Superseded by Amend. #12

6.3.4 COMPONENT TESTING

6.3.4.1 Coils

(a) The coils were stressed during manufacture by an internal pressure of 3,500 psig and later tested at 200 psig after assembly to assure leak tightness.

(b) A typical coil section was performance tested at DBA conditions to prove the ability of the coil to condense the steam as designed.

(c) The coils were tested under static loads to simulate the forces of pressure transients after a DBA.

6.3.4.2 Fans

(a) A fan and motor have been tested to prove their ability to operate continuously for 24 hours at the maximum design conditions following DBA.

(b) Fans and motors were tested by the fan manufacturer to assure the same characteristic performance curve for all fans.

6.3.4.3 Testing

The cooler units performance may be tested with portable thermometers, manometers, and pitot tube in the field at any time the containment building is accessible.

Service water is continued to all critical systems except the engineered safeguards pumps seal cooling supplies. Engineered safeguards pumps seal cooling is normally provided from the component cooling system; however, if that system is not operable, service water can be selected from the main control room for seal cooling.

9.1.3 DESIGN ANALYSIS

9.1.3.1 Margins of Safety

System reliability is achieved with the following features:

1. Each of the three service water pumps is capable of supplying 50% service water during normal, shutdown and post-DBA conditions.

2. Pump motor power is supplied from normal and standby sources with backup from the emergency diesel generators.

3. Fully redundant service waterlines supply critical systems. Loss of one header does not compromise plant safety.

4. The fire pumps can be valved into the service water pumps common header thereby serving as a partial backup to the service water system.

9.1.3.2 Provisions for Testing and Inspection

Components of the service water system outside the containment building are accessible for periodic inspection during plant operation. Components inside the containment building are accessible only after plant shutdown. This system is always in operation, but each service water pump can be periodically tested for auto-start by selection of one pump for standby service and tripping of one operating pump. After installation, the piping system is hydrostatically tested at one and one-half times the design pressure in accordance with the Code for Pressure Piping, ASA B31.1.

TABLE 9-8A (Contd)

Valve No	Valve Description	Normal Position	Shutdown Position	Position After Loss of Air
Service Water System (Figure 9-1)				
0823	Component Cool HX Dischg	O	O	O
0824	Supply to Containment Coolers	O	O	O
0825	Eng Safe Room Cooler Supply	C	C	O
0826	Component Cool HX Dischg	O	O	O
0835	Turbine LO Cooler Stop Bypass	C	C	O
0836	Turbine LO Cooler Stop Bypass	C	C	O
0838	Normal Cont Cooler Control	O	O	C
0839	Generator H_2 Cooler Stop Bypass	C	C	O
0843	Normal Cont Cooler Control	O	O	C
0844	Critical Service Wtr Header Iso	O	O	O
0845	Critical Service Wtr Header Iso	O	O	O
0846	Critical Service Wtr Header Cross-connect	O	O	O
0847	Return From Containment Coolers	O	O	O
0852	Generator Exciter Cooler Supply Bypass	C	C	O
0857	Critical Service Wtr Header Cross-connect	O	O	O
0861	8" Supply to Cont Coolers	C	C	O
0862	Containment Cooler Return	O	O	O
0863	Normal Cont Cooler Control	O	O	C
0864	8" Supply to Cont Coolers	C	C	O
0865	Containment Cooler Return	O	O	O
0867	8" Supply to Cont Coolers	C	C	O
0869	Containment Cooler Return	O	O	O
0870	Containment Cooler Return	O	O	O
0872	Normal Cont Cooler Control	O	O	C
0873	8" Supply to Cont Coolers	C	C	O
0876	Diesel Generator Cool Supply	O	O	O
0877	Diesel Generator Cool Supply	O	O	O
0879	Backup Cool Safeguards Pumps	C	C	C
0880	Backup Cool Safeguards Pumps	C	C	C
0884	Diesel Generator Cool Supply	C	C	O
0885	Diesel Generator Cool Supply	C	C	O
1318	Service Wtr Pump Header Isolation	O	O	O
1319	Service Wtr Pump Header Isolation	O	O	O
1359	Noncritical Service Wtr Header Isolation	O	O	C
Component Cooling System (Figure 9-6)				
0909	Letdown HX Return	O	O	O
0910	Component Cool to Cont Isolation	O	O	O
0911	Component Cool From Cont Isolation	O	O	O
0913	Supply Safeguards Pumps	C	O	O

TABLE 9-8A (Contd)

Valve No	Valve Description	Normal Position	Shutdown Position	Position After Loss of Air
0915	Comp Cool Surge Tk Vent	O	O	C
0918	Comp Cool Surge Tk Makeup	C	C	C
0937	Supply to Shutdown HX	C	O	O
0938	Supply to Shutdown HX	C	O	O
0940	Component Cool From Cont Isolation	O	O	O
0944	Supply to Spent Fuel HX	O	O	C
0945	Supply to Comp Cool HX	O	O	O
0946	Supply to Comp Cool HX	O	O	O
0947	Supply to Safeguards Pumps	O	O	O
0948	Supply to Safeguards Pumps	O	O	O
0949	Supply to Safeguards Pumps	O	O	O
0950	Return From Safeguards Pumps	C	O	O
0951	Return From Safeguards Pumps	C	O	O
	Main Steam, Main and Auxiliary Turbine Systems (Figure 9-9)			
0501	Main Steam Isolation Valve	O	O	As Is (Accumulator)
0510	Main Steam Isolation Valve	O	O	As Is (Accumulator)
0511	Steam Bypass Valve	C	Open for Bleed	As Is (Accumulator)

Service and Instrument Air Systems (Figure 9-8)

Valve 1211, Instrument Air Supply to Containment, is open during reactor operation or reactor shutdown and fails open on loss of air.

Process Sampling System (Figure 9-16)

Air-operated process sampling valves are normally closed unless sampling a specific point. All air-operated valves fail close.

Radioactive Waste Treatment System (Figures 11-2 and 11-3)

All air-operated valves in the radioactive waste treatment system, including liquid and gas discharge stop valves, fail close upon loss of instrument air.

Heating, Ventilation and Air Conditioning

Reference Section 9.8.4.

Shield Cooling System

During normal reactor operation and reactor shutdown, one of two air-operated shield cooling supply valves is open. Upon loss of instrument air, both supply valves fail open.

Extractions from the high-pressure turbine, and the main steam which is condensed in the reheaters, are routed to the high-pressure feed-water heaters. The high-pressure heater shell drains are routed to the low-pressure heaters just upstream of the steam generator feed pumps. These heater shells are drained into the moisture separator drain tank and then pumped forward into the steam generator feed pump suction by two half-capacity heater drain pumps. Water level in the moisture separator drain tank is automatically controlled by modulating the discharge from the heater drain pumps.

