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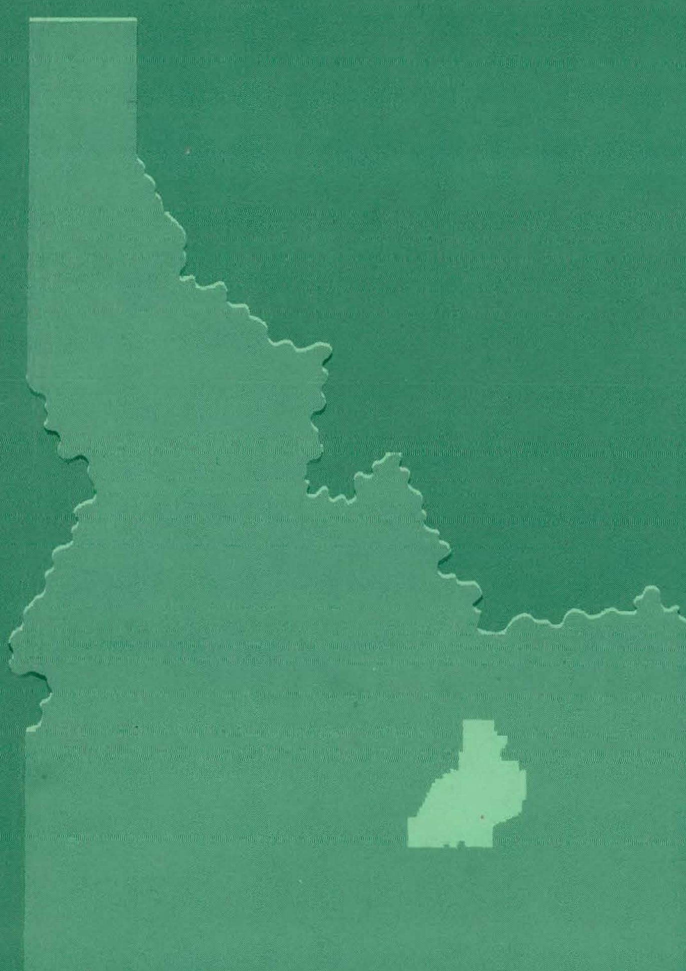
HAZARDS EVALUATION OF PROPOSED SITE FOR ETR II

D. R. deBoisblanc
R. J. Nertney
L. H. Jones

August 18, 1960



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(now designated ATR)

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ABSTRACT

This report is concerned with an analysis of the suitability, from the point of view of mutual interactions with existing reactors, of the proposed site of the ETR II on the National Reactor Testing Station on the northwest corner of the present MTR-ETR complex. The various modes of interaction between the three reactors have been analyzed in terms of the experience that has been gained in the operation of the MTR and ETR in close proximity over the last three years.

Extensive measurements have been made of the radioactive material distributed in the vicinity of the MTR and ETR reactors and their stacks during normal operation and upon occurrences of unexpected incidents. These measurements cover a continuous period of three years and cover the types of meteorological conditions which prevail at this particular location.

From the analysis of the foregoing data, it is concluded that ETR II can be located and operated in the proposed location with negligible interference with the present reactors, or loss of ETR II operating time due to events occurring in the MTR and ETR.

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HAZARDS EVALUATION OF PROPOSED SITE FOR ETR II

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I. INTRODUCTION

In the selection of a site for the construction of ETR II, the merits of a location just adjacent to the present MTR-ETR complex were explored. The sharing of certain existing facilities, which would have to be provided at any new site, the availability of technical and operating personnel with an abundance of know-how in test reactor technology, and the existence of an adequate and established degree of separation from surrounding populace favorably affected the construction cost and general feasibility of the proposed reactor. This led to a decision by the U. S. Atomic Energy Commission to construct ETR II adjacent to the MTR.[1] This report is aimed at providing information as to the suitability of so situating this new test reactor from the point of view of the mutual interactions of these plants due to the radioactive material issuing from either of the three reactors during normal operation; or in the event of an incident to either reactors or experiments causing an anomalous release of radioactive material.

The MTR and ETR have been operating for several years in such proximity and through the monitoring programs which have been carried out by Health Physics personnel, radiation levels from reactor effluents at various points have been continuously recorded covering all types of weather conditions which prevail at this site. By interpretation of these data in terms of the effect of adding a third reactor it has been possible to predict the interactions to be expected.

For reference, information is presented covering the meteorology and physical environment of the National Reactor Testing Station in general and the MTR-ETR site in particular. This information has been taken from the most recent sources available.

A description of each of the existing plants is presented with a discussion of the types and frequency of releases of radioactive material. In this manner the reader is acquainted with the sort of incidents which occur despite the elaborate safeguard procedures exercised by the operating staff.

A description is then given of the new reactor and plant with emphasis on those aspects which are pertinent either to the probability of an incident in this new reactor and its experiments, or to the elements which might cause any other type of operational interference among the reactors.

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1. Letter A. J. Vander Weyden, Acting Director, Division of Reactor Development to A. C. Johnson, Manager, Idaho Operations Office dated June 10, 1960.

II. MTR-ETR COMPLEX

A. The MTR-ETR Site

The MTR-ETR reactor lies in the west-central part of the NRTS, approximately halfway between the Central Facilities area to the south and the Naval Reactor Facilities to the northeast.

The entire NRTS is on flat plain bounded to the west, north and east by mountains. Elevation at MTR-ETR is approximately 4,925 ft. Soil is sand and gravel for an average of 40 ft followed by 2 to 5 ft of clay, then a thick level formation of dense lava rock.

Rainfall averages 7.5 in. per year, with most precipitation occurring in winter and spring. Three streams flow into the NRTS, with all three sinking into the ground. Big Lost River flows just south of MTR-ETR then turns north to sink in an area south of ANP. During most years, all streams are dry on the NRTS except during spring runoff.

Underground water level is at approximately 450 ft below grade.

The report, IDO-12015, "Diffusion Climatology of the National Reactor Testing Station", published in April 1960, summarizes ten years of meteorological research on local weather conditions. It is used as a reference for all wind and diffusion information. The figures showing wind roses and other data are taken from this report.

This report is concerned mainly with very local diffusion problems, i.e., areas within a half mile of the reactor stacks. Problems concerning hazards to other reactor areas and to populated areas adjacent to the NRTS are covered adequately in MTR and ETR hazards reports[2,3] and must ultimately be covered in a hazards summary report for ETR II.

Three separate local wind conditions at NRTS must be considered in evaluating hazards caused by evolution of radioactive materials from the reactor stacks; lapse, inversion, and fumigation. Generally speaking, lapse conditions occur during daylight hours, with predominately southeast winds. Atmospheric diffusion is good, although isolated puffs of stack effluent can hit the ground at some distance from the stack.

Inversion conditions set in during the evening hours, accompanied by a wind shift to northeast. This northeast wind at night and southwest wind during daytime is primarily due to the orientation of the Snake River Valley and its surrounding mountains. High air activity caused by stack effluents is rarely experienced during these periods.

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2. "Research Reactors", Chapter 3, United States Atomic Energy Commission, McGraw-Hill Book Company, Inc., 1955.

3. S. McLain and R. K. Winkleblack, "Hazards of the Materials Testing Reactor", Argonne National Laboratory, ANL-SM-236, June 15, 1950 (Classified report).

Shortly after daybreak, solar heating of the ground breaks up the inversion, creating a temporary situation where lapse conditions exist to an altitude slightly higher than the reactor stacks. Stack effluent can reach the ground close to the stack in relatively undiluted form, creating the most hazardous local weather condition. This condition is accompanied by light, variable wind or calm and, apparently, the wind direction shifts clockwise from northeast to southwest. Almost all instances of high air activity in the MTR-ETR area occur during this period.

Figures 1, 2 and 3 summarize the weather conditions at this site. Figure 1 shows variation of wind with time of day. Figure 2 shows seasonal variation of wind during lapse and inversion conditions. Figure 3 shows time of fumigation at various times during the year. These figures are the sources for the weather conditions discussed in other parts of this report.

B. The MTR-ETR Area

Locally, the MTR-ETR area can be divided into two parts, limited area and reactor area. The limited area was originally planned to house all nonnuclear equipment. The reactor area contains offices and warehouses in addition to MTR, ETR, and three zero power reactors (RMF, ARMF, and ETRC) Figure 4 gives the location of all buildings, including those proposed for ETR II.

The limited area, lying in the northern half of the MTR area, contains utilities serving both MTR and ETR I. These include transformers and switchgear, wells, raw water storage and pumphouse, demineralizer, steam plant, fuel oil and diesel oil storage, MTR cooling tower, and cooling tower pump house.

Raw water may be drawn from the subterranean water table, approximately 450 ft below grade, by any of three wells having a combined capacity of 7,700 gpm. It is then stored in three 500,000 gal ground level storage tanks from which pumps can draw water for site usage. Some distribution pumps supply the 12 in. fire mains, others send water to the MTR raw water system via an overhead storage tank. Still others supply the ETR cooling tower evaporative losses.

The demineralized water system ion-exchange resin beds purify the water destined for canals, reactor cooling and experimental usage. Both cations and anions are removed in separate resin beds so that water of high purity is produced. Pumps send the water to both reactors and canals as necessary, and to numerous experiments for both makeup and cooling.

The largest short term demand for demineralized water is that required for reactor flushing at each shutdown. 100,000 gal at 2,000 gpm are needed for an ETR flush. 50,000 gal at 1,000 gpm are used for an MTR flush. Total storage capacity is 200,000 gal.

Two fuel oil storage tanks and two diesel oil storage tanks are located along the north side of the limited area. Diesel oil is used for MTR and ETR site-generated electrical power and for the oil-fired experimental air heaters at ETR. Fuel oil is used in the steam plant.

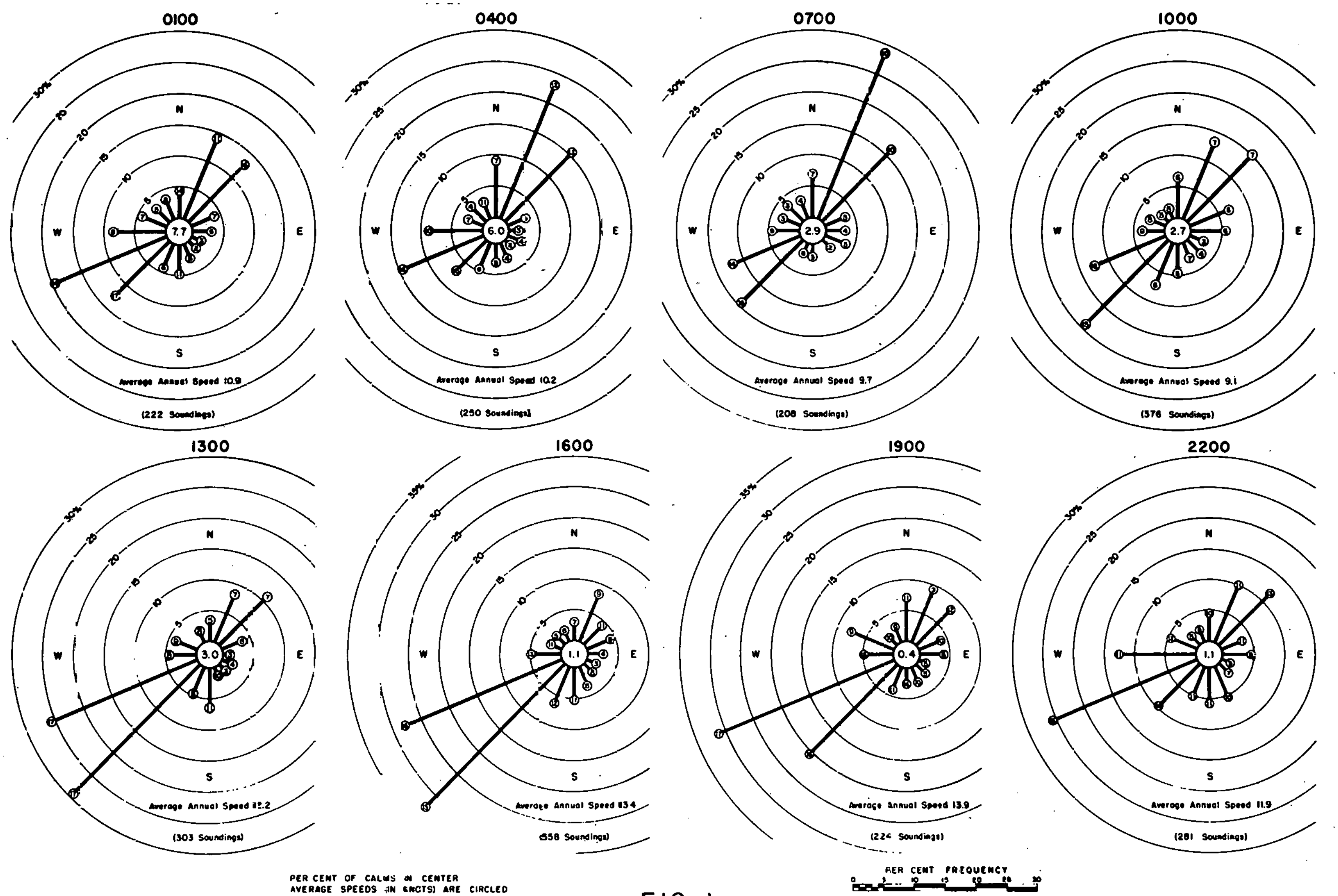

FIG. 1

WIND ROSES AT SCHEDULED SOUNDING TIMES (MST) - 500 FOOT LEVEL

Pilot Balloon Soundings for the Two Year Period Sept., 1950 through Aug., 1952 Central Facilities (WBO)

