Health & Safety

RICHLAND OPERATIONS OFFICE

Richland, Washington

SUMMARY REPORT

of

ACCIDENTAL NUCLEAR EXCURSION

RECUPLEX OPERATION

234-5 FACILITY

Facsimile Price $ 2.60

Microfilm Price $ .95

Available from the
Office of Technical Services
Department of Commerce
Washington 25, D. C.

Summarized by:

Carl N. Zangar

Date of Incident:

April 7, 1962

SUMMARY REPORT

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ACCIDENTAL NUCLEAR EXCURSION
RECUPLEX OPERATION
234-5 FACILITY
APRIL 7, 1962

A. Introduction

On Saturday morning, April 7, 1962, at approximately 10:59 a.m., an accidental nuclear excursion occurred in a 60 liter glass tank (known as K-9) of a Hanford plutonium waste recovery facility, Recuplex. At the time of the incident, Recuplex was not engaged in normal operation. Personnel were essentially through with a clean up of the facility which had started in March. The investigation conducted subsequent to the excursion disclosed a concentrated plutonium solution of approximately 30 grams/liter in K-9. The solution is believed to have been sucked-up accidentally from the floor of the Solvent Extraction (SE) process hood through a temporary one-inch diameter plastic tube after it had found its way to the hood floor through an overflow tube from a product receiver tank called J-1. The operators on duty, however, do not recall manipulating the valve which would have effected the solution transfer. The accidental nuclear excursion, which is the first to have occurred in any Hanford production facility, resulted in three men being overexposed to gamma and neutron radiation. The radiation dose received by the three men is estimated to be 110, 43, and 19 rem, respectively. In each case the overexposure was recognized promptly, and following medical observation and testing, the men were returned to work in apparent good health.

The emergency plan was executed well. Personnel left the building immediately. Responsible AEC and contractor management were rapidly notified of the event, even though the accident occurred on a weekend day. The Emergency Control Center was activated and staffed rapidly with top management, consultants, and specialists. Individuals thought possibly to be significantly exposed to radiation were identified immediately and put under medical supervision. Radiation doses received by all persons were quickly determined. Control of entry and exit of personnel to and from the accident area was established early.

The excursion followed a generally predictable pattern. The course of the reaction comprised an initial rapid rise to a peak rate of fission, a subsidence, a rise to one or more later peaks, and after a period of the order of half an hour, the onset of approximately a 36-hour period of declining rate of fissions. Final subcriticality was probably caused by the loss of water, principally through evaporation. It has been calculated that the total number of

etween the time of the initial criticality and
(about 37 hours later) was 8 x 10^{17}. Calcula-
that approximately 8 x 10^{15} fissions occurred
receiving the highest exposure left the room.
al damage resulted from the excursion and there
spread.

ace Recuplex had been made prior to the incident,
l been authorized for both design and construction.
der construction now and is scheduled for com-
964. The old Recuplex facility started out as
ch successive changes it had become a production
of product output about twenty times its
y. Consideration of various factors such as
g Recuplex safety, the estimated available
en reactivation and permanent replacement, etc.,
not reactivate Recuplex. At the present time
s are being stored for recovery in the new
are being reclaimed by alternate methods.

r, along with other plants at Hanford, is operated
ric Company as prime contractor for the Atomic

and Process

r is a multipurpose plutonium recovery operation
r and purification of plutonium from waste streams
utonium Processing Plant and miscellaneous wastes
s both offsite and onsite.

rs, feed preparation tanks, solvent extraction
llaneous auxiliary equipment. A process flow
portion of the process of immediate interest
The solvent extraction process is performed in
ns. The feed solution is continuously fed to
l point of the H-1 column. This feed contains
a nitrate salting agent, and plutonium, which
arily by ionic impurities rather than by uranium
By counter-current flow the aqueous phase
per cent tributyl phosphate (TBP) in carbon
in the column which extracts the plutonium
tively into the organic phase, but leaves the
ntially quantitatively in the aqueous phase.
eam (CAS) introduced at the bottom of the column
purities back from the outgoing solvent phase
se. An intermediate scrub (CAIS) or product
ee fect above the CAS feed point concentrates
columns to about 100 grams per liter.

ontaining the plutonium is pumped to the top of
a counterflow of aqueous strip solution (a
tant in a 0.15 M nitric solution) transfers the

plutonium back into an aqueous phase. This stripping column product (CCP) is initially or partially used as the intermediate scrub (CAIS) in the extraction column (H-1 and H-2). Recycling of product into the system is continued until the concentration is about 100 grams per liter, at which point product is removed from the top of the stripping column (H-3) and received in the product receiver tank (J-1).

The organic solvent, virtually free of plutonium, leaves the bottom of the H-3 column and enters the solvent treatment tanks (K-1 and K-2). Essentially all of the plutonium in the effluent organic forms a strongly organic-favoring plutonium complex with dibutylphosphate (DBP), a primary decomposition product of tributylphosphate. This trace of "unstrippable" plutonium is removed from the organic phase in the solvent treatment tanks (K-1 or K-2) as the organic phase falls through (and is periodically agitated with) an aqueous cap (FS solution) of ferrous ammonium sulfate, sulfamic acid, and nitric acid. After the plutonium concentration in this cap reaches about three grams/liter, as determined by sampling in the K-1 or K-2 tanks, the cap is transferred to the wash receiver tank (G-58) via the transfer tank (K-9). Periodically, the DBP is removed from the organic phase with a carbonate wash.

Fig. 2 is a photograph of a model of the SE hood. This illustration more clearly shows the physical locations of the equipment in the hood, including the J-1 tank overflow point and the K-9 tank in which the nuclear excursion took place.

Fig. 3 is a pictorial flow diagram of the SE process. This figure concerns itself mainly with the route by which product solution entered the K-9 tank, viz., from the J-1 tank via the J-1 overflow to the sump, and from the sump via the one inch temporary plastic tube to the K-9 tank.

C. Operations Prior to Incident

On February 22, 1962, it was recommended that the Recuplex operation be shutdown to remove material which had accumulated on the floor of the solvent extraction hood, and so the decision was made to shut off all rich feed to the system until the solvent extraction floor could be cleaned up and certain piping and structural members could be replaced. The material on the floor had accumulated over a period of months due to deterioration of the equipment with resultant leakage of liquids to the hood floors. These liquids, composed of both process organic and aqueous solutions, had attacked the decomposed, contaminated plastic bags and neoprene gloves which had accumulated on the floor, resulting in some sludge resembling black tar containing varying concentrations of plutonium. Detailed procedures were prepared for this clean up program. The clean out occurred during the month of March, and the solvent extraction hood floor was reported as clean on March 30, 1962.

The floor clean up procedures required that successive volumes of aluminum nitrate and nitric acid be added to the floors, sampled and analyzed and, depending upon analysis, specific volumes transferred by vacuum through a temporary one-inch plastic tube (which had been installed on March 14, 1962 for this specific purpose) to the K-9 tank to which cadmium nitrate had previously been added as a safety precaution. This material from K-9 was then transferred to L-2, a waste tank, see Fig. 4, into a solution of water, nitric acid, aluminum nitrate, sodium nitrate and mistron. This operation was continued until four batches from K-9 had been accumulated in the L-2 tank, at which time 200 liters of contact organic containing 8 liters of dibutyl butyl phosphonate was added to the L-2 tank and agitated for two hours to extract the Pu from the aqueous phase. Then, it was sampled and analyzed. The aqueous phase, when stripped of plutonium, was discarded to cribs. The organic phase was washed with an extractant composed of water, nitric acid, ferrous sulfamate and hydrofluoric acid. This solution was then run through the solvent extraction system for plutonium recovery and the organic phase was saved for subsequent contacts. The procedure was repeated during the month until such time as the floor was cleaned.

Following the floor clean up the Recuplex system became coated with the undissolved contaminated, tarry floor material which required that the system itself be cleaned thoroughly before it could be put back into normal operation.

The system clean-out was initiated on March 31, 1962, and was composed of a series of hydrofluoric acid flushes, followed by aluminum nitrate to complex the fluoride ion, starting at the waste tanks and working through the system with basic emphasis on recovering the plutonium and discarding the sludge-contaminated organic and aqueous solutions.

During the above operations considerable difficulty was experienced with plugging of lines, flooding of the organic extraction columns, and system leaks. This caused considerable rework of both the organic and aqueous streams. The clean-out had proceeded up to the point that the auxiliary systems, i.e., organic receiver tanks (K-1, K-2) organic transfer-decant tank (K-9), and waste tanks (L-2, L-3, L-8) were in the final stages of the flush, and steps were being taken to commence clean-out of the extraction columns when the excursion took place.

The specific operations leading up to the incident were as follows:

1. On the 12-8 shift on April 7, 1962, 550 liters of used contact organic solution containing plutonium above the cribbing limits, was moved from its storage tank (G-36), shown on Fig. 4, to waste receiver tank (L-2) and sampled. The analysis which was reported on the same shift showed 2.11 grams Pu/liter (later corrected to 2.19 grams/liter), and that approximately 1200 total grams of plutonium was in the tank. The shift specialist decided to wash part of this organic to reduce the Pu content.

