

# **Idaho National Laboratory Fuel Reprocessing Complex Historic American Engineering Record Report – ID-3-H**

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December 2006



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operated by Battelle Energy Alliance

INL/EXT-06-11969

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Complex Historic American Engineering Record  
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**Prepared for the  
U.S. Department of Energy  
Office of Nuclear Energy  
Under DOE Idaho Operations Office  
Contract DE-AC07-05ID14517**

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PART ONE  
INTRODUCTION

The Atomic Energy Act of 1946 established the civilian U.S. Atomic Energy Commission (AEC) to direct atomic energy “toward improving the public welfare, increasing the standard of living, strengthening free competition among private enterprises so far as practicable, and cementing world peace.”<sup>1</sup> The Act also required the AEC to conduct research in nuclear energy “through its own facilities....”<sup>2</sup> In 1949, following a nation-wide search, the AEC established the National Reactor Testing Station (NRTS) in southeastern Idaho, its first field test facility and only dedicated reactor proving ground. The AEC chose to locate the NRTS at the site of the former Arco Naval Proving Ground, an area used during World War II to proof test naval ordnance. The AEC chose this area because of its isolation, climate, geology, abundant subsurface water, and a variety of social-economic factors including local government support, existing infrastructure, and availability of manpower, land, and materials for construction.<sup>3</sup> At the time it was established, the NRTS consisted of 177,000 acres but it was eventually expanded to encompass its present 569,000 acres (890 square miles) of cool desert terrain in portions of five counties on the northeastern Snake River Plain. Its name was changed three times, once in 1974 to the Idaho National Engineering

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<sup>1</sup>“Atomic Energy Act of 1946”, 42 U.S.C. Sect. 2011 - Sect. 2259, P. L. Section 1. (a), available at <http://www.eh.doe.gov/oepa/laws/aea.html>.

<sup>2</sup>Ibid, P. L. Section 3. (c)

<sup>3</sup>J. M. Holl, “The National Reactor Testing Station: The Atomic Energy Commission in Idaho, 1949 – 1962,” *Pacific Northwest Quarterly* 85(1):15-24, 1994. Also, “Survey Report Fort Peck, MT – Pocatello, ID”, Smith, Hinchman, and Grylls, eds. (Idaho Falls: U.S. Atomic Energy Commission, 1949) pp. 14-16.

Laboratory (INEL), again in 1997 to the Idaho National Engineering and Environmental Laboratory (INEEL), and to the Idaho National Laboratory (INL) in 2005.<sup>4</sup>

The original mission of the NRTS was to provide a remote area where nuclear energy research, development, and testing could be conducted with minimal impact to the public. Initially the AEC planned to construct only five reactors at the proving ground over a ten-year period. However, rapidly expanding technologies and a nationwide sense of optimism that set virtually no limits on the potential for use of nuclear energy clearly affected construction plans for the remote testing facility. Eventually, fifty-two mostly first-of-a-kind reactors were constructed at the NRTS. Experiments in safety, reactor design, and nuclear propulsion conducted at these Idaho facilities influenced every reactor in the world, particularly with regard to safety and design.

In 1950, construction began on the first four NRTS facilities. They included the Experimental Breeder Reactor I (EBR-I), the Naval Reactor Facility (NRF), the Materials Test Reactor (MTR), and the Idaho Chemical Processing Plant (ICPP). Facilities originally constructed for the Arco Naval Proving Ground were also expanded at this time to form the administrative center of the new testing station, Central Facilities Area (CFA). Over the years, several more centers of activity would appear on the NRTS landscape, each reflecting a new direction in nuclear research or filling necessary operational functions for the NRTS as a whole (Figure 1).

From the beginning, political tides and changing world events shifted priorities at the NRTS. These changes spilled over into the programs and projects that the NRTS conducted. Although the influences were varied, they fall into two broad categories of interest: national defense and peaceful applications for nuclear energy.

Throughout history, almost all government facilities have bent to the needs of national defense at one time or another, some in small subtle ways and others with great gusto. Conceived as it was in the aftermath of World War II, the initial throes of the Korean War, and amid the heightening tensions that defined the Cold War, the NRTS exhibited both extremes. For example, one NRTS facility, the Naval Reactors Facility, devoted itself almost entirely to projects that supported national defense. Here employees worked energetically on several projects, one of which involved the development of reactors that could power a fleet of U.S. Navy submarines and surface ships. Other NRTS facilities contributed to the cause of national defense less directly.

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<sup>4</sup>For additional background information on the NRTS/INEL/INL see Arrowrock Group, "Historic Context, Idaho National Engineering and Environmental Laboratory, Part 1," *INEEL/EXT-97-01021* (Idaho Falls: U.S. Department of Energy, 1997).

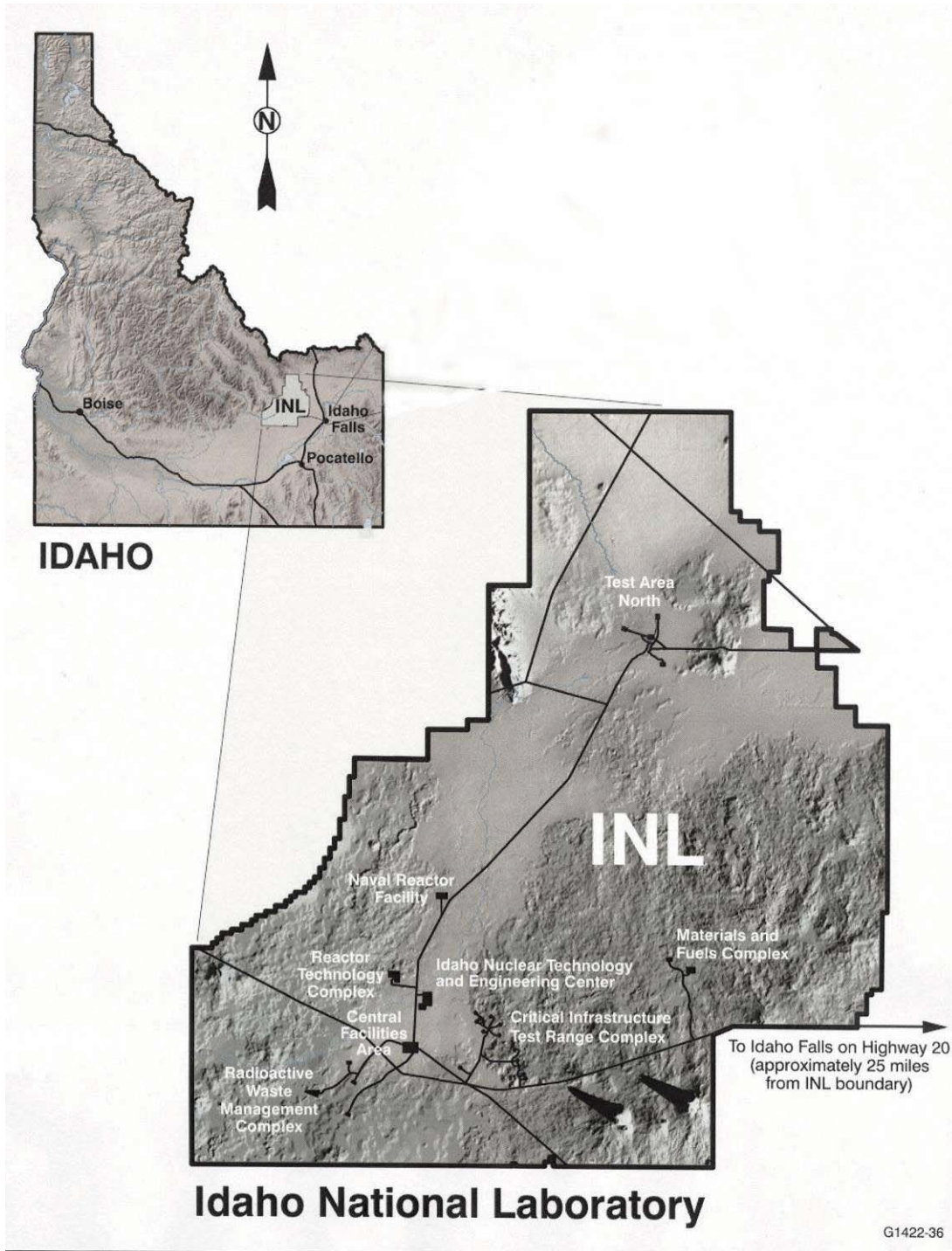


Figure 1. INL vicinity map. Source: INL Drawing G1422-36.

At the ICPP for example, construction schedules were given a boost when shortages of uranium and plutonium threatened to compromise weapons production at other AEC labs across the country. The first batch of uranium recycled at the ICPP originated from plutonium production reactors used to produce atomic weapons at the Hanford Site in Washington State. This material was destined to return to the weapons production cycle. But few of the subsequent fuel reprocessing runs at the ICPP maintained such a direct connection with weapons production and national defense.

Following the use of atomic bombs to effectively end World War II, the United States encouraged the development of peaceful uses for nuclear energy and many facilities constructed at the NRTS were oriented toward this research. Across the country, the potential for nuclear energy seemed limitless and many specific potential uses were identified including the production of electricity, medical applications, and food irradiation, among others. At the NRTS, power production was a major focus and several landmark activities and facilities helped to resolve a variety of technical issues that required attention before production could begin. One of the most pressing issues was how different materials and components, such as fuel assemblies and construction materials would perform under the intense radiation present within a nuclear reactor. The MTR, a high flux, slow thermal neutron reactor, was designed to test, in a relatively short period of time, how well materials that were being considered for use in future reactors could withstand several years of exposure to radiation. This testing was accomplished by bombarding the materials with neutrons. For some materials, just three weeks exposure in the MTR equaled two or more years of use in a reactor.

The MTR used uranium enriched with isotope U-235 as fuel. The most abundant isotope in natural uranium is U-238 in proportions that exceed 99%. U-238 will not fission or “split” when bombarded with neutrons but the small amounts of U-235 (less than 1%) also present in natural uranium will fission.<sup>5</sup> To sustain a chain reaction in most reactors, concentrations of U-235 must be increased to at least 3 – 5% and some reactor technologies, such as those employed by the MTR, required U-235 “enrichments” that exceeded 93%. Before being inserted in the MTR core, this enriched uranium fuel was *clad* or enclosed in an aluminum alloy to provide structural integrity. The fuel elements required frequent replacement because of depletion of the fissionable U-235, the build-up of byproducts that effectively stopped the fissioning process, and also because of the radiation damage that the fuel elements received inside the reactor.<sup>6</sup> Every

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<sup>5</sup>P. C. Upson, “Isotopic Enrichment of Uranium,” in *The Nuclear Fuel Cycle: From Ore to Waste*, edited by P. D. Wilson, (Oxford: Oxford University Press, 1996), pp. 67-68.

<sup>6</sup>J. R. Buck and C. F. Leyse, eds., *The Materials Testing Reactor Project Handbook*, (Oak Ridge, TN: Oak Ridge National Laboratory, 1951), pp. 1.9 and A6.1.



seventeen days the MTR was shut down and its depleted fuel elements were removed and replaced with fresh ones. More than 70% of the original U-235 in these depleted or *spent* fuel elements remained unfissioned and economical operation of the reactor required that this unconsumed fissionable material be recycled for later use. The Idaho Chemical Processing Plant (ICPP), or Chem Plant as it was known to many of the people who worked there, originated as a support facility for the MTR to recover fissionable material from these spent fuel elements.<sup>7</sup> And for nearly four decades, the Chem Plant fulfilled this important mission, reprocessing thousands of kilograms and millions of dollars worth of uranium (U-235) that could be fabricated into new fuel elements to power the MTR or other reactors.

Fuel reprocessing expertise and facilities at the Chem Plant also supported a variety of research programs in addition to those focussed on the MTR fuel cycle. Through the years, fuels from nearly one hundred different research and power reactors were brought to the Chem Plant for recycling of uranium and other valuable fission products. Some fuel elements originated from research reactors on the NRTS, where reactor construction actually peaked during the 1960s, but fuel was also shipped to the Chem Plant from reactor programs across the country. Four decades of fuel reprocessing experience also led Chem Plant scientists and engineers to significant achievements in technologies and facilities to manage the high level liquid wastes that were the by-products of the fuel reprocessing cycle.<sup>8</sup>

The end of the Cold War as marked by the beginning of dismantlement of the Berlin Wall in 1989 had a profound impact on nuclear research programs, both military and peaceful, across the country. At the NRTS, the effects were felt most acutely at the ICPP because early in 1992, the Secretary of the Department of Energy (DOE) issued an order to terminate all programs for the recovery of uranium from spent nuclear fuel.<sup>9</sup> But

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<sup>7</sup>Richard G. Hewlett and Francis Duncan, *Atomic Shield: A History of the U. S. Atomic Energy Commission, Volume II: 1947 – 1952*, (Berkeley: University of California Press, 1990), p. 496.

<sup>8</sup>“Chemical Processing of Reactor Fuel Elements at the Idaho Chemical Processing Plant”, in *Chemical Processing and Equipment, TID-5276* selected volume of reference material presented to delegates at the International Conference on Peaceful Uses of Atomic Energy, Geneva, Switzerland (Idaho Falls: Phillips Petroleum Company, Atomic Energy Division, 1955) , p. 8.

<sup>9</sup>“Phaseout of Reprocessing at the Idaho Chemical Processing Plant,” Richard A. Claytor, Assistant Secretary for Defense Programs memo dated May 1992 to A. A. Pitrolo, DOE Idaho Field Office Manager.

shipments of spent fuel, particularly from the U. S. Navy's submarine fleet, continued to arrive at the NRTS, by then called the Idaho National Engineering Laboratory (INEL), and in the absence of reprocessing, began to accumulate in temporary storage areas. The State of Idaho reacted quickly to this situation by demanding that the DOE develop a plan for managing the accumulating fuel elements, the liquid wastes from reprocessing, and the various other waste materials present across the remainder of the INEL. A lawsuit to prevent any further receipt or storage of spent fuel until such a study had been completed accompanied the State's demand.

In 1993 the conflict resulted in an agreement between DOE, the State of Idaho, and the U. S. Navy outlining the future of fuel storage and waste management at the INEL.<sup>10</sup> The agreement refocused research at the ICPP toward fuel storage technologies and waste management. A name change reflected these new missions. Although the name "Chem Plant" is still used by many employees, the ICPP is now officially known as the Idaho Nuclear Technology and Engineering Center (INTEC). Although research on spent nuclear fuels continued there particularly in regard to storage technologies, its original mission, fuel reprocessing ceased. In 1993, an important ICPP waste processing structure, the Waste Calcining Facility, was removed and an Historic American Engineering Record report written for it. In 1998, DOE identified the Main Processing Building (CPP-601) for removal, along with the Fuel Storage Building (CPP-603), and several support structures. In 2005, DOE identified the remaining ICPP structures as obsolete and deactivation, decommissioning, and demolition (DD&D) of its buildings and structures began, including those associated with spent fuel reprocessing.

## PART TWO SPENT NUCLEAR FUEL

Just as automobiles need fuel to operate, so do nuclear reactors. When fossil fuels such as gasoline are burned to power an automobile, they are consumed immediately and almost completely in the process. When the fuel is gone, energy production stops. Nuclear reactors are incapable of achieving this near complete burn-up because as the fuel (uranium) that powers them is burned through the process of nuclear fission, a variety of other elements are also created and become intimately associated with the uranium. Because they absorb neutrons, which energize the fission process, these accumulating fission products eventually poison the fuel by stopping the production of

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<sup>10</sup>“Settlement Agreement Between the State of Idaho, the Department of Energy, and Department of the Navy, October 16, 1995,” U. S. District Court of Idaho, Civil No. 91-0035-S-EJL and 91-0054-S-EJL, 1995; available online at <http://www.inel.gov/environment/agree.html>.

energy from it. The fission products may also damage the structural integrity of the fuel elements. Even though the uranium fuel is still present, sometimes in significant quantities, it is unburnable and will not power a reactor unless it is separated from the neutron-absorbing fission products by a method called fuel reprocessing.

## 2.1 History of Fuel Reprocessing

In the U.S., the first large-scale nuclear reactors were built during World War II. They were designed to produce plutonium for use in nuclear weapons. Chemical reprocessing was an integral part of this system, but it was focused solely on the recovery of plutonium from the spent natural uranium fuel. The uranium was discarded with other fission products into the waste stream. In late 1944, Oak Ridge National Laboratory (Oak Ridge) in Tennessee became the site of a pilot plant to recover plutonium for weapons purposes. It was soon followed in early 1945 by a full-scale facility at the Hanford site (Hanford) in Washington State.<sup>11</sup>

Even in the mid 1940s, scientists realized that in addition to plutonium, uranium was also a valuable product of spent nuclear fuel and significant advances were made in developing methods for its recovery in the immediate post-war period. Nearly all of the processes for uranium recovery at this time were developed on the same basic premise: liquefying, called *dissolution*, of the reactor fuel elements in acid solutions appropriate to their composition followed by solvent extraction of the uranium from the resulting liquid. Laboratory work leading to the development of the first solvent extraction process, called REDOX,<sup>12</sup> started in 1944 at AEC laboratories all over the country.<sup>13</sup> By 1945, a

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<sup>11</sup>R. G. Cochran and N. Tsoulfanidis, *The Nuclear Fuel Cycle: Analysis and Management*, (La Grange Park, IL: American Nuclear Society, 1990), p. 202; Also, Hewlett and Duncan 1990; R. G. Hewlett and J. M. Holl, 1989, *Atoms for Peace and War 1953 – 1961: Eisenhower and the Atomic Energy Commission*, (Berkeley: University of California Press, 1989), pp. 161-162; G. S. Selvaduray, *Comparative Evaluation of Nuclear Fuel Reprocessing Techniques for Advanced Fuel Cycle Concepts*, Ph.D. dissertation, (Ann Arbor, MI: Department of Applied Earth Sciences, Stanford University, University Microfilms International, 1978), p.p 10-11; C. E. Stevenson, "How AEC Plans to Process Power Reactor Fuels," *Nucleonics* (November 1960), pp. 72-73.

<sup>12</sup>REDOX process uses nitric acid and aluminum nitrate for dissolution and hexone (methyl isobutyl ketone) as an organic solvent.

<sup>13</sup>Participating laboratories included Clinton Engineering Laboratory, Metallurgical Laboratory of the University of Chicago, Argonne National Laboratory, Oak Ridge National Laboratory, Knolls Atomic Products Laboratory, Hanford site.

REDOX pilot plant was operating at the Hanford site. Improvements on the REDOX process began immediately, leading to development of the PUREX process.<sup>14</sup> The pilot plant for this process was constructed at Oak Ridge in 1950 and after successful process testing, full-scale plants went into operation at the Savannah River plant (Savannah River) in South Carolina in 1954 and the Hanford site in 1956.

In the decades to follow, researchers expanded these basic processes in many ways, developing a host of new solvent extraction techniques.<sup>15</sup> By the early 1950s, the AEC had initiated construction on several large-scale plants to bring the more promising reprocessing methods into routine production. Four plants were built around this time; the ICPP was one and Oak Ridge, Hanford, and Savannah River were the others. Each of the four U.S. processing plants was specialized to handle very specific types of fuel. With the Materials Test Reactor and Experimental Breeder Reactor-I nearby, the ICPP was set up from the start to handle highly enriched fuels clad in aluminum and stainless steel, respectively. The ICPP's proximity to the Naval Reactor Facility, the developmental and training center for the U.S. Navy's nuclear propulsion program, also led to zirconium reprocessing. Similarly, facilities at Oak Ridge were also designed for processing highly enriched fuels but the Hanford and Savannah River plants were designed to handle low enriched fuels. Even so, all four of the plants were highly adaptable in their processing capabilities. In the constantly changing scientific and political environment of the 1950s, 1960s, and 1970s, all of the AEC laboratories had to remain flexible and open for new tasks.

With passage of the Atomic Energy Act in 1954, private U.S. industry was permitted to enter the field of nuclear energy for the first time. Although high costs initially tempered reaction by the private sector, by 1960, twenty-six power reactors were under construction across the country<sup>16</sup> and by 1962, that number had nearly doubled.<sup>17</sup> From the outset, the Atomic Energy Commission power reactor program assumed that economic operation of the civilian power reactor program would require reprocessing of the uranium from spent fuel from privately owned and operated reactors. Continued high demand and limited (known) raw sources had combined to give uranium a fairly high

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<sup>14</sup>PUREX process uses nitric acid for dissolution and tributyl phosphate as an organic solvent.

<sup>15</sup>THOREX, DAREX, SULFEX, ZIRFLEX, HALEX, BUTEX, etc.

<sup>16</sup>Hewlett and Holl, 1989, pp. 511-512.

<sup>17</sup>T. R. Fehner and J. M. Holl,, "Department of Energy 1977 – 1994: A Summary History," *DOE/HR-0098* (Washington, D.C. U.S. Department of Energy, 1994), p. 14.

dollar value,<sup>18</sup> so incentive for recovery of the unburned material trapped in fuel assemblies was strong. But in the late 1950s when the power reactor program began to grow, there were no facilities for the reprocessing of the private operators' fuels. The preferred AEC solution for this problem was to develop a reprocessing capability in the private sector. However as an interim step, the AEC was forced to use its own existing facilities at the ICPP, Hanford, Oak Ridge, and Savannah River.

In 1957 the AEC formally announced plans for fuel reprocessing across the country, including that for fuels discharged from private reactors. Provisions in this plan terminated all contracts if and when reasonably priced commercial operations became available.<sup>19</sup> The ICPP was an important player in this interim program and was initially designated to process all highly enriched fuels including those from the Shippingport Core, the Organic Moderated Reactor Experiment, the Army Package Power Reactor or SM-1, the Vallecitos Boiling Water Reactor, and various other research and test reactors from the NRTS and across the country.<sup>20</sup> As years passed, other fuels were added to this inventory so that ultimately the ICPP processed highly enriched fuels from more than 100 different reactors.

## 2.2 Basic Uranium Recovery Process

As reactor technology and fuels evolved, so did the processes and facilities required for uranium recovery. However, the basic steps involved in the recovery process remained largely unchanged. An appropriate analogy may be made between the basic uranium recovery process and the act of doing laundry.<sup>21</sup> Fuel reprocessing is like a

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<sup>18</sup>Prices for uranium rose steadily and reached a peak in the late 1970s (1967 - \$269/oz, 1971 - \$300/oz, 1975 - \$1000/oz, 1979 - \$1100/oz., \$111/kg, 1982 - \$45/kg, 1983 - \$62/kg, 1984 - \$43/kg, 1985 - \$38/kg, 1986 - \$41/kg, 1987 - \$44/kg. (Idaho Falls: U.S. Department of Energy, Thumbnail Sketches, 1967-1979; 1981-1987).

<sup>19</sup>Federal Register, March 12, 1957.

