

# THE SL-1 REACTOR

*That experience eclipses all of the other experiences I had up there.*

–Dr. George Voelz, NRTS Medical Director–

In the arctic tundra, a treeless plain north of the conifer forests of Canada and Alaska, plant life relies on shallow bogs and a few inches of top soil. Below, the soil is frozen all year long, permanently unresponsive to the spring thaw. Vast acreages of the tundra allow practically no life at all, the ground a dark and flinty mat of stones.

This was the setting that the U.S. Army described to the Argonne Lab as the destination for a small nuclear power plant. The Army had in mind the Distant Early Warning system, the DEW Line. Beginning in 1953, dozens of manned radar stations ringed the Arctic Circle, on constant watch for a Soviet air invasion. The Army regularly shipped diesel fuel to each station for heat and electricity. This was costly and sometimes hazardous in such remote areas, and the

Army hoped to replace the diesel supply line with nuclear power.

The vision was to package a power plant in three or four pieces, fit them into cargo planes or trucks, and have soldiers assemble them in a few hours. Easy to operate, a plant would run at least three years on one fuel loading. The plant need generate only a thousand kilowatts, and

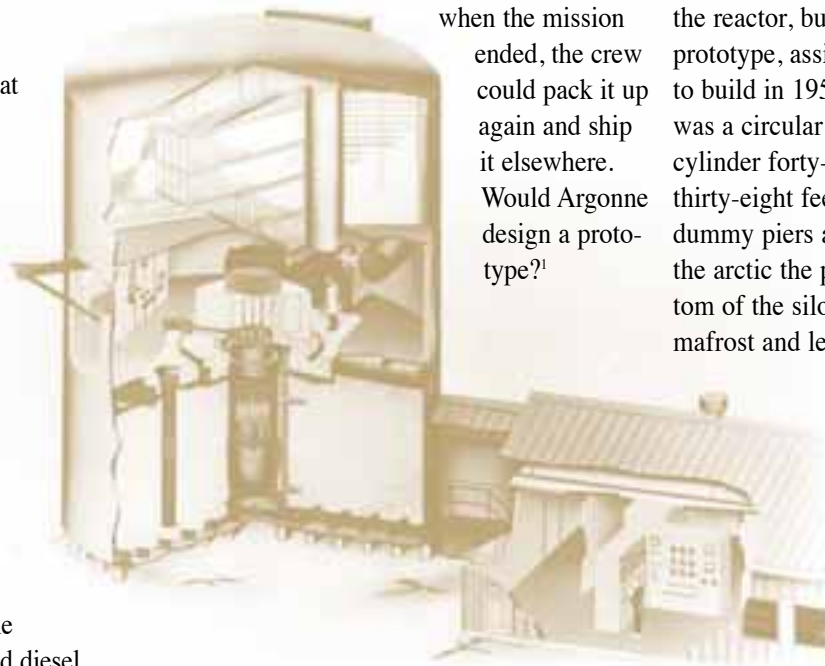
when the mission ended, the crew could pack it up again and ship it elsewhere. Would Argonne design a prototype?<sup>1</sup>

Applying its BORAX experience, Argonne developed the project using a boiling water reactor concept. The virtue of the system was that steam from the boiling water powered the turbine directly, eliminating the weight and complexity of a secondary loop and heat exchanger equipment.<sup>2</sup>

With tundra permafrost conditions in mind, the Army wanted to test not only the reactor, but its building as well. The prototype, assigned to Idaho, was ready to build in 1957. The building shell was a circular steel tank, a silo-like cylinder forty-eight feet high and about thirty-eight feet in diameter. It sat on dummy piers arranged in a circle. In the arctic the piers would hold the bottom of the silo two feet above the permafrost and leave airspace between the floor and the ground.

This would prevent transferring heat to the permafrost. Despite its armored appearance, the silo was not intended as a containment structure. Both the NRTS and potential arctic

destinations were sufficiently remote, and the power level of the reactor



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*Cutaway of SL-1 reactor and the control building. Reactor floor is above shielding gravel. Fan floor is above reactor floor.*



*Pressure vessel for Stationary Low-Power Reactor has been placed during construction. Steel plate is going up around the reactor building. Circa 1958.*

