Task 2 Description

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2015 INTEGRATED RESEARCH PROJECT KICKOFF MEETING

Task 2 Overview

- **Loop Thermal-Hydraulics –**
  - A complete thermal hydraulic study will be conducted that focuses on the experimental loops placed within the TREAT Facility. These include a comprehensive evaluation of historical data collected from previous sodium experiments as well as expansion of existing data through design, development, and utilization of a new experimental loop that is representative of a proposed TREAT water flow loop.
    [Led by Oregon State University]

    - **Sodium Loop** – Data from historically collected sodium loop calibration experiments will be used in a benchmark study against Nek5000 (DoE NEAMS code) and Star CCM+ (Industry code).

    - **Water Loop** – Empirical data resulting from the new experimental flow loop will be benchmarked against RELAP5-3D (Industry code) and TRACE (U.S. NRC code). The experimental loop will also be used to support operational shake-down efforts for a TREAT Facility prototype

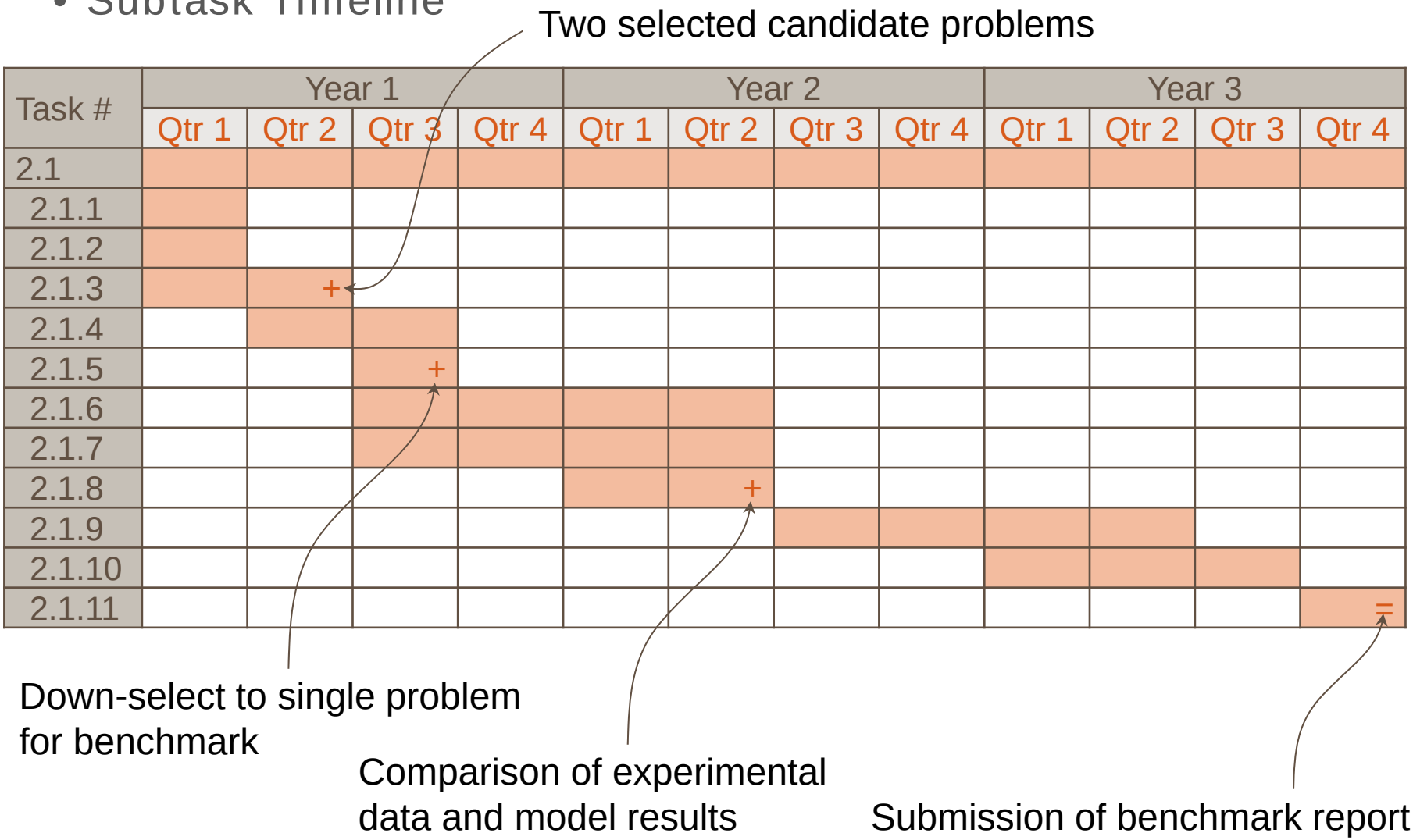
Task 2.1 Description (Sodium Loop)

- Subtask Overview

Task #	Description	Owner
2.1	Sodium Loop	
2.1.1	Survey literature of existing sodium test data	B. Woods
2.1.2	Select two candidate problems	B. Woods
2.1.3	Organize and document data for two candidate problems	B. Woods
2.1.4	Identify and review industry needs for sodium loop data	B. Woods
2.1.5	Down-select to one problem for benchmark evaluation	B. Woods
2.1.6	Preliminary modeling with industry tool Star CCM+	K. Weaver
2.1.7	Preliminary modeling with NEAMS code Nek5000	D. Pointer
2.1.8	Comparison of experimental data & model results for problem	B. Woods
2.1.9	Benchmark level evaluation of problem	B. Woods
2.1.10	Evaluation of uncertainties in selected problem	B. Woods
2.1.11	Submission of benchmark for peer review	B. Woods

Task 2.1 Description (Sodium Loop)

- Subtask Timeline



Task 2.1 Description (Sodium Loop)

- Task 2.1.1 Survey literature of existing sodium test data
  - A representative from OSU will engage ANL and INL for a period of one academic term for the purpose of working with staff at each respective institution (Nicolas Woolstenhulme and Colby Jensen from the INL and Chang-ho Lee from ANL) to collect and organize sodium test data that is presently available from the sodium testing campaign(s) conducted by the TREAT Facility.

