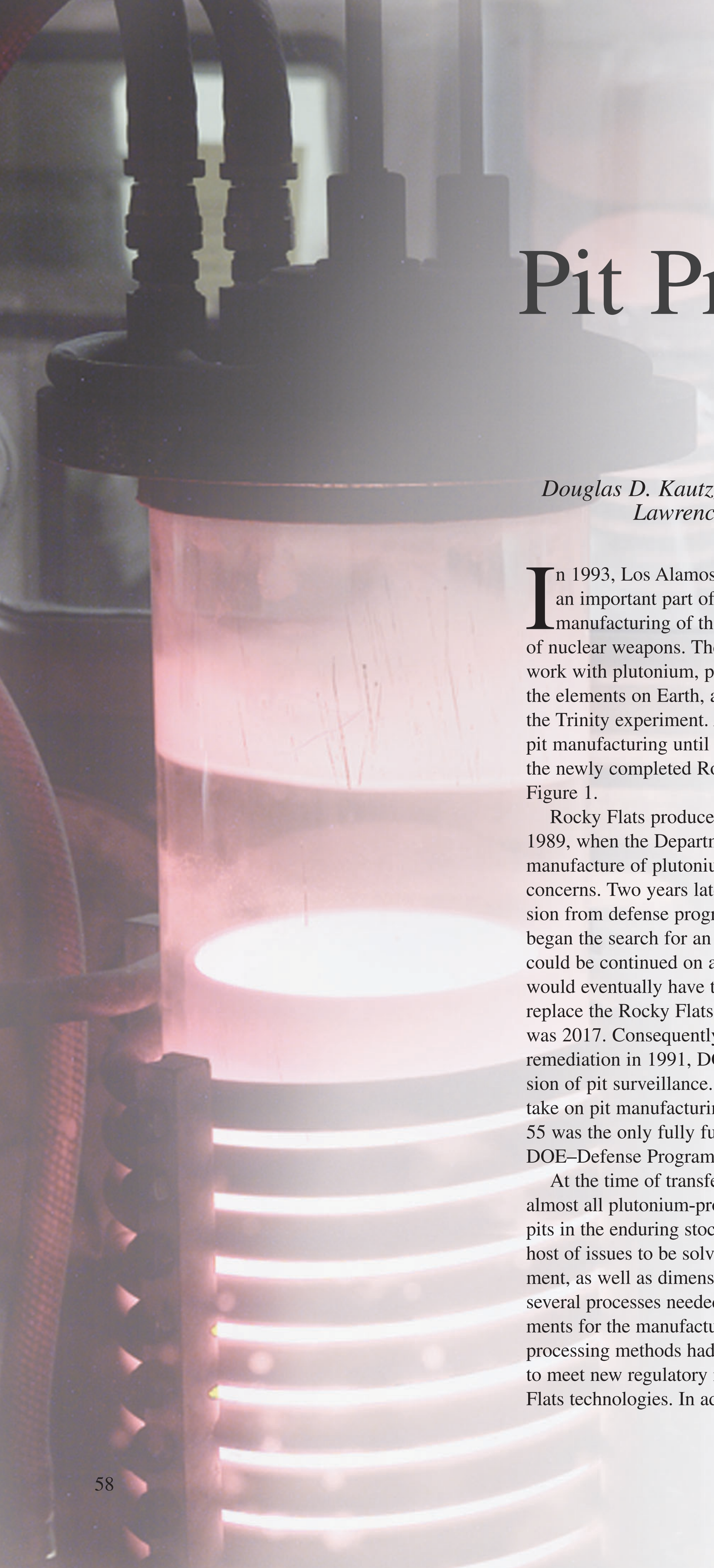

The Pit Production Story

Douglas D. Kautz, David B. Mann, Richard G. Castro, Lawrence E. Lucero, and Steven M. Dinehart

In 1993, Los Alamos National Laboratory was asked to return to an important part of its roots. It would once again tackle the manufacturing of the plutonium-bearing pit, a major component of nuclear weapons. The Manhattan Project pioneers had learned to work with plutonium, perhaps the strangest and most reactive of all the elements on Earth, and they had built the first pit, testing it in the Trinity experiment. After World War II, Los Alamos continued pit manufacturing until 1952, when that mission was transferred to the newly completed Rocky Flats Plant in Golden, Colorado—see Figure 1.

