La-54-61A

NUCLEAR INCIDENT AT THE IDAHO CHEMICAL PROCESSING PLANT OF JANUARY 25, 1961

REPORT OF THE ACCIDENT REVIEW COMMITTEE
J. W. Latchum, Chairman
F. C. Haas
W. M. Hawkins
F. M. Warzel

Phillips Petroleum Co.
Atomic Energy Division
(Under Contract No. AT(10-1)-205)
Idaho Operations Office
U.S. Atomic Energy Commission

Date Issued: 4 April 1961

D R Wenzel

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Accident Review Committee

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PHILLIPS PETROLEUM CO.
ATOMIC ENERGY DIVISION
(UNDER CONTRACT NO. AT (10-1)-205)
IDAHO OPERATIONS OFFICE
U. S. ATOMIC ENERGY COMMISSION

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R. E. Commander
D. Ludlow
R. E. Baker
M. R. Smith

J. Operating Instruction Bulletin No. 1024 - Cleaning Plugged Process Lines

K. Listing of Other Reports Available on Incident

~ 2.83 l / cm-height in 2' dia disengaging head

For uniform rise (assuming over flow line plugged)

40 l ⇒ 14 cm

$\frac{H}{D} \Rightarrow \frac{14}{60} = 0.24$

$\frac{M_{cyl}}{M_{sb}} \cong 2.3$

$\therefore M_{sb}^{UNREF} @ 200\ gU(90)/l \Rightarrow 6+kg^{-25}$

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by

THE ACCIDENT REVIEW COMMITTEE
J. W. Latchum, Chairman
F. C. Haas
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I. SUMMARY

On January 25, 1961 at approximately 0947, a critical mass of U-235 accumulated in H-cell evaporator H-110 vapor disengaging head at the Chemical Processing Plant, National Reactor Testing Station, Idaho. Plant radiation alarms were set off by prompt gamma radiation and subsequent radioactive gas release from the plant stack to the atmosphere. The incident occurred five days after operations were resumed following a shutdown period of almost one year.

Available evidence indicates the most likely reason for accumulation of uranium solution in the critically unsafe vapor disengaging head of evaporator H-110 was the application of pressure to the base of the evaporator. Air pressure had been applied to solutions going to the product pumps from H-110 just prior to the incident, which occurred concurrent with opening a remotely operated valve in a line from the evaporator to the pumps. The approximate 200 g/l concentration uranium evaporator solution was thus forced momentarily into the expanded vapor disengaging section. Sufficient volume and concentration accumulated to cause a criticality reaction of apparently very short duration. The resultant evolution of heat and fission products produced an activity release through the off-gas system and out the plant stack. There were 188 Phillips Petroleum Company employees and 48 construction contractor employees that evacuated the plant.

Of the 15 AED personnel in close proximity to the reaction, the highest gamma exposure amounted to approximately 55 mrem or approximately one day's permissible exposure. Essentially zero beta radiation was detected. Additional checks have disclosed no neutron exposure in excess of 55 mrem nor significant internal dose from inhalation. There were 5 Phillips' personnel known to have been exposed to the cloud of fission gases. The highest assigned gamma exposure that can be given these individuals is 30 mr.

Limited visual inspection and operating tests indicate no significant property damage resulted from this incident. Radiation levels have precluded detailed inspection of the evaporator or other H-cell equipment. Costs of the plant shutdown resulting from the incident are estimated at $4200. Material balances on uranium indicate no loss within accuracy of measurement methods.

II. BACKGROUND

On the morning of January 25, 1961, CPP Operations were processing ETR fuel elements on a planned 20-day run. This was the first hot processing that had occurred in G- and H-cells in approximately one year. Previously, a cold run of a 12-day duration had been made using cold chemicals followed by enriched uranium scrap solutions to assure equipment was functioning and personnel reoriented. Dissolution and TBP extraction were being accomplished in G-cell and scrubbing, stripping, and concentration of the extract in H-cell.

Feed to the H-110 evaporator (Exhibit D) originates from G-cell solvent wash column, from whence it is airlifted to H-109, a packed (Raschig ring) steam stripping column. The H-109 column provides additional steam stripping of entrained or dissolved Amsco, as well as tributylphosphate, before feed solution reaches the evaporator. Column overhead vapors are condensed and routed to process equipment waste system for disposal. Residual gases leave the plant through the dissolver off-gas system and thence to the plant stack. Liquid from H-109 flows by gravity to the approximate mid-point of the cold leg of H-110 evaporator. A raffinate feed from the Chemical Process Modification system containing approximately 0.1 g/l of uranium had been substituted for regular uranium feed of approximately 4 g/l on the prior evening shift, so the uranium from this raffinate batch could be salvaged. The thermosyphon evaporator (Exhibit D) has a cold leg consisting of a $5\frac{1}{4}$"O.D. diameter by 7' long pipe where feed comes in and concentrated residues are held, and a hot leg consisting of an assembly of twelve $1\frac{1}{2}$" diameter tubes incorporated in a steam-jacketed heat exchanger. The mixture of solution and vapor moving out of the top of the heater goes via a 6-5/8" O.D. header and horizontal pipe to a 24" diameter vapor disengaging chamber several feet long mounted directly above the cold leg of the evaporator and connected to it by a standard dished head. Fluids enter tangentially to improve disengagement and immediately above the cold leg is an anti-swirl baffle of two plates, approximately 1"x8", at right angles to each other.

Steam leaving the vapor chamber goes overhead to H-109 steam stripper where it contacts the incoming feed stream to the evaporator. Steam stripper product flows by gravity to the evaporator. Available for transfer of concentrate from H-110 are: pump PA-238 capable of transferring directly to salvage (J-cell) or second cycle P- and Q-cells; pump PA-239 capable of transferring directly to storage (N-cell) as well as salvage or second cycle cells; a jet available for transfer to salvage and then by subsequent transfer through several lines and vessels to storage (N-cell); and a line to permit syphoning H-110 concentrate storage to N-cell when the level in N-cell is below 30% full. (The jet is considered in the nature of emergency equipment due to subsequent washing of lines required as well as extremely fast pumping rate.) Evaporator product is normally pumped to P- or Q-cell for second cycle extraction or to N-cell for temporary storage; only salvage materials are sent to J-cell.

During design it was recognized that the 24" vapor disengaging space of H-110 was not geometrically safe and a $1\frac{1}{2}$" diameter overflow line was provided below the disengaging head. Overflow material is accumulated in vessels H-111 and H-112 which are geometrically safe. Should these vessels become full, any additional material overflows to the cell floor.

Considerable maintenance has been required on the transfer pumps due to sticky check valves, plugging, etc. The decontamination system installed in the Process Makeup Area as a means of purging vessels, pumps and piping upon shutdown has also been useful in opening plugged lines, cleaning pump diaphragms, motor valves, etc., in order to keep the process functioning. Several years ago hoses, quick disconnect couplings and other temporary facilities were replaced by permanent piping and a 11.5 gallon pressure tank to reduce the physical and radiation hazards involved in keeping pumps, motor valves, and piping free of plugs. The usual procedure followed for water flushing with this equipment is to introduce the desired quantity of water into the tank, build up the pressure in the tank with air to 20-25 psig, and discharge water to decontamination lines by opening the appropriate valves.

III. EVENTS PRIOR

The 0000 to 0800 shift had reported trouble in transferring material from evaporator H-110 to intermediate storage in N-cell. A raffinate salvage feed from the CPM system containing approximately 0.1 g/l of uranium had been substituted for the regular 4 g/l feed. Efforts had been made to effect transfer of concentrate from evaporator H-110 to N-cell storage without success. Shortly after the start of the day shift a decision was made to pump to J-cell (salvage). Varying amounts of water had been pressured into the lines from H-110 to J-cell in an effort to start the pumps functioning or freeing obstructions that were preventing transfer. Flow was started for a short period using pump PA-238 to J-cell; however, this pump could not be used to transfer to N-cell and further attempts were made to make PA-239 operable. The lines from the pumps to H-110 were steamed and found to be open. Water was forced from the suction side of the pumps to J-cell by air. This line first appeared to be plugged, but then opened up. When flow had been established to J-cell the decontamination system operator was verbally instructed through a pipe chase between the Operating Corridor and the Process Makeup Area to turn off the water injection and an affirmative reply thought to be heard. Pump PA-239 was started up and momentarily operated with the suction valve closed. The suction valve to H-110 was opened. Immediately after opening the valve, the overflow vessels (H-111 and 112) high level alarm sounded as well as several radiation alarms. The plant superintendent, after surveying the process panel momentarily, went to the HP office (approximately 50' distance) and found a high percentage of the 38 alarm lights in the central radiation instrument control panel illuminated. Without delay he proceeded to the end of the corridor and pulled the evacuation alarm (elapsed time estimated at less than one minute).

Personnel in the immediate area who were concerned with the H-cell operation at the time of the incident were: PM Area, W. V. Rudd, Operator, was making additions of water using air pressure through the small decontamination pressure tank; Operating Corridor, K. Ludlow, Utility Operator, was at the control board, R. Commander, Plant Engineer, J. Whyte, Shift Supervisor, and A. L. Ayers were observing or supervising operations; Access Corridor, R. E. Baker, Mechanical Foreman, together with two mechanics L. Merkley and D. Wadsworth, were checking transmission fluid on PA-238 and PA-239 pumps for vapor lock. (Exhibit I)

IV. THE INCIDENT

The balance of liquid volume and uranium around the evaporator and overflow tanks follows:

	Vessel H-110		Vessel H-111,112		Total	
	Volume l	Uranium kg	Volume l	Uranium kg	Volume l	Uranium kg
Before Incident	40.1	8.01	13.8	0.48	53.9	8.49
Immediately after Incident	40.9	4.67	23.7	1.91	64.6	6.58
After Shutdown	56.8	6.7	24.0	1.93	80.8	8.63

Based on pertinent process charts and the material balance calculation shown above, it would appear that a minimum of 10.7 liters of solution was added to the system during the incident. This liquid may have come either from the pressure pot or from the steam stripper. Considering the uranium in these vessels, it appears that the uranium was reduced from 8.49 kg to 6.58 kg, or by 1.91 kg, during the criticality incident. It is estimated that at the time of shutdown there was 8.63 kg of uranium in these vessels. It is probable that 2 kg of uranium which disappeared during the incident was driven up into the steam stripper and that this material was washed back into the evaporator prior to and during shutdown of processing equipment, although it could be a result of estimating the uranium content from instrument readings.

An over-all uranium material balance for the plant is presented in the exhibits. Input to plant prior to shutdown was measured at 42.743 kg, while the estimated amount of uranium in plant is 43.611 kg. N-cell inventory is an estimate based on volume and specific gravity, while all other amounts are based on sample analyses. The balance indicates that gross amounts of unaccounted for uranium are not spread through the system.

The mechanism by which the uranium was accumulated in the head of evaporator H-110 has not yet been established. There are several possibilities, none of which, in light of data accumulated to date, can be definitely established as the correct one. The most probable cause appears to be the introduction of air, or air and water, into the bottom of the evaporator. The line from pumps PA-238 and PA-239 had been flushed with water just prior to the incident. Air pressure on a pressure pot in the Process Makeup Area was the driving force for this flushing. At the conclusion of the last water flush, pump PA-239 was turned on and the incident occurred almost immediately after the valve in the suction line to this pump from H-110 was opened.

The sequence of operations in the Process Makeup Area as described by the operator indicated that the valve on the pressure pot remained open until the pressure gauge on the pot read 5 to 10 psi. This would indicate that considerable liquid had been driven out of the line between the pressure pot and J-cell. Air may have then been released to the evaporator when the valve between the pump and the evaporator was opened. There is always some possibility that the operator did not accurately remember the sequence of

operations and that the air header could have been open between the pot and the decontamination system or that the line between the pressurized pot and the process system could have remained open until the suction valve between the evaporator and the pump was opened.

The excursion's magnitude has been estimated at 6×10^{17} fissions within a maximum 25% error. This estimate is based primarily on radiochemical analyses for Mo-99 and Ce-143 in samples of solution involved in the incident. Thermal neutron integrated flux, as determined by scintillation spectrometer counting of activated indium foils obtained from various operating areas in the plant, range from below limits of detection ($3 \times 10^{2} n/cm^2$) to $3.3 \times 10^{7} n/cm^2$.

Examination of instrument and radiation detection charts indicate the nuclear excursion was of short duration. As the radiation alarms sounded almost simultaneously through the building, it would appear they were activated by prompt gamma radiation from the critical incident. Gaseous or air borne contamination did not appear to enter the building. Fission gas evolved through the dissolver off-gas system to the plant stack. No significant hazard to personnel or environment appears to have resulted from this release.

V. POST INCIDENT EVENTS

Response of Phillips' personnel to the evacuation sirens was excellent. Within 3½ minutes, 98% of Phillips' employees had reached the main gate. The remaining 2% included two employees who were in the SF Storage Building (CPP-603) at the time of evacuation. These two men were delayed because of the necessity to clear construction personnel who were working in the basin. The other two individuals were an HP supervisor and technician who, being equipped with portable radiation instruments, were able to determine effectively that all personnel in CPP-602 had been evacuated and gain a preliminary apprisal of the situation existing in the plant. Within 5 minutes of the time the sirens were activated, evacuation wardens and CPP supervisors had accounted for all Phillips' personnel. One Ferguson construction employee (R. D. Sermon) did not leave the area until 11 minutes after all the other employees had left. He stated he was working inside a canopy at the south ramp of CPP-601 and did not hear the alarm. (His film badge indicated no detectable exposure.)

Phillips' employees were evacuated to the CPP parking lot adjacent to the main gate and Construction employees to the junction of Cleveland and Lincoln Boulevard.

After all personnel had evacuated, the vehicle gate at the main guard house was closed and an accumulative list of all authorized personnel re-entering the plant area was maintained until it was determined that the plant was secure and no unusual hazard existed.

As it appeared there was insufficient preliminary evidence to permit re-occupancy of the building, buses were called to provide evacuated personnel adequate shelter and transportation if desired.

A team of operating and health physics personnel re-entered the plant approximately 20 minutes after evacuation to shut down all processing equipment. At the same time, various operations were checked for indication as to source of the activity released.

Filters from the stack gas monitor and an air sample from the west vent at G-cell were recovered and analyzed. The presence of Cs-138 was reported approximately 45 minutes after the incident, indicating criticality. Observations of process instruments together with knowledge of significant quantities of uranium indicated H-cell as the most likely location of the excursion. Counting on some personnel neutron detectors, previously placed along the Access Corridor, were received by 1030 and one showed 1161 counts/min on the indium in the detector nearest H-cell. This was the only one activated and indium-116 was indicated. This slight neutron activity confirmed the cell location of the incident. The solution in H-110 was transferred by jetting to J-cell where analysis showed it to contain extremely short lived fission products. Subsequent metallurgical examination verified the reaction took place in the disengaging head of H-110. Detailed discussion of the analyses is shown in the attached exhibits.

Management approval was given at 1445 for the return of all employees, based on HP observations of no external contamination, radiation level in excess of normal, and no other potentially hazardous situations.

VI. HEALTH PHYSICS REVIEW

Film badges were collected at the gate from two people from each representative plant area as well as the four men in the Access Corridor. Film in the badges had been routinely changed January 19, 1961, so exposures, with the exception of visitors badges (changed daily), had been accumulating since January 20, 1961. Results on 46 badges returned by IDO Health and Safety read zero beta. The highest Phillips gamma reading was 55 mr. Activity due to neutrons was barely detectable on the badges of two of the men in the Access Corridor.

The four individuals in the Access Corridor had blood and urine analyses as well as whole body counts. No abnormal conditions were reported.

Four Phillips' personnel were on a locomotive east of the CPP and one employee at the incinerator at the time of the incident. These individuals were exposed to the radioactive gases which were caught and dispersed into the atmosphere from the plant stack. Based on the two film badges available, the highest level of radiation on any of these individuals was estimated at 30 mr gamma.

Evacuated personnel were checked for contamination and their badges for radioactivity. Nothing significant was found. "Hot" area lab coats were collected and personnel issued "clean" area coats and shoe covers to be worn over "protective" clothing. Buses took the evacuated personnel to the Central Facilities Cafeteria for lunch.

Data available from 52 recording radiation detection instruments have been surveyed. Other than a sharp rise at the time of the incident, nothing unusual appears evident.

Counting information on personnel neutron detector foils previously located at specific points along the Access Corridor is given in the attached Exhibit H, Warren Burgus' letter of February 2, 1961, (File: Bur-2-61A).

VII. CONCENSUS OF COMMITTEE

A. Nature of Incident

A criticality incident of 6×10^{17} fissions occurred in a first cycle product evaporator H-110 at about 0947 on January 25, 1961. Available information indicates the criticality occurred as a result of accidental lifting of uranyl nitrate solution (approximately 200 g/l of highly enriched uranium) from the lower geometrically safe section of the evaporator ($5\frac{1}{4}$" OD) into the upper critically unsafe vapor disengagement section in sufficient volume for the incident to occur. The cause of this rise in liquid level is not certain;, however, a review of events occurring just prior to the incident suggests that a burst of air was inadvertently introduced into the bottom of the evaporator. Because of the uncertainty, other less probable theories were also evaluated.

B. Evacuation

Response by plant personnel to radiation alarms and the evacuation signal was prompt and orderly. Re-entry and evaluation of information leading to location and nature of the incident was efficiently and adequately performed. No personnel exposures in excess of a daily dose, 60 mrem, were incurred. The Plant Emergency Committee is reviewing the need for several minor improvements as a result of observations made during the incident which it was felt would further improve performance.

C. General

Problem areas exist in communication of instructions and replies between operating areas. No specific instructions covering use of the pressure pot on the decontamination system were located. Job training should be improved particularly with reference to non-routine operations. Personnel were not aware of full dangers inherent in use of compressed air in "cleaning" lines, etc. Use of air should be very carefully regulated and hydraulic means are preferred in cleaning lines, etc. Fool proof controls to prevent criticality in a known critically unsafe vessel had not been developed. The close coupled design of the steam stripper H-109 and the evaporator H-110 should be investigated as previously large amounts of liquid holdup had dumped into H-110, upsetting operations.

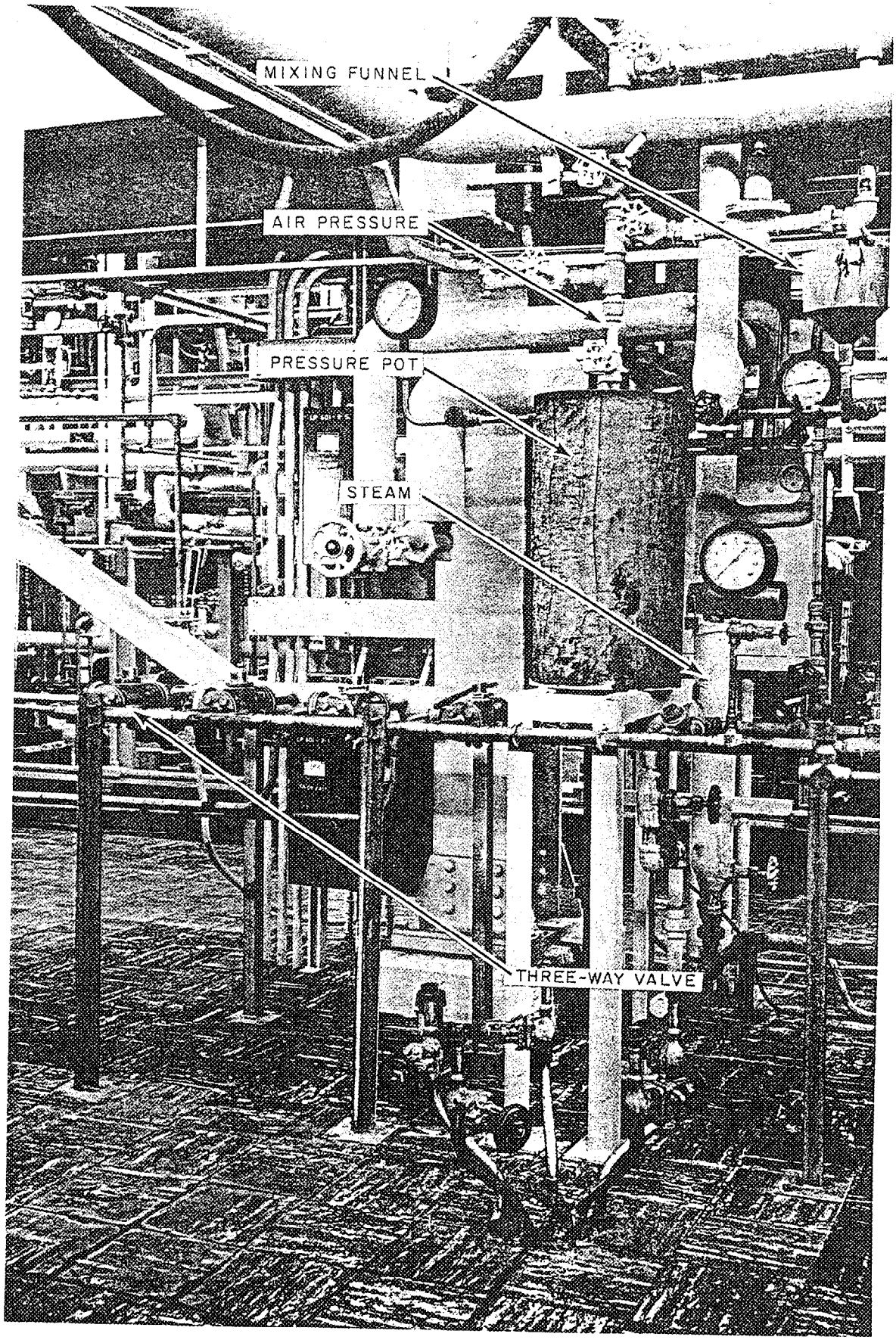
D. Criticality

All uranium processing and storage equipment should be reviewed and protection provided against criticality where feasible. Any known critically unsafe equipment now in the CPP should be redesigned or modified, if possible.