Approximately 130 liters were moved from L-2 back to G-36 and 200 liters were to be drawn in four batches from L-2 to K-9 tank by vacuum and dropped by gravity to the K-2 tank for washing with an aqueous phase containing ferrous sulfamate and hydrofluoric acid to extract the plutonium. This aqueous phase, after sufficient contact time, was to be decanted into the K-9 tank and then pumped to the G-58 tank for later use (see Fig. 4)

2. On the 12-8 shift, the first transfer of 55 liters was made from the L-2 tank to K-9 and dropped by gravity to the K-2 tank. This transfer was made by drawing the material back through the 431 valve into the bottom of K-9 because it was thought to be a faster means of transfer than through the normal routing through the 506 valve into the top of K-9. It was reported by the operator on the 12-8 shift that there was essentially no aqueous layer on the organic in K-9, although this could have been in error due to the poor visibility in the hood and the difficulty of seeing in the tank from the operating floor level.

3. The 8-4 shift continued the transfer of contact organic from L-2 thru K-9 to K-2 by opening valve 506 (shown on Fig. 4) which is the normal route from L-2 to K-9. The 543 and 431 valves opened and used for transfers by the operator on the previous shift, and reportedly left open by him, apparently were not closed by employee No. 1, the employee who conducted these transfers. This allowed material to be moved into K-9 from L-2 by two routes simultaneously. This transfer continued intermittently during the morning of April 7, 1962, until a total of 3 or 4 batches of approximately 50-55 liters each had been transferred into K-2 tank. (Operator recollection is hazy as to whether 3 or 4 batches were transferred). The intermittent operation occurred due to interruptions caused by a flooding condition in the solvent extraction columns which required the operator's attention.

4. At approximately 10:30 a.m., a process operator (Employee No. 18) relieved the regular operator, Employee No. 1, for personal relief and finished transferring the last 25 liters from L-2 to K-9. He dropped a total of 50 liters into K-2 from K-9 and notified the regular operator, when he returned, that the transfer had been completed. The regular operator then took over and reported subsequent to the incident that there was an aqueous cap of 10-30 liters on the top of the organic phase in K-2 with a total of 210 liters of organic in K-2.

5. The operator started a vacuum decant of the cap from K-2 back up to K-9 and was in the process of getting ready to add wash chemicals (ferrous sulfamate and water) from K-8 (chemical addition tank) to K-2 when the incident occurred in K-9 tank. Employee No. 1 stated that "I had started to open my K-8 to K-2 chemical addition valve" (433) when he saw a blue flash and heard a sound like that made by the drawing of an electric arc.

D. Description of Accident and Postaccident Events

The 234-5 Building, of which Recuplex operation is a part, and the immediate environs contained 24 persons at the time of the accident. Twenty-two of the twenty-four persons were in the 234-5 Building, and two patrolmen were in a nearby Gate House, 2701-Z. The duties of these twenty-four employees are briefly indicated below. Since the accident occurred on a Saturday, most of the people normally assigned to day work in the building were absent.

Employee No.	Job	Employee No.	Job
*1	Process operator	13	Process operator
2	Patrolman	14	Process operator
3	Engineer	15	Process operator
4	Engineer	16	Engineer
5	Power operator	*17	Specialist in Recuplex
6	Accounting clerk	18	Process operator
7	Power operator	19	Patrolman (in 2701-Z)
8	Chemical analyst	20	Patrolman (in 2701-Z)
9	Technologist	21	Pipefitter
10	Laboratory Leader	22	Chemical analyst
11	Radiation monitor	*23	Utility operator
12	Utility operator	24	Process chemist

The operator (employee #1) was standing directly in front of and somewhat below K-9 (his head is estimated to have been three feet in front of and four feet below the center of K-9). He reported that the flash was above him, and in K-9 or possibly to the right of K-9 by a foot or two. Employee #17, the shift specialist, was standing a few feet to the rear and left of employee #1. His view was somewhat obstructed both by employee #1 and by the lead shields which stand in front of the hood. However, he also saw the flash and heard the sound reported by employee #1, and generally agreed with employee #1 as to the location of the flash. Employee #1 described the flash as having a "jagged" appearance, "somewhat like lightning". (Employee #1 has an apparent muscular imbalance of his eyes, which might make his visual observations somewhat unreliable under some conditions. This eye imbalance is a condition of long standing and antedates the accident by some years).

Employee #1 heard the building poppies first, followed by the criticality alarm siren in a very short time. He turned one of the emergency switches which shuts off power to certain process operations and left the area immediately. Employee #17 also left instantly by

*Employees overexposed

a different route. Employee #23, who was on the mezzanine floor also left promptly, as did a pipefitter, employee #21, from an area which was essentially a part of but somewhat shielded from the operating area. All but two of the 22 employees in the building also evacuated quickly. One of the two was employee #7, a power operator who was at work in the attic of the building at the end away from the Recuplex Area. This employee was discovered to be missing when an informal accounting of those remembered to be in the building was made by other employees at the 234-5 badge house. Employee #7 was called on the telephone from the badge house and immediately left Building 234-5. He had heard the alarm but thought it was an alarm attached to some of the equipment for which he was responsible, and accordingly was investigating this possibility when telephoned. The other employee whose exit was slightly delayed was employee #6, an accountability clerk, who paused to lock up her safe. These two employees took about four and two minutes, respectively, to reach the gate house. All the others were at the gate house in a much shorter time. All but one employee in the 234-5 Building left by the most direct route. All but one of the employees in the building at the time of the accident were wearing their film dosimeters. The exception had his film dosimeter on his coat which was hanging a few feet from him. A few supplementary dosimeters (finger rings, neutron badges) were being worn at the time of the accident.

After leaving the building, all employees congregated either in the 2701-Z Gate House or on the northeast side of an adjacent building, using it as a shield from the 234-5 Building. A radiation monitor who had been present in the 234-5 Building left by a back exit, got into a pickup truck, and drove promptly around to the Gate House. He was able, therefore, to make radiation measurements almost immediately in the Gate House and warn all personnel to evacuate further since dose rates up to 200 mr/hour were registered. Most of the 234-5 Building personnel boarded the evacuation bus and were driven to the 200-W Area First Aid Building. Some others had private cars which were used and patrol vehicles transported the rest. Approximately five to ten minutes elapsed between the time of the incident and evacuation of the Gate House.

A patrolman who had been in 234-5 at the time of the alarm went at once to the Gate House where at 11:02 a.m. he notified the 200 West radio operator (by telephone) that the 234-5 alarm had sounded. Immediately following, a second patrolman also at the Gate House telephoned the 200 West radio operator that the alarm appeared genuine. The radio operator contacted the patrol lieutenant in the 200 Area and dispatched two patrol cars to the 234-5 vicinity. At 11:07 a.m., the radio operator notified the Emergency Patrol Officer in Richland of the incident although the radio operator did not yet know the nature of the emergency.

Employee #17, who was the senior supervisory employee in the building, telephoned his Section Manager in Richland with the news of the accident at about 11:03 a.m. This was probably the first external notification of the accident.

Upon arrival at First Aid, all employees were given a "Quick Sort" check, i.e., a Geiger-Mueller tube was placed on the abdomen, the employee bent his body over the tube, and the count rate due to any neutron-induced activity in the body was measured. Several, but not all, were also given immediate contamination surveys. In addition to the Quick Sort procedure, bioassay samples were taken and dosimeters were exchanged.

The Quick Sort procedure identified three employees (#1, #17, and #23) as having sufficient induced radioactivity to warrant their being put under immediate medical observation.

These three employees were sent to the hospital in a radio patrol car, leaving the 200-W Area at 11:32 a.m., and arriving at the hospital in Richland, a distance of approximately 25 miles, a few minutes before noon. Upon arrival, the three employees were first given an examination for radioactive contamination, which required only a few minutes. During this examination, a Company physician arrived and took charge of the three patients.

Meanwhile, in the 200-W Area, the following events were transpiring: Employees #10 and #11 (a Laboratory Leader and a Radiation Specialist) immediately following the evacuation to the First Aid Building started a survey of the 234-5 Building perimeter fence and roadways, finding no contamination and radiation levels of about 50 mr/hr at the Gate House. They alerted personnel in surrounding plants and also obtained spare instruments from one of the plants. They checked the laundry building for contamination since all of its beta-gamma detector instruments responded at the time of the excursion.

Employee #24 had arranged for barricade of pertinent roadways upon evacuation.

The contractor's Manager of Control Operation, Finished Products, who had been telephoned at his home in nearby Sunnyside, Washington, by employee #24, arrived a few moments before noon. Employee #6 (Accounting Clerk) was found at the area gate and instructed to return to the First Aid Building. Arrangements were made at First Aid to obtain bioassay specimens from all personnel, including the patrolmen in the area, to send all health badges in for processing, and also to perform the Quick Sort procedure for the patrolmen and employee #6. Employee #21 was then sent to the hospital because he had been moderately near the source. Employees #10 and #11 returned from their tour at about 12:20 p.m. and reported everything under control. They were requested to stay out of all radiation zones.