Rocky Flats produced thousands of pits year after year until 1989, when the Department of Energy (DOE) abruptly ended the manufacture of plutonium components because of environmental concerns. Two years later, DOE changed the plant's official mission from defense programs to environmental remediation and began the search for an interim location where pit manufacturing could be continued on a small scale. Although the United States would eventually have to build a new pit-manufacturing facility to replace the Rocky Flats Plant, the projected time for its completion was 2017. Consequently, when Rocky Flats began environmental remediation in 1991, DOE asked Los Alamos to take on the mission of pit surveillance. And in 1993, the Laboratory was asked to take on pit manufacturing since our facility at Technical Area (TA) 55 was the only fully functional plutonium facility in the DOE–Defense Programs complex—see Figure 1.

At the time of transfer, the Laboratory could nominally perform almost all plutonium-processing steps needed to manufacture most pits in the enduring stockpile; however, close inspection revealed a host of issues to be solved. Some machining and welding equipment, as well as dimensional inspection capabilities, were absent; several processes needed improvement to meet the quality requirements for the manufacture of war reserve components; and several processing methods had to be converted to fit existing equipment or to meet new regulatory mandates that disallowed the use of Rocky Flats technologies. In addition, several pieces of equipment, although functional, required replacement or additional backup capability so that the mission could be viable at Los Alamos. Substantial upgrades were also needed in the processing capability for nonnuclear components. Despite many challenges, the pit-manufacturing effort began but as a very small project. Many of the participants performed several functions, and they focused on developing processes rather than product. As the project matured and needs were better understood, the emphasis shifted toward manufacturing pits that would be certifiable, that is, that would meet all the specifications required for inclusion in the enduring stockpile. The successes described here reflect the dedication of a large number of people in many organizations across the Laboratory. The largest contributors were the Nuclear Materials Technology, Engineering Sciences and Applications, Materials Science and Technology, and Chemistry (formerly Chemical Science and Technology) Divisions.

Early Decisions on Materials and Processes

Early in the project, we made several major decisions that would influence the entire manufacturing effort—from preparing the plutonium metal to fabricating the components and assembling the pits. First, we would reduce the use of various process chemicals to meet environmental and waste-processing concerns. Next, we would develop new welding processes for various joints, and finally, we would develop methodologies to ensure that highly reactive plutonium did not exhibit undue corrosion upon assembly into the pit. An overriding factor in all our decisions was, and remains, the necessity to produce pits that are equivalent to those manufactured at Rocky Flats.

Figure 1. The Rocky Flats Plant and TA-55
These pictures are aerial views of the Rocky Flats Plant (top) and TA-55 at Los Alamos (bottom).

The choice of solvents posed a particularly thorny problem. At Rocky Flats, carbon tetrachloride and 1,1,1-trichloroethane had been used in large quantities, but their use at Los Alamos was prohibited by modern environmental and waste-processing constraints. To develop processing strategies that employ different solvents and minimize the amount needed, we launched several compatibility studies with plutonium

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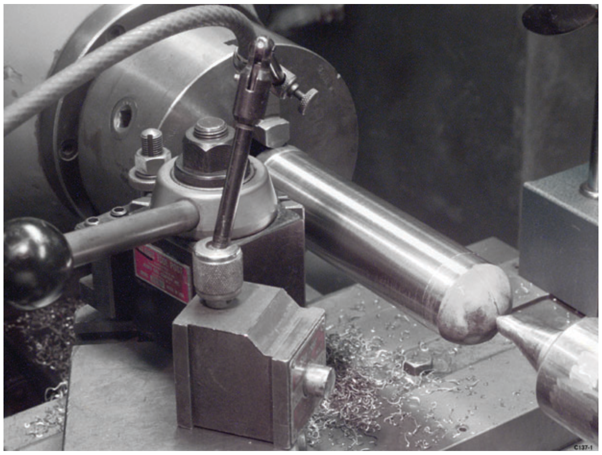

(b)

Figure 2. The Dry Machining Process
(a) The new dry machining process avoids heavy use of lubricants, which are expensive and difficult to dispose of when becoming waste. In this process, no chemical changes take place on the surface of the plutonium parts, and thus all the plutonium shavings can be collected for reuse. The dry machining process, therefore, generates no plutonium waste. (b) Star machinist Dean Martinez is programming the T-base lathe to machine a component.

and other materials. We not only developed those strategies but also continued to reduce the waste stream by purifying and reusing the solvents while ensuring the cleanliness of components assembled into pits.

The heavy use of lubricants at Rocky Flats posed two additional problems that we had to avoid. First, the lubricants themselves generated hazardous waste streams. Second, because plutonium is highly reactive, each time a lubricant is used, a cleaning step involving large quantities of solvent must follow to ensure that the plutonium does not reduce to plutonium hydride, in which case it must be scrapped and reprocessed. Our solution was to reduce the use of lubricants through development of a "dry" machining process. Unlike traditional processes, dry machining requires lubricant only during the finishing of parts—refer to Figure 2. We also reduced the lubricants in other operations that had used them during Rocky Flats processing.