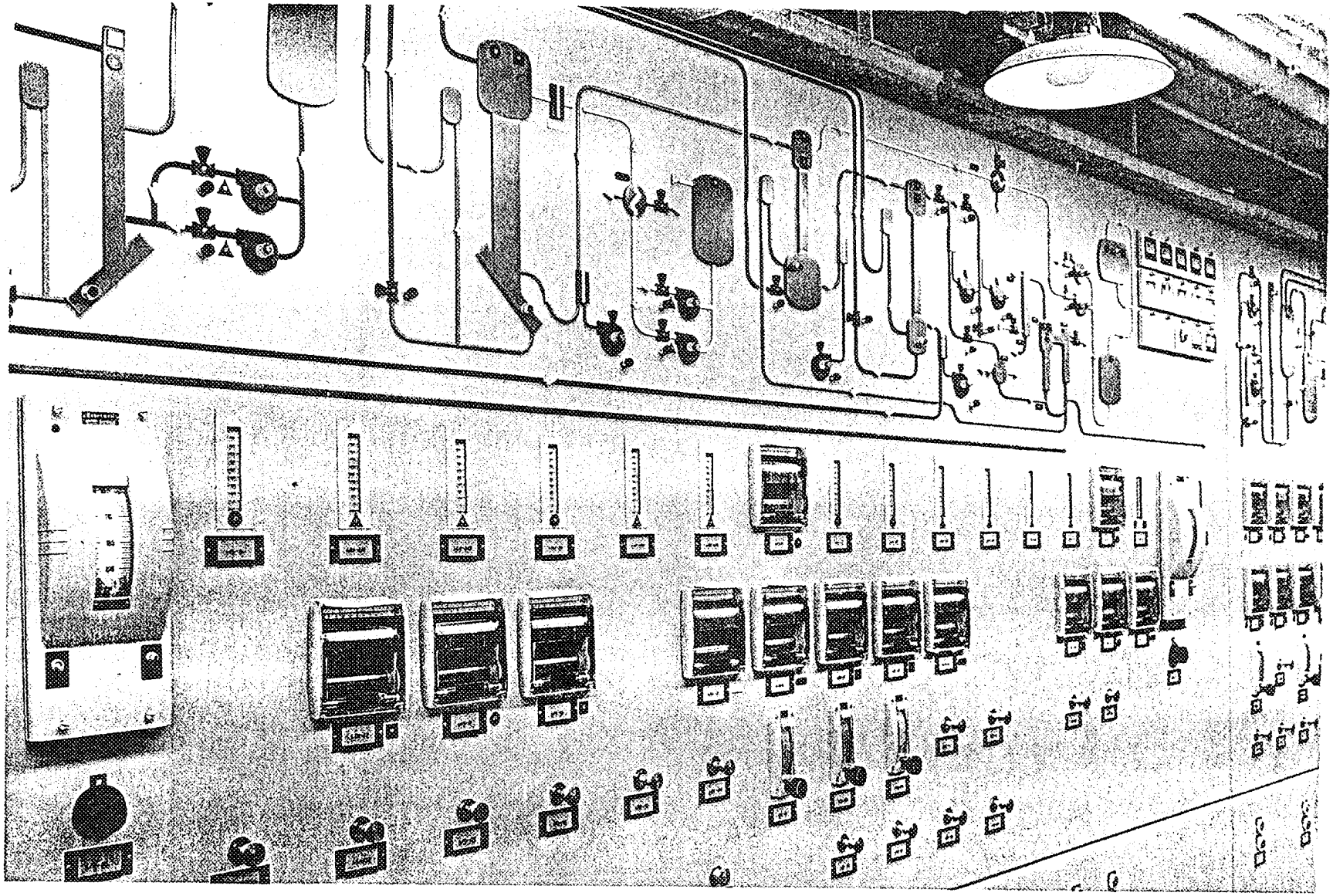
While subsequent detailed inspection of equipment in H-cell after decontamination may develop additional data, it is not believed it will measurably affect the data or conclusions in this report.

Assisting personnel are to be commended for their prompt action in retrieving and analyzing samples.

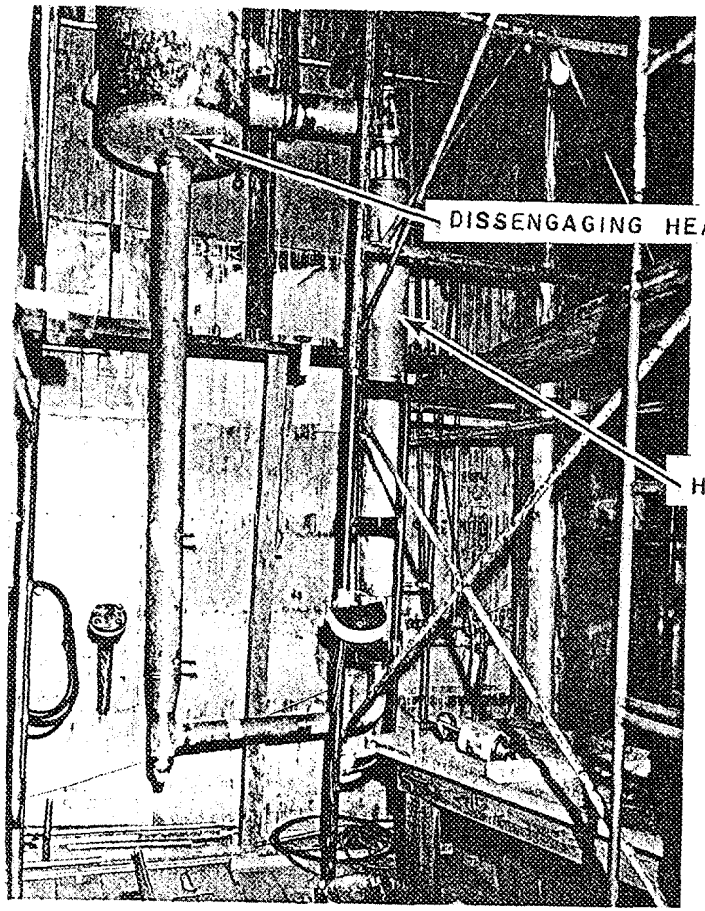
A - PHOTOGRAPHS

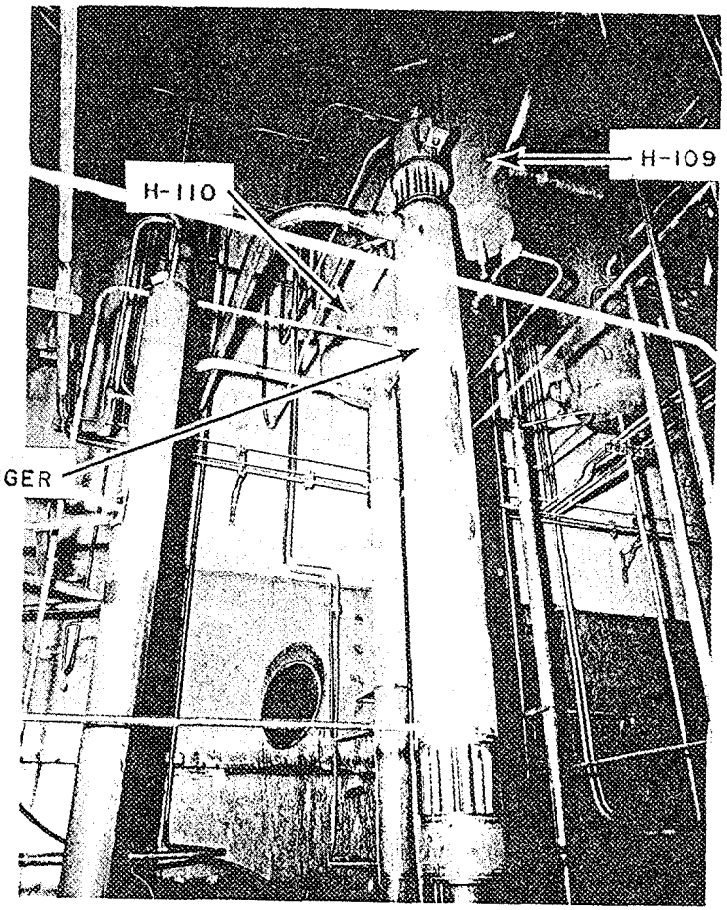


H-CELL - DECONTAMINATION SYSTEM P.M. AREA

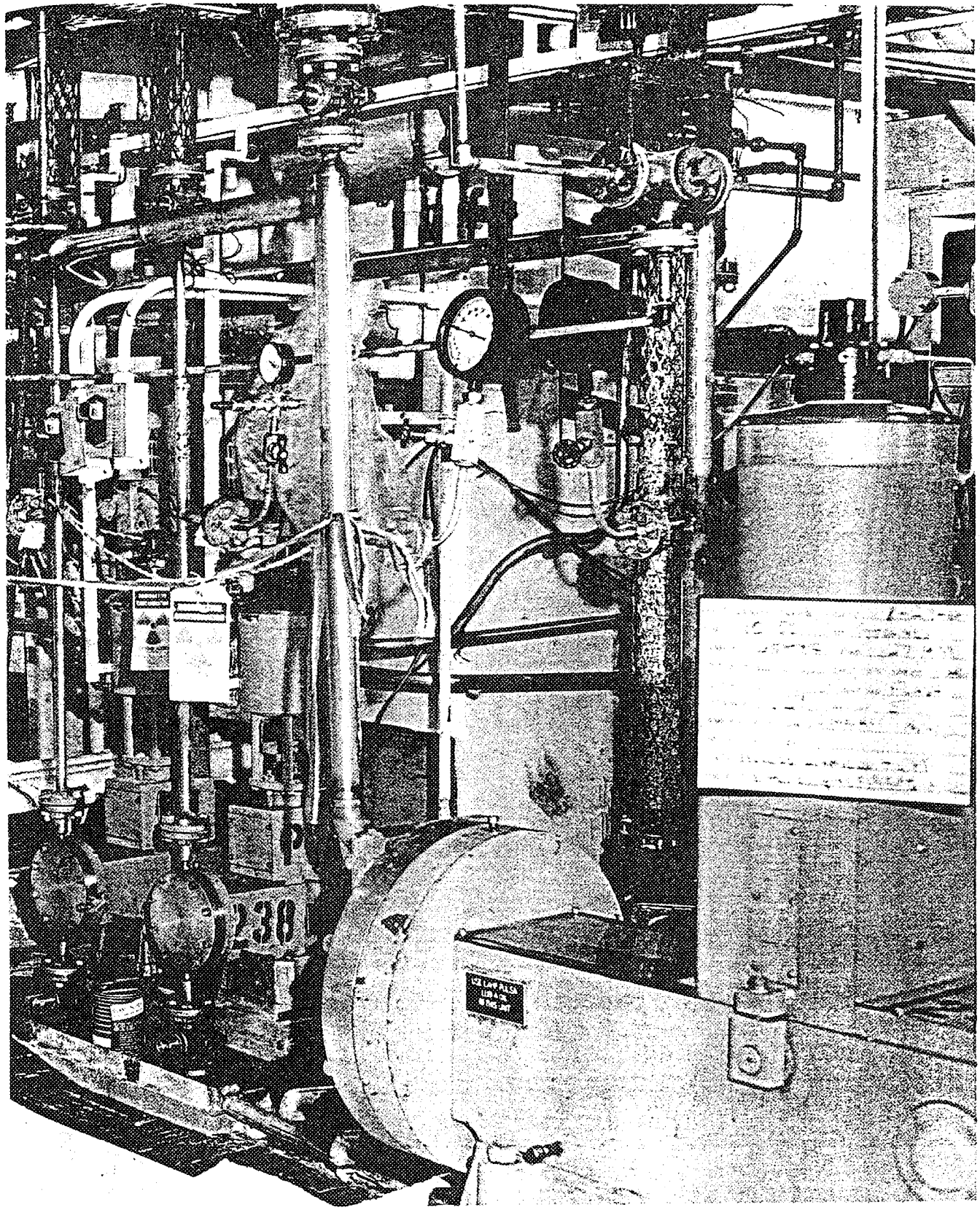


OPERATING CORRIDOR – G & H-CELL INSTRUMENT PANEL



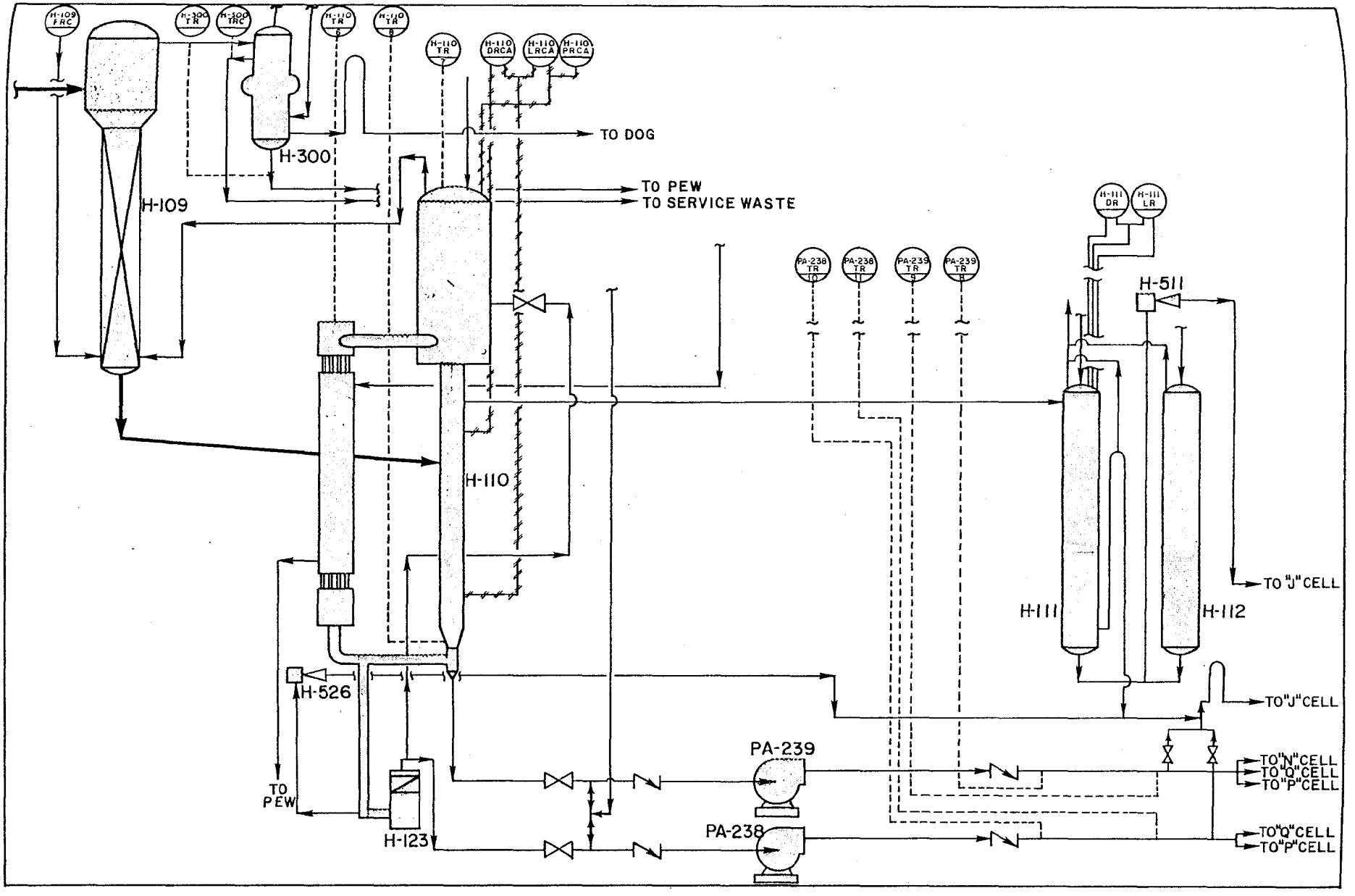


H-CELL INTERIOR, EVAPORATOR, H-110



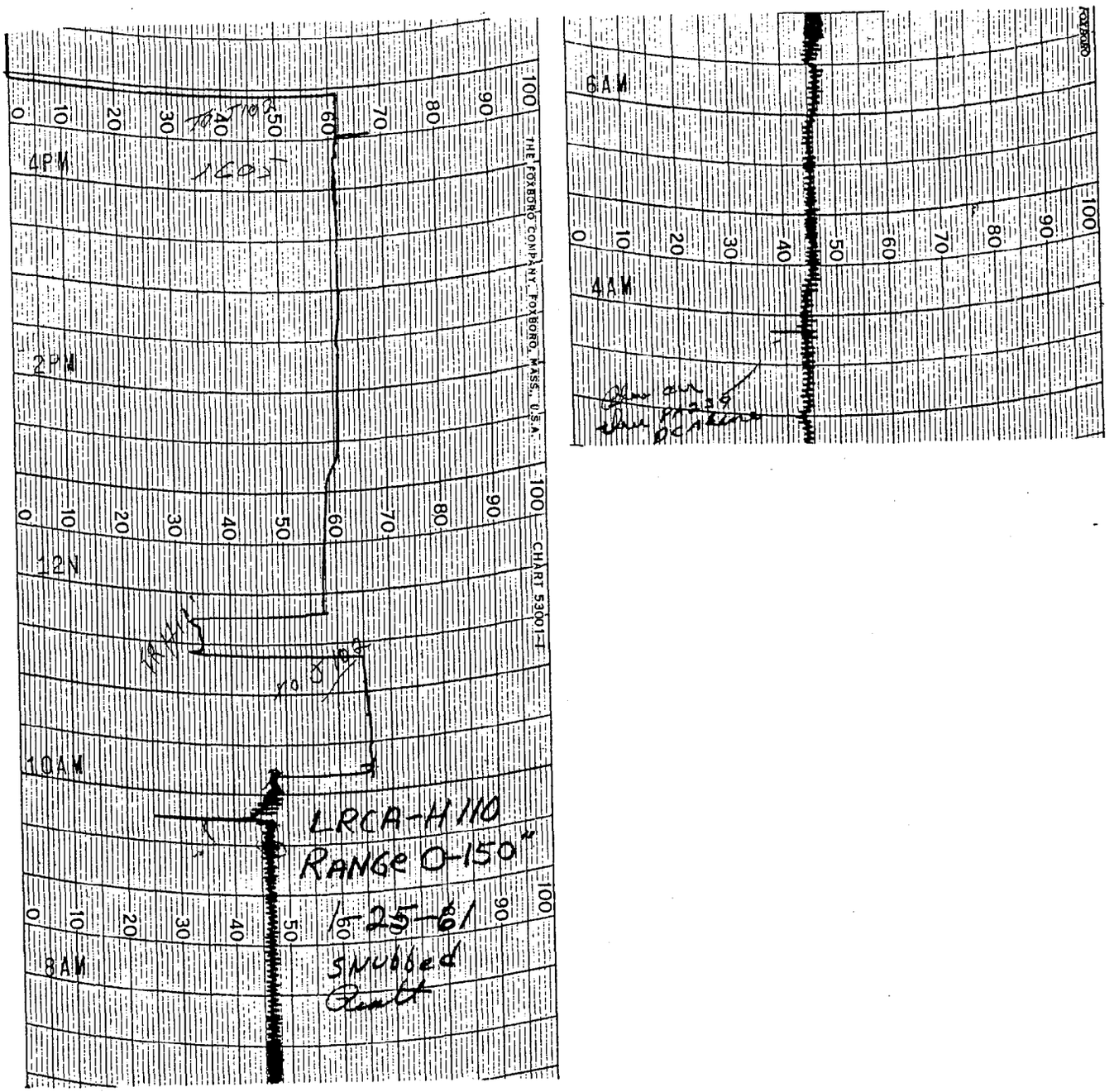
H-CELL - H-110 TRANSFER PUMPS - PA-238 - PA-239

B — PROCESS FLOW DIAGRAM



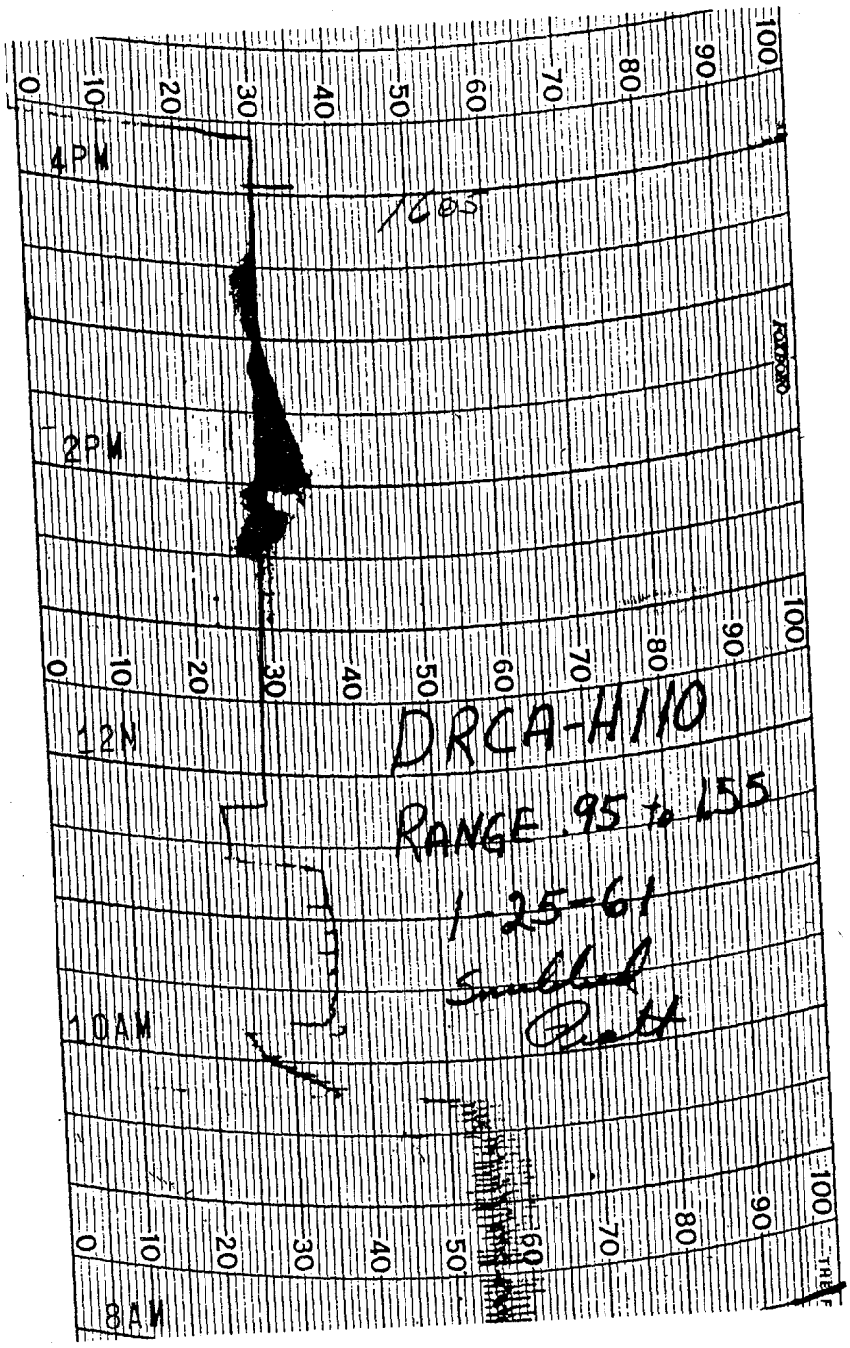
H-CELL PERTINENT EQUIPMENT
PROCESS FLOW DIAGRAM

C - H-CELL OPERATIONAL CHARTS
Jan. 25, 1961



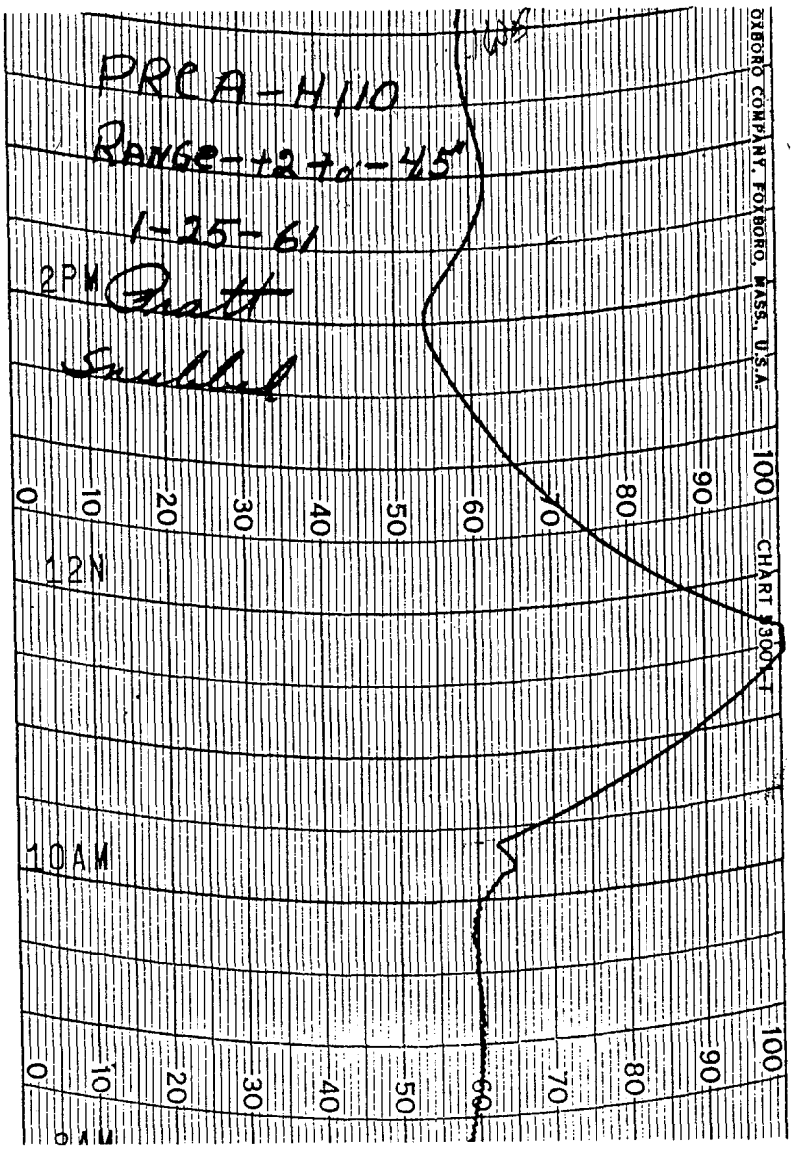
C(a)

