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FY 07 Summary of System Interface and Support Systems R&D and Technical Issues Map

S. R. Sherman

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ABSTRACT

This document provides a summary of research and development activities performed in the System Interface and Support Systems area of the DOE Nuclear Hydrogen Initiative in FY 2007. Project cost and performance data obtained from the PICS system, at least up through July 2007, are presented and analyzed. Brief summaries of accomplishments and references are provided. A mapping of System Interface and Support Systems technical issues versus the work performed is updated and presented. Lastly, near-term research plans are described, and recommendations are provided for additional research.

CONTENTS

TABLES

FIGURES

1. INTRODUCTION

The System Interface and Support Systems area under the US Department of Energy (DOE) Nuclear Hydrogen Initiative (NHI) is responsible for developing the technologies needed to connect a high-temperature nuclear reactor to a nuclear hydrogen production plant. Also falling into this area are efforts to develop the balance-of-plant components of the nuclear hydrogen plants, and the identification of infrastructure needs for those plants. Overall system safety and environmental analyses are an important part of this technical area too. This technical area is one of three research areas of the DOE NHI. The other technical areas are the Thermochemical area and the High Temperature Electrolysis area.

The System Interface and Support Systems (SI&SS) area has been an active area of research since 2004, as evidenced by the total funding summaries shown in Table 1. As in the past, a majority of the total funding for FY07 ($2,000K) was sent to the University of Nevada Las Vegas (UNLV) in order to perform research through their High Temperature Heat Exchanger Project, while $860K was spent under controlled conditions at the national laboratories (i.e., Argonne National Laboratory, Idaho National Laboratory, and Oak Ridge National Laboratory). An additional $60K was used to fund a sub-contract between the Idaho National Laboratory and the Ohio State University that will involve the testing of metallic compact heat exchangers in an existing helium loop during FY08 and FY09.

Table 1. DOE NHI System Interface and Support Systems Yearly Funding

	FY 2004	FY 2005	FY 2006	FY 2007	FY 2008
Funding ($M)	1.86	2.79	2.90	2.93	*2.35-3.0+*

Although the funding profile has been flat, the climate for research into high temperature heat exchange is becoming more energized, especially as a related program, the Next Generation Nuclear Plant (NGNP) Project, becomes more organized and gains momentum. The NGNP Project is a program initiated in response to the Energy Policy Act 2005 (Ref. 1). The Energy Policy Act of 2005 calls for the creation of a program that is responsible for the research, development, design, construction, and operation of a prototype GenIV nuclear facility that is capable of producing electricity and/or hydrogen. The NGNP Project was funded at about $20M in FY07 and potential funding for the program in FY08 may be in the range of $30-50M. As that program grows, it is anticipated that much of the controlled work scope in the System Interface Area under the DOE NHI be handed over to the NGNP Project.

This document provides a summary of research and development activities performed at UNLV and its sub-contractors, and at the national laboratories. In the case of the national laboratories, work funded with FY07 dollars will be described. In the case of the UNLV High Temperature Heat Exchanger Project, work performed using FY06 carryover funding will be described, as FY07 funded work was just getting underway at the end of FY07.

In addition to a summary of work performed, an update is provided to the System Interface Technical Issues Map (Ref. 2). Plans and recommendations for future work are also described.

2. FUNDING AND PERFORMANCE MEASURES

Work in the DOE NHI is governed by work packages. Work packages are informal contracts between DOE and the laboratories or universities performing work that state the work scope, budget, milestones, deliverables, and timetables for individual work tasks. A work package is applicable to the current fiscal year, but may contain information about work to be performed in future consecutive fiscal years.

The DOE NHI distinguishes between controlled work packages and UNLV work packages. Controlled work packages are used at the national laboratories and other organizations operated or sub-contracted by a contractor working for DOE. The work is controlled in the sense that milestones and deliverables are closely monitored for timeliness and content, and that Earned Value is closely tracked and is expected to stay within +/- 10% of baseline cost and schedule. The funding contract between DOE and UNLV is not currently tied to performance goals, and so UNLV is not bound to the same funding and schedule expectations as the national laboratories. As a result, UNLV work packages are used to govern the work performed at UNLV and its subcontractors but +/- 10% requirement is not enforced concerning the Earned Value statistics. Though UNLV is only obligated to provide quarterly results to DOE, it chooses to participate voluntarily in the monthly Earned Value tracking to help them transition to becoming a full programmatic partner in the DOE NHI.

In FY07, $2.93M was provided by DOE to fund work in the System Interface and Support Systems area. Of this amount, $2.0M was allocated for work to be performed by the UNLV High Temperature Heat Exchanger Project, and $860K was allocated for work at the national laboratories (i.e., Argonne National Laboratory, Idaho National Laboratory, and Oak Ridge National Laboratory). An additional $60K was used to fund a sub-contract between the Idaho National Laboratory and the Ohio State University that calls for the testing of three compact metallic heat exchangers at Ohio State in FY08 and FY09.

Though the work performed by the national laboratories in FY07 is directly linked with the funding provided in FY07, work performed by the UNLV High Temperature Heat Exchanger Project has lagged the national laboratories by almost one year, and expenditures of FY07 funds are just now beginning. Instead, the UNLV High Temperature Heat Exchanger Project spent nearly all of FY07 working with FY06 carryover funds ($1,898K) to finish up work initiated at the end of FY06. The time lag is not ideal, and is a response to delays caused by the Continuing Resolution period in FY06, and a handover of the DOE contract for heat exchanger work from the UNLV Research Foundation to UNLV at mid-year FY06. Work initiated at UNLV in FY06 did not start until August 2006, and this delay has persisted into FY07 with no acceleration of schedule.

The lag in schedule at UNLV is not likely to be eliminated if left to UNLV to manage, because it is to UNLV's advantage to have a lag. UNLV does not receive its yearly funding until after any Continuing Resolution period has been resolved. There is no defined time limit on Continuing Resolution, and such periods can last many months before final appropriations are awarded. Imposing a time lag on the start of new work in any current fiscal year provides insurance against Continuing Resolution periods and helps maintain continuous funding for professors and students.

While the lag makes good business sense for UNLV, it created problems for the DOE NHI. Work expected in FY06 was not delivered during that fiscal year, and is only now being delivered in FY07. Two million dollars of new funding was allocated in FY07 to pay for work at UNLV that will not substantially begin until FY08. This is opportunity lost, as that same $2M could have been used to fund controlled work packages in FY07 that would have been completed within the current fiscal year. Since UNLV is essentially $2M in arrears for research owed to the DOE NHI, it is up to UNLV going forward from here to ensure that the value of the research delivered by that $2M is at least as good or superior to the value of research that would have been obtained from the national laboratories. In other words, the research must be good enough to be "worth the wait." UNLV's research plans and conduct of research will need to be matched closely to the needs of the national program to continue to insure its relevancy to the larger program goals of the DOE NHI and, more recently, the NGNP Project.

In FY07, work under controlled work packages was performed at three national laboratories: Argonne National Laboratory (ANL), Idaho National Laboratory (INL), and Oak Ridge National Laboratory (ORNL). In broad terms, ANL was tasked with assisting INL in the development of steady-state system models for the combined nuclear plant/hydrogen plant facility and in the performance of an I-NERI project with the Korea Atomic Energy Research Institute (KAERI). The INL was assigned a leadership role in the NHI program to serve as technical director of SI&SS research and also performed system modeling work with ANL as part of the I-NERI agreement with KAERI. The INL also coordinated exchanges of system interface information with the Commisariat à l'Energie Atomique (CEA) under an existing I-NERI agreement, and completed work with ORNL to develop a new NHI Materials and Components Development Plan. ORNL served as lead editor for the development of a new NHI Materials and Components Test Plan and worked with the INL to achieve this goal.

At UNLV, work was performed using FY06 carryover money to complete projects on materials property measurements, heat exchanger modeling, corrosion and surface analysis, and prototype heat exchanger testing. Most of the work occurred at UNLV, but some work was completed at Ceramatec, Inc., General Atomics, Massachusetts Institute of Technology, and University of California – Berkeley.

The Program Information Collection System (PICS), developed by the Performance Results Corporation, was used to track program performance for the controlled work packages. In PICS, a baseline schedule (Base Cost Work Scheduled or BCWS) was established at the start of the work packages, and the Base Cost Work Performed (BCWP), and Actual Cost Work Performed (ACWP) were recorded monthly.

Table 2 shows the PICS numbers for the controlled work packages. Actual numbers are provided for the first three quarters, and projected numbers (*shown in italics*) are provided for the 4th quarter since PICS information for August and September will not be available until September and October, respectively. The projections are based upon the assumption that 100% of all available funds (FY06 carryover plus FY07 funds) are used for each work package, and that 100% of all work scope is completed by the end of the fiscal year. According to the year-end projections, the work packages should all be completed on or before the end of the year with a small amount of carryover (less than 10%). This trajectory is justified by the 4th quarter projections that the projects must perform with a schedule variance of -6.3% and a cost variance of -2.7% in order to reach the $0 mark. This means that the projects would have to slow down their progress by 6.3% and increase their spend rate by 2.7% in the 4th quarter just to reach the break-even point. Therefore, chances are very good that all scheduled work in the 4th quarter should be completed on time or earlier, and that there will be some small amount of carryover (<10%) available at the three national laboratories to support work in FY08.

Table 2. SI&SS Controlled Work Packages for FY07

	Fiscal Quarter				
	1st	2nd	3rd	4th*	Totals*
ANL (N-AN07SS0101)					
BCWS	55,000	57,000	56,000	49,181	217,181
BCWP	59,537	43,069	76,847	*37,728*	*217,181*
ACWP	59,538	43,069	76,847	37,727	*217,181*
SV%	8.3	-24.4	37.2	*-23.3*	
CV%	0.0	0.0	0.0	*0.0*	
INL (N-IN07SS0101)					
BCWS	83,284	114,983	57,258	35,254	290,779
BCWP	83,048	115,223	57,199	*35,309*	*290,779*
ACWP	86,555	81,599	89,507	*33,118*	*290,779*
SV%	-0.3	0.2	-0.1	*0.2*	
CV%	-4.2	29.2	-56.5	*6.2*	
INL (N-IN07SS0102)					
BCWS	88,204	115,323	129,205	173,104	524,836
BCWP	90,553	112,936	129,109	*173,238*	*524,836*
ACWP	72,066	110,202	138,151	*185,417*	*524,836*
SV%	2.7	-2.1	-0.1	*0.1*	
CV%	20.4	2.4	-7.0	*-7.0*	
ORNL (N-OR07SS0101, $100,000)					
BCWS	40,071	13,892	18,000	18,768	90,731
BCWP	40,071	10,437	27,500	*12,723*	*90,731*
ACWP	40,071	11,017	29,839	*9,804*	*90,731*
SV%	0.0	-24.9	52.8	*-32.2*	
CV%	0.0	-5.6	-8.5	*-22.9*	
Overall Performance					
BCWS	266,559	301,198	260,463	276,307	1,123,527
BCWP	273,209	281,665	290,655	*258,998*	*1,123,527*
ACWP	258,230	245,887	334,344	*266,066*	*1,123,527*
SV%	2.5	-6.5	11.6	*-6.3*	
CV%	5.5	12.7	-15.0	*-2.7*	

*4th quarter is projected based on the assumption that each work package uses 100% of available funding and has completed 100% of the work scope.

Table 3 shows the number of Level 2 milestones scheduled, delivered early or on-time, provided late, or that remain to be submitted as of August 2007 for the four controlled work packages. So far, no milestones have been delivered late and all completed milestones were delivered early or on-time. Five milestones remain to be met in September 2007, but all are expected to be submitted on-schedule.

Table 3. SI&SS Controlled Work Package Level 2 Milestone Performance

	Scheduled	Delivered On-Time or Early	Provided Late	Remaining
N-AN07SS0101	3	2	0	1
N-IN07SS0101	4	2	0	2
N-IN07SS0102	7	5	0	2
N-OR07SS0101	2	2	0	0

Table 4 shows the PICS results for the UNLV work packages. For these work packages, $2M of new funding has been provided in FY07, and $1.989M was carried over from FY06. No work has been performed on the work packages using FY07 funds (N-ID07SS0101 through N-ID07SS0105) as of August 2007, and at this point work will probably not start in these areas until the end of the fiscal year. For the FY06 Carryover work packages, the general trend is for the work to be performed behind schedule. Work packages N-ID07SS0106, N-ID07SS0108, N-ID07SS0110, N-ID07SS0111, and N-ID07SS0113 were completed or will be completed beyond the scheduled length of the work.

Table 4. SI&SS UNLV Work Packages for FY07.

	Fiscal Quarter				
	1st	2nd	3rd	4th*	Totals
FY07 Materials, N-ID07SS0101, *$700,000*					
BCWS	0	0	0	*0*	*0*
BCWP	0	0	0	*0*	*0*
ACWP	0	0	0	*0*	*0*
SV%	0	0	0	*0*	
CV%	0	0	0	*0*	
FY07 Modeling, N-ID07SS0102, *$350,000*					
BCWS	0	0	0	*0*	*0*
BCWP	0	0	0	*0*	*0*
ACWP	0	0	0	*0*	*0*
SV%	0	0	0	*0*	
CV%	0	0	0	*0*	
FY07 Liquid Salts, N-ID07SS0103, *$250,000*					
BCWS	0	0	0	*0*	*0*
BCWP	0	0	0	*0*	*0*
ACWP	0	0	0	*0*	*0*
SV%	0	0	0	*0*	
CV%	0	0	0	*0*	
FY07 Materials Surface Characterization, N-ID07SS0104, *$350,000*					
BCWS	0	0	0	*0*	*0*
BCWP	0	0	0	*0*	*0*
ACWP	0	0	0	*0*	*0*
SV%	0	0	0	*0*	
CV%	0	0	0	*0*	

	Fiscal Quarter				
	1st	2nd	3rd	4th*	Totals
FY07 Chemistry Support, N-ID07SS0105, *$350,000*					
BCWS	0	0	0	*0*	*0*
BCWP	0	0	0	*0*	*0*
ACWP	0	0	0	*0*	*0*
SV%	0	0	0	*0*	
CV%	0	0	0	*0*	
FY06 Carryover Alloy Measurement (UNLV, Dr. Roy), N-ID07SS0106, $289,210					
BCWS	155,336	51,057	82,817	0	289,210
BCWP	101,000	80,500	105,000	2,710	289,210
ACWP	89,867	80,768	114,449	4,126	289,210
SV%	-35.0	57.7	26.8		
CV%	11.0	-0.3	-9.0	-50.3	
FY06 Carryover Crack Growth (GA, Dr. Wong), N-ID07SS0107, $334,200					
BCWS	80,000	74,900	20,300	159,000	334,200
BCWP	66,000	72,900	27,000	*168,300*	*334,200*
ACWP	66,000	42,900	56,200	*169,100*	*334,200*
SV%	-17.5	-2.7	33.0	*5.8*	
CV%	0.0	41.5	-108.1	*-0.5*	
FY06 Carryover Heat Exchanger Analysis (UNLV, Dr. Chen), N-ID07SS0108, $174,087					
BCWS	27,000	84,000	63,087	0	174,087
BCWP	46,000	54,483	46,000	*27,604*	*174,087*
ACWP	46,009	54,000	22,962	*51,116*	*174,087*
SV%	70.4	-35.1	-27.1		
CV%	0.0	0.9	50.1	*-85.2*	
FY06 Carryover C-SiC Heat Exchangers (UC-Berkeley, Dr. Peterson), N-ID07SS0109, $135,130					
BCWS	54,000	21,315	40,399	19,416	135,130
BCWP	56,623	21,767	28,558	*28,182*	*135,130*
ACWP	40,399	28,558	24,981	*31,759*	*135,130*
SV%	4.9	2.1	-29.3	*45.2*	
CV%	0.0	0.0	12.53	*12.7*	
FY06 Carryover Ceramatec #1 (Ceramatec, Dr. Wilson), N-ID07SS0110, $32,688					
BCWS	32,688	0	0	0	32,688
BCWP	0	32,688	0	0	32,688
ACWP	0	32,688	0	0	32,688
SV%	-100		0	0	
CV%		0	0	0	
FY06 Carryover Ceramatec #2 (Ceramatec, Dr. Wilson), N-ID07SS0111, $150,000					
BCWS	20,000	60,000	70,000	0	150,000
BCWP	8,000	33,000	63,000	*46,000*	*150,000*
ACWP	7,813	32,776	62,719	*46,692*	*150,000*
SV%	-60.0	-45.0	-10.0		
CV%	2.3	0.7	0.5	1.5	

	Fiscal Quarter				
	1st	2nd	3rd	4th*	Totals
FY06 Carryover HX Project (UNLV, Dr. Hechanova), N-ID07SS0112, $673,403					
BCWS	198,603	210,000	140,397	124,403	673,403
BCWP	75,807	122,174	163,000	*312,422*	*673,403*
ACWP	75,807	118,748	160,321	*188,109*	*673,403*
SV%	-61.8	-41.8	16.1	*151.1*	
CV%	0.0	2.8	1.6	*2.0*	
FY06 Carryover Pt-added Materials (MIT, Dr. Ballinger), N-ID07SS0113, $110,000					
BCWS	20,664	59,336	30,000	0	110,000
BCWP	19,000	53,500	21,500	*16,000*	*110,000*
ACWP	18,549	49,252	18,928	*7,271*	*110,000*
SV%	-8.1	-9.8	-28.3		
CV%	2.4	7.9	12.0	45.4	
UNLV Overall					
BCWS	588,291	560,608	447,000	302,819	1,989,718
BCWP	372,430	471,012	454,058	*692,218*	*1,989,718*
ACWP	360,668	432,899	460,560	*735,591*	*1,989,718*
SV%	-36.7	-16.0	1.6	128.6	
CV%	3.2	8.1	-1.4	-6.3	

*4th quarter is projected

The lack of adherence to schedule is also shown in Table 5, which shows the listing of milestones scheduled, completed on-time or early, completed late, and those still awaiting completion. Out of thirteen Level 2 milestones that were scheduled in FY07, seven were delivered on-time or early, four were delivered late, and two are late and still have not yet been completed.

