

## **THE ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE PIPE OVERPACK CONTAINER FOR TRU WASTE STORAGE AND SHIPMENTS**

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### **ABSTRACT**

The Pipe Overpack Container was designed to optimize shipments of high plutonium content transuranic waste from Rocky Flats Environmental Technology Site (RFETS) to the Waste Isolation Pilot Plant (WIPP). In February 1997 the Nuclear Regulatory Commission approved the container for use in the TRUPACT-II shipping container; storage of WIPP ready transuranic pyrochemical salt waste in the Pipe Overpack Container began in January 1998. Other WIPP ready wastes were stored in the Pipe Overpack Container starting in April 1998.

The container optimizes shipments to WIPP by increasing the TRUPACT-II criticality limit from 325 fissile grams equivalent (FGE) to 2800 FGE and provides additional shielding for handling wastes with high americium-241 ( $\text{Am}^{241}$ ) content. The container was subsequently evaluated and approved for storage of highly dispersible TRU wastes and residues at RFETS.

Additional evaluations of the container show that the container will mitigate the impact of worst case events from RFETS plutonium bearing residues. These materials contain hazards postulated by the Defense Nuclear Facilities Safety Board for interim storage. Packaging these residues in the container without stabilizing the materials is in the approval process at RFETS and the Department of Energy.

The design, testing, and evaluations used in the approvals, and the current status of the container usage, will be discussed.

### **INTRODUCTION**

The Rocky Flats Environmental Technology Site located near Denver, Colorado, is currently storing a backlog of approximately 756 m<sup>3</sup> (3700 drums 0.21 m<sup>3</sup> volume and 3500 smaller containers) of plutonium-bearing residues. The residues comprise a category of materials that historically had sufficiently high concentrations of plutonium to warrant recovery of the plutonium. With the change in mission for RFETS and the Department of Energy (DOE) complex from weapons production to environmental restoration and waste management, plutonium recovery operations will not be required for the foreseeable future. The ultimate disposition of the residue backlog still needs to be performed.

Since the early 1950's, residues were generated at Rocky Flats as a by-product of production operations. These residues consist of a variety of materials such as incinerator ash, pyrochemical salts, casting materials, paper, cloth, plastic, metal, glass, rubber gloves, filters, insulation, firebrick, and ion exchange resins. At RFETS, each residue type is given a unique identifier known as an Item Description Code (IDC). Residues and wastes are packaged according to their IDC. There are approximately 100 residue IDCs at RFETS undergoing disposition.

Over the past several years, the Residue Stabilization Program at RFETS has developed a robust stainless steel container inside a 0.21 m<sup>3</sup> drum, commonly known as the Pipe Overpack Container. This was developed as a means to ship residues to WIPP in a more efficient and cost-effective manner. The RFETS Residue Stabilization organization has proposed that the Pipe Overpack Container, due to its large mass, structural integrity, and high heat capacity, could be used to store and ship selected residues without performing costly and time-consuming stabilization operations. These operations are designed to eliminate possible hazards associated with interim storage (Reference 1).

By undertaking this course of action, RFETS could accelerate the reduction of risks to both RFETS workers and the public. In addition operator exposure to both radioactive and hazardous materials will be reduced, and significant cost savings will be realized. The most significant advantage would be to support the expedited closure of former plutonium production buildings and the decommissioning of RFETS.

### **PIPE OVERPACK CONTAINER DESIGN**

The Pipe Overpack Container system incorporates the Pipe Component as its central feature. It was originally designed, tested, and qualified as a Nuclear Regulatory Commission approved, enhanced TRUPACT-II payload container. This system allows for more efficient transport and disposal of certain RFETS residues and wastes at WIPP.

The Pipe Component is placed within a standard DOT-17C Type A 0.21m<sup>3</sup> drum. The drum is lined with the standard rigid drum liner. Celotex® fiberboard and plywood are used as spacers. They also serve to preclude damage to the pipe on impact and function as thermal insulation. The drum lid is fitted with a carbon composite filter. The drum lid is secured to the drum with a standard drum lid-locking ring. A schematic of the entire Pipe Overpack Container system is shown in Figure 1.

