STATE OF RHODE ISLAND AND PROVIDENCE PLANTATIONS

ATOMIC ENERGY COMMISSION

Docket No. 50-193 April 16, 1963

Chairman
U. S. Atomic Energy Commission
Washington 25, D. C.

Attention: Division of Licensing and Regulation

Gentlemen:

The Rhode Island Atomic Energy Commission (RIAEC) hereby submits for approval of the U. S. Atomic Energy Commission (USAEC) information to establish an atmospheric dilution factor of 10^{-4} sec/m^3 for determining the permissible average concentration of radioactive effluent from the reactor effluent disposal stack which is 22 inches in diameter and 115 feet higher than the surrounding terrain. Such a dilution factor applied to the disposal of airborne radioactive material is sufficient to ensure that the yearly average concentration of such materials at all points in unrestricted areas around the stack, which could be occupied by individuals will not exceed the maximum permissible, non-occupational concentrations established by the USAEC.

The information which follows indicates that disposal of airborne radioactive material from a stack which provides a dilution factor of 10^{-4} sec/m^3 can be safely permitted. This factor will be regarded as a limit and gases will be released at a minimum level after careful monitoring.

The reactor building ventilation system and the systems for removal of ambient atmosphere undergoing neutron bombardment in the beam ports, dry gamma facility, and allied reactor experimental facilities, has been described previously (1,2,3). This exhaust system will also be used for the removal of various flushing gases,

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1. "Information Supplied in Response to Questions Compiled by the USAEC Regarding the Rhode Island Atomic Energy Commission Reactor", answers A-3 and A-4, submitted to USAEC on June 29, 1962.

2. "Information Supplied by the Rhode Island Atomic Energy Commission to Questions Compiled by the U.S. Atomic Energy Commission", answers Item 11 and attached flow sheet, Item 13, submitted to USAEC on May 2, 1962.

3. "Information Supplied by the General Electric Company in Response to Questions Compiled by the USAEC Regarding the Rhode Island Atomic Energy Commission Reactor", answers 11, 14, submitted to USAEC on May 2, 1962.

such as helium required in certain experimental set ups in the general research program. These gases will be collected in a manifold and after careful monitoring exhausted to the exterior of the building through particulate filters. These systems will exhaust through a stack 115 feet above the surrounding terrain by means of a 4000 cfm blower. All building ventilation intakes are fitted with louvers to close them off automatically in the event of the necessity of using the building clean-up system following a reactor incident.

In releasing gaseous activity to the atmosphere, the RIAEC realizes the necessity of protecting inhabitants of unrestricted areas near the reactor site from over exposure due to the stack effluent. However, due to diffusion in the atmosphere and variations in wind speed and direction, effluent concentrations of radioactive gases in excess of the MPC can be safely discharged from the stack. It is the purpose of the remainder of this transmittal to review the reactor location, the appropriate operating procedures, and the applicable meteorological diffusion theory in order to justify this statement.

The reactor facility environment has been described in prior transmittals to the Division of Licensing and Regulation (4,5,6,7). A summary of this information follows.

The reactor is located on three acres of land on a 27 acre abandoned military reservation formerly called Fort Kearney. The reservation is in the Town of Narragansett, R. I. on the west shore of Narragansett Bay approximately 22 miles south of Providence, R. I. and approximately 6 miles north of the entrance to the Bay from the Atlantic Ocean. Located on this 27 acre site are the R. I. Nuclear Science Center (the reactor) and the University of Rhode Island Marine Laboratory. There is a separation of about 400 feet between these facilities. In addition the U. S. Public Health Service is presently constructing the Northeast Shellfish Research Laboratory and will soon construct a Polluted Water Laboratory adjacent to the 27 acre site. The land surrounding the reactor is essentially controlled by the State of Rhode Island through the University of Rhode Island. The distance from the reactor building to the boundary of the three acres of reactor land is

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4. Letter, Arthur L. Quirk to USAEC, dated August 3, 1962.

5. Letter and enclosures, Arthur L. Quirk to USAEC dated May 2, 1962.

6. Letter, Arthur L. Quirk to USAEC dated January 19, 1962.

7. Technical Specifications to be submitted to USAEC.

140 feet. This boundary is to the east of the building toward the shore of Narragansett Bay. The closest off site structure is the Old Ferry Church (Old Narragansett Church) at about 1300 feet. The closest private dwelling is 1400 feet from the facility.

