Contract No:

This document was prepared in conjunction with work accomplished under Contract No. DE-AC09-08SR22470 with the U.S. Department of Energy (DOE) Office of Environmental Management (EM).

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INTER-OFFICE MEMORANDUM

APRIL 19, 1993

ESH-HPT-93-0126
Rev. 1

To: A. S. Morrison, 233-H
HP Technology - Field Technical Support Group

From: L. T. Burckhalter / E. J. Kvartek, 735-A
HP Technology

TECHNICAL BASES FOR PLASTIC SUIT REDUCTION FACTORS AGAINST AIRBORNE TRITIUM EXPOSURE (U)

Introduction

Radiological Engineering was requested [1] to provide bases for the Tritium Stay Time Charts [2]. These charts were developed by calculating stay times based upon unprotected exposure to HTO concentrations in air and applying correction factors according to the type of plastic suit being worn.

Summary/Recommendations

Values calculated for the original "No Respiratory Protection" Tritium Stay Time Chart [2] were calculated utilizing intake data from ICRP 30, biological data from ICRP 23 and calculating doses based on different HTO air concentrations. The "12 mil Thick Suit" Tritium Stay Time Chart [2] appears to have been derived by multiplying stay times in the "No Respiratory Protection" chart by a factor of ~250. Likewise, the "9 mil Thick Suit" Tritium Stay Time Chart [2] appears to have been derived by multiplying the "12 mil Thick Suit" stay times by a factor of 10.

No technical bases could be located or determined from available empirical data to justify the factors used for the 12 mil and 9 mil plastic suits. Based upon available empirical data [3,4,5] and the following discussion, we recommend the revision of these charts as shown in Tables 1 through 3.

Discussion

Tests performed at Los Alamos National Laboratory (LANL) on the SRP airline-type supplied air tritium suit [6], showed that the plastic suit provided a fit factor well above 10,000 for all test conditions. These tests primarily tested the suit for in-leakage of contaminants by introducing a non-tritiated challenge aerosol. The aerosol had a Mass Median Aerodynamic Diameter of approximately 0.42 - 0.66 microns. This sub-micron particle size distribution resulted in a behavior similar to that of gases [7]. While the plastic suit had a fit factor of 10,000 or greater, these tests do not account for the fact that HTO will permeate the suit material, thus reducing the protection afforded the user.

To determine the protection afforded by the plastic suit in a HTO environment, the breakthrough time and permeability of the suit must be considered. The permeability will be a function of the HTO concentration outside the suit and the suit material.

Available empirical data [3] allowed the calculation of a reduction factor for the 12 mil polyvinylchloride (PVC) suit relative to room air activity. The reduction factor (RF), or ratio of room air HTO concentration to suit equilibrium HTO concentration, was used to determine the protection afforded by the 12 mil PVC suit in a HTO vapor atmosphere.

Additional empirical data [4,5] allowed the calculation of a "Saran Suit" (9 mil Saran-Chloropel suit) reduction factor (SRF) relative to the 12 mil PVC suit RF. Two SRFs were required to characterize the protection afforded by the Saran suit relative to the PVC suit. The first SRF was developed by calculating the ratio of the 9 mil Saran suit breakthrough time to the 12 mil PVC suit breakthrough time. The first SRF is only valid until breakthrough occurs, which is 95 minutes for the 9 mil Saran suit. The second SRF was developed by calculating the ratio of the 12 mil PVC suit permeation rate to the 9 mil Saran suit permeation rate. This SRF is valid after breakthrough occurs in the 9 mil Saran suit.

Bases for the calculation of the revised stay times, the RF, and the SRFs follow in the Bases/Assumptions section. Additional information can be found in Radiological Engineering's Job Folder LTB0115.

Bases/Assumptions

Equation for Stay Time

(No Respiratory Protection)

$T = D / 1887*A$ where T= time in minutes
D= dose in mrem
A= HTO air activity in μCi/cc

The 1887 value is a conversion factor derived as follows:

1887 (mrem*cc/μCi*min) = (6.29E-02 mrem/μCi)(2E+04 cc/min)(1.5)

6.29E-02 mrem/μCi is the committed dose equivalent per intake of unit activity [8].

2E+04 cc/min is the respiration rate for reference man [9].

The 1.5 value accounts for the fact that 2/3 of the intake is received through inhalation and 1/3 of the intake is received through skin absorption.

12 mil PVC Suit Reduction Factor

Data obtained from integrity testing [3] of the 12 mil PVC plastic suit allowed the determination of a RF for the 12 mil PVC suit air activity relative to room (box) air activity. The RF was obtained by dividing the room (box) air HTO concentration by the HTO concentration in the plastic suit. The RF was then plotted as a function of room (box) air activity (shown in attached Diagram). An exponential equation gives the best fit to describe the reduction factor as a function of the room air activity. This equation is given by

$$RF = 320.01 \times 10^{(-7.4415E-07A)}$$

where A is the room air activity in E-5μCi/cc. This equation has a correlation coefficient, R^2, of 0.83.

The RF was multiplied by the "No Respiratory Protection" stay times to obtain stay times when using the 12 mil PVC suit.

