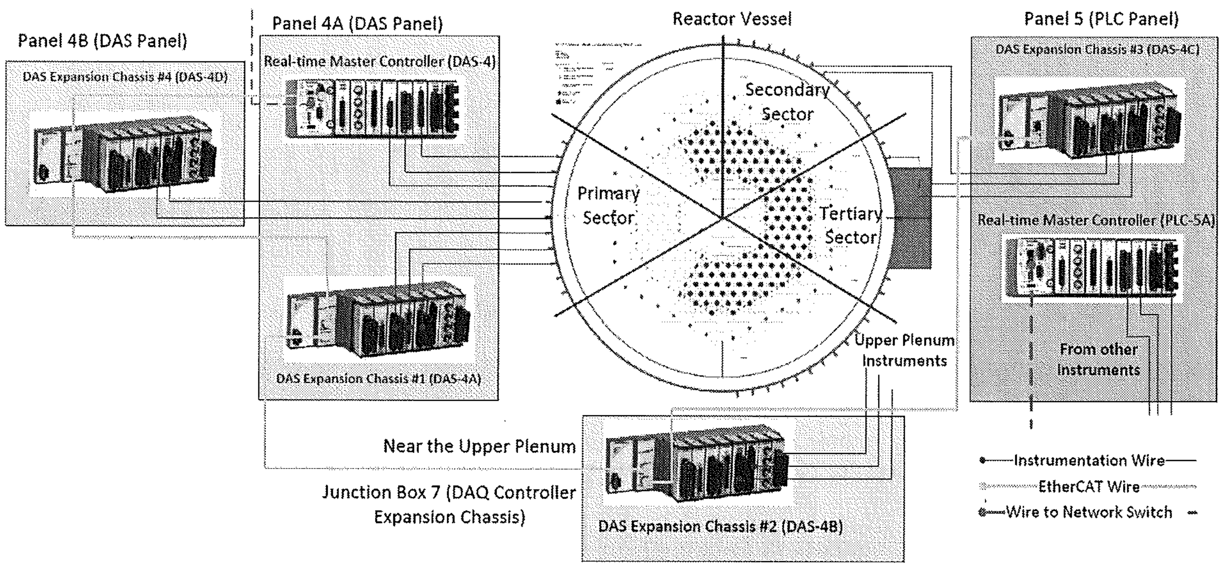

Figure 5-2: DAQ and PLC Panel Locations

Greater detail will be given on the panel configurations in later sub-sections. The following sub-section will describe the hardware that is being used in each of the panels, including the master controllers and modules.

5.2 NATIONAL INSTRUMENTS DAQ HARDWARE DESCRIPTIONS

In the nuclear industry, NQA-1 and ISO-9001 are used as standards for nuclear facilities around the United States. While NQA-1 is more of a safety-driven standard, ISO-9001 is a process-based standard. Being a process-based standard, ISO-9001 is applicable to the quality of the hardware produced by a manufacturer. In order to give industry quality data to the project sponsors, both NQA-1 and ISO-9001 standards are being used in the HTTF program.

Another standard that is part of the facility's quality assurance program is the ISO-17025 standard. ISO-17025 is a calibration accreditation standard.

The DAQ hardware is provided by National Instruments (NI). National Instruments products meet the standard set by ISO-9001 for hardware quality, and NI is also accredited to perform ISO-17025 calibrations on their DAQ hardware.

Details will be given in the following pages on the NI DAQ hardware used in the facility. Information and pictures are from the NI website (http://www.ni.com/).

5.2.1 Real-time Master Controller (CompactRIO 9024)

From NI, the real-time master controllers are the CompactRIO (cRIO) 9024, shown below in Figure 5-3. There are two cRIO-9024 in the facility. One is used for data acquisition, and the other is used for control in the PLC. The cRIO-9024 controller has the following features and capabilities:

- Embedded controller that runs the software LabVIEW® Real-Time for control, data logging and analysis.
- -20 to 55 °C operating temperature range.
- Mean-time-before-failure (MTBF) of 293,538 hours at 77 °F

There are several peripheral items that go along with the cRIO-9024 that make it operational. To run the controller, a VDC power supply is connected to the cRIO-9024. The power supply is the NI PS-15, which provides single phase, 24 VDC, 5 A outputs. It is the power supply meant for the cRIO series provided by NI.

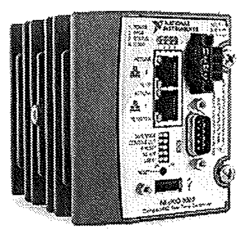

Figure 5-3: CompactRIO-9024 Real-time Master Controller from NI

Other peripheral items include kits that allow the master controller to be mounted in the panel and connected to the power supplies. Along with the master controller, there is a control chassis that allows for the placement of various instrument modules, such as thermocouple modules and analog input/output modules. The complementing control chassis is described below in Section 5.3.2.