Shell drains from the remaining low-pressure heaters are cascaded to the next lower pressure heater and ultimately to the condenser.

Hydrazine and ammonium hydroxide are added to the feed-water header downstream of the condensate pumps for oxygen scavenging and pH control, respectively.

A typical listing of secondary water chemistry is as follows:

Total Solids	<500 Ppm
Suspended Solids	<10 Ppm
Total Chlorides	<5 Ppm
Total Oxygen	~ 0.0 Ppm
Total Silica	<5 Ppm
pH	8.5 to 10.5

10.2.4 CIRCULATING WATER SYSTEM

Circulating water for the condenser is taken from the lake through a submerged crib and a 3300-foot long pipe tunnel into the intake structure and pumped by two half-capacity, motor-driven pumps through the condenser tubes to the discharge canal. A warmwater recirculation pump is provided in the circulating water discharge structure to permit recirculation of the warm discharged water to the intake for protection against ice formation. The discharge canal water is continuously monitored for radioactivity and samples are continuously collected for laboratory analysis.

Two motor-driven traveling screens are installed ahead of each circulating water pump to remove debris from the circulating water. The debris picked up by the screens is removed by wash water supplied by a motor-driven screen wash pump taking suction from the intake structure. Periodic injection of a sodium hypochlorite solution into the circulating water system provides control of slime and algae growth.

10.2.5 FEED-WATER REGULATING SYSTEM

Two feed-water pumps are used to furnish the feed-water flow rate required at unit loads greater than 50%. Each turbine driver and pump must be set up locally and brought up to speed before the driver can be controlled from the main control room. The suction and discharge pressures of the feed-water pumps are indicated and annunciated in the main control room. If the suction pressure falls below

outlined above, a minimum 30-day decay period is available. The effect of decay on total gaseous activity is shown below based upon 1% fuel rod defects.

In Primary Coolant	As Received In Surge Tank	1-Day Decay	7-Day Decay	30-Day Decay
239.24 μc/cc	6644 μc/ccH_2	5755 μc/ccH_2	2617 μc/ccH_2	192 μc/ccH_2

Table 11-4 is a summary presentation of gaseous waste system performance under conditions of maximum coolant gaseous activity for 1% failed fuel rods as listed in Table 11-1 and maximum quantities of gaseous waste anticipated as listed in Table 11-2. A conservative atmospheric diffusion factor of 2×10^{-5} sec/m^3 was used to determine the isotopic concentration at the site boundary assuming a continuous point source at a 30-meter stack exit. No credit has been taken for the full stack height of 65 meters nor for the dilution of gas released in the stack by the normal ventilation flow.

Under the conditions listed above, the most significant isotope released to the environment is Xe-133 and it would be necessary to hold the gaseous waste for a period of about seven days to allow for natural decay before discharging. Hold periods in excess of 30 days coupled with the gas dilution in the stack will provide the ability not only to discharge well below the limits of 10 CFR 20 but to minimize the total gaseous waste activity discharged over an operating cycle.

11.1.4 PROCESS RADIATION MONITORING SYSTEM

The process radiation monitoring system is designed to assure that ionizing radiation levels are recorded, indicated and alarmed so that action, either automatic or manual, can be taken to prevent radioactive release from exceeding the limits of 10 CFR 20.

Devices are located in the various process systems to monitor radiation levels and annunciate any abnormally high activity. Instrument ranges and sensitivities are chosen to enable monitoring within the requirements of 10 CFR 20.

Sampling systems, detectors, power supplies, readout devices, and recorders are designed to operate with 0 to 100% relative humidity. Those devices located outdoors will withstand temperatures from -10° F to 110° F and those indoors will withstand 50° F to 104° F. In addition, those components required to operate in a DBA environment are designed for 100% relative humidity at 283° F.

The electronic circuitry (except for photomultipliers and geiger tubes) is solid state and each system has its own power supply and provisions for instrument operational testing while in service.

All monitors in the stack-gas, containment air, off-gas, waste gas, engineered safeguards areas ventilating system discharge, radwaste ventilation and radwaste liquid discharge systems are supplied with check sources. The check source simulates a radioactive sample and serves as a check for both the readout and detection equipment.

Two radiation monitoring equipment panels are located inside the main control room. These are the gaseous waste and the liquid waste monitoring panels which provide mounting for indicators, recorders, power supplies and alarms for each of these radiation monitoring systems. These two panels are located beside the area radiation monitoring panel. The process liquids radiation monitoring panel and the gas radiation monitoring panel are fed by the instrument a-c bus which, in the event of a loss of power, is fed by the diesel generators.

The type of detectors used and the information displayed on these panels are listed in Table 11-6. The sensitivity and alarm conditions for each instrument are also listed.

11.1.5 SYSTEM EVALUATION

All process systems which contribute to plant discharges are monitored prior to entering the various discharge systems. Each discharge system is also monitored providing redundancy of radiation detection for plant effluents. The radwaste area, containment air, waste gas, engineered safeguards pump room, and the off-gas radiation monitoring systems are backed up by the stack-gas monitoring system. The service water, radwaste liquids discharge, component cooling, and the steam generator blowdown radiation monitoring systems are backed up by the liquid discharge monitor system.

Testing and maintenance for all systems, circuit testing of readout equipment and power supplies can be performed from the panels located in the control room. The circuit being tested or repaired is inoperative during that time and acts as if it were a tripped channel.

11.2 RADIATION PROTECTION

11.2.1 GENERAL

11.2.1.1 Radiation Exposure of Personnel

The basis for the shielding design for normal plant operation is the "Code of Federal Regulations," Title 10, Chapter 1, Part 20, entitled "Standards for Protection Against Radiation." The exposure of individuals to concentrations of radioactive materials in air or water, above the contributions from natural background, is limited to values in Appendix B, of Title 10, Chapter 1, Part 20, of the Code of Federal Regulations.

All areas of the plant are subject to these regulations. The areas are zoned according to their expected occupancy by plant personnel and their designed radiation exposure level under normal operating conditions.

Allowable design dose rates for all accessible areas of the plant are a maximum whole body exposure of 1.25 rem per calendar quarter. For all areas outside the plant, the allowable dose rate is not more than 0.5 rem for one calendar year.

For the maximum hypothetical accident (MHA), the shielding design is based on the radiation exposure limits set forth in the Code of Federal Regulations, Title 10, Chapter 1, Part 100, "Reactor Site Criteria."

No individual will receive more than 25 rem of whole body exposure or 300 rem of thyroid exposure during the course of the accident. This applies to personnel who are immediately evacuated from the plant site and to personnel who remain in the central control room for up to 10 hours and subsequently leave the plant site.

Allowance is made in the calculation of these doses for short duration trips to critical equipment for minor maintenance.