The contractor's Control Operation Manager arranged for an AEC Security man and an AEC Safety Engineer to drive him to the 234-5 Building for the purpose of retrieving three radiation monitoring personnel from that Building. These three radiation monitoring personnel had re-entered the 234-5 Building at about 12:15 p.m. for about 15 minutes. One man kept time while the other two made surveys with gamma-beta sensitive instruments and recovered a Hurst dosimeter

from Recuplex and one located near the south door to 234-5. Dose rates as high as 5 r/hr were measured by this team in Recuplex. Readings outside the building were also made by this team and ranged from 10-50 mr/hr from the door on the northeast side of the building to the main entrance on the north side of the building. Inside the building dose rates up to 350 mr/hr were measured on the top of the stairs inside the main entrance, and in a corridor. No alpha contamination could be found. On emerging from the 234-5 Building, the three monitors were met by the Control Operation Manager, AEC Safety Engineer and the Processing Operation Manager who had just arrived. They were ordered to leave the area immediately.

It was decided to make neutron measurements. The nearest BF_3 instrument available outside the 234-5 Building was in a building about 100 yards away. The Radiation Analyst from a nearby plant who had just arrived with other monitors was dispatched with a patrolman to obtain it. It was observed and reported at this time that the nuclear reaction was continuing. At about 12:40 p.m., the contractor's Manager of Production of the Chemical Processing Department arrived at the 234-5 Gate House from his headquarters at the 200-W Patrol Building, and, subject to the direction of the Emergency Control Center in Richland, took firm charge of field operations. All personnel were withdrawn to the Patrol Building, and First Aid and Laundry operations were shut down. By this time a considerable number of radiation monitoring personnel and some technically trained supervisory personnel had arrived from other areas in the plant and from Richland.

Events in Richland

In Richland, mobilization of the Emergency Control Center (ECC) was proceeding. At about 11:10 a.m., the AEC duty officer in Richland was notified of the accident by the Patrol Duty Captain in the ECC. This station is manned by GE Patrol 24-hours a day, 7 days a week. Other telephone notifications to AEC and GE top management followed in quick succession. By approximately 11:25 a.m., persons who had received these telephone communications began to arrive at the Center. These included the Manager of the Chemical Processing Department (of which Recuplex is a part), the Manager of the Hanford Laboratories, the General Manager of GE-HAPO, the Manager of the Richland Operations Office, the Director of the RLOO Production Division, and many other specialist in nuclear safety, criticality, radiation protection, and the Recuplex Operation. Within the first hour after activation of the ECC, the following events took place:

a. Barricades were requested to control traffic approaching the 200 West Area.

b. Environmental survey teams were dispatched to evaluate any resultant ground contamination.

c. Radiation monitoring assistance was sent to the 200-W Area.

d. Kadlec Hospital was notified that three men who were involved in a radiation accident were being brought to Kadlec. Radiation Specialists were sent to Kadlec to await arrival of the men.

e. The 3705 Building (film badge processing) was activated to provide personnel dosimeter evaluation.

f. The 329 Building (radiological analysis) was activated to provide counting of the criticality dosimeters, blood samples, and other activated materials which could help in the dosimetry evaluations.

g. Periodic reports from Meteorology - particularly wind directions and speed - were requested and utilized in directing the environmental survey teams.

h. Technical assistance was dispatched to the 200-W Area. As noted above, the Manager of Production, Chemical Processing Department, was dispatched from the ECC to be Field Operations Manager during this period also, arriving and setting up his command post in the 200-W Patrol Headquarters at about 12:34. There was constant communication between the ECC, 200-W Area, various patrol posts, and cars.

By 12:40 p.m., April 7, about one hour and 40 minutes after the accident, the ECC had been activated, a Field Operations Manager had been established and had gone into action. The situation thus entered a new phase, in which it continued until it was established that the chain reaction had ceased.

Realization that the chain reaction was actually continuing appears to have crystallized about 12:35 p.m., although the possibility had been recognized from the first. When this fact became known, the principal aim of operations became the avoidance of any act which would cause an intensification of the reaction, and the development of means of safely stopping the reaction. It was quickly decided that no further entry of personnel to the 234-5 Building would be permitted except for the correction of conditions which might otherwise cause further serious damage. Accordingly, only the following additional entries were carried out:

1. Two men entered to shut off a dissolver left running in one of the laboratories (about 1:50 p.m., April 7).

2. Four men entered to shut off five electric appliances known to have been left on. While in the building, they also recovered the remaining dosimeters, and radiation levels in the building were noted and mapped. Both neutron and gamma-beta sensitive badges and instruments were used. Dose rates up to 2.5 r/hr and above 250 mrem/hr neutrons were encountered. A laboratory gas burner was shut off from outside the building at the gas bottle manifold.

Radiation levels at various points in the vicinity of the 234-5 Building were taken. Within about eight hours, it began to appear

that after the first two or three hours (before fully systematic observations had started) the chain reaction rate had been decreasing. For this reason, although a number of proposals for stopping the reaction had been made and seriously considered, it was concluded that the best course of action consisted of allowing the reaction to die by itself if it would do so, as seemed likely. Fig. 5 shows the measured neutron counting rates at a point about 110 feet from the K-9 tank, and somewhat shielded from it by concrete walls. As shown on the chart, the neutron flux dropped to background about 37 hours after the accident. Gamma measurements taken during this period are in agreement with the cessation of the chain reaction at about midnight, April 8.

By 3:00 p.m., April 7, top management had created three distinct groups:

1. A Working Group, to investigate all the approaches that might be taken with ultimate objective of safely quenching the reaction. This group was to create plans, but could not put them into effect without approval of an Advisory Council. The Working Group was made up of employees having detailed technical and operational familiarity with the Recuplex facility.

2. An Advisory Council, to review and approve the plans of the Working Group. The Advisory Council was made up of senior technical management individuals, one of whom was the Manager of the Chemical Processing Department.

3. An Investigation Committee, made up of senior technical staff of management personnel, charged with determining the cause of the accident if possible, and with making recommendations to prevent a recurrence.

   This Committee was composed of two RLOO employees, one of whom was Chairman, and five GE-HAPO employees. An additional GE employee who had considerable technical background in the field of interest served as secretary of the Committee.

Termination of the chain reaction meant that the objective of operations became primarily to assure that no chain reaction could recur, and secondarily, to acquire information which would enable a valid explanation of how the accident had occurred.

1. Steps to Render Facility Safe

   It was determined that the first step would be entry by a small remotely-controlled robot which had been constructed for use in the event of a reactor accident requiring the remote handling of irradiated fuel slugs (Fig. 6). This device was rigged up to carry a television camera and other equipment. The TV camera enabled the remotely-situated operator to steer the robot clear of obstructions, and also to perform a variety

of manipulations. The TV camera also made it possible to obtain readings of gages and dials remotely, without having to send a man into the process room itself. The TVRM (Television Robot Monitor) made numerous entries, controlled by an operator situated in a corridor about 100 feet from the suspect tank K-9 and enjoying some protection from intervening walls. It was estimated that in the event of an excursion in K-9 of 5×10^{17} fissions, the TVRM operator would receive a dose less than one rem. (The original excursion plus the subsequent periods of fluctuating or sustained chain reaction was then estimated to have involved about 4×10^{17} fissions). Thus, operations with the TVRM could be conducted in relative safety insofar as personnel exposure was concerned. Early entries were for the purpose of reconnoitering the status of the room, reading dials and gages, placing lights in strategic locations, moving furniture, equipment, etc., out of obstructive positions, and placing instruments where needed. These entries confirmed that there was no mechanical damage outside the hood, that all external gages read as they should have at the point in the process where the accident occurred, and that there was no alpha contamination above normal background in the room. The most significant result was obtained when on April 12 the TVRM was equipped with a highly directional gamma probe, and the hood was surveyed for gamma activity with it. This survey disclosed unmistakably that tank K-9 was the only strong source of gamma radiation in the room, thus confirming that the excursion had occurred in K-9 and that the resulting fission products were still confined to K-9 and not outside it, e.g., in the glove box sump.

Attention turned next to the problem of restoration of K-9 to atmospheric pressure. At the time of the accident, the vapor space in K-9 was connected to a vacuum manifold (it is by this means that liquids are moved into K-9 from lower tanks). The pressure in the vacuum manifold was possibly as low as about 26" Hg subatmospheric. It seemed possible that there might be boiling of the liquid in K-9 or air in-leakage through connections to the bottom of K-9. In either case, the average density of the liquid layer in K-9 would be reduced by the boiling or sparging, and it seemed possible that the condition of subcriticality might be being maintained by this means. In that case, restoration of atmospheric pressure might cause another nuclear excursion. (For this reason, an important concern during this period was to assure the maintenance of the vacuum. Fortunately, the vacuum pumps were located outside the building proper and so were accessible with little risk.) A valve located on top of K-9 controlled its communication with the vacuum header; actuation of this valve would shut off vacuum and vent the tank to the hood atmosphere. The valve is an air-actuated type, and is in turn controlled by a control-panel-mounted air valve. Turning the panel-mounted valve 90° should actuate the vacuum-vent valve on K-9.

