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SCHWENCER,A. Licensing Branch 2

SEE DRAWINGS & REP

SUBJECT: Forwards responses to Hydrologic Engineering Section Safety Questions 371.015,371.016,371.017 & 371.018 contained in NRC 811104 ltr.Other responses will be submitted by 820115.Ten oversize drawings encl.Aperture cards are in PDR.

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December 30, 1981
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Docket No. 50-397

Mr. A. Schwencer, Director
Licensing Branch No. 2
Division of Licensing
U. S. Nuclear Regulatory Commission
Washington D. C. 20555

Dear Mr. Schwencer:

Subject: NUCLEAR PROJECT NO. 2
HYDROLOGIC ENGINEERING SECTION SAFETY QUESTIONS

Reference: Letter, A. Schwencer to R. L. Ferguson, "WNP-2 FSAR Request for Additional Information", dated November 4, 1981

Enclosed are sixty (60) copies of the completed responses to the Hydrologic Engineering Section Safety Questions Nos. 371.015, 371.016, 371.017 and 371.018 transmitted to the Supply System by the referenced letter. These responses will be incorporated into the next amendment to the FSAR. The remaining responses (to Question Nos. 371.019 and 371.020) will be transmitted to the NRC by January 15, 198~~1~~2.

Very truly yours,

G D Bouchey

G. D. Bouchey, Deputy Director
Safety and Security

CDT/sm

Enclosures

cc: R. Auluck - NRC
WS Chin - BPA
R Feil - NRC Site

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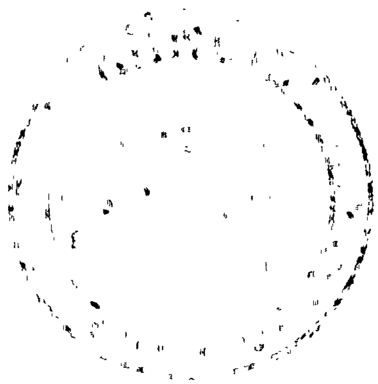

Q. 371.015

We have repeatedly requested information on the design basis rainfall for the roofs of safety-related buildings (Q. 371.1 and 371.8). The purpose of this request is to allow the NRC staff to verify that the roofs of safety-related structures can withstand the stresses resulting form Probable Maximum Precipitation (PMP) and other normal loads that are combined with PMP. Past practice indicates that the applicant generally has two choices as follows:

1. Where the structural distress level (safety-related roofs), in terms of ponded rainfall in combination with other normal coincident loads, exceeds the height of the parapet walls, it is acceptable to provide the structural distress level and indicate that since this level exceeds the height of parapet walls, PMP is not the controlling design basis event.

2. Where the structural distress level (as previously defined) for the roof of a safety-related building is below the level of the parapet wall, the applicant must provide sufficient data for the NRC staff to independently determine the maximum depth of ponded water (PMP) and whether it is less than the structural distress level. The minimum data required is:

    a. Area of confined roof.
    b. If credit is taken for the roof drains, provide details of drains and justification for percent blockage assumed. Consider ice and other possible debris.
    c. Elevation of roof and parapet wall.
    d. Number, size, and elevation of scuppers.
    e. Probable Maximum Precipitation rate and basis.
    f. Where the above information is provided on drawings, they should be full scale; reduced drawings are generally not legible.

Response:

The safety-related structures addressed are as follows:

I	Diesel Generator (D) Building
II & IIA	Radwaste/Control (W) Building and adjacent corridor
III & IIIA	Reactor (R) Building
IIIB & IIIC	and adjacent corridors
IV	Standby Service Water Pumphouse (IA, IB)

The subparagraphs for each building correspond to the subparagraphs in the question requiring data.

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I <u>DIESEL GENERATOR BUILDING</u> (METHOD 1)

Area of Confined Roof (Cols. P to S/3.8 to 10)

Total Area (within enclosure) = 12,058 sq. ft.

Parapet Height = 3'-8-½" from L.P. @ Top L.W. Conc.
3'-1" from H.P. @ Top L.W. Conc.

Maximum Water Weight = 3.71 x 62.5 = 232 PSF
Original Live Load = 274 PSF

Therefore, structural distress level = 274/62.5
= 4.39ft.>3.71 ft.

Since the structural distress level exceeds the parapet height based on design loads, the PMP loading is not controlling.

II <u>RADWASTE/CONTROL BUILDING</u> (METHOD 2)

a. Area of Confined Roof (COLS. H.3 to L.9/9.4 to 15.1)
Total Area (Control Tower encl.) = 10429 sq. ft.

b. Provided 4 roof drains - assumed clogged

c. Top of conc parapet EL. 545'-0"
Top of built-up roof L.P. EL. 542'-4½" (I)*
Top of L.W. Conc. L.P. EL. 542'-1½"

Top of built-up roof H.P. EL. 543'-1½" (I)*
Top of L.W. Conc. H.P. EL. 542'-10½"

d. Provided 4 overflow scuppers
Size: 6" Ø sch. 40 pipe
Invert EL. 542'-10½" (±)

e. The point value (11.7"/6hr) of the PMP specified in FSAR Subsection 2.4.3.1 was used to evaluate roof loading.

f. Items (a) thru (d) shown on dwgs. A511, A513, A522 and A524.**

Roof design checked for PMP loading for a maximum water level of 1.53 ft. and found to be adequate. The accumulation included runoff from the Reactor Building west wall and assumed all drains and scuppers clogged. Thus, PMP loading is not the controlling design basis event.

* Actual top of roof
**Drawings submitted separately

IIA <u>RADWASTE/CONTROL BUILDING</u> (METHOD 2)
<u>CORRIDOR BETW W AND T BUILDINGS</u> (COLS H to H.3/9.4 to 15.1)

a. Area of confined roof
Total Area (within enclosure) = 835 sq. ft.

b. Provided 3 roof drains - assumed clogged

c. Top of Conc. Parapet EL. 532'-0½"
Top of L.W. Conc. L.P. EL. 530'-4½"
Top of L.W. Conc. H.P. 530'-9½"

d. Provided no scuppers in this area.

e. Refer to Item (e) in Area II.

f. Items (a) through (d) shown on drawings A511, A513, and A516.**

Roof design checked for water loading equal to the full height of parapet and found to be adequate. The above ponding assumed all drains clogged. Thus, PMP loading is not the controlling design basis event.

III <u>REACTOR BUILDING</u> (METHOD 2)

a. Area of Confined Rool (COLS. H.3 to N.8/3.2 to 9.4)
Total area (within enclosure) = 19817 sq. ft.
(South Side) from Roof H.P. - Area = 10728 sq. ft.
(North Side) from Roof H.P. - Area = 9089 sq. ft.

b. Provided 4 roof drains - assumed clogged

c. Top of steel parapet EL. 671'-2"
Top of metal deck L.P. EL. 668'-2" (±)*
Top of steel H.P. EL. 667'-0

Top of metal deck H.P. EL. 668'-11¼"*
Top of steel H.P. 668'-9¼"

d. Provided 8 overflow scuppers
(4) Scuppers on North Side
(4) Scuppers on South Side
Size: 6"Ø sch. 40 pipe
Invert EL. 668'-2" (±)

e. Refer to item (e) in Area II

* Actual top of roof
**Drawings submitted separately

f. Items (a) thru (d) shown on dwgs. A511, A512, A515 and A522.**

Roof design checked for maximum water loading of 12 inches above L.P. of roof and found to be adequate. Thus PMP is not the controlling design basis event.

IIIA <u>REACTOR BUILDING</u> (METHOD 1)
<u>CORRIDOR BETWEEN R AND T BUILDINGS</u>
<u>(Cols. H to H.3/3.4 to 4.1)</u>

Total area of confined roof = 133 sq. ft.
Parapet height = 1'-7½" from L.P. built up roof

Maximum water weight = 62.5 x 1.62 = 101.3 PSF
Original live load = 250.0 PSF

Structural distress level = 250/62.5 = 4.0 ft. >1.62 ft.

Since the structural distress level exceeds the parapet height, PMP is not controlling.

Details shown on A511 and A516 (typical in corridors)

IIIB <u>REACTOR BUILDING</u> (METHOD 1)
<u>CORRIDOR BETWEEN R AND T BUILDINGS</u>
<u>(Cols. H to H.3/4.1 to 6.8)</u>

Total area of confined roof = 497 sq. ft.
Parapet height = 1'-6" from L.P. built up roof

Maximum water weight - 62.5 x 1.5 = 94 PSF
Original live load = 250 PSF

Structural distress level = 250/62.5 = 4.0 >1.5 ft.

Since the structural distress level exceeds the parapet height, PMP is not controlling.

**Drawings submitted separately

IIIC REACTOR BUILDING (METHOD 1)
CORRIDOR BETWEEN R AND T BUILDINGS
(Cols. H to H.3/6.8 to 9.4)

Total area of confined roof = 413 sq. ft.
Parapet height = 1'-6" from L.P. built up roof

Maximum water weight = 62.5 x 1.5 = 94 PSF
Original live load = 250 PSF

Structural distress level = 250/62.5 = 4.0 ft. >1.5 ft.

Since the structural distress level exceeds the parapet height, the PMP is not controlling.

IV STANDBY SERVICE WATER PUMPHOUSE (METHOD 2)

a. Area of confined roof = 1682 sq. ft.

b. No roof drains provided.

c. Top pf conc. parapet EL. 467'-5"
Top of roof L.W. Conc. fill L.P. EL. 465'-6½"
Top of roof L.W. conc. fill H.P. EL. 466'-2"

d. Provided two overflow scuppers
Size: 6" Ø sch. 40 pipe
Invert EL. 465'-6½" (t)
Scuppers shown on drawings A515 and A570**

e. Refer to Item (e) in Area II

f. Items (a) through (d) shown on drawings A515 and A570

Roof design checked for maximum water level of 11.7 inches and found to be adequate. The above ponding assumed all scuppers clogged. PMP is not the controlling design basis event.

**Drawings submitted separately

Q. 371.016

Reference previous questions numbers 371.1 and 371.8. Your responses did not provide sufficient information. Provide a unreduced post-construction topographic map(s) that clearly shows site drainage features including: (1) Road and railroad grade elevation, (2) invert elevation and size of drainage ditches, (3) culvert invert elevations, cross-sectional area, type, length and inlet and outlet features, (4) where drainage water is temporarily ponded (maximum level close to plant grade) provide the area-capacity information for the storage area, and (5) show the drainage sub-areas, direction of flow, drainage area, hydrograph and peak discharge and method of computation.

Response:

Figures 371.016-1 and 371.016-2 show post construction site topography and drainage features. Figure 371.016-1 shows the drainage plan for the PMP flood (Ref. FSAR 2.4.3.1) runoff, and Figure 371.016-2 shows the drainage sub-areas used in calculating peak discharges. Where drainage ditches are provided along roads, they are typically one foot deep with side slopes of 2 to 1 maximum. The culvert provided on the east side of spray pond 1B is a 38 foot long·8 inch diameter corrugated metal pipe with a 0.5% slope, and inlet invert elevation at 433.7. Peak discharge flows from the storage areas in Figure 371.016-2 are given in Table 371.016-1.

Table 371.016-1

Zone	Storage Capacity	Peak Discharge	Remarks
I	-	-	Open area - no calculation
II(No. of RR)	-	2.0 cfs	
II(So. of RR)	-	3.3 cfs	Due to Zone II South
		16.3 cfs	Due to overflow of Zones II,III,V and VI
III	-	2.3 cfs	
IV	-	0.0 cfs	Zone is composed of 8" crushed rock
V	36,000cu.ft.	8.9 cfs	
VI	10,000cu.ft.	1.9 cfs	
VII	-	1.7 cfs	
VIII	-	1.3 cfs	
IX	1500cu.ft.	negligible	
X	2250cu.ft.	negligible	
XI	60,000cu.ft.	0.0	
VII	-	0.4 cfs	
XIII	-	0.3 cfs	
XIV	-	4.0 cfs	
XV	-	2.7 cfs	
XVI	-	21.5 cfs	Including runoff from Zone XV
XVII	-	25.2 cfs	Including runoff from Zone XV and XVI
XVIII	83,200cu.ft.	26.3 cfs	
XIX	-	10.4 cfs	
XX(No. of CT 1A)	-	4.9 cfs	
(So. of CT 1A)	-	-	Flows directly to borrow area
XXI	-	-	Flows directly to borrow area

Methods of computation used were Izzards formula and the Rational formula.

Q 371.001

Provide detailed post-construction topographic maps of the WNP-2 site and its surrounding area since neither Figures 2.4-2 and 2.4-9 of the FSAR are legible nor do they have sufficient detail. These revised maps should clearly show, in addition to the plant structures, the locations of streams, ditches, culverts, and other pertinent drainage features.

Response:

~~Figure 2.1-4 shows the projected post construction topographic map of the WNP-2 site. Details of the locations of ditches, culverts and other drainage features are presently under design and will be presented at a future date as stated in 2.4.2.1.2. The legibility of Figures 2.4-2 and 2.4-9 have been improved.~~

~~Figure 2.1-4 shows the projected post-construction topographic map of the WNP-2 site. The legibility of Figures 2.4-2 and 2.4-9 has been improved.~~

~~Details of the locations of ditches, culverts, and other drainage features are shown on Figures 371.016-1 and 371.016-2.~~

See response to NRC Question 371.016.

Q. 371.8

As requested in Item 371.1 of the first acceptance review questions issued on June 24, 1977, provide a detailed post-construction topographic map of the plant area with particular emphasis on the locations of streams, ditches, and drainage structures. Where any drainage structures, including roof openings, are relied upon to convey runoff from the local Probable Maximum Precipitation (PMP), provide pertinent details of these structures, including their size, slope, elevation, and cross-sectional area.

Response:

~~A detailed post-construction topographic map of the plant area is not completed at this time. It is expected that the drawings of the final site grading and drainage features will be developed by October 1979 so that a contract for this work can be let in 1980.~~

~~All safety-related facilities are located above the elevation of the Probable Maximum Flood (PMF) produced by the PMP. Final site grading will assure that the rainfall is carried away from the plant. Discharge from roof drains, and non-radioactive floor and equipment drains is carried by pipeline to an outfall area approximately 1200 feet from the main plant structure and at an elevation approximately 40 feet lower than the final plant grade.~~

See response to NRC Question 371.016.

Q. 371.017
(2.4.13.3)

The groundwater pathways analyses in this section are inconsistent both within the section and with other parts of the FSAR and ER.

a. The analyses for the two cases is impossible for the staff to follow because you gave no details on the physical situation. For example in the "first case" analysis, it is not clear whether you assumed saturated or unsaturated flow in the region above the water table. In the second case analysis the physical situation you envision is not at all clear. Furthermore, neither case appears to be directly solved by the equations on page 2.4-40, (Amendment 13). Please elaborate extensively on the physical situations and how they were modeled.

b. Values of physical parameters of the groundwater flow disagree widely with reported values in other parts of section 2.4.13 of the FSAR and 2.4.2 of the ER. For example, you used an effective porosity of 0.2 in your transport analysis. The ER, page 2.4-8, Amendment 2, estimates that available porosity of the glaciofluvial sediments is between 0.048 and 0.11, and the average effective porosity is 0.09.

The values of permeability of 50.2 ft/day which you used appear to be much too low. Values of permeability for the glaciofluvial sediments are reported elsewhere in the FSAR and ER to range from 1,200 to 12,000 ft/day.

The actual migration of chemical and and radioisotope plumes from fuel reprocessing at the Hanford reservation strongly indicates that groundwater movement is substantially greater than your estimates. A rough estimate of plume movement based on figure 2.4 indicates that your estimates of groundwater movement are too low by at least an order of magnitude. Groundwater mounding at the disposal operation would account for only a small fraction of the plume movement. Please revise your migration estimates to take these data into account.

Response:

Subsections 2.4.13.3 and 15.7.3 have been revised to eliminate confusion regarding the postulated accident event and apparent inconsistencies between sections. The hydraulic conductivities of the unconfined aquifer vary greatly over the Hanford Site. As suggested by the question, plumes from the 200 Area move through soils with conductivities exceeding 10,000 ft/day. However, the aquifer down gradient from the Supply System projects has a hydraulic conductivity on the order of 100 ft/day. Refer to Figure 2.4-35 (as amended).*

*Attached

LIST OF FIGURES (Continued)

2.4.13 GROUNDWATER

2.4.13.1 Description and Onsite Use

Subsurface soil conditions, across the site, have been classified as follows:

a. Loose to medium dense, fine to coarse sand with scattered gravel (glaciofluvial sediments).

b. Very dense, sandy gravel with interbedded sandy and silty layers (Ringold Formation, Middle Member).

c. Very dense, interbedded layers of sandy gravel silt and soft sandstone (Ringold Formation, Lower Member).

d. Basalt bedrock which forms the bedrock beneath the area.

The lithologic character and water bearing properties of the geologic units occurring in the Hanford region are summarized in Table 2.4-8. In general, groundwater in the surficial sediments occurs unconfined, although locally confined zones exist. Water in the basalt bedrock occurs mainly under confined conditions. Occasionally, the lower zone of the Ringold Formation occurs as a confined aquifer, separated from the overlying unconfined aquifer by thick clay beds which possess a distinct hydraulic potential.

The unconfined aquifer consists of both glaciofluvial sand and gravel deposits and the Ringold silts, clays and gravels. Since these materials are very heterogenious, often greater lithologic differences occur within a given bed than between beds. In the vicinity of WNP-2 the water table [is] below the top of the Ringold Formation (see figures 2.5-64 and 2.5-65). The unconfined aquifer bottom is the basalt bedrock in some areas and silt/clay zones of the Ringold Formation in other areas. Clearly the bottom of the unconfined aquifer is not a continuous lithologic surface.

The Hanford Reservation contains over 2200 wells constructed from pre-Hanford work days to the present (Reference 2.4-30). Approximately 600 of these wells are used for groundwater monitoring (Reference 2.4-30). Figure 2.4-24 identifies the well locations in the Hanford Reservation as of September 1975. Figure 2.4-25 shows the December 1975 groundwater contour map. In general, the groundwater gradient resulting from groundwater flowing under the Reservation is the highest in the southwestern area toward Rattlesnake Mountain, and slopes toward the Hanford 200 Areas near the center of the reservation. From the 200 Areas the general slope in the gradient is toward northeast and southeast.

A groundwater contour map based on the potential construction of the Ben Franklin Dam at approximately River Mile 348 is illustrated by Figure 2.4-26. The WNP-2 design basis groundwater level is based on the possible construction of the Ben Franklin Dam and is taken to be 420 feet MSL, whereas the most recent study indicates that the water table would be about 405 ft MSL (Reference 2.4-32). The ~~proposed~~ feasibility of constructing Ben Franklin Hydroelectric Dam ~~continues as not Federally authorized~~ has been extensively studied. Its proposal was strongly contested by local groups and individuals concerned with environmental protection and preservation. Additionally, the matter of the impact such a facility would have on the DOE Hanford Reservation was believed by some to preclude its construction. Finally, the cost/benefit ratio was believed by many to be too low to make the project viable. The combination of the unresolved impediments to the project has effectively, though not conclusively,

relegated it to a very low priority status. Planning studies for the project by the Corps of Engineers were suspended in 1969 and reinitiated in October 1979 ~~1978~~ as part of the development of a management plan for the Hanford reach. The most recent studies were terminated in November 1981.

Impermeable groundwater boundaries are the Rattlesnake Hills, Yakima Ridge, and Umtanum Ridge on the west and southwest sides of the Hanford Reservation. Gable Mountain and Gable Butte also impede the groundwater flow, as well as other small areas of basalt outcrop above the water table. The Yakima River recharges the unconfined aquifer along its reach from Horn Rapids to Richland. The Columbia River forms a hydraulic potential boundary which is a discharge boundary for the aquifer. The major source of natural recharge is precipitation on Rattlesnake Hills, Yakima Ridge and Umtanum Ridge.