<sup>20</sup>F.P. Baranowski, "Scope of the Power Fuel Processing Program, *Proceedings of the AEC Symposium for Chemical Processing of Irradiated Fuels from Power, Test, and Research Reactors TID-7583*, (Richland Washington: U.S. Atomic Energy Commission, October 1959), p. 11. In 1962, ICPP accepted the first AEC shipment of private spent fuel from the General Electric Vallecitos Reactor in California. (C.M. Slansky, C. M., "A Survey of Headend Processes For Nuclear Fuel Reprocessing," *PTR-595*, [Idaho Falls: U.S. Atomic Energy Commission, 1962]), p. 26.

<sup>21</sup>Basic Recovery Process discussion based on several general texts including: Cochran and Tsoulfanidis 1990; C. M. Slansky, "Preparation of Fuels for Processing,"

washing machine for irradiated nuclear fuel. It is a system whereby *spent*, meaning used or dirty, fuel assemblies are subjected to chemical processes that separate the unspent or clean uranium from the spent or dirty fission products that accumulated during energy production in the reactor core. Elements that provided structural integrity for the uranium are also selectively removed at this time.<sup>22</sup> As a result of this recovery operation, the clean uranium can ultimately be returned to a reactor to produce more energy; while the *high level waste*, or dirt, can be sent for long term storage.

Just like a conventional washing machine, most U.S. fuel reprocessing operations use *aqueous*, or water-based, methods. Solid fuel assemblies are converted to liquid through various chemical means and are then subjected to techniques that separate the uranium from other undesirable elements that have accumulated with it as a result of irradiation in the reactor core. Structural materials for the fuel assembly are also dissolved and discarded. There are at least five basic steps in this process:

1. fuel cooling
2. fuel dissolution
3. solvent extraction (two - four cycles)
4. product preparation
5. waste handling.<sup>23</sup>

In some operations, a sixth step involving the recovery of valuable fission products and/or rare gases is also included. Furthermore, a variety of other tasks, such as off-gas handling, criticality control, product sampling, and recycling are necessary to keep the operation safe, protect the environment, and minimize waste accumulation.

### 2.2.1 Fuel Cooling

Most of the radioactivity and fission products associated with a fuel element at the

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*Chemical Processing of Reactor Fuels*, (New York: Academic Press, 1961); Selvaduray 1978; and Upson 1996.

<sup>22</sup>Uranium can be manufactured into many forms for fuel assembly construction. Pellets, pins, plates, rods, and powders have all been used. Regardless of form, the uranium employed in a reactor will usually be clad or alloyed with some type of metal to provide structural stability and containment.

<sup>23</sup>First cycle extraction and fuel dissolution may be referred to as the “headend” of the fuel recovery process, while the latter stages of solvent extraction and product denitration combine to form the “tailend.”

time of discharge from a reactor are short-lived. So if recently discharged fuel is allowed to cool for a specified period of time as a first step in the reprocessing operation, it becomes easier and safer to handle. Advance cooling also simplifies heat-removal problems during transport, reduces overall shielding requirements and radiation damage to plant facilities and equipment. For highly enriched fuels such as those processed at ICPP, at least one hundred and twenty days of cooling are needed to minimize these potential problems.<sup>24</sup>

### 2.2.2 Fuel Dissolution

In the second step of fuel reprocessing, cool spent fuel elements are converted into a liquid that is suitable for further processing and isolation of uranium. Different dissolution procedures and equipment must be developed for each type of fuel element processed.<sup>25</sup> However, nearly all fuels will dissolve in some type of acid solution. For those that are clad in or alloyed with aluminum, boiling nitric acid with a mercury catalyst provides rapid dissolution. Zirconium clad fuels or alloys of uranium and zirconium are tougher, but will eventually dissolve in hydrofluoric acid. Fuels that are clad in stainless steel involve a more complicated chemistry with two stages of dissolution involving sulfuric and nitric acids. This two-step dissolution effort can be avoided if the stainless steel fuel is immersed in nitric acid and then subjected to an electrical current in a specialized dissolver vessel.<sup>26</sup>

Specialized equipment is required to dissolve fuel elements (Figure 2).<sup>27</sup> The most important piece, where the actual conversion of solid fuel to liquid is accomplished, is the dissolver vessel. Two types of dissolver are common: batch and continuous. Most dissolver vessels, regardless of type, are constructed of stainless steel, which has proven to be highly resistant to the nitric acid solutions that are capable of dissolving uranium.

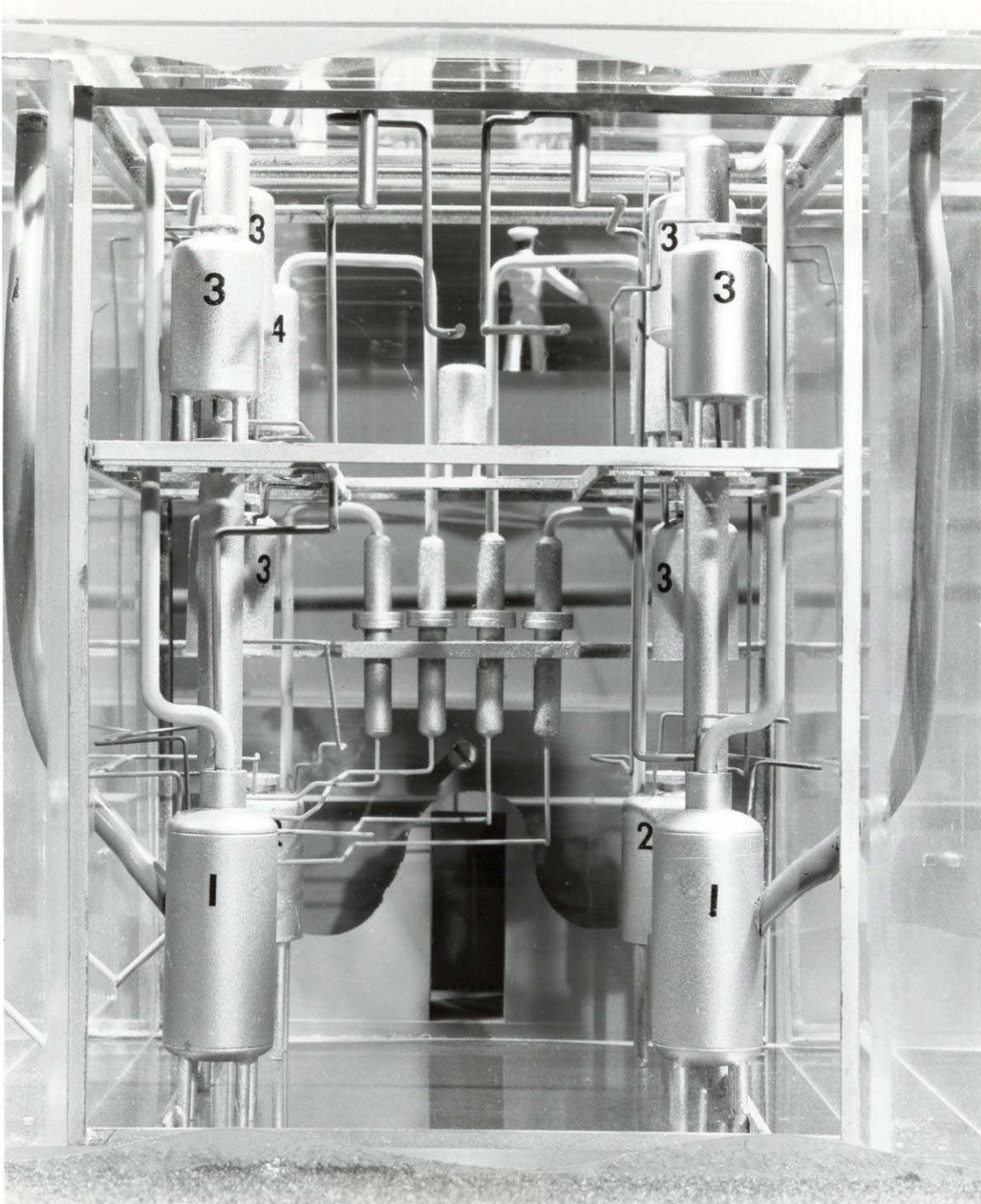
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<sup>24</sup>J.A. Buckham, "Head-End Steps in Preparation of Fuels For Aqueous Processing," *PTR-145*, (Idaho Falls, ID: Phillips Petroleum Company, 1957), p. 3.

<sup>25</sup>Buckham 1957, pp. 5-7. Also, J.A. Buckham and C. E. Stevenson, "Dissolution Equipment," *Symposium on the Reprocessing of Irradiated Fuels, Session V: Engineering and Economics*, TID-7534, (Brussels, Belgium: International Atomic Energy Commission, May 1957), pp. 831-847.

<sup>26</sup>This is electrolytic dissolution and it is also suitable for other types of fuel. See more detail on ICPP's electrolytic dissolution system in Section 4.1 of this report.

<sup>27</sup>Buckham and Stevenson, p. 834.



**Figure 2.** Model of a typical fuel dissolution cell. *Source:* INL Photo 55-1911.  
dissolver vessels, regardless of type, are constructed of stainless steel, which has proven to be highly resistant to the nitric acid solutions that are capable of dissolving uranium.



However, other construction materials such as rubber, plastic, Monel, and Hastelloy<sup>28</sup> are also used because stainless steel does not resist the highly corrosive nature of all types of acids. Hydrofluoric acid, used to dissolve fuels clad in zirconium, is particularly troublesome on stainless steel equipment. In the evolution of fuel processing techniques, batch dissolvers were developed first and they are still often used as an initial step in the development of a new fuel processing technique. These rather squatty-looking vessels, nearly as tall as they are wide, are sized specifically to hold a predetermined amount of fuel plus acid dissolvent. A set number of fuel elements are *charged*, or placed, into the vessel via pipes specially configured or shielded to prevent radiation leakage. A calculated amount of dissolvent is also added at a prescribed rate. The resulting mixture is allowed to stand for a set amount of time to undergo the necessary chemical reactions. Heat may be applied to speed the process.

Continuous dissolvers are generally tall thin columns. These columns are designed to be *geometrically favorable* meaning that they are sized specifically to prevent an accumulation of a critical mass of fissile material.<sup>29</sup> Fuel is charged intermittently into these vessels remotely from a heavily shielded room or cell often called a *cave*. Only a portion of the fuel charged to the dissolver at any one time is actually in direct contact with the dissolvent. The column of fuel elements drops slowly and constantly into a countercurrent flow of acid solution where the fuel dissolves. The constant activity within the dissolver causes vapors and foam to form and necessitates the presence of a condenser in the system. Solutions have the capacity to flow continually through this system rather than as a single unit or *batch*.

Both types of dissolver transform the solid fuel into a liquid solution containing mixed uranium, metal, and fission product nitrates. In order to successfully progress through the next step in reprocessing where the uranium will be selectively removed, the dissolver product must have a uniform composition. At the ICPP, filters were originally used to remove particulates from the solution, but high maintenance and criticality problems led to their abandonment. Centrifuges replaced some of them and chemical adjustments were also used to dissolve some resistant chemical bonds and stubborn emulsions that formed on process equipment. The result was a uniform solution ready for continued processing.

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<sup>28</sup>Monel and Hastelloy are trademarks for a series of high strength nickel-based corrosion resistant alloys.

<sup>29</sup>Within the confines of a reactor, self-sustaining nuclear chain reactions are desirable and controllable. They are not desirable within a fuel reprocessing plant and many steps are taken to ensure that a "critical mass" of fissile material (i.e. uranium), which could initiate an uncontrolled chain reaction, is not accumulated.

### 2.2.3 Solvent Extraction

The solvent extraction step in the fuel reprocessing operation is designed specifically to remove the uranium from the fission products and structural elements that accompanied it while it was deployed in the reactor.<sup>30</sup> As the liquid passes through two, three, or sometimes four cycles of solvent extraction, radioactivity decreases incrementally so that the end product is a solution of nearly pure uranium that can be handled without shielding.

The initial separation of uranium in the solvent extraction step is carried out in a tall, narrow piece of equipment called an extraction column. The mixture from the dissolver vessel enters this new column near the top. Feeding in near the bottom of the column is the organic liquid solvent. At the Chem Plant, Hexone was the solvent of choice for first-cycle extraction, while other plants used tributyl phosphate and a variety of other chemicals. Since this organic solution is lighter than water, it rises as it mixes with the descending dissolver product, which contains the uranium in aqueous solution. The two liquids are forced to mix thoroughly by pulsers and sieves within the column. The aqueous uranium has a special affinity for the organic liquid and forms a chemical complex with it. The remainder of the dissolver product, containing fission products and dissolved metals, does not share this affinity. These *raffinates* or wastes pass out the bottom of the column in aqueous solution while the uranium solution dissolves in the organic solvent and passes with it to the top.

From the top of the extraction column, the uranium-bearing organic stream goes to a scrub column where additional decontamination of the uranium is achieved. The action of the uranium solution through the scrub column is opposite of that in the extraction column. The uranium-bearing organic stream enters the scrub column near the bottom and additional process chemicals are added near the top. Mixing occurs as in the previous column, and most of the remaining fission products pass from the organic to the aqueous solution and go out the bottom of the column. The uranium-bearing organic solution again rises and goes out the top.

After passing through the scrub column, the uranium-bearing organic solution goes to a third tall and narrow column where the uranium will be stripped from the organic solvent and returned to the acid stream. The uranium-laden organic solution is introduced near the bottom of the stripping column and again rises upward counter-

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<sup>30</sup>R. B. Lemon and D.G. Reid, "Experience with a Direct Maintenance Radiochemical Processing Plant," Proceedings of the International Conference on the Peaceful Uses of Atomic Energy, Volume 9: Reactor Technology and Chemical Processing. New York: United Nations, 1956, p. 534.

currently to a stream of dilute nitric acid added near the top. Pulsing and mixing of the uranium-bearing organic solution and the nitric acid encourages the uranium to separate from the organic solvent and pass back into aqueous solution with the acid. Once stripped, or back-extracted, the uranium solution passes out the bottom of the column while the organic solvent flows out the top. In the Chem Plant operations, a fourth column was used to wash the aqueous uranium stream with pure organic diluent to remove any stubborn solvent and the resulting uranium solution was concentrated<sup>31</sup> through a steam heated evaporator for efficient storage and feed to the second cycle of extraction. Solvents were also collected, cleaned, and recycled to minimize waste.

The second and third cycles of solvent extraction function to purify the uranium product even further to a dense deeply yellow liquid that is essentially pure uranium. The chemicals and equipment used to produce the liquid uranium are different from those used during first cycle extraction in a couple of key ways, particularly in ICPP operations; however, the basic process remains the same. The uranium solutions handled during these stages of solvent extraction is concentrated to a high level<sup>32</sup> and additional criticality controls are built into the columns and other equipment. All of the extraction columns used in second and third cycle extraction are designed to be geometrically favorable. As a result, flow rates through the equipment are significantly decreased over those obtained during first cycle extraction<sup>33</sup> and extraction columns are equipped with features to minimize the potential for problematic concentrations. Second and third cycle extraction also relied on an entirely new solvent, tributyl phosphate with a kerosene diluent.

#### 2.2.4 Product Preparation, Waste Handling, and Isotope Separation

The final step for the uranium product in the fuel recovery process involves evaporation and denitration to transform the liquid uranium product into a form more suitable for remanufacture into clean fuel for a reactor. At many plants the liquid was transformed to powder in an oxygen reducing atmosphere. However, at the Chem Plant, a unique process was developed wherein direct heat was applied to the solution in a fluidized bed of uranium oxide. In either case, the end product of the fuel reprocessing

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<sup>31</sup>Uranium solution was concentrated from 0.5 – 10 grams of uranium per liter to 250 – 300 grams per liter in this stage.

<sup>32</sup>Concentrations ranged from 100 – 400 grams of uranium per liter during second and third cycle extraction.

<sup>33</sup>Second and third cycle flow rates were 5 – 10 liters per hour as opposed to the 200 – 700 liter per hour rates achieved during first cycle extraction.

cycle was a clean uranium oxide powder generally suitable for forming into pellets or other basic fuel forms that can be further processed for redeployment in a reactor.

Once the deep yellow uranium liquid is transformed into a dry uranium powder, the washing cycle is complete. The wastes, or dirt, resulting from the various fuel reprocessing steps are treated in several ways to reduce their volume prior to safe disposal. Evaporators and denitrators are used initially at nearly all plants and, at the ICPP, waste calcination completes the waste minimization effort. This latter process converts the wastes to a granular solid that requires only about one-tenth of the storage space required for liquids.<sup>34</sup> Once solidified, the uranium product is stored in fully retrievable steel storage bins. Gaseous wastes produced during dissolution and solvent extraction must also be treated before being released to a stack and ultimately to the open air. Dilution and interim storage are two methods used to ensure that these releases cause no harm to the environment.

Additionally, although most of the fission products that are intimately associated with the uranium in spent fuel assemblies are largely a nuisance, some are quite valuable for research. Neptunium-237, a valuable isotopic heat source, isotopes of krypton and xenon, useful as radioactive tracers for leak detection in pipelines, and barium-140, a highly radioactive element used in radiochemical research, are all useful fission products that can be isolated during the reprocessing cycle and packaged for later use.

### PART THREE THE IDAHO CHEMICAL PROCESSING PLANT

Originally, the Idaho Chemical Processing Plant was conceived as a companion facility to the nearby Materials Test Reactor, with a mission to reprocess spent fuel that often contained more than 70% of its original uranium. However, even before design was complete, new missions were identified and the facility eventually became a multipurpose plant capable of processing fuels from reactors located all over the NRTS and the country. As one of only four plants in the U. S. with production level capabilities for fuel reprocessing as well as experimental capabilities for pilot-level demonstration, the ICPP could scarcely afford to focus narrowly on a single type of fuel or reprocessing technique. This was particularly true in the scientific and political environment of the times - new reactors were being built at an unprecedented rate, innovative reactor concepts were being tested constantly, hints of significant expansion of the civilian power

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<sup>34</sup>For more information on waste calcination see Introduction to S. M. Stacy, Historic American Engineering Record No. ID-33-C, "Idaho National Engineering and Environmental Laboratory, Idaho Chemical Processing Plant, Old Waste Calcining Facility, CPP- 633," *INEEL-97-01370*, (Idaho Falls, ID: DOE-ID, 1998), pp. 9-13.

reactor program were on the horizon, and rules of supply and demand were helping to push the cost of uranium higher every year.

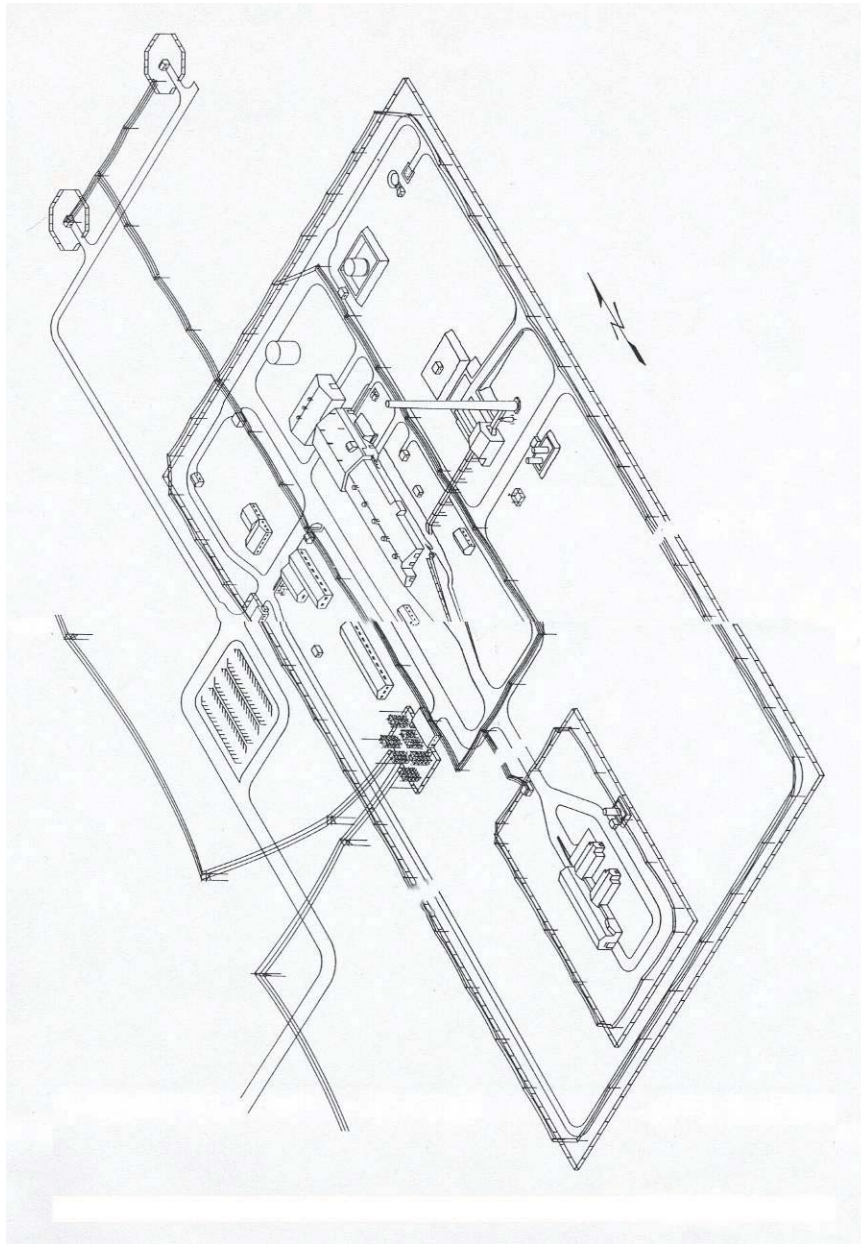
All of the AEC's fuel reprocessing plants were designed for flexibility and the Chem Plant was no exception. Room for expansion was incorporated into the initial facility plan. Figure 3 shows the Chem Plant as built in the 1950s with additional acres of land available for expansion. Eventually, the plant would grow to fill more than twice its original set-aside of eighty-two acres.<sup>35</sup> Initially, however, only a few structures were built: CPP-601, the main fuel processing building, CPP-602, the main laboratory attached to CPP-601, CPP-603, the fuel storage building, CPP-604, a waste treatment building, CPP-605, a blower building, CPP-606, a service building, and CPP-608, a simple storage building. Along with a pair of deep wells for water and a substation for power, these buildings formed the core of the original Fuel Reprocessing Complex.

Construction of the Fuel Reprocessing Complex at the Chem Plant started in 1950 with the Bechtel Corporation serving as construction contractor and American Cyanamid Company as operating contractor. Although the Foster Wheeler Corporation assumed responsibility for the detailed working design of the overall plant, scientists at Oak Ridge designed all of the equipment that would be employed in the uranium separations process. After three years of construction activity and extensive testing, the plant was ready to handle its first load of irradiated fuel. Phillips Petroleum took over as operating contractor in 1953 shortly after fuel reprocessing activities became routine. Construction costs initially ran to nineteen million dollars,<sup>36</sup> although modifications to the original

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<sup>35</sup>Reference material for the ICPP abounds and includes everything from press releases to detailed technical reports. A multitude of maps, plans, and other visual media are also available. Many technical reports were consulted for the written material included here and specific references are included as appropriate. The following general overviews were also very helpful: Thumbnail Sketches of the NRTS/INEL 1957 – 1986; general pamphlets for the ICPP produced by Phillips Petroleum Company, Idaho Nuclear Corporation, and the Department of Energy. The report also builds upon work previously completed by: Arrowrock Group, "Historic Context, Idaho National Engineering and Environmental Laboratory, Part 1," *INEEL/EXT-97-01021*, 1997 and S. M. Stacy, 1998. All of these documents are available at the INL Technical Library located in Idaho Falls, Idaho.

