50-[illegible]

ENVIRONMENTAL MONITORING DATA

Received w/Ltr Dated ____________

7912160009 A

2.6 SEISMOLOGY

No active or recent faulting has been recognized in the area of the proposed site. The closest known fault is the Brevard Zone, approximately 11 miles northwest of the site.

The Reactor Buildings' foundations are located on rock which has excellent strength properties and relatively small amplification of ground motion resulting from an earthquake.

The structural design criteria for the maximum hypothetical earthquake are 0.10g and 0.15g for Class 1 structures founded on bedrock and overburden, respectively. The structural design criteria for the design earthquake is 0.05g.

A detailed Seismology Study is included as a part of Appendix 2B in the PSAR. Additional information on seismology is included in Answers to Questions 2.7 and 8.5 of PSAR Supplement 1 and Question 11.3 of PSAR Supplement 4.

2.7 OCONEE ENVIRONMENTAL RADIOACTIVITY MONITORING PROGRAM

2.7.1 INTRODUCTION

The purpose of the environmental radioactivity monitoring program is to measure and evaluate the significance of contributions to the existing environmental radioactivity levels from plant operations.

The program is divided into pre-operational and operational phases, with the assumption that pre-operational levels may provide a base line to which operational levels can be compared. Such comparisons are complicated by additional nuclear weapons testing, seasonal and annual variations in fallout level, and discharges of radioactive material from other installations. However, pre-operational monitoring does document the existing radioactivity levels and their variability. Also the use of control locations well out of the influence of the plant can serve as a means of comparison for evaluating the plant's contribution to the environment during the operational phase.

During the operation of a nuclear power plant, the only contribution of radioactive materials to the environment will be due to the release of low level radioactive wastes; that is, from controlled releases of radioactive gases, airborne particulates, and liquid wastes. This activity, if it can be detected at all, is most likely to be found in the air and water beyond the plant where these materials are dispersed and diluted by stream flow and wind. Air and water are therefore considered as primary samples. They serve as one of the earliest indicators of change in environmental radioactivity levels. Samples of secondary significance, in this regard, include river bottom and lake sediment, vegetation, fish and animals, and milk.

2.7.2 THE PRE-OPERATIONAL PROGRAM

Table 2.1 describes the pre-operational environmental radioactivity monitoring program for the Oconee Nuclear Station. It lists the type samples, sampling locations, and the collection frequency. In general, the samples are counted for gross alpha and gross beta radioactivity. Gamma spectral analyses are also performed to identify the radionuclides involved. Specific analyses such as for tritium in water, cesium-137 and strontium-90 in milk, water, fish, and animal samples are also performed. The measurement of gamma dose and dose rate is considered as an appropriate sample to determine the radiation background of an area as well as to measure the effects of gaseous activity released during the operating period. Thermoluminescent dosimeters, environmental film badges, and beta-gamma survey instruments (geiger counters) are used for this measurement.

Criteria for the selection of the various sampling locations were as follows:

1. Water	For comparison purposes water samples are collected: (a) Upstream (b) Near liquid effluent release point (c) Downstream of Site and Exclusion Area Particular emphasis has also been given to water sampling to evaluate the effect of the filling of Lake Keowee.
2. Airborne Particulates, Rain and Settled Dust	Comparison of on-site vs. off-site locations near towns and populated areas; consideration given to prevailing wind direction.
3. Radiation Dose and Dose Rate	Comparison of on-site vs. off-site locations near towns and populated areas; consideration given to prevailing wind direction.
4. Silt (River and lake bottom sediment; filtered solids from municipal drinking water supplies)	For comparison purposes, silt samples are collected: (a) Upstream (b) Near liquid effluent release point (c) Downstream of Site and Exclusion Area
5. Terrestrial Vegetation	Comparison of on-site vs. off-site locations; consideration given to prevailing wind direction.
6. Aquatic Vegetation, Algae and Plankton	For comparison purposes, samples are collected: (a) Upstream, from Lake Keowee (b) Downstream, from Hartwell Reservoir

7. Milk — From local area dairies within 10 miles of site.

8. Fish and Animals — Samples are collected in accordance with the recommendations of, and in cooperation with, the S. C. Wildlife Resources Commission from:

(a) Lake Keowee
(b) Exclusion Area
(c) Hartwell Reservoir

9. Miscellaneous — Investigation of special situations made to provide program flexibility and extended coverage; such as may be required due to nuclear weapons testing or unusual fallout conditions. Includes study of Lake Keowee tributary streams and modification as lake fills. Investigation of reported deposits of uranium or thorium in area of plant.

The sampling stations were established in the Oconee environs at the end of 1968, and a laboratory for the analysis and counting of the samples was also established at that time. The laboratory equipment includes a low background gas flow porportional counter for measuring gross alpha and gross beta radioactivity and a 400 channel gamma scintillation spectrometer (multi-channel analyzer). In addition, some samples are sent to commercial laboratories for analysis.

The full scale environmental sampling program was begun in January, 1969. Thus, two years of pre-operational monitoring data will be obtained prior to the operation of Unit 1. Water samples from the Keowee and Little Rivers which flow by the site and well water from private residences in the area have been collected, analyzed, and counted since late 1966. The results of this early sampling as well as the results for the first quarter, 1969, are shown in Table 2-2.

The pre-operational environmental radioactivity program for Oconee has been discussed with the South Carolina State Board of Health, Division of Radiological Health, and the South Carolina Pollution Control Authority. The U. S. Government Fish and Wildlife Service has also been advised of the program through their district office in Atlanta, Georgia. In addition, the program was discussed with the South Carolina Wildlife Resources Department. This latter department is cooperating with Duke Power Company in regard to the collection of fish and animal samples. They have made recommendations as to what specimens should be collected and are supplying fish samples from the Hartwell Reservoir and Lake Keowee. They have also issued a special research permit to Duke Power Company for the collection of animal samples.

The results of the environmental radioactivity monitoring program to date are comparable to those reported from throughout the country by the U. S. Department of Health, Education, and Welfare (Public Health Service) in their "Radiological Health Data and Reports," for the same period. It is of interest also to note that radium daughter products have been observed, as a result of gamma analysis, to exist in considerable amounts in deep well water. Further investigation has shown that this condition seems to be peculiar to the Piedmont area of the Carolinas.

2.7.3 THE OPERATIONAL PROGRAM

The environmental radioactivity monitoring program will continue during the operating period. However, the operational program will be modified as indicated by experience, particularly by the kinds and quantities of radioactive liquid and gaseous wastes released, as well as by environmental monitoring results. Prior to initial operation, the existing sampling station within the Exclusion Area will be supplemented by others in locations where the highest ground level concentrations of radioactivity from station vent releases are expected to exist, based on site meteorological studies. Thermoluminescent dosimeters will be used to measure radiation dose at the station fence and at significant locations throughout the Exclusion Area.

Various authorities, including the Federal Radiation Council, state that the extent of surveillance activities should vary in accordance with environmental radioactivity levels. Therefore, additional monitoring stations will be established, both on-site and off-site, or the frequency of collection of existing samples will be increased, if the quantitites of radioactive waste effluents approach significant fractions of the average annual limits. Also, existing sampling locations may be supplemented with continuous airborne particulate and iodine samplers or continuous water samplers if such sampling is indicated by waste releases. The extent of sampling may be decreased if warranted.

2.7.4 CONCLUSION

The environmental radioactivity monitoring program for the Oconee Nuclear Station is conducted by the station Health Physics Supervisor who is assisted by the station Chemist. The program is directed and reviewed by the Duke Power Company Staff Health Physicist.

Environmental monitoring results will be correlated with information on station radioactive waste releases, site meteorological data, and radiological controls and with information obtained from the installed process radiation monitoring system. Results will also be compared with published information from the national radiological surveillance programs reported by the U. S. Public Health Service and with environmental monitoring reports of other nuclear installations in the area.

Results of the Oconee Environmental Radioactivity Monitoring Program will be made available to the State of South Carolina and to the Federal agencies mentioned above who have a direct interest and concern in these matters.

It is expected that the results of the Environmental Radioactivity Monitoring Program for the Oconee Nuclear Station will demonstrate the effectiveness of plant control over radioactive waste disposal operations and of compliance with Federal and State regulations for the disposal of these materials.

Table 2-1

OCONEE PRE-OPERATIONAL ENVIRONMENTAL
RADIOACTIVITY MONITORING PROGRAM

CODE	
Monthly - M	Frequency
Quarterly - Q	
Annually - A	
Type of Sample - (A) thru (M)	

Code No.	Location	(A) H_2O Well - Residence	(B) H_2O Finished - Water Supply	(C) H_2O Raw - Water Supply	(D) H_2O Surface - River, Lakes	(E) Rain, Settled Dust - Fallout	(F) Air - Particulate	(G) Vegetation - Terrestrial	(H) Vegetation - Aquatic	(I) Bottom Sediment Water Supply & Lakes	(J) Radiation Dose & Rate TLD & Film, Instrument	(K) Animals (3) 1 Mile Radius	(L) Fish (3) Lakes	(M) Milk - Local Daries
000	Site: Visitors Center					M	M	Q			Q			
000.3	1st Bridge North of Site on New 183 Connecting Canal				M+A				Q	Q				
000.4	2nd Bridge North of Site on New 183				M									
000.5	1 Mile Radius of Site - Specify N, S, E, W											Q		
000.6	Keowee Lake												Q	
000.7	@ Bridge on 183 Existing				M					Q				
000.8	Residence within Exclusion Area	Q												
000.9														
000.10														
001	Salem: Vol. Fire Dept. Lot										Q			
001.3	4.5 Mi. N.E. of Salem on Hwy. 11 @ Bridge (Cedar Creek)				A									
001.4	8.0 Mi. E. of Salem @ Bridge (Crow Creek)				A									
001.5														
001.6														
002	Walhalla: Branch Rd. Sub Station					M					Q			
002.1	7.5 Miles West of Site on Hwy. 183													Q
002.2														
003	Keowee: High School Hwy. 16 (Opposite Side)										Q			
003.1														
003.2														
004	Seneca: Oconee Memorial Hospital										Q			
004.1	Water Supply, Lake Keowee Intake, (When Completed)		M	M						Q				
004.2														
005	Newry: Abandoned High School on S. C. 130							Q			Q			
005.1	Spill Dam (L.R. & Keowee Spill)				M					Q				
005.3	Hwy. 27 at Bridge				M					Q				
005.4	3.75 Mi. W. of Newry on Keowee Hwy. @ Bridge (Cain Creek)				A									
005.5	3.25 Mi. N.W. of Newry on Keowee Hwy. @ Bridge (Crooked Creek)				A									
005.6														
005.7														
006	Clemson: Meteorology Plot					M	M	Q			Q			
006.1	Water Supply		M	M										
006.2	Intake Hartwell Reservoir K-3				M+A				Q	Q				
006.3														
006.4														
006.5														
007	Central, S. C.: Joint Sub Station Hwy. 93										Q			
007.1														
007.2														
008	Liberty, S. C.: Branch Office Yard										Q			
008.1														
008.2														

POOR ORIGINAL

(Cont'd)

Table 2-1

OCONEE PRE-OPERATIONAL ENVIRONMENTAL RADIOACTIVITY MONITORING PROGRAM

CODE	
Monthly - M	Frequency
Quarterly - Q	
Annually - A	
Type of Sample - (A) thru (M)	

Code No.	Location	H_2O Well - Residence (A)	H_2O Finished - Water Supply (B)	H_2O Raw - Water Supply (C)	H_2O Surface - River, Lakes (D)	Rain, Settled Dust - Fallout (E)	Air - Particulate (F)	Vegetation - Terrestrial (G)	Vegetation - Aquatic (H)	Bottom Sediment Water Supply & Lakes (I)	Radiation Dose & Rate TLD, Film, Instrument (J)	Animals (3) 1 Mile Radius (K)	Fish (3) Lakes (L)	Milk - Local Dairies (M)
009	Six Mile, S. C.: Microwave Tower Hwy. 137										Q			
009.1														
009.2														
010	Pickens, S. C.: Branch Office Yard					M					Q			
010.1														
010.2														
011	Floating Station: Subject to Change with Conditions										Q			
011.1														
011.2														
012	Anderson, S. C.: Water Supply		M	M						Q				
012.1														
012.2														
013	Hartwell Reservoir: 5.8 Mi. South of Keowee Dam												Q	
013.1														
013.2														

Note:
1. 000.3 and 006.2 will be sent to outside services for analysis for ^{3}H and ^{90}Sr (2 gals. each location).
2. Fish speciments will be collected alternately from Lake Keowee and Hartwell.
3. 001.3, 001.4, 005.4, and 005.5 will be collected once per year during rainy season.

Note: Location numbers that appear in Table 2-2 which are not shown above are results of special investigations at the general location indicated.

POOR ORIGINAL

TABLE 2-2
SUMMARY OF PRE-OPERATIONAL MONITORING RESULTS

1.	Water	Suspended Solids pCi/l alpha	Suspended Solids pCi/l beta	Dissolved Solids pCi/l alpha	Dissolved Solids pCi/l beta	Total Activity pCi/l alpha	Total Activity pCi/l beta		Tritium pCi/l
A.	Rivers								($< 2.7 \times 10^{-3}$ = N.D)
1967	Keowee River At Site	N.D. - 4.73	1.16 - 24.09	N.D. - 2.17	N.D. - 7.67	N.D. - 5.03	5.58 - 25.57	range	
		2.02	8.21	0.75	3.20	2.78	11.41	average	$< 2.7 \times 10^{-3}$
1967	Little River At Newry, S.C.	N.D. - 3.19	N.D. - 6.80	N.D. - 5.36	4.59 - 16.73	0.34 - 6.74	6.11 - 20.18	range	
		1.03	2.52	1.85	10.17	2.88	12.68	average	$< 2.7 \times 10^{-3}$
1968	Keowee River At Site	N.D. - 5.42	N.D. - 9.36	0.96 - 21.70	8.00 - 38.20	1.45 - 23.78	11.19 - 43.57	range	
		1.31	4.52	5.75	17.75	7.04	23.33	average	$< 2.7 \times 10^{-3}$
1968	Little River At Newry, S.C.	N.D. - 2.17	N.D. - 12.07	0.28 - 3.29	6.25 - 30.14	0.28 - 8.68	7.28 - 31.81	range	
		0.82	5.22	2.30	13.30	3.82	19.70	average	$< 2.7 \times 10^{-3}$

B. Open and Deep Wells at Residences On-Site and in Surrounding Area

Designation	Year	Total Activity alpha	Total Activity beta		Tritium
On-Site (3 locations, from residences then existing)	1966	3.30 - 5.92	11.86 - 28.58	range	
		4.16	17.74	average	
Surrounding Area (3 locations, from residences still existing)	1966	2.17 - 4.96	10.26 - 25.70	range	
		3.72	16.20	average	
On-Site 1	1967	N.D. - 11.94	2.69 - 26.97	range	
		4.57	16.17	average	$< 2.7 \times 10^{-3}$
On-Site 1	1968	N.D. - 33.64	9.85 - 62.46	range	
		7.82	25.00	average	
On-Site 2	1967	N.D. - 7.60	1.36 - 19.96	range	
		2.70	10.40	average	$< 2.7 \times 10^{-3}$
On-Site 2	1968	N.D. - 4.91	10.17 - 34.78	range	
		3.00	20.00	average	

Note: 1. Above measurements at 90% confidence level, based on natural uranium alpha and "apparent Cesium-137 beta activity," calibration standards.
2. N. D. = non-detectable

TABLE 2-2 (Continued)
SUMMARY OF PRE-OPERATIONAL MONITORING RESULTS
Averages For First Quarter 1969

1. Water	Suspended Solids pCi/l		Dissolved Solids pCi/l		Total Activity pCi/l		Gamma Analysis Results
	alpha	beta	alpha	beta	alpha	beta	
Residences							
000.1	-	-		-	N.D.	3.55	Indications of Radium daughter products
000.2	-	-		-	N.D.	2.86	
Municipal Water Supplies							
006.1 Clemson-Pendleton							
raw water	0.12 (2)	0.64 (2)	0.08 (2)	3.80 (2)	0.16 (3)	4.78 (3)	background
finished water	-	-	-	-	N.D.	2.62	
012 Anderson							
raw water	0.08 (2)	0.49 (2)	N.D. (2)	4.04 (2)	0.05 (3)	4.30 (3)	background
finished water	-	-	-	-	N.D.	3.44	
Rivers and Lakes							
000.3 Site	0.11	0.83 (2)	0.08	3.20 (2)	0.13	3.56 (3)	background
001.1 Salem	0.07	0.30 (1)	0.08	1.98 (1)	0.21	4.96 (2)	background
001.2	0.15	N.D. (1)	0.08	1.90 (1)	0.29	2.63 (2)	background
005.1 Newry	0.52	2.59 (2)	0.17	2.89 (2)	0.81	6.87 (3)	background
005.2	0.16	0.98 (1)	0.08	1.90 (1)	0.64	4.93 (2)	background
005.3	0.20	0.56 (2)	0.08	3.10 (2)	0.29	3.81 (3)	background
006.2 Clemson	0.24	0.45 (2)	0.21	2.75 (2)	0.44	4.19 (3)	background

2. Rain and Settled Dust	Total Activity $\mu Ci/m^2$ alpha	Total Activity $\mu Ci/m^2$ beta	Gamma Analysis Results
002 Walhalla	0.02	5.81	Indications of fission products, possibly Ce^{144} - Pr^{144}
010 Pickens	0.03	6.73	

3. Terrestrial Vegetation	pCi/g alpha	pCi/g beta	Gamma Analysis Results
000 Site	2.38	558.6	Appears to be K^{40}
005 Newry	N.D.	1006.5	
006 Clemson	3.06	647.2	

TABLE 2-2 (Continued)
SUMMARY OF PRE-OPERATIONAL MONITORING RESULTS
Averages for First Quarter 1969

	Total Activity pCi/g alpha	Total Activity pCi/g beta	Gamma Analysis Results
4. Plankton			
005.3 Newry	3.70	22.86	Appears to be K^{40}
006.2 Clemson	9.27	38.33	
5. Bottom Sediment			
000.3 Site	0.34	0.64	
001.1 Salem	0.46	1.90	
005.1 Newry	0.23	0.91	
005.3	1.36	7.12	
006.1 Clemson	1.04	3.88	
012 Anderson	0.61	2.49	

6. Radiation Dose & Dose Rate

000 Site
001 Salem
002 Walhalla
003 Keowee (High School)
004 Seneca (Mem. Hosp.)
005 Newry
006 Clemson
007 Central
008 Liberty
010 Pickens
011 Lake Jocassee Area

Initial data indicates a gamma dose rate of 0.01 mR/h and a dose of approximately 21mRem/90 days for all locations, measured at three feet above the ground.

7. Animals

		pCi/g
000 Site (Rabbit)	Sr^{90} bone	22.52 ± 0.45
	Cs^{137} muscle	0.50 ± 0.01

8. Fish

Lake Hartwell	Sr^{90} (pCi/g)	Cs^{137} (pCi/g)
Carp (Adult)	1.52 ± 0.13	0.08 ± 0.02
Largemouth Bass (Fingerlings)	1.19 ± 0.07	0.36 ± 0.04
Gizzard Shad (Fingerlings)	0.35 ± 0.11	0.39 ± 0.02

9. Milk

	pCi/l Cs^{137}	pCi/l Sr^{90}	pCi/gCa	
002 Walhalla	11.4 ± 1.9	13.5 ± 1.7	Sr^{90}	11.9 ± 1.5

Results of gamma analysis show natural K^{40} as the predominant activity.

NOTE: Samples in categories 1 through 5 were measured at the 90% confidence level, based on RaD+E alpha, and "apparent $Cesium^{137}$ beta activity," calibration standards.

N.D. = non-detectable

(1), (2), (3) refer to numbers of samples averaged.

SUMMARY OF RESULTS RECEIVED TO DATE ON FISH AND WILDLIFE SAMPLES FROM OUTSIDE VENDORS

FISH

Date Collected	Description	Locations	Results	Sr-90 (pCi/g wet weight)	Cs-137 (pCi/g wet weight)
2-25-69	Carp (Adult)	Lake Hartwell	Homogenized Sample	1.52 ± 0.13	0.08 ± 0.02
	Bass (Fingerling)	"	"	1.19 ± 0.07	0.36 ± 0.04
	Shad (Fingerlings)	"	"	0.35 ± 0.11	0.39 ± 0.02
5-26-69	Carp (Adult)	Lake Hartwell	Homogenized Sample	0.74 ± 0.01	0.14 ± 0.01
	Bass (Adult)	"	"	1.15 ± 0.01	0.02 ± 0.00(4)
	Shad (Fingerlings)	"	"	0.21 ± 0.00(2)	0.02 ± 0.00(3)

WILDLIFE

Date Collected	Description	Location	Results	pCi/g Cs-137 dry weight	pCi/g Cs-137 wet weight
3-19-69	Rabbit	Exclusion Area	Tissue	0.50 ± 0.01	0.15 ± 0.01

Date Collected	Description	Location	Results	pCi/g Sr-90 ashed weight	pCi/g Sr-90 wet weight
3-19-69	Rabbit	Exclusion Area	Bone	22.52 ± 0.45	4.19 ± 0.09

DOCKET NO. 50-269
50-270 TSA 287

Enclosure #3

Received w/Ltr Dated 10-18-69

Regulatory File Cy.

MEMORANDUM
OCONEE NUCLEAR STATION
SUMMARY OF INVESTIGATIONS OF THERMAL
EFFECTS OF COOLING WATER
DUKE POWER COMPANY

July 25, 1969

Comprehensive studies of water behavior are, and have been, an integral part of our power plant engineering design for hydro as well as thermal stations. The results of our studies for each successive thermal plant are in the form of engineering calculations of simulated models of water bodies to forecast limnological, hydraulic, and thermal behavior. We have not had occasion to convert these studies to a form suitable for published reports.

For large thermal stations, we have been using our hydro lakes as a source of cooling water and for heat dissipation. In order to more fully understand the many interrelationships between power generation and the many other uses of water resources, we established in 1959 a full time department consisting of administrative, laboratory and field personnel to conduct research on our hydro lakes. These efforts have been supplemented with valuable help from a number of consulting limnologists and biologists. The results of these investigations have served as direct input to siting decisions and engineering design of our new power plants of all types. From the inception of this program ten years ago and continuing today, we worked very closely with the pollution control and the fish and wildlife agencies of North and South Carolina.

With regard to Oconee Nuclear Station, we did our thermal pollution homework in 1964 before deciding to proceed with the Keowee-Toxaway Project of which Oconee is a part. Using the research results developed by our water resources research group, plus the work of others in this field, a thermal model of Lake Keowee was constructed for each month of the year for examination of various combinations of heat dissipation. These studies, using criteria confirmed by field measurements or existing lakes in the area established that Lake Keowee could readily dissipate cooling-water heat from 7000 mw of thermal generating capacity distributed among three sites. Two future sites would involve dissipation from the lake's surface, and the third site, selected for Oconee would utilize the heat sink of the hypolimnetic waters during the summer. Cooling water for Oconee Nuclear Station will come from the bottom of the lake under a skimmer wall across the intake canal at sufficiently low velocity to prevent breaking up the lake stratification. This water will be of such low temperature that, after the addition of heat in the condenser, it is returned to the lake below or near the naturally occuring summer temperature of the lake surface. A similar skimmer wall has been in successful service at Duke's most recent steam plant since 1965. As is done at our other plants, when Oconee goes into service, field tests will be made to compare results with the predicted behavior and serve as a further basis for the two additional thermal plants on Lake Keowee.

Our application to the Federal Power Commission in early 1965 for a hydro license covering the Keowee-Toxaway project specified that one of the purposes of the Keowee hydro development was to serve as a source of cooling water for a 3000 mwe nuclear plant at the Oconee site, then known as "Site L". We made it quite clear that we would not undertake the hydroelectric development unless the license specifically permitted this cooling water use. Our studies showing its compatibility with the environment were reviewed with the South Carolina Pollution Control Authority and the U S Fish and Wildlife Service to their full satisfaction. Then Secretary of Interior Udall retained Dr C J Velz and Associates to make an independent study. Their report issued in April 1966 was entitled "Report on Waste Heat Dissipation in Streams, Ponds and Reservoirs with Application to the Duke Power Company Proposed Keowee-Jocassee Developments", and was submitted by these consultants to the U S Fish and Wildlife service in Washington. The report was in substantial agreement with our findings and Secretary Udall on April 7 1966 wrote the Federal Power Commission concluding: "In consideration of the above findings, we conclude that the thermal effects of the Site 'L' 3000 MW plant would produce no detrimental effects upon the fishery resources within the Lakes Jocassee or Keowee.", and further, "We do not expect that this discharge would affect a sufficient amount of the surface acreage of the reservoir to be deleterious to the recreation resources." The FPC license was then granted in September 1966, after which we filed an application with the Atomic Energy Commission for the Oconee Nuclear Station construction permit in December 1966. The point of this narrative is that we emphasize doing our environmental homework in advance of deciding to proceed with a project.