11.2.1.2 Radiation Exposure of Materials and Components

No regulations similar to those established for the protection of individuals exist for materials and components. Materials are selected on the basis that radiation exposure will not cause significant changes in their physical properties which adversely affect their operation during the design life of the plant. Materials for equipment required to operate under accident conditions are selected on the basis of the additional exposure received in the event of an MHA.

11.2.2 RADIATION ZONING AND ACCESS CONTROL

The radiation zoning of the plant areas is shown on Figures 11-4 and 11-5.

The following list identifies the different zones used for the Palisades Plant:

Zone Designation	Design Dose Rate (Mrem/Hr on a 40 Hr/Week Basis)	Description
I	≤0.5	Uncontrolled, unlimited access.
II	≤1.5	Controlled, unlimited access. 40 hr/week.
III	≤15	Controlled, limited access for routine tasks. 6 hr/week.

Five Years as Major Equipment Operator on Two 256 Mw Reheat Units

Six Months as Assistant Shift Supervisor at 8-Unit Plant

One Year's Work Experience at Big Rock Point Plant in Capacity of Assistant Shift Supervisor

Six Weeks at Haddam Neck Plant

Reactor Console Experience on Big Rock Point Reactor

12.2 TRAINING

12.2.1 The primary training for the Palisades supervisory personnel, prior to their arrival at the site, took place at the Big Rock Point Plant. The key administrative technical and supervisory personnel experienced extensive on-the-job training in their respective areas of responsibility.

TECHNICAL STAFF

Key members of the technical staff were selected from an expanded staff gaining work experience at the Big Rock Point Plant. These key people gained experience in all phases of nuclear plant operation including reactor operation, refueling operation, radiochemistry, radiation protection, reactor physics, nuclear instrumentation, and nuclear steam supply system maintenance.

The Big Rock Point experience was supplemented by Taft Engineering Center courses in radiological health, management of radiation accidents, etc, as appropriate, in addition to six weeks of specific work experience at the Haddam Neck pressurized water reactor plant for the Chemical Engineer, Technical Supervisor, the Assistant Plant Superintendent and the six Shift Supervisors.

The Technical Staff, Shift Supervisors and several members of the General Office Technical Staff will attend a Palisades Plant technology course conducted by Combustion at its Windsor, Connecticut, complex. This will be a four-week course (160 classroom hours) in the technical and operational aspects of the plant appropriate to the course participants.

The program is designed for experienced personnel who will, in turn, train the operating and maintenance crews at the site. The Combustion instructors will generally be engineers who have been directly involved in the development or design of the Palisades NSSS. The subject areas to be covered are reactor design, mechanical systems design, instrumentation, control and electrical system design, operating procedures, NSSS response, safety analysis, and start-up testing program. Participants in the course will practice refueling on a mock-up utilizing much of the permanent plant refueling equipment.

PLANT SHIFT SUPERVISORS

Of the six Palisades Plant Shift Supervisors, five were selected from licensed Control Operators at the Big Rock Point Plant and had experienced the entire training program, plant start-up and five years' operating experience at that plant. These men were selected for Palisades Supervisors in January 1968 and placed on shift at the Big Rock Point Plant to gain experience as Supervisors at a nuclear installation. Classroom work in reactor physics, radiation protection and plant systems was conducted at Big Rock Point to prepare these men for a license examination. Four of the Supervisors secured an AEC Senior Operator License on the plant at the end of the training review. The remaining two now hold AEC Operator Licenses on Big Rock Point.

All of these men spent six weeks at the Haddam Neck pressurized water reactor plant to become familiar with the differences (such as chemical shim) between the PWR and BWR plants.

CONTROL OPERATORS

The Control Operators will be moved to the Palisades site for training approximately eight months prior to the initial fuel loading. It is expected that approximately one half of the Control Operators will come from the Big Rock Point organization and that they will hold AEC Operator Licenses on the Big Rock Point Plant. The training of these and other operators for the Palisades Plant will be accomplished on the Palisades site through classroom work and operation of installed equipment during preoperational and hot functional tests. Classroom instruction will be by plant supervision, assisted by qualified Combustion, Bechtel and equipment supplier personnel. It is expected that the Control Operators will be ready for license examination no later than a few months after initial fuel loading.

TECHNICIANS

The instrument and control groups as well as the chemical and radiation protection groups will be selected and moved to the site eight months prior to fuel loading. These people will be trained as required in their assigned disciplines at the site and in some instances at Big Rock Point. The men selected will be qualified in their respective fields and the training received at the site will pertain to the specific application on the Palisades Plant installation.

12.2.2 The main body of plant supervision will arrive on site ten months prior to the scheduled initial fuel loading. This period will be utilized to allow the staff to become thoroughly familiar with the plant equipment and systems as well as conducting a course in plant technology for the operators, preparing operating procedures, performing systems acceptance testing and preparing for precritical license examinations if appropriate. Seven hundred ninety hours of classroom instruction, as indicated by subject and classroom hours in Tables 12-1, 12-2, and 12-3, are scheduled as part of the training effort at the site.

14.22 MAXIMUM HYPOTHETICAL ACCIDENT

14.22.1 GENERAL

For the purpose of evaluating the suitability of sites for power reactors, guidelines have been established which serve to identify some of the factors that must be considered. The guidelines are set forth in Title 10, Chapter I, Code of Federal Regulations, Part 100 (10 CFR 100).

A partial requirement of 10 CFR 100 is to evaluate whole body and thyroid doses as a function of distance from the reactor and time following a postulated accident which results in a release of fission products. This accident is hypothesized for the purposes of site evaluation and is considered to release substantially more fission products and result in more severe consequences than any accident considered credible. This section, therefore, is intended to identify the exclusion area required, the distance to the outer boundary of the low population zone, and the minimum population center distance allowable.

14.22.2 METHOD OF ANALYSIS

The method of analysis generally follows the model given in TID 14844.(1) The major assumptions used in the analysis are as follows:

(1) The reactor has been operating at a power level of 2650 Mwt.

(2) 100% of the noble gases, 50% of the halogens and 1% of the remaining fission products are released from the core into the containment building.

(3) One half the iodines released to the containment building deposit on surfaces within the containment building and are not available for release to the atmosphere.

(4) The containment design leak rate is 0.2% per day at the design pressure of 55 psig.

(5) The dose receptor is a standard man, ie, standard thyroid mass and breathing rates.(2) Biological half life, decay energy deposited in the thyroid and uptake fractions are as recommended by the ICRP.(2)

Following an accident which releases reactor coolant to the containment building, the pressure within the building will increase to some maximum value and then decrease. The pressure history within the building is discussed in Section 14.18.

Figure 14.18-7 shows the envelope of the pressure history for various size reactor coolant system ruptures. The leakage from the containment building is governed by the pressure, temperature, and composition of the atmosphere within the building; consequently, as the pressure decreases within the building the leakage from the building will also decrease.

