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BNL-26970

CONF-791037--14

A Critique of Source Term and Environmental Measurement at Three Mile Island

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Introduction

The most serious malfunction to date at an operating power reactor in the U.S. occurred at Unit 2 of the Three Mile Island Nuclear Power Station (TMI) at 0400 EST on March 28, 1979. Subsequently, between 3X and 10×10^6 Ci of radiogases (principally ^{133}Xe) were released to the atmosphere from the plant vent in decreasing concentrations over the next few weeks, accompanied by about 10 Ci of ^{131}I. During this period, the plant's typical effluent monitors and field radiation monitoring program were unable to supply prompt and reliable radiological information.

About four hours post-incident, the concentration of radiogases exceeded the upper range limit of the plant vent monitor. A few hours thereafter, the upper range of its radioiodine monitor was also exceeded. With the effective disabling of the vent monitoring system, it was impossible to make prompt projections of probable ground level concentrations of the radiogases and ^{131}I being released from the plant and of the related radiation exposure of the population. This situation was aggrevated by the concurrent effective disabling of the plant's radiological analytical laboratory for the assay of the effluent and/or environmental samples due to contamination from a high level process sample.

At the time of the incident, the only in-place field monitoring for external exposure consisted of eight fixed on-site thermoluminescent dosimeters (TLD) and twenty off-site TLD's. Passive particulate and charcoal samplers were also operated at two on-site and four off-site stations. Thus, the only source of readily available information about exposure rates in the effluent plume was from measurements obtained with portable survey meters carried by ground level and helicopter survey teams. The ground level

TEAMS ALSO UTILIZED PORTABLE AIR SAMPLERS AND HAD PROVISIONS FOR ESTIMATING CONCENTRATIONS OF ^{131}I FROM FIELD MEASUREMENTS. HOWEVER, ERRONEOUSLY HIGH LEVELS WERE SUGGESTED BY MOST OF THESE SAMPLES, DUE TO THE RETENTION OF RADIOGASES ON THEIR FILTER MEDIA.

IN ORDER TO PROVIDE A SUFFICIENT RADIOANALYTICAL CAPABILITY FOR THE LARGE NUMBER OF IN-PLANT AND ENVIRONMENTAL SAMPLES (AIR, WATER, SOIL, VEGETATION AND MILK) WHICH WERE OBTAINED, THE EXISTING ON-SITE FACILITIES WERE AUGMENTED BY MOBILE LABORATORIES. THE LABORATORY FACILITIES OF THE BUREAU OF RADIOLOGICAL HEALTH (BRH-PA) OF THE PENNSYLVANIA DEPARTMENT OF ENVIRONMENTAL CONSERVATION WERE SUPPLEMENTED BY A NEARBY TEMPORARY FACILITY FOR GAMMA ANALYSIS SET UP BY THE DEPARTMENT OF ENERGY (DOE). MANY ENVIRONMENTAL SAMPLES, PRINCIPALLY OF MILK, WERE ALSO TRANSPORTED TO MORE REMOTELY ESTABLISHED RADIOANALYTICAL LABORATORIES OF STATE AND FEDERAL AGENCIES.

THE LACK OF READILY ABAILABLE INFORMATION ABOUT PLANT RELEASE RATES, THE DELAYS INHERENT IN THE ASSESSMENT OF THE RADIOLOGICAL SITUATION FROM FIELD DATA AND THE LACK OF COORDINATION OF THE SEVERAL (LOCAL, STATE AND FEDERAL) AGENCIES INVOLVED, ALL AGGREVATED THE CLIMATE OF UNCERTAINTY WHICH WAS GENERATED BY THE PLANT OPERATOR'S DIFFICULTY IN ESTABLISHING A PROMPT ASSURED SAFE SHUTDOWN, AS WELL AS THEIR APPARENT INABILITY TO FULLY CONTROL AIRBORNE RELEASE FROM THE PLANT.

CURRENT (OCTOBER, 1979) ESTIMATES OF GAMMA EXTERNAL RADIATION DOSE TO THE POPULATION ARE FROM 2,000 TO 3,500 PERSON-REMS FROM RADIOGASES. THERE WAS A RELATIVELY SMALL DOSE TO THE THYROID FROM INHALED AND/OR INGESTED RADIOIODINES.

Effluent Release and On-site Measurements

THE INSTALLED IN-PLANT INSTRUMENTS, WHICH WERE ESSENTIAL TO THE PROVISIONS OF INFORMATION ABOUT ACTUAL OR POTENTIAL RELEASE RATES ARE SHOWN IN TABLE 1. THEY ARE TYPICAL OF THOSE CURRENTLY IN PLACE AT PRESSURIZED WATER REACTORS.

ALTHOUGH THE PRIMARY COOLANT MONITOR WAS NOT USEFUL FOR THE DEFINITION OF THE SOURCE TERM OF POSSIBLE ATMOSPHERIC RELEASES, IT NORMALLY WOULD HAVE PROVIDED THE FIRST INDICATION OF FAILED FUEL. HOWEVER, DUE TO THE UNUSUAL SEQUENCE OF EVENTS, IN WHICH AMOUNTS OF STEAM AND/OR WATER WERE DISCHARGED DIRECTLY FROM THE PRIMARY COOLANT SYSTEM THROUGH THE PRESSURIZER RELIEF VALVE INTO THE CONTAINMNET, THE FIRST INDICATION OF A MASSIVE FUEL FAILURE WAS IN FACT PROVUDED BY THE RESPONSE, SHORTLY AFTER 0500, OF THE INTERMEDIATE COOLING WATER LETDOWN COOLER MONITOR TO BACKGROUND INCREASES FROM CONTAMINATED PRIMARY COOLANT WATER, WHICH WAS COLLECTING IN THE CONTAINMENT BUILDING SUMP[2].

ALTHOUGH THE CONTAINMENT MONITOR WAS NOT CALIBRATED IN UNITS OF CONCENTRATION OF AIRBORNE ACTIVITY, ITS READING (IN MR/HR) WAS THE BASIS FOR A PROJECTION OF OFF-SITE DOSE CONSEQUENCES IN THE EVENT OF A LOCA. ITS RESPONSE BETWEEN 0630-0730, WHEN THE EFFECTS OF THE FUEL FAILURE WERE ALSO APPARENT FROM MANY OTHER IN-CONTAINMENT AIR MONITORS, IS SHOWN IN FIGURE 1. SUBSEQUENTLY, THE MONITOR REACHED A LEVEL OF 6×10^6 MR/HR AT 0900. DUE TO A MISINTERPRETAION OF THE MONITOR READOUT, THE FIRST OFF-SITE EXTERNAL DOSE RATE PROJECTION AT 0655 WAS 40 R/HR AT GOLDSBORO, 1.1 MILE WEST OF THE PLANT. A SUBSEQUENT RECALCULATION, USING THE CORRECT SCALE, SHOWED THAT THE PROJECTION SHOULD HAVE BEEN 2.2 MR/HR. THIS PROJECTION WAS PREDICATED ON GROUND LEVEL LEAKAGE AT A MAXIMUM OF 54 PSI OVER-PRESSURE IN THE CONTAINMENT, WHICH IN FACT DID NOT EXIST. THE ACTUAL LEVEL AT 0700 WAS ABOUT 1 PSI. THERE WAS NO APPARENT DIRECT LEAKAGE FROM THE CONTAINMENT DURING THE INCIDENT.