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Presently running into issues accessing information due to "Applied Technology" limitations and export control (Help Requested!)

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  - The documentation and literature will be organized and archived using a database system so as to provide valuable access to all other collaborative members on the project.

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Presently running into issues accessing information due to "Applied Technology" limitations and export control (Help Requested!)

  - The documentation and literature will be organized and archived using a database system so as to provide valuable access to all other collaborative members on the project.

Already developed (under development) at ANL. Access to this database will resolve item above.

Task 2.1 Description (Sodium Loop)

- Task 2.1.2 Select two candidate problems
  - OSU, ORNL, and TerraPower will collectively review all the experimental tests (documented within the created database) acquired as a part of the recovery effort in task 2.1.1.

  - The organization leads from the three institutions will agree on two candidate problems for further consideration as a benchmark problem.
    - The down selection criterion will be based on two figures of merit;
      - (1) the completeness of available test data (the sets which include the most rigorous documentation and detailed experimental outcomes), and

      - (2) the tests which clearly align with most relevant industry needs as compared to their counterparts.

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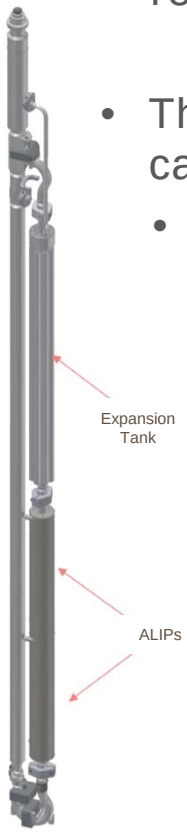


  - The organization leads from the three institutions will agree on two candidate problems for further consideration as a benchmark problem.
    - The down selection criterion will be based on two figures of merit;
      - (1) the completeness of available test data (the sets which include the most rigorous documentation and detailed experimental outcomes), and

At present, it appears that "completeness of data" will be the limiting criterion

      - (2) the tests which clearly align with most relevant industry needs as compared to their counterparts.

Task 2.1 Description (Sodium Loop)

- Task 2.1.3 Organize data for two candidate problems
  - A **description report** will be generated which summarizes and organizes all relevant information associated with the two down-selected problems from task 2.1.2.

  - This description report will be distributed to all primary collaborators and advisory board members. The purpose of this report is to provide a single document which places objective context and information regarding the two candidate problems so that the advisory board, along with the primary collaborators within the project may further down-select the two candidate problems to a single benchmark problem which will be evaluated.

Task 2.1 Description (Sodium Loop)

- Task 2.1.4 Review industry needs for sodium loop data
  - A review of industry needs will be conducted. This task will focus on needs from industry partners who have clearly shown a desire to conduct transient fuel tests within the TREAT Facility using sodium coolant after its restart.
    - TerraPower is one such member in order to ensure that the problem which is selected for benchmark evaluation yields the highest impact and most economically feasible.

Task 2.1 Description (Sodium Loop)

- Task 2.1.5 Down-select to one benchmark problem
  - Based on the documentation developed within task 2.1.3 and the industry feedback received within task 2.1.4 a single problem will be selected to pursue through the conduct of a benchmark level evaluation of sodium loop tests.
  - This benchmark evaluation will be conducted by means of two independent CFD software packages.
    - Star CCM+ (TerraPower)
    - Nek5000 (ORNL and OSU)

Task 2.1 Description (Sodium Loop)

- Task 2.1.6 Preliminary model with industry tool Star CCM+
  - TerraPower will lead activities using the Star CCM+ software package for the CFD benchmark study associated with the selected sodium experiment.
  - Given the information resulting from task 2.1.3 in the description report, TerraPower will conduct a ‘blind calculation’ using idealized boundary conditions.

Task 2.1 Description (Sodium Loop)

- Task 2.1.7 Preliminary model with NEAMS code Nek5000
  - ORNL will lead activities using the Nek5000 software package for the CFD benchmark study associated with the selected sodium experiment.
  - Given the information resulting from task 2.1.3 in the description report, ORNL will conduct a ‘blind calculation’ using idealized boundary conditions.

Task 2.1 Description (Sodium Loop)

- Task 2.1.8 Comparison of experimental data & model
  - Using the figures of merit called out within the description report, an objective comparison between the two computational codes will be made against the experimental data.
    - This effort will demonstrate each tool's ability to blindly model the defined sodium test with limited information.
  - The description report will be updated to include an additional chapter detailing the outcome of the blind calculations. The report will be shared with all primary collaborators and advisory board members on the project after the working group meeting.

Task 2.1 Description (Sodium Loop)

- Task 2.1.9 Benchmark level evaluation of problem
  - A meeting will be held between the task lead and the primary collaborators within task 2.1.
    - This meeting will provide further detail associated with the test problem under consideration, and expanded figures of merit (along with their required criterion [e.g. residuals, etc.]) necessary to successfully complete the benchmark level evaluation.
  - Each respective organization participating in task 2.1 will work to complete a comprehensive model which appropriately and objectively aligns with the experimental data. The intent of this 'open calculation' is to describe the required changes made between the blind calculation completed under tasks 2.1.6 and 2.1.7 and the open calculation so as to most effectively model the experimental data.

Task 2.1 Description (Sodium Loop)

- Task 2.1.10 Evaluation of uncertainties in selected problem
  - OSU will lead the synthesize all experimental data in collaboration with ORNL and TerraPower for the benchmark problem to objectively quantify as much measurement and stochastic uncertainty as feasible and compare the appropriate figures of merit in a single final report.

  - The final report will all
    - computational efforts (i.e. all necessary independent input variable which influence the final outcome of this study) and
    - their experimental counterpart.

Task 2.1 Description (Sodium Loop)

- Task 2.1.11 Submission of benchmark for peer review
  - A benchmark level report will be submitted to the project team for review including all advisory board members.
  - This report will be ultimately submitted to the TREAT Facility restart staff at the INL, appropriate personnel within the NEAMS program, and its outcomes published in scientific journal articles.