LIQUID LEVEL IN H-110



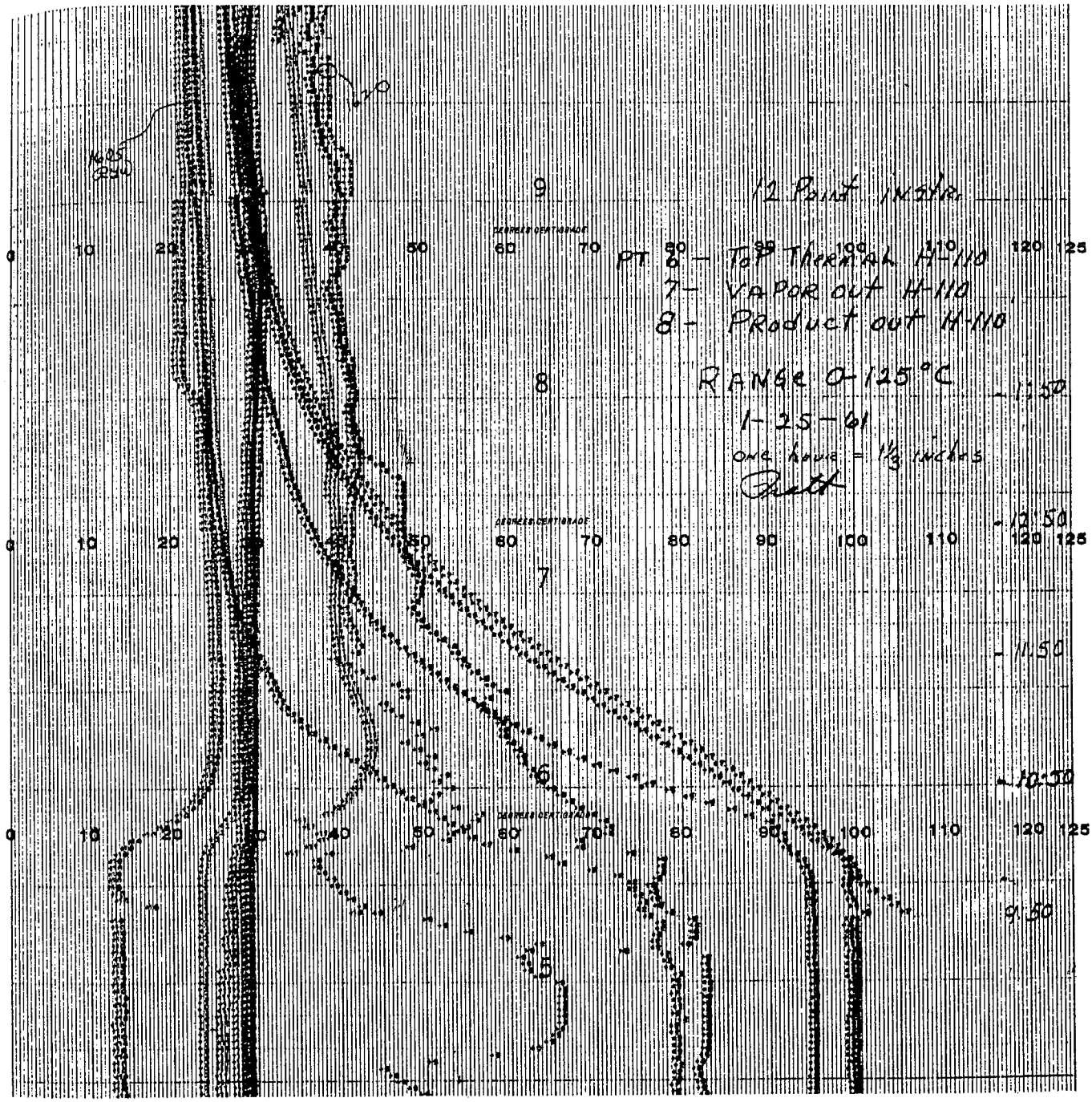
C(b)

SPECIFIC GRAVITY IN H-110



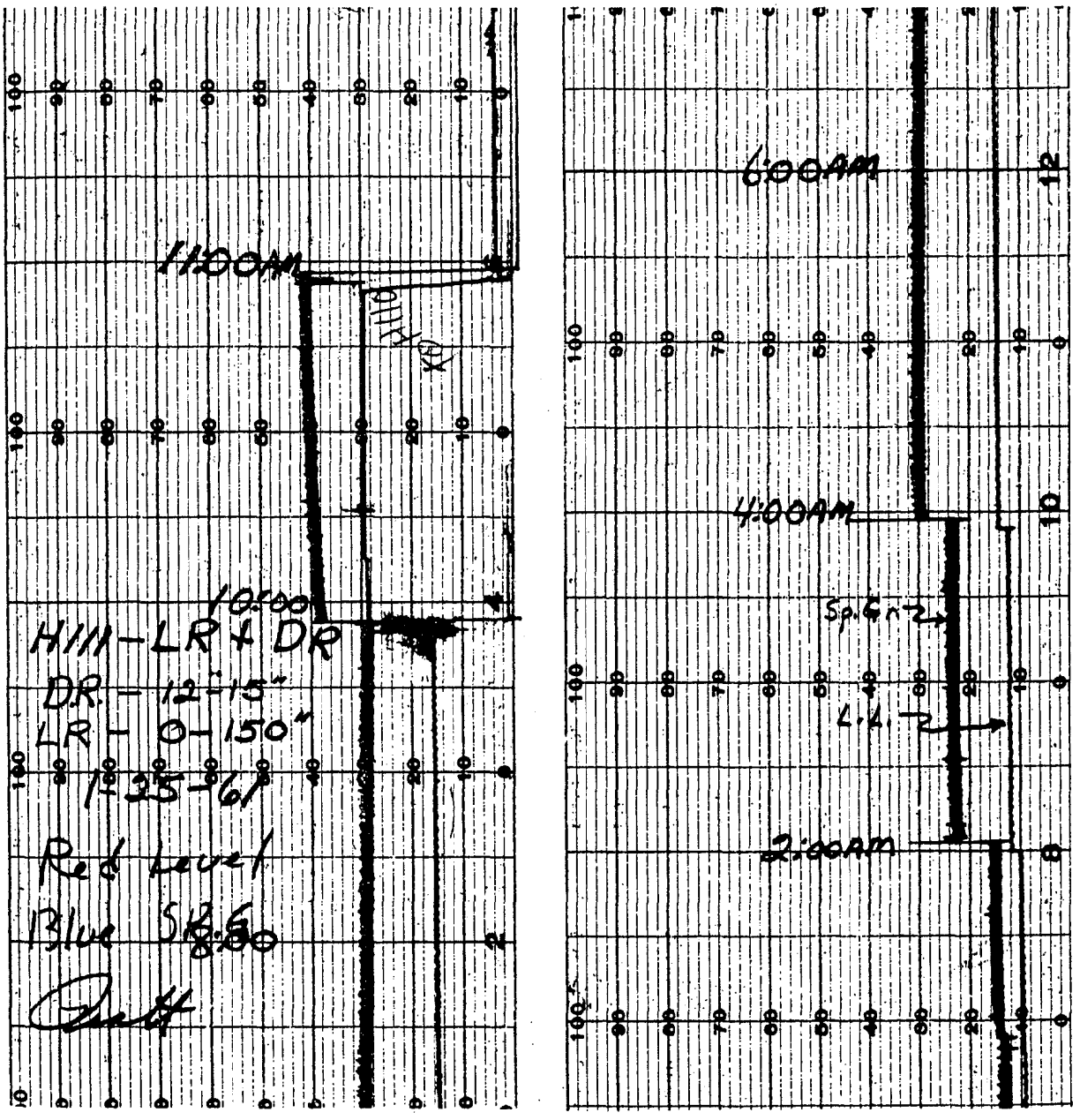
C (c)

PRESSURE IN H-110



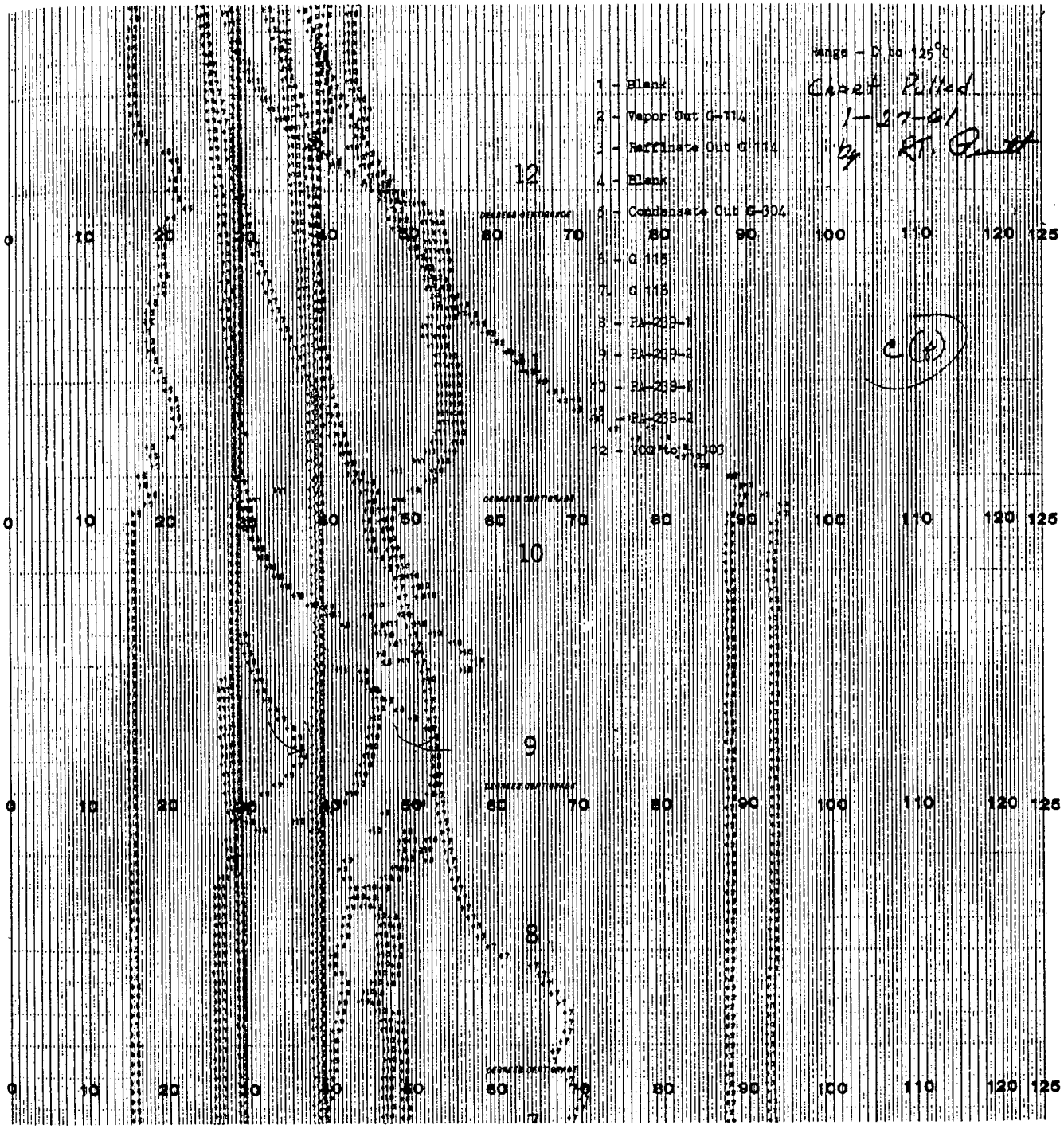
C (d)

TEMPERATURE H-110



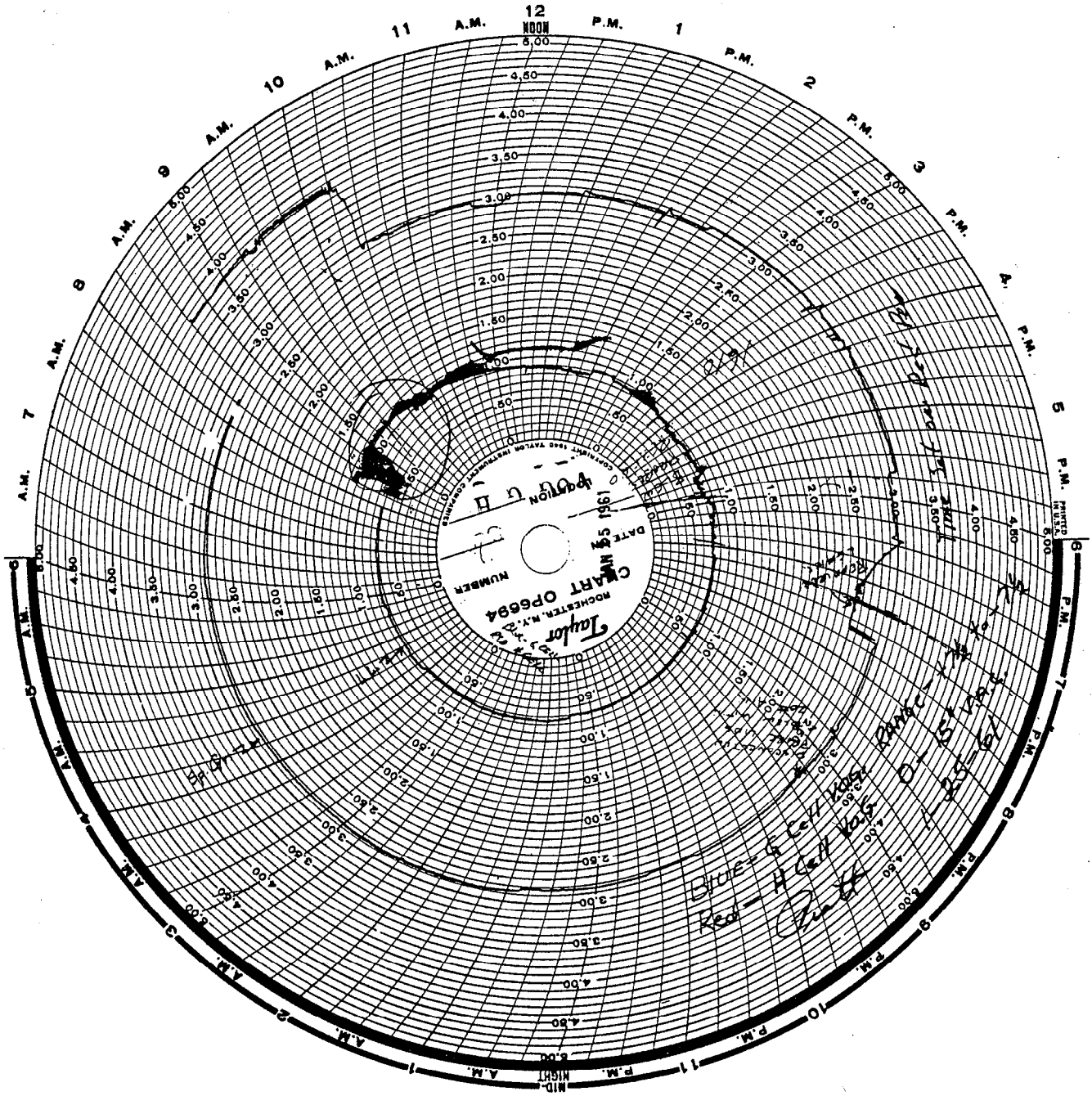
C(e)

SPECIFIC GRAVITY & LEVEL IN H-111 & H-112



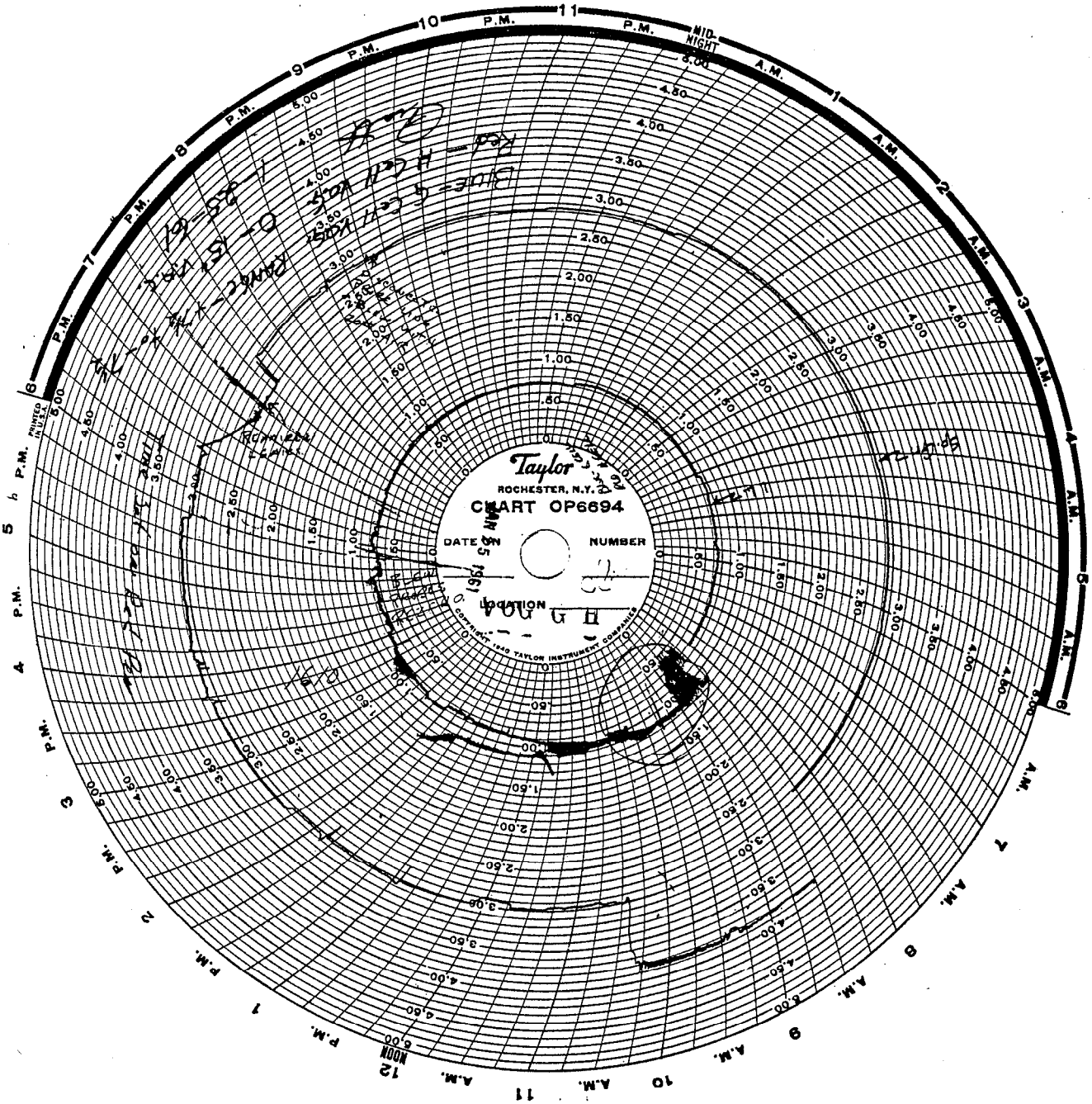
C(f)

TEMPERATURE OF DISCHARGE LINE - PUMPS PA-238 - PA-239



C(g)

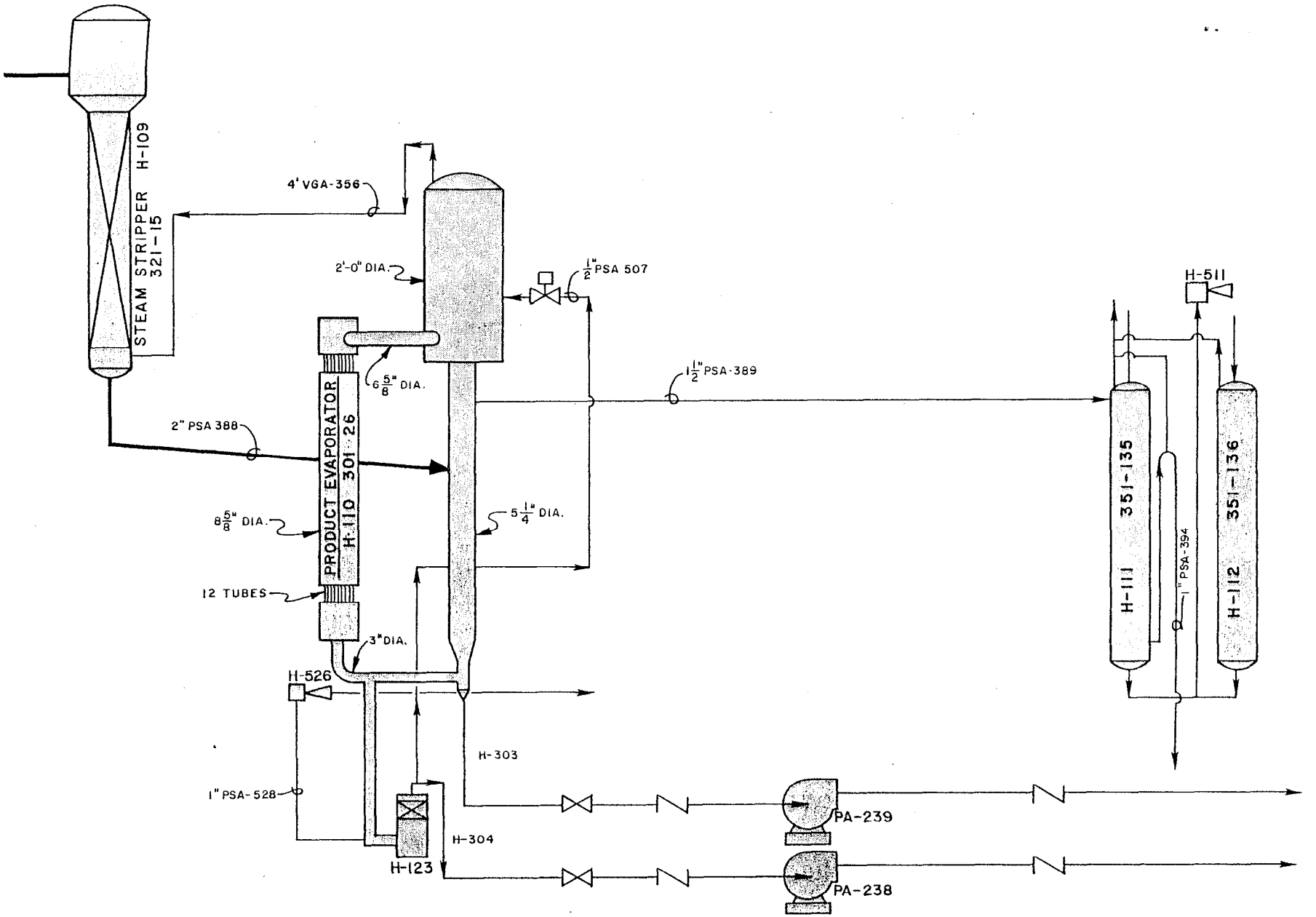
VESSEL OFF-GAS SYSTEM, PRESSURE



C(h)