No gaseous effluent will be released from the stack without the knowledge of the reactor operating staff and without appropriate monitoring. Prior to the conduct of any experiments, the operating staff, the scientists involved, and the Reactor Utilization Committee analyze potential hazards connected with the experiment, including studies of the amounts of any radioactive gases to be evolved. Experiments involving the release of such gas are then fitted with appropriate monitors. After monitoring, the gas would be discharged through the stack providing the stack dilution factor is sufficient to result in concentrations below MPC for unrestricted areas.

The maximum ground concentration of gaseous effluents from a stack is calculated using the Sutton diffusion relation (8)

$$\chi_{max} = \frac{2Q}{\pi e h^2 u} \frac{c_z}{c_y},$$

where

χ_{max} = concentration ($\mu c/cc$) at ground level for the position of maximum concentration downwind from the stack

Q = emission rate of radioactive gas (curies/sec)

h = height of stack (meters)

u = wind velocity (meters/sec)

$\frac{c_z}{c_y}$ = the ratio of the vertical to horizontal atmospheric diffusion coefficients, which is always less than unity.

In Table I, Column 1 and 2 are presented the χ_{max}/Q for a stack 115 feet in height and for various wind speeds. The rise of the exhaust plume above the stack because of the exhaust velocity (17 mph) has been included in the calculation.

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8. U.S. Department of Commerce "Meterology and Atomic Energy", AECU-3066 July 1955, p. 49.

Table I, Column 3, presents the percentage frequency of the various wind speeds for the location. The data is taken from Reference 9.

Table I, Column 4, presents the product of χ/Q and frequency of wind occurrence. The atmospheric dilution factor χ/Q averaged over wind speed and frequency is the sum of the last column of Table I and is 5.35×10^{-5} sec/m^3.

Table II presents the percentage frequency of wind direction based on 16 compass points and an annual average. The data is taken from Reference 9. From the table it is seen that the wind direction is quite variable but that the most frequent direction, referred to the sixteen compass points occurs no more than 10.5 percent of the time and occurs from either the south west or north west direction. Therefore, the year round χ/Q averaged over wind speed and adjusted for wind direction is (5.35×10^{-5}) (.105) or 5.6×10^{-6} sec/m^3.

The distances downwind from the stack where these maximum concentrations occur are computed from the relation (8)

$$d_{max} = \left(\frac{h^2}{c^2} \right)^{\frac{1}{2-n}}$$

where

d_{max} = distance (meters) of maximum concentration from the stack

h = effective stack height (meters)

n = Sutton stability parameter

c = generalized diffusion coefficient.

9. "Climatography of the United States No. 30-37, Summary of Hourly Observations, Providence, R. I.", U. S. Department of Commerce Weather Bureau.

Table III presents the d_{max} for an 115 foot stack and for various choices of the stability parameter. The diffusion coefficients appropriate for the particular stack height, wind velocity, and meteorological conditions are obtained from Tables III and VII of IDO-12005 (10).

This calculation is conservative for the following reasons:

1. C_z/C_y is assumed equal to 1.
2. The radioactive decay of the gaseous effluents is ignored. This factor can become important for the dispersal of a gas of relatively short half life under the condition of low wind speed - e.g. for 1.8 hour Argon-41 which is assumed to be the major radioactive constituent of the beam port atmospheric content.
3. The dilution factor calculated is for the position on the ground where the maximum concentration occurs. The extent of this position is limited. In the cross wind direction the concentration in the exhaust plume is gaussian in shape and its value falls off rapidly as distance from the plume centerline increases. It can be shown that the average concentration in the cross wind direction is .57 of the maximum of the gaussian when 97°/. of the gaussian is included.
4. The effluent cone, especially under inversion conditions, is limited in cross wind size and its effective cross wind diameter especially under inversion conditions is often small compared with the distance intercepted by the 22 1/2° wind sector over which averages were made for wind direction.

The above calculations show that the average dilution factor χ/Q is at least 5.6×10^{-6} sec/m^3 at the location of maximum ground concentration; therefore, it is requested that the USAEC permit the RIAEC to utilize an atmospheric

10. "Workbook in Atmospheric Diffusion Calculations, G. A. DeMarrais, IDO-12005, February 1959, p. 49.

dilution factor of 10^{-4} sec/m^3 for the release of radioactive gases from its stack.

Very truly yours,

Arthur L. Quirk

Arthur L. Quirk,
Chairman

Subscribed and Sworn to before me this 16th day of April 1963.