Table 5. SI&SS UNLV Work Package Level 2 Milestone Performance

	Scheduled	Delivered On-Time or Early	Provided Late	Remaining*
N-ID07SS0101	0	0	0	0
N-ID07SS0102	0	0	0	0
N-ID07SS0103	0	0	0	0
N-ID07SS0104	0	0	0	0
N-ID07SS0105	0	0	0	0
N-ID07SS0106	4	3	1	0
N-ID07SS0107	1	1	0	0
N-ID07SS0108	1	0	1	0
N-ID07SS0109	1	0	0	1
N-ID07SS0110	1	1	0	0
N-ID07SS0111	1	1	0	0
N-ID07SS0112	3	1	2	0
N-ID07SS0113	1	0	0	1
Total	**13**	**7**	**4**	**2**

*The two milestones in this column are overdue and have not yet been completed.

The performance of UNLV in the area of schedule needs to be much improved going forward from this point. Budgets must be more accurately determined and less optimistic than have been offered before, so that the schedule more accurately paces the expected rate of work. Milestone dates must be adjusted to help ensure that they are met on-time, and also must be taken seriously by the principal investigators. Missed deadlines and late delivery of milestones do not inspire confidence in the UNLV program to deliver the results, and may harm UNLV's opportunities to become involved in related programs in the future if the trend continues into FY08.

The performance of UNLV in comparison to their performance in FY06, however, is much improved, and it is hoped that the re-structuring of UNLV's program under specific technical areas and specific associate technical directors will help improve the UNLV program still further. In FY06, UNLV ended the fiscal year with much of its work unfinished because of funding problems. In FY07, they will have completed all work scope that was planned using FY06 carryover funds, and will have at least set up the fully detailed work packages for work to be completed in FY08 using the FY07 funds. It is recommended that new funds for UNLV in FY08 be set aside for UNLV, but not allocated to UNLV until the FY07 work scope is nearly complete and performance data is available on the conduct of their work, as is done with the national laboratories. At least in this way, DOE will have some influence on UNLV's work performance, and this may encourage UNLV to tighten their programmatic controls in order to honor their schedules.

3. ACCOMPLISHMENT HIGHLIGHTS

The accomplishments described here are organized by work package. The work accomplished under the controlled work packages will be covered first, followed by descriptions of the work accomplished under the UNLV work packages. Greater detail on any one project can be found by examining the reports and documents that were generated by the individual work packages, and by looking up the Earned Value performance data in PICS.

3.1 Controlled Work Packages

Controlled work packages were performed by Argonne National Laboratory, Idaho National Laboratory, and Oak Ridge National Laboratory.

3.1.1 N-AN07SS0101 – Steady-state and Transient Modeling of Combined Nuclear Hydrogen Plant

Work Scope

Argonne National Laboratory (ANL) is assisting the development of nuclear hydrogen production technology in part by helping to create and test integrated system models that will be used to study system configurations, optimize operating conditions, and examine transient behaviors such as experienced during start-up, shudown, and off-normal events. ANL will assist the Idaho National Laboratory (INL) in the development of steady-state and transient integrated models. ANL will also participate in an I-NERI project with the Korea Atomic Energy Research Institute (KAERI) for the development of HyPEP. HyPEP (Hydrogen Process Efficiency Program) will be a GUI-operated software package that will allow for rapid assessment of differing configurations of electrical power conversion units, intermediate loop designs, and nuclear plant and hydrogen plant operating conditions with the goal of determining overall hydrogen process efficiency. The scope of work to be accomplished in FY07 is the following: 1. Assess methods and models for developing dynamic simulations of the system interface and related components. 2. Perform dynamic analyses of coupled nuclear plant/hydrogen plant. 3. Work with INL and KAERI to prepare the HyPEP software for beta-testing in early 2008.

Work Package Manager

Dr. Rick Vilim, Argonne National Laboratory, (630) 252-6998, rvilim@anl.gov.

Accomplishments

In December, 2006, ANL released a report (Ref. 3) describing the candidate modeling approaches and the numerical methods that may be used to study the operability and safety of the combined nuclear plant in respect to the dynamic changes that occur during start-up, shutdown, and other time-dependent activities. The report did not recommend a specific code to perform this work, but rather described the mathematics and the general approach to performing such modeling, and also cataloged the basic phenomena that must receive attention during any integrated modeling exercise (e.g., load changes at the IHX, start-up, reactor trip, etc.). This report has application to any future dynamic modeling work.

In parallel, preliminary studies of plant start-up were examined that assumed a high-temperature gas-cooled reactor connected to a high-temperature electrolysis hydrogen plant. These calculations were performed using a modified version of GAS-PASS/H and showed that the nuclear reactor could reach full power (and full temperature) from a cold start-up in less than 5 hours with no consideration given to limiting thermal stresses. The GAS-PASS/H code is a 1-D systems code that can handle gas-cooled nuclear reactor neutronics, power conversion, and interactions with a hydrogen plant. Other analyses were performed also, and it was found that a request to increase the hydrogen plant output by 10% would result in a 0.1-0.2ºC/s temperature rise in the hydrogen plant before the control system would be able to re-establish equilibrium with the rest of the combined plant. This temperature rise is tolerable and is believed to be within the temperature stress limitations of typical high-temperature electrolysis equipment.

In January 2007, Dr. Vilim met with Dr. Barton and Dr. Kazimi of MIT to discuss with them ways of collaborating on dynamic system modeling. Dr. Barton and Dr. Kazimi are involved in the NERI Project 06-041, "Dynamic Simulation and Optimization of Nuclear Hydrogen Production Systems." Dr. Vilim's approach is on the development of system codes to study basic transient events, while the NERI project's focus is on the development of more basic modeling capabilities to handle continuous and discrete events in a nuclear hydrogen plant. Agreement was reached that the two groups would continue to work together and compare results as their work goes forward.

The equations worked out in Ref. 3 were incorporated into the modified GAS-PASS/H model for the purposes of examining the effects of quasi-static load changes on an idealized NGNP. Analyses of the transients caused by these quasi-static load changes are still underway. A significant result of this work is that it appears the VHTR core acts to attenuate the passage of temperature fronts from inlet to outlet, thereby minimizing the potential for out-of-phase oscillations between the core and heat sink. Evidence of this result is shown in Figure 1. In fact, the size of the VHTR components (and their associated heat capacitances) lead to near-complete dampening of such oscillations in the core. A summary report on this work is due to the DOE NHI on September 15, 2007, and will be posted into PICS.

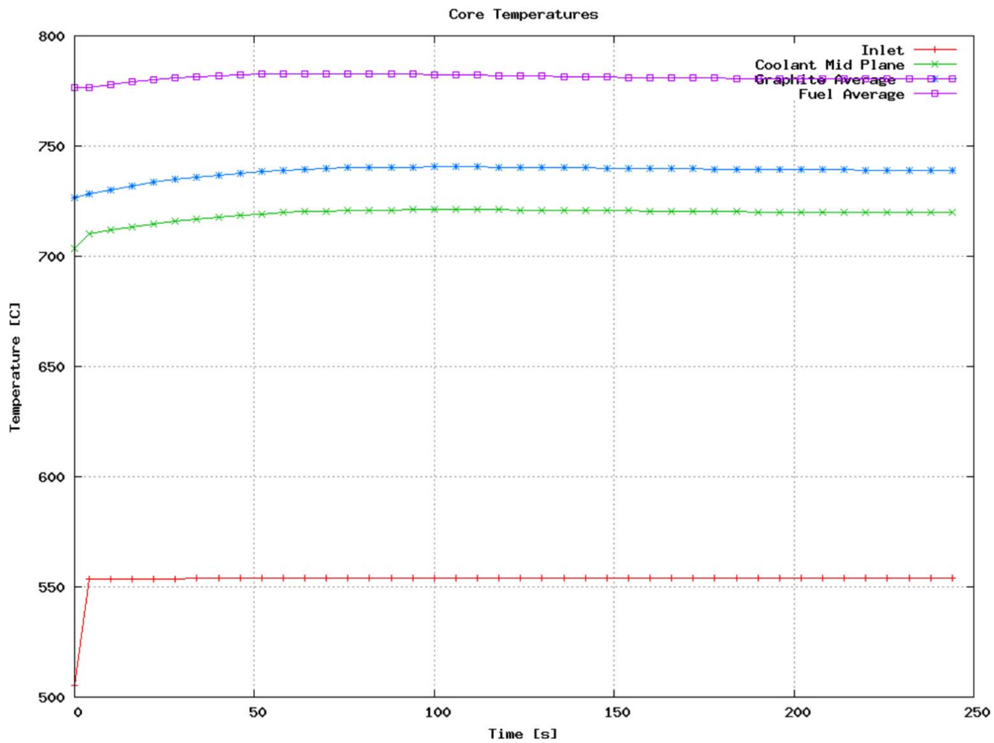

Figure 1. Core Temperature for Near-Step Increase in Core Inlet Temperature

Two papers were presented at the ICAPP 2007 meeting in Nice, Italy, on May 14-16 (Ref. 4, 5), and one paper was presented at the ANS Meeting in Boston, MA (Ref. 6).

Work will continue on this project, funding permitting, in FY08.

3.1.2 N-IN07SS0101 – Steady-State and Transient Modeling of Combined Nuclear Hydrogen Plant

Work Scope

Idaho National Laboratory (INL) is participating in the effort to develop nuclear hydrogen production technology by helping to create and test integrated system models that will be used to study system configurations, optimize operating conditions, and examine steady-state operations and transient behaviors that would occur during start-up, shutdown and off-normal events. INL, with the assistance of Argonne National Laboratory (ANL), will participate in an I-NERI project with the Korea Atomic Energy Research Institute (KAERI) for the development of the Hydrogen Process Efficiency Program software (HyPEP). HyPEP will be a GUI-operated software package that will allow for the rapid assessment of differing configurations of electrical power conversion units, intermediate loop designs, and nuclear plant and hydrogen plant operating conditions with the goal of determining overall hydrogen production efficiency. As a corollary assignment, INL will assist ANL in the development of transient models. The scope of work to be completed in FY07 is the following: 1) Determine efficient power conversion unit (PCU) configurations for electrical generation, 2) Explore design options for the combined plant PCU, choice of working fluid, and other options, 3) Couple reference combined plant configuration with detailed HTE flowsheet and explore coupling with available S-I flowsheet(s), 4) Work with ANL and KAERI to prepare the HyPEP software for beta-testing in early 2008, and 5) With ANL and KAERI, issue annual technical report detailing the work performed during this collaboration.

Work Package Manager

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Accomplishments

HYSYS models of a VHTR coupled to a high-temperature electrolysis hydrogen production plant were developed. The HYSYS model is intended to provide a benchmark against which the HyPEP model being developed with KAERI can be checked. Validation of the HYSYS calculations was performed by comparing JAEA GTHTR-300 design calculations to a comparable model constructed using the HYSYS flow sheeting tool, and the results obtained for that nuclear reactor were within 5% of the published data. Validation of the high-temperature electrolysis model was performed by comparing the results obtained from user-defined HYSYS functions to experimental numbers provided in published high-temperature electrolysis papers. This comparison was also favorable.

Parametric studies were then conducted to examine the effects of changing the working fluids for the nuclear reactor and energy transport loop(s), and the effects of choosing different basic plant configurations (e.g., direct power conversion, indirect power conversion, parallel electrical and hydrogen generation, serial electrical and hydrogen generation, etc.). An example plant configuration is shown in Figure 2, and results obtained for a calculation of overall plant efficiency for various working fluid combinations is shown in Table 6. The results of this work are available in an INL report on the subject (Ref. 7) and an AIChE presentation (Ref. 8).

In March 2007, an invention disclosure was filed with the Idaho National Laboratory concerning a particular nuclear plant/hydrogen plant configuration that emerged from this work. The invention is the application of certain features that allow the outlet temperature of the nuclear reactor to be lowered to 700ºC while still maintaining a relatively high plant efficiency of 44%, which is within 1-2% of the overall plant efficiency that can be achieved by using an all-helium system with a nuclear reactor outlet temperature of 900ºC. The exact details of the invention will be released once the patent application has been filed with the U.S. Patent and Trademark Office.

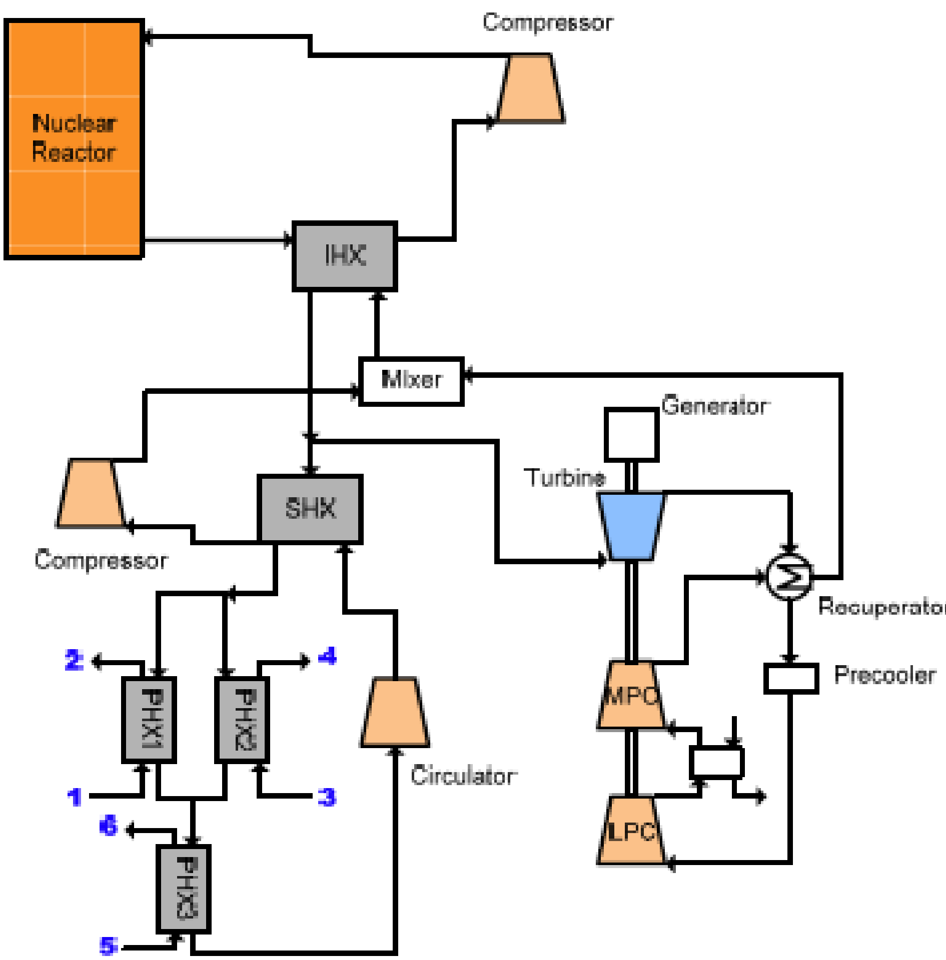

Figure 2. VHTR with HTE, parallel configuration, indirect power generation.

Table 6. Comparison of Overall Efficiencies for Parallel Configuration and Various Working Fluids

Primary	Secondary	Ternary	Efficiency (%)
He	He	He	44.12
He	He	CO_2	44.47
He	He	Flinak	46.13
He	CO_2	He	43.35
He	CO_2	CO_2	43.5
He	CO_2	Flinak	43.41
Flinak	He	He	45.25
Flinak	He	CO_2	45.5
Flinak	He	Flinak	47.24
Flinak	CO_2	He	44.83
Flinak	CO_2	CO_2	45.06
Flinak	CO_2	Flinak	45.39

An I-NERI project review meeting was held between INL, ANL, and KAERI participants in Korea on April 23-25, 2007. The meeting was used to provide updates on the status of the US and Korea work, and to discuss the state of HyPEP code development, coupling schemes of the VHTR and a high-temperature electrolysis plant, and validation and verification methods involving the use of the recently developed HYSYS and GAS-PASS/H models for benchmarking HyPEP.

A validation and verification strategy for beta-testing of the HyPEP code was developed following this collaboration meeting. The strategy consists of the following measures. First, the gas property models will be compared with NIST chemistry database information and a process analysis code. Then, HyPEP component models will be validated by comparing HyPEP component behaviors with results obtained from the corresponding HYSYS models. Lastly, the integrated system will be analyzed using HyPEP, HYSYS, and GAS-PASS/H and the results compared.

Future work on the HyPEP model is in doubt, as its continued development appears to have waning support at DOE. Though the quality of the HyPEP work is not in question, there is question about the market for another steady-state NGNP system code at this time. The NGNP Project employs its own methods and modeling team, and may even rely on vendors to perform some of this modeling using their own modeling tools. The DOE NHI already has access to the HYSYS and GAS-PASS/H models developed in this country, and is moving on to perform dynamic system modeling, which the HyPEP code has not been programmed to do. It is likely that the HyPEP work will be discontinued in FY08. In that event, the HYSYS and GAS-PASS/H modeling tools developed under this project will be used to support more detailed dynamic modeling activities in FY08, and to support future safety analyses of different plant configurations.

A year-end report on this work will be submitted to the DOE NHI on September 15, 2007.

