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TITLE

HAZARDS STUDY - SELF-BOILING RADIOACTIVE WASTES STORAGE FACILITIES - PROCESS TECHNOLOGY - RECOMMENDATION REPORT

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HAZARDS STUDY
SELF-BOILING RADIOACTIVE WASTES STORAGE FACILITIES
PROCESS TECHNOLOGY - RECOMMENDATION REPORT

By H. W. Stivers

Process Design and Development
Facilities Engineering Operation
CHEMICAL PROCESSING DEPARTMENT

December 1, 1957

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HANFORD ATOMIC PRODUCTS OPERATION
RICHLAND, WASHINGTON

PRELIMINARY REPORT

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This report has been reviewed and approved as a basis for establishing operating limits to assure safe containment of self-concentrating radioactive wastes.

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E. Doud — 5/7/58
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HAZARDS STUDY
SELF-BOILING, RADIOACTIVE WASTES STORAGE FACILITIES

I. INTRODUCTION

Safe containment of radioactive wastes, specifically those generated in the separations plants, is a prime responsibility of the Chemical Processing Department. High level wastes from the bismuth phosphate process were retained as a non-boiling liquid in underground storage tanks and subsequently removed for uranium recovery. The present Redox and Purex processes produce waste with sufficient fission product concentration to support self-boiling in the storage tanks. Considerable savings in capital investment for storage space have resulted from this self-concentration of the wastes. However, the storage of radioactive wastes as a boiling liquid is considered to be an interim retention only. Technology is being developed to provide a process to convert the wastes to a more stable form for safe permanent containment.

Two significant problems have stemmed from self-concentration of high-level radioactive wastes. The first was the "bumping" of the liquid in the tanks, a phenomenon caused by the sudden release of superheat. The second, and more recent problem, is the build-up of high temperatures near the tank bottoms at times when the wastes have become slightly overconcentrated.

The "bumping" hazards were evaluated in a study presented in 1955 by R. E. Tomlinson(1) with the assistance of other HAPO personnel which established the "hydrostatic head limitation" to insure that "bumping" would not produce excessive pressures. Since that time, procedures have been established to insure safe operation of the tank farms containing self-boiling wastes. For these control measures it was assumed that the bulk contents of the tank would remain free flowing and that a fail-safe type air-lift circulator would be developed.

Theoretical "bumping" pressures could damage a tank if the "bump" were sudden and of enough magnitude. However, under controlled operating conditions, there has been no bump recorded in the Purex or Redox tanks which approached this theoretical hydrostatic head limit. The maximum recorded bumps at Purex and Redox have been approximately 20 percent and 10 percent, respectively, of the hydrostatic head. Testing programs are in progress to define the rate of pressure rise as well as the maximum vapor pressure produced by a "bump". Results of this program will be used to assist in the re-evaluation of the "hydrostatic head limit".

Suspended solids containing heat producing fission products settle out and produce high temperatures near the tank bottom. Air-lift circulators were not intended to prevent this settling out of solids. Purex Technology has been studying self-concentration of Purex 1WW wastes to define a limit, based on sodium ion molarity, which would preclude gross precipitation of solids. Maximum temperatures attained for short periods on the tank bottom of stored Redox wastes have been lower (maximum temperature 412° F) than at Purex (maximum temperature 500° F), probably due to the lower concentration of fission products in the wastes.

(1) HW-37207, "Storage of High Activity Wastes", R. E. Tomlinson, August 8, 1955.

II. PURPOSE

The purpose of this report is to review waste storage data accumulated since 1955, to evaluate the latest operating data, to evaluate the potential hazards resulting from loss of control, and to make recommendations for maintaining the maximum integrity of the waste tanks.

III. SUMMARY AND CONCLUSIONS

The storage tanks at Purex and Redox were designed for wastes which were expected to boil for about two to four years after a heating-up period of about six months. Under these conditions, it was believed that these tanks would serve for 25 to 35 years. Volume reductions predicted for Purex extraction wastes from the two-cycle flowsheet will provide concentrated fission products capable of a maximum heat evolution of approximately 16×10^6 BTU per hour from one 241-A tank. The heat generation will decrease as the fission products decay and the solution will continue to boil until the heat loss to ground equals the heat generation. Thus if the wastes remain in the tank, boiling periods in excess of ten years and possibly as long as 200 years would be experienced. Similarly, Redox wastes would attain a maximum heat evolution of 4×10^6 BTU per hour with boiling periods of three to four years.

From structural analysis it is reasonable to assume that the present 241-A and 241-SX tanks will provide safe containment of boiling wastes for about a decade if the temperature controls presented in the recommendations are observed. Data obtained during this period will be evaluated to determine when the tanks should be abandoned and the wastes converted to solid form for ultimate storage or transferred to other tanks.

The potential for releasing hazardous doses of high-level radioactivity to the surrounding environs increases when storing fission products as a boiling liquid. The extent of contamination spread to the environs and duration of high-level radioactivity which would result has yet to be fully evaluated.

A preliminary evaluation was made of incidents which could result in the uncontrolled spread of contamination. Chemical Effluents Technology concluded that the ion exchange capacity of the soil beneath a tank would be adequate for retaining about 50,000 gallons of waste from one tank before contaminating the ground water. If large leaks occurred and remained undetected until the radioisotopes accumulated in the ground water, the normal ground water flow toward the Columbia River, could cause contamination of the Columbia River for several years. Pressure surges exceeding the design pressure of the by-pass seal pot could cause hazardous "fall-out" beyond 1,000 feet from the vapor exhaust stack. The resulting contamination could exist for several weeks depending upon weather conditions and the characteristics of the released vapors.

IV. RECOMMENDATIONS

It is recommended that the boiling period for wastes in the 241-A or 241-SX tanks be limited to ten (10) years under controlled operating conditions. To assure structural integrity, the following temperature limitations are recommended in addition to the hydrostatic head limitation:

(1) Heating of tanks shall be incremental, raising the temperature of the stored waste from ambient to boiling in two equal steps of 80 ± 10° F allowing a maximum time between steps, preferably over 6 months. It would be permissible to exceed the hydrostatic head limitation during the second filling periods, if necessary to maintain this temperature limitation.

(2) Maximum waste temperature shall not exceed 300° F.

V. FUTURE PROGRAMS

The following programs are contemplated for providing additional information which will be beneficial for future review and revision of the recommended limitations for safe containment of radioactive wastes:

1. Develop methods for cleaning and inspecting storage tanks after self-boiling wastes have been recovered. It would be desirable to inspect a tank which had contained boiling wastes for three or four years.

2. Develop, if possible, a more adequate leak detection method for existing storage facilities.

3. Study methods of furnishing an emergency water supply for Purex tank farm vapor condensers and storage tanks.

4. Continue the study of methods to minimize the deposition of sludge on the tank bottom.

5. Continue current test programs to develop process criteria and tank designs for new Purex and Redox waste storage facilities. These criteria will need to be established by January 1959 for Purex and about October 1960 for Redox.

6. Continue the development programs to define processes which can safely solidify or stabilize extraction wastes to provide safer and more permanent storage of the fission products.

7. Continue the structural review of Purex and Redox tanks with the aid of outside consulting services.

VI. DISCUSSION

A. Bases of Study

Only self-boiling aqueous wastes capable of self-concentration and containing hazardous levels of highly radioactive long half-life fission products were evaluated for this study. The fission products in these wastes which currently cause the most concern are Sr^{90} and Cs^{137}, and their interim retention period must be positively controlled for about 600 years.

The removal of cesium[137] by the recently proposed fission product recovery program[(2)] probably will have no significant effect on current storage costs and waste handling methods. The effect of removing all the cesium[137] and strontium[90] would shorten the time of boiling for a given set of conditions, but would have insignificant effect on the maximum heat evolution. The reduced boiling time would not relax the design requirements for initial storage tanks. It could, however, reduce the design requirements of facilities for containment after the interim boiling period.

The criteria established for this study were based upon the current Purex process and production rates with no allowances for peak production rates or occasional higher irradiation levels. Pertinent factors for the criteria are as follows:

Irradiation level	=	550 megawatt days/ton U
Pile power level	=	5.5 megawatts/ton U
Cooling time	=	90 days
Purex Processing Rate	=	1.68 C.F. at 100% Eff.
Heat Loss to Ground at Steady State	=	150,000 BTU/hr (For each storage tank half full)
Finite Life of Structure	=	estimated at 10 years

Table I, Page 10, compares these criteria with those for a design basis for Purex tank farm[(3)] prepared about two years ago.

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(2) HW-50668, "Engineering Study Cesium Recovery Plant. Part I Wet Chemistry", H. G. Johnson and J. M. Gerhart, June 26, 1957.

(3) HW-42565, "A Design Basis for Tank Farm Vapor Systems", G. L. O'Neill, April 17, 1956.

Table 1. Comparison of Criteria

Item and Units	Criteria This Report	Criteria HW-42565	Goal Trends 1959
Irradiation level MWD/T	550	800	650
Pile power level MW/T	5.5	8	6
Cooling Time - Days	90	90	90
Purex Processing Rate	1.68	3.0	2.0
Operating Efficiency %	100	100	100

The criteria for this report were based on average, rather than peak production rates, irradiation level, and power level during the past few months to permit maximum usage of existing storage tanks. It is recognized that the criteria in HW-42565 are for peak production rates and irradiation levels, etc., and they would be reviewed before using them as a design basis for new facilities.

The goal trends estimated for 1959 will increase the heat generation rate and increase the boil period for the Purex tanks when storing fission products from the same quantity of production; however, these increases would not alter the recommended temperature limitations.

B. Current Operations

The Purex waste storage tank 241-A-103, attained a maximum self-concentration rate of about 10 gallons per minute in April, 1957. As of November 1, 1957, this tank had received an accumulated waste volume (including make-up water) greater than 4,828,000 gallons, but had only 443,000 gallons in storage for a gross self-concentration ratio of 11:1. In contrast to this, the "hottest" Redox tank, 241-SX-107, attained a self-concentration rate of about two gallons per minute in August, 1957. It has received an accumulated waste volume of 1,240,000 gallons with 552,000 gallons remaining in storage for a gross self-concentration ratio of 2.2:1.

Improvements in the Purex and Redox processes accompanied with increased power and irradiation levels predicted for the 100-Area Reactors will yield a waste volume of 30 and 300 gallons per ton of uranium processed, respectively, for Purex and Redox extraction wastes after self-concentration. Even more important is the expected boil period of these stored fission products when stored in a concentrated mass. For example, Figure 1, page 47, illustrates the current Purex wastes from 2,240 tons of uranium stored in one 241-A tank could boil for about 10 years. The Purex wastes from 10,220 tons of uranium stored in one 241-A tank could boil for more than 200 years based on latest calculations.

Figures 2, 3, and 4, have been developed from data taken from the 241-A-103 and 241-A-101 waste storage tanks since they began to self-concentrate. In reviewing these figures the following can be concluded:

1. From Figure 2, Purex Tank 241-A-103, Waste Storage History

   (a) As of November 1, 1957:

   Net waste volume in storage = 443,000 gallons

   Total water added to maintain liquid level = 1,815,000 gallons

   Total wastes (+ water) routed to tank = 4,828,000 gallons

   Total wastes routed to tank (IWW, carbonate and cell drainage) = 3,010,000 gallons

   Total volume boiled off = 4,392,000 gallons

   Maximum Temperature = 230° C (446° F)

   Routing of the IWW wastes stream to this tank ceased June 28, 1957. Water addition has been steadily decreasing since this time with 402,000 gallons being delivered in July, 259,000 and 184,000 gallons being delivered in September and October 1957 respectively. During the peak heat evolution period, the volume boiled off each month equalled the volume stored in the tank at the end of the month.

   (b) The condensate rate is determined by the algebraic sum of the volume change within the tank and the volume of make-up water added to maintain a liquid level divided by the lapsed time interval. The volume change within the tank is determined by a liquid level gage located on one of the dome risers. The make-up water to the tank is metered. Approximate checks on this method can be made by performing heat balance calculations on the contact condensers when the heat loss to ground is known.

   Another check is to calculate the heat evolution of the stored fission products as determined by their pile histories. These calculations, when using accurate process data are reliable; but they are very laborous to perform. Because of the unknown heat loss to ground for the entire system, small leaks from the storage tank in the neighborhood of 0.2 to 2 gpm could go undetected. At a leakage rate of 2 gpm it takes only about two weeks to yield a "significant leak" of 50,000 gallons.

(c) Two rapid temperature rises to 230° C and 209° C have been recorded, one in April 1957 and one in June 1957. These temperatures were detected from the thermometer located about midway between an active and an idle air-lift circulator and about 25 feet from the nearest wall. The tank bottom consists of a flat membrane about 4,400 square feet in area and the temperature was determinate at only this one point. These high temperatures were reduced by increasing the flow of make-up water to the tank, which reduced the molarity of the sodium ion and by unplugging and increasing the air supply to the circulators, which restored better circulation of the liquid waste.

The resulting stresses in the thick concrete wall would be above the yield strength of the concrete and reinforcing steel and considerable cracking of the concrete wall would be anticipated, had the average temperature of the liquid waste near the tank bottom actually attained this recorded temperature.

2. Figure 3, Purex Tank 241-A-103 Waste Temperature Profile

In August 1957, temperature profile equipment was installed in a dry well of this tank. Curve 1 represents the actual profile recorded in July 1957 by thermocouples located at various depths in the dry well. Curve 2 represents the theoretical temperature profile used in HW-47087 for temperature studies. Curve 3 represents the actual profile recorded in February 1958. It is believed that the circulators are performing adequately to minimize superheat in the liquid layer. However, there is a definite increase of stored superheat in the sludge layer as indicated by the sharp temperature rise near the bottom of the tank.

Stress calculations for the structural members become imperical at the most likely section to fail, namely, the sharp T-joint between the tank bottom and wall at or near a weld seam. At present, derivation of mathematical equations based on laboratory tests are being considered to more thoroughly investigate these critical sections.

Temperature gradients obtained through the T-joint during a heat transfer study(4) did not conform to the theory derived for the determination of the heat loss to ground when using an analog computor. It was assumed that the temperatures of the structure and surrounding earth would uniformily decrease as the distance from the heat source was increased. The heat source was assumed to be the stored liquid. Imaginary lines called "rays" were plotted on a cross-sectional view of the tank originating at the center of mass of the stored liquid and terminating at the ground surface above the tank, and at the water table below the tank, and at an infinite distance from each side of the tank. The calculated temperatures along the "ray" through the T-joint indicated a temperature rise in the thick concrete footing

(4) HW-47087, "Waste Tank Temperature Studies", M. W. Cook, J. M. Gerhart, January 28, 1957.

while all temperatures along the adjacent "rays" decreased as the "ray" progressed away from the heat source. The temperatures along the "ray" through the T-joint plotted in Figs. 22 and 23, HW-47087, were extrapolated from the temperatures of adjacent "rays". Therefore, to use these extrapolated temperatures through the T-joint for stress calculations could be misleading.

3. Figure 4, Purex Tanks 241-A-101, 241-A-103, Radiation Profile

These radiation profiles were obtained August 28, 1957, and recorded in HW-52504, issued September 12, 1957. The accuracy of the absolute gamma intensity level (R/hr) is ± 30 percent and the relative accuracy between readings is ± 15 percent.

The gamma intensity of the vapor phase is about the same in each tank. The gamma intensity of the liquid layer for tank 101-A is greater than that in tank 103-A. The sludge layer of tank 103-A has an intensity almost twice that of tank 101-A. The maximum gamma intensity is 23,000 R/hr in the bottom of tank 103-A. At this recording tank 103-A had received wastes from the Purex process for 13 months, but had received no wastes for two months prior to the readings. Tank 101-A had received Purex process wastes for three months: January, February and March in 1956, and then for two months just prior to the readings. In checking the drawing of the dry well, it was determined that about a two-foot layer of high gamma intensity exists in each tank, rather than the six-foot layer indicated by the recordings. There is a definite settling out of fission products in the lower portion of the tank, but there is not sufficient data to conclude a rate or percentage of settlement.

C. Potential Hazards

1. Undetectable Equipment Failures

The real hazard of storing these high level radioactive process wastes is the potential of uncontrolled release of the harmful long half-life radioisotopes to the environs along with the duration of the consequence. Uncontrolled release of these isotopes would be most hazardous as a result of equipment or facility failure which is not readily detected by present control methods. Under this category are the following potentials:

(a) The release of radioactive liquids to the sub-strata from the storage container at a slow rate (0.2 to 2.0 gallons per minute). Only two weeks to six months would be required to obtain the "significant leak", which is considered to be about 50,000 gallons from one tank. Only 10 percent of the condensate rate from a Purex self-boiling tank would be equivalent to about one gallon per minute.

(b) Corrosion of the concrete ceiling and reinforcing steel, and the air-lift circulator air supply piping which is exposed to the vapor phase of the stored solution. This could cause serious weakening of the dome and loss of air supply to circulators, respectively.

(c) Corrosion of the underground facilities such as fill lines, vapor manifold lines and vapor condenser equipment. This could permit small leaks to go undetected.

(d) Excessive or rapid temperature build-up near the wall of the tank which is remote from the temperature gages and air-lift circulators. At this writing, one temperature gage exists in the 103-A tank and it is 25 feet from the nearest wall and about 14 feet from the nearest active air-lift circulator.

(e) Plugged air-distributor or air line for the air-lift circulator. This could permit pressure surges and rapid temperature increases before being detected.

(f) The inability to perform preventative maintenance on the tank and equipment due to high radiation. Total gamma intensity in the lower portion of the 103-A tank have been recorded at 23,000 R/hr.

2. Detectable Equipment Failures

The hazardous potentials for uncontrolled release of these isotopes as a result of equipment or facility failure which is readily detected are as follows:

(a) Discontinuity in cooling water make-up for the vapor condensers and storage tanks in the event of failure of the export water system. Loss of cooling water would permit the Purex storage tanks to boil to dryness at uncontrolled rates and could attain temperatures high enough to damage the tank.

(b) Discontinuity of electrical power supply. Make-up water supply to the 241-A-201 water storage tank and make-up water to the self-boiling tanks would be discontinued.

(c) Pressure surges greater than the by-pass seal pot (2.38 lbs/sq in) would release contaminated vapors to the atmosphere. This could contaminate the air in the vicinity of the tank farm and prevent repair of equipment or obtaining instrument data from the control building.

3. Effects of Hazards

Chemical Effluents Technology, in their study for inclusion in this report, evaluated the effects of air contamination in the vicinity of

the short stack at the Purex farm and beta and gamma dose rates resulting from "fall-out" of contamination entrained in the vapors. Results of their study are shown graphically in Fig. 6, 7, and 8, in the Appendix. "Concentrations greater than maximum permissible concentration (MPC air) will be encountered out to distances of 110, 65 and 40 meters (360, 213, 130 feet) from the stack for stable, neutral, and unstable atmospheric conditions respectively during vapor emission period". (5)

For the purpose of this study it was assumed that three million gallons of high activity waste were accidently released to the sub-strata. The bases for this assumption were as follows.

