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FOR THE DEPARTMENT OF ENERGY

Deep Burn Team



Deep Burn: Development of Transuranic Fuel for High-Temperature Helium-Cooled Reactors

Monthly Highlights

September 2010



TRISO-Coated Particle with Mixed Pu, Th Oxide
Kernel after High Pu Burnup

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Monthly Highlights for September 2010

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Acronyms and Abbreviations

ANL	Argonne National Laboratory
BP	Burnable Poison
CFP	Coated Fuel Particles
CTE	Coefficient of Thermal Expansion
DB	Deep Burn
DBSF	Deep Burn Spent Fuel
DFT	Density Functional Theory
DOE	Department of Energy
EELS	Electron Energy Loss Spectroscopy
FIMA	Fission per Initial Metal Atom
GA	General Atomics
GK	Green-Kubo method
HEPA	High Efficiency Particulate Air (filter)
HFIR	High Flux Isotope Reactor
HTR	high temperature helium-cooled reactor
IFEL	Irradiated Fuel Examination Laboratory (ORNL)
INEST	Institute for Nuclear Energy Science and Technology
INL	Idaho National Laboratory
LAMDA	Low Activation Materials Development and Analysis
LANL	Los Alamos National Laboratory
LOGOS	LOGOS Nuclear Systems
LPCC	Low Pressure Conduction Cooling
LWR	Light Water Reactor
METROX	metal recovery from oxide fuel
MTC	Moderator Temperature Coefficient
NEMD	Nonequilibrium Molecular Dynamics
ORNL	Oak Ridge National Laboratory
PCEA	a candidate nuclear graphite manufactured by UCAR Carbon Co.
PF	Peaking Factor
ppm	parts per million
PPV	Reactor Pressure Vessel
REDC	Radiochemical Engineering Development Center (ORNL)
SEM	scanning electron microscopy
SFR	Sodium cooled Fast Reactor
TAMU	Texas A & M University
TEM	transmission electron microscopy
TRISO	tri-structural isotropic
TRU	transuranic elements
UCB	University of California, Berkley
UNLV	University of Nevada, Las Vegas
UW-M	University of Wisconsin-Madison
XRD	X-ray Diffraction

1. Project Management and Planning

Program reporting (ORNL)

The DB Program monthly highlights report for August 2010, ORNL/TM-2010/184, was distributed to program participants by email on September 17.

Archiving program records (ORNL)

The monthly report for August was posted on September 17 to the Deep Burn website, http://www.ms.ornl.gov/deep_burn/index.shtml. Program participants are reminded to send reports, milestone documents and other pertinent documents to the webmaster, Shirley Shugart shugartsa@ornl.gov, for uploading to the website.

2. Core and Fuel Analysis

Work was completed on HTR Prismatic and Pebble Bed core and fuel analysis. Two Level 2 Milestone reports were delivered. The summary/introduction sections of the two milestone reports are included below.

In the Phase II of the Project, we conducted nuclear analysis of TRU destruction/utilization in the HTR prismatic block design (Task 2.1), deep burn fuel/TRISO microanalysis (Task 2.3), and synergy with fast reactors (Task 4.2). The Task 2.1 covers the core physics design, thermo-hydraulic CFD analysis, and the thermofluid and safety analysis (low pressure conduction cooling, LPCC) of the HTR prismatic block design. The Task 2.3 covers the analysis of the structural behavior of TRISO fuel containing TRU at very high burnup level, i.e. exceeding 50% of FIMA. The Task 4.2 covers the core design and analysis of sodium cooled fast reactor (SFR) for a synergy with DB prismatic block reactor. Also, the Task 4.2 includes the self-cleaning HTR based on recycle of HTR-generated TRU in the same HTR.