The Pipe Component was designed in two sizes: 15.2 cm and 30.5 cm in diameter, each with a nominal length of 63.5 cm. The usable volumes are approximately 12,000 cm<sup>3</sup> and 48,000 cm<sup>3</sup>, respectively. These volumes will accommodate a large majority of the RFETS residues when it is desirable to package a drum to the 200 FGE limit. The 15.2-cm diameter version is constructed of Schedule 40 304L stainless steel.

The 30.5-cm diameter model is fabricated from Schedule 20 stock. The minimum wall thickness in both cases is 0.63 cm. The bottom end of the pipe is closed with a 0.63-cm minimum thick weld cap. The top end of the pipe is fitted with a 59 kg weld neck flange for the 15.2 cm diameter component and a non-standard, lighter weight flange for the 30.5 cm diameter component that accommodates 2.54 cm thick bolt-on lids. The flange is machined to incorporate a 3.2-mm cross-section diameter ethylene propylene O-ring gasket to ensure containment of particulate material. Incorporated into the lid design is a sintered stainless steel filter similar to one used to vent flammable gases from 0.21 m<sup>3</sup> drums.

## **TRANSPORTATION TESTING AND ANALYSES**

A test and analysis program was developed and implemented to demonstrate the integrity of the Pipe Overpack Container under hypothetical transportation accident conditions. The test program also bound normal conditions of transport. Test procedures and results are documented in Reference 2 and are summarized as follows.

Two series of tests, to simulate the interaction effects of fully loaded Pipe Overpack Containers within a TRUPACT-II during accident conditions were performed. The first, consisting of 9.1 m top impact drops of loaded Pipe Overpack Containers in the following configurations:

- Two stacked Pipe Overpack Containers containing 15.2-cm diameter pipe components.
- Two stacked Pipe Overpack Containers containing 30.5-cm diameter pipe components.
- Two stacked Pipe Overpack Containers; one containing a 30.5 cm diameter pipe component and one containing a 15.2 cm diameter pipe component.

The second series of tests simulated a side impact test. The test included dropping an uncertified but functional TRUPACT-II Inner Containment Vessel (ICV) with a 14 Pipe Overpack Container payload assembly. The payload assembly consisted of a top layer of seven Pipe Overpack Containers containing 15.2-cm diameter pipe components and a bottom layer of seven Pipe Overpack Containers containing 30.5-cm diameter pipe components. This drop demonstrated a worst case scenario. Damage to the Pipe Overpack Containers would be less severe within the entire TRUPACT-II package that includes 25.4 cm of impact-absorbing foam.

There was no loss of containment in any drop test, and the filters showed no damage from the tests. The filters were verified to have met TRUPACT-II flow and filtering requirements after the tests.