Argonne National Laboratory-West 103-4055



## PROVING THE PRINCIPLE

sufficiently low, that the AEC deemed such a feature unnecessary.<sup>3</sup>

Inside, the plant was arranged like a three-layer cake. In the bottom third, native stone and gravel shielded the pressure vessel containing the reactor. The middle third was the operating level, giving the crew access to the top of the reactor, the turbine generator, and control rod machinery. On top, a “fan floor” attic contained equipment to condense and cool the recirculating water. A weather-protected stairway snaked up the side of the cylinder to connect the adjacent control building to the operating floor level.<sup>4</sup>

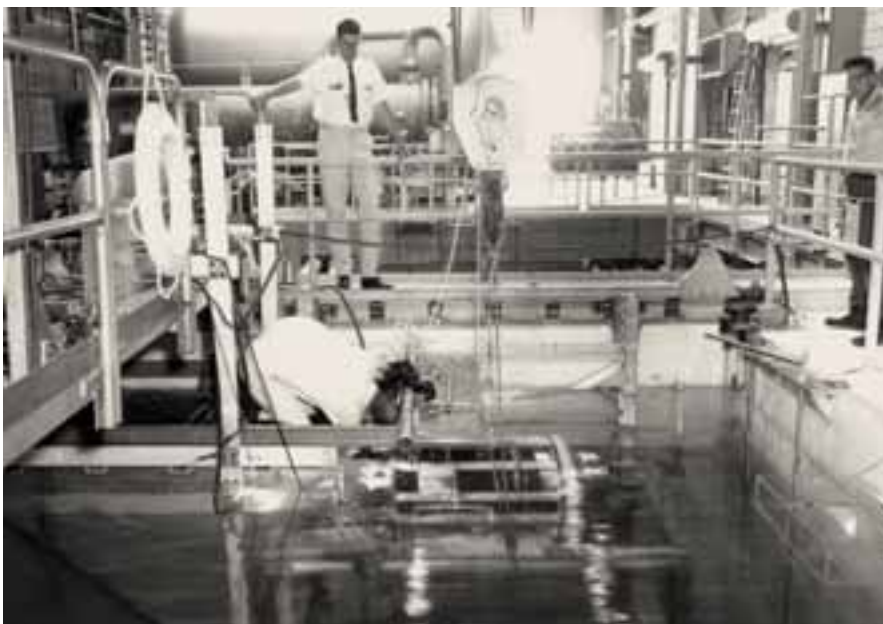
After Argonne handed over the finished plant to the Army’s operating contractor, Combustion Engineering (CE), the Army named the reactor Stationary Low-Power Reactor Number One, or SL-1. This name distinguished the reactor from a whole family of other small reactors that the Army already had built

or was planning. Reactors were to be “stationary,” “portable,” or “mobile,” depending on the intended field application, and rated for “low,” “medium,” or “high” power.<sup>5</sup>

The IDO opened up an Army Reactor Experimental Area (AREA) about a half mile north of State Highway 20 and ten miles east of Central Facilities.



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The SL-1 was the first of three anticipated Army experiments at the NRTS. The other two were intended to perfect a “mobile” reactor so miniaturized that it would fit on a truck and move whenever a field station moved. As of 1958 all the reactors built in the United States had been cooled with water or liquid metal. But gas was a coolant possibility and the Army chose to explore it for mobile reactors. Ultimately, the Army hoped ordinary air could be used, further simplifying the power plant and eliminating more weight. The Army contracted Aerojet General Corporation to design a Gas Cooled Reactor Experiment (GCRE) and do for the gas-cooled concept what BORAX, SPERT, and TREAT had done for the other concepts: determine its safe operating parameters and select the best fuel. That done, the Army would use the remoteness of the NRTS to field-test a prototype for the Mobile Low-Power Reactor, or ML-1.<sup>6</sup>

The IDO reserved sites for the three reactors at half mile intervals along an access road it named Fillmore Avenue. The GCRE, a water-moderated reactor situated in a “swimming pool” pit below the floor, went critical in 1959, and the ML-1 was expected to arrive sometime in 1961.<sup>7</sup>

*Above. Cadremen at SL-1 control panel. Left. Operators make adjustments in GCRE reactor pit.*

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The Army planned to train its future DEW Line crews at the SL-1, so CE ran the reactor with a military crew. The Army and the Air Force sent trainees; the Navy, interested in the potential of the SL-1 for Navy missions, sent Seabees. The mixed “cadres” trained together and rotated to Idaho after several months of instruction at Fort Belvoir, Virginia, where the Army operated its prototype Stationary Medium-Power (SM-1) reactor eighteen miles from the White House.