2.1 Core Design Optimization in the HTR Prismatic Design (Logos)

From the design and analysis of the 600 MWth DB-HTR core physics, the following results have been obtained:

- Based on a 3-batch radial and axial hybrid fuel management scheme, over 60% Transuranics burnup can be achieved when the burnup reactivity swing is about 3000 pcm.
- With regard to burnable poison, both B_4C and Er_2O_3 are promising burnable poison (BP) material for the DM-HTR core, and B_4C provides a little higher fuel discharge burnup. The moderator temperature coefficient (MTC) of the core is positive with the B_4C , while it can be strictly negative with Er_2O_3 . The power coefficient of the core with both BPs is negative at the full power condition, while the power coefficient can be positive with B_4C at a low power level. But, the cycle length of DB-HTR core with Er_2O_3 BP is shorter than that of the DB-HTR core with B_4C . If the B_4C & Er_2O_3 mixed burnable poison is used in the DB-HTR core, both the MTC and the power coefficient can be negative. Also, the cycle length of the DB-HTR core with B_4C & Er_2O_3 mixed BP can be considerably longer than that of the DB-HTR core with Er_2O_3 BP. Therefore, it recommends that the B_4C & Er_2O_3 mixed BP should be used in a TRU loaded DB-HTR core.
- In terms of safety aspects such as a LPCC event, a 600 MWth of a DB-HTR core cannot meet the nominal design limit 1600°C for an LPCC event. Therefore, it recommends that the thermal power should be reduced to 450 MWth in a 5-ring TRU loaded DB-HTR core design.
- From the results of the decay heat of the 600 MWth TRU loaded DB core, the short-term decay heat of the TRU loaded DB-HTR core is highly dependent on the fuel loading. The americium isotope in the DB-HTR core strongly affects the short-term decay heat of the DB-HTR core. For a given TRISO design, the fuel PF should be minimized for a minimal decay heat of the TRU loaded DB-HTR core.

From the hot spot fuel temperature analysis of the fuel block in the DB-HTR, the following results have been obtained:

- The predicted hot spot fuel temperatures for the 600 MWth DB-HTR cores (i.e., Case A and Case B) are 1243 and 1223°C, respectively. The predicted hot spot fuel temperatures for the 450 MWth DB-HTR cores (i.e., Case C and Case D) are lower than those for the 600 MWth designs by ~30°C.
- The predicted hot spot fuel temperature of the core design with a 0.2% UO₂ mixed TRU is found to be slightly higher than that with a 30% UO₂ mixed TRU.
- For all the considered cases, the predicted hot spot fuel temperatures are below the generic design limit of 1250°C in spite of the sufficiently conservative assumption about the local fuel pin power profile within fuel block.

From the analysis of the thermal-fluid design performance at the steady state and LPCC analysis of the DB-HTRs, the following results have been obtained:

- Key design characteristics of the DB-HTR core are more fuel rings (five fuel-rings), less central reflectors (three rings) and the decay power curves due to the TRU fuel compositions that are different from the UO₂ fuel.
- At the steady state, average 88.7, 7.1 and 4.2% of total RCS flow go to the coolant channel, the CR/RSC hole and the fuel block bypass gap, respectively. It shows that the maximum fuel and RPV temperatures are less than the normal operation limit of 1250°C for TRISO fuel and the SA508 steel limit of 371°C, respectively.
- For a 0.2% UO₂ mixed or a 30% UO₂ mixed TRU fuel loaded 600 MWth DB-HTR, the reduced decay power obtained by removing the initial Am isotopes and by reducing the PF decreases the peak fuel temperature. However, the peak fuel temperatures are still higher than 1600°C due to the lack of heat absorber volume in the central reflector.
- The 450 MWth DB-HTR core is suggested as the optimization core design, which has the allowable maximum power reactor of a 450 MWth to the accident fuel design limit for 0.2% UO₂ mixed TRU (PF=6.9%) or 30% UO₂ mixed TRU (PF=8.0%) using the mixed burnable poison of B₄C and Er₂O₃.
- Based on JAEA method for the graphite annealing, the effect of graphite annealing on the peak fuel temperature is small. The GA method indicates a much larger impact, but it may not be applicable to the fluence and temperature conditions of the HTR. In addition, it shows that the impact of the FB end-flux-peaking on the peak fuel temperature is not significant.