The exact relationship between containment building leakage and the conditions within the building is not easily established since the nature of the leakage path is unknown. It is possible, however, to establish the type of leakage path which yields conservative results and yet is a reasonable approximation of the type path to be expected. It is assumed that the leakage paths are rough passages within which the flow will be turbulent. The ratio of leakage for this type flow is given by.[3]

$$\frac{L_b}{L_a} = \left[\frac{1 - \frac{1}{P_b{}^2}}{1 - \frac{1}{P_a{}^2}} \times \frac{R_b T_b}{R_a T_a} \right]^{1/2}$$

Where:

$\frac{L_b}{L_a}$ = Leakage ratio between conditions b and a.

P = Containment pressure, atmospheres absolute.

R = Gas constant.

T = Temperature, absolute.

Leakage from the start of the accident to 1000 seconds was assumed to be 0.2%/day. The pressure was then assumed to decrease to 19 psig and remain constant thereafter resulting in a leakage rate of 0.168%/day, as determined from the above relationship. The effect of decreasing the pressure within the building in this way is to reduce the effective leakage to 86% of the peak pressure leakage for the first two hours and to 84% for the remainder of the accident.

The site meteorological characteristics are discussed in Section 2 and Appendix D. Atmospheric dispersion is calculated using the Sutton equation for a ground level point release.

$$\frac{X}{Q} = \frac{2}{\pi \, C_y C_z \, \bar{u} \, (d + d_o)^{2-n}}$$

Where:

$\frac{X}{Q}$ = Concentration-source ratio, sec/m^3.

C_y = Crosswind dispersion coefficient, $(m)^{n/2}$.

C_z = Vertical dispersion coefficient, $(m)^{n/2}$.

$\bar{u}$ = Windspeed, m/sec.

n = Dimensionless stability parameter.

d = Downwind distance, m.

d_o = Virtual source distance, m.

Initial dilution in the wake of the containment building is accounted for by the addition of the virtual source distance d_o in equation 14.22-2. The virtual source distance is determined as follows:

$$d_o = \left[\frac{2}{\pi \, C_y C_z \, A}\right]^{\frac{1}{2-n}}$$

Where:

A = Building projected area normal to ground plane, m^2.

The containment building area used is 2210 m^2.

During the first two hours following the hypothetical release of fission products the wind is assumed to be from a constant direction under conditions of stable atmosphere. The parameters selected for the Palisades site are:

C_y = 0.4

C_z = 0.05

n = 0.33

$\bar{u}$ = 2 m/sec

For the period beyond two hours, long term diffusion coefficients are used. The diffusion parameters used are:

$C_y = 0.50$

$C_z = 0.10$

$n = 0.25$

From two to 24 hours the windspeed is assumed to be 2 m/sec. Beyond 24 hours the windspeed is assumed to be 6 m/sec. The long term diffusion parameters include the effects of wind variability.

Whole body submersion dose from the fission product leakage is calculated assuming an infinite hemispherical cloud of uniform concentration equivalent to the ground concentration at the plume centerline.

14.22.3 RESULTS

Figure 14.22-1 shows the thyroid dose as a function of distance for two hours, 24 hours, and 30 days exposure. The dose to the thyroid in the first two hours after the postulated release is 265 rad at the minimum plant exclusion distance of 700 meters. The calculated distance to the outer boundary of the low population zone, ie, 30 day dose equal to 300 rad, is 2900 meters which results in a minimum required population center distance of 3867 meters.

Figure 14.22-2 shows the whole body submersion dose as a function of distance and exposure time. Whole body submersion dose is not controlling for the Palisades site.

14.22.4 CONCLUSION

At the minimum exclusion distance of 700 meters, the two-hour thyroid dose is 265 rad which is below the 300 rad guidelines of 10 CFR 100. The calculated low population zone outer boundary is 2900 meters. Within this radius there are approximately 275 full-time residents and 1035 summer residents. The average population density based on the full-time and summer residents is 190 persons per square mile. Of the total summer residents, approximately 85% are located almost due south of the reactor along the Lake Michigan coast. The average population density of full-time residents only is about 40 per square mile.

The nearest population center with 25,000 or more population is the Benton Harbor, St. Joseph, Euclid Center, Benton Heights, Fair Plain area with a combined population of 52,844. This combined area is more than 15 miles southwest of the site.

It is concluded that the Palisades Reactor Site meets the guideline values of 10 CFR 100.

REFERENCES

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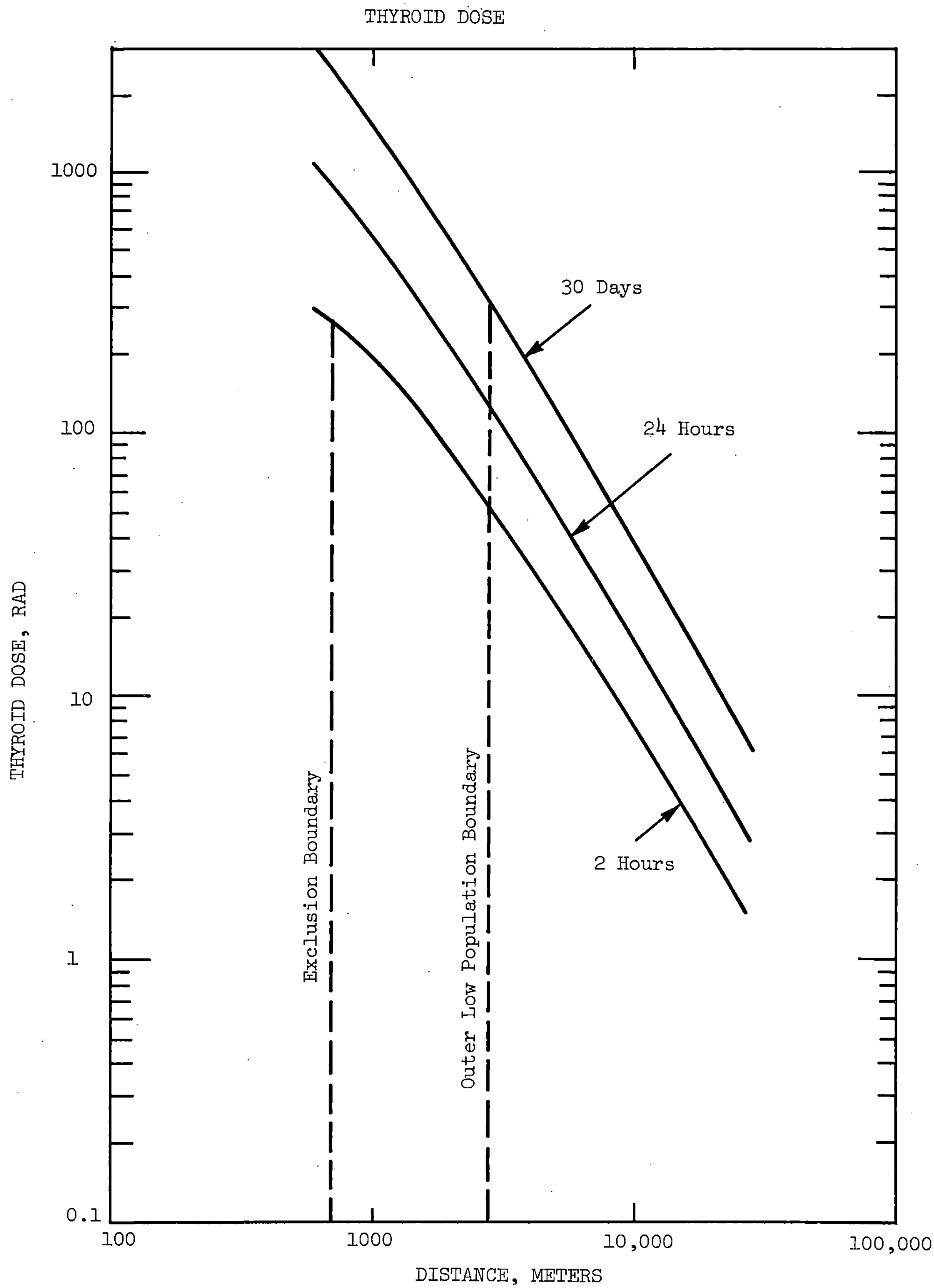
2. Recommendations of the International Commission on Radiological Protection ICRP Publication 2, Report of Committee II on Permissible Dose for Internal Radiation (1959) Pergamon Preso.