Minor changes would be expected in the groundwater elevations during the summer months because of the charging stage of the Columbia River, which historically reaches peak flood stage in June. Because WNP-2 is located about 3 miles from the river and because of the permeability characteristics and enormous volume of the Ringold Formation, there is a substantial time lag in changing water levels. For the same reasons, the range in water table fluctuations is very small.

Natural recharge due to precipitation over the lowlands of the Hanford Reservation is not measurable as the evaporation potential during the summer months greatly exceeds total precipitation. Data on migration of moisture from natural precipitation in deep soils (below 30 feet) show movement rates less than 1/2-in./yr at one measurement site (References 2.4-29, 2.4-37 and 2.4-38). The major artificial recharge of ground water to the unconfined aquifer occurs near the Hanford 200 East and 200 West Areas. The large volume of process water (1.35×10^{11} gallons) discharged to ground during 1944-1973 has caused the formation of significant groundwater mounds in the water table (Figures 2.4-27 and 2.4-28). Other local groundwater mounds formerly existed along the Columbia River. The present Hanford 100-N Area mound is the only one of these remaining. A minor recharge mound also exists at the Hanford 300 Area.

The unconfined aquifer is characterized by its hydraulic conductivity, the storage coefficient, and the effective porosity. The hydraulic conductivity relates the water flow quantity to the hydraulic potential gradient, while the effective porosity gives the fraction of porous media volume that is available to transmit ground water flow. The storage coefficient relates a change in the water table elevation to a change in the volume of water contained in the aquifer per unit horizontal area. In the limit of no delayed yield, the storage coefficient is equal to the effective porosity of the soil through which the water table moves. These parameters vary widely over the Hanford Reservation.

Qualitatively the hydraulic conductivity, storage coefficient, and effective porosity distributions are a function of the different geologic formations in the unconfined aquifer. Ancestral Columbia River channels which incised in the Ringold Formation are now filled with more permeable glaciofluvial sediments. These channels have been identified extending eastward along the northern and southern flanks of Gable Mountain and extending southeastward from the 200 East Area to the Columbia River (~~Reference 2.4-37~~). These permeable channels are reflected in the groundwater flow pattern of the region. see Figure 2.4-35

INSERT A

~~Quantitative measurements of the hydraulic conductivity were~~ made at locations over the Hanford Reservation using a variety of techniques (References 2.4-29, 2.4-37 and 2.4-38). Excluding the clay zone, the values obtained for the Ringold Formation range between 6 to 200 ft/day. In sharp contrast are the very large hydraulic conductivities of glaciofluvial sediments, ranging from 1,200 to 12,000 ft/day.

Field measured hydraulic conductivity values were determined from pump tests on wells in the vicinity of the project site and are as follows (References 2.4-29, 2.4-37 and 2.4-38):

Field Measured Hydraulic Conductivity Values

Well Number	Hydraulic Conductivity (ft/day)	
699-2-3	130-280	unconfined aquifer
699-17-5	5-11	unconfined aquifer
699-10-E12-P	19-21	confined aquifer
699-14-E6-P	7-11	confined aquifer
699-20-E5-P	1.0-1.4	confined aquifer
699-20-E12-P	8-10	confined aquifer

The storage coefficient is much more difficult to measure in the field. Values of 0.0008 to 0.2 were estimated for the Hanford area from field tests, but the quality of these measurements is poor (Reference 2.4-39). A typical range of storage coefficient for unconsolidated sediments is 0.05 to 0.4. No field measurements of effective porosity have been ~~made on the Hanford Reservation.~~

A.

Quantitative measurements of the hydraulic conductivity of the unconfined aquifer have been ~~over~~ made on the Hanford Reservation using a variety of techniques: pumping tests; specific capacity tests; and tracer tests. The most common method has been the pumping tests. Values obtained for the Ringold Formation range between 10 to 650 ft/day with a median of about 130 ft/day. In sharp contrast are the very large hydraulic conductivities of glaciofluvial sediments, ranging from 1,200 to 12,000 ft/day (Reference 2.4-39).

The storage coefficient is much more difficult to measure in the field and estimates are, therefore, less common. For the unconfined aquifer, estimates of the storage coefficient have ranged from 0.01-0.1 (Reference 2.4 - 39). An areal estimate of 0.11 has been provided for the 200 West Area based on the growth of groundwater mounds (References 2.4-39 and 2.4 - 46). The median specific yield (effective porosity) has been estimated by various researchers at Hanford to range from 4.8% to 11%; most commonly it is assumed to be 10% (Refernce 2.4 - 54).

Only 90 wells on the Hanford Reservation have been drilled to basalt. Thus data on the confined aquifers in the basalt flows are limited and more would have to be gathered to fully characterize the confined aquifers.

The plant is located on glaciofluvial outwash sands and gravels which are about 50 feet thick. Below this layer occurs very dense gravel. Sandy gravel occurs in a sequence approximately 200 feet thick which is assumed to be the middle member of the Ringold Formation. The lower member of the Ringold Formation consists of a very compact, interbedded gravel, sand, silt and clay and extends down to a depth of about 500-525 feet. Basaltic bedrock underlies the lower Ringold member, at approximately 550 feet depth.

The water table is about 60 feet below the ground surface level at WNP-2. The water table elevation is about 378 $\pm$ 4 feet MSL and appears to be stable. The effective bottom of the unconfined aquifer is assumed to be at about 220-260 feet MSL at the top of the lower Ringold Formation. Groundwater potentials from the lower Ringold and from the basalt water bearing zones are about 25 feet higher than that of the unconfined aquifer. Test borings down to 925 feet reveal there are water bearing zones in the lower basalt flows and sedimentary interbeds at WNP-2. Piezometric level in basalt is 10 feet above unconfined water table and hence artesian.

Under the WNP-2 site the unconfined groundwater is moving easterly toward the Columbia River, the nearest discharge boundary. ~~Preliminary~~ Studies of the uppermost confined aquifer indicate that the potential gradients at the proposed site are oriented in the same general direction as those of the unconfined aquifer.

Three water supply wells are located on the WNP-2 site (see Subsection 2.4.13.2). Two onsite wells draw from the unconfined aquifer in the Ringold formation and a third well penetrates the confined aquifer in the underlying basalt flows. ~~During construction~~ The deepest ~~these~~ well~~s~~ supplies potable/sanitary water requirements and provides water to support construction activities (concrete, dust control, pipe flushing, fire suppression, etc.). Well water consumption for these purposes is not expected to exceed 10,000 gpd for the balance of construction. ~~For the operating phase, the wells will~~ provide makeup water for ~~the~~ potable and demineralized water system during outages. The design is for a peak requirement of 250 gpm although average usage should be less than 20 gpm. When the plant is operating, normal water supply will be from the river and the deep well~~s~~ will be maintained in the standby mode.

2.4.13.2 Sources

Regional use of the unconfined aquifer is at three locations. The first is at the DOE's Fast Flux Test Facility construction site, located about 3 miles southwest of the WNP-2 site as shown in Figure 2.1-3. Groundwater to this construction site is supplied from two wells and is used for sanitary and operation purposes. Maximum expected usage rate is between 2 million and 2.5 million gal/month. No data is available on drawdown tests performed on the FFTF water supply wells 699-SO-7 and SO-8.

The second location of ground water use is the WNP-1/4 site about one mile east of WNP-2. Water is drawn from two wells for construction, sanitary, and potable water requirements. Usage rate is approximately 250,000 gal/month.

The third location is the WNP-2 site with the wells described in 2.4.13.1. The two wells which draw from the unconfined aquifer (699-13-1A and 1B) are 234 and 244 feet deep. Drawdown tests for each well showed 22 and 91 feet of drawdown respectively, at pumping rates of 250 gpm and test durations of about 25 hours. The third well (695 feet deep) is sealed from the unconfined aquifer and draws from confined water in the basalt. Drawdown on this well was 163 feet at a pumping rate of 275 gpm with a test duration of 25 hours.

Water table contours in the vicinity of WNP-2 site can be seen in Figure 2.4-28. The aquifer is assumed to be isotropic, therefore, flow occurs along instantaneous streamlines perpendicular to the equipotential contours. The groundwater flow is toward the discharge boundary at the Columbia River to the east of the site. The hydraulic potential gradient in this area is about 8 ~~10-15~~ 10 feet/mile in the unconfined aquifer. As described in 2.4.13.1, recharge and discharge of riverbank storage occur along the Columbia River with daily fluctuations superimposed on the seasonal variations in river stage. Hydrographs of wells in the vicinity of the plant site (Figure 2.4-33) show that riverbank storage is not detectable even in years of extreme spring runoff at the two wells that are about one mile from the riverbank. Thus no seasonal reversability of the gradients driving the groundwater flow occurs. In other areas of the Hanford Reservation, the seasonal fluctuations of groundwater levels from riverbank recharge can be detected 3-4 miles inland from the riverbank.

The historical well hydrographs for the uppermost confined aquifer in the vicinity of the plant site are given in Figure 2.4-34. Well number 699-20-E12-P shows a rather rapid rise of the confined aquifer potential in 1962-65. It has been postulated that this rise reflects recharge to the confined zones from irrigation across the river in the Columbia Basin Irrigation Project. The hydraulic potential in the uppermost confined aquifer near the plant site is presently about 390 feet MSL, which is about 25 feet higher than the potential of the overlying unconfined aquifer.

The effects of the groundwater withdrawal at the WNP-2 site have been estimated to be local. No drawdown has been detected ~~outside of WNP-2 on the Hanford Reservation~~ in the nearest observation wells, numbers 699-17-5 and 699-9-E2. The latter well is perforated over multiple aquifers so it does not give a representative measurement of the water table elevation. The radius of influence (defined to be the radius at which a 0.1 ft. drawdown exists) of the WNP-2 wells has been estimated to be about 3500-4500 feet. This is based on the ten months of high rate of withdrawal during compaction operations taking into account the ambient water table gradient. The subsequent reduction in withdrawal flow rate to 25% of the early value would shrink the radius of influence considerably.

There is no groundwater recharge area within the influence of the plant. The 60 foot depth from the land surface to the water table and the arid condition of sediments above the water table make it virtually impossible to detect any recharge from precipitation over this area.

2.4.13.3 Accidental Effects

INSERT B

~~The effects of accidental release of liquid radioactive material to the ground at the site area were investigated.~~

~~There are two condensate storage tanks, 45 feet in diameter and 35 feet high, protected by a seismically designed dike. Water from these tanks is delivered by means of a 16 inch diameter steel pipe to the turbine generator building and a 24 inch diameter pipe to the service building.~~

~~Water stored in these tanks contains radionuclides, and the failure of any of the delivery pipes outside the dike could release radioactive liquids to the ground.~~

B

2.4.13.3 Accident Effects

The accident scenario evaluated here involves a postulated rupture of a Decontamination Solution Concentrator Waste Tank within the Radwaste Buildind (see Figure 11.2-1). The released effluent is then assumed to reach the soil environment outside the building and to percolate to the water table unimpeded. Upon entering the groundwater, the postulated radwaste release is dispersed, sorbed, decayed, and diluted along the potential groundwater pathway from the ~~path~~ plant towards the Columbia River.

In the unconfined (water-table) aquifer, there are no down gradient groundwater users between the WNP-2 site and the Columbia River. However, the construction water needs at WNP-1/4 are supplied by two deep wells that withdraw groundwater from the uppermost confined aquifer downgradient from the WNP-2 Radwaste Building. During operation of WNP-1/4, these wells will be maintained in an stanby mode. The uppermost screens in these wells are about 240 feet below the ground surface in the lower Ringold Formation. The effective bottom of the unconfined aquifer is generally assumed to be at the top of the lower Ringold Formation or about 200 feet below the surface. Thus, in all likelihood, any liquid radioactive spill to the groundwater beneath the WNP-2 Radwaste Building would travel through the unconfined aquifer towards the Columbia River. However, for conservatism, analyses of postulated radionuclide movement assume that the WNP-1/4 wells draw from the unconfined aquifer. The remainder of this subsection provides estimates of travel times of critical radionuclides to move from the postulated spill to receptors and the corresponding concentration reduction factors.

For an assumed one-dimensional groundwater movement, the groundwater travel time, t, is the path length, L, divided by the groundwater velocity (seepage velocity), u.

$$\cancel{t=L/u}$$

The groundwater velocity is the Darcy (apparent) velocity divided by the effective porosity.

$$u=Ki/n_e$$

(B) Cont'd 2 of 5

where K is the lateral permeability (hydraulic conductivity) of the aquifer, i is the hydraulic gradient, and n_e is the effective porosity of the aquifer material.

For computational purposes, a conservative value for lateral permeability of 500 ft/day was selected to represent the unconfined aquifer located in the Ringold Formation beneath WNP-2 (see Figure 2.4-35). From Subsection 2.4.13.1, effective porosity is taken 0.10.

From Figure 2.4-28, the gradient in the water table aquifer between the plant and the Columbia River is about 8 or 9 ft/mile, and is taken conservatively as 10 ft/mile.

Using the above parameter values, groundwater velocities were computed to be 10 ft/day. With path lengths of 3.4 miles to the river and 1.0 mile to the WNP-1/4 wells, the respective travel times are estimated to be 5.2 years and 1.5 years.

Generally, the critical radionuclides of concern for a postulated liquid radwaste spill are tritium, ^{3}H, strontium, ^{90}Sr, and cesium, ^{137}Cs. These three radionuclides are fairly representative in terms of sorption characteristics, of those found in liquid radwaste tanks, since tritium does not sorb onto soil particles at all, strontium is an intermediate sorber, and cesium strongly sorbs to soil particles. The half-life of tritium is 12.3 years, whereas those of ^{90}Sr and ^{137}Cs are 29.0 and 30.1 years, respectively.

The travel time, t_i, for a particular radionuclide moving through groundwater depends upon the velocity, u_i, of the radionuclide

$$t_i = L/u_i$$

where the radionuclide velocity is

$$u_i = r_f u$$

in which r_f is the velocity reduction factor attributable to sorption

$$r_f = 1/(1 + \frac{\rho_b}{n} K_d)$$

In this equation, ρ_b is the bulk density of the aquifer material, n is the total porosity, and K_d is the equilibrium distribution coefficient for a particular radionuclide. The bulk density and total porosity are further related physically as

$$\rho_b = R_s (1 - n)$$

where R_s is the real specific gravity or particle density of the solid particles in the aquifer media.

Ⓑ Cont'd 3 of 5

Reference 2.4-55

The particle density, R_s, for Hanford soils is usually taken to be constant at 2.65 gm/cm^3.(*) The bulk density, ρ_b, of Hanford soils has been determined to range from about 1.5 gm/cm^3 to about 1.75 gm/cm^3, with a median value of about 1.65 gm/cm^3.(*) For the median value of bulk density, the corresponding total porosity is about 0.377.

Reference 2.4-56

Using the above values for bulk density and total porosity, radionuclide travel time, t_i, through the groundwater beneath WNP-1/4 can be expressed as

$$t_i = (1 + 4.4\ K_d)\ t$$

The following summarizes radionuclide travel times (in years) to the WNP-1/4 wells (1.0 miles) and to the Columbia River (3.4 miles):

Nuclide	Half-life, yrs	K_d	t_i @ 1.0 mi	t_i @ 3.4 mi
^{3}H	12.3	0	1.5	5.2
^{90}Sr	29.0	10	67	230
^{137}Cs	30.1	100	660	2300

The radionuclide concentration at the point of water use will be determined by the amount of decay, dispersion, and sorption on the aquifer media.

The minimum concentration reduction factor, CRF_{min}, along the centerline of the contaminant plume from an instantaneous point source is given by( )

Reference 2.4-57

$$CRF_{min} = \frac{C_o}{C} = \frac{(4\pi t)^{3/2}\ (K_x\ K_y\ K_z)^{1/2}}{2V}$$

for an effluent volume, V, with a specific gravity of 1.0 and an initial concentration, C_o, released to soil with dispersion coefficients, K_x, K_y, K_z, in the x, y, and z directions, respectively. This expression neglects the phenomena of sorption and decay which will be considered later.

B Cont'd 4 of 5

D

It is generally accepted that the dispersion coefficients are proportional to groundwater velocity for unidirectional flow, i.e.

$$K_{x,y,z} = \alpha_{x,y,z}\, u$$

where $\alpha_{x,y,z}$ are constants called dispersivities which are a function of the nonhomogeneity of the material. The range in dispersivities in homogeneous granular aquifers may approach 1000 cm (33 ft).(Reference 2.4-58) Substituting this relationship into the above expression for concentration reduction, and noting that travel time is determined by path length and velocity, results in

$$CRF_{min} = \frac{(4\pi L)^{3/2}\,(\alpha_x \alpha_y \alpha_z)^{1/2}}{2V}$$

For the conservative condition of $\alpha_x = \alpha_y = \alpha_z = 1.0$, then

$$CRF_{min} = \frac{(4\pi L)^{3/2}}{2V}$$

D

The concentration reduction factors at the WNP-1/4 wells and at the bank of the Columbia River, due only to dispersion, are ~~2.9~~ 9.1 x 10^4 and 5.7 x 10^5, respectively, for the 700 gallon Concentrated Waste Tank.

When sorption and decay are included, the concentration reduction is given by(Reference 2.4-58)

$$CRF = \frac{(4\pi L)^{3/2}\,(\alpha_x \alpha_y \alpha_z)^{1/2}}{2V}\, e^{\lambda t_i}$$

in which λ is the radionuclide decay constant defined in terms of the half-life, $T_{1/2}$, of a particular radionuclide as

$$\lambda = \frac{\ln 2}{T_{1/2}}$$

The concentration reduction factor can be expressed as

$$CRF = CRF_{min}\left(e^{\lambda t_i}\right)$$

The exponential term accounts for the effects of sorption and decay. The only effect of sorption on concentration reduction is to increase the travel time, thus allowing more time for decay.

Ⓑ Cont'd 5 of 5

The resulting concentration reduction factors for the radionuclides of interest are given below for path lengths of 1.0 miles (to WNP-1/4 wells) and 3.4 miles (to Columbia River):

Nuclide	CRF (1.0 mi)	CRF (3.4 mi)
^{3}H	1.0×10^{5}	7.7×10^{5}
^{90}Sr	4.5×10^{5}	1.8×10^{8}
^{137}Cs	3.7×10^{11}	5.8×10^{28}

¶ The above factors, ~~have been~~ derived through the application of conservative parameters, are used in Section 15.7.3 to evaluate concentrations off-site. The consideration of the WNP-1/4 wells is especially conservative. Groundwater contamination from the 200 Areas which reached WNP-2 over six years ago (see Subsection 2.4.13.1) has not been detected at WNP-1/4. This substantiates that the WNP-1/4 wells do not draw from the unconfined aquifer or, alternatively, the hydraulic conductivities are much less than assumed.

¶ It should also be noted that

If Ben Franklin Dam were ever constructed, the concentration reduction factors at the river bank would be even larger than those noted above. This would be true, because the groundwater gradient (thus, the groundwater velocity) would be decreased as shown in Figure 2.4-26.

~~Analysis was made considering that 800,000 gallons of con-~~ densate, the total capacity of the two tanks, was accidentally released to the area. It was assumed that no significant lateral movement of liquids will occur until water reaches the water table. The water table at the site area is at a depth of about 60 feet, and the river is approximately three miles from this location. Water has to pass through the 60-foot thick layer of soil and then start to move laterally toward the river as it reaches an impervious layer.

Typical cross section of soil layers in the vicinity of the plant, and corresponding permeability values were obtained from the Battelle, Final Hydrology Report Studies of WNP-2 (Reference 2.4-7a).

Two cases were investigated. In one case, the 800,000 gallon volume of water for both tanks, was assumed to be accidentally released by the failure of the 24-inch diameter pipe outside the dike. This would pond an area of approximately 3.04 x 10^6 sq. ft. Once the water infiltrates through the first three layers of soil of varying permeability (Figure 2.4-35), it reaches the fourth layer which is watertight. The major movement of flow would then follow the boundary between layers three and four. The physical condition will be that of a horizontal capillary (Reference 2.4-48).