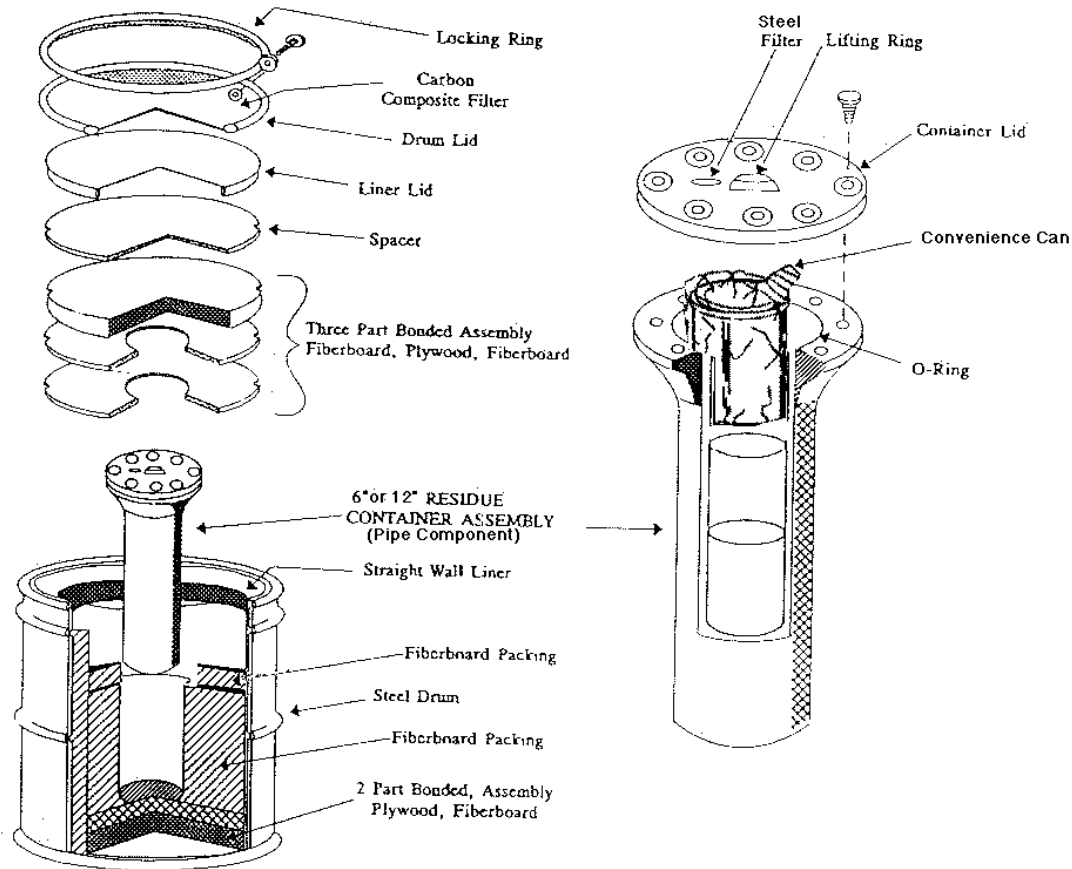


Figure 1. Pipe Overpack Container

### CRITICALITY ANALYSIS OF THE PIPE OVERPACK CONTAINER

A series of criticality analyses modeled TRUPACT-II payload assemblies of Pipe Overpack Containers to evaluate the highest system “k-effective” value possible (Reference 3). The analyses constructed potential configurations of postulated accident geometries for a payload of Pipe Overpack Containers. The model evaluated a loading of 200 grams of  $\text{Pu}^{239}$  per Pipe Overpack Container in both dry and water-saturated forms. Conservative assumptions were used in the analyses for normal transport conditions and hypothetical accidents. The assumptions included:

- Elimination of the  $0.21 \text{ m}^3$  drums, packing material, and any cans used inside the Pipe Components as migration barriers.
- Uniform distribution of water moderator in the waste.
- Closely packed geometry of fourteen Pipe Components without the presence of any other material.
- Flooding of the TRUPACT-II with the moderation medium.
- Reflection of escaping neutrons into the system.

These assumptions are comparable to those used in the criticality analyses performed for other authorized payload containers with one exception. One key assumption used to analyze the criticality potential and to establish control limits for other TRUPACT-II payload containers. The assumption was that all fissile material within the payload containers would breach the packaging to come together under hypothetical accident conditions. The Pipe Overpack Container testing results demonstrate that the structural integrity of the Pipe Component prevents the release of its contents under hypothetical accident conditions. Thus, the criticality analysis assumes no loss of containment by the Pipe Component. The assumption is made despite the elimination of the drum, packing material, and any layers of confinement used inside the Pipe Overpack Container.

The results of the analysis show that no combination of TRUPACT-II payload assemblies of Pipe Overpack Containers exceeded an average k-effective value of 0.9. This demonstrates that the system was subcritical in all cases. Therefore, a TRUPACT-II shipment of 14 Pipe Overpack Containers with 200 FGE each meets criticality requirements for transport during normal and hypothetical accident conditions for transportation.

#### **SHIELDING ANALYSIS OF THE PIPE OVERPACK CONTAINER**

The Pipe Overpack Container has been assessed for its radiation shielding (Reference 4). Effective radiation shielding depends on a continuous barrier of dense material (e.g., steel) without openings that would allow radiation “streaming” or leakage. The Pipe Component designs provide 0.63-cm steel for shielding of 60 Kev gamma radiation from americium ( $\text{Am}^{241}$ ). The Pipe Component has the following design features to prevent radiation streaming through the relatively low-density filter media of the filter vents.

The design of the 15.2 and 30.5 cm diameter Pipe Components is such that the filter vent does not penetrate the entire thickness of the lid. The shielding is provided by the remaining steel at the bottom of the tapped hole for the filter vent. Continuous venting is provided by four small holes that penetrate the remaining steel lid thickness. The holes are offset from the filter media, avoiding a line of sight radiation-streaming path.