THE PLANT AIR EFFLUENT MONITOR FOR THE AUXILIARY BUILDING VENT, WHICH WAS THE SOLE NORMAL RELEASE POINT TO THE ATMOSPHERE, SHOWED A SMALL INCREASE IN THE CONCENTRATION OF RADIOIODINE AT 0415, COINCIDENTAL WITH THE INITIAL PUMPING OF PRIMARY COOLANT FROM THE CONTAINMENT SUMP TO A MISCELLANEOUS WASTE TANK IN THE AUXILIARY BUILDING. IT INDICATED A RAPIDLY INCREASING CONCENTRATION OF RADIOGASES AT ABOUT 0645 AND WENT OFF SCALE AT ABOUT 0730 AT WHICH CONCENTRATION THE RELEASE RATE OF RADIOGASES FROM THE PLANT VENT WAS ABOUT 2 CI/SEC. THE RADIOIODINE MONITOR SATURATED 1-2 HOURS THEREAFTER, APPARENTLY DUE TO THE RETENTION OF RADIOGASES ON ITS SAMPLING MEDIUM. ITS UPPER RANGE LIMIT CORRESPONDS TO A RELEASE RATE OF ^{131}I OF ABOUT 0.4 UCI/SEC.

IN THE ABSENCE OF DIRECT MEASUREMENTS OF THE CONCENTRATIONS OF RADIOACTIVITY RELEASED FROM THE PLANT VENT, THE AMOUNTS RELEASED HAVE BEEN INDIRECTLY ESTIMATED FROM RELATED DATA. A CONTRACTOR TO THE PLANT OPERATOR, WORKING BACKWARD FROM TLD MEASUREMENTS, CALCULATED THE GROUND LEVEL CONCENTRATIONS OF RADIOGASES (ESSENTIALLY ^{133}Xe, WITHIN TWO DAYS AFTER THE INCIDENT) AND APPLIED AN APPROPRIATE DILUTION FACTOR (X/Q) TO ARRIVE AT AN ESTIMATE OF RELEASES. DOE PERSONNEL UTILIZED DATA FROM GRAB SAMPLES OF RADIOGASES IN THE VENT EFFLUENT, WHICH WERE OBTAINED ON AND AFTER TO 4/5, AS WELL AS PERIODIC SAMPLES OF ^{131}I FROM 3/28 ON.3 THEY APPLIED THE SAME REGULAR DECREASING TREND TO THE DAILY AVERAGE CONCENTRATIONS OF STACK EFFLUENTS AS WAS OBSERVED IN THE DAILY AVERAGE EXPOSURE RATE IN THE PLUME, TO MAKE THE INDEPENDENT ESTIMATES OF THE AVERAGE CONCENTRATIONS OF ^{133}Xe AND ^{131}I IN THE VENT RELEASES BETWEEN 3/28 AND 4/10 .WHICH ARE SHOWN IN FIGURE 2.

THE RESPECTIVE TOTAL AMOUNTS OF ^{133}Xe AND ^{131}I, AS CALCULATED BY NRC PERSONNEL FROM THE TLD MEASUREMENTS AND BY DOE PERSONNEL FROM THE STACK GRAB SAMPLES ARE SHOWN IN TABLE II

FIELD RADIATION SURVEYS AND AIR SAMPLING

THERE WERE NO INSTALLED ACTIVE DEVICES FOR THE MEASUREMENT OF EXTERNAL RADIATION OR OF THE CONCENTRATIONS OF RADIOIODINES IN THE FIELD, EITHER ON- OR OFF-SITE. THERE WERE $CaSO_4$ TLDs AT EIGHT ESTABLISHED LOCATIONS ON-SITE AND AT TWELVE OFF-SITE. FIXED AIR SAMPLERS FOR PARTICULATES AND RADIOIODINES WERE ALSO OPERATED AT TWO LOCATIONS ON-SITE AND AT FOUR OFF-SITE, BY A CONTRACTOR TO THE PLANT OPERATOR.

WITH THE EFFECTIVE DISABLING OF THE PLANT VENT MONITORING SYSTEM, THE NEXT MOST PROMPT BASIS FOR ESTIMATES OF PLANT RELEASES AND/OR OF THEIR RADIOLOGICAL IMPLICATIONS WAS FROM DATA OBTAINED IN THE FIELD. THE PLANT OPERATOR DISPATCHED TEAMS THAT UTILIZED PORTABLE SURVEY METERS AND AIR-SAMPLERS TO MAKE SHORT-TERM MEASUREMENTS OF AMBIENT RADIATION LEVELS AND CONCENTRATIONS OF RADIOIODINES IN AIR.

EACH UNIT AT TMI WAS PROVIDED WITH A RADIOCHEMISTRY LABORATORY, WHICH INCLUDED A GELI DETECTOR EQUIPPED WITH A MULTI-CHANNEL GAMMA ANALYSIS SYSTEM IN ADDITION TO CONVENTIONAL GROSS ALPHA, GROSS BETA AND BETA SCINTILLATION COUNTERS. HOWEVER, THE GELI SYSTEM FOR UNIT 2 HAD NOT BEEN OPERATIVE SINCE ITS STARTUP. THE UNIT 1 LABORATORY WAS EFFECTIVELY DISABLED AT ABOUT 0900 DUE TO CONTAMINATION FROM HIGH AIRBORNE ACTIVITY FROM A PRIMARY COOLANT SAMPLE. THE LOSS OF THIS FACILITY LEFT THE STATION WITHOUT ANY ON-SITE GAMMA IDENTIFICATION CAPABILITY UNTIL THE ARRIVAL OF A NRC MOBILE LABORATORY AT 1930.