3. Maccary, R. R., Holt, A. B., DiNunno, J. J., Arlotto, G. A., "Leakage Characteristics of Steel Containment Vessels and the Analysis of Leakage Data Determinations," TID 20583, Division of Safety Standards, USAEC, Washington, DC.



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WINDSOR, CONNECTICUT

FIG. 14.22-1

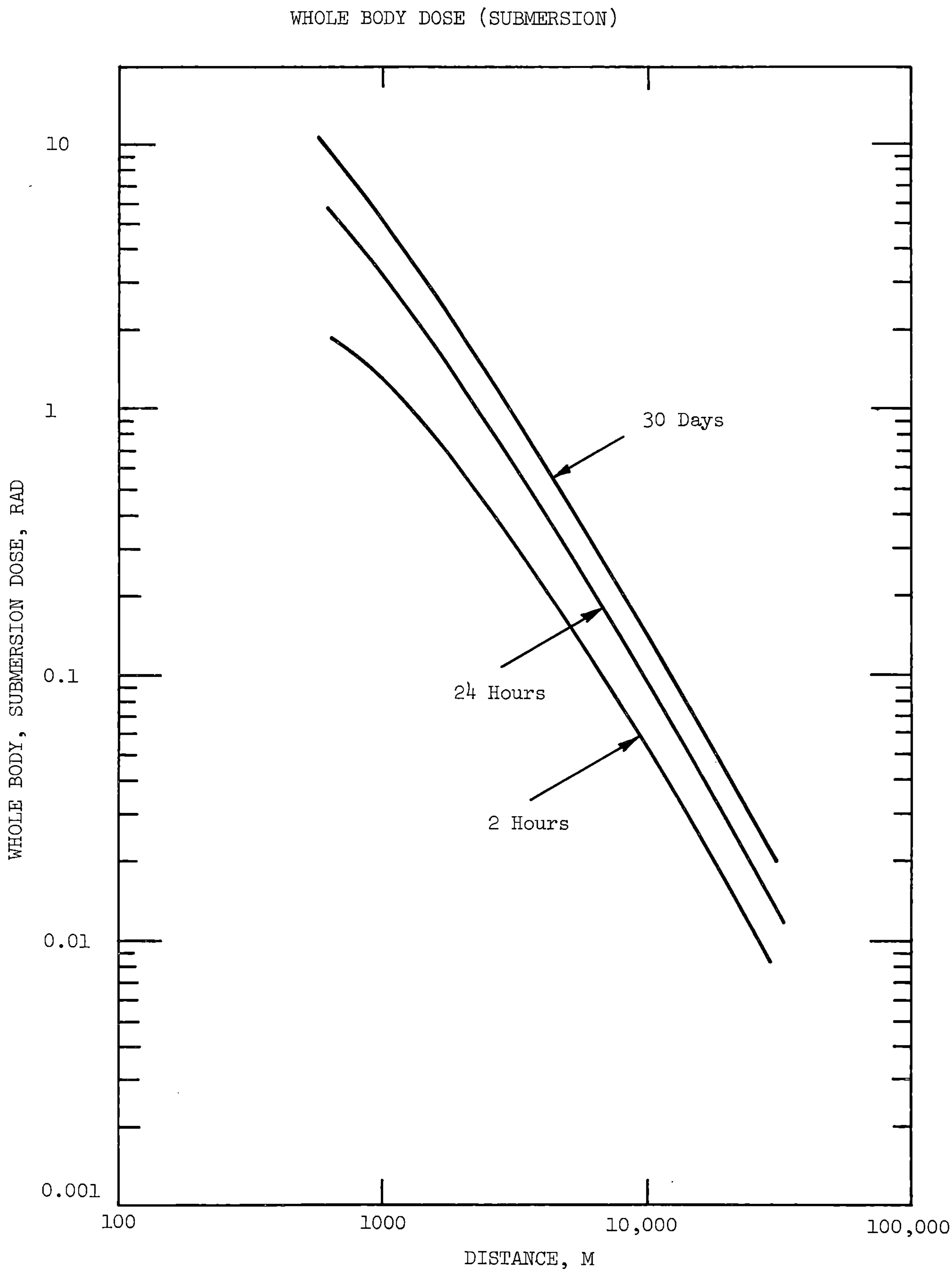

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FIG. 14.22-2

APPENDIX D

METEOROLOGY

1. General Climatology of the Palisades Plant Area

In terms of the Koppen System of climatic classification, the lower peninsular area of Michigan has a "humid continental climate with cool summers." The continental characteristics include great departures from seasonal temperature means and a summer maximum in rainfall, but these features are somewhat modified due to the proximity of the Great Lakes, so that the magnitude and persistence of the larger temperature anomalies are reduced and the annual rainfall maximum is shifted toward fall, when the lake water is relatively warm.

The surface winds blowing across the area are basically westerly, with considerable variability in summer and the transition seasons. Southwesterly winds with a lake trajectory of about 75-100 miles are especially common in summer, but the mean wind speed is at a maximum of approximately 20 miles per hour in December-January, falling to 10-15 miles per hour the rest of the year.