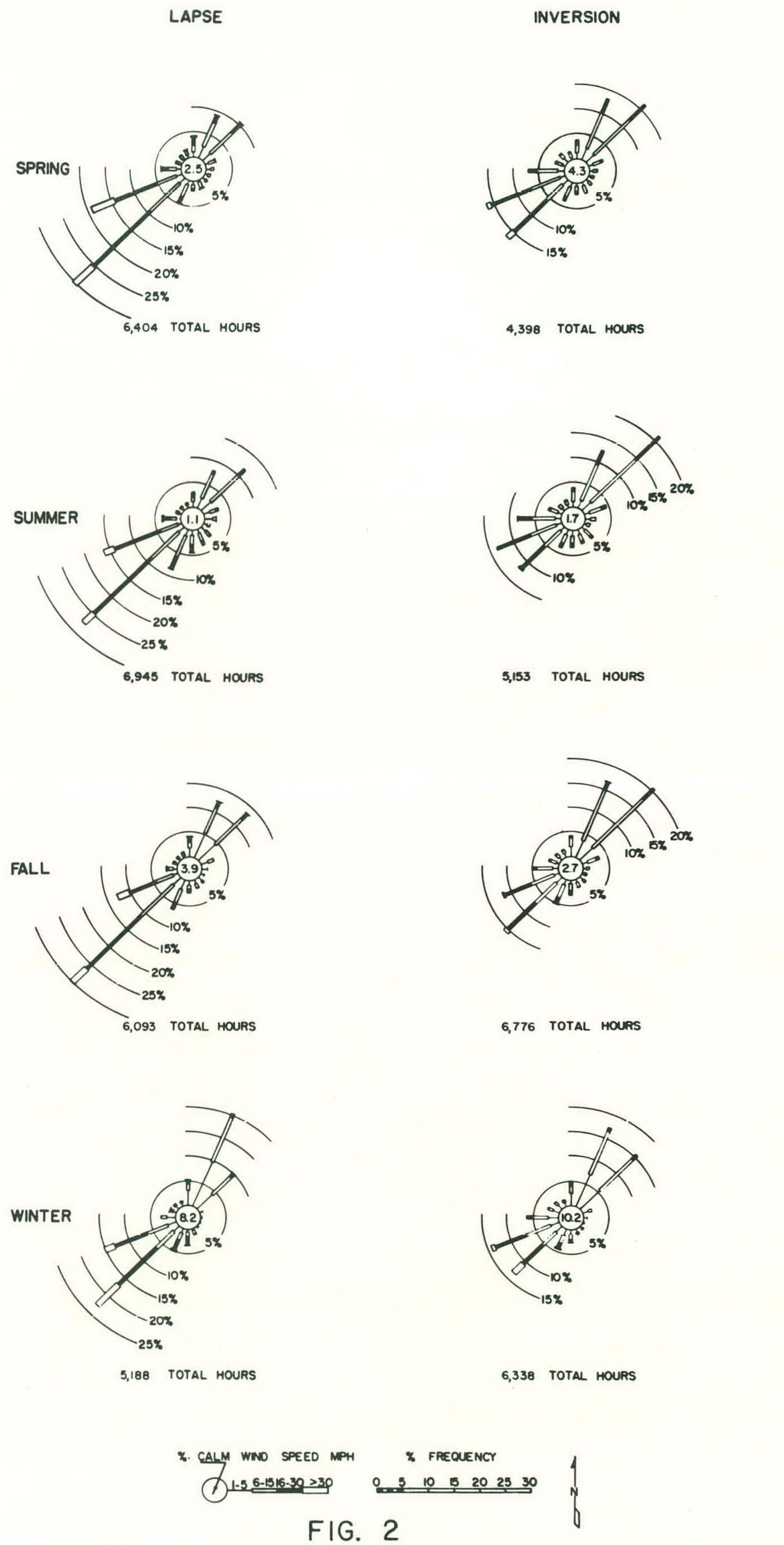

FIG. 2

WBO 250 FOOT LEVEL WIND ROSES — 1952 THROUGH 1956

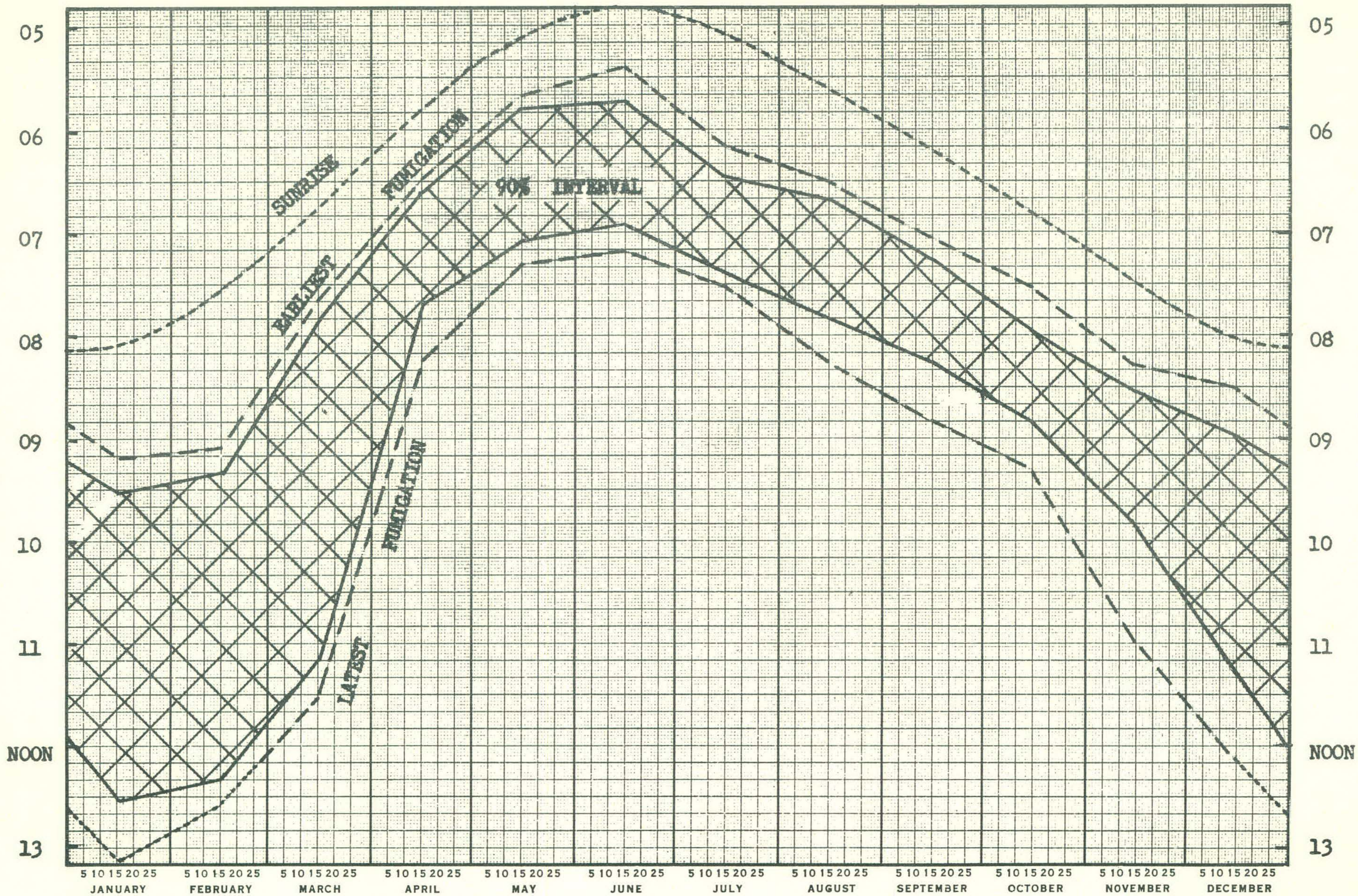

FIG. 3

TIME OF FUMIGATION, WBO. JULY, 1951 THROUGH DECEMBER, 1953

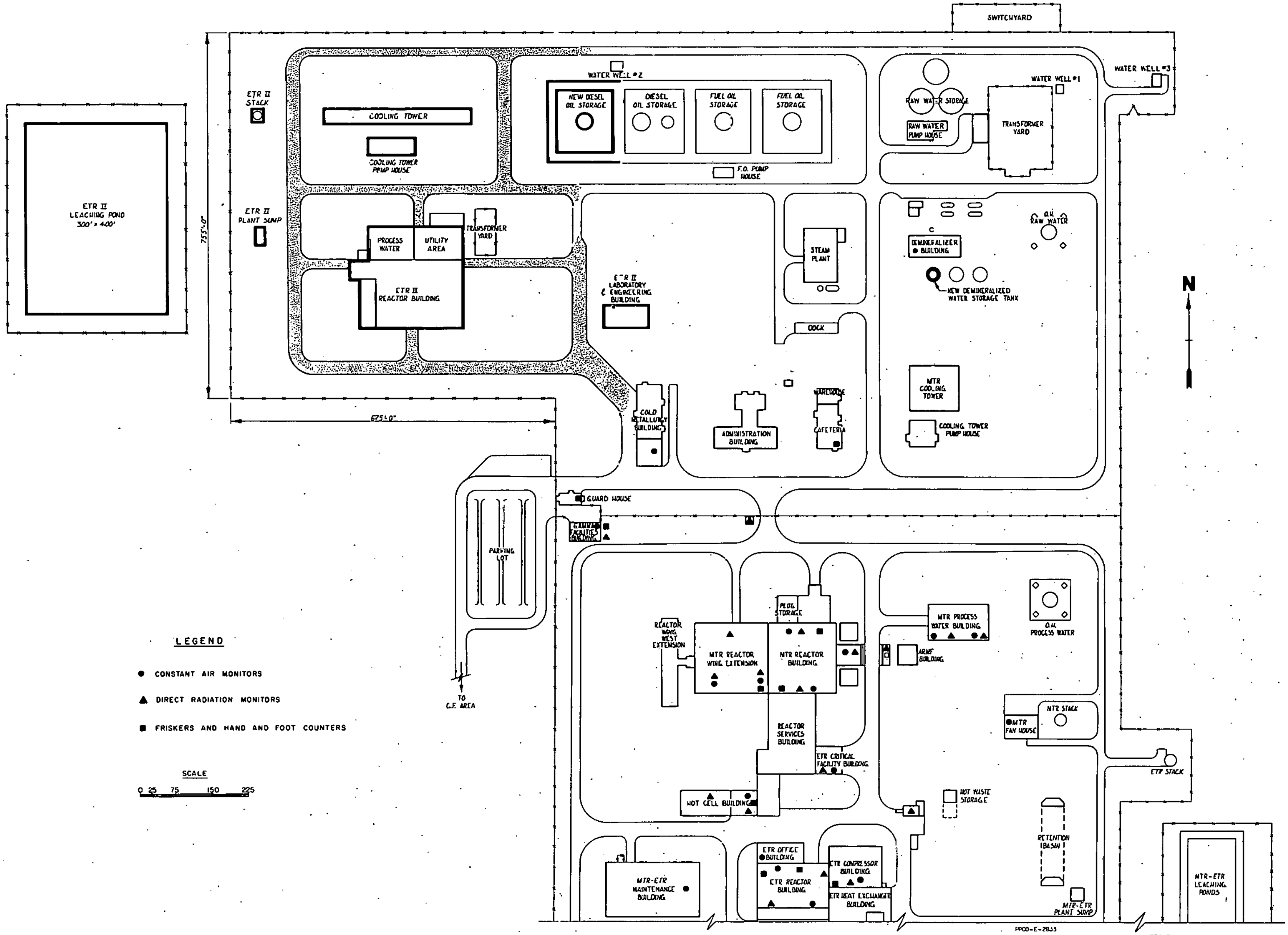

FIG. 4
SITE PLAN

Steam for heating and process usages has been supplied by two 17,500 lb per hour boilers at 135 psi. An additional 17,500 lb per hour boiler is being installed. Most of this steam is used for building heat, although 600 lb per hour is needed in the MTR process water flash evaporator.

Four compressors, three 300 cfm and one 200 cfm, furnish air for the area at 165 psi to two receivers of about 1300 cubic ft capacity. A large portion of the air passes through silica gel dryers where its dew point is reduced to $-40^{\circ}F$. This is used for all pnuematic instruments in the area. If receiver air pressure drops to 115 psi, plant air is automatically shut off. One compressor is operated from emergency power, making the instrument air system independent of commercial power.

A 750 kva, 2400 volt emergency power generator driven by an 880 horsepower diesel engine is located in the steam plant building. This is automatically started on commercial power failure, and takes about fifteen seconds to reach full capacity. Emergency power from this source may be used in cases where a continuous outage cannot be tolerated, but a fifteen second outage is not important. Critical uses include charging the batteries on the MTR failure-free electrical system and on the MTR experimenter's failure-free electrical system, and operating the MTR emergency air compressor.

C. <u>The MTR Reactor Building Area</u>

The MTR is located in a reactor building which contains the reactor structure itself plus extensive experimental facilities and a storage canal. The main building is 130 ft sq and 80 ft high, with a 17 ft high basement.

The reactor shielding structure is located in the center of the building and is approximately 35 ft x 35 ft x 25 ft high. The top head of the reactor is removable to provide access to the reactor core for refueling and experiment handling. Most irradiated material leaves the reactor tank through a discharge mechanism, passing downward through the subpile room to the canal.

Irradiated samples from horizontal beam holes are pulled out horizontally into shielded containers. All experimental facilities which are located outside the reactor are located in shielded cubicles in the basement. One single cycle gas loop discharge line runs through the south basement area to the southeast corner of the building, then goes to the stack in an unshielded line twelve feet above ground.

The MTR canal, 8 ft wide by 18 ft deep extends 140 ft eastward from the west wall of the reactor. It contains spent fuel, irradiated samples and associated equipment. The east end of the canal is used by the RMF.

The RMF is operated by Phillips Petroleum Company in a program of budgeted research. An MTR pool-type reactor, its operating power is essentially zero.

An advanced RMF is presently being installed in a new building just west of the present RMF.

D. The ETR Reactor Building Area

The ETR is housed in a building 112 ft x 136 ft x 58 ft high above ground with two complete floors below grade. The first basement, called the console floor, houses all experiment control panels. The second basement contains all heavy and radioactive experimental equipment housed in heavily shielded concrete cubicles.

The reactor main floor is relatively clear of plant and experimental equipment. The reactor top is about 8 ft above floor level. A thirty ton crane and a five ton crane are available to handle heavy experiment and reactor equipment. The tee shaped canal consisting of a 35 ft long working canal and a 60 ft long storage section, is 20 ft deep.

The irradiated reactor fuel elements and smaller experimental equipment are moved underwater from the reactor tank to the canal. Major experiments are usually pulled upward from the experimental tubes inside the reactor into heavily shielded casks.

A building attached to the east end of the reactor building contains air compressors and heaters and several water systems for experimenter use. It also contains four 15,000 gpm pumps, four banks of heat exchangers, and a bypass demineralizer system for the reactor water.

Reactor water flows at a rate of 60,000 gpm, approximately 110°F, and 200 psi reactor inlet pressure. All nuclear heat is transferred through heat exchangers to a secondary water system which exchanges the heat to the atmosphere through a series of nine cooling tower loops.

The ETR uses two sources of emergency power. One consists of a bus loaded by one 1,000 kw diesel generator or by two 500 kw diesel generators. Normally 80 per cent of the bus load is fed from the diesels and 20 per cent from commercial power. If either the diesel or the commercial power fails, the reactor is scrammed. If the diesel fails, commercial power feeds the diesel bus. If commercial power fails, the diesel power continues to operate. Another 250 kw system is operated by battery through an invertible motor-generator set after diesel failure.

Careful distribution of critical loads among the three electrical systems renders the probability of complete loss of power on any critical load negligible.

E. Other Areas

The ETRC, a low power swimming pool type mockup of the ETR core, is located in a building attached to the southeast corner of the reactor services building. It is used for measuring reactor physics properties of the ETR needed for reactor operation or design of experiments.

The MTR process water building contains all out-of-reactor components of the process water system for the MTR. The reactor exit water passes to the process water building through a 36 in. line and enters the 17,000 gal seal tank. Water is drawn from the seal tank to the flash evaporators, where it is at a pressure corresponding to 100°F water. A portion evaporates and the remainder, cooled by the evaporation, falls into the sump tank. Three 10,000 gpm pumps force the water from the sump tank into a 150,000 gal overhead working reservoir, from which it flows by gravity into the reactor.

The flash evaporators both cool and degasify the bulk of the reactor water. The water that evaporates is condensed by cooling tower water flowing through condenser tubes in the evaporator. Off-gases are vented to the MTR stack. The room housing the sump and seal tanks and the evaporator is also vented to the stack.

The equipment in the process water building can collect some very hot sources from the reactor water. However, it is shielded to handle any foreseeable accident.

The overhead working reservoir can act as a radiation source if reactor water is sufficiently contaminated or if an irradiated piece of material passes through the water system and lodges in the reservoir. The working reservoir is 170 ft high and located in an isolated area, minimizing the consequences of such an incident.

The MTR reactor wing extension building houses laboratories and offices for technical people working at MTR and ETR. The basement contains all switchgear for the MTR and associated equipment. Here, all electrical power is reduced from 2,400 volts to the working voltages (usually 440 volts, three phase or 110 volts, single phase). In this area, two failure-free power systems operate- one for the essential reactor instrumentation and controls, and one for experimental equipment.

The reactor system is composed of eight machines (four motors and four generators) so arranged that when commercial power fails, the connected electrical load is unaffected. This is accomplished by having batteries normally floating on the system, which drive the dc motor in case of power failure. This system furnishes power to reactor controls and reactor instrumentation.

The experimental motor generator set is rated at 125 kw and is an invertible system. Batteries on this system will supply power for thirty minutes at full load.

Both of the above systems normally operate from commercial power, but can be connected to diesel power.

The MTR ventilating system takes in air from a location a short distance southwest of the MTR reactor building. The reactor building, reactor basement and reactor service building have one set of filters and steam heaters. From these areas, the air is drawn into the reactor top, passes through the reactor graphite, then exits up the MTR stack.

F. The MTR Liquid Waste System

The MTR liquid waste system is designed so that all effluent water is monitored before disposal. Final disposal is into a leaching pond, where it enters the area's underground water system. The radioactivity content of all water released to the leaching pond must be below the levels specified by the Idaho Operations Office.

The MTR liquid waste system can be broken down into four parts; catch tanks, hot storage tanks, retention basin, and leaching pond.

Four 1,056 gal stainless steel catch tanks located a short distance southwest of the reactor building collect all contaminated waste in the area. One receives water from the reactor hot drain system, a second is on standby. A third tank receives waste from the vent scrubber and hot sinks in the laboratories while a fourth is on standby.

Two 8,700 gal stainless steel glass lined hot waste tanks (two additional tanks are being installed) receive water that is too active for disposal. It may be stored in these tanks until radiation level reaches an acceptable value. It may then be drained to the retention basin or to the leaching pond. A system to transport extremely hot wastes out of the MTR-ETR area for concentration and permanent storage is now under construction. These hot waste storage tanks, the retention basin, and the leaching pond are used by both MTR and ETR.

The retention basin, two underground concrete tanks each 130 ft long, 20 ft wide, and 20 ft high, is baffled so that inlet water is uniformly delayed before leaving the tanks. One tank is kept full at all times, having a normal throughput of 180 gpm. The other is kept partially empty in order to receive flush water from either reactor system.

The leaching ponds consist of two open pits 130 ft wide and 240 ft long, with a capacity of 3,000,000 gal. Water leaches into the underground water table from this point.

G. The MTR Gaseous Waste System

The MTR gaseous waste system may be separated into three parts; the reactor air cooling system (which also serves the experimental cubicles and experiment venting needs), the contaminated air system serving the laboratory hoods and glove boxes, and one experiment air line that enters the stack plenum chamber.

Air from the main reactor floor is drawn through filters into the reactor graphite zone then out to the fan house through underground ducts. Normal flow is 1,900 lb per minute, with two blowers handling the load and a third on standby. Two low capacity auxiliary blowers are used during commercial power outages. One operates on diesel power and the other by gasoline engine.

Since the reactor graphite area operates at a significant thermal neutron flux level, the argon naturally occurring in the air is activated. Maximum argon-41 activity released is about 250 curies per day from the MTR stack.

It is vital that air flow be maintained through the reactor during periods of reactor operation in order to cool this graphite. The reactor graphite must also be at negative pressure during shutdown, to prevent spread of irradiated graphite powders into the occupied area surrounding the reactor.

One experiment discharges up to 360 lb per minute of air at up to 300°F into the plenum chamber of the stack. This system is rigidly controlled to prevent excessive fission products from entering the stack.

The MTR stack, located southeast of the MTR process water building, is 250 ft high. Constructed of re-enforced concrete, its inside diameter is 10 ft at the base and 5 ft at the top.

All stack effluent is monitored for both particulate and gaseous activity.

H. ETR Liquid Waste System

The ETR liquid waste system is similar to the MTR system, with the hot storage tanks, retention basin, leaching pond, and resin bed common to both facilities.

Cold drain effluent is discharged directly to the retention basin sump for disposal to the leaching bed.

Warm drain effluent is accumulated in the warm drain sump tank, a 5,000 gal tank located below the ETR basement. Here it is collected, diluted, and sampled. Water can be transferred from the warm sump tanks to the MTR hot waste storage tank or to the retention basin, depending on activity level.

Hot drain effluent is accumulated in a 500 gal tank located below the ETR basement. After sampling, it can be transferred to the MTR hot waste storage tanks or to the retention basin.

A 1,000 gal hot catch tank has been installed by an experimenter in parallel with the existing 500 gal hot catch tank. Effluent can be routed to either the hot sump tank or into a shielded tank truck for shipment to the Chemical Processing Plant for processing. The 1,000 gal tank will be mainly used by experimenters for storage of contaminated loop water and decontamination solutions.

I. ETR Gaseous Waste System

There are three sources of gaseous waste: 1) experimental air leaving the reactor, 2) exhaust air leaving the experimental cubicles and experimental venting systems, and 3) exhaust from the reactor's degassing tank.

The experiment exhaust air leaves the reactor, is cooled to less than 500°F, filtered, and is sent to the stack through a 20 in. diameter line. (The maximum possible flow rate is 30 lb per second). This is the most likely source of contaminated air.

The cubicle exhaust system is designed for pulling air from the console floor to the basement, into the experiment cubicles, subpile room, experiment waste gas tunnel, sump and drain pit, and nozzle trough, then venting it from these areas to the stack. Cubicle exhaust flow is approximately 15,000 cfm. Each experimenter's cubicle is allocated a maximum of 1,000 cfm, and is required to have a minimum face velocity of 150 ft per minute through cubicle penetrations.

Approximately 20 scfm of air from the reactor water degasifying tank is added to the cubicle exhaust system before it vents to the stack.

The cubicle exhaust system is not normally expected to contribute any air activity. However, during emergencies large quantities could be released into the system for a short time.

J. Radiation Monitoring Systems at MTR and ETR

Both the MTR and the ETR have extensive radiation monitoring systems. Each has a system of constant air monitors covering all critical areas inside the reactor buildings and in surrounding occupied areas. In both the MTR and ETR all constant air monitors may record locally or in a remote station such as the reactor control room.