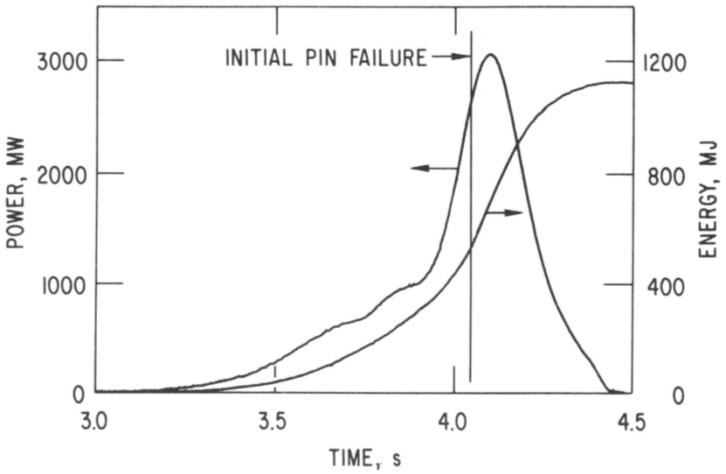
Task 2.1 Description (Sodium Loop)

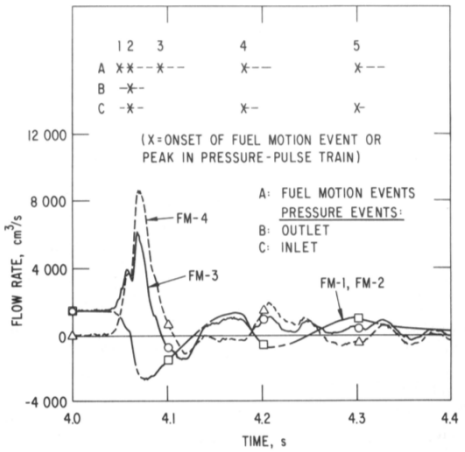
- Summary
  - Access to information is the biggest **concern** in successfully completing task 2.1
    - Need to resolve to maintain critical path schedule
  - Meetings with ANL resulted in pragmatic understanding that best candidate problems are
    - Most recently perform tests (1980s tests)
      - Most thoroughly documented and most resolved instrumentation

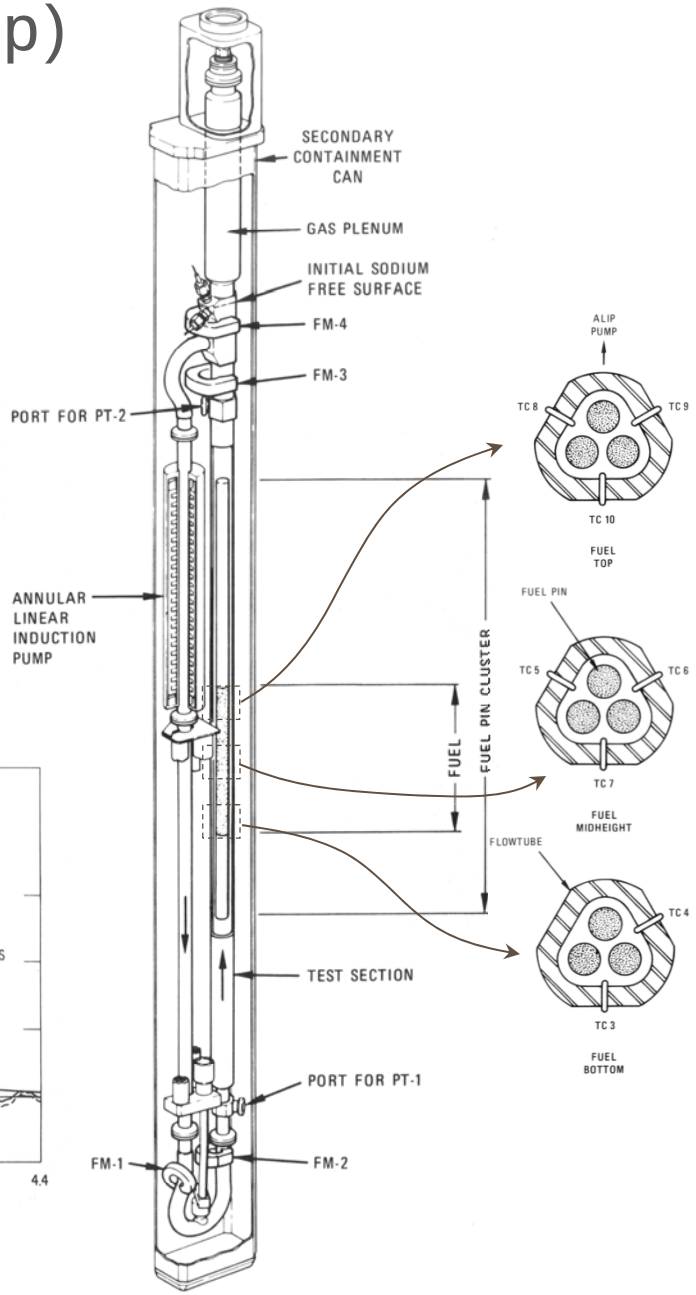
Task 2.1 Description (Sodium Loop)

- Summary
  - Candidates
    - L-0 series tests (oxide fueled experiment)
    - M-8 cal tests
    - E-8 (seven pin test)