The SL-1 went critical for the first time on August 11, 1958, and produced its first electricity two months later on October 24. Thereafter, the rhythm of work involved running the reactor for periods ranging between one and six weeks and then shutting down for training in maintenance and repair or to install improvements. The first cadre had been trained, tested, and certified by May 1959, and many others followed. CE’s Christmas routine was to shut down the reactor, celebrate the holiday, and then do annual maintenance tasks before the next start-up.<sup>8</sup>

Accordingly, on December 23, 1960, CE shut down the reactor. Crews returned on December 27, reporting to work in three shifts around the clock. Start-up was scheduled for January 4, 1961. The men calibrated instruments and attended to the valves, pipes, and pump that circulated coolant water through the reactor. To do part of this work, they lowered the water level in the reactor about two feet.

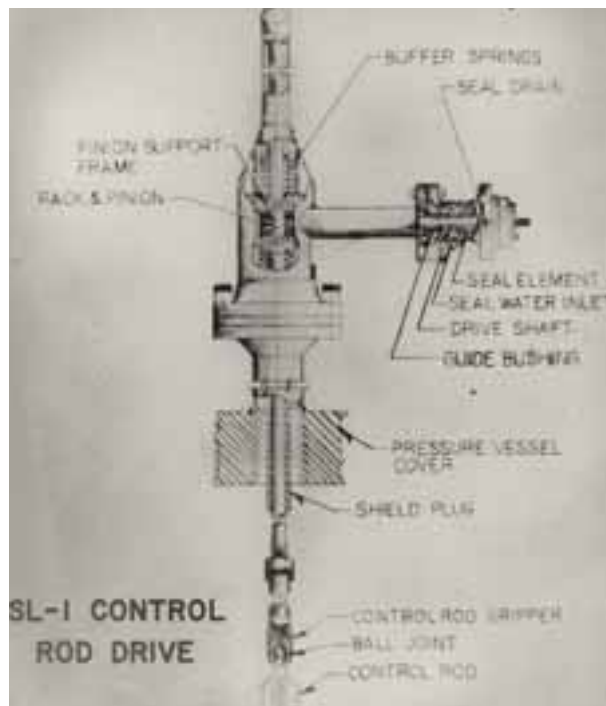
The last task was to insert forty-four new cobalt flux wires into the core for later mapping of the reactor’s neutron flux. The January 3 day shift inserted the flux wires. To gain access to the reactor core, they had moved out of the way several large concrete shielding blocks that ringed the top of the reactor. Then they disconnected the control rods from their drive mechanisms, these also being in the way. It would fall to the 4 p.m. shift to reconnect the control rods to the drive mechanism.<sup>9</sup>

In miserably cold weather—the temperature was headed for seventeen degrees below zero that night—the three-man crew arrived from Idaho Falls and set to work, the only workers at the SL-1 area. As usual for night shifts, no guards were posted at the entry gate, which the day-shift cadremen had locked behind them as they left.

Reconnecting the drive mechanisms involved several steps, one of which was to lift the control rod—manually—about three inches out of the reactor. At the top of the control rod was a small ball. A “gripper” from the drive mechanism latched onto this ball, completing the connection between the rod and the rest of the mechanism and its motor.



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Above. Enclosed stairway from SL-1 support building to operating floor of reactor silo. Left. The control rod drive mechanism. Note cruciform shape of control rod (bottom of drawing).

## P R O V I N G   T H E   P R I N C I P L E

The control rods were not cylindrical in shape, as the name “rod” might imply. Rather they were cruciform, with four narrow fin-like projections that moved up and down the length of the core in narrow sheaths. The fuel zone was nearly twenty-eight inches long. Moving the rods three inches was safe and not enough to invite a chain reaction.<sup>10</sup>

In recent weeks, the control rods had seemed to stick slightly, perhaps because other items in the reactor core had bowed, invading clearance spaces and putting pressure on the sheath, crowding the slender fins of the control rods. The three men, wearing their gray coveralls, were in the silo at 9 p.m., two of them directly over or very close to the top of the reactor, working with the central control rod. At 9:01 something happened, the reactor went “prompt critical” and blew up.