From the design and analysis of the self-cleaning HTR (SC-HTR) core physics, the following results have been obtained:

- The self-cleaning of self-generated TRUs is feasible and deep-burning of the self-generated TRU can be achieved in SC-HTR. The TRU discharge burnups in SC-HTR is shown to be over 63%. It was found that transmutation of Pu-239 is near complete (~99%) in the SC-HTR core and that of Pu-241 is also extremely high.
- It is observed that the power distribution is rather flat within the uranium fuel zone, but the power sharing of TRU fuel zone is significantly lower due to the very high TRU fuel burnup.
- It is expected that the TRU deep-burn can be improved if the fuel management and core design are optimized.

2.2 Core Design Optimization in the HTR Pebble Bed Design (INL)

The Deep-Burn (DB) concept focuses on the destruction of transuranic nuclides from used light water reactor (LWR) fuel. These transuranic nuclides are incorporated into tri-isotopic (TRISO) coated fuel particles and used in gas-cooled reactors with the aim of a fractional fuel burnup of 60 to 70% in fissions per initial metal atom (FIMA). This high performance is expected through the use of multiple recirculation passes of the fuel in pebble form without any physical or chemical changes between passes.

In particular, the concept does not call for reprocessing of the fuel between passes. In principle, the DB pebble bed concept employs the same reactor designs as the presently envisioned low-enriched uranium core designs, such as the 400 MWth Pebble Bed Modular Reactor (PBMR-400).

Although it has been shown in the previous Fiscal Year (FY) (2009) that a PuO₂ fueled pebble bed reactor concept is viable, achieving a high fuel burnup while remaining within safety-imposed prescribed operational limits for fuel temperature, power peaking, and temperature reactivity feedback coefficients for the entire temperature range, is challenging. The presence of the isotopes Pu-239, Pu-240, and Pu-241 that have resonances in the thermal energy range significantly modifies the neutron thermal energy spectrum as compared to a standard, UO₂-fueled core. Therefore, the DB pebble bed core exhibits a relatively hard neutron energy spectrum. However, regions within the pebble bed that are near the graphite reflectors experience a locally softer spectrum. This can lead to power and temperature peaking in these regions. Furthermore, a shift of the thermal energy spectrum with increasing temperature can lead to increased absorption in the resonances of the fissile Pu isotopes. This can lead to a positive temperature reactivity coefficient for the graphite moderator under certain operating conditions. Regarding the coated particle performance, the FY 2009 investigations showed that no significant failure is to be expected for the reference fuel particle during normal operation. It was found, however, that the sensitivity of the coating stress to the CO production in the kernel was large. The CO production is expected to be higher in DB fuel than in UO₂ fuel, but its exact level has a high uncertainty. Furthermore, in the fuel performance analysis transient conditions were not yet taken into account. The effort of this task in FY 2010 has focused on the optimization of the core to maximize the pebble discharge burnup level, while retaining its inherent safety characteristics. Using generic pebble bed reactor cores, this task will perform physics calculations to evaluate the capabilities of the pebble bed reactor to perform utilization and destruction of LWR used-fuel transuranics. The task uses established benchmarked models, and introduces modeling advancements appropriate to the nature of the fuel considered (high transuranic [TRU] content and high burn-up).

2.3 Microfuel analysis for the DB HTR (*INL, GA, Logos*)

From the analysis of the TRISO fuel microanalysis of the DB-HTRs, the following results have been obtained:

- All the fuels of the DB-HTRs had good mechanical and thermal integrity during normal operation. During the accident such as LPCC event, however, all coated fuel particles (CFPs) in the 600 MWth DB-HTRs are broken. The failure fractions due to the pressure vessel failure are between 5.8 and 31.3 %. These high failure fractions indicate that it is necessary to reduce the gas pressure in a CFP during the LPCC. The gas pressure can be reduced by increasing the buffer size of the CFP or by reducing the accident temperature. The failure fraction due to the thermal decomposition is unit. Therefore, it indicates that active core cooling systems must be used to prevent excessive temperatures in the event of a LPCC of the 600 MWth DB-HTR core.
- In the 450 MWth DB-HTRs, the failure fraction due the pressure vessel failure are between 1.79×10^{-3} and 2.09×10^{-2} , and the failure fraction due the thermal decomposition are between 1.51×10^{-3} and 3.00×10^{-2} . It is necessary to scrutinize if these failure fractions are acceptable. The 30% UO₂ mixed TRU loaded DB-HTR is most favored in the aspect of fuel integrity.
- The fractional releases of all the fission products considered are below 0.001 during normal operation. They should be scrutinized through the environmental impact if they are acceptable. More than 40% of silver is released during an accident regardless of the reactor power and the fuel types. Some measures should be taken in order to prevent excessive occupational doses of silver. The fractional releases of cesium, strontium and krypton are above 10% during an accident in the 600 MWth DB-HTRs, which are very high. On the other hand, they are below 0.001 during an accident in the 450 MWth DB-HTRs except the fractional release of strontium in the TRU loaded 450 MWth DB-HTR, 1.66×10^{-3} .
- It is desirable in the safety aspects of DB-HTR that the CFPs sufficiently survive some accident conditions of a HTR. Therefore, the 600 MWth DB-HTR is not appropriate for burning TRU. It is

judged that the failure fractions in the 450 MWth DB-HTRs are not sufficiently low. It thus is necessary to further decrease the thermal power and increase the buffer size of a CFP.

3. Spent Fuel Management

3.1 TRISO repository behavior (*UNLV*)

Uranium sorption to graphite at elevated ionic strength was measured (Up to 4 molal NaCl). No effect of increased ionic strength on sorption noted. Experiments under 100% CO₂ atmosphere completed. Sorption was inhibited completely in the near-neutral region and inhibited in all pH regions where experimental work was performed. Short term (Time < 1 hr) kinetics experiments performed to examine the initial sorption kinetics of the system. Results suggest a two component system, with a fast sorption site and slow site. In the next month sorption experiments for the neptunium system will be initiated and column experiments to confirm uranium sorption kinetics will be performed.

3.2 Repository performance of TRISO fuel (*UCB*)

The UCB research team has identified several key pieces of literature that have helped to shape the geochemical modeling of radionuclide solubilities in J-13 well water in contact with DBSF. TSPA-LA Model/Analysis and supporting documentation has provided guidance in developing a robust model for simulating the solubilities of radionuclides leached from DBSF. The solubilities of U, Am, and Th have been modeled largely according to the framework found in the TSPA-LA using PHREEQC with the LLNL.dat (EQ3/6) database. To within the performance capability of the software, the solubilities of U and Am have demonstrated a fair degree of sensitivity to the fCO₂ of the system, however, owing to the lack of thermodynamic data for carbonate species of thorium in the LLNL.dat database, there are no carbonate species of Th present. This is in disagreement with the supporting documentation of the TSPA-LA, and will be investigated further. In the next month the solubilities of U, Am, and Th will be modeled with a hybrid PHREEQ/OECD thermodynamic database and the results compared with the previous month's work. Additional solubilities of radionuclides will be modeled with both databases as time permits.

4. Fuel Cycle Integration of the HTR

4.2 Synergy with other reactor fuel cycles (*GA, Logos*)

No report for September.

5. TRU HTR Fuel Qualification

5.1 Thermochemical Modeling

Thermochemical Behavior (*ORNL*)

The improved database was exercised to generate phase compositions and oxygen potentials as a function of burn-up for model UO₂ fuel. The results were compared to experimental information in the literature, providing evidence for additional oxidation processes that may be occurring.

5.2 Actinide and Fission Product Transport

Pd Interactions With SiC (ORNL)

Work has been completed on studying the interaction of Pd with the surface of SiC. The results have been written up for a journal article which is currently being reviewed internally. The highlights include finding reactions mechanisms with low energy barriers for the removal of C (0.04 eV) and Si (1.52 eV) from SiC. The energy barrier for Si removal is the rate limiting step.