  - AX-1 Test (Mark IICB loop)
    - *Nuclear Technology*, Vol. 58, pp 465-482







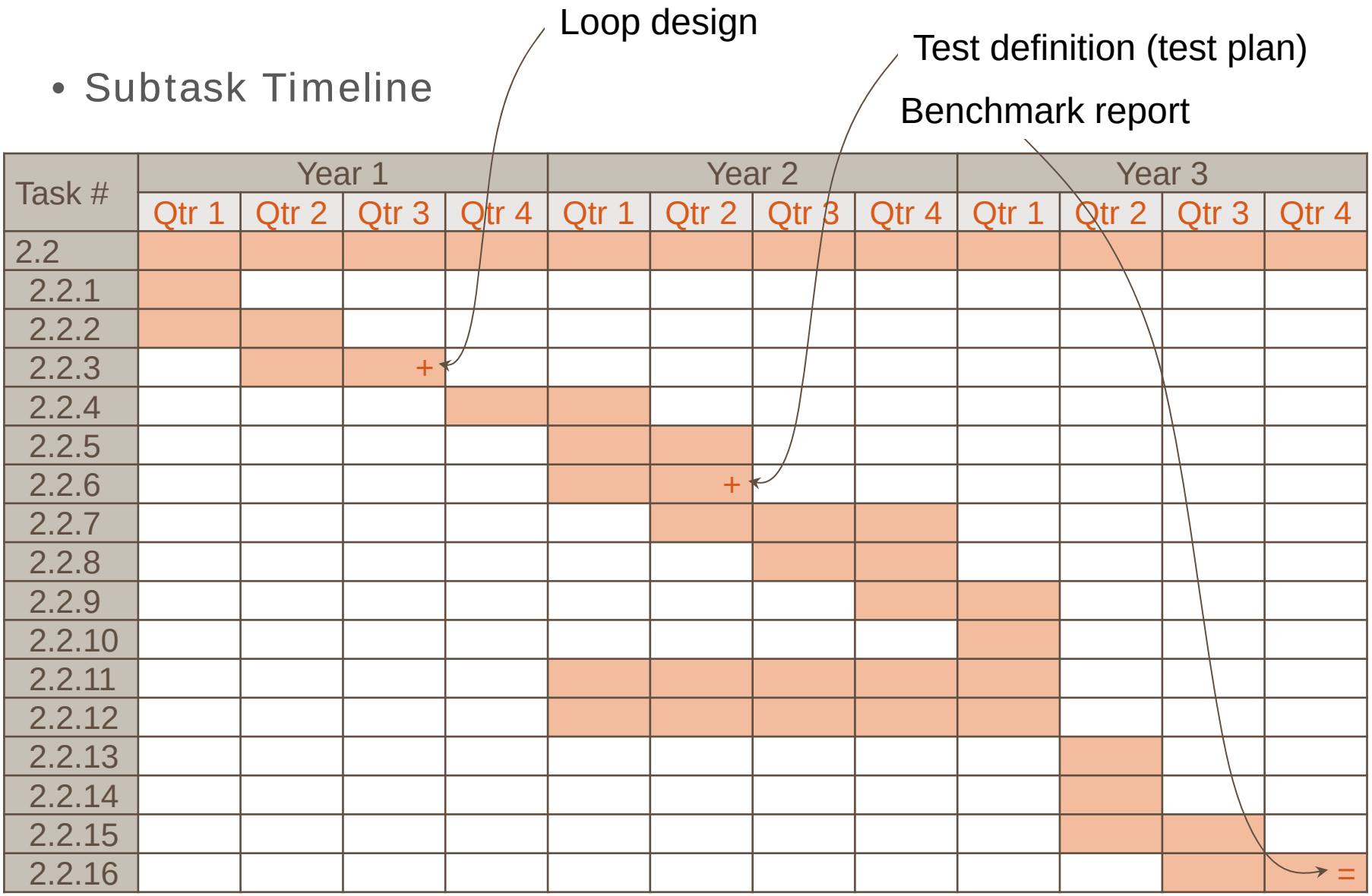
Task 2.2 Description (Water Loop)

- Subtask Overview

Task #	Description	Owner
2.2	Water Loop	
2.2.1	Identify and review industry needs for water loop	W. Marcum
2.2.2	Develop loop technical and functional requirements	W. Marcum
2.2.3	Loop design	W. Marcum
2.2.4	Loop fabrication	J. Nylander
2.2.5	Loop shakedown	W. Marcum
2.2.6	Define flow loop ‘operations tests’ and ‘benchmark tests’	W. Marcum
2.2.7	Operations test conduct	W. Marcum
2.2.8	Synthesis of operations tests data	W. Marcum
2.2.9	Benchmark test conduct	W. Marcum
2.2.10	Synthesis of benchmark test data	W. Marcum
2.2.11	Modeling of benchmark test with U.S. NRC code TRACE	C. Jensen
2.2.12	Modeling of benchmark test with RELAP5-3D	C. Jensen
2.2.13	Comparison of experimental data & model results for problem	C. Jensen
2.2.14	Benchmark level evaluation of problem	C. Jensen
2.2.15	Evaluation of uncertainties in selected problem	W. Marcum
2.2.16	Submission of benchmark for peer review	C. Jensen

Task 2.2 Description (Water Loop)