3.1.3 N-IN07SS0102 – Technical Director and Project Management SI&SS

Work Scope

The Idaho National Laboratory (INL) will support the DOE NHI in part by coordinating the overall research effort as Technical Director, providing project management support for PICS reporting, and by helping to develop and implement the DOE NHI Materials and Components Test Plan. Scope to be completed in this IN work package during FY07 is the following: 1. Support system interface and support systems (SI&SS) activities as needed for DOE NHI as technical director. 2. Provide quarterly updates of the map of SI&SS technical activities and corresponding research and development. 3. Produce year-end summary of SI and SS research and development that relates technical issues to ongoing work, and containing near-term research needs and directions. 4. Support I-NERI and NERI collaborations as needed.

Work Package Manager

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Dr. Steven Sherman, Idaho National Laboratory, (208) 526-6582, Steven.Sherman@inl.gov.

Accomplishments

In addition to the routine activities expected of the Technical Director of System Interface and Support Systems for the DOE NHI, the Technical Director worked with Oak Ridge National Laboratory to develop the NHI Materials and Component Development Plan (Ref. 9). The Plan describes a decision process for evaluating the technical readiness or maturity of components (i.e., heat exchangers, chemical reactors, valves, etc.) for use by the U.S. DOE Nuclear Hydrogen Initiative. Figure 3 shows the Technical Readiness Levels that will be applied to any particular component as a means to characterize the component's technical maturity. This system is used by the DOE NHI to assess individual components in relation to their readiness for pilot-scale and larger-scale deployment and to drive the research and development work needed to attain technical maturity. A description of the evaluation system is provided, and examples are given to illustrate how it is used to assist in component R&D decisions. In addition to the written report, a presentation on the Plan will be given at Global 2007 in Boise, Idaho, in September 2007 (Ref. 10). As a companion, a preliminary implementation plan was also written and submitted to the DOE NHI in May 2007 (Ref. 11).

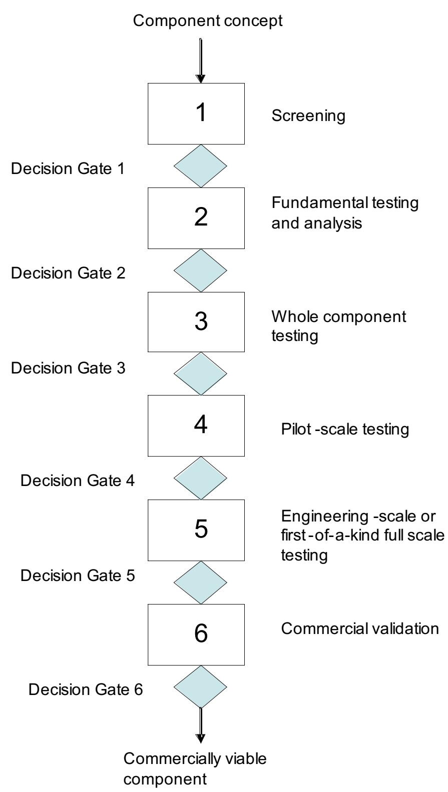

Figure 3. NHI Technical Readiness Evaluation System.

The technical director represented the System Interface project area at the Annual DOE H_2 Merit Review in Arlington, VA, in May 2007. An overview presentation was provided on the System Interface area (Ref. 12), and a poster was presented on the current status of the HyPEP modeling work being performed under Work Package N-IN07SS0101 (Ref. 13).

Two papers were presented by the technical director at the ANS Spring Meeting in Boston, MA, in June 2007. One paper concerned a discussion of approaches to safely designing a combined nuclear plant/hydrogen plant facility, and was an invited paper (Ref. 14). The other paper provided an update on technical progress made in the development of System Interface technologies (Ref. 15).

During the course of the year, the Technical Director served as a mentor for Dr. Hirofumi Ohashi, a Fuji-ie Assignee from the Japan Atomic Energy Agency. Dr. Hirofumi performed tritium migration calculations on two NGNP configurations that involved either a HTE plant or a SI hydrogen plant. The results of his work are available in an INL report (Ref. 16) and will eventually be published in an ANS journal.

The Technical Director participated in reviews of the pre-conceptual design work for the NGNP, and attended meetings involving industrial teams led by AREVA, General Atomics, and Westinghouse. These industrial teams were tasked in part with studies related to energy transport and heat transfer, and hydrogen production, and so the involvement of the DOE NHI personnel in these reviews was needed to help the NGNP Project make decisions related to the technical merit and applicability of the information provided by the pre-conceptual design teams.

In the future, it is anticipated that the DOE NHI and the NGNP Project will work more closely together, and the point of contact will be the System Interface area. In the future, some of the work scope in the DOE NHI System Interface area will be changed from the DOE NHI to the NGNP Project, though this does not imply any transfer of funds from one program to the other. Even after such a change, it is expected that the System Interface and Support Systems function will continue under the DOE NHI in order to manage the NERI and UNLV portions of the program, and to provide a point of contact for the NGNP Project in regard to long-distance heat transfer and heat exchanger development issues.

3.1.4 N-OR07SS0101 – Development of NHI Materials and Components Test Plan

Work Scope

The DOE NHI is developing hydrogen production technologies to be coupled with an advanced Gen IV nuclear energy system. Oak Ridge National Laboratory is assisting in the development of this effort by serving as editor and chief reviewer of the

NHI Materials and Components Test Plan. The NHI Materials and Components Test Plan will define the decision process for determining which materials and component designs are chosen for further development and, ultimately, pilot-scale testing. The Plan will be written with the assistance of the Idaho National Laboratory and will be reviewed by the NHI leadership team at certain intervals to obtain consensus on its contents. The scope of work to be completed in FY07 is the following: 1. With INL, develop draft plan and use the S-I decomposer as an example component to illustrate the decision process. 2. With INL, issue the NHI Materials and Components Test Plan. 3. Assist in its implementation.

Work Package Manager

Dr. Dane F. Wilson, Oak Ridge National Laboratory, (865) 241-0215, wilsondf@ornl.gov.

Accomplishments

Oak Ridge National Laboratory fulfilled its role as editor and chief reviewer of the DOE NHI Materials and Component Development Plan (Ref. 9), and worked closely with the Idaho National Laboratory to complete the plan by the assigned deadline. It was Oak Ridge's recommendation to change the title of the plan from "…Test Plan" to "…Development Plan" because the Plan does not lay out a specific test matrix for testing components, but rather provides a logical framework on which to base component development decisions (i.e., tasks, sequencing, budgets, etc.). Oak Ridge's involvement was essential in the development in the Plan and provided valuable insights that hopefully will make the Plan acceptable and useful to the larger program during implementation in FY09.

3.2 UNLV HTHX Project Work Packages

UNLV High Temperature Heat Exchanger (HTHX) Project work packages were performed at the University of Nevada Las Vegas, Ceramatec Inc., General Atomics, Massachusetts Institute of Technology, and the University of California – Berkeley. These work packages consist of FY06 carryover work packages (work packages using only FY06 carryover funds) and FY07 work packages (work packages that use only FY07 funds).

3.2.1 N-ID07SS0101 – UNLV NHI Materials Support

Work Scope

UNLV is tasked with the performance of experiments and measurements of the mechanical and creep properties of high-temperature alloys (i.e., Inconel 617, Haynes 230) in support of high-temperature heat exchanger development efforts. The work may also include examinations of ceramic materials and the development of methods for assessing the reliability of ceramic components. Since this work package is still in draft form, the exact work scope has not yet been identified.

Work Package Manager

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Accomplishments

Work under this work package has not yet begun. Work is anticipated to begin before the end of the current fiscal year, but the work scope has not yet been finalized. Once finalized, the negotiated work scope and funding will be carried over into FY08.

3.2.2 N-ID07SS0102 – NHI Momentum-Heat-Mass Transfer

Work Scope

This work package covers work to be performed at the University of Nevada, Las Vegas, and its sub-contractors in the area of momentum/heat/mass transfer in support of the DOE Nuclear Hydrogen Initiative. The focus of work in FY07 will be on the analysis of specific sulfuric acid decomposer and heat exchanger concepts, the testing of prototype heat exchanger channels, thermal insulation concepts, and related activities. More precise definition of funding and work tasks will be provided at a later time after the FY07 budget is appropriated and upon agreement of work scope between the associate technical director and the national technical director.

Work Package Manager

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Accomplishments

Work under this work package has not yet begun. Work is anticipated to begin before the end of the current fiscal year, but the work scope has not yet been finalized. Once finalized, the negotiated work scope and funding will be carried over into FY08.

3.2.3 N-ID07SS0103 – NHI Liquid Salt Systems

Work Scope

This work package covers work to be performed at the University of Nevada, Las Vegas, and its sub-contractors in the area of liquid salt systems support of the DOE

Nuclear Hydrogen Initiative. The focus of work in FY07 will be on the analysis of practical liquid salt heat transfer systems, liquid salt chemistry and corrosion, properties determination, and related activities. More precise definition of funding and work tasks will be provided at a later time after the FY07 budget is appropriated and upon agreement of work scope between the associate technical director and the national technical director.

Work Package Manager

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Accomplishments

Work under this work package has not yet begun. Work is anticipated to begin before the end of the current fiscal year, but the work scope has not yet been finalized. Once finalized, the negotiated work scope and funding will be carried over into FY08.

3.2.4 N-ID07SS0104 – NHI Materials-Surface Characterization

Work Scope

This work package covers work to be performed at the University of Nevada, Las Vegas, and its sub-contractors in the area of materials/surface characterization support of the DOE Nuclear Hydrogen Initiative. The focus of work in FY07 will be on the surface characterization of high temperature electrolysis electrodes, analyses related to integrated lab-scale (ILS) materials, degradation mechanisms, materials/surface analysis studies related to hydrogen production process membranes, and related activities. More precise definition of funding and work tasks will be provided at a later time after the FY07 budget is appropriated and upon agreement of work scope between the associate technical director and the national technical director.

Work Package Manager

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Accomplishments

Work under this work package has not yet begun. Work is anticipated to begin before the end of the current fiscal year, but the work scope has not yet been finalized. Once finalized, the negotiated work scope and funding will be carried over into FY08.

3.2.5 N-ID07SS0105 – Chemistry Support

Work Scope

This work package covers work to be performed at the University of Nevada, Las Vegas, and its sub-contractors in the area of chemistry support for the DOE Nuclear Hydrogen Initiative. The focus of work in FY07 will be on tritium diffusion and isotope exchange, identification and/or development of analytical techniques for the integrated lab-scale (ILS) and pilot-scale hydrogen production plants, and other chemistry-related activities. More precise definition of funding and work tasks will be provided at a later time after the FY07 budget is appropriated and upon agreement of work scope between the associate technical director and the national technical director.

Work Package Manager

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Accomplishments

Work under this work package has not yet begun. Work is anticipated to begin before the end of the current fiscal year, but the work scope has not yet been finalized. Once finalized, the negotiated work scope and funding will be carried over into FY08.

3.2.6 N-ID07SS0106 – Measurement of Alloy Mechanical Properties at UNLV – FY06 Carryover

Work Scope

This work package covers work that was planned for execution in FY06, but due to equipment problems and problems related to funding allocation was performed in FY07 at UNLV. Work performed in this work package is funded entirely by FY06 carryover money and does not include any tasks that will be funded by FY07 money. Specific activities in this work package include: 1) Complete tensile property measurements of C-22, C-276, Waspaloy, and 800H that were planned for completion in FY06, 2) Stress corrosion cracking studies of metal alloys exposed to sulfuric acid solutions, 3) Crack growth rate measurements of samples exposed to sulfuric acid solutions, 4) Crack growth rate measurements of alloys exposed to cyclic loads in an air environment, 5) Fracture toughness testing of specimens in air.

Work Package Manager

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Accomplishments

The full work scope was completed in FY07, and the results of the research are available in two reports (Ref. 17, 18). The results of the tensile data measurements showed that the austenitic alloys Waspaloy, C-22, and C-276 all sufficient tensile strength at 800ºC to be used for high-temperature nuclear hydrogen production applications, though Waspaloy exhibits reduced ductility in relation to the other metals at that temperature. Figure 4 shows tensile measurements measured for Alloy C-276.

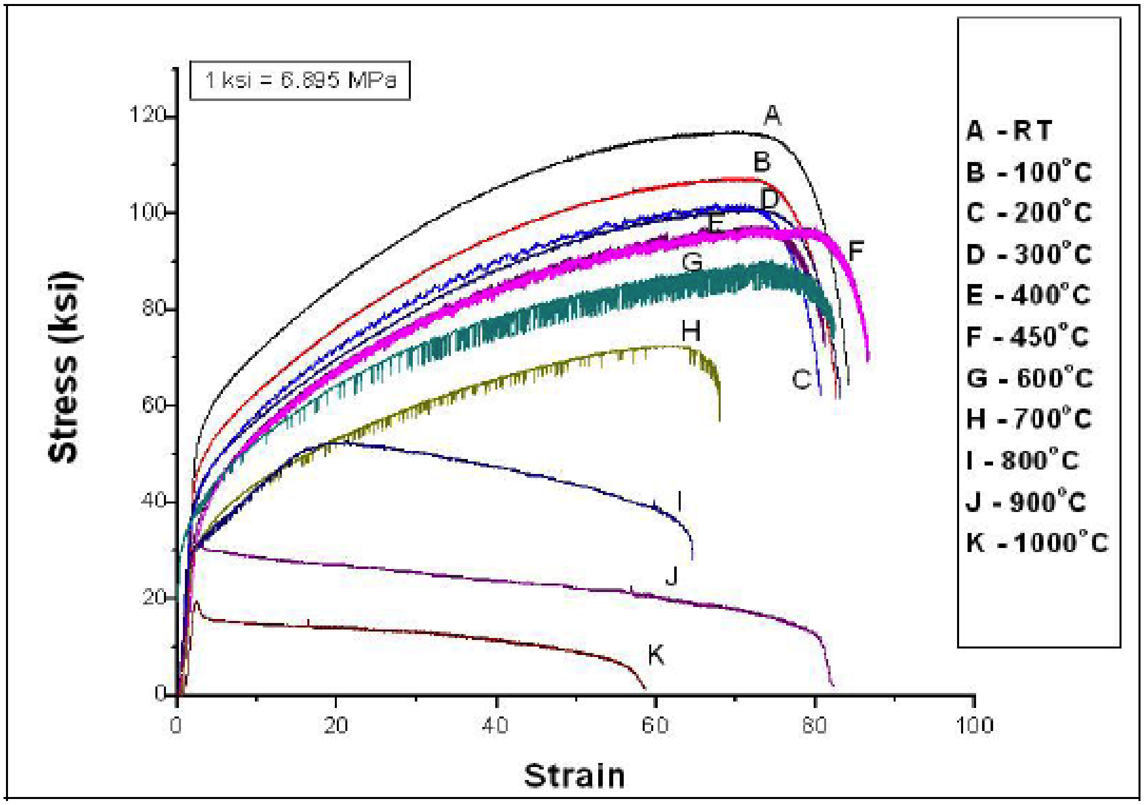

Figure 4. Tensile strength measurements for Alloy C-276.

In the crack growth rate work, the rate of crack growth was studied using C-22, C-276, Inconel 617, and Inconel 718. Crack growth rates were measured using a cyclic loading experiment at temperature. Data were provided in terms of the log of the slope of the curve generated by plotting measured crack length versus the number of stress cycles in pre-cracked specimens. Data curves were generated, but the meaning of the curves and their implications for heat exchanger design in sulfuric acid environments were not discussed. Presumably, this information could be used to help predict the probable lifetime of heat exchangers exposed to temperature cycles by examining the length of time it takes for a crack to propagate through given materials and material thicknesses. While this may not have a large impact on shell-and-tube heat exchangers, it may have a significant impact on the design and operation of compact metallic heat exchangers which use thin plates and small flow channels.

3.2.7 N-ID07SS0107 – Corrosion and Crack Growth Studies in HIx Solutions at Generation Atomics – FY06 Carryover

Work Scope

This work package covers tasks performed by General Atomics while working under a sub-contract with UNLV. Funding for this work was provided by FY06 carryover and did not include any new FY07 money. The work activities performed under this work package included: 1) Continued studies of stress corrosion cracking in HIx environments, 2) Corrosion testing with weldments, c-rings, and u-bend specimens for the purposes of studying crack initiation in HIx environments, 3) Studies of the effects of contaminants on HIx corrosion, and 4) Construction and testing of an HIx circulation loop for the testing of valves, pumps, and other components.

Work Package Manager

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Accomplishments

An initial round of materials corrosion testing was completed in December 2006 and has been detailed in Ref. 19. In the initial round of tests, samples composed of various materials were exposed to the fluids and environments typical of the HI decomposition section of an SI process using extractive distillation. Figure 5 shows the results of one such test involving the exposure of C-276 U-bend specimens exposed to a gaseous mixture of HI, I_2, and H_2 at 450ºC for varying lengths of time. The results of these tests showed that Ta, Ta-2.5W, Ta-10W and SiC are appropriate for use in the iodine separator and phosphoric acid concentration processes. Also, Hastelloy B-2, C-22, and C-276 may be used for gaseous HI decomposition environments.

After December 2006, work has continued on the corrosion studies, and some additional findings have been developed. SiC appears to be appropriate for use in a hydrogen separation membrane, as it showed no corrosion for more than 960 hours in that environment. The reliability of Ta-coated or clad parts is lower than pure Ta or Ta alloy components due to defects that can occur in the surface layers during manufacturing. Ta-10W resists corrosion in boiling phosphoric acid and in the presence of iodine impurities for than a thousand hours. A report describing these additional findings is expected by the end of the fiscal year. Corrosion work will continue in FY08, though it may be folded into the Integrated Lab-Scale activities in the DOE NHI Thermochemical area instead of the System Interface area.