Many of our activities have been reported in the literature, and the following enclosures may be of interest.

1. Copy of W S Lee's testimony from the record of Hearings before the Committee on Public Works, House of Representatives, 91st Congress, First Session on HR4148 and Related Bills.

2. "Diffusion of Cooling Water Discharge from Marshall Steam Station into Lake Norman," by R Fred Gray and J Ben Stephenson (ASCE National Meeting on Environmental Engineering in Chattanooga Tennessee, May 13-17, 1968)

3. "Water Quality and Power Plants," by Austin C Thies (General Session of EEI Annual Convention, Portland Oregon, June 10, 1969)

4. "Improvement in Quality of Reservoir Discharges through Turbine or Tailrace Aeration," by W S Lee (ASCE Specialty Conference, Research Needs in the Civil Engineering Aspects of Power Panel on Water Quality Control, Pullman Washington, September 11-13, 1968)

5. "Nuclear Power at Oconee," by W S Lee and W H Rowand (American Power Conference, Chicago, Illinois, April 25, 1968)

6. A brief description of a very comprehensive physical and biological study sponsored by the Edison Electric Institute on our 32,500 acre Lake Norman in the vicinity of our Marshall Steam Station. Due to the many different interests and disciplines involved in this project, each participant agreed at the onset not to make individual "piece meal" releases of interim findings or results. Enclosure #3, the paper by our Mr A C Thies, also describes some facets of this project. Duke Power Company's costs in this study are estimated at $100,000.

W S Lee

WSL/s
7-25-69

Encl 1 of Encl # 3

FEDERAL WATER POLLUTION CONTROL ACT AMENDMENTS—1969

(91-1)

HEARINGS

BEFORE THE

COMMITTEE ON PUBLIC WORKS HOUSE OF REPRESENTATIVES

NINETY-FIRST CONGRESS

FIRST SESSION

ON

H.R. 4148 and Related Bills

TO AMEND THE FEDERAL WATER POLLUTION CONTROL ACT, AS AMENDED, AND FOR OTHER PURPOSES

FEBRUARY 26, 27, MARCH 4, 5, 6, 1969

Printed for the use of the Committee on Public Works

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and their steam-electric-power producing applicants in some areas that they should heed the strong objections to permitting licensees to heat up the waterways. Such acquiescence is not sufficient—as in the case of the Federal Power Commission, we feel there should be written into the law, perhaps a strengthening section 14(b) of H.R. 4148, dictating a review, study, and a prescription for measures to be taken in order to comply with established water quality standards of all license applicants by State and Federal conservation agencies, which would help solve this problem.

The Sport Fishing Institute wishes to go on record as solidly behind the intent and purposes of H.R. 4148 as being in the greatest public interest to America, with consideration given our suggestions, noted above, as strengthening measures.

Mr. BLATNIK. Mr. William S. Lee, vice president engineering, Duke Power Co., Charlotte, N.C., representing Edison Electric Institute.

STATEMENT OF WILLIAM S. LEE, VICE PRESIDENT ENGINEERING, DUKE POWER CO., CHARLOTTE, N.C., REPRESENTING EDISON ELECTRIC INSTITUTE

Mr. LEE. Mr. Chairman and members of the committee, my name is William S. Lee and I am vice president, engineering of Duke Power Co., headquartered in Charlotte, NC. I am appearing here today representing the Edison Electric Institute. This testimony will review briefly the projected cooling water requirements of electric generating plants; the methods of providing this cooling and what we know about their effect on the environment; the mechanism that already exists for regulating thermal discharges; and, of special interest to this committee, what utilities are doing to see to it that cooling can be provided for these future power plants in a manner fully compatible with the environment and at the same time conducive to making electricity available to the consumer at the lowest possible cost.

The trend of powerplant efficiencies is important to any projection of future cooling water needs. Over the years, the utility industry has achieved remarkable improvements in powerplant efficiency, and it is reasonable to expect this trend to continue in the future. For example, the national average powerplant efficiency as reported by the Federal Power Commission in 1938 resulted in a heat rejection of about 10,000 B.t.u. to the cooling water for each kilowatt-hour produced. Today, the average fossil powerplant discharges about 55 percent of the 1938 heat per kilowatt-hour. As this committee has heard, the currently available nuclear powerplant using a light-water reactor will reject about 50 percent more heat to the cooling water per kilowatt-hour than the most modern fossil fuel plant; however, this is only 10 percent more heat rejection per kilowatt-hour than the average of all powerplants in service today. Looking to the future, improvements in the efficiency of light-water nuclear plants as well as fossil plants, plus the advent of breeder-type reactors with much higher efficiency, are expected to resume the downward trend of heat rejection to cooling water per kilowatt-hour generated. Neglecting the possibility that generation will become practicable by some means of direct conversion which rejects little or no heat to the environment, it is reasonable to assume that by

POOR ORIGINAL

the year 2000 the national average thermal plant efficiency will match the efficiency of today's most modern fossil plant. This expected efficiency gain will result in a 20-percent decrease of heat rejected per kilowatt-hour compared to today's average experience. Based on this assumption and using a typical 16° F. temperature rise of the cooling water passing through the steam condensers, the average energy generated by 1.8 billion kw. of thermal capacity expected in 2000 will require 800 billion gallons a day of cooling water.

As has been outlined to this committee, the heat load added to this cooling water can be rejected to the environment by natural surface cooling in the receiving stream, river, lake, or tidal water; or can be rejected by a cooling tower to the atmosphere.

Where natural surface cooling is used, the heat is dissipated by a combination of radiation, conduction, advection, and surface evaporation. Of these, only surface evaporation causes a consumptive loss of water from the water course receiving the warmed water. The testimony of witness Kolflat[1] before this committee agrees with the findings of the U.S. Geological Survey[2] in their experiments on Lake Hefner to the effect that in natural cooling about one-half the added heat is dissipated by evaporation and the balance is dissipated by the other nonconsumptive mechanisms. Under average weather conditions and with a typical 16° F. rise through the condensers, the surface evaporation portion of heat dissipation will cause a consumptive loss of about three-quarters of 1 percent of the flow passing through the condensers. By the year 2000, this flow is estimated to be 800 billion gallons per day, and if all this heat is dissipated in the natural water courses, it will result in an evaporative loss of about 6 billion gallons per day.

In contrast, we see that the cooling mechanism in a cooling tower is quite different. Just as blowing on your wet finger cools the finger, a cooling tower uses high-velocity air to cool by evaporation without significant benefit from the other cooling mechanisms. For the same average weather conditions and 16° F. rise used in the above example, a cooling tower will evaporate about 1.5 percent of the throughput water. In addition, another 1 percent of the water is lost by "drift," which is the term applied to the small unevaporated water droplets that are carried away in the airstream. Thus the total consumptive loss of water through a cooling tower is about 2.5 percent. If cooling towers were applied to all of the capacity in service by the year 2000 requiring cooling water of 800 billion gallons per day, we will throw away into the atmosphere about 20 billion gallons per day which is 14 billion gallons per day greater loss than would occur if we let nature do the work for which nature is so ably equipped. With many of our towns and cities already seeking additional sources of water supply to meet the needs of our rapidly growing population, it would be foolhardy to waste 14 billion gallons per day which is equivalent to the water supply needs of a population of 110 million people. Further, large cooling towers will often cause heavy ground fogs, with resulting public discomfort and inconvenience, if not hazard, to air traffic.

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[1] Kolflat, statement before the Subcommittee on Air and Water Pollution of the Senate Committee on Public Works, Feb. 6, 1968.

[2] Harbeck, G. Earl, Jr., U.S. Geological Survey Circular No. 282, 1953.

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a cooling tower
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the throughput
lost by "drift,"
water droplets
onsumptive loss
f cooling towers
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hrow away into
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many of our
f water supply
on, it would be
equivalent to the
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to air traffic.

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In the early stages of conceptual development is a different type cooling tower employing hundreds of thousands of small tubes through which the cooling water would be passed in a sealed system with high-velocity air blown over the outside of the tubes to remove heat and thus avoid consumptive loss of water. This would operate on a principle similar to an enormous automobile radiator. It has been estimated that, once developed, this dry-type cooling tower will add 25 to 35 percent to the cost of a powerplant, further raise the cost of its operation, and cause a concomitant substantial increase in the cost of electricity to the consumer. Once developed, the dry-type cooling tower may find very special applications, but it should not be generally applied because of its expense to the public. Thus, the arbitrary use of cooling towers of the present or future type is not the panacea if alternative solutions are available that are in the public interest and otherwise compatible with the environment.

Now let's look at what utilities have done and are doing toward achieving that compatibility with environment with respect to cooling water. The utility industry fully understands and appreciates that the success of any electric company depends directly upon the economic health and welfare of the people in the area it serves, and this public welfare in turn requires freedom from pollution and wise and judicious management of environmental resources. Recognizing there is no way to make electricity without involving the environment, the electric industry is deeply involved in the areas of thermal discharges, water quality control, water resources research, air pollution control, meteorology, wirespread public recreation, soil conservation, flood control, and the development of fish and wildlife facilities. How attractive to investors would be an electric utility serving an area stagnated by blight?

For many years, this interest in the environment has influenced the design and operation of cooling water facilities at steam generating plants. It is true, however, that the design criteria have been based largely on empirical experience with respect to biological effects. Upper temperature limits of cooling water discharges have been selected, which, from long observation, do not kill fish, and on the contrary enhance sport fishing. Although as a general rule this method has been fully succesful to date and compatible with the environment, it did not recognize the possibility of subtle changes in biota that may be effected by thermal discharges until the pioneering work by several utilities a few years ago. There is disagreement among aquatic biologists as to the effect of thermal discharges. This committee has heard testimony to the effect that thermal discharges are patently bad, although any supporting evidence has not been made clear. In contrast, Dr. Charles B. Wurtz, biologist of LaSalle College, has pointed out [3] that fish food production and propagation of most fish species are enhanced by water warmed to a reasonable extent. In reviewing Dr. Wurtz' article, Dr. Charles M. Weiss, of the department of environmental sciences and engineering at the University of North Carolina, writes in private correspondence from which I quote with his permission, "In fact as Dr. Wurtz has pointed out and as has been found in every attempt to carefully examine thermal pollution and

[3] Wurtz, Charles B.—assistant professor, biology, LaSalle College, Philadelphia, Pa., "Misunderstandings About Heated Discharges," Industrial Water Engineering, September 1967.

its effect on aquatic ecology, outside of any immediate area of discharge, no demonstrable effects have been found. If any are shown, they appear in many instances to improve rather than degrade water quality." As evidenced by the crowded banks and full creels, sports fishermen well know that fish seek out the warmed waters near the steamplant condenser discharges. In two specific cases, utilities have come to agreement with local interest to help aquatic life with warmed water. In one case, a fish hatchery will be made possible with water otherwise too cold, and in another the oyster crop is to be increased by the beneficial effects of the warmed environment.

We do not, however, claim that the net effect is either good or bad. We need facts, and the industry is to take whatever steps necessary to prevent large-scale environmental changes as a result of power generation. To resolve the conflicting views of the experts, our industry, through the Edison Electric Institute, has undertaken a massive nationwide research program to determine the thermal effects upon aquatic biota. We have asked the biological experts to tell us not what we want to hear but tell us the facts. The next witness will tell the committee more about this research program. Using the facts gathered from this program, supplemented as needed by study of the specific local situation, we are confident that the application of sound engineering principles will permit the dissipation of cooling water heat in a manner that is fully compatible with the environment and that best serves the public interest in the broadest sense.

One of the stated purposes of this hearing is to determine the extent to which additional legislation is needed to regulate thermal discharge. Regulation of thermal discharges has already been established by law. The Federal Water Quality Act of 1965 requires each of the 50 States to develop water quality standards. Under the authority of this act, the Federal Water Pollution Control Administration has promulgated Federal guidelines to each of the 50 States. The water quality standards of each State must conform to these guidelines. The States are holding public hearings to revise their standards to conform to the guidelines, and submitting them to the Department of the Interior for approval. Standards of many States have now been approved and enforcement is underway. Others are pending. Each State standard includes specific temperature regulations. These standards apply to warmed water whether emanating from nuclear plants, fossil plants, or nonutility sources. Yet, in the face of this established regulatory mechanism, a proliferation of conflicting legislation has been introduced that would add redundant regulation of thermal discharges by the AEC, by the FPC, by a proposed National Resources Council, and by a proposed National Council on Environment. Clearly, the public interest would not be served by more legislation duplicating regulation already established.

I thank the committee for its kind attention.

Mr. BLATNIK. We have statements of witnesses scheduled here who asked that they be submitted for the record at the convenience of the committee, and without objection, will the staff file in proper order these statements.

Encl 2 of
Encl #3

DIFFUSION OF COOLING WATER DISCHARGE FROM MARSHALL STEAM STATION INTO LAKE NORMAN

For Presentation at the

ASCE National Meeting on Environmental Engineering

Power Division

Chattanooga, Tennessee

May 13-17, 1968

By

R. Fred Gray and J. Ben Stephenson

Duke Power Company

Charlotte, North Carolina

DIFFUSION OF COOLING WATER DISCHARGE
FROM MARSHALL STEAM STATION INTO LAKE NORMAN

By

R. Fred Gray[1] and J. Ben Stephenson[2]

Introduction

All practical methods for generating large quantities of electricity involve effects on the environment.

With this in mind, we at Duke Power Company have made it a part of our business to become involved in such things as water quality control, water resources research, flood control, air pollution control, soil conservation, public recreation, meteorology, development of fish and wildlife facilities and the study of our thermal discharges.

The design and operation of our hydro and steam generating plants have been influenced greatly by our interest in the environment.

We do this as a matter of good citizenship; but we also do it as a matter of good business because our long range success is closely related to the wise management of environmental resources in the area we serve.

EEI Cooling Water Studies

Duke Power Company and other electric utilities have been conducting field studies on the heat dissipation patterns of power plant cooling water discharges for several years.

[1]Environmental Test Engineer, Steam Production Department
Duke Power Company, Charlotte, North Carolina

[2](Now Deceased) Manager, Environmental Research,
Duke Power Company, Charlotte, North Carolina

Realizing that there was a need for correlation between field surveys and theoretical analyses of thermal discharges, our industry initiated such a study at representative locations over the United States in 1966. This program is being carried out through the Edison Electric Institute and under the direction of the Department of Environmental Engineering Sciences of Johns Hopkins University. This research project, known as EEI RP-49, is a very comprehensive undertaking which includes studies of heat dissipation in tidal estuaries, rivers, cooling ponds, and deep inland reservoirs.

Duke Power's Marshall Steam Station was selected as one of eleven study sites for the RP-49 project. At this site, our company collects the necessary temperature data to monitor the diffusion of the station's cooling water, and we also measure the various meteorological factors which have an effect on heat dissipation.

Test data is collected weekly and forwarded to Johns Hopkins where it is accumulated in the data bank of a computer. This information will be processed and studied along with the data from the other research sites. Findings are expected to be of great value in predicting and analyzing heat dissipation characteristics. This special testing around the Marshall Steam Station has enabled us to thoroughly evaluate some of the special features of this particular power plant location.

Site Features

The Marshall Steam Station is located on Lake Norman approximately in the center of Duke Power Company's service area (Fig. 1). Lake Norman has a surface area of 32,500 acres and a volume of over 1 million acre-feet. Weather conditions are relatively mild for this area; as shown in Table I.

Marshall Steam Station presently has two units in operation with nameplate capacities of 350 MW each. Under construction are two 650 MW units which will bring the total station capacity to 2,000 MW. This will make it the largest generating plant on the Duke Power system.

In order to accomplish special testing for RP-49, we have established a series of synoptic and continuous temperature monitoring stations (Fig.2) which measure the diffusion of Marshall Steam Station's condenser cooling water.

A complete weather station records the following information: wind speed and direction, solar radiation, relative humidity, rain fall, maximum and minimum weekly temperatures.

When Lake Norman is stratified during the summer months, Marshall's condensers are assured of cooling water that is 20 to 25°F cooler than the surface water of the lake.

The two principle features that make this arrangement possible are:

(1) A submerged skimmer wier, (Fig. 3) which is located 17 miles down lake from Marshall Steam Station at the Cowans Ford Hydro Plant. This wier allows the higher quality (dissolved oxygen) upper levels of the reservoir to be passed downstream; while holding back the colder bottom water.

(2) An inverted skimmer wall (Fig. 4 and 5) which is located at the mouth of the intake cove, about a mile from the plant intake. The skimmer wall is a continuous barrier except for openings in the lower 10 feet. These openings

allow water 60 to 70 feet below lake surface to be drawn into the intake cove.

With the present two units in operation, there is a detention time of 2 to 3 days after this cold bottom water is on the plant side of the skimmer wall. During the hot summer months, this is enough time for this cove to start to stratify as illustrated by data taken on July 12, 1967 (Fig. 6). On the above date the temperature profile at sampling station "A", located on the lake side of the skimmer, showed the surface water temperature to be 79°F and the average temperature of the water going under the skimmer to be 58.5°F.

The coldest water recorded at the plant intake during the conditions shown in Figure 6 was 61°F, at depths 15 through 30 feet. The condensers were receiving 62°F water at this time. So, under these conditions, the plant cooling water was heated 3.5°F by solar radiation and conduction before it entered the plant condensers.

When the total capacity of 2000 MW is in operation, the intake canal detention time will be reduced to approximately 17 hours. With this shorter travel time, intake water is expected to be closer to the temperature of the water coming under the skimmer wall.

Diffusion Studies

Marshall's discharge canal (Fig. 2), from station "F" to station "H" is 4,800 feet in length. At full pond elevation, there are 60 acres of surface area between these two points. Reductions of 3 to 15°F in the plant's effluent have been measured before it reaches station "H", its entrance point to Lake Norman.

The following temperature profiles, which are representative of the different seasons and meteorological conditions throughout the year, show how the cooling water discharge from Marshall Steam Station is dispersed in a portion of Lake Norman.

The synoptic survey that was conducted on December 14, 1967 (Fig. 7) was on an extremely mild day for that time of year. Consequently the parameters that speed heat dissipation were at a minimum. Average relative humidity was 85%. Air temperature at the time of the survey was as high as 67°F. Wind speed ranged from 1.0 to 4.5 mph.

With a plant load of 770 MW and a cooling water flow of 252,000 gpm, the discharge temperature was 76°F; by the time this water had reached station "H", it had cooled 3°F. The temperature profile shows there was little or no mixing below the 53° isotherm. In fact, the 60° isotherm indicates most of the heated water stayed in the top three feet of the reservoir.

But even under the adverse meteorological conditions that existed when this survey was made, the condenser cooling water had reached average lake temperature before reaching stations "23" and "45".

The February 21, 1968 data (Fig.8) presents an altogether different story. During the preceding 24 hours a predominantly down lake wind averaged 9.5 miles per hour. Average air temperature was 34°F at the time of the survey. Average relative humidity was 50%. In the vicinity of the plant intake, the lake was isothermal at a temperature of approximately 41°F. Plant generation was at maximum capacity of 800 MW. Cooling water flow was 252,000 gpm at a discharge temperature of 68°F. The cold air temperature and wind had dissipated the heat from the discharge water so that the warmest water recorded at station "H" was 54°F. This represents a 14°F drop in temperature in the 4800 foot length of the discharge canal.

The sharp dip in the 44° isotherm from station "H" to stations "I" and "J" indicates that a cold wind of moderate speed for a long duration can cause mixing. This mixing is more clearly shown by the 43.5°F isothermal condition at station "45" which is 2.5°F warmer than up lake stations "23" and "A".

The April 14, 1967 data (Fig. 9) shows that the lake has begun its seasonal stratification pattern. Surface temperatures are around 65°F with bottom temperatures of 49 to 50°F. Up lake winds of 6 mph appear to cause some mixing in the top ten feet of the lake between station "H" and "I". This is indicated by the depression of the 64°F isotherm between these stations.

A possible reason for the upswing in the 64° isotherm at stations "23" and "A" is that the temperature of the inflow to the lake was 62°F.

The lake was in a state of complete stratification when the data was taken on June 28, 1967 (Fig. 10). There is a 25°F differential between surface and bottom temperatures.

With both units near maximum load and intake water at 60°F and with all four cooling water pumps in operation, there is a 16.5°F temperature rise across the condensers. Discharge water is only 76.5°F while the lake's surface temperature is 80°F.

This 3.5°F temperature difference causes the plant's discharge to dip under the surface and settle to its appropriate density level. The bulging of the isotherms at the mouth of the discharge canal clearly illustrates this.

Data recorded on August 31, 1967 (Fig. 11) shows the discharge water to be only 1 to 2°F cooler than the surface waters of Lake Norman. There is not enough difference in the densities of these two waters to cause separation. Therefore, the discharge water blends with the lake surface water and stays in the top few feet of the reservoir.

By autumn, the cooler air temperature has caused vertical mixing and the lake is undergoing its natural pattern of destratification.

The synoptic survey that was made November 1, 1967 (Fig. 12) illustrates this natural mixing and also shows the rapid dissipation of heat from the plant's effluent.

Water was discharged at 83°F but by the time this water had reached station "H" at the end of the discharge canal, its temperature was reduced by 7°F. There was no effect seen at the upstream stations. Very little, if any, effect was seen at station "45".

Conclusions

Distinct advantages result from the Marshall Steam Station's location on a large reservoir where bottom water can be used for condenser cooling. During the colder months of the year, the heated water spreads over the lake surface where it is quickly cooled by the air and wind. In the hot summer months, use of the cold bottom water for cooling results in discharge temperatures close to those of the lake surface water.

Extensive temperature surveys have shown that only a small part of Lake Norman's cooling capacity is required to dissipate the waste heat from the Marshall Steam Station.

Future Studies

Although the only obvious effect of heated water discharges at our steam stations is a noticeable improvement in fishing, biologists have expressed conflicting views and theories regarding the effects of heated water discharges.

Beginning in the summer of 1968, Duke Power will carry out a comprehensive 3-year study of biological conditions in Lake Norman to determine the effects of the heated water discharged from the Marshall Station. Our study will be coordinated with similar studies at other power plant locations which are being supervised by Johns Hopkins University for the Edison Electric Institute.

We are confident that these studies will provide factual answers to the questions and speculations about the biological effects of heated water discharges.