1. Structural damage to the tanks by an "Act of God" such as an earthquake could cause all the tanks to leak. There are currently about 6,500,000 gallons of self-boiling wastes stored in 10 tanks at the 241-A and 241-SX tank farms.

2. A slow leak from a self-boiling tank could go undetected for several months during the peak heat evolution rate. A leak at the rate of two gallons per minute from four tanks for a period of eight months would constitute a volume of 2,000,000 gallons.

3. The 103-A tank alone could have lost about 450,000 gallons of waste to ground assuming only 10 percent of the vapor condensate made up this leakage volume. The present leak detection systems at Purex and Redox would not detect a leak at this low percentage.

It has been established by Chemical Effluents Technology that 50,000 gallons from one tank would be a "significant leak" when the loss occurred through a small crack or hole in the tank. Under the conditions developed by Facilities Engineering, CPD, and Chemical Effluents Technology, the loss of three million gallons would cause contamination of the Columbia River even to off-site MPC, would be a very serious occurrence and would compel drastic action in curtailing use of the Columbia River water for domestic use and as a media for reactor effluent disposal.(6) It would take several years for the contamination to reach the river, but once there, it could take generations for the river to flush itself of the contamination.

Any loss of high-level radioactive wastes, especially those containing cesium^{137} and strontium^{90} radioisotopes, constitutes a hazard; the extent of which is dependent on the quantity released and the characteristics of the geographic location. Chemical Effluents Technology has established a volume limit of 50,000 gallons for these wastes at Hanford. The limit is intended as a criteria for providing leak-proof structures and leak detection equipment. It is not to be interpreted as a permissible leak.

(5)& Letter, L. C. Schwendiman to E. Doud, "Hazards Study - Underground
(6) Storage of Liquid Radioactive Wastes", January 7, 1957.

D. Description of Supporting Utilities

1. General

The following review of the supporting utilities for the Purex 241-A and Redox 241-SX tank farms which will be available at the completion of construction projects CA-719 and CG-717 revealed that the absence of adequate emergency condenser make-up water at 241-A presents the greatest hazard for the continued safe storage of self-boiling, high-level radioactive wastes. Essentially the source of water is from the 241-A-201 reservoir which is filled by two electric drive pumps taking their suction from a small pump pit that is supplied by the Purex process cooling water effluent. The only source of power to these pumps is the primary electrical supply from the 202-A Building. Either a primary power outage or a pipe line failure in this system would cause a water shortage at the condensers within a few hours. The ensuing consequence could be the wide spread and uncontrolled release of hazardous radioactivity to the environs of uncondensed vapors which would be discharged from the vapor exhaust stack and hot liquids released to the ground water from ruptured storage tanks. The potentiality of such an outage is relatively great and the risk involved is high. Accordingly, corrective measures should be initiated without delay.

Adequate cooling water for the surface condensers, make-up water for the storage tanks, and continuous circulation of the stored waste must be unconditionally guaranteed for continued safe storage of these wastes. Except the raw water supply for Purex as described above, either adequate back-up facilities have been provided, or additional emergency facilities could be installed at both Purex and Redox tank farms for all other supporting utilities. Make-up water for the storage tanks is provided either by the raw water distribution system or by the return of the vapor condensate. Motive air to the air-lift circulator is provided by electric driven air compressors at the tank farm. Back-up for this is provided by a gasoline driven generator which provides emergency electrical power. A portable air compressor could be used temporarily if the emergency continued. A failure in the control instrumentation could be corrected before any hazard existed.

2. Water Supply

Water is pumped from the Columbia River via 100-B, D, F, and H Areas to the 200 Areas through a network of underground piping called the Export Water System. The system consists of a 30-inch, 250 lb per sq in., reinforced concrete pipe from 100-H Area which joins the same size of pipe from 100-F Area. The pipe size of this line is increased from 30 inches to 42 inches at the junction from 100-D Area. The line turns South at this junction and continues for about six miles as a 42-inch, 250 lb per sq in., reinforced concrete pipe to the 1901-Y. Another four miles of 42-inch line of the same type connects at the

1901-Y from 100-B Area. From the 1901-Y to the 2901-Y which is about three miles south, there are two 30-inch, 200 lb per sq in, reinforced concrete pipes lying parallel about 200 feet apart. Flow can be directed from any of the four 100-Areas to either or both of these 30-inch lines. From the 2901-Y, the system divides into a single 24-inch, 150 lb per sq in, reinforced concrete pipe to each of the 200 Areas. One 24-inch line terminates at the 282-W reservoir in 200-West Area and one at the 282-E reservoir in 200-East Area. The flow can be directed to either 200-Area from the 2901-Y. Maximum capacity of the system is approximately 26,000 gallons per minute when the valving system to each reservoir is fully open. If all the flow is directed to one reservoir, the maximum capacity is about 18,000 gallons per minute. The reservoirs have a capacity of 3,000,000 gallons each. From the reservoir the water is pumped into the distribution system within its respective area. The Export Water System is further described in HW-39115. A sketch of the distribution system is included in SK-1-2019 of the Appendix.

Each 100-Area has one 6000 gpm, 475-ft head, raw water pump with steam turbine drive which could supply the water demand to the 200-Areas in the event of an electrical power outage.

In the event of a failure in the piping system at the 1901-Y or 2901-Y, service to the 200 Areas would be interrupted. At current average raw water demand rates for the 200-Areas, and assuming the 282-reservoirs were full when the failure occurred, the 282-E reservoir would be emptied in about five hours and the 282-W reservoir would be emptied in about 11 hours. The flow can not be routed from one 200-Area to the other.

(a) Purex Tank Farm 241-A (Refer to Fig. 15)

The primary source of water for the tank farm is the process cooling water effluent from the 202-A process building. From the building, the effluent is routed to a pump pit where it can be pumped to the 241-A-201 tank. The excess is drained by gravity to the cooling water swamp. From the 241-A-201 tank, the water flows by gravity through a 16-inch pipe to the tank farm. The reservoir tank has a capacity of 750,000 gallons and the capacity of the 16 inch line is about 2000 gallons per minute.

The secondary source of water for the tank farm is through the 200-East Area distribution system via 221-B Building and the Hot Semi-Works. There is considerable pressure drop in this source due to the length and size of piping. Maximum flow through this line is about 200 gallons per minute.

If the 241-A-201 reservoir pumps were to fail, the raw water supply from 282-E could by-pass the reservoir through a 6-inch line and discharge into the 16-inch line. Flow through this

small line would be less than 200 gallons per minute and should not be relied upon to relieve the outage.

The primary use of the raw water at the farm is to provide cooling water to the vapor condensers (800 gpm maximum) and make-up water (60 gpm) to the six waste storage tanks when they are self-concentrating. After completion of CG-719, "Additional Facilities - Purex Tank Farm Vapor Wastes", the vapor condensate will be returned to the waste storage tanks thus eliminating the need of make-up water except in lieu of the condensate return. Other uses of the raw water are cooling water for the air compressors, cleaning water for the diversion box and valve pit.

Only the 241-A-201 reservoir can supply an adequate flow of cooling water to the vapor condensers. Discontinuity in this supply would present a hazard if the flow could not be restored within six to twelve hours. Insufficient cooling water to the vapor condensers would permit the release of high-level radioactive vapors to the atmosphere in the vicinity of the tank farm. The ensuing contamination could prevent remote maintenance. In addition to the hazardous air polution, the liquid level in a self-boiling tank, after about four days, could be expected to be lower than the discharge level of the low-lift circulators. The temperatures in the tank would then increase due to the inadequate circulation and the uncontrolled increase in the molarity of the sodium ion. The resulting pressure surges and thermal stresses would jeopardize the structural integrity of the tank. This situation could cause complete destruction of the container in a few days if the heat evolution rate of the contained fission products was greater (by a factor of 3 to 5) than the heat loss to ground.

A study of an emergency water supply should be made which could supply condenser cooling water at the rate of 600 to 1000 gallons per minute for several weeks. This emergency supply should be independent of the Export Water System from the 100-Areas, and from the 200-East Area distribution system. The power source for the pumps should be either diesel or gasoline motors. Activating this emergency system could be manual because there would be a safe time lag of four to twelve hours.

(b) Redox Tank Farm 241-SX (Refer to Fig. 16)

The primary source of water at the Redox Tank Farm, 241-SX, is through a 2000-foot, six-inch cast iron lateral connected to 6300 feet of 20-inch cast iron main line from the 282-W pump house. The six-inch line supplies water to the two condenser buildings (241-SX-401 and 402), and to the emergency reservoir tanks (2901-SX-1 and 2). Normal flow through this line is currently less than 100 gallons per minute. Maximum capacity of this primary supply is about 500 gallons per minute.

The emergency water facility consists of two 150,000 gallon steel storage tanks at ground level and a pump house with two 1000 gpm pumps serviced by a panel board for automatic operation. The normal water pressure at the farm in the six-inch raw water header from the 282-W building is 135 lb per sq in. and when this pressure is reduced to 55 lb per sq in. a meletron switch starts the No. 1 pump. The No. 2 pump is a stand-by in the event the No. 1 pump develops mechanical trouble. The stand-by pump also starts automatically. A red signal light and Klaxon are mounted on the pump house roof which are activated when the pump starts operation. The Klaxon will continue to sound until shut off manually, also when water service is restored in the six-inch line. The tanks are equipped with automatic shut-off valves which close when the full level is reached.

An additional 8-inch cast iron lateral has been installed to the Southeast corner of the SX farm from the same 20-inch main. Another 8-inch line terminates near the Southwest corner of the SX farm which connects to the existing 6-inch line. The two condenser buildings (241-SX-401 and 402), a 2-inch line to the compressors and circulators, and the two raw water storage tanks (2901-SX-1 and 2) take their supply from this 8-inch line. A temporary 6-inch, schedule 40, welded steel pipe located above ground is connected to this 8-inch line at the Southwest corner and terminates near the 8-inch stub in the Southeast corner of the SX tank farm. Design has been provided but construction has not been started on CA-625 to complete the permanent installation of the 8-inch line and a valve pit and to remove the temporary 6-inch line.

Equipment has been installed in the 402 condenser building identical to that in the 401 condenser building. Only a five-foot section of the vapor header needs to be installed within the 402 building. The 402 building has not been put into service for vapor cooling because the condenser capacity of the 401 building is adequate. The 402 building also houses the instrument control panels for storage tanks 107 through 115-SX.

The loss of raw water to the Redox farm is not as hazardous as that at Purex because of the much lower heat evolution rate in individual waste storage tanks. If necessary the self-boiling tanks could be quenched by returning the condensate from the 106-SX tank or by trucking water to each tank. Quenching the tanks would minimize and probably eliminate the flow of vapors. Even in the hottest tanks it would take about three weeks to reduce their volumes until the liquid level was below the discharge of the low air-lift circulators. Therefore at the current heat evolution rate no additional water supply should be required at the tank farm.

3. Instrumentation

The tank farm instrumentation provides information on the stored radioactive wastes. The information instruments may be grouped according to the type of operation or element as follows:

Manual - liquid level tapes

Pneumatic - pressure, weight factor, and specific gravity

Electrical - temperature

Mechanical (gas bulb) - temperature

A failure of one or more of these instruments or the air and/or electrical supply to these would not create an immediate hazard. Although prolonged operation without the instruments would not be advisable as the lack of information could result in development of a hazardous condition; e.g. high temperatures, unaccountable changes in volume, or high pressures.

The control instruments are both pneumatic and electrical and a failure of these instruments or loss of air or electricity could produce the following conditions:

(a) Purex Control Instrumentation 241-A (Refer to Fig. 17)

(1) Normal Operation

After installation of the surface condensers (Project CG-719), one or more surface condensers will be on line with the condenser water to each controlled by an individual air operated (normally open - air to close) valve. The operating air to this valve is regulated by a temperature control instrument which adjusts the water flow to hold a pre-set temperature difference between the inlet and outlet water. The temperature elements are electrical resistance type.

Normally no water will flow through the contact condensers. However, one of these will be on line to accommodate pressure surges. The water supply to each contact condenser is controlled by an individual air operated (normally closed - air to open) valve. In case of a pressure surge in one or more storage tanks, the pressure operates a pneumatic switch which energizes an electrical circuit. This circuit supplies current to solenoid air valves supplying air to open the contact condenser water inlet valves and the quick opening condenser vent line valve in the fan house.

[redacted]

(2) Instrument Failure

A failure of any one or several of these instruments would result in one of the following conditions:

Inadequate water supply to the surface condensers permitting radioactive vapors to escape through the vent stack to the atmosphere; or

Contact condensers not operating to relieve surge pressure resulting in blowing the seal pot thus permitting a large volume of radioactive vapor to escape to the atmosphere.

(3) Instrument Air Failure

A failure of the instrument air would result in the following conditions:

Water valves to each surface condensers would open to full open position.

Drain valves from water seals in the vapor header to each surface condenser would open.

The contact condensers would be inoperable since air pressure is required to open the water inlet and vent valves.

While this condition existed, pressure surges would have to be dissipated through the surface condensers. If the three condensers were on line they would have sufficient capacity to take a bump. However, if only one or two are on line the pressure surge would probably blow the seal-pot permitting radioactive vapors to escape to the atmosphere.

(4) Instrument Electrical Failure

A failure of the electrical circuits would result in the following conditions:

The temperature controllers for the surface condensers would stop operating thus holding the water inlet valves in their respective positions.

The contact condensers would be inoperable.

In this case there would be no control for pressure surges which would blow the seal pot and release radioactive vapors to the atmosphere.

(b) Redox Control Instrumentation 241-SX (Refer to Fig. 18)

(1) Normal Operation

Cooling water to the six condensers is controlled by a single air operated (normally open - air to close) valve. The air to this valve is regulated by a temperature recorder controller which receives its signal from a thermocouple temperature element in the water outlet header. The water flow is controlled to maintain a pre-set water outlet temperature. A second temperature controller which receives its signal from one of six (three normal and three spare) thermocouple temperature elements in the primary condenser vent line energizes an electrical circuit which closes a solenoid air valve. This releases the air pressure on the water valve allowing it to open wide.

Thus when there is an increase in temperature of the primary condenser off-gases due to an increase in vapor flow or other cause, the flow of water will be increased to give additional condensing capacity.

(2) Instrument Failure

Failure of one of the temperature elements or control instruments would prevent the normal operation of the water valve and permit radioactive vapors to escape to the atmosphere. However, there are three thermocouples in the vent line, any of which may be connected to the controller through a switch as well as a spare thermocouple for each of these three, so that the result of a failure of one of these thermocouples could easily be compensated.

(3) Instrument Air Failure

Failure in the air supply to the water control valve would allow the valve to open wide with no serious hazard.

(4) Instrument Electrical Failure

Failure of the instrument electrical circuit would prevent the solenoid valve from operating. This would permit higher temperature vapor to enter the secondary condensers and possibly the release of radioactive vapors to the atmosphere.

4. Electrical

Electrical power is supplied, to the 241-A and 241-SX tank farms from their respective process buildings 202-A and 202-S, at 2300 volts by a

single, overhead transmission line. The voltage is reduced at the tank farm to 480-volts, 3-phase and 120/240 single phase. The loads at each farm are essentially the same consisting of lighting, heating, and instrument air compressors.

(a) Purex Tank Farm 241-A

In addition to the above loads, there are two electric drive motors (one 3 and one 5 horsepower) for the two vapor exhaust fans in the vapor handling system, two 40 horsepower air compressor drive motors for the air supply to the air-lift circulators, and at the completion of CG-719 there will be two electric powered pumps at the retention tank. One of each of these units is on stand-by and will take over automatically at the control of pre-set instrumentation. The large stand-by air compressor will take over when the pressure on the system falls below a pre-set value. In case of power failure, a gasoline driven generator will start automatically and assume the load of one 40-horsepower compressor and the instrument air compressors and the two vapor exhaust fans. When a power failure occurs, an alarm is sounded at the 202-A Building. The condensate return pumps on the retention tank to be provided on Project 719 are not connected to an auxiliary power system.

Primary electrical power is supplied from the 202-A Building to the two raw water pumps which fill the 241-A-201 reservoir tank. There is no emergency electrical system or other type of drive provided for these pumps.

The absence of emergency power for the 241-A-201 reservoir pumps would cause a hazardous shortage in the cooling water supply to the surface condensers which are to be furnished on Project 719. There is one 3000 gpm - 250 head pump with steam turbine drive at the 282-E Building which supplies the entire 200-E Area raw water and sanitary water systems during an electrical power outage. However, this system does not provide adequate cooling water to the condensers. In addition to permitting the hot vapors to escape to the condensate crib, there would also be insufficient condensate to return to the self-boiling tanks. The resulting predicament would be very hazardous if allowed to continue beyond six hours.

(b) Redox Tank Farm 241-SX

At 241-SX emergency power is provided by a 2300-volt line from the 284-W Building. This emergency power supplies the large air compressors and the emergency water supply pumps and comes on automatically 15 seconds after the power failure. This system now supplies adequate emergency power in 200 West Area to the Redox area and tank farms since the U-Plant process and electrical "pots" at 224-U Building have been discontinued.

E. Heat Evolution

Fig. 1, Page 47, illustrates the tremendous increase in the maximum heat evolution rate and the anticipated boil period resulting from the decay of concentrated fission products contained in one waste storage tank. This high heat evolution rate and long boiling period is the result of step-by-step operating improvements and process changes. The evolved heat is used to further concentrate the waste by self-boiling to minimize the net storage volume. Dissipation of the high temperatures developed near the tank bottom caused by settling out of the fission products is currently the greatest single hazard.

The TBP and Redox heat evolution - decay curves were based upon peak production rates and reactor power levels to establish maximum peak heat evolutions and maximum boiling periods. These bases provided a factor of safety for operating procedures of the tank farm. For the TBP wastes, the curve indicates no hazard because the maximum heat evolution rate barely attains the rate of heat loss to the ground. When using the "cascade" method of filling about 400 equivalent tons of fission products from the TBP process could be retained in the first tank of a three-tank cascade. For the Redox wastes, the curve indicates a maximum heat evolution rate about four times greater than the maximum rate of heat loss to ground. Redox can store about 800 equivalent tons of fission products in one tank while using only one tank and while observing the hydrostatic head limitation. These wastes are expected to boil from 2.5 to 3.5 years.

The Purex heat evolution - decay curve was based upon average power level, production rate, exposure, and cooling experienced during the past six months of operation to establish the maximum heat evolution and maximum boiling period. These bases do not provide a factor of safety for operating procedures of the tank farm. These bases provide a maximum safe limit of the equivalent tons of fission products to be stored in one 241-A waste storage tank. For the Purex wastes, the curve indicates a maximum heat evolution rate of 8.5 times greater than the maximum rate of heat loss to the ground and a boil period of about 10 years. With the steady state heat loss to ground of 150,000 BTU per hour and a finite life of 10 years for the 241-A tank, 2,240 equivalent tons of fission products can be safely stored in one tank.