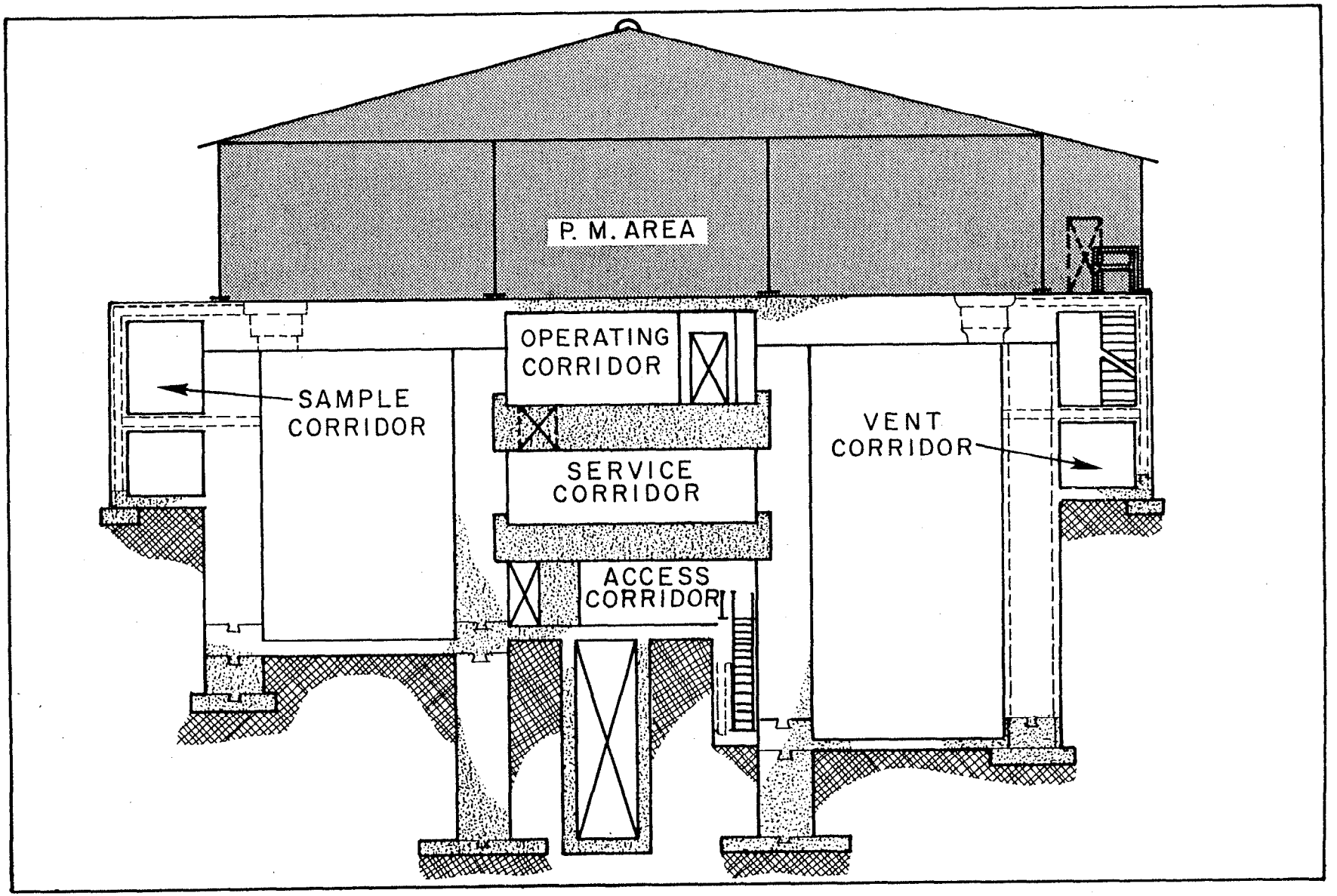
DISSOLVER OFF-GAS SYSTEM, PRESSURE

D-EQUIPMENT FLOW DIAGRAM



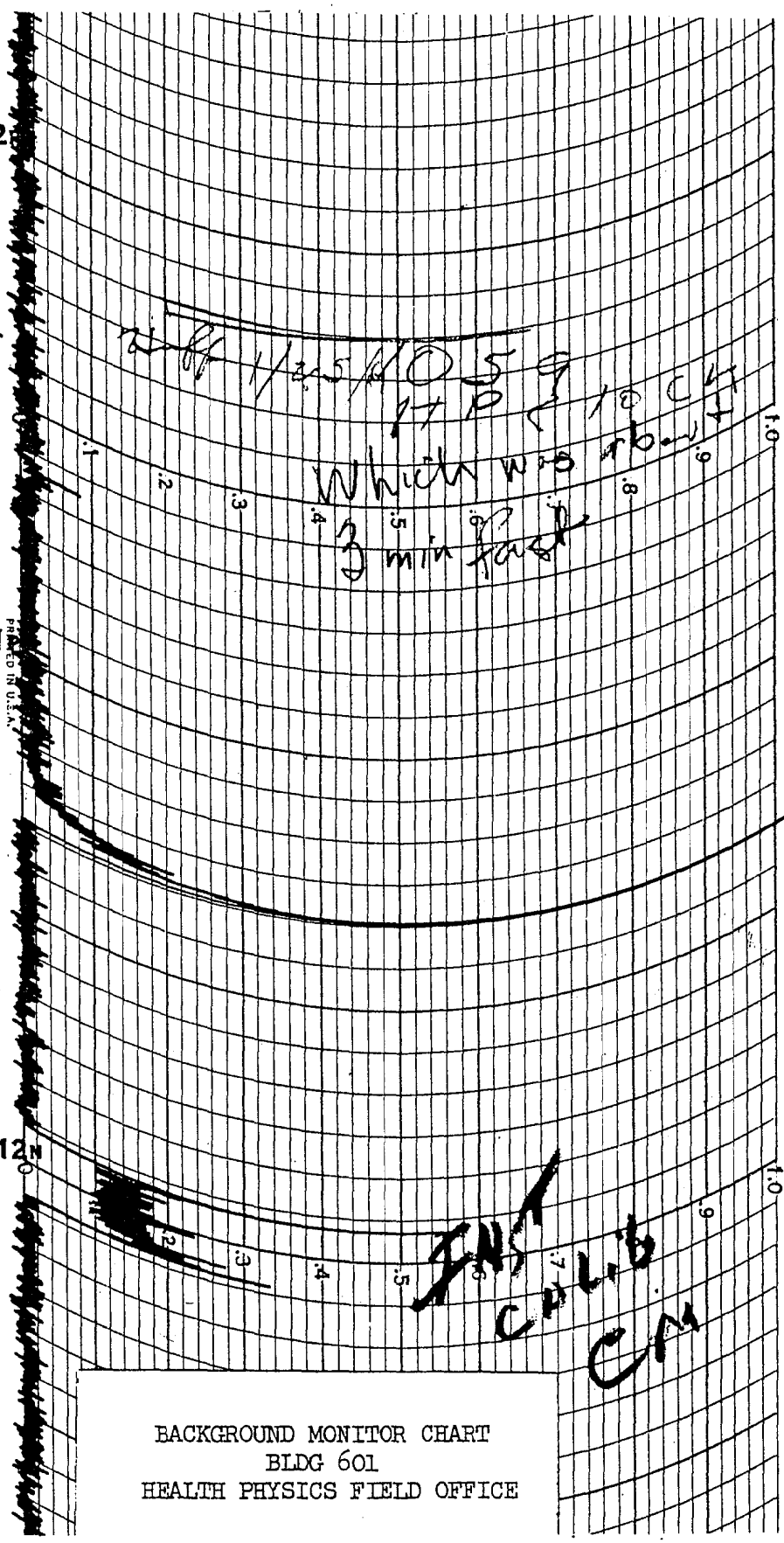
H-CELL PERTINENT EQUIPMENT- FLOW DIAGRAM

E - SECTION OF PROCESS BUILDING



SECTION OF PROCESS BUILDING CPP-601

F - TYPICAL RADIATION DETECTION INSTRUMENT CHARTS, 1-25-1961



BACKGROUND MONITOR CHART
BLDG 601
HEALTH PHYSICS FIELD OFFICE

DEGREES CENTIGRADE
0
10
20
30
40
50
60
11
1100 1-25-61
10
9
8
MONITRON CHART - BLDG 604
OPERATING CORRIDOR

G-ESTIMATED PLANT URANIUM BALANCE PRIOR AND POST INCIDENT

ESTIMATED MATERIAL BALANCE OF URANIUM IN PROCESSING EQUIPMENT

PRIOR AND POST INCIDENT

INPUT	Kg-Uranium
Batch 2010 ETR	31.970
Cold Uranium	6.417
N-cell Recycle	4.356
Total Uranium in Plant	42.743

OUTPUT	
Uranium to Waste (G-115, G-116)	0.194
Vessel or Tank J-102	3.896
J-105	8.624
G-108	0.700
G-106	0.173
G-115	0.316
G-116	0.005
H-110	0.680
D-106	0.269
D-156	0.782
D-155	0.064
D-152	0.110
D-102	0.075
WG-101	1.338
WH-100	0.036
WG-100	0.008
WH-101	0.004
N-100) N-130)	26.337*
Total Uranium in Plant	43.611

*Estimated from volume and sp.gr. of solution in N-100 and N-130.

H-LETTERS
W. H. BURGUS TO R. L. DOAN
CPP INCIDENT OF JAN. 25, 1961

D. G. OLSEN TO R. C. SHANK
ANALYSIS: RCA ACTIVATED METAL
FROM H-CELL

INTER-OFFICE CORRESPONDENCE

PHILLIPS PETROLEUM COMPANY

Idaho Falls, Idaho

February 2, 1961

CPP Incident of January 25, 1961
Bur-2-61A

R. L. Doan
O F F I C E

Dear Sir:

This letter summarizes certain data which we have collected on the CPP criticality incident of January 25, 1961. The first section concerns early identification of short-lived fission products which provided an early indication of a nuclear excursion. The second section of the letter deals with the radiochemical determination of the total number of fissions involved. The third section deals with measurements of the activation of certain neutron detector foils which had purposely been placed in the CPP access corridor adjacent to the area in which the incident occurred. From this activation data it has been possible to calculate neutron dosages (nvt) at the point of measurement. In cases where activations were too low for measurement, the upper limits for dosages have been calculated. As you suggested during our telephone conversation of January 26th, we are leaving it up to J. W. McCaslin to report on the neutron and gamma dosages received by personnel (as measured by the personnel monitoring badges). We are also leaving it up to McCaslin to report on the biological measurements such as whole body counting, activation of blood sodium, etc.

I. Early Identification of Short-Lived Fission Products

At approximately 10:30 on January 25, 1961 R. C. Shank contacted R. L. Heath and informed him that there had been a release of radioactive material from the CPP stack. The time of this release was given as approximately 10:00 am. Heath was also informed that the area had been evacuated as a precautionary measure, but that personnel had re-entered the laboratory building to attempt analysis of radioactive material obtained from the Stack Activity Monitor. It was requested that Heath assist in the identification of this radioactive material.

Heath arrived at the CPP shortly before 11:00 am and proceeded to the Counting Room. At this time he reviewed with Ralph Shank, Dale Olson, and Denzel Jensen (CPP - HP) the events following the activity release. It had been determined that there was no evidence of surface contamination within the laboratory areas. The particulate filter from the Stack Activity Monitor had been removed and brought to the Counting Room for analysis. Sections representing a known fraction of the total area of the filter were examined on a gamma-ray scintillation spectrometer to obtain the gamma-ray

spectrum of radioactive material on the filter. Repeated observations were made to obtain the half-lives of the various radiations. Examination of these data established that the principal activity present on the filter for times less than one hour after the release of activity was 32 min Cs-138. This identification was established by measurement of gamma-ray energies of the three most intense radiations from this isotope (0.46, 1.02, and 1.44 Mev) and by measurement of the half life for these gamma rays of approximately 30 min. This activity is the daughter of 17 min Xe-138, one of the major fission products. Positive identification of the presence of Cs-138 activity on the stack filter was considered to be very strong evidence that fission had occurred, and Ralph Shank so notified J. P. Lyon. Subsequent measurements on the sections of the filter material indicated the presence of daughters of the other fission gas chains in about the expected abundances. These included: 85 min Ba-139, 12.5 d Ba-140 and its La-140 daughter, 9.7 hr Sr-91 and its daughter Y-91, and 2.7 hr Sr-92.

II. Total Number of Fissions Involved in the Incident

The radiochemical determination of the number of fissions involved in the nuclear excursion is, in principle, quite simple and straight forward. From an aliquot of the entire volume of solution containing all the non-volatile fission products, a single fission product nuclide is isolated and its concentration at the time of the incident determined (in terms of atoms per unit volume of solution). The number of atoms is obtained by radiochemical separation and purification of a selected nuclide, followed by determination of its absolute disintegration rate. This involves an accurate knowledge of the decay scheme of the nuclide chosen, particularly an accurate knowledge of the abundance (branching ratio) of the particular radiation chosen for counting. It further requires accurate knowledge of the efficiency of the counter used, and an accurate knowledge of the radioactive decay constant. Corrections are made for losses encountered in the isolation and purification procedures and for radioactive decay between the time of the incident and the time of counting. From the number of atoms per unit volume of solution and the known fission yield of the chosen nuclide, the corresponding number of fissions per unit volume may be calculated. The total number of fissions in the entire solution is then obtained by multiplication by a factor which is the ratio of the volume of the entire solution to the volume of aliquot analyzed.

The preceding of course requires that 1) the entire solution must be uniform in composition so that the aliquot withdrawn for analysis is representative, 2) the volume of the entire solution must be accurately known, and 3) there must have been no loss or partial loss of the specific fission product isolated. Further, as was actually the case in the ICPP January 25th incident, if the solution containing all the non-volatile fission products is divided into more than one portion, the volume of each portion must be accurately known and each portion must be uniform in composition

although it is not necessary that all portions have the same composition. Moreover it is clear that dilutions of any portion encountered in transfers and rinsings will not affect the final result since decreases in concentrations are exactly compensated for by increases in volume.

Following the ICPP nuclear excursion in H cell, all of the solutions which possibly could have been involved were transferred to vessels J-102 and J-105. Arnold Ayers has stated that after transfers and rinsings these two vessels do indeed contain very close to 100% of the material involved in the incident. Further he has stated that after complete removal to J-102 and J-105 the respective contents of each of these vessels would be quite homogeneous. Prior to sampling, each vessel was sparged for 30 minutes to ensure uniform mixing of its contents. Duplicate samples were then withdrawn by use of the standard ICPP sample re-circulation technique which provides for recirculation in this instance of about 100 ml per minute. The first samples withdrawn from each vessel had ~15 minutes of recirculation and the second samples, taken immediately after the first, had ~10 minutes additional recirculation. That the contents of the vessels were quite uniform is shown by comparison of the total uranium contents of the samples and by comparison of the gross beta activities of small but equal aliquots evaporated and beta-counted. Comparisons are shown in Table I.

TABLE I

Uniformity of Solutions Analyzed

Sample	Vessel J-102	Vessel J-105
Sample Bottle 1	U = 54.63 g/l	U = 58.86 g/l
Sample Bottle 2	U = 54.63 g/l	U = 59.07 g/l
Sample Bottle 1	Gross Beta = 5.44×10^5 c/m	5.08×10^5 c/m
Sample Bottle 2	Gross Beta = 5.39×10^5 c/m	5.26×10^5 c/m

Samples were all crystal clear, quite acidic, and homogeneous. No solids were visually discernible. For analytical purposes these samples were much superior to the samples collected from the October 16, 1959 incident at ICPP and high confidence can be placed in them.

The measured total volumes of solutions after transfer were also provided by Arnold Ayers and were 77 liters for J-102 and 153 liters for J-105. The errors in measurement are conservatively estimated to be $\pm$ 1 liter in each case. In view of other larger errors in the analyses, the small error involved in total volume measurement is not significant.

Because of the early availability of representative samples (within 8 hours after the incident) it was possible to select several different fission product nuclides for measurement of the total number of fissions. In selecting these it was of course necessary to choose rather short-lived nuclides which would be indicative only of fissions which occurred in the incident and which could not have remained (after first cycle decontamination) from fission which had occurred during reactor operation. Consideration also had to be given to the question of measurement of a chosen short-lived nuclide over a possible high background of a longer-lived isotope of the same element which might have come through first cycle extraction or possibly had remained as contamination in the vessels in which the excursion occurred or to which solutions were later transferred. Notable among long-lived fission nuclides which are not well removed in the first cycle of the process (TBP extraction) is Zr-95 ($T_{\frac{1}{2}}$ = 65 d). A generally used nuclide for measurement of a relatively low number of fissions is Zr-97 ($T_{\frac{1}{2}}$ = 17 h). The measurement of this nuclide over a relatively high Zr-95 background is possible however because the Zr-97 has a 60 minute half-life Nb-97 daughter which can be extracted from Zr-97 and measured independently. (Zr-95 has a Nb-95 daughter also but it has a half-life of 35 days as compared to 1.0 hour for Nb-97. It may be seen therefore that Nb-95 will contribute only slightly to the total Nb fraction activity when the differences in parent and daughter half lives are all considered.) Because considerable quantities of rare gas fission products escaped in the incident and because Zr-97 is known to have no rare gas parentage, it is ideal from this standpoint. Its decay scheme and the decay scheme of its daughter are well known. Likewise its fission yield is well established. A disadvantage however is that daughter milkings are necessary thus introducing further possible error. A further disadvantage is that zirconium tends to hydrolyze and is often partially lost by deposition on vessel walls. Nonetheless Zr-97 analyses were run.

The ideal fission product, and one most generally used for measurements of total fission is Mo-99 ($T_{\frac{1}{2}}$ = 67 h). It has no rare gas ancestory, has a very well known fission yield and decay scheme and has no longer-lived isotopes to interfer with its measurement. Mo-99 was therefore also chosen for measurement. Values of total fission based on Mo-99 are probably the most accurate of all values obtained.

Other nuclides which could also serve for measurement of total fission are Ba-140, Ba-139, Sr-91, Sr-92, and Ce-143. For each of these nuclides however, decay of a rare gas ancestor provides a portion of the total fission yield. Ordinarily the use of these nuclides for measurement of fission is justified in situations where gaseous parents cannot and do not escape (e.g. as in the case of a solid uranium fuel, tightly clad). However in cases where all or a portion of the gaseous ancestor may escape, measurements based on such nuclides may be expected to yield a low and somewhat incorrect result. The degree of error is clearly dependent on

the fraction of the chain which comes via a rare gas and upon the fraction of rare gas which may have escaped. In the CPP incident extensive escape of rare gases is expected since a boiling solution was involved and in addition radiolytic gas would be expected to also sweep the fission gases out of solution. That this occurred is of course backed up by the observation of short-lived rare gas decay products in the CPP stack monitor. Despite the expectation that measurements based on Sr-91, Sr-92, Ba-139, Ba-140 were expected to yield low results, these measurements were made to provide "order of magnitude" confirmation of the number of fissions involved. Table II lists the available pertinent information on rare gas ancestory of these measured nuclides. The data in this table may be used to calculate maximum expected errors if all the gaseous parents were to escape. It should be noted that since only a very small fraction of Ce-143 comes through a gaseous parent, only a very small error would be involved in gas escape in this case. Therefore measurements with Ce-143 may be considered very reliable in this respect and Ce-143 measurements were also made.

TABLE II

Rare Gas Precursors of Selected Fission Product Nuclides

Measured Nuclide	Rare Gas Precursor	Fission Yield at Rare Gas in the decay Chain	Total Fission Yield at the Measured Nuclide	% of Measured Nuclide Coming Through Rare Gas
Sr^{91} (9.7 hr)	Kr^{91} (10 sec)	3.45%	5.81%	59%
Sr^{92} (2.7 hr)	Kr^{92} (3 sec)	1.87%	5.3%	35%
Ba^{139} (83 m)	Xe^{139} (41 sec)	5.4%	6.55%	82%
Ba^{140} (12.8 d)	Xe^{140} (16 sec)	3.8%	6.35%	60%
Ce^{143} (33 hr)	Xe^{143} (1 sec)	0.051%	6.0%	<1%

While it was not the main purpose of these measurements to obtain information on the fractions of rare gas fission products which did escape, the information in Table II may be used along with measured data of Table IV to indicate roughly the fractional escape of the gaseous predecessors of Ba-140, Ba-139, Sr-91 and Sr-92. This should be done and the results correlated, if possible, with stack gas measurements.

The actual fission product analyses were carried out by personnel of the Analytical Section at CPP. Standard radiochemical procedures were used in making the analyses. Determinations of absolute disintegration rates were made by counting each sample on a scintillation spectrometer to measure a specific gamma ray. All samples were counted through a standard polystyrene absorber (1.25 g/cm^2) to absorb beta rays. The parameters used to convert measured gamma counting rates to absolute disintegration rates were those

supplied by R. L. Heath and are given in IDO-16408. The values of other constants used in the calculations are given in Table III. At this time there is available to the writer no sound indication that the nuclear excursion continued over a period as long as a few minutes. Therefore in lieu of any better information, the excursion has been considered as nearly instantaneous, taking 0950 on January 25th as the time of the incident. Since the shortest half-life isotope measured was 82.9 minute Ba-139 it is believed that no significant error will result from assumming a very short burst.

TABLE III

Values Used in Calculations of Number of Fissions

Nuclide	Half-Life	Energy of γ-ray Measured	Branching Ratio (γ abundance)	Fission Yield
Sr-92	2.6 hr	1.39 Mev	0.90	5.3%
Sr-91	9.67 hr	0.551 Mev	0.60	5.81%
Ba-139	82.9 min	0.164 Mev	0.231	6.55%
Ba-140	12.8 d	0.54 Mev	0.250	6.35%
Mo-99	66.5 h	0.75 Mev	0.14	6.06%
Ce-143	33 h	0.29 Mev	0.43	6.0%
Zr-97	17.0 h	0.66 Mev (Nb-97 daughter)	1.00	5.9%

As mentioned previously, two samples were withdrawn from each vessel, J-102 and J-105. For the Mo-99, Sr-91 and Sr-92 determinations duplicate analyses were run (four analyses per vessel). This was also true for the Ce-143 measurements. For the Zr-97, Ba-140 and Ba-139, single analyses of each of the four samples were run. The Zr-97, Mo-99 and half of the Ce-143 analyses were run by J. E. Rein, W. J. Maeck, S. F. Marsh and M. E. Kussey. The other half of the Ce-143 analyses, the Ba-140, Ba-139, Sr-91 and Sr-92 analyses were run by D. G. Olson, J. G. Scott, L. B. Bishop, and J. E. Baker. A typical work sheet (that for Mo-99) showing methods of calculation is included in the appendix. All work sheets are available for inspection by persons who may be interested in the precision of the measurements.