It was decided, in view of the risk of criticality, to use the TVRM to turn the panel-mounted valve. However, on the first attempt (April 13), due probably to the awkward angle at which the TVRM had to work, the valve handle was broken off, leaving only a short stub. It was then necessary to make a special tool for the TVRM by which, on April 14, the handle was successfully turned. The crucial parameter under observation at this time was the neutron flux as recorded by instruments previously placed in the vicinity of K-9. No significant change in flux whatever was observed, thus indicating no change in multiplication in K-9. However, it was impossible to be sure whether this meant that vacuum had been removed from K-9 without causing criticality, or whether the K-9 vacuum-vent valve had simply not been actuated. This possibility had been foreseen, and could have been obviated by simply shutting off the vacuum pump, so that the entire vacuum header would come quickly to atmospheric pressure. However, this procedure had been rejected because it might result in suck-back of liquid from the vacuum header into K-9, and a resulting renewal of criticality. The next step, therefore, was to close the valve connecting the vacuum trap (J-6) to the vacuum header. This trap, located between K-9 and the vacuum header, was indicated to be empty by the gage reading as seen with the TVRM camera. Prior to closing the J-6 valve, however, the TVRM was again used to survey the SE hood floor and tanks. The survey showed all the fission activity still to be in K-9. Had there been a sizable leak below liquid level in K-9, some fission activity would have been expected to show up on the floor upon shutting off the vacuum. The survey, therefore, showed that either no such leak existed, or that the vacuum had not been shut off of K-9, or both.

The J-6 valve was shut off on April 16 after spending considerable effort in evaluating the risks involved if it should develop that, contrary to indications, J-6 contained liquid and the K-9 vacuum-vent valve was still open to the vacuum system. The closing of the J-6 vacuum valve was uneventful.

During the above described operations, plans had been under intensive study for the removal of at least a large part of the contents of K-9 to a geometrically favorable vessel. The plan adopted involved sucking the contents of K-9 out through its sampling tube, which was to be connected to a long plastic tube terminating in a geometrically favorable tank located in a room in the laboratory wing of the building about 130 feet from K-9. However, before this or any other plan of similar purpose could be adopted, it was judged necessary to send a human observer into the room. Since this represented a distinct departure from previous operations, new procedures had to be devised and evaluated. Initially, the observation team (two were always sent) was permitted only to observe conditions, and to take instrumental readings. They were forbidden to touch any valves or to operate any controls. They were required to stop at

stated points and wait for determination that their presence was not affecting the neutron multiplication, although indications and calculations were that K-9 was safely subcritical. This observation procedure was carried out on April 18. The K-9 drainage procedure above mentioned was adopted and executed successfully on April 20. The turning of the valve which allowed the contents of K-9 to be removed through its sample tube was accomplished by an electrically driven, remotely-operated actuator, built for the occasion. The connection of the plastic tube to the sample valve handle had to be performed manually. Of the approximately 39 liters of liquid in K-9 at the start of the removal, about 25 were removed to the external tank. The operation proceeded smoothly. A sample of the extracted liquid was analyzed and found to contain about 34.8 grams/liter of Pu and fission product activity equivalent to 2×10^{16} fissions/liter. It is thus implied that the solution in K-9 contained about 1360 grams of Pu, and that the fissions in the incident came to about 8×10^{17}.

Although the most obvious criticality hazard had been removed by the actions just described, there was some uncertainty as to the quantity, type (organic or aqueous), Pu concentration, and other chemical composition of the contents of the other tanks in the area. It was clearly necessary that these vessels be sampled, but that significant residual criticality risk must be assumed still to remain. Although K-9 had been identified as the vessel in which the excursion had occurred, the manner in which the Pu concentration had arrived at K-9 had not been determined. The next step, therefore, was to add cadmium nitrate solution to those vessels in Recuplex which were not geometrically favorable and in which there was any significant probability of plutonium in critical quantities. In planning this step, it was believed necessary to take a very conservative view of what might be contained in any given tank since data available permitted only rough estimates in some cases, and the fact of the accident itself indicated anomalous conditions in the equipment. Cadmium nitrate solution addition could conceivably have caused another criticality under adverse conditions. Addition of the cadmium nitrate solution was accomplished on April 24 and 25. A line through which one of the additions was to be made was found to be plugged, and a new procedure had to be devised for introducing the solution into that tank, K-2. It was necessary to agitate the contents of each tank to which cadmium nitrate was added to assure that it would be effectively distributed. This was done using the regular process agitators, but wired so that they could be turned on or off from a remote location. This obviated the necessity for a man to be present in the room during agitation, when, conceivably, a temporarily critical condition could have been caused. The agitation was completed without incident and a number of samples were taken for chemical analysis on April 25.

Procedures for systematically taking and analyzing samples from all tanks were then carried out over a period of several weeks.

The Investigation Committee began its inquiries by first interviewing the men involved in the incident, the operators on several shifts preceding the incident, and other staff and management personnel. These inquiries failed to disclose precisely the cause of the incident. Therefore, the Committee assisted by numerous individuals of the Chemical Processing Department, GE-HAPO, sought to determine the cause of the incident by obtaining a complete chemical analysis of each vessel, by noting the position (open or closed) of each valve, and by determining the as-built location of all pipe lines, tubes, etc. Many types of records were examined but in spite of careful review of a large mass of evidence and testimony, it was not possible for the Committee to develop an explanation of the accident which completely agreed with all the technical data or all the personal testimony. An acceptable explanation was, however, developed. The most plausible explanation of the accident comprises the following statements:

1. During the latter part of the 12-8 shift on April 7, product solution flowed intermittently from the top of column H-3 (solvent extraction stripping column - see Fig. 3 for flow diagram) to vessel J-1 (a product receiver tank) and was intermittently removed from J-1 during this period. However, during part of the period, input sufficiently exceeded output to cause J-1 to fill and then to overflow. The overflow went via a line provided for the purpose to the floor of the SE hood.

2. At some time within several minutes before 10:59 a.m., and while suction was on tank K-9, valve #944 was opened, allowed to remain open for a few minutes, and then closed. This resulted in sucking some of the strong product solution from the sump (where it was in a thin slab geometry and therefore, necessarily subcritical) into K-9 where its geometry became such as to make it almost critical.

After the accident, K-9 contained about 39 liters of aqueous solution of 34.8 grams/liter Pu concentration plus a crudely estimated 68 grams (max.) of Pu in solids, and a few hundred milliliters of strong organic Pu solution in the lower connected piping for a total quantity of 1400-1500 grams of Pu. From certain instrument flow charts it was estimated that a total volume of about 48 liters overflowed from J-1 to the hood floor between the hours of 6:00-8:00 a.m., on April 7. The Pu concentration found in the J-1 tank after the accident was 34.4 grams per liter, but the Pu concentration in the J-1 liquid during the interval 6:00-8:00 a.m. was estimated to have been about 45 grams/liter average. Hence, the Pu overflowing onto the floor was about 48 x 45 = 2160 grams.

Brown rings left on the glass walls of K-9 suggest that the volume of the solution at the time of the accident was about 45 liters, which decreased by evaporation and radiolysis to the 39 liters found afterward. The concentration of Pu in the original K-9 solution would then have been about 30 grams/liter. The difference between the 45 grams per liter concentration in the overflow to the floor and the 30 grams per liter in K-9 is accounted for by assuming dilution of the floor solution with aqueous phase drawn from L-2, through K-9 and thence into K-2, where it formed the 10-30 liter aqueous cap reported by both the

8-4 shift operators. This solution would presumably be of the same concentration as that later found in L-2, i.e., 0.118 gram/liter. Mixing of the two liquids in the ratio two parts J-1 overflow to one part L-2 aqueous phase would give 45 liters of 30 grams/liter solution in K-9. Such a calculation is obviously not very accurate, since it does not take into account possible dilution of the J-1 overflow while on the floor; however, the impression given by all the operators was that there was only a little liquid (of the order of several liters) on the floor during the day or two before the accident.

E. Measures Which Would Have Prevented the Accident

Certain conditions existed in the Recuplex facility on April 7 which were necessary to the accident, and which were not necessary to operation of the equipment. Correction of these specific conditions would probably have presented the accident. The conditions referred to are:

1. K-9 was geometrically unfavorable, and although the introduction into it of fixed poison had been considered, no such poison was present.