An Ethernet port on the controller allows for daisy-chaining other expansion chassis to the controller, and for connecting the controller to a network switch outside of the facility. The line to the network switch leaves the panel and the facility, and it is depicted by blue lines in Figure 5-2. At the network switch, data is sent to both a server for data collection and to a host computer for collection, analysis, and controller.

5.2.2 CompactRIO Reconfigurable Chassis (cRIO-9114)

The chassis that goes along with the CompactRio-9024 master controller is the cRIO-9114. This chassis has eight slots for any cRIO input/output (I/O) module, making it ideal for instrumentation acquisition. It is a reconfigurable chassis with a field-programmable gate array (FPGA) core. Additionally, the chassis can synthesize custom control using LabVIEW. Like the real-time master controller, it has an operating temperature range of -20 to 55 °C, and a DIN-rail mounting kit is required to place it in the panel. The MTBF of the chassis is 815,216 hours at 77 °F.

There are two cRIO-9114 chassis in the facility. One is installed with the DAS panel master controller, and the other is with the PLC panel master controller. As shown in Figure 5-2, the controller/chassis combination in the DAS panel is labeled DAS-4, and the controller/chassis combination in the PLC panel is called PLC-5A.

The following figure shows two pictures: The picture on the left depicts the cRIO-9114 without any peripheral items, and the image on the right shows the master controller combined with the cRIO chassis filled with some I/O modules. The right picture is intended to show relatively how the modules, controller, and chassis combine; it does not show the actual modules that will be placed in the chassis of the HTTF. Chassis configuration details will be discussed in Section 5.4.

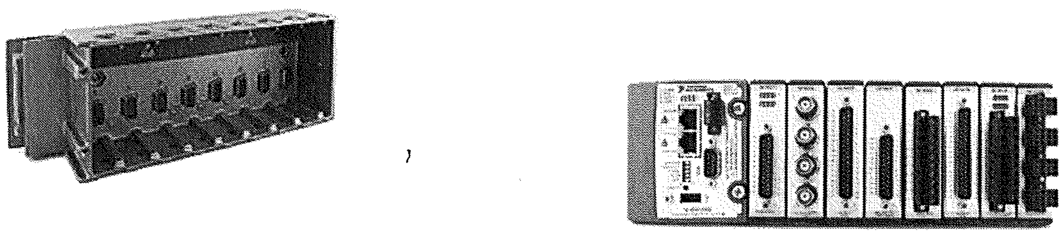

Figure 5-4: cRIO-9114 Chassis without Periphery Items (Left); Master-Controller combined with cRIO Chassis filled with I/O Modules (Right)

5.2.3 Expansion Chassis (NI 9144)

As shown in Figure 5-2 above, there are four expansion chassis that are connected to the real-time master controller in the DAS panel. Although not all of the expansion chassis are in the same DAS panel, they are all daisy-chained back to the DAS panel master controller (shown in orange). The daisy-chain connection is done through an Ethernet connection or some equivalent data bus.

Similar to the cRIO-9114, the NI 9144 expansion chassis is an 8 slot chassis for any C-series input/output module. C-series refers to the modules applicable to the CompactRIO. The NI 9114 has an integrated FPGA for inline processing and control. It has an operating temperature range of -40 to 70 °C. The MTBF of the slave chassis is 458,557 hours at 77 °F.

One expansion chassis is located in the DAS panel with the DAQ master controller. This expansion chassis is labeled DAS-4A. Instruments that are wired to the DAS panel chassis (both the controller and expansions chassis) are predominantly Primary Sector RPV and RCCS instruments. A second expansion chassis, called DAS-4B, is located in a panel near the upper plenum. This panel is called Junction Box 5 (JB-5). Upper plenum thermocouples, upper plenum gas sensors, and RCCS ceiling TCs are routed from the top of the vessel and into this panel before an Ethernet wire connects it back to the DAQ master controller. It was decided to place a chassis in a panel near the upper plenum to reduce wiring and complexity.

The third expansion chassis is placed in the PLC panel, and it is daisy-chained back to the DAQ master controller. This expansion chassis is labeled (DAS-4C). Instruments that are wired into this expansion chassis are Secondary Sector RPV, cross-duct, rake, and RCST instrumentation. Considerably less instruments are in these parts of the facility, so only one expansion chassis is sufficient.

Section 5.4 will discuss which C-series I/O modules will be used to fill up all these chassis. Below, description will be given on the types of I/O modules used in the facility.