<sup>36</sup>J. L. Schwennesen, "Capital and Operating Cost Information on Several Existing U. S. Nuclear Fuel Processing Plants," *IDO-10033* (Idaho Falls: U.S. DOE-ID, 1958), p. 14.



**Figure 3.** Isometric view of the Idaho Chemical Processing Plant ca. 1952.  
*Source:* “Chemical Processing of Reactor Fuel Elements at the Idaho Chemical Processing Plant.” Chemical Processing and Equipment, Report No. TID-5276. Idaho Falls: Phillips Petroleum Company, 1955), p. 16.

design, which began almost immediately after completion of the basic plant, continued to push the price tag even higher.<sup>37</sup>

From the very beginning in 1953, the Chem Plant was continually evolving to safely and efficiently process new types of spent fuel and isolate other valuable products that resulted from the reprocessing cycle.<sup>38</sup> Typically, as new fuel types were submitted for reprocessing, the processes and equipment developed for them would be tested on a small pilot plant scale, usually using batch techniques. Cold tests (with no radioactive elements) of the equipment were followed by warm tests (with low level radioactive elements) until plant personnel developed specific chemical flowsheets<sup>39</sup> for each fuel recovery operation. Eventually, this type of work led to the establishment of full scale production lines for four major fuel types at ICPP, including aluminum, zirconium, stainless steel, and graphite. Appendix A includes simplified chemical flowsheets developed for these main operations.

To meet the needs of so many different customers and the various fuel types that they offered, the Chem Plant went through many different makeovers and upgrades to plant facilities, the first beginning almost as soon as the first batch of fuel was dissolved. One of the first additions to the footprint was a multipurpose analytical facility, CPP-627 the Remote Analytical Facility (RAF), built in 1955, where samples of highly radioactive plant streams could be processed and decontamination studies could be completed.<sup>40</sup> Plant personnel were also able to conduct larger, bench-scale high-level radioactive development work in a Hot Chemical Lab within CPP-627. This versatile laboratory

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<sup>37</sup>In 1979, basic plant cost \$25 million, total operation cost \$86 million. This information is available in the 1979 Thumbnail Sketch, p. 26.

<sup>38</sup>Concise summaries are found in D. A. Knecht, M. D. Staiger, J. D. Christian, C. L. Bendixsen, G. W. Hogg, and J. R. Berreth., "Historical Fuel Reprocessing and High Level Waste Management in Idaho," *Radwaste Magazine*, 4(3) (, 1997) pp. 35-47 and E. P. Wagner "Process Description and Operating History for the CPP-601/-640/-627 Fuel Reprocessing Complex at the Idaho National Engineering and Environmental Laboratory," *INEEL/EXT-99-0040*, (Idaho Falls, ID: U.S. DOE-ID, 1999), pp. 2-1 – 2-8.

<sup>39</sup>Chemical flowsheets graphically represented the processes that went on within the various dissolvers, columns, and other equipment. They were important for operators because virtually all plant operations were restricted to shielded cells and were not directly visible.

<sup>40</sup>G. A. Huff, "Remote Analytical Facility Operational Experiences," *IDO-14434*, (Idaho Falls, ID: U.S. DOE-ID, 1958), pp. 7-13.

included a Multi-Curie Cell where highly radioactive samples could be handled remotely. The 1950s also saw construction of new offices, laboratories, and modifications to fuel handling and storage facilities, all to support the basic mission of the plant.<sup>41</sup>

In the 1960s, as the AEC power fuel reprocessing program expanded to include fuels from civilian reactors, additional buildings, structures, and equipment were added to the Chem Plant to accommodate an influx of new materials. The Hot Pilot Plant/Headend Process Plant, CPP-640, was one of the first new facilities of this period.<sup>42</sup> Though it would eventually be dedicated to specific processing activities, CPP-640 was initially intended to expand the bench-scale laboratory capabilities of the Custom Processing Facility. Waste management also moved ahead at the Chem Plant with construction of the Waste Calcining Facility in 1960.<sup>43</sup>

Federal environmental laws<sup>44</sup> passed in the late 1960s and 1970s created a flurry of plant upgrades at the Chem Plant. Concerns about uranium accountability pushed changeouts in some piping systems and installation of monitoring equipment throughout the plant. And as always, decontamination and maintenance activities constantly changed all plant systems in mostly subtle ways. However, installation of a pump here, a newly designed air-lift there, and p-traps in drains everywhere did leave their marks on the facility as a whole. Computers also appeared for the first time and though few plant employees trusted them at first, they soon became irreplaceable.<sup>45</sup>

The 1980s began a period of replacement for aging structures and systems at the Chem Plant. At this time, new fuel storage, fuel processing, and waste calcination facilities were all constructed. In 1982, the Old Waste Calcining Facility was replaced by a New Waste Calcining Facility. In 1983, the dry Fuel Storage Area of CPP-666 was

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<sup>41</sup>C. B. Leek, L. F. Morrow, and D. G. Hill, "Idaho Chemical Processing Plant Fuel Element Cutting Facility Equipment Manual," *PTR-280* (Idaho Falls, ID: U.S. DOE-ID, 1958), p. 44.

<sup>42</sup>J. A. McBride, "Technical Programs and Projects at the Idaho Chemical Processing Plant," *IDO-14555* (Idaho Falls, ID: U.S. DOE-ID, 1961), pp. 54-55.

<sup>43</sup>Stacy 1998, p. 12.

<sup>44</sup>Among them the National Environmental Policy Act, the Resource Conservation and Recovery Act, and the Comprehensive Environmental Response, Compensation, and Liability Act.

<sup>45</sup>Wagner, 7/1/99.



built to largely replace the underwater fuel storage basins in CPP-603, or at least to prepare them for phaseout. Also in 1983, zirconium dissolution facilities in CPP-601 were largely replaced by the Fluorinel Dissolution Plant (CPP-666). Finally, if it had been completed, the Fuel Processing Restoration Facility (CPP-691) would have made extraction and denitration facilities in CPP-601 largely obsolete. The halt to fuel processing in 1992 left CPP-601 only half-finished.

As the Chem Plant approaches the turn of the century, many of the older facilities, including several within the Fuel Reprocessing Complex (CPP-601, CPP-603, CPP-627, and CPP-640), are being demolished, their mission ended by the DOE in 1992.

### 3.1 Chem Plant Layout

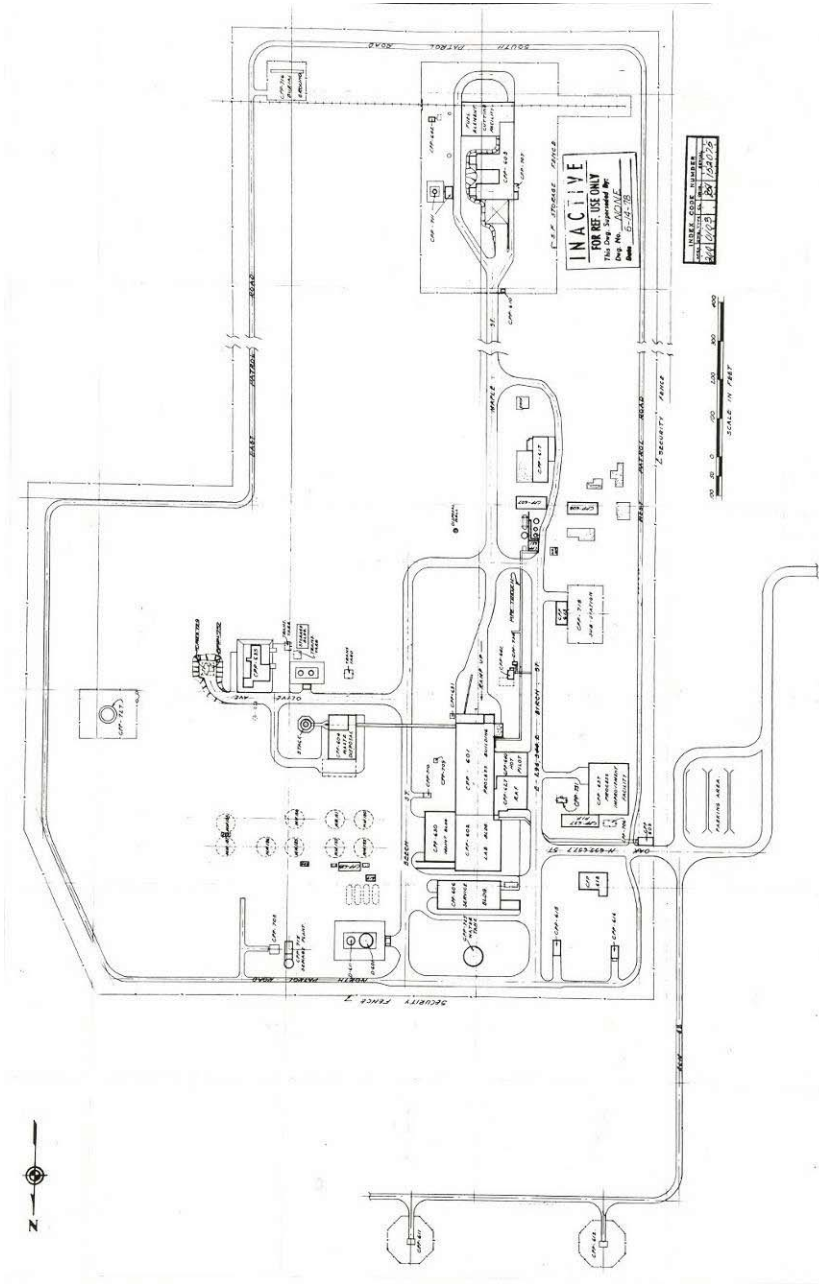
Safety and security considerations strongly influenced the physical design and layout of the Idaho Chemical Processing Plant from the very beginning. This is seen in everything from the geographic placement of the facility in a wide open, sparsely populated area to the arrangement of the structures within the tall security fence that surrounds everything. Because it contained appreciable amounts of special nuclear material, like uranium and to a lesser extent, plutonium, the plant had to be designed with extra security and safety measures in place. CPP-603, where the fuel elements would be stored, was one of the first structures to be built. It was located some distance from the construction site for the main processing building, CPP-601, surrounded by a fence within the main security fence, and placed under guard. Security issues drove many of these precautions, since very few of the construction workers employed to build the facility had gone through the background checks that the AEC completed before allowing workers to handle or even get near special nuclear materials.<sup>46</sup> Under the press to complete construction, there simply was not time to go through this kind of investigation for everyone who was needed. As a result, extra barriers were erected to keep the special nuclear material secure.

Figure 4 shows the original footprint of the plant. The main processing building, CPP-601, is the center of the operation. Basically rectangular in shape, this tall building has always shared a structural firewall with CPP-602, the main laboratory for the plant.

Originally, these common buildings stood alone, albeit in fairly close proximity to a service building, CPP-606, which housed a steam plant, electrical equipment, and the main plant ventilation system. CPP-603, the fuel storage building, was also an integral part of the original plant but it was located one-third mile to the south of the main processing building due to safety and security issues discussed above. Facilities to

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<sup>46</sup>Don Reid interview with Susan Stacy, ca. 1999.



**Figure 4.** Original footprint of the Idaho Chemical Processing Plant ca. 1953. *Source:* INL Drawing 152075.

handle the waste products that inevitably resulted from reprocessing activities were also an important consideration in the original plant design (CPP-604, CPP-605, CPP-628); these evaporators and other treatment equipment, a series of waste storage tanks, collectively known as the *Tank Farm*, and various monitoring and control devices occupy an area east of the main plant.

The evolution of the basic plant described above began even before the original designs were completed. In anticipation of new projects, the original designers called for construction of several processing cells within the main building (CPP-601) for which no clear purpose had yet been identified. The designers were not wrong in their assumptions. New work did come and it was not long before all of the processing cells were in use and plans were being drawn up for new laboratories and a hot pilot plant where more process experimentation could be conducted. This trend of adding new analytical facilities continued at the ICPP for its entire fuel processing history. In fact, many of the structures that appeared within the ICPP boundaries over the years provided support for the near continual construction activities.

Safety concerns were another catalyst for change within the Chem Plant. Beginning in the 1970s, it began a series of upgrades to many of its basic services to bring them into compliance with new environmental guidelines.<sup>47</sup> New air treatment and circulation systems, chemical transfer and storage systems, electrical systems, heating/cooling systems, and monitoring stations for all manner of process activities appeared. Plans were also made to replace several aging scientific facilities. In the late 1980s, a major effort to upgrade extensive piping systems for transporting hazardous wastes throughout the plant was initiated and new buildings began to appear.

Decontamination activities were a final source of constant change to ICPP structures. This was especially true inside of the processing and analytical buildings where worker safety depended on a thorough decontamination program. Modifications of this type were instituted immediately following the first runs at the plant. Through time, decontamination activities would also affect the overall footprint of the plant through demolition of highly contaminated obsolete structures.

### 3.2 Direct Maintenance Design

Equipment maintenance is an integral function of any industrial plant, but at plants such as ICPP where spent nuclear fuel was processed, maintenance activities were complicated by the fact that much of the equipment requiring repairs, servicing, and upgrading was radiologically contaminated. Precautions had to be taken to prevent the

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<sup>47</sup>Particularly the Resource Conservation and Recovery Act.

spread of contamination to workers and the environment. At some plants, all repairs, replacements, and upgrades were completed remotely using manipulators and other built-in equipment. However, the ICPP Main Processing Building was designed for direct, hands-on maintenance.<sup>48</sup> This distinction is at least partially attributable to the fact that from the beginning, the plant was destined to handle highly enriched fuels. In order to prevent an unwanted criticality event during the initial processing of fuels of this type, all vessels had to be quite small in size. Additionally, the small size of the equipment effectively precluded the effective installation of the myriad of manipulators, cranes, specialized pipes, connections, and other items that would have allowed for remote maintenance. Hands-on maintenance was really the only alternative. Facilities designed to process highly enriched fuels at Oak Ridge are also based on direct maintenance, while those that handle low enriched fuels (Hanford and Savannah River), which do not pose such a great criticality risk, rely on remote maintenance.

In the direct maintenance approach, equipment that may be subject to radioactive contamination is of simple mechanical design for easy decontamination and repair.<sup>49</sup> All systems contain a minimum of moving parts and critical items such as transfer jets, valves, and pumps are installed in pairs or alternate transfer routes are provided so that failure of one piece of equipment will not require a large-scale plant shutdown for repair. Much of the equipment with high maintenance potential (i.e., pumps, samplers) has been placed in lead-shielded cubicles located outside of the main processing cells for easier access. To minimize maintenance requirements during the processing of radioactive solutions, all equipment is leak-tested and operated with simulated process solutions before actual operations begin. To facilitate decontamination, all process cells are lined with stainless steel and include spray nozzles and solution addition funnels for introducing chemical cleaners. Outlets to the plant's liquid waste system are also built into each of the processing cells. Ladders and platforms are provided in many cells to allow maintenance personnel easy access to otherwise hard to reach equipment, but without the complex equipment required for remote maintenance, the cells remain relatively simple. As a result, they are smaller, hold considerably more equipment, and are less expensive to construct than the remotely maintained cells found elsewhere.<sup>50</sup>

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<sup>48</sup>V. W. Irvine, L. G. Pearson, R. B. Lemon, and D. G. Reid, "Direct Maintenance Experience at the Idaho Chemical Processing Plant," *IDO-14327* (Idaho Falls, ID: U.S. DOE-ID, 1954), pp. 6-7.

<sup>49</sup>J. L. Schwennesen, "Operating Experience at Several Existing U. S. Nuclear Fuel Processing Plants," *IDO-10032*, (Idaho Falls, ID: U.S. DOE-ID, 1957), p. 2.

<sup>50</sup>Phillips Petroleum Company 1955, pp. 14-15.

The direct maintenance approach implemented at the ICPP had several benefits. First and foremost, it helped to reduce the initial cost of the basic plant and accommodated an aggressive construction schedule that might have been compromised by the complexities involved in the construction of necessarily large, complex, remotely maintained cells and equipment. Costs were lower because the relatively simple equipment could be fabricated according to standard industrial techniques using commercially available equipment. By using standard stock supplies and equipment, the plant design was also potentially exportable to the commercial sector, a possibility that the AEC was actively considering. Lastly, the direct maintenance approach also allowed for very efficient use of space within the processing facility. Quite simply, the processing equipment alone, without the added volume of remote handlers, could fit into smaller cells, so more processing cells could be built within the available laboratory space.

Although the direct maintenance approach minimized actual hands-on work within the highly contaminated process cells to the greatest possible extent, some hands-on work was still necessary and it was not easy.<sup>51</sup> Spaces within the cells were cramped, full of miles and miles of piping, and fitted with equipment of all shapes and sizes. While scaffolding and ladders were added over time, operators still had to scale heights of as much as forty-five feet to access certain pieces of equipment. Lighting was generally poor and sometimes unreliable, and bulky and often clumsy protective clothing, called *Anti-C's*,<sup>52</sup> had to be donned each time a worker entered. Each entrance to the cells also carried a risk of contamination to the workers and, as time passed, health physicists revised their recommendations for radiation exposure,<sup>53</sup> adopting a stance that

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<sup>51</sup>Ed Wagner, an engineer at ICPP, has safely logged many hours in processing cells below ground in CPP-601. In ca 1994 he penned a humorous summary of some of the challenges faced during his work in "A Traveler's Guide to the Top 10 Adventures in CPP-601," including the "G-cell Dissolver Traverse," "Island in the Sky – the H-130 Head," "The Air Up There – N-cell VOG," "Q-cell Fly Walk," "The E-cell Web of Steel," "Upper Y-cell Tour," "P-cell – the Coffin Corner," "M-cell Wall Crawl," "High Anxiety – the U-cell Mobile Scaffold," and "Black Holes Under the East Vent Tunnel – Tales from the Crypts."

<sup>52</sup>Anti-C's (Anti-Contamination Clothing) are a form of personal protective equipment. Usually made of tough plastic, rubber, or some other type of impervious material, they cover the worker from head to toe and create a barrier against hazardous materials and conditions.

<sup>53</sup>Attitudes toward radiation safety have become increasingly stringent over time. Exposure limits have changed from 15 r per year a decade ago to 5 r per year (J. R. Horan and J. B. Braun "IDO-INEL Occupational Radiation Exposure History", *EGG-CS-11143* (Idaho Falls, ID: U. S. Department of Energy, 1993), pp. 9-10.

contamination to personnel be as low as reasonably achievable, known as the *ALARA* approach. During large-scale facility upgrades at the ICPP in the 1980s,<sup>54</sup> efforts were initiated to correct many of these safety issues.

#### PART FOUR FUEL REPROCESSING AT THE IDAHO CHEMICAL PROCESSING PLANT

The fuel reprocessing operation at the ICPP took place in four main structures: CPP-603 (Fuel Storage Building), CPP-601 (Main Processing Building), CPP-627 (Remote Analytical Facility), and CPP-640 (Hot Pilot/Headend Process Plant). With the phaseout of the fuel reprocessing mission at ICPP, all of these buildings or portions of them are being converted to a safe and stable shutdown condition awaiting future decontamination and demolition.<sup>55</sup>

When it was active, the ICPP fuel reprocessing operation basically followed the five main steps outlined in Section 2.2 of this report. The first involved the transfer of actual spent fuel elements to the plant. These highly radioactive elements were brought to the ICPP in lead shipping casks transported via truck or railcar. They were received by a large crane in the fuel storage building, CPP-603, where they were stored for days, months, or even years until enough fuel of a particular type had accumulated to make a processing run economical. No fresh fuel was accepted at CPP-603; all had a minimum of ninety days cooling. Prior to arriving at the ICPP, even ninety-day old fuel had to be stored in CPP-603 for at least thirty additional days in order to meet the minimum one hundred and twenty days cooling time, before being submitted for reprocessing.<sup>56</sup>

Once the fuel assemblies stored in CPP-603 had cooled sufficiently and a large enough quantity of a specific fuel type had accumulated, specific amounts could be placed into a shielded cask and loaded onto a specialized Gerlinger straddle truck (Figure 5) for transfer to the fuel processing area of the plant. Typically this transfer involved

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<sup>54</sup>H. V. Chamberlain, R. N. Henry, R. L. O'Dell, and C. M. Cole, "Idaho Fuel Processing Facility Objectives Document," *ENI-195* (Idaho Falls, ID: U.S. DOE-ID, 1982), p.3.

<sup>55</sup>M. W. Patterson, "Nuclear Fuel Reprocessing Phaseout for the Idaho Chemical Processing Plant," *WINCO-1193*, (Idaho Falls, ID: U.S. DOE-ID, 1994), pp. iii.

<sup>56</sup>"Idaho Chemical Processing Plant, National Reactor Testing Station, U. S. Atomic Energy Commission, Idaho Operations Office", pamphlet, *Idaho Nuclear Corporation*, (Idaho Falls, ID: U.S. DOE-ID, 1968).

a trip of approximately one-third of a mile down Maple Street from the Fuel Storage Building, CPP-603, to the Main Processing Building, CPP-601. Fuels clad in graphite and stainless steel and processed after 1961 were also transported down Maple Street, but their final destination was the Hot Pilot Plant/Headend Process Plant, CPP-640, constructed adjacent to the main processing building. After 1986, some fuels alloyed with zirconium were stored and initially processed in a new facility, the Fluorinel Dissolution Facility (CPP-666).



**Figure 5.** Gerlinger straddle truck transporting fuel elements from the Fuel Storage Building, CPP-603, to the Main Processing Building, CPP-601. *Source:* Phillips Petroleum Company, *Idaho Chemical Processing Plant, National Reactor Testing Station, Idaho* (Idaho Falls: PPCo, no date), p. 30.

Chargers, the specialized transfer casks used at ICPP (Figure 6) were capable of discharging fuel directly to a dissolver, to a shielded chute leading into a dissolver, or to a remote cave or cell, from which the dissolver could be loaded remotely with manipulators.<sup>57</sup> Once in the dissolver vessel, the fuel was combined with various acid-based chemical reagents that would ultimately transform it into liquid. Next came at least two cycles of separation when the uranium was extracted from the acids, structural

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<sup>57</sup>A. L. Ayers and C. B. Leek, "ICPP Facilities for Receiving, Storage, and Mechanical Treatment," in Proceedings of the AEC Symposium for Chemical Processing of Irradiated Fuels from Power, Test, and Research Reactors, TID-7583; (Richland Washington: U. S. AEC, October 1959), p. 109.

alloys, and fission products, through the use of organic solvents. As a final step, the uranium solution (uranyl nitrate) was separated from the solvents, which were often purified and recycled for new processing runs.