In the second case, a continuous leakage was assumed to occur from the pipe outside the dike located about 60 feet above the water table, and the surrounding soil was saturated.

The seepage velocity, Vs, at any lapse time t is dx/dt. From Darcey's Law, the following relationship is established ~~(Reference 2.4-48).~~

$$\cancel{X^2 = 2K\left(\frac{1+e}{e}\right) h_c t}$$

$$t = \frac{X^2}{h_c} \cdot \frac{e}{2K\,(1+e)}$$

K = permeability (50.2 ft./day from Figure 2.4-35)

e = void

$$\frac{1+e}{e} = \frac{1}{P}$$

P = Porosity in percent (average value used 20%)

X = distance in feet

t = time in days

$i = \frac{h_c}{X}$ = hydraulic gradient (10 ft./mile Reference 2.4-7a)

Substitution of P and i yields:

$$t = \frac{X}{i} \cdot \frac{P}{2k}$$

In the first case, the area ponded would have a diameter of approximately 2,000 square feet. For the first arrival of accidental releases at the Columbia River, it would take about 42.8 years; and for the last 48.4 years. In the second case, it will take 15.2 years for the first arrival. For both cases, the long travel time would result in activities released to the Columbia River which would be orders of magnitude below the permissible concentrations specified in Appendix B, Table II of 10 CFR Part 20.

There are no other groundwater users in the vicinity down gradient to the Columbia River from WNP-2 site that could be ~~affected by accidental releases of hazardous liquids to the ground~~.

2.4.13.4 Monitoring or Safeguard Requirements

The only release of water to the ground will be the sanitary wastewater ~~treated~~ effluent from the ~~sanitary sewer systems~~ three Supply System plants. ~~The effluent will be percolated via the tile field.~~ Approximately 50,000 gal/day of waste water ~~is anticipated to~~ may be discharged from the ~~plant.~~ septic tanks or the waste stabilization lagoons. This discharge rate will not produce a significant local rise

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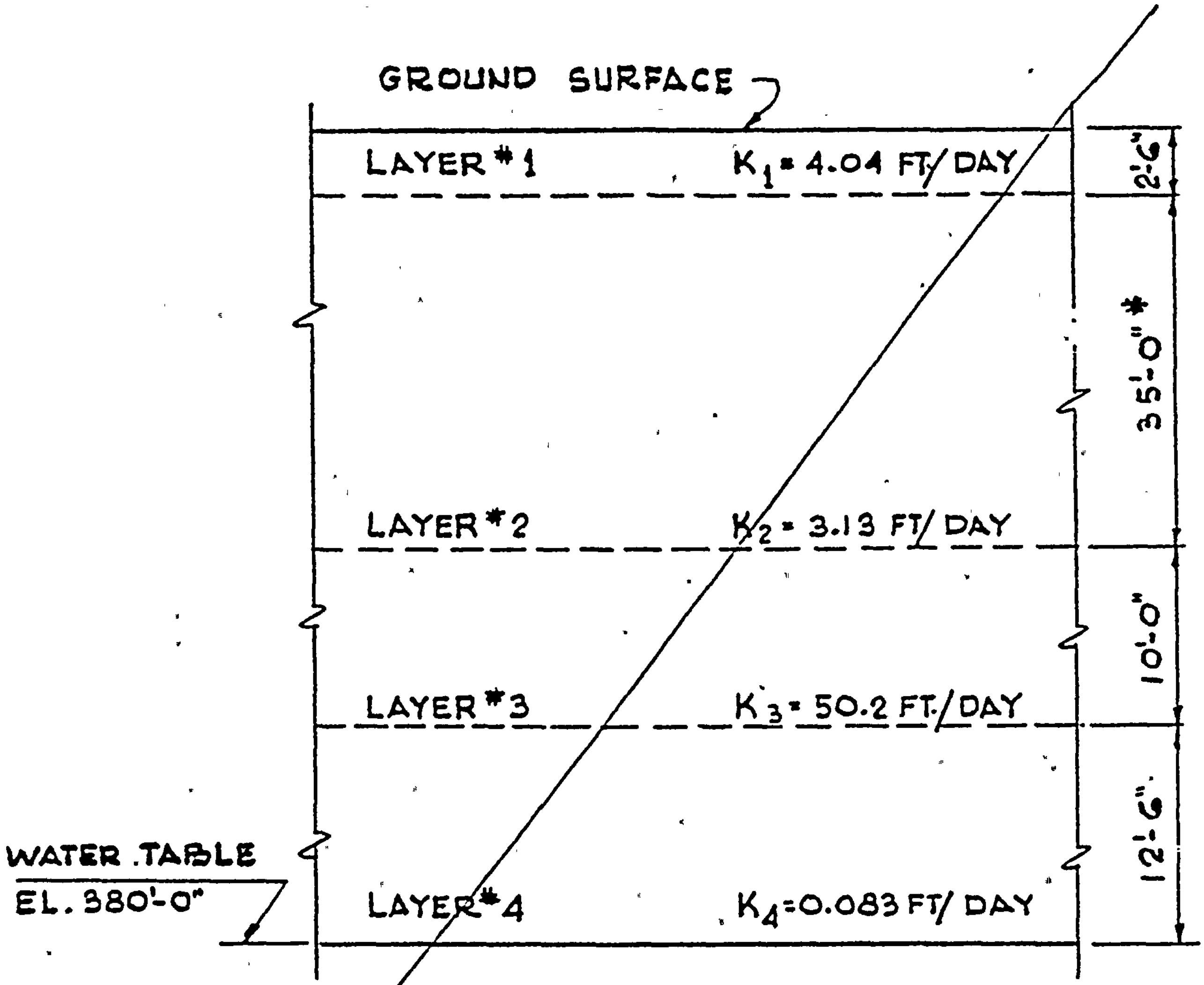
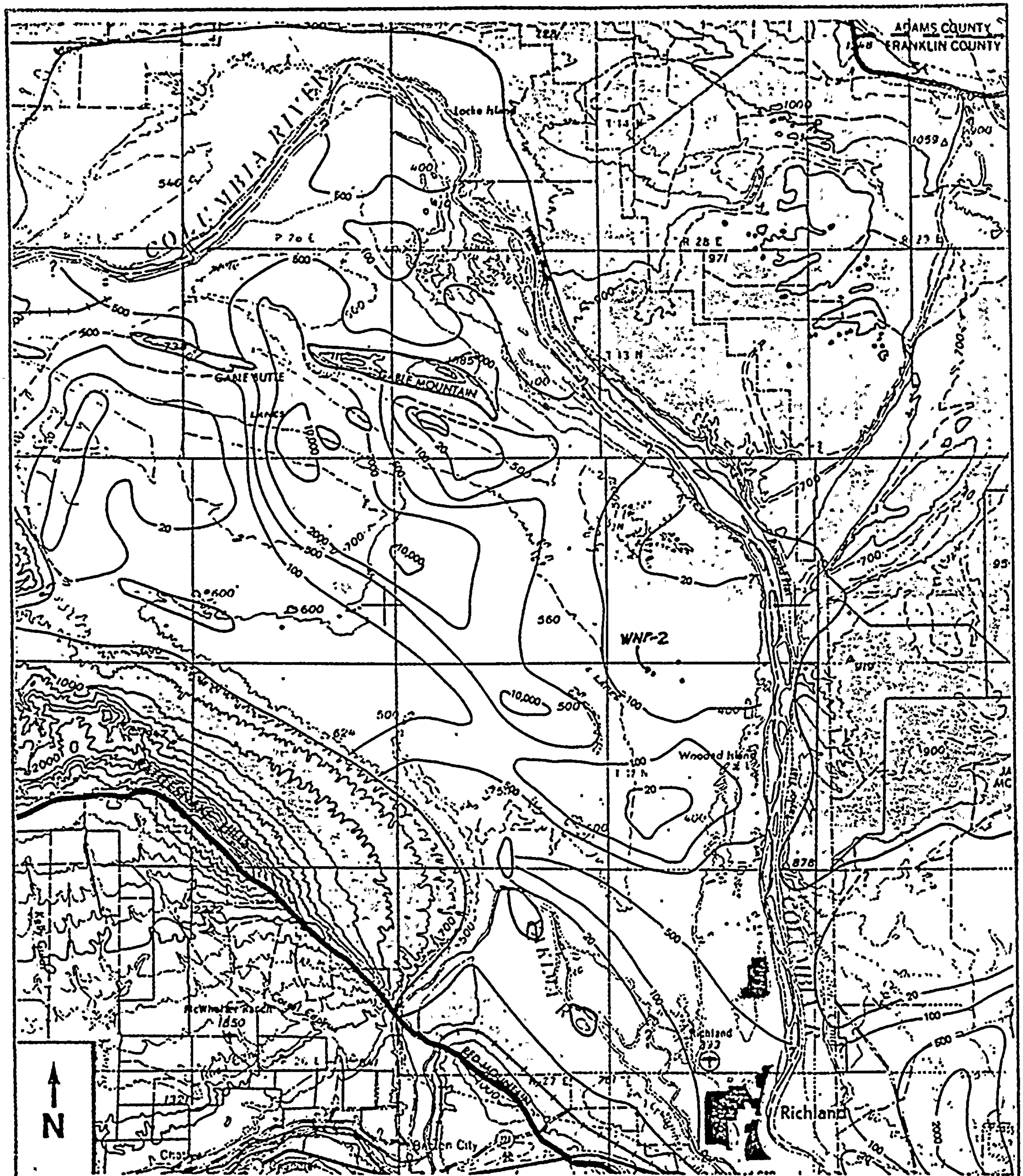


* ADJUSTED FROM 20'-0"

Replace with new Fig # 35

SOURCE: REFERENCE 7A

WASHINGTON PUBLIC POWER SUPPLY SYSTEM NUCLEAR PROJECT NO. 2	INTER~~PRETED SOIL LAYER~~ ~~SEQUENCE AT WNP-2 SITE~~ AREA	FIGURE 2.4-35



Hydraulic Conductivity Isopleths in feet per day.

Source: Plate III-5 from Reference 2.4-39

WASHINGTON PUBLIC POWER SUPPLY SYSTEM NUCLEAR PROJECT NO. 2	~~INTERPRETED SOIL LAYER~~ HYDRAULIC ~~SEQUENCE AT WNP-2 SITE AREA~~ CONDUCTIVITIES IN THE UNCONFINED AQUIFER	FIGURE 2.4-35

Groundwater at the site did not influence construction, since the water table was below the limits of excavations. Furthermore, the groundwater at the site will not affect the foundation of the plant structures during their operational life, provided no changes will occur from other potential future projects. For a discussion of the effects of a rise in the water table on the foundation stability of the WNP-2 plant structure, refer to 2.5.4.8.

P As explained in Subsection 2.4.13.1, the Department of Energy (DOE) ~~Approximately 2100 wells in the Hanford Reservation area were constructed from pre-Hanford work days to the present. DOE presently~~ monitors approximately ~~1600~~ 600 wells on the Hanford Site. Figure 2.4-24 identifies the well locations in the Hanford Reservation as of about September 1975. Figure 2.4-25 shows the December 1975 groundwater contour map. In addition, water level data were obtained from observation wells installed in test borings during exploration for the WNP-2 site facilities. Table 2.5-10 tabulates the elevation of the water table measured from April, 1971 through July, 1972 in observation wells at the WNP-2 site. Based on these data, the water level beneath the site is at an elevation of about 380 feet and appears to be stabilizing at or near this level. In January, 1944, the water level beneath the WNP-2 site was at an elevation of about 368 feet (see Figure 2.4-27).

Fluctuation of the water table at the plant site due to river stage changes on the Columbia River or to pumpage from water wells should be minimal. Hydrographs of wells in the plant vicinity show that effects of riverbank storage were not detected, even in years of extreme spring runoff.

~~The configuration of the water table, based on September 1973 water level data, is presented on Figure 2.4-28. The figure indicates that groundwater moves in an easterly direction from the site towards the Columbia River, which is the closest discharge area. The hydraulic potential gradient is about 10 to 13 feet per mile. The hydraulic conductivity of the unconfined aquifer system is highly variable, depending largely on the hydrostratigraphic framework of the system. Base on pumping tests of wells located in the vicinity of project area, the hydraulic conductivity of the unconfined aquifer system ranges from 6 to 300 feet per day, but in places was measured as high as 12,000 feet per day.~~ Refer to 2.4.13 and 2.5.1.2.6 for additional discussion of groundwater conditions.

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TABLES

15.7.3 POSTULATED RADIOACTIVE RELEASES DUE TO LIQUID RADWASTE TANK FAILURE

15.7.3.1 Identification of Causes and Frequency Classification

15.7.3.1.1 Identification of Causes

The liquid radwaste tanks are constructed to strict engineering codes and standards and to the uniform building code seismic requirements. These tanks operate at atmosphere pressure and low temperatures. A positive action interlock system is provided to prevent inadvertant opening of a drain valve because of operator error. Accordingly, the possibility of a complete tank failure or drainage is considered small.

An unspecified event is postulated to cause the complete release of the average radioactivity inventory in the tank containing the largest quantities of significant radionuclides in the liquid radwaste system. The tank postulated to rupture is one of the Concentrated Waste Tanks. (see Figure 11.2-1)
two Decontamination Solution

15.7.3.1.2 Frequency Classification

This accident is categorized as a limiting fault.

15.7.3.2 Sequence of Events and System Operation

15.7.3.2.1 Sequence of Events

The sequence of events expected to occur is as follows:

Sequence of Events	Elapsed Time
a. Event begins-failure occurs	0
b. Area radiation alarms alert plant personnel	∿ 1 min.
c. Operator action begins	∿ 10 min.

15.7.3.2.2 Identification of Operator Actions

The operator would, upon receiving the alarms, alert personnel to evacuate affected areas of the radwaste building and isolate the radwaste building ventilation system.

15.7.3.2.3 System Operation

Failure of a concentrated waste tank does not require a shut-down nor does it impair a safe shutdown. It will lead to limited operation of the concentrated waste system using the remaining tank.

The liquid contents of this tank will be contained by an unlined 18 inch high concrete dike around the radwaste tank area. Floor drain sump pumps would receive a high water level alarm, activate automatically, and remove the spill liquid.

15.7.3.2.4 The Effects of Single Failures and Operator Errors

This event has been analyzed without taking credit for any expected operator action or system operation discussed in 15.7.3.2.2 and 15.7.3.2.3; therefore, a discussion of SEF or SOE is not applicable.

If credit were taken for the expected operator action and system operation, the radiological consequences of this event would be less severe than those presented in Tables 15.7-14 and 15.7-15.

15.7.3.3 Core and System Performance

The failure of this liquid radwaste system component does not directly affect the nuclear steam supply system (NSSS). It will lead to decoupling of NSSS with the subject system.

This failure has no applicable effect on the reactor core or the NSSS safety performance.

15.7.3.4 Barrier Performance

This event does not involve any containment barrier integrity except the tank itself and the radwaste building. The dike around the radwaste tanks and the portion of the radwaste building housing the tanks is built to Seismic I criteria. No credit is taken for the radwaste building in recontaining the spilled liquid. ~~activity.~~ dike or

In the analysis of spill consequences

INSERT C

15.7.3.5 Radiological Consequences

~~Two separate radiological analyses are provided for this~~ accident:

a. The first is based on conservative assumptions considered to be acceptable to the NRC for the purpose of determining adequacy of the plant design to meet 10 CFR Part 20 guidelines. This analysis is referred to as the "Design Basis Analysis".

b. The second is based on realistic assumptions reflecting expected radiological consequences. This analysis is referred to as the "Realistic Analysis".

15.7.3.5.1 Design Basis Analysis

The design basis analysis is based on NRC Standard Review Plan 15.7.3. The specific models, assumptions and the program used for computer analysis are described in Reference 15.7.4. Specific values of parameters used in the analysis are presented in Table 15.7-13.

15.7.3.5.1.1 Fission Product Release

It is assumed that each liquid radwaste tank contains the inventory of radioactive material presented in 11.2 following correction to be consistent with an offgas release rate of 350,000 μCi/sec after 30 minutes decay. The tank with the largest inventory of radioactive materials is assumed to fail releasing the entire contents of this tank (equal to 80% of the tank capacity) to the radwaste enclosure.

15.7.3.5.1.2 Fission Product Transport to the Environment

The dispersion mechanism for the accidental release of radioactive liquids to the site grounds is described in 2.4.13.3.

The time between the postulated tank rupture and the first release of radioactive material to the river is 42.8 years. The dilution factor (DF) afforded by the river is in excess of one million. This can be shown by comparing the minimum licensed river flow, 36,000 cfs, with the volume of the tank, ~100 ft^3, which would slowly seep into the river. This ~~analysis assumes a DF of one million. No credit is taken for groundwater dispersion.~~

C

The hypothetical radwaste tank failure was evaluated using conservative assumptions which are described in Subsection 2.4.13.3. Important among these are the assumptions of no containment in the Radwaste Building and unimpeded flow vertically through 50-60 feet of sands and gravel. The results of this conservative analysis are given in Table 15.7-3.

It can be seen that the calculations show the strontium concentration exceeding the unrestricted area limitation at the WNP-1/4 wells. It is important to note that these wells are a temporary water supply and are under the control of the Supply System. Should a spill occur at WNP-2 there will be ample time to assess the severity and extent of contamination. Additionally, it was noted in Subsection 2.4.13.3 that these wells most likely draw from a deeper confined aquifer.

Concentration at the river bank will be immediately diluted by the river flow. The nearest surface water users are several miles downstream.

~~15.7.3.5.1.3 Results~~

The calculated concentrations and the concentration limit set forth in 10 CFR Part 20, Appendix B, Table II, Column 2 are presented in Table 15.7-14.

15.7.3.5.2 Realistic Analysis

The realistic analysis is based on a realistic but conservative, assessment of this accident. The specific models, assumptions and the program used for computer evaluation are described in Reference 15.7-4. Specific values of parameters used in the evaluation are presented in Table 15.7-13.

15.7.3.5.2.1 Fission Product Release

The fission product release is the same as that identified in 15.7.3.5.1.1 except that it is based on an offgas release rate of 100,000 μCi/sec. after 30 minutes decay.

15.7.3.5.2.2 Fission Product Transport to the Environment

The dispersion mechanism for the accidental release of radioactive liquids to the site grounds is described in 2.4.13.3.

The time between the postulated tank rupture and the first release of radioactive material to the river is 42.8 years. The DF afforded by the river is assumed to be one million. No credit is taken for groundwater dispersion.