Creating the dry machining process took approximately 18 months and involved development of new tools, procedures, machining parameters, and airtight gloveboxes (Figure 3). We altered materials processing. At Rocky Flats, wrought processing techniques had produced the plutonium. But installation of the equipment for that process at the Los Alamos facility would have forced major facility changes with consequent lengthy delays in acquiring a revised facility operating permit. Instead, both our pit-manufacturing and certification staff compared the properties achieved through wrought processing and casting and concluded that cast material could indeed meet the needs of the weapons community—refer to Figure 3.

To study all replacements for process chemicals and materials used in pit manufacture, as well as their effects on the materials used in pits, the War Reserve Materials Compatibility Board was convened. Once the board found that the new materials were compatible with the pit materials, an extensive quality-control program was instituted to ensure that no changes occurred in the formulation or processing of those materials. That same quality-control program daily ensures that all materials in the manufacture of pit components meet the established standards of uniformity and high quality (Figure 4).

A simple example of quality control concerned rubber bands that hold a marking mask on the pit. The rubber bands for our first pits were made from pure rubber and left no residues on the pit. A second batch received from the vendor contained an extra ingredient that would have left an unacceptable residue on the pit. The materials compatibility board studied the new material and rejected its usage for the war reserve product.

This description gives only a glimpse of the many decisions about materials, processing, and quality control. Both the production staff and those in advisory roles worked together long and hard to develop and approve changes in numerous processes involved in pit manufacture, paving the way for us to meet our production milestones.

The Road to Quality Pits

Early on, the production staff and the Los Alamos weapons design groups decided that the major changes in processing should be tested by manufacturing a series of development pits and then checking whether the processing changes reduced their functionality. We manufactured nine pits for this purpose.

With the first pit, we tested an important welding process imported from Rocky Flats. That test was a success. For the second pit, we used processes and tracking systems that were available at that early stage and achieved only mixed success, taking three tries to complete fabrication satisfactorily. The finished pit was subjected to an environmental test, and the results were compared with those from pits manufactured at Rocky Flats.

We used the third pit to compare the surface reactivity of plutonium fabricated at the Laboratory with that of pits made at Rocky Flats. During manufacture of the fourth pit, we tested the effectiveness of new cleaning materials chosen to meet new waste-generation regulations. We exposed the plutonium to larger-than-normal quantities of various processing materials known to be difficult to remove and then showed that the new cleaning material, trichloroethylene, could successfully remove the materials. Postfabrication testing indicated no significant differences from pits that had undergone conventional processing.

Then, in 2000, two major problems caused significant delays in our fabrication schedule. First, during the Cerro Grande fire in May, the TA-55 plutonium facility was entombed for the first time since its opening in December 1978 for fireproofing upgrades. After the fire, all pressurized gas and fluid lines were tested for leaks in response to a corrective action from a contamination incident that had occurred earlier in the year. After resolving those issues, we returned to manufacture a pit that tested the effects of glovebox atmospheres on the plutonium material and on the processing used to remove any reacted material from the plutonium before final fabrication.

Although by that time significant work had been done to qualify materials and processes, our development pits still deviated from any pit that would ever be allowed to enter the enduring stockpile. We decided to produce a series of "standard pits" that were as close as possible to war reserve specifications and processing. We made the first in this series mainly to exercise the newly formulated systems for tracking data and parts. Although several difficulties were noted during the processing of this pit, the lessons learned helped the project mature greatly. The next in the development-pit series was purposely manufactured with several defects to test the capabilities of our major nondestructive testing processes. We then manufactured a second standard pit, which tracked much better than the first, but the experience showed that we still had several challenges to overcome before we could successfully meet all required product specifications and quality standards.

The next development-pit test assessed the integrity of Los Alamos components by directly comparing each one with the corresponding Rocky Flats component. After the pit was successfully fabricated, it was tested to ensure that no reactivity differences could be discerned between the different materials. Finally, we built a third standard pit to check our quality control and assurance systems and to demonstrate the efficacy of the last remaining nondestructive testing process.