In addition, most exits and entrances to the reactor building are monitored by "Friskers" which are batteries of Geiger-Mueller tubes positioned around a doorway and set to alarm if a contaminated person walks through. These have local readout only. Hand and foot counters are available at MTR, ETR, and the hot cell building.

Direct radiation monitors with central readout monitors all occupied areas where high radiation levels might exist. In addition, all experiment cubicles have direct radiation monitoring systems with readout at the experiment consoles.

Both the MTR and ETR stacks have monitors which continuously record gaseous and particulate activity. Table I summarizes the numbers of activity monitors at the MTR-ETR site.

TABLE I

RADIOACTIVITY MONITORING INSTRUMENTS OTHER THAN PORTABLE HAND DETECTORS AND COUNTING ROOM EQUIPMENT

	MTR	ETR
CONSTANT AIR MONITORS (particulate)		
Portable β, γ	10	6
Portable γ	5	
Portable α, β, γ	2	
Stationary, recorder and alarms at central control panel β, γ	7	
DIRECT RADIATION MONITORS		
Remote Area Monitors Audio and visual alarms on detector and in central control area plus moving chart recorder β, γ	41	27
Remote Area Monitors Alarms as above, no recorder β, γ	1	2
Portable Area Monitors Alarms on instrument only β, γ	13	2
Neutron Long Counter $_0N^1$	1	
CONTAMINATED PERSONNEL MONITORS		
Door and Passageway Frisker β, γ	7	12
Hand and Foot Counter β, γ	4	2
Alpha Hand Counter α	1	
EFFLUENT MONITORS		
Stack Gas and Stack Particulate Monitors α, β, γ	1	1
Stack Fission Gas Monitor	1	1
Liquid Waste Effluent Monitor β, γ	1	
Vent Seal Off-gas Monitor β, γ		
REACTOR COOLANT MONITORS		
Iodine Fission Product Monitor	1	1
Secondary Water Monitors β, γ		

In addition to the above environmental and personnel monitoring equipment listed for each plant, the individual experiments and reactors have various radiation detectors such as direct radiation monitors and exhaust and coolant monitors. These instruments belong to the individual experiments or reactors and are furnished as required for their safe operation.

III. INCIDENT RECORD

As will be discussed in further detail in Section V, there are basically three coupling mechanisms which are capable of causing simultaneous unfavorable incidents with operational and/or biological consequences at two or more closely situated reactors. These three coupling modes are:

1. Coupling by direct radiation.
2. Meteorological coupling.
3. Coupling through common plant facilities.

The coupling through common plant facilities includes both effects due to simultaneous failure of important utilities, e.g., commercial power, at two or more reactors and effects due to mechanically connecting the plants with common piping, e.g., certain components of the radioactive waste disposal system at MTR-ETR.

The material presented in this section is intended to present a phenomenological account of happenings at MTR-ETR due to these coupling mechanisms and to indicate incidents within the MTR or ETR plants which might have propagated themselves into effects at the neighboring plant. Conclusions to be drawn from these events are reserved for later sections of the report.

The MTR-ETR summaries presented first are divided so as to separate the MTR experience from that of the ETR, to illustrate the general trend of stack effluent release for the two reactors and to give a summary of the over-all radiation exposures to personnel at both reactors for the year. Because of the combined facilities and personnel shared by both plants, no attempt has been made to assign exposures to personnel as being due to one or the other of the reactors except where an individual high exposure occurs due to a localized radiation experience.

Included in the summary of incidents at the two sites is a review of the Health Physics log entries on air activity during October and early November. This was done to point up the major problem that existed due to a series of capsule ruptures in the MTR tank during October.

A. Summary of Unusual Events with Health Physics Implications that Occurred at the MTR during 1959

There were eleven unplanned events which occurred at the MTR during 1959 that caused severe restrictions of entry to and/or evacuation of major operating areas of the reactor building and facilities (Table II). There were also twenty-one events which caused severe restrictions to entry and/or occupancy of small sections of operating areas. Events are classed as minor incidents if the areas affected were less than a whole operating floor of the reactor building.

TABLE II

Summary of Unusual Events with Health Physics Implications which Occurred at the MTR During 1959

Date & Time 1959	Identity and Cause	Location	RAD/hr	d/m/smear	Units of Air Activity One Unit = $3x10^{-9}$ μc/cc	Major Activities or $T_{1/2}$	Restricted Entry or Evacuation: Period, Area and Classification	Reactor Down Time	Remarks
1/8 1115-2200	ORNL-44-1 fission gas purge line plugged causing diffusion of gases up feed line and out through a leak in the line.	Gas feed line from HB-3 to NW corner of reactor	15,000 at surface of line	Short lived	> 1000	Xe^{133} Xe^{135} Kr^{88} Kr^{89} and daughters	Total evacuation of MTR Reactor Building and complex for 8 hours. (Major)	Down time - 52 hours and power reduction .52 hours due to removal of ORNL-44-1 and evacuation.	
1/16 1340-1410	Cleaning fluids containing chlorine became activated in the CRC HB-5 facility and diffused back out into Reactor Building.	HB-5 beam hole opening RF south	Minor	Short lived	Estimate > 1000	Cl^{38} $T_{1/2}$ = 37.5 min.	Evacuated local area around reactor face south for approx. 30 min. (Minor)	None	
2/11 1350	The ANP foil cask became pressurized due to the plugging of a purge line and released a burst of contaminated air into the ETRC facility when the cask was opened.	ETRC	Minor	Neg.	> 20	Cs^{138}	Evacuated the ETRC and returned wearing respiratory protective equipment. (Minor)	None	Activity removed by building ventilation in approx. 30 min.
2/24 1730	High gamma heating caused the evolution of radioactive gases from GE-ANP-1 which escaped into the reactor building as the experiment air lines were cut prior to its removal.	HT-1 south and north reactor faces	Minor	None	3 to 10 in reactor building	I^{131} I^{132} I^{133}	Evacuated the reactor building for 1 hour and 10 minutes. Respiratory protection worn by those who re-entered. (Major)	Increased shutdown time: estimated one hour.	The element was moved to a high gamma heat zone in order to cut the air lines.

TABLE II (Continued)

Date & Time 1959	Identity and Cause	Location	RAD/hr	d/m/smear	Units of Air Activity One Unit = $3x10^{-9}$ μc/cc	Major Activities or $T_{1/2}$	Restricted Entry or Evacuation: Period, Area and Classification	Reactor Down Time	Remarks
3/3 2100	Two walls on the ANL-43-1 container ruptured allowing a Nak-water reaction which caused a vent line to split and release fission gases into the reactor building.	Reactor top	Max. .5 around reactor main floor	Max. 6 x 10^5 on reactor main floor	> 1000	Na^{24}, I^{131}, I^{132}, I^{133}, I^{139}, I^{135}, Te^{132} Noble fission gases and daughters	ETR evacuated. Evacuated MTR complex for 27 hours except for personnel wearing respiratory protection. (Major)	Down time - 48.22 hours. Due to evacuation and removal of ANL-43-1.	Short half-life material decayed off rapidly. Air activity removed by normal ventilation after experiment was discharged.
4/3 1155	WAPD-22-2 ruptured and apparently the fission gases diffused up to the thermo couple head of the experiment on the reactor top causing high fields of direct radiation.	Reactor top	4.5	None	None	Fission products	Evacuated reactor top for estimated 1 hour before reactor was scrammed. (Minor)	See entry below.	
4/3 2000	Fission gases from the ruptured GEH-4-36 experiment were released into the reactor building through a faulty isolation valve as the experiment was being discharged from the reactor.	Reactor tank	Max. approx. 30	4700 Reactor top	Approx. 900 on reactor tank	Fission gases - Rb^{88} particulate	Evacuated MTR reactor building for 4 1/2 hours. (Major)	19.13 hours - Down time due to evacuation and removal of both GEH-4-36 and WAPD-22-2.	Contamination decayed off rapidly.
4/6 1320	Fission gases leaked through the cladding of the PW-18-230 experiment into the lead pipe and escaped into the reactor building when the leads were cut to discharge the experiment.	Reactor tank	Minor	None	Max. 60	Fission gases - Rb^{83} particulate	Evacuated reactor top for 20 min. Returned with Scott Air Paks. (Minor)	Increased shutdown time by approximately 20 minutes.	

TABLE II (Continued)

Date & Time 1959	Identity and Cause	Location	RAD/hr	d/m/smear	Units of Air Activity One Unit = $3x10^{-9}$ μc/cc	Major Activities or $T_{1/2}$	Restricted Entry or Evacuation: Period, Area and Classification	Reactor Down Time	Remarks
4/9 1500	The GEANP-2-23 experiment in HG-9 caused intense beams of neutron and gamma radiation from HG-9 because of insufficient shielding in this facility for the reactor power level attained.	HG-9 facility - east side of reactor	11	None	None	None	Evacuated local area in front of beam hole for approximately 90 minutes. (Minor)	Down time 5.57 hours to remove GEANP-2-32 experiment.	Fast and thermal neutron fields were noted throughout the main floor area of the reactor building.
5/12 0100	ORNL-43-15 ruptured causing some air activity in the MTR-ETR area from fission gases released out the stack.	Reactor tank - process water system off gas	.06	None	General 6 - Max. 30	Fission gases - Kr and Xe	No evacuation but personnel in areas of high activity wore respiratory protective equipment.	Down 14.65 hours. Due to ORNL-43-15 fission break.	A cloud of gas released when the reactor was scrammed caused direct radiation fields up to 6 mr/hr in the ETR building for 20-30 seconds as it floated over.
5/15 2400	Fission product gases from ANL-35 rupture escaped into reactor building when the reactor tank was opened.	Reactor top	Minor	None	Max. 5	$T_{1/2}$ = 30 sec. Short lived	Evacuated reactor building for approximately 15 minutes. (Major)	Increased down time approx. 1 hour. (est.)	Activity removed by normal ventilation and decay.
6/2 2220	The WAPD-22-4 lead experiment was ruptured by an explosion attributed to a hydrogen, oxygen reaction. The ruptured lead leaked process water onto the reactor top and caused high radiation fields around the top of the reactor.	Reactor top	Max. 25 at 1 foot	130,000	None	Mn^{56} K^{42} Na^{24} and low level fission products from process water	Evacuated the reactor top for approximately 10 minutes and returned with respiratory equipment. Reactor top ribboned off. (Minor)	None	Cover from thermo couple lead box blown off by force of explosion.

TABLE II (Continued)

Date & Time 1959	Identity and Cause	Location	RAD/hr	d/m/smear	Units of Air Activity One Unit = $3x10^{-9}$ μc/cc	Major Activities or $T_{1/2}$	Restricted Entry or Evacuation: Period, Area and Classification	Reactor Down Time	Remarks
6/11 2022-2028	High fields of neutron and gamma radiation resulted from an attempted flux run at NL with the door open on HB-3.	HB-3 - NE side of reactor	.1 at 15 ft. β, γ - neutron flux not measured	None	None	None	Evacuated main floor until source was found. Approx. 3 min. (Minor)	Power reduced. < 6 minutes.	Long counter on SW side of reactor showed a neutron increase of > 1000 c/m.
6/12 1100-1400	The GEH-4 experiment ruptured and gave three separate releases of noble fission gases as it was being discharged from the reactor.	Reactor tank and top	Minor	Neg.	Max. 285 in tank - 25 on RFS and 7.6 in basement	Noble fission gases - Rb^{88} and Cs^{138}	Main floor evacuated 40 minutes. Basement evacuated 70 minutes. ETRC evacuated 21 hours. (Major)	Down time 7.08 hours. Reduced power .65 hours. Due to high activity and removal of GEH-4.	Personnel re-entered building wearing positive air supply equipment.
6/14-6/16	Rupture of the ETR GEEL experiment caused high level radiation fields around the lines leading to the ETR stack and low level air activity in the ETRC.	ETR reactor and exhaust lines	.1 at MTR fan house	None	Low level	Noble fission gases	None	None	Direct radiation from the GEEL lines caused MTR stack gas monitor to indicate a release from the MTR.
6/16 1315	Fission gases from GA-308-1 leaked into the oil reservoir of the experiment's vacuum pump and escaped into the reactor building when the reservoir seal was broken for maintenance.	Reactor top	.4 at pump	Neg.	Max. > 1000 - General 1 - 6	Noble fission gases - Rb^{88} and Kr^{88}	Evacuated immediate area around pump for estimated 10 minutes to obtain respiratory protective equipment. (Minor)	None	Activity removed by building ventilation.

TABLE II (Continued)

Date & Time 1959	Identity and Cause	Location	RAD/hr	d/m/smear	Units of Air Activity One Unit = $3x10^{-9}$ μc/cc	Major Activities or $T_{1/2}$	Restricted Entry or Evacuation: Period, Area and Classification	Reactor Down Time	Remarks
7/24 0700	Radioactive gases diffused back through the ETRC sump causing air activity in the ETRC after GEH-4-40 ruptured and released water containing fission gases into the reactor drain system.	MTR Reactor drain system	Minor	Neg.	> 900	Fission gases Rb^{88}	Evacuated ETRC for 9 hours except for occasional entry with respiratory protection. (Minor)	7.38 hours to remove GEH-4-40.	
8/3 1015	Apparently water from the GEH-4 loop was released into the reactor drain system and fission gases again diffused into the ETRC causing high air activity.	MTR Reactor drain system	Minor	Neg.	Est. 60	Noble fission gases Rb^{88}	Evacuated ETRC about one hour. (Minor)	None	
8/17 1430	The ANP foil cask became pressurized during a purging operation and released a burst of contaminated air into the ETRC when the cask was opened.	ETRC canal	Minor	4000	Est. 10	Unknown	Evacuated ETRC for a few minutes while normal ventilation removed the contaminated air. (Minor)	None	
8/31 0300	The ANP-1 experiment stuck, as it was being removed from the HT-1 facility, between the shielded coffin and the reactor face causing high fields of direct and scattered radiation.	RF north HT-1	> 500 at reactor face - 25 at 6 feet	None	None	None	Evacuated areas on main floor of reactor building for estimated 10 minutes. (Minor)	Prolonged shutdown time estimated 10 minutes.	Cask bumped into line and experiment slid in.

TABLE II (Continued)

Date & Time 1959	Identity and Cause	Location	RAD/hr	d/m/smear	Units of Air Activity One Unit = 3×10^{-9} μc/cc	Major Activities or $T_{1/2}$	Restricted Entry or Evacuation: Period, Area and Classification	Reactor Down Time	Remarks
9/5 0100-0425	GEANP-1 loop developed an air leak in the drawbar seal on the south reactor face releasing radioactive gases and short half-life particulate material.	RF south HT-1	Neg.	None	Not extremely high. Level unknown.	$T_{1/2}$ = 4 minutes	Reactor face south area evacuated and placed on a limited access basis for 90 minutes. (Minor)	Power reduced 1.28 hours while leak was repaired.	
9/8 1500	A clamp on the drawbar of the GEANP-1 experiment slipped and allowed the experiment to be pulled into a higher flux zone than scheduled resulting in a large increase in the stack gas activity and an increase in direct radiation from the experiment exhaust lines.	HT-1 Reactor basement south	0.6 in basement	None	None	Unknown	Restricted entry to reactor basement south aisleway for 15 min. (Minor)	Junior scram. 1.88 hours.	
9/16 1730-1830	The GEH-4 defect test evolved fission product gases into the experiment loop which were released into the reactor building when the loop was opened.	Reactor top	Minor	None	RT - 10-15, R floor - 5-8	Kr^{88} Rb^{88}	Partial evacuation of reactor top and main floor for 1 hr except for respiratory equipment. (Major)	Down time - 8.47 hours. Due to release of activity and removal of experiment.	
9/30 1300	Normal Eu on the outside of a capsule became activated when the capsule was irradiated and contaminated the experimenters hands, clothes, and face during the removal of the capsule from VG-7.	RT - VG-7	.03	Smear from face read 10 mrad/hr	Minor	Eu^{154} Eu^{152}	None	None	No air activity noted. Contamination detected by doorway frisker. Negligible internal exposure indicated by urinalyses.

TABLE II (Continued)

Date & Time 1959	Identity and Cause	Location	RAD/hr	d/m/smear	Units of Air Activity One Unit = $3x10^{-9}$ μc/cc	Major Activities or $T_{1/2}$	Restricted Entry or Evacuation: Period, Area and Classification	Reactor Down Time	Remarks
10/12 0150-0315	Noble fission gases from a ruptured experiment (KAPL-2-95 and perhaps others) diffused up through the process water after shutdown and escaped into the reactor building when the reactor tank was opened.	Reactor top	Minor	Neg.	5-25 in Reactor building	Kr^{88} Rb^{88} Xe^{138} Cs^{138}	Evacuated reactor top and main floor except for respiratory equipment for 2.5 hours. (Major)	None	Reactor tank vented to the stack to remove activity.
10/21 1330	Large bubbles of contaminated air were released from the reactor tank as the manhole cover was removed. Apparently a NaK containing experiment (BMI-32-3) ruptured. Majority of the activity was vented to the stack by a stack suction hose.	Reactor top	Minor	Neg.	Minor	Ni^{65} I^{131} I^{132} I^{133}	Evacuated reactor top and then returned with Scott Air Paks for a period of 2 hours. (Minor)	Down time 19.18 hours due to RT evacuation and search for fission break.	
October 1959 -	See summary sheet for October and early November air activities due to a number of ruptured capsules in the MTR.								
10/31 2100	A burst of air activity (apparently trapped fission gases) was released when the BWC loop experiment was being removed from the reactor.	Reactor top	Minor	Neg.	Max. 100 on RT	Rb^{88} I^{133}	Reactor top evacuated except for those wearing Scott Air Paks for an estimated 1 hour. (Minor)	None	

TABLE II (Continued)

Date & Time 1959	Identity and Cause	Location	RAD/hr	d/m/smear	Units of Air Activity One Unit = $3x10^{-9}$ μc/cc	Major Activities or $T_{1/2}$	Restricted Entry or Evacuation: Period, Area and Classification	Reactor Down Time	Remarks
11/1 1600-2400	A series of capsule ruptures (NAA-47-3L apparently the major one) released fission gases to the process water and subsequently to the MTR stack. The activity from the stack came back into the area causing high air activity.	Reactor tank	Minor	Neg.	ETR - 17 MTR - 3 - 7	Rb^{88} Rb^{89} Cs^{138}	None	Reduced power 5.68 hours because of high activity in area.	Personnel in areas of high activity wore respirators.
11/1 0420	Process water containing iodine leaked through a packing gland in a lead experiment onto the reactor top contaminating the top and causing air activity as the iodine vaporized.	Reactor top	Minor	Small area - 2000	6-8 on RT and reactor main floor	I^{131} I^{132} I^{133}	Evacuation of reactor top and main floor for 40 minutes. (Major)	Reduced power 3.22 hours while repairing leak.	Personnel wore positive air supply respirators while repairing leak.
11/5 0855-1100	Radioactive gases were released into the reactor building from the reactor when it was opened immediately after a scram in an effort to locate which experiments were ruptured and giving off gas bubbles.	Reactor top	.027	4000 - Reactor top	RT - 270 - Reactor floor - 70 - Reactor wing - 2	Cs^{138} Rb^{89}	Evacuated MTR Reactor Building and wing building for 2.1 hours. (Major)	Down time 22.78 hours due to removal of suspect capsules and evacuation.	
11/16 2208	The UCRL-29 capsule gave off radioactive bubbles when the capsule was moved which escaped from the reactor tank into the reactor building causing high air activity.	Reactor tank	Minor	Neg.	> 1000 on Reactor tank, 2 on main floor	Fission product gases	Evacuated reactor top and closed off main reactor building. Personnel remaining in building wore respiratory protection for 1 hour. (Minor)	Down time 13.29 hours due to RT evacuation and search for leaky capsule.	

