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NUCLEAR REGULATORY COMMISSION

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OFFICE OF SECRETARY
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BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

Glenn O. Bright
Dr. James H. Carpenter
James L. Kelley, Chairman

In the Matter of CAROLINA POWER AND LIGHT CO. et al. (Shearon Harris Nuclear Power Plant, Units 1 and 2)	Dockets 50-400 OL 50-401 OL ASLBP No. 82-468-01 OL

Wells Eddleman's Response re 2.758 Petition of 6-30-83 on Need for Power and Alternatives to Shearon Harris Plant

Pursuant to an oral order of Judge Kelley 9-22-83, this response and the attached affidavit of Dr. Reeves are now filed. Dr. Weintraub's letter in support of the original petition is also attached.[1]

Staff (8-26-83 Response at 8-9) and Applicants (8-31-83 Response at 4) make the same fundamental error about analysis: Both say we have not compared the fuel cost savings from Harris with the benefits of the alternative. But that's exactly what we DID do, at CP&L's ER amendment 5 assumptions of 70% capacity factor and 25-year unit life. That analysis is summarized in the Eddleman affidavit of 6-30-83 at page 10; calculation of the 1982 constant dollar fuel savings from Harris operation (at CP&L assumptions, including CP&L's discount rate) is shown in the Eddleman 6-30-83 Appendix, item 15, pp 3-4, as cited on page 10 of the affidavit.

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[1]This verification was promised in the 6-30-83 filing. Dr. Blackburn has not been available to make his affidavit yet; it will be filed as soon as practicable.

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I have examined Dr. Reeves' 9-29-83 affidavit, attached, and its numbers and analysis are correct. That leaves the alternative with a net benefit of $6.855 billion (1982 dollars) vs. CP&L's claimed fuel savings of 403 billion. The difference in favor of the alternative is over $2.8 billion dollars.

Staff also argues (8-26-83 at 9,10) that establishing the environmental superiority of the alternative is not enough. Quite so. The 3 Reeves affidavits and the first part of the Eddleman affidavit (all filed 6-30-83) demonstrate in detail the economic superiority of the alternative, which is explained further below. [1A]

Staff, as to environmental effects, completely ignores the conclusion of Holdren <u>et al</u> (Eddleman 6-30 affidavit at 14-15) that alternatives generally have less environmental impact than nuclear power plants (for comparable energy produced). Our argument begins from this foundation, and goes on to show, via comparison with the Medsker analysis, that the alternative to Harris as set out by Dr. Reeves has even less environmental impact than most alternatives. (W.E affid at 15-19) Thus the alternative is environmentally superior to the Harris plant in operation.

At the end of their filing, Staff faults Dr. Reeves for not explaining how his alternatives would be implemented; in fact, Reeves affidavits #1 (7-14-82) at 12-16 re financing, and #3 (6-28-83) at 1-3 re cost-effectiveness, and 3-14 explaining how the further savin beyond his affidavits 1 and 2 would be implemented, cover this. See his 9-29-83 affidavit, item 4, p.3. The only institutional barrier to the program that I know of is CP&L management. Staff (p.11) fails to show that any barriers to the program exist, thus Dr. Reeves' original analysis remains uncontradicted.

[1A] See Reeves Affidavit #1, 7-14-82, pp2-8 and 29-31 re CP&L system loads; 9-11 and 17-29 re specific alternatives; 12-16 re financing them; #2, 2-11-83 pp 1-9 re cost-benefit of the 7-14 alternatives; #3, 6-28-83 re cost-effectiveness pp 1-3; pp3-14 re further specific alternatives beyond CP&L.

Both CP&L (footnote 2, pp 5-6, 8-31-83) and Staff (8-26-83 at 9) are simply wrong to suggest that CP&L's current load management or conservation are included in any of Dr. Reeves' analysis. See Reeves 9-29-83 affidavit, item 3, p.3. In fact, at my instruction, Dr. Reeves ONLY analyzed conservation and load management measures beyond CP&L's existing programs, as stated in his affidavits filed 6-30. Dr. Reeves had a complete summary of CP&L's 1982 load management program in hand when he made his affidavitss.

Staff claims (pp 7-8) that we didn't consider O&M (operation and maintenance) and capital charges in our analysis. O&M is included in CP&L's fuel savings estimate which we did use. Capital charges were not considered since they relate to sunk costs per NRC rulings.

However, for the sake of argument, consider that less than $2.1 billion is as yet sunk in Harris. Add that cost to the 4.03 billion fuel savings (CP&L estimate) and you have $6.13 billion. The alternative, however, saves 6.855 billion, and remains superior. (See Eddleman 6-30-83 affidavit, p.10 and notes thereto; Reeves 9-29-83 affidavit, item 2, pp 2-3).

CP&L suggests that we should do both the alternative and run Harris to save on fuel. It is illogical to combine Harris with the alternative to it, particularly when that alternative shows that Harris' capacity and one unit's generation will not be needed. That is why we argue that fuel savings are the only possible benefit of Harris.[2] As shown above, the alternative is superior even if fuel savings at CP&L's estimate AND sunk costs of Harris are added to compare to it.

Staff asks why we used consumer rates (8-26 at 7). The consumers are the ones who pay the costs and receive the benefits (if any, net) from power plants, as the late Shearon Harris himself used to say.

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[2]See Reeves affid #1, 7-14-82, pp 2-6 and 30-31; Eddleman affid. 6-30-83 pp 3-5 and citations therein.

Dr. Reeves explains this in his 9-29 affidavit, item 1, p.2, citing his 2/10/83 affidavit page 1, line 10. To this I only add that any fuel savings would flow through to consumers, as do the savings from the Reeves alternatives. The Reeves alternative simply allows the customers to gain the savings without consuming as much electricity. They still get just as much useful work and service under the alternative, but they save more money. Even if consumers were forced to pay off the sunk investment in Harris, they come out ahead under the alternative. (see p.3 above).

Staff also argues (pp5-6) that the Nuclear Regulatory Commission had rejected the claim that it was cheaper and environmentally superior not to operate a nuclear power plant because the Lovins analysis "lacked sufficient analysis and documentation to support it." Here, Dr. Reeves and I have produced extensive analysis and documentation specific to CP&L showing why the Harris plant is economically and environmentally inferior to the Reeves alternative. Significantly, neither Staff nor Applicants present evidence contradicting this. Thus, our <u>prima</u> <u>facie</u> case required by 10 CFR 2.758, is still intact after Staff and Applicants had 2 months to respond to it.

Staff also claims (p.4) that we have shown no"special circumstances" unique to Harris. There are 2: The existence of an environmentally and economically superior alternative to operating Harris, fully documented; and the fact that Harris is the only nuclear plant I know of where 2 units were scrapped by the utility in favor of alternatives, and the official State consumer advocate proposes that a third unit be scrapped and the fourth and final unit be delayed until 1992 because it isn't needed now. (NCUC Public Staff 1983 report, excerpts attached to 6-30-83 filing)

In sum, neither CP&L nor NRC Staff has been able to contradict the case made in my 2.758 petition and supporting affidavits (with documentation) filed 6-30-83, that Harris should not operate because there is an environmentally and economically superior alternative to it.

Department of Economics
Duke University
Durham, North Carolina, 27706

Mr. Wells Eddleman
718-A Iredell Street
Durham, NC, 27705

Dear Mr. Eddleman,

Persuant to our phone conversation, I am indeed able to submit the following statement to you for the use of the Nuclear Regulatory Commission:

To Whom It May Concern:

I am a Professor of Economics and Chairman of the Department of Economics at Duke University. I received my Ph.d from the University of Pennsylvania in Applied Mathematics in 1969, and I have been on the faculty at Duke University since 1970. I have written four books and numerous articles in economics, primarily on topics related to economic theory. I have on three occasions prefiled testimony, and testified, before the North Carolina Utilities Commission as a public witness. These filings all concerned electricity load forecasts, and the methodology of the load forecasts, by the Public Staff of the Commission.

Based on my own research which was directed to an informed criticism of the methods by which forecasts of the demand for electricity in North Carolina were to be generated by an econometric model of the demand for electricity, it is my informed professional opinion that the most sensible point estimate of the elasticity of demand for electricity is -.20 in the short run and -1.0 in the long run.

Yours truly,

E Roy Weintraub

Dr. E. Roy Weintraub
Professor of Economics

STATE OF NORTH CAROLINA

COUNTY OF WAKE

Today Dr. G. George Reeves appeared before me and affirms that the attached information is true and correct to the best of his knowledge and belief and was prepared by him for Wells Eddleman.

Dr G George Reeves this 29th day of September 1983

Dr. G. George Reeves

Gladys F Ferrell, Notary Public
Wake County, North Carolina

My Commission Expires October 26, 1985

<u>If SH 1 not licensed to operate and construction ceases 12/31/83</u>

Sunk construction cost 12/31/83	$1,763,116,000
Annual capital charge cost[e]	$202,758,340
Annual depreciation cost[f]	35,262,320
Total annual cost	$238,020,660
Comparing the two options	$583,273,200
	- 238,020,660
Net annual saving from <u>not</u> licensing and operating SH 1	$345,252,540

a) from CP&L's 1983 construction budget
b) 20% of total capital cost of SH 1 in commercial operation
c) 4% of total capital cost to allow for wear out of SH 1 in operation
d) computed using 60%capacity factor and 0.8 ¢/kWH fuel saving according to NCUC public staff estimates
e) 11.5% of sunk 12/31/83 cost. A non-operating SH 1 would not be included in CP&L's rate base but would probably be allowed capital costs at the long term debt rate which for CP&L is 11.5%.
f) A non-operating plant in a preservation mode would not be subject to the wearout, corrosion and radiation damage of an operating plant. It would have a much longer useful life as standby generation that could be brought on line in a few years if needed at some time in the future due to increase in load or retirement of present operating plants. The 2% annual depreciation rate is my estimate of the cost to bring a preserved plant up to then current safety standards in preparation for operation. It would, for example, allow for the expenditure of $352 million to modify SH 1 if it is needed after 10 years of preservation.

3. page 9, lines 11-24: The staff missed the discussion of my method of estimating system air conditioning load reductions due to increased EER. This is on page 18, lines 15-20 of my 7/14/82 affidavit. Also on page 27 of the same affidavit I make clear that all system air conditioning is considered, not just the room air conditioner used as an example. The same page has the rationale for estimating market penetration of high EER units by 1995. My estimated peak load reduction due to higher EER was 1000 MW, 200 MW from CP&L's present program plus a further 800 MW due to better promotion and no-net-cost financing.

4. page 11, lines 11-19: There are no institutional or legal barriers to the no-net-cost loan program. It is merely an extension of the low interest rate conservation loan program that CP&L already offers.

CP&L's response dated August 31, 1983 erroneously asserts that my estimates of future load reductions are based upon nothing more than my opinion (their footnote 2 on pages 5 and 6) In fact my three affidavits simply apply existing proven technologies to the problem at hand; outline an attractive means for financing and implementation; and assume that people will act to reduce their electric bills if they are shown how to do so without cost, inconvenience or loss of comfort.

I have examined the Affidavit in Support of 2.758 Petition by Wells Eddleman dated June 30, 1983. I find the information, analysis and conclusions it presents are true and correct except for the 5 minor corrections listed below. None of these corrections change the resulting conclusion that neither Shearon Harris reactor should be licensed for operation. The sooner their construction is stopped the better for CP&L, its customers and the society at large.

1. page 5, line 5: "6200MW" should be 5700 MW

2. a) page 8, line 1 of Table 2: "800 GWH/yr saved" should be 686 GWH/yr saved

   b) line 1 of Table 2: "$24,160,000" should be $20,717,200

   c) line 2 of Table 2: "7,840,000" should be 7,929,600

   d) line 4 of Table 2: "6,768,000" should be 6,937,500

   e) line 8 of Table 2: "1994 GWH/yr" should be 1880 GWH/yr; "$75,658,000" should be $73,674,300

3. page 9, line 10: "$1.891" should be 1.842
   line 12: "$6.905" should be 6.855

4. page 12, line 8: "314" should be 312
   line 10: "8.75" should be 8.73

5. Appendix page 5, item 21: "75,658,000" should be 73,674,300 and "314,038,000" should be 312,054,300

I have examined the NRC Staff Response dated 8/26/83 and find that it contains the following 4 major errors and misconceptions relative to my three affidavits dated July 14, 1982; Feb. 10, 1983; and June 25, 1983.

1. page 7, line 21: The staff doesn't seem to understand why retail rates were used in the analysis. As stated in my 2/10/83 affidavit page 1, line 10; it was assumed that existing electric rates reflect true costs. They will if the utilities commissions are doing their jobs. True costs are the only reasonable basis on which to make economic comparisons. Thus electric costs and costs of alternatives are compared at the same retail billing point.

2. page 7, line 25: The staff has overlooked my discussion of the economic benefits of not liscensing the plants for operation. In my 7/14/82 affidavit, pages 9-10 I showed that even under the most favorable possible assumptions the future fuel savings do not pay back the cost of licensing the plants for operation. I assumed that if licensed both plants would be completed by spending $2 billion in 1984-1990; that if operating license is denied then future construction expenses cease at the end of 1983; that all past and future construction costs are carried into rate base at 20% capital charge rate; that both plants could operate at 70% capacity factor; that the NC Utilities Commission public staff numbers for fuel costs saving of uranium over coal are valid; that these plants will not have the high maintenance costs of other similar plants. Under these assumptions ratepayers save 400-88 = $312 million per year if license is denied. Since it is so obvious that the construction and operation of the plants cannot be justified on fuel cost savings no further analysis was presented.

   Since there is apparently a misunderstanding of the savings from operating one of these plants, consider the following details with more reasonable assumptions about unit 1 which is nearest completion.

   <u>If SH 1 licensed to operate and completed</u>

Sunk construction cost 12/31/83 [a]	$1,763,116,000
Cost to complete [a]	824,869,000
Total capital cost	$2,587,985,000
Annual capital charge cost [b]	$517,597,000
Annual depreciation cost [c]	103,519,400
Less fuel and operating saving [d]	-37,843,200
Net annual cost	$583,273,200

(2) DKt 50-400

STRONTIUM-90 RELEASED IN TMI VENTING

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Accord Research and Educational Associates, Inc.

INTRODUCTION

Between 28 June and 11 July 1980, Metropolitan Edison (Met Ed) vented the containment building of their damaged Three Mile Island (TMI) Unit 2 nuclear reactor near Harrisburg, Pennsylvania. Prior to the venting Met Ed reported that the building atmosphere contained approximately 57,000 curies of krypton-85, a few curies of tritium, and far smaller amounts of other isotopes present as suspended particulates, e.g. radioactive cesium and strontium. Met Ed claimed that the amount of suspended particulate radioactivity was very small and that the exhaust stack filtration system was good enough to keep emission of radioactive particulates below detectable limits. The United States Nuclear Regulatory Commission (NRC) waived the 'required' environmental impact statement for the venting. The NRC further compromised public health by temporarily suspending the federal regulations limiting the concentration of airborne isotopes that may result offsite from plant releases. Finally, the releases were made without the NRC requiring immediate check on the amount of beta activity that was being released in the form of suspended particulates, specifically leaving them blind to strontium-90, one of the most abundant and lethal isotopes in the reactor.

Accord Research and Educational Associates (AREA), a New York City based environmental group, set up 24 hour monitoring

in the field during this entire two week period, to measure radiation levels and collect air particulate samples in the vicinity of TMI. AREA detected the released krypton as far away as two miles from the plant and often observed ground level concentrations of krypton-85 substantially greater than the maximum permissible concentration (MPC) of 300,000 picocuries per cubic meter. In addition, AREA sampling of air particulates yielded a positive result for strontium-90, indicating that the release of this hazardous isotope was approximately four million times greater than what Met Ed had estimated as possible.

METHOD

Radiation levels were measured with a thin (1.4mg/cm^2) mica window (total area 16 cm^2) Geiger-Mueller (GM) 'pancake' probe connected to a Victoreen "Thyac III" portable rate meter. The audio output of the rate meter was fed into a digital accumulator-timer. This arrangement detects changes in the count rate of 10 counts per minute (CPM), using a one minute counting period. The total counts registered on the accumulator were recorded at intervals of from one to five minutes, along with the real time and location of the detector. Hourly average count rates were computed and plotted as a function of time. The background count rate in the Three Mile Island area consistently averaged around 30 cpm except for brief periods of rain during which the background count rate may have risen by approximately 20 cpm. Excess counts above background were converted to krypton concen-

tration using a calibration factor determined from laboratory experiments with a similar detector performed at Pennsylvania State University (Jester et al., 1980a). In these experiments the detector was placed in a large test chamber containing 6.7 microcuries per cubic meter of krypton-85 in air. The observed count rate was between 2000 and 2200 cpm above a background of about 50 cpm, yielding a factor of 310 cpm above background per microcurie of krypton-85 per cubic meter. Comparison of field measurements made by the Penn State group with measurements made by the AREA group at the same time and location during the venting confirmed this calibration factor (Jester et al., 1980b).

Round-the-clock monitoring was performed during the TMI venting. Monitoring teams in the field used the GM detector to locate the point of maximum ground level activity. This point is directly downwind from the containment building exhaust stack and somewhat further away than the point at which the spreading cloud or 'plume' of effluent gas and aerosol first touches the ground. Low-lift helium balloons were released frequently both up- and downwind of the stack in order to study the local wind patterns and locate the plume centerline.

Air particulate samples were collected on one-inch diameter Millipore membrane filters (pore size 0.45 microns), at a flow rate of 10 liters per minute. These samples were collected in the plume at the point of maximum ground level activity, and that activity was recorded continuously. While one monitoring team tended the air sampling pump and recorded radiation levels during sample collection, a second team continued surveying the surrounding

area with a second radiation detector in order to verify that the pump had indeed been set up at the point of maximum ground level activity and to detect, as quickly as possible, any shift in the location of this maximum.

This method of sampling air particulates, i.e. always keeping the filter and pump at the most active point in the plume, was designed to maximize our sensitivity to radioactive particulates released during the venting. After aging for several weeks, each filter was counted for gross beta activity using a low background thin plastic phosphor scintillation detector. Subsequently, all filters were conbimed and analyzed for gamma emissions using a Ge(Li) detector. In order not to miss a significant finding we also combined all the filters and subjected them to radiochemical analysis for strontium-90 and strontium-89, obtaining the positive result discussed below. This procedure is contrary to the typical government and industry practice of dividing the monitoring region into sectors, employing fixed samplers and not pooling samples, all of which is designed to allow significant releases of radionuclides to go undetected and unreported.

The gamma analysis and the measurement of strontium-90 deposited on the combined filters was performed by Teledyne Isotopes, of Westwood, New Jersey. Their method of determining strontium is a standard one involving chemical separation and low level beta counting. The result was independently checked by measuring the ingrowth of yttrium-90.

RESULTS

Figure 1 shows the measured ground level activity averaged over one hour intervals for the entire monitoring period. Gaps in the graph indicate periods during which no data was recorded. Figure 2 is a map of the TMI area showing the sixteen sectors around the plant stack. The scale of distance is indicated on the map by concentric circles centered on the stack with radii of 1, 2, 3 and 4 kilometers respectively. Table I lists the total number of excess counts accumulated above the nominal background count rate of 30 cpm in each sector for each day of monitoring. However, excess counts were not included in Table I unless they were accumulated during periods for which the observed count rate was greater than 35 cpm.

From Figure 1 it is evident that the NRC-specified maximum permissible concentration for krypton-85 was exceeded for several hours around midnight 30 June, 2 July and 5 July and for ten daylight hours on 8 July. The results in Table 1 show that most (63%) of the radioactive emissions were distributed among sectors 5 and 6.

The ground level measurements of krypton-85 concentration provided an estimate of the rate and pattern of the releases. Using a simple atmospheric dispersion model (Turner, 1970) one calculates a release rate of 100-150 curies per hour for most of the daylight hours 30 June through 7 July. This value is consistent with Met Ed's data for that period, given in NRC 'purge status reports', obtained from the Middletown office of the NRC during the venting. However, for late night and

early morning hours during this period and for the daylight hours of 8 July one calculates release rates 3 to 4 times higher. These higher release rates were acknowledged in the available purge status reports only for the daytime releases of 8 July. To date no release-rate data has been made available by Met Ed or the NRC for nighttime venting.

The high rate of nighttime venting is evidenced by the peaks of activity observed around midnight on 30 June, 3 July and 5 July. The absence of such midnight peaks on other nights is probably due to conditions of atmospheric stability and low wind speed that caused the plume to rise very high resulting in low ground-level activity. Other periods of low activity in Figure 1 may be due to the occurrence of similar atmospheric conditions or interruptions in the venting. At times the monitoring teams were not in the centerline of the plume; for example, when the wind was blowing down the river.