   On at least three previous occasions there had been "overbatch" incidents in K-9, i.e., the specified maximum quantity of Pu allowed in the tank at any one time had been exceeded. Because these mass limits are set quite conservatively, there was no criticality in any of these cases. Partly as a result of these incidents, the installation of Pyrex glass raschig rings in K-9 had been considered. The boron contained in the Pyrex would have been a powerful suppressant of neutron multiplication. However, there were some objections to the installation of the rings (mixing of the contents of the tank would be more difficult, hold-up of liquid on the surface of the rings would be increased, sampling would be less reliable).

2. K-9 was not equipped with an alarm-sounding neutron counter which would signal the presence of too-large quantities of Pu. The installation of a neutron counter (which would sense the spontaneous fission neutrons from Pu^{240}) for detection of too-large quantities of Pu in K-9 had also been discussed. However, no decisive action had been taken, it being indicated that a counter of the type desired would be quite expensive and further study seemed desirable. Counters are available on various of the process vessels, but in order to get a reading from them, one must first set a selector switch to the counter of interest, since several counters feed into the same meter through a selector switch. No counter was installed on K-9.

3. The directly associated operating organization did not realize that a J-1 overflow would bypass J-5.

   Until about three years ago the overflow from J-1 was directed to J-5, a tank which serves also as an overflow catch tank for

various other vessels. J-5 itself overflows to the sump, but is provided with a high level alarm which notifies the operator to pump out J-5 into another tank from which appropriate final disposition of the overflow can be made. About three years ago, it was found that occasionally there would be contamination of J-1 with less pure overflow solutions from another vessel. The contamination was traced to a form of backing-up through the overflow line. To make sure of curing this trouble, a new overflow line was installed directly from J-1 to the floor. This change did not introduce a direct nuclear hazard, since the floor of the hood is geometrically favorable. However, after the accident it was found that relatively few people in the operating organization were aware of the existence of the direct overflow line from J-1 to the floor, and the operators relied upon the J-5 alarm signal to notify them of an impending overflow to the floor. The installation of the line was reviewed and approved by the Critical Mass Engineer at the time of installation, but the operating procedures do not mention the line or its effect on operations.

4. The operators did not observe or did not properly interpret the weight factor indication on J-1.

That an overflow might be occurring could have been inferred from the fact that the weight factor chart indicated the vessel to be full. However, this, in turn, would have required knowledge of the specific gravity of the solution in J-1. The input-output flow charts would also have given some hint of overflow had they been studies continuously. However, even in normal circumstances, the operator and the shift specialist are too busy to be expected to do such work. On April 7, they were doubly busy since there had been difficulty in keeping the H-1 and H-2 columns from flooding and this had taken much of the operator's attention on both the 12-8 and 8-4 shifts. Thus, while it would have been possible for the operator to have detected the overflow from J-1, it is not reasonable to expect him to have done so.

5. Valve #431 was open.

The Committee learned that when suction is applied to K-9 there are two routes by which liquid may be drawn from the same opening at the bottom of L-2 into K-9. One of these routes admits the liquid to the top of K-9, through valve #506. (See Fig. 4) The other admits liquid to K-9 through its bottom, via valve #431, the pump, and valve #543. The "normal" path was through valve #506, into the top of K-9. However, some of the operators felt that the transfer went faster if the other route (via valve #431) was used. Operating instructions did not forbid the use of the route through valve #431, and this route had been used on the 12-8 shift in making transfers from L-2 to K-9 and thence to K-2. Valve #431 was left open as a result of these transfers. The

S-4 operator did not make a complete valve status check when he came on duty, and was, hence, unaware that #431 was open. Had it been closed, the accident would not have happened.

6. The temporary one inch diameter tube from the sump to valve #944 had been allowed to stay in place after its usefulness was past. During the planned use of this tube, the procedure called for first determining the Pu content of the sump contents, then placing in K-9 a specified quantity of cadmium nitrate solution before sucking the sump liquid into K-9. These precautions were carefully detailed in a special instruction which had Critical Mass Engineering approval, but the instruction was silent on the subject of removal of the temporary plastic tube after the floor clean-up had been concluded. However, the supervisor's instructions to the operating crew after the floor clean-up had been completed included directions to cease using the temporary plastic tube. A work order for removal of this tube had been written four days after need of the tube ceased, however, three days later the work itself of removing the tube had not been performed. The work order was being handled as a routine scheduling item at the time of the incident. Thus, a full week had passed without correction of this primary hazard to critical mass safety.

7. Valve #944 was operated, contrary to oral instructions. No one admits to having operated valve #944, but no other plausible explanation is available.

7

ding, all employees congregated
on the northeast side of an adjac
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in the 234-5 Building left by a b
and drove promptly around to the
to make radiation measurements al
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Building. Some others had privat
vehicles transported the rest. A
lapsed between the time of the inc
House.

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where at 11:02 a.m. he notified
ephone) that the 234-5 alarm had
a second patrolman also at the
t radio operator that the alarm a
erator contacted the patrol lieut
tched two patrol cars to the 234-
io operator notified the Emergenc
the incident although the radio
e of the emergency.

the senior supervisory employee i
Manager in Richland with the new
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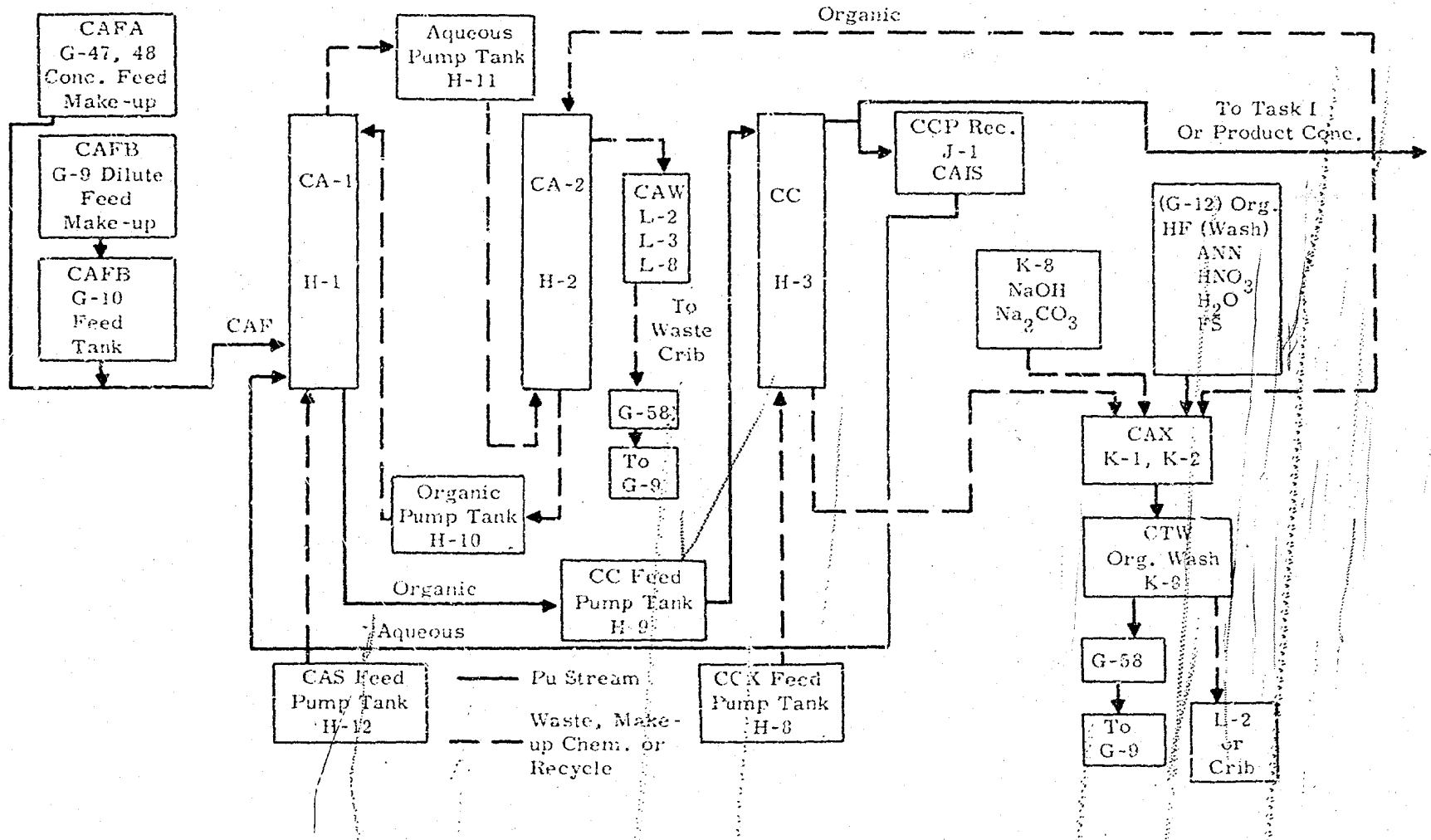
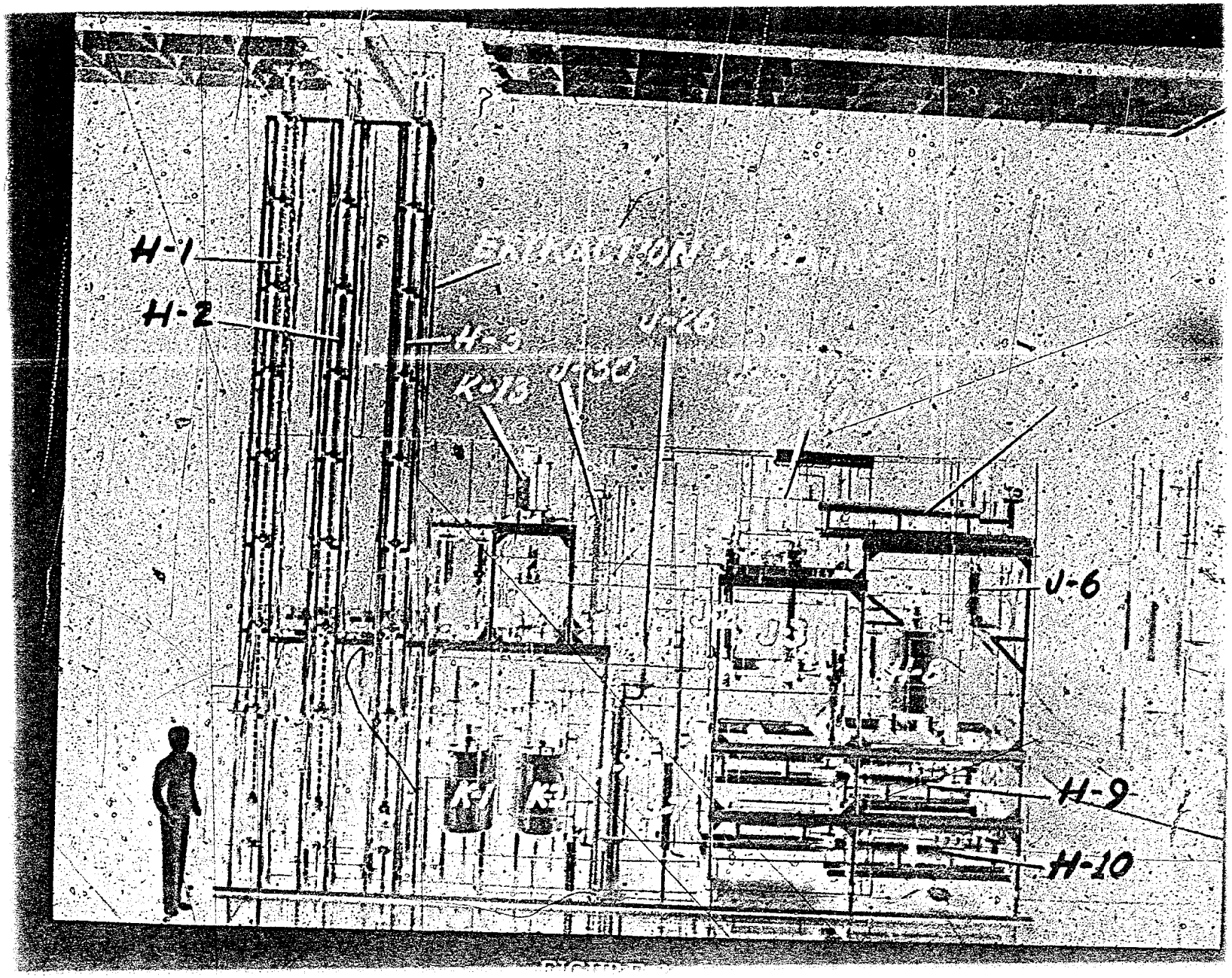