TABLE II (Continued)

Date & Time 1959	Identity and Cause	Location	RAD/hr	d/m/smear	Units of Air Activity One Unit = $3x10^{-9}$ μc/cc	Major Activities or $T_{1/2}$	Restricted Entry or Evacuation: Period, Area and Classification	Reactor Down Time	Remarks
11/20 23 25	High level floor contamination occurred on three separate days from a contaminated cask which had previously been used to transfer a ruptured experiment to the hot cells.	Reactor main floor and canal area	1.5 Max.	435,000 Max.	None	Zn^{95} Mo^{99} Fission products	Small areas roped off for about 30 min. until mopped. (Minor)	None	Smears from each contaminated area and the cask gave identical spectroms on the spectrometers.
12/2 1530	An air leak developed in the downstream portion of the GEANP loop allowing radioactive gases to escape into the reactor building causing air activity.	Reactor face south	.2 γ .015 Nf .025 Nt	Neg.	9 RFS	Nb^{95} Na^{24} Rb^{89} Mn^{56}	Evacuated RFS and returned with respirators. 4 hours. (Minor)	None	
12/3 2130	Contamination, apparently from an organic wrapping material used to wrap a stainless steel capsule while it was being irradiated, contaminated the experimenters, the lab and the HP office.	RT and lab	1.5	Approx. 2000in hallways and from hands	None	$T_{1/2}$ was very short	None	None	Activity decayed off rapidly due to short half-life.
12/5 1110	The ANP-3-58 rupture caused high radiation fields on the reactor top from the loop lines and evolved considerable activity out to the stack.	Reactor top	5	None	None	Fission gases	Evacuated reactor top for 20 minutes until experiment was removed from flux. (Minor)	None	

TABLE II (Continued)

Date & Time 1959	Identity and Cause	Location	RAD/hr	d/m/smear	Units of Air Activity One Unit = $3x10^{-9}$ μc/cc	Major Activities or $T_{1/2}$	Restricted Entry or Evacuation: Period, Area and Classification	Reactor Down Time	Remarks
12/9 1315	Direct radiation from the removal of a thermo couple lead on the reactor floor north coincident with direct radiation from the upper grid of the reactor being removed to the canal triggered numerous radiation alarms and inadvertently caused a total evacuation.	Reactor top and main floor	20	None	None	None	Evacuated entire MTR complex for about 10 minutes. (Major)	Increased down time .1 hour.	The total evacuation signal was tripped by mistake instead of the reactor building evacuation signal.
12/14 2000	The GEANP foil cask released air activity into the ETRC as the air pressure in the cask was being bled off.	ETRC	Minor	Neg.	> 6	$T_{1/2}$ - Approx. 30 min.	Evacuated ETRC except for personnel wearing respiratory equipment for 1 1/2 hours. (Minor)	None	Activity removed by normal ventilation.
12/14 2345	The reactor top, main floor and basement were contaminated to very high levels from an unknown source. (Probably by tracking from the chopper cubicle which had the highest smear count.)	MTR Reactor Building	Minor	500,000	Neg.	Pa^{233}	Partial evacuation and restricted entry to contaminated areas. (Minor)	None	All areas cleaned by mopping.
12/16 0600	Powdered graphite from the graphite balls in the reactor clung to a removal tube until the tube was over head and then showered down contaminating several men and the reactor top.	Reactor top	Neg.	3000	None	Na^{24} Zn^{65} Mn^{54}	Evacuated the reactor top except for personnel wearing protective clothing. (Minor)		Top ribboned off until it could be mopped. Personnel completely decontaminated with nose swabs and a shower.

TABLE II (Continued)

Date & Time 1959	Identity and Cause	Location	RAD/hr	d/m/smear	Units of Air Activity One Unit = $3x10^{-9}$ μc/cc	Major Activities or $T_{1/2}$	Restricted Entry or Evacuation: Period, Area and Classification	Reactor Down Time	Remarks
12/23 1500	Contaminated water from a shipping cask leaked onto the bed of a commercial truck contaminating the truck bed and driver while enroute to the MTR.	Shipping cask	20 mr on drivers clothes	70,000 on truck bed	None	Unknown	None	None	Driver and truck decontaminated and released.
12/28 2100	Radioactive fission gases from the GEANP loop were bypassed around a loop filter and the unfiltered gases caused an increase in direct radiation from the loop lines and an increase in the activity going to the stack.	HT-1 Reactor face south	.045	None	None	Na^{24}	None	None	Bypass closed and radiation subsided.

Total major area restricted entry and/or evacuations - 11. Total time involved - 48.22 hours.

Total minor area restricted entry and/or evacuations - 21.

TABLE II (Continued)

Summary of Log Entries on Air Activity at the MTR during the period October 1st through November 8th, 1959

Date	Time	Area Affected	Duration	Units of Air Activity One Unit = 3×10^{-9} μc/cc	Source and Remarks
October 2	1500	MTR fuel shop	Few minutes	> 10	Wind blowing from MTR stack
October 3	0500	MTR-ETR Areas	1 hour	1	Probably MTR stack and inversion conditions
October 4	0500	MTR-ETR Areas	30 minutes	CAMs to 10 x scale	Probably MTR stack and inversion conditions
October 5	0140	MTR-ETR Areas	40 minutes	CAMs 0.5	Probably MTR stack
October 7	0100	MTR fan house and Process Water Building	Continued most of day	4-fan house - activity up over rest of area	Probably MTR stack - wind from NNE
October 9	1700	Process Water Building	15 minutes	< 1.0	Probably from gases released from process water
October 11	1000	MTR-ETR Areas	1 hour	< 1.0	Probably MTR stack
October 15	2340	Fan house and Process Water Building	45 minutes	4 - 6	Probably from gases released from process water
October 16	0130	Fan house		< 1.0	Still showing activity
October 16	1100	Fan house	30 minutes	6	
October 17	0400	MTR Area	30 minutes	.5 - 1.5	All over area - probably from MTR stack and inversion conditions
October 18	2230	MTR Reactor Building	1 hour	1	
October 19	0500	MTR Area	30 minutes	1 - 3	
October 20	1000	Process Water Building	1 hour	1	
October 20	1630	Reactor basement southwest		.8	MTR stack - general rise over area

TABLE II (Continued)

Date	Time	Area Affected	Duration	Units of Air Activity One Unit = $3x10^{-9}$ μc/cc	Source and Remarks
October 21	0245	NRF (called because of air activity)	Blips of activity every 15 minutes		MTR stack gas monitor at 12 on high range - wind toward NRF
October 23	0410	MTR Area varied activity		12 - 30	Apparently from MTR stack with a strong inversion condition
October 24	1600	MTR Area	All day	> 1.0	General rise over entire area
October 25	1600	MTR-ETR Area	8 hours	All CAMs to 10 x scale	General level greater than $3x10^{-9}$ μc/cc over entire area
October 26	0620	MTR Area	8 hours	1	General activity over entire area
October 27	0900	Process Water Building	5 hours	1 - 5	Due to ruptured experiments in the MTR
October 28	0330	Process Water Building	1 1/2 hours	30	Rb^{88} and Cs^{138} fission gases and daughters from process water
October 28	2000	Process Water Building		4	Rb^{88} and Cs^{138} fission gases and daughters from process water
October 29	0000	Process Water Building		30	Activity released from process water and drawn into building by ventilation system
October 29	0000	MTR Basement		< 1	
October 29	0115	Demin. Building	1 hour	1 - 2	
October 30		CAM in fan house to 10 x scale		CAM to 10 x scale	Activity up over area - wind from N at 40 mph
October 31	1445	Process Water Building	2 hours	3 - 6	Probably from gases released from process water
November 1	0410	Reactor Building		CAM rise	
November 1	1660	MTR-ETR Areas	2 hours	1 - 6	
November 1	1630	ETR evacuated	1 hour	> 10	

TABLE II (Continued)

Date	Time	Area Affected	Duration	Units of Air Activity One Unit = 3×10^{-9} μc/cc	Source and Remarks
November 1	2100	Fan house CAM		2	
November 1	2310	Reactor Building		< 1	Activity varying over entire area for entire day - probably from MTR stack
November 2	0000	Process Water Building		1 - 5	
November 2	0120	Process Water Building		> 100	Probably from gases released from process water
November 6	2200	ETR evacuated		30	
November 7	1130	Process Water Building	2 hours	6	High air activity - probably from gases released from process water

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During October and early November, 1959, a series of ruptures of fuel bearing structures in the MTR caused so many air activity problems that the whole period of time can be classed as a major event. To give some idea of the problems involved, a summary of the MTR Health Physics log entries on air activities during this period of time is included. To further illustrate this problem, graphs of curies per megawatt-day of gaseous stack effluent per cycle from both the MTR and ETR reactors are included (Figures 5 and 6 respectively). It should be noted that these graphs include total effluent from each stack including both argon-41 and gaseous fission products. Later in the section a correlation equation is introduced which is based on gaseous fission products only.

B. Summary of Unusual Events with Health Physics Implications that Occurred at the ETR during 1959

There were seventeen unplanned events which occurred at the ETR during 1959 that caused severe restrictions of entry to and/or evacuation of major operating areas of the reactor building and facilities (Table III). There were also eighteen events which caused severe restriction to entry and/or occupancy of small sections of operating areas. Again events are classed as minor incidents if the areas affected were less than a whole operating floor of the reactor building.

C. Air Contamination Levels

It is extremely difficult to accumulate quantitative information regarding ingestion of airborne radioactive material except in those cases which, because of their seriousness, were subjected to special study and are indicated in the preceding summaries. The MTR-ETR Health Physics philosophy is to use routine continuous environmental monitoring, with special studies to be directed toward any individuals exposed to an unfavorable environment. This system is backed up by a routine urinalysis program but, because of the extremely low level of ingestion in workers at this site, it is usually impossible to detect any statistically significant effects except in those cases which have already been detected by the environmental monitors.

Because of the importance of environmental control it is informative to consider the frequency distributions of air activity readings in selected areas.

Table IV-(1) indicates the frequency distribution of airborne particulate activity in the ETR area as indicated by the constant air monitors for the 1959 calendar year. The readings indicated here are based on the highest reading constant air monitor during periods of general activity rise in the ETR building. These frequency distributions may be interpreted either as the probability that the highest reading CAM will exhibit a reading within the indicated levels in a randomly selected time interval, or as the fraction of total time that the highest reading CAM exhibits a reading within the specified limits. These CAM data correspond to the stack data given in Figure 5 and 6.

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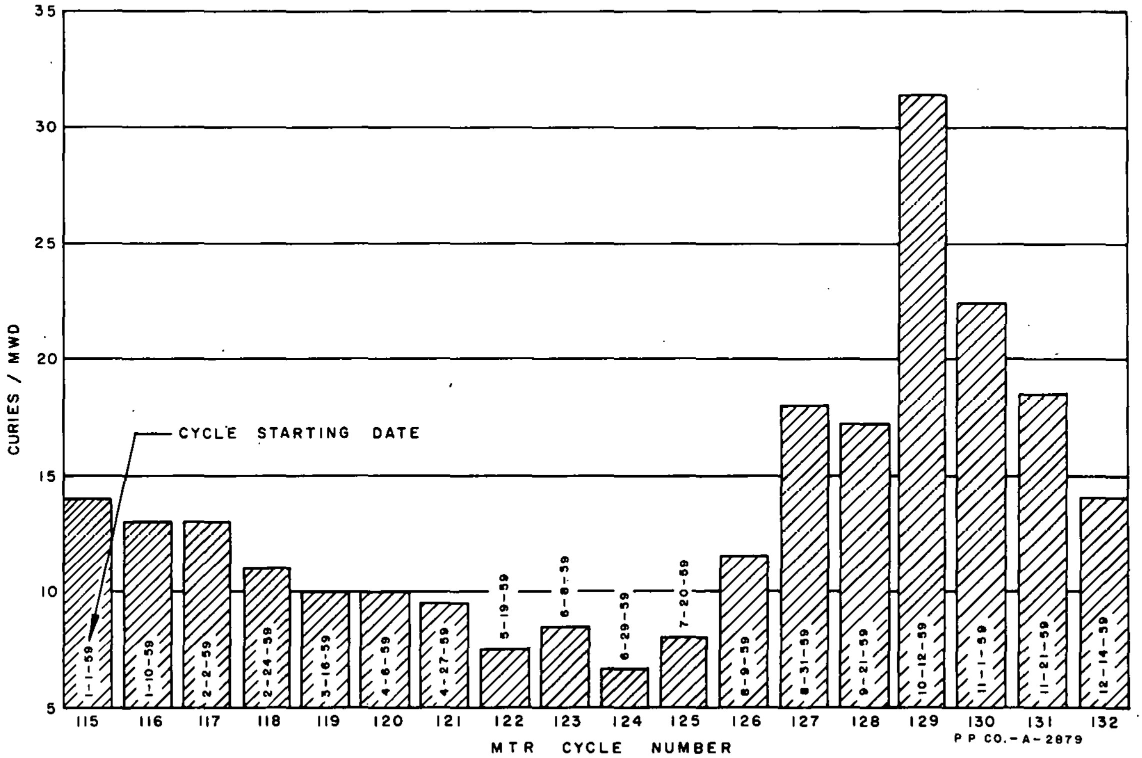

FIG. 5

MTR STACK GAS RELEASE RATE DURING 1959

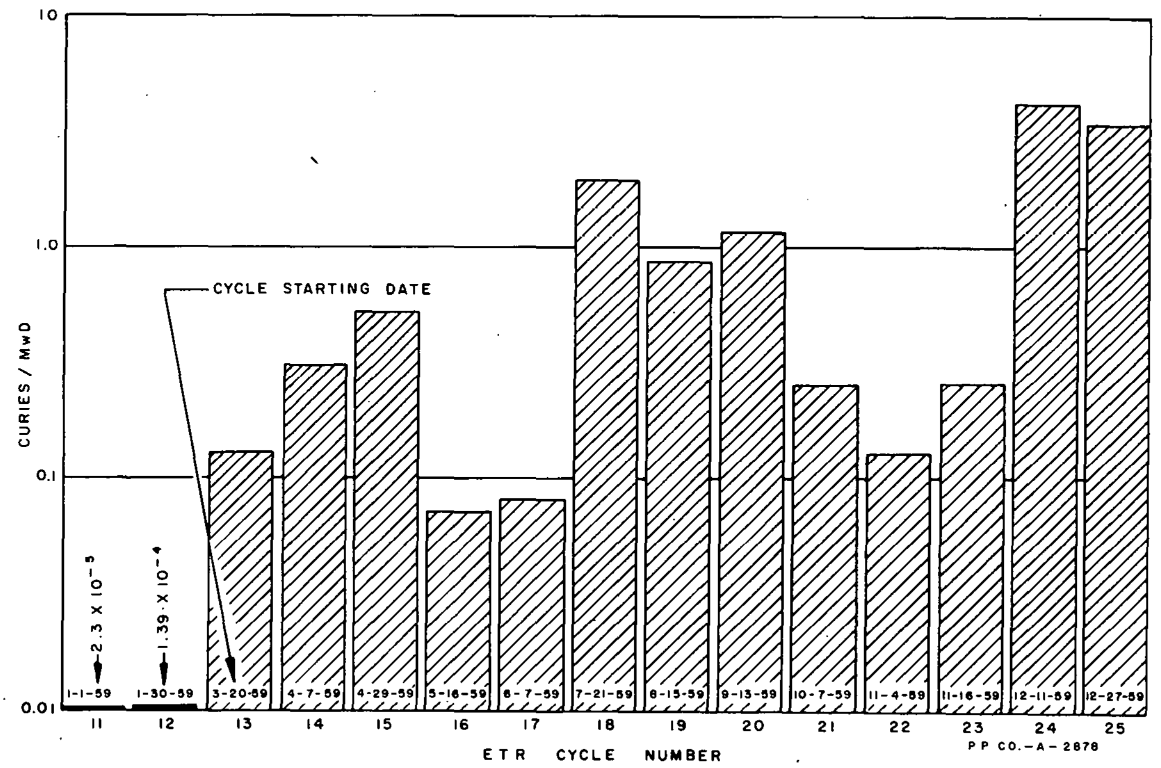

FIG. 6

ETR STACK GAS RELEASE RATE DURING 1959

TABLE III

ETR - 1959

Date & Time	Identity, Cause and Location	RAD/hr	Dis/m/smear	Units of Air Activity One Unit = $3 \times 10^{-9} \mu c/cc$	Major Activities or $T_{1/2}$	Restricted Entry or Evacuation: Period, Area and Classification	Reactor Down Time	Remarks
1/8 1630	Air activity from MTR source.	Low	Low	9.6	29 min.	1.5 hr. - ETR (Major)	Extended shut-down 1.5 hr.	
2/1 1230	KAPL-33 loop water sprayed on personnel and floor of sample area when sample bomb was removed.	.03	Unknown	Negl.	Fission products	Floor of sample area restricted for cleanup.	None	Personal clothing confiscated from four people.
2/6 1005	Air activity caused by leak of process water at flange on reactor tank.	Low	Low	Average < 5	Fission product gases	None - ETR	None	Continued until shutdown on 2/9/59.
2/9 1100	Release of activity from under reactor dome during scheduled shutdown.	Low	Low	10	Approx. 30 min.	None - ETR	None	Lasted about 20 minutes.
2/12 1100	Frozen valve allowed backup from ETR resin bed causing contamination of ground and entry of Demin. Valve Room.	.2	Unknown	None	Co^{60} Mo^{99} Mn^{56}	Demin. Valve Room entry restricted for decay. (Minor)	None	Area ribboned off and activity allowed to decay.
2/13 0410	Overload of warm drain system causing backup onto ETR Basement floor.	1.	7000	None	Fission and activated corrosion products	ETR Basement south and west sides restricted for cleanup. (Minor)	None	Entry restricted during cleanup and decay.
3/3 2105	ETR evacuated due to evacuation alarm initiated at MTR.	Minor	Minor	< 10	25 min.	1.75 hr. - ETR (Major)	None - Shut-down extend-ed 1.75 hr.	Caused by the ANL-43-1 incident at the MTR.
3/7 2340	1" drain opened to emergency pump header caused reactor tank to drain so that top of control rods broke the water surface in the tank. Friskers and area monitor alarmed.	2.	None	None	-	Restricted area around reactor top for about 20 minutes. (Minor)	None	Level of activity noted in vicinity of reactor tank. Level of water controlled with makeup water until drain was closed.