Figure 1 also shows the time periods during which air particulate samples were taken. The volume of air sampled and the amount of krypton-85 in each sample is shown in Table II for each filter. A total of 6.3 microcuries of krypton-85 in a sampling volume of 51 cubic meters passed through the set of 12 filters. No filter disc showed gross beta activity above the detection limit of 1.2 picocuries. The average gross beta background in the Harrisburg area is 0.02 picocuries per cubic meter (reported as cesium-137). Thus background gross beta activity deposited on each filter is well below the detection limit.

The gamma scan of the combined filters showed no radio-

nuclides above the detection limits shown in Table III. However, the radiochemical analysis of the combined filters for strontium-90 yielded 0.95±0.45 picocuries or 0.018 picocuries of strontium-90 per cubic meter of sampled air. The error on the measurement includes an estimated 10% error associated with the chemical procedures and a two sigma, 95% confidence, counting error. The amount of strontium-90 measured in the collected air particulates is <u>at least</u> 9 times above that expected from bomb test fallout (Toonkel, 1980). This result indicates an average strontium-90 to krypton-85 activity ratio of 1.6×10^{-7} for the effluent vented from the TMI Unit 2 containment building. According to Met Ed's reported containment atmosphere inventory given in Table IV, the maximum ratio of strontium-90 to krypton-85 in the plume, assuming no filtration at all, is 2.1×10^{-10}, approximately 800 times less than our result. Assuming the claimed particulate filtration efficiency of 99.98%, one calculates that Met Ed released 4 million times as much strontium-90 as they had originally predicted possible.

The measured limits on gross beta activity for individual filter discs are consistent with the result of the strontium analysis and provi an upper limit to the ratio of gross beta activity to krypton-85 activity of 2.0×10^{-6} in the filtered air. This limit is consistent with the results of the gamma analysis.

HEALTH IMPACT

On the basis of our field observations we conclude that

an individual located on the plume centerline and at the distance of maximum ground level activity throughout the entire venting received a krypton-85 skin dose of approximately 2 millirems. Doses due to inhalation and direct exposure to other components of the plume are apparently negligible. However, the long term health effects of particulate radionuclides deposited on the surrounding farmlands are much more serious.

Using Met Ed's post-venting estimate of 43,000 curies of krypton-85 released and our measured ratio of strontium-90 to krypton-85 activity, we calculate a total of 7 millicuries of strontium-90 released. A reasonable estimate of cesium-137 released is approximately 20 millicuries. This estimate is consistent with our strontium, gamma emission and gross beta measurements and with the higher volatility of cesium. Based on the relative inventories of strontium-89 and -90 given in Table IV we estimate that 1.5 millicuries of strontium-89 was also released. We calculate here only the effect of strontium-90, the most important isotope.

About 40% of the land in the TMI area is cropland including pastureland for milk cows. We assumed therefore that 40% of the released strontium-90 is deposited on crops or pasture, and of this amount, 1% is ingested by humans every year. Allowing for radioactive decay, the result is a total of 1.1 millicuries of strontium-90 eventually ingested by humans, resulting in a population dose of 2000 person-rems to the whole body from ingested strontium-90. In order to estimate the biological effects of this population dose, we utilize the dose/effect relationship observed for the exposure of radiation workers to

low levels of ionizing radiation over long periods of time, published by Kneale et al. (1978). Using doubling doses derived by these authors of 34 rem and 9 rem for all forms of cancer in adult males and females, respectively, we find approximately 100 doubling doses delivered to the population. Since 28% of the people in the Harrisburg area are expected to die of cancer, this much radiation will yield 28 additional cancer deaths. Children, infants and the unborn are much more vulnerable to the effects of radiation. Studies on the carcinogenic effect of x-rays (Bithell, 1975) indicate a doubling dose for the unborn of approximately 1 rem. Thus, the additional risk of cancer and other radiation-induced effects may be 10-30 times greater in the unborn than in adults.

CONCLUSION

AREA's resuls show that a significant amount of strontium-90 was released to the environment from TMI during the 28 June - 11 July venting period. Significant releases of strontium-89 and cesium-137 must also be inferred. As AREA wished to know the ratio of strontium-90 to krypton-85 in the TMI releases, and to measure specifically the amount of strontium-90 in those releases, we drew air samples from the plume centerline and at the distance of maximum ground level activity whenever possible. In this way, background strontium-90 from global fallout was

only a small fraction (less than 10% or .10 picocuries) of the reactor effluent strontium-90. Therefore, background strontium-90 did not limit the sensitivity of our measurement, and we were able to measure the strontium-90 activity to krypton-85 activity ration in the reactor effluent to be 1.6 parts in 10 million.

The United States Environmental Protection Agency (USEPA), using their fixed air samplers, relied on chance to blow the narrow plume their way. This design also increased the volume of air ratio to the reactor effluent strontium-90, and resulted in collection of significant and variable amounts of background strontium-90 from fallout. This background deposit substantially reduced the sensitivity of their measurement of the crucial strontium-90 to krypton-85 activity ratio. The significant and remarkable quantity of strontium-90, released to this agricultural region and measured by AREA, was not reported by the USEPA.

SUMMARY

Accord Research and Educational Associates monitored the venting of Metropolitan Edison's damaged Three Mile Island Unit 2 reactor containment building and found toxic radionuclides including significant amounts of strontium-90 were released in the two week venting period 28 June - 11 July 1980. The quantity of strontium-90 released is four million times greater than the published predictions of Metropolitan Edison that were accepted by the United States Nuclear Regulatory Commission at the time. The airborne toxic radionuclides patterned

themselves in a pie shaped wedge called a plume, with the highest concentrations observed downwind of the reactor at the distance of maximum ground level activity. The long term health effects of strontium-90 released as particulates to the surrounding farmlands were calculated yielding 28 additional fatal cases of cancer to adult humans eventually ingesting food from this area. It is noted that children are much more vulnerable to the effects of radiation. No reports of deposits of strontium-90 or other particulate radionuclides, released as a result of the venting, have been made by the Metropolitan Edison or the United States Environmental Protection Agency.

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FIGURE 1

Measured Ground Level Activity at TMI
During Venting of Unit 2 Containment
June 28 to July 11, 1980

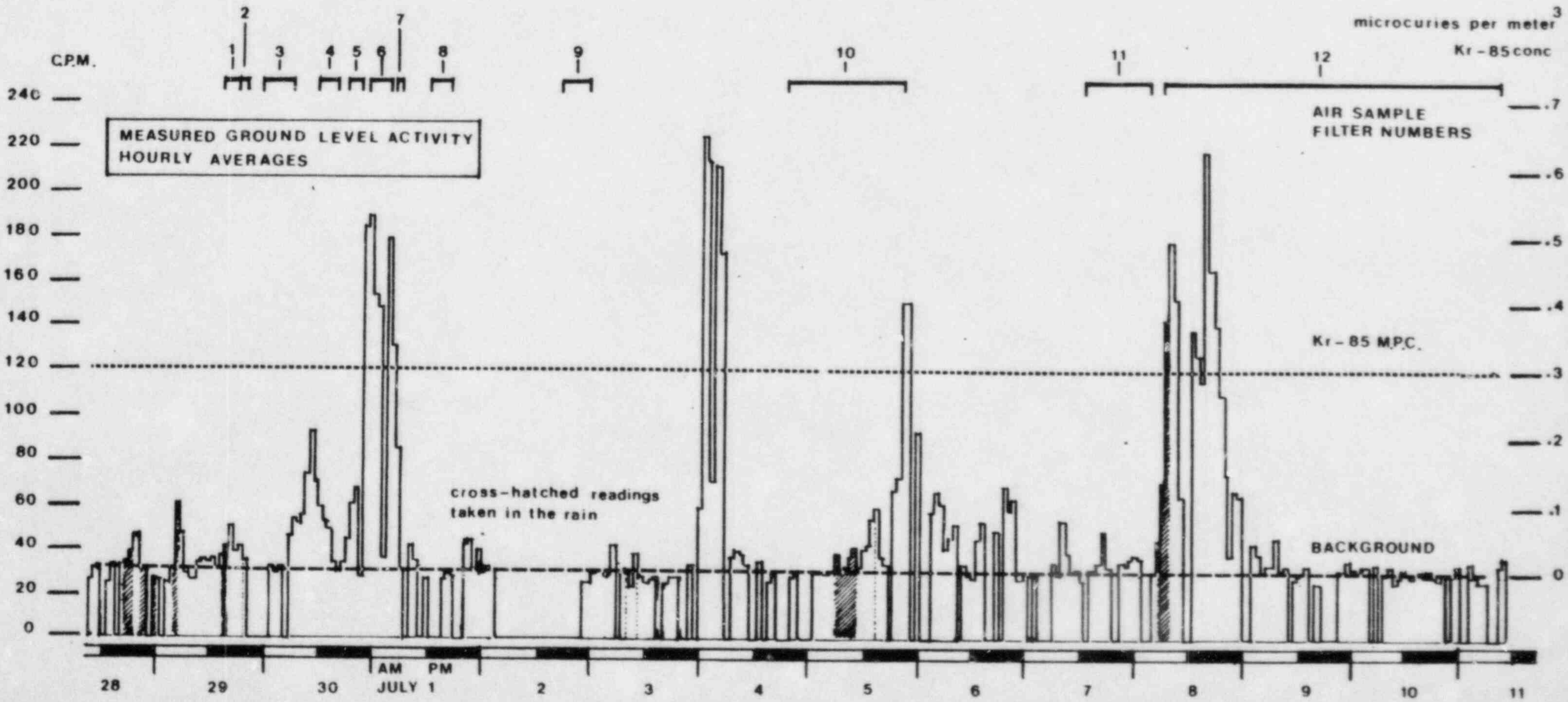
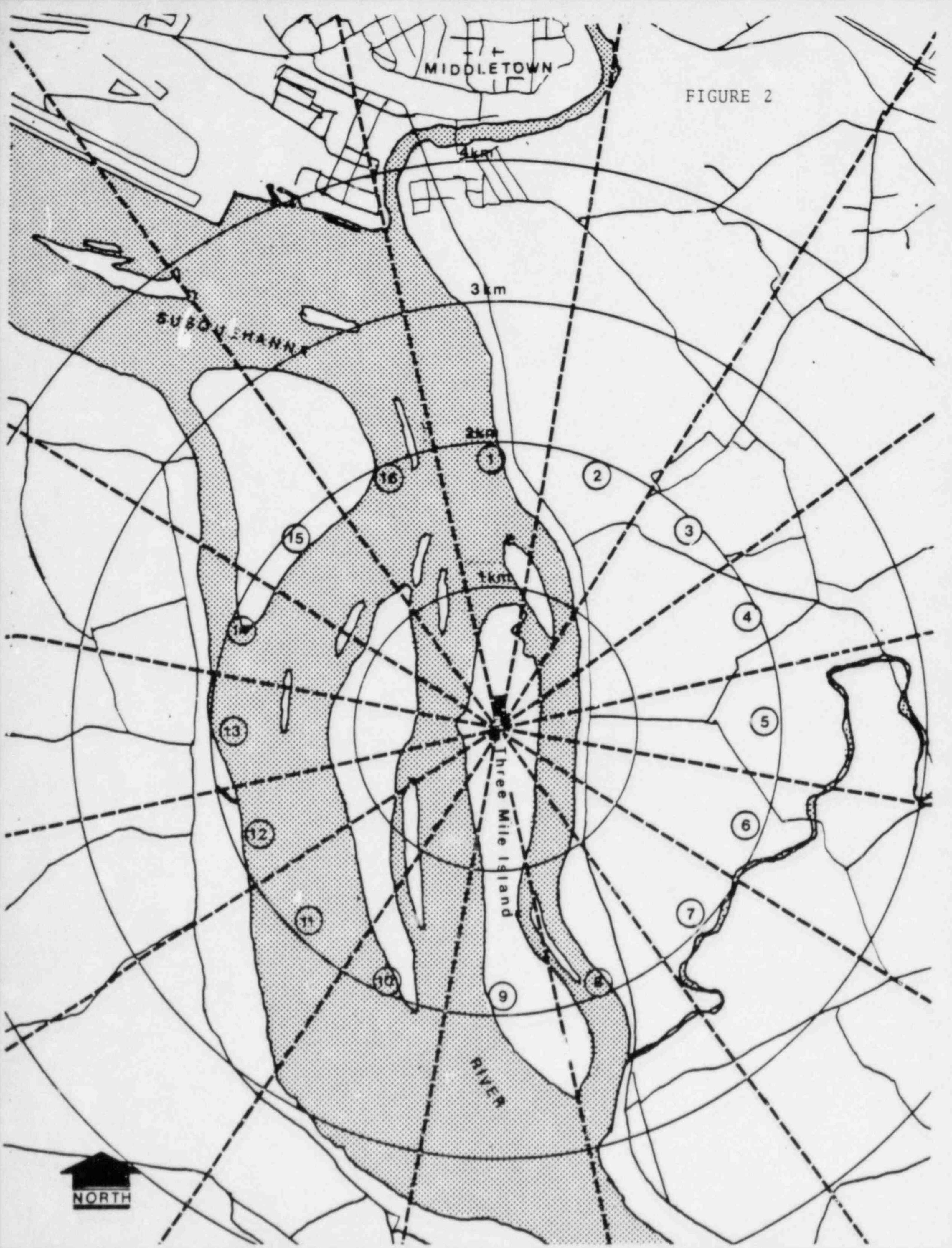


FIGURE 2



MIDDLETOWN
4km
3km
2km
1km
SUSQUEHANNA
RIVER
Three Mile Island
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
NORTH

TABLE I

Accumulated excess counts by sector

	SECTORS															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
28 June	902	0	0	0	0	0	0	0	0	0	0	25	0	55	0	195
29 June	3,136	2,963	409	0	0	0	0	0	0	0	0	0	0	0	0	0
30 June	0	285	5	0	466	34,472	1,784	0	0	0	0	0	0	0	0	0
1 July	50	1,079	143	0	78	28,487	269	245	0	0	0	0	0	0	0	0
2 July	60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3 July	0	0	0	0	0	0	0	0	70	6	866	6	224	297	0	0
4 July	156	0	0	0	282	4,800	21,903	1,025	30	0	0	0	0	0	0	0
5 July	698	1,020	1,029	0	19,895	2,452	0	0	0	0	0	0	0	0	0	196
6 July	0	0	0	904	1,335	8,498	277	8,367	141	0	0	0	0	0	0	0
7 July	185	30	10	189	1,473	1,529	0	198	78	0	0	0	0	0	0	77
8 July	1,972	8,933	1,118	16,938	30,458	2,356	390	560	0	0	0	0	0	0	0	0
9 July	0	37	130	50	1,124	213	749	12	0	0	0	0	0	0	0	0
10 July	35	0	0	0	213	61	30	15	0	0	0	0	0	0	0	0
11 July	0	0	0	0	353	234	0	0	0	0	0	0	0	0	0	0
Totals	7,194	14,347	2,844	18,081	55,677	83,102	25,402	10,422	319	6	866	31	224	352	0	468
Percent	3.3%	6.7%	1.3%	8.3%	25.4%	38.0%	11.6%	4.8%	.1%	0%	.4%	0%	.1%	.2%	0%	.2%

Excess counts are counts above the nominal background count rate of 30 cpm accumulated during periods when the observed count rate is greater than 35 cpm.

TABLE II

Sample volumes and krypton-85 activity

for each air particulate sample

Filter No.	Volume Filtered (cubic meters)	Krypton-85 Filtered (nanocuries)
1	2.1	97
2	0.9	16
3	4.3	nd*
4	2.7	180
5	1.9	130
6	3.2	830
7	14	290
8	1.6	nd
9	4.2	710
10	12	1,700
11	5.0	50
12	16	2,900
TOTAL:	51	6,300

*no data

TABLE III

Results from combined filters*

Gamma-ray emission Ge(Li) Spectroscopy**	Total activity (picocuries)
beryllium-7	LT 30
potassium-40	LT 60
manganese-54	LT 2
cobalt-58	LT 2
cobalt-60	LT 3
zirconium-95	LT 3
ruthenium-103	LT 20
iodine-131	LT 6
cesium-134	LT 3
cesium-137	LT 3
barium-140	LT 4
cerium-141	LT 4
cerium-144	LT 20
radium-226	LT 50
thorium-228	LT 5
Radiochemical analysis**	
strontium-89	LT 2
strontium-90	0.95 ± 0.45

*Total filtered volume of 51 cubic meters containing 6.3 microcuries Krypton-85. LT = less than.

**Measurements performed by Teledyne Isotope, Westwood, New Jersey.

TABLE IV

Reactor building air sample results (Met Ed)

Nuclide	Half-Life	Concentration (Curies per cubic meter)
Hydrogen - 3	12.26y	$5 \pm 1 \times 10^{-5}$
Carbon - 14	5730y	$4 \pm 1 \times 10^{-7}$
Iron - 55	2.6y	$< 6 \times 10^{-11}$
Cobalt - 58	71.3d	$< 1 \times 10^{-11}$
Cobalt - 66	5.26y	$< 1 \times 10^{-11}$
Kryton - 85	10.76y	$0.93 \pm .07$
Strontium - 89	52d	$1.1 \pm .5 \times 10^{-10}$
Strontium - 90	28.1y	$2.2 \pm .2 \times 10^{-10}$
Ruthenium - 103	39.6d	$< 2 \times 10^{-9}$
Ruthenium - 106	367d	$< 2 \times 10^{-10}$
Silver - 110m	253d	$< 2.5 \times 10^{-11}$
Iodine - 129	1.7×10^{7}y	$6 \pm 2 \times 10^{-11}$
Cesium - 134	2.05y	$1.7 \pm .1 \times 10^{-10}$
Cesium - 137	30.23y	$9.3 \pm .3 \times 10^{-10}$
Uranium - 235	7.1×10^{8}y	$< 5 \times 10^{-12}$
Uranium - 238	4.51×10^{9}y	$< 2 \times 10^{-11}$
Plutonium - 238	86y	$< 2 \times 10^{-12}$
Plutonium - 239/240	24,400y/6580y	$< 2 \times 10^{-12}$

All nuclide concentrations listed with a less than symbol indicate that those nulcides are below the listed instrumentation sensitivity for those nuclides.

Note: Sample taken April 1980 through containment penetration R-626. Approximate inventories can be calculated by multiplying the concentration by the free volume of the containment building, 5×10^{4} cubic meters.

(2) DKT 50-400

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MOBILE MONITORING OF AIRBORNE RADIOACTIVE EFFLUENT FROM THE OYSTER CREEK NUCLEAR GENERATING STATION

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INTRODUCTION

Nuclear power plants release radioactive materials into the environment in the course of normal operations. Federal regulations require the licensee to monitor all such releases at the point of discharge and to limit these releases so that the total dose delivered to individuals off-site through all exposure pathways is kept as low as reasonably achievable.[1] This dose, which includes both external and internal contributions, is not measured. Instead, it is calculated from the measured release rates using an approved set of formulas that model the dispersion of plant effluent in the environment. Large uncertainties inherent in such modeling may cause significant discrepancies between the actual and the calculated dose.[2]

The licensee is also required to carry out an approved off-site environmental monitoring program for the purpose of checking the model used to calculate off-site dose. Such a program usually consists of a fixed array of thermoluminescent dosimeters and a set of sampling stations from which environmental samples are collected for laboratory analysis. The typical environmental monitoring program is not designed to provide prompt discovery of significant changes in off-site dose rates.[3] Excessive off-site dose rates due to plant effluent could therefore persist for weeks without being detected.

An even greater lag exists between the time monitoring results are obtained and the time they are made available to the public. The results of environmental monitoring by the licensee may not be available for a year or more after the monitoring was

performed. The results of on-site monitoring of releases at point of discharge are also available only after a similar delay. Then only the total amount of each isotope released during a three month period is reported. Data on specific releases, including time of release, are published only in the case of unplanned releases. Detailed data on routine releases are not available. Therefore, reliance on the licensee's monitoring program for protection against excessive doses is unwarranted. Independent monitoring is needed both as a check during routine operation and for early warning at the onset of a radiological emergency.

One form of independent off-site monitoring carried out by a group of concerned citizens living near the Maine Yankee nuclear power plant in Wicasset, Maine, was to manufacture and deploy a network of continuously recording electronic radiation monitors.[4] Another method is to actively track and measure the plume of air-borne effluent using a mobile radiological monitoring unit. This type of monitoring was carried out by AREA researchers at TMI during the venting of the Unit 2 containment atmosphere during the summer of 1980[5] and in routine monitoring of several nuclear power plants.