When the reactor went critical, it released so much heat energy in four milliseconds that it flashed the water surrounding the fuel to steam. The steam, being of lower density than liquid water and thus a less effective moderator, quenched the nuclear reaction. The decay heat built up rapidly. With no system operating to remove the heat, twenty percent of the fuel melted. The steam forced upwards the seven-foot column of still-liquid water above it. The water rushed through the two feet of air space. It slammed against the lid of the pressure vessel at a velocity of 160 feet per second and 10,000 pounds per square inch exactly as if it were a piston—a water hammer. The entire vessel jumped nine feet into the air, hit



INEEL 61-4

the ceiling, and thumped back into place, shearing all of its connections to the piping and instrumentation systems. Iron pellets packed near the reactor as thermal insulation and radiation shielding scattered all over the floor. The water hammer expelled the control-rod shield plugs, water, fragments of fuel, fission products, and other metal from the top of the reactor, leaving open holes. The violence of the explosion killed all three of the men.<sup>11</sup>

Two of them died instantly, one thrown sideways against a shielding block and the other straight upwards, where one of the shield plugs pinned his body to the ceiling. The head wounds of the third were fatal, but his pulse continued for another two hours. The blast blew shards of radioactive metal into their bodies, making them a danger to those who soon would try to rescue and recover them.<sup>12</sup>

*Scene at control station set up near junction of Highway 20 and Fillmore Avenue.*

It would take nearly two years of tenacious inquiry to make plain what had happened in two seconds, and the long process of discovery began immediately.

At 9:01 p.m., the heat-sensitive fire alarm above the SL-1 reactor radios one long and two shorts—the code for the SL-1 complex—at the security center and the three NRTS fire stations. Accident response procedures commence. A security force notifies the duty officer and sets off for SL-1. The firemen at Central, the closest to the Army complex, grab a card detailing the potential hazards at SL-1 and review it as the fire engine rolls. The duty officer tunes in to their conversation. Nine minutes later, they arrive at the locked gate. Equipped with keys, a detail covered by prior planning, the firemen unlock the gate. They observe no fires, no apparent disturbance, and

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no one about in the freezing cold. They note a slight trail of steam coming from the reactor building, a typical sight in the cold.<sup>13</sup>

The firemen enter the control building carrying radiation detection instruments. They walk down the central corridor, calling, inspecting each room. In one, they see three lunch pails on a table. Finding nothing amiss, they move toward the door at the bottom of the covered stairway. The radiation indicator moves sharply. They withdraw.

By 9:17 p.m., an HP from the MTR arrives and, together with a fireman, approaches the stairs. Each wears a Scott Air-Pak, a 40-pound tank of air harnessed and buckled onto the back with a hose to a face mask. It pumps air to the face, so that if the mask leaks, air is expelled, protecting the wearer from dangerous gas or contaminated dust. As the rescuers start up the stairs, the detectors read 25 R/hr; they withdraw. By now, the security detail has determined that the men are nowhere else at the NRTS. Other searchers find no one in the SL-1 support buildings. The growing crowd of rescuers is forced to conclude that three cadremen are somewhere inside the very quiet reactor building.

In a few minutes, two more HPs arrive, dressed in fully protective clothing and equipped with Jordan Redectors, an instrument able to detect gamma radiation up to 500 R/hr. One of them ascends the stairs with two of the firemen, a constant eye on the Jordan. At the top of the stairs, they discern damage inside, no men. The indicator needle pegs. The HP orders all to withdraw.

Meanwhile, in accordance with the emergency plan, CE and IDO authorities had been notified. Around 9:20 p.m., John Horan, the IDO director of Health and Safety, answers the telephone at home and then tells his wife, "There's been an accident." He leaves for his Idaho Falls office where he has radio communication with the entire Site. As he passes the security desk, the guard tells him three people are missing, but there is no fire.

Horan declares a "Class 1" emergency, meaning the incident is restricted to one location. IDO personnel in Idaho Falls speed to the site—the IDO duty officer, environmental HPs, the medical director and his assistant, others. The news goes to AEC Headquarters. The weather station reports the direction of the wind. The Radiological Assistance Plan goes into effect, activating the HPs in other complexes for response. The fire department sets up an operations trailer

at the intersection of Highway 20 and Fillmore Avenue. Security forces prepare to block Highway 20 traffic, if necessary.<sup>14</sup>

The environmental HPs take detectors into the desert beyond the SL-1, looking for radioactivity on the sagebrush that might have come from a cloud in the light breeze. Others head for Highway 20 and collect samples there. Horan orders an aircraft and asks the aerial-monitoring team to stand by. Then he thinks better of an idea to send them on a night monitoring expedition. Heretofore, they had not practiced low-level night flights. They will fly at 6:30 a.m. Meanwhile the ground surveyors conclude that the public—and they—can travel safely on Highway 20.<sup>15</sup>

*HPs check Highway 20 for contamination on the morning after the accident.*



INEL 61-9



## P R O V I N G   T H E   P R I N C I P L E

Around 10:30 p.m., the CE supervisor and HP arrive at SL-1, equip themselves, and enter the reactor building to look for the men. They find one badly mutilated and clearly dead, and they observe a small movement by another.