**Figure 6.** Fuel transport cask being lowered over a charging chute. *Source:* INL Photo 6940.

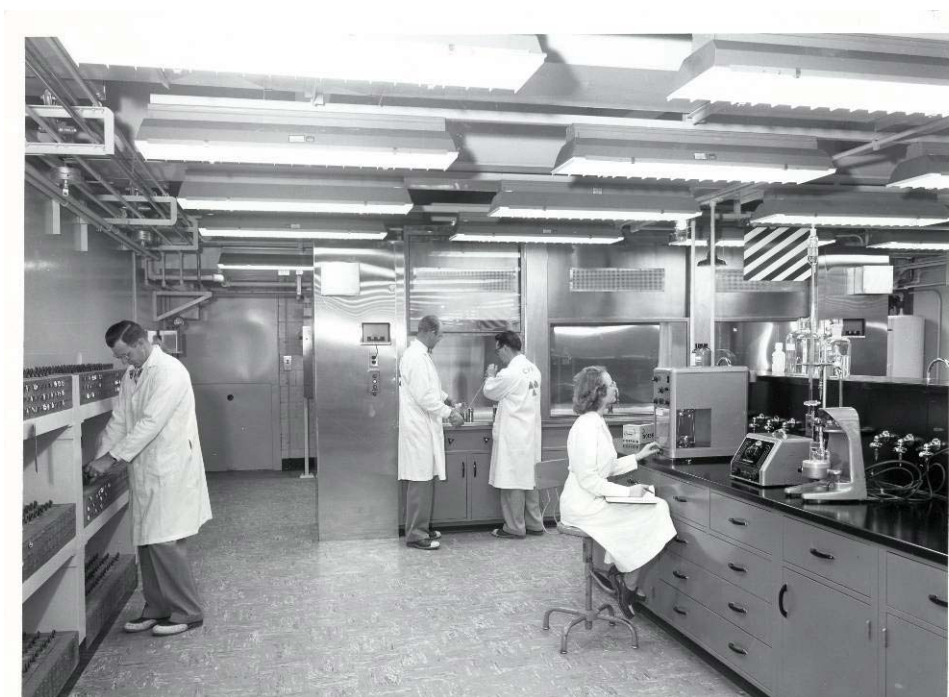
For many years the highly concentrated uranium solution was bottled and then shipped as a liquid to Oak Ridge to be further refined and manufactured into reactor fuel. After 1969, it was converted to a solid uranium trioxide before leaving ICPP using a fluidized-bed process developed and implemented at the Chem Plant. Further purification at Oak Ridge transformed the material, whether liquid or solid, into uranium that was suitable for use in a reactor. Some was eventually used to power reactors at Savannah River, but even more was simply kept in storage at Oak Ridge.

Some of the fission products present in the dissolved fuel were valuable, particularly for research. A few of these, including isotopes of neptunium and barium as



well as the gases xenon and krypton, were isolated and packaged for shipment at ICPP. Specialized facilities and equipment were necessary to accomplish this.

A variety of other processes supported the fuel reprocessing activities at ICPP, making them safe for people and the environment. The radioactive liquids that pulsed through the various stages of reprocessing were sampled constantly with remote equipment installed in the process cells. ICPP chemists and technicians (Figure 7) used shielded glove boxes installed in plant laboratories to analyze these samples and help to ensure a safe operation.



**Figure 7.** Chemists and technicians at work in the Hot Pilot Plant. *Source:* INL Photo 55-1525.

#### 4.1 Main Processes at ICPP

The ICPP was designed and/or modified over time to process four primary types of highly enriched uranium fuel.<sup>58</sup> Fuels clad in aluminum were first, followed by those clad or alloyed with zirconium. Stainless steel clad fuels were next and those alloyed

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<sup>58</sup>B. R. Wheeler, J. A. Buckham, and A. L. Ayers, "Feasibility and Economics of Commercial Operation of the Idaho Chemical Processing Plant," *PTR-754* (Idaho Falls, ID: U. S. AEC, 1965), pp. 4-7.

with graphite were last. Both batch and continuous dissolvers were employed in all four of these main headend processes, along with electrolytic and fluidized bed combustion processes developed later. For many years, a facility designed for custom processing of unique fuel types was also operated at ICPP. In all reprocessing operations, dissolution was typically followed by three cycles of liquid-liquid solvent extraction to separate the uranium from fission products and from structural and alloying material contaminants (Figure 8). In the first cycle of extraction, Hexone<sup>59</sup> was used as the solvent to extract uranium from the dissolver product.

Specially designed air-pulsers installed in the extraction columns helped to increase the efficiency of this stage. Using tributyl phosphate in a kerosene diluent as the solvent in the second and third cycles of extraction yielded an essentially pure solution of uranyl nitrate, which was shipped to Oak Ridge for further processing into fuel that could be redeployed to power a reactor. After 1969, the liquid uranyl nitrate was converted into uranium trioxide granules prior to shipment using a fluidized bed process developed and implemented at the ICPP.<sup>60</sup> Waste streams, both liquid and gaseous, were also carefully managed, monitored, and stored. Strict controls were put in place to prevent an unwanted criticality. Uranium concentrations within the processing equipment were under constant surveillance and physical limitations (small sized equipment, raschig rings<sup>61</sup>) kept many pieces of equipment safe by their geometry. For equipment that was not sized specifically to prevent an unwanted accumulation of fissile material, soluble neutron poisons were used to keep uranium concentrations in check. Workers were carefully monitored to ensure that radiation exposures did not exceed levels recommended for the time. Devices to measure radiation exposure were worn continuously and portable Geiger counters, fixed monitoring portals, and devices that could detect all types of contamination were also placed strategically throughout the plant to protect workers and prevent the spread of contamination.<sup>62</sup>

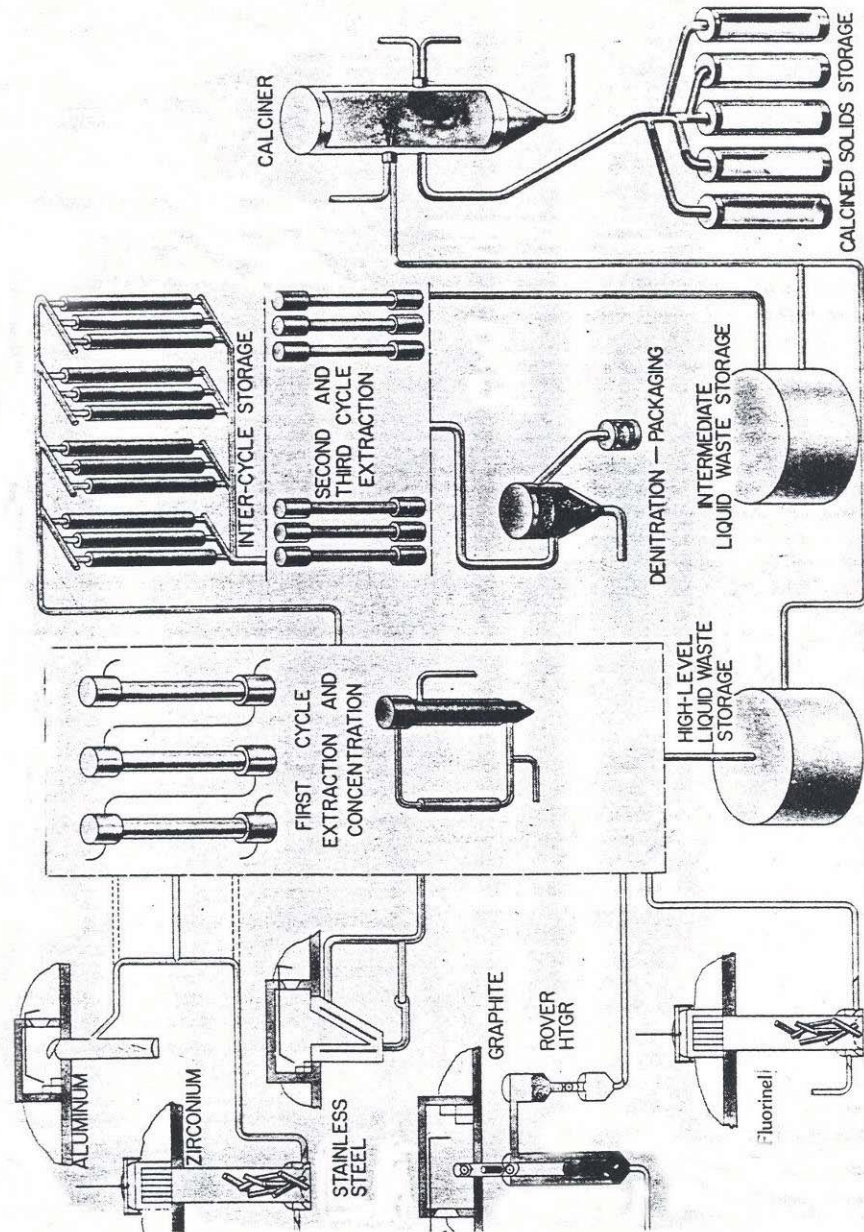
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<sup>59</sup>Hexone is a trade name for methyl isobutyl ketone

<sup>60</sup>W. J. Bjorklund and G. F. Offutt, "First Product Denitration Campaign with Enriched Uranium at ICPP," *IN-1475* (Idaho Falls, ID: U.S. AEC, 1971), p. 2.

<sup>61</sup>Raschig rings are like "napkin" rings installed inside the walls of vessels or on the floors of processing cells. They effectively increase surface area for contact with concentrated uranium solutions and prevent problematic accumulations.

<sup>62</sup>Phillips Petroleum 1955, pp. 40-42.



**Figure 8.** Simplified process flowchart for main reprocessing activities.  
*Source:* Knecht, et al. "Historical Fuel Reprocessing and High Level Waste Management in Idaho," *Radwaste Magazine* Vol. 4, 1997, p. 38.

The first reprocessing technique developed at ICPP was a batch process developed for fuels clad or packaged in aluminum. Stainless steel vessels contained the nitric acid solution that dissolved these types of fuel. Hanford supplied the first uranium slugs to be sent through the process in 1953. However, most of the next batch, plates of aluminum-clad aluminum-uranium alloy contained in an aluminum box assembly, came from the Materials Test Reactor, only a few miles away. They were also processed in 1953. Nearly pure uranium slugs and aluminum tubing from nearby Experimental Breeder Reactor-I were also processed through the batch aluminum processing equipment at ICPP in 1955. Approximately 2,740 kilograms (kg) of uranium were recovered during batch processing of aluminum clad and alloyed uranium at ICPP.

From 1955 on, aluminum clad fuels were processed through continuous dissolvers, which increased output significantly. The tall slim dissolver vessel used for this process was also constructed of stainless steel, which was able to withstand the caustic solution of near-boiling nitric acid and various catalysts that dissolved the uranium and its metal constituents.<sup>63</sup> Fuel elements were charged into the continuous dissolvers from a cave in the Process Makeup area of CPP-601. The cave was equipped with a viewing window and a remote manipulator which operators used to feed the fuel elements, one at a time, down a chute to the dissolver vessel. Fuels from many different university and test reactors from all over the world were processed using the continuous aluminum dissolution process at ICPP, resulting in the recovery of approximately 12,896 kg of uranium. At the time fuel reprocessing was halted at the Idaho Chemical Processing Plant, the continuous aluminum dissolution process was primed and ready for ongoing work.

The zirconium used to clad fuels used by the U.S. Navy in nuclear submarines was very resistant to dissolution. This tough material was insoluble in nitric and hydrochloric acids and was only marginally affected by sulfuric acid. Only hydrofluoric acid could penetrate it effectively,<sup>64</sup> but this extremely caustic reagent also attacked the stainless steel equipment and piping that was used throughout the Chem Plant. Consequently, zirconium dissolver vessels were made of Monel<sup>65</sup> and carbon steel tanks

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<sup>63</sup>A. F. Boeglin, J. A. Buckham, L. Chajson, R. B. Lemon, and D. M. Paige, "The Nitric Acid Dissolution of Uranium-Aluminum Alloy in a Flooded Continuous Dissolver," *IDO-14321* (Idaho Falls, ID: U. S. AEC, 1954), pp. 8-11.

<sup>64</sup>D. G. Reid, C. E. Stevenson, R. B. Lemon, and F. K. Wrigley, "Reprocessing of Fuel Containing Zirconium," in "Proceedings of the Second International Conference on Peaceful Uses of Atomic Energy", Geneva, Switzerland, September 1958, *Volume 17*. (Geneva, Switzerland: International AEC, 1958), p. 154.

<sup>65</sup>Monel is an alloy of nickel, copper, iron, manganese, silicon, and carbon.

for storing the acid were lined with rubber. Only 68 kg of uranium were recovered from batch processing of zirconium alloys at ICPP from 1956 to 1965. During one of the batch processing runs in 1957-1958, approximately 15 kg were obtained through reprocessing of the fuel elements that propelled the world's first nuclear submarine, the Nautilus, for nearly 62,500 miles.

A system for batch processing of fuels clad in stainless steel was also developed early in ICPP's processing history. Beginning in 1956, fuels from government reactors were put through a sequence that started with sulfuric acid as a dissolvent. Since stainless steel was also prone to corrosion from sulfuric acid, Carpenter-20<sup>66</sup> was selected for construction of the dissolver vessel. The uranium in the fuel elements remained undissolved in the sulfuric acid, necessitating a second stage of dissolution where nitric acid was added to dissolve the uranium and to inhibit corrosion of stainless steel piping and equipment during later cycles of solvent extraction. The first civilian fuel reprocessed at ICPP from the Vallecitos Boiling Water Reactor in California passed through the stainless-steel batch process in 1965. A total of approximately 136 kg of uranium was recovered between 1956 and 1970.

In 1965, significant advances were made in the development of processing technology for zirconium-uranium alloy fuels. For the first time ever, these highly resistant fuel elements were processed semi-continuously using a soluble neutron poison (boron) for primary criticality control.<sup>67</sup> With the neutron-absorbing boron added to the solution,<sup>68</sup> very large amounts of fuel could be charged to the original bell-shaped dissolver, up to 600 kg at a time, and processing rates were up to ten times greater than those achieved during previous zirconium batch processing campaigns. In 1978, a new dissolver was installed and its annular design increased the capacity of the process by another 25 percent. To reduce the corrosive nature of the liquid produced by hydrofluoric acid in the semi-continuous zirconium headend, the solution was sent through a second stage of dissolution where aluminum nitrate and chromic acid were added. Uranyl nitrate was the end product. Eventually, the process would be modified slightly to reduce the amount of waste produced by the plant as a whole. Instead of

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<sup>66</sup>Carpenter-20 is a stainless steel alloy of nickel and chromium with small amounts of copper and molybdenum.

<sup>67</sup>J. R. Bower, "Zirconium Processing Capability of the Idaho Chemical Processing Plant," *IDO-14645*, (Idaho Falls, ID: U. S. AEC, 1964), p. 8.

<sup>68</sup>G. F. Offutt, and B.R. Wheeler "First Zirconium Alloyed Fuel Reprocessing Campaign Using Soluble Nuclear Poison," *IN-1021* (Idaho Falls, ID: U.S. AEC, 1968), p. 19.

adding fresh aluminum nitrate to the zirconium dissolver product, aluminum nitrate output from the continuous aluminum dissolver would be recycled to the zirconium process. The uranyl nitrate that resulted from this coprocessing could then be recombined with the product from the aluminum headend for solvent extraction and uranium purification.<sup>69</sup> Semicontinuous zirconium dissolution with soluble neutron poison was a productive headend at ICPP, resulting in the recovery of approximately 3,789 kg of uranium from 1965 to 1986.

Plant modifications made in 1973 added processing capability for stainless steel fuel elements using an electrolytic dissolution process.<sup>70</sup> In this headend, fuel elements were placed in a nitric acid-flooded electrically inert niobium basket between a titanium cathode and a platinum anode. Under a direct current, the stainless steel became anodic, dissolved in the acid, and was transformed into a solution that was compatible with subsequent solvent extraction and uranium purification processes. Gadolinium, another nuclear poison, was added to ensure that process was critically safe. All of the equipment used for electrolytic dissolution was located in CPP-640, then known as the Hot Pilot Plant. However, solutions from the electrolytic dissolver were still sent next door, to the CPP-601 processing cells, for solvent extraction and final isolation of the uranium. The total quantity of uranium recovered using electrolytic dissolution of stainless steel clad fuel was 5,900 kg. The use of this headend in CPP-640 ended in 1981.

From 1978 to 1983, a portion of the Hot Pilot Plant, CPP-640, was modified to support headend processing of graphite-based fuel.<sup>71</sup> Soon the name of the building was changed to the Headend Process Plant. Much of the fuel for this work came from a joint AEC and National Aeronautic and Space Administration project, named Rover, to develop a nuclear powered rocket. When the project was abandoned, fuel was sent to ICPP for processing. The dissolution process for this graphite-matrixed fuel used two hot fluidized beds of alumina particles to convert the fuel elements into gaseous combustion products and a uranium and niobium bearing ash. Ash was collected, weighed, and then sent to a specialized plastic dissolver, where it was dissolved in a mix of hydrofluoric

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<sup>69</sup>G. F. Offutt and H. S. Cole, "Run Report of First Campaign of Co-Processing Aluminum and Zirconium Fuel at ICPP," *IN-1472* (Idaho Falls, ID: U.S. AEC, 1971), p. 5.

<sup>70</sup>G. F. Offutt, R. D. Modrow, and R. A. Brown, "Design Criteria for ICPP Electrolytic Dissolution Process," *CI-1095*, (Idaho Falls, ID: U. S. AEC, 1968), p.iii.

<sup>71</sup>A. P. Roeh, G. W. Hogg, L. C. Borduin, P. E. LaMont, and J. A. Rindfleisch,, "Design Criteria for Rover Fuels Processing Facility," *ACI-128* (Idaho Falls, ID: U. S. AEC, 1972), pp. 4-10.

acid and nitric acid. The resulting uranium-rich solution was sent to CPP-601 to go through the standard uranium separation cycles. Though it only operated for a relatively short time, the graphite combustion process worked quite well; approximately 3,000 kg of uranium were recovered.<sup>72</sup>

After 1986, the zirconium dissolution equipment in CPP-601 was idled by development of a new three-step dissolution process, called fluorinel dissolution. This move to a new process was prompted by U.S. Navy adoption of a new generation of tough zircaloy<sup>73</sup> fuel elements that proved to be too much for the Monel dissolver traditionally used for zirconium-based fuels. In the fluorinel dissolution process headend, the zircaloy fuel elements were dissolved in three steps using hydrofluoric and nitric acids with aluminum nitrate as a complexing agent. A fourth step dissolved the stainless steel elements in the fuel in sulfuric acid. Cadmium, a strong neutron absorber, was employed throughout the process for criticality control. An entirely new structure, CPP-666, was built to house this new headend process.<sup>74</sup> However, dissolver solutions from this process continued to be sent back to CPP-601 for solvent extraction and uranium purification; that is, until 1992, when all fuel reprocessing was halted.

#### 4.2 Custom Processing

From 1958 to 1991, custom processing also took place within the Hot Chemical Laboratory and the Multi Curie Cell, both located in the Remote Analytical Facility, CPP-627.<sup>75</sup> The dissolvers and equipment installed there were used to process small to moderate quantities of fissile material from fuels that could not be processed by conventional facilities and equipment. Many of them came from experimental reactors at the NRTS, including gravel-bearing fuel from the Stationary Lowpower I reactor and sodium-contaminated scrap from the EBR-I meltdown core. Other problem-type materials that were processed included Vycor glass from the Experimental Breeder Reactor-II Fuel Cutting Facility, sand and gravel contaminated fuel from an explosive test associated with the Systems for Nuclear Auxilliary Power (SNAP) project, and

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<sup>72</sup>D. B. Schanz, "Final Report for the CPP-640 Rover Facility Material Handling Cave and Cells 3 and 4 Uranium Recovery and Deactivation," *INEEL/EXT-98-00262* (Idaho Falls, ID; U.S. DOE-ID, 1998), p.1.

<sup>73</sup>Zircaloy is an alloy of zirconium and stainless steel often used by the U.S. Navy.

<sup>74</sup>Thumbnail Sketch 1979, p. 29.

<sup>75</sup>Knecht et al. 1997, pp. 35-44; Also, Wagner 1999.

aluminum alloyed fuel that was coated with a polyethelene.<sup>76</sup> In all, 1,329 kg of uranium were recovered from unique fuels such as these. In 1991, the final custom processing campaign was terminated when a small explosion occurred in one of the two custom dissolver vessels, spreading contaminated solution throughout much of the Hot Chemical Lab. Decontamination followed but the facility was never used again.

### 4.3 Isotope Recovery

The radioactive isotopes that contaminate spent reactor fuel are not only a nuisance but also a source of valuable products. At ICPP several were isolated during the fuel reprocessing operation and shipped to other laboratories for use in research and weapons production. In CPP-601, two specialized processes were developed to isolate neptunium-237, an isotope formed in uranium fuel by neutron absorption and beta decay, and lanthanum-140, a short-lived product of the radioactive decay of barium-140. At the Rare Gas Plant in CPP-604, dissolver off-gasses were filtered to recover two inert gases, krypton-85 and xenon-133. For possible future needs, the unique storage bins which house calcined waste were also designed to permit removal of materials for leaching out of valuable isotopes such as these.

For most of ICPP's processing history, the small amounts of neptunium and plutonium present in plant dissolver products were sent, with other fission products as waste, to the Tank Farm. But from 1965 to 1972, the first cycle extraction raffinate streams that contained these isotopes were resubmitted to the first cycle extraction equipment along with chromic and nitric acids, which reoxidized the neptunium so that extraction could eventually take place. For seven years, these neptunium-plutonium bearing solutions were stored in tanks in CPP-601 (N-Cell), awaiting a final processing run. Then, in 1972, an increased demand for neptunium combined with an immediate need for more storage space in N-Cell, drove a three-week campaign to recover them.<sup>77</sup> A further cycle of extraction with careful control of the tributyl phosphate concentration separated the neptunium and plutonium from the remaining fission products. The product solution that resulted, containing 5,412 grams of neptunium and 544 grams of plutonium, was pumped from the CPP-601 processing equipment to a temporary packaging facility in the CPP-627 Multi-Curie Cell. Here it was bottled, packaged, and

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<sup>76</sup>B. R. Wheeler, R. D. Modrow, A. L. Ayers, and J. A. Buckham, "Multiple Fuels Processing Program at ICPP," *CI-1046* (Idaho Falls, ID: U. S. AEC, 1967), p. 17.

<sup>77</sup>J. E. Johnson, L. C. Lewis, M. E. Jacobson, and M. K. Valentine, "First Neptunium Processing Campaign at ICPP," *ICP-1019*, (Idaho Falls, ID: U. S. AEC, 1973), pp. 2 and 7.



shipped in specialized containers to the Savannah River site for further purification and ultimate conversion to plutonium-238, a valuable isotopic heat source.