J. Lester Mallow
Notary Public

My Commission expires June 30, 1966

Encl:

(1) Table I
(2) Table II
(3) Table III

TABLE I

Wind Speed MPH	χ / Q Sec/m^3	Frequency of Occurrence for Designated Wind Speed f	$(\chi / Q) \times f$
< 1	11.7×10^{-5}	.05	0.585×10^{-5}
1 - 3	12.4×10^{-5}	.093	1.15×10^{-5}
4 - 7	6.9×10^{-5}	.25	1.7×10^{-5}
8 - 12	4×10^{-5}	.298	1.19×10^{-5}
13 - 18	2.7×10^{-5}	.238	0.64×10^{-5}
19 - 24	2×10^{-5}	.05	0.1×10^{-5}
> 24	$.18 \times 10^{-5}$	.013	0.002×10^{-5}
		TOTAL	5.35×10^{-5} sec/m^3

Encl (1) to RIAEC ltr
Dated: April, 16, 1963

TABLE II

PERCENTAGE FREQUENCY OF WIND DIRECTION

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	SUM	SUM/12
N	9	9	7	6	8	3	4	5	6	7	6	5	75	6.25
NNE	7	6	6	8	8	4	3	5	6	8	5	3	69	5.75
NE	3	4	5	4	7	4	3	4	5	6	4	4	53	4.42
ENE	1	1	2	1	2	2	1	1	1	1	2	1	16	1.33
E		1	1	2	2	1	1	1	1	1	1	1	13	1.08
ESE	1	1	2	1	2	1	1	2	1	1	1	1	15	1.25
SE	4	3	7	8	12	7	7	7	4	4	3	4	70	5.83
SSE	4	4	4	6	8	8	5	4	5	4	4	3	59	4.92
S	4	5	4	7	5	7	7	7	7	6	6	4	69	5.75
SSW	8	4	6	8	6	12	12	12	11	7	8	7	101	8.42
SW	10	7	5	10	6	14	16	13	13	12	10	10	126	10.50
WSW	7	5	4	6	4	6	8	7	5	6	8	11	77	6.42
W	7	6	6	6	5	7	8	6	6	6	9	10	82	6.83
WNW	11	16	15	8	7	8	7	6	7	7	9	13	114	9.50
NW	13	14	13	10	8	8	7	8	9	9	13	13	125	10.42
NNW	7	11	9	6	6	4	4	6	6	8	7	7	81	6.75
CALM	5	4	3	3	5	4	6	7	7	6	5	3		

TABLE III

Stability Parameter n		Wind Velocity mph	Diff. Coef. C	d_{max} miles
.2	(super adiabatic)	1	.39	0.21
		5	.34	0.12
		10	.31	0.12
.25	(adiabatic to isothermal)	1	.2	0.56
		5	.16	0.33
		10	.15	0.362
.33	(Isothermal and slight inversion)	1	.1	1.7
		5	.08	1.07
		10	.07	1.25
.5	(strong inversion)	1	.05	0.11
		5	.03	8.1
		10	.024	0.11

Encl (III) to RIAEC ltr
Dated: April 16, 1963

EF ST HT 14000 DAVID

	A	B	C	D	E	F	G	H
1								
2								
3								
4						delta H	H + delta H	
5				26.95/COLC	COL D^1.4	d x COL E	COL F + 35	COL G - 14.6
6							EFFECTIVE	EFFECTIVE
7	WIND SPEED		U	W/U			STACK	STACK HGT -
8			AVG. WIND				HEIGHT	HGT OF BLDG
9	MILES / HR	METERS/SEC	METERS/SEC				METERS	METERS
10	1	0.447	0.45	60.29	310.71	173.62	208.67	194.04
11	1 TO 3	.44 TO 1.32	0.89	30.28	118.48	66.21	101.26	86.63
12	4 TO 7	1.76 TO 3.08	2.45	11.00	28.70	16.04	51.09	36.46
13	8 TO 12	3.52 TO 5.28	4.47	6.03	12.37	6.91	41.96	27.33
14	13 TO 18	5072 TO 7.92	6.93	3.89	6.70	3.74	38.79	24.16
15	19 TO 24	8.36 TO 10.56	9.61	2.80	4.24	2.37	37.42	22.79
16	> 24	>10.56	10.56	2.55	3.71	2.07	37.12	22.49
17								
18								
19	W = STACK DRAFT = 26.95 METERS PER SECOND							
20	CACS BLDG HGT = 48 FEET = 14.6 METERS							
21	d = DIAMETER OF STACK = 22 IN = .5588 METERS							