15.7.3.5.2.3 Results

The calculated concentrations and the concentration limit set forth in 10 CFR Part 20, Appendix B, Table II, Column 2 are ~~presented in Table 15.7-15.~~

TABLE 15.7-13

LIQUID RADWASTE TANKS FAILURE - PARAMETERS AND CONCENTRATIONS

~~TABULATED FOR POSTULATED ACCIDENT ANALYSES~~

		~~Design Basis Assumptions~~	~~Realistic Analysis Assumptions~~
I.	Data and assumptions used to estimate radioactive source ~~from postulated accidents.~~	*Entire volume (700gal) of Concentrator Waste Tank assumed to spill with isotope inventory given in Table 11.2-8. Tritium concentration assumed to be 0.01 μCi/ml from WNP-2 ER-OL Sec. 3.5.1.*	
	~~The concentrated waste tank~~ contains the inventory ~~of radioactive material presented in 11.2 following correction to be consistent with an off-gas release rate of~~:	~~350,000μCi/sec~~	~~100,000μCi/sec~~
II.	Data and assumptions used to estimate activity released		
	A. Containment Leak rate (%/day)	NA	~~NA~~
	B. Secondary containment leak rate (%/day)	NA	~~NA~~
	C. Valve movement times	NA	~~NA~~
	D. Absorption and filtration efficiencies	NA	~~NA~~
	(1) Organic Iodine	NA	~~NA~~
	(2) Elemented Iodine	NA	~~NA~~
	(3) Particulate Iodine	NA	~~NA~~
	(4) Particulate fission products	NA	~~NA~~

TABLE 15.7-13 (Continued)

		Design Basis Assumptions	Realistic Analysis Assumptions
E.	Recirculation system parameters	NA	NA
	(1) Flow rate	NA	NA
	(2) Mixing Efficiency	NA	NA
	(3) Filter Efficiency	NA	NA
F.	Containment spray parameters (flow rate, drop size, etc.)	NA	NA
G.	Containment volumes	NA	NA
H.	~~All~~ Other pertinent data and assumptions	See Subsection 2.4.13.3	
	~~(1) Dilution factor afforded by surface water supply~~	~~1,000,000~~	~~1,000,000~~
	~~(2) Time to reach surface water supply~~	~~42.8 years~~	~~42.8 years~~
III.	Concentration Data		
~~A.~~	~~Concentration calculation~~ method	~~Reference 15.7-4~~	~~Reference 15.7-4~~
~~B.~~	~~Peak activity concentrations in containment~~	~~NA~~	~~NA~~
~~C.~~	~~Concentration and concentration limit~~	~~Table 15.7-14~~	~~Table 15.7-15~~

Radionuclide	Conc. @ WNP-1/4 drain (μCi/ml)	Conc. @ Col. R. (μCi/ml)	Conc. Limit (μCi/ml) (a)
^{3}H	1.0×10^{-7}	1.3×10^{-8}	3×10^{-3}
^{90}Sr	1.7×10^{-4}	5.4×10^{-7}	3×10^{-7}
^{137}Cs	2.2×10^{-10}	1.3×10^{-27}	2×10^{-5}

(a) from 10 CFR Part 20, Appendix B, Table II, Column 2

DELETE

TABLE 15.7-14

LIQUID RADWASTE TANKS FAILURE

(DESIGN BASIS ANALYSIS)

CONCENTRATION AND CONCENTRATION LIMIT

(μCi/ml)

Isotopes	Calculated Concentration After 42.8 Years Decay	Calculated Concentration in surface water supply	Concentration Limit[1]
Co-60	9.8E-7	9.8E-13	5E-5
Sr-90	4.6E-5	4.6E-11	3E-7
Cs-134	5.3E-11	5.3E-17	9E-6
Cs-137	5.3E-5	5.3E-11	2E-5
H-3	4.2E-5	4.2E-11	3E-3

[1] See 10 CFR Part 20, Appendix B, Table II, Column 2

TABLE 15.7-15

LIQUID RADWASTE TANKS FAILURE

(REALISTIC ANALYSIS)

CONCENTRATION AND CONCENTRATION LIMIT

(μCi/ml)

DELETE

Isotopes	Calculated Concentration After 42.8 Years Decay	Calculated Concentration in surface water supply	Concentration Limit(1)
Co-60	2.8E-7	2.8E-13	5E-5
Sr-90	1.3E-5	1.3E-11	3E-7
Cs-134	1.5E-11	1.5E-17	9E-6
Cs-137	1.5E-5	1.5E-11	2E-5
H-3	1.2E-5	1.2E-11	3E-3

(1) See 10 CFR Part 20, Appendix B, Table II, Column 2

15.7.6 REFERENCES

15.7-1 Stancavage, P. P. and E. J. Morgan, "Conservative Radiological Accident Evaluation - The CØNACO 1 Code," NEDO-21143, March 1976.

15.7-2 Nguyen, D., "Realistic Accident Analysis for General Electric Boiling Water Reactor the RELAC Code and User's Guide," NEDO-21142, to be issued.

15.7-3 N. R. Horton, W. A. Williams, J. W. Holtzclaw, "Analytical Methods for Evaluating the Radiological Aspects of the General Electric Boiling Water Reactor," APED-5756, March 1969.

15.7-4 DELETED ~~Stancavage P. P., Abbott, D. G., "Liquid Discharge Doses LIDSR Code," NEDM-20609-01.~~

Q. 371.018

Ultimate Heat Sink

1. In order for the staff to perform an independent analysis, please provide the following information on nozzle characteristics:

   a. drop diameter distribution at operating pressures;

   b. pattern of drops leaving spray nozzles (e.g., height, width, density) for range of pressures;

2. Provide results of preoperational testing of sprays performed at the site so far.

3. Did the design basis of the spray ponds consider the effects of volcanic ash on the reduction of pond volume or the operation of pumps? Please elaborate.

Provide a commitment on operational (or preoperational) testing of the spray ponds to verify performance characteristics. Although the staff can make a preliminary determination of acceptability based on the manufacturers suggested performance criteria, it is necessary to verify the performance parameters under load. The Hydrologic Engineering Section is especially concerned with the thermal and water use characteristics. The seepage rates will also have to be verified unless it can be shown that the makeup capability can survive all natural events and combinations thereof.

Response:

1. The spray characteristics for the oriented spray cooling system are given in the Ecolaire Topical Report, "Oriented Spray Cooling System for Ultimate Heat Sink Applications". Figure 371.018-1 gives drop size spectrum as a function of pressure.

   The operating pressure varies with elevation of nozzles in the spray trees. For a flow rate of 10,300 gpm, the top nozzle pressure was measured at 17.3 psi. Spray region dimensions were not measured in Supply System testing, but were estimated from photographs. Estimates indicate that the spray region has an outer diameter of about 140 feet and a width of about 24 feet. The dimensions tend to vary depending on wind conditions. The height of the spray region is about 25 feet.

2. In 1979, the Supply System conducted a test of the Ultimate Heat Sink Spray System to verify its performance characteristics. The results of the testing have been analyzed and documented in Reference 1.*

3. In the design basis of the ultimate heat sink, a 6-inch sedimentation allowance was used for inventory considerations. This allowance included all forms of accumulation, such as dust, silt, or volcanic ash. Recent data from the Mt. St. Helens eruption is being evaluated to determine an appropriate design basis volcanic ashfall. Preliminary indications are that the 6-inch allowance will be sufficient for displaced water volume. The spray ponds will be cleaned whenever the sedimentation reaches a level which, with design basis ashfall, would exceed the 6-inch allowance.

   With regard to pump operation, experience has indicated that there may be some increased leakage from seals as a result of a volcanic ashfall. The potential impact on pumps is being evaluated, and will be reported when complete. Preliminary indications are that increased seal leakage will be the only significant effect, and that will not affect the ability of the pumps to perform their safety function.

The Supply System has performed a preoperational test to establish the performance characteristics of the spray ponds, as discussed in Item 2 above. The results of that test are being used to update the UHS safety evaluation in the FSAR. The results of those analyses, specifically the temperature and inventory margins, will be considered in determining whether or not additional testing is warranted. Preoperational testing will be done to establish seepage rates following the repair of joints in the spray pond.

*Attached.

REFERENCE:

1. Supply System Report WPPSS-EN-81-01, "1979 Ultimate Heat Sink Spray System Test Result", by K. R. Conn, included as attachment to G02-81-561.

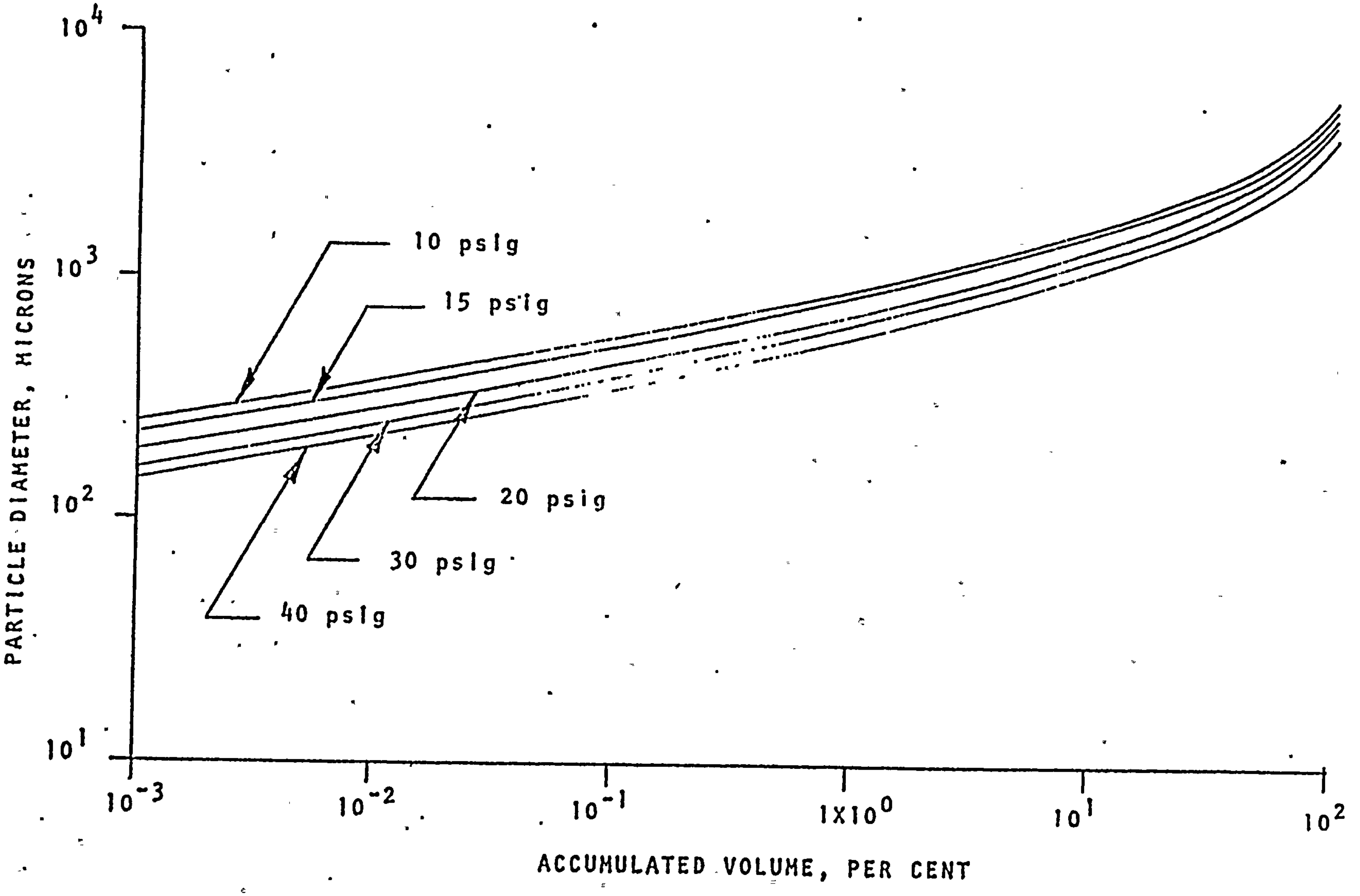

Figure 371.013-1
PARTICLE SIZE VS VOLUME PERCENTAGE

WASHINGTON PUBLIC POWER SUPPLY SYSTEM

NUCLEAR PROJECT NO. 2

1979 ULTIMATE HEAT SINK SPRAY SYSTEM TEST RESULT

By

Kenneth R. Conn

K. R. Conn
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1. INTRODUCTION

The WPPSS Nuclear Project No. 2 includes the first application of the Ecolaire Condenser Inc. Oriented Spray Cooling System (OSCS) in a nuclear power plant ultimate heat sink (UHS). The OSCS concept provides the potential for achieving the high overall spray efficiency levels that historically have been predicted for spray systems but which have not been achieved in conventional spray networks because of the decrease in local cooling potential at the spray segments located in the internal and downwind areas of the network. This high performance potential has been demonstrated for the OSCS in model and full scale tests[1]. These tests provided the correlation basis for the performance prediction model used by the designer to develop a prediction of the OSCS performance for the WNP-2 UHS design.

However, no testing has been performed on an actual OSCS installation of the same design as that at WNP-2 and under conditions that would confirm the validity of the designer's performance prediction for the WNP-2 UHS spray system. In addition, there has been no correlation of the designer's drift loss prediction models with test results. In order to verify the validity of the designer's predictions, the Supply System conducted a test program on the WNP-2 OSCS installation during

1 Oriented Spray Cooling System (OSCS) For Ultimate Heat Sink Applications (UHS), Ingersoll Rand Topical Report IR 100 P, January 1977.

August and September, 1979. This report describes the test program, presents the test data and analysis, and correlates the designer's predictions to the test results.

II. SUMMARY

Twenty tests were conducted during the spray test program. Tests were run at various times of the day and for durations of 14 minutes to 5-1/4 hours. Test data was obtained at wet bulb temperatures from 45 to 63°F, wind speeds from zero to 25 mph gusts and relative humidity levels from 28 to 76%. Test cooling potentials from 9°F to 33°F were obtained.

The designer's spray performance prediction data did not include wind velocity or relative humidity as variables. However, the test results showed a positive influence of wind velocity on the spray thermal performance. The test results indicated that the predicted spray performance is conservative or nonconservative depending on whether the wind velocity is above or below 7-1/2 mph. At a wind speed of 10 mph, for example, the predicted spray performance is conservative by about 6%; however, at zero wind velocity the predicted performance is nonconservative by about 17%. The test results were inconclusive with respect to defining any influence of relative humidity level on the spray performance.

Drift loss rates, calculated from total water loss measurements were determined for 6 of the tests. The test drift rates were significantly greater than the predicted drift rates.

III. DESCRIPTION OF UHS

The WNP-2 ultimate heat sink (UHS) consists of two concrete ponds incorporating spray cooling systems. The standby service water (SW) system circulates cooling water from the ponds to equipment required to shut down the plant from either a normal or accident condition and maintain it in a safe shutdown condition, and discharges the warm return water through the spray system to dissipate the heat. There are two redundant SW loops, each serving an independent division of systems and equipment. Each loop takes water from one pond and returns it through the spray system in the alternate pond. If only one loop is in operation, water is transferred between the ponds through a siphon. There is a third standby service water loop which provides cooling to the High Pressure Core Spray (HPCS) system and related equipment. This loop takes water from pond A and discharges it directly back into pond A. Figure 1 shows a simplified schematic of the standby service water and spray systems. Figure 2 shows the spray piping arrangements.

The spray system in each pond is a circular design referred to by the designer, Ecolaire Condenser, Inc., as an "oriented spray cooling system" (OSCS). In concept, the OSCS simulates the cooling action of a natural draft cooling tower without the physical structure of a tower.

As shown in Figure 2, the spray system consists of a circular arrangement of spray tree modules. The circle is 140 feet in diameter and includes thirty-two spray trees. The SW discharges to a 20 inch ring header which distributes the water to the vertical risers. Horizontal arms are attached to the vertical risers in a helical pattern. The top arm is 18 feet above the centerline of the ring header (or approximately 20 feet above the normal pond surface). A Spraying Systems Company 1-1/2 CXSS 27-55 Whirljet nozzle is located at the end of each arm.

The spray system design was based on a SW loop flow rate of 9,725 gpm. This resulted in a design flow rate per spray tree of 304 gpm and a predicted top nozzle design pressure of 17 psi. The SW operational flow rate is presently expected to be approximately 10,300 gpm. During the test program operation at this flow rate resulted in a top nozzle pressure of 17.3 psi.

Each pond is 250 feet square and contains approximately 6.25 million gallons of water. The distance from the spray ring header to the sides of the pond is 55 feet. The distance from the header to the corners is approximately 107 feet.

IV. TEST DESCRIPTION

A. General Arrangement

Figure 3 shows the general arrangement of the test equipment for the UHS test program. Since the complete standby service water system was not operational at the time of the test temporary piping was installed between the standby service water pump and the spray system supply header of Pond A. Some of the stop logs were in place; therefore, the flow from the pond into the pumphouse was from the upper pond level. Orifices were used to remove the excess pump head and to obtain the desired spray flow rate and top nozzle pressure. Once the test program was started the pump was operated continuously (except for shutdowns for orifice changes and pump checks) to provide a heat load (approximately 3.9 million Btu's per hour) into the pond. The flow was returned to the pond through a straight dump during nontest periods. To initiate a spray test the flow was simply diverted from the dump line to the spray system.

Two meteorological stations were used with one placed on the east side and one on the west side of the pond. The station on the west side was later (prior to test #5) moved to the southwest corner of the pond so it would be further removed from any physical influence of the pumphouse. Each station provided

measurements of wet bulb temperature, dry bulb temperature, wind velocity and wind direction.

The spray operating conditions were defined by pressure measurements in the temporary piping near the pump and the interface with the spray supply header and at three top nozzles. The hot water temperature (THOT) was measured in the temporary piping at a location upstream of the pressure reducing orifices. The flow rate was measured with an orifice meter located in the temporary piping.

Pond water temperatures were measured at four different levels at three pond locations by stratification temperature stations.

Cooled spray water was collected in catch pans and temperature measurements made. There were 24 pans, arranged in 8 groups (on 45 degree radials) of 3 each.

A stilling well with a hook gauge, located in the S.W. corner of the pond, was used for water level measurements for determining pond level changes during a test.

B. Test Equipment and Measurements

1. Meteorological Stations

The meteorological stations were supplied by WeatherMeasure Corp.

The stations consisted of:

a.	Cup anemometer	- Model W103-3SS
	Accuracy	- Greater of ± 1% or 0.15 mph
	Threshold	- 0.9 mph
	Speed Transducer	- HF Tachometer
	Signal conditioning module	- MD103-HF
b.	Vane	- Model W104-2
	Threshold	- 0.75 mph
	Resolution	- 0.72 degree
	Signal conditioning module	- MD104-540
c.	Wet bulb and dry bulb temperature unit	- Model R020-10
	Sensors	- Platinum resistance bulbs
	Probe aspiration	- By fan, 600 feet/min.
	Wet bulb sensor	- Kept moist by gauze wick dipped in water reservoir
	Accuracy	+ 0.5°C
d.	Power supply module - MD910	

The anemometers and wind vanes were mast-mounted and located approximately 13 feet above ground level.

The wet and dry bulb temperatures were recorded on the datalogger. The wind speed and direction were recorded on the brush recorder. Beginning with test #4, they were also recorded on the datalogger.

2. Water Temperature Measurements

Water temperature measurements were made with precision platinum RTD's having an accuracy of $\pm 0.1^{o}F$. Signal conditioning was performed by, and the data recorded, on the datalogger.

3. Cooled Spray Water Collection Pans

Floating conical collection pans three feet in diameter were used for collecting the cooled spray water. The water collected in the pan discharged through a 1-5/8 inch (I.D.) drain pipe installed at the apex of the pan. A holder was attached to the pipe for holding an RTD for obtaining a temperature measurement of the cooled spray water as it discharged from the collection pan.

4. Water Pressure Measurements

The water pressure measurements were by direct reading gauges directly mounted on the pipe or, in the case of the top nozzle pressures, mounted at a readable location with connection to the pressure source by tubing. Beginning with test #4, two of the top nozzle pressures were recorded on the datalogger.

5. Flow Rate

A sharp edged orifice with a bore diameter of 12.595 inches (in a pipe with an inside diameter of 17.25 inches) was used for measuring the spray system flow rate. Flange taps were used. The orifice was sized for a flow range of 0 to 11,000 gpm with a differential head range of 0 to 300 inches of water. The flow rate was recorded as percent of full range differential head on the datalogger. Beginning with test #3, the flow rate was also recorded on the chart recorder.

6. Pond Level

Pond level (for use in determining the total water loss during a test for calculating the drift loss) was measured with a stilling chamber and a hook gauge. The hook gauge was of a micrometer type graduated in thousandths of an inch.

C. <u>Data Acquisition System</u>

1. Datalogger

A Doric Model 220-100.04 datalogger was used for a digital printed (paper) record of data. The unit could record up to 100 data channels with a resolution of ± 0.1°F with the data recorded at intervals selectable from 1 to 60 minutes. The sampling speed was 2 readings per second.