TABLE III (Continued)

ETR - 1959

Date & Time	Identity, Cause and Location	RAD/hr	Dis/m/smear	Units of Air Activity One Unit = $3x10^{-9}$ μc/cc	Major Activities or $T_{1/2}$	Restricted Entry or Evacuation; Period, Area and Classification	Reactor Down Time	Remarks
3/16 1750	NW corner of reactor basement contaminated by water flowing out of an open drain.	Unknown	13,500	None	Fission products	NW corner of reactor basement restricted for cleanup and decay. (Minor)	None	Water from the KAPL-33 cubicle.
3/17 1730	ETR evacuated due to air activity caused by a flux run. Activity stopped when flux run ended. Activity came from the reactor tank.	Unknown	Unknown	70 Max. 30 Av.	34 min.	4.5 hr. - ETR (Major)	None	Scott Air Paks used by personnel remaining in area during flux run.
3/22 2245	GEH air annulus line draining into bucket overflowed, ran out of cubicle, contaminated basement floor and caused air activity.	.1	High	3.8	33 min.	1.75 hr. - ETR Basement (Minor)	None	Personnel required to wear respirators in basement during incident.
3/23 1900	Air activity released when packing removed from ANP experiment in preparation to pull reactor head.	Unknown	Low	1200 over tank, 50 on reactor floor	18 min.	4 hr. - ETR Main Floor (Major)	None	Personnel required to use Scott Air Paks in area of air activity.
3/28 0615	Air activity due to bubbles leaking from the discharge chute cover.	Low	Low	5	21 min.	None - ETR Reactor Bldg.	None	Activity reduced to 2 MPC by venting bubbles to hot drain. Continued to shutdown on 3/31/59.
3/31 2015	Air activity released from under reactor dome when removed from tank.	Low	Low	16	18 min.	45 min. - ETR (Major)	Shutdown extended 45 min.	Source from unknown fuel structure in reactor tank.
4/10 1215	Air activity from reactor tank around GEEL leads.	Low	Low	14	18 min.	3.8 hr. - ETR (Major)	Caused shutdown. Power reduced 3.3 hr.	Evacuated except for personnel wearing Scott Air Paks.
4/10 1615	Air activity released following shutdown on removal of reactor dome.	Low	Low	17	18 min.	2.25 hr. - ETR (Major)	Shutdown extended 2.25 hr.	Early shutdown. Caused air activity around GEEL leads.

TABLE III (Continued)

ETR - 1959

Date & Time	Identity, Cause and Location	RAD/hr	Dis/m/smear	Units of Air Activity One Unit = $3x10^{-9}$ μc/cc	Major Activities or $T_{1/2}$	Restricted Entry or Evacuation: Period, Area and Classification	Reactor Down Time	Remarks
5/15 1500	Contaminated water gushed out of eductor when regenerating ETR anion bed.	Unknown	High	None	Estimated 30 mc of Co^{60}	500 ft^2 restricted for cleanup. (Minor)	None	Necessary to remove 4 1/2 yds^3 of dirt to decontaminate.
5/17 0630	Fission break in GEH-10 caused radiation field on outside of cubicle and intermittent air activity until discharged to canal.	1.	Unknown	79 Bsmt. 3.0 Main Floor	15 min.	1 hr. - Reactor Basement (Major)	Scram caused by rupture - Power reduced 37 minutes before scram.	Other work than clean-up done during shutdown. Extended shutdown an estimated 24 hours.
5/24 0845	Water leak from a cubicle spread out over north side of reactor basement floor.	.2	Unknown	None	2.2 hr.	24 hr. restricted entry for decay. ETR Bsmt, north side. (Minor)	None	
6/5 0835	Water backed up from clean-out for hot drain when reactor tank water level was lowered.	Unknown	4000	Slight	I^{132} Ce^{141}	NW section of reactor basement restricted entry. (Minor)	None	
6/10-11	Intermittent leaks from the tank access nozzle of KAPL-33. Air activity fluctuated with leaks so that the reactor main floor was evacuated several times for the total time indicated.	Low	Low	10	20 min.	45 min. - ETR Main Floor (Major)	None	
6/14 0745	High radiation from ANP discharge lines due to release of fission products caused high field in subpile room after shutdown and high radiation in yard during operation.	18 in subpile room - 4.5 in yard	-	None	-	Subpile room restricted for 37 days during shutdown. Yard and MTR Fan House restricted for 13 hours. (Minor)	Scram caused by ANP radiation.	The long shutdown was to install a different experiment. Impossible to estimate extra time of shutdown due to ANP.
6/14 2130	Air activity and contamination from water leaking from GEH-6 x 9 cubicle onto basement floor.	.5	$2x10^5$	19	63 min.	4 hr. - ETR Bsmt. (Major)	None	Basement evacuated for indefinite period with entry then restricted using respiratory equipment.

TABLE III (Continued)

ETR - 1959

Date & Time	Identity, Cause and Location	RAD/hr	Dis/m/smear	Units of Air Activity One Unit = $3x10^{-9}$ μc/cc	Major Activities or $T_{1/2}$	Restricted Entry or Evacuation: Period, Area and Classification	Reactor Down Time	Remarks
6/15 0030	Air flush of reactor dome caused air to be blown out of hot catch tank and drain system into building.	Low	Unknown	> 1000	Kr^{88} Rb^{88}	8 hrs. - ETR (Major)	Shutdown extended 8 hours.	
6/15 2000	Back up of air from ANP discharge lines through filters into Compressor Building.	1.5	1500	5	I^{131} I^{133}	1.5 hrs. - ETR Compressor Bldg. (Minor)	None	All of building contaminated. Low level I exposures to 7 personnel.
7/16 0115	Extensive flooding of reactor basement due to lowering reactor tank water level and backup out of hot drains.	Unknown	3000	Slight	Fission products and Cr^{51}	Restricted entry for 2 days - ETR Basement (Minor)	None	Work other than cleanup performed in contaminated area.
7/22 2150	Drain hose from the air annulus of the GEH 3 x 3 loop pulled from drain causing flooding of cubicle and basement floor and some air activity.	Unknown	Unknown	2.5	Xe^{138} Cs^{138}	No significant restriction - ETR Basement (Minor)	None	Area of contamination at cubicle was small.
7/23 0235	Heat exchanger gasket failed on GEH 6 x 9 loop causing leak of water from cubicle to basement floor and air activity in basement.	.1	6500	3.2	Cs^{138}	Restricted entry for 1 day - ETR Basement (Minor)	Caused scram	Regular shutdown started early due to scram.
7/23 1430	Air activity caused by lowering reactor tank level.	Low	Low	3.5	Te^{132} Kr^{88} Rb^{88}	1.0 hr. - ETR (Major)	Shutdown extended 1 hour.	Evacuation ordered because of long $T_{1/2}$ of air activity components.
7/24 0045	WAPD sample being lowered into tank from cask because of high radiation from cask. Hand crank got away from operators and sample dropped down the WAPD tube.	5 at 3' in air	None	None	-	None	Est. 12 hrs. to install new tube.	10 mrem exposures to 3 men. Two men received minor injuries. Inpile tube had to be replaced.

TABLE III (Continued)

ETR - 1959

Date & Time	Identity, Cause and Location	RAD/hr	Dis/m/smear	Units of Air Activity One Unit = $3x10^{-9}$ μc/cc	Major Activities or $T_{1/2}$	Restricted Entry or Evacuation: Period, Area and Classification	Reactor Down Time	Remarks
8/5 2045	Intermittent release of air activity from Log N Monitor tube.	Low	None	2.6	> 1 hr.	0.5 hr. - ETR Reactor Top (Minor)	None	
8/17 2332	Reactor scrammed manually to prevent possible damage to reactor and equipment due to an earthquake.	None	Low	None	-	None - ETR	25 hr. shutdown.	No damage.
8/20 0830	High air activity in GEH 3 x 3 cubicle when lines were cut in the cubicle.	Unknown	Unknown	> 1000	Very short $T_{1/2}$	Approx. 16 hrs. - GEH 3 x 3 cubicle (Minor)	None	
8/22 0030	Argon purge to ORNL-41 instruments escaped to building and caused alarms on direct radiation monitors and friskers on main floor.	.002	None	Unknown	A^{41}	None - ETR	None	
8/25	Discovered contamination of overhead horizontal surfaces by tracing contamination on gloves of construction worker.	Slight	880 d/m ft^2 of surface	Very low	Co^{60} Zr^{95} Nb^{95}	None - ETR	None	Origin believed to be long term fall out of low level air activity coming from the reactor tank.
9/1 1715	Air activity escaped from reactor tank in preparation for removal of reactor top.	Low	Low	3.9	18 min.	None - ETR	None	30 minute duration.
9/8 0130	Air activity and smoke from ANP Suterbilt filters.	Low	Low	20	32 min.	20 min. - ETR (Major)	Shutdown extended 20 minutes.	
9/8 1808	Air activity appeared from unknown source.	Low	Low	2	Na^{24}	None - ETR	None	Lasted 20 minutes.
10/13 0640	Water ran onto basement floor from leak in GEH 3 x 3 cubicle.	Low	3000	Slight	Fission products	Small area of ETR Basement north restricted until cleanup. (Minor)	None	

TABLE III (Continued)

ETR - 1959

Date & Time	Identity, Cause and Location	RAD/hr	Dis/m/smear	Units of Air Activity One Unit = $3x10^{-9}$ μc/cc	Major Activities or $T_{1/2}$	Restricted Entry or Evacuation; Period, Area and Classification	Reactor Down Time	Remarks
10/14 0200	Air activity from process water when ventilating fans were left off in the Compressor Building.	Low	Low	2.5	30 min.	2.5 hr. - Restricted entry in Compressor Bldg. (Minor)	None	Area restricted until cause of activity could be determined.
10/18 0015	Air activity from MTR.	Low	Low	2.6	30 min.	None - ETR	None	Lasted 5 hours.
10/18 1210	Air activity due to cutting of MTR-34 experiment lines in ETR tank.	.020	Low	7.5	Approx. 30 minutes	None - ETR	None	Respiratory protection used in tank for approximately 2 hours.
10/23 0345	Air activity from MTR.	.002	Low	8	20 to 40 minutes	None - ETR	None	Direct radiation from cloud released from MTR stack.
10/24 1330	Air activity from MTR.	Low	Low	12	30 min.	.75 hr. - ETR, TPP and Maint. Bldgs. (Major)	Extended shutdown 45 min.	
10/59	See summary sheet for October and early November air activities due to MTR sources.	-	-	-	-	-	-	-
11/1 1000	Air activity from MTR.	Low	Low	17	25 min.	45 min. - ETR (Major)	Extended shutdown 45 min.	Intermittent air activity all day with maximum level shown.
11/5 0830	Air activity in reactor basement from unknown source.	Low	Low	5	Cs^{138}	None - ETR Bsmt.	None	Of short duration in North Reactor Basement area.
11/8 1140	Gas cloud from MTR stack caused radiation field and radiation alarms at ETR. And some air activity.	.0015	Low	7.5	25 min.	No evacuation or restriction. ETR, TPP and Maint. Buildings	None	Quoted radiation level was in ETR Reactor Bldg. Air activity lasted 30 minutes.

TABLE III (Continued)

ETR - 1959

Date & Time	Identity, Cause and Location	RAD/hr	Dis/m/smear	Units of Air Activity One Unit = $3x10^{-9}$ µc/cc	Major Activities or $T_{1/2}$	Restricted Entry or Evacuation: Period, Area and Classification	Reactor Down Time	Remarks
11/30	The rupture of the GEH 6 x 9 loop allowed water to be forced into the air annulus then into the instrument air lines and then finally onto floors in the reactor basement and console levels.	25. at 1' in air	$5 x 10^5$	Slight	Mn^{56} Na^{24} Cu^{64} Ag^{110} Ag^{111}	6 hr. - ETR Basement (Major)	Scram - started scheduled shutdown early	Contamination spread to main floor of reactor. Cleaned up in about 1 week. Clothing contaminated and confiscated from large number of people.
12/1	Air activity in reactor basement caused by draining of the GEH 6 x 9 air annulus.	Unknown	Low	> 1000	Approx. 18 min.	10 min. - ETR Basement (Major)	None	

Total major area restrictions and/or evacuations - 17. Time involved 41.3 hours.

Total minor area restrictions and/or evacuations - 18.

TABLE III (Continued)

Summary of Log Entries on Air Activity at the ETR during the period October 1st through November 8th, 1959

Date	Time	Area Affected	Duration	Units of Air Activity One Unit = 3×10^{-9} μc/cc	Source and Remarks
October 1	1630	All areas		2	Wind NE
October 1	1800	All areas	Still persists	2	From MTR wind NE (27 min $T_{1/2}$)
October 3	0030	All areas			From MTR wind NE (31.5 min $T_{1/2}$)
October 3	1500	All areas	Off and on for 15 hours	1.3	Air activity each time wind shifts to N or NE
October 4	0530	All areas	Approx. 1 hour		Wind from NE caused general rise in air activity
October 4	1530	All areas	Approx. 7 hours	Max. 2	Wind from NE
October 5	0130	All areas	Approx. 30 minutes		Wind from NE brought burst of air activity
October 7	1850	Reactor Building	70 minutes	2.4	Wind N NE 3 mph (24 min $T_{1/2}$)
October 8	0030	All areas	1.5 hours		Wind NE causing air activity
October 8	2105	Reactor Main floor	40 minutes	4.4	From reactor tank when dome removed (32 min $T_{1/2}$)
October 10	1100	All areas	1 hour	1.8	($T_{1/2}$ = 28 minutes)
October 11	0440	All areas	25 minutes	1	($T_{1/2}$ = 24 minutes)
October 11	0600	All areas	4.5 hours	Gradual increase	Wind NE
October 14	0200	Compressor Building	2.5 hours	2.5	From sample lines in sink
October 16	0730	All areas	7.5 hours	1.6	
October 16	2100	Compressor Building	Approx. 20 minutes	Sharp rise	From sampling area
October 17	0020	All areas		Same activity	Wind from NE
October 17	0230	All areas	2.5 hours	2 x	(33 min $T_{1/2}$)

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TABLE III (Continued)

Date	Time	Area Affected	Duration	Units of Air Activity One Unit = $3x10^{-9}$ μc/cc	Source and Remarks
October 18	0015	All areas		1.9 x	NE wind
October 18	0530	All areas	5.33 hours	2.6	NE wind - air activity reached peak of 2.6
October 18	1210	Reactor top	Approx. 1 hour	7.5	Sniffer hose to reactor tank
October 19	0020	All areas		More air activity	NE wind
October 20	2330	Reactor Main floor	Approx. 2 minutes		All PMS ringing - no activity on CAMs - appears to be gaseous activity
October 22	2135	All areas	21 minutes	1.5	(21 min $T_{1/2}$) MTR fission break
October 23	0345	All areas	Approx. 1.5 hour	8	MTR source
October 23	1200	All areas	45 minutes	4	Wind SW 5 mph (21 min $T_{1/2}$) (Very peculiar due to wind direction - wind had probably shifted around shortly before activity was observed.)
October 24	1030	All areas			Rise on CAMs - from MTR source
October 24	1330	All areas	1 hour	12	Another burst from MTR
October 24	1620	All areas			Shifted CAMs down from 10 x scale
October 25	1745	All areas	Approx. 1.5 hour	3.6	Wind NE (32 min $T_{1/2}$)
October 25	2300	All areas		Max. 1600 cpm	Air activity increasing again
October 26	0100	All areas		3.8	Wind from NE
October 26	0150	All areas		1.8	(27 min $T_{1/2}$)
October 26	1615	All areas		11	Air activity increasing
October 26	1910	All areas			Air activity diminished 'til all CAMs are back on 2 x scale
October 27	0030	All areas	15 minutes	5.6	

TABLE III (Continued)

Date	Time	Area Affected	Duration	Units of Air Activity One Unit = 3×10^{-9} μc/cc	Source and Remarks
October 28	0340	All areas	Approx. 15 minutes	3	No wind - MTR scrammed for fission break
October 28	1930	All areas	Approx. 15 minutes	4	Wind NE - activity dropped when wind shifted
October 28	2200	All areas	45 minutes	5	Wind from NE again
October 29	0010	All areas		Approx. 1.5	Activity from previous shift decaying off to 2500 c/m
October 31	0855	All areas		1.6	($T_{1/2}$ = 25 minutes)
October 31	1140	All areas		4.5	
November 1	1000	All areas		1.4	(32 minutes = $T_{1/2}$)
November 1	1320	All areas		Increasing	Air activity increasing (32 min $T_{1/2}$)
November 1	1347	Compressor Building	Approx. 1 hour	7	Activity diminishing when big door closed
November 1	1530	All areas		2.8	New rise
November 1	1615	All areas		17.5	Air activity up
November 1	1745	All areas			Air activity decaying
November 1	1815	All areas	20 minutes	3.4	Air activity again
November 1	2230	All areas		1.9	Another burst of air activity
November 5	0145	Compressor Building		CAM on 2nd scale	ETR Heat Exchanger Building
November 5	0830	ETR Basement	30 minutes	Sharp rise	ETR Basement
November 6	0030	Compressor Building		Approx. .5	Probably from sample sink
November 6	2245	All areas		2.8	Wind NE (32 min $T_{1/2}$)
November 6	2400	All areas		2.7	MTR fission break - MTR scrammed - activity decaying