TABLE I

METEOROLOGICAL CONDITIONS*

IN THE VICINITY OF LAKE NORMAN

1. Winds

A. Speed Annual Averages

Speed (knots)	0	1-3	4-6	7-10	11-16	17-21	22-33
Frequency (%)	8.0	7.0	34.5	34.1	13.3	1.8	.3

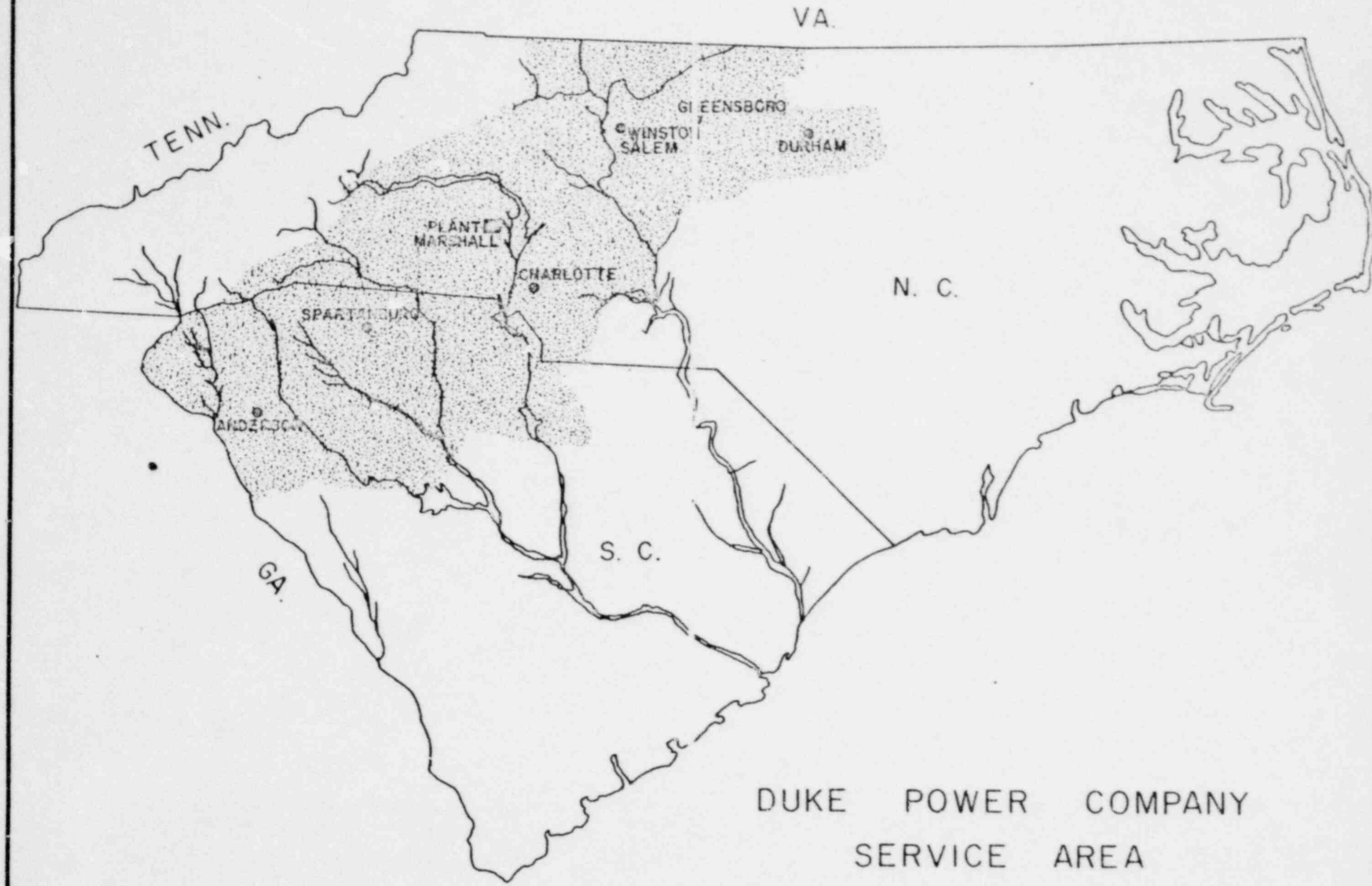
B. Direction - Predominantly from northeast and southwest, but does blow from all directions.

2. Air Temperatures

Range	Percent Frequency
25°F and lower	1.8
25-50°F	29
50-70°F	35
70-95°F	34
95°F and over	0.2

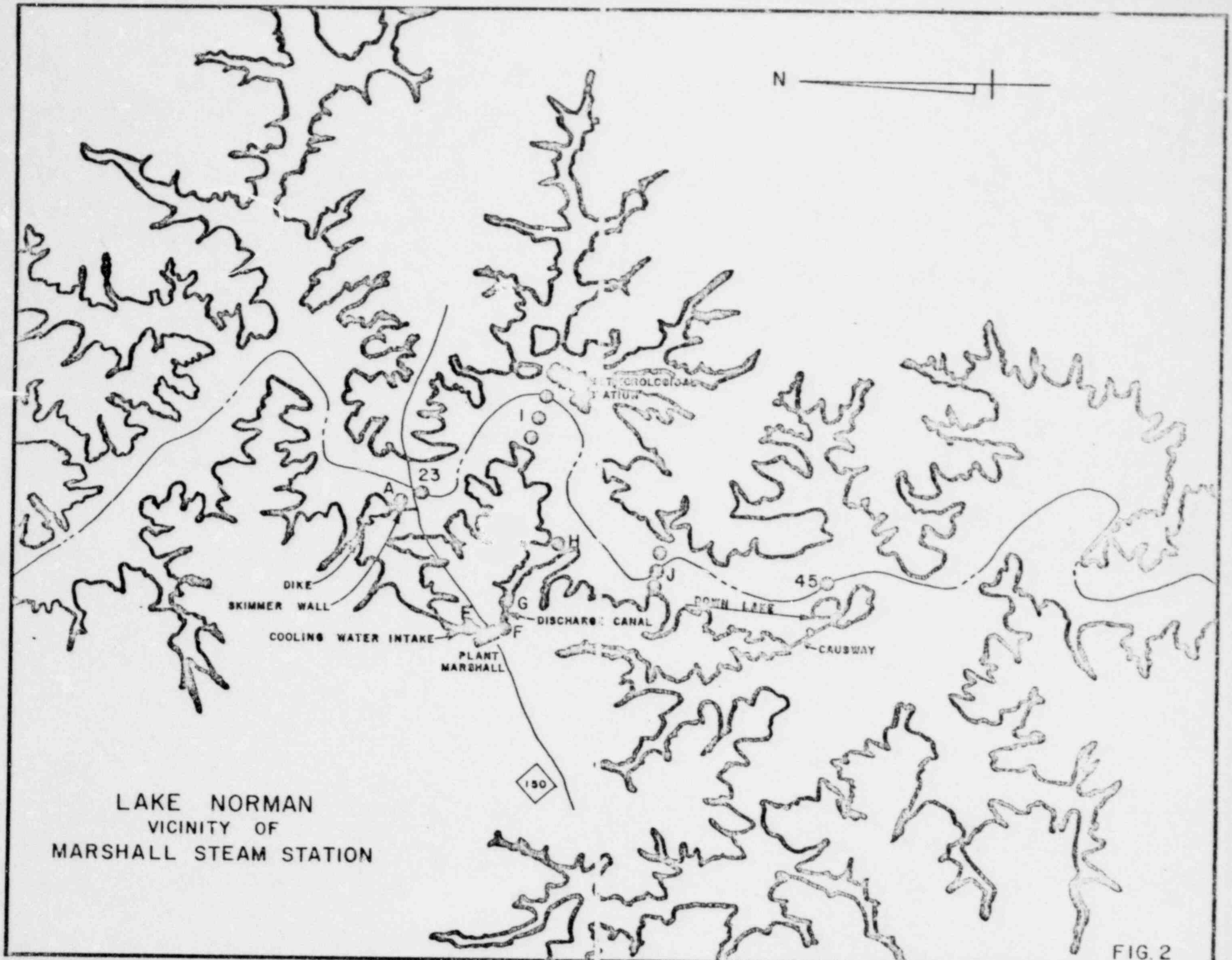
3. Rainfall - Occurs all during the year averaging 45 inches per year, monthly ranges are 2-1/2 to 5 inches.

*Observations made by U. S. Weather Bureau at Douglas Municipal Airport, Charlotte, North Carolina. Marshall Steam Station located 26.2 miles northwest of Charlotte.



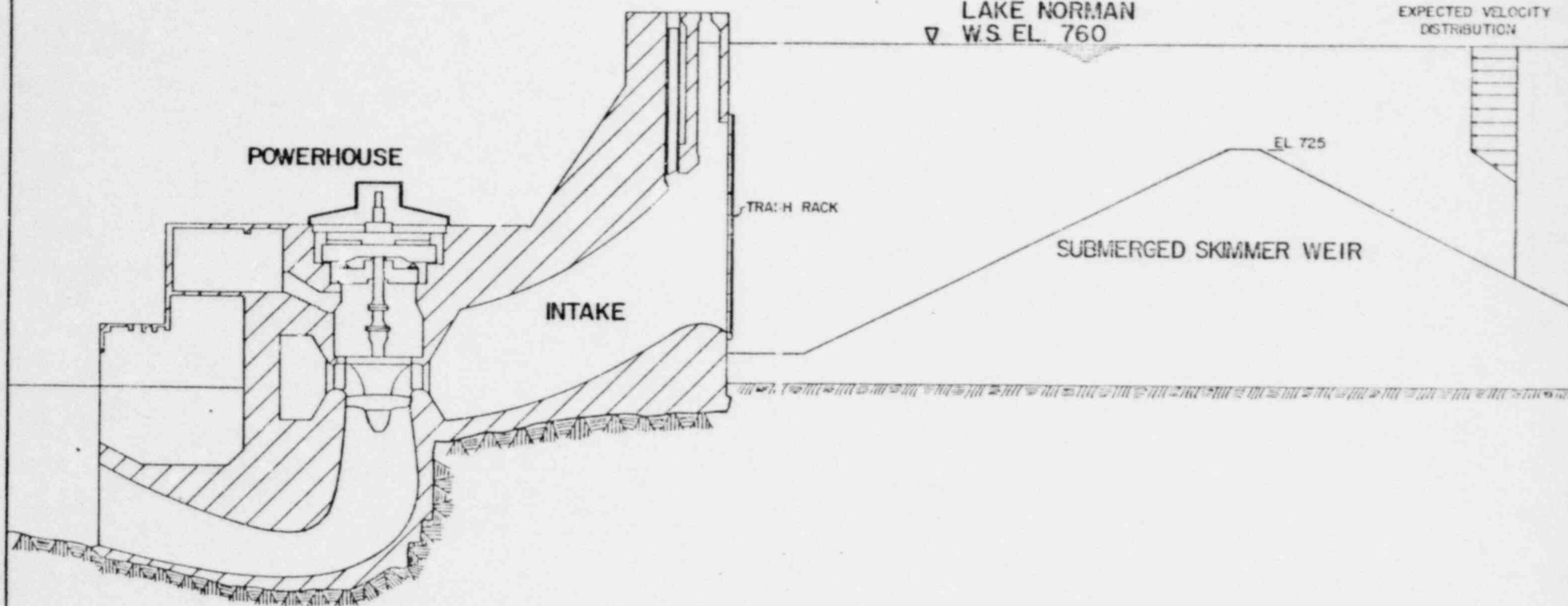
DUKE POWER COMPANY SERVICE AREA

FIG. 1



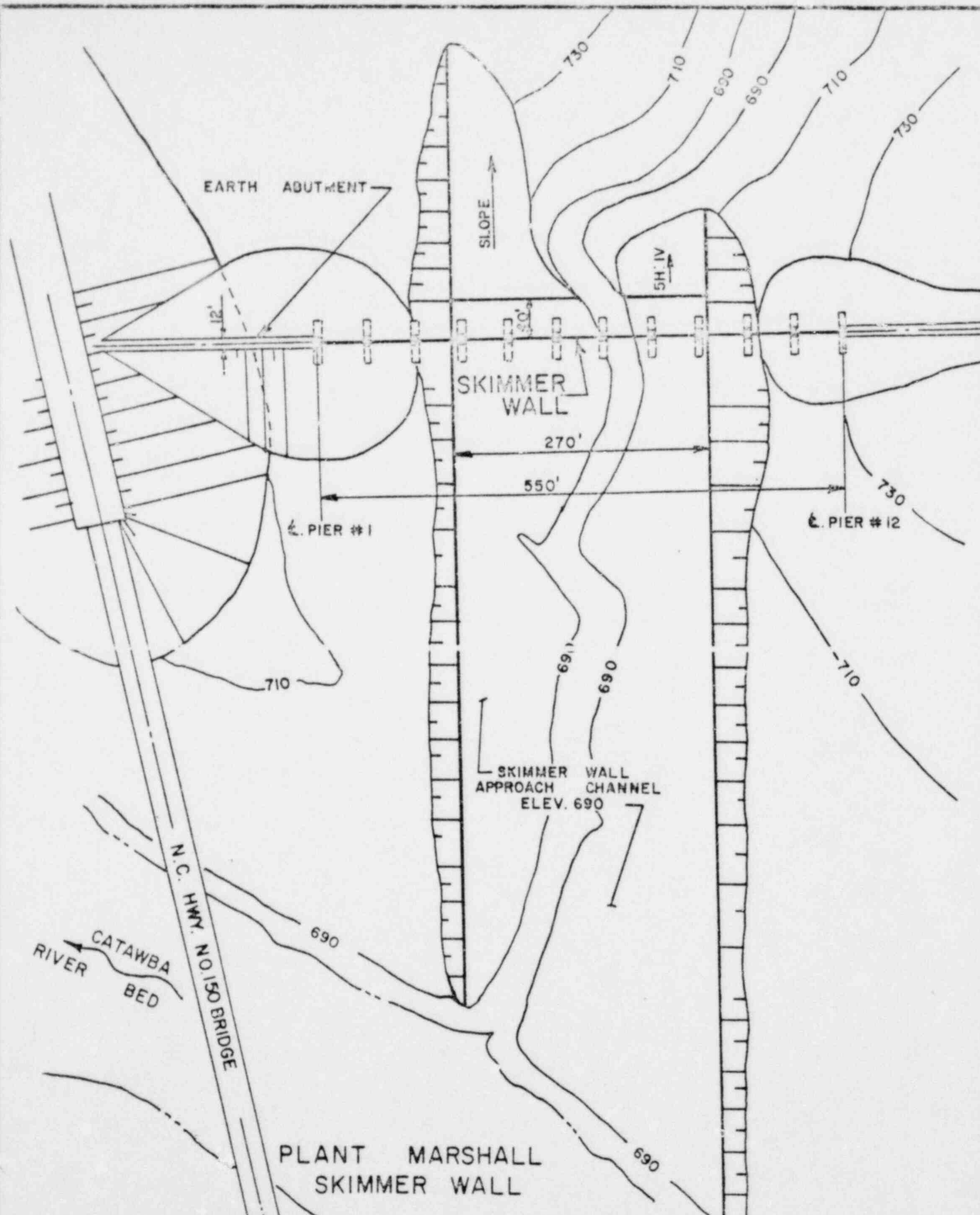
LAKE NORMAN
VICINITY OF
MARSHALL STEAM STATION

FIG. 2



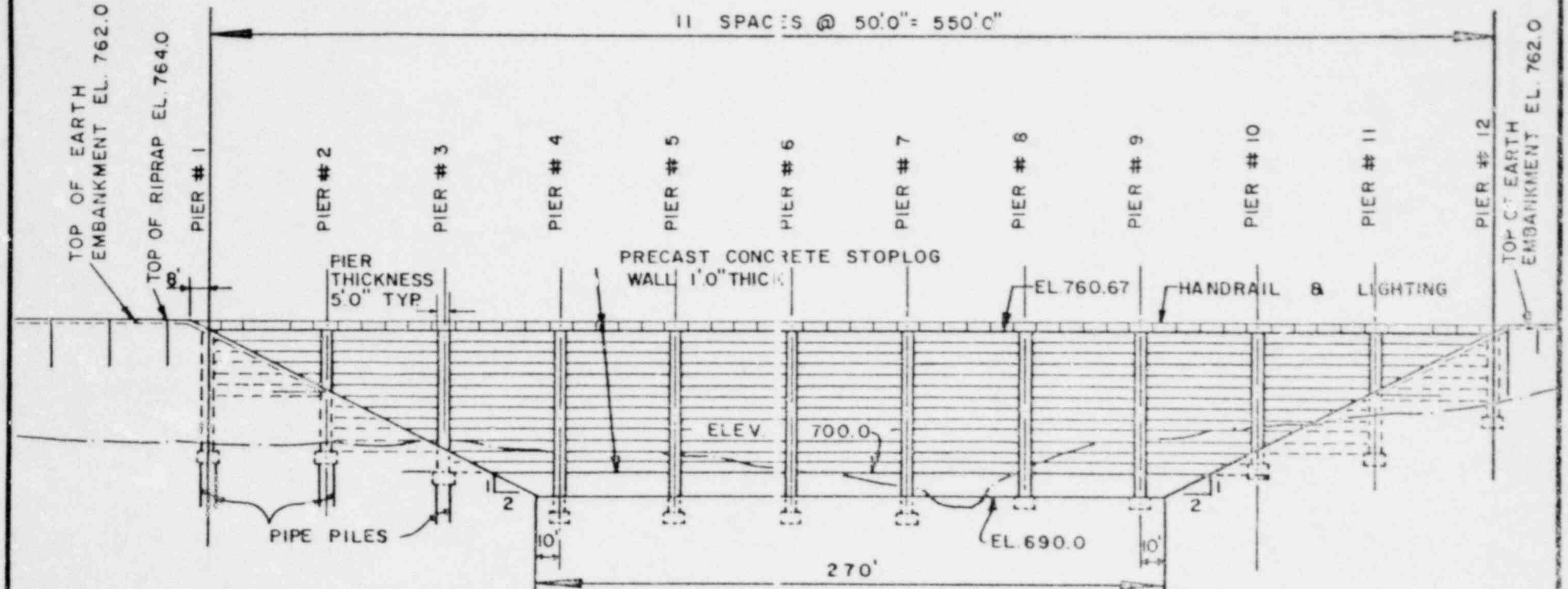
COWANS FORD DAM
WITH WEIR

FIG. 3



PLANT MARSHALL
SKIMMER WALL

FIG. 4

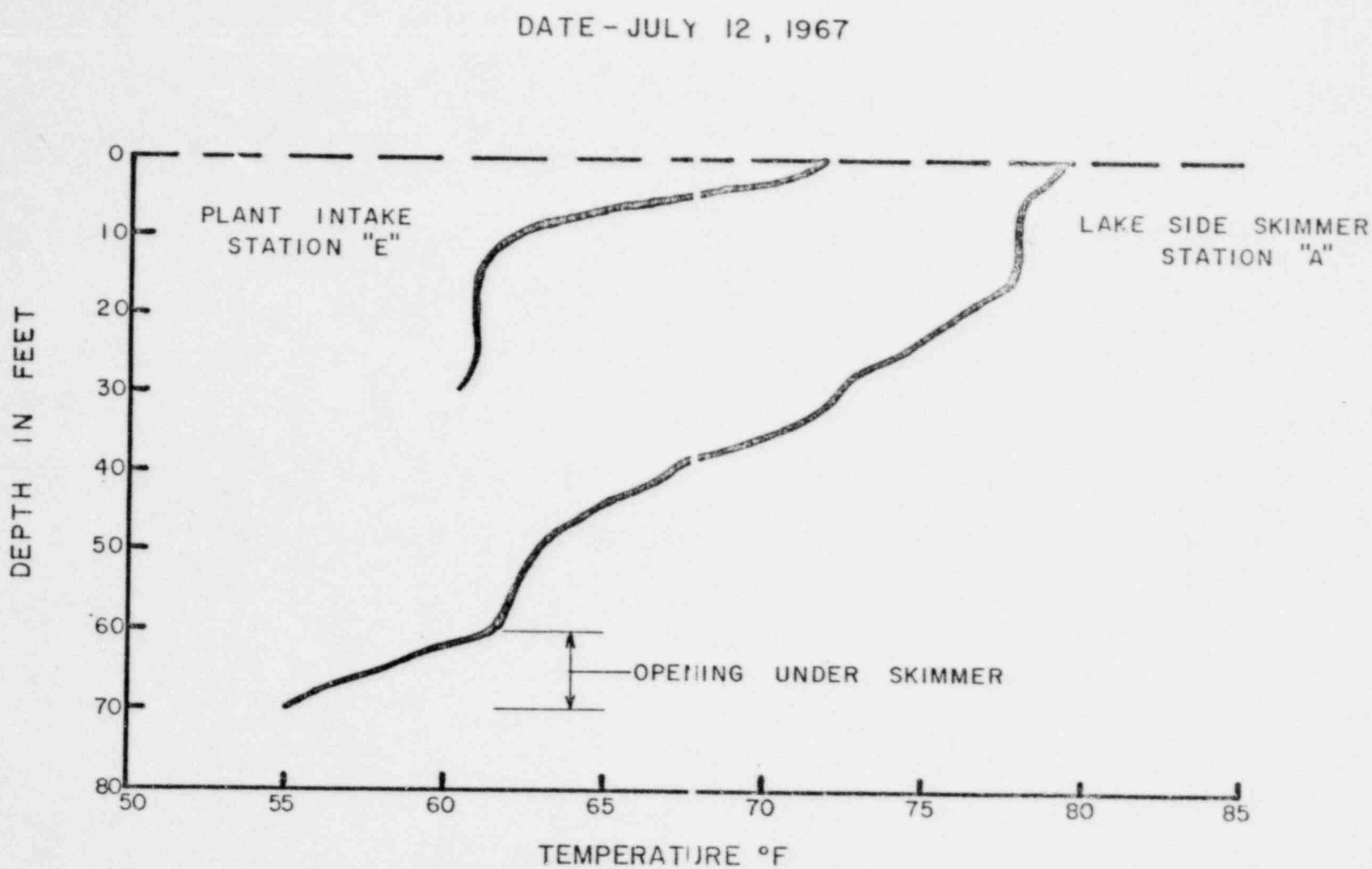


DOWNSTREAM ELEVATION

PLANT MARSHALL SKIMMER WALL

FIG. 5

GGH.