Table IV presents a summary of the results. Values of the number of fissions represented in each vessel are the average of the four (or in some cases two) analyses run on samples from that particular vessel.

TABLE IV

Summary of Determinations of Total Number of Fissions

Nuclide Measured	Vessel J-102	Vessel J-105	Total Fissions
Mo-99	2.08×10^{17} f.	3.67×10^{17} f.	5.75×10^{17} f.
Ce-143	2.16×10^{17}	4.10×10^{17}	6.26×10^{17}
Zr-97	1.39×10^{17}	2.26×10^{17}	3.65×10^{17}
Sr-92	1.64×10^{17}	3.26×10^{17}	4.90×10^{17}
Sr-91	1.31×10^{17}	2.50×10^{17}	3.81×10^{17}
Ba-140	0.93×10^{17}	1.71×10^{17}	2.64×10^{17}
Ba-139	1.24×10^{17}	2.02×10^{17}	3.24×10^{17}

From preceding discussions on the choice of fission products to measure, it was expected that Mo-99, Ce-143 and Zr-97 would all indicate the same number of fissions unless there had been some zirconium loss. Table IV shows that indeed the number of fissions based on Zr-97 measurements is low. It is apparent that somewhere Zr-97 had been lost. The number of fissions based on Mo-99 and Ce-143 are however considered to be quite accurate and are estimated to be better than about ± 25% on an absolute basis. Together they provide the best estimate of the number of fissions, 6.0×10^{17}. This accuracy appears adequate for any purpose to which the information may be put. As expected, the results based on the strontium and barium isotopes indicate a lower number of fissions due to gaseous precursor escape. When the half-lives and fission yields of the rare gas ancestors are considered these data appear to be quite consistent.

III. Neutron Activation of Monitor Foils

Approximately one year ago a number of personnel neutron monitors were sealed in thin polyethylene envelopes and stationed at fixed convenient locations in the CPP access corridor. These monitors contain essentially the same detector materials as the picture-identification-badges commonly used in the CPP area. Included in each of these is a bare indium foil of ~280 mg weight, a gold foil weighing ~28 mg and a sulfur sample weighing ~ 1.65 g. The monitors had been numbered for identification purposes. Their locations in the access corridor are given in Table V and shown in circled numbers in the diagrams in the appendix. After the incident, at the suggestion of R. L. Heath, certain of these were picked up for examination for induced activity before excessive decay had occurred. They were carefully removed from the plastic envelopes, the badges disassembled and the various items examined for activity. Great care was exercised to avoid possible contamination. Only a few of the indium foils were active. The indium foil from monitor number 28 was sufficiently active to be counted

with the CPP scintillation spectrometer and its absolute disintegration rate was so determined. From the γ spectrum and decay observations there was no doubt that the activity measured was In-116. This foil was also beta counted for comparison with other foils. Indium foils from monitors number 25, 26 and 27 had too low counting rates for examination on the spectrometer but did have sufficiently high rates for beta counting. All of the foils were counted between 12:30 and 12:45 on the 25th of January so less than three half lives of decay had occurred in every case. From the absolute disintegration rate of In-116 in monitor No. 28, corrected for decay to 09:50 (the time assumed for the incident), a thermal nvt of 3.3×10^7 n/cm^2 was calculated. Assumming that all the beta activity measured in indium foil No. 28 and in all other foils was In-116, comparisons of beta counting rates permitted calculations of the nvt values for the other foils. Other than the In foils from monitors number 28, 25, 26, and 27, all other foils had no significant activity measurable over counter background, indicating thermal nvt values of less than $\sim 3 \times 10^5$ n/cm^2, the limit of detection. This information is summarized in Table V.

TABLE V

Activation of Indium Neutron Monitor Foils

Monitor No.	Location in Access Corridor	nvt(th)
25	West Wall at foot of Stairwell	5.5×10^5 n/cm^2
26	East Wall between W and Y cells	4.7×10^6
27	Over door to J cell	4.8×10^6
28	Above ladder to U cell	3.3×10^7
29	Over G cell door	$<\sim 3 \times 10^5$ (limit of detection)
30	Suspended by string in P, Q and S ladder well	$<\sim 3 \times 10^5$
31	Center of access corridor above O cell grating	$<\sim 3 \times 10^5$
33	Above D cell doorway	$<\sim 3 \times 10^5$
35	Above C cell doorway	$<\sim 3 \times 10^5$
36	Center of access corridor near C cell doorway	$<\sim 3 \times 10^5$
41	Stairwell near door access corridor level	$<\sim 3 \times 10^5$
21	In operating corridor over head on J cell piping	$<\sim 3 \times 10^5$

The gold and sulfur samples in the fixed personnel monitors were also examined for activity. Gross beta counting of the sulfur showed no significant levels above background. As of this writing, the samples have not yet been processed by making a P-32 separation. (A somewhat more sensitive measurement is possible by processing the sulfur samples.) Examination of the gold samples with a scintillation crystal spectrometer indicated no detectable Au-198 gamma rays. Gross beta counting at ~50% geometry showed only about 6 c/m over background and without chemistry or half-life determination it is by no means certain that the beta activity so observed was Au-198. Since the indium detectors are about two orders of magnitude more sensitive, calculations based on gold have been omitted. Counting of the various foils was done by A. C. Hill and D. G. Olson at CPP.

One other neutron activation detector that is perhaps worth mentioning was a so-called "High Range" monitoring detector located ~5 feet above the floor near the doorway to H cell and shown in the diagram in the Appendix as [Au]. It consisted of a paraffin-filled mild steel can 13 5/8" in diameter and 14 inches high, in the center of which was a 5/32" diameter, 5 mil thick gold foil weighing 28.6 mg. A drawing of this monitor is designated as CPP-C-1193. The gold monitor is a standard one used by the MTR counting room as a thermal flux monitor. Such foils, beta counted at a standard geometry in the MTR Counting Room counters, have been calibrated in terms of thermal neutron dosage only.

The foil from this detector was counted (by E. H. Turk) in the MTR counting room at 1600 on January 25, 1961. No activity was detected. Any result from this monitor would however be ambiguous with respect to intensity-spectral considerations. No thermal neutron shield at the periphery (e.g. Cd) was included and the detection efficiency for incoming thermal neutrons is unknown. As a fast neutron detector, the efficiency is also unknown. Calibrations have never been made for either fast or thermal neutrons and therefore information from this monitor may be considered of little or no value at this time.

It should be added that a nuclear accident dosimeter was also removed from its location at CPP and transferred to the IDO Health and Safety personnel for appropriate measurements. Presumably J. W. McCaslin will get the information obtained from this dosimeter.

J. F. Sommers has stated that at the MTR the maximum permissable thermal neutron flux is taken as 1750 n/cm^2 sec. If during the excursion a man had been standing at the position of monitor No. 28 where the total neutron dose (nvt) was 3.3×10^7 n/cm^2 his thermal neutron dosage would then be the equivalent of only 1.8×10^4 secs or ~5 hours of exposure at the maximum permissable rate.

In collecting data and checking the calculations mentioned herein, the assistance of R. P. Schuman has been very valuable. R. L. Heath has also helped extensively with measurements and calculations.

Very truly yours,

W. H. Burgus

WHBurgus:mjh

cc: R. L. Doan - 2
J. R. Huffman
J. P. Lyon
A. L. Ayers - 2
J. E. Evans
R. C. Shank - 5
F. H. Tingey
J. A. McBride
J. W. Latchum - 2
R. L. Heath
J. W. McCaslin - 2
W. H. Burgus

WORK SHEET

Mo-99 Analysis CPP Incident

	J-102				J-105			
	1-A	1-B	2-A	2-B	1-A	1-B	2-A	2-B
Sample Size	100 λ	250 λ	100 λ	250 λ	100 λ	250 λ	100 λ	250 λ
c/2 min 750 kev γ	13,772	32,032	13,844	32,759	11,968	26,640	12,560	32,690
c/min	6,886	16,016	6,922	16,380	5,984	13,320	6,280	16,345
Chem. Yield	.503	.473	.489	.428	.481	.429	.492	.526
c/m corr. for yield	13,690	33,860	14,155	38,271	12,441	31,049	12,764	31,074
c/m/ml	1.369×10^5	1.354×10^5	1.416×10^5	1.531×10^5	1.244×10^5	1.242×10^5	1.276×10^5	1.243×10^5
x 24.75 = γ/m/ml	3.39×10^6	3.35×10^6	3.50×10^6	3.790×10^6	3.08×10^6	3.07×10^6	3.16×10^6	3.08×10^6
γ/.14 = d/m/ml	2.42×10^7	2.39×10^7	2.50×10^7	2.71×10^7	2.20×10^7	2.19×10^7	2.26×10^7	2.20×10^7
time counted	2211	2213	2218	2220	2223	2225	2228	2231
t_o = 0950								
Δt (hr.)	12.35	12.38	12.47	12.50	12.55	12.58	12.63	12.68
$e^{-\lambda t} = \frac{.693}{66.55} \Delta t$	.8799	.8790	.8781	.8780	.8775	.8772	.8767	.8763
d/m/ml @ t = 0	2.75×10^7	2.72×10^7	2.85×10^7	3.09×10^7	2.51×10^7	2.50×10^7	2.58×10^7	2.51×10^7
$\frac{dn}{dt} = N\lambda$ atoms Mo/ml	1.58×10^{11}	1.57×10^{11}	1.64×10^{11}	1.78×10^{11}	1.44×10^{11}	1.44×10^{11}	1.49×10^{11}	1.45×10^{11}
X vessel vol. factor	1.22×10^{16}	1.21×10^{16}	1.26×10^{16}	1.37×10^{16}	2.20×10^{16}	2.20×10^{16}	2.28×10^{16}	2.22×10^{16}
÷ .0606	2.01×10^{17}	2.00×10^{17}	2.08×10^{17}	2.26×10^{17}	3.63×10^{17}	3.63×10^{17}	3.76×10^{17}	3.66×10^{17}

2.00×10^{17} $\quad$ 2.17×10^{17} $\quad$ 3.63×10^{17} $\quad$ 3.71×10^{17}

2.08×10^{17} $\quad$ 3.67×10^{17}

2.08×10^{17} f. (J-102)
3.67×10^{17} f. (J-105)
5.75×10^{17} f. Total

SOUTH ACCESS CORRIDOR

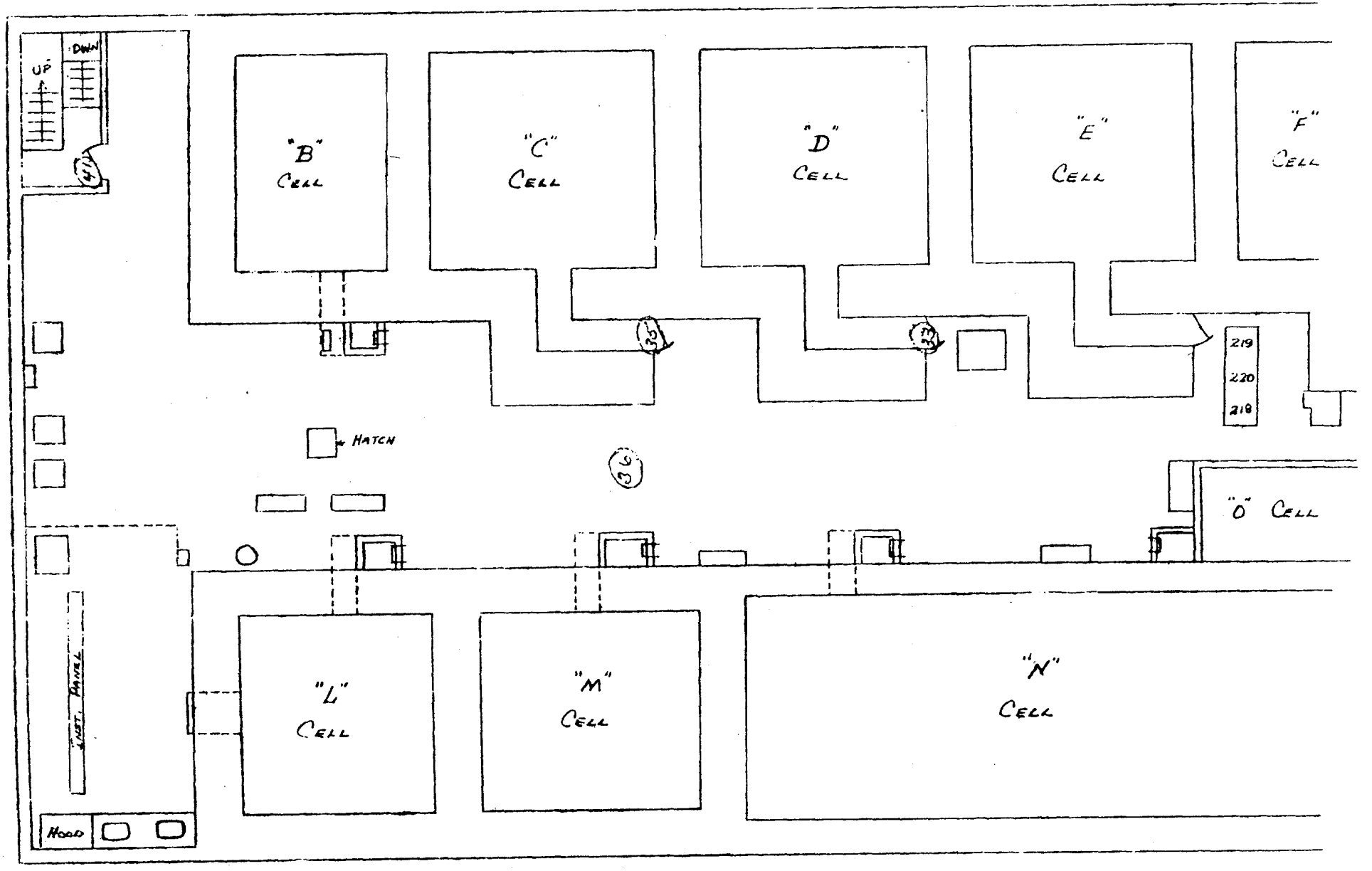
Date: _____

Time: _____

Type of Survey: _____

Requested by: _____

Surveyed by: _____



NORTH ACCESS CORRIDOR

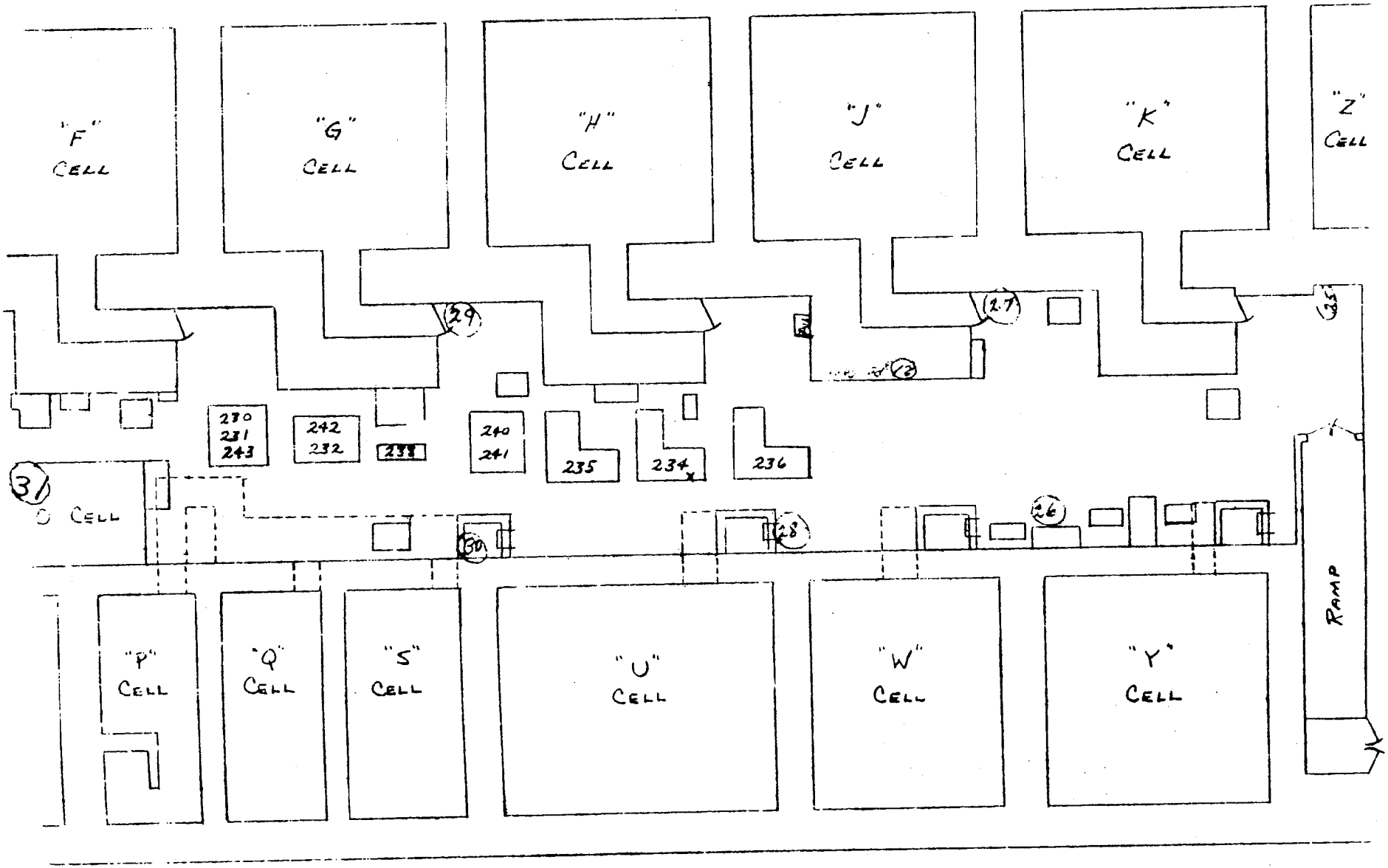
Date: _____

Time: _____

Type of Survey: _____

Requested by: _____

Surveyed by: _____



Idaho Falls, Idaho

March 24, 1961

Analysis: RCA Activated Metals from H Cell
DGO-3-61A

Mr. R. C. Shank
O F F I C E

Dear Mr. Shank:

A stainless steel nut was retrieved from the flange supporting H-110 disengaging head, the flange supporting H-110 thermal leg, and the marking tag from the nozzle head on H-109 steam stripper. A mixture of hydrofluoric and nitric acids was used to externally decontaminate the objects.

Gamma spectral analyses indicated 27.8 d. Cr^{51} [Cr^{50} (n,γ) Cr^{51}] , minor amounts of 45 d. Fe^{59} [Fe^{58} (n,γ) Fe^{59}] , and 71 d. Co^{58} [Ni^{58} (n,p) Co^{58}] were present. It is assumed that the first two reactions proceeded predominantly with thermal neutrons while the latter required fast neutrons.

Calculations showed the neutron field intensity to have the following ratios at the sample locations:

	Indicating Gammas	
Location	.31 mev Cr^{51}	.82 mev Co^{58}
H-110 Disengaging Head	100 (thermal neu.)	100 (fast neu.)
H-110 Thermal Leg	20 "	7 "
H-109 Steam Stripper	50 "	35 "

The above values were obtained by scanning the entire samples and calculating specific nuclide activities. Appropriate corrections were made for self absorption.

An integral neutron flux measurement was made on a portion of the nut removed from the H-110 disengaging head. The segment nearest the reaction vessel was cut from the nut, dissolved in aqua-regia, and analyzed for Cr^{51} and Co^{58}. Chemical separations were made, then specific activities calculated from the gamma spectra. Insufficient Fe^{59} activity was present to warrant this analysis. Parameters used in the calculations were obtained as follows: branching ratios from "Reference Data Manual" found in Nov. 1960 NUCLEONICS; crystal efficiencies from IDO-16370 by Vegors and Heath; and mass absorption coefficients from "Beta and Gamma Ray Spectrometry" by Siegbahn. The stainless steel was typed by x-ray analysis to be approximately 18 - 10. Cross sections used in the calculations were 15 barn for the Cr^{50} (n,γ) Cr^{51} and 91 millibarn for the Ni^{58} (n,p) Co^{58} reactions.

Integral neutron flux seen by nut segment:

Nuclide	γ Energy	nvt
Cr^{51}	320 kev	2.94×10^{12} thermal n/Cm^2
Co^{58}	820 kev	2.92×10^{12} fast n/Cm^2

Drawing of H-110 evaporator locates the nut 2-3/4" from the side of the reaction vessel.

It can be concluded from the data that the reaction took place in the H-110 disengaging head.

Very truly yours,

ORIGINAL SIGNED BY
D. G. OLSON

DGOlson:dsa

cc: R. L. Doan
J. P. Lyon
J. W. Latchum (2)
A. L. Ayers
W. H. Burgus
M. E. Weech
D. G. Olson (2)
Log #61-2382

I - PERSONAL STATEMENTS

①   1-25-61   ③ I

Came on Shift @ 0800 and Relieved Harry and Shift
all the process was running smooth with the
exception of PA238 & PA239 - Supervision came out
and we worked with these two pumps trying to get
them to pump either to H Cell or J Cell.
after we had tried several different combinations
on these pumps - Supervision had Maintenance go to
the Access Corridor and recharge the pumps.
Maintenance did this and it still did no good.
So Jim Whyte asked me to go and apply steam
to PA238 & PA239 through the DCA line
in the PM area.
I went to the PM area and to the DCA lines.
Joe Songe was close by and I asked him if there
was any thing special about this DCA Manifold - He
said no there was nothing special about this.
So I blew the steam header down - opened up
the two manual valves from the DCA line to PA.
238 & 239 - I then turned the steam on
and went over to the DCA line going down to these
pumps - When this DCA line got so hot I could not
hold the line I shut the manual valve from the
DCA line to PA238 & 239. I then closed the
steam header valve on the DCA line. I returned to
the operating corridor to see how we had done.
no good had been done with steam so I was told

W V Rudd   witnessed [illegible] 1/25/61

② to go back and add two funnels of water
to the DCA pot and follow this with air pressure.
How much air pressure to add was not said.
I went back up to add this to the DCA line
and then to PA238 & 239.
I asked Ken Ludlow about these two funnels
of water to add and he told me [illegible]
Before going any [illegible] adding this air and water I did not notice any [illegible]
I opened the air bleed line to the DCA Pot
and began to add the two funnels of water. after
the water had been added I applied 20# of air
through the reducing valve on the air supply line to
the DCA pot. at twenty (20#) of air in the Pot
I closed off the air supply and then opened the two
manual valves to PA238 & 239. When the
air pressure had fallen to approx 0# pressure I
closed the manual valves to PA238 & 239. I then
went over to the pipe lines running from
the PM area to the operating corridor - and asked if
there was good. My answer that I got back was
no but to add two more funnels of water with
40# of air pressure. I added the water to the
DCA Pot then added the air up to 40# pressure
and then closed the air supply valve. to get
this 40# of air pressure to the DCA Pot
I had to use the air bypass valve because
the other air supply line to the DCA pot had a
reducing valve on it that goes only to 20# pressure

W V Rudd   witnessed [illegible] 1/25/61

[illegible] through [illegible] on the DCA Pot.