FIELD SURVEYS WERE MADE INITIALLY ON AN HOURLY BASIS ON- AND OFF-SITE BY THE PLANT TEAMS. THEIR EFFORTS WERE SUPPLEMENTED FROM MID-DAY OF THE 28TH ON AND FOR THE NEXT FEW WEEKS, BY TEAMS FROM THE NRC AND FROM THE DOE RADIOLOGICAL ASSISTANCE PROGRAM (RAP). THE LATTER ALSO OPERATED A PORTABLE NaI DETECTOR AND GAMMA ANALYZER. OCCASIONAL MEASUREMENTS OF RADIATION LEVELS IN THE PLUME CLOSE INTO THE PLANT WERE ALSO MADE USING A UTILITY CONTRACTOR HELICOPTER. STARTING ON THE AFTERNOON OF THE 28TH, REGULARLY SCHEDULED MEASUREMENTS, WEATHER PERMITTING, WERE MADE FROM A DOE AERIAL MEASUREMENTS SYSTEM HELICOPTER. IT CARRIED AN ON-BOARD GAMMA MEASUREMENT SYSTEM, WHICH PROVED TO BE TOO SENSITIVE FOR THE LEVELS ENCOUNTERED IN THE PLUME, SO THAT RESORT WAS MADE TO CONVENTIONAL PORTABLE SURVEY METERS. BOTH AIRBORNE AND GROUND LEVEL PORTABLE GAMMA SPECTROMETER EVALUATIONS INDICATED THAT THE PRINCIPAL GASEOUS CONSTITUENTS OF THE PLUME WERE 9.2 HR ^{135}XE EARLY ON AND SUBSEQUENTLY 5.2 DAY ^{133}XE. THE CONCENTRATIONS OF ^{131}I WERE TOO SMALL FOR IT TO BE IDENTIFIABLE.

FROM FIELD SURVEYS, IT IS APPARENT THAT THE PLUME'S DIRECTION WAS PREDOMINANTLY IN A NORTH THROUGH WESTERLY DIRECTION ON MARCH 28 AND 29. GROUND LEVEL EXPOSURE RATES ON-SITE INCREASED FROM A FEW MR/HR LATE IN THE MORNING OF THE 28TH TO TENS OF MR/HR IN THE AFTERNOON AND TO A MAXIMUM OF 300-400 MR/HR IN THE LATE EVENING. NEARBY, OFF-SITE RATES WERE ABOUT A FACTOR OF TEN LESS. A PROJECTION OF THE MAXIMUM GROUND LEVEL EXPOSURE RATES, BETWEEN 1700 AND 2400 (BASED ON THE DOE ESTIMATED VENT RELEASE RATE AT THAT TIME) IS SHOWN IN FIGURE 3. THE MEASURED GROUND LEVEL EXPOSURE RATES DECREASED THEREAFTER TO A FEW MR/HR BY THE EVENING OF THE 29TH.

THE FIRST COLLECTION AND FIELD MEASUREMENTS OF RADIOIODINES BY THE PLANT TEAMS ON THE DAY OF MARCH 28 INDICATED CONCENTRATIONS OF ^{131}I IN EXCESS OF 1×10^{-8} uCi/cm^3. SUBSEQUENT ANALYSES AT THE BRH-PA LABORATORY AT HARRISBURG REVEALED THAT ITS TRUE CONCENTRATIONS WERE $<1 \times 10^{-11}$ uCi/cm^3 IN ALL CASES. THIS ANALYSIS SHOWED THAT THE INITIAL FIELD RESULTS WERE ATTRIBUTABLE TO THE COLLECTION OF ^{133}Xe AND ^{135}Xe ON THE CHARCOAL MEDIUM OF THE PLANT TEAM'S AIR SAMPLERS. FIELD MEASUREMENTS ON MARCH 28 AND 29 BY THE DOE-RAP TEAM, UTILIZING A SAMPLER AND MEDIUM DESIGNED TO MINIMIZE THE RETENTION OF RADIOGASES, CONFIRMED THE BRH-PA FINDINGS.

WHEN IT BECAME APPARENT THAT, ON THE AVERAGE, THE RELEASES OF RADIOGASES WERE DECREASING, BUT THAT THE ASSURED SHUTDOWN OF THE PLANT IN A NORMAL COOLING MODE MIGHT BE DAYS AWAY, IN ADDITION TO CONTINUATION OF THE REGULAR HELICOPTER SURVEYS, AN AUGMENTED DOE-RAP EFFORT WAS DEVOTED TO SAMPLING AIR, WATER, SOIL AND VEGETATION IN DOWNWIND DIRECTIONS, SO AS TO PROVIDE AN INDICATION OF ANY UNUSUAL AIRBORNE RELEASE OF ^{131}I. A TEMPORARY COUNTING ROOM WAS ESTABLISHED AT THE DOE COMMAND POST AT THE CAPITOL CITY AIRPORT, UTILIZING PERSONNEL AND γ-ANALYSIS EQUIPMENT FROM SEVERAL REGIONAL DOE LABORATORIES. AS SHOWN IN TABLE III, ^{131}I WAS PRESENT IN CONCENTRATIONS IN THE ORDER OF 10^{-12}-10^{-11} uCi/cm^3 IN ABOUT HALF OF THE AIR SAMPLES. HOWEVER, EXCEPT IN A FEW INSTANCES, IT'S DEPOSITION WAS GENERALLY LESS THAN THE MINIMUM DETECTABLE (~0.1 nCi/m)^2. THESE FINDINGS WERE VERIFIED IN THE FIELD BY EXTERNAL EXPOSURE RATE AND GAMMA SECTRUM MEASUREMENTS, WHICH WERE MADE DIRECTLY BY DOE'S ENVIRONMENTAL MEASUREMENTS LABORATORY STARTING ON APRIL 2, UTILIZING THEIR SENSITIVE PRESSURIZED ION-CHAMBERS AND A PORTABLE GE(LI) SPECTROMETER.[4]

SOME 200 SEPARATE MEASUREMENTS OF EXPOSURE RATES AT VARYING DISTANCES FROM TMI WERE LOGGED DURING 60 FLIGHTS OF THE DOE HELICOPTER, BETWEEN MARCH 28 AND APRIL 10. PARTICULAR EFFORTS WERE MADE TO OBTAIN DATA AT DISTANCES OF ONE MILE AND THREE MILES DOWNWIND IN THE PLUME CENTERLINE, TYPICALLY AT AN ELEVATION OF 500-1,000 FT ABOVE GROUND LEVEL. THIS PROVIDED A MORE EXTENSIVE AND CONSISTENT DATA BASE FOR SUBSEQUENT ESTIMATES OF THE DOSE TO THE POPULATION THAN DID THE GROUND LEVEL MEASUREMENTS, SINCE THE LATTER WERE MADE AFTER MARCH 29 ONLY DURING DAYLIGHT HOURS RELATIVELY CLOSE TO THE PLANT WITH SEVERAL DIFFERENT TYPES OF PORTABLE SURVEY INSTRUMENTS.