They withdraw, formulate a plan, and enter once more, this time with two other military men and an IDO HP. Radiation is estimated at up to 1,000 R/hr, lethal. The HPs will allow no one inside the building for longer than one minute, and they use stopwatches to time the rescuers and order them out when the minute is up. The five men rush up the stairway with a stretcher. They skid and slip on the water and the marble-like pellets littering the floor. Face masks fog up. Two men collect the man for whom they have some hope of survival while the others try, but fail, to locate the third man.

The rescuers place the man in a courier vehicle and drive toward the intersection with Highway 20. On the way, they meet an ambulance and transfer him. As they reach the intersection, the NRTS night nurse, Hazel Leisen, arrives in her car and enters the ambulance, hearing what proves to be the man's last breath. She applies an oxygen resuscitator to no avail. Around 11:00 p.m. the assistant medical director, Dr. John Spickard, pronounces the man dead.<sup>16</sup>

The accident was unprecedented. These were the first reactor casualties in the fourteen-year history of the AEC. Emergency planning had not accounted for an event quite like this one. All those involved in the recovery, therefore, now confronted situations and made decisions unlike any they had faced before.

One of the first was made by Dr. George Voelz, the medical director, who arrived a few minutes after his assistant and considered what should be done with the body. The dispensary at Central was completely unsuited for receiving a contaminated body. The small facility had been designed for the living; it consisted of one shower head installed under the dispensary's basement stairway. It was useless for this situation. Dr. Voelz recalled:

*Because his level of radiation was so high, we had no place to put him. We left him in the ambulance until we could figure out what we were going to do next. The ambulance was sitting out in the desert, amongst the sagebrush. We decided the first thing we would do was see how much radioactive material we could remove by taking off the clothing. We wanted to get this done before the morning traffic came onto the Site. It was about four o'clock in the morning when we decided to try to take the clothing off under the lights of a couple of automobiles. Because the radiation levels were 500 rads per hour, we decided to work outside at 20 below zero in anti-C [anti-contamination] coveralls...*

*With the moisture [released in the explosion] and the cold temperatures, the [clothes] were just one solid chunk of ice, having sat out there most of the night. The health physicists had given us about a minute's working time [to remove his coveralls]. But we had anticipated this, and had some pretty heavy-duty tools that we could use on these coveralls... They had a stopwatch on us, and we got the job done. I remember we went a few seconds over. I think it was a minute and seventeen seconds.*

*That gives you an idea of how you have to improvise when you get into accident scenarios. We were able to get the clothing off, and we put him back in the ambulance...<sup>17</sup>*

Removing the clothes didn't help. Radiation levels remained as before. They wrapped the body in blankets and draped lead aprons to protect the driver's seat in the ambulance. Around 6:30 a.m., the ambulance drove to the Chem Plant and into a large enclosed receiving bay. Near it a decontamination room lined with stainless steel served as a mortuary. Dr. Voelz had the body submerged in alcohol and ice to preserve it until he could develop a plan.

Because the reactor had not been operating, early speculation was that a chemical explosion had caused the accident. But of this no one could be certain. Radiation fields were extremely high within the silo. If the explosion hadn't killed the three men, the radiation would have.<sup>18</sup>

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INEEL 61-1221

*A crew prepares to collect a water sample from within the SL-1 reactor building.*

In the daylight of January 4, Horan deliberately slowed the pace of recovery operations. The victims were beyond saving, and it was now imperative to prevent further injuries. Allan Johnson told Horan, “John, I’m setting up a special account for the SL-1. Don’t hold back on anything you need...it will be covered.” They decided to document pictorially everything they could about the accident and the subsequent proceedings.<sup>19</sup>

*We wanted the nation and the world to learn what our experience was. It was unique, and we wanted to make sure that people knew our successes and our failures. That is why three movies were produced. For the first one of the basic accident, we took all the people that*

*were involved in the initial response, and they played in the movie the role that they actually did that night. That was part of our effort to be as factual as we could and not have some actor do it.*<sup>20</sup>