Lanthanum-140 is produced when barium-140 undergoes radioactive decay. Recovery of lanthanum-140 was a complicated process completed in a specialized processing cell, L-Cell, in CPP-601<sup>78</sup> (Figure 9). Complications during the process were due in large part to the extremely high radioactivity present in the fuel elements. The short-lived barium isotopes were present in irradiated fuel removed from the Materials Test Reactor (MTR), but they decayed rapidly after being removed from the reactor core. After about forty days, they were gone. To isolate these short-lived products, fuel elements were processed immediately after being removed from the MTR. These intensely radioactive fuel elements were placed in a hot sodium hydroxide solution that dissolved the aluminum cladding, leaving the barium and other fission products as solids. This combination, or *slurry* of solids and liquids, somewhat akin to a mixture of mud and water, was sent to one of two centrifuges where the whirling motion drove the barium with other solids to the wall of the bowl and the clear liquid, with its dissolved metal, to the center where it could be skimmed off. Successive dissolution with other reagents, centrifuging and skimming, left barium nitrate only on the wall of the centrifuge bowl. It was then dissolved in water so that it could be moved to a product cup by skimming. Here it was evaporated to dryness. The cup was placed in a shielded shipping container with lead thick enough to contain the tens of thousands of curies of radiation from the tiny source (a gram or so). This product was shipped to other AEC labs for specialized uses requiring high radioactivity and rapid decay.

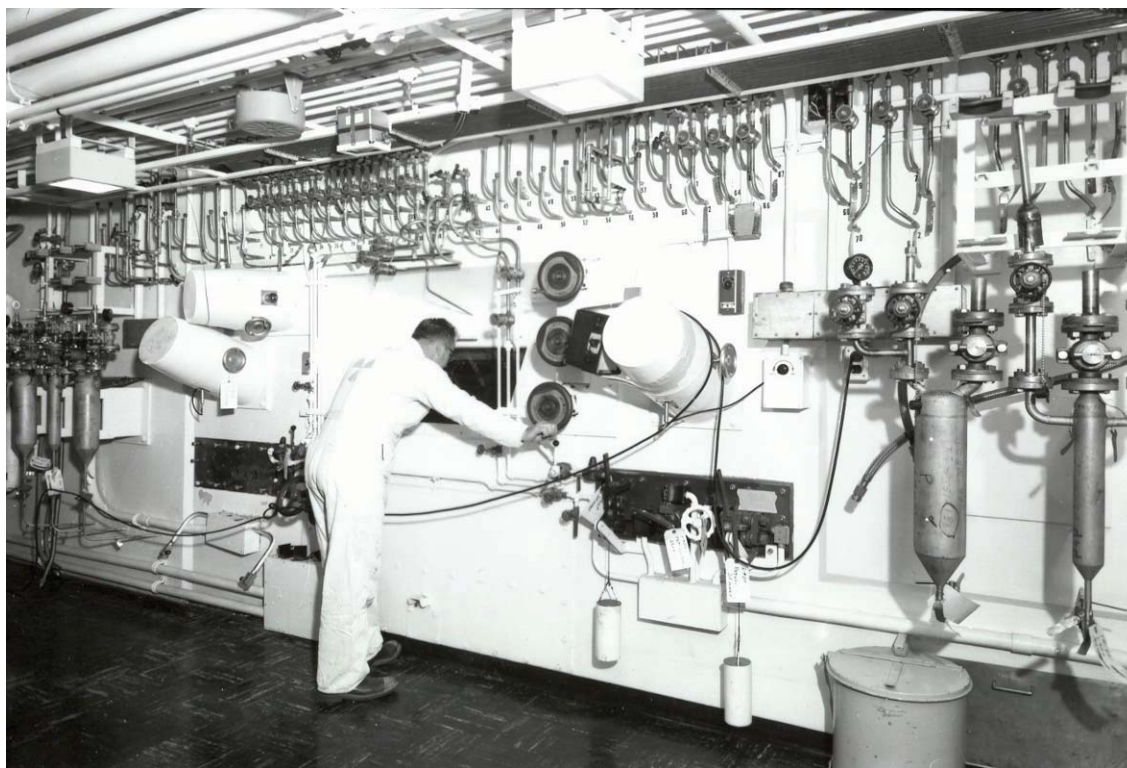
Isotopes of krypton and xenon were recovered at the ICPP from off-gas produced in the aluminum-clad fuel dissolver.<sup>79</sup> The recovery took place in specialized equipment in the Rare Gas Plant within the waste disposal building, CPP-604. Here the off-gas was first passed through catalytic converters, then at high temperature and in the presence of rhodium, the nitrogen oxides in the off-gas were converted to nitrogen and water. Next the gas stream was passed through a rectification column where it met a counter flow of liquid nitrogen. The heavier gases, including the krypton and xenon, settled to the bottom of the column where they were condensed and collected. Column bottoms were withdrawn periodically to a batch still, where fractional distillation completed the

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<sup>78</sup>D. L. Smith. and J. G. Scott, "Final Report Decontamination and Decommissioning of CPP-601 Process Cells A, B, C, D, and L," *EGG-2304*, (Idaho Falls, ID: U. S. DOE-ID, 1984), p. 14.

<sup>79</sup>A. L. Ayers, W. B. Lewis, and C. E. Stevenson, "Production of High Specific Activity Radioisotopes," in *Proceedings of the Second International Conference on Peaceful Uses of Atomic Energy, Volume 20*; (Geneva, Switzerland: International AEC, September 1958), p. 37.

separation of gases. High-pressure pumps were used to move the gases to shipping containers. Because of their chemical inertness, these gases were especially useful as radioactive tracers for leak detection in pipelines.



**Figure 9.** Operating face of L-Cell in the Main Processing Building. *Source:* INL Photo 56-2097.

#### 4.4 The ICPP Fuel Reprocessing Complex

Externally, the buildings that make up the ICPP Fuel Reprocessing Complex (CPP-601, CPP-603, CPP-627, CPP-640) are rather unremarkable. All are utilitarian in construction and materials. But the relative austerity of the plant was intentional and derived largely from a limited initial construction budget, an aggressive construction schedule, and a very practical and functional government-wide approach to construction activities in general. In contrast, the interiors of these buildings are exceedingly complex and when in use, they were also in a fairly constant state of evolution due to mission changes, ongoing research, safety, and decontamination activities. Descriptions of the main buildings within the Fuel Reprocessing Complex are included in the sections to follow.

#### 4.4.1 CPP-603: The Fuel Storage Building

The safety and security concerns which dictated placement of the Fuel Storage Building, CPP-603, one-third mile away from the Main Processing Building and other analytical facilities probably also entered into the decision to install systems that made the building nearly self-contained within the remainder of the Chem Plant. Heat and power were supplied by internal systems separate from the main processing area and although water was obtained from the main plant source, it was metered, filtered, and recirculated by equipment housed within the building. An auxiliary generator was installed to power these systems in the event of an emergency.

The building itself is constructed of structural steel covered with Transite, the trade name for a fireproof construction material comprised of asbestos fibers and Portland cement molded under high pressure. This superstructure covers a series of interconnected underground basins, canals, and pools, all made of concrete and designed to hold millions of gallons of water for shielding. The original structure was F-shaped (Figure 10) and occupied approximately 26,851 square feet. The building was designed to receive fuel elements in a main crane bay via a 15-ton crane. A long transfer canal paralleled the crane bay and branching off from here were two basins where the fuel was stored. The two storage basins, designated north and middle,<sup>80</sup> were each 40' wide x 60' long x 21' deep and covered with metal grating. Concrete spacers divided each into twenty-nine separate channels. Stainless steel buckets of fuel in storage were suspended in the channels between the spacers by bucket yokes, which rode on overhead monorails. The two basins provided storage for about one thousand buckets which could hold as many as four thousand separate fuel elements, depending on overall size and criticality considerations. At least 15' of water covered all radioactive materials that were handled outside of the lead casks used for transportation.<sup>81</sup>

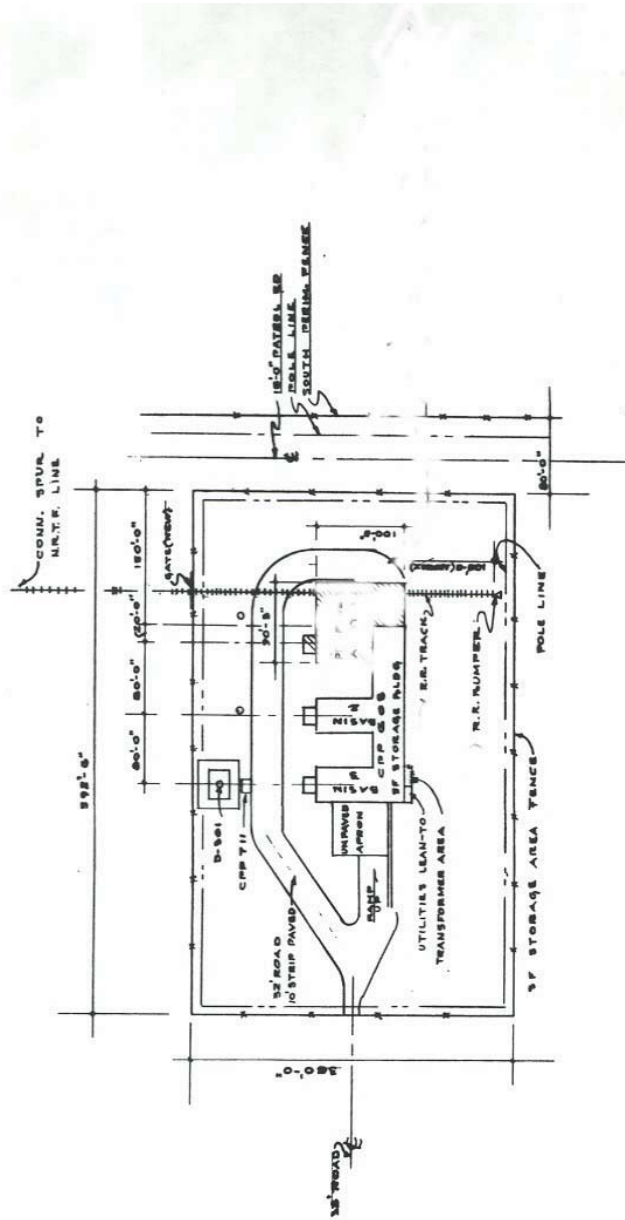
In 1957 and 1958, CPP-603 was expanded in response to planned shipments of fuel elements from the Savannah River site. These fuels were too large to store and process within existing facilities and equipment. The new 137' x 90' "Fuel Element Cutting Facility"<sup>82</sup> added to CPP-603 at this time created an E-shaped structure that

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<sup>80</sup>Original plans called for construction of a third, "south," basin but it was deemed unnecessary for the operation and never completed. Later in 1958, the foundation for this third basin would be re-excavated and used for the Fuel Element Cutting Facility expansion.

<sup>81</sup>Ayers and Leek, pp. 99-101.

<sup>82</sup>Ayers and Leek, p. 106.



**Figure 10.** ca. 1965 plan view of CPP-603, Fuel Storage Building. *Source:* INL Drawing 1287.

housed a large crane bay serviced by two cranes (75 ton and 15 ton), a new storage basin that was 21' x 40' x 80' in size, and a hot cell that was 31' x 10' x 14' with concrete walls five feet thick and four windows for viewing remote operations. Large fuel elements in casks weighing up to 75 tons were received in this facility via truck or rail and then unloaded into the transfer basin where they could be removed. Once the fuel elements were free of their shielded casks, operators used a 3,000 pound transfer crane, complete with a riding car, to place them in cadmium-poisoned<sup>83</sup> storage racks which could then be moved into the new storage basin. Oversized pieces were delivered to the new hot cell where operators used hydraulically operated saws and other equipment to mechanically alter their shapes and make them suitable for storage and reprocessing at ICPP.<sup>84</sup>

The water in all three of the storage basins and associated interconnecting canals and transfer pools in CPP-603, totaling about 1.5 million gallons, was treated with sodium nitrate to inhibit corrosion of fuel elements and chlorine to control the growth of microorganisms. It was also recirculated at the rate of 400 gallons per minute through filters to maintain clarity and could be recycled through ion exchange vessels to remove fission products that may have entered the water from fuel elements with ruptured cladding.

In 1974, as the Chem Plant began to experiment with, and ultimately begin production-level processing of, graphite-based fuel elements, facilities for dry storage were added to CPP-603. These additions were necessary because the graphite fuel elements reacted violently if exposed to water and thus could not be stored in any of the existing underwater basins. Called the "Irradiated Fuels Storage Facility,"<sup>85</sup> this was the first dry storage facility designed, built, and actively used in the U.S. Initially, the facility consisted of forty-seven underground vaults, 3' x 20', lined with stainless steel, and capped with removable heavy concrete covers.<sup>86</sup> In 1975, another building was added to

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<sup>83</sup>Cadmium is a strong neutron absorber that prevents uranium from achieving a criticality.

<sup>84</sup>Wheeler, et al., p. 28.

<sup>85</sup>W.J. Venable, "Design Criteria for ICPP-603 Fuel Storage Basin Modifications," *ACI-140*. (Idaho Falls: Atomic Energy Commission, 1973), p. 5.

<sup>86</sup>1973 Thumbnail Sketch, p. 17.

handle more shipments of graphite fuels. At that time, all of the dry storage facilities at CPP-603 were scheduled for increased and ongoing use,<sup>87</sup> while the underwater storage facilities were destined for eventual decontamination and decommissioning.

#### 4.4.2 CPP-601: The Main Processing Building

The main processing building, CPP-601, which housed the bulk of the processing equipment and controls, is a simple-looking structure with extensive below ground facilities.<sup>88</sup> It is rectangular in shape, approximately 244' x 102', and more than 95' tall. It extends from a maximum of 57' 6" below grade to nearly 38' above grade at the peak of the roof. Nearly 30% of the building consists of thick steel reinforced concrete walls for shielding and structural purposes. Architecturally it consists of two levels; the lowest level has four stories and is constructed of steel reinforced concrete, while the upper, above ground level includes a single story constructed of Transite and structural steel. Figure 11 is an elevation view of the building.

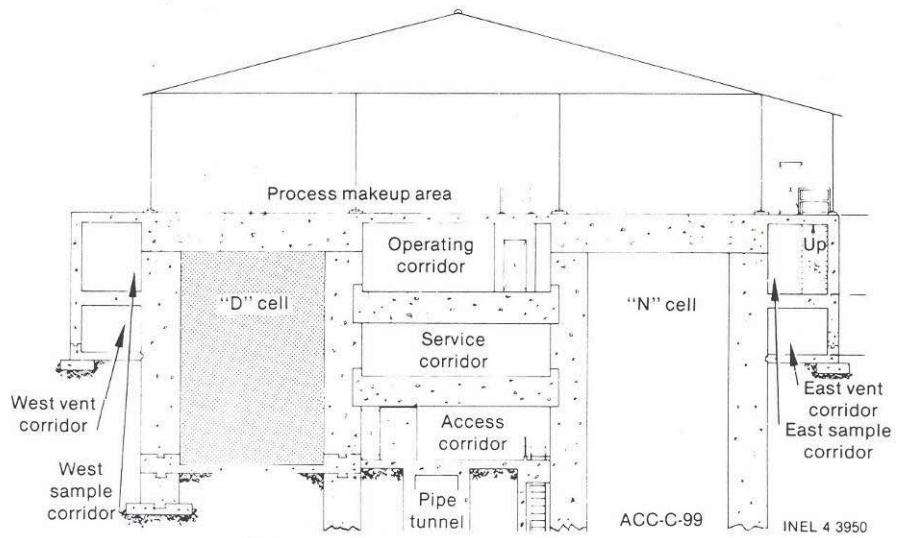
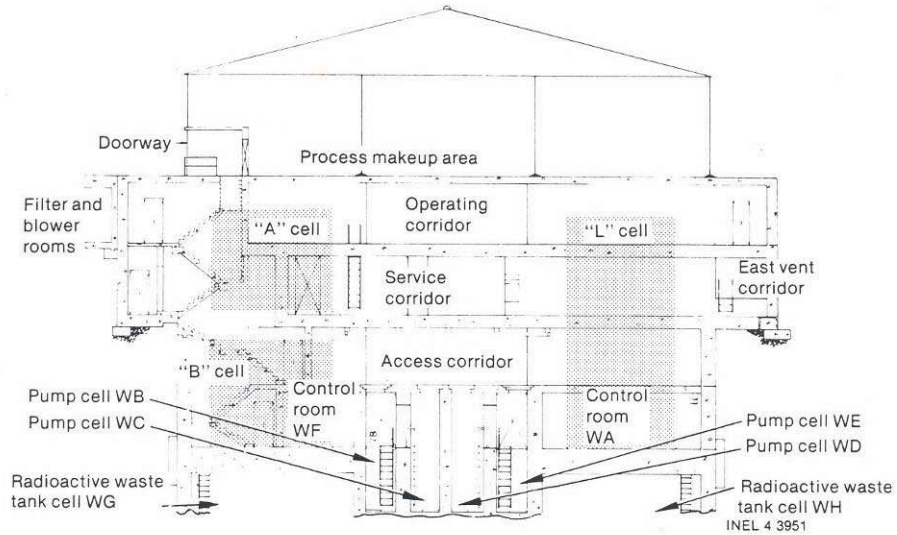
The top story of the building was an unpartitioned space for storage and makeup of chemical solutions and transfer of fuel elements to the processing equipment below; it was known as the Process Makeup Area. High bay doors on the south side led to a wide ramp for vehicle access. Many tanks were located there along with charging chutes and caves for introducing fuel elements into the cells below. Hatches to many cells also opened in this area, providing access for equipment installation, maintenance, or removal. Two cranes facilitated these activities. When direct maintenance was necessary, plant workers entered the cells through doors at the floor level of each processing cell many feet below. Below the Process Makeup Area, CPP-601 was divided into a number of corridors and twenty-four cells as shown in further detail in Figure 12.

The cells were arranged in two parallel rows with Operating, Service, and Access corridors extending down the middle. All of the equipment for the actual processing of spent fuel elements was contained in these two rows of shielded cells, all uniquely identified by alphabetic designators. Rooms housing vacuum equipment, pumps, and tanks were also called cells, though they were usually not given alphabetic designations. Each cell had an average floor area of 400 square feet, an average height of 28', and floors and walls lined with stainless steel. Thick concrete walls, ranging from two to five feet thick, provided shielding. At the Operating Corridor level, these thick walls were

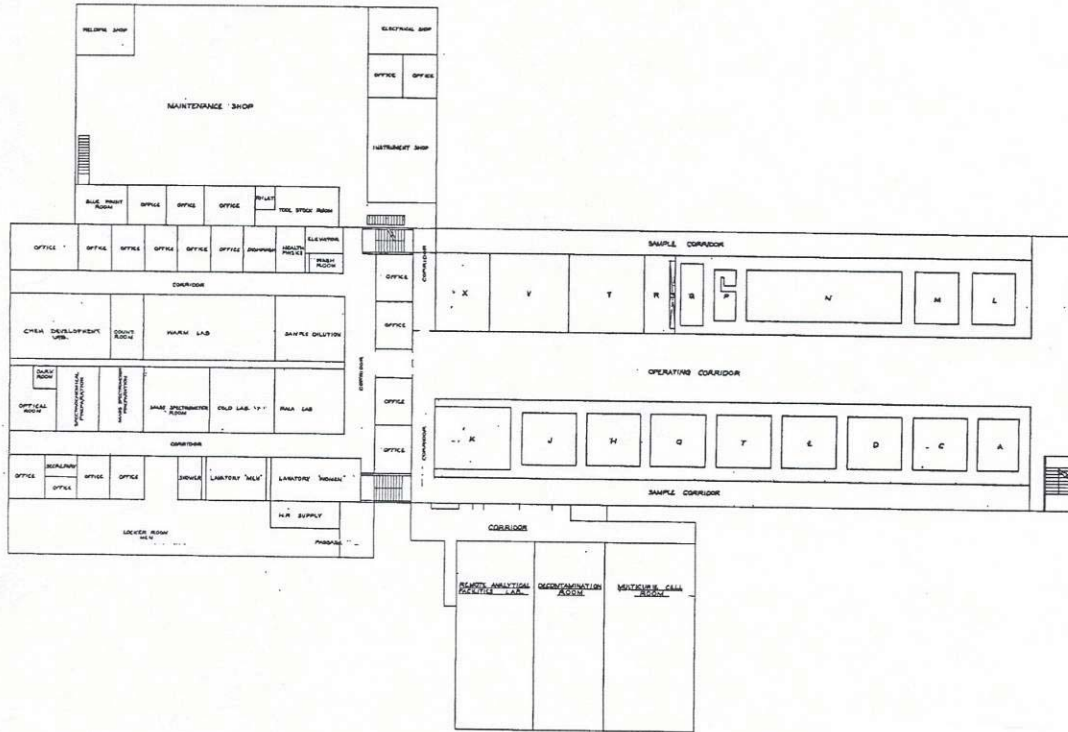
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<sup>87</sup>M.W. Patterson, "Nuclear Fuel Reprocessing Deactivation Plan for the Idaho Chemical Processing Plant," *INEL-94/0165* (Idaho Falls: U.S. Department of Energy, 1994), p. 84.

<sup>88</sup>Patterson, p. 11.



**Figure 11.** Elevation view of the Main Fuel Processing Building, CPP-601.  
 Source: Smith and Scott. Final Report Decontamination and Decommissioning of CPP-601 Process Cells A, B, C, D, and L, Idaho Falls, ID: EG&G Inc. Report No. EGG-2304, 1984, p. 5.



**Figure 12.** Plot Plan of the Main Processing Building, CPP601, at Operating Corridor Level. *Source:* INL Drawing 51979.

honeycombed with offset pipe sleeves for entrance and exit of utility, process, and instrumentation lines. Most of the equipment within the cells was constructed of stainless steel or other acid-resistant materials. Only one cell, L-Cell, was equipped with a viewing window, the remainder of the equipment was not visible during operation. Equipment in the cells could be reached and moved with large cranes through hatch openings in the ceilings but plant workers could only enter through doors installed in the Access Corridor three floors below ground.

Each of the shielded cells housed equipment necessary for performing various steps in the reprocessing cycle. Though the basic footprint of the building and each cell within has remained basically the same since initial construction in the 1950s, the equipment housed within has been in a constant state of evolution. Maintenance, decontamination, safety upgrades, and experimentation leading to new processes have all left their mark on the contents of the cells. Further detail and an abbreviated summary of the major activities that were conducted in each cell can be found in Appendix B as well as the drawings and photographs that accompany this report.



Most of the process equipment within the cells was controlled from an Operating Corridor that ran the length of the building between the two rows of cells in the first story below ground. A double row of instrument panels arranged back to back was installed in the center of this gallery (Figure 13). From here, operators could monitor the workings of the cells below and control the flow of solutions into and out of the processing cells. Diagrams and chemical flowsheets<sup>89</sup> that illustrated all of the main processes conducted in the plant were posted here to guide the operators when necessary. Service lines for water, steam, and condensate also entered the cells at the Operating Corridor level. Directly beneath the centralized Operating Corridor were the Service and Access Corridors (second and third stories, respectively). Sampling corridors ran along the outside of each cell row along with cell exhaust ventilation ducts and off-gas treatment systems.