Fission Product Transport in PuO_{2-x} Kernel (LANL)

Density functional theory (DFT) calculations of the diffusion of Pd in PuO₂, focusing on Pd's movement on the oxygen sublattice, continue. The focus is on a large supercell, corresponding to a 1 atomic percent concentration of palladium atoms. Our refined calculations predict an energy barrier of around 180 meV for diffusion associated with two oxygen vacancies.

Diffusion Mechanisms (UW-M)

Ab initio studies of Cs and Ag diffusion in ZrC are being completed with calculation of barriers to potential cooperative hopping mechanisms for Ag_{Zr-1Va_{Zr}} and Ag_{C-1Va_C} defect clusters. In addition, Cs and Ag diffusion barriers with three images in the elastic band run, replacing calculations to date which have been done with only one image. The increased number of images is necessary for establishing the results more reliably. For the systems studied to date the single image values have agreed well with the three image values, suggesting the new results will not change the previous interpretations.

5.3 Radiation Damage and Properties

Thermal Conductivity of SiC (ORNL)

The influence of both individual vacancies and small voids on the thermal conductivity of SiC were calculated using the Green-Kubo molecular dynamics (MD) method. The MD results were compared with those obtained from the standard Klemens continuum model and experimental data. MD predictions for the thermal conductivity of SiC containing voids with a radius of 2.86 Å are in good agreement with experimental data. Possible improvements to the Klemens model are being assessed.

6. HTR Spent Fuel Recycle

6.1 TRU Kernel Development (ORNL)

DOE-ORO has approved the document entitled "System Safety Analysis for Actinide-Bearing Ceramics Research and Development." This approval was required before plutonium and neptunium could be used in the new glove boxes at the Radiochemical Engineering Development Center (REDC).

The Journal of Nuclear Materials published the following manuscripts:

- 1) Valmor F. de Almeida, Rodney D. Hunt, and Jack L. Collins. "Pneumatic Drop-on-Demand for Production of Metal Oxide Microspheres by Internal Gelation." *Journal of Nuclear Materials*, **404**: (2010) 44-49.
- 2) R.D. Hunt, F.C. Montgomery, and J.L. Collins. "Treatment Techniques to Prevent Cracking of Amorphous Microspheres Made by the Internal Gelation Process." *Journal of Nuclear Materials*, **405**: (2010) 160-164.

The demonstration runs using the new internal gelation system for the fuel kernel fabrication were completed successfully with and without SiC particles. As shown in Figure 1, the last test run produced quality Zr-Y gel spheres containing SiC particles.



Figure 1. Zr-Y gel spheres with SiC particles in gelation column and associated tubing.

6.2 Coating Development (ORNL)

Progress since the last periodic report has been in the area of continued detailed design and procurement of deep burn coating equipment and facility infrastructure. The basic plan remains the same as that reported in prior updates. The effort since the last report has been in generating the detailed design. Issues including, but not limited to, booster fan size model and capacity, electrical circuit identification and specification, lighting plan, filter and duct sizing and structural support, flange connections, pipe size and routing, instrumentation panel layout and specifications, alarm strategies, specification and procurement package preparation for the various components, and engineering controls methodology are being specified in detail.

A purchase order for the standard glove boxes has been awarded to Flanders Filters Incorporated with delivery expected on November 30, 2010.

The design of the coating furnace glove box is nearing completion. The procurement package preparation is ongoing with purchase request (request for vendor bids) initiation expected in November of 2010.

The coating furnace itself is out for fabrication with delivery of the first components expected in October 2010.

The detailed design and specification for facility infrastructure related to the deep burn coating laboratory is progressing. Procurement of components is expected to begin shortly as the specification packages are completed.

6.3 Characterization Development and Support

No Activity this quarter.