Data initially recorded on the datalogger consisted of:

a. The 24 TCOLD temperatures
b. The 12 pond stratification station temperatures
c. The THOT temperature
d. The 2 meteorological station wet and dry bulb temperatures
e. Flow rate

The following data was added to the datalogger prior to test #4:

a. The 2 meteorological station wind speeds and directions
b. Two of the top nozzle pressures

The temperature data was recorded in °F. All other data was recorded in percent of full range.

2. Strip Chart Recorder

A 6 channel Model 260 Brush Recorder was used for continuous recording of the wind speed and direction data from the two meteorological stations. The flow rate was also recorded on this recorder. The recorder was operated at a chart speed of 5 mm/minute during the test periods.

D. Data Calibration

Various calibration checks were performed on the measurement and data-acquisition systems prior to, during, and following the test program.

An end-to-end calibration error check was made on the cold-water temperature measurements prior to the initiation of the test program and after the conclusion of the tests. The pond was used as a "bath" for the calibration error checks with the reference temperature obtained with a calibrated thermometer. With the exception of one channel during the pretest calibration, all temrature channels showed a negative error (i.e., the indicated temperature from the datalogger was low) during both calibration checks. The error varied from -0.97 to +0.10°F, with an average of -0.50°F, during the pretest check and from -1.02 to -.38°F, with an average of -0.63°F, during the post-test check.

E. Thermal Performance Tests

A total of 20 spray tests were conducted during the period from August 18, 1979, to September 28, 1979. The tests are summarized in Table 1. Thermal performance data was collected during all of the tests. The initial tests were run in the early morning, when the wet bulb temperature was low, to achieve the greatest cooling potential. Also, the winds were normally light and more steady at that time of day. Some of the later tests were run at later times during the day in order to obtain test results under higher wind conditions and at lower relative humidity levels. The last test covered an extended period from 10:14 a.m. to 3:30 p.m. Tests were performed at wet bulb temperatures from 45°F to 63°F with wind speeds from zero to 25 mph gusts and relative humidity levels from 28 to 76%. Test cooling potentials from 9°F to 33°F were obtained.

During the first four tests, the top nozzle pressure was below the design value of 17 psig. Prior to test #5, the orificing in the temporary piping was revised to increase the spray flow to the presently expected operational level of 10,300 gpm. This raised the nozzle pressure to 17.3 psig.

The total cumulative test time was approximately 17 hours. The data on the datalogger was normally recorded every minute.

However, during portions of tests #14, #15, and #17 and all of test #20, the data was recorded every five minutes. A total of approximately 670 sets of data were recorded.

F. Drift Loss Tests

Pond level data was collected in conjunction with six (6) of the tests for use in calculating spray drift rates. Water level measurements were made, with a hook gauge and stilling chamber, before and after the test. This data was used to determine the total loss of water from the pond during the test. The loss of water due to drift was calculated by subtracting the losses due to other causes (e.g., spray and surface evaporation and leakage) from the total pond loss.

V. THERMAL PERFORMANCE DATA REDUCTION AND ANALYSIS

A. Introduction

The cooling potential (CP) of a spray system is defined as the differential between the temperature of the water at the spray nozzles, THOT, and the ambient air wet bulb temperature, TWB. This represents the physical limit of cooling that can be achieved in the spray process. The cooling range (CR) is the amount of cooling actually achieved in the spray process and is defined as

the differential between THOT and the temperature of the sprayed water as it contacts the surface of the pond, TCOLD. The effectiveness of the spray system in removing heat from the sprayed water is described by the spray efficiency, defined as the ratio of cooling range to cooling potential.

The performance predicted for the WNP-2 spray system by the designer, Ecolaire Condenser, Inc., is shown in Figure 4. This figure gives a prediction of the cooling range for a specified cooling potential and wet bulb temperature. The spray efficiency is the slope of the constant wet bulb temperature lines. The constant wet bulb temperature lines are not linear; thus, the predicted efficiency varies with cooling potential as well as wet bulb temperature. Over the ranges of CP and TWB shown in Figure 4 the efficiency varies from approximately 47% to 60%. Note that the designer's performance prediction only recognizes wet bulb temperature and cooling potential as variables.

The objective of the thermal performance test program was to establish the validity of the designer's prediction of the performance of the WNP-2 spray system. Therefore, the approach followed in the data reduction and analysis was to compare the test performance with the designer's predicted performance and to establish a correlation for any deviation of the test performance from the predicted performance due to factors other than wet bulb

temperature and cooling potential.

B. Discussion of Test Data

The wet bulb temperature readings from the two meteorological towers were normally different. This was concluded to be due to the difference in location of the towers with respect to the wind, spray and pond. Whereas a tower located upwind of the pond would be exposed to normal ambient air, the tower located downwind of the pond would be exposed to air that had picked up moisture from the spray and/or pond. The latter would indicate a higher wet bulb temperature.

The conditions of interest are the local ambient meteorological conditions uninfluenced by the pond or spray. Therefore, the minimum value was always assumed to be the upwind value and was always selected as the ambient wet bulb temperature for the purpose of calculating the spray performance. When the wind was from an easterly or westerly direction the wind direction data from the towers would verify the assumption of the minimum wet bulb temperature value as the upwind value. However, when the wind was from the northerly or southerly directions it was not always apparent from the wind data which tower, if either, was in an upwind relationship to the pond. It should be noted that the consideration of a low wet bulb temperature results in a high

value of cooling potential and a net high value of predicted cooling range. Thus, the use of the minimum value of wet bulb temperature results in a conservative comparison of the test performance with the predicted performance.

The dry bulb temperature values from the two towers were also usually different. It is likely that these measurements were influenced by the same factors as the wet bulb temperature measurements. Therefore, the dry bulb temperature associated with the minimum wet bulb temperature was always selected for data analysis purposes.

At rated flow the standby service water pumps generate approximately 500 feet of head. During the tests about 80% of this head was removed by orifices. It is assumed that the orifices converted this pressure energy to thermal energy. The energy conversion would be equivalent to approximately 1/2°F temperature rise in the pumped fluid. The hot water temperature was measured at a location upstream of the pressure reducing orifices and thus did not include this temperature differential. The actual water temperature at the nozzles would have been higher than the measured THOT by this differential. As a result the indicated test performance (CR) should have been lower than the actual test performance by the same differential. The predicted performance would likewise have been lower but only by the temperature differential times the efficiency. The indicated test

performance would thus be conservative with respect to a comparison of test to predicted performance.

The cold water temperature was measured at 24 locations. Measurements were made at each of eight equally spaced (45 degrees) angular locations around the spray circle. Three measurements, at different locations along the radial cross section of the spray annulus, were made at each angular location. It was originally planned to determine profiles of the concentration of cold water across the spray radial cross sections. These profiles would be utilized in computing a weighted average cold water temperature at each angular measurement location. These eight values would then be averaged to obtain an overall effective TCOLD for the spray system. However, when testing was initiated it was discovered that the cold water impact envelope at the pond surface was constantly shifted and reshaped under variable and shifting wind conditions. It was apparent that it would not be feasible to determine the cross sectional profile of the spray, and its physical orientation to the temperature measurements. Thus, some other approach was necessary in order to determine an effective cold water temperature value for each group of measurements.

During the early tests correlation of the cold water temperature measurements with visual observation of the locations of the collection pans relative to the spray pattern indicated that at a given angular location the cold water temperature measurement

varied with the concentration of spray cold water. The highest temperature value in the group of three was from the collection pan located in the heaviest concentration of water. Since the spray test performance varies inversely with TCOLD, consideration of a high value of TCOLD would result in a low or conservative value for the test performance. Therefore, it was decided to use the highest temperature from each group of measurements as representative of the effective TCOLD at that location. These values were then averaged to obtain an overall effective TCOLD for the spray system.

The presence of a wind results in an increase in the local spray performance (illustrated by a decrease in the cold water temperatures) on the upwind side of the spray circle with a decrease in local performance (with higher cold water temperatures) on the downwind side. The resulting angular cold water temperature distribution is similiar to a sine wave. However, the pattern appears to flatten out, with less variation between the upwind and downwind TCOLD measurements, at wind speeds greater than 15 mph. This is apparently due to a diminishing of the adverse effect on the downwind side of the spray system as the air flow through the spray becomes large due to the high wind. Typical cold water temperature distributions for various wind conditions are shown in Figure 5 and 6. These figures also show typical variations that occurred in the cold water temperature measurements at the same angular location.

C. Data Reduction

The data reduction plan consisted of determining the absolute and percent differences between the test cooling range and the designer's predicted cooling range. The test cooling range was calculated from the hot water temperature (THOT) and the overall effective cold water temperature (TCOLD). The predicted cooling range was determined from the designer's predicted performance data (Figure 4) at the minimum test wet bulb temperature and the test cooling potential (CP). The CP was calculated from THOT and the minimum wet bulb temperature (TWB). For consistency and ease of determination the following equation was fit to the graphical data of Figure 4:

$$CR=(-.761+.009\ TWB)+(.2677+.004029\ TWB)\ CP+(.001179-7.14\times10^{-6}\ TWB)\ CP^2$$

Where CR = cooling range

TWB = wet bulb temperature

CP = cooling potential

All the data was reduced for each test (except for nonstabilized points at the beginning of spray operation). The test conditions and results are summarized in Table 2. Figures 7 and 8 show graphical summaries of the reduced test data for two typical tests.

Since the test data was not recorded on magnetic tape it was considered impractical to correct the raw data for the individual cold water temperature measurement calibration errors. Instead, the average calibration error of -0.56°F was applied discriminately during the data reduction.

D. Data Analysis

Evaluation of the results indicated that the diversity in test performance was due primarily to variations in wind velocity with a possible second factor being relative humidity levels. It was apparent that further analysis and correlation against these parameters was necessary in order to more precisely define the performance characteristics of the spray system.

Although all the test data was reduced, and it provided an overall general indication of the performance of the spray system, much of the data was not usable for correlation analysis because of unsteady wind conditions. There were problems of disagreement between the data from the two towers and time response factors between indicated meteorological changes at the towers and the overall spray system performance. It was concluded that a final data analysis should be based on test data recorded during periods of steady wind and consistent meteorological conditions.

The data selected for final data analysis and correlation is given in Table 3. The primary criteria for selecting this data was steady wind conditions. When the wind was steady during the entire test, an average value was determined for the total test. However, where steady conditions existed only during portions of a test, or at individual test points, data was selected and averaged as practical.

The data from Table 3 is plotted in Figure 9 in terms of deviation of test performance from predicted performance versus wind speed. This figure shows that there is a significant beneficial effect of wind on the spray system performance. A straight line was fitted to the data by linear regression. The slope of this line is 2.12, indicating that the spray performance is nominally improved 2% for every one mph of wind velocity.

The designer's performance prediction does not include wind velocity as a variable. Since wind has been considered to have a positive effect on spray performance, the designer's prediction should represent low (zero) wind conditions. The linear regression fit of the test data indicates that at zero wind conditions the predicted performance is nonconservative by approximately 17%. However, due to the positive influence of wind on the spray performance shown by the test data, the predicted performance is progressively less nonconservative with increasing wind velocity

and is equal to the indicated test performance at a wind speed of approximately 7-1/2 mph. With higher wind speeds, the predicted performance is progressively more conservative.

Prior to the test program, there was speculation of an adverse effect of relative humidity on the spray system performance. Tests were run at different times during the day to obtain test data at various relative humidity levels. In order to evaluate the possibility of a relative humidity factor, the data from Table 3 was plotted in Figure 10 as a function of relative humidity. The wind velocity for each data point is also shown on the figure. There are isolated indications of an adverse influence of relative humidity (e.g., the data points at 7, 8, and 8-1/2 mph wind velocity). However, other data points tend to indicate no influence. Therefore, because of the scatter in the data and the limited amount of data at the same wind velocity, but different relative humidity levels, it can not be concluded from the test results whether or not a relative humidity influence did exist. If relative humidity does influence the spray performance, the test data tends to indicate that it is a weak effect.

E. Summary of Data Analysis

The results of the test program show that the performance of the spray system was strongly affected by the presence of wind. The

results indicate that in general, the spray performance increased approximately 2% for each mile-per-hour of wind velocity.

It could not be concluded from the test results whether or not the spray performance is affected by relative humidity. The results did indicate that any influence of relative humidity is apparently small.

A linear regression correlation of the results from the analysis of the selected (on the basis of steady wind conditions) test data indicates that, for the conditions of the test program, the designer's predicted spray performance is nonconservative by as much as 17%. However, because of the favorable effect of wind, the predicted performance is less nonconservative with increasing wind velocity. The predicted performance is equal to the indicated test performance at a wind velocity of about 7-1/2 mph and is increasingly conservative at higher wind velocities.

IV. DRIFT LOSS DATA REDUCTION AND ANALYSIS

A. Introduction

The drift rate predicted by the designer (Ecolaire Inc.) for the WNP-2 UHS is based on a theoretical analysis and has not been substantiated by actual drift loss data. The predicted drift rate

is relatively insignificant (0.11%). However, because of the elevated profile of the OSCS spray there was concern about the potential magnitude of the actual drift loss rate from the UHS under significant wind velocities. Therefore, it was decided to perform drift loss measurements during the spray performance test program.

Several methods have been tried or proposed for experimentally determining drift losses from spray systems. For this test program the concept of determining the drift losses from the total pond water losses was applied.

B. Drift Loss Test Summary

Drift loss data was collected for tests 14, 15, 17, 18, 19 and 20. The primary criteria for selecting tests for the collection of drift data was wind velocity. It was desired to obtain data under different, but significant, wind velocities. The data collected for drift loss purposes consisted of pre- and post-test pond water level measurements. The level measurements were made with a hook gauge and stilling chamber.

C. Drift Loss Data Reduction and Analysis

The change in pond level during a test reflected the total loss of water from the pond. This total loss consisted of the following:

a. Spray evaporation

b. Surface evaporation

c. Pond or piping system leakage

d. Drift loss

The change in pond level during a test was obtained from level measurements taken before and after the test. During test 20, level measurements were also made at several different times during the test. The level data for tests 14, 17, 18 and 20 consisted of four separate measurements at each time point. The arithmetic average of the four values was used for the water level value at that time. In most cases the variation between the four measurements was less than 0.015 inches, which is equivalent to an increment of drift rate less than 0.1% for a sixty minute test duration. This is sufficient accuracy for establishing the pond total water loss for use in calculating drift rates.

In Test 18 there was a variation of 0.11 inches between the four post-test level measurements. The pond level change based on the pre- and post-test averaged measurements was only 0.148 inches. The accuracy of the drift rate calculated from this data is thus questionable.

Only single values of pond level measurement were available for tests 15 and 19. During the drift loss tests, the air dry bulb temperature was generally within a few degrees of the hot water temperature. As the spray drops cooled, conductive heat transfer was negligible. It was therefore conservative from a drift loss standpoint to assume that all heat removed from the spray water was by evaporation. The spray evaporation rate was calculated from the following relationship:

$$M_E = M_S \times \frac{C_p \cdot T_{CR}}{Q_{HV}}$$

Where: M_E = Spray evaporation rate - GPM

M_S = Spray flow rate - GPM

C_p = Specific heat - Btu/lb - ^oF

T_{CR} = Spray cooling range (THOT-TCOLD) - ^oF

Q_{HV} = Heat of vaporization - Btu/lb

The spray flow rate was a nominal constant 10,300 gpm during the tests. The specific heat was assumed to be 1. An average value of cooling range was assumed for each test. The heat of evaporation was based on an average of THOT and TCOLD..

The loss of water from the pond due to surface evaporation was calculated from the test meteorological conditions and pond surface temperature by the following relationships:

$$\dot{M}_{ES} = 181.6 \frac{\dot{Q}_{ES}}{\rho Q_{Hv}}$$

Where: $\dot{M}_{ES}$ = Rate of water loss from the pond due to surface evaporation - gpm

ρ = Density of water at pond surface temperature - lbm/ft3

Q_{Hv} = Heat of vaporization of water at pond surface temperature -Btu/lbm

$\dot{Q}_{ES}$ = Rate of heat transfer from pond due to surface evaporation - Btu/ft2-day.

The heat transfer rate, $\dot{Q}_{ES}$, was calculated from the following relationship[1]:

$$\dot{Q}_{ES} = (e_s - e_a)\ (70 + .7U^2)$$

Where: e_s = Saturated vapor pressure at the water surface temperature - mmHg

e_a = Air vapor pressure - mmHg

U = Wind velocity - mph

[1]Reference: Surface Heat Exchange at Power Plant Cooling Lakes, D.K. Brady, W.L. Graves and J.C. Geyer of John Hopkins University for Edison Electric Institute Research Project No. 49., Nov. 1969.

It was assumed that there was no evaporation from that portion of the pond surface influenced by the presence of the spray (namely, that portion within the confines of the ring header and the downwind projection of the ring header).

Nominal average test values of pond temperature, wind speed, and upwind meteorological data were used to calculate a total surface evaporation loss for the test.

There was no direct evidence of leakage from the pond or piping system during the tests. A later independent evaluation of the various pond level data collected during the test program indicated that any leakage from the pond was relatively insignificant (less than 5 gpm, which would be equivalent to a drift loss of less than 0.05%). Therefore, zero leakage was assumed for the drift loss analysis. Any leakage that may have existed was thus included in the calculated drift rate.

The drift loss was calculated by subtracting the water losses due to spray and surface evaporation from the pond total water loss. The drift loss test data and analysis results are summarized in Tables 4 and 5. The calculated drift rates are plotted in Figure 11 as a function of wind speed.

Figure 11 shows considerable scatter in the test drift rates, specifically between tests 14, 17, 18 and 20. The causes of the

scatter are difficult to define. Normally, the accuracy of the calculated total water consumption would be suspect due to the relatively small changes in pond levels that occurred during the tests. However, as discussed previously, there is a high level of confidence in the total water consumption values for tests 14, 17 and 20. Thus, this factor is not considered to be the source of the variation in drift rates between test 20 and tests 14 and 17. There was considerable variation in the post-test level measurements for test 18 and this factor could account for a significant portion of the variation in drift rate between this test and the others.

The calculated test spray evaporation rates are of significant magnitude. Significant inaccuracies in these values could result in large variations in the calculated drift rates. On the other hand, the calculated test surface evaporation rates are fairly small in magnitude and significant inaccuracies in these values would only result in small variations in the calculated drift rates.

Therefore, except for test 18, no conclusions can be made with respect to the causes or magnitudes of the apparent scatter in the calculated test drift rates. For purposes of UHS evaluations an upper bound curve fit of the the calculated test drift rates is considered representative of the drift loss rates that may be expected from the WNP-2 spray system for wind speeds within the range (up to 9 mph) covered by the drift tests.

D. Summary of Test Analysis

The data analysis results for the drift test data are shown in Figure 11 along with the predicted drift rate. The predicted drift rate is essentially constant for wind speeds below 12 mph. The test data, however, indicates that the drift rate varied with wind velocity even at low velocities, and also that the actual drift rate is much greater than predicted by the designer's theoretical analysis.

There is considerable scatter in the test drift rates which, except for test 18, is not explainable. For UHS evaluations, it is recommended that the upper bound curve fit of the calculated drift rates, shown in figure 11, be considered representative of the potential drift rates for the WNP-2 UHS spray system for wind speeds up to 9 mph.