AEC Headquarters appointed an investigating committee and a technical advisory committee. Most of them arrived on January 4, ready to begin. The JCAE sent one of its staff to provide it with independent information as soon as possible. The national press sent reporters. AEC Headquarters staff arrived, and other AEC labs sent specialists as well. Later, the investigating committee complimented the IDO on its management of the crisis, but said also that the rapid arrival of so many outsiders, including themselves, had been a disservice to the IDO and the contractors as they undertook the recovery.<sup>21</sup>

IDO’s immediate priorities were to determine what threat the accident posed to public health, retrieve the other two men, and discover if the reactor was stable or not. The airplane pilots reported that the roof of the reactor was intact, undamaged. A cloud of radioactive iodine-131 had drifted south toward Atomic City, but its dispersion and mixing with air had reduced its concentration well below any health concerns. Ground surveys found that the only place needing to be quarantined was the immediate SL-1 yard, where the rescue attempt had tracked some contamination. Beyond that, amounts above background levels were negligible.<sup>22</sup>

A squad of six volunteers, all cadremen, spent January 4 rehearsing a plan to retrieve the body of the second man in two-man relays. Someone else ran into the silo to grab the logbook and a neutron detector. Crews decontaminated the ambulance. The medical staff set up a temporary decontamination center at the GCRE building just up the road from SL-1. The men who had retrieved the first body had not waited for special gloves; they—and in particular their hands—had to be washed clean of contamination, a process involving water, potassium permanganate, and plenty of scrubbing. All who had been involved received medical check-ups. The medical staff found no radiation injuries and hospitalized no one.<sup>23</sup>

That night, the cadremen retrieved their second comrade. The film and radiation foils in his dosimeter badge had been blown away by the explosion. In lieu of those items, radiochemists examined the gold buckle of one victim’s watch-



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band and a tiny screw in a pocket cigarette lighter. They found radioactive gold-198 and copper-64. Only neutron capture could have created such isotopes. Then they identified other fission products and several isotopes of uranium in the debris that had come out of

the reactor building with the men. All of this evidence proved that the reactor had gone critical.<sup>24</sup>

The third man finally was found. His position directly above the reactor presented a new hazard. Aside from the obvious difficulty of working in a high radiation field at an awkward location, physicists feared that if pieces of debris near him fell onto or into the reactor through the open shield-plug holes, the disturbance might start a chain reaction. A photographer suited up and entered the room for one minute, taking as many photographs as possible. With the help of the photos, a plan took shape for the retrieval. Army volunteers from a special Chemical Radiological Unit at Dugway Proving Ground wanted the practical experience offered by the challenge of removing the body. The twenty-four enlisted men and five officers perfected a plan and rehearsed their moves on a full-scale mock-up of

the SL-1 erected at Central. They rigged a special net on the boom of a crane and positioned it to prevent the body or anything else falling onto the reactor. Metal workers shielded the crane operator's cab. On January 9, eight men, paired in two-man relays limited to sixty-five seconds inside the building, recovered the body and lowered it to the ground.<sup>25</sup>

The body joined the other two at the Chem Plant. A team of health physics specialists and a forensic pathologist from Los Alamos conducted autopsies, improvising with long-handled instruments and other procedures to keep themselves safe. They hoped that the men's injuries might contribute some insight into where they had been at the moment of the accident and what might have caused it. Most urgently, they managed to reduce the radiation fields emanating from each body to between one and ten percent of the original levels.<sup>26</sup>



INEEL 61-685



INEEL 61-674

The subject of burial already had been quietly controversial within the top ranks of IDO and AEC management. A.R. Luedecke, AEC general manager, had proposed that the men be buried together somewhere on the NRTS site and a monument erected in their memory. Johnson and other IDO officials objected strenuously, feeling that the men's families deserved the right to conduct funeral rites of their own choosing and as naturally as possible. Their view prevailed. The IDO ordered

*Above. Recovery crews practiced at a mock-up, seen here under construction, at Central Facilities Area. Left. Crew from Dugway Proving Ground.*

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three standard metal caskets from Idaho Falls and had them delivered to one of the NRTS shops. Craftsmen lined them with lead. Extra lead wrap shielded body parts still heavily contaminated. Aside from protecting people who would handle the caskets, the caskets had to meet radiological shipping standards set by the Interstate Commerce Commission. Preparations complete, the respective military services took possession of the bodies and flew them to the destinations requested by the families. A health physicist accompanied each to provide any necessary advice and consultation.<sup>27</sup>

The retrieval of the third body ended what came to be known as Phase One of the SL-1 recovery. Phase Two lasted from January 10 through late April, the time it took for CE to be certain that the reactor was stable. No one entered the silo during those months. Operators dangled remotely controlled closed-circuit television and other equipment inside the reactor from the boom of a crane. CE finally concluded that the core no longer contained any moderating water and that the reactor could not go critical again.