THE TREND OF THE RATE OF RELEASES OF RADIOGASES FROM THE PLANT WAS NOT READILY DISCERNIBLE FROM THE GROUND LEVEL SURVEY MEASUREMENTS. HOWEVER, THE DAILY AVERAGES OF THE EXPOSURE RATES IN THE PLUME CENTERLINE, AS MEASURED FROM THE HELICOPTER, WERE FOUND TO DECREASE EXPONENTIALLY WITH A HALF-TIME OF ABOUT TWO DAYS, AS SHOWN IN FIGURE 4. THEY WERE ALSO FOUND TO DECREASE EXPONENTIALLY WITH INCREASING RADIUS WITH A HALF-DISTANCE OF ABOUT TWO MILES, AS ALSO APPARENT FROM FIGURE 4.

MILK SAMPLING AND ANALYSIS

SINCE THE THYROID DOSE FROM THE INGESTION OF ^{131}I IN MILK PRODUCED LOCALLY CAN CONSIDERABLY EXCEED THAT FROM DIRECT INHALATION, PARTICULAR ATTENTION WAS DEVOTED TO ITS ANALYSIS. AIDED BY THE BUREAU OF RADIOLOGICAL HEALTH OF THE FOOD AND DRUG ADMINISTRATION (BRH-FDA) AND THE EPA, THE BRH-PA ESTABLISHED A MUCH EXPANDED MILK SAMPLING NETWORK. IN ADDITION TO THE UTILITY CONTRACTOR AND THE BRH-PA LABORATORIES, SAMPLES WERE ANALYZED AT THE BRH-FDA LABORATORY AT WINCHESTER, MA AND THE EPA LABORATORY AT LAS VEGAS, NV. AS SUGGESTED IN THE SUMMARY OF THE RESULTS SHOWN IN TABLE IV, POSITIVE SAMPLES, AVERAGING <20 pCi/L OF ^{131}I, WERE APPARENT IN LESS THAN HALF OF THE SAMPLES COLLECTED THROUGH APRIL 4. ALL RESULTS WERE <10 pCi/L THEREAFTER. THE LARGEST CONCENTRATIONS WERE ABOUT 1/10 OF THOSE FOUND IN MID-PENNSYLVANIA AFTER FALLOUT FROM A CHINESE WEAPONS TEST IN OCTOBER 1976.[5]

POPULATION DOSE ESTIMATES

INDEPENDENT POPULATION DOSE ESTIMATES WERE MADE BY AN AD HOC INTERAGENCY DOSE ASSESSMENT GROUP (COMPOSED OF REPRESENTATIVES OF THE NRC, BRH-FDA AND THE EPA), WHO UTILIZED TLD DATA AND BY THE DOE DOSE ASSESSMENT GROUP, WHO UTILIZED THE EXTENSIVE SET OF HELICOPTER MEASUREMENTS OF EXPOSURE RATES IN THE PLUME. A COMPARISON OF THE EXPOSURE ISO-DOSE CONTOURS, AS PROJECTED BY THE DOE TEAM WITH THE UTILITY TLD DATA FOR DISTANCES UP TO TWO MILES, IS SHOWN IN FIGURE 5 AND FOR DISTANCES 0-10 MILES IN FIGURE 6.

THE DOE ESTIMATES OF THE COLLECTIVE DOSE TO THE POPULATION UP TO 50 MILES FROM TMI IS SHOWN IN TABLE V. THEY ARE BASED ON THE AVERAGE EXPONENTIAL DECREASE OF OFF-SITE EXPOSURE RATES WITH DISTANCE INDICATED PREVIOUSLY. THE USE OF A $1/R^2$ RELATIONSHIP WOULD ADD ABOUT 500 PERSON-REMS TO THIS ESTIMATE. THE SEVERAL ESTIMATES BY THE INTERAGENCY GROUP ARE SHOWN IN FIGURE 7. THEIR LARGER ESTIMATES WERE BASED UPON THE INDICATIONS OF THE SUPPLEMENTARY 37 TLD'S PLACED IN THE FIELD BY NRC ON MARCH 30. THE INCREMENTS IN DOSE THEY SUGGEST AFTER THAT DATE ARE INCONSISTENT WITH THE ESTABLISHED REGULARLY DECREASING AVERAGE RATE OF RELEASE OF RADIOGASES. THUS, THE LOWER INTERAGENCY GROUP ESTIMATES APPEAR TO BE THE MOST RELIABLE. THERE IS GOOD AGREEMENT BETWEEN THESE AND THE INDEPENDENT DOE ESTIMATE. HOWEVER, THE LATTER MAY BE EXCESSIVE SINCE IT IS BASED ON UNCORRECTED DATA OBTAINED WITH A PORTABLE SURVEY METER, WHICH HAD A SUBSEQUENTLY ESTABLISHED 2-3X OVER-RESPONSE TO LOW-ENERGY PHOTONS.[7]

CONCLUSIONS AND RECOMMENDATIONS

THE MONITORING DURING THE INCIDENT WAS SUFFICIENT TO ASSURE THAT THE RESULTANT RADIATION EXPOSURE OF THE PUBLIC WAS SMALL, NAMELY LESS THAN A MAXIMUM OF 100 MREM EXTERNAL WHOLE BODY DOSE TO PERSONS NEARBY AN AVERAGE OF LESS THAN 1 MREM TO THE 2×10^6 PERSONS WITHIN 50 MILES AND AT THE MOST A FEW MILLIREMS TO THE THYROIDS OF CHILDREN CONSUMING MILK FROM NEARBY DAIRY HERDS. FROM THE INTERAGENCY GROUP'S REPORT, IT MAY BE ESTIMATED THAT THE TOTAL POPULATION DOSE OF ABOUT 2,000 PERSON-REMS WOULD LEAD TO LESS THAN ONE PROJECTED FATAL CANCER, IN ADDITION TO THE 325,000 OTHERWISE ANTICIPATED TO THE POPULATION OF ~2,000,000 PERSONS WITHIN 50 MILES OF TMI.

NEVERTHELESS, A NUMBER OF DEFICIENCIES IN PLANT EQUIPMENT AND IN THE RESPONSE EFFORT AND CAPABILITIES WERE APPARENT. THE FOLLOWING MEASURES ARE SUGGESTED FOR THEIR ALLEVIATION:

1. EFFLUENT RELEASE POINTS THROUGH WHICH LARGE AMOUNTS OF RADIOGASES AND/OR RADIOIODINES FROM FAILED FUEL COULD BE RELEASED SHOULD BE PROVIDED WITH HIGH RANGE MONITORS. THOSE FOR RADIOIODINES SHOULD BE CAPABLE OF DISCRIMINATING AGAINST RADIOGASES.