5.2.4 Thermocouple Module (NI 9214)

For measuring thermocouples, the NI 9214 will be used (shown in the figure below). The NI 9214 is a 16-channel TC module with 0.02 °C measurement sensitivity. Each TC module also comes with an isothermal terminal block that has measurement accuracy up to 0.45 °C and allows for ease of installation. Additionally, the NI 9214 has several cold-junction compensation (CJC) sensors already in place, and it accommodates both the K- and C-type thermocouples that are used throughout the facility. It has a 24-bit analog-to-digital (ADC) resolution.

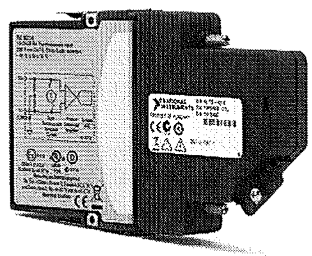

Figure 5-5: NI 9214 TC Module with Terminal Block

From Table 4-1, there are 364 total thermocouples in the facility (both K- and C-types). Since each NI 9214 can accommodate at most 16 TCs, this results in 23 NI 9214 modules for TC measurement. Due to locations of the instruments, not every module can be filled to capacity. However, this means that additional thermocouples can be placed in the modules if it is decided to add more TCs in the future.

5.2.5 Analog Current Input Module (NI 9208)

The NI 9208 is a 16-differential channel analog current input module that operates between ±21.5 mA and has a 500 Hz sampling rate. It has a 24-bit ADC resolution, and a MTBF of 1,099,293 hours at 77 °C.

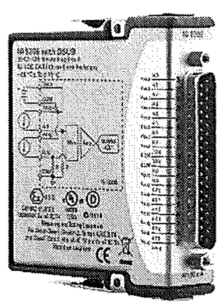

Figure 5-6: NI 9208 Analog Current Input Module

The NI 9208 modules will be used throughout the facility for acquiring the 4-20 mA signals from the pressure instruments, voltage measurements, and various process instruments (TTs, PTs, LDPs, FTs, and gas analyzers).

The NI 9208 utilizes a 37 pin D-sub cable for connection. As such, a 37 pin D-sub connector kit is one of the module's accessories. Since connection is done via a 37 pin D-sub cable, instrumentation wires are routed to a terminal block (CB-37FH) with a 37-pin D-sub on one end. From the terminal block, a 37-pin D-sub I/O cable connects to the NI 9208 for data collection. One advantage to the terminal block is its easy access to probe windows for signal tests. Additionally, the terminal blocks can be placed near their respective instruments, and only one cable becomes necessary to connect to the DAQ module in the chassis.

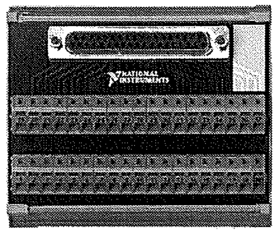

Figure 5-7: 37-Pin D-Sub Terminal Block

For the DAQ controller, there are 9 total pressure sensors (DPTs and PTs) and 10 voltage measurements, resulting in a total of 19 instruments that utilize the 4-20 mA input signal. As such, in the DAQ controller chain, there are 2 NI 9208 modules, one in chassis DAS-4A and another in DAS-4C.

The remaining 4-20 mA signal instruments are the process instruments outlined under Table 4-12. These instruments are the TTs, PTs, LDPs, FT,, AITs, and KWs, totaling 31 process instruments and thus 2 NI 9208 modules in the PLC chassis.

Between the DAQ and PLC system, there are, ultimately, 50 channels that are dedicated to the 4-20 mA analog input signals, meaning there are 4 NI 9208 modules in the facility.

5.2.6 Analog Voltage Input Module (NI 9205)

For measuring the signals from the gas concentration sensors, an analog voltage input module is being used. From National Instruments, the NI 9205 will satisfy the ±20 mV signal required by the gas concentration sensors. The NI 9205 modules is, like the NI 9208, a 16-differential channel analog input module that has the following features:

- 250 kS/s total sampling rate
- Programmable input ranges of ±200 mV, ±1 V, ±5 V, and ±10 V
- -40 to 70 °C operating temperature range
- Allows for D-sub connectivity
- 16-bit ADC resolution.
- Mean-time-before-failure of 775,832 hours at 25 °C.

Since these modules allow for D-sub connectivity, the 37-pin D-sub terminal boards discussed under 5.2.5 will be used. In this way, the terminal boards will receive the voltage signals and a single I/O cable will connect to the NI 9205 modules in the DAS/PLC panels.

There are a total of 48 gas concentration sensors used throughout the facility, resulting in 4 NI 9205 cards. Due to the location of the panels, 26 gas sensors will be routed to the DAS panel chassis DAS-4A. These gas concentration sensors are the core, upcomer, and lower plenum sensors. The eight upper plenum gas sensors will be wired to the JB7, where they are connected to the one NI 9205 module in chassis DAS-4B.