DATE - JULY 12, 1967
PLANT INTAKE
STATION "E"
LAKE SIDE SKIMMER
STATION "A"
OPENING UNDER SKIMMER
DEPTH IN FEET
0
10
20
30
40
50
60
70
80
50
55
60
65
70
75
80
85
TEMPERATURE °F

FIG. 6

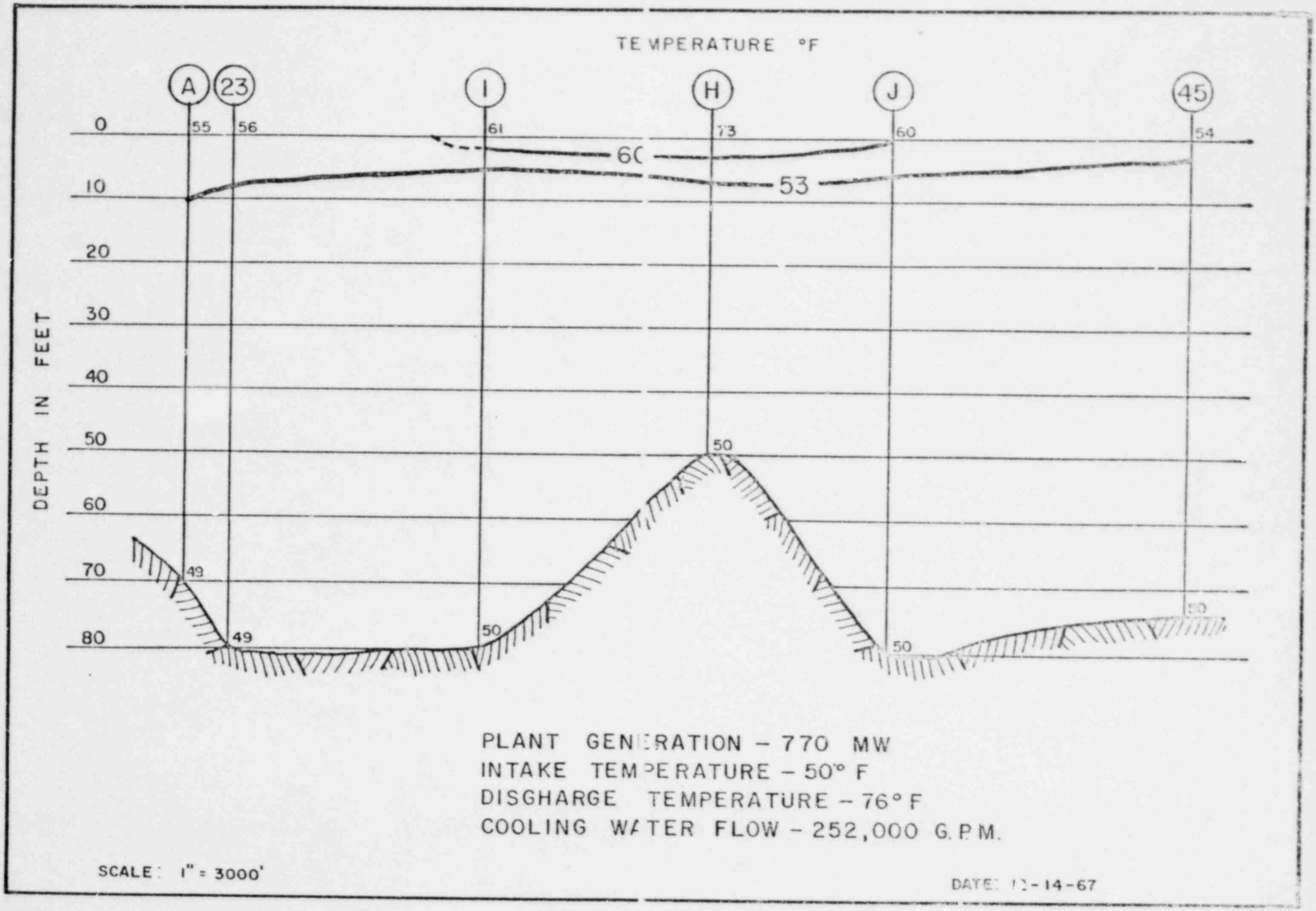

TEMPERATURE °F
A
23
I
H
J
45
DEPTH IN FEET
0
10
20
30
40
50
60
70
80
55
56
61
73
60
54
60
53
49
49
50
50
50
50
PLANT GENERATION – 770 MW
INTAKE TEMPERATURE – 50° F
DISGHARGE TEMPERATURE – 76° F
COOLING WATER FLOW – 252,000 G.P.M.
SCALE: 1" = 3000'
DATE: 12-14-67

FIG. 7

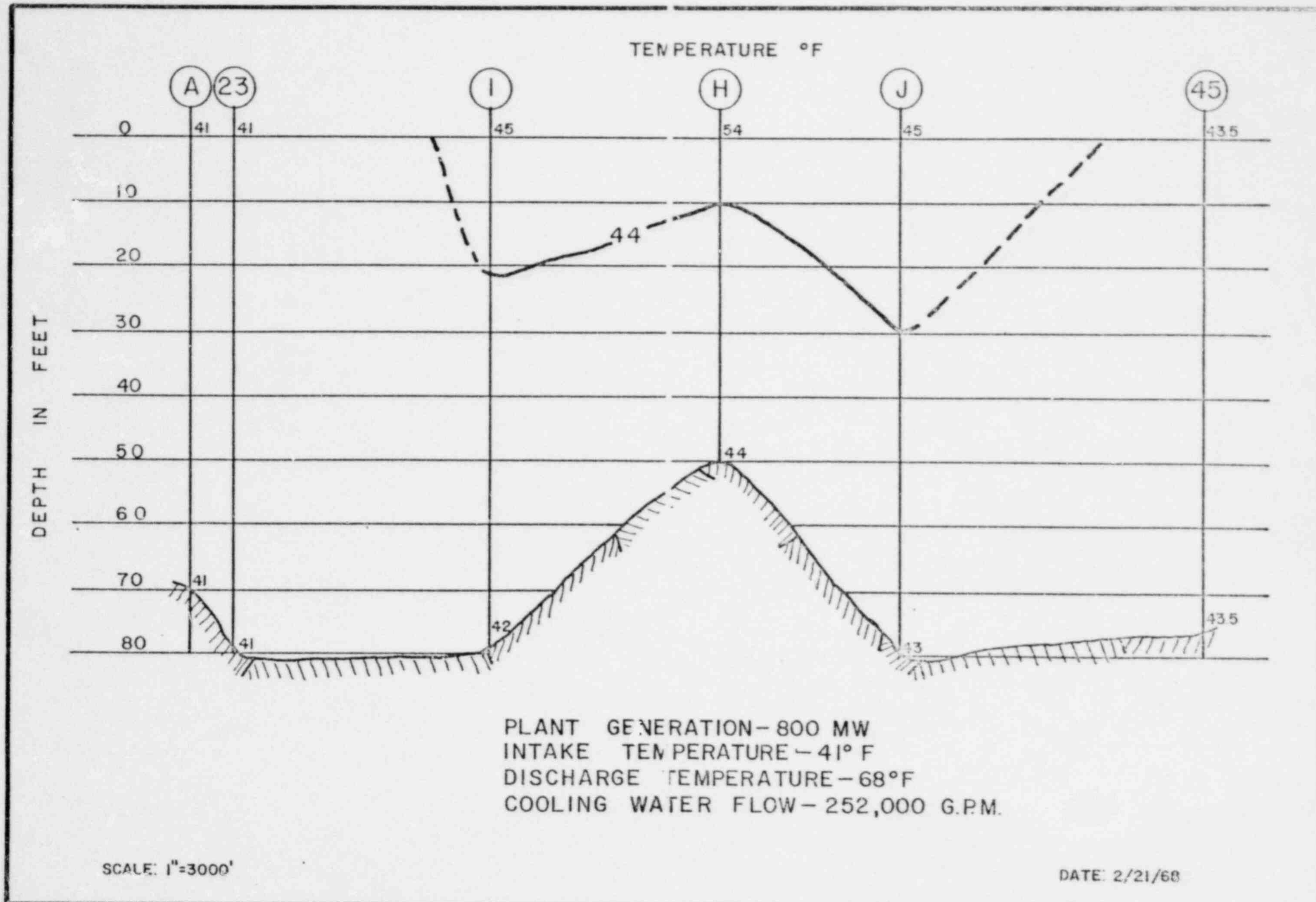

TEMPERATURE °F
A
23
I
H
J
45
0
10
20
30
40
50
60
70
80
DEPTH IN FEET
41
41
45
54
45
43.5
44
44
41
42
41
43
43.5
PLANT GENERATION - 800 MW
INTAKE TEMPERATURE - 41° F
DISCHARGE TEMPERATURE - 68°F
COOLING WATER FLOW - 252,000 G.P.M.
SCALE: 1"=3000'
DATE: 2/21/68

FIG. 8

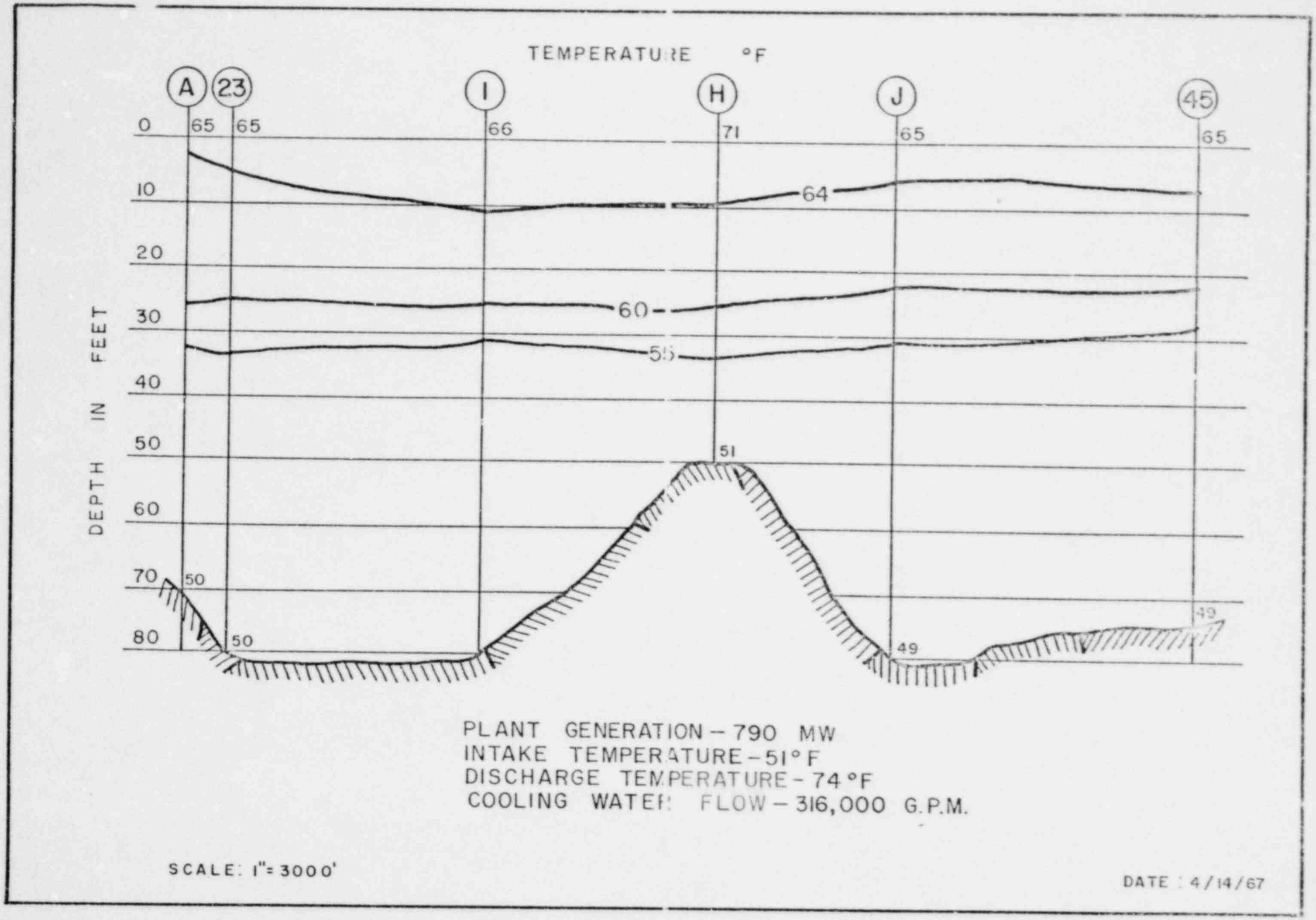
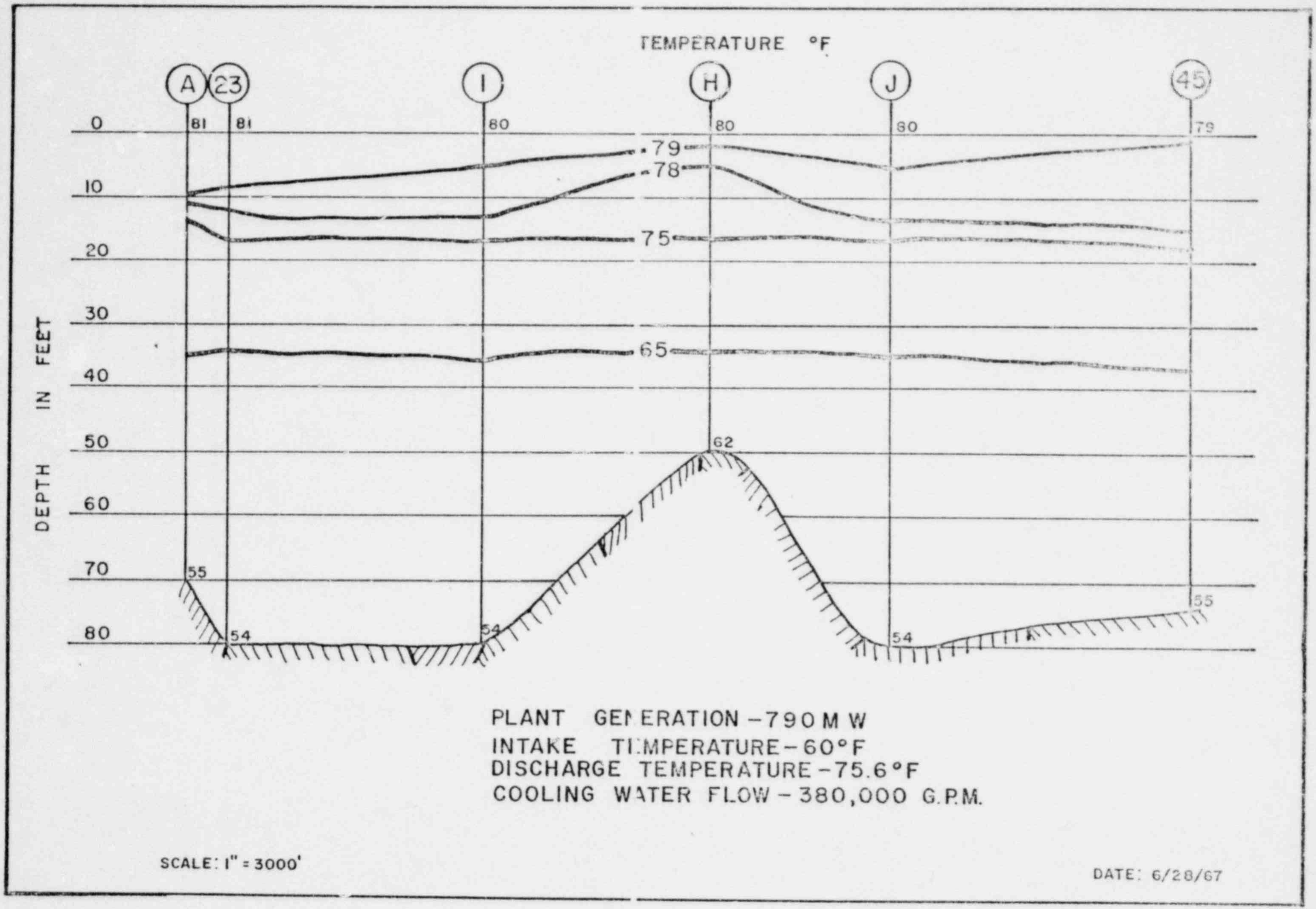

TEMPERATURE °F
A
23
I
H
J
45
65
65
66
71
65
65
64
60
55
51
50
50
49
49
0
10
20
30
40
50
60
70
80
DEPTH IN FEET
PLANT GENERATION - 790 MW
INTAKE TEMPERATURE - 51° F
DISCHARGE TEMPERATURE - 74 °F
COOLING WATER FLOW - 316,000 G.P.M.
SCALE: 1" = 3000'
DATE : 4/14/67

FIG. 9



TEMPERATURE °F
A
23
I
H
J
45
0
10
20
30
40
50
60
70
80
DEPTH IN FEET
81
81
80
80
80
79
79
78
75
65
62
55
54
54
54
55
PLANT GENERATION - 790 M W
INTAKE TEMPERATURE - 60°F
DISCHARGE TEMPERATURE - 75.6°F
COOLING WATER FLOW - 380,000 G.P.M.
SCALE: 1" = 3000'
DATE: 6/28/67

FIG. 10

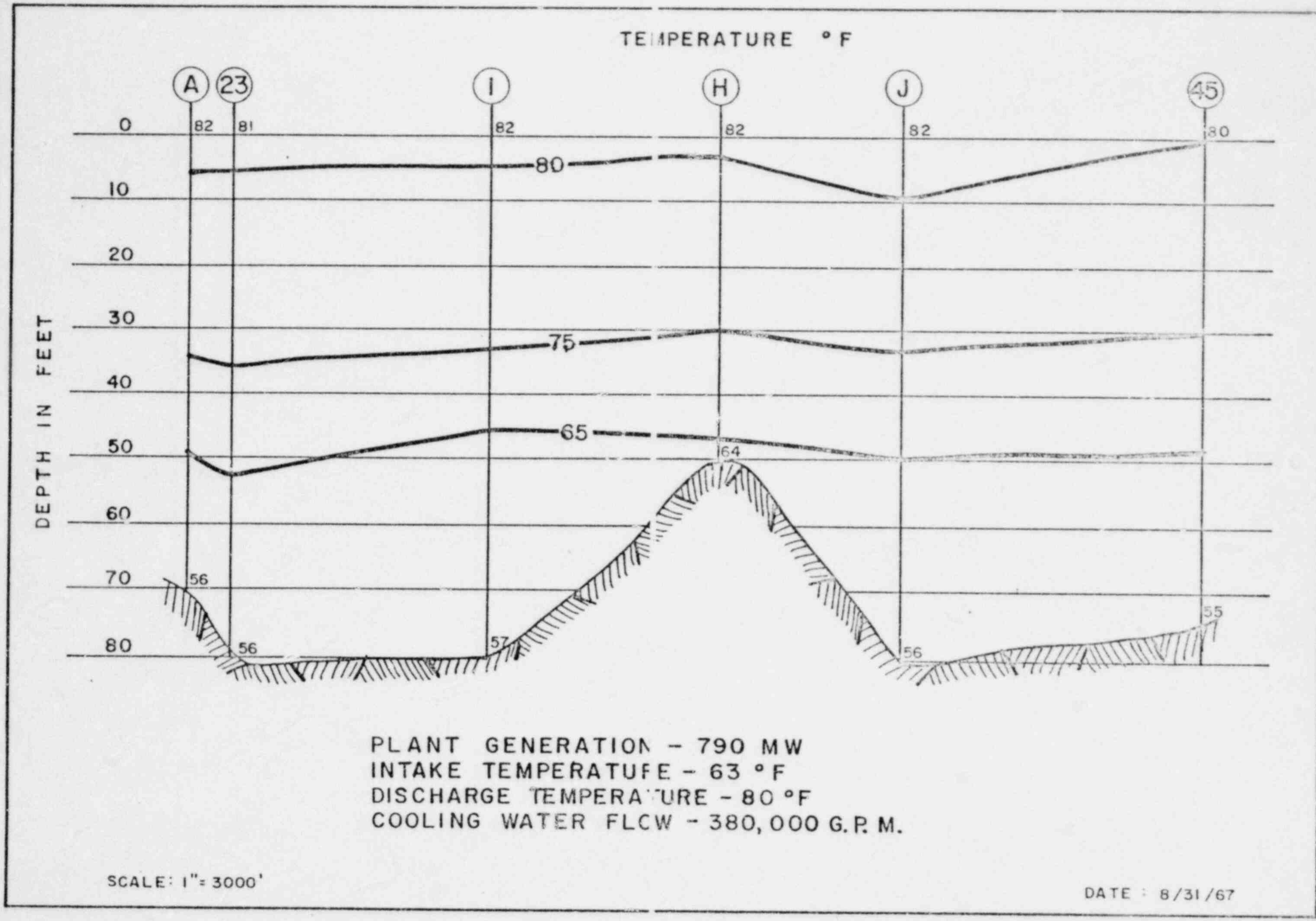

TEMPERATURE °F
A
23
I
H
J
45
DEPTH IN FEET
0
10
20
30
40
50
60
70
80
82
81
82
82
82
80
80
75
65
64
56
56
57
56
55
PLANT GENERATION - 790 MW
INTAKE TEMPERATURE - 63 °F
DISCHARGE TEMPERATURE - 80 °F
COOLING WATER FLOW - 380,000 G.P.M.
SCALE: 1" = 3000'
DATE : 8/31/67

FIG. 11

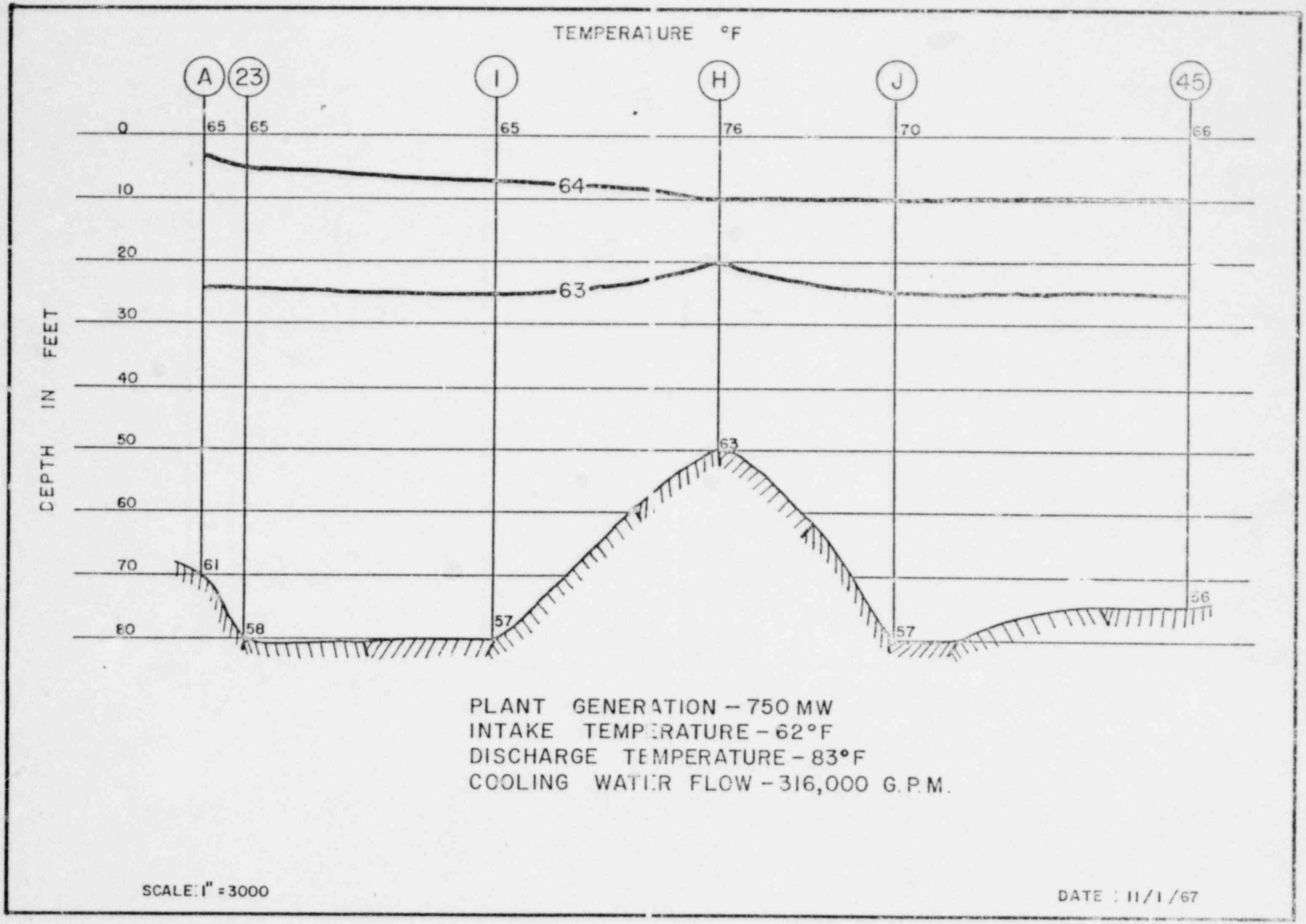

TEMPERATURE °F
A
23
I
H
J
45
DEPTH IN FEET
0
10
20
30
40
50
60
70
80
65
65
65
76
70
66
64
63
63
61
58
57
57
56
PLANT GENERATION - 750 MW
INTAKE TEMPERATURE - 62°F
DISCHARGE TEMPERATURE - 83°F
COOLING WATER FLOW - 316,000 G.P.M.
SCALE: 1" = 3000
DATE : 11/1/67

FIG. 12

Encl 3 of
Encl #3

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By Austin C. Thies

Vice President, Duke Power Co., and Chairman, Water Problems Task Force, EEI Committee on Environment

UTILITIES may spend up to $4 billion for unneeded control of thermal effects by 1980, depending on what we do to influence legislation with [illegible].

Secretary of the Interior Walter J. Hickel has announced that President Nixon will establish a new interdepartmental environment quality council over which he will personally preside as chairman.

The Rockefeller Committee in releasing its report said, "The movement to promote environmental quality is growing, thriving and permanent—industry must adjust to it."

All over the country there is growing public concern over air and water pollution, and hardly a week goes by that you do not see some reference to so-called thermal "pollution" from power plants in your local newspaper or on your radio or television set. Whether we like it or not we live in a fishbowl. We are the largest and most accessible target of those preservationists and others who would accuse us of doing great and permanent harm to the waters of the nation without having the facts. They have set out to block our proper use

An address before the 37th Annual Convention of Edison Electric Institute, Portland, Ore., June 10, 1969.

Every utility should give environmental matters a high priority in its corporate planning. As the use of water multiplies and the industry concentrates in single units huge blocks of power, the problems of heat release are certain to multiply.

3314

What the Industry Is Doing to Solve Water

Figure 1

Figure 4

Figure 2

Figure 5

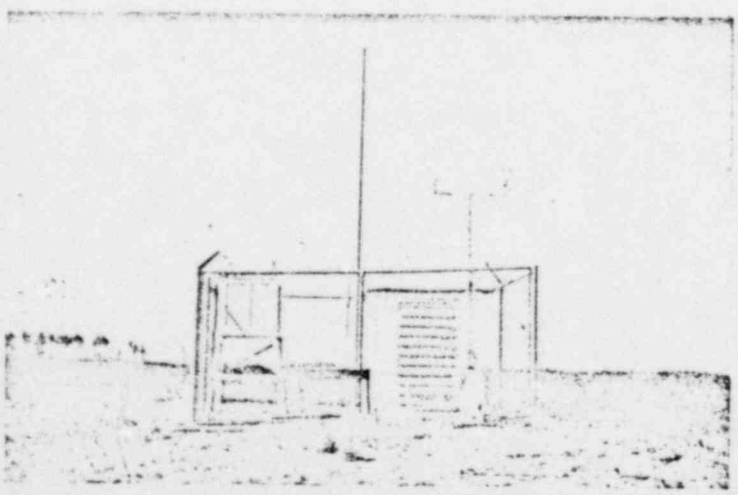

Figure 3

Figure 6

Problems

Figure 7

Figure 8

Figure 9

of this necessary natural resource, even though we have assured them that we will take whatever steps are necessary to correct any harmful effects from warm water discharges.