A recent forecast for Purex two-cycle flowsheet has predicted that the fission products from 10,000 tons of uranium could be stored in less than 500,000 gallons of space on a "volume stored" bases. A plot of the decay curve for the fission products from 10,220 tons of uranium indicates a heat evolution rate of 4.5×10^5 BTU/hr after 10,000 days (27.4 years) of retention. The actual boil time is dependent on the rate of heat loss to the ground and the rate of decay of the fission products. Currently the boil period is estimated to be in the range of 200 to 300 years when storing the fission products from 10,000 tons of uranium in one Purex tank. Neither present day construction materials, nor construction methods could provide a facility to last even a fifth this long under current operating control in the Purex-type tanks. To fill a tank with this quantity of long half-life isotopes could remain a hazardous threat to this area and the lower Columbia River for hundreds of years.

F. Heat Loss to Ground

The heat losses from the 241-A tank farm have been estimated as high as one million BTU per hour for each self-boiling tank. This heat loss would also include all losses at the vapor exhaust stack, piping facilities, and condensing facilities. Although these losses could be this high now for the entire tank farm, it is believed that 150,000 BTU/hr steady-state heat loss for a single tank is more appropriate for establishing the expected boil period of a tank. A waste storage tank will continue to boil so long as its heat evolution rate is greater than the heat loss to the ground.

An extensive study was performed in 1956 to determine the heat loss to ground from the 241-A, SX, SY storage tanks.(7)(8) In this study the coefficien of thermal conductivity (k) was assumed to be 0.5 BTU/hr, (ft.)(° F), for the concrete and surrounding backfill material. All wastes were assumed to be 900 MWD/T, 5MW/T and 90-day cooled. These valves are higher than the ones selected for this study and would produce higher heat evolution for the same quantity of stored fission products.

Ground surface and ground water temperatures were set at 50° F and 65° F and the tank was assumed to be isolated so that the heat flow from the tank would be symmetrical. This study was based on a full tank and the assumption that the sludge layer could not become hotter than the liquid above it. Agitation with the air-lift circulators were to remove the heat from the sludge rapidly enough to prevent buildup of superheat. The maximum temperature of the waste was therefore assumed to be equal to the boiling point of the waste at the bottom of the tank and the temperature would be dependent only on the liquid depth and specific gravity of the wastes.

Assumptions which would tend to make the heat loss to ground less than the calculated 150,000 BTU per hour for each tank are as follows:

1. The heat loss from a tank in a farm of several boiling tanks would be less than from one isolated tank.

2. The heat loss from a tank half-full of boiling wastes would be less than that from a full tank due to decreased surface area.

3. A steady state heat loss of 150,000 BTU per hour is equivalent to about 12.5 BTU per hour (sq ft) of surface area which is relatively high for this type of buried heat source.

(7) HW-47087, "Waste Tank Temperature Studies", M. W. Cook, J. M. Gerhart, January 28, 1957.
(8) HW-47088, "The Design and Application of Heat Transfer Analogue for Radially Symmetrical Problems", M. W. Cook, January 30, 1957.

[redacted]

Therefore, until the heat loss to ground can be better established through actual measurements, the 150,000 BTU per hour per tank is believed to be a realistic quantity.

G. Finite Life of a Waste Storage Tank

The finite life of the existing Purex and Redox storage facilities, 241-A, and 241-SX, respectively, is recommended at 10 years for containing self-boiling wastes provided that the temperatures and chemical properties of these wastes can be controlled during this time and especially during initial filling and peak heat evolution periods. Literary reviews have not provided conclusive data on the effects on these structural materials when exposed to the simulated conditions of these waste storage tanks.

Steel corrosion samples recently obtained from the 101-A tank after being exposed to the waste for about five months showed low corrosion rates for SAE 1020 steel samples.(9) Samples suspended in the radioactive vapor showed less percent weight loss and a lesser degree of pit penetration than those immersed in the radioactive wastes. It must be pointed out that during this time wastes in the 101-A tank were very dilute compared to the wastes in the 103-A tank and that the highest temperature attained was less than 80° C. Therefore, any conclusions drawn from this first set of samples could be misleading.

Two-inch cubes of concrete specimens were installed in the 103-A during this past summer. However, results extrapolated from small, unstressed cubes can be misleading when compared to mass concrete under high stress.

A study of municipal structures and facilities similar to these storage tanks reveals that to achieve maximum service and dependability, the structures have certain limitations based upon the design and the service of the structure along with scheduled protective maintenance and repair. Even with these precautions it is common to find water storage reservoirs leaking during their entire life span at low rates and when these become excessive, the reservoirs are drained for repair. Highway bridges constructed of carbon steel and exposed to atmospheric conditions are painted as frequently as two to five years for corrosion protection. Preventative maintenance or repair of the Purex and Redox waste storage tanks is impossible. It is even impossible to inspect these tanks by visual means while they are storing wastes.

A periscope is currently being used on older tanks, which stored TBP process wastes, but which have never stored self-boiling wastes. The field of vision is limited and the lighting is generally poor for this type of inspection. Remote control camera equipment is currently being studied to photograph the interior of the structure to aid in detection of distortion

(9) HW-49574, "Examination of Corrosion Test Coupons in Purex 101 Waste Storage Tanks RM 147", D. H. Parks, April 8, 1957.

or corrosion of the carbon steel liner and the concrete ceiling of the dome. Even in the older tanks, this inspection is hazardous due to radiation exposure and photographs taken during the winter months have been unsuccessful due to fogging of the camera lens.

Benefits to be gained through the investigation of a "failed" tank would be negligible compared to the hazards of uncontrolled release of the high-level, long half-life, radioisotopes such as cesium^{137} and strontium^{90}. The "failure" could be anything from a corroded pin-hole to a structural collapse of the tank. The mechanics of the failure would be the complex combination of stress concentration, stress corrosion, high temperatures and stresses due to the characteristics of current self-boiling wastes. High-level radioactivity and contamination would prevent a detailed study of the failure.

If the temperatures are controlled in accordance with the RECOMMENDATIONS, the 241-A and 241-SX tanks can be expected to have a finite life of about 10 years. Other limitations such as the hydrostatic head limitation, hydrogen ion concentration, sodium ion molarity, and decomposition of other compounds have been discussed in other documents and further discussion of these is not in the scope of this report.

A method for controlling the boiling period would be to limit the quantity of fission products stored in a single tank. For the proposed two-cycle Purex extraction wastes, this would be the fission products from 2240 tons of uranium. A 100 percent increase in the boiling time would permit an increase of only 34 percent (from 2240 to 3000) in the equivalent tons of fission products stored in one tank.

There is incentive to increase the heat losses from a storage tank. If the design of a tank could increase the steady-state heat loss (say from 150,000 BTU/hr to 300,000 BTU/hr) then the equivalent tons of fission products could be increased 87 per cent (from 2240 to 4200) without increasing the boil time. This concept would probably not be desirable yet with Redox wastes because this comparative increase in the heat loss to ground may prevent the tanks from boiling.

H. Limitations for Purex 241-A and Redox 241-SX

In addition to the hydrostatic head limitation established in document HW-37207, it is prudent, at this time, to provide more realistic limitations for the 241-A and 241-SX tanks for safe storage of current self-boiling wastes. These limitations are presented to aid personnel in the safe handling of these tank farms for the duration of their existence or until the retained fission products are deemed harmless to the environs. Also, these limitations are to be used in current construction budget reviews to establish "ready-for-use" dates for new waste handling facilities for the Purex and Redox processes.

The limitations are as follows:

1. Heating of tanks shall be incremental, raising the temperature of the stored waste from ambient to boiling in two equal steps of 80 ± 10° F allowing a maximum time between steps, preferably over 6 months. It would be permissible to relax the hydrostatic head limitation during the second filling periods, if necessary to maintain this temperature limitation.

2. Maximum waste temperature shall not exceed 300° F.

The incremental heating of the waste storage tanks was recommended to achieve a minimum temperature gradient across the wall of the retaining structure without eliminating the use of the Purex and Redox storage tanks. Structural calculations based on preliminary heat transfer calculations indicate that the tank cannot be heated from ground temperature to boiling temperature in one increment slowly enough under predicted operating conditions to prevent overstressing of the structure. This limitation also minimizes the temperature differential between the steel liner and the thick concrete wall.

Several years ago during the design of these tanks it was conceived that the wastes would attain boiling temperatures after about six months of self-heating and would remain boiling for only a short time. At Redox, the wastes have heated to boiling temperatures in less than two months. At Purex, the wastes have heated to boiling in about two weeks after the tank had been heated 12 months previously to approximately 170° F (and remained at about this temperature during this interim period). There has been no detected evidence of tank damage from this treatment; although the tanks were originally designed for a much slower heating rate and a temperature gradient across the concrete of only 60° F.

The maximum waste temperature was recommended to prevent dangerously high temperatures in the concrete. If concrete is allowed to become thoroughly dry before being subjected to high temperatures, it has been reported by many observers to be able to withstand temperatures of the order of 500° F with no appreciable loss in strength. However, if saturated concrete is suddenly subjected to high temperatures, the entrapped water will flash to steam, and if the steam pressure exceeds the tensile strength of the concrete, the concrete will spall violently. At 422° F the vapor pressure of the confined water is equal to the ultimate tensile strength of the concrete.(10) If other tensile forces are present in the concrete, the spalling temperature could be less than 400° F.

(10) Raphael, Jerome M., "The Structural Properties of Magnetite Concrete", Journal of the Structural Division, Proceedings of the American Society of Civil Engineers, Vol. 84 No. ST 1, January 1958.

The high temperatures and the differential temperatures affect the thick concrete wall in four ways.(11)

1. High temperatures may alter the internal structure of the concrete and affect its properties generally.

2. The range from high temperature inside to low temperature near the outer surface tends to cause a restrained differential expansion which stresses the concrete structurally.

3. High temperatures and moist conditions of storage are necessary conditions for continuing volume changes caused by alkali aggregate reaction if a deleterious combination of materials is already present in the concrete.

4. Cycles of temperature may cause increase in the volume in the concrete with consequent danger of wide cracking.

I. Future Trends

Waste handling facilities, which will be required in the near future, for Redox and Purex neutralized waste streams are currently taking the following trends:

1. Storage facilities will be less expensive based on unit of material processed due to reduced storage volumes; but will be more expensive than existing facilities based on cost per gallon stored.

2. Storage containers will be smaller and more complex, but will provide more adequate control of agitation and temperature changes, of the stored liquid and will also be designed to absorb rapid temperature changes.

3. Simplified and safer methods of vapor handling and heat dissipation are being reviewed.

4. Instrumentation for new facilities are to be reviewed for more dependability and more complete data.

5. The real challenge of self-boiling aqueous wastes now is to develop the control for the rate of self-concentration, high temperatures, and agitation of the stored waste such that solidification could be achieved without damaging the container. This would retain the fission products in a small volume sludge containing little or no free liquid at the end of the boiling period. The thick concrete walls of the original storage container could prevent the leaching of solidified fission products to

(11) Raphael, Jerome M., "The Structural Properties of Magnetite Concrete" Journal of the Structural Division, Proceedings of the American Society of Civil Engineers, Vol. 84, No. ST 1, January, 1958.

the environs. Transfer of wastes would not be required except for the recovery of the fission products for commercial benefits.

6. Research and Engineering Operation, Chemical Processing Department, has requested Hanford Laboratories to conduct a development program to define a process which can solidify extraction wastes from the Purex process. It is conceived that storage of these wastes in solid form would be safer, although more expensive than the current self-boiling method.

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VII. ACKNOWLEDGEMENTS

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Hanford Laboratories Operation
Chemical Effluents Technology Operation

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VIII. APPENDIX

A. Chemical Effluents Technology Hazards Review

Figures 6, 7 and 8 were developed from information received from Chemical Effluents Technology, Hanford Laboratories Operation, at the request

of (and in accordance with the Hazards Study Outline by) Radiological Development, Facilities Engineering Operation, Chemical Processing Department. A study was made to evaluate the consequence of releasing to the environs 50,000 pounds per hour of uncondensed vapors from self-boiling underground storage tanks at the Purex farm and 3,000,000 gallons of high activity liquid waste from the same tanks.

Two possible hazards were considered in evaluating effects resulting from the release of uncondensed vapors from the short stack at the Purex farm:

1. The extent of air contamination in the vicinity of the stack resulting from discharge of radioactive droplets entrained in the vapors.

2. Beta and gamma dose rates resulting from fallout of contamination entrained in the vapors.

Isotopic analysis of samples of condensed vapors obtained on November 2, 1956, from the vent header after the vapors had passed through the cyclone separator showed a ruthenium^{106} concentration of 0.1 µc/cc, and a cesium^{137} concentration of 0.036 µc/cc. These two radioisotopes accounted for 97% of total beta activity; the remaining 3% consisted of a mixture of fission products at much lower concentrations. For purposes of this study, all of the activity was assumed to be due to a 70% Ru^{106}, and 30% Cs^{137} mixture at a total activity level of 0.14 µc/cc.

The boil-off rate at the time the sample was collected was 2,000 pounds per hour, or four percent of the rate considered in making this evaluation. The current average boil-off rate is approximately 6,000 pounds per hour for the 101-A and 103-A tanks. No attempt has been made to predict the increased entrainment due to the higher vapor velocity through the system; however, a considerable increase in entrainment would occur, and the tabulated estimate of air concentrations and dosage rates should be increased accordingly.

The release of radioactive vapors to the atmosphere, via the 24-inch emergency relief header and stack, at a rate of 50,000 pounds per hour and a concentration of 0.14 µc/cc will result in an activity emission rate of 880 µcc/second. The following table is plotted in Figure 8. It shows the radioactivity concentrations in the air near ground level that would probably be encountered at various distances downwind of the stack under stable, neutral, and unstable atmospheric conditions, and at an emission rate of 880 µc/second*. For rapid comparison purposes the concentrations have been expressed as the ratio of actual concentration to the macimum permissible concentration for occupational exposure of a 70% Ru^{106} + 30% Cs^{137} mixture in air (4×10^{8} µc/cc).

Table 2. Radioactivity Concentrations in the Air Near Ground Level

(Plotted in Figure 8)

Ratio: Actual Concentration / MPC (Air)

Distance from Base of Stack		Stable Atmosphere	Neutral Atmosphere	Unstable Atmosphere
Meters	Feet			
10	32.8	82	43	21
50	164	3.7	1.7	0.55
100	328	1.1	0.38	0.12
300	984	0.17	0.05	0.01
500	1640	0.065	0.017	0.003

* Expected air and ground deposition concentrations were evaluated by J. J. Fuquay of Atmospheric Physics Operation.

Concentrations greater than MPC (air) will be encountered out to distances of 110, 65, and 40 meters from the stack for stable, neutral, and unstable atmospheric conditions, respectively during the vapor emission period.

Table 3, below is plotted in Figure 6 and illustrates the gamma dose rates at one meter above ground level, resulting from fallout of entrained activity downwind of the stack. Dose rates have been calculated for sustained emission periods of one hour, eight hours, and one week.*

Table 3. Gamma Dose Rates

(Plotted in Figure 6)

Distance From Base of Stack		Gamma Dose Rates (mr/hr) at one meter above ground level		
Meters	Feet	One Hr. Emission	8 Hr. Emission	1 Week Emission
10	33	6	50	1025
50	164	<1	2	40
100	328	<1	<1	9
300	984	<1	<1	<1
500	1640	<1	<1	<1

*Equations for dose rate calculations for a Ru^{106}, Cs^{137} mixture were supplied by E. E. Donaldson, Experimental Physics Operation.

Table 4, below, is plotted in Figure 7 and illustrates the beta dose rates at one meter above the ground resulting from fallout of entrained activity under the same conditions.

Table 4: Beta Dose Rates

Distance From Base of Stack		Beta Dose Rates (mrad/hr) at one meter above ground level		
Meters	Feet	One Hr. Emission	8 Hr. Emission	1 Week Emission
10	33	65	530	11,000
50	164	3	20	420
100	328	1	2	35
300	984	<1	<1	12
500	1640	<1	<1	2

Several assumptions were made in evaluating the hazards resulting from accidental release of 3,000,000 gallons of high activity waste to the soil beneath the tanks:

1. Each of the six containers will lose 500,000 gallons of waste.

2. Loss of liquid from the tank will be through a crack or hole in the bottom such that escaping liquid waste will not be evenly distributed over the surface of the soil immediately adjacent to the bottom of the tank. (This, admittedly, is perhaps a "worst-case" assumption. In view of the uncertainties of the fate of liquid delivered to dry soil, some conservatism is justified.)

Previous calculations of a "significant leak" from an underground storage tank indicate that 50,000 gallons of waste from each tank may be retained in the soil pore spaces beneath the tank. The remaining 90% of the liquid would enter the regional ground water table beneath the farm. Soil samples from wells sunk in the vicinity of the farm present no evidence of the existence of low permeability clay strata that might provide appreciable lateral spread of wastes discharged to the ground in this area.

No experimental data are available concerning soil adsorption characteristics of radioisotopes as found in the high salt, very high activity Purex waste; however, approaching the problem from a pessimistic side, some predictions of the hazards resulting from this waste entering the regional ground water and subsequently entering the Columbia River by shore line discharge have been made.

Considering only Sr^{90} concentrations in the waste (25 curies per gallon after concentration by a factor of three), and assuming that the waste will enter the regional ground water with no soil absorption of Sr^{90} taking place, the waste could enter the Columbia River at a rate of only one-half gallon per day without exceeding the maximum permissible concentration in drinking water, 8×10^{-8} µc/cc (off plant limit). This assumes complete dispersal of the waste in the River flowing at a rate of 500,000 gallons per second. If a soil decontamination factor of 1,000 can be realized, waste addition of 500 gallons per day would maintain the Sr^{90} concentration in the River near 8×10^{-8} µc/cc. Fifteen years would be required to dispose of 2,700,000 gallons of waste at this rate.

These "leak" rates are quite nominal and could be realized under the condition assumed of a crack or small area leak in the bottom of the tank. It is true that several years may elapse between losses of the liquid and its appearance in the Columbia River. However, when equilibrium was reached, the steady addition to the River would continue for some fifteen years at 500 gallons per day (0.35 gallons per minute). Contamination of the Columbia River even to the off-site MPC would be a very serious occurrence and would compel drastic action in curtailing use of the Columbia River for domestic use and as a media for reactor effluent disposal.

Until more factual data defining soil adsorption factors for Purex wastes, dispersal of liquids in soil, adsorption and/or dilution of radioisotopes in the regional ground water strata, travel time to the River, and characteristics of shore line discharge are available, a pessimistic approach to the problem is warranted.

B. Ground Water Profile

Figure 9 is a contour map of the Hanford Works Area defining the water table as it existed in March 1957. Data for these maps are obtained periodically by recording the ground water level from the many test wells provided throughout the Area. For reference purposes, the wells as shown are located as follows:

1. 699-48-79 near NW corner of 200-W.

2. 699-35-78 near SW corner of 200-W.

3. 699-45-42 near NE corner of 200-E.

Figure 10 is a profile of the water table and land taken along Section A-A. This section was arbitrarily selected to illustrate the two water mounds which have developed since 1944. Also, the section passes through the 241-SX and 241-A tank farms and tanks located at these places have been included to show their location with respect to the water table.