The other 14 gas concentration sensors are the rake sensors, RCST sensors, and the lower instrumentation break gas sensor. They will be wired to the chassis DAS-4C in the PLC panel.

5.2.7 Analog Current Output Module (NI 9265)

Utilizing a 4-20 mA signal, the NI 9265 module outputs a current that controls the facility's SCRs, VSDs, and variable position valves. Variable position valves are shown under Table 4-13 as pressure, level, and flow control valves (PCVs, LCVs, and FCVs, respectively). The NI 9265 has a 16-bit ADC resolution, and a MTBF of 1,014,487 hours at 25 °C.

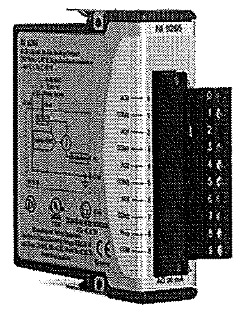

Figure 5-8: NI 9265 Analog Current Output Module

The NI 9265 is a 4-channel output module with a range of 0 to 20 mA. It has hot-swappable operations, with 100 kS/s outputs. Its operating temperature range is -40 to 70 °C. With the 10 SCRs, 4 VSDs, and 5 control valves, totaling 19 channels, 4 NI 9265 modules are necessary in this facility. It amounts to 4 modules because the 10 SCRs can share common grounding wires, resulting in 5 total channels from the SCRs. This means, physically, that 14 channels are used, resulting in 4 NI 9265 modules.

5.2.8 Digital Output Module (NI 9477)

Most of the valves and relays in the facility do not require variable position. They are either ON or they are OFF, meaning the NI 9477, shown below, will suffice for providing the appropriate ON/OFF signal. The NI 9477 is a 32 channel sourcing digital output module with a 37-pin D-sub connector. It has hot-swappable operation, and an operating temperature range of -40 to 70 °C. Since it has a D-sub connector, a terminal board with D-sub on one end will be used to connect the instruments to the NI 9477 module. The NI 9477 has a MTBF of 717,920 hours at 25 °C.

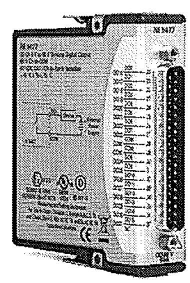

Figure 5-9: NI 9477 Digital Output Module

For what is required of the digital output modules, a signal will be needed to toggle the 10 SCRs ON and OFF, which under Table 4-13, is called the control relay (CR). Additionally, to turn on the pumps, a digital signal is sent to what is called the HOA, or Hands-Off-Automatics. Lastly, 13 channels will be dedicated to control of the facility's solenoid valves, and another two channels are for the two emergency stop switches. This results in a total of 30 digital output signals and thus only 1 NI 9477 module is required.

5.1.1 Digital Input Module (NI 9425)

A digital input module will also be used in the facility, serving as a feedback signal. In this way, instruments can be verified ON/OFF or OPEN/CLOSE through both an output and input feedback signals. The NI 9425 module is a 32-channel digital input module with a 37-pin D-sub connector and capable of hot-swappable operation. Its operating temperature range is -40 to 70 °C. As with the NI 9477, this module will require a terminal board for connectivity with a D-sub cable. This module as a MTBF of 1,256,699 hours at 25 °C.

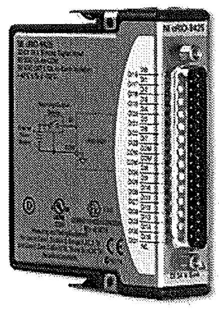

Figure 5-10: NI 9425 Digital Input Module

Signals that will require feedback are the contactors to the SCRs, the VSDs, and emergency stop switches, resulting in a dedicated 18 channels. Additional signals will be used for alarms, including the RCCS water tank pressure and level alarms, and the circulator oil temperature and pressure alarms. The remaining signals are for position switches, which will confirm if the solenoid valves are either open or closed. Ultimately, this configuration results in a total of 27 digital input channels, meaning only 1 NI 9425 module is required for the facility's needs.

To summarize, the following table will outline the number of modules that will be required to meet the needs given the system's current configuration.

Table 5-2: HTTF System Requirements

Channel Type	Module Type	Module Quantity
Thermocouple Channels	NI 9214	23
4-20 mA Analog Input	NI 9208	4
4-20 mA Analog Output	NI 9265	4
±20 mV Analog Input	NI 9205	4
24 VDC Digital Input	NI 9425	1
24 VDC Digital Output	NI 9477	1
	TOTAL MODULES	**37**

The following sections are going to describe the chassis configurations and the instruments that will be wired to each I/O module.

5.3 DAQ AND PLC PANEL CONFIGURATIONS

With the individual parts described above, greater detail will be given here to each chassis and panel, describing the modules used in the chassis and how the modules are connected to their respected instruments. This section will be divided into smaller subsections that discuss each chassis individually, starting with the master chassis in the DAS Panel-4A.