Spreadsheet 1

EF ST HT 14000 BOSANQUET

	A	B	C	D	E	F	G
1							
2							
3							
4							delta H
5							
6	AVERAGE	W/U	(W/U)^2		.615/COL D	1.31 - COL E	COL FxCOL Bx
7	WIND SPEED						3.14x.5588
8	METERS/SEC						
9							
10	0.447	60.29	3634.98	60.30	0.01	1.30	137.50
11	0.89	30.28	916.93	30.29	0.02	1.29	68.52
12	2.45	11.00	121.00	11.03	0.06	1.25	24.21
13	4.47	6.03	36.35	6.08	0.10	1.21	12.79
14	6.93	3.89	15.12	3.96	0.16	1.15	7.88
15	9.61	2.80	7.86	2.90	0.21	1.10	5.40
16	10.56	2.55	6.51	2.66	0.23	1.08	4.83

Spreadsheet 2

EF ST HT 14000 HOL.

	A	B	C	D	E
1					
2		26.95/COL A	1.5x.5588xCOL B	COL C + 35	
3					
4	U	W/U			
5	WIND		delta H	H + delta H	Heff -
6	SPEED				BLDG HT
7					
8	METERS / SEC				
9					
10	0.447	60.29	50.54	85.59	70.96
11	0.89	30.28	25.38	60.43	45.80
12	2.45	11.00	9.22	44.27	29.64
13	4.47	6.03	5.05	40.10	25.47
14	6.93	3.89	3.26	38.31	23.68
15	9.61	2.80	2.35	37.40	22.77
16	10.56	2.55	2.14	37.19	22.56
17					
18					
19					
20	delta H = 1.5dW/avg u				

Spreadsheet 3

LINE SOURCE 14000 HOLL

	A	B	C	D	E	F	G	H	I	J	K
1		.12/COL A	COL B/.01	COL Cx3.7EXP 07	COL E SHEET 3	COL D/4COL E	COL F/400	COL Gx1000		COL HxCOL I	COL Jx.1
2											
3											
4	U										
5	AVERAGE	LINE SOURCE		LINE SOURCE	DISTANCE	FLUX AT	DOSE RATE	DOSE RATE	FREQUENCY	DOSE RATE	DOSE RATE
6	WIND SPEED	STRENGTH		STRENGTH	LINE TO	RECEPTOR		MICROR/HR	OF WIND	CORRECTED FOR	CORRECTED
7					RECEPTOR				SPEED	WIND SPEED	FOR
8	METERS/SEC	mCi/METER	mCi/CM	D/SEC-CM	CM	PHOTONS PER	MR/HR				DIRECTION
9						SQ CM-SEC				MICRO R/HR	MICRO R/HR
10	0.447	0.27	0.00268456	99328.86	7096	3.50	0.00874867	8.75	0.05	0.44	
11	0.89	0.13	0.00134831	49887.64	4580	2.72	0.00680781	6.81	0.093	0.63	
12	2.45	0.05	0.0004898	18122.45	2964	1.53	0.00382[illegible]37	3.82	0.25	0.96	
13	4.47	0.03	0.00026846	9932.89	2547	0.97	0.0024374	2.44	0.0298	0.07	
14	6.93	0.02	0.00017316	6406.93	2368	0.68	0.00169102	1.69	0.238	0.40	
15	9.61	0.0[illegible]	0.00012487	4620.19	2277	0.51	0.00126817	1.27	0.05	0.06	
16	10.56	0.01	0.00011364	4204.5[illegible]	2256	0.47	0.00116482	1.16	0.013	0.02	
17											
18	THIS LINE SOURCE CALCULATION IS TAKEN FROM LAMARSH				,PAGE 462					2.58	0.26
19	AND CALCULATES THE PHOTON FLUX AT A RECEPTOR X CM										
20	FROM AN INFINITE LINE SOURCE. THE PHOTON FLUX IS THEN CONVERTED										
21	TO DOSE RATE IGNORING ATTENUATION DUE TO AIR SCATTERING										
22	AND ABSORPTION AND IGNORING BUILD-UP										
23											
24	GAMMA'S/SQ CM-SEC = GAMMAS/CM-SECDIVIDED BY 4TIMES SOURCE TO RECEPTOR DISTANCE IN CM.										
25											
26	IT TAKES 400 GAMMAS/SQ CM-SEC TO PRODUCE 1MR/HR										
27	FOR 1.3 MEV GAMMAS.										