The West Area water mound has raised the water table about 85 feet, while the East Area water has raised only 25 feet. The movement of the West Area mound is to the southeast and the East Area mound is moving generally in a westerly direction and spreading both to the Northwest and Southeast.

The soil column under Redox tank farm has decreased by 40 percent since 1944, while the soil column under the Purex tank farm has decreased only about 10 percent due to the short operating time of Purex.

These water mounds are saturating soil columns which have been dry for about 10,000 years. Until the soil becomes saturated with these process cooling water wastes, they have a specific retention of 0.5 to 4 percent moisture content and an average porosity of 20 percent.

C. Sludge Temperature Theory

The sludge temperature theory was presented by M. W. Cook, Separations Design and Development in an undocumented summary of 241-A waste disposal studies in 1954.(12) This theory is presented graphically in Figure 5 and was used to derive the present hydrostatic head limitation. Excerpts from his work are presented herein. The following assumptions were made to permit calculations:

1. Sludge is laid down in a uniform layer in the bottom of the waste tank.

2. Fifty percent of the fission products are adsorbed in a three-foot layer of this sludge. (Compared with 85% at Redox). For other sludge thicknesses, the concentration of fission products in the sludge remains constant (e.g. for an 18-inch layer, 25 percent of the fission products would be absorbed).

3. Water is excluded from the sludge by means of film boiling.

4. The surface of the sludge has a temperature equal to the boiling point of the supernate.

5. No heat is transferred through the bottom or sides of the tank. Heat is assumed to flow only to the supernate.

6. The sludge is assumed to have a thermal diffusivity, α, and, equal to that of water. $\alpha = k/c\rho$, k = thermal conductivity, c = heat capacity, ρ = the density, all in consistent units. The thermal diffusivity is assumed to be independent of the temperatures.

(12) Undocumented Report, "Summary of 241-A Waste Disposal Studies", W. M. Harty from M. W. Cook, June 18, 1954.

Assumption five leads to higher temperature than will actually exist; however, assumption two will tend to make the results low. Assumption six appears to be ultra conservative since the thermal conductivity of water is five to ten times less than for solid $NaNO_3$. However, the sludge will probably be a porous mass which will exhibit a much higher resistance to heat flow than would be calculated for a homogeneous crystalline sludge.

The equation for steady state temperature distribution was derived from the general equation for heat transfer from the sludge according to the above assumptions.

$$t = \frac{q}{2k} (X_1^2 - X^2) + 220$$

where

t = temperature
q = heat generation per unit volume
k = thermal conductivity
x = distance measured up from the bottom of the sludge
x_1 = sludge thickness

Solving this equation for temperatures with various sludge thicknesses and at various depths, the curves shown in Figure 5 were obtained. Also shown on the curves are the total heat content for the various thicknesses of sludge and the approximate time required to reach steady state.

The time to reach steady state was estimated by assuming that on the average, one half of the heat was accumulated in the sludge and one half was transferred to the supernate.

Although the foregoing treatment is admittedly very approximate, the following conclusions can be reached:

1. The heat generation term, q, is about six times greater for Purex than for Redox because the waste is initially more concentrated.

2. Building up a sludge layer in the waste tanks is potentially very dangerous.

3. Even though a tank is not allowed to concentrate to the point of forming a precipitate, the water make-up will tend to layer out on the surface of the more dense supernate and a precipitate can be obtained.

4. Means should be sought to agitate the supernate in the waste tanks undergoing self-concentration.

5. A probable mechanism for eruptions is as follows:

   (a) Sludge becomes dry due to film boiling.

   (b) Heat is stored in the sludge due to lowered heat transfer.

   (c) The irregular sludge layer produces an opening as it dries and water is admitted.

   (d) The sudden local cooling causes further cracks to occur and the heat stored in the sludge is liberated rapidly by steam.

   Based on the calculations in the undocumented report by M. W. Cook, the rate of temperature rise for a sludge layer is in the range of 16° F to 32° F per hour.

   Several temperature limitations have been plotted on these curves to identify the thickness of sludge layers which can cause extensive damage to the structure. For example, even a one-foot layer of sludge could develop a steady state sludge temperature in excess of the melting point for sodium salts, as well as exceeding the maximum desirable temperatures for structural materials regardless how slow the rate of temperature rise could be controlled.

D. Effects of High Temperatures on the Physical Properties of Construction Materials

Figures 11, 12, and 13, have been prepared to illustrate, in general, the effects of high temperatures on the physical properties of construction materials. These effects were obtained without considering the additional effects of radiation exposure, corrosive or saturated atmospheres, duration of loads, or highly stressed materials. A literary review was not conclusive for results and data that would simulate the conditions of self-boiling Purex or Redox high-level radioactive wastes. The following information clearly emphasizes the need of development studies to insure safe and economical storage of these wastes.

Figure 11 shows the reduction of the modulus of elasticity for various types of steels at elevated temperatures. Carbon steel, similar to the type used in the Purex and Redox tanks, is the most seriously effected. At about 500° F there is a reduction of about 15 percent in strength and above this temperature the modulus of elasticity drops sharply. It is the general belief that the modulus of elasticity is a definite inherent property of steel. Most authorities are in agreement that such metallurgical factors as composition variations within a given grade, cold working, and heat treatment have little influence on the modulus of elasticity.(13)

(13) Miner, D. F., Seastone, J. B., Handbook of Engineering Materials, First Edition, John Wiley and Sons, Inc., New York, 1955, pp 2 - 05.

Changing the stable metallographic phases has little effect on the modulus of elasticity although marked crystallographic orientation produces substantial changes, and the presence of any discontinuities, such as quenching cracks, blowholes, or graphite, lowers the modulus.

Other mechanical properties of metals at high temperatures such as yield point, ultimate strength, ductility, proportional limit, creep, etc. have been summarized from footnote 14, in the following excerpts:

> "Experiments show that the yield point and the ultimate strength of a metal in tension depend considerably on the temperature. Up to about 250° C the ultimate strength of the steel increases, but with farther increase in temperature, it drops off rapidly. Also, the yield point becomes less pronounced as the temperature increases, and at 300° C it cannot be distinguished on the stress-strain diagram. The proportional limit of the steel diminishes as the temperature increases above room temperature. The ductility of steel increases with an increase in temperature and is characterized by increased elongation and increased reduction in area.
>
> Experiments at high temperatures show that the results of tensile tests also depend on the duration of the test. As the duration of the tensile test increases, the load necessary to produce fracture becomes smaller and smaller. Steel specimens tested at 500° C for durations of six minutes, 70 minutes and 240 minutes experienced a 25% reduction in ultimate strength between the short and long times.
>
> For loads acting over a long period of time and at high temperatures - for example, the dead weight of the structure. heavy earth loads, etc., - additional information is needed regarding 'time effect'. Experience shows that under such conditions a continuous deformation or 'creep' takes place, which is an important factor to be considered in design. Although a considerable amount of research work has been carried out on the subject and much more is now in progress, the question of the behavior of metals under high temperature and prolonged loading cannot be considered completely answered.
>
> In most experiences pertaining to creep, the gradual elongation of a material under prolonged tension is studied. Tensile test specimens at high temperature are subjected to a certain constant load and temperature, and the 'progressive creep' under this load is investigated. Two phenomena must be kept in mind, (1) hardening of the metal due to plastic strain and (2) removal of this hardening, or 'softening' of the material due to the prolonged action of the high temperatures."

(14) Timoshenko, S., Strength of Materials, Part II, Advanced Theory & Problems, Third Edition, D. Van Nostrand Company, Inc., Princeton, New Jersey, March 1956.

[redacted]

"Other experiments have shown for instance, no strain hardening was observed with mild carbon steel (0.17 percent carbon) at a stress of 2,200 psi and a temperature of 647° C. Under such conditions the time extension curve shows that the rate of creep increases continuously with time."

Figure 12 shows the increase in reduction of the compressive strength of standard Portland cement concrete when exposed to high temperatures.

"Concrete is often proposed for locations where it will be exposed to dry air at relatively high temperatures. There are, however, no coordinated data available from which the length of service to be expected can be predicted for all conditions of this kind. From observations of concrete structures in service, and from tests made on small specimens, some general conclusions can be made."(15)

"While many fire tests have been made on wall and floor sections of various designs and materials, the test is of relatively short duration (a few hours). From such tests, fire rating periods have been established for each type of construction and Portland cement concrete has been given a very high rating. This is one reason why it is so widely used in fire-proof construction."

"The subject of this discussion is concrete exposed to lower temperatures than the very high ones encountered in fire tests, but exposed to heat for a much longer period. Unfortunately, there are not data available from tests of large specimens comparable to the masses of concrete usually encountered in structures. Tests made on small specimens show appreciable reductions in strength upon exposure to temperatures much above normal. 'Bulletin 43' of the Engineering Experiment Station, University of Washington, reports tests made by Miller and Faulkner on 2 by 4-inch cylinders of 1:2:4 concrete with $\frac{1}{2}$-inch maximum size aggregate heated for four hours when the concrete was 27 days old and then tested on the 28th day. The reduction in strength for various temperatures is shown graphically in Figure 12."(16)

Other tests of small specimens are reported by C. L. Norton in "Proceedings, National Association of Cement Users", 1911 and by I. H. Woolson in "Proceedings, American Society of Testing Materials", 1905 and 1906. The reductions in strength found by these investigators were somewhat less than those reported above.

(15) Miner, D. F., Seastone, J. B., Handbook of Engineering Materials, First Edition, John Wiley and Sons, Inc. New York, 1955, pp 2 - 05.
(16) Portland Cement Association, "Effects of Long Exposure of Concrete to High Temperatures" ST 32-3-53.

The type of aggregate used has some effect on the amount of reduction in strength. In general, limestone aggregates and calcareous sands and gravels give better results than siliceous materials. This is varified also in fire tests. (Sands and gravels used at HAPO are siliceous materials).

Considering the results of tests on small specimens, fire tests on representative types of construction and the performance of structures in actual service, concrete should not be exposed continuously to temperatures above 500° F in important load-bearing members, such as columns, and particularly where all surfaces of the member will be exposed to the heat.(17)

For the purpose of this Hazards Study, the maximum sludge temperature of 300° F has been recommended for the following reasons:

1. The seriousness of the hazard resulting from tank failure.
2. Inability to observe the behavior or perform maintenance on the structure.
3. Temperature instrumentation control is inadequate and results have been questionable.
4. The vapor pressure of the confined moisture at about 422° F is equal to the ultimate tensile strength of the concrete.
5. Provides a small margin of safety in case control is momentarily lost.
6. Required finite tank life and stresses existing in the structural materials.

Excerpts from footnote 18:

> "Corrosion of the steel reinforcement has recently caused the failure of a number of precast I - type beams supporting the roof of lumber drying kilns at the Brunswick - Balke- Collendar Company Plant at Muskegan, Michigan. The beams were exposed to the warm moist atmosphere inside the kilns, and the only protection for the reinforcement was that provided by the concrete of the beams themselves, which is usually not much in this type of beam (approximately one inch). The kilns were built in 1947 and corrosion proceeded at such a high rate that, in some of the beams, bars of 7/8-inch diameter were reduced to ½-inch or less by the summer of 1955. Failure occurred under the weight of the structure only.

(17) Portland Cement Association, "Effects of Long Exposure of Concrete to High Temperatures" ST 32-3-53.
(18) Shermer, C. L. (Member ASCE) "Corroded Reinforcement Destroys Concrete Beams", Civil Engineering, December 1956, Vol. p. 818.

"Of particular interest was the way in which the beams failed. Although the concrete was of fair quality (small specimens cut from the beams tested between 3,000 and 4,000 psi), the steel had so little covering that both moisture and air evidently penetrated readily. The steel corroded, and because the oxide occupied a larger volume than the steel, the bars increased in size and literally burst the beams. The longitudinal steel caused very noticeable cracks, which often extended the full length of the beam along one or more faces of the flanges. The 3/8-inch diagonal web bars in several cases simply popped the concrete from one face of the web, leaving the steel exposed.

"Although the manner of cracking left little doubt that it was caused originally by bursting, due to the corrosion of the steel, it progressed far more rapidly near the ends of the beams that at the center. The best explanation for this seems to be that although the primary cause of the cracking was bursting due to steel corrosion, the cracks progressed as a result of other causes also, and they progressed most rapidly where the shearing stresses were greatest and where there was some slipping due to loss of bond. In each case, where ultimate failure occurred, this failure was close to the support.

"It is likely that the difficulty of casting the narrow beams, especially when the volume of steel was so great, resulted in the use of a wetter mix and hence in more porous concrete, permitting easy penetration of both air and moisture."

Figure 13 compares the thermal expansion of reinforced concrete with various types of steels. At temperatures only slightly above normal the coefficient of expansion for reinforced concrete is 5.5×10^{-6} inches per inch ($^{\circ}$ F) and for carbon steel is 6.5×10^{-6} inches per inch ($^{\circ}$ F). For design considerations at these temperatures the coefficient of thermal expansion for concrete is assumed equal to that of carbon steel. The error induced by this assumption is negligible.

When dealing with temperature changes in structures, most of the error is induced by assuming a temperature gradient through a thick concrete wall, or the temperature differential between two structural materials such as a thin steel liner against a thick concrete wall, or the rate of temperature change incurred due to processes.

Methods of calculating these heat flow temperature gradients are currently being reviewed by Hanford Laboratories Operation for adoption to the analog computor. Without this equipment, the true evaluation of the temperature gradient through a thick material, when experiencing temperature changes at various rates, would be an endless task.

E. Corrosion Data of Waste

In January 1955, a metals study program was initiated to evaluate various types of steels for welding characteristics, and field corrosion tests in Purex and Redox waste storage tanks of stressed, unstressed, base metal and welded specimens.(19) A summary report, HW-37642, was prepared in June 1955, outlining the setup of the program to be conducted over the next several years.

Two field corrosion test units were installed as the initial portion of a joint program by the Corrosion and Welding Unit and the Utilities and Services Design and Development Unit, designed to produce long term corrosion data on SAE 1020 carbon steel, two low alloy-high strength steels, as an alloy steel in neutralized process wastes. One unit was placed in Redox 241-SX-107 storage tank, and the other unit in Purex 241-A-101 waste storage tank.

The four metals chosen for exposure were SAE 1020 carbon steel, Cor-Ten, Mayori-R and Carilloy T-1. It was planned to expose these samples to the vapor and liquid phases of the stored waste for periods of 4, 8, 16, 32, 64 and 128 months or as early test results dictated.

Document HW-49574 presents the results of the first samples taken from the Purex tank 241-A-101. These samples were placed in the 101-A tank prior to Plant start-up because the best information available at the time predicted the 101-A tank would reveal the quickest results from corrosion tests. After Purex start-up, and with the usual difficulties experienced in new plant operations, the 101-A tank was filled to the hydrostatic head limitation with non-boiling wastes. Since then, the 102-A tank was filled in the same manner and boiling wastes were not encountered until use of the 103-A tank had commenced. At present, the 103-A tank has experienced far more strenuous service than the 101-A tank as illustrated in the presentation of this study.

Currently, the 101-A tank began self-concentrating in August, and the next corrosion samples obtained from this tank are believed to be more revealing than were the results compiled in the first survey in HW-49574.

F. History of Design Criteria

Figure 14 illustrates the basic design criteria and structures that have been used during the history of HAPO to provide safe storage facilities for neutralized wastes. Waste characteristics common to both Purex and Redox, although different in magnitude which need to be established for the tank design criteria of new facilities are as follows:

(19) Letter, H. W. Stivers to W. R. Smith, "Metals Study Program", January 25, 1955.

1. The maximum vapor pressure, rate of rise, and frequency of occurrence.

2. Temperature gradient in the stored solution, both transient and steady state and rate of change.

3. Quantity of stored heat in an individual tank. (Defines maximum sludge temperatures and boil time.)

4. Total waste volume to be stored. (Defines the size of tank and tank farm.)

5. Final concentration of waste to be stored.

6. Tank appurtenances which should be studied for these new waste characteristics are:

   (a) Leak detection devices.

   (b) Replaceable air-lift circulators.

   (c) Economic dissipation of stored heat.

   (d) Protection of concrete from exposure to vapors as well as liquids.

   (e) Improved methods of instrument control.

G. Principle Study Program

There are several study programs in progress, the results of which will better establish and define the characteristics of self-boiling Purex and Redox neutralized wastes. The results will be used also to achieve maximum utilization of existing storage facilities under controlled and safe operation and will be used as a bases to provide the design criteria for future facilities. Primary programs are as follows:

1. Steel corrosion studies are being continued by Development and Corrosion Chemistry, Chemical Development Operation, HLO, and the current program is defined in HW-37642.

2. Gradual filling of the 241-SX storage tanks is being advanced on a test basis under the supervision of Redox Technology to better define the hydrostatic head limitation and to study the sludge temperatures. Process specifications for Operational Control have been documented recently in HW-50360.

3. Two modified Taylor aneroid pressure recording instruments have been developed. One instrument records pressure surges from 0-100 inches of water and was installed on the 103-A waste storage tank. One instrument records pressure surges from 0-20 inches of water and is being installed in 107-SX. The purpose of these instruments is to measure the rate of pressure rise during a bump.

4. A laboratory program has recently been requested by Purex Technology Operation to review the Chemical behavior of Purex process wastes which are self-concentrating beyond 8M Na^+ at elevated temperatures. This program is defined in a letter entitled "Laboratory Program for Concentrated Purex Waste Data" to K. M. Harmon, Manager Process Chemistry Operation, CPD, and R. E. Burns, Supervisor Development and Corrosion Chemistry, HLO, from R. C. Forsman, Purex Technology Operation, CPD, June 12, 1957.

5. Another laboratory program has recently been requested by Purex Technology Operation to determine the physical behavior of self-concentrating wastes as described in item 4 above. This study is defined in a letter entitled "Simulated Waste Tank Physical Behavior Program" to R. G. Geier, Chemical Engineering Development, Chemical Research and Development, HLO, from W. H. Swift, Purex Technology Operation, Research and Engineering, CPD, August 16, 1957.

6. Types of a replaceable circulator for new tank design are being studied for future tank farms by Power and Mechanical Design Operation, CEO.

7. Methods of leak detection for existing, as well as new facilities, storing these high level radioactive wastes are being studied.

8. Research and Engineering Operation, CPD, has requested Hanford Laboratories Operation to conduct a development program to define a process which can solidify extraction wastes from the Purex process. It is conceived that storage of these wastes as a solid would provide safer and longer interim storage, although at higher costs, than present method of liquid storage tanks.

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I. Figures and Graphs

Fig. 1, Heat Evolution and Decay Curves

Fig. 2, Purex Tank 241-A-103, Waste Storage History

Fig. 3, Purex Tank 241-A-103, Waste Temperature Profile

Fig. 4, Purex Tanks 241-A-101, 241-A-103, Radiation Profile

Fig. 5, Purex Wastes, Steady State Sludge Temperatures

Fig. 6, Purex Wastes, Gamma Dose Rates

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Fig. 8, Purex Wastes, Ratio Actual Concentration to Maximum Permissible Concentration (MPC)

Fig. 9, Hanford Works Area, Controus of the Water Table, March 1957.