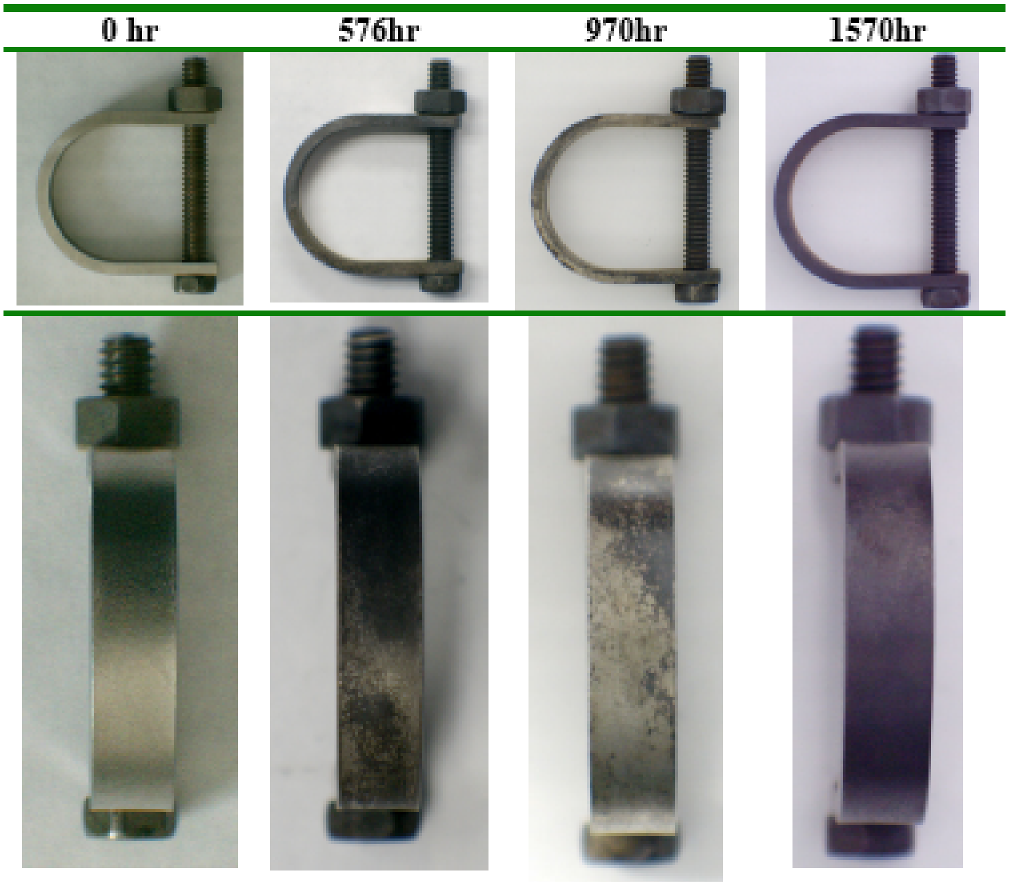

Figure 5. C-276 U-bend specimen coupon tested in the gaseous HI decomposition environment ($HI+I_2+H_2$) at 450°C.

3.2.8 N-ID07SS0108 – Numerical Analysis of Advanced Heat Exchanger Concepts at UNLV – FY06 Carryover

Work Scope

In the development of new heat exchangers and high-temperature components, computational analyses are often needed to predict component function, study potential mechanical and thermal stresses, and to provide the basis for optimized component designs. UNLV assisted in the development of advanced heat exchanger concepts and other components by performing numerical analyses of proposed heat exchanger concepts for sulfuric acid decomposition for the S-I process. Of particular interest is the Sandia bayonet design for the S-I decomposition step. Laboratory work has begun on this concept, but little is known about its potential scaleability, stress concentrations, temperature, pressure, and reactivity profiles, and so on. UNLV provided computational and numerical analyses of the Sandia bayonet design and alternative sulfuric acid decomposer designs to the extent that the available FY06 carryover money allows. This work package only includes FY06 carryover funds and does not include any new FY07 funding.

Work Package Manager

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Accomplishments

UNLV focused on the analyses of three basic sulfuric acid decomposer types – the Sandia bayonet, the Ceramatec ceramic compact decomposer, and the shell-and-tube heat exchanger. Each of these device concepts use SiC as the structural material for the flow channel(s) and assume the use of a Pt-based catalyst on either a solid support or as part of a coating. The numerical analyses of these concepts included examinations of thermal and mechanical stresses, and chemical reaction conversion based on assumed reaction kinetics.

Two-dimensional models of the Sandia bayonet were generated and tested against laboratory data obtained from Sandia experiments, and the models compared well with the experiments. A model representation of a section of the Sandia bayonet is shown in Figure 6. The bayonet model was then used to examine the effects of various parameters (i.e., cylindrical versus tubular catalyst pellets, Reynolds number, pressure) on the conversion of SO_3 to SO_2 and O_2 in the decomposer. As expected, the model shows that higher conversions are achieved at higher surface-to-volume ratio of the catalyst region, higher operating pressures, and lower Reynolds numbers (thus increasing the residence time in the catalyst zone). The details of this work are provided in Ref. 19.

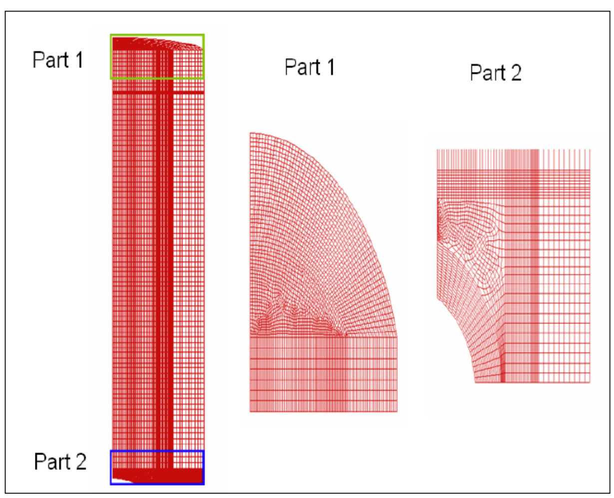

Figure 6. Sandia Bayonet mesh independence study using GAMBIT (33,306 cells, 35,374 nodes). GAMBIT is mesh generation software produced by Fluent Inc.

Two- and three-dimensional models have been prepared for the Ceramatec compact decomposer and shell-and-tube decomposer designs, and these models are being examined to determine functionality and the probability of failure during transient warming. The assumption for the transient warming is that the decomposer is at room temperature and a no-flow condition at the start of the transient, and is then exposed to 950ºC helium under full flow conditions. So far, these decomposers are showing that they have a very low probability of failure under this condition, but more calculations are being done to verify this.

Though input manifold design has been studied for the last couple of years in regard to the Ceramatec design, little has been done on developing manifold designs for the relatively simpler shell-and-tube decomposer concept. Analyses performed at UNLV of the flow distribution through a shell-and-tube decomposer using 24 flow channels has shown that flow is not naturally evenly distributed, and some attention needs to be paid to design of the input manifold. Work on manifolding is expected to continue into FY08.

3.2.9 N-ID07SS0109 – C-SiC Materials for HTHXs at UCB – FY06 Carryover

Work Scope

University of California – Berkeley (UCB) is engaged in experiments involving the development and construction of C/SiC composite heat exchangers for high-temperature applications as part of the UNLV High Temperature Heat Exchanger Project. Due to delays in receiving FY06 funding and problems with a sub-contract with COI (Composite Optics Inc.), some of the work tasks in FY06 work package ID06SS13 will need to be extended into FY07. These tasks are the following: 1) Perform helium permeation testing under hot test conditions, 2) Identification and demonstration of optimized candidate ceramic heat exchanger materials and fabrication methods, and scale size and design to demonstrate prototype-scale fabrication, 3) Perform studies of chemical and tritium safety and corrosion control methods in ceramic heat exchangers with liquid salt as heat transfer fluid.

Work Package Manager

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Accomplishments

A two-dimensional transient porous media model was developed for studying ceramic compact heat exchanger transient flow and heat transfer. More specifically, the code is being used to examine a C-SiC heat exchanger design developed as a joint project between UC-Berkeley and the German Aerospace Center DLR through the cooperation of Dr. Jens Schmidt (Ref. 20). The interest in this particular technology is for application to sulfuric acid decomposition, liquid salt heat transfer, and, as a corollary, development of chemical vapor deposition (CVD) techniques for applying pyrolytic carbon coatings for the purposes of sealing heat exchanger surfaces against porous gas transfer through the relatively porous C-SiC heat exchanger plates. A prototype heat exchanger plate of this type that is composed of wood is shown in Figure 7. Heat exchanger fabrication work is underway using UCB molds and employing the new CVD coated plates.

Figure 7. DLR prototype wood composite test plate (80x120mm) with fins (~10mm).

A liquid salt intermediate loop viability assessment was begun for the purposes of eventually demonstrating the use of liquid salts as an intermediate fluid for the NGNP intermediate heat transport loop. This project is being done in conjunction with a small amount of funding from Oak Ridge National Laboratory. In conjunction with this study, the C-SiC materials and the CVD coatings are being evaluated for corrosion resistance against candidate liquid salts.

The behavior of tritium in a liquid salt loop is of great interest, but work in this area has progressed more slowly than anticipated due to the transitioning of a new student into the project. UCB had been assigned to produce a report related to the movement of tritium and safety implications of using a liquid salt loop, but this report will not be completed until the end of the fiscal year.

3.2.10 N-ID07SS0110 – Ceramatec Heat Exchanger Development for Application to NHI Hydrogen Production Processes – FY06 Carryover

Work Scope

The purpose of this work package is to provide bridge funding between the end of FY06 and the start of additional work in FY07 (using additional FY06 carryover funds to be awarded by UNLV). This money is needed to complete the final report on work completed in FY06.

Work Package Manager

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Dr. Anthony Hechanova, University of Nevada Las Vegas, (702) 895-1457, hechanova@unlv.nevada.edu.

Accomplishments

The final report on work performed in FY06 was completed on October 23, 2006. This report concerned three areas of study: sulfuric acid decomposer materials, sulfuric acid decomposer design, and oxygen recovery materials (Ref. 21). Some key findings of this work are as follows.

- Si_3N_4, SiC, and Al_2O_3 were corrosion resistant to sulfuric acid, steam, and oxygen atmospheres at 900°C for 1000 hours, as demonstrated through measurement of mechanical strength and the weight gains of test coupons. As a benefit, SiC showed a statistically significant increase in sample strength after exposure due to the formation of a surface layer of SiO_2.
- A revision of the basic Ceramatec compact heat exchanger design from FY05 was developed, and it was calculated to have a projected failure rate of less than 1 failure per 1000 heat exchanger installations for SiC-based ceramics. The stress safety factor exceeds 2.0 for an assumed 15 atm (~1.5 MPa) pressure differential across the heat exchanger.
- Another revision of the FY05 design was made to employ advanced microchannel designs and catalytic effects.
- UNLV flow models for the heat exchanger designs were confirmed to match measured flow data obtained from test coupons to within +/- 5%.
- Literature data was obtained on materials that might be used for an oxygen chiller, and it was concluded that Al_2O_3 and ZrO_2 might be good materials for this application. Further work is planned in this area in future years.
- A two-stage oxygen chiller concept was developed that can potentially use "off-the-shelf" technology, and a drawing of this concept is shown in Figure 8. More work will be needed to develop the details of the design. The design may require a pre-chiller oxygen separator in order to separate oxygen from water vapor in order to protect the chiller materials against moisture attack, especially if ZrO_2 is used instead of Al_2O_3.

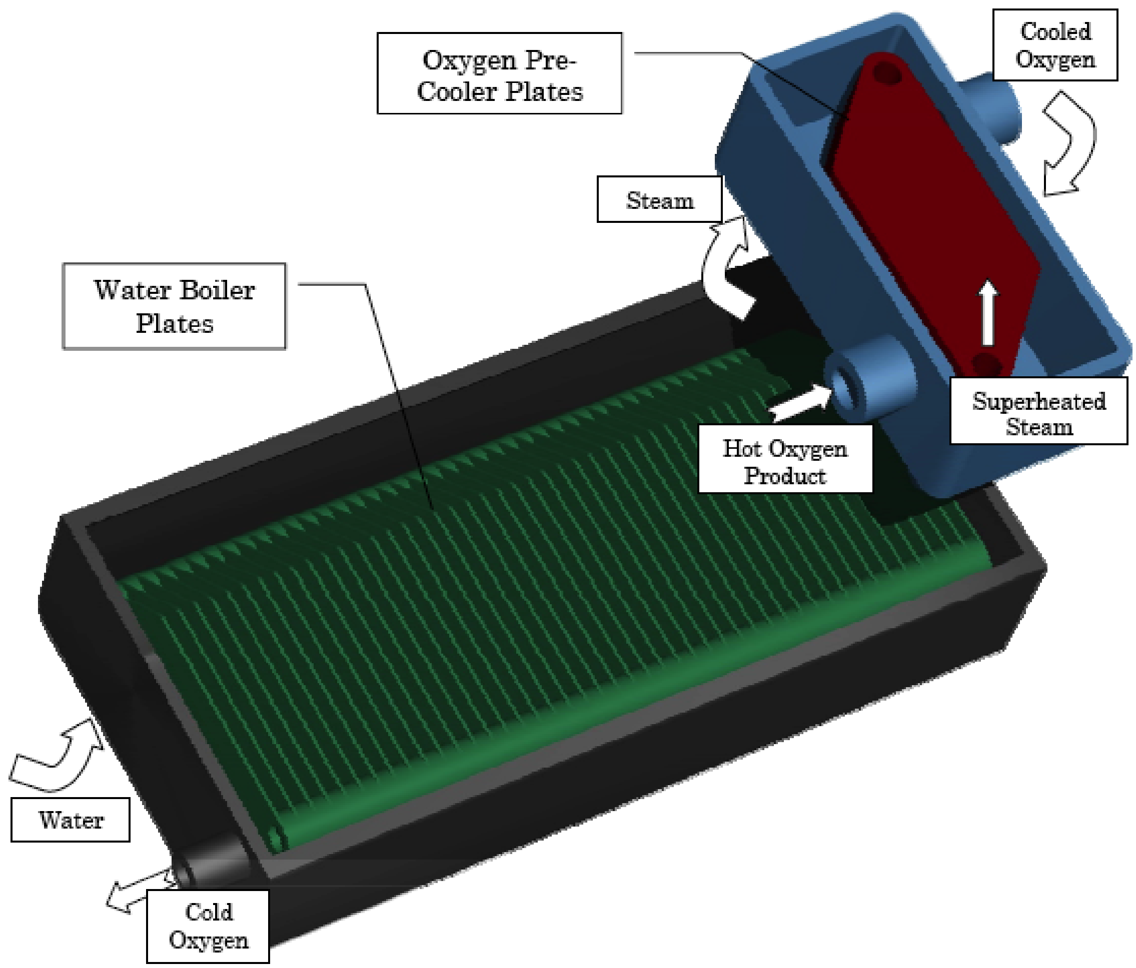

Figure 8. Ceramatec proposet concept for O_2 chiller.

3.2.11 N-ID07SS0111 – Ceramatec Heat Exchanger Development for Application to NHI Hydrogen Production Processes – FY06 Carryover

Work Scope

This work package continues the work that was described in the FY06 final report from work package N-ID07SS0110. The end objective of this development work is the fabrication of full-size wafers ready for experimental evaluation. In order to attain this goal 3 sub-tasks have been defined: 1) Materials Characterization for H_2SO_4 Service, 2) Ceramic Heat Exchanger scale-up, and 3) Development of Catalytic Substrates. The following describes these activities: 1) Material Characterization - The candidate materials will undergo more extensive H_2SO_4 corrosion testing at decomposition temperatures and potentially boiling temperatures/conditions. Additionally, parametric studies for processing silicon carbide will be made to reduce its thermal conductivity. This will be included into a Materials Testing Report. 2) HX Scale-up - In collaboration with UNLV, the full-size design will be advanced to revision 2.5. Based on this design full-size wafers will be constructed for evaluation testing. This sub-task also includes the development and characterization of joining (ceramic to metal and ceramic to ceramic) techniques required for demonstration of full-size components. This will be included into a Design Report. 3) Catalyst Substrates - The preliminary work in developing catalytic reactors will require development of porous substrates. This sub-task will develop methodologies for incorporating porous substrates into the decomposer design. This will be included into a Design Report.

Work Package Manager

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Accomplishments

The final report on work performed in FY07 was completed on July 30, 2007. This report concerned five areas of study: further examinations of materials corrosion due to exposure to sulfuric acid at elevated temperature, development of porous ceramic structures for catalyst support, further design revisions of the Ceramatec decomposer, fabrication of test wafers, and ceramics joining for application to metal/ceramic joints and the joining of individual heat exchanger plates (Ref. 22). Some key findings of this work are as follows.

- Revision 2.5 of the compact sulfuric acid decomposer design was completed. Heat exchanger effectiveness is projected to be as high as 95% due to the incorporation of enhanced three-dimensional micro-channels.
- The revised design is expected to have a failure rate of less than 1 in 1000 heat exchanger installations.
- Over 60 flow coupons were fabricated with a net yield of better than 40% of wafers passing post-manufacturing inspections.
- Eight full-size wafers were fabricated with a yield of six wafers passing post-manufacturing inspections.
- Results of this work have formed the basis of two papers at the ASME annual heat transfer conference on July 8-12, 2007 (Ref 23, 24), one paper at ICONE 2007 on April 22-26, 2007 (Ref. 25), and one paper to be given at the annual AIChE Conference in November 2007 (Ref. 26).

Full-sized wafer samples were delivered to the Technical Director of System Interface and Support Systems and to Carl Sink, NHI Program Manager as proof of task completion.