In this paper the equipment and procedures developed by AREA for mobile monitoring are described and the results of monitoring in the vicinity of the Oyster Creek Nuclear Generating Station in Tom's River, New Jersey are reported. The monitoring method was designed to determine the external dose rate due to gamma radiation from the plume, to measure the short-lived air particulate activity

in the field, and to sample airborne particulates for laboratory analysis for long-lived radionuclides. A novel and important feature of the method employed in this study is the ability to detect the radioactive plume without prior background measurement by observing fluctuations in the environmental radiation field caused by the meandering motion of the plume.

THE OYSTER CREEK NGS

The Oyster Creek plant is a boiling water reactor (BWR) manufactured by the General Electric Company for the Jersey Central Power and Light Company. The station began operating in 1969 and reached its present maximum power level of 1930 megawatts thermal in 1971. The station is located in a relatively flat marshland area of Ocean County, New Jersey, about 3.2 km inland from the shore of Barnegat Bay. The site is situated 14.5 km south of Tom's River, New Jersey, and 56 km north of Atlantic City. It is bounded on the east by U.S. Route 9, on the west by the Garden State Parkway, on the north by the south branch of Forked River, and on the south by Oyster Creek. The station is located approximately 100 km south of New York City. Figure 1 is a map of the Oyster Creek vicinity showing 43 numbered locations where measurements were made.

Several pathways exist for the discharge of airborne effluent from the Oyster Creek plant.[6] The main sources of gaseous waste are (1) offgas from the main steam condensers, (2) leakage from the turbine gland seals, (3) building ventilation air, and (4) exhaust from the mechanical vacuum pump.

The mechanical pump is used during reactor startup to remove offgas from the main condenser. The offgas is vented through a short (1.75 minute) delay line to the plant stack without filtration. Building ventilation air from the reactor building, the radwaste building, the turbine building, and the offgas building is vented to the stack without delay or filtration. The turbine, radwaste, and offgas buildings are also ventilated through rooftop vents. In a 1971-73 study of the Oyster Creek plant by the United States Environmental Protection Agency (USEPA), it was found that the turbine building was the second largest source of airborne emissions, due to leaks in the steam systems.[7] The steam leakage rate was found to be substantially greater than the 770 kg/hr value assumed in the plant Environmental Statement;[8] Xenon-133 and Xenon-135 emission release rates from the turbine building were measured at 31 and 94 microcuries per second, 25 times greater than the rate predicted in the Environmental Statement. The main condenser offgas is the largest source of radioactive gas. Prior to 1977 the main condenser offgas was passed through a 30-minute delay line, followed by particulate air filters, before being discharged through the 112 m high plant stack.

In August 1977 the augmented offgas treatment system (AOG) was put into operation at Oyster Creek.[6] Its purpose is to reduce airborne radioactive releases and to reduce the volume of offgas processed and eliminate the possible explosion hazard of hydrogen and oxygen formed by the radiolytic decomposition of the reactor water. The AOG system consists of a series of subsystems: hydrogen recombiner subsystem, water removal subsystem, charcoal absorber

subsystem, and high efficiency particulate air filters. Offgas from the main condenser is diluted with air, passed through the AOG, and then vented through the plant stack. The charcoal absorption system, which consists of a series of four six-ton beds of activated charcoal, is designed to increase the delay time for Kr isotopes to 26 hours and for Xe isotopes to 20 days. When functioning according to specifications, the AOG eliminates virtually all short-lived noble gas isotopes from the main condenser offgas discharge, reducing the total gaseous activity released by a factor of 150. The AOG has no effect on emissions from other sources in the plant. A bypass valve may be opened in order to shunt the offgas waste stream around the AOG. During start-up the bypass valve is kept open until the power level gets above 50% of the rated capacity. When the power level decreases, the bypass valve is opened when the power level goes below 45%. The AOG cannot be operated at low power level because of the difficulty in controlling water level flow in the recombiner condenser. (This problem is specific to the design of the AOG at Oyster Creek in which the condenser offgas is diluted with air prior to passage through the AOG. AOG's at other BWR's typically employ dilution of offgas with steam and may be operated down to zero power level.) The bypass valve also opens automatically if excessively high temperature, high hydrogen concentration, or high radiation level is detected in the AOG system.

Table I contains a list of radionuclides reported released in the airborne effluent from the Oyster Creek plant during the third and fourth quarters of 1979.[9] During most of this period

the reactor was operating at nearly maximum power and it may be assumed that the AOG was functioning most of the time.

METHOD

A specially modified Volkswagen Rabbit containing radiation detectors, a high-rate portable vacuum pump, and other equipment carried a two man crew.

Gamma radiation was detected using a 1" x 1" sodium iodide high-energy gamma scintillation probe (HEGSP) (Ludlum Measurements, Sweetwater, Tx., Model No. 44-2) connected to a portable digital ratemeter/scaler (Ludlum Model No. 2200). The probe was sealed inside a foam rubber-lined Lucite housing that was mounted on the roof of the monitoring vehicle.

Air particulate samples were collected on 47 mm membrane filters (Millipore Corporation, Bedford, MA, Cat. No. HAWP-047-00) having a pore size of 0.45 microns. Filters were held in "Sterifil" filter holders (Millipore No. XXII-047-02, -04, and -07). Tygon tubing was used to connect the outlets of three filter assemblies in parallel to three "rotamer" flow meters graduated to 120 standard cubic feet per hour (scfh) (Matheson Instruments, Horsham, PA) and then to the intake ports of a portable high-volume constant displacement air pump (Gast Mfg. Co., Benton Harbor, MI, Model No. 12x2440-101A) driven by a 3 horsepower gasoline engine (Briggs and Stratton, Milwaukee, WI). The pump was capable of maintaining 120 scfh through each filter.

One of the filter holders was modified to clamp onto the front face of a Geiger-Muller "pancake" probe (GMP) (Victoreen, Cleveland, OH, Model No. 489-110) with a thin mica window (1.4-2.0 mg/cm^2

thickness, 4.45 cm diameter). Holes were cut in the sides of the filter holder to allow unimpeded air flow as shown in Figure 2. The distance between the filter and the probe window was 2.7 cm. A similar filter holder assembly, not connected to the air pump, was clamped to a second identical reference "pancake" probe.

Each GM probe was connected to a separate portable ratemeter (Victoreen, Model No. 490, Thyac III) coupled to digital accumulator/timer. The counts accumulated by the reference probe were subtracted from the counts accumulated by the probe facing the pump filter in order to determine the net activity due to particulate radioactive material accumulating on the filter.

The following procedure was used to detect the radioactive plume. Small helium-filled balloons were released near the plant to determine local wind direction. Using the roof-mounted gamma detector, a search for the plume was made downwind from the plant. If the presence of the plume at a particular location was suspected 5 consecutive 2 minute readings were taken. The mean, $\bar{X}$, of these readings X_i (i=1,5) was calculated according to:

$$\bar{X} = \frac{1}{5} \sum_{i=1}^{5} X_i$$

and the standard deviation, σ, of the five readings about the mean was calculated using

$$\sigma^2 = \frac{1}{4} \sum_{i=1}^{5} (X_i - \bar{X})^2$$

The ratio of the standard deviation to the square root of the

mean was calculated. This ratio is known as the reliability factor, $RF = \sigma / \sqrt{\bar{X}}$.

The counts recorded by a properly functioning radiation detector exposed to a constant source of radioactivity obey Poisson statistics and the expected standard deviation of a series of readings equals the square root of the mean. The meandering motion of the radioactive plume causes a variation in the radiation intensity at the detector on a time scale of minutes, while changes in background radiation intensity occur on a time scale of hours.[10] Thus the motion of the plume tends to increase the standard deviation of the series of 2-minute readings above the expected value predicted by Poisson statistics. This is reflected in an RF which is significantly greater than 1. As a practical criterion adopted in this study an RF greater than 2 was taken as indication of the presence of the radioactive plume.

The gamma detector count rate was measured in several plumes while simultaneous measurements were made with a calibrated high-pressure argon-filled ionization chamber, (Reuter/Stokes, Cleveland, Ohio, Model RS-111) on loan from the New Jersey Department of Environmental Protection. It was found that the excess gamma dose rate in the plume could be estimated using:

$$DR = 2.7 \times 10^{-3}\ T,$$

where T is the count rate above background in counts per minute (cpm), and DR is the dose rate in microroentgens per hour (μR/h).[11]

Routine verification of the response of the GMP and HEGSP probes was performed using low-intensity, depleted uranium and 0.01 microcurie ^{60}Co check sources, respectively.

After locating the plume, the air filtration system was set up to draw air through three membrane filters. In order to measure short-lived particulates present in the plume, one of the filters was monitored with a GMP, using the modified filter holder described above, while simultaneous readings were made with the reference GMP. The number of counts accumulated on each GMP was recorded in consecutive two-minute intervals for at least ten minutes before starting the pump in order to check the relative response of the two probes. Then counts accumulated by the HEGSP and both GMP's were recorded every two minutes during the pumping. If significant particulate activity was measured on the monitored filter, the monitored filter was disconnected from the pump. Readings of both GMP's were continued for at least one hour in order to determine the rate of decay of the short-lived particulates. During the measurement, wind direction was periodically observed and recorded by release of a helium-filled balloon. Flow rates through each filter were recorded, and start and finish times of pumping were noted. When the HEGSP count rate indicated that the plume had moved, pumping was discontinued, and the search for the plume began again.

Except for five upwind reference samples, all samples were collected in the plume in order to increase the possibility of detecting long-lived particulates in the plant effluent. All the downwind samples were combined and subjected to gamma-ray emission spectroscopy. The composited sample was also subjected to a

radiochemical analysis for strontium-89 and -90. Laboratory analyses were performed by Teledyne Isotopes, Westwood, N.J.

RESULTS

Figure 3 shows two series of two-minute HEGSP readings taken in the early morning of 25 June 1981 on Haines Road near Route 9 about three miles north of the plant. In the first series taken at site 12 the first five readings averaged 2378 cpm with an RF of 13.8. Then as the wind shifted to a few degrees to the west carrying the plume away, the readings decreased. The average of the last five readings was 861 cpm with an RF of 3.6. At 0340 the monitoring vehicle moved along Haines Road and the plume was found again at site 8. By 0450 the plume had again drifted out of range of the detector.

Table II contains a record of radiation measurements taken at each of the sites shown in Figure 1. The date and time of each measurement are given along with the average HEGSP and GMP count rates for a selected ten minute period. The HEGSP readings were recorded as a series of five two-minute readings, and the RF for this series is also entered in Table II. The angle between the local wind vector and the vector drawn from the stack to the site is also listed. A zero angle signifies that the site was directly downwind from the stack relative to the observed wind direction.

Figure 4 shows the HEGSP count rates recorded at the intersection of Light House Road and Route 9 (site 31) on 19 July 1981 from 0827 to 1208 (EDST). Figure 5 shows the filter

GMP and reference GMP count rates for the same period. The pump was started at 0827 and pumping was continued during the period of highest plume activity as indicated by the large HEGSP count rates. Following the sharp drop in gamma activity the monitored filter was disconnected from the pump at 0913. At this point, the filter GMP count rate stopped increasing and began to decrease at a rate determined by the decay of the accumulated particulate radioactivity. Figures 6 and 7 show data taken later the same day when the site was upwind from the plant. Both the HEGSP and reference GMP count rates were constant at their background values with variation accounted for by expected statistical fluctuations. The rise in the filter probe count rate is very small compared to that observed when the plume was present.

The results of ten such measurements are summarized in Table III. The date and location of each measurement is given, along with the start time, duration of pumping and the HEGSP count rate averaged over the entire pumping period. The logarithm of the difference between the monitoring GMP and reference GMP (two minute counts) was plotted versus time, for the first half hour of decay for the two upwind cases and for the two highest activity filters. Using the method of least squares, the best straight line fit to this plot was obtained and the slope of this line yielded the effective half-life given in Table III.

Gamma spectroscopic analysis of the combined filters detected no gamma emitting isotopes. The minimum detectable activity and minimum detectable air concentration for each

isotope is given in Table IV. Radiochemical analysis yielded less than 0.7 picocuries (pCi) in the combined filters corresponding to a minimum detectable average air concentration of 19 femtocuries per cubic meter (fCi/m^3). The strontium-89 content in the combined filters was 1.9 ± 1.0 pCi, corresponding to an average air concentration (after correction for decay) of 17.5 ± 9.2 fCi/m^3.

DISCUSSION AND CONCLUSIONS

It has been demonstrated that the radioactive plume from the Oyster Creek plant can be tracked and measured using a 1" x 1" sodium iodide scintillation detector. Analysis of the temporal variation of the radiation field proved to be an effective means of detecting the plume when prior knowledge of background radiation was not available.

Using the conversion factor obtained by comparison of the scintillation detector with the calibrated ionization chamber (Methods), it is possible to convert scintillation detector count rates to external gamma dose rates. The lower limit of detection for radiation form the plume corresponded to a dose rate of 1μR/hr. A maximum ten minute dose rate above background of 21μR/hr was observed 1 km northwest of the plant (site 40, 7/18/82, Table II). An average dose rate of 11 μR/hr above background over a period of 46 minutes was observed in a populated area 1.9 km from the plant (site 31, 7/19/82).

Using the air filtration system with filter and reference GM probes, it was possible to observe the buildup and decay of radioactive airborne particulate on the air filters. The effective half-lives for the upwind particulate samples are about one hour

for pumping times of approximately 1.5 hours. The effective half-lives of the two highest activity particulate samples collected in the plume (37 minutes and 25 minutes) are significantly shorter and indicate that a significant portion of the effluent airborne particulate radioactivity is probably a mixture of rubidium-88 (half-life 17.2 minutes) and cesium-138 (half-live 32.2 minutes). These isotopes are produced in abundance by the decay of krypton-89 and xenon-138. Krypton-88 and xenon-138 constitute a significant fraction of gaseous releases that have been reported (see Table I). Because of the half-lives of the krypton-88 and xenon-138 parents of the observed particulates are only 2.80 hours and 14.2 minutes, utilization of the AOG with design hold up times of 26 hours for krypton and 20 days for xenon, should eliminate these isotopes from the effluent stream. Thus, the results reported here indicate that a significant portion of the Oyster Creek gaseous effluent was not being processed through the AOG. On the day these results were obtained the plant was operating at between 50% and 60% of its rated capacity.[12] The low power level indicates that the AOG had been bypassed, accounting for the presence of short-lived noble gases and their particulate daughters in the plume.

By positioning the air filtration system in the plume, effluent airborne particulates were collected at a maximum rate along with a minimum quantity of background particulates. This method yields a sample with the best plume volume to background air volume ratio in the shortest possible time. The concentration of

strontium-89 in air measured by the New Jersey Department of Environmental Protection at several locations in the state, during the same period, was comparable to the value reported here. This background concentration of strontium-89 is due to an atmospheric nuclear bomb test carried out by the People's Republic of China in October 1980. Thus, the strontium-89 in the sample could not be attributed to plant effluent.

In conclusion, mobile radiological monitoring units can be used effectively to monitor routine discharges of radioactive airborne effluent from nuclear facilities. Such units can also be used to monitor possible offsite releases of airborne radioactivity during an emergency. Detection of the radioactive plume can be accomplished without prior survey of background radiation levels in the plant vicinity. The results of such measurements can reveal changes in the operating status of the plant such as changes in power level or abnormal occurrences. They can also provide the fastest way for a community to discover a gradual increase in released, long-lived radioactivity from a nuclear facility.

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TABLE I

Reported airborne radionuclides released from Oyster Creek Nuclear Generating Station during the third and fourth quarters of 1979.

Nuclides Released	Half-Life+	Third Quarter (Curies)	Fourth Quarter (Curies)
Noble Gases:			
krypton-85m	4.4h	1.07×10^{4}	9.04×10^{3}
krypton-87	76.0m	3.60×10^{4}	3.34×10^{4}
krypton-88	2.8h	3.56×10^{4}	3.13×10^{4}
xenon-133	5.27d	1.15×10^{4}	8.54×10^{3}
xenon-135	9.2h	6.10×10^{4}	5.45×10^{4}
xenon-135m	15.6m	2.70×10^{4}	2.28×10^{4}
xenon-138	17.0m	9.03×10^{4}	7.59×10^{4}
krypton-89	3.2m	8.16	5.65
xenon-133m	2.26d	$<1.47\times10^{-8}$	$<1.47\times10^{-8}$
xenon-137	3.9m	1.78×10^{2}	1.33×10^{2}
Total for period:		2.72×10^{5}	2.36×10^{5}
Iodines:			
iodine-131	8.05d	2.67	1.44
iodine-133	21.0h	9.26	4.46
iodine-135	6.7h	1.31×10^{1}	5.55
Total for period:		2.50×10^{1}	1.15×10^{1}
Particulates:			
strontium-89	50.4d	1.08×10^{-2}	1.52×10^{-2}
strontium-90	28.2y	5.22×10^{-2}	5.25×10^{-5}
cesium-134	2.19y	$<1.32\times10^{-10}$	3.20×10^{-5}
cesium-137	30.0y	8.77×10^{-4}	5.43×10^{-4}
barium-140	12.8d	8.89×10^{-2}	4.40×10^{-2}
lanthanum-140	40.2h	7.08×10^{-2}	3.56×10^{-2}
chromium-51	27.8d	4.59×10^{-4}	$<7.14\times10^{-10}$
manganese-54	291.0d	2.91×10^{-3}	4.03×10^{-4}
cobalt-58	71.0d	4.96×10^{-3}	$<1.67\times10^{-10}$
iron-59	45.0d	$<3.65\times10^{-10}$	2.98×10^{-4}
cobalt-60	5.27y	2.15×10^{-3}	2.93×10^{-3}
strontium-91	9.7h	6.22×10^{-1}	2.61×10^{-1}
niobium-95	35.0d	6.65×10^{-4}	$<2.07\times10^{-10}$
molybdenum-99	66.0h	$<5.99\times10^{-10}$	1.19×10^{-3}
technetium-99m	6.0h	6.16×10^{-2}	4.73×10^{-2}
ruthenium-103	40.0d	1.27×10^{-4}	$<6.05\times10^{-11}$
iodine-131	8.05d	7.81×10^{-3}	7.97×10^{-3}
iodine-133	21.0h	6.66×10^{-2}	6.49×10^{-2}
iodine-135	6.7h	1.49×10^{-1}	9.82×10^{-2}
cerium-141	32.5d	1.82×10^{-4}	1.24×10^{-4}
cerium-144	285.0d	4.64×10^{-4}	1.38×10^{-4}
protactinium-233	27.4d	$<1.38\times10^{-10}$	1.55×10^{-3}
neptunium-239	35.0m	1.01×10^{-3}	1.33×10^{-3}
Total for period:		1.14	5.93×10^{-1}

+y=years, d=days, h=hours, m=minutes.

TABLE II

Ten minute radiation readings at monitoring sites near the Oyster Creek Nuclear Generating Station. 10 minute GMP counts, 10 minute HEGSP counts and 5x(2 minute) HEGSP-R.F.'s.