TABLE III (Continued)

Date	Time	Area Affected	Duration	Units of Air Activity One Unit = $3x10^{-9}$ μc/cc	Source and Remarks
November 8	0300	Reactor Building	15 minutes then leveled		
November 8	0630	All areas		2	No wind (32 min $T_{1/2}$)
November 8	0900	All areas	2 hours then leveled off	4.5	($T_{1/2}$ = 30 minutes)
November 8	1140	All areas	1 hour	10	Friskers all alarmed - MTR scrammed from fission break

TABLE IV*

PERCENTAGE OF TIME PERIOD LISTED HAVING INDICATED AIR ACTIVITY UNITS

(1)

Air*** Activity Units	ETR				
	Jan. 1 - April 10	Apr. 11 - June 18	June 19 - Oct. 3	Oct. 4 - Dec. 31	Total 1959
0 - .3	71.0	56.5	85.2	71.1	72.5
.3 - .4	8.6	6.6	4.9	4.2	6.1
.4 - .5	7.0	5.8	4.3	5.9	5.7
.5 - .6	4.1	2.9	2.0	4.4	3.3
.6 - .7	2.0	4.3	1.5	3.8	2.7
.7 - .8	1.1	2.6	.6	3.0	1.7
.8 - .9	.9	2.7	.4	1.2	1.1
.9 - 1.0	.4	2.3	.2	1.1	.9
1.0 - 1.5	1.1	8.7	.6	2.8	2.8
1.5 - 2.0	1.0	3.2	.1	1.2	1.2
2.0 - 3.0	1.4	2.5	.1	.6	1.0
3.0 - 4.0	1.0	1.1	0	.2	.5
4.0 - 6.0	.3	.4	.1	.2	.2
>6.0	.2	.3	0	.2	.2

(2)

Air*** Activity Units	Gamma Facilities Building				
	Jan 1 - Mar 31	Apr. 1 - June 30	July 1 - Sept 30	Oct. 1** - Dec 31	Total 1959
0 - .3	100.0	99.5	99.8	99.2	99.7
.3 - .4	.0	.1	0	.1	.1
.4 - .5	.0	0	0	.1	0
.5 - .6	.0	.1	0	.2	0
.6 - .7	.0	.1	0	.1	.1
.7 - .8	.0	0	0	0	0
.8 - .9	.0	0	0	0	0
.9 - 1.0	.0	0	0	.1	0
1.0 - 1.5	.0	.1	0	0	0
1.5 - 2.0	.0	0	0	0	0
2.0 - 3.0	.0	0	0	0	0
3.0 - 4.0	.0	0	0	0	0
4.0 - 6.0	.0	0	0	0	0
>6.0	.0	0	0	0	0

* All numbers are rounded to include one digit at the right of the decimal point, therefore may not sum to one.

** Data from 10-9-59 to 11-12-59 are missing, however no evacuation levels were indicated at this location.

*** One unit of air activity is equal to 3×10^{-9} c/m^3

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Table IV-(2) shows a corresponding distribution obtained from one CAM located in the gamma facility building located southwest of the MTR-ETR stacks.

Since Table IV-(1) and IV-(2) are CAM level frequency distributions for stack effluent levels which are by no means constant it is informative to consider the absolute values of ground level concentrations of airborne material as a function of stack output. Such studies have been underway at MTR and ETR for some time and one preliminary correlation equation is available. This correlation relates CAM response to stack output during the fumigation condition arising during or shortly after the morning inversion break.

Regression analyses have been performed in connection with correlating ETR ground level concentrations with MTR-ETR stack output. Several equations have been developed, with appropriate uncertainty analyses, of which the simplest and most useful is as follows:

$$C = 1.519\ S$$

where

C = CAM reading in curies/meter^3 x 10^{-9}

S = Total output of gaseous fission products from MTR and ETR stacks in curies/second x 10^{-2}

Table V shows calculated values of ETR CAM readings versus stack discharge together with the error at 95 per cent confidence level. It will be noted that the relative error decreases with increasing stack output. It should also be noted that source strength S is based on gaseous fission products whereas Figures 5 and 6 were based on total gaseous output including argon-41.

TABLE V

ETR STACK DISCHARGE VERSUS CAM READINGS

Stack Discharge (curie/sec x 10^{-2})	ETR CAM Readings (curies/meter^3 x 10^{-9})	Error - 95% Confidence (curies/meter^3 x 10^{-9})
.2	.304	6.151
.4	.608	6.155
.6	.911	6.159
.8	1.215	6.168
1.0	1.519	6.175
1.5	2.279	6.207
2.0	3.038	6.248
3.0	4.557	6.368
4.0	6.078	6.522
5.0	7.595	6.732
6.0	9.114	6.993

For other values of stack discharge not included in Table V, values of C may be determined from the equation $C = 1.519 \cdot S$. The error associated with each computed C value, at 95% confidence, may be calculated using

$$E = 1.994 \sqrt{9.518 + .076618\,(S)^2}.$$

Care should be exercised in the use of this equation since it applies only to the fumigation condition arising during or shortly after the morning inversion break and only for the range of stack effluence which has been experienced. Indications are that if all fumigations are considered, the dilution factor is somewhat less favorable- possibly by a factor of two or three.

The use of the summed outputs of the MTR and ETR stacks is based on an analysis which shows that insofar as ETR CAM response is concerned there is no significant difference between the two stack locations.

No CAM data are available which will indicate directly the effects of the ETR II stack on the MTR-ETR area. Arguments in this regard must be based on meteorological data and will be presented in Section V.

D. Direct Radiation

The effects of direct radiation are nearly always confined to the local reactor areas as indicated in the incident summary sheets. The few cases in which effects have been coupled from MTR to ETR have primarily involved reaction of high sensitivity instrumentation such as friskers, hand and foot counters, and direct radiation monitors. In the case of these instruments it is possible for high radiation fields at one reactor to trigger alarms or cause false high readings at the other. In this regard, some of the ETR experiment discharge procedures which are based on the minimum shielding-short time exposure philosophy have been subjected to limitations. Probably the most serious experienced case of direct radiation coupling involved the gaseous discharge lines from the ETR to the ETR stack. During a period of abnormally high discharge, radiation levels of the order of hundreds of mr per hour were experienced at the MTR fan house (Figure 4) for short periods of time. This constituted a nuisance access problem and interfered with the MTR stack radiation monitoring equipment. However, this problem is confined to a small area of the site. At no time in MTR-ETR operating history have radiation sources existed in the MTR-ETR area which would have produced significant radiation levels in the proposed ETR II area.

E. Common Facilities

There have been no significant unfavorable experiences at MTR or ETR due to the fact that certain facilities are shared by the two reactors. There have also been no cases of synchronization of unfavorable incidents due to facility sharing, other than simultaneous reactor scrams. The latter occur mainly during commercial power outages at which time the ETR is scrammed instantaneously and the MTR is scrammed after a short time delay. This is of course, exactly what should happen following such outages.

The principal adverse effect in connection with shared facilities is in maintenance and modifications. This constitutes a problem in the scheduling of work of this kind in such a manner as to minimize interference with operating schedules. On the other hand there is a more than equivalent amount of favorable experience involving use of combined utilities because of the plant flexibility introduced by multiple units and the fact that MTR-ETR may trade surpluses of various commodities for short periods of time.

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IV. ETR II REACTOR AND PLANT

ETR II is an engineering test reactor designed to provide high neutron fluxes in a multiplicity of high-pressure water loops of small diameter in support of the Naval Reactors program.

To accomplish the objectives of the various tests planned, it has been necessary to employ a reactor of unusual design. Inasmuch as the neutron conservation features of flux-trap type reactors afford the most attractive way of combining high fluxes in experiments with low relative power density in the reactor fuel, one is faced with either using several reactors each with one flux-trap or coupling several flux-trap regions into one critical system.

The latter direction was chosen for ETR II to keep the total power required to accomplish the NR program within reasonable bounds. ETR II, operating at 250 Mw, provides nine such flux concentration regions in an arrangement shown in Figure 7.

The fuel region comprises a 4 ft long core in a four leaf clover configuration shown in solid black. The fuel is contained in circular segment, plate-type elements which establish the geometry of the active core. Experimental loops run parallel to the fuel region through the flux concentration zones. These loops are isolated from the fuel by regions containing various compositions of aluminum and water to adjust the flux spectrum according to the needs of the particular experiment.

One feature in the design concept is the use of a D_2O reflector with a region just adjacent to the fuel, in which boron is added to accomplish operational control. Four cadmium- or boron-containing blades located in the neck regions between lobes are employed as safety rods.

An alternate core arrangement would use a solid beryllium reflector and mechanical control blades located just outside each lobe. The fuel arrangement would be the same. Although less desirable from a kinetic viewpoint, the need to contain the large volume of D_2O with essentially no loss is eliminated as well as the problem of continuous control of concentration of boron.

The core is housed in a reactor pressure vessel with the top head just above the canal water line. The loops penetrate both top and bottom of the reactor. In general the arrangement is like that of ETR except that the penetrations are smaller and more regularly spaced.

The layout of the reactor building complex is shown on Figures 8 through 12. Some of the more important details pertaining to this area are discussed in material following.

The building section housing the reactor, canal, and operating office areas has been kept clean and unencumbered. Means are also provided for isolating any individual area from other areas when required.

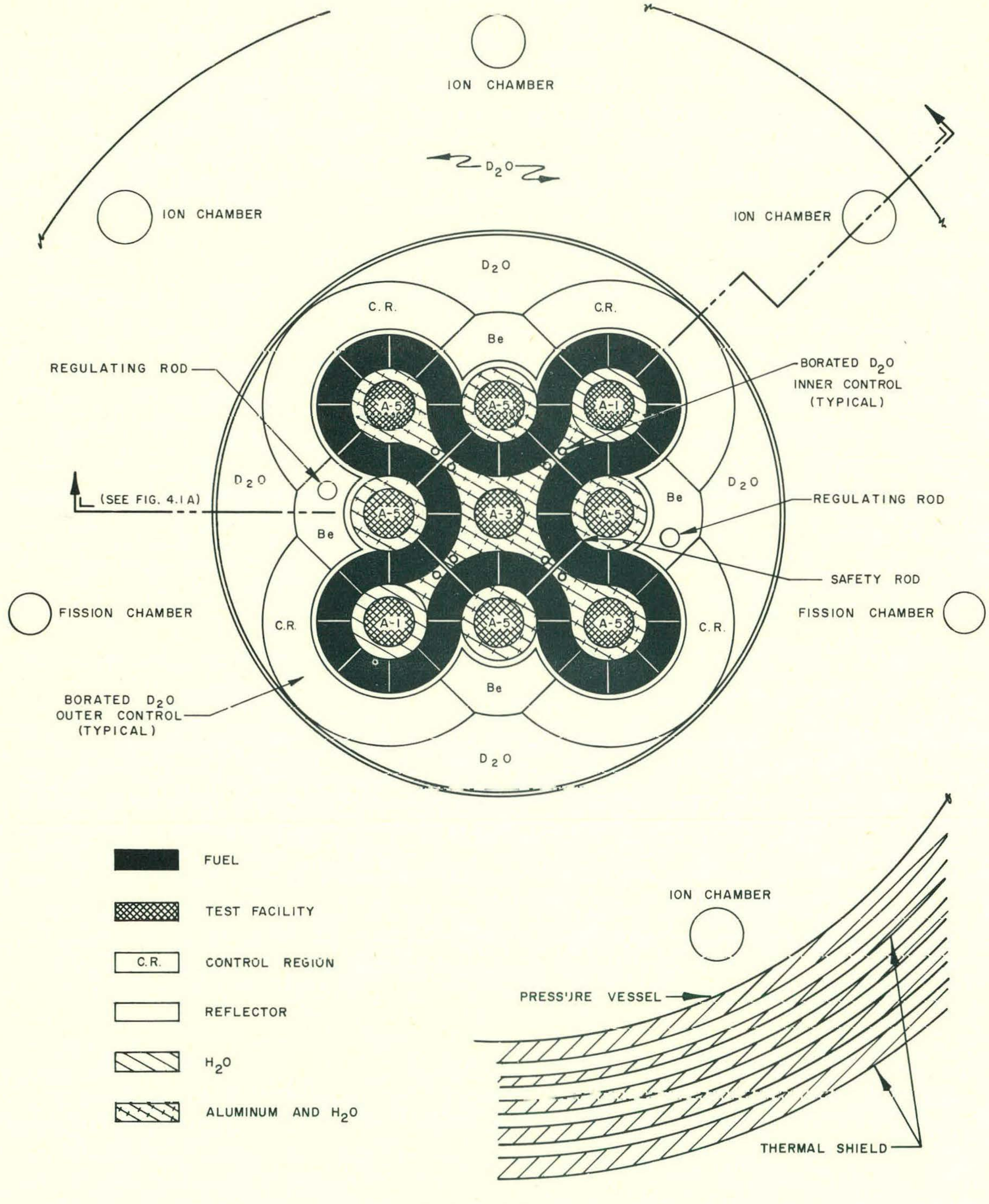
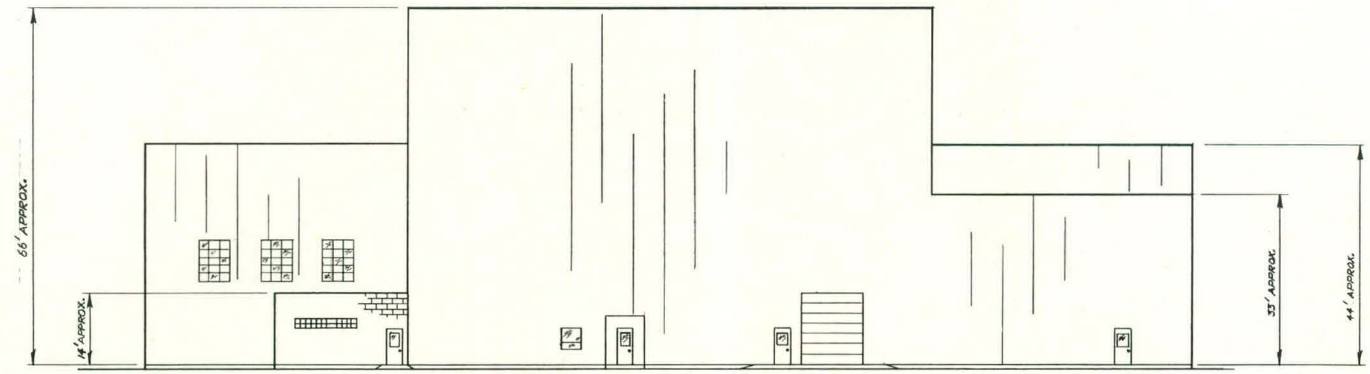
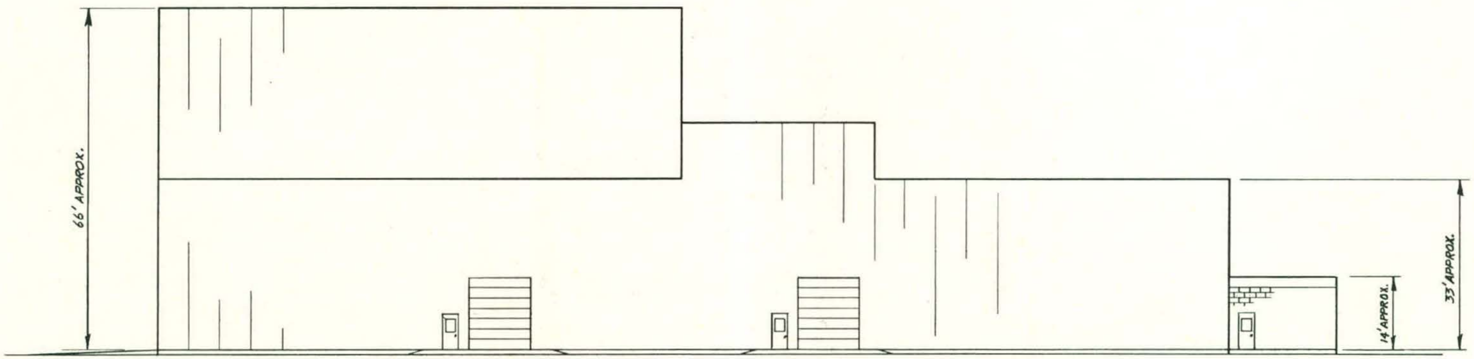