5.3.1 DAS-4 (Master DAS Controller)

In the DAS Panel-4A, which is located near the Primary Sector of the RPV, the master controller (DAS-4) is dedicated strictly to thermocouple data. Eight I/O module slots in the master chassis are filled expressly with NI 9214 TC modules. The following figure illustrates this configuration.

		Slot #1	Slot #2	Slot #3	Slot #4	Slot #5	Slot #6	Slot #7	Slot #8
cRIO-9024	cRIO-9114	NI 9214	NI 9214	NI 9214	NI 9214	NI 9214	NI 9214	NI 9214	NI 9214

Figure 5-11: DAS-4 Master Chassis Configuration

RPV thermocouples in the Primary Sector are routed from their locations in the vessel through the instrumentation bulkheads described in Chapter 4. From the instrumentation bulkheads, thermocouple wiring is run to the DAS panel and is connected to thermocouple terminal boards. Terminal boards are used to provide easy access for signal testing.

There are 20 terminal boards with 8 channels per board in the DAS Panel-4A. Only one TC type is allowed on each board, meaning there can be no C- and K-type TCs on the same terminal board.

From the terminal boards, leads are collected and wired to the terminal blocks on the NI 9214 TC modules. The terminal blocks are directly connected to the NI 9214 module. All the core thermocouples in the Primary Sector and the Lower Plenum gas temperature and side reflector TCs are wired into these 8 TC modules. This totals 127 TC channels in the entire chassis.

5.3.2 DAS-4A (EtherCat Expansion Chassis #1)

Located in the DAS Panel-4A, the first expansion chassis is the NI 9144. This chassis has thermocouples, pressure sensors, and gas sensors connected to it. Three modules are NI 9214 TC modules, 1 module is the NI 9208 4-20 mA input module, and 1 module is the NI 9205 voltage input module. Resulting, there are 3 filler modules in this chassis. The figure below depicts the configuration of this chassis.

EtherCat Slave 1		Slot #1	Slot #2	Slot #3	Slot #4	Slot #5	Slot #6	Slot #7	Slot #8
DAS-4A	NI 9144	NI 9214	NI 9208	SPARE	SPARE	SPARE	NI 9205	NI 9214	NI 9214

Figure 5-12: DAS-4A Expansion Chassis #1 Configuration

Beginning with the thermocouples, TC wiring from the Primary Sector cylinder (i.e. upcomer, outer core barrel, inner/outer RPV) and from 12 (out of 24) RCCS TCs are routed to these modules. The cold-junction compensation thermocouples from the secondary side are also routed into this chassis, which makes for a total of 44 TCs on this chassis. (The remaining RCCS TCs, which are all the ceiling TCs, are placed in the panel near the upper plenum in chassis DAS-4C.) RCCS TCs are routed to terminal boards in Jack Panels 1 through 6; and from the jack panels, the leads are brought into the DAS panel via conduit pipes, where they are connected to terminal blocks on the NI 9214 modules.

The NI 9208 modules are for the 4-20 mA signals from the pressure sensors and the voltage taps in the Primary Sector. These signals include the differential pressure instruments for the core and upcomer top. It also includes the five voltage taps in the Primary Sector (labeled ET-101, ET-103, ET-105, ET-107, and ET-109). Wiring from the pressure and voltage measurement instruments are wired into a 16-differential terminal block in the DAS panel with a 37-pin D-sub on one end. A 37-pin I/O cable connects the instruments from the terminal block to the NI 9208 module.

The NI 9205 modules are for the 12 core GCI sensors in the Primary Sector. Like the thermocouples, the wiring for the GCI sensors is connected to a terminal board. From the terminal board, the leads are wired using a 10 conductor shielded cable to the NI 9205 module.

5.3.3 DAS-4D (EtherCat Expansion Chassis #4)

In DAS Panel-4B, there is another expansion chassis (DAS-4D), which is daisy-chained back to the master chassis in DAS Panel-4A. There are four NI 9214 TC modules and 1 NI 9205 module for GCIs. This results in 3 filler modules. The following figure shows the chassis configuration.

EtherCat Slave 4		Slot #1	Slot #2	Slot #3	Slot #4	Slot #5	Slot #6	Slot #7	Slot #8
DAS-4D	NI 9144	NI 9214	NI 9214	NI 9214	NI 9214	NI 9205	SPARE	SPARE	SPARE

Figure 5-13: DAS-4D Expansion Chassis #4 Configuration

All of the remaining lower plenum instruments are wired into this chassis along with several of the secondary side thermocouples that cannot fit in the chassis DAS-4B. This results in 32 secondary side thermocouples spread out across two NI 9214 modules, and 32 lower plenum instruments in the remaining thermocouple modules. The NI 9205 measures the 4 GCIs in the upcomer and the 8 GCIs in the lower plenum.