Certainly, our industry, as it grows, will use ever-larger quantities of cooling water in its condensers; however, we have been using part of this water for almost 90 years now, and the number of instances in which power plants have been directly responsible for harmful effect on any form of aquatic life could be listed on a very short page. We are not, however, resting on our laurels. I am very proud of the genuine concern of our industry—of what it has already done to minimize the effects of warm water discharges, and of what it is doing in the way of research to see that reasonable temperatures aren't exceeded and to find out what the biological effects of slight changes in water temperature really are. We must and we will protect our environment. Let's review the existing situation.

What the ' dustry Has Done

For some years, we have been building cooling towers where necessary, putting in cooling ponds, spray ponds, building separate cooling lakes, and designing our intake and discharge structures and locating them in such a manner as to minimize the effect of the heat discharged to the receiving waters from our power stations. EEI companies recently received a summary of the environmental studies on water problems being made by 85 investor owned utilities who responded to a recent questionnaire from the Water Problems Task Force. This summary shows that 151 separate research studies have been completed; 114 studies are actively under way; and 44 research projects are proposed—a total of 309 studies of the effects of warm water discharge made by industry. This information should be made available to your legislative, educational, and regulatory people who should be aware of the research the utilities are doing.

Phase II of EEI Research Project RP49, being conducted by The Johns Hopkins University, with support from a host of researchers from other campuses, covers some immensely significant work that has to do with the analysis of surface heat exchange of power plant cooling ponds. A report on this phase, due for immediate release, will resolve some of the discrepancies disclosed by previous investigators in the relationship between the surface cooling rates and wind speed. This is *new, hard data* backed up by three years of research done on 11 power plant site in the United States that will show that cooling coefficients can be quite appreciable even with very low wind speeds. This contradicts two out of three previous investigators who had deduced that cooling coefficients became negligibly small at 0 wind speed. This report also finds that at higher than average wind speeds, cooling coefficients tend to be larger than would be predicted by using the findings of any previous investigators. This new re-

POOR ORIGINAL

search information is the kind that both industry and government never had available to them before.

Three-Year Project

Phase III of EEI RP49 is a three-year, $750,000 project covering the biological effects of warmed water on biota at actual power plant sites. Many of our standards are being established based on small-scale laboratory studies that don't represent field conditions. The need for this field research is great. One of the sites selected for this research is Duke Power's Marshall Station on Lake Norman. I would like to show you some of the work on this project—

Fig. 1 is an aerial view of Marshall Station—water intake under the skimmer wall on the left and discharge on the right. The present capacity is 1451 megawatts and ultimate capability is over 2 million kilowatts.

Fig. 2—The Division of Inland Fisheries of the North Carolina Wildlife Commission is cooperating in this project by collecting and analyzing fish samples. Here, two of their biologists are shocking and netting fish to be tagged. Fishermen are asked to return tags on fish they catch to study migration. The greatest percent of the returned tags have come from the plant discharge. In this and their gill net sampling, they have two full-time biologists and one helper and a part-time fishery supervisor on this job.

Fig. 3 is the meteorological island where we record wind speed and direction, relative humidity, maximum and minimum temperatures, rainfall, and solar shortwave radiation.

Fig. 4 is one of four instrumentation rafts which continuously record water temperature at six levels from top to bottom. Weekly synoptic surveys are made from boats at various depths at 19 other locations. Note the lead peroxide candle and dustfall jar used for air pollution work. Also, located here are some biological productivity slides.

Fig. 5 shows crews taking chemical, D O, and temperature sample readings in the left boat—while the boat on the right is collecting plankton samples by pumping about 50 cubic feet of water from five different levels through a plankton net about like parachute silk.

Some of this plankton are animal, like this "Keratella" (Fig. 6), and some are plants, such as this "Melosira" (Fig. 7).

In the laboratory of the University of North Carolina, at Charlotte, a local biologist identifies and counts plankton (Fig. 8).

In our laboratory, 14 chemistry parameters are run on the 36 water samples on a bimonthly basis (Fig. 9).

From RP49 should come the answer to the question, "Is there substantial toxicity to biota around power plants from warm water and how much?" EEI's $750,000 investment will be more than matched by the expenses of participating companies and cooperating local agencies.

Certainly additional research is needed to be sure that we are protecting our water resources. Ecologists speak of the "Chain of Life." We are involved in a chain of consumption or of use. I believe that we can learn much from the ecologists' approach—they believe, you know, that no animal or species should be viewed on its own, but always in relation to other items in the environment which surround it. It seems to me that in looking at the problem of thermal effects, it is sensible to take a similar approach. Within our own portion of the chain of use, we should be sure that our power plants have a minimal impact on the total environment, but more than that we should be constantly aware that the solutions which we devise to our own problems may upset the balance of someone else's solution to his particular problems.

For example, there is good evidence that adding large amounts of heat to water in itself is not likely to have harmful effects on the life in and around the water at low temperature levels; however, there is strong evidence that protracted additions of warm water on a long series of very hot days at low river flows in areas where sewage wastes are being dumped will upset the balance of life in and around the water in a variety of ways, some of which are harmful. This is the kind of change that we must avoid at all costs, but who should pay for the protection, the sewerage dumper or the utility? This is a very sensitive area to discuss.

Fish, Wildlife, Recreation Problems

The problems that our industry faces are mostly related to fish, wildlife, and recreation rather than public health. I don't believe the facts have established that warm water discharges from power stations cause a direct health problem. So, what it boils down to—if you will pardon the pun—is how much investment can be justified for what degree of total protection of fish populations. Let's look for a moment at some of the statements that are quoted as fact about cooling water discharges which are really more in the category of half truths.

Half truth #1—Any heat added to rivers and lakes is bad.

Actually, addition of heat can be beneficial in certain circumstances as has been well documented in the technical press. The sun adds most of the heat anyway.

Half truth #2—The utilities are sitting back and doing nothing about thermal effects from their power stations because of the cost involved.

Utility companies have spent many millions of dollars over the years to avoid undesirable temperature changes. They are presently engaged in extensive nation-wide research to determine what further degree of environmental protection is needed.

Half-Truth No. 3

Half truth #3—All organisms are killed in passing through the condenser.

Adams of PG&E at the American Power Conference in April reported a very high survival rate of all organisms that pass through condensers. Results of experiments in the laboratory that hold specimens at set temperatures for 24 hours do not correlate with the same exposure to temperatures for a few seconds while passing through the condensers and into the receiving waters. Field experience shows that the survival rate is extremely high. A biologist recently told me of being in a glass-bottomed boat in Florida observing plant specimens that according to the textbooks could not exist at the temperature he was measuring. This points up the urgent need for actual field data to prove that organisms have great adaptability to specific environmental conditions.

Half truth #4—Cooling towers are the ultimate answer to heated water discharge problems.

Cooling towers *may* be the answer in some cases; however, there may be problems associated with cooling towers that involve consumptive use of water, concentration of salts and blowdown problems, icing, and weather problems that make cooling towers unacceptable in certain applications.

Half truth #5—Warmed water discharged from power plants is low in dissolved oxygen.

Dissolved oxygen is essentially unchanged to somewhat higher in power station discharges. This has been reported much to the surprise of several utilities who find that dissolved oxygen in their discharge canals is running higher than in the source water itself.

Half truth #6—Unless we can stop the addition of heat to our water now, we will do permanent damage.

Assuming that there is some undesirable damage from warm water at a specific location, this damage would be temporary, and if the water temperature was lowered the ecology would gradually be restored.

Half truth #7—Once water is warmed, it cools very slowly.

Research Project RP49 information indicates that water actually cools much more rapidly than originally suspected. Thermal stratification of warmer water to the surface results in rapid heat loss to the atmosphere. The warmer the surface water, the quicker the heat is released.

Half truth #8—Nuclear plants discharge hotter water than coal-fired plants.

We know that there does not have to be a difference in the *temperature;* however statements made to the public indicating that nuclear plants reject 50 percent more heat, while true, have confused the public since they do not realize that this is accomplished by using 50 percent more water.

Half truth #9—Diseases of fish are more of a threat as water temperature increases.

Conditions *are* more favorable for disease-producing organisms at higher temperatures; however, Travelers Research Corp. reports that one researcher, in describing his work with non-specific infections of fish, concludes that the defenses of fish to infection vary with the temperature. At low temperatures fish may not purge the bacteria from their systems, but at higher temperatures the defenses can eliminate the disease organism. I understand that hobbyists commonly put pet fish in warm water to cure their diseases.

Half truth #10—Fish kills caused by heated water discharged from power plants are common.

FWPCA reports approximately 10 fish kills which they attribute to heated water discharge from power stations since they began keeping records. Certainly there have been very, very few instances in the 90-year history of our industry. Fish can detect temperature and will swim away from undesirable locations.

As our use of water multiplies and as we concentrate in single units large blocks of power, the problems of heat release are certain to multiply. This will be partially offset by the trend to higher efficiencies of our new power stations—no doubt accelerated by high fuel costs. Waste heat is abhorred by utility engineers. We much prefer to convert to electricity every single Btu possible. At present, in our fossil-fired stations, we are utilizing only 40 percent of our energy, and in our nuclear stations, probably 30 percent.

What can be done to improve the utilization factor? Can we use the low-grade condenser heat for desalting plants, for fish farms, for hothouse farming? So warmed water can produce algae—how about doing some algae farming since algae has 45 to 55 percent protein versus alfalfa's 20 percent protein—with alfalfa worth $40 per ton? Way-out thinking? Impractical? It may be possible that some such wild idea might conceivably provide an economic solution to some of our problems. How about the future use of the binary vapor cycles—magnetohydrodynamics, developments of breeder and later fusion reactors—greater use of extraction turbines furnishing steam for heating cities, or steam to nearby industries that will return condensate but not add heat to the natural waters? Further research efforts are needed in such areas and many of these are being actively pursued.

Aren't Doing Damage

Out of current research are coming results that indicate that we aren't doing significant damage and provide an excellent basis for future designs. Future research will give us and the regulatory agencies enough information to more completely answer the question of cause and effect and the degree of damage to the ecology. Our rate payers should not be required to carry tremendous financial burdens far beyond reasonable social or economic cost-to-benefits ratio based on someone's fear for what might be.

For example, there are some who advocate the completely closed, water-to-air, automobile-radiator-type cooling towers, which can cost $25 to $35 per kilowatt of capacity. To my knowledge, there is only one such device in service and it is in England on a small unit of less than 200 megawatts and in a cool climate. Further, it would cost millions more through its detrimental effect on plant efficiency. Designers should consider providing foundations in the initial layout for features such as alternative cooling facilities, multilevel intakes, auxiliary pumping equipment, or possible future discharge arrangements where an individual site is marginal.

Must Take Several Steps

No matter how much we know or how right we are, we may not be permitted to do the reasonable and rational thing. There are several steps that we must take if we are going to gain the understanding of the public and regulatory agencies to convince them that we will protect the environment:

- Every utility should give environmental matters a high priority in its corporate planning. One of your most capable technical people should be assigned full time to environmental matters and, in cases of larger companies, several people or a department may be in order. It is impossible for managers with responsibilities in production, operation, design, and other company functions to devote sufficient time out of their daily schedules to give these complex matters proper attention.

- Lend your financial support to research work of the Edison Electric Institute and others. Conduct your own research projects as they relate to siting of your specific power stations. This support should be generous—the alternatives are more costly.

- Know your local university biologists, your state wildlife and regulatory people. Involve them in your research projects at an early date. One of the most discouraging things that has been observed around the United States by persons involved in conducting EEI Research Project RP49 has been the time and effort spent on the part of some regulatory people just to prove a utility wrong. Conversely, one of the most encouraging things has been to observe the progress that was made when, at an early stage in research projects, state agencies, local biologists, and power company personnel get together, lay the cards on the table, and share information as it is developed through sharing in the work responsibilities associated with water research projects. You should be careful to choose the biologists from among those who are capable, objective, and who fall into the category of "doers" rather than "talkers."

- Put your public relations house in order as it relates to thermal effects. This can be done in many ways—at least one company provides fishing information to the public where they pay their power bills.

My own company recently conducted a thermal effects seminar to which we invited members of the press, TV and radio, editors of wildlife magazines, sports writers, and regulatory personnel. At this day-and-a-half seminar, they were shown an actual power plant, the processes were explained, and this was followed by a seminar which covered the subject of warm water effects as they are known today—what we do not know—and what our industry is doing to protect our waterways from damage from the heat from power stations. A full description of our work with RP49 was followed by a panel discussion with questions from the audience. You would be surprised at how many of these people thought that the steam that we were condensing was at 212 degrees instead of at body temperature, and that it was literally possible for us to create very high temperatures in cooling water discharge.

If we expect our customers and the general public to have confidence that we are solving the environmental problems which face us, we must tell them what we are doing. A group of our companies has been describing its activities in a series of newspaper advertisements. Long Island Lighting Co. has made a slide presentation for schools and clubs on the use of warm water for oyster nurseries. There are many ways to tell our story. We should be telling it over and over again.

- Our industry, through this Institute, should take steps to open communication of research results with the Federal agencies. We all want the facts, and the quicker both groups get the facts, the quicker we will have truly equitable solutions to whatever water problems do exist or may arise. Certainly we should oppose the approach certain persons have avowed that says, "If we don't know enough to set up limits, then we don't know enough to justify allowing these discharges at all."

Must Plan for Future

I believe it was John Galsworthy who said, "If you do not plan for the future, you cannot have one." I am proud of the planning and work that our industry has done to protect our environment and I am confident we will measure up to future challenges. I offer these thoughts for your consideration as you involve your company ever more deeply in environmental matters.

ASCE SPECIALTY CONFERENCE
RESEARCH NEEDS IN THE CIVIL ENGINEERING ASPECTS OF POWER
PANEL ON WATER QUALITY CONTROL
PULLMAN, WASHINGTON, SEPTEMBER 11 - 13, 1968

IMPROVEMENT IN QUALITY OF RESERVOIR DISCHARGES THROUGH TURBINE OR TAILRACE AERATION

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1. INTRODUCTION

The need for increasing the dissolved oxygen in water releases from power dams can occur for several reasons. Depressed oxygen levels can be caused by inadequate treatment (in which case artifical aeration should not be employed as a substitute for adequate treatment) ; by the discharge of effluent from efficient treatment plants into streams overloaded because of inadequate flow; or by the release of hypolimnetic waters degraded in dissolved oxygen through low level intakes. In considering alternative means of aeration, the value of the added dissolved oxygen must be weighed against the cost of providing it. Each solution involves capital investment, power consumption, and/or operating and maintenance costs. Aeration techniques have been applied both upstream and downstream of power intakes.

2. INCREASING DISSOLVED OXYGEN UPSTREAM OF INTAKES

Several methods have been applied upstream of dams to improve the quality of discharges. At several large power reservoirs submerged weirs have been successfully employed to selectively admit to power intakes oxygen-laden waters from the epilimnion of the stratified lake.[1,2] Design criteria for submerged weirs have been well established so that predicted performance can be achieved with good accuracy in cases where the stratified pattern of the reservoir is defined. Submerged weirs involve substantial capital cost, but require little or no maintenance and negligible head loss. Submerged weirs are in service at the Gaston and Roanoke dams on the Roanoke River and the Cowans Ford Dam on the Catawba River in North Carolina and are under construction at the Keowee and Jocassee Dams in the upper Savannah River Basin in South Carolina. Similar in concept to submerged weirs are multi-level intakes which can be selectively controlled to draw from desired levels in the impoundment. Folsum dam in California has been equipped with controllable shutters over the intakes for this purpose.

To aid reaeration, artificial vertical mixing has been employed to destroy stratification and progressively expose all waters of the impoundment to the surface thus creating essentially homogeneous oxygen content. The energy required to vertically mix reservoirs and prevent stratification has been estimated by Kitrell.[3] The use of mechanical pumps to create vertical mixing has met with moderate success on a reservoir[4]; and in the ship and sanitary canal of Chicago[5]; and with improved results in a Kentucky lake during 1964 and 1965.[6] Successful vertical mixing by admission of compressed air through perforated pipes on the lake bottom has been reported by Riddick[7] at a reservoir in Ossining, N Y and by Ford[8] at Lake Wohlford, California. Originally developed to prevent icing or control waves at dockside, the aerohydraulic gun has been used to break up reservoir stratification.[9] These several means of breaking up stratification have been comparatively analyzed by Thackson and Speece.[10] Their successful application to date has been limited to relatively small reservoirs. Their application to large power impoundments would cause warming of otherwise cool hypolimnetic waters, and thus destroy the hypolimnion's potential use as a source of low-temperature condenser cooling water for thermal power plants.

3. AERATION TECHNIQUES DOWNSTREAM OF POWER INTAKES

An attempt at improving downstream water quality by tailrace aeration was made by admitting compressed air through diffuser plates in the bottom of the tailrace with limited success.[11] The use of mechanical pumps as surface aerators does not seem to have practical application to tailraces. Other methods, such as aeration by pressure injection or "U-tubes" are suggested as possible aeration techniques on small streams[12], but not on the scale represented by hydro tailraces. Two aeration methods that may have tailrace application are turbine aeration and aerating weirs.

In 1957, turbine aeration at the Pixley Dam on the Flambeau River in Wisconsin was found to be successful in increasing the tailrace dissolved oxygen.[13] These encouraging results led to the application of turbine aeration on seventeen additional dams on two other rivers in Wisconsin as a cooperative state-industry program. Where waterwheels are set above tailwater level, a vacuum often develops in the draft tube. For example, a vacuum of 10.7 to 11.6 in. Hg is produced in the Pixley Dam draft tubes throughout the range of gate openings. Many of these wheels were equipped with vacuum breakers to admit air, sometimes only at low loads, for vibration or cavitation control. Aided by the turbulence in draft tubes and tailraces, air admitted by vacuum breakers often results in significant increases in dissolved oxygen. Absorption efficiency is greatest when the initial saturation level of dissolved oxygen is 40% or less. Without a change in gate setting, admission of air reduces the power output. Thus, increasing dissolved oxygen by turbine aeration has an associated energy cost. In the Wisconsin installations, from one-half to five tons of oxygen were absorbed per day for each 1000 cfs flow. This was at the expense of an energy loss ranging from 0.2 to 2.0 kwh per pound of oxygen gained.[11,14]

At the Wylie Station on the Catawba River in South Carolina, turbine aeration experiments were made in connection with wheel operation for low flow augmentation.[15] In this case, the wheel settings are such that vacua are not produced in the draft tube except at very low loads. For example, on these wheels rated at 15,000 kw, vacuum breakers are only effective at loads of 1,000 kw and below where wheel efficiencies are substantially lessened. An offpeak discharge of 1300 cfs can be passed through one of these waterwheels to develop an output of 5600 kw at which load no vacuum is produced in the draft tube and turbine aeration will not occur. Alternatively, the same flow can be split between two wheels to develop 1000 kw each with vacuum breakers fully operative but at a sacrifice of 360 kw in power output for the same 1300 cfs flow. Operation of a wheel at 1000 kw has resulted in oxygen absorption ranging from 6 to 10 tons per day per 1000 cfs flow depending upon initial saturation deficit. However, due to the inefficient wheel loading to obtain effective vacuum breaker operation, this results in an energy loss of 4 to 7 kwh per pound of oxygen absorbed.

For the many modern waterwheels set at or near tailwater level, no vacuum is produced in the draft tube except at very low loads if at all. Hence, turbine aeration by vacuum breaking is not possible in these installations. Theoretically, compressed air could be introduced in such cases into the distributor or draft tube for turbine aeration purposes, but associated costs are expected to be high. Opportunities for turbine aeration will be largely limited to older installations having high wheel settings, and modern large capacity units will only be suitable for aeration where the setting established for other reasons is coincidentially appropriate for aeration.

Where discharges from dams have a large oxygen deficit and turbines are either inappropriate for aeration or do not exist at all, a low weir across the tailrace may be justified if an oxygen gain has a high value. Gameson and others[16] developed an equation for reaeration at a weir with a single free-fall, and subsequent installation of weirs has confirmed the applicability of this equation over a wide range of circumstances.[17] For example, water at 20°C containing 2.0 mg/l of dissolved oxygen flowing over a weir can result in an oxygen absorption of 5 tons per 1000 cfs per day with a free fall over the weir of 1.6 feet. Such a head loss has an energy equivalent comparable to the energy loss experienced at some of the Wisconsin turbine aeration locations producing a similar rate of oxygen absorption. The relative effectiveness of turbine aeration at three dams and of an aerating weir is shown on Table 1. Whereas the energy losses for the same oxygen absorption are comparable for the weir and Wisconsin dams, an energy loss many times greater applies to the Wylie dam which must operate at inefficient loadings for turbine aeration to function.

4. UNKNOWN AREAS

To determine whether turbine aeration can be practical and effective at specific existing or planned installations requires a better understanding of the mechanism so that results can be predictable. Not clearly defined is the relationship between draft-tube vacuum and wheel setting, turbine type, draft tube configuration, etc. A research need is also indicated for a sensitivity analysis of vacuum versus absorption efficiency and saturation deficit. Additional work on the aerating weir will be necessary to determine its effectiveness and applicability to tailraces of large-scale power installations. From such future research, we may learn whether tailrace aeration devices represent an effective tool in water resources management or an expensive substitute for adequate waste treatment.

TABLE 1

COMPARATIVE PERFORMANCE OF STREAM AERATION DEVICES

	Examples of Turbine Aeration			Theoretical Aeration Weir
Installation	Pixley Dam	Rothschild	Wylie	-
River	Flambeau	Wisconsin	Catawba	-
Date	1958	1958	9/14/59	-
Reference	11	14	15	16
Streamflow, cfs	317[a]	1,762[a]	1,300[a]	1,000
O_2 absorbed, lb/day	3,330[a]	10,430	19,600	
O_2 absorbed, lbs/1000 cfs/day	10,340[a]	5,920[a]	15,080	10,000
Energy loss, kwh/day	1,040[a]	1,900	85,500	-
Energy loss, kwh/lb of O_2	0.31	0.184	4.9	0.275[c]
Energy loss - absorption - flow ratio, kwh/10,000 lb of O_2/day/1000 cfs	1,005	3,200	56,800	2,750[c]
Equivalent head loss in ft/10,000 lb of O_2/day/1000 cfs	0.6	1.9	33	1.6[c]

a. Data shown in reference listed in column above. All other values calculated by Lee using these and other data from respective references.

b. 1720 kwh/day is energy equivalent of 1000 cfs and 1 ft head at 85% efficiency.

c. Using equation from reference 16, water temperature 20°C, upstream dissolved oxygen 2.0 mg/l: $r = 1 + 0.11a(1 + 0.046T)h$

Where: r = ratio of upstream saturation deficit to downstream saturation deficit,
a = coefficient for water quality (1.25 for slightly polluted water, 1.0 for moderately polluted water and used in above example, and 0.8 for sewage effluent),
T = water temperature, °C, and
h = height of free fall over weir, in ft.

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LAKE NORMAN WATER RESEARCH PROJECT
DUKE POWER COMPANY

For a number of years, the Company has had a Water Research Department concerning itself with water quality in our streams and reservoirs. Close liaison has been maintained with state and local officials in our water management programs, and in 1965 the Company began a major research project to study the effects of cooling water discharge at its Marshall Steam Station site on Lake Norman. The first phase of this study involving heat dissipation capability of receiving waters has been completed. The project's second phase, which includes a study of the biological effects from cooling water discharge is now underway.

This national project is under the sponsorship of the Edison Electric Institute with Johns Hopkins University coordinating and directing the research. The Company, the North Carolina Division of Inland Fisheries of the Wildlife Resources Commission, and consultants from University of North Carolina branches at Chapel Hill and Charlotte, are assisting in the collection and analyzing of specimens. The biological phase is expected to cover a period of at least three years and should produce important factual information concerning the effects of cooling water discharge on marine life.