FIGURE 1

Solvent Extraction Process - Recuplex


H-1
H-2
H-3
J-6
H-9
H-10

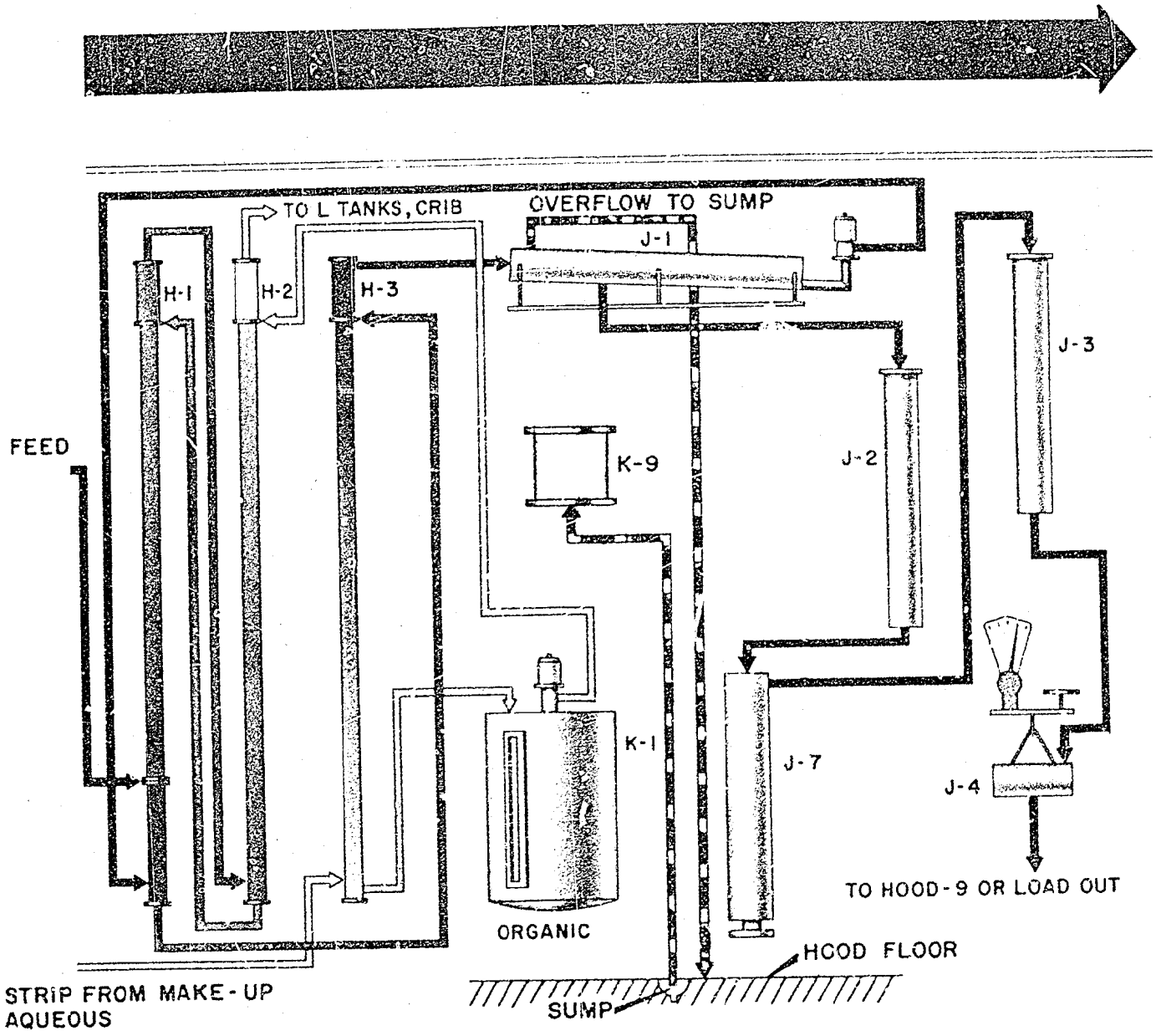


FIGURE 3
Pictorial Flow Diagram of SE Process

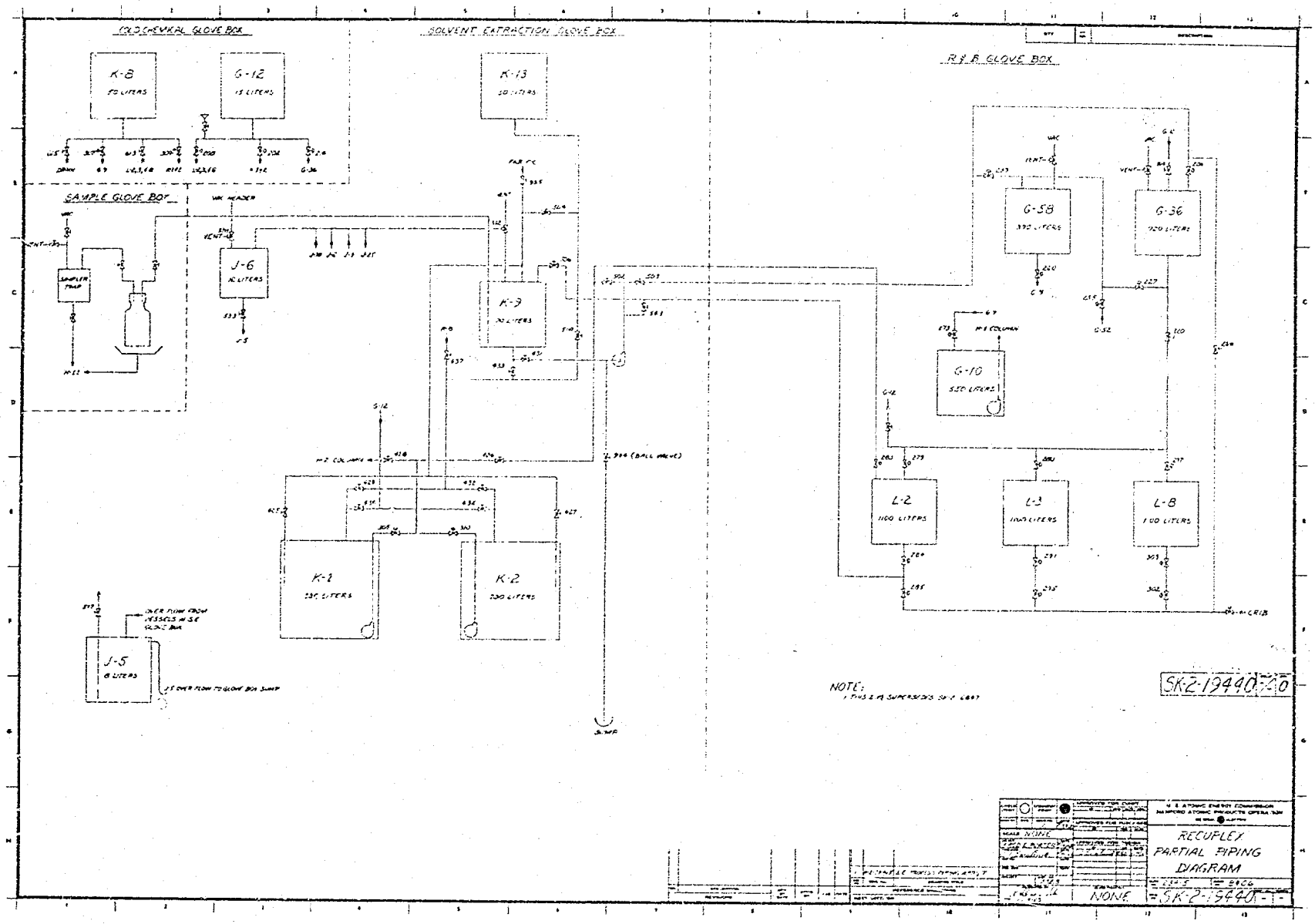


FIGURE 4

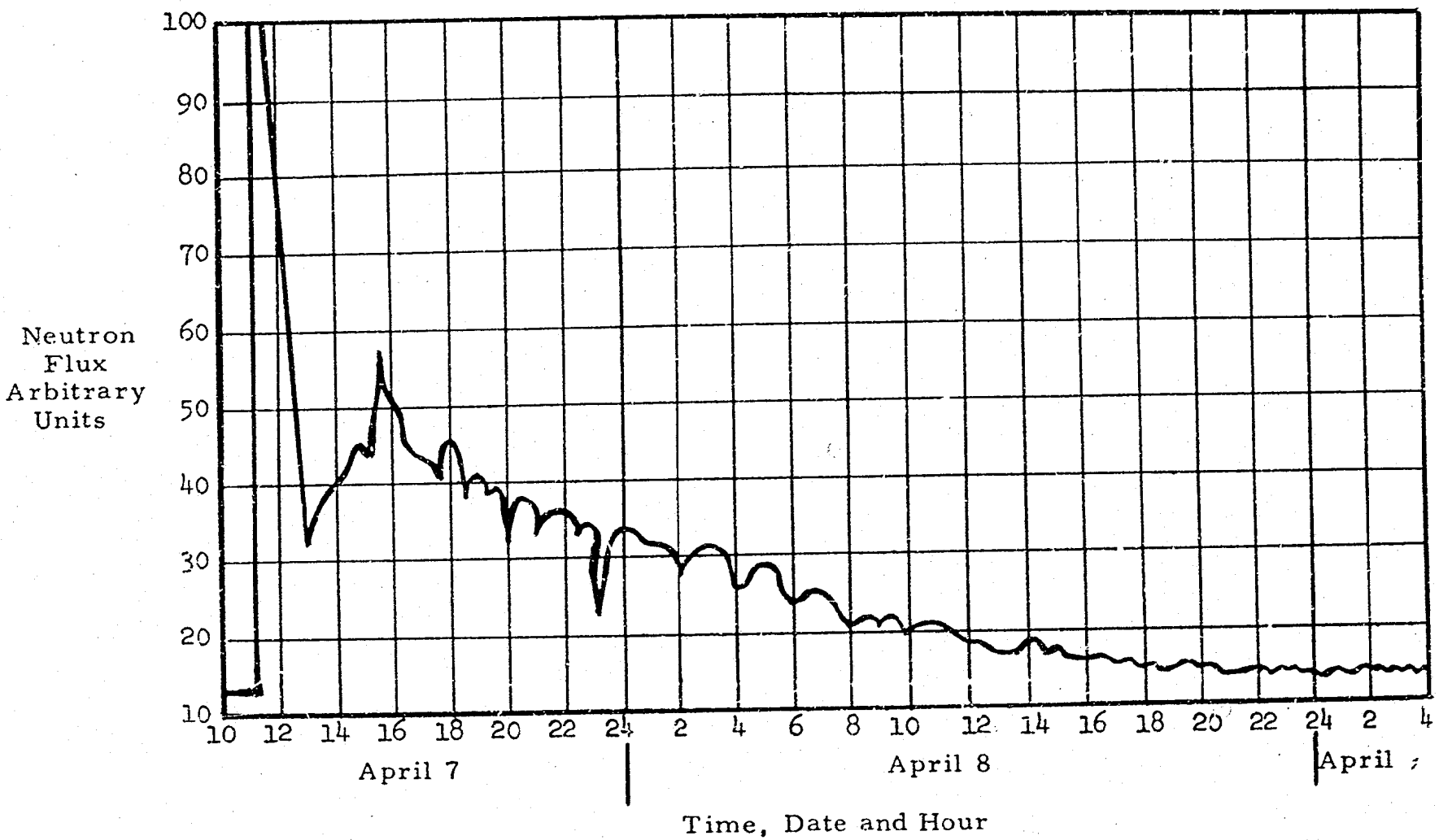


FIGURE 5
Measured Neutron Flux at Point Outside 234-5

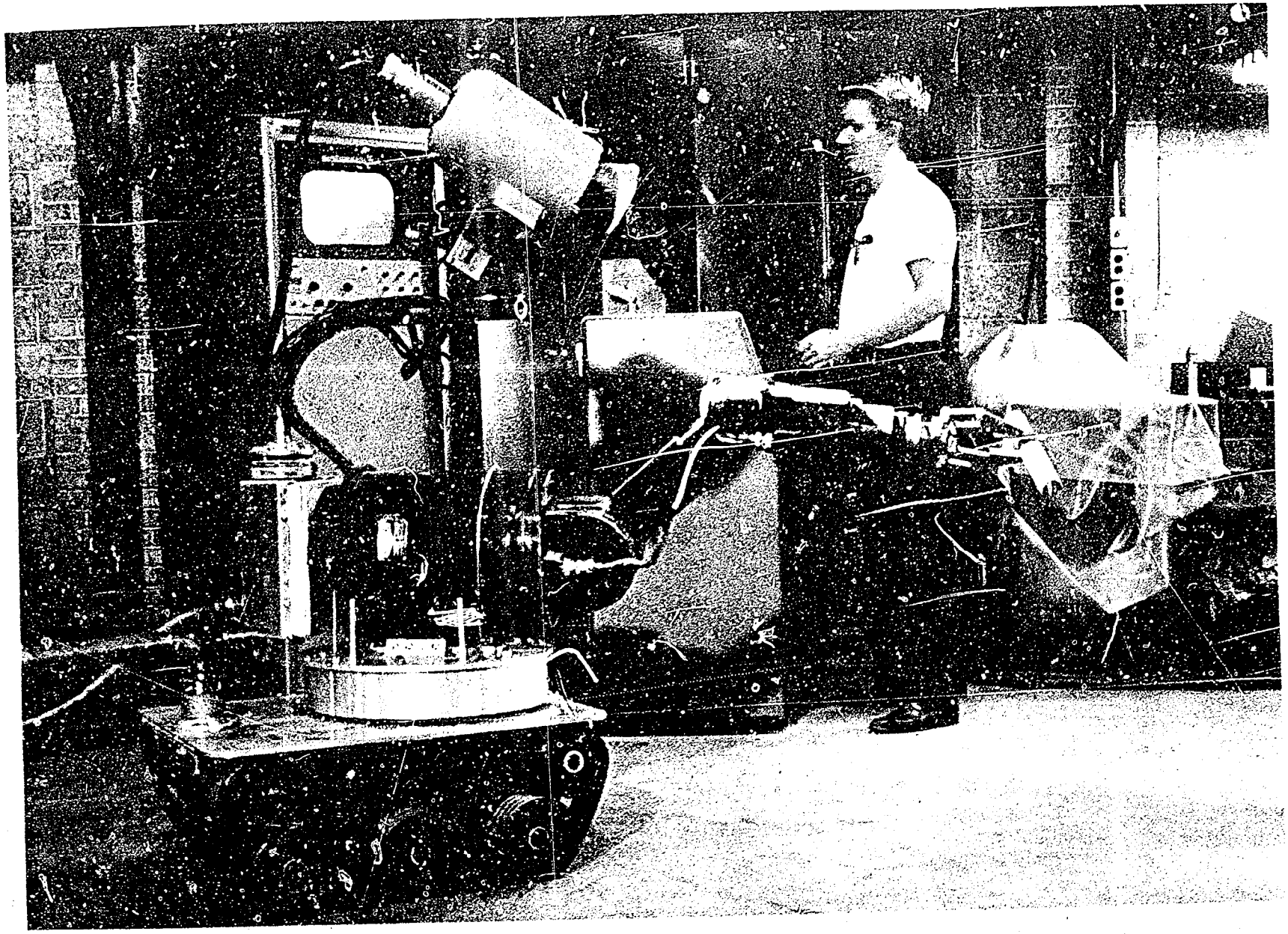


FIGURE 6

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>> 0230283 NSA Accession Number: NSA-17-020244
>> Title: SUMMARY REPORT OF ACCIDENTAL NUCLEAR EXCURSION, RECUPLEX
>> OPERATION, 234-5 FACILITY
>> Author(s): Zangar, C.N.
>> Corporate Source: Richland Operations Office, AEC
>> Publication Date: Apr. 7, 1962 Page(s): 25
>> Primary Report No.: TID-18431
>> Journal Announcement: NSA17
>> Document Type: Report
>> Language: English
>> Abstract: A description of occurrences associated with an
>> accidental nuclear excursion in a 60-l glass tank (K-9) of the
>> Hanford Recuplex facility is presented. This facility is a
>> multipurpose Pu recovery operation for processing wastes. The
>> plant and processes are described along with execution of the
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Author(s): Bender, M.A.; Gooch, P.C.
Corporate Source: Oak Ridge National Lab., Tenn.
Journal Info: Radiat. Res., 29: 568-82(Dec. 1966).
Publication Date: 1966
Secondary Report No.: ORNL-P--1859
Journal Announcement: NSA21
Document Type: Journal Article
Language: English
Subfile: NSA (Nuclear Science Abstracts)
Subfile (Bib.Info.Source): DTIE (Division of Technical Information Extension)
Contract No.: W-7405-ENG-26.
Descriptors: ACCIDENTS; CHROMOSOMES; CRITICALITY; FREQUENCY; GAMMA RADIATION; LEUCOCYTES; MALFORMATIONS; MAN; MEASUREMENT; NEUTRON BEAMS; RADIATION DOSES; TIME; USES
Subject Codes (NSA): N20420* --Life Sciences--Health Physics & Safety--Dosimetry & Monitoring

3 Complete Record
0301935 NSA Accession Number: NSA-19-004396
Title: RADIATION PROTECTION ASPECTS OF THE RECUPLEX INCIDENT OF APRIL 7, 1962
Author(s): Unruh, C.M. ed.
Corporate Source: General Electric Co. Hanford Atomic Products Operation, Richland, Wash.
Publication Date: May 14, 1962 Page(s): 108
Primary Report No.: HW-77295
Note: Revised May 1963
Journal Announcement: NSA19
Availability: NTIS
Document Type: Report
Language: English
Contract No.: AT(45-1)-1350