3.2.12 N-ID07SS0112 – UNLVRF High Temperature Heat Exchanger Project – FY06 Carryover

Work Scope

The UNLV Research Foundation will continue the implementation of the partnership between universities, private industry and national laboratories to identify and test high temperature materials and designs for NHI heat exchangers. The work performed by this partnership will identify candidate materials, perform corrosion and physical property tests necessary for NHI heat exchangers needed for thermochemical cycles and high temperature electrolysis, and perform prototype testing. All UNLV RF projects supporting the DOE NHI are reviewed directly by the technical directors, technical integrator, and DOE personnel. This Work Package covers the UNLVRF program administration including technical development and award processing, coordination activities required to support the technical work performed by and under contract to UNLVRF, and includes the scope of work performed at UNLV for project management, chemistry support research, and prototypical testing. In addition, seven work packages funded by FY06 carryover funds are administered under this work package: 1. - C-SiC Materials for HTHXs at UCB (N-ID07SS0109 - UCB) 2. - Pt-added Alloy Development (WP# N-ID07SS0113 - MIT) 3. - Corrosion and Crack Growth Studies in HIx Solutions at General Atomics (N-ID07SS0107- GA) 4. - Ceramic Heat Exchanger Development for Application to NHI (WP# N-ID07SS0110 and N-ID07SS0111- Ceramatec) 5. - High Temperature Electrolysis Experimental Development (N-ID07EL0201 - UNLV) 6. - Measurement of Alloy Mechanical Properties at UNLV (N-ID07SS0106 - UNLV) 7. - Numerical Analysis of Advanced Heat Exchanger Concepts at UNLV (N-ID07SS0108 - UNLV)

The scope of work for the following three UNLV projects are included in this work package: 1. - Administration of the UNLVRF HTHX Project including contracts, communications, collaboration and meeting coordination, and ad hoc project meetings such as the Liquid Salt Technical Working Group and the Materials Workshop hosted by UNLV (UNLV PI: Anthony Hechanova) 2. - High Temperature Heat Exchanger Prototype Testing (UNLV, PI: Samir Moujaes) 3. - Analytical Studies of Materials in the S-I cycle (UNLV, PI: Allen Johnson) In FY07, the initial UNLV Research Foundation projects (FY04-FY06) will be wrapping up and these closure activities are covered under this work package using FY06 carryover funding.

New FY07 research activities coordinated by the UNLV Research Foundation funded by FY07 funds will be covered under different work packages (i.e., N-ID07SS0101, N-ID07SS0102, N-ID07SS0103, N-ID07SS0104, and N-ID07SS0105).

The UNLVRF will also continue to coordinate extensive communication between members of the university consortium for materials selection and development and heat exchanger design, contract monitoring and reporting. Milestones and deliverables specific to the activities above, but not included in this WP are detailed in specific WPs and UNLV RF proposals.

- High Temperature Heat Exchanger Prototype Testing: This task will complete experimental testing on the different configurations of heat exchangers such as the staggered fin arrangements. The establishment and validation of the determination of the conductivity and optical absorption coefficient for fluids that absorb radiation energy passing through them will also be completed. This concept is needed eventually if properties of molten salts such as Flinak would be used in the intermediate HX. Finally, the CFD results for hydrodynamics and thermally for the flow and heat exchanger using the staggered fin geometry experimentally will be locally validated.

- Analytical Studies of HI Exposure on Structural Materials at High Temperatures: The goal of the project is to aid in the identification of suitable heat exchanger material candidate(s) for the HI Decomposition process within the SI Thermochemical Cycle for hydrogen production. In FY06, SEM, EDX, WDS, and XPS was used to study the structure and composition of Ta and Nb alloys as well as SiC and Si_3N_4 ceramics and their corrosion layers previously identified as suitable development candidates. For FY07, the study of these and other development candidates will continue. Sample preparation facilities have been constructed that can remove the last traces of HI from the test materials, making them safe for study in vacuum based analytical instruments. The instrument will be maintained and upgraded for further work involving these materials at high temperature and corrosive environments in-situ using mass spectrometry. The samples will also be studied using other techniques (XRF, XRD,etc.) as appropriate. The results will provide data on the effect of composition and material processing on the corrosion resistant of the candidate materials. WP decreased per BCP NHI-004 to bridge funding to continue GA research through FY07 until programmatic FY08 funds are available on WP N-ID07SS0112. Scope has been decreased as stated in a BCP dated 6/11/2007.

Work Package Manager

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Accomplishments

Experimental tests were designed and performed under scaled conditions similar to the working conditions of the prototype intermediate heat exchanger (IHX) proposed by UC-Berkeley. Dimensionless analysis, computational fluid dynamics simulations, and bench tests on the bench-top apparatus located at UNLV compared well with the design parameters provided by UC-Berkeley. As designed, the proposed heat exchanger has a relatively large pressure drop. It is expected that round-edge-fins would provide better hydraulic performance than square-edge-fins as a result of a reduction in the friction factor by about 40%, but the square-edged fins provided a 10% boost in heat transfer performance over the round-edge-fin design. Figure 9 and 10 show the bench-top apparatus and a close-up of the acrylic plates used to perform the scaled tests. The apparatus uses water, silicone oil, or air instead of high-temperature helium, and uses

Alloy 6061 and acrylic instead of high-temperature alloys. Fluid conditions are chosen to match Reynolds numbers between the laboratory mock-up and the UC-Berkeley design. Results of these tests are provided in Ref. 27.

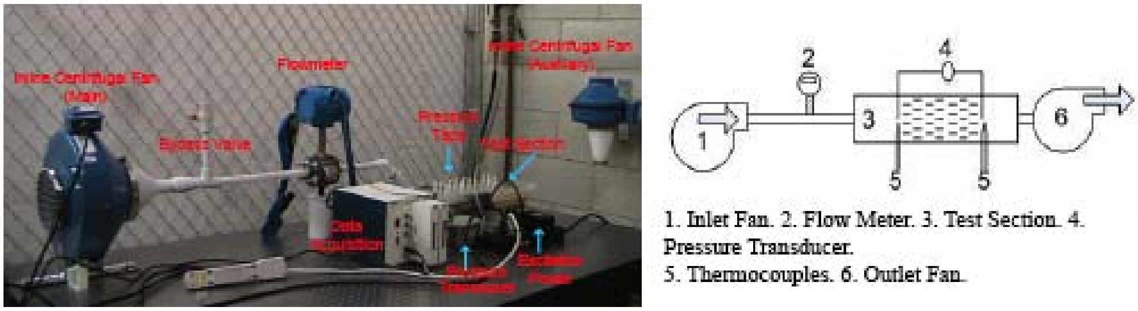

Figure 9. Experimental and schematic diagrams of ambient air hydraulic test set-up.

Figure 10. Acrylic test section fin part of 1:3 dimension ratio.

Chemistry and surface analysis support was also provided to General Atomics throughout the course of their materials corrosion work, as described in Section 3.2.7. The results of the surface analysis work are provided in the General Atomics report described in Ref. 19 and another report that may be submitted by General Atomics at the end of the current fiscal year.

3.2.13 N-ID07SS0113 – The Development of Self-Catalytic Materials for Thermochemical Water Splitting Using the Sulfur-Iodine Process

Work Scope

Activities will be focused in the following areas: (1) The fabrication of several platinum-containing alloys based on the Alloy 800 and Alloy 617 chemistries. These alloys will include the following: Alloy 800+1wt%Pt, Alloy 800+2wt% Pt, Alloy 617+1wt% Pt, and Alloy 617+2 wt% Pt, (2) the characterization of these alloys in the following areas: microstructurally, electrochemically, catalyst effectiveness, and mechanical properties-if sufficient material is available.

Work Package Manager

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Accomplishments

A second set of Pt-added alloy heats were ordered from Special Metals, Inc., Processing Laboratory of New Hartford, NY., to add to the heats already obtained during FY06. The heats are: Alloy 800H+1% Pt, Alloy 800H+2%Pt, Alloy 800H+5% Pt, Alloy 617+1%Pt, and Alloy 617+2%Pt, all measured by weight. Examination of the microstructre of each heat has also been underway using scanning electron microscopy (SEM). Preliminary results show that the new heats have a much lower carbon content than the first heat and are much more representative of what would be achievable in commercial practice.

The catalyst effectiveness test system was prepared for sulfuric acid decomposition tests, and sample fabrication is underway to support sulfuric acid decomposition tests during two months of the fiscal year. Catalyst effectiveness testing was delayed by a transitioning of new students to this work, and so the March 31, 2007 report that was expected on this work will not be submitted until the end of the fiscal year.

Though this work was directed towards using this material for decomposing H2SO4 at 800-900°C, work was done to examine this material's potential for serving as durable and effective electrodes for application to water electrolysis. Work is on-going in this area.

4. SET OF TECHNICAL ISSUES

The list of known System Interface and Supporting Systems technical issues is shown in Table 7 and Table 8. This list originated from technical issues described in the document ANL W7500-0002-ES-0, "Reactor/Process Interface Heat Exchanger and Intermediate Loop Technical Issues" and has been updated periodically as some issues were resolved and new ones were discovered. In Table 7 the issues are organized by technical area, while in Table 8, the issues are presented by the year in which they must be resolved. Estimates of the total cost of resolving each issue have not yet been developed, and so there is no linkage between the required resolution date and the cost of resolving the issue. The focus of the list is on the near-term leading up to the selection of the pilot-scale hydrogen plant demonstration decisions in 2011. The list is organized under six headings. These headings are: "1. Use of Liquid Salt for Intermediate Heat Transport Loop", "2. Use of Helium for Intermediate Heat Transport Loop", "3. General Materials and Components", "4. Balance-of-Plant and Infrastructure", "5. Safety", and "6. General Operations." The column on the right-hand-side of the table indicates when the technical issue must be resolved to provide the highest quality, lowest risk recommendations to the larger project concerning pilot-plant down selects, overall system designs, and safety. By 2011, the DOE NHI will begin a transition period from applied research and development activities to an organized construction and operation project with a sizeable industrial component. When that happens, research of the technical issues listed below may continue, but the constraints on equipment designs, plant layouts, and other considerations will become more fixed and more costly to alter. Therefore, research money is best directed to solving these issues within the prescribed time instead of waiting until design options have become more limited and resolution of unforeseen problems might be more costly to obtain.

Following the tables, Gantt charts are presented in Figures 11 through 16 for each technical area. These Gantt charts provide some information about the timing and duration of technical tasks, and the dates of select milestones.

Table 7. Set of Technical Issues

Number	Description	Needed by
1. Use of Liquid Salt for Intermediate Heat Transport Loop		
1.	Determine suitability of liquid salt for the NGNP intermediate loop and provide recommendations for/against its use in the engineering-scale demonstration.	2009
1.1	Compare liquid salt intermediate heat transport loop to helium heat transport loop (physical sizes, temperature/pressure distributions, characteristics, materials, equipment, energy costs, etc.)	2009
1.2	Develop system understanding of liquid salt intermediate heat transport loop with necessary support systems (design concepts, steady-state modeling, description of start-up, shutdown, off-normal behaviors and responses, etc.).	2009

Number	Description	Needed by
1.3	Determine redox control technique(s) or corrosion prevention methods/procedures for chosen salt(s) in order to minimize corrosion of intermediate loop containment/devices.	2009
1.4	Recommend heat exchanger designs for a He/Salt IHX and determine implications of using liquid salt on design of H_2SO_4 decomposer and related process heat exchangers.	2009
1.5	Recommend best candidate salt/structural material sets for use in the intermediate heat transport loop.	2008
1.6	Measure liquid salt data and corrosion data, as needed, to fill in "holes." Data must be collected in priority order.	2008
1.7	Assemble liquid salt data and materials corrosion data from literature sources and identify and prioritize physical data "holes."	2007 (not completed)
2. Use of Helium for Intermediate Heat Transport Loop		
2.	Develop system understanding of a practical helium intermediate heat transport loop to support intermediate heat transport fluid down-select (pipe configuration, length limitations, pressure drops, energy consumption, etc.)	2009
2.1	Determine effects of helium environments (commercial purity) on IHX candidate materials and recommend conditions to minimize corrosion/erosion.	2009
2.2	Model and test internal pipe insulation materials and methods for helium transport pipes.	2008
2.3	Recommend heat exchanger designs/materials for He/He IHX and process heat exchangers that are connected to the intermediate loop (excluding the H_2SO_4 decomposer).	2008
3. General Materials and Components		
3.	Provide detailed list of candidate component designs or concepts and suitably matched materials for use in pilot-scale demonstration plant(s) and independent pilot-scale testing.	2011
3.1	Examine use of high performance alloys and ceramics for IHX use (not code approved)	2009
3.2	Initiate assembled heat exchanger tests in the laboratory.	2009
3.3	Obtain high-temp creep, mechanical property data, permeability, manufacturing methods and so on to fill in data "holes" for IHX-suitable materials (code approved or nearly code-approved materials only).	2008
3.4	Obtain high-temp mechanical properties, permeability, and identify manufacturing methods, as needed, for candidate process heat exchanger materials to supplement heat exchanger design efforts.	2008
3.5	Identify designs and materials for high-temp oxygen cooler.	2008

Number	Description	Needed by
3.6	Perform corrosion testing of structural materials (metals, ceramics, cladded/coated samples) exposed to liquid/vapor H_2SO_4 and related chemicals.	On-going
3.7	Perform corrosion testing of structural materials (metals, ceramics, cladded/coated samples) exposed to HIx solutions under flow conditions.	On-going
3.8	Review and assess components shown on hydrogen production process flow sheets (S-I, high-temp electrolysis, and alternative processes if needed) for technical readiness.	2007, 2008, 2009, 2010, 2011
3.9	Revise the NHI Materials and Components Qualification Plan as needed to make it more usable by the program.	2007, 2008, 2009, 2010
3.10	Develop suitable database and begin implementation of the NHI Materials and Components Qualification Plan across the larger research program.	2007 (not completed)
3.11	Develop NHI Materials and Components Qualification Plan	2007 (completed)
4. Balance-of-Plant and Infrastructure		
4.	Determine baseline balance-of-plant and infrastructure configurations of candidate pilot-scale hydrogen production plants.	2011
4.1	Examine physical and spatial relationships between HTE plant units and the intermediate heat transport loop, and determine minimum heat transfer distances while maximizing distance between nuclear plant and hydrogen production/storage units.	2009
4.2	Examine physical and spatial relationships between S-I plant units and the intermediate heat transport loop, and determine minimum heat transfer distances while maximizing distance between nuclear plant and hydrogen production/storage units.	2008
4.3	Identify environmental permitting requirements for S-I and HTE plants and initiate permitting activities (as needed).	2008
4.4	Identify necessity, operational requirements and equipment options for auxiliary heat source/sink for intermediate loop.	2008
5. Safety		
5.	Submit detailed safety strategy containing defenses-in-depth, risk-based features, and operational recommendations to maximize safety of the combined nuclear plant/hydrogen plant.	2011
5.1	Perform transient analyses of combined plant to look for potential safety problems that would not be present under steady-state operating conditions.	2010

Number	Description	Needed by
5.2	Determine tritium permeation and control strategies to minimize concentrations of tritium in the hydrogen product (must be coordinated with intermediate heat transport fluid selection).	2010
5.3	Examine chemical industry safety "best practices" and begin incorporation of usable information into the DOE NHI R&D plant design process.	2008
5.4	Develop or identify high-temp isolation valve designs or concepts for further testing (applicable to IHX).	2008
6. General Operations		
6.	Develop steady-state and transient modeling capabilities for combined system that are applicable for NRC licensing	2009
6.1	Incorporate economic evaluation capabilities into HyPEP.	2009
6.2	Complete steady-state HyPEP Model to include both S-I and HTE processes.	2008
6.3	Develop transient modeling capabilities for the combined plant that are suitable for safety and operations analysis and the design of control system strategies.	2008
6.4	Complete beta testing of HyPEP model.	2008
6.5	Complete alpha testing of HyPEP model.	2007 (completed)

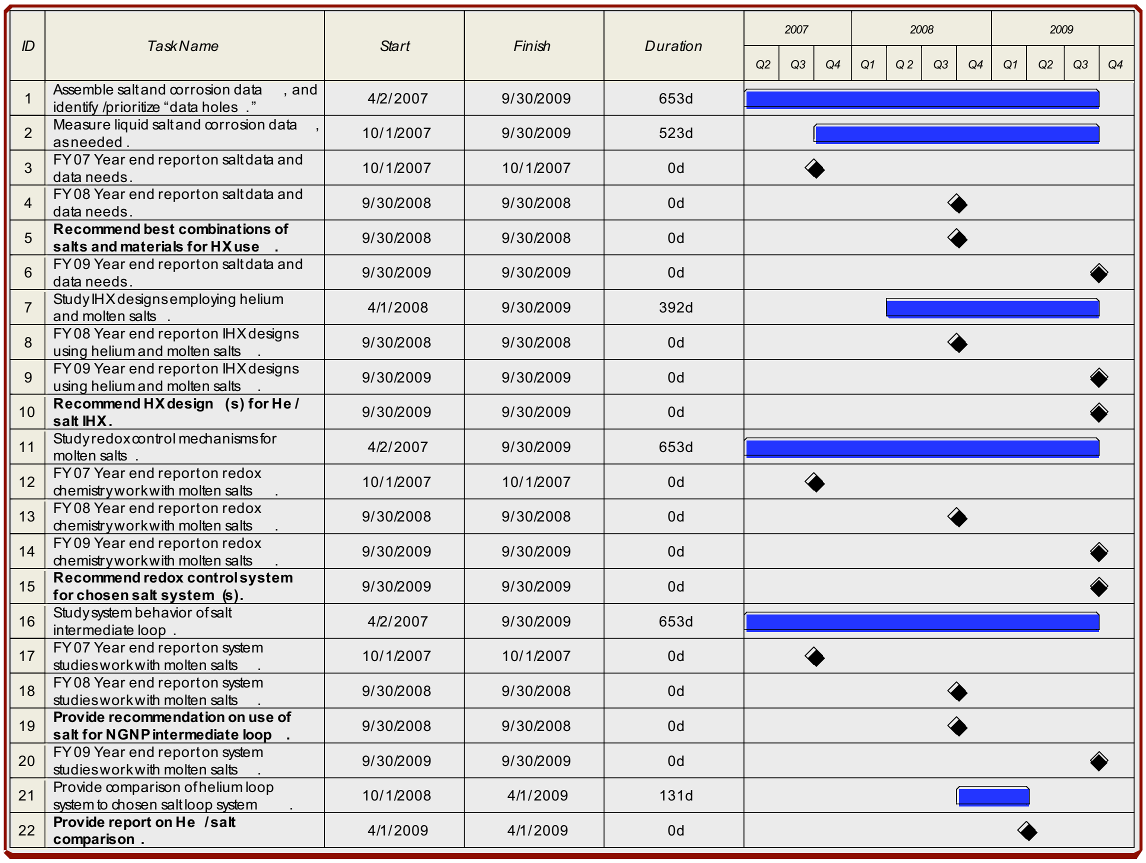
Table 8. Sequential Ordering of Technical Issues and Goals

2007	
1.7	Assemble liquid salt data and materials corrosion data from literature sources and identify and prioritize physical data "holes." (not completed)
3.8	Review and assess components shown on hydrogen production flow sheets (S-I, high-temp electrolysis, and alternative processes, if needed) for technical readiness. (not completed)
3.9	Revise the NHI Materials and Components Qualification Plan, as needed, to make it more usable by the program. (completed)
3.10	Develop suitable database and begin implementation of the NHI Materials and Components Qualification Plan across the larger research program. (not completed)
3.11	Develop NHI Materials and Components Qualification plan. (completed)
6.5	Complete alpha testing of HyPEP model. (completed)
2008	
1.5	Recommend best candidate salt/structural material sets for use in the intermediate heat transport loop.
1.6	Measure liquid salt data and corrosion data, as needed, to fill in "holes."