**Figure 13.** Main Processing Building, CPP-601, Operating Corridor. *Source:* INL Photo 55-1719.

The Sampling Corridors in CPP-601 ran along the outside of each bank of processing cells on the same level as the Operating Corridor (ground level). Because the dissolution and extraction processes relied on specific chemical inputs, sampling was an important part of process control for the plant, ensuring that the end product was as pure as possible and preventing formation of troublesome solids or chemical ions that might clog the equipment or otherwise cause a plant shutdown. Sampling was also very important for accurate accounting of the fissionable material present in the plant at any one time. In the Sampling Corridor, samplers for several cells were grouped so that a continuous 4.5” lead shield and a single set of handling tongs could be used. The remote sampling operation could be viewed through a lead glass window located directly in front of the sampling device.<sup>90</sup> Once drawn, the sample bottles were placed in lead carriers and manually transported to the Remote Analytical Facility, CPP-627, for analysis. In the mid-1980s, continuing problems with contamination in the Sampling Corridor prompted the installation of new individual samplers in many of the process cells,

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<sup>89</sup>Simple examples of chemical flowsheets developed at ICPP are included in Appendix B.

<sup>90</sup>“Chemical Processing of Reactor Fuel Elements at the Idaho Chemical Processing Plant”, pp. 15 and 30.

complete with a pneumatic transfer system to the new Remote Analytical Laboratory (CPP-684). At this time the older samplers were largely abandoned.

The Service Corridor that runs the length of CPP-601, directly beneath the Operating Corridor, is the first basement story of the structure. Its position reinforces the division of the processing area into two parallel cell banks. Four-foot thick floors and ceilings, used to shield workers, make the Service Corridor seem like a long cell running the length of the building. These shielding precautions were taken because nearly all of the pipes that carried "hot" radioactive solutions between processing cells were located here. Ventilation tunnels also ran the length of this level along the outside of the cell rows. Air from the processing cells and Sample Corridor was exhausted through these tunnels and then ultimately delivered to the main stack for discharge. The ventilation system provided twenty air changes per hour to the process cells primarily to sweep out any potentially explosive solvent vapors that might have accumulated there. Negative pressure, maintained in all of the processing areas, effectively ensured that radioactive contamination did not spread into the ventilation system. Vapors directly from the processing equipment, which could have contained radioactivity, were collected in special piping systems in the ventilation tunnels and then delivered to CPP-604 for filtration through off-gas systems.

The Access Corridor located in the third level below ground in CPP-601 contained the doorways that workers used to gain entry to the interiors of all of the processing cells. This corridor also served as a fresh air intake for the plant. Fresh air was pulled into the processing cells through louvers in the doors. When these doors were opened for entry of decontamination, maintenance, and/or construction workers, the negative pressure maintained within was reduced. Temporary tents were often placed at the entrance to cells that were to be opened to help control airflow and reduce the spread of contamination outside the shielded cell walls. Labyrinth corridors were also constructed at the entrance to each cell and around some of the pumps and other equipment located outside of the cells to prevent any direct shine of radiation out into the Access Corridor.<sup>91</sup>

There are literally miles and miles of piping in CPP-601. However, this complex maze kept the facility running by supplying acid here, solvent there, air lifting samples for analysis, spraying special solutions for decontamination, jetting liquid waste to storage, and pumping concentrated uranium from one stage to another until it was ready to be placed in containers for shipping. One of the most important networks of piping in

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<sup>91</sup>Labyrinth corridors consisted of nonstructural concrete walls with one or more right angles. Like light, radioactivity does not turn corners, so these maze-like constructs were very effective in trapping radiation and preventing it from spreading.

CPP-601 was known as the Process Equipment Waste system, which accepted wastes from process equipment and cell floors and fed it into waste collection tanks located in the deepest level of the building. Early on, any solutions spilled on the floors of the cells also drained to these tanks. However, this eventually created a criticality problem, necessitating the rerouting of these direct lines. The samplers that helped to identify this criticality problem in the deep tanks along with those which served the processing cells, were never automated. Workers had to transport them by hand from the deepest part of CPP-601 to the ground floor of one of the analytical facilities nearby (CPP-627 or CPP-684).<sup>92</sup>

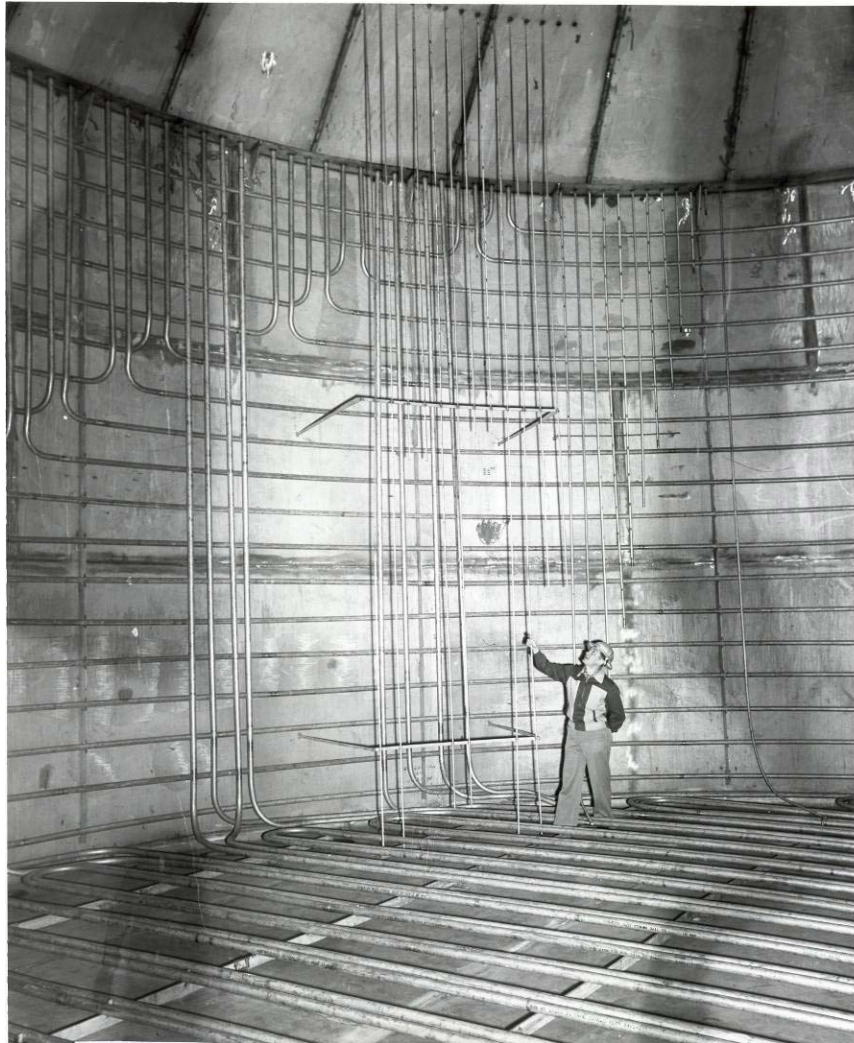
Every kilogram of purified uranium produced at the ICPP created on average over one hundred gallons of acidic liquid radioactive waste that had to be safely stored. These raffinates were maintained in an acidic solution and stored in a series of stainless steel tanks constructed at the Tank Farm. Initially only two 300,000 gallon tanks were located there but eventually nine more of these large vessels were constructed along with the four smaller 30,000 gallon tanks. The large tanks stood 21' tall at the eaves, 50' in diameter, were made of stainless steel, and were enclosed in concrete-lined vaults. More than half of them were equipped with cooling coils necessary to safely store intensely radioactive solutions (Figure 14).

The decision to store the raffinates in an acidic solution at the ICPP contrasts with decisions made at other fuel reprocessing plants like those at Hanford and Savannah River. At these sites the solutions were neutralized so that they could be stored in carbon steel tanks, which were considerably less expensive to build. However, the neutralization process significantly increased the volume of material that needed to be stored and as a result, these other sites are now responsible for 100 to 200 tanks of waste while the Chem Plant has less than a dozen. ICPP process engineers were always searching for new ways to reduce the amount of waste produced by the Chem Plant and incorporate waste treatment into the fuel recovery process. For instance, commonly used process chemicals such as Hexone were recycled again and again. When possible, cladding was physically removed prior to dissolution, making the dissolution process easier and requiring fewer chemical inputs to separate out the uranium. When co-processing aluminum and zirconium was developed, product streams from two processes were combined, eliminating the need for addition of fresh process chemicals. Development of the waste calcining process also significantly reduced the amount of waste stored at the ICPP. By converting liquids stored in the Tank Farm to solids that were much easier to handle and

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<sup>92</sup>This manual transfer of the radioactively “hot” and heavy lead containers was often no small task. Ed Wagner (interview 7/1/99) recalls that workers sometimes used a “backstair relay” to share the burden and keep individual exposures down as samples were moved to the laboratory.

retrieve if necessary, volume could be reduced by more than nine-fold and long-term storage became less difficult.



**Figure 14.** Tank Farm 300,000-gallon liquid waste storage tank with cooling coils.  
*Source:* INL Photo 55-1261.

#### 4.4.3 CPP-627: The Remote Analytical Facility

The Remote Analytical Facility, CPP-627, was home to a variety of customized dissolution processes, but it also filled an important analytical role for the plant. The building was constructed in 1955 to house analytical, experimental, and decontamination

facilities.<sup>93</sup> The analytical portion of the building, located at the ground floor, consisted of thirty-two shielded glove boxes, each measuring about one meter square, and arranged in a row much like the operating corridor in CPP-601 (Figure 15). Viewing windows and manipulators in these boxes allowed for remote sample preparation and analysis.

A remotely operated dolly and dumbwaiter system transmitted samples throughout the building. The Old Shift Laboratory occupied the second floor and provided bench and hood space for chemical analyses of samples of low to moderate activity. Analytical services were provided round-the-clock to plant operations. The middle third of the building was a high bay decontamination laboratory, providing space for water and chemical cleaning of contaminated equipment from all over the NRTS.



**Figure 15.** Shielded glove boxes in the Remote Analytical Facility , CPP-627. *Source:* INL Photo 62-6349.

Like most of the facilities at ICPP, CPP-627 was in constant evolution. In 1956, only six short months after the first hot samples were introduced for analysis, modifications were made in response to feedback from the scientists who had been using the new equipment. As a result of these analysts' concerns, remote mechanical arms and manipulators replaced the more clumsy remote switches and gears originally installed in the glove boxes.<sup>94</sup> Changes also occurred in other portions of CPP-627. In 1980 the

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<sup>93</sup>Brewer F. Boardman, The ICPP (A Factsheet). Idaho Falls: Idaho Operations Office of the AEC, 1957. Also, Wheeler et al. 1965, pp. 4-10.

<sup>94</sup>Huff, p. 10.

decontamination facility was replaced by a newer laboratory in another building (the New Waste Calcining Facility, CPP-659). The original equipment was removed and the area was rebuilt into two smaller laboratories, the Decontamination Development Lab and the Emission Spectrometry Lab. Both of these facilities saw very limited use because of safety issues and termination of the reprocessing mission.

The southern third of CPP-627 contained two experimental facilities, the Hot Chemistry Lab and Multi-Curie Cell. Both were used for small-scale custom dissolution processes and other hot analytical work. A large walk-in hood installed in the Hot Chemistry Lab was home to some of ICPP's custom dissolution equipment and the remainder was installed in the Multi-Curie Cell. This cell (5' x 10' x 11') was shielded to the same degree as the main processing cells in CPP-601, enabling researchers to mock up near production-level processes in their experiments. All work in the Multi-Curie Cell was conducted remotely with master-slave manipulators for light work and a 2,000 pound hoist for removing cask lids and other heavy work (Figure 16). A 15-ton cask dolly delivered the casks of fuel to the Cell through a massive, 18" thick, lead-filled door that weighed 20 tons.

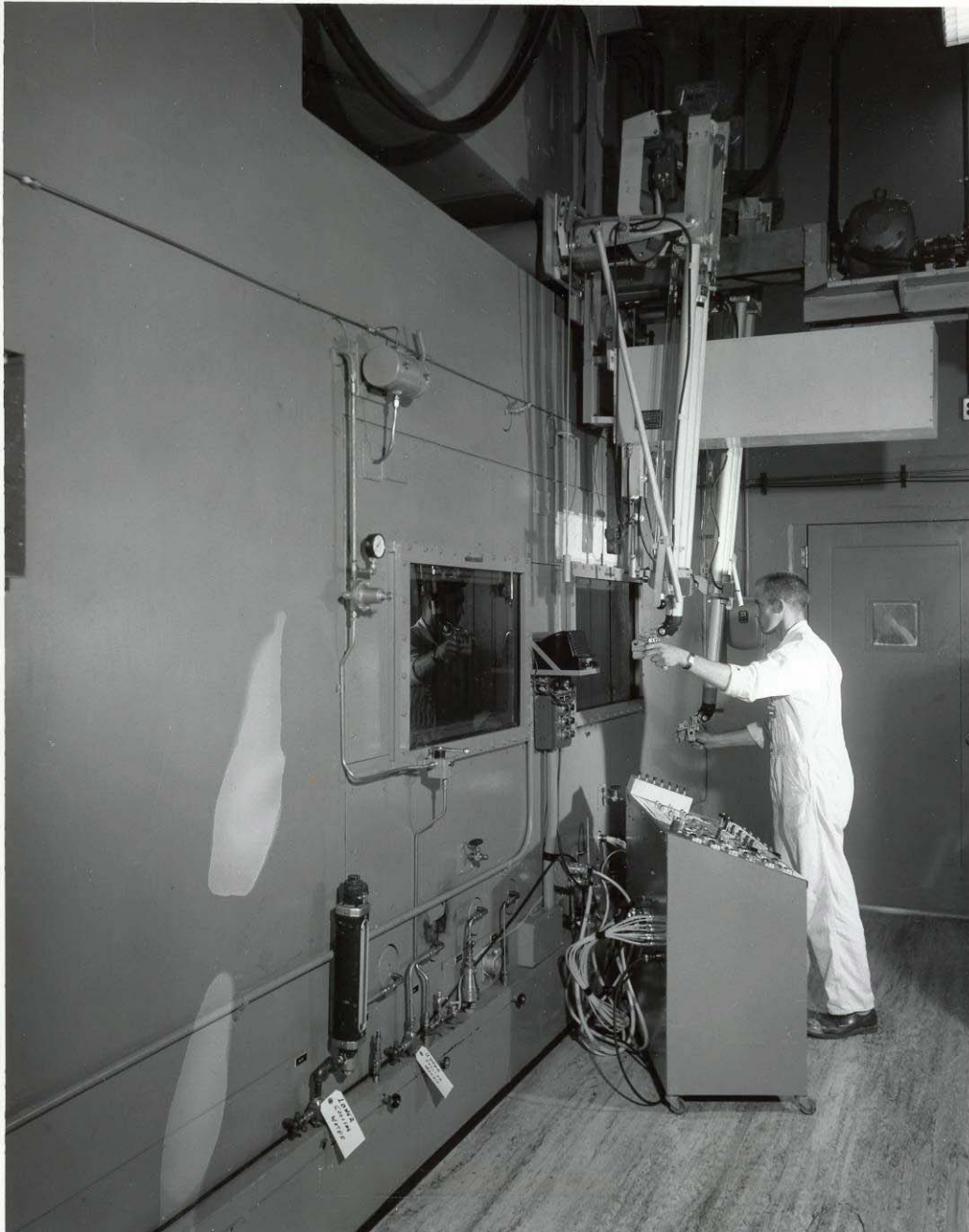
#### 4.4.4 CPP-640: The Hot Pilot Plant/Headend Process Plant

CPP-640, originally known as the Hot Pilot Plant, was initially designed to test new equipment and chemical flowsheets in support of the fuel processing operations in CPP-601. Built in 1961, the building was constructed as an empty shell with five shielded test cells, waste collection tanks in two vaults at the lowest level of the building, and an open crane loft with space for chemical makeup equipment and removal of cell roof hatches.<sup>95</sup> A major modification in the late 1970s added the shielded Mechanical Handling Cave in the process makeup area of the structure for processing graphite fuels.

The facility was designed to allow for maximum flexibility of future test assemblies. Cells 3, 4, and 5 were equipped with two removable shielding walls to allow for possible large tests. Numerous pipe slots through the cell walls (shielded with lead bricks when not in use) and cast-in-place pipe penetrations provided access for instrumentation, control piping, and wiring. A heavy-duty cart capable of transporting heavy shielded fuel casks served Cells 1 and 2. Fuel charging ports were available at the top of the other three cells. Until early in the 1970s, a variety of experiments were conducted in the facilities of CPP-640; two of these processes, involving electrolytic dissolution of stainless steel-clad fuels and combustion of those clad in graphite, were

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<sup>95</sup>McBride 1961. Also, Patterson 1994.



**Figure 16:** Operating face of the Multi-Curie cell in the Remote Analytical Facility, CPP-627. *Source:* INL Photo 56-2100.

particularly successful and soon took over. After 1973, the structure began to be known as the Headend Processing Plant, dedicated first to electrolytic dissolution and then sharing space with the graphite combustion process.

Eventually, Cell 5 of CPP-640 would be devoted exclusively to the electrolytic dissolution process. This 11.5' x 17' cell was 17' tall and stainless steel lined the floor and walls to a height of five ft. It housed a unique dissolver that consisted of a long V-shaped horizontal trough, made of titanium, with a perforated niobium basket that fit inside. When stainless steel-clad fuel elements were placed in this dissolver followed by a steady stream of nitric acid (and boric acid for criticality control) and an electrical current, they dissolved into a solution that could be processed through existing solvent extraction systems in CPP-601.

By 1983, the remainder of CPP-640 would also be devoted to a single headend, a combustion-acid leach dissolution process for recovering uranium from graphite-matrix fuels such as those deployed in the Rover (nuclear rocket) program. Four cells within CPP-640, 1 through 4, were devoted to the process and a new shielded cave necessary for charging the fuel elements to the dissolver was constructed above Cells 2 and 3 in the top floor of the building in the process makeup area. Viewing ports and master slave manipulators installed in the charging cave allowed remote handling of the fuel elements. The dry side of the process, involving two fluidized bed burners and an ash collection system was installed in Cells 3 and 4, which were combined by removal of their common wall. Cell 2 housed the dissolver and other equipment for the wet side of the process, where the ash from the dry side was dissolved in a mixture of hydrofluoric and nitric acids and eventually transferred to existing solvent extraction equipment in the CPP-601 processing cells.

#### 4.5 Summary

The ICPP was one of four AEC fuel reprocessing plants and one of only two to process highly enriched fuels. The Chem Plant's original mission was to recycle uranium from spent fuel elements taken from the nearby Materials Test Reactor, but soon after completion this mission expanded to include fuels taken from more than one hundred different U.S. government research and test reactors as well as those which powered the nuclear Navy. For nearly forty years the plant successfully reprocessed fuels clad in aluminum, zirconium, stainless steel, graphite, and many other unique materials. In addition to developing the skills necessary to reprocess highly enriched fuels from so many different sources, workers at the Chem Plant also came up with many general improvements and scientific advancements in fuel reprocessing techniques as a whole.

The Fuel Reprocessing Complex at ICPP consisted of four main buildings: the Fuel Storage Building (CPP-603), the Main Processing Building (CPP-601), the Remote



Analytical Facility (CPP-627), and the Hot Pilot Plant/Headend Process Plant (CPP-640). The first fuels processed through the operation were uranium-aluminum slugs from Hanford. These were batch processed in 1953. In 1955, the facility was modified for continuous processing of aluminum-clad fuel elements, increasing both the speed and efficiency of the operation. In 1956 a batch processor for zirconium was operational as well as a new dissolution process for stainless steel clad fuels. Semi-continuous dissolution of zirconium was initiated in 1965 when the plant also became the first to use the soluble neutron poison (boron) to prevent a criticality. At this time, advances were also made in the combination of second and third cycle extraction for aluminum and zirconium fuels where elements in the aluminum-based dissolver product complemented those in the zirconium dissolver product and in combination, minimized the addition of process reagents. In 1973, changes were made in the processing of fuels clad in stainless steel through development of a new electrolytic dissolution process with the continuing trend toward common second and third cycle extraction. Processing of graphite-based fuel was initiated in 1983. In 1986 significant changes occurred at the ICPP as a new zirconium-based dissolution process, the fluorinel dissolution process, was implemented in a new building. From the beginning of the operation, a small custom processing facility was also supported to process fuels that were not suited to conventional facilities and equipment. Finally, in addition to uranium, several other valuable isotopes, including neptunium, barium, xenon, and krypton, were isolated for future research in equipment installed in the Fuel Reprocessing Complex.

During its years of operation, nearly forty campaigns were successfully completed at the Fuel Reprocessing Complex. Approximately 31,432 kg of uranium were recovered as a result of these operations. Appendix C provides more detail on this unique processing history.

In 1992 after the end of the Cold War, the Department of Energy cited a changing world political situation and overall lack of demand for uranium as reasons to halt the reprocessing of spent nuclear fuel at facilities across the U.S. The phaseout of fuel reprocessing had a profound impact on the ICPP, reflected officially by a change in name. When the Idaho Chemical Processing Plant became the Idaho Nuclear Technology and Engineering Center in 1998, its fuel reprocessing mission was officially over. Missions focused on the development of new technologies for waste management and interim storage of spent fuel elements in preparation for long term storage and disposal in approved geological repositories took priority.

#### 4.6 Future of the ICPP

The termination of ICPP's fuel reprocessing mission makes extant structures there obsolete and most are scheduled for decontamination and demolition within the next decade. The end state that has been proposed for the Fuel Reprocessing Complex is

removal of the above-ground structures, grouting those below ground, and covering them with an impermeable cap. Proposed plans calls for existing shielding structures below ground to be left intact and filled with concrete grout, while the higher, above ground structure will be collapsed or removed. This will result in a platform about 250' x 200' at an elevation of about 11' above grade. There will be two higher spots, one 20' x 30' area (P, Q, and S cells) reaching 19' above grade, and an 18' x 33' area (CPP-640 Mechanical Handling Cave) reaching 24' above grade.

## PART FIVE SIGNIFICANCE OF THE FUEL REPROCESSING COMPLEX

During almost fifty years of processing history the buildings that make up the Fuel Reprocessing Complex (CPP-603, CPP-601, CPP-627, and CPP-640) at ICPP have exhibited an adaptability that has served them well in the constantly changing scientific and political environment of the times. Mission changes were weathered and even welcomed to expand the capability of the Chem Plant and its crews of dedicated workers. However, as the ICPP approached the turn of the twenty-first century, significant changes in world politics, plentiful supplies of raw uranium, and a widespread lack of support for nuclear research across the country combined to create a change in mission that the old fuel processing facilities will not survive. Although the aged structures will be torn down to contain the contamination present there, the process knowledge obtained through decades of experimentation in the old fuel processing complex will not be forgotten.