Snow cover is important because of rapid radiation from the snow surface and protection of the underlying soil. Lying only 350 miles from the boundary of the subarctic climatic zone to the north, the Palisades Plant area averages 80 days per year of snow cover. This tends to lower winter temperatures and to retard spring warming. The average long period temperature and precipitation values abstracted for Michigan[1] are as follows:

Annual mean monthly temperature range: 20° F (February) to 70° F (July).

Monthly precipitation: 1.5 inches (February) to 3.5 inches (September), with a yearly total of 29 inches.

With a high frequency of surface winds coming from Lake Michigan, the annual temperature of the lake regime is of interest. According to Church,[2][3] the following periods are distinguishable as gross features of the lake:

Spring Warming Period, Phase 1: A slow warming to about 4° C occurs, this temperature being attained throughout the lake water. The ending of this phase is between May 10 and June 10.

Spring Warming Period, Phase 2: After the formation of a protective thermocline near the surface, a rapid warming to about 20° C takes place. This phase ends in mid-July.

Summer Stationary Period: A fairly constant temperature is maintained, there being a heat balance at the surface. This continues until late September.

Fall Cooling Period: As autumn cooling begins and windstirring increases, the thermocline is destroyed and the lake becomes vertically isothermal. This period ends in November.

Winter Cooling Period: Further cooling continues until March, when the cycle begins to repeat itself. Ice forms in winter near the lakeshores to build inward toward the center of the lake.

The Palisades Plant area lies in maritime-polar (Pacific) and continental-polar air much of the time. However, it is frequently overrun by continental-arctic air and is reached by maritime-tropical air in all seasons. This means that there are numerous frontal passages which average two or three per week when both cold and occluded fronts are considered. Because of these frontal passages and the lake influences, there is considerable cloudiness and the overall atmospheric dispersion characteristics of the area are quite favorable.

a. Temperature Extremes

As is common in this latitude, the annual temperature range in the Palisades Plant area is large. On the basis of a study of US Weather Bureau (USWB) records for stations reasonably close to the area, the extreme 10-year minimum temperature would be about -25° F. Because of the proximity of the cool lake, the extreme 10-year maximum temperature would be a moderate 95° F.

b. Peak Winds

The wind flow in this region is generally very strong. In addition, because of the clear exposure to the prevailing westerly flow, winds at the plant site will average higher values than reported for nearby, more sheltered observation points inland. Data from the Big Rock Point Nuclear Plant site indicate that the annual average wind speed at 256 feet would be about 15 mph and at 32 feet about 12 mph.

The absolute maximum wind speed for design purposes is a speculative figure, generally associated with violent summer thunderstorms. Standard design practice requires that structures be built to withstand winds of 100 mph, which is a reasonable long-term design maximum.

c. Icing Conditions

Heavy ice storms associated with freezing rain or sleet occur in the area approximately once every two years. Standard design practice provides for an external loading of 40 psf for snow and/or ice.

d. Tornadoes

Records[6] of tornado occurrences in a 14-county area in *southwestern Michigan were analyzed for the period 1897 through 1965. A total of 58

*The counties were Ottawa, Allegan, Van Buren, Berrien, Cass, Barry, Kalamazoo, St. Joseph, Eaton, Calhoun, Branch, Ingham, Jackson and Hillsdale.

tornado sightings was reported. Of this total, 18 were sighted in the shore line counties of Ottawa, Allegan, Van Buren and Berrien. Only three tornadoes were reported within 10 miles of Lake Michigan; none were sighted within a mile of the shore. These data indicate that, although tornadoes are relatively common in Michigan, they rarely occur near Lake Michigan. Two recent papers(7)(8) reported results of studies which clearly show that the cool, stable air overlying the lake tends to diminish convective activity over the lake and also inland for a considerable distance. The available evidence, then, indicates that the severest forms of convective activity, eg, tornadoes and hailstorms, would be extremely rare occurrences at a shoreline site on Lake Michigan.

2. Descriptive Meteorology

The meteorology program at the Palisades Plant Site consists of the taking and interpretation of data from two stations located within the site boundary. Each station has a self-standing tower with thermistors mounted at the 10 foot and 55 foot levels for temperature measurement. Also mounted at the 55 foot level on each tower is a Gill Type Propeller Vane for wind speed and direction measurements. All of the above signals are recorded on strip chart recorders located in the construction office building with signals transmitted via underground cables. The inland station is located approximately 2400 feet east and 1350 feet north of the containment building. This station is at the eastern foot of the dunes with a ground level elevation of approximately 610 feet. The shoreline station is located 150 feet east and 40 feet south of the containment building. It is part way up the western slope of a dune with the 55-foot tower level being at the same elevation as the top of the containment building, or about 200 feet above the lake.

Starting on September 1, 1967, and ending on September 1, 1968, data was abstracted by hand from the strip chart recorders. Periodically during this period the wind speed sensors were calibrated by use of a calibrating unit which is a synchronous speed motor with an attached flexible coupling and is used to drive the propeller shaft. The maximum error found in a nonconservative direction was 3 mph fast at the calibrating point of 21.3 mph. This is equivalent to a +0.27 mph error at 2 mph.

The manual abstraction of the strip chart data consisted of the following. Wind speed and wind direction were visually averaged over 15 minute intervals and then recorded as the reading for the 15 minute period. The temperature reading for each 15 minute interval was recorded as a point reading at the beginning of the interval.

Where there was missing chart data, the gap was filled in primarily from data taken at the US Weather Bureau Station located at the Muskegon Airport which is approximately 70 miles north of the Palisades Site. To assure that wind speed and direction at Muskegon were applicable to the Palisades Site an hourly plot of wind speed and direction was made of Muskegon and Site data for the months of November 1967 and January 1968.

The plotted data showed very good correlation between the two sites. Where Muskegon data was used to fill in missing site temperature data, the equivalent site temperatures were based on Muskegon air temperatures, sky cover and wind speed. In a few instances where site temperature data was missing, the data was filled in with temperature data taken from University of Michigan meteorology instruments located on a tower 35 miles north of the site. Height differences of temperature sensors equivalent to those on the site were used to fill in the missing data.

a. <u>Wind Distribution</u>

The monthly wind roses, Figure 3 based on Table 1 data, for a one-year period indicate the broad outlines of the regional climatology. The winter months are characterized by large variations in the wind direction which are attributable to the frequent passage through the region of migratory pressure centers. In fact, the relatively high frequency of easterly winds in the winter and early spring months may be attributed directly to the presence of polar highs with their accompanying frontal systems moving south from Canada. As the frontal zones retreat northward with the advent of spring, the air mass contrasts become much weaker and so do the circulation patterns that maintain them. Consequently, middle and late summer becomes the calmest period of the year. With these diminished pressure gradients during the calm period, the winds show the effects of the local factors such as the lake. As fall comes and goes, the winter regime becomes reestablished.