ENCLOSURE No. 7

LAKE KEOWEE WATER MONITORING PROGRAM

The purpose of this program is to monitor the physical and chemical characteristics of surface water in the vicinity of Lake Keowee and the Oconee Nuclear Station.

The program was initiated in the summer of 1965 with the establishment of 8 monitoring stations on the Keowee, Little River and Seneca River arms of the Hartwell Reservoir.

Samples are taken from a vertical profile (summer months 1', 5' thru 40', 50', 60' etc; winter months 1', 10' 20' etc.) at each station. The following parameters are measured from each depth at each station: temperature, dissolved oxygen, pH, turbity, total Fe and Mn. A composite (surface, mid-depth and bottom) B.O.D. is also measured at each station.

Stations were sampled periodically in 1965 and 1967 (total of ten (10) times each station.) Since January of 1967, all stations have been monitored on a monthly basis.

The continuation of this program will include the establishment of appropriate sampling and monitoring stations in Lake Keowee after it fills. In addition, provisions are being made for the installation of multi-point temperature recorders at the cooling water intake and unit effluent lines and in the connecting canal between the two arms of the lake, plus continuous temperature and dissolved oxygen measurements in the tailrace.

DEV:RFG/pc

September 10, 1969

Encl 5 of
Encl #3

Nuclear Power at Oconee

3314

Nuclear Power at Oconee

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Chicago, Illinois
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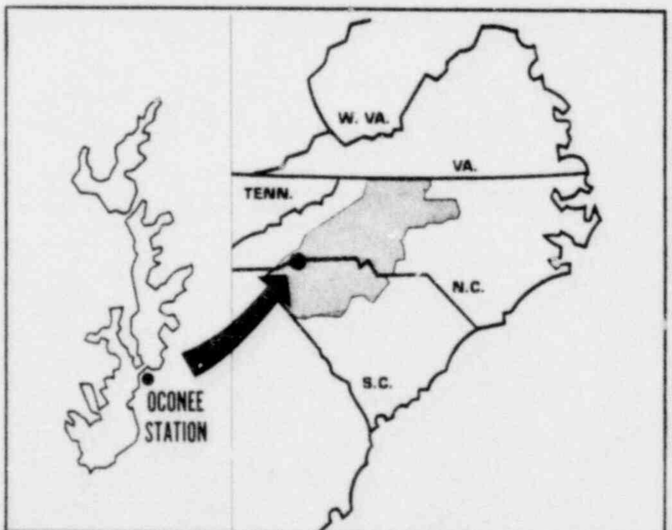
Introduction

The three-unit 2658 Mwe Oconee Nuclear Station of Duke Power Company is the largest private utility nuclear power plant licensed for construction today. With an expected net station heat rate of 9,951 Btu/kw-hr, it appears that Oconee will be the most efficient commercial light water reactor nuclear plant in the world and the first to break 10,000 Btu/kw-hr. When all three units are in commercial operation in 1973, Oconee will represent 28 per cent of the 9300 Mw Duke system capability.

As a part of the Keowee-Toxaway Project in the Piedmont Carolinas, Oconee is located **(Fig. 1)** in Oconee County, at the western end of the Duke Power System in northwestern South Carolina near the North Carolina-South Carolina borders.

The Keowee-Toxaway Project[1], was begun in March 1967 and will consist of two lakes used for sources of cooling water, hydro power and pumped storage capacity. The lower Lake Keowee is actually two lakes, connected by a canal, and is formed by dams on the Little River and Keowee River. Keowee Station will have two conventional 70-Mw hydroelectric generators. Construction of the 385 ft high Jocassee Dam will form upper Lake Jocassee permitting installation of four 152.5 Mw reversible pump turbines. When the initially committed construction is completed in 1978, the Keowee-Toxaway Project will represent an investment of $365,000,000 and a total generating capability of 3408 Mw. Later, two additional thermal plants are planned on Lake Keowee plus further pumped storage upstream of Lake Jocassee which will bring Keowee-Toxaway's ultimate capacity to 8000 Mw or more at a cost of over $700,000,000.

Consistent with Duke's traditional policy, Lakes Keowee and Jocassee will be available for public recreation and as a water supply for neighboring communities. Property around the lakes will be available for picnicking, camping, hunting, summer-home sites, wildlife resources, and other uses to provide maximum public benefit through utilization of all natural resources of the area.



1.

2.

Station site

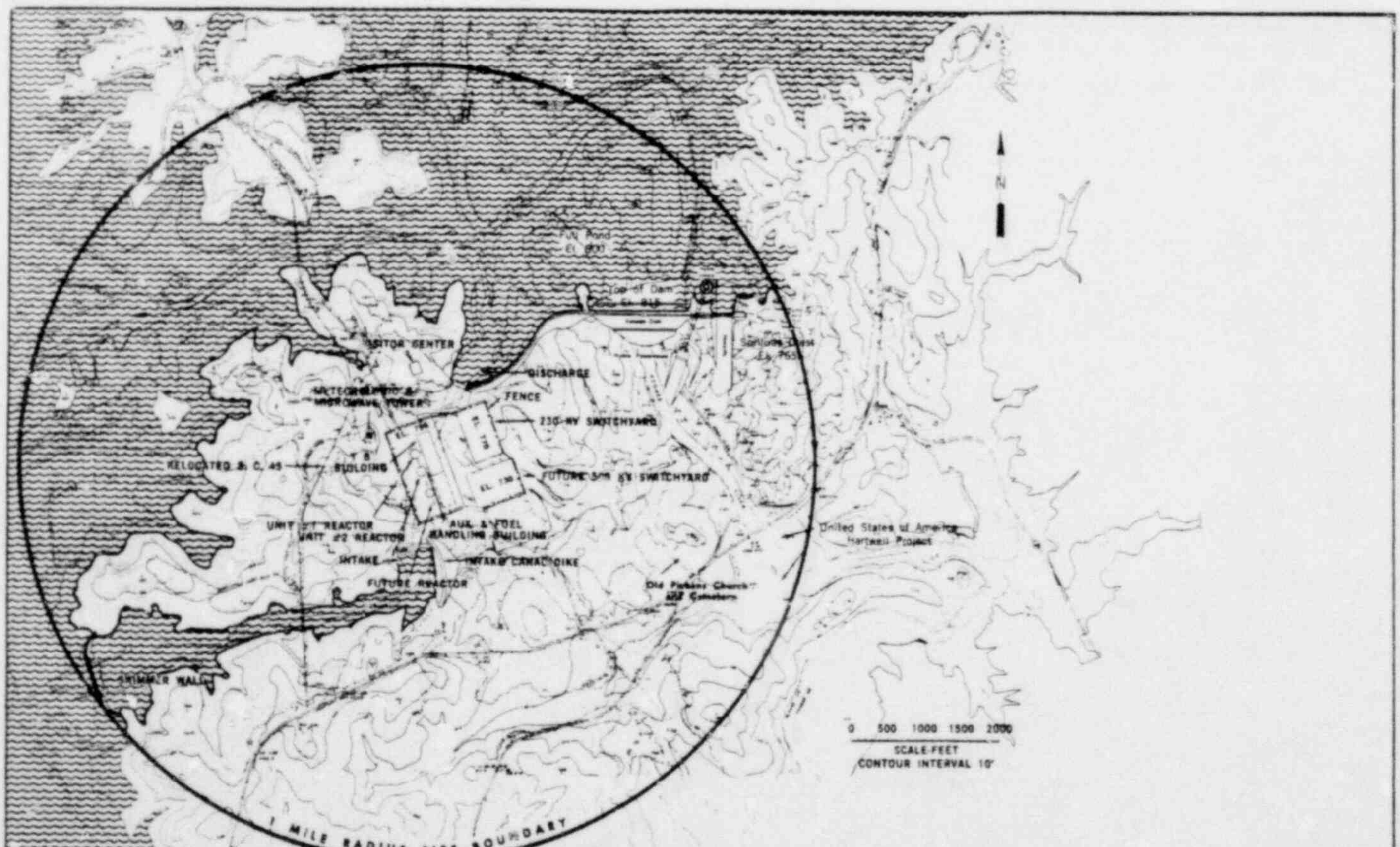
Oconee Nuclear Station is located west of Keowee Dam and south of the canal connecting the two lower lakes as shown in **Fig. 2.**

A posted one-mile exclusion radius will form the actual site boundary. Activities within the site boundary are under the control of Duke Power Company and are limited to highway traffic, observers at the Duke Visitors Center located on a hill overlooking the plant from the north, and recreation on the lakes.

Total estimated population within a five-mile radius is about 2160 people, or approximately 28 persons per square mile. By the year 2010 this is expected to increase to about 2970, or 40 persons per square mile. With this low total population even projected to the year 2010, the site area qualifies as a low population zone and is believed to be favorable among those licensed to-date on the basis of population density.

Meteorology at the site is favorable for a nuclear plant under light wind conditions where the presence of the lakes will increase humidity and wind speed. On-site meteorology is being recorded to document dispersion calculations used in environmental analyses.

The station site takes full advantage of the separation of the twin lakes forming Lake Keowee. **(Fig. 3)** An intake canal south of the plant provides the inlet flow for condenser cooling from the Little River arm of the lake while cooling water is discharged to the Keowee River arm of the lake. Duke's experience with circulating water at Marshall Steam Station has been incorporated in the design of Oconee. Use of a skimmer wall there has improved summer station heat rate through use of cooler water from lower depths of the cooling water source. A skimmer wall for Oconee is being provided at the entrance to the intake canal drawing water from a depth of 70 ft. Temperature of the circulating water is expected to be 15 to 25 F below the summer surface water temperature. Limnological studies have shown that under the worst summer conditions, the water discharged from the condensers into the Keowee River arm of the twin lakes will be at a lower temperature than the lake surface. This arrangement is a means of controlling thermal effects which have become an important subject to utilities.



General station arrangement

Layout

Each of Oconee's three nuclear steam systems is located in its own reactor building. A common fuel handling building and storage pool for both fresh and spent fuel serves Units 1 and 2 and is located between the two reactor buildings. Unit 3 has a separate and independent fuel handling building and storage pool. A machine shop designed to handle and maintain slightly radioactive equipment is located next to the fuel storage pool for Units 1 and 2.

Support equipment and facilities for Units 1 and 2 reactors are housed in a nine-floor auxiliary building. Equipment includes pumps, heat exchangers, tanks, instrumentation, and switchgear as well as laboratories, lockers, showers, a laundry, and health physics facilities. The auxiliary building also houses a combined control room for Units 1 and 2 at elevation 822. A similar arrangement with its independent control room is used for Unit 3 in a separate but connected auxiliary building.

A single turbine building located adjacent to the auxiliary buildings houses three General Electric turbine-generators and support equipment for the steam, feedwater, and condensate systems. The building is about 800 ft long and 200 ft wide. The operating floor is located at elevation 822 to provide for easy access between the turbine operating floor and the control rooms.

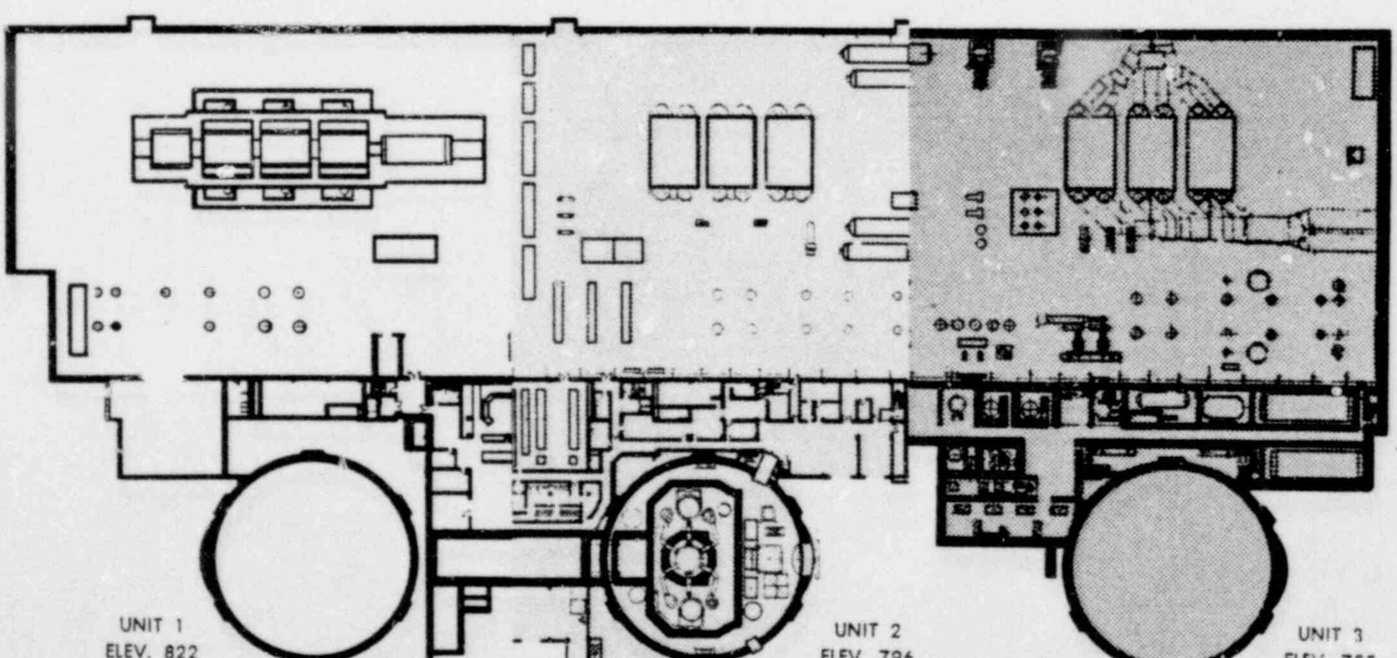
The station has 230 KV and 500 KV switchyards located east of the buildings. Emergency power enters the station through an underground 13.8 KV line from Keowee Hydro Station and through a 100 KV switching station located west of the buildings.

Other structures include an administrative building connected to the north end of the auxiliary and turbine buildings, a 100,000 gallon elevated water storage tank, and a microwave tower also used for weather observations.

Description

A composite plan view of three elevations is shown in **Fig. 4.** Unit 1 view is taken at the turbine operating floor and the combined control room for Units 1 and 2. The turbine-generator is a six-flow machine with 38 in. last stage blading coupled to a 1,038,000 KVA water cooled generator. Two 34 in. diameter steam lines carry 11,194,000 lb/hr of 925 psia steam to the turbine.

The auxiliary building at this elevation contains ventilation equipment, the combined control room for Units 1 and 2, and office space for shift personnel. The shielded control room contains the control console, nuclear instrumentation cabinets, engineered safeguards cabinets, and computers for Units 1 and 2. Each unit has its own computer utilized for turbine cycle control, sequence monitoring, equipment



status reports, controllable loss calculations, recording of in-core instrumentation readings, core power distribution, and fuel management calculations.

The area of each of the reactor buildings through which all of the electrical, instrumentation, and piping penetrations pass is enclosed by walls to form a room. In the unlikely event of a loss-of-coolant accident, followed by a release of fission products, a ventilation system consisting of fans and filters is started which produces a slight negative pressure in the room. Therefore, any leakage through the penetrations will enter the room and, after filtration, will be discharged to atmosphere through the Unit vent.

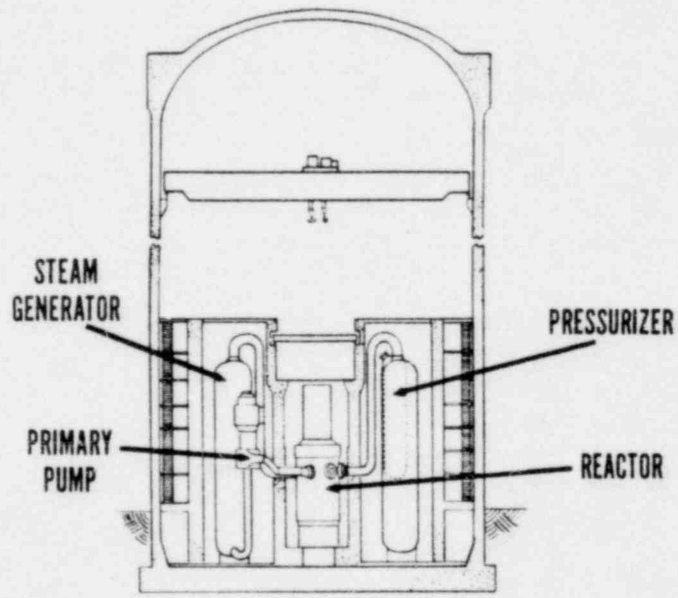
The plan view through Unit 2 is taken at yard grade, elevation 796. The turbine building at this elevation houses the upper portion of the condensers, the four combined moisture separators, and reheaters for each turbine, turbine valves, and the plant switchgear. The auxiliary building at this level includes shipping and receiving areas, equipment rooms, laboratories, health physics offices, locker rooms, and laundry facilities.

Unit 3 is shown at elevation 775. The turbine building houses the condensers, condensate polishing and feedwater systems, service water, turbine driven feedwater, and emergency turbine driven feedwater pumps, and other turbine generator auxiliary equipment. Condenser cooling water lines enter and leave the building just under the floor. In addition to the main condenser cooling water lines, a small line is provided running from the discharge of each condenser to the tailrace of Keowee Hydro. Upon loss of circulating pumps or loss of power, a valve in this line opens and a gravity flow of cooling water, sufficient to remove reactor decay heat, is initiated through the affected condensers. This flow, coupled with turbine driven feedwater pumps, permits the removal of decay heat from the reactor without the need for electric power.

The auxiliary building at this level houses the purification system, decay heat removal system, and waste disposal system tanks. The elevations not shown house additional auxiliary and engineered safeguards equipment for the reactor coolant system.

Each reactor building is a pre-stressed post-tensioned concrete structure with a steel liner. The building has an inside diameter of 116 ft, a height of 208 ft, and is designed for a pressure of 59 psig.

Fig. 5 is a cross-section of the building showing the two once-through steam generators, the reactor vessel, reactor coolant pumps, and the fuel transfer canal. Secondary shield walls around each coolant loop and shielding floors protect personnel from direct radiation. Areas between floors are accessible during power operation.



5.

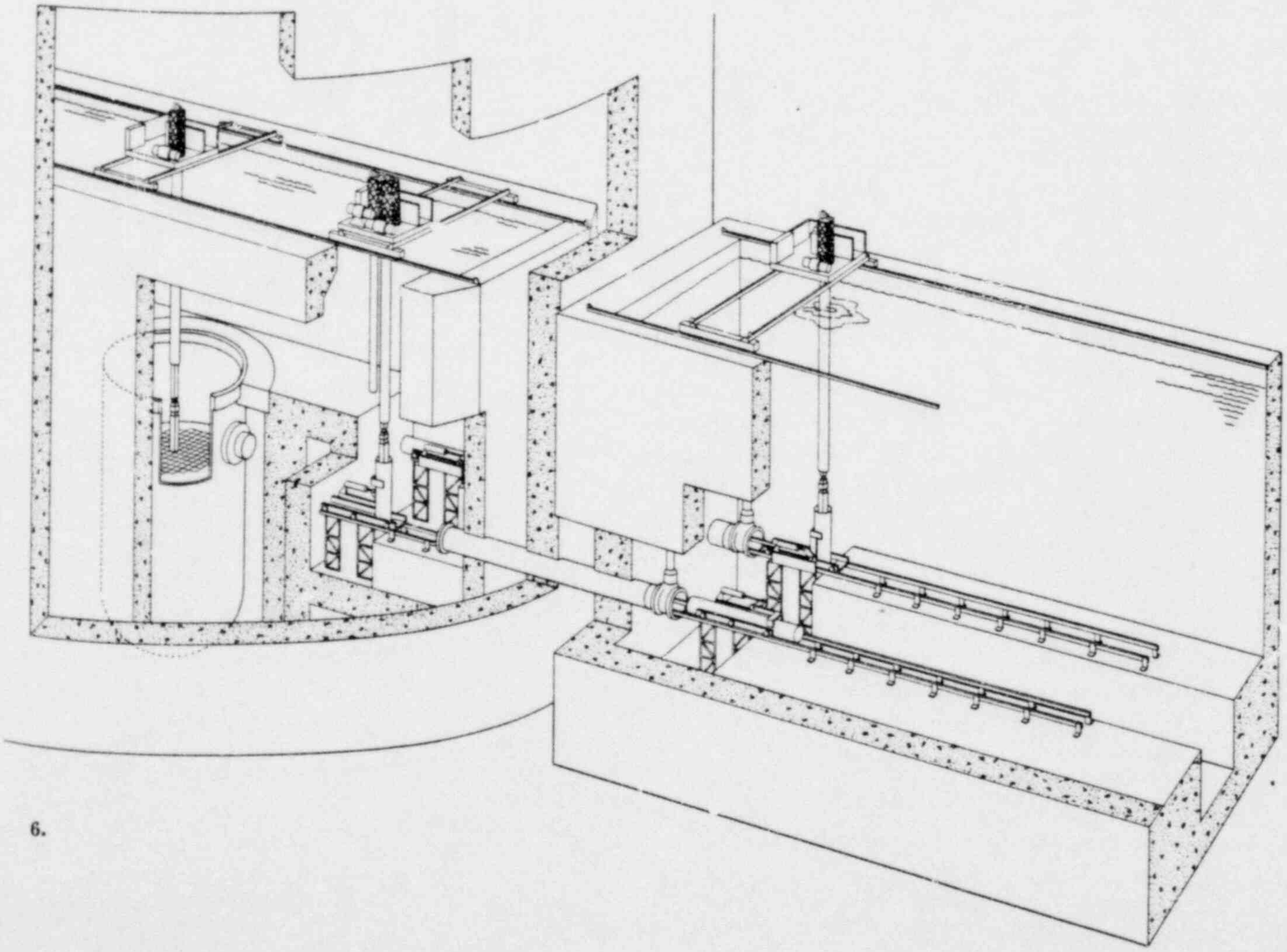
The openings at the top and bottom of each of the secondary shielding compartments are sized to permit the escape of steam in the unlikely event of a major loss-of-coolant accident. A 19 ft diameter equipment hatch at the grade elevation of 796 permits easy access to the main floor of the reactor building.

The fuel handling system for each Unit is shown in **Fig. 6.** New and spent fuel assemblies are transferred between the reactor building and fuel storage pool by dual transfer mechanisms. Within the reactor building fuel is carried by two handling bridges, one of which transports fuel assemblies between the reactor core and the transfer mechanism. The other is free to rearrange fuel assemblies and control rods within the core.

Fuel assembly accounting is maintained by the Unit computer. Information on the replacement and relocation of fuel assemblies and control rods is fed from the computer to the operator by means of a refueling panel mounted on each of the bridges. However, only the bridge operator has control of bridge and tool movement.

Fuel assemblies are carried by a similar handling bridge in the fuel storage building where they are stored in racks to await shipment. Crane facilities and building dimensions are sized for either a small two-assembly shipping cask or a large multiple-assembly cask.

Each unit is supplied with identical handling bridges, handling tools, and storage facilities.