Fig. 10, Hanford Works Area, Ground Water Profile, 1957.

Fig. 11, Effect of High Temperatures on the Modulus of Elasticity for Steels

Fig. 12, Effects of High Temperatures on the Compressive Strength of Concrete

Fig. 13, Thermal Expansion of Steels and Concrete

Fig. 14, Basic Design Criteria for High Level Radioactive Storage Tanks

Fig. 15, Schematic Diagram of the 241-A Raw Water Supply

Fig. 16, Schematic Diagram of the 241-SX Raw Water Supply

Fig. 17, Purex 241-A - Condenser Control Instrument Diagram

Fig. 18, Redox 241-SX - Condenser Control Instrument Diagram

Fig. 19, SK-1-2019, Plot Plan Export Water System

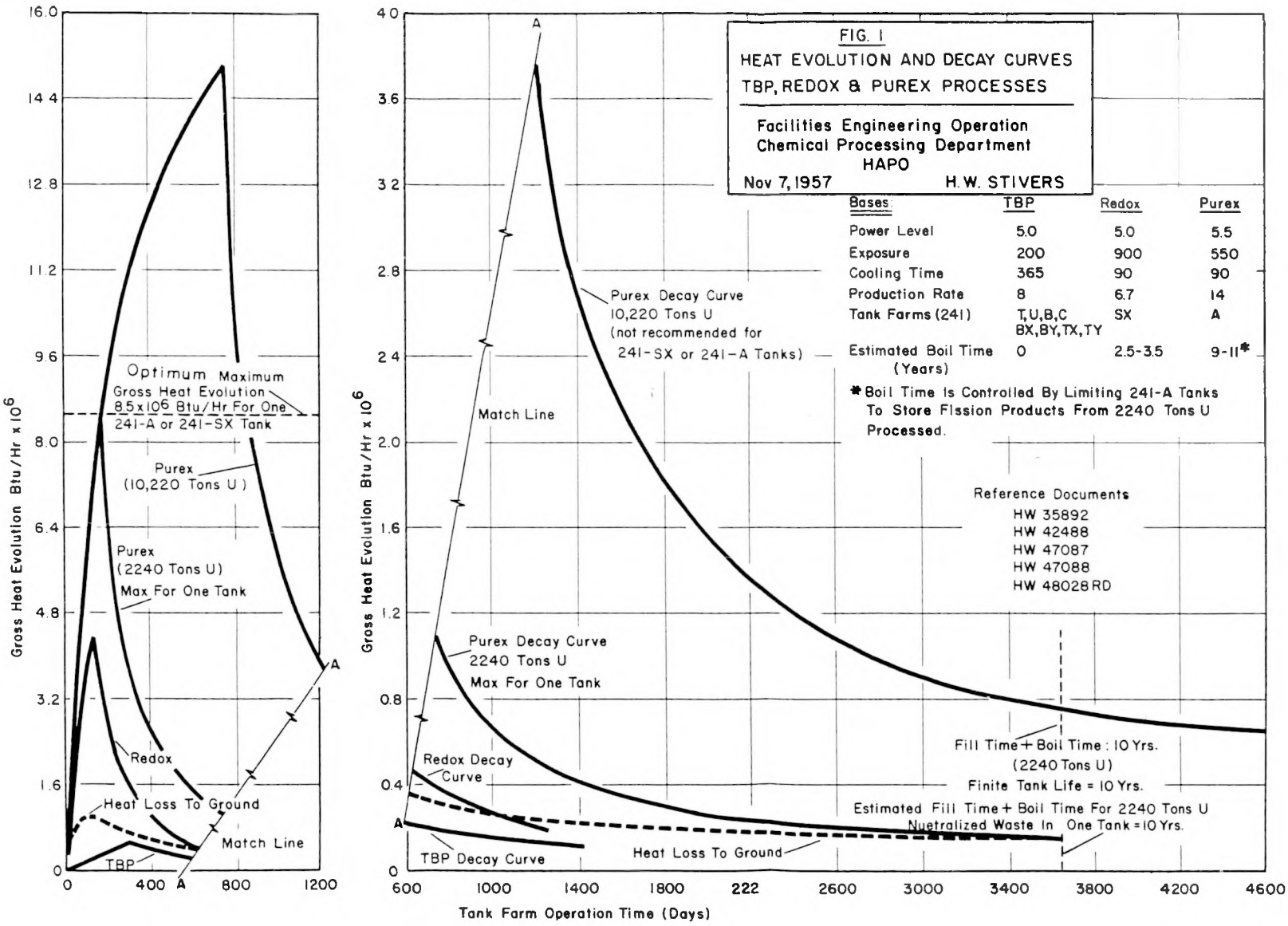


FIG. 1
HEAT EVOLUTION AND DECAY CURVES
TBP, REDOX & PUREX PROCESSES

Facilities Engineering Operation
Chemical Processing Department
HAPO
Nov 7, 1957 H.W. STIVERS

Bases	TBP	Redox	Purex
Power Level	5.0	5.0	5.5
Exposure	200	900	550
Cooling Time	365	90	90
Production Rate	8	6.7	14
Tank Farms (241)	T,U,B,C BX,BY,TX,TY	SX	A
Estimated Boil Time (Years)	0	2.5-3.5	9-11*

* Boil Time Is Controlled By Limiting 241-A Tanks To Store Fission Products From 2240 Tons U Processed.

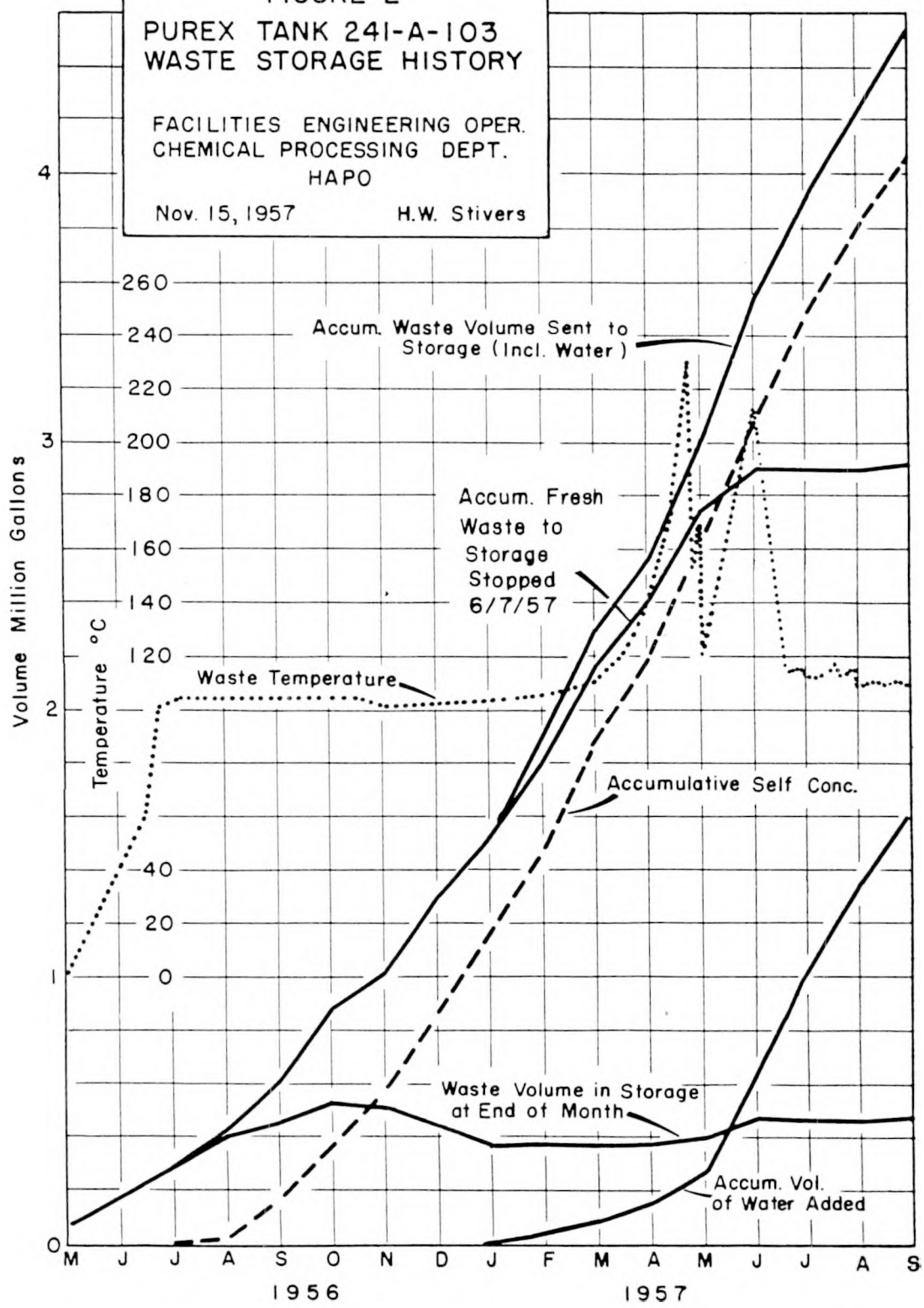
Reference Documents
HW 35892
HW 42488
HW 47087
HW 47088
HW 48028 RD

AEC-GE RICHLAND WASH

FIGURE 2
PUREX TANK 241-A-103
WASTE STORAGE HISTORY

FACILITIES ENGINEERING OPER.
CHEMICAL PROCESSING DEPT.
HAPO

Nov. 15, 1957 H.W. Stivers



AEC-GE RICHLAND, WASH.