2. EACH PLANT OPERATOR SHOULD EITHER IDENTIFY AN EXISTING NEARBY RADIOANALYTICAL LABORATORY OR ESTABLISH A STANDBY ONE TO BACKUP THEIR IN-PLANT CAPABILITY.
3. A FEW CONTINUOUSLY OPERATING ACTIVE INDICATING EXTERNAL RADIATION MONITORS AND RADIOIODINE SAMPLERS SHOULD BE INSTALLED IN PREVAILING DOWNWIND DIRECTIONS IN THE PERIPHERY OF PLANTS. ADDITIONAL TLD STATIONS SHOULD BE INSTALLED IN EACH 22.5^{0} COMPASS SECTOR, SO AS TO ASSURE COVERAGE AT DISTANCES OF ABOUT ONE AND ABOUT FIVE MILES, AS WELL AS IN POPULATION CENTERS OUT TO 20 OR SO MILES FROM EACH REACTOR SITE.
4. EMERGENCY RESPONSE TEAMS SHOULD AUGMENT THEIR ABILITY TO MAKE ASSESSMENTS OF INCIDENTS OF PROLONGED DURATION. RESPONSE CAPABILITY SHOULD INCLUDE RADIATION LEVEL AND AIR SAMPLING EQUIPMENT THAT CAN BE IN ONE PLACE AND OPERATED OVER A PERIOD OF SEVERAL HOURS AND EVEN DAYS, SO AS TO PROVIDE TIME INTEGRATED MEASUREMENTS OF RADIATION LEVELS AND/OR OF THE CONCENTRATIONS OF AIRBORNE RADIOACTIVITY.
5. SINCE IN-PLANT ANALYTICAL AS WELL AS OUT OF PLANT ROUTINE ANALYTICAL FACILITIES MAY NOT BE AVAILABLE AND/OR ARE LIKELY TO BE OVERLOADED WITH SAMPLES IN THE EVENT OF AN INCIDENT, EMERGENCY RESPONSE TEAMS SHOULD PROVIDE INSTRUMENTS AND PERSONNEL SO AS TO BE ABLE TO SUPPLY PROMPTLY AVAILABLE RADIOANALYTICAL CAPABILITIES AT A SUITABLE LOCATION PROXIMATE TO THE SITE.
6. EMERGENCY RESPONSE EFFORTS SHOULD INCLUDE PROVISION FOR THE DEPLOYMENT AND READOUT OF TLD'S IN THE FIELD, SO AS TO MINIMIZE THE TURNAROUND TIME FOR READING THEM AT REMOTELY LOCATED CONTRACTOR FACILITIES.
7. THE ENERGY RESPONSE OF PORTABLE SURVEY INSTRUMENTS WHICH MAY BE UTILIZED DURING AN INCIDENT SHOULD BE ESTABLISHED FOR THE RADIONUCLIDES THAT ARE MOST LIKELY TO BE RELEASED.

References

1. Final Safety Analysis Report, Unit 2, Three Mile Island Nuclear Power Station, Metropolitan Edison Co., Pennsylvania Power and Light Co., Jersey Central Power and Light Co., (1974).
2. These and subsequently indicated details of the sequence of events in-plant were obtained from "Investigation into the March 28, 1979 Three Mile Island Accident by Office of Inspection and Enforcement", NUREG 0600 (1979).
3. These data were supplied by informal communication from the NRC-Region II to the DOE field HQ at Capitol City Airport on April 12, 1979.
4. K. Miller, et.al., "Radiation Measurements Following the Three Mile Island Reactor Accident", EML-357 (1979).
5. Data presented by Commonwealth of Pennsylvania Department of Environmental Resources at December, 1976 Fallout Workshop, Mail Address: Bureau of Radiological Health, Box 2063, Harrisburg, PA 17130.
6. Population Dose and Health Impact of the Accident at the Three Mile Island Station, NUREG-0558 (May, 1979).
7. L. V. Spencer, NBS Report of Test of Two Radiation Survey Instruments, Communication from NBS to EG&G, May 25, 1979.

Tables

Figures

TABLE I

INSTALLED COOLANT, CONTAINMENT AND ON-LINE AIR EFFLUENT MONITORS AT UNIT 2, THREE MILE ISLAND NUCLEAR POWER STATION

PRIMARY COOLANT LET DOWN	NaI-SCINT	^{135}I: 10^{-5}-1 $\mu Ci/cm^3$ (WITH Pb COLLIMATOR 10^{-2}-10^{3} $\mu Ci/cm^3$)
REACTOR CONTAINMENT	ION CHAMBER (IN 2" Pb SHIELD ASSIGNED ATTENUATION FACTOR OF 100)	10^{-1}-10^{7} MR/HR (PROVIDED WITH SIX "EXPANDED" THREE DECADE AS WELL AS FULL SCALE READOUT)
PLANT VENT	GAS β-SCINT	^{85}Kr: 2.6×10^{-7}-1×10^{-2} $\mu Ci/cm^3$
	PART.-SCINT	^{137}Cs: 1.8×10^{-11}-1.6×10^{-6} $\mu Ci/cm^3$
	IODINES-Na(Tl)	^{131}I: 1×10^{-10}-1×10^{-5} $\mu Ci/cm^3$

FROM REF. 1

TABLE II

ESTIMATED AMOUNTS OF PRINCIPAL RADIOGASES AND RADIOIODINES RELEASED FROM PLANT VENT OF TMI TO UNIT 2, 3/28-4/10/79

			UTILITY			DOE		
NUCLIDE	T½	CORE INVENTORY Ci	Ci	% OF CORE	% OF PRIMARY*	Ci	% OF CORE	% OF PRIMARY*
^{133}Xe	5.3 D	1.2×10^{8}	9.7×10^{6}	7.5		2.9×10^{6}	2.4	-
^{131}I	8.05 D	6.4×10^{7}	12.5	1.9×10^{-5}	2.8×10^{-4}	7.7	1.1×10^{-5}	1.7×10^{-4}

*BASED ON PRIMARY VOLUME (90,000 GALS.)