Sector	Site No. (Stack Bearing)	Date of Observation	Time of Observation (EDST)	HEGSP (cpm)	HEGSP-R.F.	GMP (cpm)	Stack Bearing Minus Surface Wind Direction (±10)
I	1	7/18/82	1630	5238	52.9	64.2+	0
	2	6/21	0327	810	2.7	--	-20
	3	4/5	0616	676	0.8	26.0	-40
II	4	4/5	0230	3346	13.7	56.6	0
	4	4/5	0659	1584	3.1	33.2	0
	4	7/18	0222	3036	4.4	33.8+	0
	5	4/5	0430	4066	9.7	80.5	0
	5	4/11	0422	2382	9.9	48.6	0
	6	6/22	0122	1259	13.4	--	0
	7	6/21	0436	1788	6.8	--	-10
	7	6/28	0451	2507	2.4	--	0
	8	6/25	0408	2679	1.8	--	-10
	8	7/1	0100	732	1.2	--	-40
	9	7/18	2000	2249	8.2	36.8+	-10
	10	4/7	0421	3423	4.3	47.7	0
	11	4/7	0516	1798	3.4	29.0	0
	12	6/25	0315	2450	7.7	--	-10
	12	7/1	0344	793	1.0	--	-70
	13	4/11	0300	2362	5.9	--	0
III	14	4/11	0142	2371	13.6	48.7	0
	15	4/17	0722	2455	3.3	45.2‡	0
	16	4/17	0745	1789	5.6	37.7‡	0
	17	6/6	0214	3036	3.4	--	0
	17	6/6	0655	3370	1.3	--	0
	18	4/17	0651	2680	2.8	40.0‡	+10
	19	7/18	2132	2489	20.1	42.0	-20
	20(239°)	4/14	0320	1558	0.9	31.6	+120
	20(239°)	4/17	0348	4372	1.4	31.2	-30
	20(229°)	4/17	0528	4916	4.1	52.9‡	-10
	20(234°)	6/4	0245	3634	1.2	--	0
	20(234°)	6/22	0304	3959	2.1	--	-10
	20(231°)	7/19	0053	4517	2.5	48.2+	0
IV	21	6/12	0209	3113	1.2	--	-15
V	22	6/26	0414	774	4.3	--	0
	23	6/11	0345	1863	0.5	--	0
	23	6/11	0355	1867	1.5	--	0
	23	6/19	0130	2936	1.3	--	+90
	23(271°)	7/9	0137	2820	1.8	--	0
VI	24	7/11	0103	492	1.4	27.7+	0
	25	7/9	0248	524	1.4	--	0
	26	6/5	0633	543	1.0	--	0

Sector	Site No. (Stack Bearing)	Date of Observation	Time of Observation (EDST)	HEGSP (cpm)	HEGSP-R.F.	GMP (cpm)	Stack Bearing Minus Surface Wind Direction (±10)
VII	27	6/5	0329	1683	1.3	--	0
	28	7/15	0320	3124	2.2	47.7+	+10
	29	6/19	0436	656	1.2	--	+100
VIII	30	7/12	0428	758	1.2	28.3+	+20
	31	7/11	0628	973	1.6	28.3+	-30
	31	7/19	0849	7097	6.1	92.0+	0
	31	7/19	1645	682	1.6	26.9+	+180
	32	7/7	0336	1092	1.8	29.5+	-20
	33	7/8	0312	905	3.0	--	0
IX	34	6/18	0158	757	1.0	--	-20
	35	6/1	0218	1714	6.6	--	-10
X	36	6/1	0333	2174	12.2	--	0
	36	6/18	0325	1014	5.0	--	0
	37	6/8	0204	1066	3.9	--	0
XI	38	4/16	0312	1622	8.1	34.7	0
	38	5/10	0346	628	1.0	31.5	+15
XII	--						
XIII	--						
XIV	39	4/14	0603	1629	10.8	33.8	-10
XV	40	4/14	0436	3462	13.7	49.0	0
	40	7/18	1250	8560	34.4	214.0+	0
	41	7/1	0344	628	0.6	--	+40
	42	7/15	0103	611	1.3	26.3+	-200
	43	7/19	2100	644	0.8	25.9	+100

+ GMP shielded by "dummy" filter holder.

‡ GMP shielded with lucite and aluminum during part of the 10 minute count.

TABLE III

Measurement of shortlived air particulate activity.

Date	Site No.	Start of Pumping (EDST)	Duration of Pumping+ (min)	Average HEGSP (cpm)	Maximum Excess Filter Activity (cpm)	Effective Half-life First ½ Hr. of Decay (min)
7/11	31	0520	201	802	51.2	--
7/11	42	1637	58	636	36.9	--
7/18	4	0143	92	2380	80.6	--
7/18	4	0430	161	1278	92.9	--
7/18	40	1144	67	5989	433.4	37.0
7/18	1	1633	75	4038	92.9	--
7/19	20(231°)	2353	97	2985	39.3	--
7/19	31	0827	46	4874	595.5	25.3
7/19	31	1623	100	683	49.3	55.7*
7/19	43	2116	92	641	67.3	62.4*

+Flow rate was 120 scfh for all samples.

*Upwind sample.

TABLE IV

Gamma Spectroscopic detection limits and minimum detectable average air concentrations for long-lived gamma emitters in air particulate samples collected downwind from Oyster Creek Nuclear Generating Station

Isotope	Half-life	Detection limit (pCi)	Minimum detectable average air concentration** (fCi/m^3)
beryllium-7	53.6d	10	58
potassium-40	$1.3x10^9$y	40	110
manganese-54	291d	1	3.1
cobalt-58	71d	1	4.8
iron-59	45d	3	20
cobalt-60	5.27y	2	5.5
zinc-65	245d	3	9.6
zirconium-95	65d	2	10
ruthenium-103	40d	2	15
ruthenium-106	1.0y	10	30
iodine-131	8.0d	2	470
cesium-134	2.19y	2	5.7
cesium-137	30y	2	5.4
barium-140	12.8d	2	103
cerium-141	32.5d	2	19
cerium-144	285d	9	28
radium-226	1622y	30	81
thorium-228	1.91y	3	86

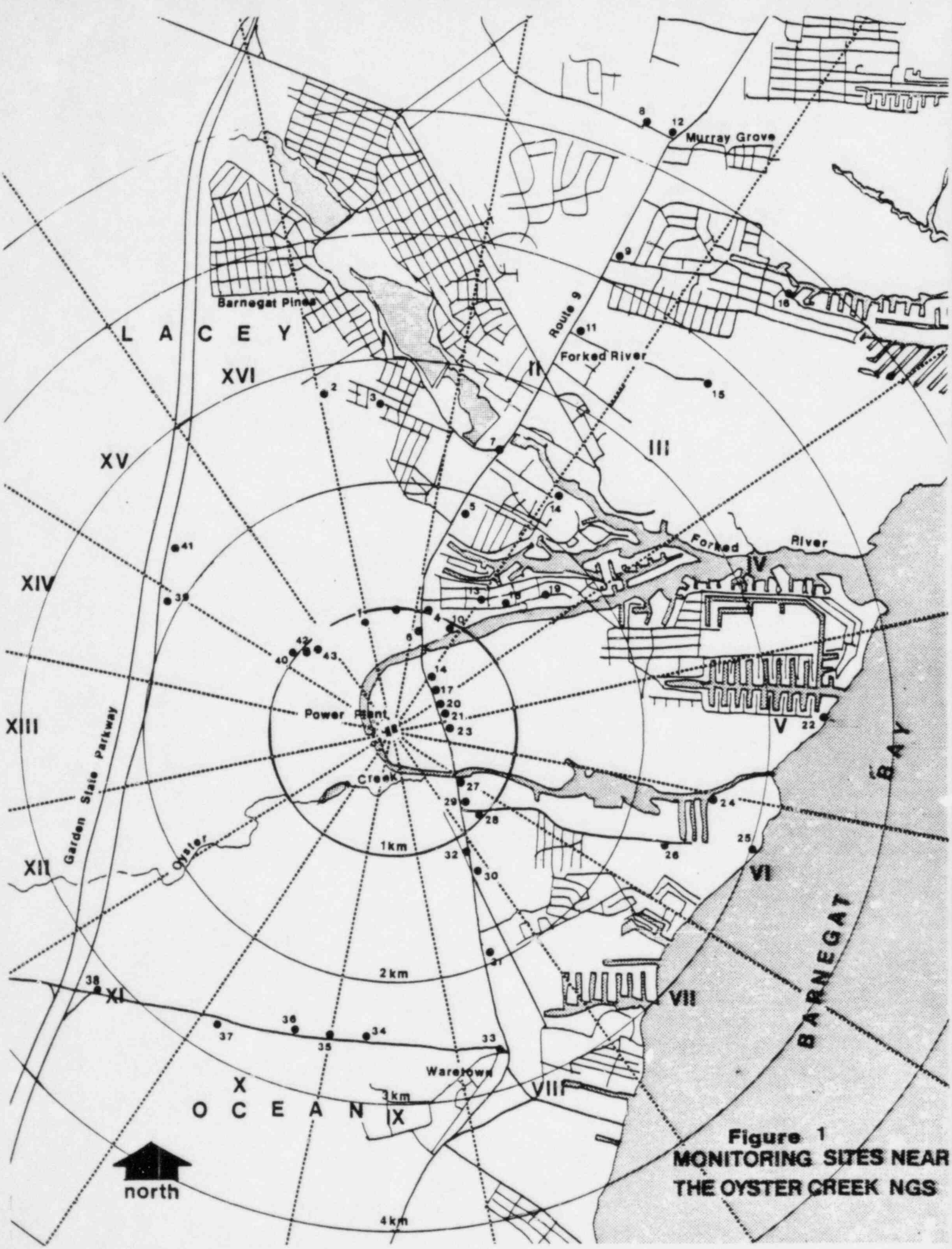
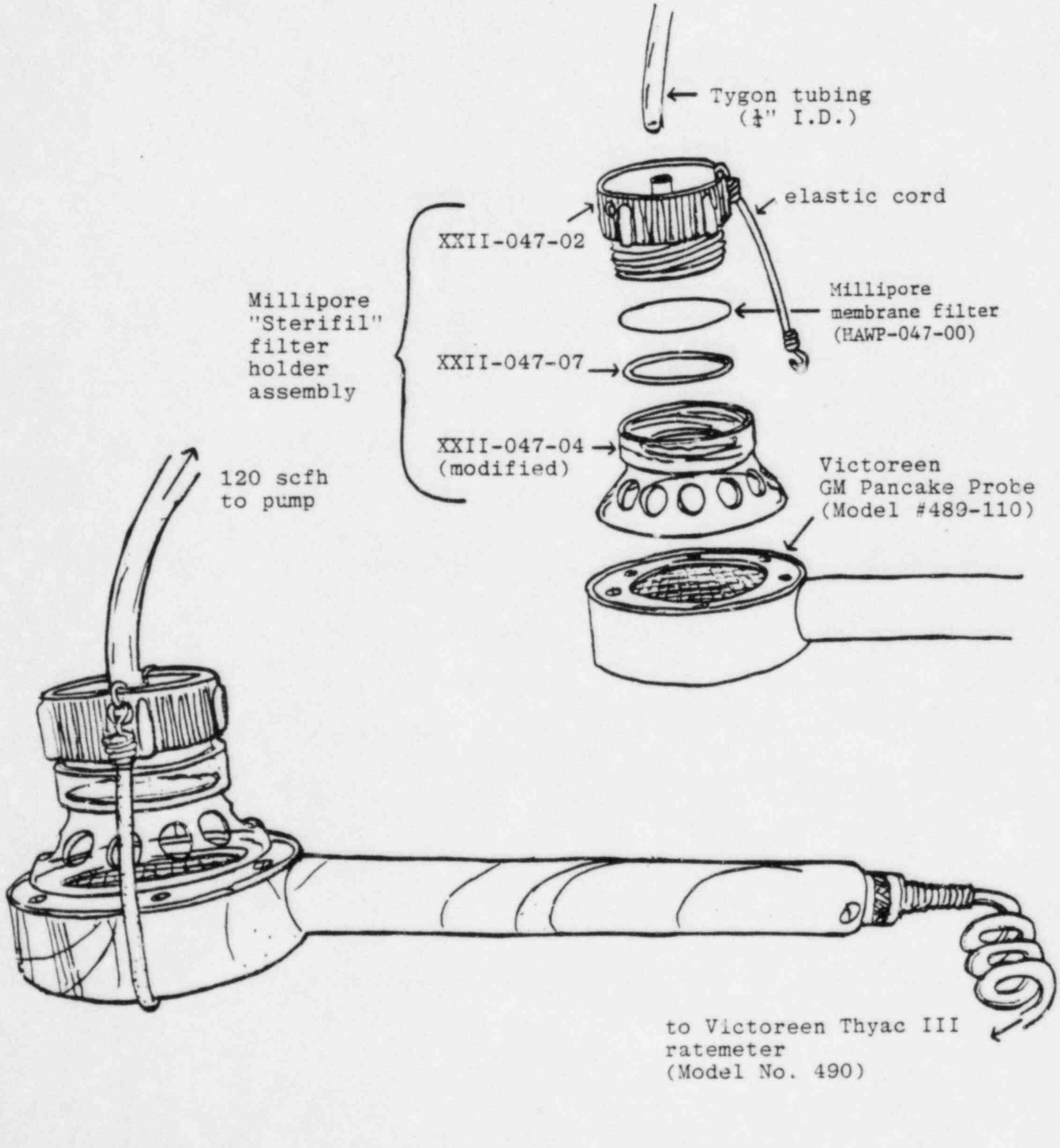


Figure 1
MONITORING SITES NEAR THE OYSTER CREEK NGS

Figure 2



Tygon tubing
(¼" I.D.)
elastic cord
XXII-047-02
Millipore
"Sterifil"
filter
holder
assembly
Millipore
membrane filter
(HAWP-047-00)
XXII-047-07
XXII-047-04
(modified)
120 scfh
to pump
Victoreen
GM Pancake Probe
(Model #489-110)
to Victoreen Thyac III
ratemeter
(Model No. 490)

Gamma radiation levels at two locations along Haines Road near Route 9 on 25 June 1981, measured with HEGSP (1"x1" NaI) detector. Distance to Oyster Creek stack is 5.2 km.

During this period the wind shifted so that first site 12 and then site 8 was downwind from the reactor.

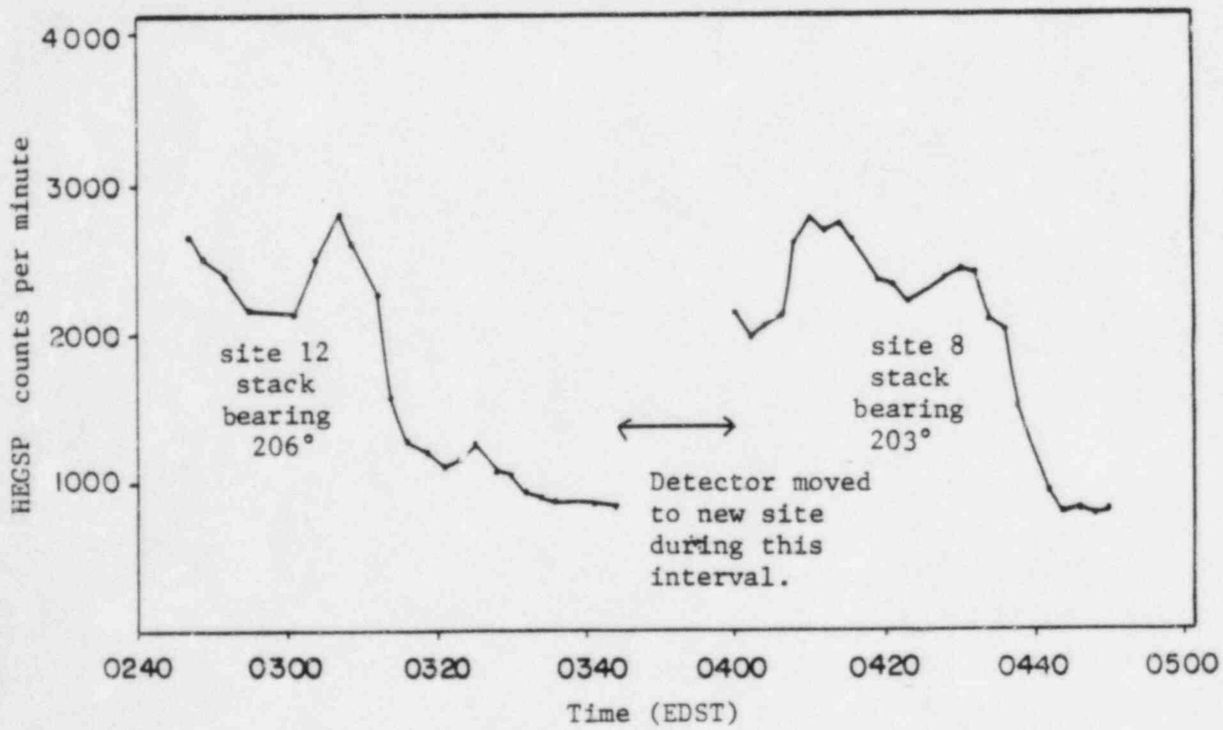
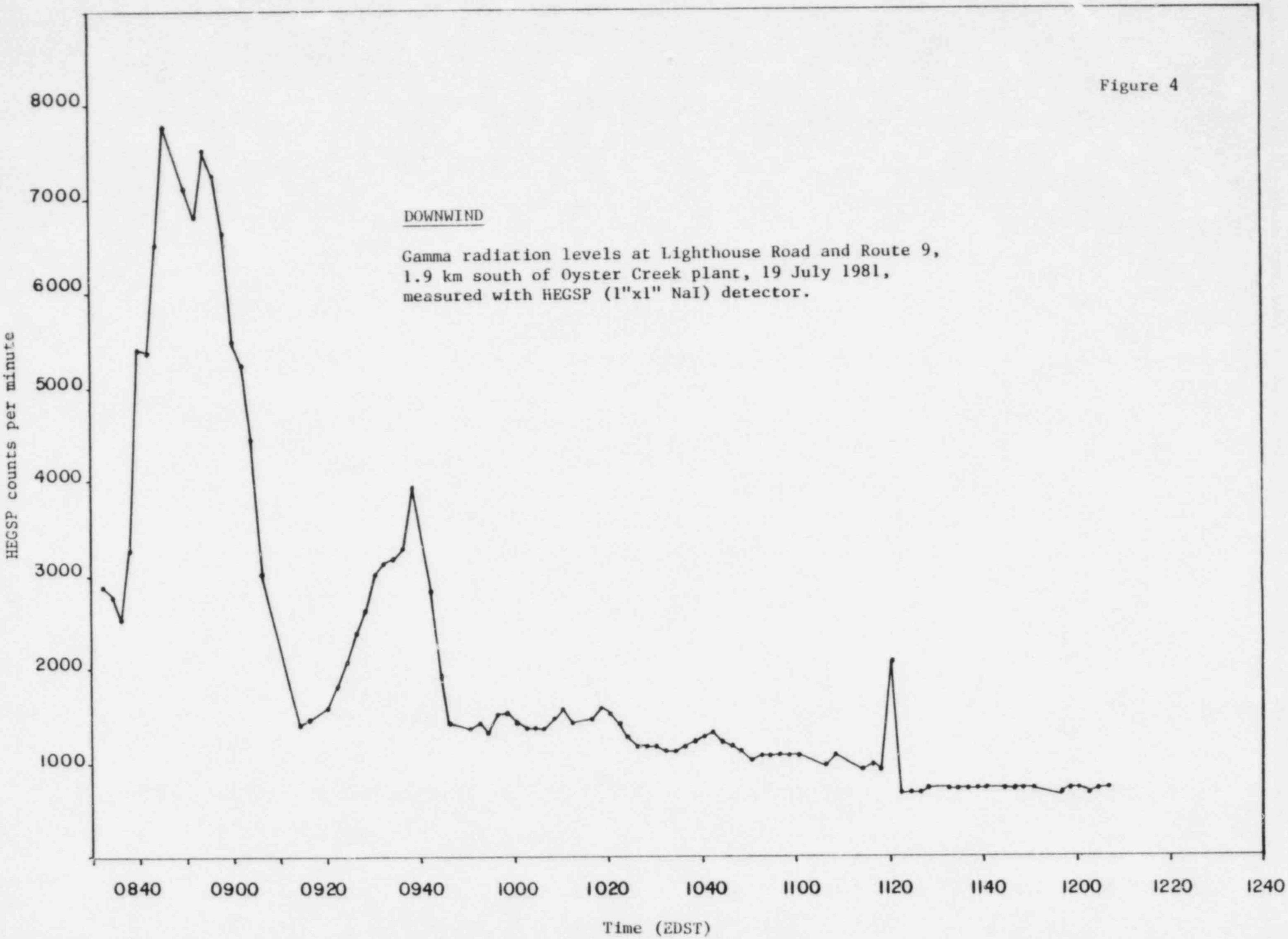


Figure 4



DOWNWIND

Gamma radiation levels at Lighthouse Road and Route 9, 1.9 km south of Oyster Creek plant, 19 July 1981, measured with HEGSP (1"x1" NaI) detector.