- Subtask Timeline



Task #	Year 1				Year 2				Year 3			
	Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2	Qtr 3	Qtr 4
2.2												
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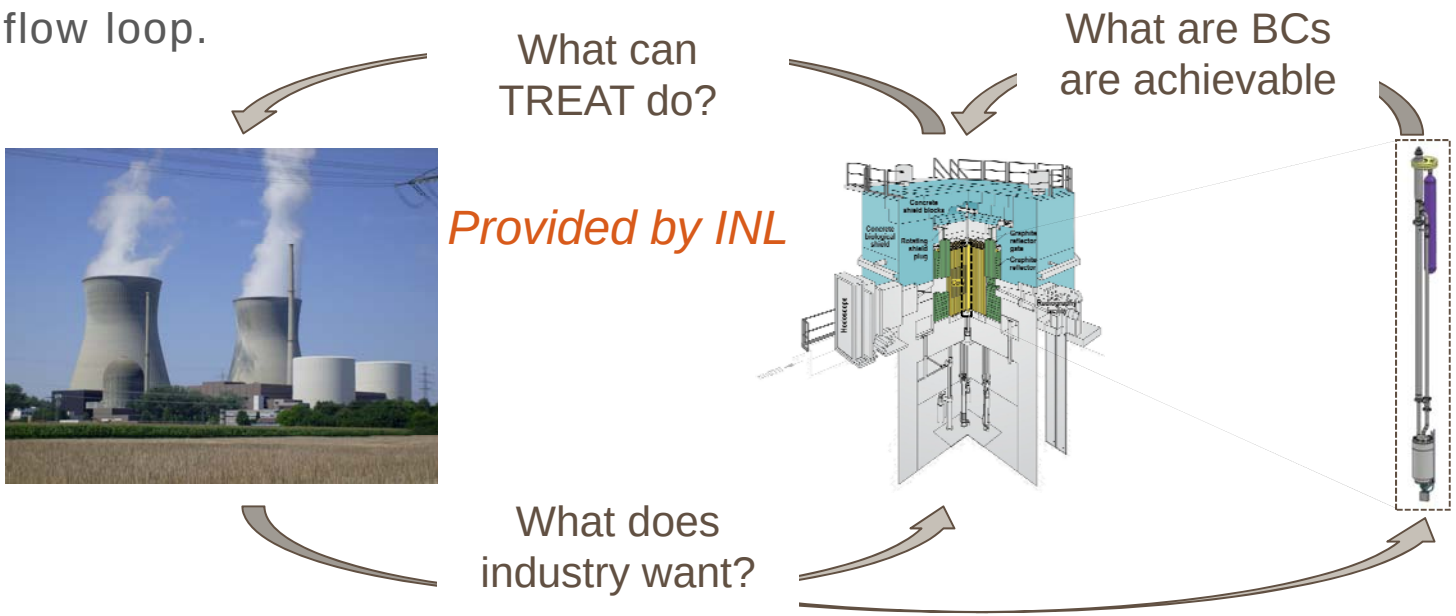
2.2.15												
2.2.16												

Task 2.2 Description (Water Loop)

- Task 2.2.1 Review industry needs for water loop
  - In order to construct and utilize the most high impact and robust water flow loop prototype a clear set of functional requirements (customer requirements) must first be defined.

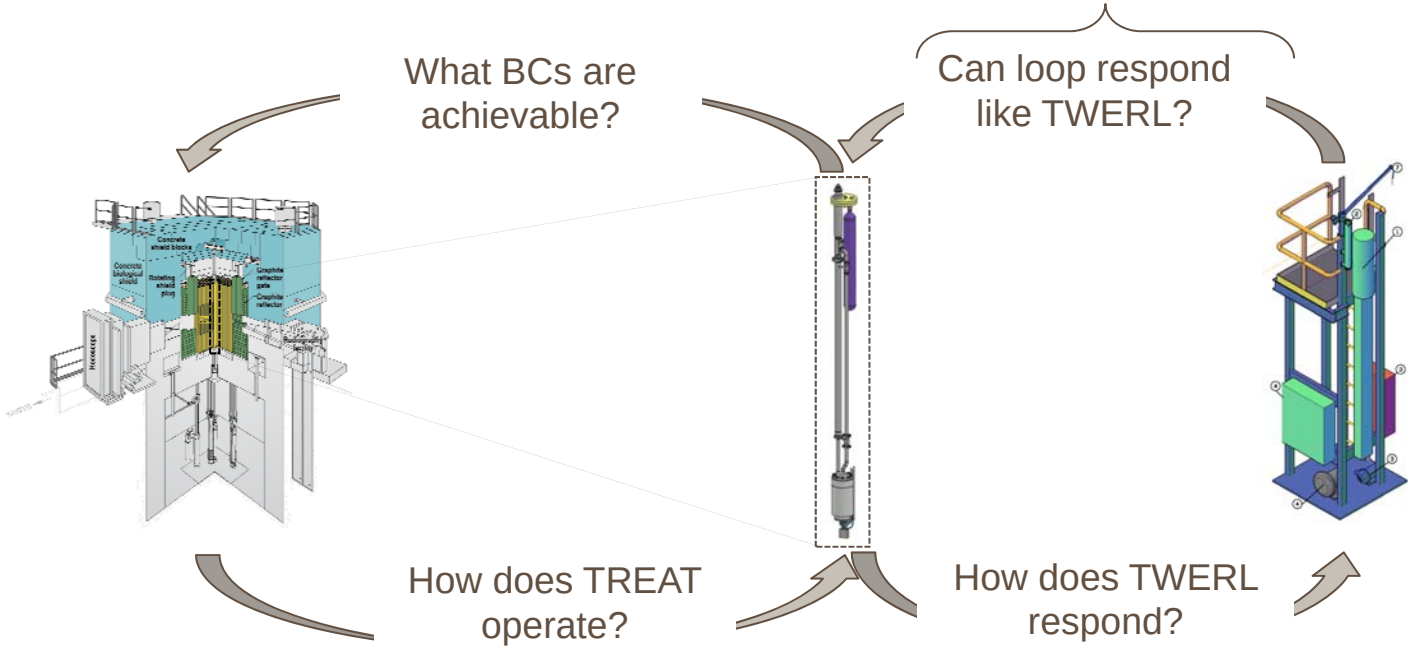
  - OSU will work with the TREAT Facility restart staff to engage the integrated individuals who derive the end-user of the water flow loop(s) to be utilized within the TREAT Facility.
    - Define a series of high level customer requirements for a TREAT Facility water flow loop.



Task 2.2 Description (Water Loop)

- Task 2.2.2 Develop loop T&FRs
  - Once a list of functional requirements has been outlined OSU will work with the TREAT Facility restart scientific staff to review the customer requirements and detail a partner set of technical requirements.
    - This will be documented in a master technical and functional requirements (T&FR) report.