ESTIMATES OF AMOUNTS OF ACTIVITY IN CORE FROM REF. 1

TABLE III

SUMMARY OF ANALYTICAL RESULTS FOR IODINE-131 IN SAMPLES COLLECTED AND ANALYZED BY DOE

	Sample Type	No. of Samples Collected	No. of Samples Less Than MDA*	No. of Samples Greater Than MDA*	Range of Positive Values
Period From	Stagnant Surface Water	122	122	-	
3/28	Rain Water	0	0	0	- -
4/6	Vegetation	236	234	2	0.1-0.3 nCi/m^2
	Soil	225	224	1	0.3 nCi/m^2
	Air	19	11	8	7×10^{-12} to 3×10^{-11} uCi/cc
Period From	Stagnant Surface Water	60	60	0	-
4/7	Rain Water	17	17	0	-
4/16	Vegetation	78	69	9	0.05 to 0.7 nCi/m^2
	Soil	27	27	0	-
	Air	23	11	12	6×10^{-12} to 9×10^{-11} uCi/cc

*Minimum detectable activity (concentration)

TABLE IV

MILK SAMPLES
(MARCH 28 TO APRIL 4)

	PENNSYLVANIA	FDA	EPA	METROPOLITAN EDISON
NUMBER OF ANALYSES PERFORMED	133	106	4	21
NUMBER OF POSITIVE RESULTS	7	41	2	18
AVERAGE VALUE OF POSITIVE RESULTS (PCI/LITER)	15	20	17	7
RANGE OF POSITIVE RESULTS (PCI/LITER)	11-20	13-36	10-24	1-41
AVERAGE MINIMUM DETECTABLE	<20	·10	·10	<1

FROM REF. 5

TABLE V

COLLECTIVE DOSE TO POPULATION 0-50 MILES FROM THREE MILE ISLAND NUCLEAR STATION, MARCH 28 THROUGH APRIL 3, 1979

RADIUS (MILE)	COLLECTIVE DOSE PERSON-REM**	TOTAL POPULATION*	AVERAGE INDIVIDUAL EXPOSURE (MR)
0-1	51.2	658	77.8
1-2	66.7	2,017	33.1
2-3	482.2	7,579	63.3
3-4	352.2	9,676	36.4
4-5	76.4	8,891	8.6
5-10	810.0	137,474	5.9
10-20	137.4	577,288	0.24
20-30	27.3	433,001	0.063
30-40	1.9	273,857	0.0069
40-50	0.3	713,210	0.00048
TOTAL	2,005.7	2,165,651	0.92
	(2,000)		(0.9)

* ESTIMATED POPULATION FOR 1980, BY 22.50 SECTORS AND DISTANCE OBTAINED FROM FSAR FOR THREE MILE ISLAND II.

** BASED ON PROJECTED GROUND LEVEL EXPOSURE RATES UNDER THE PLUME OF RADIOACTIVE GAS, WHICH WERE ASSUMED TO HAVE BEEN ONE-HALF OF THOSE FOUND DURING THE HELICOPTER FLIGHTS WITHIN IT.

DERIVED FROM DEPARTMENT OF ENERGY AERIAL RADIATION SURVEY DATA.