Descriptors: ACCIDENTS; BIOLOGY; CONTROL; EXCURSIONS; INSTRUMENTS; LIQUIDS; PERSONNEL; PLUTONIUM; RADIATION DETECTORS; RADIATION DOSES; RADIATION PROTECTION; RADIOCHEMISTRY; SAMPLING; SOLUTIONS; TRANSPORT
Subject Codes (NSA): HEALTH AND SAFETY

4 Complete Record
0300097 NSA Accession Number: NSA-19-002555
Title: RECUPLEX INCIDENT, APRIL 7, 1962-EMISSION OF FISSION PRODUCTS FROM THE 291-Z STACK
Author(s): Soldat, J.K.
Corporate Source: General Electric Co. Hanford Atomic Products Operation, Richland, Wash.
Publication Date: May 23, 1962 Page(s): 17
Primary Report No.: HW-77345
Journal Announcement: NSA19
Availability: NTIS
Document Type: Report
Language: English
Contract No.: AT(45-1)-1350
Descriptors: ACCIDENTS; ENVIRONMENT; FILTERS; FISSION PRODUCTS; FREQUENCY; GAMMA SPECTROMETERS; GASES; ORBITS; QUANTITY RATIO; RESIDUES; SAMPLING
Subject Codes (NSA): HEALTH AND SAFETY

5 Complete Record
0230283 NSA Accession Number: NSA-17-020244
Title: SUMMARY REPORT OF ACCIDENTAL NUCLEAR EXCURSION, RECUPLEX OPERATION, 234-5 FACILITY
Author(s): Zangar, C.N.
Corporate Source: Richland Operations Office, AEC
Publication Date: Apr. 7, 1962 Page(s): 25
Primary Report No.: TID-18431
Journal Announcement: NSA17
Document Type: Report
Language: English
Abstract: A description of occurrences associated with an accidental nuclear excursion in a 60-l glass tank (K-9) of the Hanford Recuplex facility is presented. This facility is a

multipurpose Pu recovery operation for processing wastes. The plant and processes are described along with execution of the emergency plan. Measures which could have been used to avoid the accident are discussed. (J.R.D.)
Subject Codes (NSA): HEALTH AND SAFETY

6 Complete Record
0228365 NSA Accession Number: NSA-17-018325
Title: DOSIMETRY INVESTIGATION OF THE RECUPLEX CRITICALITY ACCIDENT
Author(s): Gamertsfelder, C.C.; Larson, H.V.; Nielsen, J.M.; Roesch, W.C.; Watson, E.C.
Corporate Source: General Electric Co. Hanford Atomic Products Operation, Richland, Wash.
Publication Date: Aug. 22, 1962 Page(s): 32
Primary Report No.: HW-SA-2730
Journal Announcement: NSA17
Document Type: Report
Language: English
Contract No.: AT(45-1)-1350
Abstract: The dosimetry investigation made following a criticality accident in a Pu waste chemical recovery plant is described. Four men were hospitalized as a result of the accident but were released after medical observation. (J.R.D.)
Descriptors: ABSORPTION; ACCIDENTS; CONTROL; MASS; MEASURED VALUES; PERSONNEL; RADIATION DOSES; REPROCESSING