6.4 ZrC Properties and Handbook

Mechanical properties of zone-refined ZrC (ORNL)

Benchmarking experiments to evaluate the high temperature strength of ZrC stoichiometric variants were started with all the involved apparatus working satisfactorily. Experiments with a fixed strain rate of 0.002 /sec were completed on all five stoichiometric variants at 300, 1073, and 1273 K. Tests at 1473, 1673 and 1873 K are underway. Significant changes in strength are expected beyond 1473 K. The experiments are planned to include at least five strain rates to obtain details on the high temperature deformation and associated mechanisms of all the five stoichiometric variants. The experiments will conclude with detailed microstructural observations. The results of these tests are to be included in the final version of the ZrC properties handbook.

Pd/ZrC interaction (UNLV)

Using the recently enhanced high-temperature capabilities of the Scienta surface spectroscopy system, we continued to optimize our ZrC surface modification procedures, in particular Ar⁺ ion sputtering and heating to 1150°C, which is now routinely possible. The heating resulted in only a minimal re-oxidation of the surface (due to desorbed species from the heater environment). In contrast, the Zr 3d core levels show a significant shift after the high-temperature annealing step, which is ascribed to a “healing” of surface defects induced by the ion sputter step. A substrate prepared this way will be used for further deposition experiments.

With this data, a manuscript for a peer-review publication on the ZrC surface preparation and the Pd/ZrC interface formation is being initiated.

Ag/ZrC interaction (UW-M)

Two final [ZrC/Ag gas] constant source diffusion couples between ZrC_{0.89}/ZrC_{0.95} disks and encapsulating Zr-Ag solid solutions were constructed and diffusion annealed, respectively. Ag concentration on those samples, and thus Ag diffusivities, will be measured using SIMS by the end of this October.

Irradiation effects in ZrC (UW-M)

The proton irradiation on ZrC at 1400°C is getting started. The elemental segregation at dislocation loops was examined using high resolution STEM; atomic resolution EELS mapping will also be performed.

7. HTR Fuel Recycle

7.1 Graphite Recycle (ORNL)

Coefficient of Thermal Expansion (25-900°C) measurements on the machined pilot scale Graftech recycle PCEA samples continued through September. The twelve rabbit capsules containing the PCEA bend bars were successfully inserted into HFIR for cycle 427. Six rabbit capsules were removed after four cycles (6.4 dpa) at the end of cycle 430 in August 2010. The remaining six rabbits will stay in HFIR for a further two cycles. Cycle 431 is expected to commence on 10/10/2010.

7.2 Aqueous Reprocessing

No work funded.

7.3 Pyrochemical Reprocessing METROX Process Development (ANL)

Chemical analysis of the samples collected from the recent METROX test, using the redesigned anode compartment that was fabricated last month, revealed that a significant amount of neptunium metal deposited on the cathode. The amount of neptunium collected from the stainless steel cathode rod was 61 mg or 19.1 wt% of the cathode submitted for analysis (i.e., cathode rod, neptunium deposit, and residual salt). Collecting this

quantity of neptunium metal at the cathode establishes the feasibility of the separations process to treat used TRISO fuel containing neptunium oxide. METROX testing will be continued to optimize the performance of the cell. However, a neptunium recovery run will be performed to recycle the unused neptunium oxide and the neptunium in the analytical samples in order to provide the needed neptunium oxide feed for the test. In addition, electrochemical-grade graphite will be procured to fabricate a replacement anode and a new BeO crucible will be prepared for the tests.