During operations from 1953 to 1992, many key processing innovations were first achieved at the ICPP. These accomplishments have been discussed in previous sections to illustrate the working of the Chem Plant and the multitude of operations conducted there. They are summarized here as a demonstration of the overall significance of the ICPP in the overall development of fuel reprocessing capabilities across the country.

As one of only four spent fuel reprocessing facilities in the U.S. and the only such installation in the state of Idaho, ICPP is notable for the following firsts:<sup>96</sup>

- dissolved spent nuclear fuel on a routine schedule and reprocessed the resulting highly enriched uranium on a production basis
- demonstrated direct maintenance of highly-contaminated equipment while achieving a firm production schedule

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<sup>96</sup>Knecht et al. 1997, p. 44; Thumbnail Sketch 1985, p. 13; C. M. Slansky, "Process Development and Demonstration in Nuclear Fuel Reprocessing at the Idaho Chemical Processing Plant," *PTR-518* (Idaho Falls: Atomic Energy Commission, 1961), pp. 9-10.

- operated a multiple headend fuel processing plant
- demonstrated that multiple headend processing of various fuels is compatible with common second and third cycle extraction and purification
- processed breeder reactor fuels
- processed zirconium alloyed fuels by dissolution in hydrofluoric acid
- processed stainless steel-alloyed fuel by sulfuric acid dissolution
- dissolved stainless steel fuels using electrolytic dissolution
- employed an innovative coprocessing flowsheet (combining zirconium and aluminum products) to minimize waste volumes
- employed fixed and soluble neutron poisons for criticality control
- applied air pulsers to extraction columns for improved recovery of special nuclear materials
- developed and implemented a production-scale fluidized bed denitrator to convert uranyl nitrate liquid to uranium trioxide granules for easier shipping
- operated a radioactive rare gas recovery plant in conjunction with a fuel recovery process
- developed, installed, and operated a process for the routine production of 30,000 – 50,000 curie batches of radio-barium
- demonstrated computerized monitoring of sensitive nuclear materials and tracking of process solutions during fuel reprocessing
- demonstrated decommissioning and reuse of process cells (C, L, S, and F)
- stored high level liquid waste in stainless steel tanks
- developed and implemented a production-scale liquid waste calciner to solidify and reduce the volume of high level liquid waste resulting from the fuel recovery operation
- demonstrated routine shearing of spent fuel elements
- operated a dry storage facility for spent fuel elements

## PART SIX PROJECT INFORMATION

In 1997, primary buildings associated with the Spent Nuclear Fuel Reprocessing Facility were proposed for complete or partial demolition. Consideration was given to reuse and preservation but found to be infeasible due to reasons of environmental concern, human health and safety, and security and economy. In recognition of the adverse impact demolition would cause these historic properties and the need to mitigate such impact, DOE-ID, in consultation with the Idaho State Historic Preservation Office and Advisory Council on Historic Preservation, reached agreement on mitigation measures. They are contained in a Memorandum of Agreement signed by all three consulting parties in the summer of 1998. Primary among the measures was the development of this Historic American Engineering Record report (HAER) to document

the Spent Nuclear Fuel Reprocessing buildings. In a letter dated June 30, 1998, the Pacific West Area of the National Park Service outlined the documentation requirements for completion of the HAER report.

The proposed demolition project was delayed for a variety of reasons, not the least of which, was funding. In 2002, the demolition project was revived as part of a DOE complex-wide effort to reduce the structural footprint. As funding became available, the draft HAER report was revived and completed. The following paragraphs provide information on personnel who contributed to the report completion.

Brenda Ringe Pace was the report's primary author and is a professional archaeologist with a BA and MA in Anthropology from Idaho State University. Ms. Pace is the lead archaeologist at the Laboratory and has over 25 years of experience in the field. Ms. Pace is adjunct faculty at Idaho State University, serves as chair of the Idaho Falls Historic Preservation Commission, and is a Registered Professional Archaeologist with the Society for American Archaeologists.

Julie Braun oversaw the HAER report development and assisted with the narrative and photograph preparation. She has worked as an archaeologist at the Laboratory since 1990. In 1993, she founded the INL History Program to protect historic INL buildings and structures and is the Principal Investigator for that Program. Ms. Braun is presently team lead for the INL Cultural Resources Management Program and holds a BA from ISU in American Studies and an MA in Historic Preservation from Goucher College. She is a member of several professional societies, presently serves as board chair of the Bonneville County Historical Society/ Museum of Idaho, and is a member of the Idaho Historic Sites Review Board and the Idaho Falls Historic Preservation Commission.

Hollie Gilbert coordinated completion of the HAER photographs in this report and assisted in the completion of HAERs: ID-33-E, ID-33-F and ID-33-G. She has a BA in History from Idaho State University and is expected to complete an MS in Anthropology at Idaho State University in 2007. Hollie has extensive experience in photography and has worked at the Laboratory for 22 years in various capacities, including as a professional photographer, historian, and archaeologist with 9 years experience in the management of cultural resources. Ms. Gilbert is a member of Phi Alpha Theta, the Society for Historical Archaeology, and the Society for American Archaeology.

Mike Crane has 40 years of experience as a professional photographer; 30 of those years spent at the Idaho National Laboratory. Mr. Crane is the master photographer for the INL and has provided the photographic media for seven INL HAER reports.

APPENDIX A

CHEMICAL FLOWSHEETS FOR MAIN FUEL  
 REPROCESSING OPERATIONS

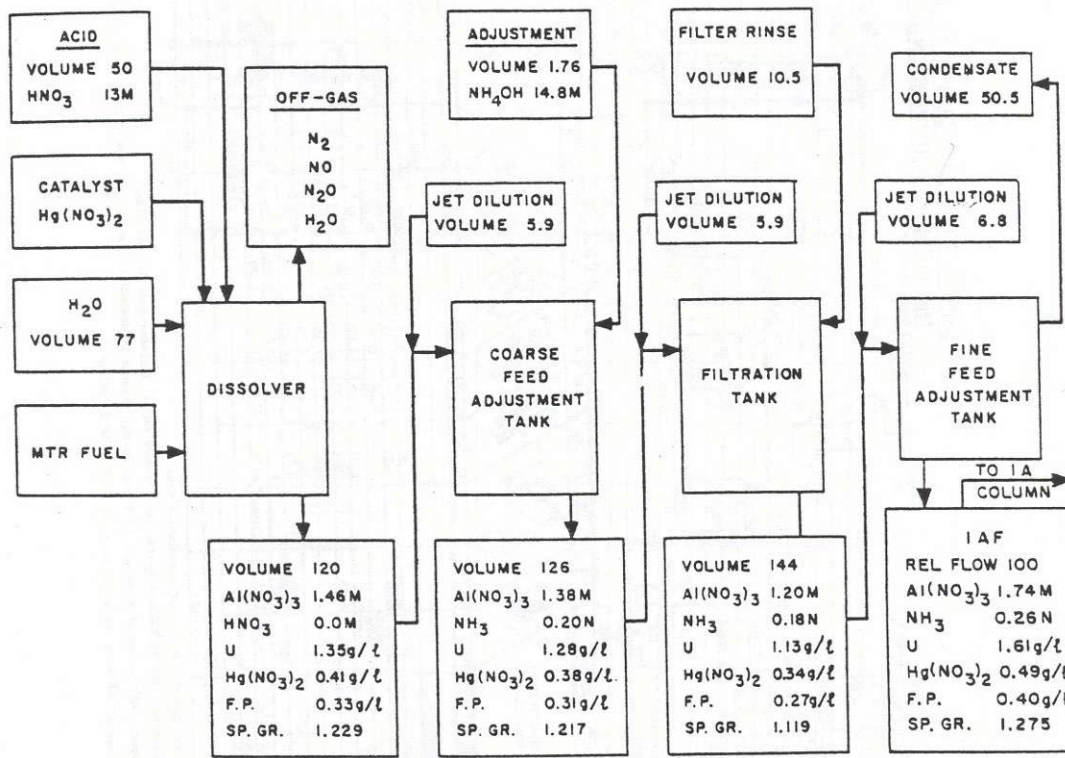
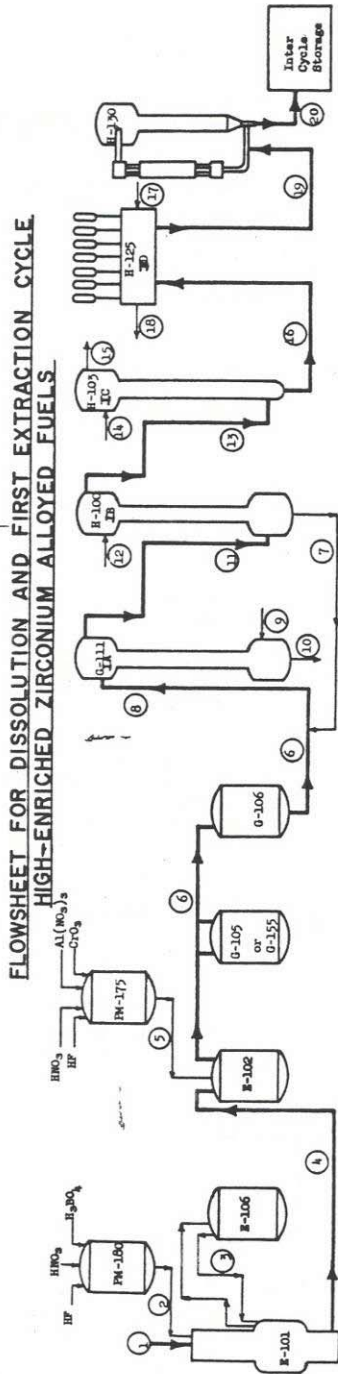


Figure A-1. Aluminum Dissolution (MTR Fuel elements).



DESCRIPTION	STREAM																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17 and 18	19	20	
Flow, l/hr	5.17 (a)			1.52 (c)	1.27 (b)	1.50	1.00	1.00	1.50	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
Temp, °C																				
Diluent																				
Zr, kg/match																				
U, kg/match																				
Al, kg/match																				
NO <sub>3</sub> <sup>-</sup> , M																				
NO <sub>2</sub> <sup>-</sup> , M																				
Cr, g/l																				
B, g/l																				
U, g/l																				
Density at 25°C																				
Zr, kg/match	1.03																			
U, kg/match	1.03																			
Sn, kg/match	1.1																			

(a) Average rate for a 16-hour dissolution cycle.  
 (b) Average rate for continuous extraction (24-hour day). Includes some jet dilution.  
 (c) Assumes a 40% burnup of uranium. (Critical safety assured in absence of burnup, i.e., for up to 16.7 kg fuel; enriched uranium.)  
 (d) The use of DIBM in the scrub makes it 1.1% acid deficient.

Figure A-2: Zirconium Dissolution.

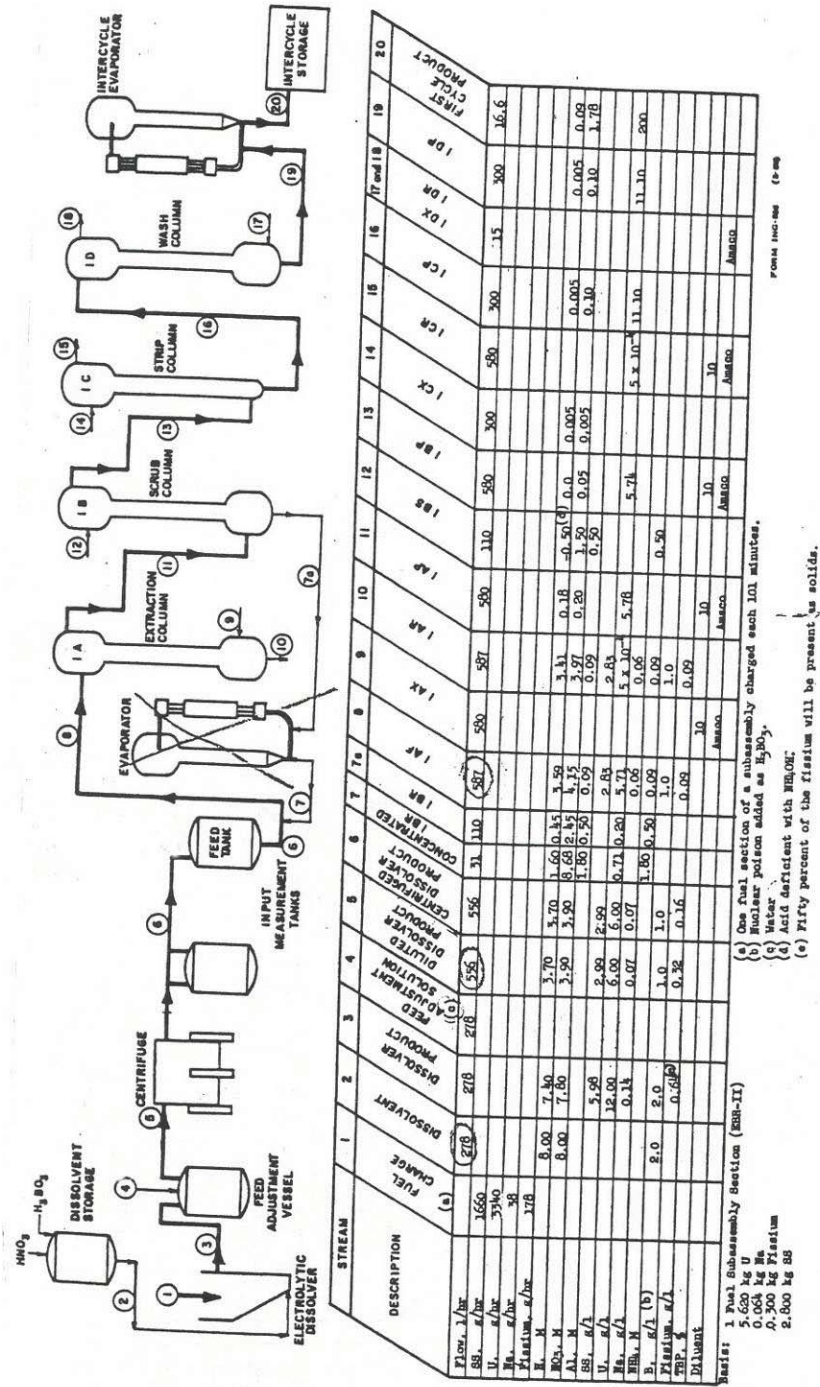
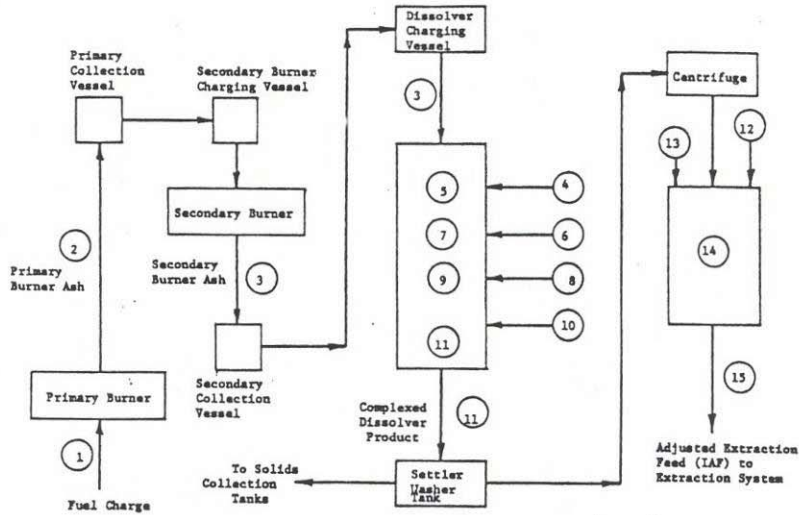


Figure A-3. Electrolytic Dissolution.



DESCRIPTION	STREAM	1	2	3	4	5	6	8	9	10	11	12	13	14	15	16
		Fuel Charge	Primary Burner Product Ash	Secondary Burner Ash	Nitric Acid	Dissolver Solution	Boiled Water Dilution	Diluted Dissolver solution	Hydrofluoric Acid solution	Di-solvent	Aluminum Nitrate Solution	Complexed Dissolver Prod.	IAF	Feed Adjustment Solution	Complexed IAF Solution	IAF
Flowrate l/h			90	90	220	310	120	430	287	717	1200	1860	3060	3777		
Flowrate l/hr			3.75	3.75	9.17	12.9	5.0	17.9	12.0	29.9	50	77.5	127.5	157		
C kg/d	144.3	16.4	0.5	0.5	0.5			0.5	0.5							
UC <sub>2</sub> kg/d	33.1															
NbC kg/d	22.6															
Al <sub>2</sub> O <sub>3</sub> kg/d	1.8	2.0		2.0	2.0		2.0		2.0							
Nb <sub>2</sub> O <sub>5</sub> kg/d	8.6	10.4		10.4	10.4											
U <sub>2</sub> O <sub>8</sub> kg/d	31.8	31.1														
Nb <sub>2</sub> O <sub>5</sub> kg/d	23.5	22.5		22.5	22.5		5.63		5.63							.049
Total Solids kg/d	200	82.1	66.5	35.4	35.4		8.13		8.13							.049
U g/l				293	85.1		69.8		41.9	.24				.094	8.03	
Nb g/l							37.4		22.4						4.25	
NO <sub>3</sub> M			8.0	8.0		2.3		1.66	6.6	3.64	2.40	1.92	2.11	2.40		
H M			8.0	8.0		2.3	28.4	9.58	5.75	.70	2.5	1.79	2.54			
F M+							28.4	7.93	4.76		.55	.33	1.17			
Al M									2.2	.88	.5			.20	.33	
B g/l			3.5	3.5	5.4	4.8		3.5	3.5	3.5					.66	
NH <sub>4</sub> M												.20			.078	.063
Density																
Solids g/l				388		113		17.8		10.7						.013

Figure A-4. Graphite Combustion/Acid Dissolution (Rover Fuels).



**FLWSHEET FOR SECOND AND THIRD EXTRACTION CYCLE  
 (HIGH-ENRICHED URANIUM)**

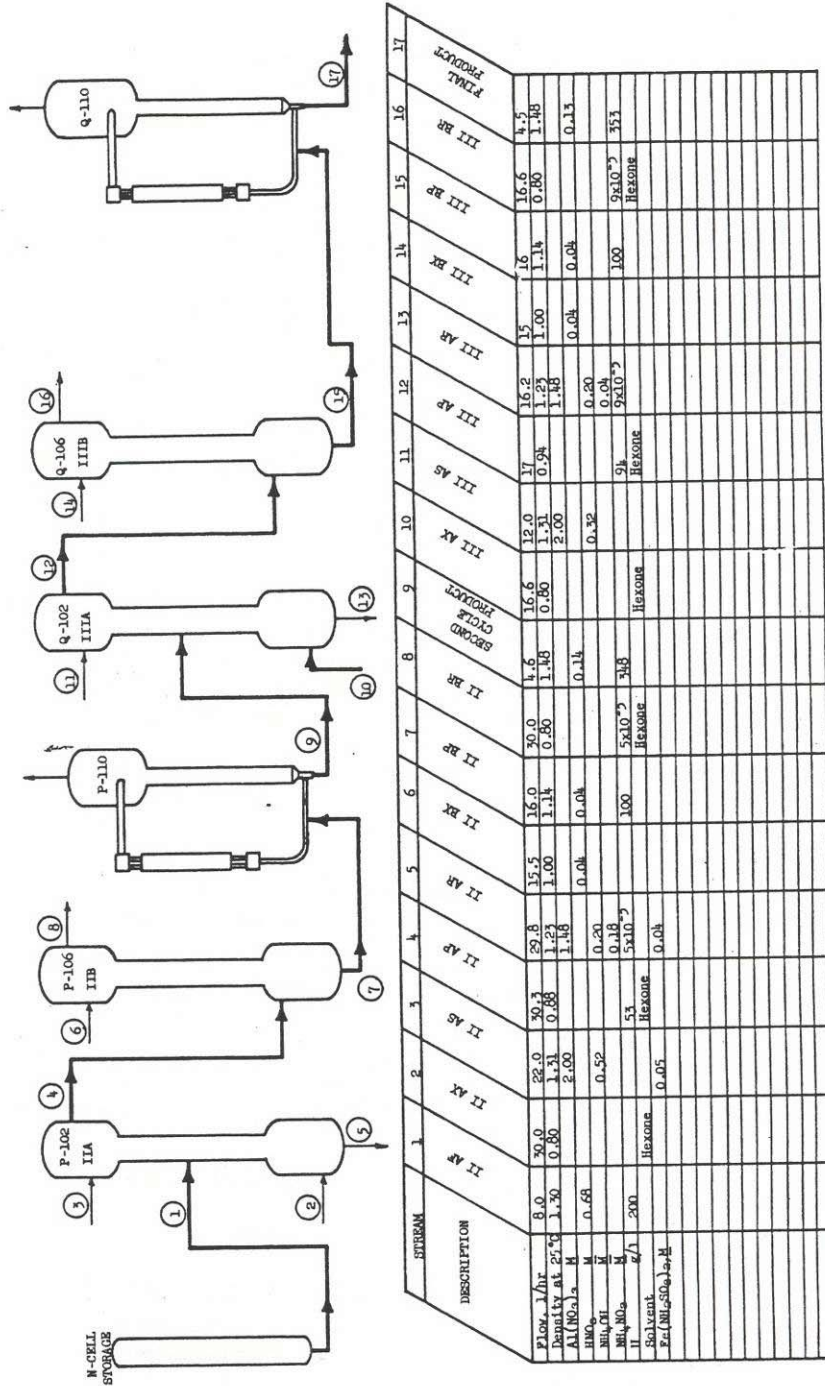


Figure A-5. Common Second and Third Cycle Extraction.

## APPENDIX B

### CPP-601 FUEL PROCESSING BUILDING CELL DESCRIPTIONS

The main fuel processing building, CPP-601, at ICPP contained twenty-four cells arranged in two rows. Descriptions of each cell are included here.<sup>97</sup>

A-Cell is located in the western bank of processing cells. It is shorter than many of the other cells in CPP-601 (15' x 19' x 16') because it was built directly above B-Cell. The 4'-thick concrete floor that separates A-Cell from B-Cell is lined with stainless steel as are the walls up to 3'. The EBR-I batch dissolvers, various tanks, and an off-gas condenser installed in the cell were designed specifically to process nearly pure uranium that had once been clad in stainless steel to provide power for EBR-I. They were used only once, in 1954. In the 1960s, all of the equipment in A-Cell was viewed as expendable, to be replaced as necessary to increase the fuel processing capability of the ICPP. Early in 1980, the cell was cleaned out, but no other processes were ever installed there.

B-Cell is located directly below A-Cell in the southwestern corner of CPP-601. Like A-Cell it is also just half-size (15' x 19' x 17') as compared to most of the other cells in the facility. B-Cell originally held sixteen tall slender tanks, sized and spaced to provide critically safe storage of concentrated solutions of highly enriched uranium from various dissolvers in the plant. While the tanks themselves were geometrically safe, in 1959 a small amount of solution siphoned from one of the tanks into the process equipment waste system, resulting in a criticality. After decontamination, the cell and tanks were used once again for interim storage of various chemical solutions, including a mixture of neptunium and plutonium, from 1972 to 1977. In the 1980s, B-Cell was cleaned out in preparation for new processes, but it remains empty today.