Materials shipped to WIPP in the Pipe Overpack Container must meet the TRUPACT-II Safety Analysis Report for Packaging (SARP) and WIPP Waste Acceptance Criteria requirements for dose rate limits. The measured radiation dose rates of each Pipe Overpack Container must comply with the 200 millirem/hour at the drum surface requirement. In addition, a 10 millirem/hour reading at two meters distance requirement must be met. It is estimated that the worst case loading using the Pipe Overpack Container will produce no more than 10 millirem/hour combined gamma and neutron at the surface of the drum. Use of the Pipe Overpack Container does not remove the requirement that all containers to be transported in the TRUPACT-II be individually measured. The measurement evaluates compliance with the dose rate limits.

Up to 14 Pipe Overpack Containers can be shipped in a TRUPACT-II. Each container may have a maximum fissile gram equivalent loading of 200 grams, for a total TRUPACT-II load of 2800

FGE. For shipments of waste packaged in payload containers other than the Pipe Overpack Container, the limit is 325 FGE per TRUPACT-II. After additional testing, this system was also approved at RFETS as a safe interim storage container for the storage of highly dispersible materials.

### **RFETS ON-SITE STORAGE TESTING AND ANALYSES**

A test and analysis program was developed and implemented to demonstrate the integrity of the Pipe Overpack Container under hypothetical RFETS design basis and other storage accident conditions. Test procedures and results, documented in References 5 and 6 are summarized below.

A dynamic crush test of the Pipe Overpack Container was performed where the container was placed on an unyielding surface; a 500-kg steel plate 1 m square was dropped from 9 m height onto the container. The test was performed with the container in an upright orientation, as it is the orientation they will be in during storage. The test was designed to simulate the impact the container would receive if the roof of the storage building were to collapse onto the package.

A bare Pipe Component drop test was performed. This test consisted of dropping bare inner Pipe Components onto an essentially unyielding target from a height of 3 m. The tests were performed with the bolted closure of the pipe impacting the target first. These tests were performed to simulate a handling accident in which the pipe is dropped prior to being placed into its overpack materials. The resulting test demonstrated safety for a scenario where the interim storage of the pipes in storage racks may be done without protective overpacking materials.

Pressure transient testing of the Pipe Component was performed to demonstrate if the component would contain the energy of sudden, spontaneous chemical reactions of materials packaged within the container. To be an effective TRU waste container, the pipe component must handle possible temperature transients (Reference 1). In addition, the pipe component must handle a pressure transient comparable to that expected from ignition of hydrogen that could be generated by the residue materials stored in the container. Structural calculations indicated that the Pipe Component would maintain its integrity following the maximum credible pressure event. As a conservative test, a 30.5-cm pipe component was filled with a stoichiometric hydrogen/oxygen (67 volume percent hydrogen, 33 volume percent oxygen) mixture. The gasses were then ignited. A second pressure test was performed when the pipe component's filter was replaced with a plug, and the component was subjected to a hydrostatic pressure test to 1000 psi.

There was no loss of containment in any detonation or pressure test. The filters showed no damage from the tests, and they were verified to have met flow and filtering requirements.

The final test was an engulfing pool fire test to simulate a fire in a storage building. In this test four Pipe Overpack Containers were placed on an open support stand with 1 m spacing between them. The bottom of the units were 1 m above the surface of a 10 m<sup>2</sup> pool of jet fuel floating on top of a layer of water. The fuel is ignited and allowed to burn for 30 minutes. This type of fire test generally results in a flame temperature between 1073 K and 1373 K. Two designs of drum

filters were tested in the fire: stainless steel housing - carbon media filter, and a polyethylene housing - carbon filter media filters.

The engulfing pool fire test had mixed results. With one exception, all Pipe Components were found to be leak tight after the fire test. One Pipe Component had a helium leak rate of approximately  $24 \text{ cm}^3/\text{s}$  after the fire test. Leakage was detected between the lid and the weld neck flange and between the filter and the lid. The drum, which contained this unit, had the stainless steel-housed filter rather than the polyethylene filter. During the fire test, this drum became sufficiently pressurized to blow off the drum lid.