That done, it was time to clean up the site and see if the reactor core could reveal the cause of the accident. After President Kennedy canceled the nuclear airplane project in March, GE had people

available and offered to clean up the building, decontaminate the site, and investigate. GE physicist Jay Kunze said later that the GE scientists considered the SL-1 job to be a choice assignment. BORAX and SPERT had failed to blow up. SL-1 should have been inherently safe. What had gone wrong? They welcomed a chance to solve the puzzle. But the cleanup had to come first. Kunze continued:



*The stretcher rig. Crews practiced before the rig was inserted into the reactor building to collect the body of the third man.*

*When IDO first asked GE if it could use the Hot Shop to analyze the reactor, GE said, "It's not available." But after the cancellation, the word was, "The Hot Shop is available!" GE had about five hundred people at the Site, eighty percent of whom were due to be terminated, most of those to be transferred to other GE sites as a result of the cancellation of the Aircraft Nuclear Propulsion Project. All of the profes-*

*sionals managed to find jobs with this project.*

*The SL-1 was a mess. It hadn't been cleaned up at all. To clean it up, people had to make short trips inside and do limited tasks within a couple of minutes and then get out. Even though you suited up, those couple of minutes would expose you to your quarterly dose of radiation, and you couldn't go back in*

*for three months or do any other work that could potentially expose you. Hundreds of people at GE, including those about to be transferred and many workers from other locations at the Site [and from Dugway], volunteered to take their quarterly radiation dose doing clean-up at the reactor. For many clean-up tasks, that was the only way of handling it. I don't remember*

*anyone being particularly fearful of the risk.<sup>28</sup>*

The time keepers were the HPs, who stood half-way down the stairway and banged on metal when someone's vacuum-cleaning stint was over. By November, the passage of time and removal of debris had reduced radiation levels. It was time to remove the reactor. Anticipating that the forty-mile truck ride to the TAN Hot Shop might disturb some of the evidence, the GE team went underneath the reactor and drilled several holes in the bottom of the pressure vessel. Through a special

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tube, they inserted a camera and took pictures inside the core.

The GE team had for months been examining debris fragments and other recovered reactor parts in an attempt to acquire as much information as possible before having to take the drastic action of cutting the pipes connecting the vessel to the rest of the plant's equipment. Kunze recalled:

*Our main concern was how to cut those large pipes so that a crane could lift the vessel up thirteen feet and then out and onto a truck. At first we envisioned no method except to use manpower in the form of many welders with their pipe-cutting torches, taking turns cutting as much pipe as possible before receiving their allowable maximum radiation dose.*