	Data must be collected in priority order.
2.2	Model and test internal pipe insulation materials and methods for helium transport pipes.
2.3	Recommend heat exchanger designs/materials for He/He IHX and process heat exchangers that are connected to the intermediate loop (excluding the H_2SO_4 decomposer).
3.3	Obtain high-temp creep, mechanical property data, permeability, manufacturing methods and so on to fill in data "holes" for IHX-suitable materials (code-approved or nearly code-approved materials only).
3.4	Obtain high-temp mechanical properties, permeability, and identify manufacturing methods, as needed, for candidate process heat exchanger materials to supplement heat exchanger design efforts.
3.5	Identify designs and materials for high-temp oxygen cooler.
3.8	Review and assess components shown on hydrogen production process flow sheets (S-I, high-temp electrolysis, and alternative processes, if needed) for technical readiness.
3.9	Revise the NHI Materials and Components Qualification Plan as needed to make it more usable by the Program.
4.2	Examine physical and spatial relationships between S-I plant units and the intermediate heat transport loop, and determine minimum heat transfer distances while maximizing distance between nuclear plant and hydrogen production/storage units.
4.3	Identify environmental permitting requirements for S-I and HTE plants and initiate permitting activities, as required.
4.4	Identify necessity, operating requirements and equipment options for auxiliary heat source/sink for intermediate loop.
5.3	Examine chemical industry safety "best practices" and begin incorporation of usable information into the DOE NHI R&D pant design process.
5.4	Develop or identify high-temp isolation valve designs or concepts for further testing (applicable to IHX).
6.2	Complete steady-state HyPEP Model to include both S-I and HTE processes.
6.3	Develop transient modeling capabilities for the combined plant that are suitable for safety and operational analysis and the design of control system strategies.
6.4	Complete beta testing of the HyPEP model.
2009	
1.	Determine suitability of liquid salt for the NGNP intermediate loop and provide recommendations for/against its use in the engineering-scale demonstration.
1.1	Compare liquid salt intermediate heat transport loop to helium heat transport loop (physical sizes, temperature/pressure distribution, characteristics, materials, equipment, energy costs, etc.)
1.2	Develop system understanding of liquid salt intermediate heat transport loop with necessary support systems (design concepts, steady-state

	modeling, description of start-up, shutdown, off-normal behaviors and responses, etc.)
1.3	Determine redox control technique(s) or corrosion prevention methods/procedures for chosen salt(s) in order to minimize corrosion of intermediate loop containment/devices.
1.4	Recommend heat exchanger designs for He/Salt IHX and determine implications of using liquid salt on design of H_2SO_4 decomposer and related process heat exchangers.
2.	Develop system-level understanding of a practical helium intermediate heat transport loop to support intermediate heat transfer fluid down-select (pipe configuration, length, limitations, pressure drops, energy consumption, etc.)
2.1	Determine effects of helium environments (commercial purity) on IHX candidate materials and recommend conditions to minimize corrosion/erosion.
3.1	Examine use of high performance alloys and ceramics for IHX use (not code approved).
3.2	Initiate assembled heat exchanger testing in the laboratory.
3.8	Review and assess components shown on hydrogen production flow sheets (S-I, high-temp electrolysis, and alternative processes if needed) for technical readiness.
3.9	Revise the NHI Materials and Components Qualification Plan as needed to make it more usable by the program.
4.1	Examine physical and spatial relationships between HTE plant units and the intermediate heat transport loop, and determine minimum heat transfer distances while maximizing distance between nuclear plant and hydrogen production/storage units.
6.	Develop steady-state and transient modeling capabilities for combined system that are applicable for NRC licensing.
6.1	Incorporate economic evaluation capability into HyPEP.
2010	
3.8	Review and assess components shown on hydrogen production process flow sheets (S-I, HTE and alternative processes if needed) for technical readiness.
3.9	Revise the NHI Materials and Components Qualification Plan as needed to make it more usable by the program.
5.1	Perform transient analysis of combined plant to look for potential safety problems that would not be present under steady-state operating conditions.
5.2	Determine tritium permeation and control strategies to minimize concentrations of tritium in the hydrogen product (must be coordinated with the intermediate heat transport fluid selection).
2011	
3.	Provide detailed set of candidate component designs or concepts and suitably matched materials for use in pilot-scale demonstration plant(s) and independent pilot-scale testing.

3.8	Review and assess components shown on hydrogen production flow sheets (S-I, HTE and alternative processes if needed) for technical readiness.
4.	Determine baseline balance-of-plant and infrastructure configurations of candidate pilot-scale hydrogen production plants.
5.	Submit detailed safety strategy containing defense-in-depth, risk-based features, and operational recommendations to maximize safety of the combined plant.



ID	Task Name	Start	Finish	Duration
1	Assemble salt and corrosion data, and identify /prioritize "data holes."	4/2/2007	9/30/2009	653d
2	Measure liquid salt and corrosion data, as needed.	10/1/2007	9/30/2009	523d
3	FY07 Year end report on salt data and data needs.	10/1/2007	10/1/2007	0d
4	FY08 Year end report on salt data and data needs.	9/30/2008	9/30/2008	0d
5	**Recommend best combinations of salts and materials for HX use.**	9/30/2008	9/30/2008	0d
6	FY09 Year end report on salt data and data needs.	9/30/2009	9/30/2009	0d
7	Study IHX designs employing helium and molten salts.	4/1/2008	9/30/2009	392d
8	FY08 Year end report on IHX designs using helium and molten salts.	9/30/2008	9/30/2008	0d
9	FY09 Year end report on IHX designs using helium and molten salts.	9/30/2009	9/30/2009	0d
10	**Recommend HX design (s) for He / salt IHX.**	9/30/2009	9/30/2009	0d
11	Study redox control mechanisms for molten salts.	4/2/2007	9/30/2009	653d
12	FY07 Year end report on redox chemistry work with molten salts.	10/1/2007	10/1/2007	0d
13	FY08 Year end report on redox chemistry work with molten salts.	9/30/2008	9/30/2008	0d
14	FY09 Year end report on redox chemistry work with molten salts.	9/30/2009	9/30/2009	0d
15	**Recommend redox control system for chosen salt system (s).**	9/30/2009	9/30/2009	0d
16	Study system behavior of salt intermediate loop.	4/2/2007	9/30/2009	653d
17	FY07 Year end report on system studies work with molten salts.	10/1/2007	10/1/2007	0d
18	FY08 Year end report on system studies work with molten salts.	9/30/2008	9/30/2008	0d
19	**Provide recommendation on use of salt for NGNP intermediate loop.**	9/30/2008	9/30/2008	0d
20	FY09 Year end report on system studies work with molten salts.	9/30/2009	9/30/2009	0d
21	Provide comparison of helium loop system to chosen salt loop system.	10/1/2008	4/1/2009	131d
22	**Provide report on He / salt comparison.**	4/1/2009	4/1/2009	0d

Figure 11. Liquid Salt Systems Technical Area

ID	Task Name	Start	Finish	Duration
1	Analyze HX concepts for He /He IHX.	4/2/2007	9/30/2008	392d
2	FY07 Year end report on IHX analysis .	10/1/2007	10/1/2007	0d
3	FY08 Year end report on IHX analysis .	9/30/2008	9/30/2008	0d
4	**Recommend He /He IHX design for intermediate loop .**	9/30/2008	9/30/2008	0d
5	Analyze HXs and systems that use alternative fluids (steam, CO2).	10/1/2007	9/30/2008	262d
6	Report on HX and systems using alternative fluids .	9/30/2008	9/30/2008	0d
7	Analyze and test pipe insulation for high-temp systems .	4/2/2007	9/30/2009	653d
8	FY07 Year end report on pipe insulation .	10/1/2007	10/1/2007	0d
9	Initiate pipe insulation experiments	4/1/2008	4/1/2008	0d
10	FY08 Year end report on pipe insulation work .	9/30/2008	9/30/2008	0d
11	**Provide recommendation and report on pipe insulation .**	9/30/2009	9/30/2009	0d

Figure 12. Helium Systems Technical Area

ID	Task Name	Start	Finish	Duration
1	NHI Materials and Components Development Plan	10/2/2006	9/28/2007	260d
2	**Issue Materials and Components Development Plan**	4/2/2007	4/2/2007	0d
3	**Initiate Plan Implementation**	5/30/2007	5/30/2007	0d
4	Develop and test NHI Components Database	1/30/2007	3/28/2008	304d
5	Perform corrosion testing of Hix materials.	4/2/2007	9/30/2008	392d
6	Perform corrosion testing of sulfuric acid materials .	4/2/2007	9/30/2008	392d
7	**Identify best materials for sulfuric acid decomposition section .**	9/30/2008	9/30/2008	0d
8	**Identify best materials for Hix section.**	9/30/2008	9/30/2008	0d
9	Perform testing of materials for high - temp oxygen cooler .	10/1/2007	6/30/2008	196d
10	**Identify best materials for high -temp oxygen cooler .**	6/30/2008	6/30/2008	0d
11	Measure high-temp alloy properties in support of ASME code cases .	4/2/2007	12/30/2010	979d
12	Perform assembled heat exchanger testing .	6/2/2008	12/30/2010	674d
13	Measure ceramic materials properties for HX use .	4/2/2007	12/30/2010	979d
14	FY07 Year end report on materials progress.	10/1/2007	10/1/2007	0d
15	FY08 Year end report on materials progress.	9/30/2008	9/30/2008	0d
16	FY09 Year end report on materials progress.	9/30/2009	9/30/2009	0d
17	FY10 Year end report on materials progress.	9/30/2010	9/30/2010	0d

Figure 13. Materials Technical Area

ID	Task Name	Start	Finish	Duration
1	Examine use of auxiliary heat sink / source .	10/1/2007	9/30/2008	262d
2	**Recommend solution for aux . heat sink/source.**	9/15/2008	9/15/2008	0d
3	Review environmental permitting requirements.	6/2/2008	9/30/2009	348d
4	**Provide summary document on permitting needs .**	9/30/2009	9/30/2009	0d
5	Examine physical layout of H 2 plant(s).	10/1/2007	9/30/2009	523d
6	**Provide minimum -risk plant layout(s).**	9/30/2009	9/30/2009	0d
7	Examine BOP requirements and needs for pilot-scale plants	6/1/2009	9/30/2010	349d
8	**Provide report on BOP requirements for pilot -scale plants .**	10/1/2010	10/1/2010	0d

Figure 14. Balance-of-Plant Technical Area

ID	Task Name	Start	Finish	Duration
1	High-temp isolation valve research	10/1/2007	10/1/2010	785d
2	**Recommend isolation valve designs for NGNP.**	10/1/2010	10/1/2010	0d
3	Examine chemical industry safety “best practices”	10/1/2007	9/30/2009	523d
4	**Provide summary report on “best practices” for H_2 plant**	9/30/2009	9/30/2009	0d
5	Examine tritium movement to H_2 plant.	10/2/2006	9/30/2008	522d
6	**Assess tritium implications for NGNP.**	9/30/2008	9/30/2008	0d
7	Perform transient and steady-state analyses of combined plant.	10/1/2007	9/30/2010	784d
8	**Summary report on transient responses.**	9/30/2010	9/30/2010	0d
9	Risk-based safety analyses of combined plant.	4/2/2007	12/30/2010	979d
10	FY08 Year end report on risk analysis work.	9/30/2008	9/30/2008	0d
11	FY09 Year end report on risk analysis work.	9/30/2009	9/30/2009	0d
12	FY10 Year end report on risk analysis work.	9/30/2010	9/30/2010	0d

Figure 15. Safety Technical Area

ID	Task Name	Start	Finish	Duration
1	Develop steady-state and transient models	10/2/2006	10/1/2009	784d
2	Complete alpha-testing of HyPEP	10/1/2007	10/1/2007	0d
3	Complete beta-testing of HyPEP	9/30/2008	9/30/2008	0d
4	Initiate transient modeling of integrated system	10/1/2007	10/1/2007	0d
5	Complete steady-state models of HTE and SI process	9/30/2008	9/30/2008	0d
6	Incorporate economic capabilities into HyPEP	10/1/2008	9/30/2009	261d
7	Perform system analyses to support NGNP licensing activities	10/1/2008	10/1/2009	262d

Figure 16. Operations Technical Area

5. SET OF PROJECTS

The list of past and on-going System Interface and Supporting Systems projects is shown in Table . The table provides the project date, the description, and origin (location) for the project. Where reports or documents have been written, report or document titles are provided under the description heading. Where work is underway and reports or project documents have yet to be issues, the work package or NERI project title is provided under the description heading instead.

Table 9. Set of System Interface and Supporting Systems Projects/Reports

Identifier	Description	Origin
FY 2004		
UNLV 1Q_2004	UNLV HTHX Project Quarterly Report, 1Q FY04	UNLV
UNLV 2Q_2004	UNLV HTHX Project Quarterly Report, 2Q FY04	UNLV
UNLV 3Q_2004	UNLV HTHX Project Quarterly Report, 3Q FY04	UNLV
UNLV 4Q_2004	UNLV HTHX Project Quarterly Report, 4Q FY04	UNLV
ANL W7500-001-ES-00	Reactor/Process Interface Requirements	ANL-W
ANL W7500-002-ES-00	Reactor/Process Interface Heat Exchanger and Intermediate Loop Technical Issues	ANL-W
ANL W7500-003-ES-00	Balance of Plant Requirements for a Nuclear Hydrogen Production Plant	ANL-W
INEEL EXT-04-01791	Infrastructure Requirements for a Nuclear Hydrogen Pilot Plant	INEEL
FY 2005		
UNLV 1Q_2005	UNLV HTHX Project Quarterly Report, 1Q FY05	UNLV
UNLV 2Q_2005	UNLV HTHX Project Quarterly Report, 2Q FY05	UNLV
UNLV 3Q_2005	UNLV HTHX Project Quarterly Report, 3Q FY05	UNLV
UNLV 4Q_2005	UNLV HTHX Project Quarterly Report, 4Q FY05	UNLV
UNLV 2005	UNLV HTHX Project FY 2005 Year-End Report	UNLV
INL EXT-05-00137	An Engineering Analysis for Separation Requirements of a Hydrogen Production Plant and High-Temperature Nuclear Reactor, Revision 0	INL
INL EXT-05-00453	Thermal-Hydraulic Analysis of Heat Transfer Fluid Requirements and Characteristics for Coupling a Hydrogen Production Plant to a High-Temperature Nuclear Reactor	INL
INL EXT-05-00690	Engineering Analysis of Intermediate Loop and Process Heat Exchanger Requirements to Include Configuration Analysis and Materials Needs	INL
NERI 05-032	Silicon Carbide Ceramics for Compact Heat Exchangers (3-year project)	Johns Hopkins University
NERI 05-154 1Q	Molten Salt Transport Loop: Materials Corrosion and Heat Transfer Phenomena, 1st Quarterly Report	U of Wis.
NERI 05-154 2Q	Molten Salt Transport Loop: Materials Corrosion and Heat Transfer Phenomena, 2nd Quarterly Report	U of Wis.