At this point, the Pipe Component was exposed directly to the heat from the fire. As a result the elastomeric O-ring and filter gaskets were destroyed. The polyethylene-housed drum filters installed in the lids of the other three drums melted and were blown out of the drum lid. This provided a pressure relief pathway sufficient enough to prevent the lids from blowing off. Although the containment provided by the drum was compromised, the Pipe Components contained therein retained their integrity and did not leak.

Of ten filters pressure tested (via the hydrogen/oxygen ignition test) two filters showed increased flow rates after the test, while still meeting a 99.9 percent particulate retention criteria. Examination of these filters showed that a retaining ring, which holds the sintered metal filter element in place had become loosened either during the test or during post-test handling. A minor design change to the filter was made to improve the filter element-retaining ring. The 1000-psi hydrostatic pressure test showed bulging in the bottom of the pipe component. However, no leakage from the pipe was identified.

### **FINITE ELEMENT ANALYSIS OF THE PIPE OVERPACK CONTAINER**

Finite element modeling was used to support analysis of the Pipe Overpack Container to resolve storage accident scenarios where physical testing of the container could not be easily performed. Two scenarios were evaluated (Reference 7). One risk to the integrity of the Pipe Overpack Container occurred during handling and storage. The Pipe Overpack Container drum was punctured by an accident with the tine of a forklift. The other accident scenario analyzed involves the collapse of the roof of a storage building.

The forklift accident scenario assumed a 4920-kg forklift traveling at 4.5 m/s pinning the Pipe Overpack Container against a rigid wall. The position of the forklift tine at impact was chosen to maximize damage of the Pipe Component. Both the 15.2 and 30.5 cm diameter Pipe Components were capable of stopping the forklift without a total failure of the Pipe Component. The pipes were bent significantly, but remained relatively intact. The strain concentrations caused when the outside tip of the tine impacted the pipe were high enough to assume that localized tearing of the pipe wall would occur. The design of the tine used in the analyses had a squared off end which significantly contributed to the strain concentration.

A slightly off-center impact was analyzed to determine whether it was a more severe impact than the symmetrical impact conditions. The ability of the Pipe Component to move away from the tine was effective at keeping the strains in the Pipe Component to below the failure strain limits.

The building collapse scenario evaluated the collapse of the roof structure of the storage building onto the Pipe Overpack Container. Three possible impact orientations were selected for the analysis: a flat section of roof impacting the top of the Pipe Overpack Container, a flat section of roof impacting the side of the container, and the edge of a roof section impacting the side of the container. In all of these analyses, the roof section was assumed to be rigid and traveling at constant velocity. The amount of energy absorbed by the package at its failure point was calculated. This allowed the risk assessment to determine the weight of a roof section necessary to cause the container to fail.

In a real accident, it is possible that more than one container will be impacted by the collapsing roof structure. Under these conditions, the total energy absorbed will be equal to energy absorbed by each package. The number of packages impacted by the falling roof structure multiplied this value. The amount of energy absorbed by a single package gives an indication of how massive a roof section can fall from a given height without causing package failure.

From the analysis, a single 15.2-cm Pipe Overpack Container upright in an end impact orientation, implies that this package would not fail if impacted by a 2950-kg roof section falling from 6.1 m. For a 10.2-cm thick reinforced concrete slab, this equates to a section more than 3.65-meter square. For the impact of an edge of a roof section onto the side of the 30.5-cm Pipe Overpack Container, the absorbed energy is equal to a 232-kg roof section falling from 6.1 m. For a 10.2-cm thick roof slab, this weight is equal to a 1.06-meter square section. The edge of a roof section falling on the side of a 30.5 cm Pipe Overpack Container in its most vulnerable location is the most damaging case.

### **PIPE OVERPACK CONTAINER APPROVALS**

The Pipe Overpack Container testing and analyses demonstrate the ability of the container to provide three significant control functions: 1) criticality control, 2) shielding of high Am<sup>241</sup> content materials, and 3) containment of fine particulate waste materials during normal conditions of transport and hypothetical accident conditions.

As a result of the testing and analyses, the Nuclear Regulatory Commission approved use of the Pipe Component as part of the Pipe Overpack Container system. This approval was granted with the issuance of a new Certificate of Compliance for Radioactive Materials Packages (Reference 8). In a related approval, Kaiser-Hill (the integration contractor at RFETS) evaluated the Pipe Overpack Container and credited the container as a safe storage system for the storage of highly dispersible materials (Reference 9). When the Pipe Overpack Container is used for shipping wastes to WIPP, appropriate content codes designating specific waste material and packaging must be in the TRUPACT-II Content Codes (TRUCON) document.