FIG. 7
CORE CROSS SECTION
ETR II: FOUR-LOBE REACTOR

PPCo.-C-2700



REACTOR BUILDING SOUTH ELEVATION



REACTOR BUILDING EAST ELEVATION

FIG 8

REACTOR BUILDING — BUILDING ELEVATIONS

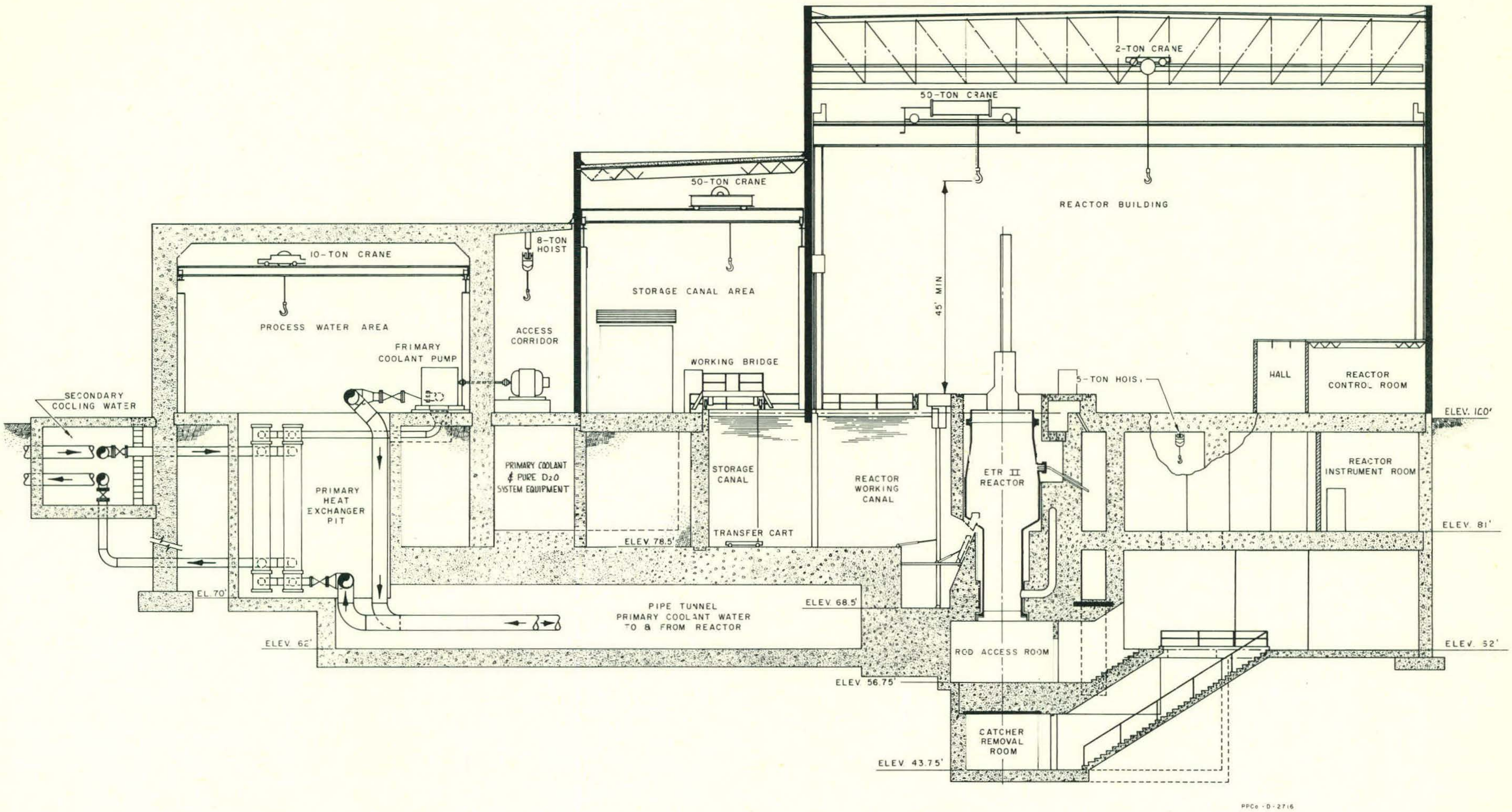


FIG. 9

REACTOR BUILDING — SECTIONAL ELEVATION "A-A"

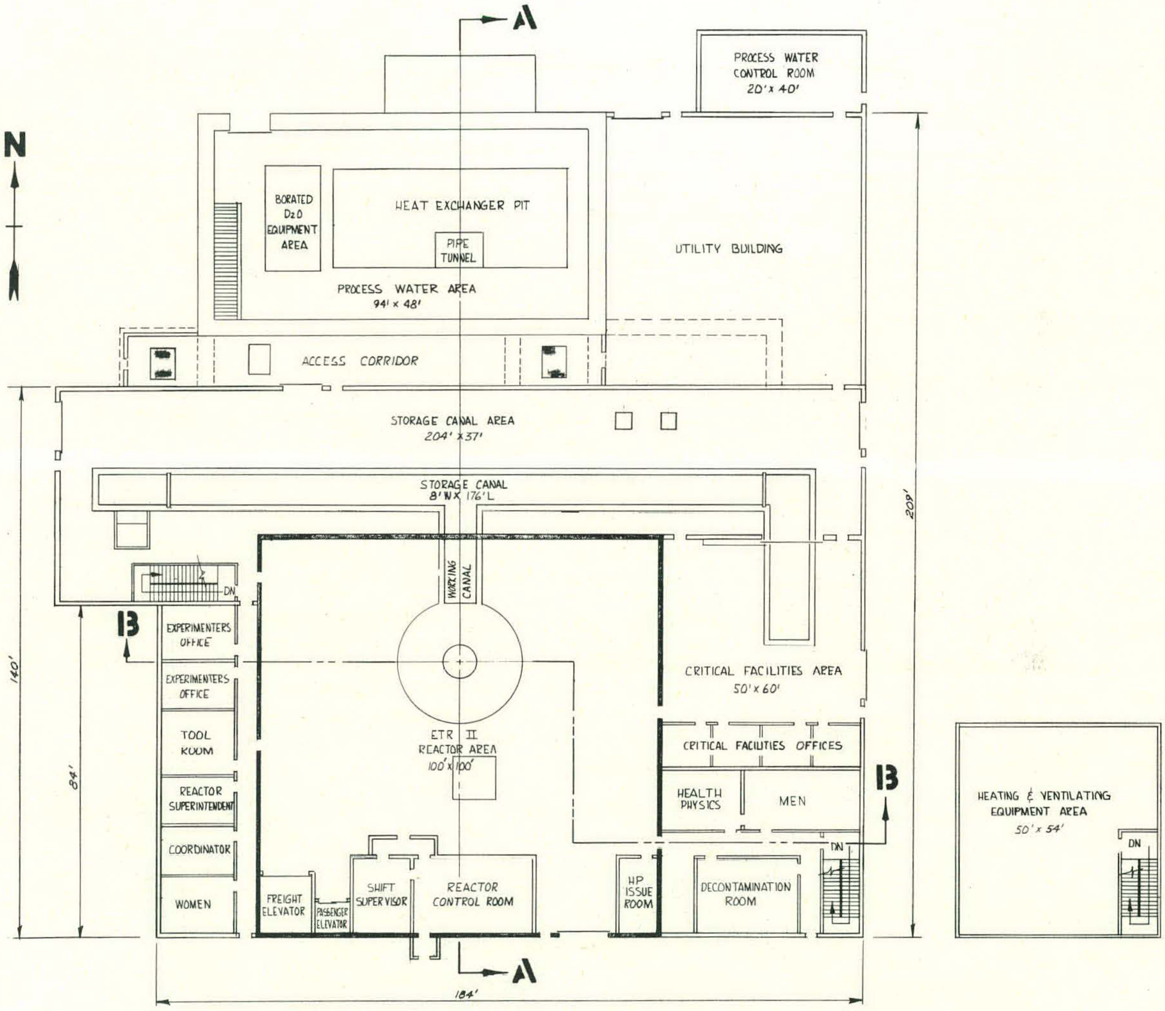


FIG. 10
REACTOR BUILDING – FIRST FLOOR PLAN

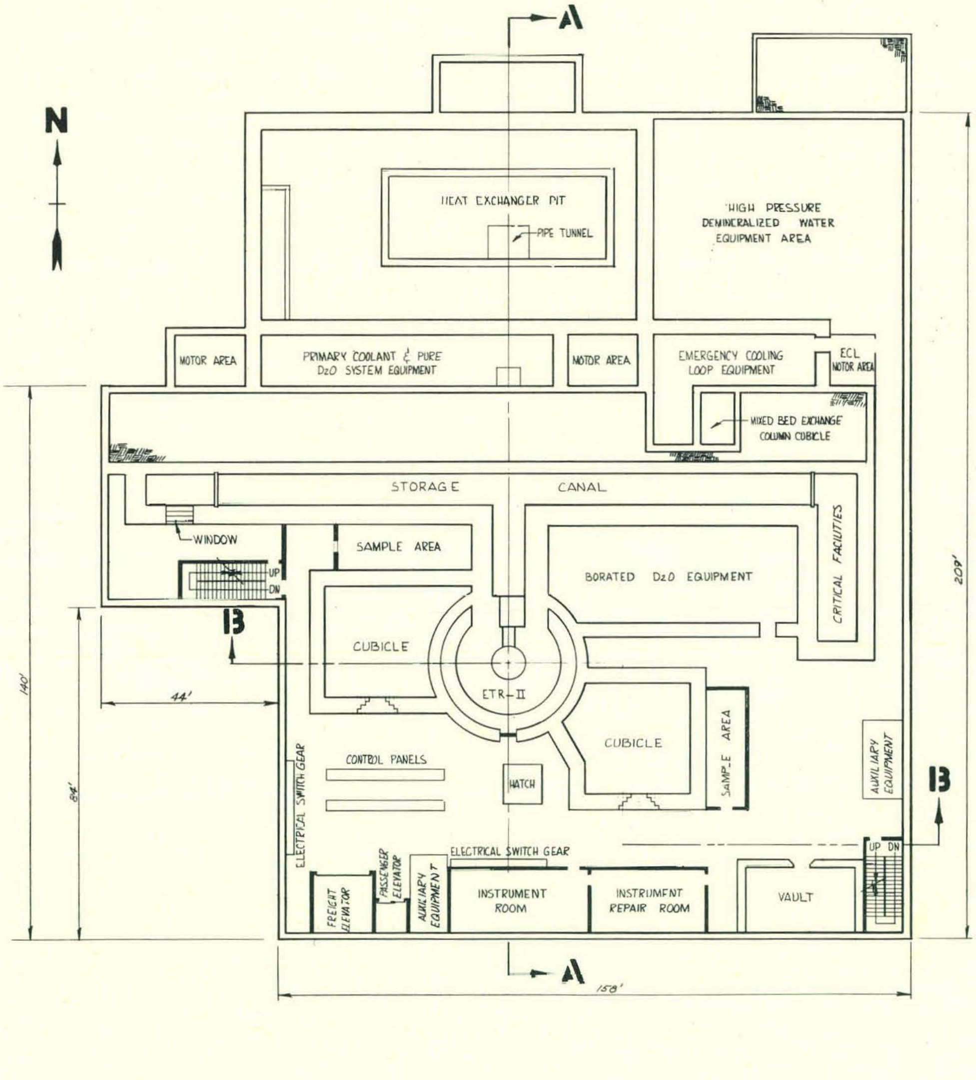


FIG. 11

REACTOR BUILDING — FIRST BASEMENT PLAN

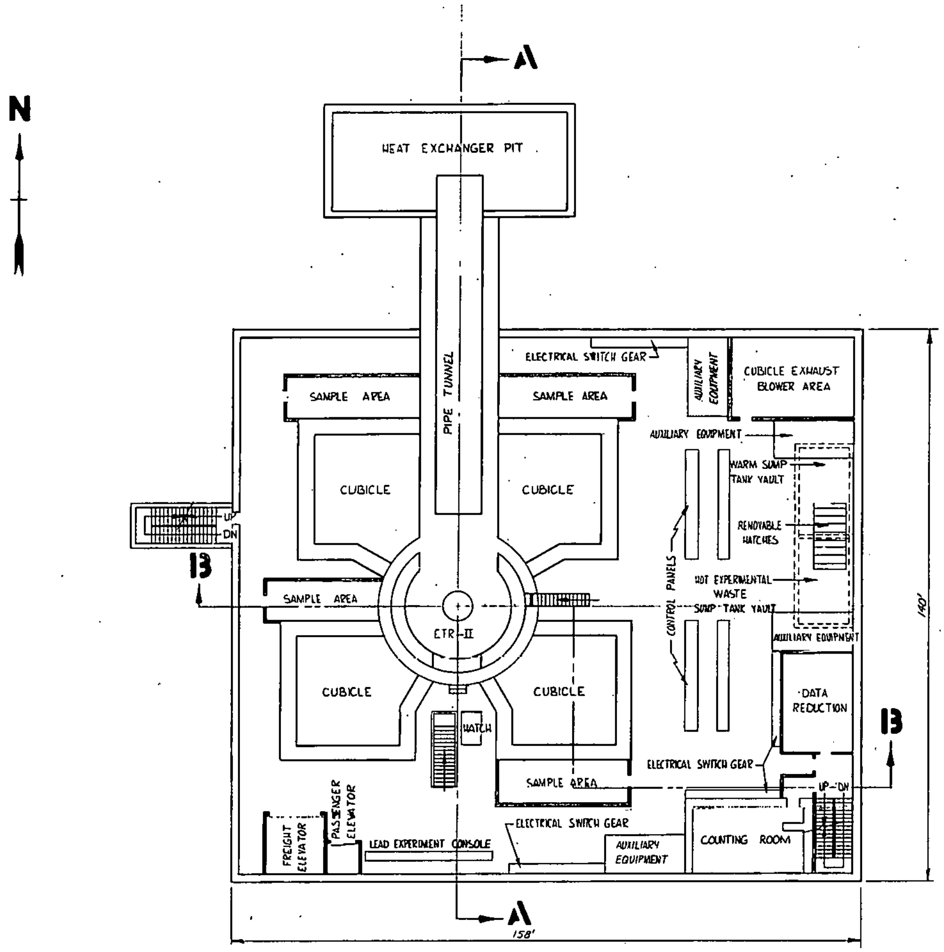


FIG. 12
REACTOR BUILDING — SECOND BASEMENT PLAN

The reactor building proper is of insulated panel construction with an over-all main floor area of some 34,000 sq ft. Of this area approximately 10,000 sq ft are devoted to the reactor proper, with another 9,000 sq ft occupied by the main canal and its access and operating areas. The reactor is serviced by its own overhead crane; a second crane covers the main canal area. The remainder of the building is occupied by a critical facility, and an office and control room area.

Office areas within the reactor building are intended for shift reactor operating supervisory personnel. Two wing buildings connected to the reactor building, provide additional office and service space for functions essential to operation of the reactor. Health Physics personnel and counting equipment are housed in this area. One decontamination room is located in the wing building so that maintenance on contaminated material may be performed as expeditiously as possible.

An instrument rack room for the control room is located directly below the control room on the first basement level. A separate instrument repair room is also located on this level for the repair and servicing of instruments from the reactor.

The remainder of the first basement level and the second basement level are devoted to experiment cubicles, control panels, switch gear, etc. Numerous hatchways, stairwells, and elevators provide communication between the three floors for equipment and personnel.

The reactor is connected to the main canal by means of a lateral, this is in addition to the critical facility. An experimenters' work area is included in the main canal. The main canal will be some 18 ft in depth, 8 ft wide and 150 ft long over-all. This canal area, although part of the main reactor canal, will be equipped with bulkheads to separate it when required. Similar bulkheads will be provided for the critical facility.

Working areas are provided on both sides of the main canal. A through truck aisle parallels the main canal. This aisle is serviced by the canal crane and permits convenient loading and shipping of experiment casks.

It is anticipated that the canals will be lined with stainless steel to minimize the leak potential and to keep canal water contamination at the lowest possible levels. Demineralized water at a pH of 6.5 will allow storage of fuel elements, experiments, etc., for long periods of time with little or no corrosive attack.

The process water area is situated immediately adjacent to the reactor building, with an enclosed motor area separating the two buildings some 12 ft at grade level. The building proper is heavily shielded for protection against a potential gross fission break into the reactor cooling water stream. The main coolant pumps are located at approximately grade elevation and are connected to drive motors by shaft extensions through the shield wall. A heat exchanger pit 24 ft wide by 60 ft long by 30 ft deep is provided. The pit is sized to accommodate ten vertical heat exchangers and necessary piping. An overhead crane serves the heat exchanger and pump areas and has a lift adequate to pull any exchanger from its pit to the grade level floor for maintenance work. Ion exchange resin beds are located in shielded lean-tos next to heat exchanger pits.

A control room for the reactor cooling system is provided adjacent to the process water building.

A. Waste Disposal

1. Liquid Disposal System

Cold Waste. Nonradioactive liquids from the cooling tower, the laboratory and engineering building, the maintenance and warehouse building, and the utilities building flow directly by gravity to the plant sump. The warm plant effluents also discharge to the plant sump and are diluted with the cold wastes before being discharged to the leaching pond. Two motor-driven plant sump pumps (2,000 gpm, 25 ft TDH, 20 hp) pump the liquid wastes directly to the leaching pond via a 10 in. tile line for disposal to the atmosphere by evaporation and to the subsoil by percolation.

Warm Waste. Radioactive liquid wastes from the canal, the reactor building, the heat exchanger building, the laboratory and engineering building, and the primary coolant system degassing tank flow by gravity through 2 in. and 4 in. stainless steel piping to the 5,000 gal stainless steel warm sump tank located in a shielded cubicle below the reactor building basement floor. Two motor-driven turbine pumps (200 gpm, 100 ft TDH, 7.5 hp) pump the warm wastes to the 10 in. stainless steel primary system flush line, which discharges to the plant sump. The warm sump tank is equipped with a level indicator controller which automatically starts and stops the warm sump pumps.

Hot Experimental Waste. Coolant and decontamination solutions from the experimental loops and the laboratories will be the only sources of wastes whose radioactivity concentrations are too high to permit ultimate discharge to the leaching pond. The hot wastes from the laboratories are estimated to be only a few gallons per week.

If experimental capsule or reactor fuel element failures contaminate the primary systems to such a degree that the primary coolant cannot be flushed directly to the leaching pond via the plant sump, the reactor will be shut down and the primary coolant circulated and decontaminated by means of the primary bypass demineralizer until the radioactivity concentration of the primary coolant is reduced to a low enough level to be discharged to the leaching pond.

Hot wastes from experimental loops will drain via 2 in. stainless steel lines to the 1,000 gal hot experimental waste sump tank located in a shielded cubicle below the reactor building basement floor. Either of two motor-driven pumps (50 gpm, 100 ft TDH, 2 hp) transfers the liquid from the sump tank to the MTR hot waste storage tanks, to the ETR resin system, or to a shielded tank truck for disposal at CPP.

The hot experimental waste collection system is constructed of stainless steel since the decontamination solutions used on the experimental loops are highly corrosive to carbon steel.

2. Gaseous Disposal System

The gaseous waste disposal system exhausts air from potentially high air activity areas such as the experimental cubicles, the primary pipe tunnel and heat exchanger area and the subpile room, and purges the radioactive hot and warm waste tanks and the primary system degassing tank.

Provisions are made to exhaust the reactor working platform when the reactor vessel top closure is removed for in-tank work, so that gaseous activity in the reactor vessel is exhausted to the cubicle exhaust system and does not contaminate the building air. A portable canal exhaust hood removes radioactive gases from the surface of the canal water when ruptured samples are stored in the canal below this hood.

Total waste gas quantity, which will be monitored prior to disposal through the stack, is estimated at 78,800 cfm. The gaseous and particulate monitor is described in further detail below.

Two blowers (40,000 cfm, 50 hp) are provided and operate in parallel. One motor blower is connected to the diesel power bus and the other to the commercial power bus. System flow and pressures are recorded in the primary control room.

Over-pressure safety devices (rupture discs and pressure relief valves) on the experimental loops discharge into an experimental vent header which discharges into the cubicle exhaust duct on the downstream side of the blowers. Steam and radioactive gases when released from an experimental loop are thus vented to the stack to minimize contamination of the experimental cubicles and equipment.