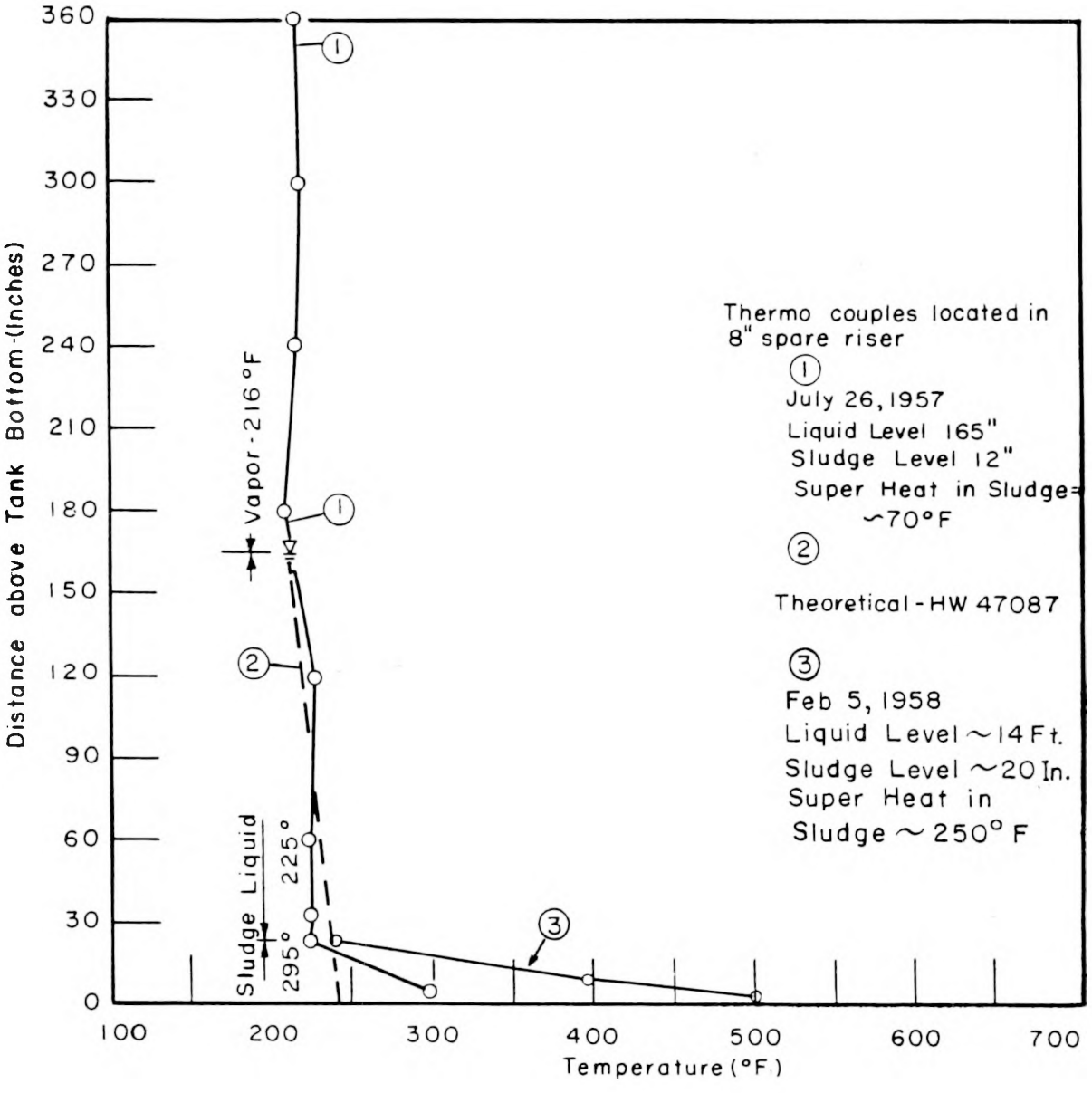


FIGURE 3
WASTE STORAGE TANK
241-A-103
TEMPERATURE PROFILE

AEC-GE RICHLAND WASH

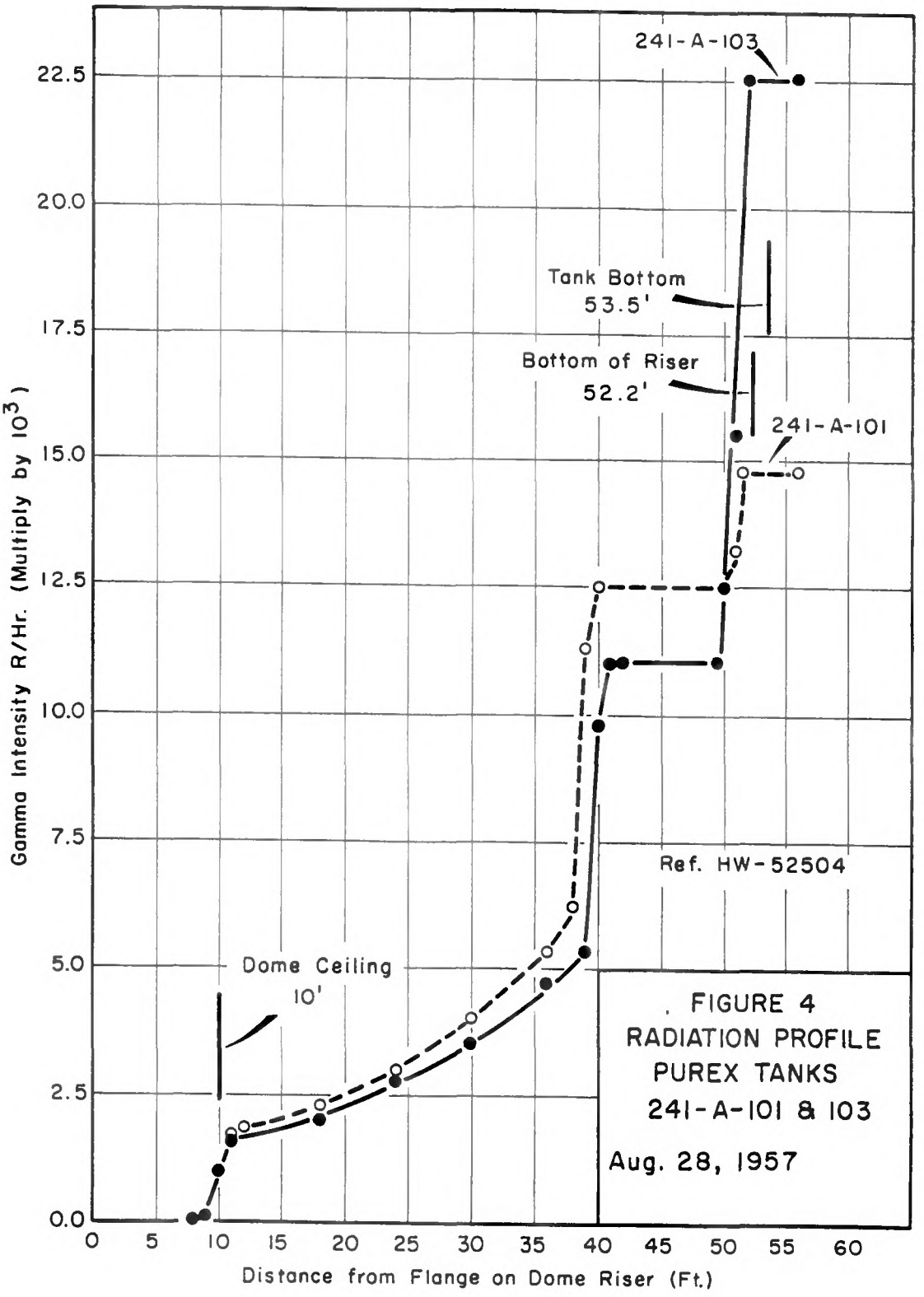


FIGURE 4
RADIATION PROFILE
PUREX TANKS
241-A-101 & 103
Aug. 28, 1957

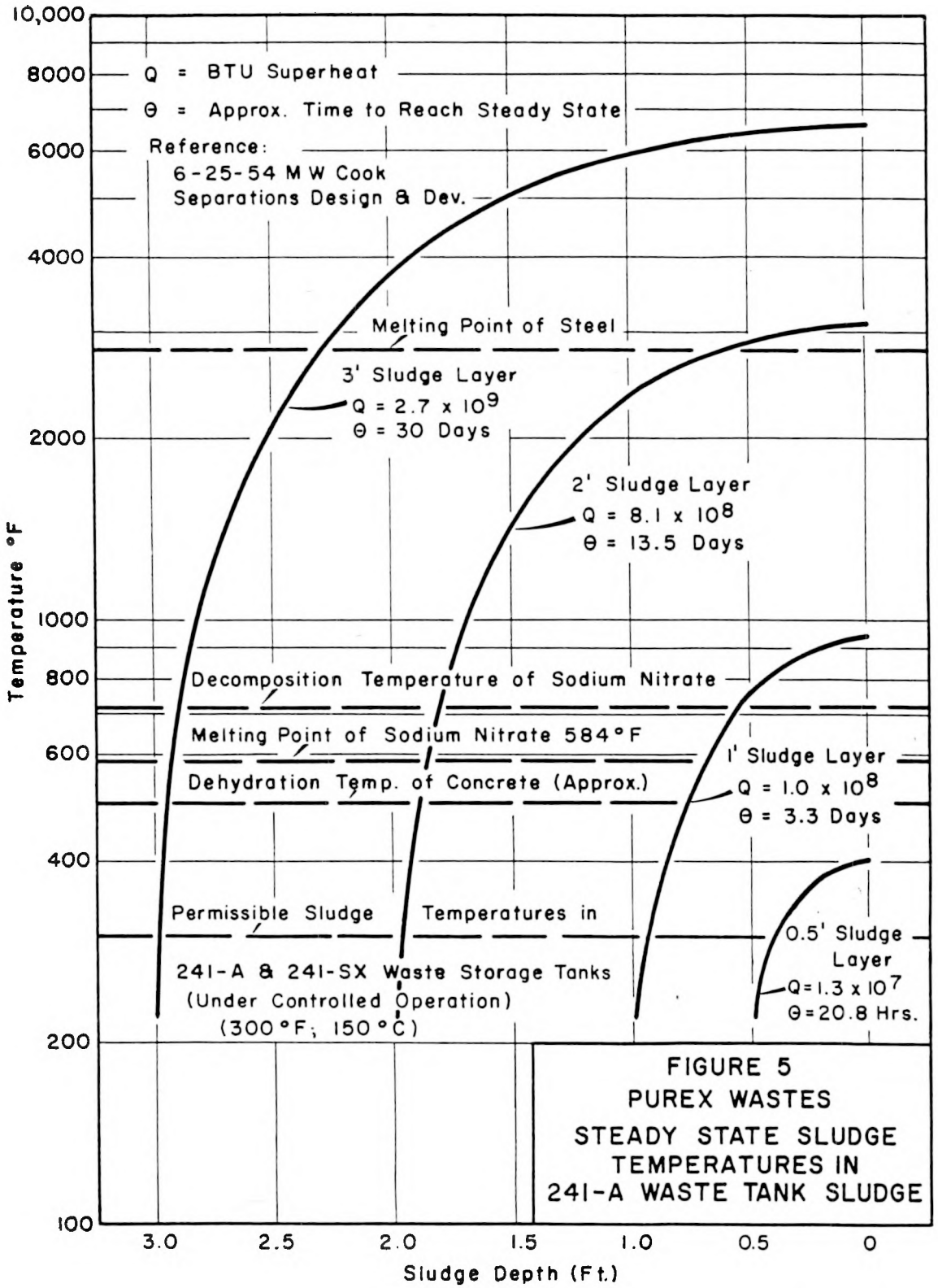


FIGURE 5
PUREX WASTES
STEADY STATE SLUDGE TEMPERATURES IN 241-A WASTE TANK SLUDGE

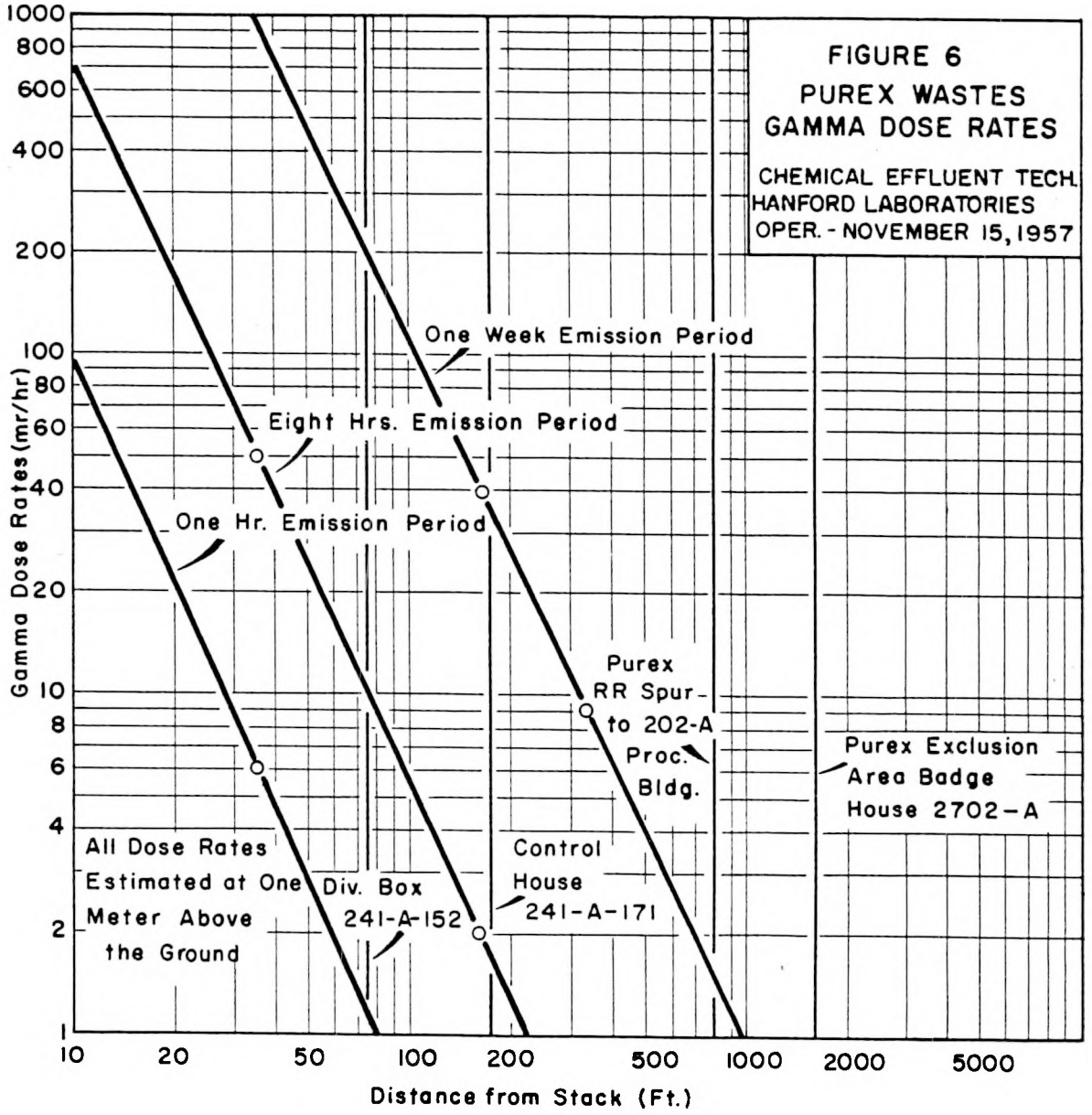


FIGURE 6
PUREX WASTES
GAMMA DOSE RATES
CHEMICAL EFFLUENT TECH.
HANFORD LABORATORIES
OPER. - NOVEMBER 15, 1957
Gamma Dose Rates (mr/hr)
1000
800
600
400
200
100
80
60
40
20
10
8
6
4
2
1
One Week Emission Period
Eight Hrs. Emission Period
One Hr. Emission Period
Purex
RR Spur -
to 202-A
Proc.
Bldg.
Purex Exclusion
Area Badge
House 2702-A
All Dose Rates
Estimated at One
Meter Above
the Ground
Div. Box
241-A-152
Control
House
241-A-171
10
20
50
100
200
500
1000
2000
5000
Distance from Stack (Ft.)

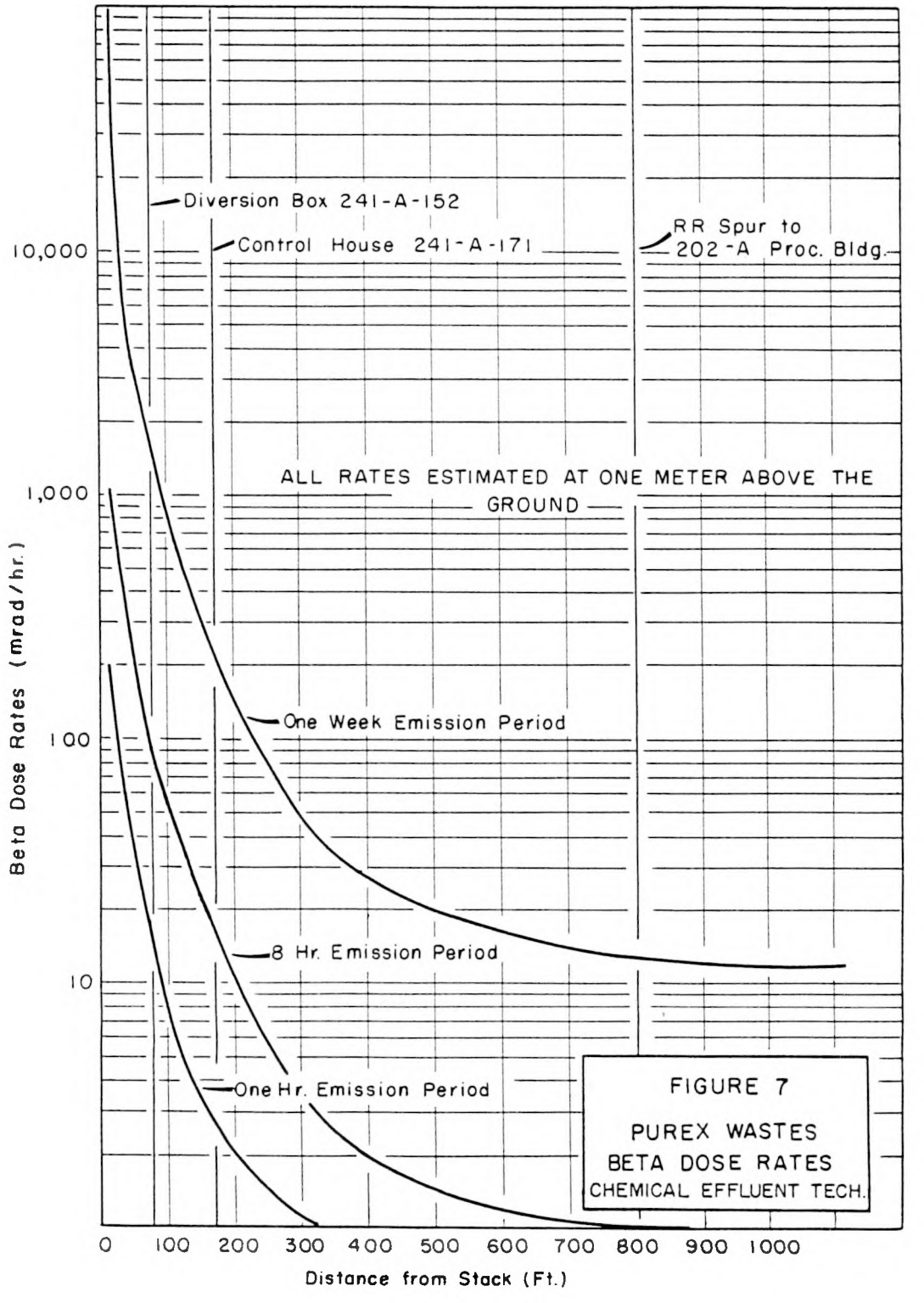


FIGURE 7

PUREX WASTES
BETA DOSE RATES
CHEMICAL EFFLUENT TECH.

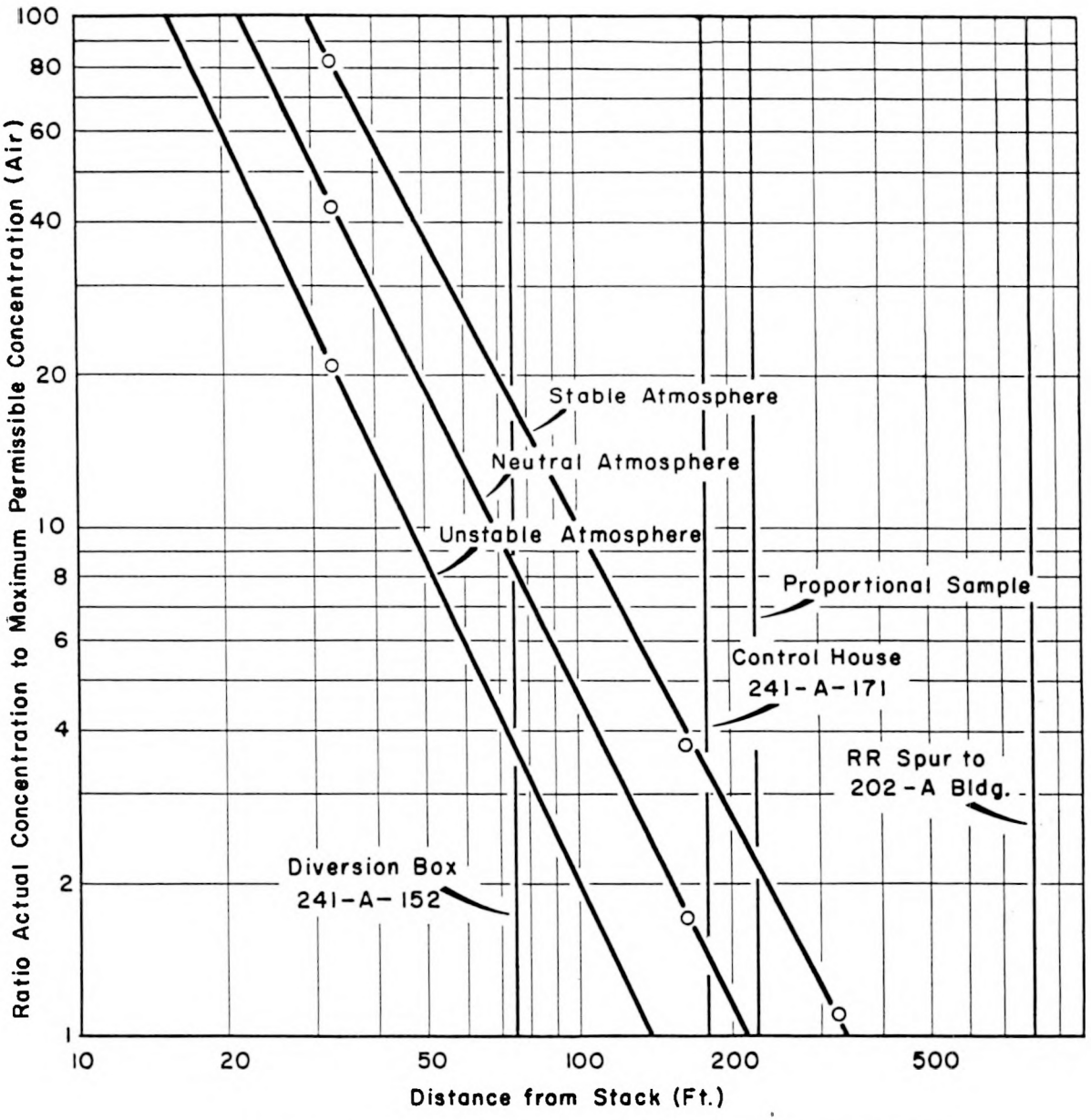


FIGURE 8

PUREX WASTES

RATIO ACTUAL CONCENTRATION TO MAXIUM PERMISSABLE CONCENTRATION (MPC)

Chemical Effluent Technology
Hanford Laboratories Operation
Nov. 15, 1957

AEC-GE RICHLAND, WASH.

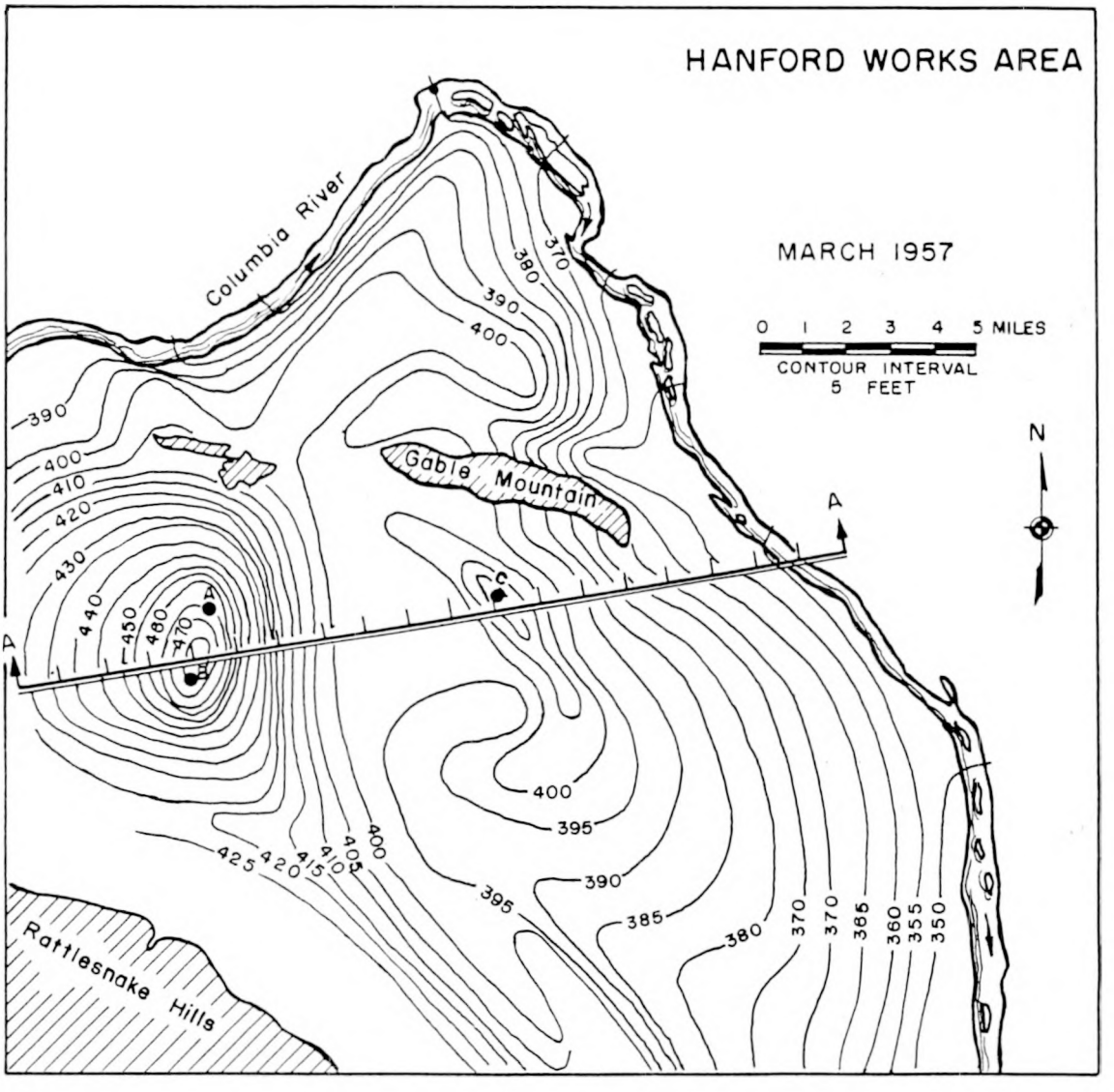
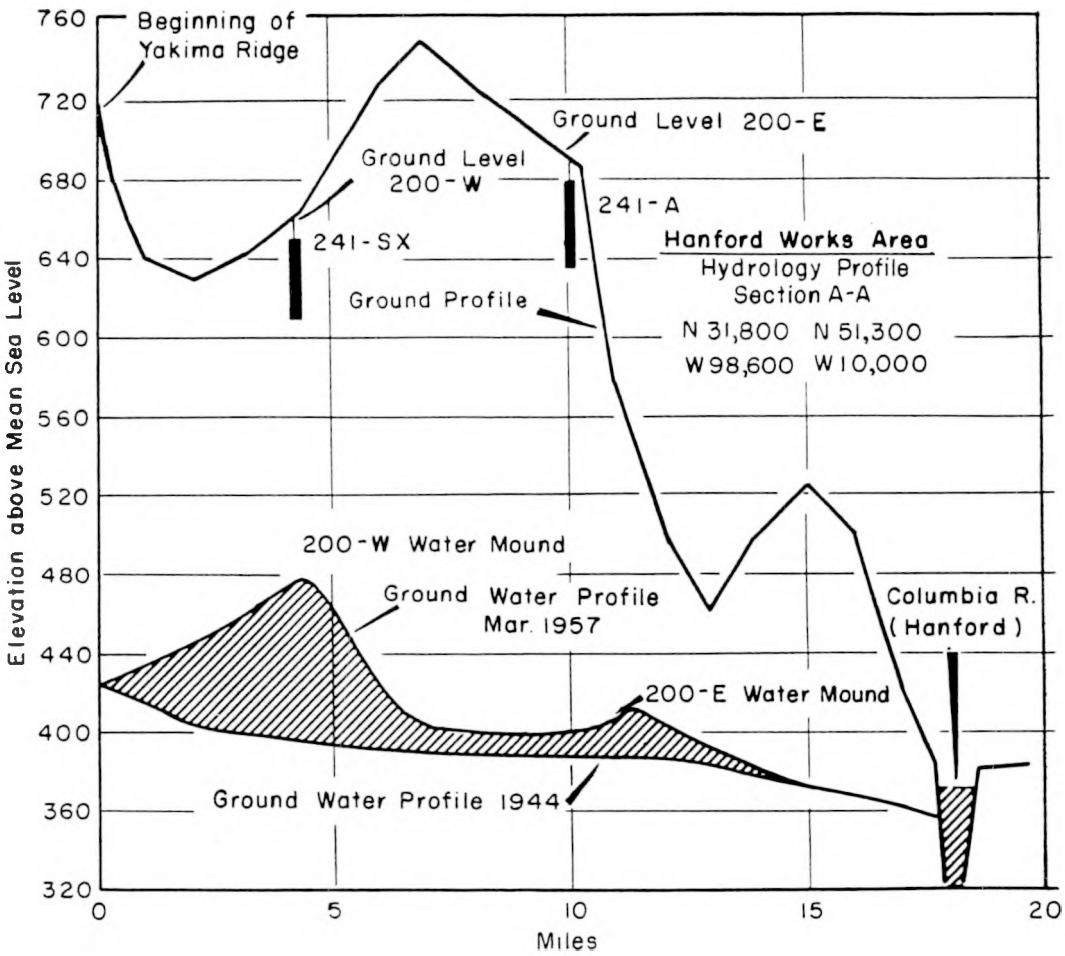