	A	B	C	D	E	F	G	H	I	J	K
1											
2	U	S	µS								
3	AVERAGE	PLUME		I SUB 1	I SUB 2	kI SUB 2	I SUB 1 +	COL G TIMES	COL H	f	DOSE RATE
4	WIND SPEED	CENTERLINE					k I SUB 2	F19	DIVIDED BY	FREQ OF	PER UNIT
5		TO RECEPTOR	.0073XS						WIND SPEED	WIND SPEED	EMISSION
6		DISTANCE									RATE
7								DavgU/Q	D/Q		Davg/Q
8	METERS/SEC	METERS									
9											
10	0.447	70.96	0.52	0.65	0.46	0.506	1.156	6.0276E-06	1.3485E-05	0.05	6.7423E-07
11	0.89	45.8	0.33	1.6	0.82	0.902	2.502	1.3046E-05	1.4658E-05	0.093	1.3632E-06
12	2.45	29.64	0.22	2.4	1	1.1	3.5	1.825E-05	7.4488E-06	0.25	1.8622E-06
13	4.47	25.47	0.19	2.6	1	1.1	3.7	1.9292E-05	4.316E-06	0.0298	1.2862E-07
14	6.93	23.68	0.17	2.7	1	1.1	3.8	1.9814E-05	2.8591E-06	0.238	6.8048E-07
15	9.61	22.77	0.17	2.7	1	1.1	3.8	1.9814E-05	2.0618E-06	0.05	1.0309E-07
16	10.56	22.56	0.16	2.7	1	1.1	3.8	1.9814E-05	1.8763E-06	0.013	2.4392E-08
17											
18										TOTAL	4.8362E-06
19		0.1616	0.0073	0.0034	1.3	5.2142E-06					
20											
21		DIRECTION									
22	Davg/Q X	FREQUENCY	X Q X	sec/hr =							
23	4.83624E-06	0.1	0.00012	3600	2.0893E-07	RAD/HR	0.00020893	mR/HR			

Assume $\mu\sigma_I$ = .0073 because σ = 1

$\sigma_x = \sigma_y = \sigma_z$

μ_a = .0034

k = buildup factor = 1.1

for Argon-41, $E_\gamma = 1.3$ MEV

μ = .0073

$$D^{\gamma}_{receptor} = (.1616\ \mu\mu_a E_\gamma)\ Q(I_1 + kI_2) / u_{avg}$$

where I_1 and I_2 are from pages 341 and 342 of Meteorology and Atomic Energy, 1968

MAX GRD CONC 14000 HOLL

	A	B	C	D	E	F
1			C=B/A		E=D/C	
2						
3				f	CORRECTED	
4	AVERAGE	FROM PAGE		FREQUENCY	FOR WIND	
5	WIND	410		OF WIND	SPEED AND	
6	SPEED	PASQUILL A		SPEED	FREQUENCY	
7	METERS/SEC					
8	$\bar{U}$	$\Psi\ \bar{U}/Q$	Ψ/Q		$\Psi avg/Q$	
9						
10	0.447	0.000052	0.00011633	0.05	5.81655E-06	
11	0.89	0.0001	0.00011236	0.093	1.04494E-05	
12	2.45	0.00018	7.3469E-05	0.25	1.83673E-05	
13	4.47	0.00025	5.5928E-05	0.0298	1.66667E-06	
14	6.93	0.00027	3.8961E-05	0.238	9.27273E-06	
15	9.61	0.00035	3.642E-05	0.05	1.82102E-06	
16	10.56	0.00035	3.3144E-05	0.013	4.30871E-07	
17						
18				TOTAL	4.78246E-05	
19						
20	$\Psi avg/Q$	X DIRECTION	X Q =			
21	4.782462E-05	0.1	0.00012	5.73895E-10	CURIES PER	
22					METER CUBED	
23	UNRESTRICTED MPC FOR ARGON-41 IS			0.00000004	MICROCURIES / CC	
24	262000	5.738955E-10	0.000001	1.3	1.95469E-10	R/SEC
25					7.03688E-07	R/HR
26					0.000703688	mR/HR

$X = 2.62 \times 10^5 \varphi E$ R/sec, Lamarsh page 568

where φ is Ci/cm^3

E is MEV