5.3.4 DAS-4B (EtherCat Expansion Chassis #2)

In Junction Box 7, the third DAS expansion chassis (DAS-4B) is for acquiring signals from the upper plenum instrumentation. DAS-4B is daisy-chained back to the master chassis in the DAS panel. The current configuration for the DAS-4B chassis is shown below.

EtherCat Slave 2		Slot #1	Slot #2	Slot #3	Slot #4	Slot #5	Slot #6	Slot #7	Slot #8
DAS-4B	NI 9144	NI 9205	SPARE	SPARE	SPARE	SPARE	NI 9214	NI 9214	NI 9214

Figure 5-14: DAS-4B Expansion Chassis #2 Configuration

As seen in Figure 5-13, there are 3 NI 9214 TC modules, and 1 NI 9205 module for GCI sensors. The thermocouples that are wired into Slot #8 are the upper plenum TCs, which include the shroud, vessel, gas tube, and control rod drive break TCs. Additionally, 4 RCCS ceiling TCs and all the door outlet TCs for the RCCS are routed to the module in Slot #7. The slot #6 module is for the remaining gas temperature thermocouples in the upper plenum control rod guide tubes.

Wired into the NI 9205 module are the six upper plenum gas tube gas sensors and the control rod drive break gas sensor. In JB7, GCI wires are brought to terminal boards, where they are then collected at the NI 9205 module. Due to the few instruments that are connected to the DAS-4B chassis, there are 4 spare module slots, which are filled with NI 9977 filler modules until additional modules and instruments are added.

5.3.5 DAS-4C (EtherCat Expansion Chassis #3)

Located in the PLC panel is the third and last expansion chassis that is daisy-chained back to the master chassis in the DAS panel. The current module configuration for the DAS-4C chassis is shown below.

EtherCat Slave 3		Slot #1	Slot #2	Slot #3	Slot #4	Slot #5	Slot #6	Slot #7	Slot #8
DAS-4C	NI 9144	NI 9205	NI 9208	SPARE	NI 9214	NI 9214	NI 9214	NI 9214	NI 9214

Figure 5-15: DAS-4C Expansion Chassis #3 Configuration

There are five NI 9214 modules for the TCs. All Tertiary Sector TCs and some Secondary Sector TCs (20 in total) are wired into these modules. Additionally, 5 Rake 1 TCs are wired into Slot #5.

The TC module in Slot #8 contains the remaining 14 Lower Plenum TCs. These include the lower plenum floor, lower head, lower instrumentation break, and the MCSS TCs. All 14 thermocouples are brought from various bulkheads in the RPV and wired into a terminal boards in JB3. From the junction box, the leads are connected to the module in Slot #8.

Thermocouples from Rakes 2 and 3 (5 in total) are wired to terminal boards in Junction Box 6A, which is near the RCST. The Rake thermocouples along with the 3 RCST TCs are all wired to the terminal boards in JB-6A. From this board, the TCs are routed to the terminal block in Slot #7.

There is one NI 9208 module for the 4-20 mA analog input signals. This module contains the differential pressure instruments for the upper plenum, lower plenum, MCSS, RCST, RCCS, Hot Leg, and the static pressure in the cold leg (7 sensors in total). The rest of the module is filled by the five Secondary Sector voltage measurements, labeled ET-102, ET-104, ET-106, ET-108, and ET-110. A total of 11 channels occupy the NI 9208 module in this chassis. Sensing wires from these instruments are connected to a terminal board in JB3. From there, the leads are brought through a conduit into the module on the DAS-4C chassis.

The NI 9205 module is for the remaining gas concentration instruments, 14 in total. Leads from the GCI are brought in from two separate junction boxes. In JB3, GCI from the lower instrumentation break and from Rake 1 are collected at a terminal board before brought to the NI 9205 module via a conduit. The remaining GCI are the Rake 2 and 3 sensors and the RCST sensors (8 in total). These sensors are wired to a terminal board in JB-6A before connected to the module on the DAS-4C chassis.

5.3.6 PLC-5A (Master PLC Controller)

In the PLC panel is the master PLC controller and chassis, labeled PLC-5A. There is only the 1 PLC chassis in the facility, which is dedicated to process and control instrumentation for safely operating the facility. An Ethernet cable connects the PLC controller to a switch, where data is both sent to a server and the host computer for data processing. The master controller (NI 9204) is connected to a chassis (cRIO 9114). The 8 slots are filled with various modules, and the configuration is shown in the figure below.