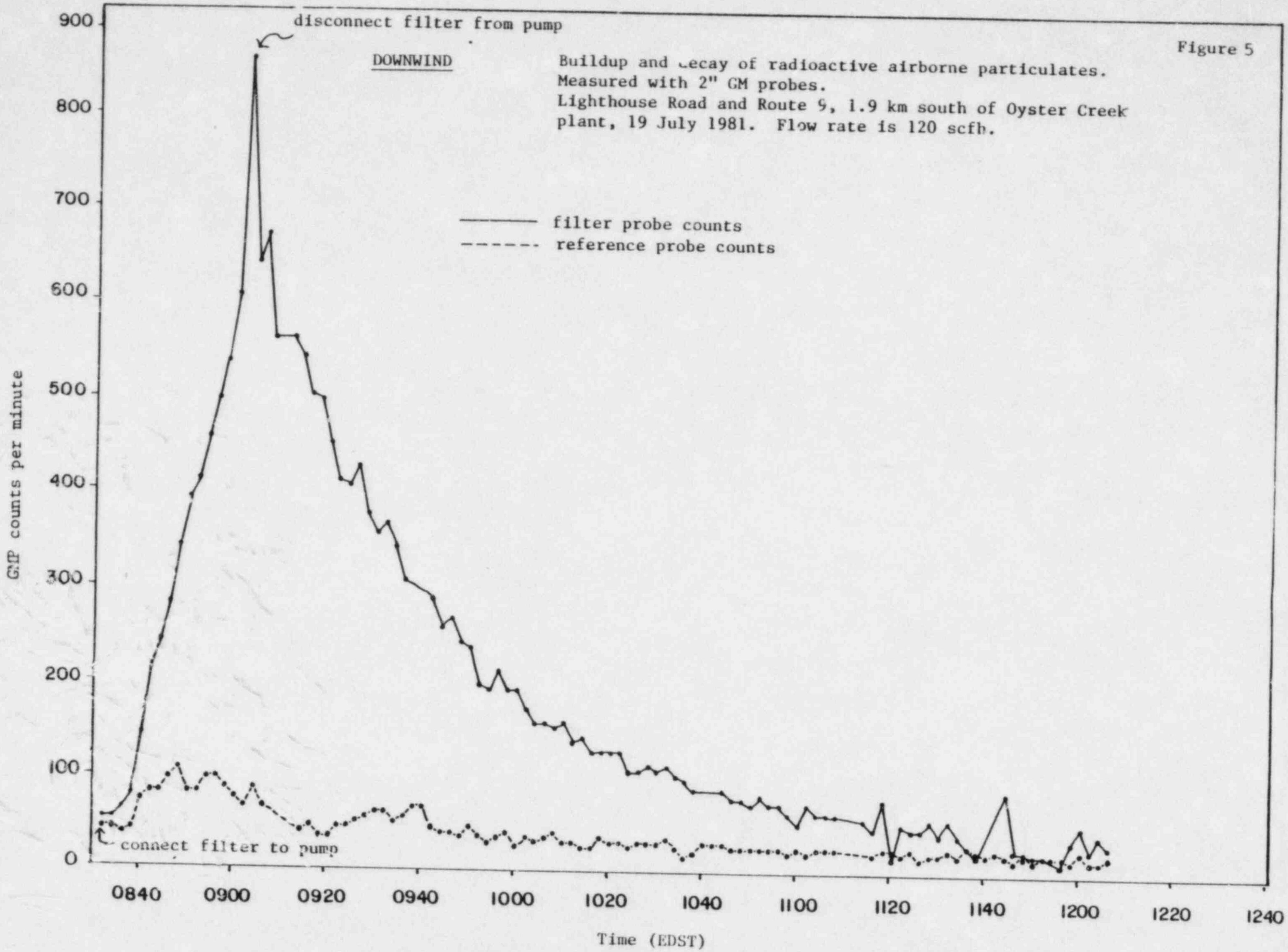
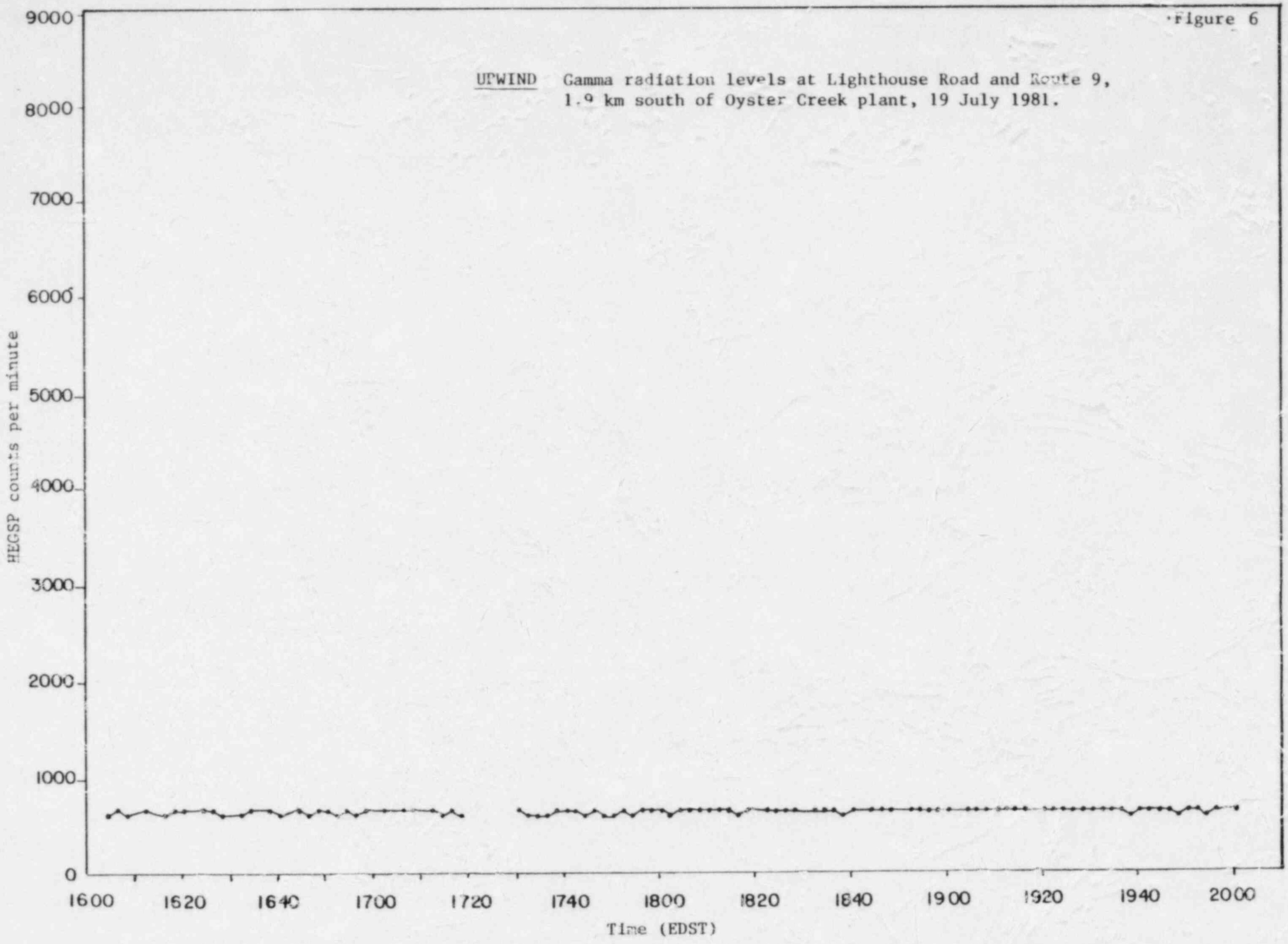


Figure 5
DOWNWIND
Buildup and ‿ecay of radioactive airborne particulates.
Measured with 2" GM probes.
Lighthouse Road and Route 9, 1.9 km south of Oyster Creek plant, 19 July 1981. Flow rate is 120 scfh.
disconnect filter from pump
connect filter to pump
filter probe counts
reference probe counts
GMP counts per minute
0
100
200
300
400
500
600
700
800
900
0840
0900
0920
0940
1000
1020
1040
1100
1120
1140
1200
1220
1240
Time (EDST)

Figure 6



UPWIND Gamma radiation levels at Lighthouse Road and Route 9, 1.9 km south of Oyster Creek plant, 19 July 1981.
HEGSP counts per minute
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
1600
1620
1640
1700
1720
1740
1800
1820
1840
1900
1920
1940
2000
Time (EDST)

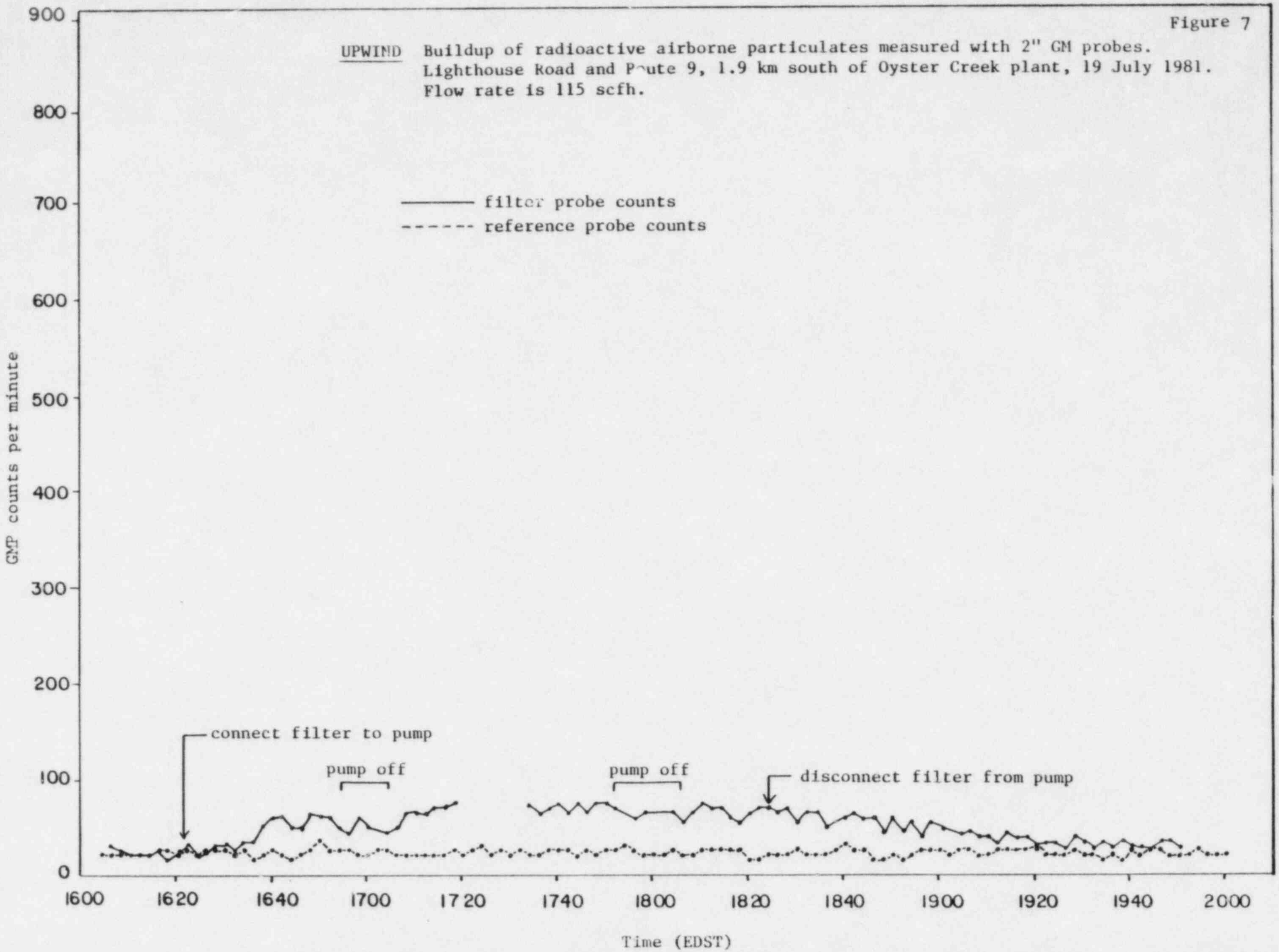


Figure 7

UPWIND Buildup of radioactive airborne particulates measured with 2" GM probes. Lighthouse Road and Route 9, 1.9 km south of Oyster Creek plant, 19 July 1981. Flow rate is 115 scfh.

(2) DKt 50-400 "81 Report"

REPORT TO CONGRESS ON ABNORMAL OCCURRENCES

OCTOBER-DECEMBER 1981

NUCLEAR POWER PLANTS

The NRC is reviewing events reported at the nuclear power plants licensed to operate during the fourth calendar quarter of 1981. As of the date of this report, the NRC had determined that the following were abnormal occurrences.

81-7 Blockage of Coolant Flow to Safety-Related Systems and Components

Preliminary information pertaining to this event was reported in the Federal Register (Ref. 1). Appendix A (Example 12 of "For All Licensees") of this report notes that recurring incidents, and incidents with implications for similar facilities (generic incidents), which create major safety concern can be considered an abnormal occurrence.

Date and Place - The NRC has received notifications from several nuclear power plant licensees indicating that the heat transfer capabilities in some safety-related and nonsafety-related cooling systems were degraded by unanticipated blockage of the coolant flow paths. Table 1 lists several incidents of a generic nature with varying degrees of safety significance. The incidents are listed by dates of discovery. The incident discovered at Brunswick Unit 1 was the most significant from the safety standpoint due to the total loss of both redundant trains of the residual heat removal system. The other incidents, which were of lesser safety significance, are other recent examples of the recurrent nature of flow blockage problems which have been experienced. The principal cause for the flow blockages in many of these situations was a buildup of biological organisms.

Nature and Probable Consequences - In a nuclear power plant, it is imperative that the heat generated by the nuclear reactor and the components of safety systems be dissipated to the environs. This process is usually performed by transferring the heat being generated to various cooling systems via heat exchangers and then to a heat sink such as a river, lake, or cooling tower. These processes are utilized during normal operations and subsequent to normal plant shutdowns or accidents. Failure to provide adequate cooling could result in severe damage to the safety-related components or systems designed to safely shut down the plant and to mitigate the consequences of a major occurrence (such as a loss of coolant accident, LOCA).

The events described in Table 1, although limited in actual consequence, clearly are precursors to a possible common cause failure that could lead to more serious consequences, particularly in conjunction with postulated accidents. The nature of aquatic fouling in piping systems is such that it may go unnoticed, or not severely degrade normal system performance, until the system is called upon to function following an incident. Some of the ways that this can be postulated to occur are described below.

Table 1 Incidents Involving Coolant Blockage to Safety Systems and Components

Date/Plant/Location/Licensee	Event Description
1. September 3, 1980; Arkansas Nuclear One, Units 1 and 2; Pope County, Arkansas; Arkansas Power and Light Company. (See Note 1)	Coolant flow in the service water systems was blocked due to debris from asiatic clams growing in the system and from a buildup of silt and corrosion products. Containment coolers, high pressure safety injection pump bearing and seal coolers, and containment spray and low pressure injection pump seal water coolers were most significantly affected. Clam shells were also found in the Auxiliary Cooling Water System (ACWS) which serves nonsafety-related equipment in the turbine building. Due to design differences, Unit 2 had more severe problem than Unit 1.
2. March 18, 1981; Rancho Seco Unit 1; Sacramento County, California; Sacramento Municipal Utility District. (See Note 2)	During a refueling outage, the licensee observed that the inlet plenum of the safety-related lube oil cooler on each of the high pressure injection pumps was 80 to 90% clogged with corrosion products. The cause was attributed to excessive corrosion of the lube oil cooler cast steel heads. Routine surveillance testing did not previously verify performance of this equipment.
3. April 25, 1981; Brunswick Units 1 and 2; Brunswick County, North Carolina; Carolina Power and Light Company. (See Note 3)	Coolant flow in the service water systems was blocked due to debris from marine organisms growing in the system. Species present included American oysters, blue mussels, barnacles, and tubeworms. The Residual Heat Removal (RHR) systems, which provide decay heat removal capability following normal shut downs and during post-accident recirculation cooling, at both units were affected. Some shells were also found in other safety and nonsafety-related component coolers such as the diesel generator heat exchangers, core-spray pump room cooler and the turbine building component cooling water heat exchangers. Three RHR heat exchangers (both of those on Unit 1 and one on Unit 2) had their baffle plates displaced, as a result of the high differential pressure caused by the change in flow rate, allowing the service water to bypass the heat exchanger tubes. Therefore, the heat exchangers were inoperable.

Table 1 (Continued)

Date/Plant/Location/Licensee	Event Description
4. June 9, 1981; San Onofre Unit 1; San Diego County, California; Southern California Edison Company. (See Note 4)	Growth of gooseneck barnacles on the salt-water discharge pipe of the safety-related component cooling water heat exchangers caused a low coolant flow and the malfunctioning of a butterfly valve. This growth was noticed while making preparations to restart the plant following a 14-month protracted shutdown. No problems were noted previously when the plant was in normal operation with routine flushings of the system with heated water.
5. August 28, 1981; Pilgrim Unit 1; Plymouth County, Massachusetts; Boston Edison Company. (See Note 5)	While conducting an inspection in conjunction with an NRC Information Notice 81-21 (Ref. 2), the Reactor Building Closed Cooling Water (RBCCW) heat exchanger "B" was discovered to be inoperable. A water bypass condition existed because the heat exchanger baffle plates had deformed allowing water to bypass the heat exchanger tubes. Although the heat exchanger problem involved a design deficiency, the growth of mussels in the Salt Service Water (SSW) system contributed to the degradation of the SSW system capabilities. Pilgrim had experienced problems with mussels growing in the cooling system for several years. The RBCCW system cools both nonsafety- and safety-related systems. The degradation of the RBCCW heat exchanger affects the heat removal capability of the residual heat removal system, as well as safety-related pump lube oil and bearing coolers and safety-related area coolers. (NOTE - The RBCCW heat exchanger design deficiency is being reviewed separately for generic implications as a possible common mode failure mechanism.)
6. January 14, 1982; Arkansas Nuclear One, Unit 2; Pope County Arkansas; Arkansas Power and Light Company. (See Note 1)	While the plant was shut down, a weekly surveillance flow test was being conducted of the containment fan cooler heat exchangers. For the "C" cooler, flow dropped from about 1800 gpm to about 600 gpm within five minutes. A normal flush did not increase flow; however, a high velocity flush

Table 1 (Continued)

Date/Plant/Location/Licensee	Event Description
	did get the flow through the "C" cooler back to about 1300 gpm (technical specification value is 1250 gpm). The "C" and "D" coolers were disassembled and about five gallons of Asiatic clams were removed from the "C" cooler inlet water box; some clams were also found in the "D" cooler inlet water box. Most of the clams were dead. Other coolers were inspected, but no significant amount of clams were found.

Notes to Table 1:

1. Arkansas Nuclear One, Units 1 and 2 utilize pressurized water reactors designed by Babcock & Wilcox and Combustion Engineering, respectively.
2. Rancho Seco Unit 1 utilizes a pressurized water reactor designed by Babcock & Wilcox.
3. Brunswick Units 1 and 2 both utilize boiling water reactors designed by General Electric.
4. San Onofre Unit 1 utilizes a pressurized water reactor designed by Westinghouse.
5. Pilgrim Unit 1 utilizes a boiling water reactor designed by General Electric.

///

a. During normal operation, particularly if an adequate control program is not being followed, fouling organisms can grow in large diameter piping if the flow velocity is low. A quantity of fouling organisms, sufficient to cause severe flow blockages in Safety-related coolers under accident conditions, could accumulate in such piping without causing significant flow degradation under normal operating conditions. Therefore, a situation such as this could go undetected for a long time since a large accumulation of fouling organisms would be required before any noticeable flow degradation was observed. These fouling organisms may potentially be slowly swept into components requiring cooling water causing tube plugging and degraded performance. If additional service water pumps are started following an incident, the tendency for live organisms, marine shell fragments, and other debris to be swept down the piping into heat exchangers would increase due to the higher flow velocity.

b. Fouling organisms also thrive in stagnant runs of piping in operating systems or in piping systems which have been inactive for long periods of time. Particularly during initial construction or extended maintenance

outages, systems that would normally be operating may be laid up for months or even years without the implementation of an adequate control program, allowing fouling organisms ample time to become established in systems that otherwise might be unaffected during operation. The concern here is that plants could begin operation without the operators being aware of the fouling that could exist.

An example of this, that did not go undetected by the licensee, is the described occurrence at San Onofre Unit 1. This plant had been shut down for steam generator tube repairs for over one year. During this time, the periodic flushing of the system with heated water (heat treatment) normally used by the licensee to control the growth of marine organisms, was curtailed. Due to the lack of periodic heat treatment, the licensee discovered, after observing a low saltwater coolant flow rate, that gooseneck barnacles were present on the component cooling water heat exchanger discharge tubesheet and in the saltwater discharge piping. The growth of the barnacles effectively (1) reduced the flow area of the piping causing low flow and (2) caused the malfunctioning of a butterfly valve.

Fire protection systems using service water are also a prime candidate for fouling by aquatic organisms since they inherently contain stagnant branch lines that are conducive to marine growth. Branch lines in fire protection sprinkler systems can be as small as one-inch nominal pipe size, and sprinkler heads generally have orifices of one-half inch. These would be susceptible to plugging. In addition, live organisms or marine shell fragments would be swept toward the open sprinkler head in the event of a fire.

c. Seismically diked emergency ponds utilized by some power plants as the ultimate heat sink could also support the growth of Asiatic clams. If makeup to the pond is from a waterbody in which the Asiatic clams are known to be present, then it is likely that the clams will be found in the ultimate heat sink and possibly in the service water supply header leading to the plant from the ultimate heat sink.