Appendix I - Status of FY2010 Milestones – September 30, 2010

(Ordered by Task, then by Date)

Milestone number and description	Level	Responsible Organization	Due Date	Completed or % Complete
2.1.1 – Core design optimization methods - Modeling sequence		TAMU		80*
2.1.2 - Core design optimization methods – Algorithm development		TAMU		25*
2.1.3 - Core design optimization methods – Testing and verification		TAMU		0*
5.0.3 – Determine cost and schedule for installation of a system for thermogravimetric measurements of highly radioactive actinides to verify fundamental models	M3	ORNL	11/23/09	11/10/09
5.0.5 – Assessment of modeling approaches for transport and radiation damage	M3	ORNL	2/18/10	2/17/10
5.0.4 – Complete review of mechanisms for silver transport in the particle and palladium transport and attack on SiC coating	M2	ORNL/UCB	9/30/10	9/30/10
5.1.1 – Investigate compound energy formalism model of plutonia with selected transuranics and first order model database	M3	ORNL	5/27/10	5/27/10
5.2.1 – Design a series of benchmark experiments to provide validation & testing data for the presumed mechanisms of Ag transport through pyrolytic C/SiC/PyC layers	M3	ORNL/UCB	8/26/10	8/26/10
5.2.2 – Provide model-based preliminary estimate of the impact of fission products on the lifetime of TRISO fuel based on chemical attack by fission products through transport through the kernel and fission product release due to transport mechanisms in SiC	M3	ORNL	8/26/10	8/23/10
5.3.1 – Develop physics-informed models for influence of irradiation on TRISO thermal conductivity that is suitable for use in fuel performance codes	M3	ORNL	9/13/10 (Revised)	9/13/10
6.1.4 - Initiate facility safety review and modification of procedures and work permits for installation and operation of TRU kernel fabrication equipment in existing glove boxes	M3	ORNL	10/30/09	10/29/09
6.1.5 - Identify candidate sources for heavy metal feedstock needed for TRU kernel fabrication	M2	ORNL	11/20/09	11/20/09
6.1.6 - Complete development of process for fabrication of kernels with internal dispersed oxygen getter	M3	ORNL	3/31/10	3/22/10
6.1.7 - Complete installation of kernel manufacturing equipment in existing glove box	M3	ORNL	7/15/10	7/14/10
6.1.8 - Demonstrate manufacture of Zr/Y surrogate kernels using glove box kernel fabrication facility	M2	ORNL	9/30/10	9/27/10
6.1.9 - Acquire heavy metal feedstock needed to start TRU kernel fabrication in FY11	M3	ORNL	9/30/10	8/11/10
6.2.5- Initiate facility modification and safety approvals for operation of a fluidized bed coater and associated peripherals using glove box containment for TRU materials	M3	ORNL	11/23/09	11/10/09
6.2.6 - Complete modification of coating equipment for glove box operation	M3	ORNL	7/31/10	7/30/10
6.2.7 - Procure glove boxes for TRU-TRISO coating	M2	ORNL	9/15/10	Deferred to FY2011
6.2.8 - Complete safety analysis and approval for coating glove box operations	M3	ORNL	9/30/10	Deferred to FY2011
6.4.1 - Design and install an upgraded system for high temperature measurement of creep properties	M3	ORNL	11/23/09	11/20/09
6.4.2 - Complete initial planning for ZrC irradiation effects study	M3	ORNL	6/30/10	6/30/10
6.4.3 - Complete additional ZrC properties measurements	M3	ORNL	9/30/10	9/30/10
6.4.4 - Report on extended study of interaction of metallic fission products with ZrC	M3	UNLV	6/30/10	6/30/10
6.4.5 - Complete proton irradiation of ZrC at a temperature of 1400°C up to 2 dpa and subsequent analysis of microstructure	M3	UW-M	6/30/10	Deferred to FY2011
6.4.6 - Attempt 1500°C for 500 hr Ag/ZrC diffusion couple study		UW-M	6/30/10	7/1/10
7.2.2 – White paper on collaboration opportunities with	M3	ORNL	12/17/09	12/17/09

GIF/Carbowaste				
7.2.1 – Complete rabbit capsules for insertion in HFIR	M3	ORNL	2/26/10	1/27/10
7.2.3 – Report on completed study on recycled graphite.	M3	ORNL	8/27/10	8/27/10
7.3.1 – Interim progress report on METROX studies		ANL	5/21/10	5/21/10
7.3.2 – Report documenting used TRISO fuel treatment process development		ANL	9/30/10	9/30/10

* Update information not available.

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