Identifier	Description	Origin
FY 2006		
UNLV 1Q_2006	UNLV HTHX Project Quarterly Report, 1Q FY06	UNLV
UNLV 2Q_2006	UNLV HTHX Project Quarterly Report, 2Q FY06	UNLV
UNLV 3Q_2006	UNLV HTHX Project Quarterly Report, 3Q FY06	UNLV
UNLV 4Q_2006	UNLV HTHX Project Quarterly Report, 4Q FY06	UNLV
UNLV Ceramic_2006a	NHI Report: Hydrodynamic, Thermal and Decomposition Performance for Ceramic Sulfuric Acid Decomposer	UNLV
UNLV Ceramic_2006b	Mechanical and Thermal Stress Analysis of Ceramic HTHX	UNLV
UNLV Stripfin_2006	NHI Report: Optimization Studies and Manifold Design of Compact Off-set Strip Fin HTHX	UNLV
GA Corrosion_2006	Corrosion Studies of Construction Materials in HI Decomposition Environment	GA
Ceramatec 2006	FY2006 Materials Characterization and Heat Exchanger Design Development for NHI Applications	Ceramatec
INL EXT-06-11232	Balance of Plant Requirements for a Nuclear Hydrogen Plant, Revision 1	INL
INL EXT-06-11482	Assessment of Codes and Standards Applicable to a Hydrogen Production Plant Coupled to a Nuclear Reactor	INL
INL EXT-05-00137 Rev. 1	An Engineering Analysis for Separation Requirements of a Hydrogen Production Plant and High-Temperature Nuclear Reactor	INL
INL EXT-06-11725	HyPEP FY06 Report: Models and Methods	INL, ANL, KAERI
ORNL TM-2006 563	NHI Materials and Components Development Plan	ORNL, INL
ORNL TM-2006 69	Assessment of Candidate Molten Salt Coolants for the NGNP/NHI Heat-Transfer Loop	ORNL
NERI 05-032	Silicon Carbide Ceramics for Compact Heat Exchangers (3-year project)	Johns Hopkins University
NERI 05-154 3Q	Molten Salt Transport Loop: Materials Corrosion and Heat Transfer Phenomena, 3rd Quarterly Report	U of Wis.
NERI 05-154 Y1	Molten Salt Transport Loop: Materials Corrosion and Heat Transfer Phenomena, Year 1 Report	U of Wis.
NERI 05-154 5Q	Molten Salt Transport Loop: Materials Corrosion and Heat Transfer Phenomena, 5th Quarterly Report	U of Wis.
NERI 05-154 6Q	Molten Salt Transport Loop: Materials Corrosion and Heat Transfer Phenomena, 6th Quarterly Report	U of Wis.
NERI 05-154 7Q	Molten Salt Transport Loop: Materials Corrosion and Heat Transfer Phenomena, 7th Quarterly Report	U of Wis.
NERI 06-024	Ni-Si Alloys for the S-I Reactor/Hydrogen Production Process Interface (3-year project)	U of Mo and INL
NERI 06-041	Dynamic Simulation and Optimization of Nuclear Hydrogen Production Systems (3-year project)	MIT
FY 2007		
INL EXT-07-12746	Tritium Movement and Accumulation in NGNP System Interface and Hydrogen Plant	INL
N-AN07SS0101	Steady State and Transient Modeling of Combined Nuclear Hydrogen Plant	ANL

Identifier	Description	Origin
N-ID07SS0101	UNLV NHI Materials Support	UNLV
N-ID07SS0102	UNLV NHI Momentum/Heat/Mass Transfer	UNLV
N-ID07SS0103	UNLV NHI Liquid Salt Systems	UNLV
N-ID07SS0104	UNLV NHI Materials/Surface Characterization	UNLV
N-ID07SS0105	UNLV NHI Chemistry Support	UNLV
N-ID07SS0106	Measurement of Mechanical Alloy Properties at UNLV – FY06 Carryover	UNLV
N-ID07SS0107	Corrosion and Crack Growth Studies in HIx Solutions at General Atomics – FY06 Carryover	GA
N-ID07SS0108	Numerical Analysis of Advanced Heat Exchanger Concepts at UNV – FY06 Carryover	UNLV
N-ID07SS0109	C-SiC Materials for HTHX's at UC-Berkeley – FY06 Carryover	UCB
N-ID07SS0110	Ceramic Heat Exchanger Development for Application to NHI Hydrogen Production Processes (FY06 Carryover)	Ceramatec
N-ID07SS0111	Ceramic Heat Exchanger Development for Application to NHI Hydrogen Production Processes (FY07 Bridge Package)	Ceramatec
N-ID07SS0112	UNLV RF High Temperature Heat Exchanger Project – FY06 Carryover	UNLV
N-ID07SS0113	The Development of Self-Catalytic Materials for Thermochemical Water Splitting Using the Sulfur-Iodine Process	MIT
N-IN07SS0101	Steady-State and Transient Modeling of Combined Nuclear Hydrogen Plant	INL
N-IN07SS0102	Technical Director and Project Management Support for the DOE NHI	INL
N-OR07SS0101	Development of NHI Materials and Components Test Plan	ORNL
UNLV 1Q_2007	High Temperature Heat Exchanger Project: Quarterly Progress Report, October 1, 2006 through December 31, 2006	UNLV
UNLV 2Q_2007	High Temperature Heat Exchanger Project: Quarterly Progress Report, January 1, 2007 through March 31, 2007	UNLV
UNLV Alloy_2007a	Tensile Property Measurements of Structural Materials for High-Temperature Heat Exchanger Applications	UNLV
GA Corrosion_2007a	FY2006 Year End Report: Corrosion Studies of Construction Materials for HI Decomposition Environment	GA
ANL Model_2007a	Dynamic Modeling Efforts for System Interface Studies	ANL
NERI 05-032	Silicon Carbide Ceramics for Compact Heat Exchangers (3-year project)	Johns Hopkins University
NERI 05-154	Molten Salt Transport Loop: Materials Corrosion and Heat Transfer Phenomena (3-year project)	U of Wis.
NERI 06-024	Ni-Si Alloys for the S-I Reactor/Hydrogen Production Process Interface (3-year project)	U of Mo and INL
NERI 06-041	Dynamic Simulation and Optimization of Nuclear Hydrogen Production Systems (3-year project)	MIT
NERI 07-030	Liquid Salts as Media for Process Heat Transfer	U of Wis.

6. MAPPING OF PROJECTS TO TECHNICAL ISSUES

Table 10 shows the mapping of projects to technical issues. The project identifiers are the same ones used in Tables 8 and 9 to differentiate between projects. If the project identifier box is empty in Table 10, then no projects have yet been pursued to solve the technical issue. The “Resolved?” indicator shows whether the technical issue has been resolved or will be resolved this fiscal year. The “Year Needed” column shows when the particular technical issue must be solved in order to support the construction and operation of pilot-scale and engineering-scale equipment. If the “Year Needed” box is filled with an “On-going” indicator, then the work is expected to be ongoing and does not have a defined resolution.

Table 10. Map of Projects and Issues

Issue	Documents/ Projects	Description	Status	Year Needed
Use of Liquid Salt for Intermediate Heat Transport Loop				
1.1 Judgment of suitability for engineering-scale use	INL EXT-05-00453	Thermal-Hydraulic Analyses of Heat Transfer Fluid Requirements and Characteristics for Coupling a Hydrogen Production Plant to a High-Temperature Nuclear Reactor	Not resolved	2009
1.2 System-level understanding of practical molten salt system	INL EXT-05-00453 N-ID07SS0103 UNLV 1,2Q_2007	See 1.1 (above) UNLV FY07 work package directed towards a system-level analysis of practical molten salt systems UNLV quarterly progress reports available on-line at nstg.nevada.edu/heatexchangers.html	Not resolved FY07 work package will begin Sept 07 Updated quarterly	2009
1.3 Redox control techniques for molten salt systems to reduce corrosion	UNLV 2,3,4Q_2006 N-ID07SS0103	UNLV quarterly progress reports available on-line at nstg.nevada.edu/heatexchangers.html See 1.2 (above)	Not resolved Updated quarterly FY07 work package will begin Sept 07	2009
1.4 Recommend molten			Not resolved	2008

Issue	Documents/ Projects	Description	Status	Year Needed
salt HX designs	UNLV (1,2,3,4)Q_2004 UNLV (1,2,3,4)_2005 UNLV 2005 UNLV (1,2,3,4)Q 2006 N-ID07SS0109	UNLV quarterly progress reports available on-line at nstg.nevada.edu/heatexchangers.html UNLV quarterly progress reports available on-line at nstg.nevada.edu/heatexchangers.html Year-end report available at nstg.nevada.edu/heatexchangers.html UNLV quarterly progress reports available on-line at nstg.nevada.edu/heatexchangers.html UC-Berkeley FY06 carryover work package concerning C/SiC HX development for He/Salt IHX		
1.5 Recommend best materials/salt combinations	ORNL TM-2006 N-ID07SS0103	Assessment of Candidate Molten Salt Coolants for the NGNP/NHI Heat-Transfer Loop See 1.2 (above)	Not resolved FY07 work package will begin Sept 07	2008
1.6 Measure salt data to fill in data “holes”	NERI 05-154 NERI 07-030	Molten Salt Heat Transport Loop: Materials Corrosion and Heat Transfer Phenomena Liquid Salts as Media for Process Heat Transfer	Not resolved Concludes FY07 Continuation	2008

Issue	Documents/ Projects	Description	Status	Year Needed
		from VHTRs: Forced Convective Channel Flow Thermal Hydraulics, Materials and Coatings	of NERI 05-154	
1.7 Assemble database of known molten salt data	NERI 05-154 (1,2,3,,5,6,7)Q NERI 05-154 Y1,2 ORNL TM-2006 N-ID07SS0103	NERI 05-154 quarterly reports NERI 05-154 yearly reports See 1.5 (above) See 1.2 (above)	Not resolved 3rd year report available in FY07 Active Sept 07	2007
Use of Helium for the Intermediate Heat Transport Loop				
2. System-level understanding of practical helium system	ANL W7500-002-ES-00 INL EXT-05-00453 INL EXT-05-00690	Reactor/Process Interface Heat Exchanger and Intermediate Loop Technical Issues See 1.1 (above) Engineering Analysis of Intermediate Loop and Process Heat Exchanger Requirements to Include Configuration Analysis and Materials Needs	Not resolved	2009
2.1 Effects of He contaminants on materials	N-ID07SS0101	UNLV FY07 work package will be directed towards data supporting ASME codification of Inconel 617 in air and helium environments	Not resolved Work package will be active Sept 2007	2009

Issue	Documents/ Projects	Description	Status	Year Needed
2.2 Identification of practical internal pipe insulation and configuration			Not resolved	2008
	INL EXT-05-00453	See 1.1 (above)		
	INL EXT-05-690	See 2. (above)		
	N-ID07SS0102	UNLV FY07 work package will deal with HX and pipe modeling, and will also involve pipe insulation experiments	Work package will become active Sept 07	
2.3 HX designs for He/He heat exchangers			Not resolved	2008
	UNLV reports	All UNLV quarterly and yearly reports to date involve examinations of various heat exchanger designs. See nstg.nevada.edu/heatexchangers.html.		
	INL EXT-05-690	See 2. (above)		
	N-ID07SS0102	See 2.2 (above)	Work package will become active Sept 07	
	N-ID07SS0108	UNLV FY06 carryover work package involving the numerical modeling of HX technologies	Work package will be completed August 2007	
	N-ID07SS0110	UNLV FY06 carryover work package involving the study of C/SiC HX's at UC-Berkeley	Work package will be completed	

Issue	Documents/ Projects	Description	Status	Year Needed
			August 2007	
General Materials and Components				
3. Detailed database of pilot-scale candidate components	N-IN07SS0102	NHI Materials and Components Development Plan	Not resolved Issued 4/07, but implementation will occur last quarter 07 and FY08	2011
	N-OR07SS0101	Same as above (INL/ORNL joint project)	See above	
	UNLV Ceramic_2006a	NHI Report: Hydrodynamic, Thermal and Decomposition Performance for Ceramic Sulfuric Acid Decomposer		
	UNLV Ceramic_2006b	Mechanical and Thermal Stress Analysis of Ceramic HTHX		
	UNLV Stripfin_2006	NHI Report: Optimization Studies and Manifold Design of Compact Off-set Strip Fin HTHX		
	Ceramatec_2006	FY2006 Materials Characterization and Heat Exchanger Design Development for NHI Applications		
3.1 Alloys and ceramics for IHX use			Not resolved	2010

Issue	Documents/ Projects	Description	Status	Year Needed
	UNLV Reports INL EXT-05-0453 INL EXT-05-0690	All UNLV quarterly and yearly reports to date provide information on this subject. See nstg.nevada.edu/heatexchangers.html. See 1.1 (above) See 2. (above)		
3.2 Prototype lab-scale testing of HX's	UNLV 1Q_2007 N-ID07SS0112	UNLV 1st Quarterly Report for 2007 UNLV HTHX Project administrative work package also includes a HX testing component	Initiated	2009
3.3 High-temp materials data on metals and ceramics for IHX	UNLV Reports N-ID07SS0101 N-ID07SS0104 and N-ID07SS0105	See 3.1 (above) UNLV FY07 materials work package UNLV FY07 chemistry/surface analysis work packages	On-going Will be active Sept 07 Will be active Sept 07	2009
3.4 High-temp materials data on metals and ceramics for PHX	UNLV Reports UNLV Alloy_2007a	See 3.1 (above) Tensile Property Measurements of Structural Materials for High-Temperature Heat Exchanger Applications	On-going	2009

Issue	Documents/ Projects	Description	Status	Year Needed
	N-ID07SS0101	See 3.3 (above)	Active Sept 07	
	N-ID07SS0107	UNLV FY06 Carryover work package on S-I materials corrosion by General Atomics	Concludes September 07	
	N-ID07SS0109	UNLV FY06 Carryover work package on C/SiC materials at UC-Berkeley	Concludes August 07	
	N-ID07SS0110	UNLV FY06 Carryover work package on ceramic HX development	Concluded April 07	
	N-ID07SS0111	UNLV FY06 Carryover work package on ceramic HX development – continuation of N-ID07SS0110	Concludes September 07	
	N-ID07SS0113	UNLV FY06 Carryover work package on Pt-added metals. Originally targeted for HXs but now may be used as a catalytic material exclusively.	Concludes August 07	
	NERI 05-032	Silicon Carbide Ceramics for Compact HX's	Concludes FY07 – of unknown utility	
	NERI 06-024	Ni-Si Alloys for the S-I Reactor-Hydrogen Production Process Interface	Entering 2nd year	
3.5 Designs for high-temp oxygen cooler	UNLV	UNLV quarterly reports for FY06	Unresolved	2008

Issue	Documents/ Projects	Description	Status	Year Needed
	(1,2,3,4)Q_2006 UNLV 1Q_2007 N-ID07SS0111	 UNLV 1st quarterly report for FY07 See 3.4 (above)		
3.6 Corrosion testing of materials in H_2SO_4 environments	 UNLV (1,2,3,4)Q_2006 UNLV (1,2)Q_2007 N-ID07SS0111	 UNLV quarterly reports for 2006 UNLV quarterly reports for 2007 UNLV FY06 carryover work package with Ceramatec on ceramic materials corrosion	On-going Concludes Aug 2007	2008
3.7 Corrosion testing of materials in HIx environments	 UNLV Reports GA Corrosion_2007a N-ID07SS0101	 All UNLV quarterly and yearly reports to date include results from HIx materials corrosion testing performed at General Atomics FY2006 Year End Report: Corrosion Studies of Construction Materials for HI Decomposition Environment UNLV FY06 carryover work package contains work related to stress corrosion cracking of alloys exposed to S-I solutions including NaI	On-going Concludes Aug 2007	2008

Issue	Documents/ Projects	Description	Status	Year Needed
	N-ID07SS0104 and N-ID07SS0105 N-ID07SS0107 GA Corrosion_2006	UNLV FY07 work packages will cover surface and corrosion analyses of samples exposed to HIx UNLV FY06 carryover work package concerns sample corrosion tests at General Atomics Corrosion Studies of Construction Materials in HI Decomposition Environments	Work starts Sept 2007 Work concludes Aug 2007	
3.8 Hydrogen process flow sheeting	N-IN07SS0102 N-OR07SS0101	INL Technical Director work package includes the NHI Materials and Components Development Plan. The Plan calls for development and acceptance of reference process flow sheets. Same task as above.	Not completed Plan implementation is underway and will be finished in FY08.	2008
3.9 Revise NHI Mat. & Comp. Dev. Plan, as needed	N-IN07SS0102 N-OR07SS0101	See 3.8 (above) See 3.8 (above)	Initial implementation is underway, so revision is not yet needed	2008
3.10 Develop NHI Components Database	N-IN07SS0102	Database work not yet started. Full implementation plan is being developed, and database work will	Not completed	2007

Issue	Documents/ Projects	Description	Status	Year Needed
		begin in FY08.		
3.11 Develop NHI Mat & Comp. Dev. Plan			Completed	2007
Balance-of-Plant and Infrastructure				
4. Determine baseline configurations	INEEL EXT-04-01791 ANL W7500-001-ES-00 INL EXT-06-11232	Infrastructure Requirements for a Nuclear Hydrogen Production Plant Reactor/Process Interface Requirements Balance of Plant Requirements for a Nuclear Hydrogen Plant	Not resolved	2011
4.1 Plant layout and architecture		Work on plant layouts is being done as part of the NGNP Project pre-conceptual and conceptual designs.	Not resolved Recommended plant layouts might be available by March 2009	2009
4.2 Minimum distance requirements for S-I plant	INL EXT-05-00137 Rev 0 and Rev 1	An Engineering Analysis for Separation Requirements of a Hydrogen Production Plant and High-Temperature Nuclear Reactor	Not resolved Minimum spacing is 60-110 m, but reports are being held back for further	2008

Issue	Documents/ Projects	Description	Status	Year Needed
			revision	
4.3 Identify environmental permitting requirements	 INL EXT-07-12746	 As a first step, special studies were performed during the NGNP Project pre-conceptual design phase to identify products and by-products from the H2 plants. These studies will be pursued further during the conceptual design phase as a preparation for permitting activities. Tritium Movement and Accumulation in NGNP System Interface and Hydrogen Plant	 Report will be issued in June 2007	2008
4.4 Auxiliary heat sink and source	 ANL W7500-003-ES-00	This question is being handled during the pre-conceptual and conceptual design phases of the NGNP Project Balance of Plant Requirements for a Nuclear Hydrogen Pilot Plant	Not resolved	2008
Safety				
5. Detailed safety strategy	 ANL W7500-002-ES-00 INL EXT-06-11482	 Reactor/Process Interface Heat Exchanger and Intermediate Loop Technical Issues Assessment of Codes and Standards Applicable to a Hydrogen Production Plant Coupled to a Nuclear Reactor	Not resolved	2011