PLC-5A Master Controller

		Slot #1	Slot #2	Slot #3	Slot #4	Slot #5	Slot #6	Slot #7	Slot #8
cRIO-9024	cRIO-9114	NI 9265	NI 9265	NI 9265	NI 9265	NI 9425	NI 9477	NI 9208	NI 9208

Figure 5-16: PLC-5A Master Chassis Configuration

There are 4 NI 9265 modules in the PLC chassis, which produce a 4-20 mA output signal to control pump speeds, valve positions, and SCR power. The variable speed drives (VSD) are mounted in a few different locations in the facility. VSD-010, VSD-801, and VSD-501 (for the secondary side feed line, RCCS feed line, and RCST vacuum line, respectively) are mounted between the AC-3 and PLC panels. VSD-200 for the primary side circulator is mounted near the northwest corner of the facility. All four VSDs are wired to a terminal block in the PLC panel. These terminal blocks are then wired to the Slot #4 module.

Variable positions valves LCV-013, FCV-807, PCV-400, and PCV-602 are routed first to a terminal board in Junction Box 4. Through conduits, they are then wired to another terminal board in the PLC panel before finally being routed into the module in Slot #3. The other variable position valve FCV-532 is connected to a terminal board in JB-6B. Similarly, it is then directed to a terminal board in the PLC panel before being wired to the NI 9265 module in Slot #2.

Lastly, the 10 SCRs are configured to share common wires, which results in only 5 channels to power the SCRS. The SCRs on the Primary Sector (SCR-101, -103, -105, -107, -109) are in the AC1 panel, and the Secondary Sector SCRs (SCR-102, -104, -106, -108, -110) are in the AC2 panel. From terminal boards in the AC1 and AC2 panels, SCR leads are routed into the PLC panel and connected again to terminal boards where they can share common wires. As such, SCR-101 through SCR-108 are wired into the Slot #1 module. SCR-109 and SCR-110 are wired into Slot #2, sharing it with FCV-532.

The NI 9477 module is for outputting a digital signal, which is used to actuate solenoid valves, turn on the SCRs, actuate emergency stop buttons, and turn on the HOAs. The first emergency stop button (ES-1) and the control relays for the Primary Sector heater banks (CR-101, -103, -105, -107, and -109) start in the AC1 panel. The second emergency stop button (ES-2) and the control relays for the Secondary Sector heater banks (CR-102, -104, -106, -108, and -110) start in the AC2 panel. These wires are routed, via conduits, into the terminal board in the PLC panel.

The 4 HOAs are in the AC3 panel, and they are routed to the same PLC terminal board allocated to the control relays above.

There are, however, 2 groups of solenoid valves in separate junction boxes. In Junction Box 3, there are SV-331, SV-332, SV-311, SV-313, SV-203, PCV-010, LCV-010, and PCV-701 connected to a terminal board. In Junction Box 6B, there are SV-502, SV-531, SV-533, SV-541, and SV-551, which are also connected to a terminal board. From these junction boxes, the signals are brought in the terminal board in the PLC panel.

All 30 channels for digital output connect to a terminal board in the PLC panel. A 37-pin D-sub cable connects the terminal board to the NI 9477 module.

For the digital input module, NI 9425, there are 27 channels wired to it. Like for the NI 9477 module, the contactors for the SCRs and the feedback terminals for the emergency stop buttons are both in the AC2and AC3 panels. They are wired to a terminal board in the PLC panel. In the AC3 panel, the feedback switches from the VSDs are wired first into a terminal board in the AC3 panel before being routed into a terminal board in the PLC panel.

All 27 channels for digital input connect to a terminal board in the PLC panel. A 37-pin D-sub cable connects the terminal board to the NI 9425 module.

The process instrumentation that requires a 4-20 mA input signal is wired into the 2 NI 9208 modules in Slots #7 and #8. Part of the process instrumentation is wired to a terminal board in junction box 4. This includes the following instruments: TT-010, TT-801, TT-100, TT-200, TT-201, TT-202, TT-602, PT-100, PT-200, PT-201, PT-202, PT-601, LDP-601, FT-801, FT-010, and AIT-201. From the terminal board, a 37-pin D-sub cable connects the instruments to the Slot #7 module.

The remaining process instruments are wired to a terminal board in the PLC panel. These include DPT-500, PT-700, PT-300, TT-700, TT-532, AT-533, and KW-101 through KW-110. From the terminal board, a 37-pin D-sub cable connects the instruments to the module in Slot #8.

6 REFERENCES

1. Woods, B.G., Jackson, R.B., and Nelson, B.L., *Scaling Analysis for the Very High Temperature Reactor Test Facility at Oregon State University,* Report OSU-HTTF-XXX, Oregon State University.

2. Ball, S.J. and e. al., *Next Generation Nuclear Plant Phenomena Identification and Ranking Tables (PIRTs).* NUREG/CR-6944, Vol. 2: Accident and Thermal Fluids Analysis PIRTs, 2008.