### **RFETS USE OF THE PIPE OVERPACK CONTAINER**

RFETS is using the Pipe Overpack Container for the following:

- Preparation of wastes and residues for shipment to WIPP. The use of the Pipe Overpack Container will maximize the plutonium per TRUPACT-II shipment. This will involve the

shipment of non-gas generating inorganic materials packaged in a metal can, and will allow a maximum of 200 FGE per drum. The material being shipped will have appropriate plutonium content and density to allow packaging of the full 200 FGE in the Pipe Overpack Container.

- Optimize shipment of high  $\text{Am}^{241}$  content wastes to WIPP. The high americium content in some of the waste forms substantially restricts the amount of material placed in a waste drum. Use of the Pipe Overpack Containers radiation shielding capability allows the packaging of 200 FGE high-americium content materials while still meeting the exposure criteria. Use of the Pipe Overpack Container results in an estimated reduction of 40,000 TRU waste drums for the Rocky Flats Molten Salt Extraction Salt residues.
- On-site storage of waste forms at RFETS. The use of the Pipe Overpack Container as a structurally enhanced storage container reduces risk to the worker and the public. In addition, the container stores high americium content residues and dispersible materials. Use of the Pipe Overpack Container (to store dispersible residues) is one of the seismic risk mitigation methods to be used as part of RFETS response to the Defense Nuclear Facilities Safety Board Recommendation 94-3.

RFETS use of the Pipe Overpack Container started with the packaging of stabilized pyrochemical salt residues in January 1998, and with packaging of other residues in April 1998. Over 800 Pipe Overpack Containers are currently storing residues at Rocky Flats.

#### **RFETS PIPE AND GO INITIATIVE**

Another potential use for the Pipe Overpack Container is in the approval process. Reactive metals (including elemental plutonium) contained in selected residues are a continuing concern to the Defense Nuclear Facilities Safety Board. It is part of the subject of their Recommendation 94-1 the recommendation calls for the chemical or thermal stabilization of these forms.

Recent calculations have shown that the Pipe Overpack Container is sufficiently robust to mitigate the impact caused by the oxidation of worst-case concentrations of reactive materials in these residue forms. This analysis resulted in a proposal for using packaging in the Pipe Overpack Container as mitigation for selected potentially unstable residues. The container was proposed instead of performing currently planned oxidation stabilization processes. This proposal supports the expedited closure of RFETS by allowing residue stabilization operations to be expedited in Building 707. In addition, the proposal allows for quicker reduction of risk to the public and worker, and a substantial cost savings over the planned stabilization operations. The proposal covers the processing of the RFETS pyrochemical salt and ash residues. The following activities have occurred to obtain approval of this approach:

- Safeguards Termination Limit Variances for the selected residues have been obtained.
- Compliance with WIPP Waste Acceptance Criteria has been verified.
- Interim Safe Storage Criteria (Reference 9) has been documented.
- The Rocky Flats Residue Characterization program is in the process of showing that the perceived hazard does not exist.
- Cost savings estimates have been developed. It is anticipated that a \$60 million saving will result by implementation of the program.

- Implementation and processing schedules have been developed.
- Verification of compliance with National Environmental Policy Act requirements is underway.
- Radiation exposure savings estimates for the alternative have been developed. The estimate shows an expected 57 man-rem reduction in exposure by implementation of the alternative.
- Temperature transient calculations have been verified.
- An assessment of the corrosion potential for the unprocessed residue forms in the Pipe Overpack Container has been completed.

The results of these analyses are documented in a final technical report (Reference 6).

## **CONCLUSION**

The development, testing, and approval of the Pipe Overpack Container have resulted in its approval for use. Use of the Pipe Overpack Container results in substantial optimization of packaging TRU wastes and their shipment to WIPP. The container further reduces risk to the worker and the public. A follow-on initiative is underway to use the Pipe Overpack Container to mitigate the perceived risk of selected residue forms. If implemented, this initiative will support the expedited closure of Rocky Flats, reduce risk to the worker and the public. Finally the initiative will result in substantial cost savings to the Department of Energy.

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