The wind roses for September and October show a dominance of winds from the north and south. In September, the north and south winds have a definite easterly preference, while in October, they develop a westerly bias. This westerly flow grows stronger in November and continues into December. Easterly winds are prominent in December and January. February is dominated by a strong northwesterly flow. March and April are dominated by southwesterly winds. By May and through the summer, the warm season regime of southerly and westerly winds are prominent.

In general, the shoreline station shows significantly higher wind speeds and a much lower frequency of calms (winds less than 0.5 mph) than the inland station. These differences are primarily due to the difference in instrument height and exposure. The shoreline data being typical of the unobstructed flow off the lake, while the inland data are typical of turbulent flow in the lee of the sand dune. At the shoreline station, there is somewhat less seasonal fluctuation in the wind speeds than is apparent from the inland station data. The effect of the land and lake breezes at the shoreline is to maintain the favorable, vigorous wind flow during the normally quieter summer season. It should also be noted that the annual wind direction distribution is quite variable. There is no evidence of strong channeling of the flow at either station. Although the southwest quadrant is favored, there is no direction without significant representation.

At the shoreline station, April was the month with the highest frequency of calms, 3.19 percent. At the inland station, July was the month with the highest frequency of calms, 7.66 percent. Both figures are relatively low and demonstrate further the well-ventilated characteristics of shoreline plant sites. For an hour to be assigned a calm wind speed designation, the wind speed had to average less than 0.5 mph for the hour.

b. Temperature Lapse Rates and Wind Speed Distributions

Figures 1A and 1B present information on the month-by-month variation in temperature lapse rates over the one-year period. (Table 6 defines the various lapse condition categories.) The greatest frequency of stable and very stable lapse rates occurs during the period of February through August, with April anomalously lower and February a bit higher than the long range climatology records. These stable conditions are caused when warm spring air flows over the cold surface water of Lake Michigan.

These stable conditions have been proven to be local phenomena by the smoke plume diffusion experiments conducted at Big Rock Point. They do not persist inland for more than five miles even when they are most severe at the shoreline. They are usually broken up, after they move inland a relatively short distance, by mechanical and thermal turbulence during the day and by mechanical turbulence at night, with moderate to strong winds.

Figures 1A and 1B also show the variation of wind speed with lapse condition on a month-to-month basis at both stations. A one-year average shows that the average wind speed under unstable conditions at the shoreline is 13.2 mph and inland 9.6 mph; under near-neutral lapse conditions at the shoreline, 17.7 mph and inland 10.2 mph; under stable lapse conditions at the shoreline, 12.8 mph and inland 8.3 mph; and under very stable lapse conditions at the shoreline, 9.3 mph and inland 5.1 mph. This indicates that, on the average, the natural ventilation of the shoreline station is high even under the most severe inversion conditions. Figures 1A and 1B also show that stable atmospheric conditions exist about 30 percent of the time. This high percentage of inversions is not a good index as to the frequency of occurrence of poor atmospheric diffusion conditions at the site, and Figures 1A and 1B must be considered in conjunction with Tables 2, 3 and 4.

The frequency of occurrence of winds in various speed categories at the shoreline and inland stations in relation to categories of stability is presented in Table 2 for the full year period. Stable and very stable conditions occur most frequently when the winds are from 4 to 9 mph at the inland station. There appears to be no such correlation at the shoreline station. This table also emphasizes the high frequency of occurrence of wind speeds of 10 mph or greater, approximately 70 percent of the time at the shoreline station and 45 percent at the inland station.

c. Variations in Temperature Lapse Rate

Figure 2 shows the monthly variations in the percentage frequency of stable atmospheric conditions as a function of time of day for the year period and indicates that dispersion characteristics of a shoreline site vary markedly throughout the day. The yearly maximum generally occurs during the months of May, June and July. The month of February was a very unusual month in that it also showed an unusual peak in stable atmospheric conditions. The diurnal maximum occurs between the hours of 2000 and 0400. This is attributable to the land breeze circulation which brings the air that has been cooled by the ground (which has lost heat by radiation to the clear sky) past the shoreline. The lake water, which has been heated during the day, provides the other component of the thermally direct circulation. The high frequency of stable conditions around 1200 during May, June and July reflects the influence of the lake breeze. During this time of the year with its frequent clear, but cool, sunny days with weak gradient winds, the land breeze regime frequently gives way directly to a lake breeze regime. It is believed that the rapid heating and cooling of the shallow water along the shoreline contributes greatly to these effects. Temperature rises of 3° C to 4° C in 24 hours are common in the shallows.

The annual peak in unstable lapse conditions occurs during the months of November, December and January. The diurnal unstable maximum occurs between 1200 and 2200. The annual transition from maximum stability to minimum stability occurs quite rapidly. The midday hours lead the change, reflecting the importance of solar heating and the diminution of the temperature difference between the land and the shallow water near the shore.

d. Persistence of Calm Conditions

Table 5 shows the frequency of occurrence and the duration of low wind speed conditions (< 4 mph) at the Palisades inland and shoreline stations, respectively. During the year, the longest low wind speed period lasted 18 hours at the inland station and 19 hours at the shoreline station. Over the year of data collection, there were 33 occurrences of low wind speed periods lasting 8 hours or longer at the inland station, while there were 6 periods at the shoreline station.

3. Diffusion Climatology

The nature of the surface over which the air flows is the prime factor in determining the atmospheric diffusion characteristics of airborne material released at the plant site, inasmuch as these diffusion characteristics are governed by surface-generated turbulence.

a. Turbulence and Diffusion Regimes

Atmospheric diffusion processes are governed by turbulence generated in either of two ways: (1) by mechanical action as the

airflow is made irregular as the air moves over a rough surface, and (2) by thermal buoyancy forces which either stimulate or inhibit vertical turbulence and mixing.

The critical vertical temperature gradient, or vertical temperature lapse rate, is 10° C per km or 5-1/2° F per 1000 feet. This critical lapse rate is known as the dry adiabatic lapse rate. When the temperature decreases or lapses with height at a rate greater than 10° C km^{-1}, the air is unstable, and active vertical churning known as thermal turbulence occurs. Under such conditions, plume looping is observed. If the lapse rate is less than 10° C km^{-1}, the air is stable and vertical mixing is inhibited. When an inversion occurs in which the temperature increases with height, the air is very stable and mixing is very slight. A fanning plume with pronounced horizontal dispersion but minimal vertical dispersion occurs with an inversion.