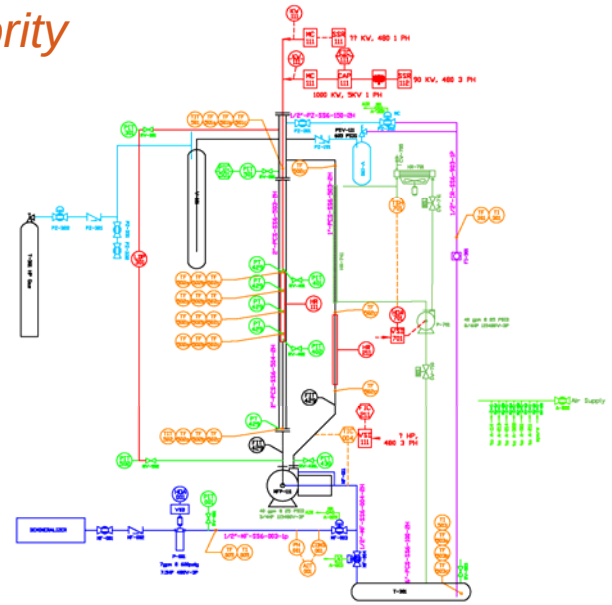
Possible testing with ATF clad heater elements

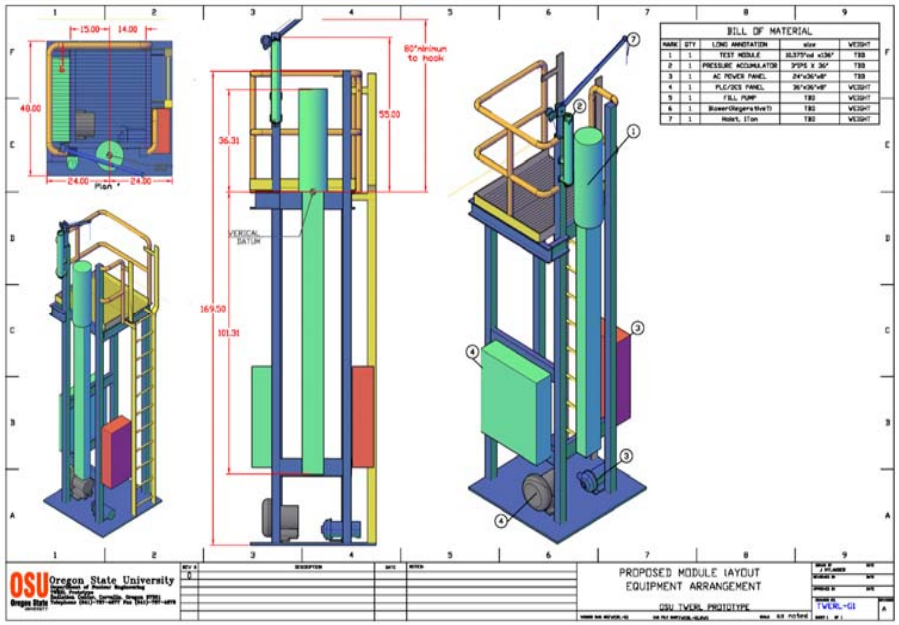


Task 2.2 Description (Water Loop)

- Task 2.2.3 Loop design
  - OSU will work with TREAT Facility restart staff and Harris Thermal Transfer Products to extend the preliminary design of the water flow loop into a comprehensive experimental facility.
    - A final design package will be disseminated to the AB for review.

Flexibility for future use, and instrumentation selection integration of high priority



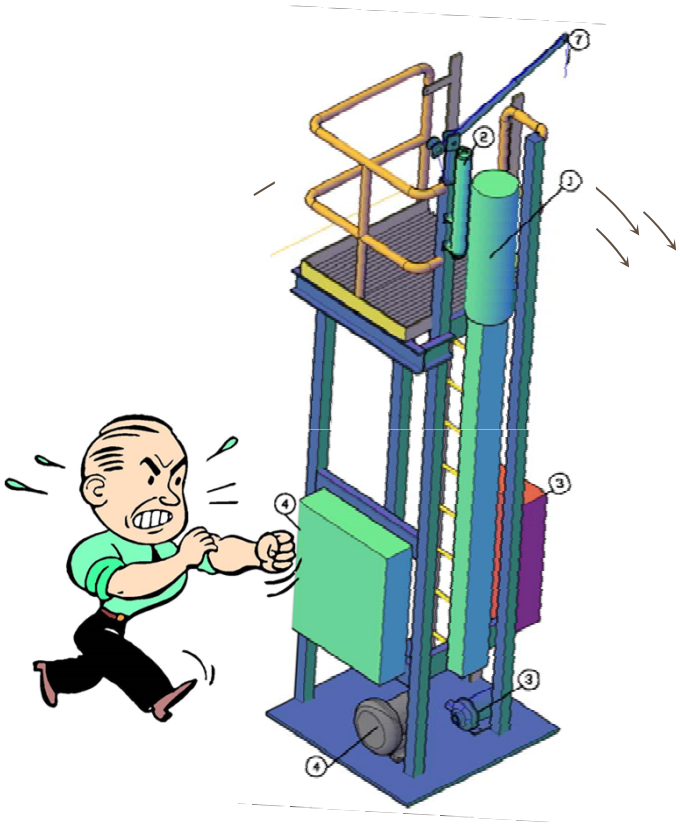


Task 2.2 Description (Water Loop)

- Task 2.2.4 Loop fabrication
  - Loop fabrication will be led by Harris Thermal Transfer Products.
    - Approved design package will be handed off to HTTP for loop fabrication.
    - Loop fabrication will include all frame work, electrical conduit, piping systems, and vessels necessary to operate the facility in modular form on a single experimental frame structure, which is transportable via truck.
    - The loop will to be installed in place, both mechanically and electrically for ‘turn-key’ transfer of the system from HTTP to OSU.
    - Present known issues
      - *Capital cost of primary pump*
      - *Lead time for heater rod fabrication*