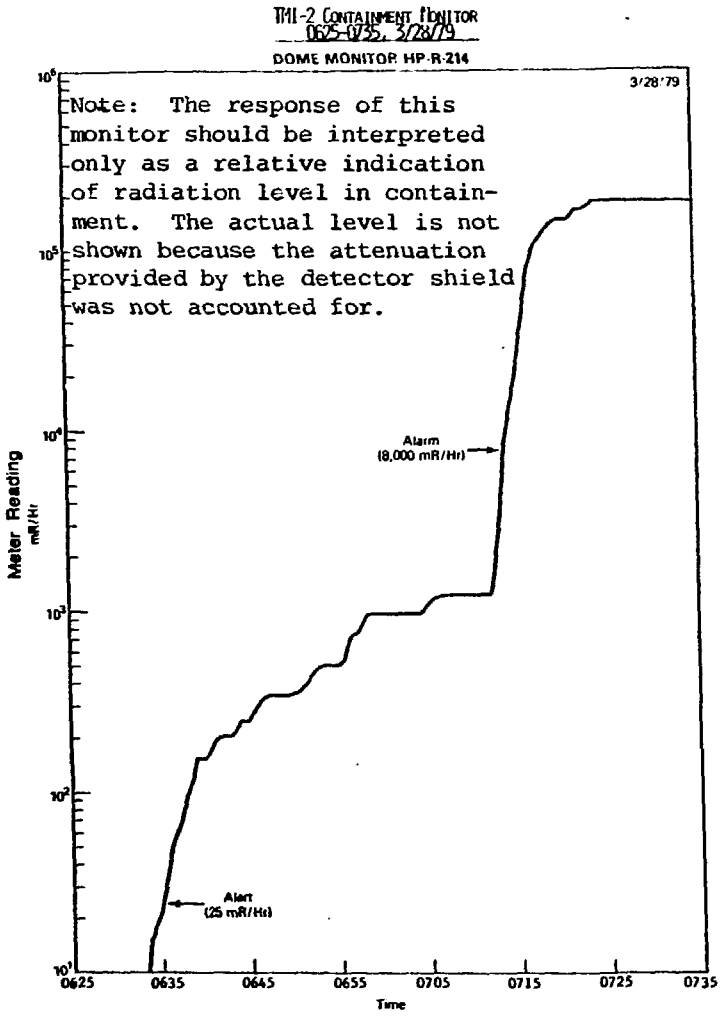

FIGURE 1 FROM REF. 2

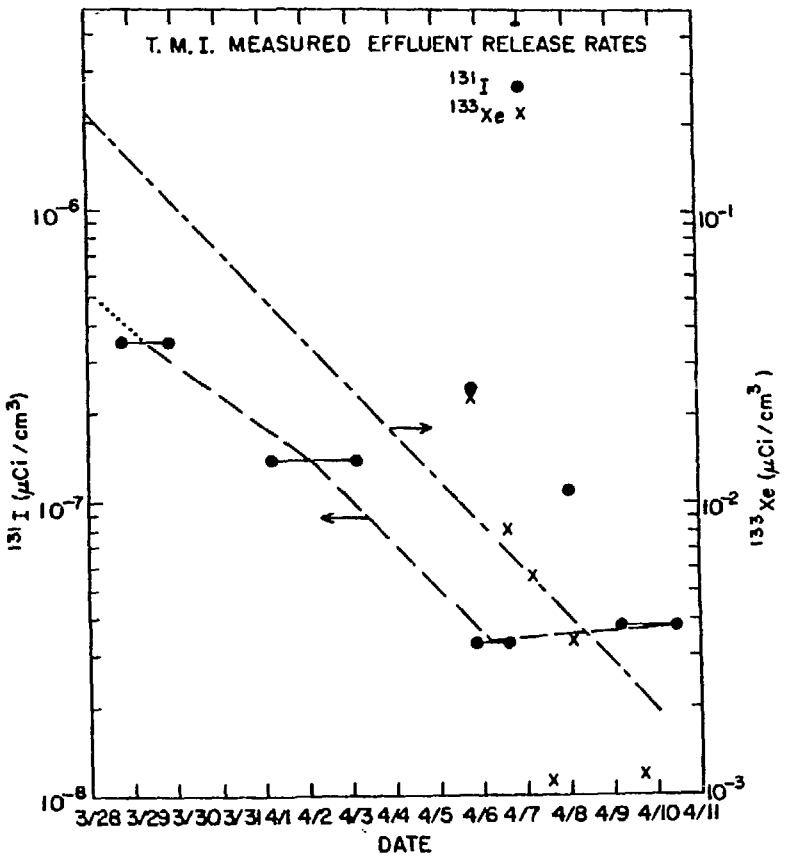

FIGURE 2

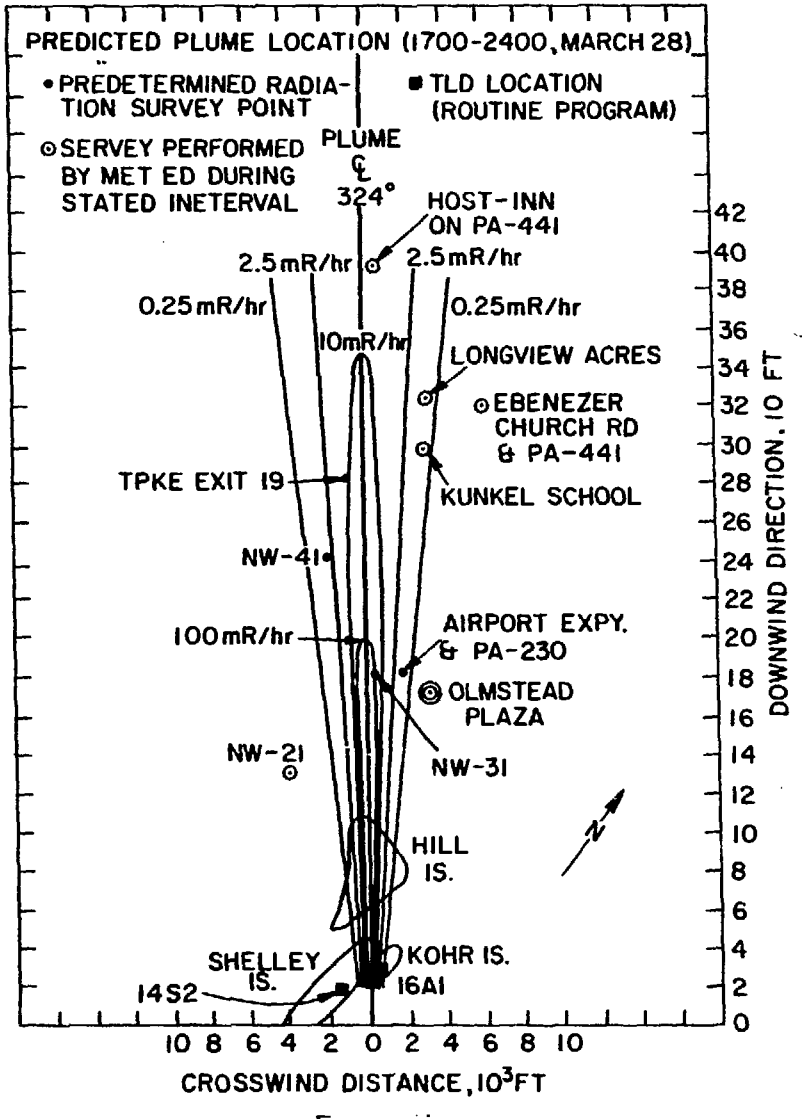

FIGURE 3

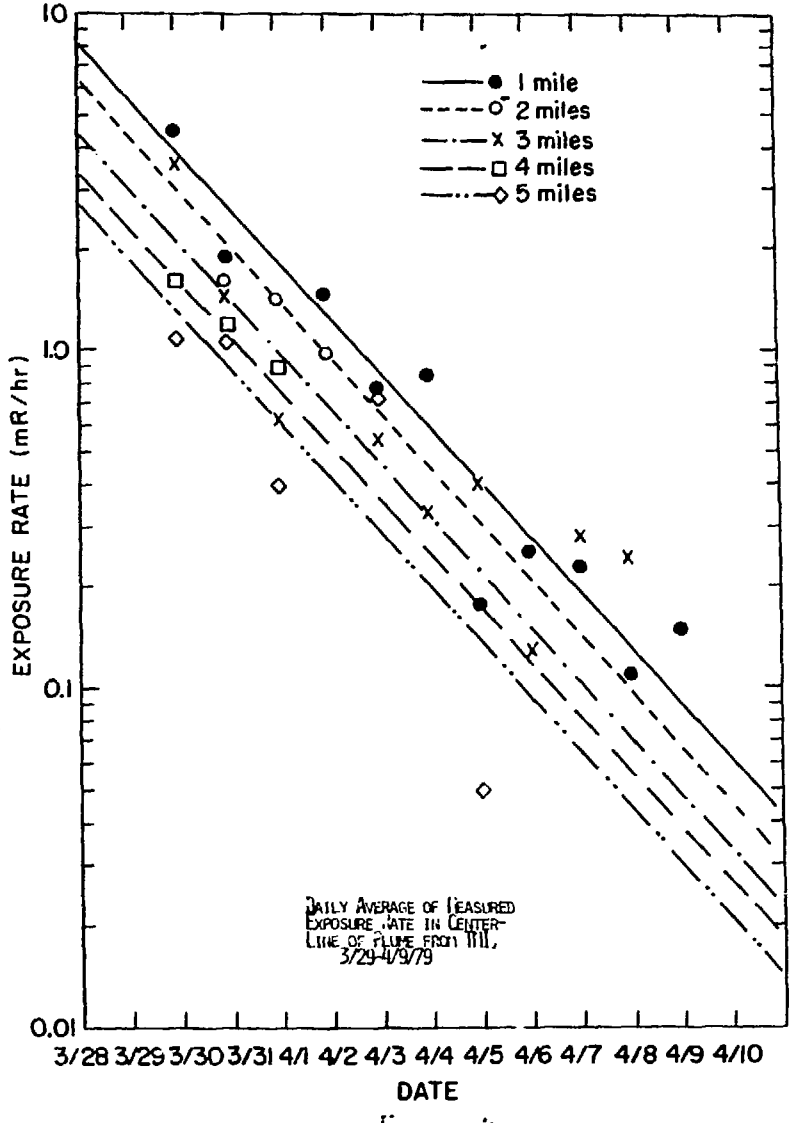

FIGURE 4

0-2 MILES

ESTIMATED DOSE IN VICINITY OF TMI 3/28-4/3/79