FIGURE 9
CONTOURS ON THE
WATER TABLE

Chemical Effluent Technology
Wm.H. Bierschenk



Ground Water Profile
Section A-A

FIGURE 10
HANFORD WORKS AREA - GROUND WATER PROFILE
FACILITIES ENGR. OPERATION - CPD
Nov. 15, 1957 H.W. Stivers

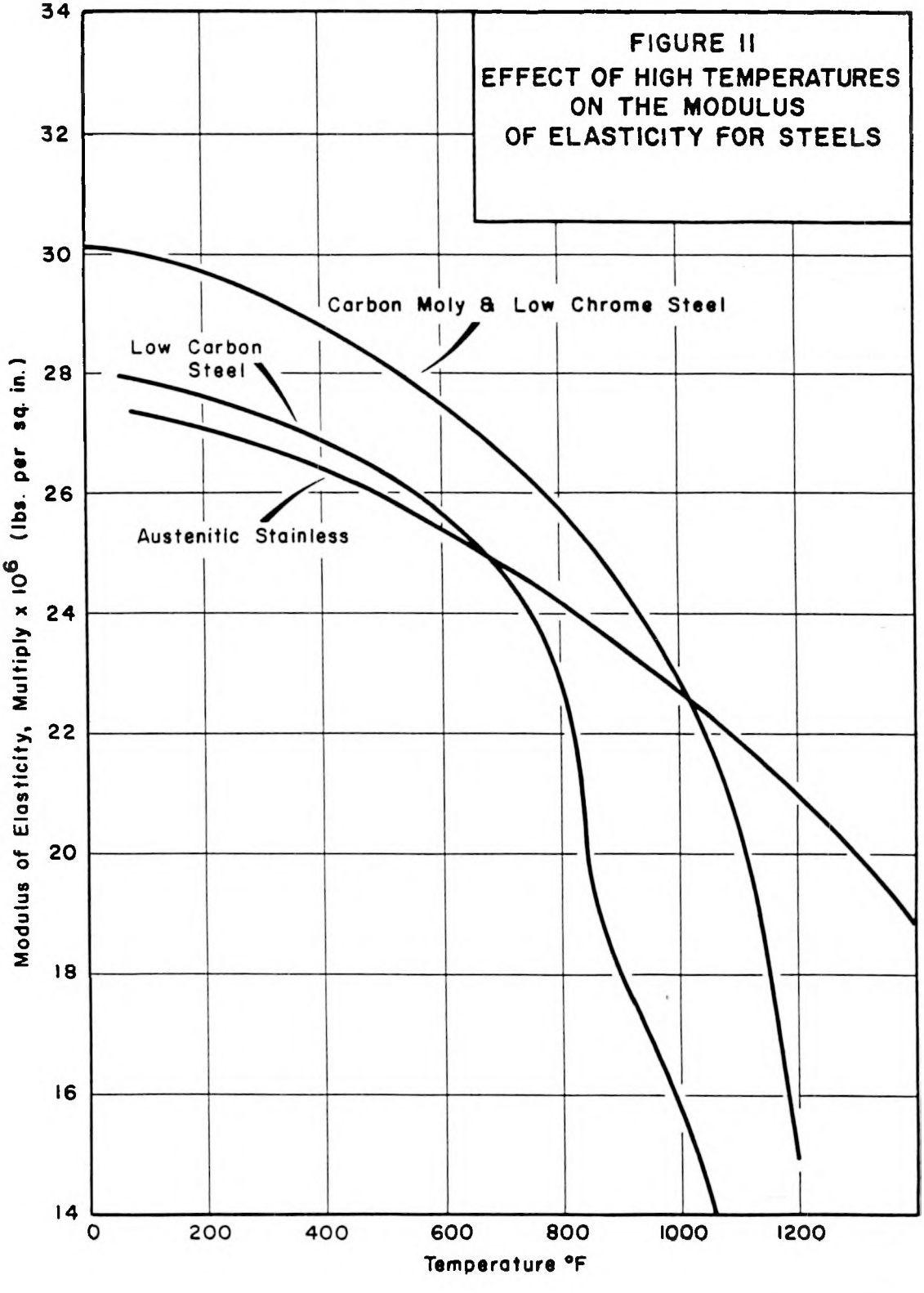


FIGURE II
EFFECT OF HIGH TEMPERATURES
ON THE MODULUS
OF ELASTICITY FOR STEELS
Carbon Moly & Low Chrome Steel
Low Carbon
Steel
Austenitic Stainless
Modulus of Elasticity, Multiply x 10^6 (lbs. per sq. in.)
34
32
30
28
26
24
22
20
18
16
14
0
200
400
600
800
1000
1200
Temperature °F

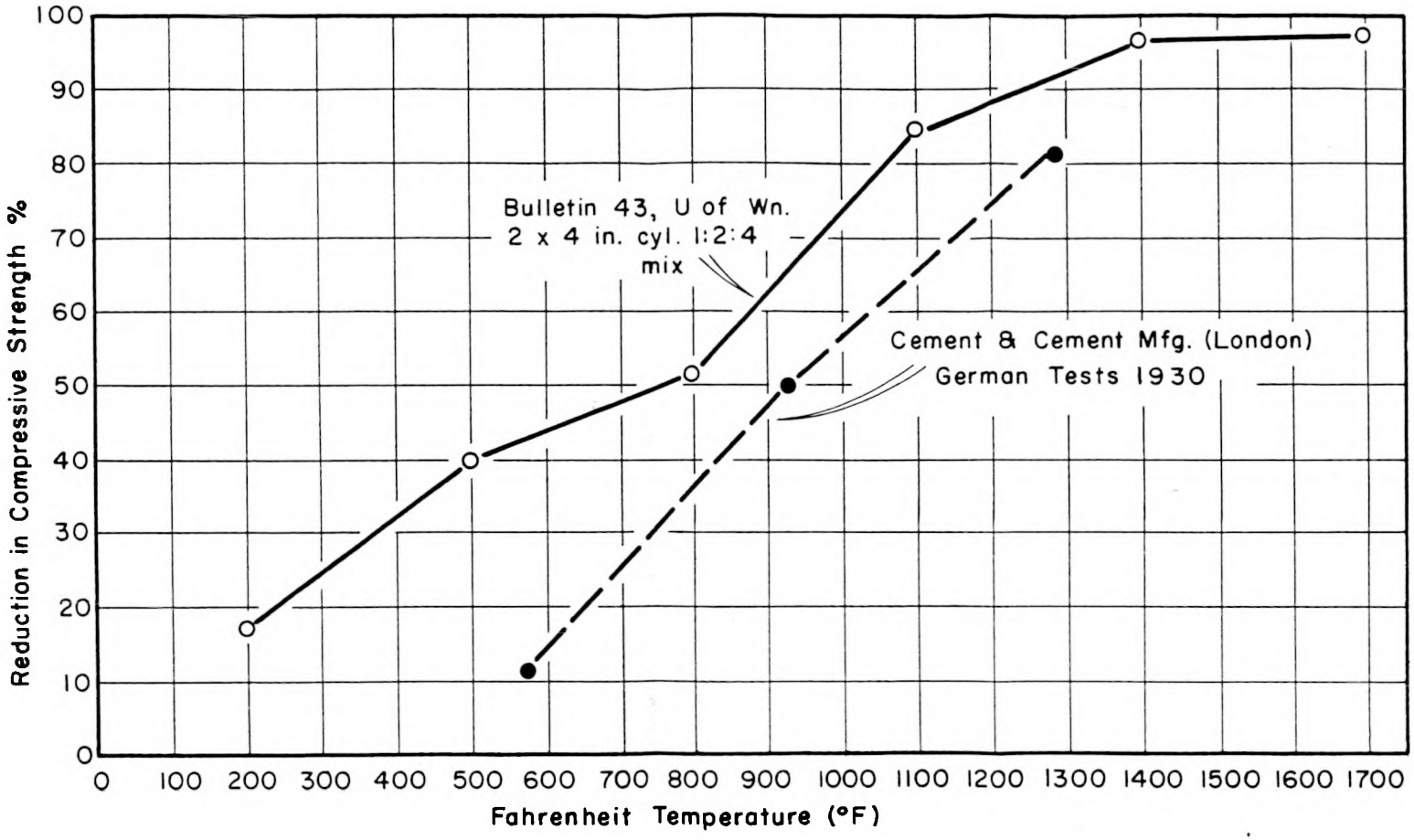


FIGURE 12
EFFECTS OF HIGH TEMPERATURE
ON THE
COMPRESSIVE STRENGTH OF CONCRETE

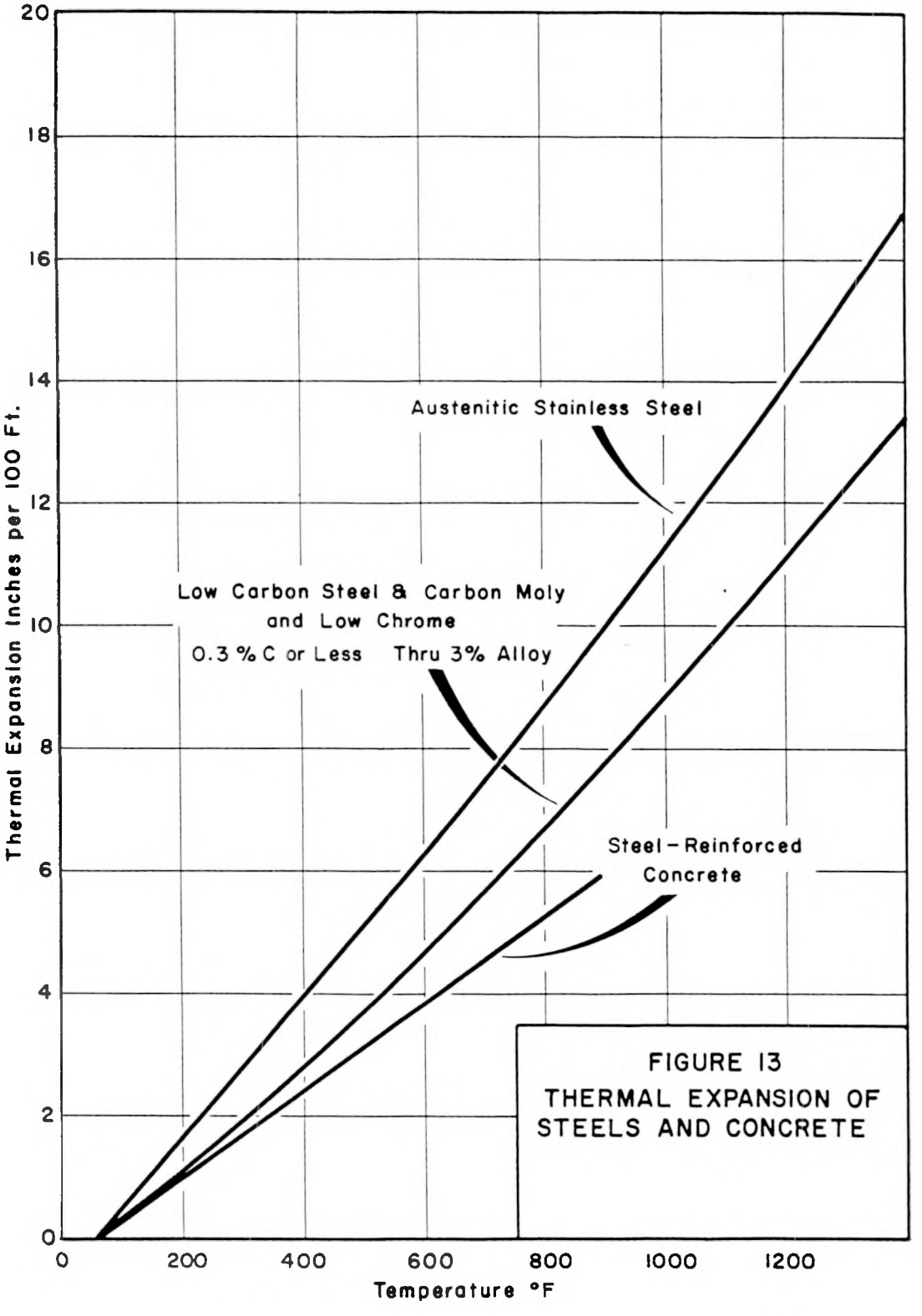
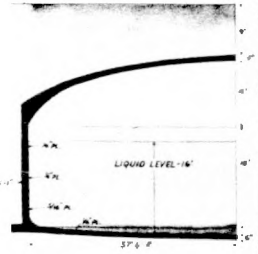
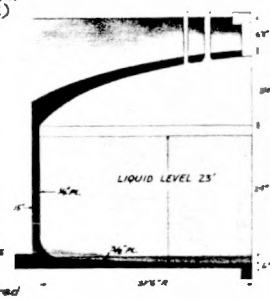


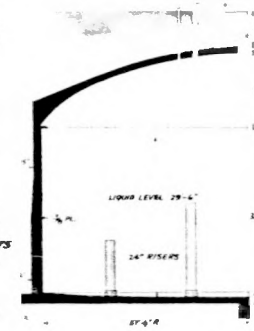
FIGURE 13
THERMAL EXPANSION OF
STEELS AND CONCRETE

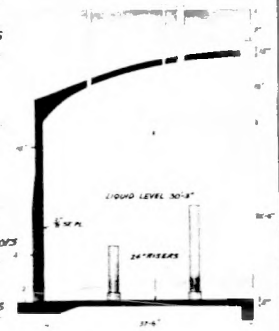
FIGURE 14
BASIC DESIGN CRITERIA FOR HIGH LEVEL RADIOACTIVE STORAGE TANKS

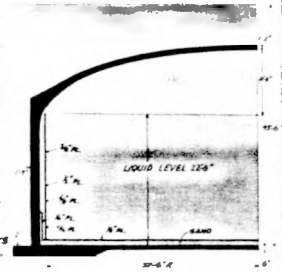
WASTE CHARACTERISTICS	241-U, T, B, C, BX 533,000 GAL.	241-S, BY, TX, TY 750,000 GAL	241-SX 1,000,000 GAL	241-A 1,000,000 GAL.	FUTURE TANK
SPECIFIC GRAVITY	1.2	1.25	1.35	2.0	PUREX 2.0 (Sludge Sp Gr)
MAXIMUM TEMPERATURE	220°F	220°F	250°F	250°F	500°F
HEAT EVOLUTION (PER TANK)	NEGLIGIBLE	Less than 10^6 BTU/HR (0.15 BTU/GAL/HR.)	10^6 BTU/HR (1 BTU/GAL/HR	10^7 BTU/HR (10 BTU/GAL/HR	150 BTU/GAL/HR
BOILING PERIOD	NONE	NONE	1 TO 5 YEARS	5 TO 10 YEARS	25 to 50 Years
VAPOR PRESSURE	NONE	NONE	NONE	NONE	Equal to the max. Hydrostatic Press at the Bottom of a filled tank
FISSION PRODUCT CONCENTRATION	4000 GAL/T	4000 GAL/T	1800 GAL/T ~ 900 GAL/T	500 GAL/T 80 GAL/T	150 GAL/T ~20 GAL/T
pH	8 to 10	8 to 10	8 TO 10	8 TO 10	ALKALINE
CORROSION	Concrete Dome Exposed to Vapors	Concrete Dome Exposed to Vapors	Concrete Dome Exposed to Vapors	Concrete Dome Exposed to Vapors	Concrete Tank Everywhere Protected by Carbon S.
SLUDGE	No Control Required of Sludge Temp.	No Control Required of Sludge Temp.	No Control of Sludge Temperatures	No Control of Sludge Temperatures	Temp. Control with Carbon Steel Cooling Coils
CIRCULATION	NONE	NONE	Air-Lift Circulators (Non Replacable)	Air-Lift Circulators (Non Replacable)	Air-Lift Circulators (Replacable)
INTEGRITY	100 Year Life	100 Year Life	Not Predictable with Present Knowledge of Waste Characteristics	Not Predictable with Present Knowledge of Waste Characteristics	50 Year Min.
RADIATION					
SPECIFIC GRAVITY	2.0	1.2	2.0		REDOX 2.0 (Sludge Sp Gr)
MAXIMUM TEMPERATURE	500°F	300° to 350°F	500°F		500°F
HEAT EVOLUTION (PER TANK)	2.5×10^7 BTU/HR (33 BTU/GAL/HR.	4 BTU/GAL/HR	2.5×10^7 BTU/HR (33 BTU/GAL/HR		10 BTU/GAL/HR.
BOILING PERIOD	8-15 YEARS	NONE	8 to 15		25 YEARS MAX.
VAPOR PRESSURE	Equal to the Max. Hydrostatic Press. at Bottom of Tank (19.5 psi)	NONE	Equal to the Max. Hydrostatic Press. at Bottom of Tank (17.6 psi)		Equal to the Max. Hydrostatic Press. at the bottom of a filled tank.
FISSION PRODUCT CONCENTRATION	500 GAL/T 80 GAL/T	—	500 GAL/T 80 GAL/T		300 GAL/T ~100 GAL/T
pH	8 to 10	ALKALINE	8 TO 10		ALKALINE
CORROSION	Concrete Dome Exposed to Vapors	Concrete Tank Everywhere Protected by Carbon Steel	Concrete everywhere protected By Carbon Steel		Concrete Tank Everywhere Protected by Carbon S.
SLUDGE	No Control of Sludge Temp.	Cooled With Carbon Steel Cooling Coils	No Control of Sludge Temperatures		Temp. Control with Carbon Steel Cooling Coils
CIRCULATION	Air Lift Circulators	NONE	Air-Lift Circulators		Air-Lift Circulators (Replacable)
INTEGRITY	10 to 20 Years	1000 Year Life	25 TO 50 YEARS		25 Years Min.
RADIATION					