Reference to the meteorological data summarized in Figures 1 and 2 indicates that the ETR II stack, located crosswind from all occupied areas and from the MTR and ETR, is in a nearly optimum location. The choice of this location will be discussed in more detail in Section V.

B. Radioactive Monitoring

1. Direct Radiation

As proposed, area monitoring is performed in various parts of the plant with ion chambers incorporating built-in calibration sources. These are adjustable from the main control panel where the contact meter relays are located. All units alarm locally as well as in the Health Physics office and those of primary importance record in the control room.

There are several ion chambers located on each of the first, the basement floor levels and the sub-basement level. The control panels are in the Health Physics office and two multipoint recorders are in the reactor control room.

Ion chambers are located in the heat exchanger building, in the hot cell, and in the utilities building.

2. Air Monitoring

Constant air monitoring is accomplished by portable units in the hot cell, utilities building, and in the heat exchanger building. These record and alarm locally and alarm in the Health Physics office. Similar units are located in the reactor building and record in the reactor control room.

3. Fission Break Detectors

There is one primary coolant fission break detector. The process water sample is continuously drawn through a pressure regulator and flow meter to the monitor which may be either an iodine-activity or a delayed neutron monitor. The activity level is continuously recorded in the reactor control room.

4. Waste Gas Monitoring

The waste gas monitor measures and totalizes air flow to the stack. It also monitors a continuous sample of the air stream for particulate and gaseous activity with a moving filter tape system. Scintillation counters with totalizers are used for both gas and particulate monitors. The instantaneous level of each records in the Health Physics office on a multipoint recorder.

5. Effluent Water Monitor

Effluent water is continuously measured for flow rate and activity. A sample whose flow is proportional to discharge rate is collected for analysis and effluent water activity is monitored by a scintillation system. Flow and activity are continuously multiplied and integrated to give the total curies discharged.

6. Personnel Monitors

Two hand-foot counters are located in the reactor building. Friskers of the quintector type are located in the reactor building. Friskers of the quintector type are located at all reactor building exits, at elevator entrances, and at each stair well. Friskers are also provided at the main gate.

C. Utilities

Table VI lists all facilities which will be common to ETR, MTR, and ETR II. For comparison purposes, Table VII lists all utilities which are common only to ETR I and MTR.

TABLE VI

COMMON FACILITIES FOR MTR, ETR, AND ETR II

Air	Plant air
	Instrument air
Water	Demineralized water
	Potable water
	Fire water
	Wells
	Raw water storage
Disposal	Sanitary sewer
	Hot waste storage
	Hot waste truck loading facility
Steam and Condensate	135 psig steam
	Condensate
Chemicals and Oil	Diesel oil
	Acid
Electrical	132 kv feeder
Communications	Evacuation alarms
	Fire alarms
	Telephone

TABLE VII

COMMON FACILITIES FOR MTR AND ETR

Air	
	Plant air
	Instrument air
	Experimental air (6 in. crosstie between MTR and ETR systems)
Water	
	Demineralized water
	Potable water
	Fire water
	Wells
	Raw water storage
Disposal	
	Sanitary sewer
	Hot waste storage
	Hot waste truck loading facilities
	Retention basins
	Retention basin sump
	Leaching pond
Steam and Condensate	
	135 psig steam
	Condensate
Chemicals and Oil	
	Diesel oil
	Acid, sulfuric
Electrical	
	132 kv feeder
	132/13.8 kva transformers for ETR are located at MTR substation
Communications	
	Evacuation alarms
	Fire alarms
	Telephone

The only utilities which are peculiar to ETR II are the warm drain system, leaching pond and the diesel power.

Diesel power at 4,160 volts is supplied by two heavy duty diesel generators. One unit operates continuously and the other serves as a standby unit. The critical plant and experimental leads are split between independent commercial and diesel power for a system. When a commercial power failure occurs, the operating diesel generator continues to supply power to its normal connected loads. The reactor is automatically shut down on loss of commercial power or if the diesel generator fails. It is very unlikely that diesel generator failure and a commercial power outage would occur at the same time.

V. ANALYSIS OF POSSIBLE INTERACTION OF THREE REACTORS

As stated in an earlier section, the three basic modes of interaction between closely situated reactors are meteorological coupling, coupling by direct radiation, and coupling through common facilities. The last mechanism must be considered in the sense of one reactor interfering with another and in the sense of some malfunction external to one or more of the reactors causing simultaneous difficulties in the reactor plants, e.g., a commercial power outage on the area feeder lines.

In Section III experience over several years with two very closely situated reactors, the MTR and ETR, was outlined. We will now review this experience as it applies to the proposed location of ETR II and the possible interactions within a three reactor complex.

A. Meteorological Coupling

As one may see from Section III some trouble has been experienced due to this problem in the MTR-ETR area and in fact, of the three coupling modes, this one has given, by far, the most difficulty. This problem, of course, arises because of two factors:

1. The stack source strengths which must be maintained at MTR and ETR in order to operate the reactors and fulfill experimental requirements.

2. The geographical-meteorological location of ETR relative to the MTR-ETR stacks.

At MTR the stack gas activity has originated mainly from three sources; the argon-41 from the air which cools the reactor graphite, fission product off-gas from the process water due to experimental and reactor fuel element fission breaks, and experimental off-gas from experimental primary coolant and vent gas. At ETR the same sources exist with the exception of the graphite cooling air. The ETR II sources should be of much lower magnitude because of the absence of the large scale capsule program cooled by reactor process water and the absence of the gas cooled and fused-salt programs. The reactor fuel itself, however, is still a significant potential source of fission gases.

As is shown in Section III both the MTR and ETR stacks are capable of causing considerable quantities of airborne material to exist in the ETR area at normal curie discharge levels. This arises principally because of the location of the ETR with regard to the stacks from the meteorological point of view but, although minor operating difficulties arise at ETR due to the existing stacks, it is evident that the gross environmental situation will be relatively unaffected by the addition of ETR II.

This argument is based on Table IV of Section III. Study of this table will indicate that the area to the northwest of the MTR-ETR is little influenced by the MTR-ETR stack effluent and, in fact, if the stack output levels indicated in Figures 5 and 6 were increased ten fold, above-permissible levels of air activity would be reached less than 0.1 per cent of total time.

There are no CAM data available to indicate the possible effect of the ETR II stack on the MTR-ETR area so one must have recourse to meteorological data. If one studies the wind directions associated with unfavorable meteorological conditions (Figure 2) it appears that wind frequencies are approximately similar in the northwest and southwest directions. This would indicate that from the meteorological point of view the effect of the ETR II stack on the MTR-ETR reactor areas will be approximately equivalent on a per curie basis to the effect of the MTR-ETR stacks on the gamma facility building. This opinion is corroborated by the IDO-AEC site survey people as indicated in the letter from W. P. Gammill to J. W. McCaslin included in Appendix A. It should be remembered in making this comparison on a per curie basis that stack evolution rates for ETR II should be markedly less than the combined MTR-ETR stack output which makes the situation even more favorable. It may also be noted that the unfavorable northwest-southwest locations with respect to the ETR II stack (represented by the location of the ETR relative to the MTR-ETR stacks) are in unoccupied areas.

It may be concluded, then, that one may expect a negligible period of time during which meteorological coupling will induce operational difficulties between the MTR-ETR area and the proposed ETR II site and that such effects will be far less severe than those experienced at ETR due to the MTR-ETR stacks.

The conclusion holds true both during periods of normal MTR-ETR operation and during the periods of abnormally high stack release which have been experienced during operation of the MTR and ETR.

In the case of catastrophic release of gaseous fission products the most probable sources are the single-pass gas-cooled experiments which discharge to the stacks at MTR-ETR. Since the gas-cooled experimental program is variable in nature one must consider the operational and design criteria associated with experiments of this type. Each such experiment must be designed and operated in such a manner as to present no severe biological hazards or operational difficulties in the ETR operating area. It may be seen by reference to the material in Section III that the frequency of CAM readings greater than 6 air activity units at ETR is of the same order of magnitude as the frequency of readings greater than 0.3 air activity units at the gamma facility building (which is representative of the ETR II location). This means that design and operating criteria set up to protect personnel at the ETR afford a full decade or more additional protection to personnel in the ETR II area by virtue of its more favorable location. There should, then, be no significant probability of severe biological hazards or operational difficulties at the proposed ETR II site due to MTR-ETR stack effluent because of the over-riding design and operational criteria necessary to protect the ETR area.

In considering the case of, say, a major core meltdown at one of the three reactors, it is difficult to predict the probability of the event in the first place except to say that it is extremely unlikely. Such an event would release considerable quantities of fission gases initially and could require temporary evacuation of the ETR II area under certain conditions. It would also be possible for personnel in the ETR II area to receive significant radiation doses by ingestion during the initial evacuation. It is difficult to quantitate a risk of this type except to point out that any difficulties which would be experienced at the ETR II site would be far less severe and/or less probable at a given level than those at ETR. Considering the problem on a probability frequency basis, the dilution factors indicated at 95 per cent confidence by Table IV would probably be reduced by a decade or more. It should be pointed out in this connection that it is not possible to say, at this time, whether this means that the maximum dilution factors experienced are lower or less probable by this amount.

One may state, however, that the probability of a prolonged disablement of a reactor located in the ETR II area due to meteorological coupling to the MTR-ETR stacks or vice versa is extremely remote.

B. Coupling by Direct Radiation

As was stated earlier, the only difficulties experienced due to coupling by direct radiation between MTR and ETR have been due to response of very sensitive instruments to very large fields at the neighboring reactor or, in one case, to the unfortunate proximity of a hot ETR experimental gas discharge line to the MTR fan house. The remote location of the ETR II will eliminate difficulties of this sort completely and it is necessary to consider only a catastrophic failure at MTR or ETR which would release large amounts of fission products to unshielded above ground points. Since the experimental systems are below ground and/or shielded and/or filtered upstream of their above ground sections, the most formidable source location is probably the MTR process water working reservoir. Since the maximum fields which have been measured in close proximity to MTR fuel elements in the gamma facility a few hours after reactor shutdown are of the order of 10^7 roentgen per hour at a foot it is informative to consider the radiation fields at the ETR II area due to a point source of this strength. Even with a source of this magnitude located in the neighborhood of the MTR working reservoir the field at the ETR II location would be only a few roentgen per hour. It may be seen, then, that any event short of a major catastrophe at MTR would be capable of introducing only minor operating difficulties at the ETR II site.

C. Coupling Through Common Facilities

Common facilities for MTR, ETR and the proposed ETR II are listed in Tables VI and VII (Section IV). In this catagory it is obvious that if, say, one compressor were used to supply air to all three reactors and the compressor were to fail, all three plants would be shut down.

This risk may be made large or small depending on the engineering and economic considerations which go into the selection of multiple units, utility surpluses, etc., and involves basically the same engineering-economic considerations associated with supplying utilities for any one plant by itself.

As stated in Section III only minor scheduling difficulties have been experienced with regard to maintenance and modification due to use of common facilities at MTR-ETR and that these difficulties have been compensated by the advantages of multiple units and the ability to "trade" utility allocations.

It is useful to discuss the various utilities one by one with regard to their ability to cause one reactor area to influence another.

1. Air

There is no obvious means by which one plant could influence the other through the common air supply. In the event of full scale air failure, loss of critical air would cause shutdown of all plants but the events in any one plant would be no different than if it had lost its own air supply.

2. Water

Again each plant would react independently to loss of critical water supplies and due to its own design features would be able to survive such loss without nuclear incident. Here, as in the case of all utilities, a partial loss of supply would probably be less serious than in the case of isolated plants because of the ability to trade utility allocations from plant to plant.

3. Disposal

Here the most critical item is the hot waste storage facilities which could be usurped by one plant if proper controls are not exercised. Experience has shown, however, that properly sized facilities with proper administrative control will result in no difficulties in this regard.

4. Steam and Condensate

No difficulties of any consequence are expected due to this common system.

5. Chemicals and Oil

No difficulties are expected.

6. Electrical

This utility, because of its highly critical nature in driving primary coolant and utility circulating systems warrants the most serious study. Insofar as performance of each reactor plant is concerned, loss of commercial power is an expected event which each plant is capable of surviving on a more or less routine basis. Each plant has its own emergency power plants (we may consider the energy stored in the MTR working reservoir as a "power plant" in the general sense) which are capable of taking over all critical functions. The risk involved with regard to proper function of these auxiliary power sources in any one plant is a function only of the reliability of the auxiliaries themselves and the number of times they are asked to perform, i.e., the reliability of the commercial power. In the case of MTR and ETR a great deal of effort has been devoted toward making the systems extremely reliable and presumably the same will be true of ETR II in final design. The fact remains, however, that failures of these systems may occur during the commercial power failures and there is therefore a synchronizing effect at work.

The argument here must be that, although the failures might by chance occur at the same time, they would occur independently and the total number of reactor incidents due to power failure over a long period of time would be the same whether the reactors were located together or apart. One must also consider the extreme unlikelihood that a commercial power outage would be followed by a malfunction of an auxiliary power source resulting in a major nuclear incident. The probability of such a failure is so low that the likelihood of two or three simultaneous failures is nearly inconceivable. This is particularly true if the local philosophy of decoupling emergency power from commercial power as completely as possible is followed.

7. Communications

No compromise to the communications system will result as a result of increasing the number of stations to include a third plant.

D. General Comment

One may say, in general, that because of the extremely low risk level maintained in connection with the ability of any malfunction of the common facilities to induce a nuclear incident at one of the plants, the increased probability of simultaneous incident is negligible. That is to say, if a given failure will result in an incident of given level at one of the plants every hundred years, the increase in risk involved in exposing oneself to the simultaneous incident, say, every ten thousand years is negligible for reactors whose power levels are the same order of magnitude and for which the consequences of simultaneous failure are little more severe than a single incident.

In connection with the incidents induced at one reactor due to failure at another, one may make several statements. In the first place, the coupling through all coupling mechanisms is light. Secondly, because of automatic devices and administrative control each plant should be capable of surviving, at very low risk level, any event which is coupled from reactor to reactor. Finally, the probability of a malfunction at any plant capable of inducing effects at the second plant is extremely small. This means that any such effects are of second order at very low risk level with relatively light coupling and will increase the risk level of incident at a given plant only slightly from its own inherent risk level.

VI. CONCLUSIONS

From the foregoing analysis it has been shown that although there have been levels of activity at each of the reactor sites for short periods of time which exceeded desirable limits it has been possible by careful administrative control to carry out the complex experiment programs at the MTR-ETR without significant loss of time in one reactor through the cause arising from happenings in the reactor.

In choosing the location of ETR II attention was given to locating the reactor building and stack in the most favorable relationship consistent with reasonable proximity to the present MTR-ETR. In this location, radiation experience records which have been continually gathered over the past several years indicate that at no time would the ETR II building have reached evacuation levels from MTR-ETR effluent activity. The chosen location for the ETR II stack indicates that very little interference with the MTR-ETR will be experienced because of the low-frequency of wind velocities in that relative direction. It is felt that, although ETR II will operate at a power level greater than the combined power levels of MTR-ETR, the design features and the restricted class of experiments (e.g., pressurized water loops), will allow it to operate with lower constant evolution of radioactivity than either the MTR or ETR.

The use of a D_2O reflector imparts unusually favorable kinetic properties to ETR II, adding essentially an extra delayed neutron group with half-life of the order of one millisecond and of very high yield. The effect of these reflector delayed neutrons is to cause the periods in the excess k range of one to three per cent to be six to ten times longer than for the usual light-water reactor and to make it virtually impossible to have a prompt-criticality accident since β for these neutrons in this high-leakage core is of the order of 20 per cent. This means that a reactivity step in the core region would have to be about 21 per cent in order to achieve prompt criticality.

These kinetic properties are further enhanced by the strong negative void coefficients associated with the fuel region.

The alternate core arrangement which would use a solid beryllium reflector and mechanical control blades outside each lobe would not have this kinetic safety margin, but would be rather more like ETR.

Either arrangement is felt to offer a very low probability of release of radioactivity from the reactor core itself. It is therefore concluded that the proposed location of ETR II adjacent to the MTR-ETR complex is feasible and that the interference with the existing reactors will not significantly affect the operation of those reactors or the conduct of the experiments therein.

VII. ACKNOWLEDGMENTS

Since the authors have extracted a great deal of material in this report from reports and communications written by other individuals within Phillips Petroleum Company, we feel that special acknowledgment should be given Messrs. R. L. Finch, W. C. King, J. F. Sommers, O. L. Cordes, F. C. Haas, C. R. Ricks, V. L. Overstreet, E. C. Newman and R. S. Kern.

We also wish to gratefully acknowledge helpful consultation with W. P. Gammill, G. Wehmann of Idaho Operations Office, Site Survey Branch and N. F. Islitzer of the U. S. Weather Bureau.

APPENDIX A

UNITED STATES
ATOMIC ENERGY COMMISSION
P. O. Box 2108
Idaho Falls, Idaho

July 29, 1960

Mr. J. W. McCaslin, Supervisor
Health and Safety Branch
Phillips Petroleum Company
Atomic Energy Division
P. O. Box 2067
Idaho Falls, Idaho

Subject: ETR II STACK EFFECTS UPON MTR-ETR REACTOR BUILDING

Dear Mac:

At a meeting held on July 28, 1960 with Mr. R. J. Nertney, Phillips Petroleum Company Project Engineer, this office was requested to evaluate the possible effects that radioactive effluent discharge from the proposed ETR II Stack might have upon the MTR-ETR Reactor Buildings. This office, with the assistance of the USWB, has reviewed the problem and it will be appreciated if you would transmit the following comments to Mr. Nertney by July 29, 1960.

Review of climatological records indicate that the frequency of northwest winds is nearly the same as the frequency of southeast winds for both the lapse and inversion conditions. Therefore, it is reasonable to assume that the effects of either wind should be about equal. Since studies have revealed that points to the northwest of the existing MTR and ETR stacks have not been significantly affected by effluent from these stacks, it is our conclusion that the present MTR and ETR Reactor Buildings will not be significantly affected by effluent coming from the ETR II Stack.

These conclusions are based upon the proposed location of the ETR II Stack as shown on Phillips Petroleum Company Drawing E-2833*.

If we can be of any further assistance to you, please feel free to contact us.

Very truly yours,

W. P. Gammill, Acting Chief
Site Survey Branch
Health and Safety Division
Idaho Operations Office

cc: John R. Horan
C. Wayne Bills

*Editor: Figure 4 of this report.

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