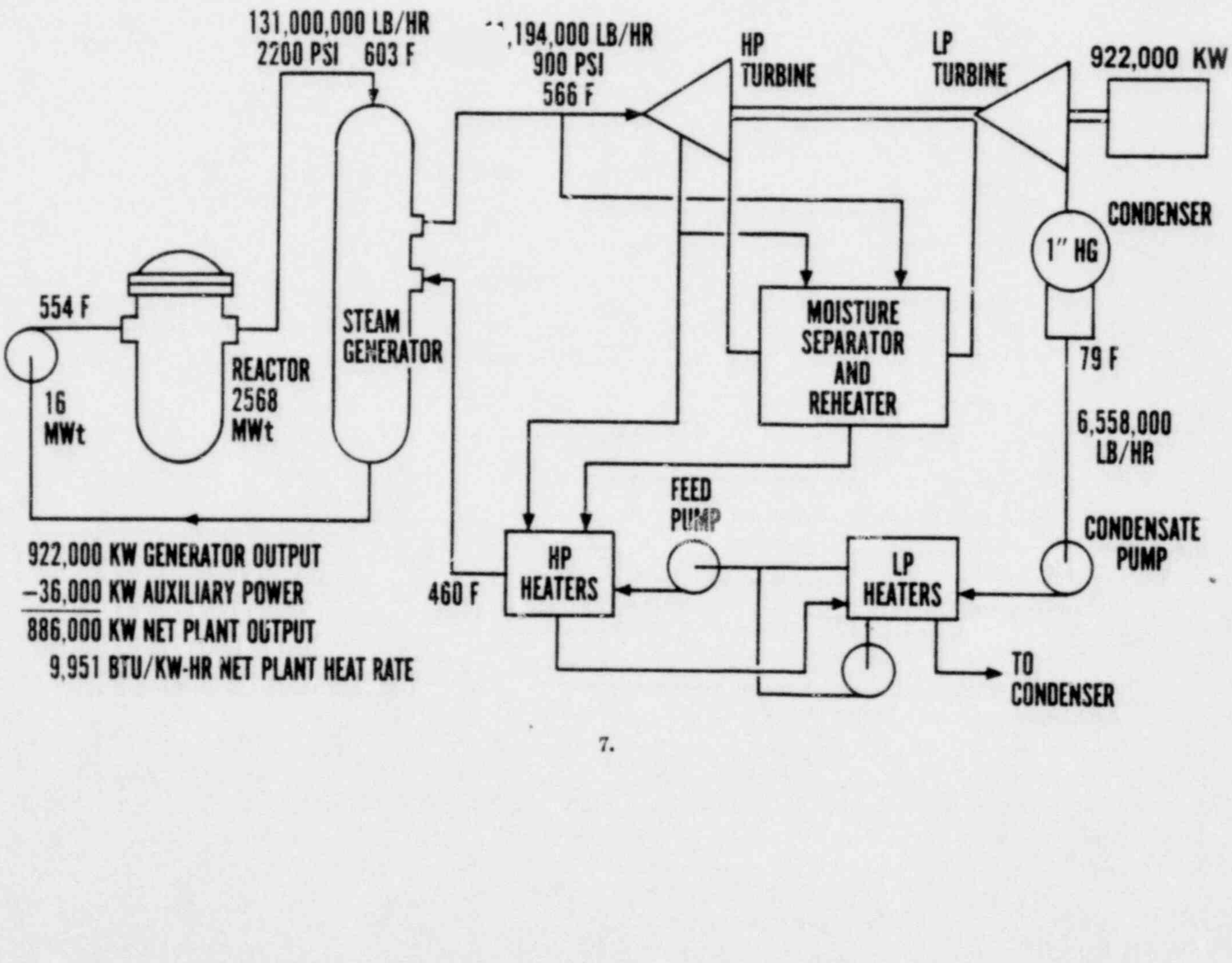
6.

Unit performance

A simplified cycle diagram is shown in **Fig. 7.** At the nuclear steam system capability of 2568 Mw thermal, the gross electrical generation is 922,000 Kw. A net unit heat rate of 9,951 Btu/kwhr is expected with zero make-up and one inch Hg condenser pressure. Feedwater is heated to 460 F by two strings of heaters, each consisting of four low pressure heaters and two high pressure heaters. Combined moisture separators and reheaters provide two stages of reheat between the high pressure and low pressure turbine stages. The first reheat utilizes extraction steam at 537 psia while the second reheat uses throttle steam.

Total unit steam flow is 11,194,000 lb/hr of which 365,000 lb/hr is used for the second stage of reheating.

Powdex polishing demineralizers capable of handling the full condensate flow of 6,558,000 lb/hr are located downstream of the hotwell pumps.



Station electrical system

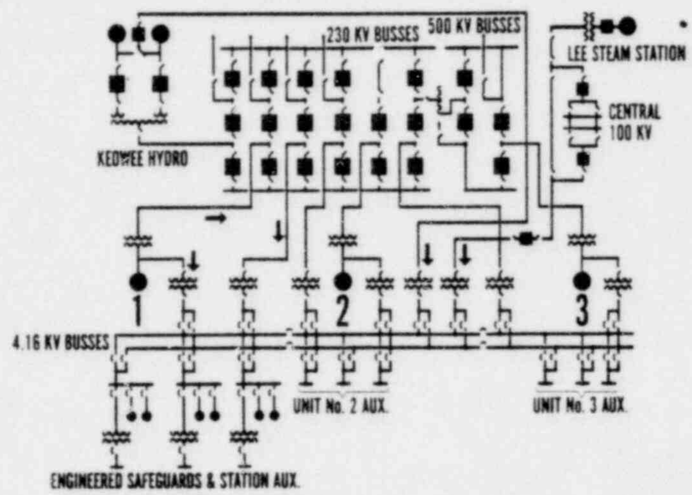
On completion of Unit 3, to ensure operating continuity of station auxiliary equipment under all conditions, each unit at Oconee will have six sources of power. These consist of power from each of the three nuclear units, a 230 KV switchyard, a 100 KV line, and a 13.8 KV underground line from Keowee Hydro. A single line diagram showing the multiple sources of power to station auxiliaries on 4.16 KV busses is shown in **Fig. 8.**

Normal power for unit auxiliaries is carried conventionally from an auxiliary transformer connected to the generator bus. With the auxiliary transformer unavailable, power is supplied through the start-up transformer fed from the 230 KV busses. There are 12 power supplies to the 230 KV switchyard which include eight 230 KV transmission circuits, the three nuclear units, and the Keowee Hydro units. Both the auxiliary transformer and the start-up transformer ratings are sufficient to carry full load auxiliaries of one unit plus another unit's engineered safeguard systems.

If a unit auxiliary transformer or any of the start-up transformers through loss of 230 KV are not available, power still can be supplied to auxiliaries and engineered safeguards from one of the other Oconee units through its auxiliary transformer.

Should power be lost from these sources, a separate 100 KV line from Duke's "Central" 100 KV transmission system provides power to the 4.16 KV busses through a transformer sized to carry engineered safeguards of all units. Under emergency conditions, the 100 KV transmission line can be isolated from the 100 KV transmission system permitting any one of three 33,000 Kw gas turbine generating units at Duke's Lee Station to supply power solely to Oconee.

In the highly unlikely circumstances of loss of power from all sources described above, Oconee has another unique and dependable source of emergency power from Keowee Hydro. The two 70 Mw Hydro units are separately and redundantly connected to Oconee through an overhead 230 KV line to the 230 KV switchyard and a 4000 ft long 13.8 KV underground cable to a transformer sized to carry engineered safeguards for one unit plus orderly shutdown of auxiliaries for all units. Operation of Keowee Hydro will be both automatic and remote-manual from the Oconee control rooms, which gives Oconee operators complete control of its hydro power generation as required for any conceivable emergency condition.



8.

IMAGE EVALUATION
TEST TARGET (MT-3)

6"

MICROCOPY RESOLUTION TEST CHART

Training

Nuclear training at Duke Power Company began over a decade ago when the Company started training engineers who would eventually participate in nuclear power programs. Duke's participation in the Parr project provided a means for continued training of personnel.

Following the decision to design and construct a nuclear station at Oconee, Duke extended training through introduction of a nuclear engineering program in the fall of 1966.[2] Babcock & Wilcox and Bechtel Corporation personnel conducted classes attended by 80 of Duke's personnel.

Part of the technical support and operating staff for the station are presently enrolled in graduate level nuclear engineering courses at North Carolina State University. This training will be completed in June 1968. These men will later teach basic theory required by the station operating staff as the first phase of the operator training program.

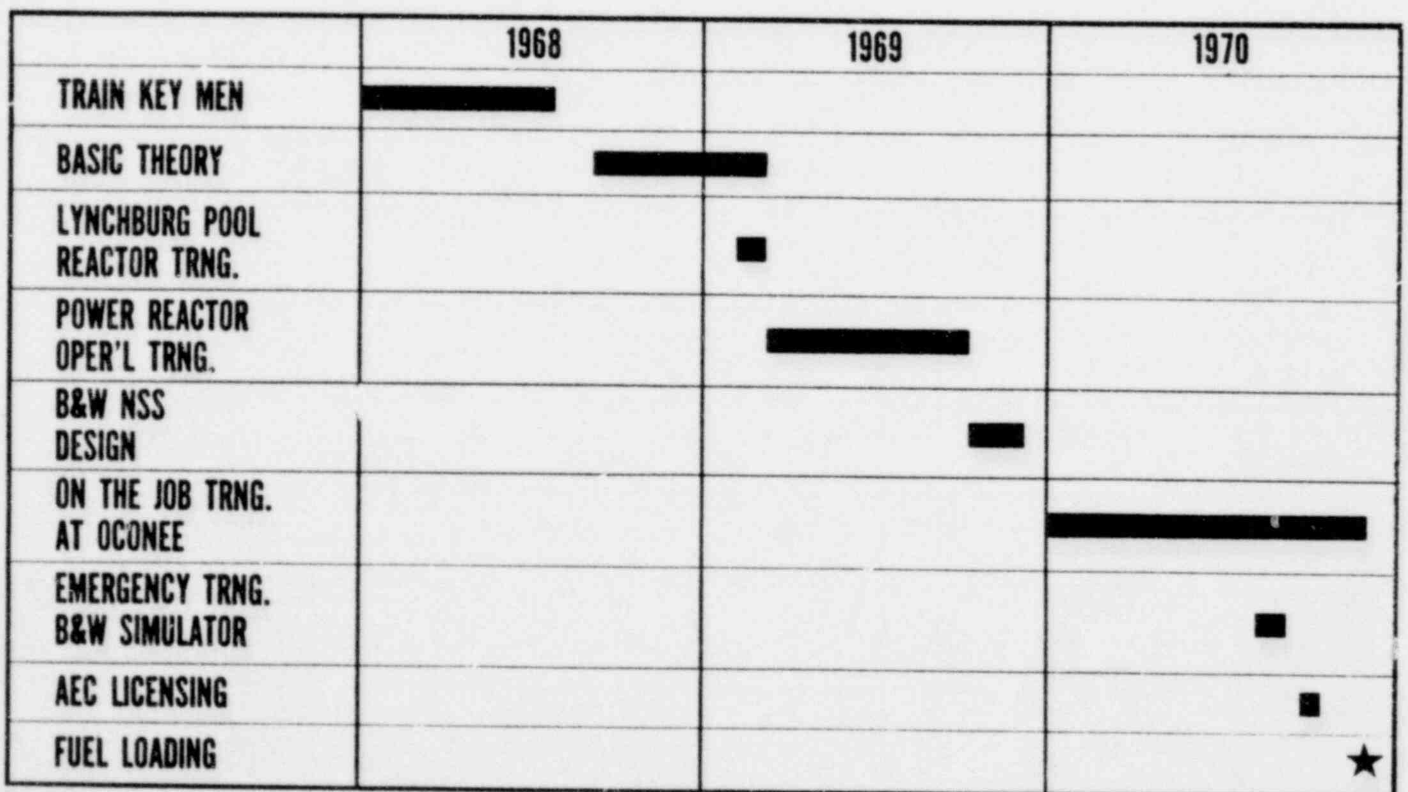
Personnel to be licensed for reactor operation will undergo a five-phase training program spread over about two years shown on **Fig. 9.**[3] The first phase is classroom training in nuclear physics, mathematics refresher, and introductory nuclear engineering.

Phase two covers introductory reactor operations conducted by B&W on the Lynchburg Pool Reactor. During this phase each trainee will conduct a minimum of ten reactor startups.

During the third phase operators will gain actual operating experience at the Saxton reactor.

The fourth phase will be detailed indoctrination in the design and operation of the Oconee reactors given by B&W engineers.

The last phase is on-the-job training at Oconee. In this phase the trainees will become thoroughly familiar with the plant by assisting in preparation of test and operating procedures and by plant operation during the pre-critical test program. AEC operator exams are scheduled for October 1970.



9.

Station construction schedule

10 Significant milestone dates in the station schedule are indicated in **Fig. 10.** The first bar is for Units 1, 2 and 3 and the remainder of the schedule is for Unit 1 only. Contract award date for Units 1 and 2 was June 20, 1966. Application for a Construction Permit was filed December 1, 1966. The award for Unit 3 was made April 21, 1967 and on April 29 the application was amended to include Unit 3.

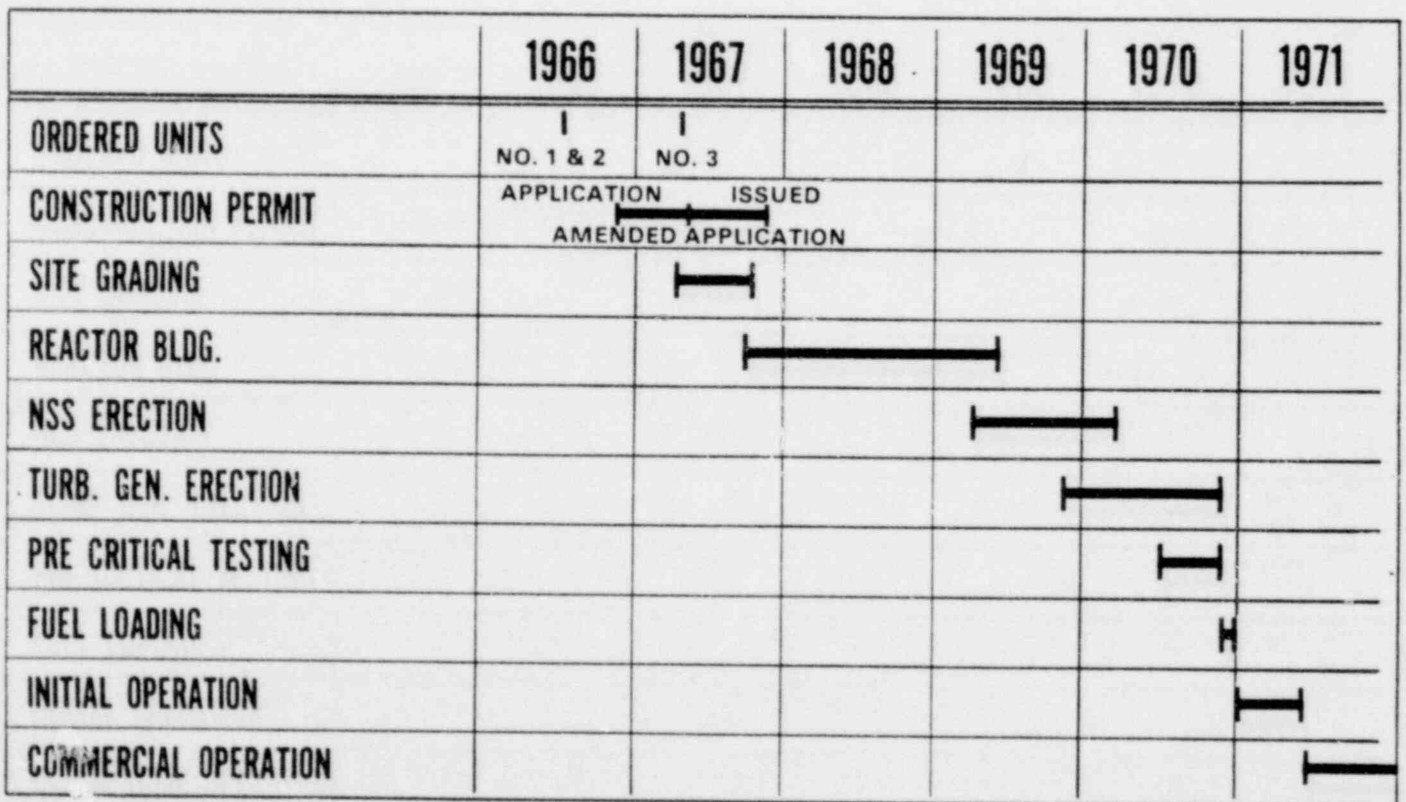
Site grading began March 20, 1967, involved the movement of 2,200,000 yards of earth and rock, and was completed November 1, 1967.

It became apparent in July 1967 that intervenors would delay issue of the Construction Permit. To avoid delay in start of construction and provide flexibility in the overall construction schedule, approval of the AEC was sought to initiate work on the tendon access gallery prior to issue of the Construction Permit. This was obtained and work began on October 15, 1967, a little more than three weeks before issue of the Permits for the three units on November 7, 1967.

The reactor building is scheduled for completion on May 15, 1969.

Start of delivery of the major components is scheduled for March 1, 1969. Continuous erection of the nuclear steam system will begin at that time and is scheduled for completion one year later.

Turbine generator erection will begin December 1, 1969 and finish one year later. During the intermediate stages of plant construction, cold testing of systems will be initiated as systems are completed. Major systems such as the reactor coolant, purification, decay heat removal, waste disposal, and feedwater systems are scheduled for completion by June 1970 and pre-critical testing will begin then. All pre-critical testing is scheduled to be completed by December 1, 1970; operators will be licensed by that time and fuel loading will begin. A total of five months has been allowed from start of fuel loading to commercial operation on May 1, 1971. It is difficult to anticipate what the exact timing of events will be within this period. Approximately two weeks are allocated for fuel loading and four weeks for physics testing. Power operation with discreet tests at various levels is expected to take eight weeks. The remaining seven weeks is contingency.



Status of site work

Construction progress to the end of March 1968 is shown in **Fig. 11**. Excavation of the rock beneath the reactor buildings is complete. The tendon access gallery and concrete mat have been poured on the Unit 1 reactor building. Work has begun on the reactor building side walls.

Des gn of Oconee is by Duke's Engineering Department with assistance from Bechtel as general consultant and designer of the reactor building. As in the case of other Duke plants, construction, including equipment erection, is by Duke personnel in its Construction Department.

11.

Nuclear Steam System

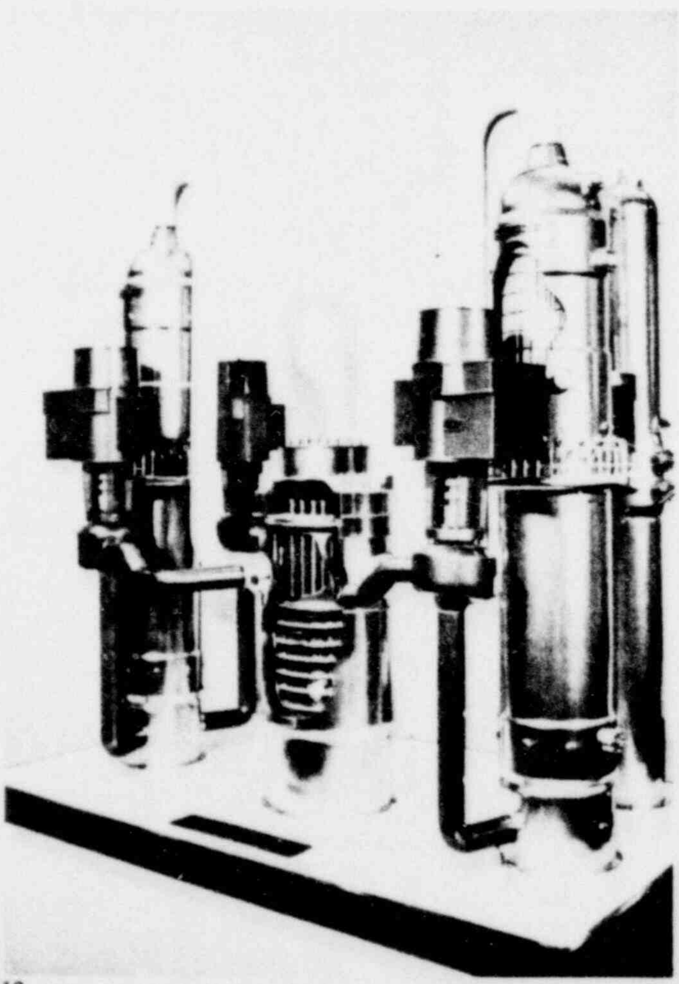
B&W's participation in the Oconee project is the design and supply of the three nuclear steam systems, including auxiliary and engineered safeguards systems, technical direction of erection of this equipment, assistance in operator training, and establishment of design criteria for the balance of plant equipment. In addition, B&W is responsible for delivery of the 350-ton reactor vessel to the site through a combination barge and overland movement. Five cores covering complete fuel supply and three cores of fuel fabrication only are also contracted for.

Reactor coolant system

The Pressurized Water System is shown in **Fig. 12** and consists of the reactor vessel with two steam generator loops. Each loop contains a straight tube once-through steam generator and two reactor coolant pumps. A pressurizer, connected to one of the loops, maintains the reactor coolant in a sub-cooled state.

Reactor coolant piping is 28 in. ID and 36 in. ID carbon steel pipe clad with stainless steel. Each outlet pipe contains a calibrated flow tube used to measure reactor coolant flow during operation.

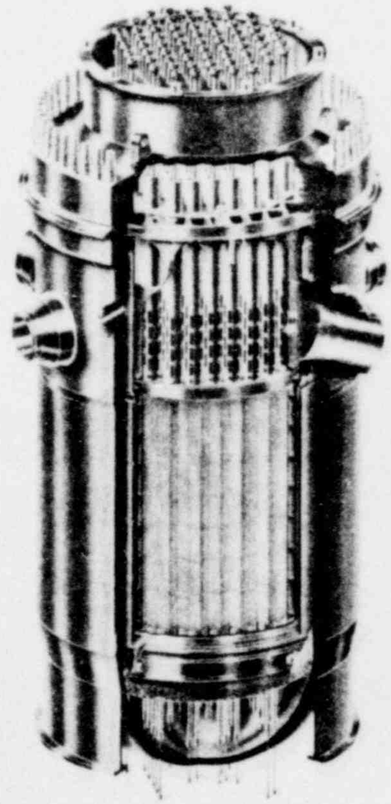
The entire reactor coolant system is designed for 2515 psia and 650 F. Reactor performance is listed in **Table I.** Normal power operation will be at 2200 psia and an average coolant temperature of 580 F. Design conservatism is shown in the average power density of 83.4 Kw/liter.



12.

Reactor vessel

The reactor vessel, shown in **Fig. 13**, consists of a cylindrical shell 171 in. ID by 8-7/16 in. thick, supported by a cylindrical skirt. Sixty 6-1/2 in. diameter studs bolt the reactor closure head to the



13.

REACTOR DATA	
Reactor heat output	2568 MWt
Reactor temperature average	580 F
Reactor operating pressure	2200 psia
Reactor flow	131×10^6 lbs/hr
Linear heat rate average	5.7 kw/ft.
Linear heat rate peak	18.4 kw/ft.
Volumetric power density	83.4 kw/liter
Fuel Weight	201,500 lbs/UO_2
No. of fuel assemblies	177
No. of control rods	69

Table I

vessel, sealed by two metallic O-rings. Pressure taps in the annulus between the seals permit hydrostatic testing of the closure following refueling. Two 10 in. emergency injection nozzles, located at the same elevation as the inlet and outlet nozzles, provide a direct path to the vessel for the injection of water.

The reactor internals are designed to direct the coolant through the core, support the fuel assemblies, and provide guidance for the control rods. The upper assembly, located directly above the core, is removable as a single component prior to fuel handling. The lower assembly is hung from the reactor vessel flange and supports the fuel assemblies, thermal shield, and in-core instrumentation guide tubes. It can also be removed as a single piece for inspection of the reactor vessel surfaces.

Steam generator

The steam generator[4], **Fig. 14**, is a vertical, straight tube-and-shell heat exchanger developed to produce superheated steam at constant pressure over the power range. Reactor coolant flows downward through the tubes and steam is generated on the shell side of the heat exchanger. The tubes are welded to tube sheets at both the top and bottom of the steam generator, and tube supports are provided to hold the tubes in a uniform pattern along the tube length.

Feedwater is sprayed into a feed heating annulus (downcomer) formed by the shell and the baffle around the tube bundle and is heated to saturation temperature by direct contact heat exchange. Dry saturated steam is produced in the film boiling region in the upper section of the tube bundle. The remaining surface increases steam temperature to about 35 F superheat at the outlet.

Reactor coolant pumps

The reactor coolant pumps are vertical, shaft-sealed units with a single-speed, water-jacketed motor.