C-Cell is also located in the west bank of processing cells adjacent to A and B Cells. This tall (20' x 19' x 28') cell is lined with stainless steel extending more than 9' up the

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<sup>97</sup>Main sources include M. W. Patterson, "Nuclear Fuel Reprocessing Deactivation Plan for the Idaho Chemical Processing Plant", *INEL-94/0165* (Idaho Falls: U.S. Department of Energy, Idaho Operations Office, 1994), pp. 4-23; E. P. Wagner, "Process Description and Operating History for the CPP-601/640/627 Fuel Reprocessing Complex and the Idaho National Engineering and Environmental Laboratory," *INEEL/EXT-99-0040* (Idaho Falls: U.S. Department of Energy, Idaho Operations Office, 1999), p. 2-30 – 2-5 ; B. R. Wheeler, J. A. Buckham, and A. L. Ayers, "Feasibility and Economics of Commercial Operation of the Idaho Chemical Processing Plant," *PTR-754*, (Idaho Falls: U.S. Department of Energy, Idaho Operations Office, 1965), pp. B-15 – B-18.

walls. It is essentially identical to its neighbor, D-Cell, and often worked in tandem with it to dissolve aluminum-alloyed fuels. In 1953, the batch dissolvers in C-Cell and D-Cell processed the first batch of hot fuel introduced into CPP-601. Many more batches of aluminum-alloyed fuel followed this pioneering run. In the 1980s, after continuous dissolvers for aluminum alloys made the C and D Cell batch dissolvers obsolete, a critically safe uranium salvage systems was installed in C-Cell. This system was used to make chemical adjustments to the product solutions, and filter them prior to transfer to storage tanks (N-Cell) for eventual solvent extraction of the enriched uranium. Similar systems were installed in J and L Cells.

D-Cell is a mirror image of C-Cell. Both were originally designed for batch dissolution of fuels with aluminum cladding and each held a complete system for this headend. In 1980, the cell was decontaminated and all equipment was removed. Then in 1989, the empty cell was adapted for temporary storage of solid, granular, calcined waste and calcine-contaminated materials.

E-Cell, the fourth cell on the west side of CPP-601, has a typical design, measuring 20' x 19' x 28' with stainless steel lining the walls up to 9.5' and also covering the floor. The primary equipment for the original batch zirconium dissolver, made of Monel to resist the corrosiveness of the hydrofluoric acid used to dissolve the zirconium, was installed here. Another vessel in E-Cell, made of Carpenter-20 steel, was used for the early two-step sulfuric/nitric acid dissolution of fuels clad in stainless steel. The zirconium dissolution equipment was modified several times during its processing history; first to accommodate semi-continuous processing and later to support co-processing with solutions from the aluminum headend. Most of the fuels processed through the E-Cell dissolvers originated with the U.S. Navy, including cores from the Nautilus and Sea Wolf submarines.

F-Cell is another typically sized processing cell (20' x 19' x 28') located in the middle of the west bank of the facility. Stainless steel lines the floor and walls up to more than 10'. After being dissolved in one of two vessels in E-Cell, Navy fuels were sent to geometrically safe equipment in F-Cell for the first cycle of solvent extraction using tributyl phosphate. This extraction equipment was last used in 1965 and was largely replaced by a new technology, electrolytic dissolution, housed in CPP-640. After decontamination, F-Cell was modified to serve as a feed clarification system for graphite and aluminum dissolver products. Centrifuges installed in F-Cell at this time were instrumental in removing the solids from these solutions to facilitate extraction of the uranium.

G-Cell was one of the busiest cells in the entire plant. This standard, west side cell (20' x 19' x 28', stainless steel floor and 10.2' of wainscot) housed two continuous dissolvers for aluminum alloyed fuels plus the large scale first cycle extraction columns that accepted solutions from many different dissolution systems in the plant. The dissolvers

first operated in 1957 and were used again and again until 1986. In 1992, when the fuel reprocessing mission at ICPP was terminated, the dissolvers were being prepped for another run. The G-111 column, which completed the initial cycle of solvent extraction of uranium from a variety of dissolver products without fail for more than twenty years, has been called the “workhorse”<sup>98</sup> of the plant. In addition to a myriad of runs with dissolved aluminum alloys, in 1969 G-111 would process the first dissolver product from co-processing of zirconium and aluminum. Years later, in 1987 and 1988, the last batch of fuel to be dissolved in CPP-601 would pass through. G-Cell also contained several holding tanks for high level liquid wastes produced during first cycle extraction. These raffinates were extremely contaminated both physically and radioactively and could be jetted directly to large 300,000 gallon cooled storage tanks in the ICPP Tank Farm.

H-Cell is located next to G-Cell on the west side of CPP-601. These cells were identical in size and also worked in tandem to process aluminum alloyed fuels and a first cycle extraction system for all types of dissolver products from the plant. Generally, H-Cell equipment received the stream of uranium-bearing liquid isolated in G-Cell, processed and purified it further, and sent the resulting high level liquid waste back to G-Cell for temporary holding. The columns, tanks, and evaporators that processed uranium-bearing solutions in H-Cell are geometrically unsafe under some circumstances so operators had to be very mindful of uranium concentrations as solutions were being processed there.<sup>99</sup> Even with strict controls in place, two criticality incidents occurred in the cell during its processing history. The first was centered in an evaporator in 1961, the last in a scrub column in 1978. Modifications to the processing equipment, particularly the evaporators, and tighter administrative controls on additions to the process stream, were designed to prevent these types of problems in the future.

None of the cells within CPP-601 were designated as “I” because of the potential for confusion with the number 1.

J-Cell (19’ x 20’ x 29’, with a stainless steel liner extending 3’ up all walls) was always devoted to uranium salvage operations. However, it did go through three main changes in configuration during its processing history. Initially, the cell contained a double bank of tanks that continually created problems because they were of insufficient capacity for plant operations. This problem was addressed by installation of a system of fixed nuclear poisons that was intended to increase the capacity of the salvage system without creating criticality problems. These controls did not work as expected and criticality problems did

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<sup>98</sup>Ed Wagner, interview with Julie Braun and Brenda Pace, 1 July 1999.

<sup>99</sup>When uranium solutions came into H-Cell they typically contained from 0.7 to 10 g per liter concentrations of uranium; after processing in the H-Cell equipment they were concentrated up to as many as 350 g per liter.

arise. As a result, in its final configuration, the cell was restricted to processing of relatively low level and low quantity solutions from the plant's process equipment waste system.

K-Cell is the northernmost cell on the west side of CPP-601. It is slightly larger than most of the other processing cells but no taller. K-Cell was devoted to recycling operations. Solvents, including both hexone and tributyl phosphate, were sent to scrubbers and evaporators in K-Cell for decontamination and purification. Uranium separated during this process went back to one of the uranium salvage operations (C, J, and L-Cells) for further purification while the clean solvents were temporarily stored for use at a later time.

L-Cell arguably became the most complex cell in CPP-601, even though it started out empty and was intended as a spare for future processing activities. It occupies the southeastern corner of the building and has slightly less floor space than many of the cells in the plant (16' x 17'). However, L-Cell is taller than many of the other cells, especially those in the west bank, extending 10' below the Access Corridor to reach a total height of 37'. Stainless steel covers the walls from floor to ceiling. Although it started out without a mission, L-Cell did not remain idle for long. Changes began to appear in 1954: a shielded viewing window, remote handling manipulators, a periscope, and intercom system were installed that would allow an operator to see and hear the work going on behind 6' of concrete shielding. A wide variety of equipment also began to appear inside the cell. The equipment included an elevator, two large centrifuges, a dissolver and its charging chute, an off-gas scrubber, and process tanks of many sizes. The setup that emerged from these changes was designed to isolate an intensively radioactive and short-lived fission product, lanthanum-140 (radioactive daughter of barium-140), from fuel elements fresh from the Materials Test Reactor (MTR). By the time most MTR fuel elements reached the ICPP processing cells (after at least 120 days of cooling), all of the lanthanum had decayed. However, the fuel brought to L-Cell was new enough that useable quantities of it were still present. These short-lived, high-energy fission products were attractive to industry and were used extensively in weapons research. When the first usable amounts of this isotope were isolated in L-Cell in 1957, it became known as the *rata cell* which was short for the radioactive lanthanum produced there and quickly shipped to Oak Ridge for research. The process continued until 1963. L-Cell remained idle for many years until 1984 when a new critically safe uranium salvage system was installed to process solutions that were known or suspected to contain recoverable amounts of uranium.

M-Cell was also originally built as a spare in the eastern row of cells. Until 1982, the ceiling of the 16' x 17' x 37' cell was made of wood. Although shielded now, it still differs from all of the other cells in CPP-601 because the top is completely removable. The principal function of M-Cell was to provide temporary storage and sampling

capability for concentrated uranium solutions flowing from the first, second, and third cycle solvent extraction operations. Four tanks and a variety of pumps complete these tasks and supply the necessary measurements of accountability for the plant. Due to the potential need for maintenance on the pumps, they are shielded from the vessels by an internal concrete wall that is 1.5' thick x 15.5' tall.

N-Cell is centrally located in the east bank of cells in CPP-601. At 57' x 19', it has the largest floor plan of any of the other cells and rising to 38', it is also one of the tallest. The six critically safe storage tanks installed in N-Cell were used to temporarily store aqueous uranium solutions from first cycle extraction awaiting processing through second and third cycles of the process. One tank was also used to store a specialized neptunium concentrate until enough had accumulated for a unique processing run. Although the tanks were critically safe by geometry, in 1959 a criticality event in B-Cell, also used to store intercycle solutions, made it clear that there was potential for inadvertent damage of concentrated uranium solution to the process equipment waste system and a corresponding vulnerability for criticality. To prevent this, ICPP engineers adapted a standard device for criticality control, raschig rings for use outside of the processing columns in which they were usually installed. Instead, they were installed on the floor of the N-Cell, where they could keep concentrations of uranium down to acceptable levels. Although the original glass raschig rings proved to be too delicate for direct maintenance, a stainless steel mesh installed over the top of them solved that problem and allowed the cell to operate for many years.

To prevent confusion with the number zero none of the operating cells within the original floor plant of CPP-601 were designated as O-Cell. Later however, a pump room located to the west-northwest of N-Cell began to carry the name. The metal plate ceiling of O-Cell is even with the floor of the Access Corridor and all of the walls and floor of the 20' x 19' x 10' room are lined with stainless steel. Raschig rings cover the floor for criticality control in the event of a spill or leak. The pumps installed in O-Cell moved solutions between the first, second, and third cycle extraction equipment.

P-Cell has always been used for solvent extraction of highly enriched uranium and often worked in tandem with similar systems installed in Q and R/S Cells. Located in the east cell bank, P-Cell is long (19') and tall (37'), but quite narrow (8'). It was well suited as a home for the tall equipment that purified the uranium at this stage of the process; six columns used for extraction, stripping and evaporation occupied more than half of the long narrow space. Most of the time, P-Cell equipment was used to process second cycle solutions using hexone as an organic solvent. For a short time early in its history, it was employed for first cycle extraction. In 1972, a special solution of concentrated neptunium and plutonium that had been collected from seven years of fuel reprocessing activities was also processed through the extraction equipment in P-Cell. Then, after thorough decontamination, it was ready to once again handle concentrated uranium.

Q-Cell is long, tall and narrow (23' x 8' x 37'), just like its neighbor to the south, P-Cell. It was designed to take second cycle uranium solutions from P-Cell and process them through a third and usually final, cycle of solvent extraction. Hexone was also used as a solvent in Q-Cell's tall columns that were used for extraction, scrubbing, stripping, and evaporation. Sometimes, however, Q-Cell was used to process solutions directly from first cycle extraction.

R-Cell does not exist as a separate entity from S-Cell since there are no physical separations between them. R-Cell is the top and S-Cell is the bottom of another long (23'), tall (37'), and narrow (8') cell in the east row of CPP-601. Originally, R/S-Cell contained extraction equipment for a fourth and final cycle of solvent extraction and uranium purification. However, after continuous dissolvers were developed and put into routine use at the plant, uranium product from the third cycle extraction equipment in Q-Cell rarely failed to meet specifications and R/S-Cell extraction columns soon became obsolete. Once cleared, the R/S-Cell space was used again though, particularly in the monitoring of other plant process streams. In 1979, a tank and a system were installed for measuring the density of concentrated uranium solutions. It was hoped that this density monitoring system would help with criticality problems in the uranium salvage system installed in J-Cell. Then, after the J-Cell uranium salvage system was replaced, the density monitoring tank in S-Cell was modified to be used as a decanter to isolate tributyl phosphate and prevent it from entering the uranium salvage system installed in C and L-Cells.

S-Cell contains the bottom half of all of the equipment installed in R-Cell. The two cells are one in the same in terms of physical space. Thus, like R-Cell, S-Cell also went through three different iterations during its processing history. Originally it held fourth cycle extraction equipment.. In 1979 a density monitoring tank was installed to help with criticality problems in J-Cell and, in 1986, a decanter was installed to remove organic solvent from the uranium process stream.

T-Cell is located in the northern end of the eastern cell bank directly above U-Cell. This cell changed very little during its lifetime. From the beginning, it was used as a reservoir for cold hexone that was received from K-Cell or added fresh from the Process Makeup floor below. The solvent was stored in T-Cell tanks, ready to be pumped to P or Q-Cells as needed for uranium extraction operations. Pumps and blowers facilitated this transfer.

U-Cell lies directly beneath T-Cell in the east cell bank. It is one of the two cells in CPP-601 (U and Y-Cells) that were devoted to the collection of aqueous waste streams from the remainder of the plant. Originally, U-Cell collected raffinate from first and second cycle extraction operations, sampled them to verify that they were critically safe, processed them through evaporators to reduce their volumes, and then sent them off to

the Tank Farm for long term storage. However, the volume reduction achieved through waste calcining would soon make the evaporators unnecessary and they were abandoned in place. Additionally, safety upgrades during the 1980s led to a reconfiguration of U and Y-Cells to combine all sources of second and third cycle wastes into a single stream that could be independently sampled for criticality at two different points.

V-Cell was held as a spare throughout the history of CPP-601 fuel reprocessing. No processing equipment was ever installed. Instead, it served as an office space for health physics personnel working in CPP-601. V-Cell is situated on the east side of the building in the north corner, directly above W-Cell.

W-Cell lies below V-Cell in the east cell bank. Tanks and equipment in this cell captured small amounts of the organic solvent, hexone, that lingered in the raffinate streams from first, second, and third cycle extraction. Eventually, lines were rerouted so that all hexone collection was combined in this cell.

X-Cell occupies the northeastern corner of CPP-601. Like V-Cell, X-Cell never held equipment for fuel processing. However, for a short time it was used as a laboratory for storage and analysis of highly radioactive samples, for the dilution of samples before transport to other laboratories, and for decontamination of the equipment used in sample preparation. These activities were carried out in six shielded areas constructed from lead-filled steel forms and lead bricks within the cell. A monorail and crane transported samples from one area to another or they were manually carried. From the beginning, this lab was plagued with contamination problems and construction of the Remote Analytical Facility (CPP-627) in 1957 made it obsolete. Pumps and blowers added later changed the focus of the cell to solvent recovery and storage.

Y-cell lies directly beneath X-Cell in the northeastern corner of the facility. It was the second of two cells used to collect liquid raffinates from process streams throughout the entire fuel reprocessing plant. Initially, Y-Cell collected some second cycle streams and all third cycle streams, sampled them for criticality, and then sent them through evaporators to reduce their volume prior to long term storage in the Tank Farm. However, eventually all second and third cycle wastes would flow through the equipment in Y-Cell for sampling and then transfer to the Tank Farm. Made obsolete by the waste calcining facility, the dissolvers were abandoned. The solvent recovery system was also removed when the liquid waste collection process was consolidated in W-Cell.

Z-Cell is a long, narrow cell located in the extreme northern end of the west bank of processing cells near the common wall with CPP-602. This was the last stop for CPP-601's final product, concentrated liquified uranyl nitrate. For a time, the liquid was stored and packaged for shipment in L-10 bottles at a facility set up within Z-Cell. However, after 1969 the liquid was converted to a solid, uranium trioxide, that was easier



to handle and ship. The denitrator used in this process, located in the CPP-602 laboratory building next door, was developed using local expertise acquired during process development for the ICPP's waste calciner.

APPENDIX C

ICPP PROCESSING RUNS

PROCESS PERIOD	RUN #	FUEL
2/53 to 8/53	1	Hanford C and J
10/53 to 12/53	2	MTR, LITR, NRX - aluminum
7/54 to 2/55	3	EBR-I, Cold Y, MTR with some Borax and LITR, Z – aluminum
3/55 to 6/55	4	Hanford J slugs, MTR, BORAX bulk shielding, BORAX, LITR;  Cold test SRP reject slugs
7/55 to 12/55		
12/55 to 3/56	5	Hanford J and C slugs, Chem Dev Test SRP reject slugs
3/56 to 5/56	6	MTR with some CR, Borax, LITR, and CP
5/56 to 3/57	7	X with some Z, Borax, ANL, MTR, LITR,  CPM cold start with LM slugs
12/56 to 1/57		
10/57 to 12/57	8	LM slugs, RaLa MTR
12/57 to 1/58	9	STR
1/58 to 2/58	10	Hanford C slugs, RaLa MTR, Savannah River LM slugs
4/58 to 11/58	11	Savannah River LM slugs, Savannah River Tube, MTR, RaLa MTR, Chalk River
12/58 to 4/59	12	Savannah River slug, Savannah River Tube, NRX, RaLa MTR
4/59 to 7/59	13	Savannah River slug, Savannah River Tube, Savannah River Tube ends, Chalk River
7/59 to 12/59	14	SIR, MORE, BMI, RaLa MTR
12/59 to 2/60	15	MTR, RaLa MTR, ETR, LITR, Convair (ASTR), Hanford C, J, and KW slugs, Savannah River LM slugs
2/60 to 3/60	16	SIR, RaLa MTR
3/60 to 4/60	17	STR, RaLa MTR
1/61 to 2/61	18	ETR
12/61 to 2/62	19	MTR, ETR, BORAX IV, RaLa MTR, Hanford C and J slugs, LITR, Chalk River, CP-5, LPTR, GTR (Convair), OWR, SL-1 scrap
10/62		SL-1
6/63 to 9/63	20	MTR, ETR, RaLa MTR, SPERT, GETR< BRR, SL-1, BNL, LITR, CP-5, LPTR, GTR (Convair), OWR, WTR, BORAX III, SUSIE, Hanford AEC, Hanford Rey, NRU
6/64 to 12/64	21	BGRR, NRX, McMasters, NRU, NRL, SWE, IRL, University of Michigan – FNR, GTR, MTR, OWR, LPTR, LITR, UF, ETR, CP-5, STR, SPERT, NASA Cold Zr, unirradiated Zr scrap, PWR Core I Seed I, Zr, EBR-I Core 3 codissolution, EBR-I Core 3, SNAPTRAN 2/10A-3 core debris
4/65 to 6/65	22	Vallecitos BWR, Atomics International UO <sub>2</sub> SO <sub>4</sub>
12/65 to 1/66	23	Cold from ATR, MTR, ETR, and SPERT; MTR, ETR, LITR, LPTR, OWR,

		SPERT, GTR, ASTR, GETR, EBR-II Vycor glass, EBR-I Mark 2, plastic-coated A1 fuel plates
6/66 to 1/68	24	EBR II Vycor glass, JRR-2 Core 1, 2, and 3, NRU, NRX, BGRR, SPERT lithcote
4/68 to 6/68	25	MTR, WSU, ETR, OWR, LPTR, CP-5, SER, GTR, ORI, NRL, LITR, GERT, IRL, graphite leaching, Zr
8/69 to 1/70	26	Zr, MTR, ETR, GETR, Korean, SER, LITR, AFNETR, JRR-2, KUR, LPTR, OWR, ATR, SPERT, SPR-III, SNAPTRAN 2/10-2 debris
1/70 to 4/70		ETR types
2/71 to 7/71	27	Zr, JRR-2 (6 batches), EBR-II scrap, WADCO
6/72 to 9/72	28	Zr, ETR, custom miscellaneous
1/73 to 5/73	29	EBR-II, EBR-II slurry and denitrator product
2/74 to 1/75	30	Zr, GETR, ATR, MTR, MTR 20%, TRA scrap, JRR, ETR, CP-5, OWR, JMTR, Juggernaut, KUR, Um, SER, LPTR, EBR-II Vycor glass, G.G. A. Thermionic, ETRC plates, University of Wyoming UO <sub>2</sub> SO <sub>4</sub> , Atomics International fission disc, HTRE scrap, Walter Reed Army Hospital, Nuclear Test Gauge/Split Table Reactor, HTGR secondary burner ash leaching, BML fission disc
2/75 to 5/75	31	EBR-II, APPR cold fuel scrap
5/76 to 9/76	32	Zr, PWR
3/77 to 6/77	33	Godiva reactor fuel, HTRE, ATR, MTR, LPT, ETR, GETR
8/77 to 9/77	34	EBR-II, MORE, SPERT, ORNL-17-1, BMI, Kinglet, Sandia (Godiva reactors), PBF metallurgical samples
7/78 to 3/79	35	Zr, custom
9/80 to 3/81	36	Zr, Rocky Flats U <sub>3</sub> O <sub>8</sub> , GETR, OWR, STIR, LPTR, UCLA-MTR, ATR, ETR, ATR-XA
8/81 to 11/81	37	EBR-II, Los Alamos metal fuel scrap, Rocky Flats U <sub>3</sub> O <sub>8</sub> , Rover cold
9/82 to 11/82	38	ETR, BSR, ATR, OWR, ORR, HFR-PETTEN, SAPHIR, GETR, FRG, FRJ/FRM, SFR, UO <sub>2</sub> SO <sub>4</sub>
4/83 to 6/84	39	Rover, Sandia, Rocky Flats, cold FLUORINEL, FLUORINEL phase I cold run
8/85 to 1/86	40	ITAL, FRG, DR-3, UCLA, MURR, OWR, HFBR, LPTR, TR-1, ATR, BSR, ORR, HMI, Triton, FRJ-2, HRF, BR-2, ORPHEE, ASTRA, SRF, R-2, JUNTA, McMaster, JRR-2, JMTR, JANUS, SR, UCSB UO <sub>2</sub> SO <sub>4</sub> , FLUORINEL Phase II cold run, FLUORINEL Pilot Plant
10/86 to 10/87	41	FLUORINEL
1/87 to 7/88	42	FLUORINEL, EBR-II Vycor glass, BYU UO <sub>2</sub> SO <sub>4</sub> , EBR-II fuel scrap, ANL-E fuel scrap

*Source:* S. M. Stacy, Proving the Principle: A History of the Idaho National Engineering and Environmental Laboratory, 1949 – 1999, (Idaho Falls, ID: U.S. Department of Energy Report No. DOE/ID-10799, 2000) pp. 269-272.

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