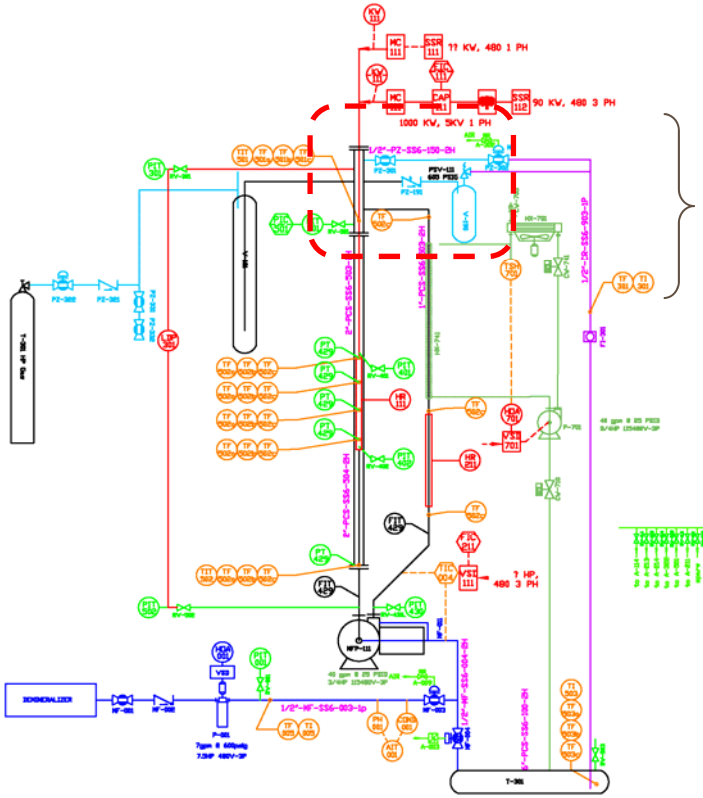
Task 2.2 Description (Water Loop)

- Task 2.2.5 Loop “shakedown”
  - Upon complete installation and inspection of the water flow loop, OSU will work with HTTP personnel to conduct all necessary hardware and software shakedown tests on the experimental loop. This will likely include approximately 14 tests ranging from ‘loop fill’ to ‘pump bump’ tests.



Task 2.2 Description (Water Loop)

- Task 2.2.6 Define flow loop ‘operations’ and ‘benchmark’ tests
  - OSU will work with TREAT Facility restart staff, an objective and manageable set of operational tests and benchmark tests.
    - Operational tests are intended on shakedown loop prototype design characteristics for preparation of remote handling and operation in TREAT and HFEF.

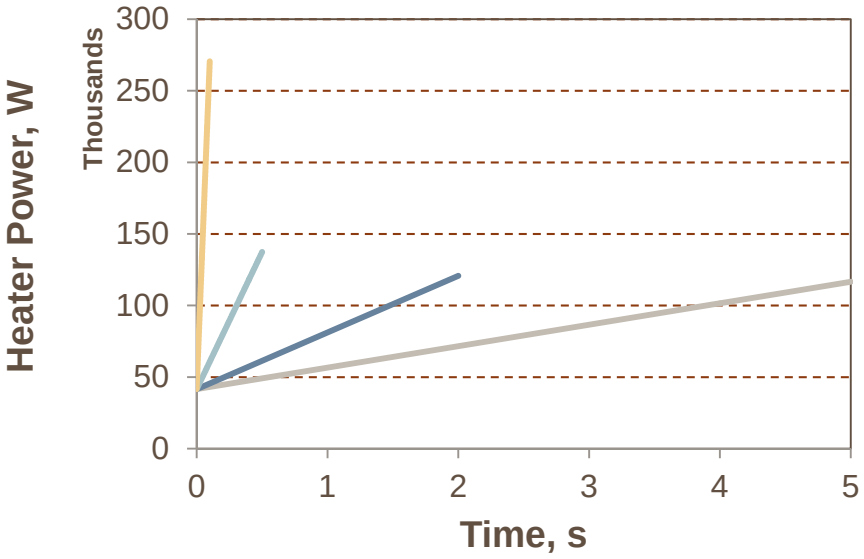


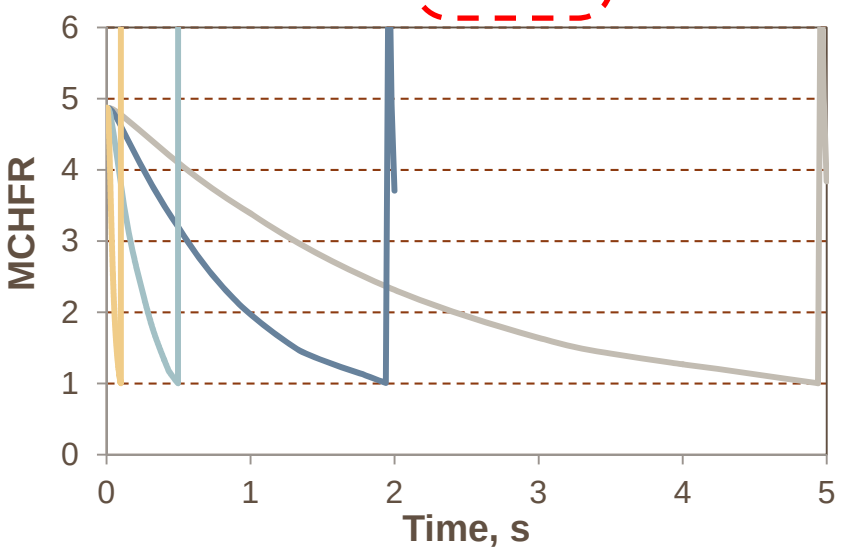
e.g. remote fill, vent, and purge

Task 2.2 Description (Water Loop)

- Task 2.2.6 Define flow loop 'operations' and 'benchmark' tests
  - Benchmark tests are intended on providing experimental data relevant to the support effort for conducting safety analyses relating to the TREAT Facility restart. Broken into three categories,
    - unheated, steady-state tests,
    - heated steady state tests, and
    - heated transient tests

Ramp Time (s)	Heater Power (kW)	CHF (MW/m^2)	Temperature Rise (Δ°C)
5	116	2.77	40.3
2	119	2.82	40.2
0.5	137	3.15	38.9
0.1	270	4.88	27.6





Task 2.2 Description (Water Loop)