Under design heat loads (e.g., post-LOCA) ultimate heat sink temperatures could reach 110 to 120°F during summer months. This is hot enough to cause a substantial mortality of the clam population. Dead clams may be more of a problem than live organisms, since they are more easily swept along by the flow. Therefore, following a LOCA that resulted in high pond temperatures, service water system performance could be gradually degraded if the dead clams are swept into the system. Even if the temperature of the ultimate heat sink does not reach the point that causes clam mortality, clams residing in the service water supply header could still be swept along the piping if the flow velocity is sufficiently high. Since the service water supply headers can be quite long, even a moderately dense infestation may translate into a large volume of clams. A small percentage of these, if swept along the piping, could overburden automatic backwash service water strainers.

d. Although all nuclear power plants are designed to withstand a seismic event, the vibratory motion induced by such an event may cause fouling organisms such as oysters, that attach themselves to piping walls by a strong but brittle bond, to be broken loose in sufficient quantities by the pipe flexure to cause flow blockage in cooling water systems. In a similar manner, during a seismic event, piping severely encrusted with corrosion products may release a substantial amount of debris which can collect in equipment bearing or seal coolers blocking the cooling water flow. In both cases, the buildup of fouling organisms or corrosion products may not noticeably degrade system performance during normal operation; however, the performance of redundant systems could be simultaneously degraded following a seismic event. Since the reactor coolant system is seismically designed, a LOCA is not postulated to result from a seismic event. A degradation of the service water system, in this case, would not be an immediate safety concern but may lengthen the time required to go to cold shutdown as a result of the unavailability or diminished heat removal capacity of the shutdown cooling system.

e. Seal coolers are generally provided on pumps that may be called upon to pump heated water from the containment sump following a LOCA; for example, such pumps include the high and low pressure injection pumps, containment spray pumps or residual heat removal pumps. Surveillance testing of these pumps is, by necessity, performed with water at ambient temperature. This is not representative of the temperatures of water encountered during the post-LOCA recirculation mode of operation. Therefore, if flow blockage existed in the pump seal coolers due to the growth of fouling organisms or a buildup of silt or corrosion products, it could go unnoticed during pump surveillance testing unless flow measurements through the coolers were part of the test. There are two reasons for this: (1) since the pumped fluid is at ambient temperature, seal cooling may not be necessary and no seal degradation would be observed even after hours of running without cooling water; and (2) generally, surveillance testing is of such a short duration that no noticeable seal degradation would occur even if cooling flow were necessary for sustained operation. Since pumps required during the post-LOCA recirculation are generally located outside primary containment (in the auxiliary building) degraded pump seals would result in the leakage of radioactively contaminated water outside containment.

Similarly, pumps provided with bearing lube oil coolers could be susceptible to flow blockages due to fouling organisms or the accumulation of corrosion products or silt deposits. Flow blockages in these coolers could also go unnoticed during surveillance testing unless the cooling water flow was monitored. This could result in premature bearing failure when the pumps are needed to run for an extended period of time, e.g., following a LOCA.

The safety concern identified by these events is the possible degradation of the heat transfer capabilities of redundant safety systems to the point where system function is lost. Preventive measures and methods of detecting gradual degradation have been inadequate in certain areas to preclude the occurrence. The above postulated events involve a common cause failure

mode that can affect redundant systems. Aquatic organisms, mud silt, and corrosion products have been the main source of flow blockage in the coolant piping system and associated heat exchangers where events have occurred.

Cause or Causes - A variety of causes led to the events reported in Table 1. At Arkansas Nuclear One, for the first event discovered September 3, 1980, the growth of Asiatic clams was unanticipated in the design, and appropriate operational control features were not provided. The design and operational control features that did exist were inadequate to prevent the buildup of mud, silt, and corrosion products from becoming a major problem.

The second event at Arkansas Nuclear One, Unit 2 on January 14, 1982 assumes additional significance as compared to the other described events since it indicates that (1) although the corrective actions taken to prevent buildup of marine organisms may not be totally effective, the increased frequency of surveillance implemented as a result of the previous event allowed the licensee to detect the clam intrusion in its early stages,* and (2) the rate of accumulation of the organisms can be rapid. During the surveillance test, the flow dropped from 1800 gpm to approximately 600 gpm over a five-minute interval indicating a sizable blockage. About six buckets of clams were removed. The event remains under investigation. The licensee is studying the service water piping to identify for inspection any portions of piping that may be conducive to Asiatic clam growth, and other long-term preventative measures; this study is planned to be complete prior to the refueling outage scheduled for October 1983.

At Rancho Seco, the corrosion occurred because the heads were cast steel. A corrosion-resistant coating such as epoxy or copper/nickel cladding would have prevented the problem. Existing surveillance testing procedures, however, were also deficient in that the safety-related heat exchanger performance was not verified under appropriate accident conditions.

At Brunswick, the chlorination program, which was part of the program to control the growth of marine organisms, was stopped for approximately 14 months due to potential operational problems and environmental effects. Although operational and administrative controls were inadequate at Arkansas Nuclear One and Brunswick to detect early signs of the problem, the plants were shut down when the technical specification limits could no longer be met. As previously discussed, the incident at Brunswick had the most safety significance of the incidents described in this report. Unit 1, which was shutdown on April 17, 1981 to begin a scheduled maintenance outage, experienced a total loss of the residual heat removal system on April 25, 1981. In order to provide residual heat removal capacity during the plant shutdown, an alternate cooling flow path had to be established. Because of the problems found on the Unit 1 RHR heat exchangers, the similar heat exchangers on the operating Unit 2 were examined. For RHR heat exchanger 2A, a higher than normal differential pressure at design flow was discovered; however, the baffle plate was not displaced. The baffle plate was found displaced for RHR heat exchanger 2B. Therefore, Unit 2 was shutdown

*Inspection of other safety-related coolers showed only traces of Asiatic clams with no significant accumulation.

using heat exchanger 2A at reduced capacity. After the Unit was in cold shutdown, an alternate cooling flow path was established (as in Unit 1 described above) and the heat exchangers were taken out of service for repair.

At San Onofre, the growth of gooseneck barnacles was attributed to the termination of a heat treatment procedure that controls their growth. The treatment was terminated during a protracted plant shutdown of 14 months. The system problems were noted during routine operational checks.

At Pilgrim, the mussels apparently grew in the Salt Service Water System even though a backflushing and cleanout program was instituted to control their growth. Routine surveillance indicated a continuing problem due to decreasing heat transfer capabilities.

In general, the causes of the incidents above related to an inadequate surveillance and monitoring of the heat exchanger performance characteristics such as flow rates, fouling factors, heat transfer coefficients, etc.

Actions Taken to Prevent Recurrence

Licensee - The licensees of Arkansas Nuclear One, Rancho Seco, Brunswick, San Onofre Unit 1 and Pilgrim have cleaned and flushed the affected cooling water systems. The licensees have also committed to improving design features and detection techniques which are intended to preclude the development of significant fouling of safety-related cooling systems in the future.

NRC - The NRC conducted special inspections regarding the events at the facilities noted above. In addition, on April 10, 1981, the NRC's Office of Inspection and Enforcement issued IE Bulletin 81-03, "Flow Blockage of Cooling Water to Safety System Components by *Corbicula* sp. (Asiatic Clam) and *Mytilus* sp. (Mussel)" (Ref. 3). The Bulletin requested licensees to determine whether either species was present in the vicinity of their station and the extent of any fouling these organisms may have caused in fire protection or safety-related systems. The responses to the Bulletin have been received from all of the operating plants. The responses received represent 48 sites. Of these, 21 sites reported positive findings either in the plant or in the source or receiving waterbody. Eight sites have seen some evidence of Asiatic Clams in the plant and six sites have seen evidence of mussels in the plant. This has ranged from occasional findings of a few shell fragments in the main condenser to major infestations. An additional seven sites have reported that while Asiatic clams were not yet present in the plant, they were present in either source or receiving waterbodies and infestations at the plant were possible in the future.

The Bulletin also asked licensees to describe their methods for preventing and detecting any future fouling at their plants. A combination of chlorination, heat treatment, flushing, backflushing, and the installation of strainers were the preventative actions taken by most of the affected plants. Many of them routinely inspect the intake canal, the pump discharge strainers, and the main condenser, cleaning them out as needed. Detection methods included surveillance programs comprised of visual inspections and measurements of flow, differential pressure, and temperature at various system locations. These actions by the

licensees can be expected to have varying degrees of effectiveness depending on the frequency with which they are performed and the severity of the infestation present at and around the plant.

IE Bulletin 81-03 addressed fouling by Asiatic clams and mussels only. Therefore, most plants discussed only these two species in their response. Some plants however, mentioned the presence of other fouling organisms such as other species of clams, oysters, barnacles, tubeworms, and algae to name a few. In addition, a number of plants reported problems caused by mud and silt. In some cases, they claimed this to be a bigger problem at the plant than marine fouling.

In July 1981, NRC issued IE Information Notice 81-21, "Potential Loss of Direct Access to Ultimate Heat Sink" (Ref. 2). The Notice described the loss of the normal decay heat removal system at Brunswick. It also emphasized the need for licensees to initiate appropriate actions, as described in IE Bulletin 81-03, for any marine organisms that could cause fouling at their plant.

A case study entitled "Report on Service Water System Flow Blockages by Bivalve Mollusks at Arkansas Nuclear One and Brunswick was issued by the NRC's Office for Analyses and Evaluation of Operational Data in February 1982 (Ref. 4).

The NRC's Office of Nuclear Reactor Regulation (NRR) is conducting a generic study of service water system malfunctions. This study is being assisted through the Special Studies program at the Oak Ridge National Laboratory (ORNL). In the program, ORNL will investigate licensee event reports (LERs) from January 1979 through June 1981 on the partial or complete loss of service water systems and organize these results systematically. From this collection of events, ORNL will evaluate the safety significance of service water malfunctions and provide their recommendations for any corrective measures that they believe may be needed. NRR will attempt to correlate specific plant design features, surveillance programs and preventive measures with the magnitude and types of service water problems reported in LERs and the responses to IE Bulletin 81-03. Based on the results of this study, corrective actions will be recommended in order to improve the reliability of service water systems.

In addition to the service water study, NRR is reviewing the design of baffle plates in "U" tube heat exchangers similar to those used at Brunswick. This review is to determine if a generic problem exists and if the design is appropriate for the given application.

Future reports will be made as appropriate.

* * * * *

81-8 Seismic Design Errors at Diablo Canyon Nuclear Power Plant

Preliminary information pertaining to this event was reported in the Federal Register (Ref. 5). Appendix A (one of the General Criteria) of this report notes that major deficiencies in management controls for licensed facilities can be considered an abnormal occurrence.

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SSIN No.: 6835
Accession No.:
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IN 81-21

UNITED STATES
NUCLEAR REGULATORY COMMISSION
OFFICE OF INSPECTION AND ENFORCEMENT
WASHINGTON, D.C. 20555

July 21, 1981

IE INFORMATION NOTICE NO. 81-21: POTENTIAL LOSS OF DIRECT ACCESS TO ULTIMATE HEAT SINK

Description of Circumstances:

IE Bulletin 81-03, issued April 10, 1981, requested licensees to take certain actions to prevent and detect flow blockage caused by Asiatic clams and mussels. Since then, one event at San Onofre Unit 1 and two events at the Brunswick Station have indicated that situations not explicity discussed in Bulletin 81-03 may occur and result in a loss of direct access to the ultimate heat sink. These situations are:

1. Debris from shell fish other than Asiatic clams and mussels may cause flow blockage problems essentially identical to those described in the bulletin.

2. Flow blockage in heat exchangers can cause high pressure drops that, in turn, deform baffles, allowing bypass flow and reducing the pressure drop to near normal values. Once this occurs, heat exchanger flow blockage may not be detectable by pressure drop measurements.

3. Change in operating conditions. (A lengthy outage with no flow through seawater systems appears to have permitted a buildup of mussels in systems where previous periodic inspections over more than a ten year period showed no appreciable problem.)

We are currently reviewing these events and the responses of the licensees to IEB 81-03. We expect licensees are performing the actions specified in IEB 81-03 such that cooling water flow blockage from any shell fish is prevented or minimized, and is detected before safety components become inoperable.

On June 9, 1981, San Onofre Nuclear Generating Station Unit No. 1 reported that as a result of a low saltwater coolant flow rate indication and an apparent need for valve maintenance, a piping elbow on the saltwater discharge line from component cooling heat exchanger E-20A was removed by the licensee just upstream of butterfly valve 12"-50-415 to permit visual inspection. An examination revealed growth of some form of sea mollusk such that the cross-sectional diameter of the piping was reduced. The movement of the butterfly valve was impaired and some blockage of the heat exchanger tube sheet had occurred. Evaluation of the event at San Onofre is continuing. However, the prolonged (since April 1980) reactor shutdown for refueling and steam generator repair is believed to have caused the problem since previous routine inspections conducted since 1968 at 18 month intervals had not revealed mollusks during normal periods of operation.

Two events at Brunswick involved service water flow blockage and inoperability of redundant residual heat removal (RHR) heat exchangers, primarily due to oyster shells blocking the service water flow through the heat exchanger tubes. On April 25, 1981, at Brunswick Unit 1, while in cold shutdown during a maintenance outage, the normal decay heat removal system was lost when the single RHR heat exchanger in service failed. The failure occurred when the starting of a second RHR service water pump caused the failure of a baffle in the waterbox of the RHR heat exchanger, allowing cooling water to bypass the tube bundle. The heat exchanger is U-tube type, with the service water inlet and outlet separated by a baffle. The copper-nickel baffle which was welded to the copper-nickel tubesheet deflected and failed when increased pressure was produced by starting the second service water pump. The redundant heat exchanger was inoperable due to maintenance in progress to repair its baffle which had previously deflected (LER 1-81-32, dated May 19, 1981). The licensee promptly established an alternate heat removal alignment using the spent fuel pool pumps and heat exchangers.

As a result of the problems discovered with Unit 1 RHR heat exchangers, a special inspection of the Unit 2 RHR heat exchangers was performed while Unit 2 was at power. Examination of RHR heat exchanger 2A using ultrasonic techniques indicated no baffle displacement but flow testing indicated an excessive pressure drop across the heat exchanger. This heat exchanger was declared inoperable. Examination of the 2B RHR heat exchanger using ultrasonic and differential pressure measurements indicated that the baffle plate was damaged. The licensee initiated a shutdown using the 2A RHR heat exchanger at reduced capacity (LER 2-81-49, dated May 20, 1981).

The failure of the baffle was attributed to excessive differential pressure caused by blockage of the heat exchanger tubes. The blockage was caused by the shells of oysters with minor amounts of other types of shells which were swept into the heads of the heat exchangers since they are the low point in the service water system. The shells resulted from an infestation of oysters growing primarily in the 30" header from the intake structure to the reactor building. As the oysters died their upper shells detached and were swept into the RHR heat exchangers where they collected. Small amounts of shells were found in other heat exchangers cooled by service water. Most of the operating BWRs use U-tube heat exchangers in the RHR system. (The heat exchangers used at Brunswick were manufactured by Perflex Corporation and are identified as type CEU, size 52-8-144.)

The observed failures raise a question on the adequacy of the baffle design to withstand differential pressures that could reasonably be expected during long term post accident operation. However, it should be noted that since the baffles at Brunswick are solid copper-nickel as are the tubesheets and the water boxes are copper-nickel clad, the strength of the baffles and the baffle welds is somewhat less than similar heat exchangers made from carbon steel. Therefore, heat exchangers in other BWR's may be able to tolerate higher differential pressure than that at Brunswick without baffle deflection. (Brunswick opted for copper-nickel due to its high corrosion and fouling resistance in a salt water environment.)

The use of differential pressure (dp) sensing between inlet and outlet to determine heat exchanger operability should consider that baffle failure could give an acceptable dp and flow indications and thereby mask incapability for heat removal. However, it is noted that shell blockage in a single-pass, straight-through heat exchanger can readily be detected by flow and dp measurement.

Evaluation of the events at Brunswick is still continuing. Under conditions of an inoperable RHR system, heat rejection to the ultimate heat sink is typically through the main condenser or through the spent fuel pool coolers. This latter path consists of the spent fuel pool pumps and heat exchanger with the reactor building closed cooling water system as an intermediate system which transfers the heat to the service water system via a single pass heat exchanger. These two means (i.e., main condenser or spent fuel pool) are not considered to be reliable long term system alignments under accident conditions.

This information is provided as a notification of a possibly significant matter that is still under review by the NRC staff. The events at Brunswick and San Onofre emphasize the need for licensees to initiate appropriate actions as requested by IEB 81-03 for any credible type of shell fish or other marine organisms; e.g., fresh water sponges, (not only asiatic clams and mussels). In case the continuing NRC review finds that specific licensee actions would be appropriate, a supplement to IEB Bulletin 81-03 may be issued. In the interim, we expect that licensees will review this information for applicability to their facilities.

No written response to this information is required. If you need additional information regarding this matter, please contact the Director of the appropriate NRC Regional Office.

Attachment:
Recently issued IE Information Notices

UNITED STATES
NUCLEAR REGULATORY COMMISSION
REGION II
101 MARIETTA ST., N.W. SUITE 3100
ATLANTA, GEORGIA 30303

50-400

JUL 21 1981

RECEIVED 1981

Gentlemen:

The enclosed information notice is provided as an early notification of a possibly significant matter. It is expected that recipients will review the information for possible applicability to their facilities. No specific action or response is requested at this time. If further NRC evaluations so indicate, an IE circular or bulletin will be issued to recommend or request specific licensee actions. If you have questions regarding this matter, please contact this office.

Sincerely,

James P. O'Reilly
Director

Enclosures:
1. IE Information Notice No. 81-21
2. List of Recently Issued
   IE Information Notices

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E. Schall 7 7

Proceedings, First International Corbicula Symposium
Texas Christian University
Fort Worth, Texas 76129 U.S.A.
October 13-15, 1977

Attachment #3

DKt 50-400

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CONTROL STUDIES ON *Corbicula* FOR STEAM-ELECTRIC GENERATING PLANTS

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ABSTRACT

Corbicula fouling problems were first noted at TVA's Shawnee Steam Plant in 1957 and have since spread to all of TVA's power plants throughout the Tennessee Valley region. An assessment was recently made as to the nature and extent of the *Corbicula* fouling problem, and studies were initiated to develop methodologies for adequate control of *Corbicula* in the various water systems associated with power plants.

Control methods currently under laboratory and field investigation include mechanical straining, controlled release surfaces, chemical biocides, and heat treatment. Controlled release surfaces being studied include tributyl tin oxide (TBTO), tributyl tin fluoride (TBTF), and triphenyl lead acetate (TPLA). Chemicals being tested include chlorine, chlorine dioxide, and bromine chloride. Detailed results of these studies along with an evaluation of potential for application in the various power plant water systems are presented.