TABLE 1

WNP-2

TEST SUMMARY

ULTIMATE HEAT SINK TEST PROGRAM

Test	Date	Time Start	Time End	THOT °F	TWB °F	TDB °F	CP °F	RH %	Wind MPH	Top Nozzle Press, PSIG	Flow Rate GPM	Drift Loss Data
1	8-18-79	5:40	6:05	78	56	63	22	63	1 to 3 steady	15.5	9,750	No
2	8-18-79	7:20	7:53	77	58	66	19	62	2 to 6 steady	15.5	9,430	No
3	8-21-79	5:41	6:04	80	60	69	20	61	16 to 3 diminishing	14.5	9,430	No
4	8-23-79	5:37	6:14	81	58	62	23	76	2 to 10 variable	14.5	9,430	No
5	8-25-79	5:35	6:04	80	51	56	29	72	0 to 3 steady	17.3	10,300	No
6	8-25-79	7:38	8:11	79	53	61	26	62	0 to 3 steady	17.3	10,300	No
7	8-27-29	8:24	8:51	81	59	70	21	53	5 to 12 variable	17.3	10,300	No
8	8-27-79	(2:04)	(2:27)	81	63	85	18	28	3 to 25 gusty	17.3	10,300	No
9	8-29-79	5:07	5:23	81	55	61	26	70	0 to 5 steady	17.3	10,300	No
10	8-29-79	(1:12)	(1:26)	82	65	85	17	32	1 to 10 gusty	17.3	10,300	No
11	8-30-79	(2:25)	(2:39)	81	63	76	18	49	5 to 20 gusty	17.3	10,300	No
12	8-31-79	(3:55)	(4:25)	81	62	82	19	33	4 to 18 gusty	17.3	10,300	No
13	9-5-79	6:44	7:13	80	49	52	31	75	1 to 8 variable	17.3	10,300	No
14	9-5-79	8:32	9:40	79	53	60	26	63	1 to 7 variable	17.3	10,300	Yes
15	9-8-79	11:37	(12:51)	80	57	76	23	32	3 to 20 gusty	17.3	10,300	Yes
16	9-12-79	5:49	6:22	78	45	51	33	60	1 to 5 steady	17.3	10,300	No
17	9-12-79	(3:11)	(4:17)	77	59	80	18	28	1 to 12 variable	17.3	10,300	Yes
18	9-14-79	9:57	10:56	76	58	73	18	41	1 to 10 variable	17.3	10,300	Yes
19	9-20-79	9:33	10:32	74	59	71	15	47	0 to 4 steady	17.3	10,300	Yes
20	9-28-79	10:14	(3:30)	68	55	70	13	40	1 to 14 mixed	17.3	10,300	Yes

Times in ( ) are p.m.

THOT - Spray hot water temperature - °F
TWB - Wet bulb temperature - °F
TDB - Dry bulb temperature - °F
CP - Cooling potential (THOT - TWB) - °F
RH - Relative humidity - %

TABLE 2

WNP-2

SUMMARY OF ULTIMATE HEAT SINK SPRAY SYSTEM

THERMAL PERFORMANCE TESTS RESULTS

	TEST # 1	TEST # 2	TEST # 3	TEST # 4
Time:	5:40 to 6:05 a.m.	7:20 to 7:53 a.m.	5:41 to 6:04 a.m.	5:37 to 6:14 a.m.
Wet bulb temp.:	55.0 to 56.2°F	57.3 to 59.3°F	60.2°F	57.6°F
Dry bulb temp.:	62.0 to 63.7°F	64.7 to 67.5°F	68.6°F	62.2°F
Hot water temp.:	77.7°F	77.2°F	80.1°F	80.8°F
Cold water temp.:*	67.9 to 68.7°F	68.8 to 69.3°F	68.7 to 71.9°F	71.2°F
Cooling potential:	21.5 to 22.7°F	17.6 to 20.1°F	19.8 to 20.1°F	22.5 to 23.9°F
Pred. cooling range:	10.7 to 11.2°F	8.9 to 10.1°F	10.3°F nom.	11.4 to 12.1°F
Test cooling range:*	9.0 to 9.8°F	7.8 to 8.5°F	8.1 to 11.5°F	9.3 to 10.0°F
Cooling range:* deviation 1	-2.2 to -1.1°F -19.3 to -10.0%	-1.8 to -1.0°F -18.5 to -11.2%	-2.1 to +1.2°F -20.8 to +11.9%	-2.3 to -1.9°F -20.0 to -16.4%
Top nozzle pressure:	15.5 psig	15.5 psig	14.5 psig	14.5 psig
Wind conditions:	1 to 3 mph, steady	2 to 6 mph, steady	16 to 3 mph, diminishing	2 to 10 mph, steady
Relative humidity:	63%	62%	61%	76%

1. Cooling range dev. = CR Test - CR Pred. -°F

or $= \dfrac{\text{CR Test} - \text{CR Pred.}}{\text{CR Pred.}} \times 100$ - %

* These data were adjusted for calibration error of -0.56°F on the cold water temperature data.

Table 2 (Continued)

	TEST # 5	TEST # 6	TEST # 7	TEST # 8
Time:	5:35 to 6:04 a.m.	7:38 to 8:11 a.m.	8:24 to 8:51 a.m.	2:04 to 2:27 p.m.
Wet bulb temp.:	50.8^{o}F	53.2^{o}F nom.	59.4^{o}F nom.	63.1^{o}F nom.
Dry bulb temp.:	55.5^{o}F nom.	59.6 to 61.7^{o}F nom.	69 to 71^{o}F	84 to 86.5^{o}F
Hot water temp.:	79.7^{o}F nom.	78.8^{o}F nom.	80.5^{o}F	80.7^{o}F
Cold water temp.:*	67.0^{o}F nom.	67.2^{o}F	68.4 to 70.2^{o}F	70.0 to 72.5^{o}F
Cooling potential:	27.8 to 29.2^{o}F	24.5 to 26.6^{o}F	21.1^{o}F nom.	16.9 to 18.3^{o}F
Pred. cooling range:	13.5 to 14.2^{o}F	12.6^{o}F nom.	10.8^{o} nom.	8.9 to 9.6^{o}F
Test cooling range:*	11.8 to 13.5^{o}F	11.7^{o}F nom.	10.3 to 12.0^{o}F	8.2 to 10.8^{o}F
Cooling range:* deviation 1	-1.9 to -0.7^{o}F -13.4 to -4.8%	-1.3 to -0.6^{o}F -10.2 to -5.0%	-0.6 to +1.22^{o}F -5.4 to +11.4%	-1.1 to +1.5^{o}F -11.6 to +16.1%
Top nozzle pressure:	17.3 psig	17.3 psig	17.3 psig	17.3 psig
Wind conditions:	1/2 to 3 mph, steady	0 to 3 mph, steady	5 to 12 mph, variable	3 to 25 mph, gusty
Relative humidity:	72%	62%	53%	28%

	TEST # 9	TEST # 10	TEST # 11	TEST # 12
Time:	5:07 to 5:23 a.m.	1:12 to 1:26 p.m.	2:25 to 2:39 p.m.	3:55 to 4:25 p.m.
Wet bulb temp.:	54.7 to 55.9^{o}F	64.0 to 65.3^{o}F	63.3^{o}F	62.4^{o}F
Dry bulb temp.:	60.7^{o}F	85.5^{o}F	76.0^{o}F	82.0^{o}F
Hot water temp.:	81.3^{o}F	81.6^{o}F	81.2^{o}F	81.2^{o}F
Cold water temp.:*	70.0^{o}F	72.7 to 75.0^{o}F	69.7^{o}F nom.	70.1 to 72.1^{o}F
Cooling potential:	26.1^{o}F	16.4 to 17.7^{o}F	18.0^{o}F nom.	18.1 to 19.4^{o}F
Pred. cooling range:	13.1^{o}F nom.	8.9^{o}F nom.	9.4^{o}F nom.	9.5 to 10.1^{o}F
Test cooling range:*	11.3^{o}F nom.	6.7 to 8.9^{o}F.	11.5^{o}F nom.	9.1 to 11.1^{o}F
Cooling range:* deviation $_1$	-2.0 to -1.2^{o}F -15.4 to -9.1%	-2.2 to +0.1^{o}F -24.6 to +1.3%	+1.60^{o}F nom. +18.0% nom.	-0.9 to +1.4^{o}F -9.3 to +14.3%
Top nozzle pressure:	17.3 psig	17.3 psig	17.3 psig	17.3 psig
Wind conditions:	0 to 5 mph, steady	1 to 10 mph, gusty	5 to 20 mph, gusty	4 to 18 mph, gusty
Relative humidity:	70%	32%	49%	33%

Table 2 (Continued)

	TEST # 13	TEST # 14	TEST # 15	TEST # 16
Time:	6:44 to 7:13 a.m.	8:32 to 9:40 a.m.	11:37 to 12:51	5:49 to 6:22 a.m.
Wet bulb temp.:	48.8°F	51.6 to 54.5°F	57.6°F	45.1°F
Dry bulb temp.:	52.4°F	56.1 to 64.5°F	74.7 to 77.7°F	51.3°F
Hot water temp.:	80.1°F	79.6 to 78.0°F	79.2 to 80.5°F	78.3°F
Cold water temp.:*	66.6°F	67.3°F	66.7 to 70.8°F	64.1°F
Cooling potential:	30.0 to 32.3°F	23.6 to 27.5°F	21.1 to 23.4°F	33.2°F
Pred. cooling range:	14.4 to 15.4°F	11.6 to 13.5°F	10.7 to 11.8°F	15.5°F nom.
Test cooling range:*	12.7 to 14.9°F	10.2 to 12.7°F	9.6 to 13.8°F nom.	14.3°F nom.
Cooling range:* deviation 1	-2.1 to -0.6°F -14.0 to -3.6%	-1.4 to -0.5°F -12.1 to -3.7%	-1.7 to +2.1°F -15.0 to +17.8%	-1.6 to -0.9°F -10.3 to -6.0%
Top nozzle pressure:	17.3 psig	17.3 psig	17.3 psig	17.3 psig
Wind conditions:	1 to 8 mph, variable	1 to 7 mph, variable	3 to 20 mph, gusty	1 to 5 mph, steady
Relative humidity:	75%	63%	32%	60%

Table 2 (Continued)

	TEST # 17	TEST # 18	TEST # 19	TEST # 20
Time:	3:11 to 4:17 p.m.	9:57 to 10:56 a.m.	9:33 to 10:32 a.m.	10:14 to 3:30 p.m.
Wet bulb temp.:	57.8 to 59.6°F	57.1 to 59.1°F	57.6 to 60.8°F	52.8 to 58.4°F
Dry bulb temp.:	79.0 to 80.3°F	70.0 to 75.2°F	68.7 to 73°F	65 to 74°F
Hot water temp.:	77.7 to 76.9°F	75.7°F	73.5°F	69.4 to 66.7°F
Cold water temp.:*	67.0 to 69.2°F	66.6 to 68.0°F	67.0°F	61.2 to 64.0°F
Cooling potential:	17.4 to 19.7°F	16.2 to 18.8°F	12.1 to 16.2°F	8.8 to 16.7°F
Pred. cooling range:	8.8 to 9.9°F	8.9 to 9.4°F	6.1 to 8.1°F	4.2 to 8.3°F
Test cooling range:*	7.9 to 10.6°F	7.5 to 9.1°F	5.5 to 7.3°F	4.8 to 9.4°F
Cooling range:* deviation 1	-1.5 to +1.1°F -16.2 to +12.0%	-1.1 to +.5°F -12.1 to +6.0%	-1.2 to -0.3°F -15.7 to -4.0%	-0.9 to +1.1°F -12.4 to +24.2%
Top nozzle pressure:	17.3 psig	17.3 psig	17.3 psig	17.3 psig
Wind conditions:	1 to 12 mph, variable	1 to 10 mph, variable	0 to 4 mph, steady	1 to 14 mph, mixed
Relative humidity:	28%	45 to 38%	47%	36 to 44%

TABLE 3

Summary of Test Data Reduction

For Wind Speed and Relative Humidity Correlations

TEST	TEST TIME	NOZZLE PRESSURE PSIG	NOM. WIND SPEED MPH	NOM. REL. HUM. %	THOT ^{o}F	TWB ^{o}F	CP ^{o}F	TCOLD* AVG. ^{o}F	CR* TEST ^{o}F	CR PRED. ^{o}F	DEVIATION* CR - ^{o}F	DEVIATION* % of CR Pred.
1	Overall	15.5	2	63	77.7	55.4	22.3	68.2	9.5	11.1	-1.6	-14.2
2	Overall	15.5	4	62	77.2	58.1	19.1	69.0	8.2	9.6	-1.4	-14.9
3	Ave. of 2	14.5	8-1/2	63	80.1	60.1	20.0	70.8	9.4	10.3	-0.9	- 9.1
4	Overall	14.5	5-1/2	76	80.8	57.6	23.2	71.2	9.7	11.8	-2.1	-18.1
5	Overall	17.3	1-1/2	72	79.7	50.8	28.8	67.0	12.7	14.0	-1.3	- 9.4
6	Overall	17.3	1-1/2	62	78.8	53.2	25.6	67.2	11.7	12.6	-1.0	- 7.5
7	Avg. - 6 min.	17.3	7	55	80.5	59.3	21.3	70.1	10.4	10.9	-0.5	- 4.3
7	Avg. - 5 min.	17.3	8-1/2	53	80.5	59.4	21.1	69.7	10.8	10.8	+0.04	+ 0.4
7	Avg. - 4 min.	17.3	10	53	80.4	59.5	20.9	69.1	11.3	10.7	+0.6	+ 5.9
7	Avg. - 3 min.	17.3	11	53	80.3	58.3	21.1	68.5	11.9	10.8	+1.1	+10.1
8	Avg. of 3	17.3	5	29	80.7	63.4	17.3	72.2	8.5	9.1	-0.6	- 6.5
8	Avg. of 4	17.3	12	28	80.8	63.3	17.5	70.8	10.0	9.2	+0.8	+ 8.6
9	Avg. - 10 min.	17.3	1	70	81.3	55.1	26.3	70.1	11.2	13.1	-1.9	-14.4
11	Avg. of 3	17.3	15	49	81.2	63.4	17.8	70.2	11.1	9.4	+1.7	+18.0
12	Avg. of 2	17.3	5	33	81.2	62.3	18.9	71.6	9.6	9.9	-0.3	- 2.4
12	Avg. of 2	17.3	8	33	81.2	62.1	19.2	70.7	10.5	10.0	+0.5	+ 5.0
12	4:14:08	17.3	11	34	81.2	62.5	18.7	70.7	10.5	9.8	+0.7	+ 7.4
13	Avg. - 14 min.	17.3	3	75	79.9	48.9	31.0	66.7	13.2	14.9	-1.7	-11.6
14	Overall	17.3	4	63	79.0	53.1	25.9	67.3	11.7	12.7	-1.0	- 8.2
15	Avg. of 2	17.3	5	32	80.5	57.6	22.9	69.8	10.7	11.6	-1.0	- 8.2

Table 3 (contd.)

Summary of Test Data Reduction

For Wind Speed and Relative Humidity Correlations

TEST	TEST TIME	NOZZLE PRESSURE PSIG	NOM. WIND SPEED MPH	NOM. REL. HUM. %	THOT °F	TWB °F	CP °F	TCOLD* AVG. °F	CR* TEST °F	CR PRED. °F	DEVIATION* CR - °F	DEVIATION* % of CR Pred.
16	Overall	17.3	4	60	78.3	45.1	33.2	64.1	14.3	15.5	-1.3	- 8.2
17	Avg. of 5	17.3	5	28	77.5	59.0	18.5	68.5	9.0	9.4	-0.4	- 3.9
18	Avg. - 8 min.	17.3	3-1/2	45	75.9	57.7	18.3	67.7	8.2	9.2	-1.0	-10.5
18	Avg. - 4 min.	17.3	4-1/2	39	75.6	58.6	17.0	67.6	8.1	8.6	-0.5	- 5.7
18	Avg. of 2	17.3	7	38	75.5	58.9	16.6	67.1	8.4	8.4	-0.01	- 0.2
19	Overall	17.3	2	47	73.5	59.1	14.4	67.0	6.5	7.2	-0.07	-10.2
20	Avg. of 18	17.3	4	42	68.5	54.9	13.5	62.4	6.1	6.5	-0.4	- 5.7

THOT - Spray hot water temperature - °F
TWB - Wet bulb temperature - °F
CP - Cooling Potential - °F
TCOLD AVG. - Avg. of highest temperature of each group of three spray cold water temperatures - °F
CR - Cooling Range - °F
DEVIATION - Differential between test cooling range and pred. cooling range

*Adjusted for average calibration error of -0.56°F on cold water temperature measurements.

TABLE 4

WNP-2

ULTIMATE HEAT SINK SPRAY SYSTEM

SUMMARY OF DRIFT LOSS TEST DATA

- Pond Level Change Method -

Test #	Test Duration Min.	Spray Flow GPM	Ave.* Cooling Range °F	Ave. THOT °F	Ave. Pond Surface Temp. °F	Ave. Wet Bulb Temp. °F	Ave. Dry Bulb Temp. °F	Ave. Dew Point Temp. °F	Ave. Wind Speed MPH	Pond Level Change Inches
14	68	10,300	11.7	79.0	79.0	53.1	60.2	47.5	4	.2903
15	74	10,300	11.7	80.3	80.1	57.6	75.8	44.6	9	.4631
17	66	10,300	9.0	77.3	77.2	59.0	79.0	44.0	5	.243
18	59	10,300	8.3	75.7	75.5	58.3	72.2	47.8	5	.148
19	59	10,300	6.5	73.5	73.2	59.1	71.2	49.5	2	.202
20	212**	10,300	6.1	68.2	68.7	55.4	67.2	41.7	6	.880

* This data was adjusted for calibration error of -0.56°F on cold water temperature data.
** Portion of test duration used for drift loss analysis.