3. Woods, B.G., Jackson, R.B., and Cadell, S., *Preliminary Test Plan for the High Temperature Test Facility at Oregon State University,* Report OSU-HTTF-XXX, Oregon State University.

4. Vierow, K., and Beeny, B., "HTTF Instrumentation Identification for MELCOR Code Validation", Texas A&M University, Letter, August 2, 2010.

5. National Instruments Website. <http://www.ni.com/>

6. ASME PTC 19.1-2005. "Test Uncertainty." The American Society of Mechanical Engineers. Three Park Avenue, New York, NY. 2006.

ATTACHMENT C

KEY PERSONNEL

Contractor and OSU agree that each individual specified below is an individual whose special qualifications and involvement in Contractor's performance of services form part of the basis of agreement between the parties for this Contract and is an individual through whom Contractor shall provide to OSU the expertise, experience, judgment, and personal attention required to perform services ("Key Person"). Each of the following is a Key Person under this Contract:

(Taken from submittals)

EXHIBIT B
CERTIFICATIONS

By signature on this certification the undersigned certifies that they are authorized to act on behalf of the Proposer and that under penalty of perjury the undersigned will comply with the following:

SECTION I. OREGON TAX LAWS

As required in ORS 305.385(6) the undersigned hereby certifies that to the best of the undersigned's knowledge, the Proposer is not in violation of any Oregon Tax Laws. For purposes of this certification, "Oregon Tax Laws" means a state tax imposed by ORS 401.792 to 401.816 (Tax For Emergency Communications), 118 (Inheritance Tax), 314 (Income Tax), 316 (Personal Income Tax), 317 (Corporation Excise Tax), 318 (Corporation Income Tax), 320 (Amusement Device and Transient Lodging Taxes), 321 (Timber And Forestland Tax), 323 (Cigarettes And Tobacco Products Tax), and the elderly rental assistance program under ORS 310.630 to 310.706; and any local taxes administered by the Department of Revenue under ORS 305.620. If a Contract is executed, this information will be reported to the Internal Revenue Service under the name and taxpayer I.D. number submitted below. Information not matching IRS records could subject Contractor to thirty one percent (31%) backup withholding.

SECTION II. AFFIRMATIVE ACTION

The undersigned hereby certifies that they have not discriminated against Minority, Women or Emerging Small Business Enterprises in obtaining any required subcontracts, pursuant to OAR 580-061-0030 (3).

SECTION III. COMPLIANCE WITH SOLICITATION

The undersigned agrees and certifies that they:

1. Have read, fully understands and agrees to be bound by the Informal Request for Proposal and all Exhibits and Addenda to the Informal Request for Proposal; and
2. Are an authorized representative of the Proposer, that the information provided is true and accurate, and that providing incorrect or incomplete information may be cause for rejection of the Proposal or Contract termination; and
3. Will furnish the designated item(s) and/or service(s) in accordance with the Informal Request for Proposal and the Contract; and
4. Has provided a correct Federal Employer Identification Number or Social Security Number with Proposal.

SECTION IV. PERMISSIVE COOPERATIVE PROCUREMENTS

If Proposer is awarded a Contract from this Informal Request for Proposal, Proposer hereby (check one)

☐ agrees
☐ disagrees

to offer the resulting contractual terms and prices to other public institutions.

Authorized Signature:______________________ Date:______________________

Name (Type or Print):______________________ Telephone:(_____)______________________

Title:______________________ Fax:(_____)______________________

FEIN ID# or SSN# (required):______________________ Email:______________________

Construction Contractors Board (CCB) License Number (if applicable):______________________

EXHIBIT C
REFERENCES

REFERENCE 1

COMPANY: ____________________ CONTACT NAME: ____________________

ADDRESS: ____________________ PHONE NUMBER: ____________________

CITY, STATE ZIP: ____________________ FAX NUMBER: ____________________

WEBSITE: ____________________ E-MAIL: ____________________

GOODS OR SERVICES PROVIDED: ____________________

REFERENCE 2

COMPANY: ____________________ CONTACT NAME: ____________________

ADDRESS: ____________________ PHONE NUMBER: ____________________

CITY, STATE ZIP: ____________________ FAX NUMBER: ____________________

WEBSITE: ____________________ E-MAIL: ____________________

GOODS OR SERVICES PROVIDED: ____________________

REFERENCE 3

COMPANY: ____________________ CONTACT NAME: ____________________

ADDRESS: ____________________ PHONE NUMBER: ____________________

CITY, STATE ZIP: ____________________ FAX NUMBER: ____________________

WEBSITE: ____________________ E-MAIL: ____________________

GOODS OR SERVICES PROVIDED: ____________________