Issue	Documents/ Projects	Description	Status	Year Needed
5.1 Transient analyses of interface and H_2 plant	N-AN07SS0101 N-IN07SS0101	GAS-PASS/H gas reactor code being adapted to PCU and H_2 plant use Model validation and cross-checking with N-AN07SS0101.	Underway Model will be ready by end of FY07 for use in FY08 Activity will continue in FY08	2008
5.2 Tritium permeation and control strategies	INL EXT-07-12746	Tritium Movement and Accumulation in NGNP System Interface and Hydrogen Plant	Not completed Report will be issued in June 2007. Work will continue in FY08	2008
5.3 Chemical safety "best practices"			Not resolved	2008
5.4 High-temp isolation valves		The need for isolation valves will be examined during NGNP Project conceptual designs. Results from those studies will be made available March 2009.	No NHI activity is planned in this area	2008
General Operations				
6. Steady-state and transient modeling capabilities	INL EXT-06-11725 N-AN07SS0101	HyPEP FY06 Report: Models and Methods See 5.1 (above)	On-going Will be	2009

Issue	Documents/ Projects	Description	Status	Year Needed
	N-IN07SS0101 ANL Model_2007a	HYSYS modeling of integrated NGNP with HTE plant in support of KAERI I-NERI (HyPEP) Dynamic Modeling Efforts for System Interface Studies	continued in FY08 Modeling will be continued in FY08, but I-NERI work will stop in Sept 07	
6.1 Economic capabilities into HyPEP		No further work on HyPEP will be performed in the U.S. in FY08.	HyPEP work being stopped in FY08	----
6.2 Complete steady-state HyPEP with S-I and HTE		Alpha version of HyPEP has been generated with the HTE model. No further work on HyPEP in the U.S. will be performed in FY08.	HyPEP work being stopped in FY08	----
6.3 Develop transient modeling capabilities		See description for 6. (above)	On-going	2008
6.4 Beta-testing of HyPEP		Task wil not be performed. HYSYS/Aspen Plus models, and other models will take its place in future years.	HyPEP work being stopped in FY08	----
6.5 Alpha-testing of HyPEP	N-IN07SS0101	Validation of basic HYSYS model is being performed using HYSYS flow sheets of the NGNP with HTE process	HyPEP work being stopped in FY08	2007

7. ASSESSMENT OF THE MAP

An independent review of the 1st Quarter Technical Issues Map was performed (Ref. 28). The conclusions from this review were that the Technical Issues Map as it was issued is not really that useful, and that it would only have a significant meaning if it were assembled in the context of a Work Breakdown Structure (WBS) and a resource-loaded schedule. Detailed engineering requirements for the systems and sub-systems are also needed to form a basis of comparison between what has been accomplished in the research thus far and what still needs to be done. Only then would this technical issues map be of use because it could be understood as a progress report towards realization of the engineering requirements. All tasks should be tied closely with the integrated schedule.

The reviewer also provided a critique of how the work is being accomplished, and noted that the work appeared to be a loose association of research projects that are not strongly tied to meeting any specific requirements. The research program was also reviewed as being inefficient in that some research was assigned to groups that did not necessarily have the right qualifications or performance history (i.e., UNLV), and that native software was being developed in areas where commercially available software might be adapted for use at less cost.

In looking at how the research has been organized and performed, these comments are valid. The work has been performed as a loose association of research projects that were not tightly coupled to meeting engineering requirements. Teams that did not necessarily have the needed experience at project initiation were assigned project tasks. Native software codes are being developed that may or may not be more efficiently and cheaply performed by using commercial software.

This approach, however, was appropriate for the stage of development of the System Interface and related devices. The System Interface components and systems, at least to this point, have been in the definition stage. The performance requirements for the System Interface are still being determined, and will determined by the NGNP Project based upon the results of pre-conceptual and conceptual engineering studies performed by three teams lead by AREVA, General Atomics, and Westinghouse, respectively. These requirements will depend upon what is physically achievable and what must be achieved in order to be economic. Work thus far has been concentrated on determining the physical and performance limits of materials and components so that realistic engineering requirements could be established. The assignment of work to previously inexperienced though qualified teams as had the added indirect benefit of increasing the expertise and knowledgebase in this area, and, as a result, a greater number of resources will be available once the NGNP Project begins to receive full funding to achieve the construction and operation of the Next Generation Nuclear Plant.

In light of the independent review, the System Interface and Support Systems area has perhaps reached the end of its life as a general research program and must make the transition into a more organized engineering project. It is proposed that the System Interface and Support Systems area be re-organized using the tools provided by the ANSI/PMI 99-001-2004 Standard and the Project Management Body of Knowledge (Ref. 29). The information provided in DOE O 413.3 may also be used, as needed, to perform project planning.

Project planning must be conducted in the areas of scope, schedule, risk, cost, communications, human resource planning, purchases and acquisitions, and quality. The outputs from planning in these areas would be the following.

- Scope
  - Project Scope Management Plan
  - Scope Statement
  - Work Breakdown Structure (WBS)
  - WBS Dictionary
  - Scope Baseline
- Schedule
  - Activity List
    - Sequencing
    - Resource Estimation
    - Duration Estimation
  - Schedule Baseline
- Risk
  - Risk Management Plan
  - Risk Register
  - Risk Response Plan
- Cost
  - Cost Baseline
  - Cost Budgeting Requirements
- Communications
  - Communications Management Plan
- Human Resources Planning
  - Staffing Management Plan
- Purchases and Acquisitions
  - Procurement Management Plan
  - Plan contracting requirements (as needed)
- Quality
  - Quality Management Plan
  - Quality Baseline

These documents would not be generated in isolation, but would be coordinated with the project planning documents already generated by the NGNP Project, which is already organized as a large project under DOE O 413.3.

As the project planning documents are completed and approved by DOE for the various areas (i.e., scope, schedule, risk, cost, etc.), they will be enacted. Starting with the 4th quarter FY07, the plans are being prepared and will be enacted in a rolling wave fashion as funding becomes available. Milestones will be set in the FY08 INL Technical Director work package to ensure adequate resources and the scheduled staged delivery of the planning documents. Implementation will be assumed upon acceptance of each planning document.

As tasks are completed on the detailed schedule, they can be formally closed out in the context of the Project, and this would be a more transparent tool for assessing progress towards research goals than this Technical Issues Map.

In regard to the development of native software versus the modification of commercially available software, native software will be developed if there are no suitable commercial alternatives both in the near term (cost savings) and in the longer term (suitability to support NRC licensing activities).

In the Technical Issues Map, as it stands, the known technical issues have been arranged into thematic areas that cross the boundaries between materials, component design, safety, and modeling. Dates have been set for their resolution to guide the future planning processes, and to show when an issue must be resolved in order stay on track with the overall NHI 10-year schedule. The schedule of issue resolution has also been chosen so that the work performed by the NHI will be most useful to the NGNP Project.

The time span of issues has been focused on the 5-year period spanning FY07 and FY11. This time period is critical for the success of the larger demonstrations (hydrogen pilot plants, engineering-scale demonstration) that are planned to begin construction in FY11 and later. It is assumed that the technical issues associated with larger-scale deployment will become apparent after the more basic issues have been resolved, and that those issues will be identified in detail at a later time.

The technical issues listed to be resolved in 2008 are funded or will be funded in existing FY08 work packages, and will be resolved by the end of FY08.

The budgets needed to resolve the technical issues by the required dates have not been determined. General forecasts of yearly budgets are available, but detailed bottom-up costing has not been performed. Due to an anticipated Continuous Resolution Period at the start of FY08, no final budget numbers are available, and only preliminary planning can be performed on all but the highest priority work that will occur in FY08.

During risk planning, alternative pathways to resolve technical issues may be identified, and these will be costed but not necessarily budgeted in the future planning exercises. The alternatives will only be budgeted if they become the preferred pathways of execution.

Overall, there is an imbalance in how the resources are being spent in regard to materials and mechanical designs. The choice of possible materials is broad, and many parallel avenues are being explored according to the interests of the researchers involved. The research needs to be more results- and application-oriented so that the underlying issues related to construction and operation of whole systems can be recognized and solved in time to support the pilot-scale plants. An assessment of the process requirements, materials candidates, and candidate unit designs must be performed, and this assessment should be the driver for which materials or design concepts will receive the most attention. The research must be convergent on solutions rather than divergent, and refocusing on the needs of the hydrogen production processes is one way to generate forward momentum towards solutions.

8. RESEARCH AND DEVELOPMENT DIRECTIONS FOR FY08

At this point, a Continuing Resolution period is assumed for at least the first month or so of FY08, and planning budgets have been reduced to the House mark of approximately $19M for the overall DOE NHI and to $2.35M for the System Interface and Support Systems Area. Of the $2.35M, it is assumed that $1.85M will be set aside for UNLV's FY08-funded work (not to begin until the end of FY08), and $500K is set aside for controlled work packages. At the end of FY07, all $2M of the money supplied to UNLV in the current fiscal year has yet to be spent, and this money will be carried over into FY08 to be used for work packages already described in Section 3.2.

8.1 Controlled Work Packages

The immediate plans are to roll all critical project work into a single work package at the Idaho National Laboratory. Tasks and funding for this controlled work package are described below.

$250K:	System Interface Technical Director (effort, travel)
$100K:	Project Management Support (accounting, project plan development, etc.)
$130K:	NHI Materials and Component Development Plan implementation and support
$20K:	Summer support for 1-2 graduate students.

$500K	

Significant deliverables for this work package will include the implementation of the DOE NHI Materials and Component Development Plan, the development of the supporting Component Case File Database, and the issue of a System Interface and Support Systems Preliminary Project Execution Plan.

No other controlled work package will be issued until additional money is allocated after the end of any Continuing Resolution period in FY08.

In addition to the single controlled work package, an FY07 carryover work package will be put in place to monitor the heat exchanger work that is occurring at Ohio State University. $60K was sub-contracted to Ohio State at the end of FY07 to assist Ohio State in the performance of high-temperature heat exchanger testing using a helium loop they have constructed using other funds. Work at Ohio State will be performed throughout FY08 and FY09 using the $60K provided.

If additional funding is provided to the System Interface area, other projects might be pursued. These projects are as follows.

8.1.1 High Temperature Heat Exchanger and Component Testing Laboratory – INL and Idaho State University

This work package calls for the establishment of a high-temperature heat exchanger and component testing laboratory in the lab space provided by the Idaho State University Thermal Fluids Laboratory. The laboratory is envisioned as a collection of single-effect tests that can be performed at less cost than experiments performed using a closed high-pressure high-temperature helium loop. The data collected from the single-effects tests will be used to calibrate and adjust heat exchanger models and to subject prototype heat exchangers to some degree of functionality and durability testing "as constructed." The laboratory is expected to contain at least the following experiments:

1) Hot air (900ºC) to colder air heat transfer experiments using heaters and blowers (flow experiment).
2) Pressure drop tests using air, water, or other fluid (flow experiment)
3) Static pressurized helium permeation and testing at 900ºC.
4) Thermal cycling under static and flow conditions (high pressure and no flow, near atmospheric pressure and flow)
5) Limited flow testing with nitrogen or once-through flow with helium.

The experiments will be instrumented and data recorded using Labview or other comparable software.

The significant tasks in FY08 are as follows:

a) Establish requirements and define equipment/software/staffing/data needs
b) Procure equipment
c) Develop preliminary experimental plans for each single-effect experiment and establish data expectations
d) Set up laboratory
e) Perform initial shakedown experiments.

The budget needed for this work package is $451K.

8.1.2 Ceramic-Based HTHX Development – Ceramatec, Inc.

Under both the Next Generation Nuclear Power and Nuclear Hydrogen Initiative programs, improved performance and efficiencies are obtained by operating at high temperatures. However, under these environments metals have insufficient mechanical, corrosion and material properties for reliable and durable heat exchangers. Under this proposed Work Package, a ceramic-based high temperature heat exchangers (HTHX) will be developed and demonstrated (FY08) in a short-stack modular configuration.

This development builds upon heat exchanger technology and ceramic materials and processing technologies investigated under prior Small Business Innovative Research (SBIR) and NHI research programs. Conceptually, this heat exchanger is built by stacking ceramic wafers with internal micro-channels into modular stacks. These micro-channels form the highly efficient, compact heat transfer surfaces that are very scalable for high throughput, MW-scale heat exchangers. The short-stack module will incorporate multiple full-size wafers such that the performance of full-scale modules can be mimicked.

The demonstration of the HTHX will be done in a high temperature, instrumented test bed where commercial operational conditions can be simulated and performance can be measured. Initially, this will include IHX temperatures (up to about 950ºC), scaled flow rates using helium or another simulant. This test bed will be designed to incorporate other gas streams such as nitrogen, air, steam and/or other gases that would simulate IHX applications.

The budget needed for this work is $310K in FY08.

8.1.3 Gelcast Ceramic HX for NGNP and NHI Applications – ORNL

The work to be performed under this work package involves the design, modeling, and construction of gelcast SiC and alumina solid block heat exchangers with integrated manifolds. The modules to be produced will be required to have input/output ports that are compatible with existing or future heat exchanger test facilities. This work will take advantage of earlier work performed by Oak Ridge National Laboratory and Brayton Energy on high-temperature alumina components. These prototype heat exchangers may have many applications including: a future IHX, a sulfuric acid decomposer, an oxygen cooler for HTE applications, heat exchangers for use in the HI decomposition section of the S-I process, and so forth. Tasks in this work package include:

1) HX module design
2) SiC gelcasting process development
3) Gelcasting mold design and fabrication
4) SiC sintering study
5) Preliminary material performance modeling
6) HX module fabrication (alumina)
7) SiC module fabrication (SiC)

The budget needed for this work is $550K.

8.1.4 Steady-State and Transient Modeling of Combined Nuclear Hydrogen Plant – ANL

The DOE NHI is developing hydrogen production technologies to be coupled with an advanced Gen IV nuclear energy system. Argonne National Laboratory (ANL) is assisting this development in part by helping to create and test integrated system models that will be used to study system configurations, optimize operating conditions, and examine transient behaviors such as experienced during start-up, shutdown, and off-normal events. ANL will employ the modified GAS-PASS/H model to study transient scenarios that may have an impact on combined plant safety and will develop control strategies for insulating the nuclear plant from changes in hydrogen plant operations. The scope of work to be accomplished in FY08 is the following:

1. Update the transient simulation model developed in FY08 to reflect changes in the reference plant design
2. Perform dynamic analyses of the combined nuclear plant/hydrogen plant.

The budget needed for this work is $225K.

8.1.5 Adaptation of GAMMA Code to PCU and H_2 Plant Applications – INL

The purpose of this work is to implement all necessary hydrogen production and power conversion models into the GAMMA code that is envisioned as an integrated computer code for the coupled NGNP-hydrogen plants for steady-state and transient analyses. In the past, GAMMA was developed as part of I-NERI project (Project number 2003-013-K), in particular, for the air ingress analyses. This work is proposed as a new I-NERI project with KAERI. The work scope for FY08 would include:

1) Approximate sizing of components within the VHTR and HTE systems.
2) Implementation of heat transport equations into the GAMMA code.
3) Implementation of the high-temperature electrolysis equations into the GAMMA code.
4) Validation and verification of high-temperaure electrolysis model against established HYSYS/ASPEN models.
5) Plans for control logic development.

Though some of these tasks are planned for the GAS-PASS/H modeling in work package N-AN08SS0101, the GAMMA code offers some advantages over the GAS-PASS/H code in the longer term. These advantages are:

a) GAMMA is a 3-D dynamic code. The equations can be simplified to 1-D for rapid calculation, but can be expanded to 3-D to develop detailed information on asymmetrical heat and mass flow, non-uniform phenomena, and so forth. GAS-PASS/H, RELAP5, and other such codes are 1-D codes and must use phenomena averaging in the direction of flow.
b) GAMMA can perform detailed transient analyses of power conversion turbines in ways that the system codes such as RELAP5, HYSYS, and other codes cannot.
c) GAMMA can handle more than 2 gas-phase species, and so can model the movement of fission products as well as helium and tritium simultaneously. RELAP5 is limited to two non-condensable gas-phase species.
d) There is no integrated code that can model the nuclear reactor core, PCU, and provide a detailed model of the hydrogen production plant. GAMMA would be capable of providing this in one model.

The budget needed for this work is $250K.

8.1.6 Tritium Transport Modeling – INL

In FY07, Dr. Hirofumi Ohashi from the Japan Atomic Energy Agency performed tritium transport calculations for a reference configuration of the Next Generation Nuclear Plant. In his calculations, he found that tritium was not something that could be ignored in the design effort. Assuming all-metallic heat exchangers, the amount of tritium in the hydrogen product from a high-temperature plant was found to be about equal to the regulatory limits established by the NRC and the EPA. For an SI plant, the amount calculated was several orders of magnitude higher that the regulatory limit. The most relevant factors affecting the concentration in the hydrogen product were the size of the heat exchangers, and the permeability of the heat exchangers to tritium diffusion. The codes used to calculate the tritium levels were JAEA-proprietary codes and could not be shared with the INL.

This work seeks to build tritium models that can be used in the U.S. to analyze NGNP/NHI configurations that were not originally analyzed using the JAEA codes. The following tasks will be performed:

1) Construct tritium models for an NGNP reference configuration using MATLAB with SIMULINK or other comparable modeling software (e.g., Mathematica, TMAP, etc.)
2) Verify and validate the models against the JAEA results
3) Analyze alternative NGNP configurations with an effort to determine how tritium levels might be lowered in the hydrogen product.

The budget required for this work is $200K.

8.2 UNLV Work Packages

The UNLV work packages N-IN07SS0101 through N-IN07SS0105 will be replaced with detailed work packages either at the end of FY07 or during FY08 that will describe the exact work scope and funding for each area. The total cost of the work packages will be $2,000,000. Funding for those work packages is supplied using FY07 funds, and no work will be done using FY08 funds at UNLV until the FY07 work packages listed above are nearly completed.

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