TABLE 5

WNP-2

ULTIMATE HEAT SINK SPRAY SYSTEM

SUMMARY OF DRIFT LOSS ANALYSIS

- Pond Level Change Method -

Test	Pond Water Loss Rate GPM	Water Loss Rate Due to Spray Evaporation GPM	Water Loss Rate Due to Surface Evaporation GPM	Spray Drift Loss GPM	Spray Drift Loss %	Average Wind Speed MPH
14	166.3	114.2	3.8	48.3	0.47	4
15	243.8	114.7	6.6	122.5	1.19	9
17	143.5	88.1	4.0	51.3	0.50	5
18	97.7	80.8	3.4	13.5	0.18	5
19	133.4	63.1	2.4	67.9	0.66	2
20	161.7	59.5	2.9	99.3	0.96	6

WNP-2

Ultimate Heat Sink

Simplified Schematic of Standby Service

Water and Spray Systems

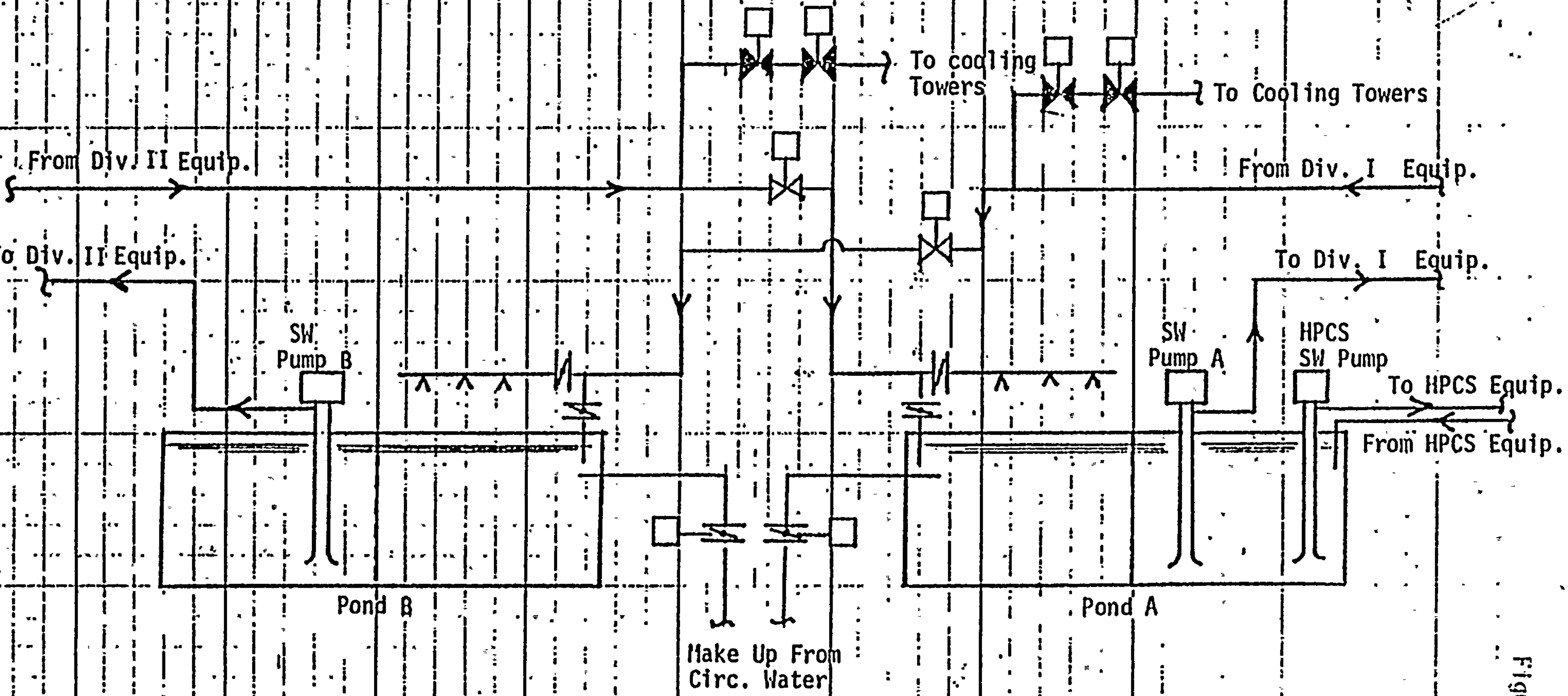
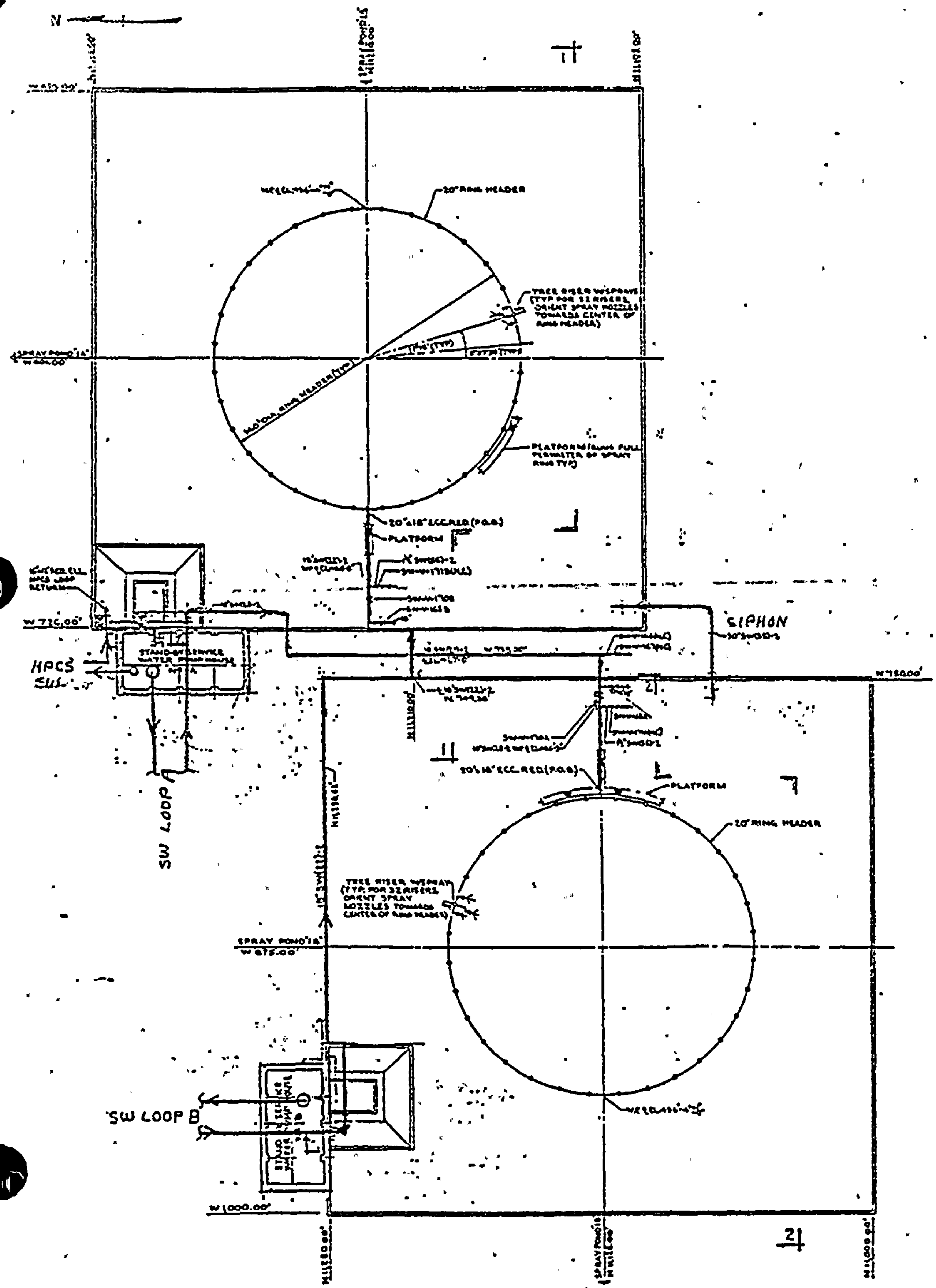


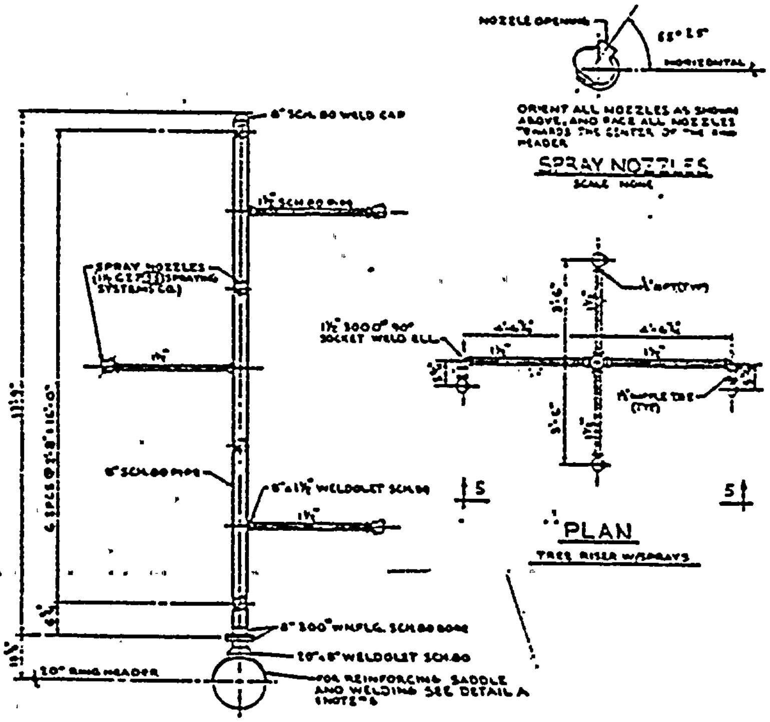
Figure 1

Figure 2
Sheet 1

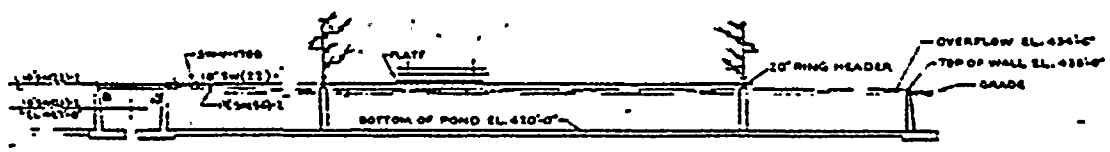
Ultimate Heat Sink
Spray Piping Arrangements



Ultimate Heat Sink
Spray Piping Arrangements



SECTION 5-5



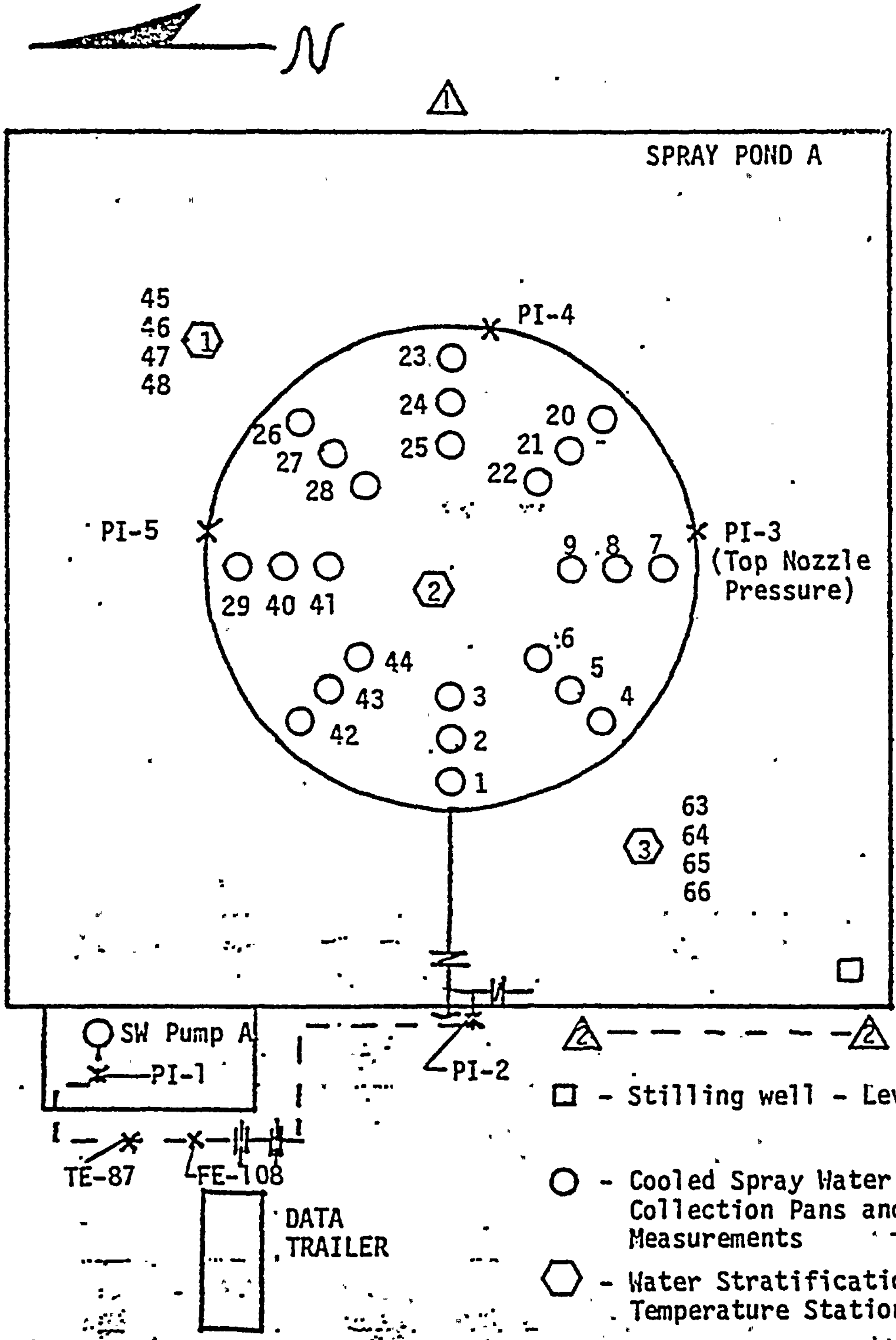
SECTION 1-1

Figure

WNP-2

GENERAL ARRANGEMENT

UHS TEST PROGRAM



- Stilling well - Level Measurement

- Cooled Spray Water Collection Pans and Temperature Measurements

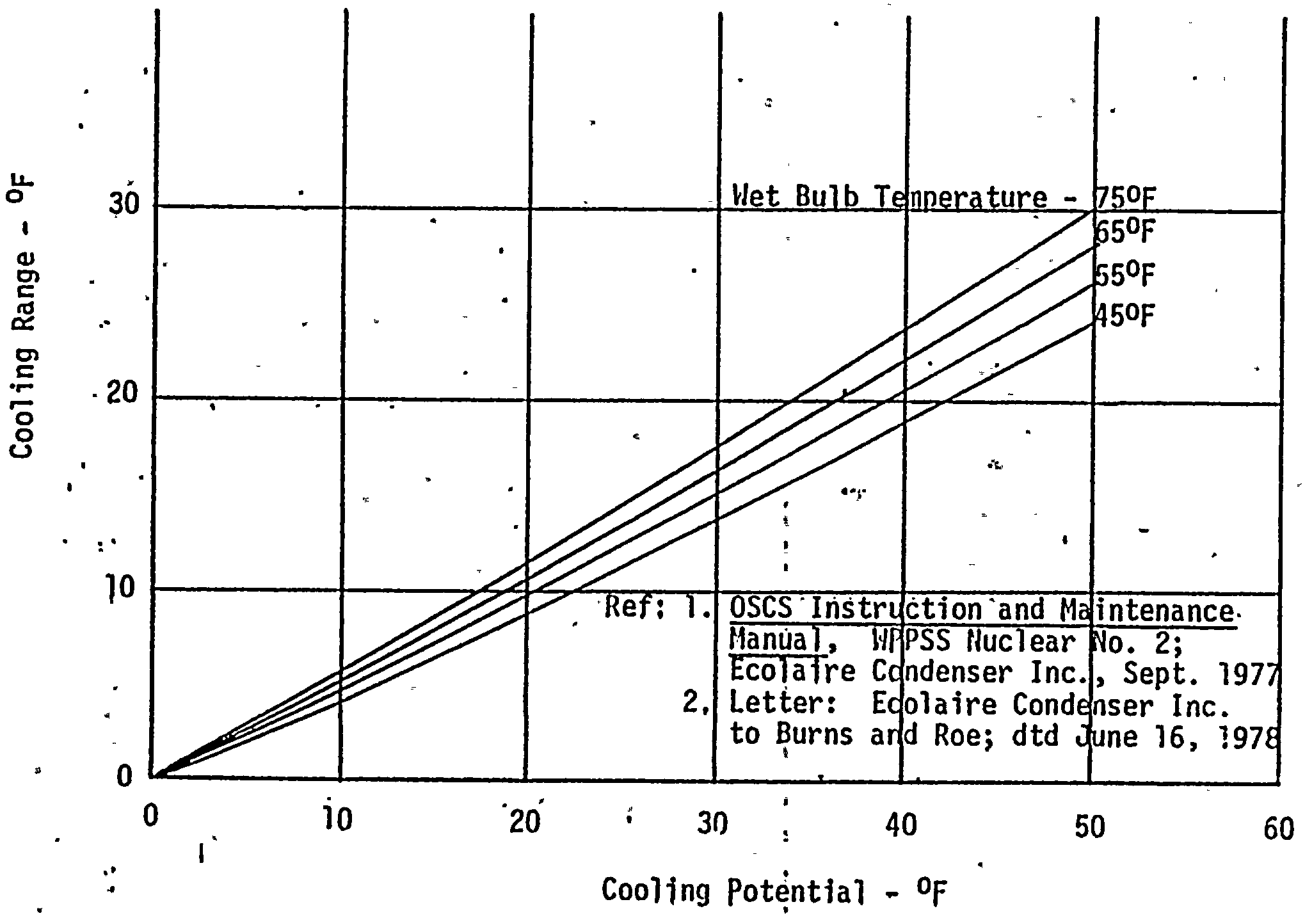
- Water Stratification Temperature Stations

- Meteorology Stations

- Temporary Piping

WNP-2

Ultimate Heat Sink Spray System
Predicted Spray Performance



WNP-2

Ultimate Heat Sink Spray System

Typical Cold Water Temperature Measurement Profiles

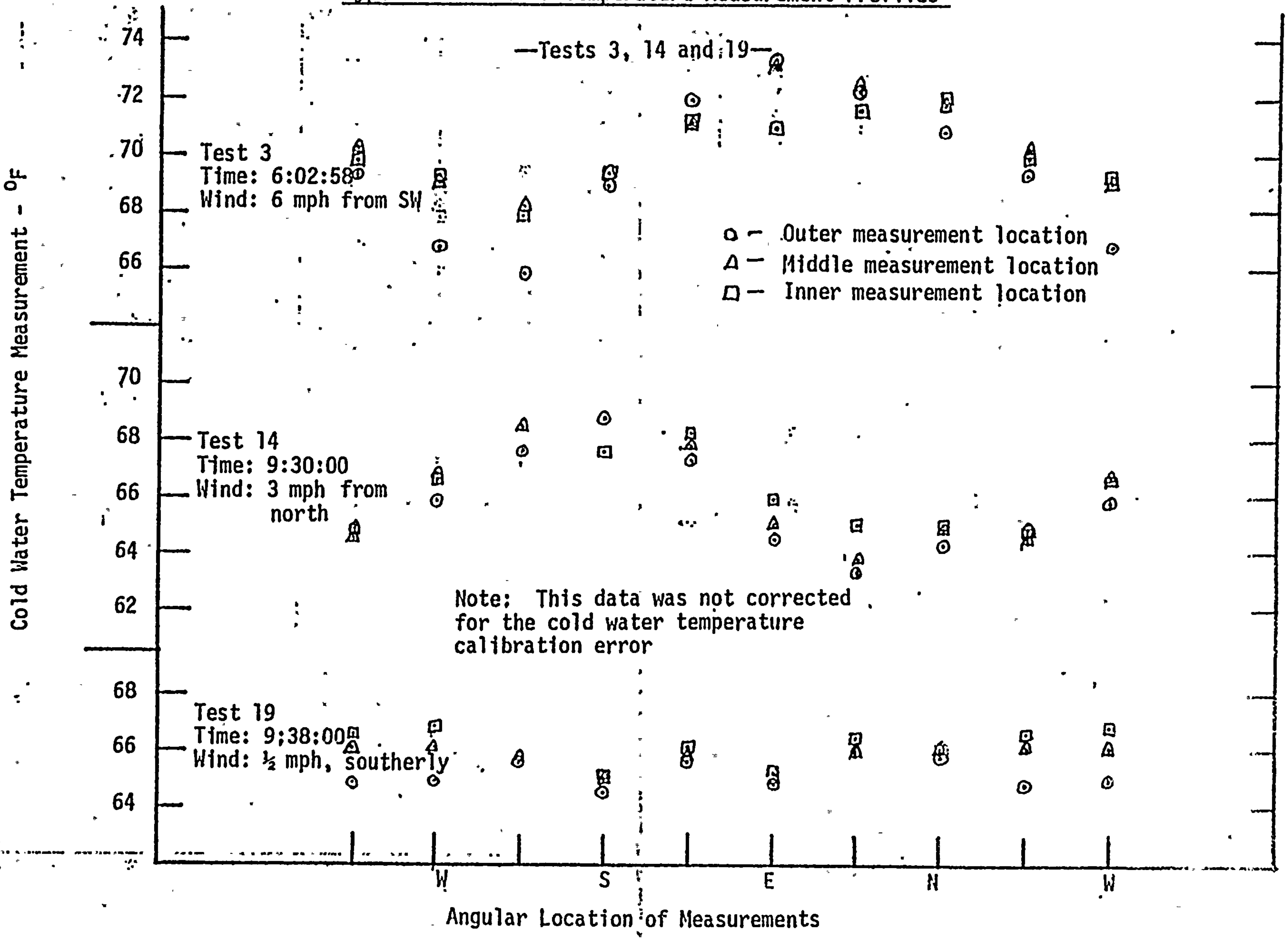
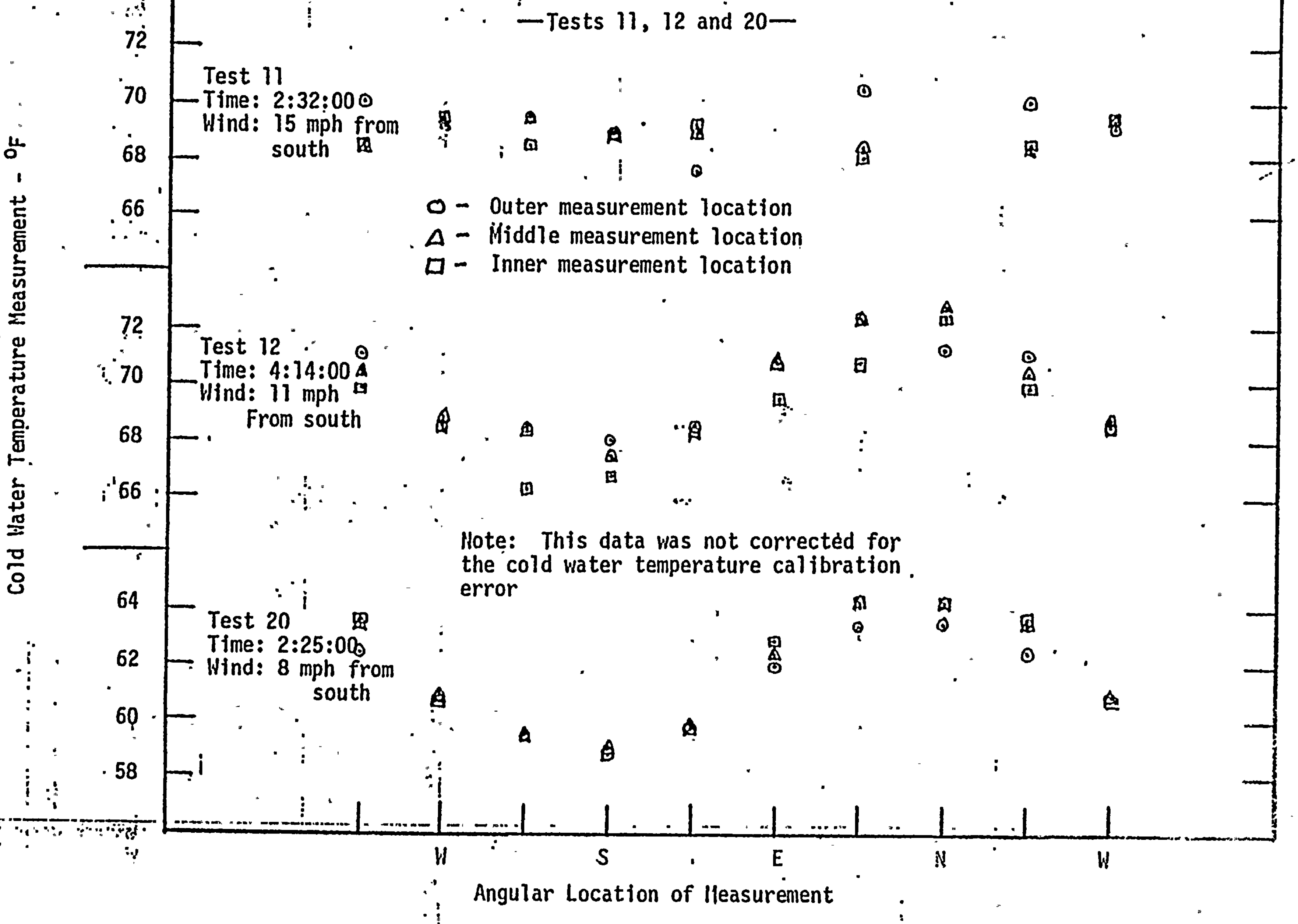