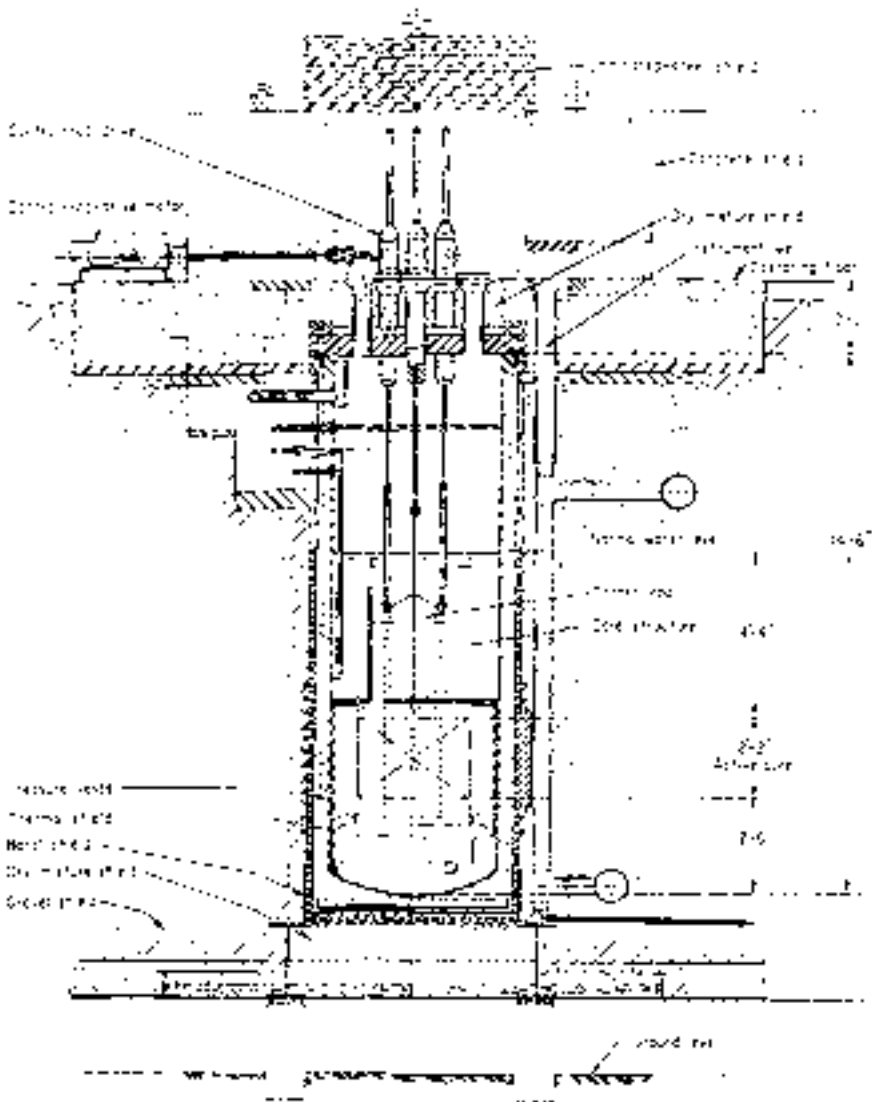
*But we continued to play around with basic physics ideas—and came across the idea that the water, ejected upward by the nuclear steam explosion, had transferred its momentum to the vessel, perhaps sufficiently to cause the vessel to break the pipes and be lifted. Our calculations indicated that the vessel may have risen enough to hit the ceiling immediately following the brief nuclear excursion. So we took a close look at the fan floor, that is, the ceiling of the reactor room, and saw that certain small dents matched up with the head of the vessel. Now we saw that there was no need to worry about how to cut the pipes. Much personnel risk and engineering frustration had been eliminated, all the result of the nature of this still somewhat mysterious accident.*

*We examined the recovered central control rod, plug, and housing mechanism carefully in the Hot Shop. The assembly had been recovered essentially with the rod in the “down” position. However, upon disassembly, scratch marks on the rod extension and the inside of the guide tube clearly showed that the guide tube had collapsed, the result of the 10,000-pound water hammer pressure, and had seized the rod extension at the 26 1/4 inch withdrawn position.*

*Subsequently, as the unit hit the ceiling, the extension rod was forced back down to nearly the zero withdrawn position.<sup>29</sup>*

Scratch marks had been made on the way back down, confirming that the rod originally had been withdrawn 26 1/4 inches. That the rod had been withdrawn and then jammed back down into the reactor to its “safe” position after hitting the ceiling was a bizarre coincidence. One finding had led to

Schematic of SL-1 reactor.





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another, and the team gradually recreated the mysterious two seconds. The mechanical and material evidence, combined with the nuclear and chemical evidence, forced them to believe that the central control rod had been withdrawn very rapidly. They built a mock-up of the reactor vessel with identically sheathed and weighted control rods. In King Arthur fashion, men of lesser, similar, and greater strength as the crew tried to lift the rod. Most managed with little difficulty. The scientists questioned the cadremen: "Did you know that the reactor would go critical if the central control rod were removed?" Answer: "Of course! We often talked about what we would do if we were at a radar station and the Russians came. We'd yank it out."<sup>30</sup>

On November 29, a large crane lifted the reactor vessel out of the silo and onto a truck for the trip to the Hot Shop the next day. Once it was inside the huge remotely-operated laboratory, the scientists re-photographed the core and plugged the holes. They filled the vessel with water and confirmed that the reactor was quite subcritical; it had given its one burst in the accident and that was all. Then they examined every inch of the vessel. They were particularly grateful that the flux wires had been freshly installed, for they portrayed the neutron flux uncompromised by previous history.<sup>31</sup>

Thus the core and the mangled pieces of metal surrendered their story. In July 1962, the GE investigators published their final report, observing that manual withdrawal of the central control rod could explain the accident: "No other means of withdrawing the rod has been found to be in accordance with the evidence."<sup>32</sup>