With brisk winds blowing over rough terrain, mechanical turbulence develops. The vertical mixing thus induced tends to maintain the lapse rate at a value close to 10° C km^{-1}, in which the air is neither stable nor unstable but neutral. Mechanical turbulence of this type leads to plume coning, which is characterized by nearly equal horizontal and vertical dispersion.

Both types of turbulence and various plume formations are readily observed in the shoreline area of Lake Michigan. As the wind blows across the shoreline, pronounced changes in mechanical turbulence and in thermal turbulence often occur. Thermal effects are greatest in the late spring and early summer when the temperature differences between water and land are greatest.

b. Shoreline Influences

Winds coming off the water are generally expected to be less turbulent than winds coming off the land, given the same meteorological conditions. This is especially the case in the late spring and early summer months when the surface lake temperature is lower than the average air temperature. This difference in air-water temperature gives rise to an inversion condition over the water and, consequently, a reduction in the turbulence. Onshore winds reaching the plant site during the months of May, June and July generally would have very low turbulence. As they move inland, winds gain somewhat in turbulence in the lower layers due to the surface roughness of the trees and the thermal heating of the land. This turbulence does not, however, in many instances extend upward as high as 200-300 feet for some distance from the site. Winds from offshore generally arrive at the plant site with marked turbulence, but this turbulence is damped out over the lake at some distance from the site.

Recent dispersion observations on the shores of Lake Michigan indicate that there are phenomena operating at shorelines which greatly enhance atmospheric dispersion. The scale of these phenomena is larger than the scale of the mechanical turbulence generally induced by airflow over a forest canopy or over open fields and orchards. Evidence from

dispersion studies performed at the Big Rock Point and Enrico Fermi Nuclear Plants, which are shoreline sites, indicates that these dispersion phenomena are induced by intermediate-scale thermal eddies and marked spatial variations of diffusion regime. A paper by Walke[5] discusses these phenomena in detail and estimates their effect on diffusion coefficients for use at shoreline sites.

c. Turbulence and Dispersion Parameters

The steady state concentration from a continuously emitting point source at the origin of the x, y and z axes is usually expressed mathematically by the Gaussian diffusion equation

$$X_{(x,y,z)} = \frac{Q}{2\pi\bar{u}\,(\sigma_y^2\,\sigma_z^2)^{\frac{1}{2}}}\ \exp - \frac{y^2}{2\sigma_y^2}\ \exp - \frac{z^2}{2\sigma_z^2} \quad \ldots\ldots (1)$$

Where:

X = Concentration of material at point (x,y,z), (M/L^3).

Q = Emission rate of the source (M/T).

$\bar{u}$ = Mean wind speed along x-axis (L/T).

σ_y^2, σ_z^2 = Horizontal crosswind and vertical variances of the plume concentration distribution (L^2).

This equation represents a mass balance and is basically a restatement of the equation of mass continuity. It is based on the following assumptions: (1) The horizontal cross plume and vertical distributions of concentration are Gaussian; (2) the mean wind velocity and turbulence are invariant with space and time for specified intervals; (3) the plume is not subject to jet or buoyancy influences; (4) the plume is not subject to depletion; and (5) no physical terrain features limit diffusion.

Nuclear reactor safety analyses more generally employ Sutton's dispersion formula. Sutton derived his formula by assuming a particular form for variances of plume concentration, namely,

$$\sigma^2 = \frac{1}{2}C^2\,x^{2-n} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where:

C = A generalized diffusion coefficient $(L^{n/2})$.

x = Distance downwind (L)

n = A dimensionless parameter which depends upon atmospheric stability.

Substituting (2) in Equation (1) yields Sutton's dispersion formula:

$$X_{(x,y,z)} = \frac{Q}{\pi \bar{u}\ C_y C_z\ x^{2-n}}\ \exp - \frac{y^2}{C_y^2\ x^{2-n}}\ \exp - \frac{z^2}{C_z^2\ x^{2-n}}\ \ . \ . \ . \ . \ (3)$$

The effluent concentration at any point can be calculated from Equation (3). To use the above equation for MHA dose calculations, all one need do is assume a reasonable set of parameters, ie, n, $\bar{u}$, C_y, C_z, for the period in question. To arrive at the average yearly dose, the frequency of occurrence of the values of n, C_y and C_z must be known, for they vary with the different stability regimes. Furthermore, the wind direction frequency must be established to calculate annual average doses at various points. In summary, then, the meteorological analysis must yield estimates of $\bar{u}$, the values of n, C_y and C_z, and their relative frequency of occurrence by wind direction.

On the basis of the meteorological program conducted at both the Palisades and the Big Rock Point sites, Table 6 lists the diffusion coefficients recommended for the Palisades site. The long-term parameters should be used for periods of from 9 hours to one year. The short-term set of parameters should be used for calculations over periods of 2 to 8 hours. This latter set of diffusion parameters represents a meteorological condition which exists for a maximum about 2 percent of the time. For the other 98 percent of the time, atmospheric diffusion conditions are at least as favorable. Both sets of diffusion coefficients represent atmospheric diffusion conditions above the surface roughness elements surrounding the site. They imply, therefore, diffusion conditions above about 100 feet.

In the choice of parameters to be used for dose calculations, it is important to note that even though stable atmospheric conditions can be expected to occur about 30 percent of the time, Table 2 shows that the average wind speed under stable conditions is about 12 mph at the shoreline station and 7 mph at the inland station. Further study of Table 2 shows that the diffusion regime of most interest, very stable lapse conditions coincident with wind speeds less than 4 mph, occurs 0.56 percent of the time at the shoreline station and 3 percent of the time at the inland station. The average wind speed for this regime is 9.3 mph and 5.1 mph for the two stations, respectively. Stable conditions with wind speeds less than 4 mph occur a total of 1.4 percent at the shoreline station and 5.8 percent at the inland station. The shoreline at Palisades is oriented almost directly north-south. Consequently, the winds of greatest interest are limited to onshore winds and hence toward inhabited areas. Table 4 shows that onshore winds under 4 mph with very stable lapse conditions occur 0.55 percent at the shoreline station and 0.35 percent at the inland station. For these two stations under the very stable regime the average wind speeds are 9.2 mph and 6.9 mph, respectively. It is clear from the

data collected (Table 4) that there is less than one chance in 45 that the onshore wind speed will be less than 4 mph at the shoreline station, and that there is further, less than one chance in 180 that the onshore wind speed will be less than 4 mph under very stable atmospheric diffusion conditions.

Considering just onshore winds under both stable and very stable lapse conditions, Table 4 shows that winds under 4 mph occur 1.21 percent at the shoreline station and 1.22 percent at the inland station.

The combination of diffusion parameters recommended on Table 6 for the short-term dose calculations was chosen after consideration of the above frequencies of occurrence of stable lapse conditions coincident with low wind speeds. Since they occur less than 2 percent of the time, the chosen combination of parameters are believed to be conservative.

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