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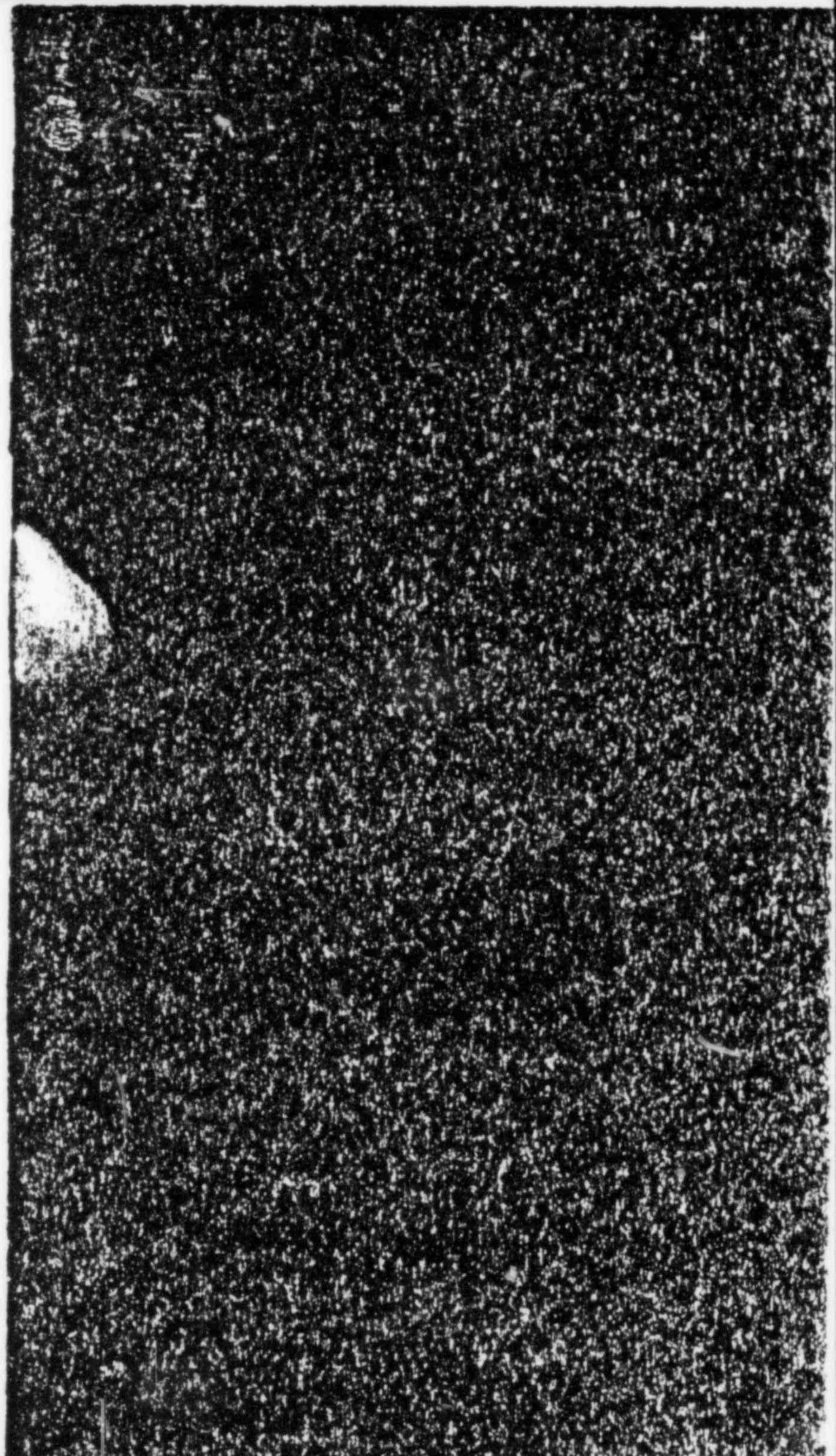
Key Words: *Corbicula*, Biofouling, Bioassay



CONTROL STUDIES ON *Corbicula* FOR STEAM-ELECTRIC GENERATING PLANTS

L. B. Goss, J. M. Jackson, H. B. Flora, B. G. Isom, C. Gooch, S. A. Murray, C. G. Burton, and W. S. Bain

INTRODUCTION

Vast quantities of water are removed daily from rivers, lakes, and streams for use in industrial processes. The greatest single industrial use of water is for cooling purposes, and the greatest noncomsumptive industrial demand for water as a heat transfer medium comes from the steam-electric generating industry. This water supports an untold diversity and quantity of biological forms, a number of which cannot be segregated from process water before it is used. If these aquatic life forms remain in process water, both the aquatic life and the industrial process can potentially be affected (Goss and Cain, 1975). This paper deals with the adverse effects the biofouling organism, *Corbicula fluminea* (= *manilensis*), has on power plant water systems and methods currently under study and being practiced to control *Corbicula* biofouling at Tennessee Valley Authority steam-electric generating plants.

BACKGROUND

TVA first experienced *Corbicula* fouling problems in condensers and service water systems at its Shawnee Steam Plant on the Ohio River in 1957. Since then, the Asiatic clam has spread across the Tennessee Valley region and is found at virtually all of TVA's steam-electric and hydroelectric generating stations.

In 1974 TVA became concerned that there might be a significant biofouling problem due to reports of fouling at Browns Ferry Nuclear Plant located on Wheeler Reservoir (Tennessee River), approximately 10 miles northwest of Decatur, Alabama. Browns Ferry unit 1 began commercial operation in August 1974. In October of that year, substantial numbers of clams were found in the inlet water boxes. It was not until later when an Amertap system installed for condenser tube cleaning was first used that the extent of the condenser biofouling was realized. The majority of approximately 4500 Amertap balls released into the system remained in condenser tubes blocked by debris and clams. The fouling was so extensive that condensers had to be dismantled and cleaned with brushes. Loss of unit efficiency associated with such severe biofouling was substantial.

It is suspected that the majority of clams fouling condenser tubes at Browns Ferry, which has ⅜ inch (0.95 cm) vertical traveling screens, had actually grown within the intake tunnel. The intake system had been flooded for more than two years before unit startup, thereby, providing a suitable environment for *Corbicula* attachment and growth.

Due to the nature and extent of the biofouling problem at Browns Ferry, an interdisciplinary task force was formed within TVA, and an effort was put forth to document the problem and determine the need for studies on means to alleviate it.

DESCRIPTION OF THE BIOFOULING PROBLEM

In order to understand the biofouling problem, a thorough assessment was made at TVA's Johnsonville Steam Plant. From this a determination was made as to what systems were affected, how they were affected, and what methods were being used to control the problem. Results of the Johnsonville assessment will be used to describe the *Corbicula* fouling problem associated with fossil-fueled power plants.

There are typically two water systems in a fossil-fueled plant which use raw river water, the condenser cooling water (CCW) system and raw service water (RSW) system. The CCW system is used to condense spent turbine steam. The RSW system provides water for machinery cooling, plant service water, and firelines.

Corbicula adversely affects the CCW system by fouling condensers. Typical *Corbicula* control methodologies for condenser cooling water systems at fossil-fueled plants include backflushing and mechanical and manual cleaning of condensers. Due to both the high flow velocities in the intake tunnels (approximately 2.1 m/s) preventing clam attachment and growth and the use of intake screens with a smaller mesh than the condenser tube size, condenser fouling by *Corbicula* is normally not a serious problem. However, any dead spaces where velocities are decreased allow for attachment and growth of clams within the tunnel to a size which can block condensers.

The RSW system components of fossil-fueled plants can be adversely affected by *Corbicula* partially or totally blocking water flows in lines and equipment. Control methodologies typically applied for fossil-fueled plant RSW systems include screening (typically ⅛ in or 0.32 cm), mechanical clam traps on branch water lines, flushing lines such as typically stagnant fire hydrant lines on a routine basis, chemical treatment of the water supply and manual cleaning. Strainers and traps help to forestall the *Corbicula* biofouling problem and reduce it to a nuisance level in the RSW system, but *Corbicula* larvae are not prevented from passing to farther points within the system. Use of straining alone eventually results in the need for manual cleaning of the RSW system components.

As opposed to a typical fossil-fuel plant's two raw water systems, a nuclear plant typically has four discrete raw water systems. These include the: (1) condenser cooling water system (CCW) (2) raw cooling water system (RCW) (3) essential raw cooling water system (ERCW) (4) raw service water/high-pressure fire protection system (RSW-HPFP)

The purpose of nuclear plant condenser cooling water systems is the same as for fossil-fueled plants, to condense turbine steam. This system is characterized by a high flow volume (1,060,000 gal/min or 4.0 x 10^6 l/min for TVA's Sequoyah Nuclear Plant). Clams again can affect the efficiency and

reliability of this system. Currently applied control methods for the CCW system include screening at the intake point, backflushing of condensers, mechanical and manual cleaning of condensers (brushes, water, hand cleaning) and operation of a partially closed loop. This is actually a closed loop in the normal sense of the word, but in relation to the clam problem, a qualification needs to be made. In a typical closed loop, there is a constant blowdown and makeup. This makeup water is, of course, a constant source of infestation of clams, at least throughout the spawning season when larvae are being released. Control methodologies for the CCW systems at TVA's nuclear plants currently range from ⅜ in (0.95 cm) mesh intake screen with backflushing and cleaning required for the condensers to closed loop operation with smaller mesh screening of makeup water.

The purpose of the raw cooling water system at nuclear plants is mainly for machinery cooling (bearings, etc.). The RCW system is characterized by a medium flow rate in relation to the CCW flow (30,000 gal/min or 1.1 x 10^5 l/min for TVA's Sequoyah Nuclear Plant). Clams affect the operational efficiency and reliability of machinery within this system. Some control systems currently being used and planned for use in TVA's nuclear plant raw cooling water systems include straining, chlorination, manual cleaning, flushing static lines and closed loop operation.

The purpose of the essential raw cooling water system of nuclear plants is to cool critical nuclear systems, and it serves as the ultimate heat sink in the event of emergency shutdown. It is characterized by a medium flow rate as compared to condenser cooling water (approximately 30,000 gal/min or 1.1 x 10^5 l/min for TVA's Sequoyah Nuclear Plant). Control methodologies being used and planned for use in ERCW systems include chlorination, screening and closed loop operation.

The raw service water/high-pressure fire protection system consists of fire protection water lines. It also is used for small water requirement procedures such as watering lawns. The RSW/HPFP system is characterized by low flow volume (100 to 1000 gal/min or 378 to 3785 l/min), and clams may affect its safety and reliability. It is the only raw water system with virtually no discharge to the receiving stream. It therefore lends itself to strong chemical treatment. Control methodologies currently incorporated for RSW/HPFP systems include straining, chlorination and flushing of stagnant lines.

RESEARCH ON CONTROL METHODS

For the past two years, TVA has been involved in a comprehensive research program to evaluate various existing and potential clam control methods and to develop systems which will ensure adequate and reliable water supplies for its steam-electric generating facilities in an economical manner. Controls currently being evaluated include chemicals (Cl_2, ClO_2, and BrCl), controlled release surfaces, temperature and mechanical systems. Results of the various studies follow.

Chlorine

A continuous-flow proportional diluter of the type designed by Mount and Brungs was used for chlorine bioassay. Test solution concentrations were designed to be 1.0 mg/l, 0.50 mg/l, 0.33 mg/l, 0.25 mg/l, 0.20 mg/l, and a control of 0.0 mg/l chlorine. Actual measurement of chlorine in the test chambers gave chlorine levels slightly below those intended for testing. Chlorine levels were determined by the DPD ferrous titrimetric method. Titrations for free available monochloramine and dichloramine chlorine were made to give a total available chlorine concentration for each test chamber. Chlorine was obtained from a 5.25 percent sodium hypochlorite solution.

Chlorine test animals were larval *Corbicula fluminea* that had developed a shell and muscular foot. The microscopic larvae were removed from the gills of adults with dissecting needles and with the aid of a binocular dissecting microscope. Larvae were removed from the gills of several adults for each test to provide a pool of test organisms. Approximately 200 larvae were used for each concentration for each test. Test organisms were placed in 50 ml beakers and submerged in chambers holding approximately one liter of test solution. Counts were made of living and dead animals at four-hour intervals and the percent mortality determined. Criteria for determining living animals were a general vital appearance, foot movement either inside or outside the shell, and/or ciliary movement inside the shell.

Sickel (1976) reported that his bioassay test with chlorine revealed that "0.1 mg/l of free residual chlorine will provide effective control if applied continuously. Chlorine concentrations of 0.5 mg/l for 52 hours are required for 100 percent mortality of larvae." Preliminary analysis of chlorine bioassay results indicates that in only 2 of 11 tests were mortalities 100 percent in 52 hrs. or less. Results of tests were highly variable, apparently depending upon percentages of monochloramine, dichloramine, and free chlorine residual. In one test where total chlorine residual was 80 to 83 percent monochloramine, all test animals died in 28 hrs, at average total chlorine residuals of 0.36 mg/l, 0.42 mg/l, and 0.72 mg/l. Further analyses of tests are being made now, but it appears that 100 percent control of Asiatic clam veligers can be achieved by a total chlorine residual in the 0.50 mg/l range in 96 to 108 hrs at temperatures between 25 to 28°C.

Chlorine Dioxide

Since current measures to control *Corbicula fluminea* as a power plant biofoulant are limited, the efficacy of chlorine dioxide (ClO_2) for use as a mollusicide was tested. Experiments were designed to determine (1) the effect of ClO_2 at various concentrations and exposure times on clam mortality; (2) the sensitivity of various size clams and stages of the life cycle to ClO_2; (3) the ClO_2 dissipation rates at various starting concentrations; (4) the residual amounts left at various periods to 24 hrs; and (5) the effect of clams on dissipation rates and residuals.

Mortality of clams was differentially affected by chlorine dioxide, depend-

ing on clam size. Larger clams (1.9 to 2.6 cm) seemed to be more susceptible to low chlorine dioxide concentrations (less than 20 ppm), accounting for 20 to 30 percent mortality, whereas smaller clams (1.0 to 1.2 cm) were more susceptible to higher concentrations (greater than 20 ppm), accounting for 19 percent mortality. Veliger mortality (60 to 88 percent) was more pronounced than that of adults at high concentrations (greater than 60 ppm) with shorter exposures.

A significant difference in residuals was found for each ClO_2 concentration. Generally, there was a greater percentage of residuals with progressively less concentrations. The presence of clams in the chlorine dioxide solutions reduced the residuals by 3 to 18 percent, depending on clam size.

Under the conditions used in these studies, chlorine dioxide does not seem to be a powerful molluscide and does not offer promise for use in power plant raw water systems.

Bromine Chloride

Gross evaluations of bromine chloride (BrCl) were conducted on Asiatic clams in August and September of 1977. Tests were conducted on larval clams taken from gravid adults.

A continuous-flow multiple diluter was used to control dilution of bromine chloride which was in the range of 0.5 to 3.0 mg/l.

The results of this study including chemical methodologies are being completed at the present time. Preliminary results indicate that bromine

Ingredient	Parts by Wt.	Lbs.	Gal.
Red Iron Oxide (softex Red 1410)	4.58	54.95	1.34
Zno[2] (XX631)[2]	21.18	253.77	5.43
Talc[3] (1313 Canadian talc)	7.85	93.99	3.38
Bentone 27[4]	0.45	5.42	0.34
Methanol	0.12	1.45	0.20
Parlon S20[5]	11.40	136.65	10.55
WW Gum Resin	6.10	23.02	8.14
Xylene	33.95	407.19	56.30
bioMeT TBTP Antifoulant	2.87	34.41	3.30
bioMeT 204 Antifoulant	11.50	137.73	11.02
	100.00	1,198.58	100.00

Viscosity 95 K.U.

1, Reichard; 2, N.J. Zinc; 3, W.C.& D.; 4, N.L. Industries;5, Bercules

Table 1. Composition of CR-1. See text.

chloride may be an effective control for adult and young Asiatic clams at concentrations of less than 1 mg/l.

Controlled Release Surfaces

Laboratory and field studies were conducted on controlled release (CR) surfaces using triphenyl lead acetate and tributyltin oxide in vinyl and rubber based paints. The composition of these paints is shown in Tables I and II. Laboratory bioassays were conducted on three types of substrates — steel plates, cement, and stone — each painted with a 3 mil coating of base-coat primer over which a 5 mil coating of the candidate CR finish was applied. Laboratory panels were identical with those used in fieldstudies except for size. Small panels (15.2 cm x 15.2 cm) were used in the laboratory to facilitate microscopic observation during exposures. Laboratory bioassays

Amount Made: Two gallons

Paste: 475 grams zinc oxide (XX604) before use ground finely
95 grams amorphous silica (aerosil 380)
3 grams carbon black (monarch 74)
594 grams TPLA containing 10% dust depressant (Irgarol BI 547)
800 grams methyl iso-butyl ketone and additional
300 grams methyl iso-butyl ketone to get a smoother paste
2267 gram paste

To: 3938 grams "four-rubber dispersion" made from:
2068 grams polyisoprene (natsyn 400) 12.5% in toluene
990 grams chlorosulfonated polyethylene (hypalon-30)
25% in benzene
330 grams styrene-dutadiene-styrene polymer (kraton 1101)
25% in toluene
550 grams polymer resin (versalon 1140) 33% in:
70% benzene
30% propanol
6205 grams

Warmed to about 50°C. (122°F) to facilitate filtration
Filtered through cheesecloth
Contains approximately 9% TPLA in wet paint, CR about 28% in dry paint
Thinner supplied: 1500 Milliliters containing two parts toluene and one part methyl iso-butyl ketone

Table 2. Composition of CR-2. See text.

consisted of placing three replicates of 100 clam larvae (benthic stage) each on the three types of test panels for a prescribed period of time. Controls consisted of one replicate of each substrate painted with an identical paint, less the toxicant, and an untreated panel of each substrate. Preliminary tests indicated that an exposure period of five minutes was adequate to produce complete mortality of the test animals. Clams so exposed demonstrated a typical and uniform behavior. Initially the clams were hyperactive, extending and retracting the foot vigorously. After about one minute of this excited behavior, they would retract into the shell and close it securely. This behavioral cycle would be repeated three to four times during a five-minute exposure, decreasing in intensity each time until at the end of the five-minute exposure, they exhibited no further movement. Moribund clams were removed from the test surfaces after five minutes and placed in clean culture dishes containing fresh stream water collected daily. In no case did clams recover after five minutes of exposure to either CR-1 or CR-2. No control mortality was experienced during this phase of the testing procedure. Clams up to 15 mm in length were exposed to test panels in the field by placing them in a cylindrical holding cage three inches (7.62 cm) in diameter made of nylon screen (16 mm mesh). Behavior of exposed clams was identical with that of the larval clams exposed in the laboratory except the exposure time necessary for mortality was extended to 30 minutes.

The antifouling properties of CR-1 have continued to be effective in preventing the attachment of Asiatic clams and other fouling organisms after 15 months in the field. This paint has demonstrated outstanding adhesive properties on metal and cement surfaces exposed in running water as well as excellent resistance to abrasion. Test panels of both steel and cement which were returned to the laboratory for testing produced mortality in exposed larval clams in five minutes, essentially the same results as with newly painted panels. Little difference was apparent in fouling of those panels painted with a 3 mil coat and those with a 5 mil coat. The metal panels painted with only a basecoat primer were badly corroded and were colonized heavily with a variety of fouling organisms.

The CR-2 rubber-based paint containing triphenyl-lead acetate (TPLA) has also continued to give outstanding results. Field panels exposed in flowing water produced 100 percent mortality in benthic larvae when exposed for five minutes in the laboratory tests. Minor periphytic growth was apparent on all cement test panels, but the surface remained toxic to the exposed larval clams.

The effect of natural sediments of the test panels was studied in the laboratory and in the field using similar test procedures after a measured thickness of sediment was allowed to settle on the panel surfaces. Panels remained effective with up to 5 mm of fine sediment covering the surface but became increasingly less effective as the sediment depth increased about 5 mm. No repellency or toxic effects were noted when the sediment thickness was 10 mm. The repellency of the surfaces was lost at 3 mm of sediment, and the toxicity was lessened proportionally.

Temperature

Laboratory experiments conducted in 1971 showed virtually instantaneous mortality of *Corbicula* placed in 43 to 50°C (109.4 to 122.0°F) water. *Corbicula* was taken from Wilson Reservoir which had a temperature of 10°C (50°F) and acclimated to 21°C (69.8°F) in the laboratory. Two animals were used in each experiment in sizes ranging from 22.3 mm to 43.5 mm, and the tests were replicated. Following exposure periods of 15 minutes, overnight recovery in lake water was allowed for final determination of mortality at each temperature. However, apparent design for future power plants dictated that time of exposure to elevated temperatures would have to be reduced to two minutes.

The objective of recent tests was to determine the temperature (47°C) required to kill veligers in 15 seconds ideally but in no more than two minutes. This design is compatible with travel times between condenser and cooling facilities at some future facilities with closed cycles.

Test animals were collected from Cypress Creek, Lauderdale County, Alabama. Adult specimens were either used directly as test organisms or checked for gravidity when the water temperature was 18°C or higher. If the gills were charged with young, they were examined to determine the degree of development to ascertain whether they would be suitable for bioassay. For the larval stages to be acceptable for bioassay, they had to be active ciliated veligers or shelled larvae with an active foot.

The clams were allowed to acclimatize to ambient temperatures in living stream aquaria until testing. Water for testing the adult specimens was heated in 250 ml glass beakers on a hot plate to the desired temperature. The clams were then dropped into the heated water. After two minutes, they were removed and placed in their original containers at the ambient temperature. Mortalities were determined, and the clams were checked again 24 hrs later to determine percent mortality.

In tests on the adult clams, water heated to 35°, 40°, 43°, 45°, 47°, 50°, and 55°C was used. The clams were allowed to acclimate to ambient temperatures of 15°, 18°, 20°, and 27°C for 72 to 120 hrs. Tests to date indicate ambient temperatures used do not appear to be a determining factor with regard to the ultimate lethal temperature. The ambient temperatures selected were used to correspond with the water temperature at the time the clams were collected and the anticipated summer temperature of 27°C.

Eighty-five experiments of two-minute duration were run on the two larger sizes of clams. Twenty-four experiments of one-minute duration were also made. Few or no mortalities occurred in the controls maintained for each test.

About 100 young clams were placed in a centrifuge tube and the heated water poured into the tube. The tubes were warmed and kept immersed in water of the appropriate test temperature to prevent heat loss during the test. After two minutes, the clams were placed in their original container at the

ambient temperature. The immature stages were examined with a microscope immediately and again 24 hrs after testing to determine mortality. Also, mortality was easily determined as the shells of dead individuals were open and the cytoplasm had erupted between the gaped shells.