③ With the above in the DCA pot and the 40# air pressure
in the DCA pot and with the air supply valve closed.
I then opened the manual valve to PA238 &
239. When the pressure in the pot had fallen to
approx 5 to 10# pressure I closed the one manual
valve to PA238 & 239 and then closed the smaller
manual valve. When I had this valve just about
closed the radiation alarms in the area started
ringing and then the evacuation alarm sounded. So I
evacuated
In approx 15 min I came back in the plant
with Jim Whyte and two HPs. to shut the process
down. We came in the operating corridor
first checked most all the instruments down through
the corridor. went then to the P.M. area to check
on this area. I shut off the acid and Colstist Pumps
first closed the manual valves on these two pumps because
the still flow after they have been shut off.
I then returned to the operating corridor and proceeded
to shut the rest of the process down.

[illegible] through [illegible] the water and [illegible]

Witnessed [illegible] 1/25/61

W V Rudd

STATEMENT: - W. V. RUDD

To whom it may concern, the following is ~~the~~ an account of the events prior to, during, and following the criticality incident involving H-110 evaporator, to the best of my recollection.

On arriving at the shift superintendents office at the CPP on the morning of Jan. 25, 1961, it was learned from the graveyard shift superintendent that they had been unable to pump product solution from H-110 evaporator to N cell storage banks during the previous shift. The pump had been shutdown during several previous shifts during the period in which the uranium concentration was being brought up to the specified value. On the graveyard shift, this point had been reached, and the pump had been started up. The N cell charts indicated that solution was not being pumped, ~~[illegible]~~ and the evaporator instruments indicated also that solution was not being moved. As the feed to the extraction system at this time was recycle material containing very little uranium, ~~the~~ ~~[illegible]~~ operation of the columns was continued during efforts ~~[illegible]~~ to get the pump (PA-239) to work properly. The graveyard shift superintendent stated that they had ~~[illegible]~~ established that the pump (PA-239), and its discharge line to N cell were not plugged. They had also had the charging of the pump checked several times, but had still not been successful in establishing flow from the evaporator to N cell.

It was the regular day shift superintendent's day off, and the relief shift superintendent, L. Whyte, the CPP Operations Superintendent, A. L. Ayers, and myself went into the operating corridor to evaluate the situation. The density and level in the evaporator were normal, and the density had not been increasing significantly during the preceding hour or two, due to the fact that the columns were operating ~~[illegible]~~ recycle feed. Therefore it was decided to continue operation of the columns while

witnessed [illegible] 1-28-61

further attempts were made to establish flow through PA-239 to N cell.

A number of operations were attempted, and my memory of the exact sequence is not clear. Roughly, however, I believe the following things were done.

1. I suggested that we switch the valving and see if the pump PA-239 would deliver solution to J cell. The valves were run by the operators. It became apparent that there was no flow from observation of the J-102 chart.

2. It was suggested by one of us that water be pressured through the pump (via the decontamination line) to J cell to establish that it was open. The pump ~~[illegible]~~ remained in operation during this time. A [illegible] buildup in J-102 indicated that the line was open. The water was shut off, and the pump suction valve (which had been closed during this operation) was opened. There was no further buildup in J-102, indicating that flow had not been established.

3. At this time it was suggested that PA-233 be operated to J cell in order to determine that the suction line to the pumps was open. This was done, and a buildup in J-102 indicated that PA-230 was pumping. PA-239 was again placed back in operation with no success.

4. About this time I suggested that we attempt to ~~[illegible]~~ establish a siphon from H-110 through PA-239 to N cell. Such siphoning has occurred in the past when pumping to an empty bank. We switched valving appropriately at the evaporator, and changed the valving of N cell to N-110 which was empty. A level increase occurred in N-110 but it appeared to be by leakage through the valve of N-130 which simultaneously showed a level decrease. The evaporator level and density, however, indicated that there was no flow from the evaporator. This line was abandoned for the time being, with however the thought of a later attempt. The reason was that during this time the mechanics were working on PA-239

witnessed [illegible]

again checking its charge.

5. Following the failure of the attempt described in item 4, new attempts were made to establish flow to J cell. PA-238 was again turned on, and this time it apparently did not deliver. Assuming that the suction line might have plugged, steam was applied via the decontamination line to the suction of the pump, and a blip on the H-110 chart indicated that the line was open.

6. Water was again pressured through PA-239 to J cell with the suction valve closed. Flow was established. I heard the supervisor tell the PH operator W. Rudd to shut off the water. When he indicated that he had done so, the order was given to open the suction valve to PA-239 which was running during this time. I did not observe the valve being opened, but shortly after hearing the order to do so, ~~the~~ alarms sounded. One alarm was the H-111, 112 high level alarm, and the others were radiation alarms. I walked down to see which lights were flashing and saw that the PA-233, 239 cold line alarm, and the G and H cell condensate alarm, both in the service corridor, were alarming. At this time I was not aware of any other alarms sounding in the building. My first thought was of a leak in the remote pump diaphragm allowing hot solution to back into the cold line. I walked back to the ~~[illegible]~~ H cell panel. About this time, ~~[illegible]~~ ~~[illegible]~~ it became apparent that other alarms were also sounding. I again walked back to the radiation alarms and to look, but about this time word was passed to leave. As I started to leave I heard a sharp report, which I thought ~~[illegible]~~ sounded something like an explosion, but could also have been something dropped up stairs. As I left I stopped in my office to see if a respirator was handy. Having [illegible] in my desk I then turned and started to leave. By this time the evacuation alarm had sounded and people were leaving the building. Arnold Ayers had taken one of the boxes containing a scott air pack off the rack. After getting out of the building

witnessed [illegible] 1-28-61 [illegible]

(4)

I assisted A. Ayers in carrying this out to ~~[illegible]~~ assembly area. I proceeded to the area where Stan [illegible] was checking names off his list and reported to him.

I remained with the group for some time trying to find out what the condition was in that area, and if so there were any air activity which would indicate moving people in some other direction. I entered the guard house and found that the condition in the plant and outside was quite safe, and that there was no immediate need for people to move out of the area. I then obtained a respirator and a pair of shoe covers, and re-entered the plant. By this time the plant had been shutdown. I proceeded, along with others, to survey the charts in the operating corridor with a view to determining what happened. At first nothing seemed to indicate anything which would account for the incident. I suggested to John Huff that he check the filter in the air pulser monitoring line for activity. He had already changed the filter previous to the incident, and the filter which had been removed had shown very little activity. I stayed at the plant during transfer of a portion of the material from H-110 to J-102 and sampling of J-102. I then left for Central with others to eat lunch.

Robert E. Commander
Production Engineering
Jan. 28, 1961

witnessed [illegible]

STATEMENT:— R. E. COMMANDER

To whom it may concern:

I came on duty at 0800 Jan. 25 1961. Relieved D. Wallgren, the operator on duty. He informed me that they had tried to get PA-239 to pump to NCell. They had checked the lines and were sure they were free but that very little if any was pumping to N. Cell. He then left for home. The rest of the Crew, Rudd, Savage, Anderson & Smith joined me at this time. As everything was smooth I agreed to watch the panel during coffee break.

At approximatly 0115 Supervision consisting of A. Ayers, Bal- Commander & J. Whyte came out to check H-110. It was decided to try putting water there to N. Cell. As I was alone in the Corridor, Jim Whyte went to the P.M. Area to get things started. ~~[illegible]~~ It was decided not to put this water in at the time. Commander suggested opening the inlet to another N cell bank & possibly H-110 would syphon over. These valves are locked & under control of supervisor. N-110 was opened momentarily but when it was apparent that the banks were equalizing it was shut.

It was decided to try pumping on PA 238 to J-Cell. This pump was turned on and almost immediately a slight rise was noted in J-102 LL. PA 238 was then shut down.

The men returned from coffee break (0930). ~~[illegible]~~ Normal data was recorded at 0830.

K. Ludlow

Witnessed J.W. Whyte 1/29/61

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W. Rudd was sent to the P.M. Area to try to put H_2O thru the decon. line PA-239 to J. Cell. It was determined from a level rise in J-102 that this line was open. The next pump still failed to pump anything over. Water was also sent to J cell via PA-238, when neither pump would deliver to J cell it was decided to steam the lines. A psi on H-110 DRC indicated the line free. As the swap the suction valves were about to direct the steam to J cell. Both lines; PA-238 & 239; were finally thought to be open. The operator in the PM Area was Called to shut off the steam. After it was off I was told to open the suction valve to the pumps. I opened RVC 28 H; PA-239 suction; almost immediately H.P radiation alarms began to sound. We started to silence them when J. Whyte said "Lets get out of here." I left the operating Corridor into the office area. Mr. Ayers actuated the evacuation alarm at this time. I left with everyone else to the parking area outside the main gate. I reported to Stan Jarbourne to be Checked as present & accounted for. There was only a slight breeze the flag was almost limp. Steam from ETR was moving from North to South. Buses arrived and most everyone boarded a bus. R. Moore, Ray Parker and myself did not immediately get on a bus but returned to the guard house. We stayed here until shortly before going to Central for lunch. Paul Kelly using an G.M. meter checked for possible Contamination none was found.

K. Ludlow

Witnessed J.W. Whyte 1/29/61

3

a short time last H.P. personnel from MTR-ETR arrived. They also Checked for Contamination and said I was O.K. I boarded a bus but before it was allowed to leave the area everyone wearing plant shoes were issued shoe covers. Hot area Coveralls were covered with Clean area lab. Coats.

After lunch I was told to report back to CPP to relieve W. Rudd. I arrived back ~1500 and reported to Jim Whyte. He told me to stand by for assignment. Shortly after I accompanied Lee Morrow & Bruce Wilson to Cold building where I remained the rest of the shift.

Decontamination

Water to pumps is accomplished by adding requested amount to a portable P.M. Area the water is pressured then decontamination lines by adding prescribed amount of air pressure to this pot. After water in transfered valves are closed & air pressure bled off.

Steaming - Steam is piped to decontamination lines and is set up by opening plug valves to line being used. To prevent liquid being sucked back up lines they are cooled.

K. Ludlow

Witnessed J.W. Whyte 1/29/61

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next page 2

We were unable to Communicate with Field via the ~~Communication~~ inter-com so I went to the P.M. Area to relay instructions to Wendell.

K. Ludlow

Witnessed J.W. Whyte 1/29/61

1. To Whom it May Concern — 1-27-61 Rubon E. Baker

I Rubon E. Baker Mechanic Foreman at CPP do hereby make this statement concerning the time I arrived at CPP 1-25-61 to the time of evacuation.

As I entered the locker room at approximately 07:55 I met A.B. Ericson maintenance shift mechanic of the 12:00 to 8:00 shift. I asked him how things were going. He said he had a busy night. The east deep well had failed to shut off and it was necessary to switch to the west well pump. And also that he had been called by the shift supervisor to check the charge on PA-239 pump as it had stopped pumping. He said he had checked and recharged the pump but had been unable to get it to pump. And the check valves were not working. He said something about operations having having trouble. (I don't know the exact words as others were talking with us at the same time) but to me this indicated he had done all he could toward getting the pump to work and it would be up to operations to let us know what to do next.

After I arrived at the maintenance office J.L. Whyte called me on the phone and requested that we check the charge on PA-239. I told him the shift mechanic on the mid-night shift had checked and recharged the pump and reported the check valves were not working. Whyte requested we check the charge again, as they had to get the pump to pumping. I told him we were short of mechanics today due to sickness. And the men I had were not too familiar with the pumps, as they had not had the occasion to work on these pumps as much as the other mechanics. But I told him we would do what we could to get the pump going. He said he would bring a work order to the maintenance office.

Arnold Ayers and Jim Whyte arrived in the maintenance shop several minutes later with the work order and requested that we get started on the pump right away, as they had to get the pump to pumping. I assigned Leslie Markley ½ mechanic CPP and Dale Wadsworth ½ mechanic on loan from MTR to check the pump. Arnold Ayers asked if I would stay with these men while they were checking out the pump. I told him I would.

I wrote out the safe work permit in the maintenance foreman office and Jim Whyte signed it in the area supervisors space. We walked to the Health Physics office as the mechanics continued on to the clothing issue room for latex gloves and shoe covers. As we were walking to the HP office I asked Whyte if PA-238 was working, he said yes but they had to have PA 239 to pump the solution when they wanted it.

After getting all approval on the permit, Markley, Wadsworth and I left for the access corridor (approx. 09:00) We arrived in the access corridor by

2. PA-239 a minute or two later. The pump was running. We located a hose, hooked it up to the water header and the hydraulic side of the pump. I then walked to the phone across to [illegible] last wall of the access corridor and called Jim Whyte. I asked him if he could stop the pump while we checked the charge. This he did.

The pump was turned over by hand until the piston was all the way forward. Thus flexing the primary diaphragm forward also. The valve on the charging setup was then opened, bringing the pressure up to 35 pounds on the hydraulic system. This flexed the remote diaphragm forward putting both diaphragms in the same forward position. The valve on the charging setup was closed. I phoned Jim Whyte in the operating corridor and asked him to start the pump. He said it would be a few minutes as they were steaming lines. Four to five minutes later the pump was started. After the pump had run two or three minutes I called the operating corridor to find out if the pump was pumping. The operator said it hadn't run long enough to tell. Four or five minutes later Jim Whyte called to say the pump wasn't pumping. I asked him to shut it down while we ran another check on it. The pressure was bled down to check for air in the hydraulic system. A little water was sprayed on the floor while doing so. Dale Wadsworth called the H.P. for a survey. He checked the area but found no change from the first survey. We followed the same charging procedure as before, and also cracked the valve open a little at the bander on the high point of the hydraulic system, tapping the line to work any air out that might be in the system. There was no air. The oil side of the pump was checked for air also, but no air. The valves were closed.

I called the operating corridor and asked the operator if the pump could be turned on again. I heard him call to someone to ask if PA-239 could be turned on. Then said yes and hung up. As I walked back to the pump I noticed it had started, then shut off. We waited for it to start again.

Approximately ½ minute later we heard and felt a heavy bang, like a weight striking the floor north and above us. This was followed by a noise like a jackhammer. Almost before the first noise stopped, the alarms by H cell went off before the second noise had stopped.

We immediately left the access corridor on the run heading north up the ramp to CPP 602 basement, up the east stair well, through the corridor of 602 bldg past the swing doors to the operating corridor. I saw Arnold Ayers running up the operating corridor toward the swing doors calling to someone in the operating corridor to pull the evacuation alarm. I continued running out through the locker room and out through the main guard gate. The evacuation alarm sounded just before I reached the main gate. The alarm at the guard house were ringing as I went through the gate. It was three or four minutes after I reached the parking lot before I checked to see what time it was. It was then 09:58

I did not return to the plant until 14:00 when I came back for my coat and hat after blood test and HP checks at the AEC Dispensary and HP Bldg.

witnessed C W Sutton [illegible] 1-27-61 Rubon E. Baker

3. 1-27-61 Rubon E. Baker

To add further to my statement. The H.P. for the job was Clyde Moser. He approved the permit for Health and Safety. And he also checked the area we were in when the water was sprayed on the floor. He had just left us a few minutes before the incident.

I ran through the big vehicle guard gate to the parking lot and across to the west side of the lot. About two dozen of us stopped at this area. A roll call was taken of members of the maintenance group at this place by Stanley Markley the CPP maintenance evacuation warden. This was after we had been at the parking lot several minutes. We were separated from the main group of people who stopped just as they came through the gate.

The construction workers left the area three or four minutes after we arrived at the parking lot. They drove past us and stopped west of CPP at the intersection of the main road to C.F. I do not know if they stopped on their own accord or because of a road block.

I noticed by the steam coming out of the PIF bldg. condensate pump pit vent that there was a slight breeze to the south.

After the buses arrived we got on bus no. 45. An HP from MTR boarded the bus and made a survey of everyone on the bus. I was told my left shoe was slightly contaminated and to go to the guard house and put on shoe covers. I asked Leslie Markley to come along too as his shoes were probably slightly contaminated also. We left the bus and walked to the guard house where I put on shoe covers while Markley was surveyed by the H.P. at the guard house. Markley's coveralls were slightly contaminated so he changed coverall and put on shoe covers. I understand they took his badge at this time. And Wadsworth's badge also. He had gone to the guard house ahead of us. My badge was picked up outside the CP Cafeteria when the guards arrived to exchange badges for everyone from CPP. After lunch I was instructed by Roy Jensen CPP HP to go to the CF Dispensary for blood and urine tests. And from there to the AEC HP bldg for a personal survey.

witnessed J. W. Sutton [illegible]

STATEMENT:— R. E. BAKER

To Whom it May Concern. (1)

at approximately 0830 Wednesday Jan 25th Jim White relief Supervisor came to the P.M. area where I was working helping Earl Murray change the valving on the catalyst lines to P-101 Dissolver so we could change Catalyst pumps and check out a new rotometer that had just been installed on the catalyst line to the dissolver. He Jim White asked me to help him pressure some water through the decontamination lines to PA 238 + PA 239 in an effort to clear a plug in the lines. We assumed the lines were plugged because the pumps would not work. When I started the procedure I found that there was already some pressure on the tank and some water in it. I bleed the pressure off and then added some more water until it was about half full. Then we shut off the

Marlin K. Smith 1-27-61 Witnessed by W. White 11:45/61

Water. closed off the sight glass on the tank. opened the necessary valve to the pumps and applied 20 pound air pressure to the tank. When it did not appear that the water was going we upped the pressure to 30 pounds and the 40 pounds pressure. When it did not appear that the water was going I shut off the air pressure opened the sight glass. From our observation of the sight glass and the air pressure gauge we assumed that the water was not going through the line so Jim said something about letting it go for now so I closed the valves from the pot to the pumps and bled the air off from the pot leaving the water still in it. at that time I dropped 2 Elbows from the cane to the dissolver then I left the P.M. Area and went to the Captains

Marlin K. Smith 1-27-61 Witnessed by W. White 11:45/61

for Coffee (3) when I got back shortly after nine George Savage was there and we charged one Batch of Elbows to the cane. Then at 0930 I charged two more elbows to the dissolver. Shortly after this Jim not sure how long George Savage and I were making up chemicals (II work) for the pressure when Wendell Rudd came to the P.M. area and started trying to pressure water through the pumps as I had done earlier. When the radiation monitor started to ring by the air pulse we started to move away as I left I saw wendell Rudd closing the valve by the floor on the decontamination line to the pumps. When I got near the stairs from the P.M. area to the operating corridor I saw and heard the constant air monitor Ringing By L Bell and

Marlin K. Smith 1-27-61 Witnessed by W. White 11:45/61

West of the cave (4) I started down the stairs and the evacuation alarm sounded as I came through the operating Corridor I saw that it was already empty of personell. I ran to the guard gate where everyone else was assembled. We stood around for awhile till the buses came then we got on the to keep warm. a little later an H.P. got on the bus and scanned our clothes to see if he could detect any contamination. Then the guys over room called let clothes and took us to Central for dinner. after dinner they took our badges to check them for exposure. then returned them to us when we came back to CPP at about 3 Oclock.

Marlin K. Smith 1-27-61 Witnessed by W. White 11:45/61

as near as I can remember I opened the three or four valves between the pressure pot and the decontamination line manifold first

Witnessed by W. White 11:45/61

Then the two way valve on the manifold (5) to PA 238 + 239 pumps then the block valve next to the floor where the line goes into the cell.

When I closed them I closed the manifold valve first then the block valve. Then the others. I'm not sure what order.

The way we could tell whether any water was going through the line was by the air pressure gauge on the pot. If the pressure dropped off we knew that the water was going through the line. But the time the air pressure held steady so we figured that the line was still plugged.

Marlin K. Smith 1-27-61

Witnessed by W. White 11:45/61

STATEMENT:- M.R. SMITH

J—OPERATING INSTRUCTION BULLETIN NO. 10.24

OPERATING INSTRUCTION BULLETIN NO. 10.24

CLEARING PLUGGED PROCESS LINES

This bulletin is intended to furnish general guidance when it becomes necessary to clear a plug from a process line. The clearing of plugged lines will always be done only when the Shift Supervisor is available to personally direct the operation. Obviously, detailed procedures cannot be written for all eventualities as each instance must be considered as a special problem. However, the following general rules will apply:

1. Health Physics should be notified of what is planned to be done so they can be available for advice and alerted to detect any unusual radiation or contamination.
2. If pressure is to be applied to a process line, never use air or steam unless specifically authorized to do so by Superintendent or Assistant Superintendent of Operations. Pressure should be applied by addition of a liquid into the process line through existing decontamination piping.
3. All valves in process line which is being pressured should be double checked to insure that solution will not be forced into the wrong equipment or into piping located in a cold area.
   Particular care must be taken when process piping contains solutions rich in uranium to prevent undue losses and possible critical concentrations.
4. All connections to decontamination lines for purpose of pressuring process lines must be constructed of stainless steel pipe or tubing. Hose with Chicago fittings or hose clamps will not be used to pressure process piping. An exception is made when instrument probes are being routinely cleared by instrument maintenance. This exception is an instance when the Shift Supervisor will need to exercise judgment.

5. Pressure applied to a process line will not exceed 80 psi unless approval is obtained from Superintendent of Operations or Assistant Superintendent of Operations.
6. If approval for use of steam or air is obtained, then the vessel instrument cell valves should be closed if pressure is to exceed 15 psi.

K—LISTING OF OTHER REPORTS AVAILABLE ON INCIDENT

OTHER REPORTS AVAILABLE ON INCIDENT

Subject	Author	File No.	Date
Gamma and Neutron Exposures due to ICPP Criticality Incident of January 25, 1961	I. J. Wells	LJW-10-61A	2-20-61
Preliminary Report ICPP Criticality Incident of January 25, 1961	J. W. Latchum	La-17-61A	1-31-61
H-110 Incident	A. L. Ayers	Ay-18-61A	1-30-61
CPP Incident - January 25, 1961	R. E. Hayden	Ha-10-61A	2-2-61
ICPP Criticality Incident	R. L. Doan	Do-25-61A	1-30-61
CPP Incident of January 25, 1961	W. H. Burgus	Bur-2-61A	2-2-61
CPP January 25, Evacuation	D. A. Davis	DAD-11-61A	1-31-61
CPP Evacuation	L. E. Taylor	LET-12-61A-M	1-26-61
H-110 Criticality	D. G. Reid	Rei-17-61A	1-27-61
Criticality Calculations for CPP Evaporator	R. S. Marsden	Mars-5-61A	2-13-61
Criticality Calculations for CPP Evaporator	R. S. Marsden	Mars-6-61A	2-13-61
CPP Criticality	R. W. Goin	Goin-1-61A	2-10-61
CPP Operation Resumption	A. L. Ayers	Ay-31-61A	2-13-61
CPP Operation Resumption	D. G. Reid	Rei-18-61A	2-1-61
CPP Safeguards Committee Meeting No. 58	D. G. Reid	Rei-32-61A	2-14-61
Analysis: RCA Activated Metal from H-cell	D. G. Olson	DGO-3-61A	3-24-61

D R Wenzel

PRELIMINARY REPORT OF THE INVESTIGATING COMMITTEE

CRITICALITY INCIDENT

at the

IDAHO CHEMICAL PROCESSING PLANT

on
JANUARY 25, 1961

by

R. C. Paulus, Chairman
A. O. Dodd
K. K. Kennedy
F. H. Tingey
F. M. Warzel

PHILLIPS PETROLEUM COMPANY - ATOMIC ENERGY DIVISION
U. S. ATOMIC ENERGY COMMISSION - IDAHO OPERATIONS OFFICE
Idaho Falls, Idaho February 16, 1961

REPORT OF INVESTIGATION

CRITICALITY INCIDENT AT THE IDAHO CHEMICAL PROCESSING PLANT

A-SUMMARY

At approximately 0950 Wednesday, January 25, 1961, a nuclear excursion occurred in a first cycle product evaporator at the Idaho Chemical Processing Plant (ICPP), National Reactor Testing Station. Radiation alarms were actuated by the prompt gamma radiation produced at the time of the nuclear excursion and from radioactive gas subsequently released through the exhaust stack to the atmosphere. All personnel (251), including construction workers, in the ICPP area evacuated to a region approximately 500 feet west of the Process Building, where the radiation level was determined to be less than 1 mr/hour.