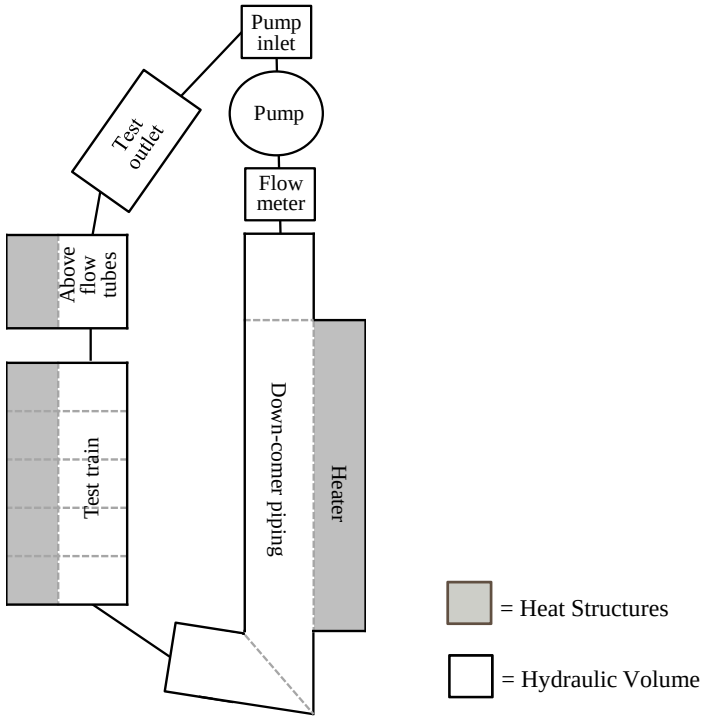
- Task 2.2.7 Operational test conduct
  - Operational tests will be conducted, following the completion of task 2.2.6. Each individual operational test will include a quick look report.
- Task 2.2.8 Synthesis of operational tests
  - The Final Report will summarize the outcome of all operational tests including the impact of associate figures of merit for each respective operational test.
- Task 2.2.9 Benchmark test conduct
  - The Final Report will summarize the outcome of all operational tests including the impact of associate figures of merit for each respective operational test.
- Task 2.2.10 Synthesis of operational tests
  - The Final Report will include the outcome of all benchmark tests. The summary of these tests will include the impact of associated figures of merit for each respective benchmark test.

Task 2.2 Description (Water Loop)

- Task 2.2.11 Modeling of benchmark test with TRACE
  - OSU will develop a TRACE model for one of the benchmark tests performed using the U.S. NRC code TRACE. Modeling of the benchmark test will be done blindly, based on the design package put together as a part of task 2.2.3. The data will not be made available until the modeling and results have been completed.

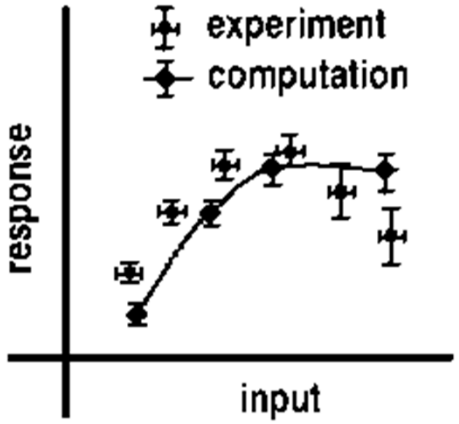
Task 2.2 Description (Water Loop)

- Task 2.2.12 Modeling of benchmark test with RELAP5-3D
  - INL will develop a model using RELAP5-3D of the water flow loop. The same test simulated in task 2.2.11 will be run as a part of the RELAP benchmark simulation. Modeling of the benchmark test will be done blindly, based on the design package put together as a part of task 2.2.3. The data will not be made available until the modeling and results have been completed.



Task 2.2 Description (Water Loop)

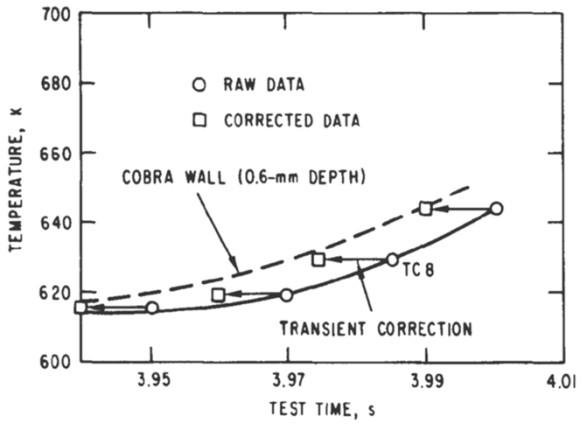
- Task 2.2.13 Comparison of experiment & models results
  - Using the appropriate figures of merit called out within the benchmark test plan, INL will work to objectively compare the results from the two computational codes (TRACE and RELAP5-3D) against the experimental data. This effort will demonstrate each tool's ability to blindly model the defined sodium test with limited information.



Task 2.2 Description (Water Loop)

- Task 2.2.14 Benchmark level evaluation of problem
  - INL and OSU will meet to provide further detail associated with the test problem under consideration, and an expanded set of figures of merit (along with their required criterion [e.g. code refinement, etc.]) necessary to successfully complete the benchmark level evaluation will be detailed.

  - INL and OSU will work to complete a comprehensive model which appropriately and objectively aligns with the experimental data.
    - The intent of this 'open calculation' is to provide a documented set of necessary model alterations made between the blind calculation and the open calculation so as to most effectively model the experimental data.



Task 2.2 Description (Water Loop)

- Task 2.2.15 Evaluation of uncertainties in selected problem
  - OSU will synthesize all experimental data to objectively quantify measurement and stochastic uncertainty and compare the appropriate figures of merit in a single final report which summarizes all computational efforts and their experimental counterpart.

- Task 2.2.16 Submission of benchmark for peer review
  - A benchmark level report will be developed by INL and submitted for review. This report will be ultimately submitted to the INL TREAT Facility restart staff, appropriate personnel within the NEAMS program, and its outcomes published in scientific journal articles.

Task 2.2 Description (Water Loop)

- Summary
  - Present loop design progress shows great promise with two exceptions:
    - Capital cost of primary pump
    - Lead time for heater rod fabrication
  - Operational tests will likely focus on large uncertainties in TWERL's operability (still in flux)
  - Benchmark tests will wrap up with RIA simulated CHF tests at pressure

Thank You