Subject Codes (NSA): HEALTH AND SAFETY

Health & Safety

RICHLAND OPERATIONS OFFICE

Richland, Washington

SUMMARY REPORT

of

ACCIDENTIAL NUCLEAR EXCURSION

RECUPLEX OPERATION

234-5 FACILITY

Summarized by:

Carl N. Zangar

Date of Incident:

April 7, 1962

of

ACCIDENTAL NUCLEAR EXCURSION
RECUPLEX OPERATION
234-5 FACILITY
APRIL 7, 1962

A. Introduction

On Saturday morning, April 7, 1962, at approximatel an accidental nuclear excursion occurred in a 60 li tank (known as K-9) of a Hanford plutonium waste re Recuplex. At the time of the incident, Recuplex wa in normal operation. Personnel were essentially th clean up of the facility which had started in March. gation conducted subsequent to the excursion disclo centrated plutonium solution of approximately 30 gra K-9. The solution is believed to have been sucked-u from the floor of the Solvent Extraction (SE) proces a temporary one-inch diameter plastic tube after it way to the hood floor through an overflow tube from receiver tank called J-1. The operators on duty, ho recall manipulating the valve which would have effec tion transfer. The accidental nuclear excursion, wh first to have occurred in any Hanford production fac in three men being overexposed to gamma and neutron The radiation dose received by the three men is esti 110, 43, and 19 rem, respectively. In each case the was recognized promptly, and following medical obser testing, the men were returned to work in apparent g

The emergency plan was executed well. Personnel left immediately. Responsible AEC and contractor manageme notified of the event, even though the accident occur end day. The Emergency Control Center was activated rapidly with top management, consultants, and special dividuals thought possibly to be significantly expose were identified immediately and put under medical sup Radiation doses received by all persons were quickly Control of entry and exit of personnel to and from th area was established early.

The excursion followed a generally predictable patter of the reaction comprised an initial rapid rise to a fission, a subsidence, a rise to one or more later pea a period of the order of half an hour, the onset of ap a 36-hour period of declining rate of fissions. Final was probably caused by the loss of water, principally evaporation. It has been calculated that the total nu

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