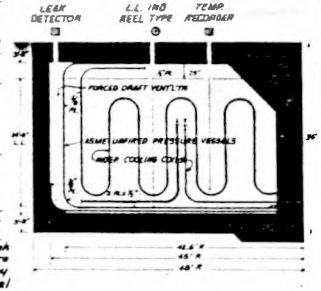


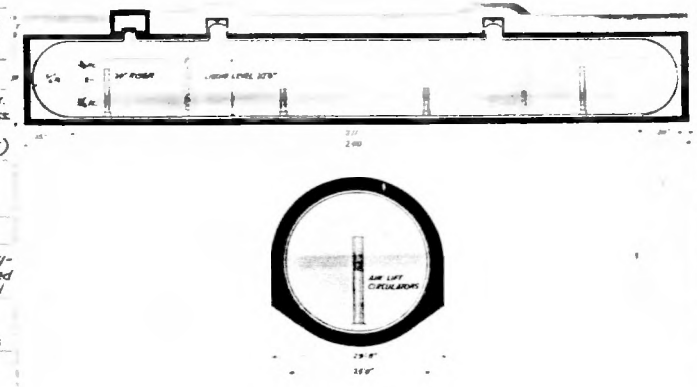










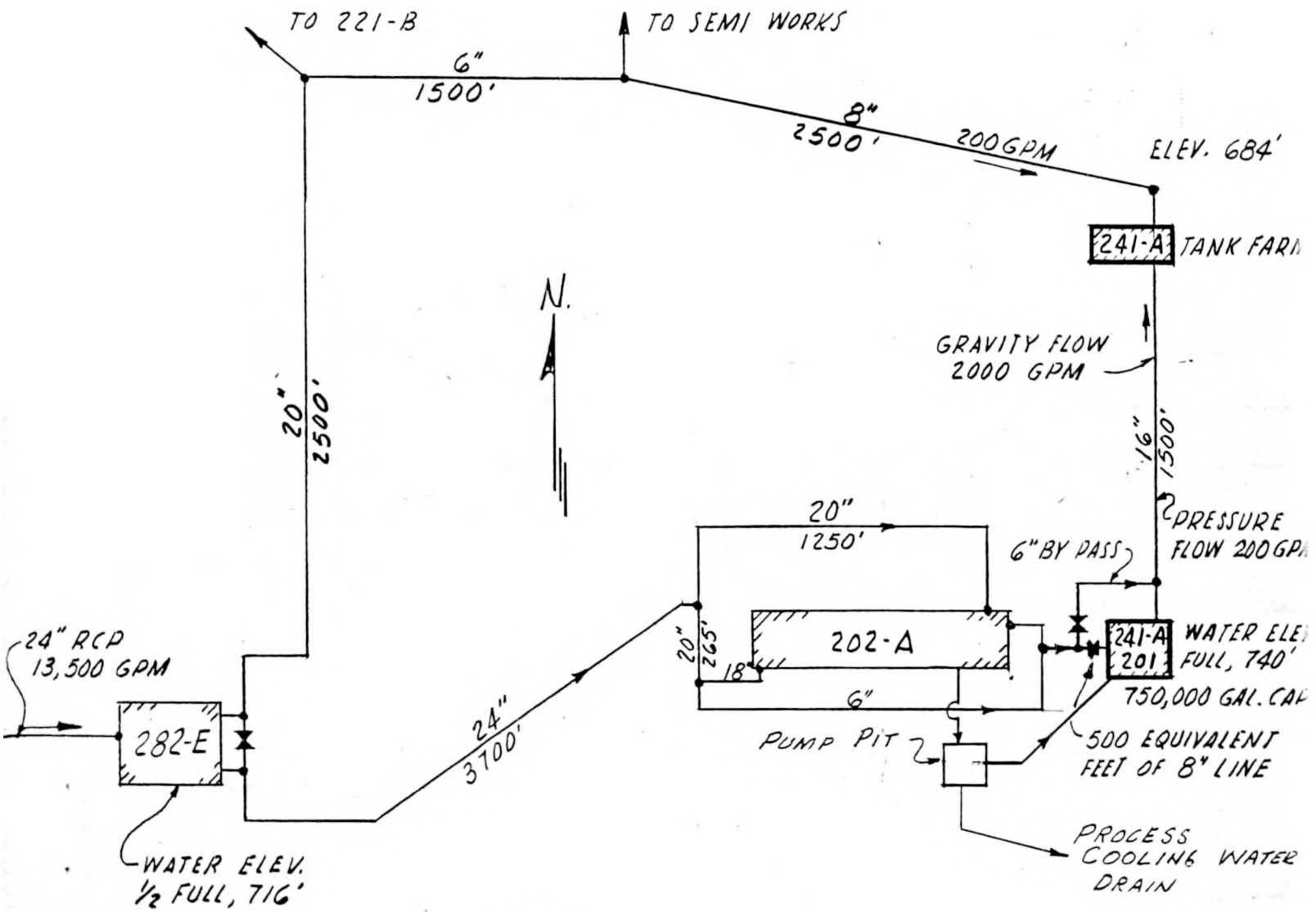


VERTICAL TANK
SK-2-2118
700,000 GAL.

DUPONT DESIGN
S R P
1,000,000 GAL.

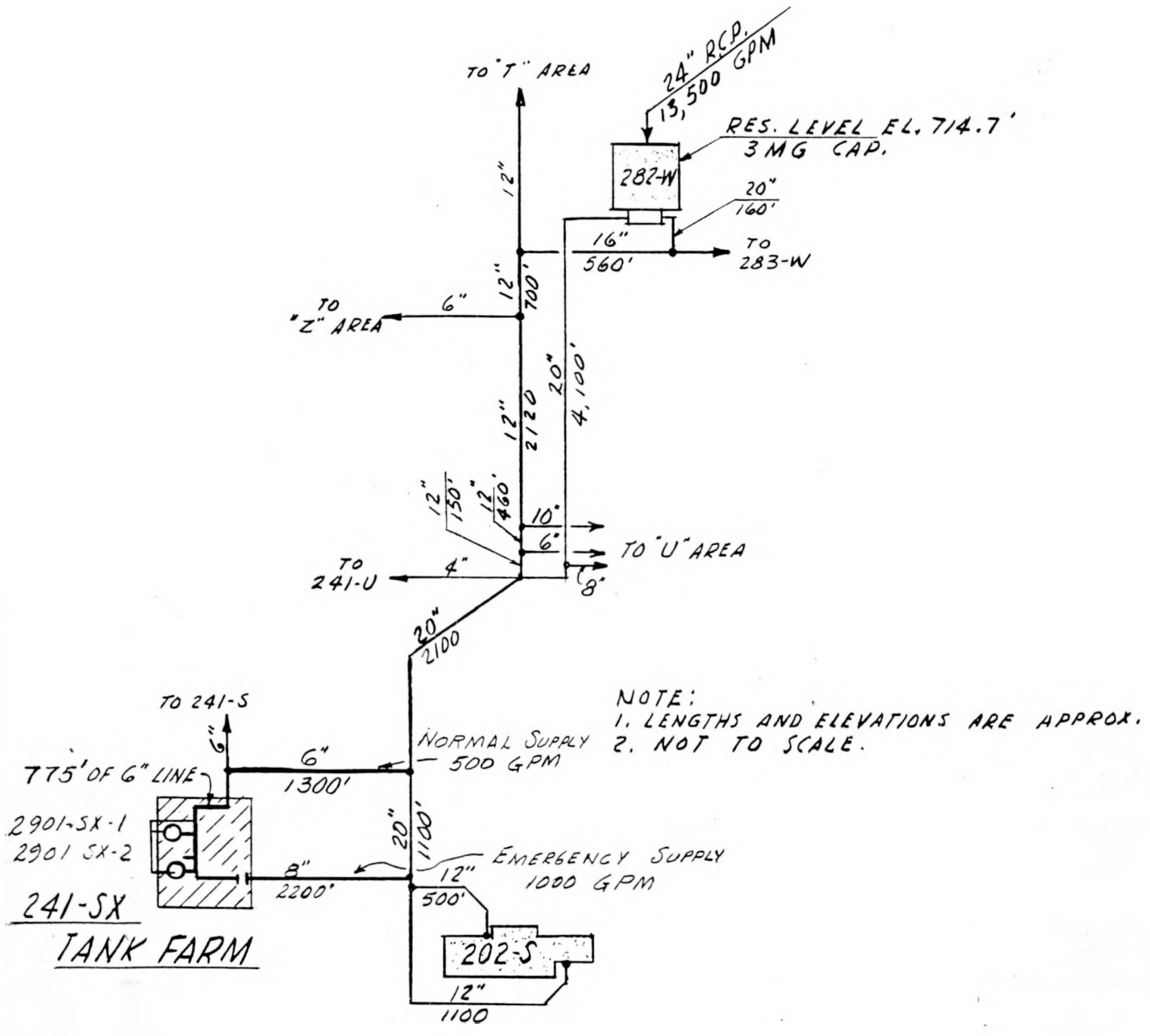
HORIZONTAL TANK
SK-2-2702
750,000 GAL.

FIGURE 15
SCHEMATIC DIAGRAM OF THE 241-A RAW WATER SUPPLY



NOTE:
1. LENGTHS AND ELEVATIONS ARE APPROX.
2. NOT TO SCALE

FIGURE 16
SCHEMATIC DIAGRAM OF THE 241-SX RAW WATER SUPPLY



LEGEND

PS – PRESSURE SWITCH
MS – MANUAL SWITCH
TDRC – TEMP. DIFFERENTIAL RECORDER CONTROLLER
– SOLENOID VALVE
– AIR OPERATED VALVE
N.O. – NORMALLY OPEN
N.C. – NORMALLY CLOSED

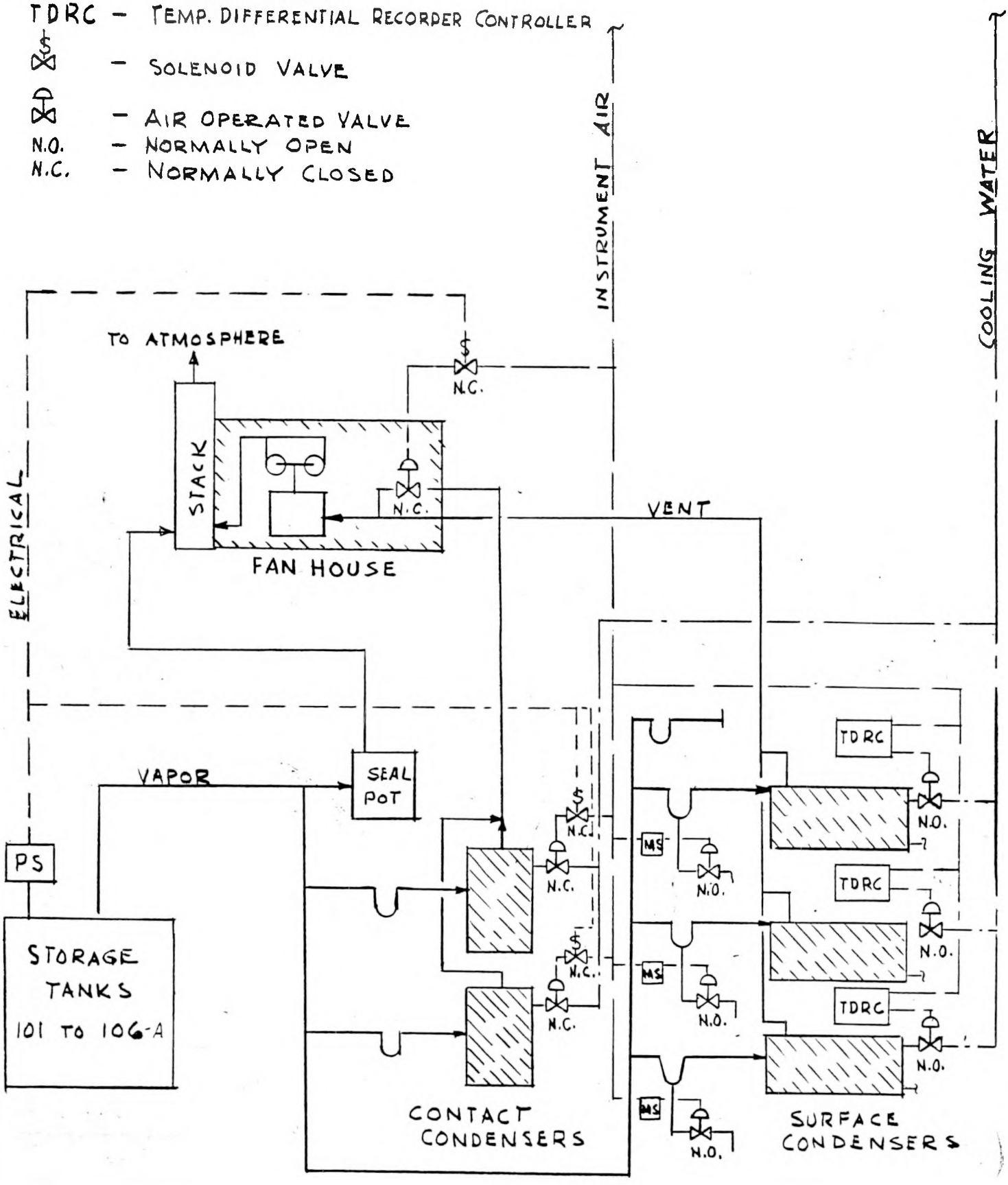


FIG. 17 PUREX 241-A CONDENSER CONTROL INSTRUMENT DIAGRAM

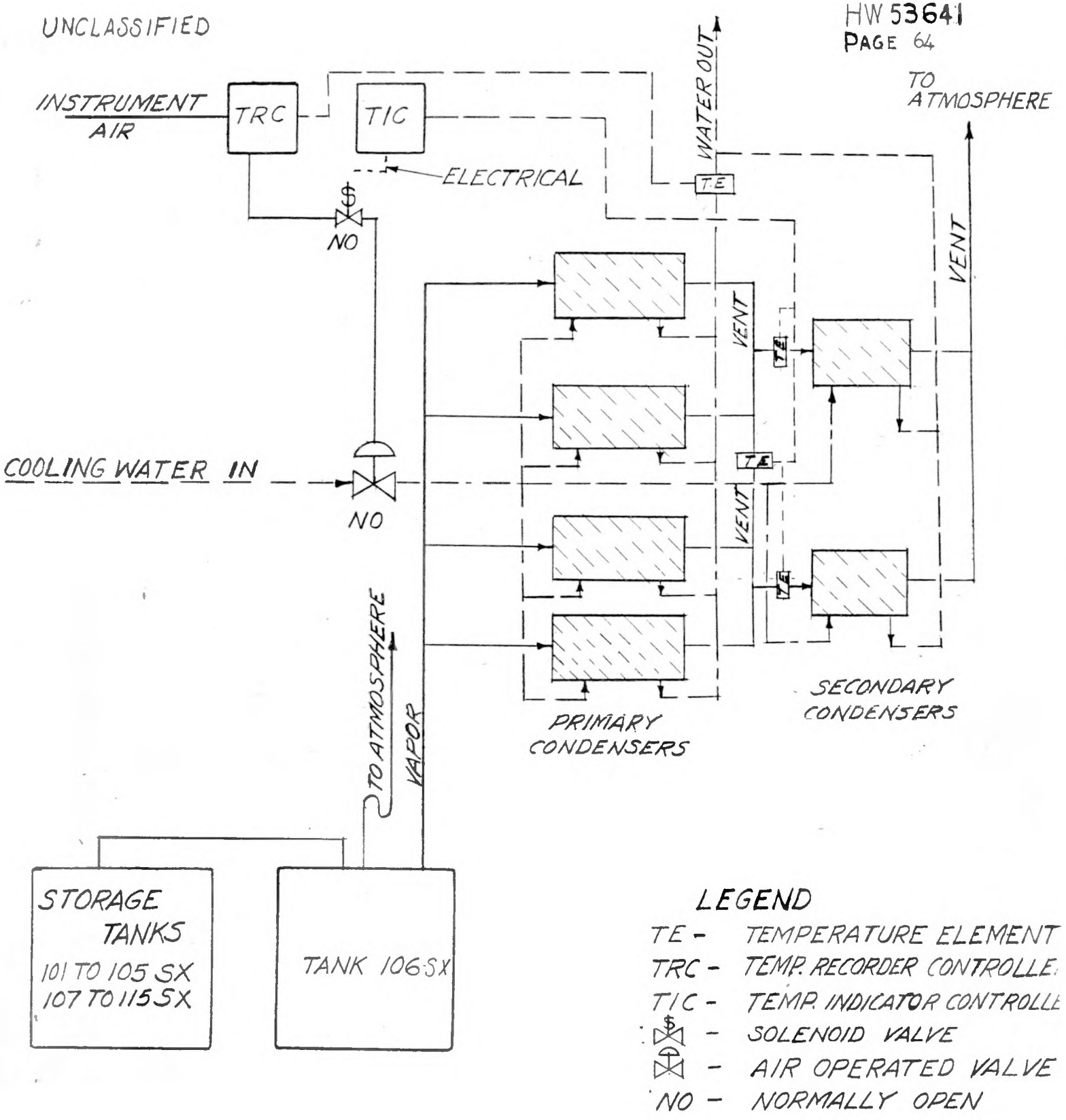


FIG. 18. REDOX 241-SX-CONDENSER CONTROL INSTRUMENT DIAGRAM