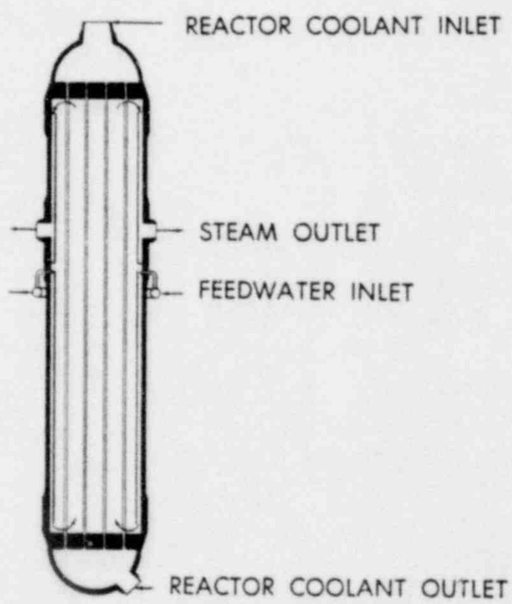
Shaft sealing is accomplished with a throttle bushing and a mechanical seal. Seal water is injected ahead of the throttle bushing at a pressure approximately 50 psi above reactor system pressure. Part of the seal flow passes into the pump volute while the remainder flows out along the throttle bushing and is returned to the seal water supply system. The outboard mechanical seal, which normally operates at a pressure of approximately 50 psig and a temperature of 95 to 100 F, is designed for full reactor coolant system pressure.

Each pump is designed to deliver 88,000 gpm at a developed head of 370 ft. The squirrel cage induction motor requires a power input of approximately 5400 Kw.

Pressurizer

As indicated in **Fig. 12**, the pressurizer is connected to one of the reactor coolant loops with a 10 in. surge line. It is used to establish and maintain reactor coolant pressure within prescribed limits and to provide a surge chamber and water reserve to accommodate reactor coolant volume changes during temperature transients.

The pressurizer contains replaceable electric heaters and a water spray to maintain the steam and water at the saturation temperature corresponding to the desired reactor coolant system pressure. Relief valves, mounted on the top of the pressurizer, function to relieve any system overpressure. The relief valves discharge to a tank containing a stored water supply to condense the steam. A recirculation system is provided to cool the tank water following any relief valve operation.

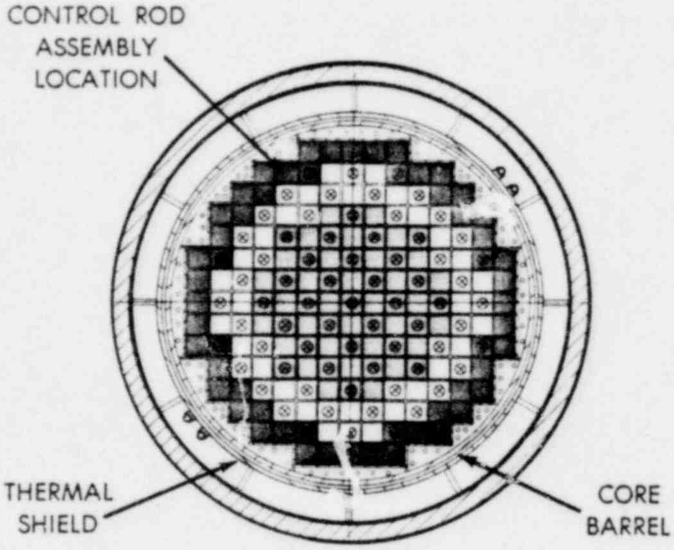


14.

Reactor core

The reactor core consists of three major components; 177 fuel assemblies, 69 control rods, and 52 in-core detector assemblies. These components are assembled into a 12-ft high uniform close-packed array with an equivalent diameter of 129 in. **Fig. 15**, a sectional view of the core, shows the arrangement of the fuel assemblies and control rods in the core.

Reactor fuel is sintered pellets of low enrichment uranium dioxide clad in Zircaloy-4 tubing. Each fuel assembly, shown in **Fig. 16**, consists of 208 fuel rods mechanically joined in a 15 x 15 array. The center tube accommodates the in-core instrumentation. The remaining 16 positions contain Zircaloy tubes used as control rod guides. In those assemblies which do not contain a control rod, the guide tubes are blocked to minimize bypass coolant flow. Fuel rods are positioned by spacer grids located axially along the fuel assembly. The spacer grids are designed to permit relative axial motion between the Zircaloy fuel rod and the assembly structure.



15.

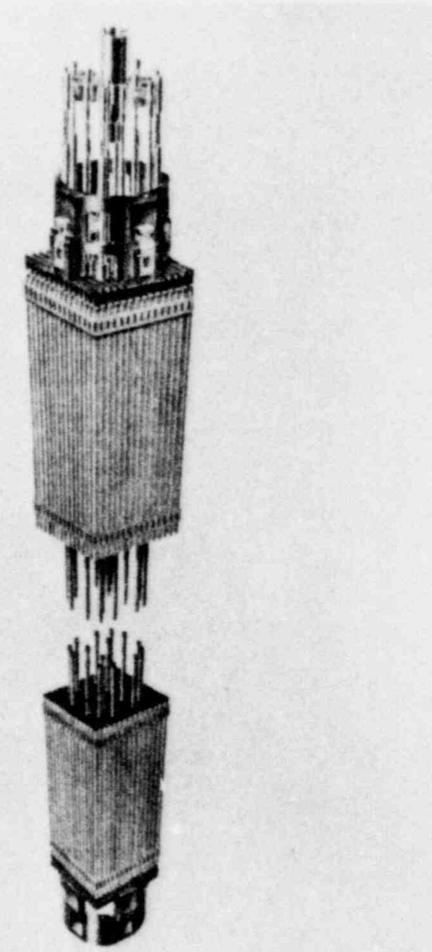
Control rod assembly

Each control rod, consists of 16 control pins coupled to a single stainless steel spider. Silver-indium-cadmium in stainless steel tubing is used as the neutron absorber. The control pins are loosely coupled to the spider to permit maximum conformity with the channels provided by the guide tubes. Each control pin is guided for its full length in the fuel assembly and in the upper plenum assembly above the core.

In-core detectors

The in-core detectors, consist of an assembly of self-powered neutron detectors and a thermocouple positioned within the center tube of fuel assemblies at pre-selected locations in the core.

The in-core neutron detectors have been under test by B&W for a number of years, including operation of a prototype detector assembly in the Big Rock Point reactor. The detector assemblies are inserted into the core through guide tubes which extend from the bottom head of the reactor vessel to an area adjacent to the refueling canal. During refueling the in-core detectors will be withdrawn from the fuel assemblies.



16.

Engineered safeguards

Engineered safeguards systems for Oconee fulfill three functions in the unlikely event of a loss-of-coolant accident:

a) Protect the fuel cladding

b) Insure reactor building integrity

c) Prevent uncontrolled leakage of reactor building contents to the atmosphere.

Each of these operations is performed by two or more systems with multiple components to insure operability.

Post-accident safeguards functions are performed with the equipment used in normal operation as its regular use provides the best possible means for monitoring availability. In cases where equipment is used for post-accident conditions only, the systems have been designed to permit periodic testing.

Emergency injection systems

General arrangement of the emergency injection system is illustrated in **Fig. 17.** The principal design basis for the emergency injection of coolant water to the reactor core is to prevent clad melting for the entire spectrum of reactor coolant system leaks, ranging from the smallest to one with an area equal to that of the largest reactor coolant pipe.

High pressure injection is provided to prevent uncovering of the core for small leaks and to delay uncovering of the core for intermediate-sized leaks.

The core flooding system and the low pressure injection system are provided to recover the core at intermediate-to-low pressures to maintain core integrity with intermediate and larger leaks.

Borated water pumped to the reactor coolant system by the injection systems is supplied from a 360,000 gallon storage tank. Additional coolant for emergency injection is contained in core flooding tanks under nitrogen pressure. This coolant is injected directly into the reactor vessel should the system pressure drop below 600 psig.

Emergency injection into the reactor coolant system is initiated at 1800 psig. The signal automatically increases high pressure injection flow to the reactor coolant system by starting the standby pumps which are switched to the suction of the 360,000 gallon borated water storage tank. Valves in the high pressure injection lines allow discharge of the borated water directly into the reactor coolant loop through four lines.

In response to the AEC licensing requirement that cooling of the core be ensured following an accident in which the simultaneous loss-of-power and severance of the largest diameter pipe is assumed, a core flooding system is provided. This system is composed of two flooding tanks, each directly connected to a reactor vessel emergency injection nozzle by a line containing two check valves. This system does not require electrical power, automatic switching, or operator action to ensure supply of emergency coolant to the reactor vessel. System volume is sufficient to recover the core hot spot assuming no liquid is contained in the reactor vessel. Gas overpressure and flooding line sizes provide core reflooding within approximately 25 seconds after the largest pipe rupture has occurred.

The low pressure injection system is normally maintained on standby during power operation. System pumps provide 3000 gpm supplemental core flooding flow during the accident through the two core flooding lines after the reactor coolant system pressure reaches 135 psig. Emergency operation of this system is initiated by a reactor coolant system pressure of 200 psig.

Low pressure injection with supply from the borated water storage tank will continue until a low level signal is received from the tank. At this time, the operator will open the valve controlling suction from the reactor building sump and recirculation of coolant from the sump to the reactor vessel will begin. Low pressure injection coolers will cool the recirculated flow, removing heat from the reactor building.

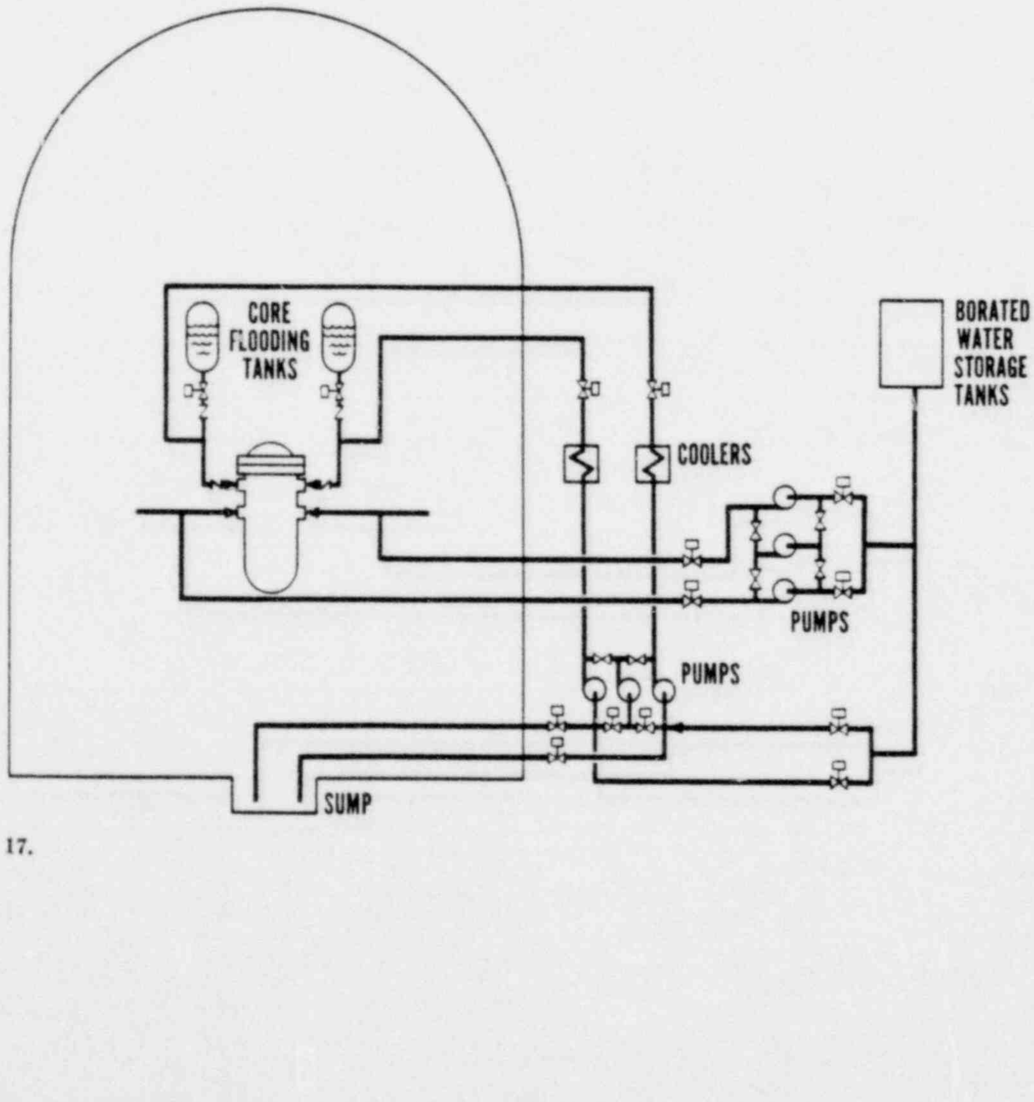
Reactor building cooling

Air recirculation emergency cooling units and reactor building sprays are provided to limit post-accident building pressures.

Each reactor building emergency cooling unit has a rated capacity of 80 x 10^6 Btu/hr with 75 F cooling water at peak post-accident conditions. When the reactor building pressure reaches 10 psig, reactor building sprays are initiated simultaneously with the air recirculation cooling. Two 1500 gpm pumps take water from the borated water storage tank until this coolant source is exhausted. After the supply from the borated water storage tank is exhausted, the spray pumps can take suction from the reactor building sump recirculation line.

Redundancy of equipment within both cooling methods ensures protection of building integrity.

During the 30 to 40 minutes that the reactor building spray pumps take their suction from the borated water storage tank, the spray system provides more than 100 per cent of the heat removal capacity of the reactor building cooling system.



Instrumentation and control

As is true with any utility operating plant, the quality and capability of the instrument and control and protective systems determine to a large extent the ability of the plant to perform to its full capability. **Table II** lists the various instrumentation systems and their functions.

Nuclear instrumentation system

The nuclear instrumentation system monitors the reactor neutron power from source level to 125 per cent of full power and supplies information to the operator, the reactor controls, and to the reactor protective system.

The power range utilizes four linear channels of neutron level over the range from approximately 1 per cent to 125 per cent full power. Each channel consists of three uncompensated ion chambers located outside the reactor vessel opposite each quadrant of the core. One of the four channels is selected for use in the reactor control system while all four channels are used in the protective system. Two out of four coincidence logic connects the overpower trip signals to the protective system.

The intermediate range uses two logarithmic signals of neutron power over the span from seven decades below full power to approximately full power. The signals originate in two compensated ion chambers located on opposite sides of the core. The source range has two logarithmic signals of neutron power over the span from source level to five decades above source level. Signals originate in two proportional counters located on opposite sides of the core.

Reactor protective system

When pre-determined conditions exist in the reactor or the coolant system, the reactor protective system acts to trip the reactor by fully inserting all control rods. Above 10 per cent of full power, four signals will trip the reactor; reactor power, power-flow ratio, reactor pressure, and reactor temperature. For each reactor coolant pump combination, there is a maximum allowable reactor neutron power which, if exceeded, trips the reactor. High reactor coolant pressure will trip the reactor to prevent lifting relief valves. Low reactor coolant pressure and high reactor coolant temperature will trip the reactor to prevent reduction in margin to departure from nucleate boiling.

SYSTEM	FUNCTION	ARRANGEMENT
NUCLEAR INSTRUMENTATION	MONITOR REACTOR NEUTRON LEVEL	2 SOURCE CHANNELS 2 INTERMEDIATE CHANNELS 4 POWER CHANNELS
REACTOR PROTECTIVE	MONITOR REACTOR AND COOLANT SYSTEM FOR ABNORMAL CONDITIONS	2 OF 4 SENSORS EXCEEDING LIMIT WILL CAUSE TRIP
ENGINEERED SAFEGUARDS	MONITOR REACTOR SYSTEM FOR ACCIDENT CONDITIONS	2 OF 3 SENSORS EXCEEDING LIMIT WILL INITIATE ENGINEERED SAFEGUARDS
IN-CORE INSTRUMENTATION	MONITOR CORE FLUX DISTRIBUTION	DETECTORS READ BY UNIT COMPUTER
NON-NUCLEAR INSTRUMENTATION	MONITOR PLANT CONDITIONS	INDICATOR AND CONTROLS AS REQUIRED

Table II

Engineered safeguards protective system

The engineered safeguards protective system initiates operation of engineered safeguards equipment when an abnormal condition exists in the reactor coolant system or the reactor building.

Each protective action is provided with dual control channels. The channels are duplicates; each containing a two-out-of-three coincidence logic network, a separate power source, and actuating relays. An energized output from either of the two channels initiates the intended protective action.

In-core instrumentation

In-core instrumentation consists of 364 self-powered neutron detectors divided into 52 channels. The output of the detectors is processed by the plant computer to provide fuel management and core power distribution information.

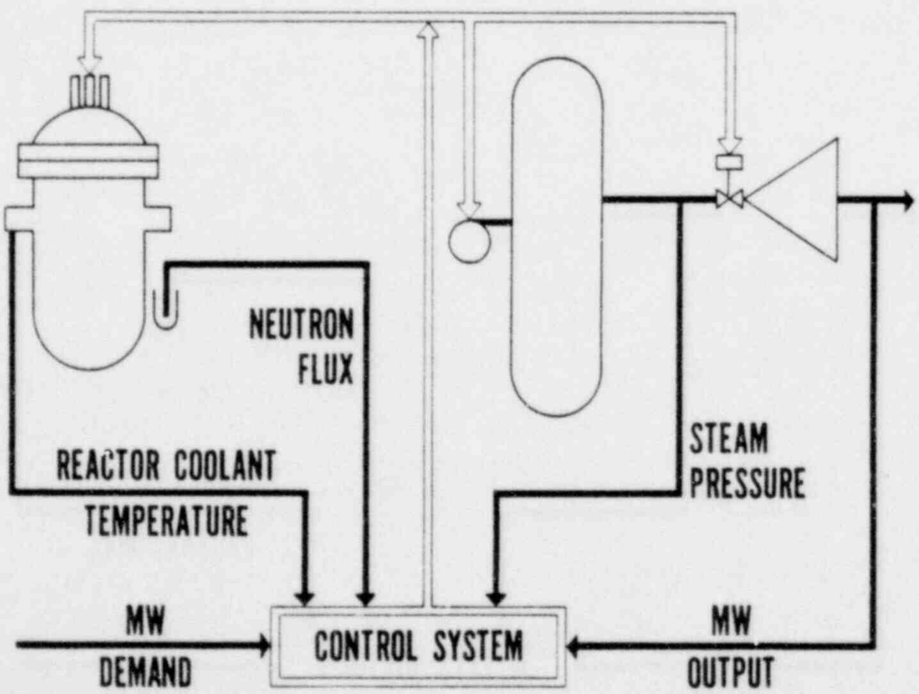
Integrated control system

The integrated control system, an adaptation of the controls developed for Universal Pressure Boilers, controls the plant electric output. It combines the stability of a turbine-following system with the fast response of a boiler-following system to provide optimum response from the reactor-boiler-turbine unit. Fig. 18 shows a simplified system arrangement.

Load demand from the system is compared to the capability of the unit to maintain or change load. The modified load demand is then applied to the feedwater, reactor, and turbine controls in parallel.

Turbine valves maintain control of steam pressure. A change in load demand generates an error signal which is used to change the steam pressure set point. Turbine valves change position to maintain steam pressure resulting in a fast load response. As generation is matched to demand, the steam pressure set point is returned to its original value.

Total feedwater demand is ratioed between the two steam generators in proportion to their capability as modified by the number of reactor coolant pumps in operation. Feedwater is controlled in each loop in response to the modified demand. The result of a change in feedwater flow is a positive and rapid response on steam flow, steam pressure, and Mw generation.



18.

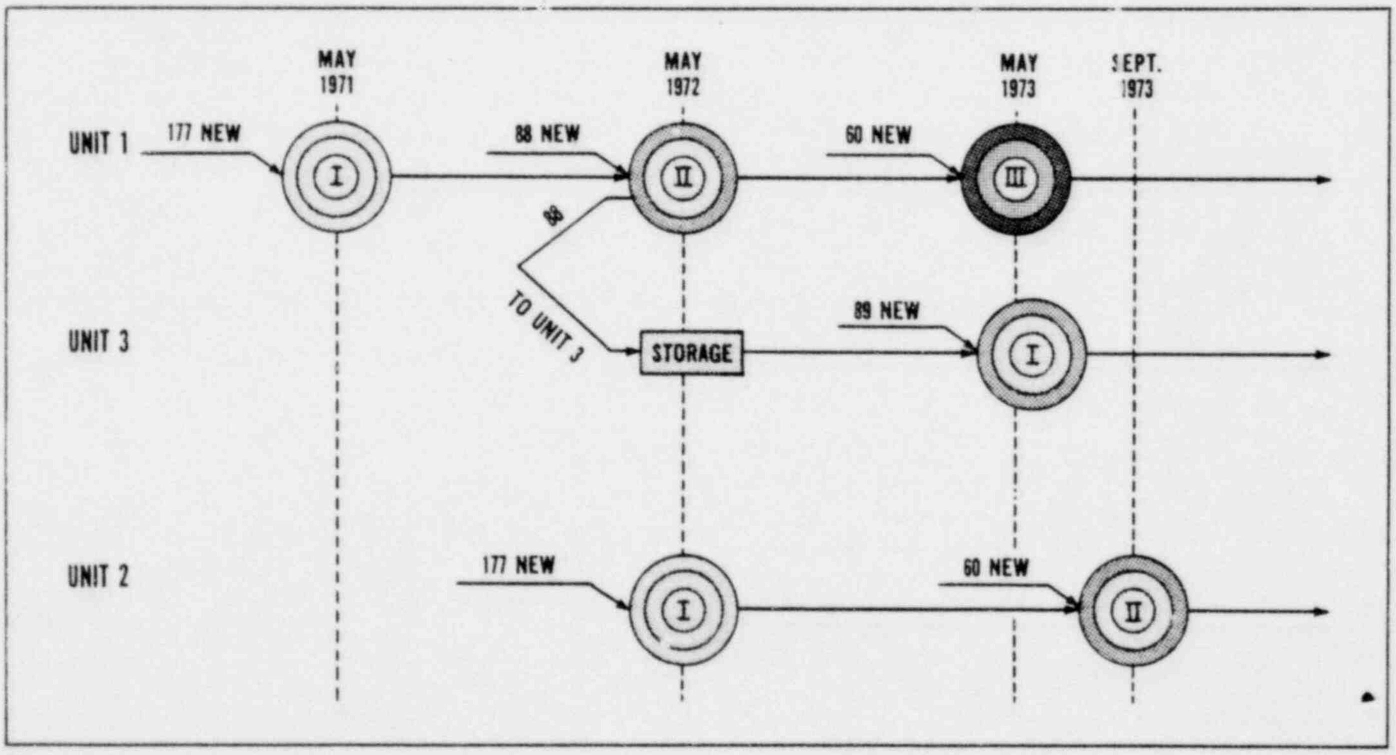
Proposed fuel cycles

The capability of the Oconee station represents a significant block of power in the southeast. For this reason, unusual attention must be paid to fuel management to insure shutdown periods for refueling consistent with peak power demands. In addition, three duplicate units at a single site present a challenge in optimization of the total station fuel cycle to reduce the first cycle fuel cost penalties usually associated with the startup of nuclear plants. Potential economies through an increase in megawatt days per metric ton and a reduction in the number of fuel assemblies which have to be purchased initially are possible through sharing of fuel between Units 1 and 3 as shown in **Fig. 19.**

The approximate one year interval between completion of the first fuel cycle on Unit 1 and commercial operation of Unit 3 permits a portion of the fuel removed from Unit 1 to be transferred to the Unit 3 spent fuel pool for use in the initial loading for Unit 3. Any changes in Unit 1 capacity factor or operating considerations, that would shift the end of the fuel cycle and refueling of Unit 1, can be accommodated in this time period. Fuel sharing between Units 1 and 2 was considered and rejected as it would require a significant reduction in the first cycle of Unit 1.

An independent cycle is planned for Unit 2. A long first cycle is planned to permit operation through the second summer peak with a refueling period in the autumn.

Following the first cycles, Units 1 and 3 will have staggered refueling periods each spring and Unit 2 will be refueled each autumn.



19.

Conclusion

In 1950 the Philip Sporn plant of Ohio Power Company became the first thermal plant to operate at a heat rate below 10,000 Btu/kw-hr. It was a significant milestone in power generation. When Oconee goes into operation in 1971 it will establish another equally significant milestone as the first large nuclear fueled generating station to operate with a heat rate below 10,000 Btu/kw-hr. We cannot predict the heat rates that will be realized in the next two decades nor the advances in technology by which they will be achieved. There can be no doubt though that utility requirements will continue to bring new challenges that the industry can look forward to with anticipation and which will continue to result in new milestones of improvement in power generation.

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