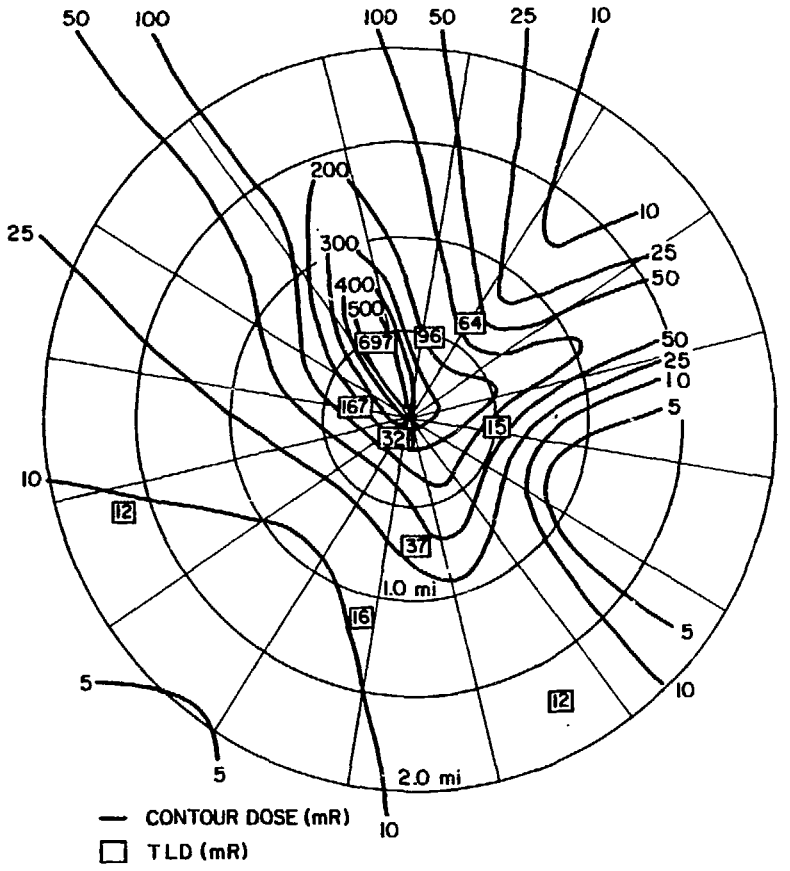

FIGURE 5

0-10 MILES

ESTIMATED DOSE IN VICINITY OF TMI 3/28-4/3/79

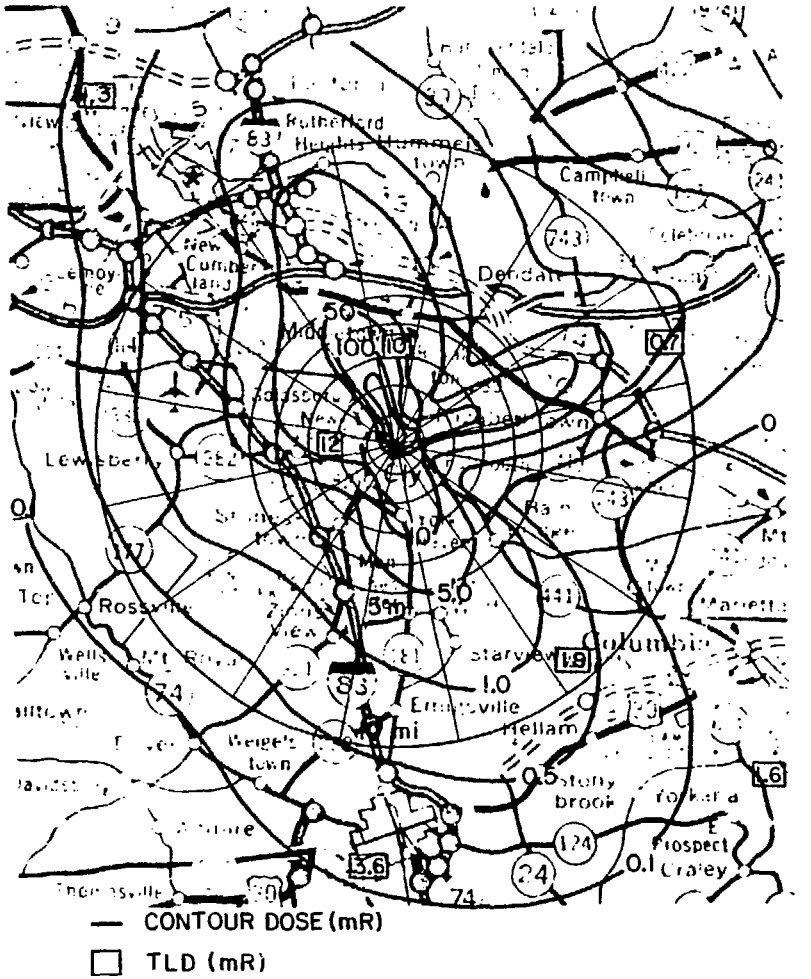

FIGURE 6

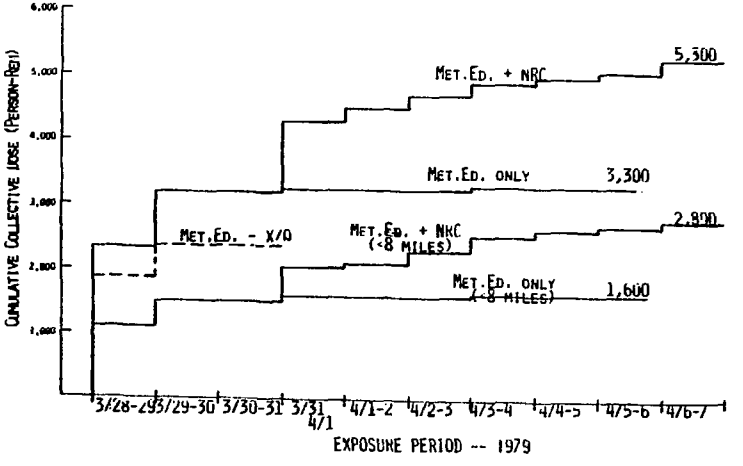

FIGURE 7

INCREASE IN COLLECTIVE DOSE AS A FUNCTION OF TIME FOR VARIOUS CALCULATION STRATEGIES

FROM REF. 5