Available evidence indicates that the state of criticality resulted from the accidental lifting of a concentrated solution of uranyl nitrate (200 gU/liter) from the lower, geometrically safe section of the evaporator into the upper, 24-inch diameter, critically unsafe, vapor-disengagement section. The most likely cause of the lift appears to have been a sudden burst of air inadvertently introduced into the bottom of the evaporator. The mechanism by which this could have occurred is well defined; however, no definite proof either from instrument records or direct testimony has been obtained to make this premise conclusive.

Of the 251 individuals present in the ICPP area at the time of the incident, none received significant radiation exposure. The highest exposure as determined from film badge readings did not exceed 55 millirem of penetrating radiation. Essentially zero beta radiation was detected. No significant neutron exposures or internal contamination from inhalation were found. The absence of significant exposures is attributable to the extensive shielding provided by the process cell in which the event took place and the control of the fission gases by the equipment.

High radiation levels resulting from normal operation of the equipment have precluded a detailed inspection of the evaporator or of other equipment contained in the cell. Limited inspection by means of brief observation, photographs, and subsequent flow tests indicated that there was no significant damage to equipment.

B-FINDINGS

Operational Background

On January 20, 1961, the ICPP began processing highly enriched uranium-aluminum fuels, after a lengthy shutdown. Initial extraction was of salvage material from previous runs. Simultaneous with the startup of the extraction equipment, dissolution of ETR fuel was started on a planned

20-day run. This was the first hot processing in the particular equipment involved in the incident in approximately 12 months. Previously, a cold run of 12 days' duration had been made using synthetic solutions. Some unirradiated enriched uranium scrap was also processed during this time for check-out of equipment modifications.

Two process cells, G and H, are routinely involved in dissolution and first cycle solvent extraction. Equipment in G-Cell includes two continuous dissolvers, two input measurement tanks, a feed adjustment tank, a column feed evaporator, a waste evaporator, two waste collection tanks, a rework tank, and the first cycle A (extraction) column. H-Cell equipment includes the first cycle B (scrub), C (strip), and D (solvent wash) columns, a steam stripper, three mixer-settlers for solvent clean-up, a solvent storage tank, a scrub collection tank and the first cycle product evaporator.

The nuclear excursion occurred in the product evaporator (H-110), which, together with associated equipment, is illustrated in the attached figure. The uranium shown entering this flowsheet is contained in an aqueous solution recovered from the first cycle strip column. The normal evaporator feed concentration is 4 grams of uranium per liter; however, at the time of the incident the actual concentration was approximately 0.1 gram per liter.

The uranium solution passes downward through the 1D solvent wash column (H-105), in which it is contacted with fresh extraction solvent diluent (Amsco). This packed column was designed to remove most of the dissolved tributyl phosphate extractant (TBP) from the aqueous uranium stream, thereby preventing its accumulation in the product evaporator with several undesirable effects. From the bottom of the 1D column the aqueous uranium solution is air-lifted to the top of the steam stripper (H-109). Steam is admitted to the bottom of the packed section of the steam stripper and passes upward, stripping entrained or dissolved Amsco, as well as additional TBP, from the descending liquid before it reaches the evaporator. The overhead steam is condensed and routed to the process equipment waste (PEW) system for re-evaporation and disposal.

The aqueous solution flows by gravity from the steam stripper to approximately the mid-point of the cold leg of the product evaporator, in which it is normally concentrated about 50 fold, to 200 grams per liter. Since, at the time of the incident, the evaporator feed was very dilute, the concentration factor in the H-110 evaporator was on the order of 2000, to give the 200 grams per liter product. Because of the low evaporator product rate, intermittent rather than continuous pumpout had been scheduled. The evaporator product is normally transferred by remote head diaphragm pump PA-238 or PA-239 to either P- or Q-Cell for second cycle extraction or by PA-239 to N-Cell for temporary storage, from which it can go to second cycle extraction. Off-specification product may be transferred to salvage equipment (J-Cell) by pump PA-238 or PA-239 or through steam jet H-526.

As indicated in the appended figure, H-110 is a continuous thermosiphon evaporator. Feed to the evaporator mixes with material already concentrated and application of heat to the tube bundle vaporizes part of the liquid in the tubes, discharging a mixture of liquid and vapor into the 2-foot diameter vapor-disengaging space atop the cold leg. Entry to the disengaging space is tangential as an aid in vapor-disengagement. The lower part of the vapor-disengaging space, immediately above the 4 7/8 inch (inside) diameter cold leg, contains an anti-swirl baffle consisting of two crossed plates set on edge, one inch high by eight inches long. Steam from the top of the evaporator flows to the bottom of H-109 stripper; additional steam is introduced in H-109 to give the desired vapor-liquid ratio.

It was recognized during design that the two foot diameter vapor-disengaging space was not geometrically safe. As a safety measure, a 1 1/2 inch diameter overflow line was provided below the two-foot diameter section. Overflow material is collected in two geometrically safe vessels (H-111 and H-112). Should these vessels fill, additional material overflows to the cell floor rather than being allowed to back up into the critically unsafe expanded section of the evaporator.

Pumps PA-238 and PA-239 have never performed as desired. Considerable maintenance has been required due to erratic pumping rates. The decontamination system (vessel at the top of the figure and associated piping) was installed as a means of purging the pumps and piping upon shutdown. It has also proved useful for opening plugged lines, cleaning out the pump check valves, etc., in order to keep the pumps working.

The decontamination system, located in the process makeup area, consists of a 10-gal. tank with sight gauge, funnel for water addition, air supply lines, pressure gauges, and associated valving. The usual procedure for water flushing with this equipment is to introduce a quantity of water into the tank, build up the pressure in the tank with air to 20-50 psig, and discharge the water to the decontamination lines by opening appropriate valves. This procedure frequently allows air to enter the process line after the water is discharged. In steam flushing, low pressure steam is introduced through a manifold bypassing the 10-gal. vessel.

Events Leading to the Incident

During the 0000 to 0800 shift on January 25, the specific gravity of the solution in the evaporator approached 1.28, indicating a uranium concentration of approximately 200 grams per liter and an attempt was made to pump material from H-110 to N-Cell. Pump PA-239 required for transferring this material to storage (N-Cell) was started but failed to deliver. An attempt was made to clear the lines. This included flushing the lines with water and air, using the decontamination equipment. The discharge line was apparently cleared as noted by a response on the

liquid level recorder on the storage vessel in N-Cell. Also, the pump suction line from H-110 to PA-239 was air-purged at this time. The pump still would not deliver. All attempts to start the pumpout of H-110 to N-Cell failed. During this period the columns were on recycle feed and there was no significant buildup of uranium in the H-110 evaporator.

The day shift continued in the effort to make pump PA-239 operate. Several attempts to pump evaporator product to N-Cell failed. In order to preclude further dilution of first cycle product in N-Cell by the water used for flushing and testing, pumping to J-Cell was attempted. Also, instrument response to transfers to J-Cell is more rapid than to N-Cell because of shorter piping runs. In addition, differences in sizes of the receiving vessels make incremental volume changes in J-Cell more discernable. The discharge lines of both pumps to J-Cell were flushed with water. The suction lines were purged from the pumps back into the evaporator with steam. An attempt to pump through PA-239 failed. Flow was established through PA-238 for a short period, indicating that the pump was operating satisfactorily and the suction line from the evaporator was not plugged. Consequently, either the discharge line from PA-239 was plugged or that pump was not operating properly. However, since PA-238 discharge is not routed to N-Cell, further attempts were made to make PA-239 operate.

Immediately prior to the time of the incident, an operator in the process makeup area was instructed to put a "couple of funnel fulls" (approximately four liters) of water into the 10-gallon flushing tank and use 40 psig air pressure to move it into the decontamination line. The process operator at the control panel, one level below the makeup area, opened PA-239 discharge valve to J-Cell. A buildup of liquid in the J-Cell storage vessel, as reflected by the liquid level recorder, equivalent to approximately four liters was noted. The operator in the makeup area was instructed, from the operating corridor through a pipe chase, to close the valve from the decontamination tank. A reply was noted; however, the words were not distinguishable. (The makeup operator later stated that the pressure in the decontamination tank had dropped to 5 or 10 psig before he closed the valve.) Pump PA-239 was then started and momentarily ran with the suction valve from H-110 closed. The process operator "had hardly taken his hand off the valve (PA-239 suction) control" after opening this valve when radiation alarms sounded throughout the plant. Immediately the operations superintendent went to the Health-Physics office (some fifty feet away) and found the master panel for radiation detectors almost completely covered with alarm lights. Without further delay he proceeded to the end of the corridor and actuated the plant evacuation alarm within no more than a minute after the area alarms had sounded.

The Nuclear Incident

From a detailed examination of pertinent instrument charts it appears that H-110 contained approximately 40 liters of uranyl nitrate solution immediately prior to the incident. The estimated concentration was 200 grams

of uranium per liter, 90% enriched in U-235. At the time of the incident both the liquid level and the density instrument traces for H-110 showed an abrupt change indicative of an air surge, a pressure transient, or both. A multi-point temperature recorder on a three-minute scan interval indicated a rise of six degrees centigrade in the H-110 vapor head and a rise of twenty-eight degrees in the condensate downstream of the condenser (H-300), the latter returning to normal within six minutes (two recorder cycles). The H-110 pressure recorder was heavily snubbed and did not respond.

A calculation of liquid volume around the evaporator and the overflow tanks before and after the incident indicated an increase of at least 11 liters. This liquid could have come from the decontamination vessel and associated lines and/or the steam stripper. It is not uncommon for the stripper to "dump" about 10 liters when disturbed. Also, it appeared from H-110 instrumentation charts that the uranium content in the evaporator was reduced by approximately two kg during the incident. After shutdown and flushing of the evaporator system a material balance well within measurement uncertainty was obtained.

An over-all uranium material balance for the plant based on measured input to process and material collected and measured after shutdown indicated that no appreciable amounts of uranium were spread through the system.

The magnitude of the excursion has been estimated at 6×10^{17} fissions with an error not to exceed 25%. This estimate was based primarily upon radiochemical analyses for Mo-99 and Ce-143 in samples of the solution involved in the incident. Thermal neutron integrated flux, as determined by scintillation spectrometer counting of activated indium foils obtained from various operating areas in the plant, ranged from below the limits of detection (5×10^{6} n/cm^2) to 3.3×10^{7} n/cm^2.

From detailed examination of instrument charts and radiation detector traces it is believed that the nuclear excursion was of short duration. No evidence exists that any gaseous or air-borne contamination entered the operating areas of the process building. Since sounding of the alarms was almost simultaneous throughout the process building, prompt gamma radiation from the excursion appears to have actuated the majority of the alarms. The fission gases were conducted through the vessel off-gas system and cell vent tunnel to the atmosphere via the plant exhaust stack. No hazard to personnel or environment is considered to have resulted from this release.

Post Incident Activities

The evacuation of the building and outside working areas by Phillips and other personnel was orderly. Evacuation was complete within 5 to 7 minutes, except for one construction employee who was working near an air compressor and did not hear the evacuation signal. This man left the area about 10 minutes after evacuation had been initiated. (His film badge indicated no detectable exposure.)

Two health physicists made a final check of the process building before evacuating. No radiation above normal background was detected with survey instruments having a range of 0-250 mr/hr.

Shortly after roll calls had been completed at the evacuation area and it had been ascertained that all personnel had evacuated, a team of operating and health physics personnel re-entered the plant and shut down all process equipment. At the same time processing systems were checked for possible indication of a source of activity release. The first re-entry was made approximately 20 minutes after the evacuation had been signalled.

A filter from the stack gas monitor was recovered for analysis and the presence of Cs-138 (T 1/2 = 32 minutes) was reported at about 1035, approximately the same time that Cs-138 was identified from a high volume air sampler filter in the Central Facilities Area, some three miles south of ICPP. Thus, the first proof of a criticality incident was received approximately 45 minutes after the incident. Observations of process instrument records and knowledge of the location of significant quantities of uranium indicated that H-Cell was the most likely site of the excursion. After the identification of Cs-138, the solution in the H-110 evaporator was transferred to J-Cell where it was sampled and subsequently shown to contain short-lived fission products.

Health Physics' approval for the return of all employees, based upon the absence of external contamination and of radiation levels in excess of normal, was given at approximately 1345. An examination of instrument charts and a review of potentially hazardous situations resulting from the incident were made prior to allowing the full plant staff to return to the CPP area at 1445.

Radiation Exposures

Shortly after evacuation, a general check of pocket dosimeters worn by process operating personnel indicated that radiation exposures were probably less than daily administrative limits (50 millirem). Following identification of short-lived fission products, selected film badges considered representative of the entire plant area were scanned for neutron activation of indium and analyzed for beta and gamma exposure. Subsequent analyses of badges from 65 individuals indicated a maximum exposure of 55 mrem gamma, 0 beta. The maximum thermal neutron exposure detected in the 65 badges analyzed was less than 10 millirem. Analyses of nuclear accident dosimeters indicated that there was no fast neutron flux associated with personnel exposures.

Selected personnel were subjected to bioassays and whole body counting. No blood sodium activation was found, indicating that there were no significant neutron exposures. Whole body counting supported this conclusion and indicated that there were no significant internal exposures.

C-CONCLUSIONS

1. A nuclear excursion of approximately 6×10^{17} fissions occurred in a first cycle product evaporator at about 0950 on January 25, 1961. Available evidence indicates that criticality resulted from accidental lifting of uranyl nitrate solution containing about 200 grams of uranium per liter (90 percent U-235) from the lower geometrically safe section of the evaporator into the upper 24-inch diameter critically unsafe vapor-disengagement section. The cause of the lifting is not certain; however, the sequence of events which occurred just prior to the incident suggests that a burst of air was inadvertently introduced into the bottom of the evaporator. Since testimony of operating personnel does not completely support this proposed mechanism, other theories of less credulity are being evaluated in the light of available evidence.

2. Intermittent operation of the ICPP presents potentially serious problems to safe operation. Morale and personnel continuity and effective training are difficult to maintain. The more frequent changes and modifications to process equipment resulting from more frequent down periods aggravate operator orientation and equipment familiarization problems. Consequences of prolonged down time on process equipment often are not assessable.

3. Personnel response to radiation alarms and the evacuation signal was prompt and orderly. Re-entry into the plant and identification of the location and nature of the incident was performed with efficiency and dispatch.

4. The use of direct reading pocket dosimeters proved to be an effective tool for immediate estimation of personnel exposures.

5. No costs were incurred which were attributable to contamination clean-up, product recovery, or equipment repair as a result of the incident.

D-RECOMMENDATIONS

The operating contractor, as a result of investigation and evaluation of the incident, has taken the following immediate steps to minimize criticality hazards presented by the evaporator and decontamination equipment in the current processing run. In listing the actions that have been taken the Committee concurs in the implied recommendations and judges the actions to be adequate for completion of the current processing run.

1. The use of compressed air or steam to clear obstructions in CPP process lines without the specific approval of the Assistant Manager for Operations has been forbidden. Only water, delivered by a low-volume, controlled pressure pump, will be permitted for this service.

2. A second shift supervisor has been assigned to each shift and two additional engineers have been assigned to assist the operations superintendent.

3. Additional instrumentation has been installed, viz:

   a. Multiple pressure gages have been mounted so that all personnel involved in using the decontamination system for purging of process lines or equipment can be constantly aware of line pressures.

   b. A differential pressure recorder between the top of the steam stripper (H-109) and the top of the evaporator (H-110) has been installed.

   c. An additional evaporator liquid level recorder-alarm, using the upper specific gravity probe for the high pressure connection, is now in use.

4. A flowsheet specifying a dilute first cycle product (30 grams uranium per liter) has been adopted. Previous operating experience indicates that 30 grams uranium per liter insures a low risk of exceeding 60 grams uranium per liter.

5. Neutron poisoning of the evaporator will be accomplished by the addition of boric acid to the C column strip solution. The boron concentration in the strip solution will provide a minimum of 2 grams of boron per liter in the evaporator product. At 60 grams U-235 and 2 grams boron per liter, the flowsheet content of H-110 evaporator would have a $k_{eff} < 0.8$ at optimum geometry. A minimum pumpout rate from the evaporator has been established to preclude the precipitation of boron salts.

6. The evaporator overflow collection tanks, H-111 and H-112, will be maintained as nearly empty as possible, consistent with operational capability.

7. Detailed, written operating procedures have been prepared covering all phases of the revised flowsheet. Responsible supervision and operating personnel have been given special review and training on the revised flowsheet and existing procedures and have acknowledged, by signature, their reading and understanding of all Standard Operating Procedures and Operating Instruction Bulletins pertinent to the current run.

8. All modifications and proposed procedures have been reviewed by the ICPP Safeguards Committee before startup.

Further, it is the Committee's recommendations that, upon termination of the current processing run, the H-Cell evaporator system be subjected to detailed inspection. Activation analyses of metal samples taken from various locations in the system should be made.

In making additional recommendations, the Committee recognizes that total protection against criticality incidents in processing enriched uranium fuels is neither possible nor practical. Neither does the Committee feel inclined to make recommendations which, to the best of the Committee's knowledge, have been and are being conscientiously practiced by the operating contractor. Safeguard reviews of process equipment have been standard practice since first startup in March of 1953. It is worth noting that in 1955 the criticality hazard presented by the product evaporator (H-110) was considered by the ICPP Safeguards Committee. Minutes of meetings on this subject, report that that committee felt the likelihood of operational circumstances resulting in a criticality incident in the equipment was small. Also, it was concluded that if criticality should occur, it would probably be accompanied by limited physical damage. Both of these predictions in a large measure have been demonstrated. Also, the Safeguards Committee had previously considered the use of air and steam under pressure in cleaning process lines. Administrative controls had been established to cover this operation. Operator training and orientation has been a continuing concern. Standard Operating Procedures and Operations Instruction Bulletins have been prepared for every major operation. Startup after appreciable down time is preceded by cold runs for equipment check out and to re-orient personnel with procedures and equipment.

The fact that criticality did occur, however, indicates that a strengthening of certain areas of safeguards is needed. The following recommendations are directed toward this end:

1. Additional limitations should be placed on the amount and manner in which expansible fluids are introduced into any part of the process system. Contingencies associated with such usage should be carefully evaluated and supplemental control systems devised.

2. Communication between safeguards committees, operating supervisors and operating personnel should be improved. Suggestions for consideration are:

   a. codification of safeguard committees' actions,
   b. chairmanship of the ICPP Safeguard Committee be a full-time assignment, and
   c. improve direction and follow-up in the area of operator training, particularly with respect to infrequent operations.

3. Safeguard reviews should always consider complete systems rather than single items of equipment. In particular, the potential for mal-operation or misuse of any part of the system should be considered.

4. Consideration should be given to the redesign of the evaporator system to increase physical protection against criticality.

5. Attention should be given to improving intercommunication between work areas.

SIGNATURE OF THE COMMITTEE

This report represents the combined efforts of the members of the investigating committee and the findings, conclusions and recommendations are concurred in by the members as witnessed by their signatures below:

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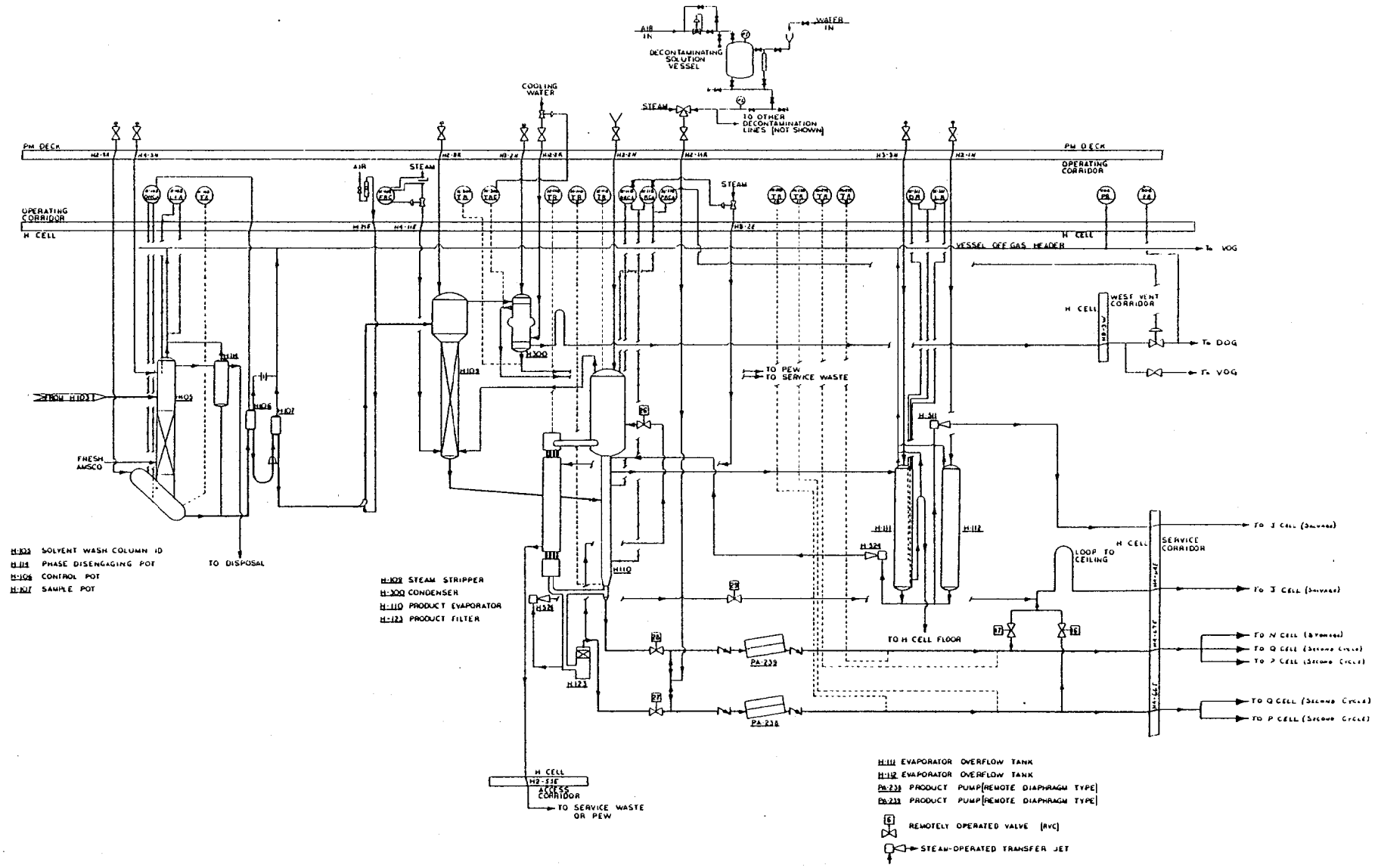


PROCESS FLOWSHEET

FIRST CYCLE PRODUCT WASH AND CONCENTRATION CELL H

CONTINUOUS ALUMINUM PROCESS

D R Wenzel

INTER-OFFICE CORRESPONDENCE

PHILLIPS PETROLEUM COMPANY

Idaho Falls, Idaho

February 20, 1961

SUBJECT

Gamma and Neutron Exposures due to ICPP Criticality Incident of January 25, 1961

IJW-10-61A

Mr. R. L. Doan
O F F I C E

Dear Sir:

Film badge processing results have shown that, as a result of the ICPP Criticality Incident of January 25, 1961, no Phillips employees received beta or gamma exposures in excess of the administrative RPG of 60 mrem/da. The highest reported gamma exposure, in fact, was 55 mrem. The film packets had been changed on January 19, 1961, as reported in Ha-10-61A, and were, therefore, accumulating the fifth day of total exposure in the various CPP environments. Such was the record of exposure for personnel actually in the CPP area at the time of the incident. Three Phillips employees without film badges were known to have been exposed to the cloud of fission gases.