A long hiatus in fabrication then ensued as the project went through major restructuring. To bring opera-

(a) (b)

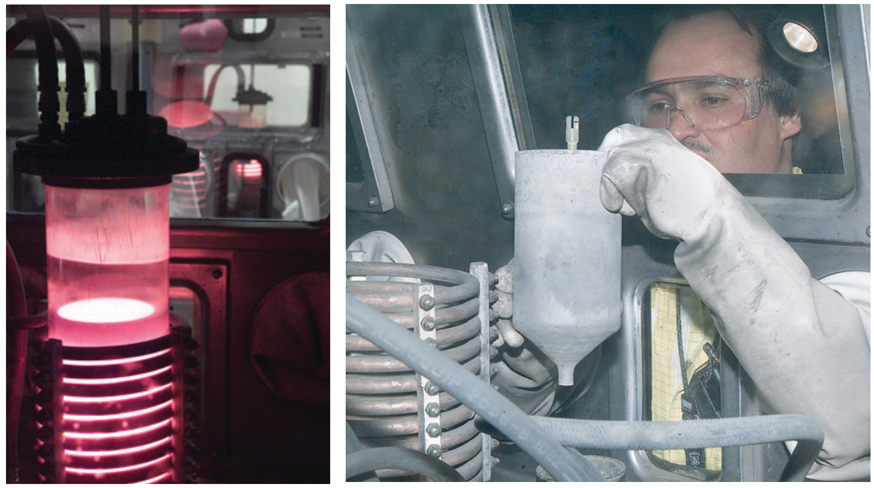

Figure 3. Cast Plutonium

(a) Shown here is an induction furnace used in the casting process. Induction heating provides good stirring of molten plutonium and a clean atmosphere for processing this highly reactive metal. (b) Casting technician Anthony Valdez is setting up the crucible used in casting.

tions back up, we built two standard pits whose status we compared with that achieved for the last fabricated pit. Although the quality control and assurance systems had matured greatly during the restructuring activities, the long period of inactivity had, as expected, some negative effects on both the equipment and the process operators. Even after the second pit was fabricated, not all the processing problems had been fully resolved.

Figure 4. Quality Assurance Audit
Los Alamos and National Nuclear Security Administration quality specialists verify that quality assurance systems support pit manufacturing.

On the other hand, during fabrication of the second pit, we successfully instituted a major, new inspection process. That process, although very difficult to install and prove out, is necessary for certifying the quality of fabricated components. Its implementation and that of another inspection process allowed us to finally fabricate a product that was fully compliant with the product specifications. All our work on honing and documenting our processes came together when we manufactured the next standard pit. It became the precursor to a major milestone for the project, namely, a pit produced with fully qualified processes and quality systems as specified in the DOE QC1 quality control policy. The final development pit was a calibration unit fabricated with several documented defects; it will be stored and periodically tested to ensure that nondestructive evaluation processes are performing in the manner expected.

Qualification Pits

The next major milestone was the delivery of a certifiable pit—a pit that met all the manufacturing specifications required for placement in the stockpile. Although the pits fabricated at Los Alamos must still undergo several engineering and physics tests before they can be fully certified and actually placed in the stockpile, all quality control and assurance systems and process qualifications associated with manufacturing will be in place.

In May 2003, the Laboratory completed the first nuclear weapons pit that meets specifications for use in the U.S. stockpile. The newly made pit, called QUAL 1 because it was built with fully qualified processes, is for use in the W88 warhead, which is carried on the Trident II D5 Submarine-Launched Ballistic Missile, a cornerstone of the U.S. nuclear deterrent.

The pit production project is restoring our nation's ability to make nuclear weapons, a capability that had been lost when the Rocky Flats Plant was shut down in 1998.

Looking Forward

Members of the project are already working on ways to improve both the yield and the efficiency of processing. We plan to reduce the waste generated during plutonium casting by replacing single-use fabrication tooling with reusable tooling. We are studying ways to remove a common machining defect encountered during turning operations. We are instituting real-time monitoring on several pieces of equipment so that process holds now encountered while waiting for batch results can be minimized. We are also embarking on an in-process monitoring strategy to gain much needed process-performance data. Having moved beyond the certifiable-pit milestone, we will institute this type of robustness initiative to provide a more consistent and higher-quality product to our DOE and Department of Defense customers. ■

Douglas Kautz graduated from the Colorado School of Mines in 1982 with a bachelor's degree in metallurgical engineering and received a master's degree in metallurgical engineering from the Colorado School of Mines in 1987. Doug worked for Rockwell International from 1982 to 1987, specializing in the process engineering of materials used in nuclear weapons. From there, he moved to Lawrence Livermore National Laboratory, working on high-energy-density welding research and materials issues with nuclear weapon components until 1994, when he became a staff member in the Nuclear Materials Technology Division at Los Alamos, where he is now a deputy leader of the Weapon Component Technology Group.