Computation of the LD_{95} by the Reed-Muench method for the experiments utilizing two sizes of adult *Corbicula* indicates lethal temperatures of 47.23°C ± 1.02° for those with 12 to 14 mm size and 46.4°C ± 1.34° for *Corbicula* with 4 to 8 mm size range.

Forty-four tests were made on the larval or juvenile stages. Controls were maintained for each test. In most controls there were no mortalities during the test period or in the holding period.

Three sizes of immature clams were used: benthic juveniles 2 mm; shelled larvae removed from the gills of adults; and ciliated veligers, also removed from the gills of adults. Ambient temperature for all tests run on these groups was 23°C. Temperatures of heated water used were 40°, 45°, 47°, and 50°C. Period of exposure for all replicates was two minutes. The number of clams in the 2 mm size per test was 5. About 100 individuals were used in each test of the other immature stages.

Four replicates of veligers were exposed to 40°C with 5 to 10 percent mortality, four replicates exposed to 45°C with 80 percent mortality, and four replicates exposed to 50°C water resulted in 100 percent mortality. Eight replicates of shelled larvae at 45°C resulted in some immediate mortality, but 24 hrs later, approximately 90 percent were living and active. Four replicates exposed to 46°C water resulted in 100 percent mortality. Seven replicates of the 2 mm size of 5 individuals exposed to 45°C resulted in an average mortality of 71 percent, and seven replicates of 5 individuals exposed to 46°C produced 100 percent mortality.

Mechanical Design

Based upon current information available on *Corbicula* biofouling and methods of its alleviation, TVA has developed proposed design standards for future plant facilities. These standards currently represent the most feasible and practical methods for the control of the Asiatic clam in raw water systems and may be revised in the future depending on results obtained from research currently underway or by changes in federal or state regulations concerning chemical discharges. The following methods of control apply to all the raw water systems except the condenser cooling water system. The incoming water to all the raw water systems will be strained. If a water system is being supplied from another water system whose water has already been strained, no additional straining is required. Straining as cited here refers to the work performed by an automatic backwash type straining unit located immediately upstream or downstream of the main pumping units of the system. The strainer will have a 1/32 inch (0.08 cm) straining media and will be designed for periodic or continuous backwashing.

Chlorine is the only chemical which is currently approved as a molluscide and whose efficacy on Asiatic clams is documented. Chlorine will be injected as close as practical in the water system inlet. Secondary water system sources (such as jockey pumps, normally open interties with other water systems, etc.) will also be chlorinated. If the water incoming to a system has previously been chlorinated, no additional injection is required.

Provisions will be made for periodic chlorine residual sampling near the discharge of normally flowing raw water systems. Provisions shall also be made in both normally flowing and stagnant water systems to periodically sample residual chlorine levels in undrained normally isolated system components which may have experienced occasional usage during the clam spawning season. If an inadequate residual level is found in any isolated area, that area will be opened for a sufficient period of time to allow chlorinated water to replace the water in that portion of the system.

System design will facilitate the following measures for clam control during plant construction and startup. Unchlorinated water will not be allowed to lie stagnant in any raw water system at any time. Design provisions will be made such that after initial testing the systems can be drained where practicable. If a water system is going to be used regularly or if draining is not feasible, temporary provisions will be made to inject some form of chlorine into the system in quantities sufficient to yield the required residual level. Filling of the system will be accompanied by chlorine injection regardless of the inlet water temperature. Subsequent continuous system operation should be accompanied by chlorine injection only during the clam spawning period (mid-March to mid-October). Sampling and residual maintenance will initially be conducted on a weekly basis for those systems being chlorinated. A longer time interval may be found adequate after sample results have been analyzed. Provisions will be made to periodically flush isolated lines in order to maintain proper residual levels.

The following are additional comments and control measures which apply to each individual system and also control measures for the Condenser Cooling Water System.

A. Essential Raw Cooling Water System
For closed cycle operation utilizing spray ponds, no provisions are required to control the growth of clams in the spray ponds other than straining the makeup water.

B. High Pressure Fire Protection System
Provisions shall be made to periodically flush the main supply line headers.

C. Raw Service Water System
Continuous chlorination of the RSW system during the entire clam spawning period is required if the RSW system is intertied with the High Pressure Fire Protection (HPFP) system. Chlorination for two three-week periods, once at the beginning of the clam spawning period and again at the end of the clam spawning period, shall be followed if the RSW and HPFP systems are independent. Continuous chlorination during the entire

clam spawning season may later be required if clam problems develop with this reduced chlorination schedule.

D. Raw Cooling Water System

The RCW system initially shall also be treated for two three-week periods a year. If the RCW system is supplied water by the heat rejection system, the two three-week periods should be established by the river temperature rather than the temperature in the heat rejection system. Continuous chlorination during the spawning period may be required if operating experience so dictates.

E. Condenser Cooling Water

The heat rejection system shall have complete drainage capability for the purpose of cleaning the system in case an excessive population of clams develop. In addition for closed cycle heat rejection systems, provisions shall be made to strain the incoming makeup water and to ensure that the makeup water passes through the condenser prior to entering the cooling tower basin. Preliminary test results have shown that clams in the 1.5 mm size range cannot withstand the high temperatures found at the main condenser discharge during the summer months. Directing the strained makeup water to the cooling tower discharge flume rather than the cooling tower basin will quickly subject the incoming clam larvae to a lethal cycling thermal stress.

SUMMARY

Corbicula fouling problems were first noted at TVA's Shawnee Steam Plant in 1957 and have since spread to virtually all of TVA's steam-electric generating facilities. For the past two years, TVA has been involved in a comprehensive research program to evaluate various existing and potential clam control methods and to develop systems which will ensure adequate and reliable water supplies for its electric generating facilities in an economical manner. Control methods currently under laboratory and field investigation include mechanical straining, controlled release surfaces, chemical biocides and heat treatment. Controlled releases being studied include tributyl tin oxide (TBTO) and triphenyl lead acetate (TPLA). Chemicals being tested include chlorine, chlorine dioxide and bromine chlorine.

Proposed design standards for future plant facilities have been developed based on current information available on *Corbicula* biofouling and methods of its alleviation. These standards currently represent the most feasible and practical methods for the control of the Asiatic clam in raw water systems and may be revised in the future depending on results obtained from research currently underway or by changes in federal or state regulations.

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Attachment #2

Evaluation and Control of Macroinvertebrate Nuisance Organisms in Freshwater Industrial Supply Systems[1]

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Introduction

Reports of macroinvertebrate nuisance problems in water supplies are not new. Kraepelin (1885) reported macroinvertebrates inhabiting water pipes at Hamburg and enumerated 60 species including sponges, mussels, snails, coelenterates, and bryozoa.

Whipple et al. (1927) cited incidences of biological nuisance in Rotterdam, Hartford, Boston, and Brooklyn. Nuisance problems were usually concerned with native fauna and, in general, with problems arising from invasion of open aqueducts, open clarifying basins, or uncovered reservoirs accessible to the fauna.

The National Electric Light Association (1926) reported on "restrictions in flow due to vegetable and animal growths in conduits." They reported problems with caddisflies and hellgrammites. The only means of control used was periodic manual cleaning of condensers and pipes and, in one instance, backwashing of condensers.

Currently there are few problems with biological nuisance organisms in Tennessee Valley area domestic water supply systems. A few problems have been reported with Asiatic clams in pump intake structures and in unchlorinated

1. To be presented at the 19th Annual Meeting of the Midwest Benthological Society, University of Notre Dame, Notre Dame, Indiana, March 24-26, 1971.

delivery pipes to water treatment facilities. Water plants that provide prechlorination at the pump intake site have no problems with biological nuisance. One exception is a TVA facility at Muscle Shoals, Alabama, which provides raw water from common intake pumps for both industrial and domestic uses. Water is chlorinated (1 ppm total residual) at the intake structure two to three times each day for continuous periods of approximately 35 minutes for slime control. During the Asiatic clam breeding season, which extends from May to September at longitude 87° and latitude 34°, chlorination (1 ppm) is practiced twice for 21 days--on May 15 and again on September 15--with good results. However, the domestic treatment facility has experienced the presence of Asiatic clams in the aeration basin. Veligers or young Asiatic clams reaching the aeration basin are apparently protected from the chlorination procedure by the aeration process.

Some Current Control Practices for Biological Nuisance

In January 1971 a survey of biological nuisance control practices was made at 10 TVA electric power stations. Some power stations were using no antifouling procedures except brushing and cleaning of condensers during "outages." Other plants cleaned condensers manually during outages and used "slug" chlorination (1 ppm total residual) for continuous periods of 30 to 60 minutes one to three times during a 24-hour operating period for slime control. Only one plant used continuous chlorination (1 ppm total residual) for slime control. Some plants discontinue chlorination for slime control when the water temperature is less than 65° F (18.3° C).

Beauchamp (1969) has reported that introduction of 0.5 ppm chlorine continuously in a coastal power station water supply has proved to be an effective control for marine fouling that is compatible with rearing of plaice and sole in the discharged water. Sinclair (1964) reported the use of 0.5 ppm chlorine r idual for the control of larval Asiatic clams.

Sundberg (1971) indicated that the use of self-cleaning, rotating, 16-mesh screens did not prevent intrusion of Asiatic clam veligers into water storage facilities where they grew to maturity. He noted that veligers are released from the adult clams when the temperature reaches 62-65° F (16.7-18.3° C) in the spring and early summer. He also indicated that "If a low chlorine residual of 0.25 to 0.35 ppm is maintained continuously for a period of 48 hours when the water temperature is above 65° F (18.3° C), the young clams are killed." Continuous low residual chlorine is now used to control Asiatic clams in cooling water systems at five pumping stations on the Colorado River aqueduct. Elsewhere, general practice for Asiatic clam control is continuous administration of 0.5-1.0 ppm total chlorine residual for one or two 3-week periods during the breeding season.

Dynamics of the Chlorination Process

Green and Stumpf (1944) found that the mode of action of chlorine on organisms is by reaction of hypochlorous acid (HOCl) with an enzyme (triosephosphoric dehydrogenase) which is essential as a catalyst for glucose oxidation. Electrical neutrality and small molecular size of HOCl probably accounts for its superior capability to kill organisms (Fair et al., 1948). Laubusch (1962) noted that the negative charge of OCl^- accounts for its low bactericidal effect.

As inferred above, biocidal capacity of chlorine is due to HOCl. HOCl concentration resulting from hypochlorites or chloramines is due to the undissociated HOCl concentration of the solution (Fair et al., 1948; Sawyer, 1960; Laubusch, 1962). Concentration of undissociated HOCl is a function of pH as will be shown. When gaseous chlorine or hypochlorite is

added to water, hypochlorous acid (HOCl) and hypochlorite ions (OCl^-) are formed.

1. Chlorine gas, $Cl_2 + H_2O \rightleftharpoons HOCl + H^+ + Cl^-$
2. Hypochlorites, $Ca(OCl)_2 + H_2O \rightleftharpoons Ca^{++} + H_2O + 2\ OCl^-$
3. $OCl^- + H^+ \rightleftharpoons HOCl$

HOCl-OCl^- equilibrium is pH dependent (Sawyer, 1960; Laubusch, 1962). Sawyer (1960) noted the same equilibria are realized in water regardless of whether chlorine or hypochlorites are added; however, ". . . chlorine tends to decrease the pH whereas hypochlorites tend to increase the pH." Percent HOCl is 100 and OCl^- is 0 at pH 4.0 and 20% C; 75% HOCl and 24.8% OCl^- occur about pH 7.0; and 0.3% HOCl and 99.7% OCl^- occur at approximately pH 10.0 (Fair et al., 1948).

Power stations or industries associated with productive waters or polluted waters carrying an organic load will nearly always experience combined chlorine residuals (chloramine residual) due to reactions of chlorine with nitrogen containing organic compounds (Sawyer, 1960). Laubusch (1962) noted that as an operating guide in water treatment plants about 25 times more chloramine than free chlorine is required to obtain 100% disinfection; to achieve the same disinfection with the same dosages of chlorine, chloramines require approximately 100 times the exposure period of free forms. Kinman and Layton (1969) noted that despite relatively low toxicity of chloramines (NH_2Cl, $NHCl_2$) and nitrogen trichloride (NCl_3) compared with free available chlorine (HOCl) 30 of 100 largest cities in the U. S. in 1962 used chloramines to disinfect their water supplies. Chloramine disinfection is practiced because of the inability to maintain free available chlorine residual in the water distribution systems. It seems reasonable that at most power station sites we

would be dealing with chloramine (combined) releases to the environment; however, most chemical evaluations have been for total chlorine residual.

Data show that the use of chlorine and chlorinated compounds in treatment of biological nuisance organisms poses a definite threat to the aquatic environment. Chlorination practices may be injurious not only to target organisms but also to the aquatic environments with which they are associated. Arthur and Eaton (1971) indicate chloramines are detrimental to fathead minnows (Pimephales promelas Rafinesque) and amphipods (Gammarus pseudolimnaeus Bousfield) in very low concentrations. Total residual chloramines having no effect were 16 and < 3.4 µg/l, respectively. Number of spawnings per fathead minnow female was reduced at 43 µg/l (P = 0.05), and the 96-hour TLm was in the range of 85-154 µg/l total chloramine under conditions of tests. The 96-hour TLm total chloramine toxicity to amphipods was 220 µg/l; reproductive success was much less in concentrations of 3.4 and 16 µg/l than in controls. Zillich (1970) has shown that chloramines associated with chlorinated sewage had a 96-hour threshold toxicity of 0.04 ppm and a 96-hour TLm average of 0.05-0.16 ppm to the fathead minnow. Coventry et al. (1935) found chloramine concentrations of 0.4 ppm killed trout and sunfish; 0.05-0.06 ppm killed trout fry in 48 hours. Other data show similar results, but more research is needed to adequately define the current and potential effect of chlorination practices associated with water treatment, control of biological nuisance in industrial cooling water systems, postchlorination, and tertiary treatment of sewage effluents.

Application of chlorine or chloramines for the control of biological nuisance may result in pollution of the aquatic environment if measures are not taken to restrict treatment to target organisms by dechlorination. Dechlorination can be accomplished with the addition of sodium thiosulfate,

sodium bisulfate, sodium sulphite, or activated carbon (Hoover, 1943). However, none of these measures would be practical at power stations because of the large volumes of water used.

Alternative Control Measures

Alternatives to chlorination for biological nuisance control are numerous. Some of them are metal ions, ultrasonic vibration, electric fields, ozonation, and hot water. Morton (1969) has reviewed a number of methods for the control of mussels (Dreissena), mostly Russian experience.

Lyakhov (1964) has noted that of extensive research with metal ions, copper proved most effective for the control of Dreissena. Ingram (1956) noted that of molluscacides available only chlorine and copper would be allowable as delineated by drinking water standards.

Lukanin (1964) noted that due to high concentrations of $CuSO_4 \cdot 5H_2O$ and relatively long retention time required to kill Dreissena that heated water is a more practical control of Dreissena in thermal power plants. Lyakhov (1964) noted the use of heated water experimentation to determine optimum water temperature required to kill mollusk but did not note optimum found. Akramowski (personal communication) indicated that a review of current USSR malacological literature revealed that use of hot water is emphasized for control of Dreissena.

Recent experiments in our laboratory showed virtually instantaneous mortality of Asiatic clams (Corbicula manilensis Philippi) placed in 43-50° C (109.4-122.0° F) water. Fifteen minutes was chosen arbitrarily as a reasonable exposure period that might be considered for power station practice. Corbicula were taken from Wilson Reservoir with a water temperature of 10° C (50° F) and acclimated to 21° C (69.8° F) in the laboratory. Two animals were used in each experiment in sizes ranging from 22.5 mm to 43.5 mm, and the test was

replicated. Following exposure periods of 15 minutes, overnight recovery in lake water was allowed for final determination of mortality at each temperature (Table 1).

More research is needed on non-chemical methods and procedures for biological nuisance control.

Discussion

Present methods for control of Asiatic clams (C. manilensis Philippi) include mechanical procedures and chlorination. Domestic water supply systems using prechlorination (0.5 ppm residual) at pump intakes experience no problems with Asiatic clams or other biological nuisance organisms.

Control of biological nuisance in industrial water supplies is principally by chlorination. "Slug" chlorination (1 ppm) for periods of 30-60 minutes one to three times daily is often used for slime control. Continuous chlorination (1 ppm) for up to 21 days once or twice during the Asiatic clam breeding season provides adequate control of Asiatic clams and associated biological nuisance organisms. Veligers usually begin to appear when water temperatures reach 62-65° F (16.7-18.3° C) in the spring or early summer. Another successful practice for the control of Asiatic clams is 0.25 to 0.35 ppm chlorine applied continuously for 48 hours.

Efficacy of chlorine or chloramines for the control of biological nuisance is in question at this time. Many data in the literature indicate chloramine toxicity to selected aquatic animals in concentrations less than 0.1 ppm and interference with reproduction capacity at less than 20 ppb.

Use of hot water for the control of biological nuisance associated with thermal electric stations may be an effective alternative to chlorination. Increasing retention time of water passing through the condensers would elevate

the water temperature for control of biological nuisance. If only one condenser was treated per unit time and the treatment water mixed with the total effluent, there would be no appreciable increase in water temperature discharged to the environment. If the condenser treatment water could be used to flush other service water conduits perhaps a system could be evolved to eliminate biological nuisance from thermal electric stations. Fifteen-minute treatment of Asiatic clams with water in the 43-50° C (109.4-122.0° F) temperature range proved lethal under laboratory conditions.

Conclusions

1. Data show that chloramine releases to aquatic environmental systems may be lethal or reduce reproductive capacity of fish and macro-invertebrates at concentrations of 0.1 ppm to less than 20.0 ppb.

2. Asiatic clams (C. manilensis) exposed to water temperature of 43-50° C (109.4-122.0° F) for 15 minutes proved lethal. Use of heated water may be an effective alternative to chemical control of aquatic nuisance organisms.

3. Present general practice for control of Asiatic clam is continuous chlorination for maintenance of 0.5-1.0 ppm total chlorine residual for one or two 3-week periods during the breeding season or when water temperature is above 18.3° C (65.0° F). Chlorine residual of 0.25 to 0.35 ppm maintained for 48 hours when the water temperature is above 18.3° C (65.0° F) has proved to be an effective control for young Asiatic clams in one water system.

Table 1. Fifteen-minute exposure of Asiatic clams (<u>Corbicula manilensis</u> Philippi) to various water temperatures

Replicate No.	Specimen No.	Temperature °C	Apparent Survival Time (min.)	Real Survival 24 hrs. After Treatment
1	1	21* (70 °F)	15:00	Alive
	2	21*	15:00	
2	1	21* (70°F)	15:00	Alive
	2	21*	15:00	
1	1	37 (98.6°F)	15:00	Alive
	2	37	15:00	
2	1	37 (98.6°F)	15:00	Alive
	2	37	15:00	
1	1	40 (104°F)	2:00	Alive
	2	40	4:10	
2	1	40 (104°F)	2:20	Alive
	2	40	2:45	
1	1	43 (109°F)	1:30	Dead
	2	43	1:30	
2	1	43 (109°F)	1:30	Dead
	2	43	1:30	
1	1	45 (113°F)	:35	Dead
	2	45	:40	
2	1	45 (113°F)	:40	Dead
	2	45	:45	
1	1	47 (117°F)	:45	Dead
	2	47	:35	
2	1	45 (113°F)	:40	Dead
	2	47 (117°F)	:40	
1	1	50 (122°F)	:05	Dead
	2	50	:07	
2	1	50 (122°F)	:10	Dead
	2	50	:15	

*Controls

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(2)

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

DOCKETED
USNRC

In the matter of CAROLINA POWER & LIGHT CO. Et al.) Dockets 50-400
Shearon Harris Nuclear Power Plant, Units 1 and 2) and 50-401 O.L.

'83 OCT -3 P4:02

OFFICE OF SECRETARY
DOCKETING & SERVICE
BRANCH

CERTIFICATE OF SERVICE

I hereby certify that copies of Response and Affidavits Responding to Applicants and Staff on Eddleman 2.758 Petition (see also *below)

HAVE been served this 30 day of September 1983, by deposit in the US Mail, first-class postage prepaid, upon all parties whose names are listed below, except those whose names are marked with * an asterisk, for whom service was accomplished by including a packet of the larger documents referenced in 9/27 responses on summary disposition (1 Board, 3 Dktg & Svc, 1 Apps, 1 Staff), which procedure was approved orally by Judge Kelley 9/28 w/consent of Applicants.

* Judges James Kelley, Glenn Bright and James Carpenter (1 copy each)
Atomic Safety and Licensing Board
US Nuclear Regulatory Commission
Washington DC 20555

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