Figure 5

Ultimate Heat Sink Spray System

Typical Cold Water Temperature Measurement Profiles



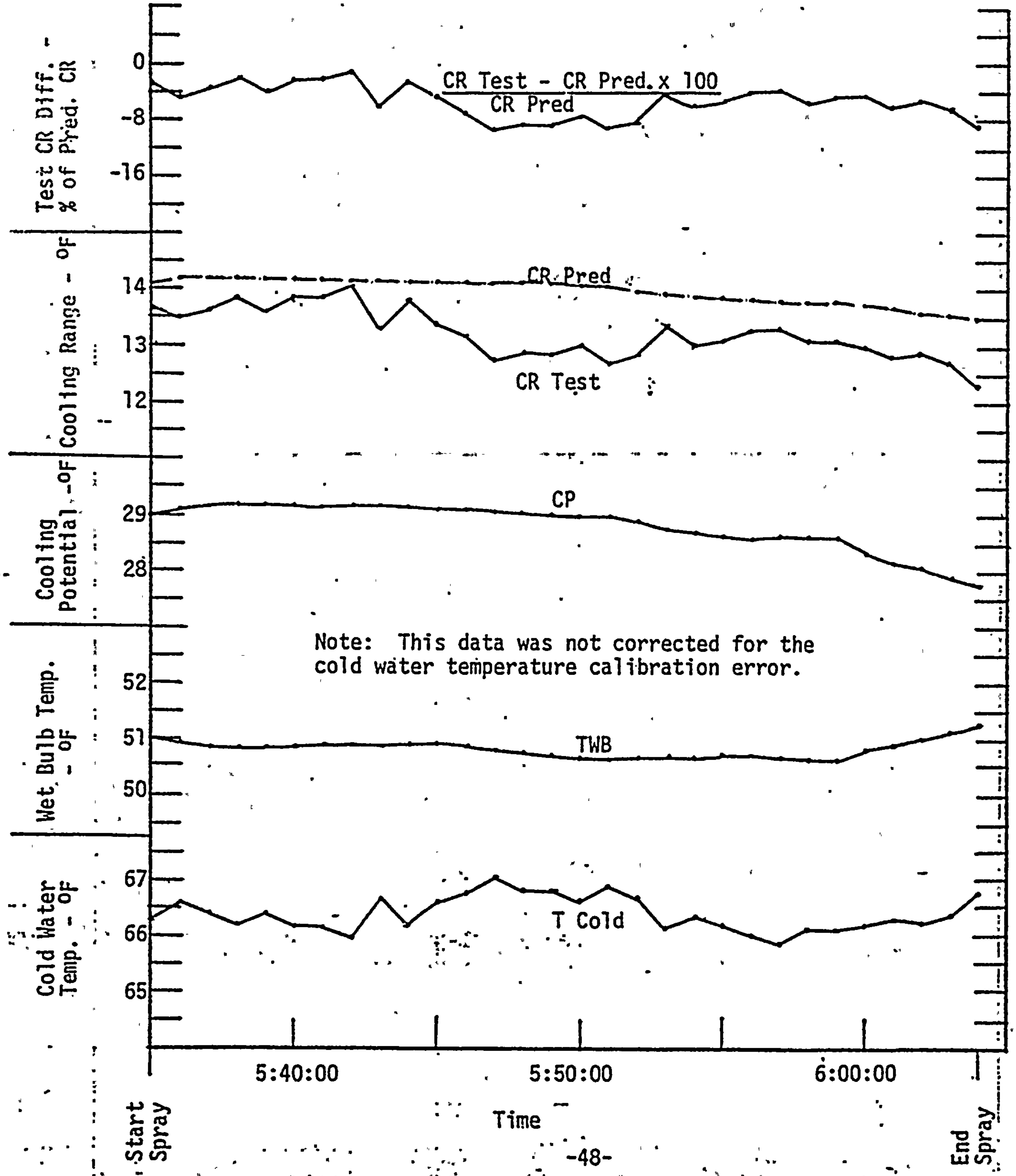
WNP-2

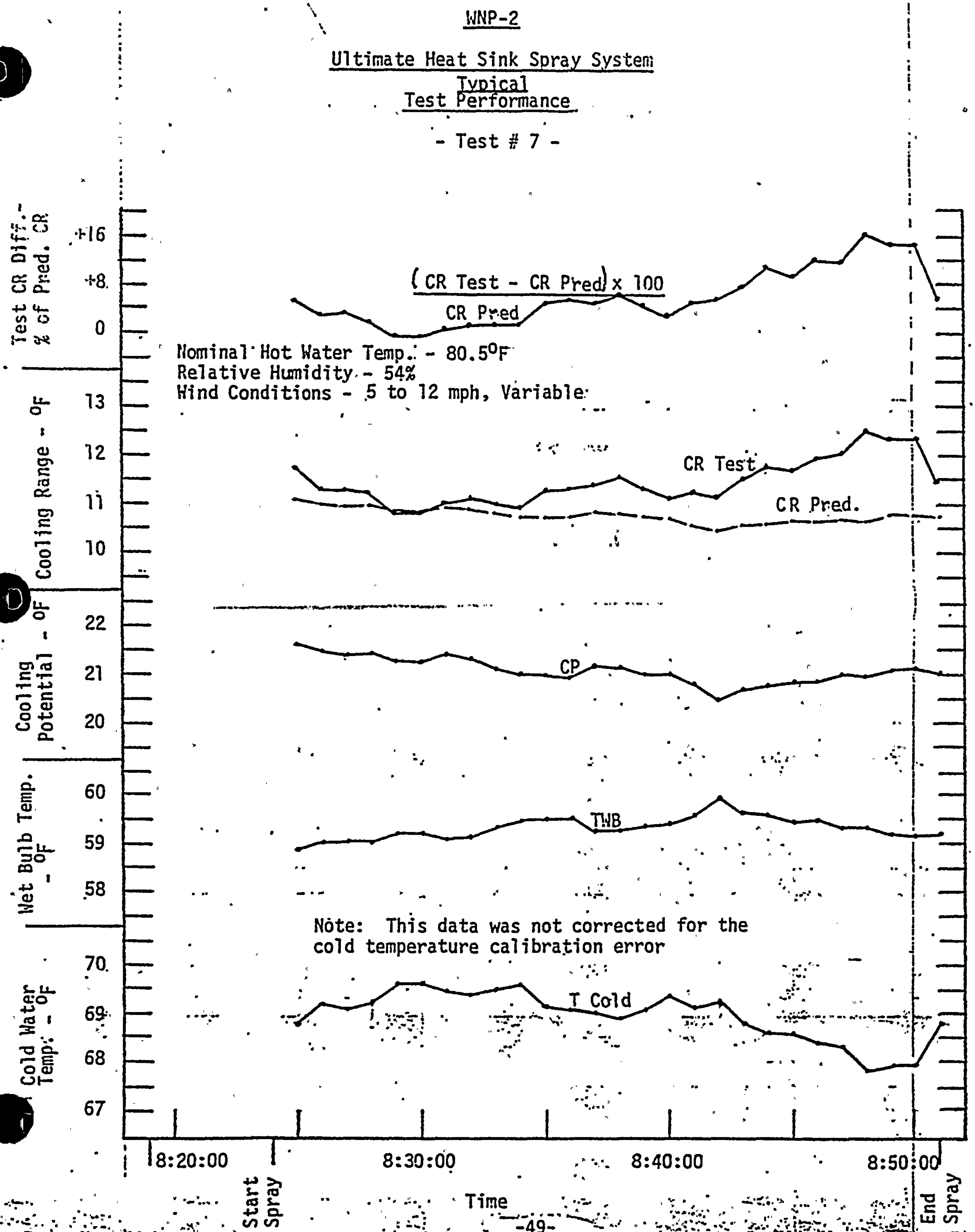
Ultimate Heat Sink Spray System

Typical Test Performance

- Test # 5 -

Normal Hot Water Temp. - 79.5°F
Relative Humidity - 72%
Wind Conditions - ½ to 3 mph, Steady




WNP-2
Ultimate Heat Sink Spray System
Typical
Test Performance
- Test # 7 -
Test CR Diff.- % of Pred. CR
+16
+8
0
(CR Test - CR Pred) x 100
CR Pred
Nominal Hot Water Temp. - 80.5°F
Relative Humidity - 54%
Wind Conditions - 5 to 12 mph, Variable
Cooling Range - °F
13
12
11
10
CR Test
CR Pred.
Cooling Potential - °F
22
21
20
CP
Wet Bulb Temp. - °F
60
59
58
TWB
Note: This data was not corrected for the cold temperature calibration error
Cold Water Temp. - °F
70
69
68
67
T Cold
8:20:00
8:30:00
8:40:00
8:50:00
Start Spray
End Spray
Time

[illegible]

WNP-2
Ultimate Heat Sink Spray System
Correlation of Test Performance
With Wind Speed

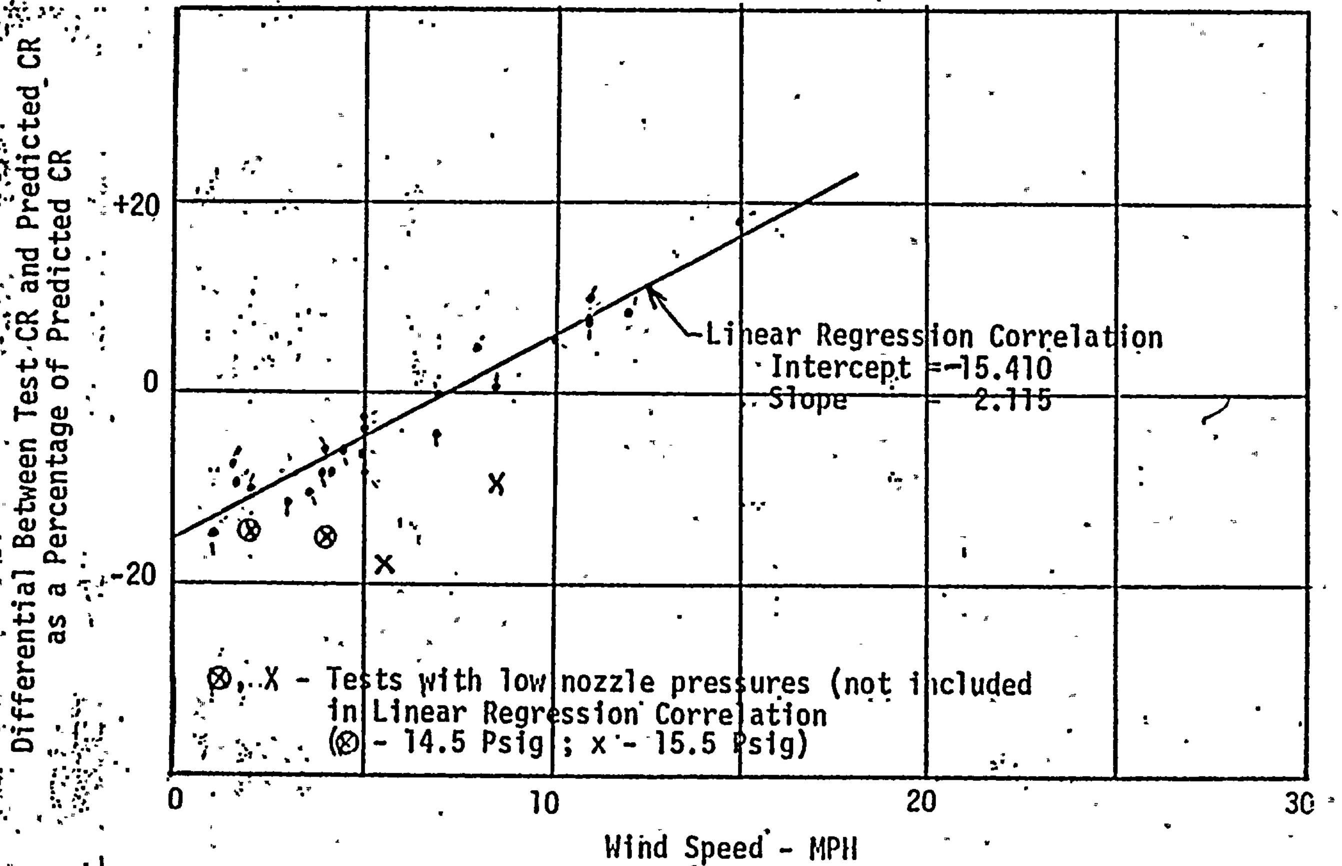


FIGURE 9

WNP-2
Ultimate Heat Sink Spray System
Correlation of Test Performance
With Relative Humidity

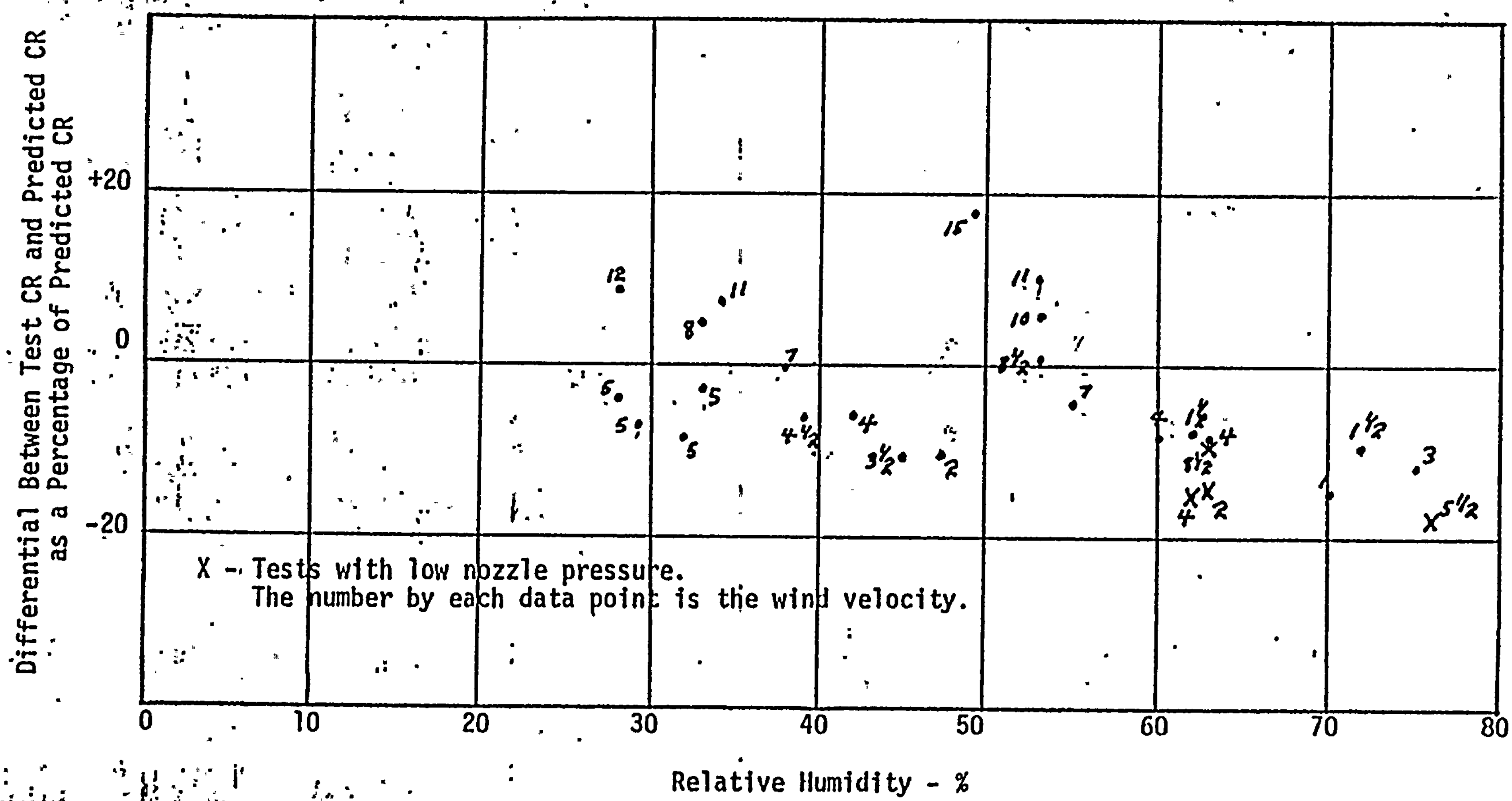


FIGURE 10

WNP-2

ULTIMATE HEAT SINK SPRAY SYSTEM

DRIFT LOSS