J. Reed Barnes, Lyle Belnap, J. B. Bischoff, and D. M. Scott, all from CF Maintenance, were on a locomotive somewhere east of CPP when the incident took place. Fortunately, though two of them were unbadged at the time, it will be possible to give an assigned dose on the basis of exposures recorded by the other two. Lyle Belnap received 20 mr gamma and J. R. Barnes received 30 mr gamma. It is recommended that D. M. Scott and J. B. Bischoff be assigned a gamma dose of 30 mr each.

J. L. Cook, also from CF Maintenance, was at the incinerator at the time of the incident. He states that he entered the area at about the time the security blockade was set up having been, prior to that, in the CF area. He remained at the incinerator for a period of three or four minutes. The blockade was set up at West Portland and Lincoln at about 1003 - 1004. The wind direction during this time varied between 16° and 9° at the 250' level and between 11° and 5° at the 140' level. The average speed was about 4 mph at the 250' level and about 2 mph at the 140' level. Assuming the greater speed the cloud should have begun to pass about midway between the incinerator and Central Facilities, slightly nearer CF, at about 1008. J. L. Cook should have been leaving the area at about the time the cloud arrived over the junction. The maximum radiation levels shown in the vicinity at any time between 1005 and 1020 was 7 mr/hr. It can be said with confidence that J. L. Cook's dose would not have approached 10 mr, the readable lower limit on a film badge had he been wearing one.

The activities of Leslie Merkley, Dale Wadsworth, and Rulon Baker, before and after the nuclear excursion, have been detailed in Ha-10-61A. Their gamma exposures were as follows:

Leslie Merkley	30 gamma	0 beta

Rulon Baker	30 gamma	0 beta
Dale Wadsworth	35 gamma	0 beta

The amount of neutron exposure which these men could have received is the subject of the remaining part of this report.

The primary evidences that these men could have received any neutron exposure at all were the indium activities observed from foils contained in Merkley's and Wadsworth's badges and from similar badges which had been distributed throughout the access corridor. In addition to these, two devices contained gold foils from which Au^{198} was detected. The first of these was contained in one of the old type nuclear accident dosimeters described along with results in Bur-2-61A. The second consisted of a pair of identical gold foils one of which was with and one of which was without a cadmium cover. The measurements of these activities will be presented along with the story of how they are used to estimate the neutron doses received by the three men in question.

A sketch has been prepared showing the estimated positions of the three men by pumps, PA238 and PA239. Their distances from the H110 vessel were then scaled off of some prints entitled Vessel Layout, Cell "H", Plan Views and Sections (two prints). All distances outside the cells were measured manually by the author with the assistance of D. K. Jenson. The horizontal distances are shown on the sketch. The nuclear reaction is assumed to have occurred at a distance of 11' 3" above the access corridor floor level. The horizontal distance from the vessel to the point at which Leslie Merkley is thought to have been standing is 30.5 ft. The line of sight distance then was $d = [(30.5)^2 + (11.25)^2]^{\frac{1}{2}} = 32.5$ ft. The horizontal thickness of concrete was 6.33 ft., the effective thickness was $t = \frac{32.5}{30.5} \times 6.33 = 6.75$ ft. of concrete.

The indium foil strips from the badges worn by Merkley, Wadsworth, and Baker were counted at about noon by the IDO Analysis Branch. In order to get direct estimate of the neutron integrated flux required to produce the activation, another indium foil was irradiated in a known flux of thermal neutrons. By comparing the count-rates of the foils from the personnel badges and from the one irradiated under controlled conditions, they were able to give us a thermal neutron equivalent integrated flux. Establishing a firm number for neutron dose is not possible with the information available. It is possible, however, to use it along with some very conservative assumptions to establish an upper limit on the dose. The thermal neutron equivalent integrated flux reported for Leslie Merkley was 6.9×10^6 neutrons/cm^2 with a probable error at the 95% confidence level of $\pm$ 20%. (Throughout this report the phrase integrated flux will be used to denote the nvt or neutrons/cm^2.)

For Dale Wadsworth, it was $(4.12 \pm 40\%) \times 10^6$ neutrons/cm^2 at the same level of confidence. There was no activation detectable from the foil worn by Rulon Baker. The first conservative assumption which will be made is that these men all received neutron exposures at the level indicated by Merkley's foil.

The shape of the spectrum at the position occupied by the men cannot be substantiated by the available evidence. It will be necessary, therefore, to make certain perhaps overly-conservative assumptions from which a reasonable upper limit can be established for the probable neutron dose.

It is assumed that the spectrum consisted of two parts, a maxwellian distribution at a temperature of 30° C, the ambient temperature of the concrete shielding wall, and the well-known E^{-1} distribution. The indium foil activation will have occurred

due to the absorption of neutrons in the maxwellian distribution plus neutrons lying mostly in the 1 - 10 ev range. The microscopic absorption cross sections in these two regions differ considerably, and the interpretation of the activation of the indium foils depends upon a knowledge of the relative numbers of neutrons in these two parts of the spectrum.

The nuclear transformation rate in a thin target is expressed as follows:

(1) $\frac{dN}{dt} = N \sigma \varphi$ where

N = number of target nuclei per cm^2

σ = microscopic activation cross section (cm^2)

φ = neutron flux in neutrons $\cdot$ cm^{-2} $\cdot$ sec^{-1} for which σ is appropriate

t = the irradiation time

When equation (1) is integrated and the proper boundary conditions are substituted, there is obtained an expression which gives the number of untransformed nuclei remaining after neutron irradiation in terms of the number N_0 of target nuclei per cm^2 in the unirradiated foil.

(2) $N = N_0 e^{-\sigma \varphi t}$

The number of transformed nuclei per cm^2 is

(3) $N' = N_0 (1 - e^{-\sigma \varphi t})$

For very small values of t the error is negligible in setting

$(1 - e^{-\sigma \varphi t}) = \sigma \varphi t$.

If the transformed nuclei are radioactive, the activity per cm^2 is (just after the short burst of neutrons)

(4) $A = \lambda N_0 \sigma \varphi t$ where λ is the decay constant of the new activity.

The information supplied by IDO concerning the activation of Merkley's badge can be used to calculate the quantity A. For indium -116 $\lambda = 1.283 \times 10^{-2}$ min^{-1} and the thermal cross section is 1.9×10^{-22} cm^2. The indium foils are .005" thick, and the number of target atoms per cm^2 is 4.85×10^{19} atoms/cm^2. The thermal neutron integrated flux was $\varphi t = 6.9 \times 10^6$ $\frac{\text{neutrons}}{cm^2}$.

The activity per cm^2, then, is

$A = 1.283 \times 10^{-2} (4.85 \times 10^{19}) (1.9 \times 10^{-22}) (6.9 \times 10^6)$

$= 816$ dis $\cdot$ min^{-1} $\cdot$ cm^{-2}.

This activity resulted from bombardment of the target by neutrons which had energies distributed in the maxwellian spectrum and in the 1-10 ev range. (It is realized that there were some neutrons in the range between 0.4 ev, the end of the

maxwellian distribution and 1.0 ev. The weighted average cross section in this interval, assuming an E^{-1} distribution, is 136.1 bns which is near enough to the thermal cross section that neutrons in this part of the spectrum will be lumped into the thermal part of the assumed spectrum.)

The above is expressed as follows:

$$(5)\quad A = \lambda N_0 \left[\sigma_t (\varphi_t t) + \bar{\sigma}_e (\varphi_e t) \right]$$

where

$(\varphi_t t)$ = thermal + 0.4 ev to 1 ev neutrons/cm^2

σ_t = thermal cross section = 1.9×10^{-22} cm^2

$(\varphi_e t)$ = epithermal neutrons/cm^2 for the 1-10 ev interval

$\bar{\sigma}_e$ = the weighted average cross section where the weighting is for the relative number of 1/E neutrons in each considered interval in the numerical integration.

$\bar{\sigma}_e$ adds up to 1404 bns = 1.404×10^{-21} cm^2.

Now, since we have no information concerning the spectrum at that point, it will be necessary to assume different ratios of thermal to epithermal flux and from this to calculate the possible neutron dosages based on the assumptions. Assume therefore $\varphi_t = n \varphi_e$ where n = 1,2,3,. . . 37.

Substituting this and the appropriate numbers in equation (5)

$$A = 6.224 \times 10^{-7} \left[190\, n + 1404 \right] (\varphi_e t) = 816 \text{ dis} \cdot \text{min}^{-1} \cdot \text{cm}^{-2}$$

$$(\varphi_e t) = \frac{1.607 \times 10^6 \quad (816)}{190\, n + 1404} = \frac{13.11 \times 10^8}{190\, n + 1404}$$

This quantity was calculated for integral values of n up to 37, the reason for which will be apparent later on. Knowing this quantity, it is simple to apply the ratio to calculate the thermal flux. Since an E^{-1} spectrum was assumed beyond the maxwellian to an energy of 10 mev (which is considered very conservative since the peak of the fission neutron spectrum is about 0.7 mev) the quantity (φet) may be taken as the integrated flux represented by the area under the E^{-1} distribution in each cycle of the plot. That is, $\ln \frac{10}{1} = \ln \frac{100}{10} = \ln \frac{1000}{100}$, etc. The dose represented by the integrated flux in each cycle is calculated by dividing (φet) by the average RPG for neutrons in each interval and summing them. The attached figure 2 shows three curves, thermal neutron dose, E^{-1} and fast dose, and total dose as a function of n. The maximum possible dose under the assumptions that have been made would have been 55 mrem. That the dose was probably less than this is indicated by such meagre additional evidence as was available and by the fact that it is meagre.

As reported in Bur-2-61A, the integrated flux at the position occupied by badge #C28 was 3.3×10^7 neutrons/cm^2. The sulfur from this badge was beta counted soon after the indium foil data was gathered, and it yielded no information. On 2-13-61, the CPP Special Analysis Section burned off the sulfur. The P^{32}, if any is present,

is expected to remain in the container. The residue was counted for 30 minutes yielding a count rate of 1.4 ± 1.96 c/m at the 95% confidence level. The count rate is, thus, not proven to be different from zero.

Whole body scans of the three men revealed no identifiable Na^{24} or any other isotope besides K^{40}. It should be said about both the Na^{24} and the P^{32} means of measuring neutron flux that these are relatively insensitive methods, the Na^{24} being probably the better. This is true because the cross section for the Na^{23} (n, γ) Na^{24} reaction is about 0.54 bn and the cross section for the S^{32} (n,p) P^{32} reaction is less than 0.1 bn. To use this evidence as a reason for reducing upper limit of the dose by subtracting neutrons from the high energy (1 - 10 mev) end of the spectrum would not be justified.

The Nuclear Accident Dosimeter (hereinafter referred to as the N.A.D.) contained one Cd covered and one uncovered gold foil. Upon removal the activation of these foils was measured at the IDO Analysis Laboratory and the results were reported verbally to one as follows:

Bare	Au	360 ± 14 c/m	95% confidence
Cd Covered	Au	139 ± 10 c/m	95% confidence

Each foil was counted at 55% efficiency. Each foil, being 5/32" in diameter, has an area of 0.1237 cm^2. The activities per cm^2, then, are 5411 d/m per cm^2 and 2089 d/m per cm^2 for the uncovered and covered respectively after a correction for 2 hours and 10 minutes decay has been made. The difference in activity is due to thermal neutron activation below the Cd cut off at 0.4 ev. The activation of the covered foil is due to neutrons above that energy and it is assumed that the bulk of activation occurs from neutrons in the 1 - 10 ev range where steep resonances occur.

Thermal neutron activation is 3322 d/m per cm^2. In the .005" thick target are 7.5×10^{20} target nuclei per cm^2. Thermal neutron cross sections given in the table in BNL 325 are for 2200 m/sec neutrons or ones having a most probable energy of .025 ev. It was assumed that the temperature of the maxwellian distribution in this case was the temperature of the concrete cell wall which in turn is assumed to be at equilibrium with the air temperature of 30°C maintained in the Access Corridor. As it turns out the most probable energy is .026 ev at this energy. The cross section of 98.8 bns is used without correction. Solving equation 4 for $(\varphi_t t)$ and substituting in the proper numbers yields

$$(\varphi_t t) = \frac{3322}{9.88 \times 10^{-23} (7.5 \times 10^{20}) \, 1.78 \times 10^{-4}} = 2.52 \times 10^{8} \text{ n/cm}^2$$

In the interval from 1 to 10 ev an E^{-1} distribution of neutrons is assumed and the average cross section weighted for their relative numbers in each interval considered was 2283 bns. Using this number in equation 4 yields an integrated flux in this interval of

$$(\varphi_e t) = \frac{2089}{2.283 \times 10^{-21} (7.5 \times 10^{20}) (1.78 \times 10^{-4})} = 6.86 \times 10^{6} \text{ n/cm}^2$$

The ratio of thermal to 1 - 10 ev neutrons at this point turns out to be

$$n = \frac{(\phi_e t)}{(\phi_e t)} = \frac{2.52 \times 10^8}{6.86 \times 10^6} = 36.8.$$

It is obvious that the number of neutrons coming out from the north side of H cell was greater than came out to the position occupied by the three maintenance people. This was true even though in the case of the N.A.D., at least, there was more concrete for them to traverse. By referring to Figure 1, the reader can see that the line of sight between the N.A.D. and the source was through the very end of the outside wall of the H cell maze. The same line also nearly parallels the cell wall on the inside, and scattering from this wall probably contributed to the observed increase. Evaluation of the integrated flux from the activation of indium foil contained in badge #C28 reported in Bur-2-61A was a thermal neutron equivalent figure similar to that reported from Merkley's and Wadsworth's badges. When that reported figure is used to calculate back to activation and when the thermal and epithermal integrated fluxes are calculated for n = 36.8, the result is

$$(\phi_e t) = 8.31 \times 10^5 \text{ n/cm}^2$$

and $(\phi_t t) = 3.06 \times 10^7 \text{ n/cm}^2$.

If an inverse square extrapolation is made from the position of the N.A.D. to the position occupied by badge #C28, the integrated thermal flux of 2.52×10^8 n/cm^2 at the N.A.D. reduces to 1.79×10^8 n/cm^2. This is a factor of six greater than was actually measured at the badge. This indicates that the neutrons were scattered into a rather narrow beam in the direction of the N.A.D. which direction was apparently such that the second thickness of concrete, the end of the maze was by-passed. The scattering would have degraded the spectrum considerably, and it will not be reasonable to assume that the ratio of thermal to epithermal neutrons observed here can be applied to neutrons on the other side. No other evidence is available. The best available estimate, therefore, of the dose received by Leslie Merkley, Dale Wadsworth, and Rulon Baker is 55 mrem each. It is recommended that this dose be entered in their records.

Very truly yours,

I. J. Wells

IJWells:ew

Attachment

cc: J. P. Lyon
J. W. McCaslin (6)
W. H. Burgus
J. W. Latchum
H&S Supervisors
I. J. Wells
File

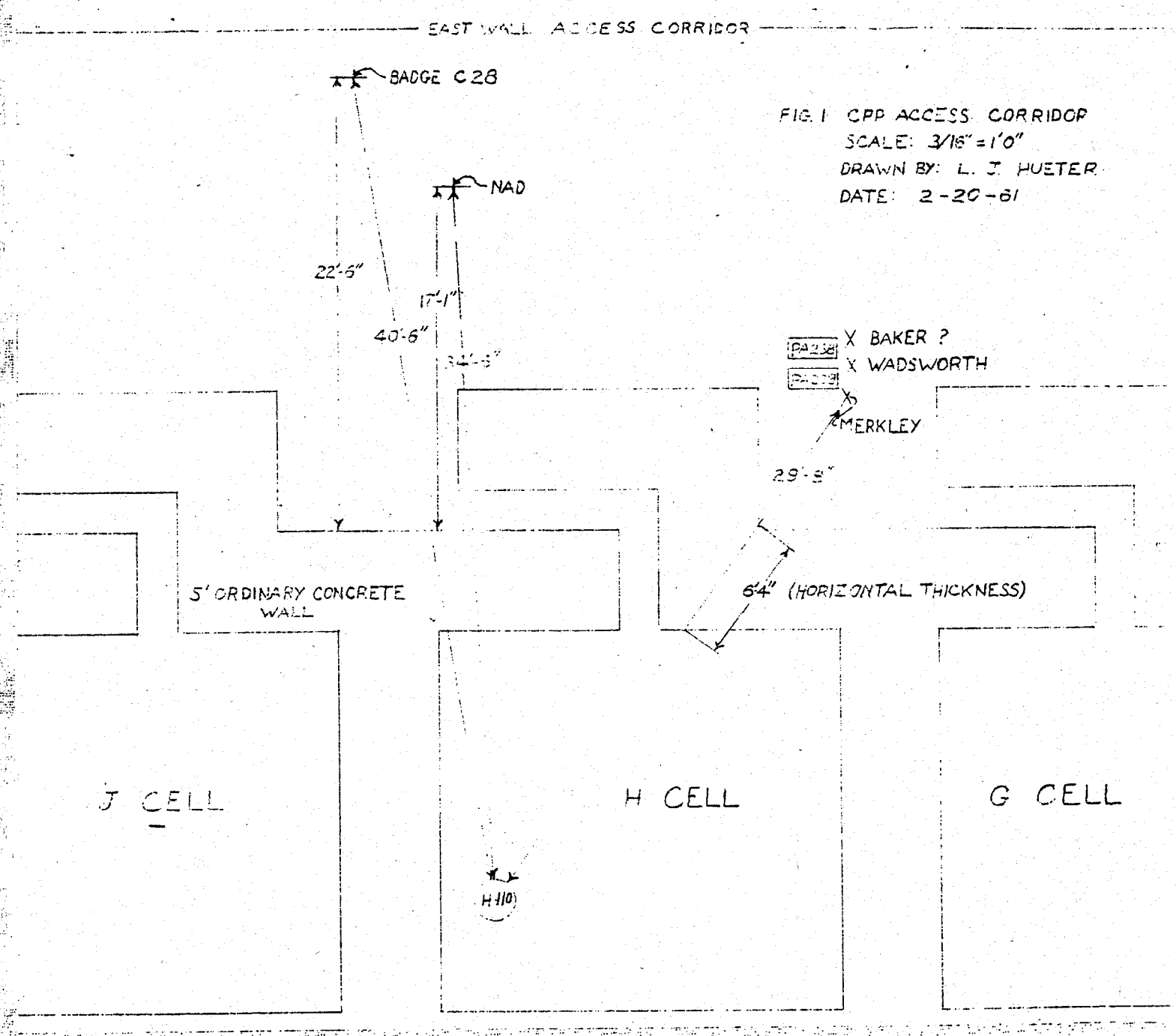
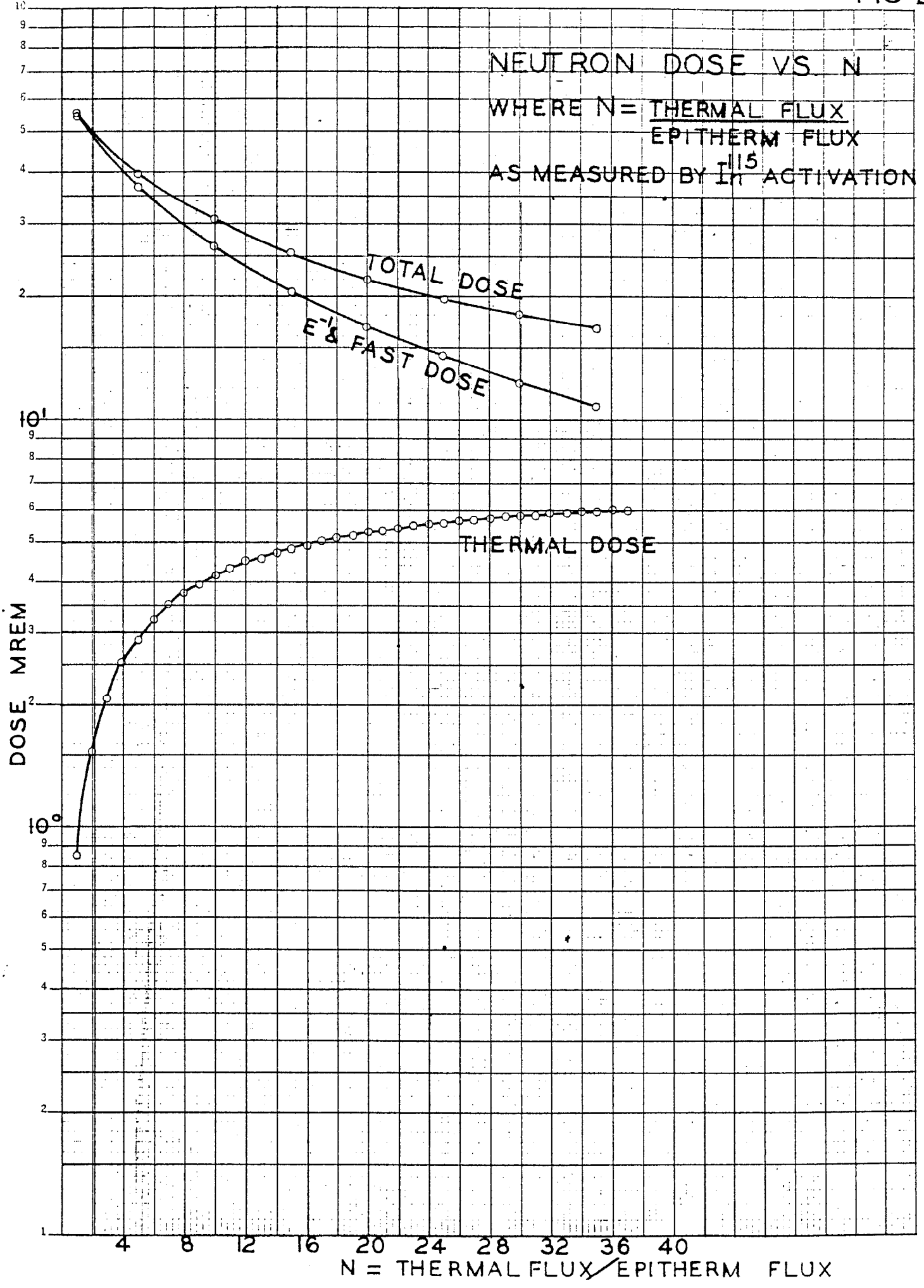


FIG. 1 CPP ACCESS CORRIDOR
SCALE: 3/16" = 1'0"
DRAWN BY: L. J. HUETER
DATE: 2-20-61

FIG 2


NEUTRON DOSE VS. N
WHERE N = THERMAL FLUX / EPITHERM FLUX
AS MEASURED BY In^{115} ACTIVATION
TOTAL DOSE
E⁻¹ & FAST DOSE
THERMAL DOSE
DOSE MREM
N = THERMAL FLUX / EPITHERM FLUX
4 8 12 16 20 24 28 32 36 40
10⁰
10¹