9 mil Saran-Chloropel (CPE) Suit Reduction Factor

Two "Saran Suit" Reduction Factors (SRF) were determined for the 9 mil Saran-CPE suit based on the ratio of the 9 mil Saran suit breakthrough time to the 12 mil PVC suit breakthrough time and on the ratio of the two permeation rates for each suit [4,5].

SRF-1 (For times $\leq$ 95 min.)

SRF-1 (Saran breakthrough time/PVC breakthrough time) = 95/16 = 6.3

SRF-2 (For times > 95 min.)

SRF-2 (PVC permeation rate/Saran permeation rate) = 0.07/0.03 = 2.3

This indicates that prior to breakthrough, the 9 mil Saran-CPE suit provides about six times more protection than the 12 mil PVC suit. After breakthrough, this protection drops to about a factor of two. The appropriate SRFs were multiplied by the 12 mil PVC suit stay times to obtain the 9 mil Saran-CPE suit stay times.

The Revised Stay Time Charts shown in Tables 1 through 3 assume the following:

- Permeation is only for HTO vapor in contact with the suit. Permeability (and consequently the stay times) of the suit changes if the HTO contacts the suit in any other form (i.e. water, oil, Freon, etc.).
- Gloves on the suit are equivalent or less permeable to HTO than the suit material.
- Suit equilibrium concentration occurs instantaneously after breakthrough.

- A minimum air flow rate of 5-6 scfm is maintained during suit use. Calculations do not address additional dilution of suit air activity due to the increased volume of air supplied to the suit (18-20 scfm).

- For Self-Contained Breathing Apparatus (SCBA) respiratory protection alone, the "No Respiratory Protection" stay times can be multiplied by three to obtain an appropriate stay time for SCBA protection. This assumes that 1/3 of the intake occurs through absorption.

References

[1] Telecon between A. S. Morrison and L. T. Burckhalter on 4/6/93.

[2] Maximum Time Exposure Limits in Tritium Airborne Concentration, 2/16/93.

[3] **Integrity of a Plastic Suit in Tritium Atmospheres**, R. W. Van Wyck and H. L. Butler, 2/14/57.

[4] IOM, **Tritium Permeability Tests for Protective Materials**, L. B. Taus to D. J. Ratchford, 3/4/81.

[5] Chemical Permeation Report DCN: 86-256-047-01, **Tritiated Water and Mixtures Containing Tritiated Water Versus Four Suit Materials**, Radian Corporation, 2/19/86.

[6] **Savannah River Plant Airline-Type Supplied Air Tritium Suit**, Los Alamos National Laboratory.

[7] ANSI N13.1-1969, **American National Standard Guide to Sampling Airborne Radioactive Materials in Nuclear Facilities**, American National Standards Institute, Inc., February 19, 1969.

[8] ICRP 30 Supplement to Part 1, **Limits for Intakes of Radionuclides by Workers**, 1980.

[9] ICRP 23, **Report of the Task Group on Reference Man**, 1981.

Maximum Exposure Time Limits - No Respiratory Protection

4/19/93 Rev. 2

Airborne Concentration uCi/cc	Airborne Concentration x E-5 uCi/cc	Time (minutes) To Receive (mrem or rem) From HTO Exposure								Dose Rate (mrem/min)
		~5 mrem	~26 mrem	~53 mrem	~100 mrem	~500 mrem	~1 rem	~5 rem	~10 rem	
0.001	100	3	14	28	53	265	529	2649	5299	1.89E+00
0.005	500	0	3	6	11	53	106	530	1060	9.44E+00
0.01	1000	0	1	3	5	26	53	265	530	1.89E+01
0.02	2000	0	0	1	3	13	26	132	265	3.77E+01
0.03	3000	0	0	1	2	9	18	88	177	5.66E+01
0.04	4000	0	0	0	1	7	13	66	132	7.55E+01
0.05	5000	0	0	0	1	5	11	53	106	9.44E+01
0.06	6000	0	0	0	0	4	9	44	88	1.13E+02
0.07	7000	0	0	0	0	4	8	38	76	1.32E+02
0.08	8000	0	0	0	0	3	7	33	66	1.51E+02
0.09	9000	0	0	0	0	3	6	29	59	1.70E+02
0.1	10000	0	0	0	0	3	5	26	53	1.89E+02
0.2	20000	0	0	0	0	1	3	13	26	3.77E+02
0.3	30000	0	0	0	0	0	2	9	18	5.66E+02
0.4	40000	0	0	0	0	0	1	7	13	7.55E+02
0.5	50000	0	0	0	0	0	1	5	11	9.44E+02
0.6	60000	0	0	0	0	0	0	4	9	1.13E+03
0.7	70000	0	0	0	0	0	0	4	8	1.32E+03
0.8	80000	0	0	0	0	0	0	3	7	1.51E+03
0.9	90000	0	0	0	0	0	0	3	6	1.70E+03
1	100000	0	0	0	0	0	0	3	5	1.89E+03
2	200000	0	0	0	0	0	0	1	3	3.77E+03
3	300000	0	0	0	0	0	0	0	2	5.66E+03
4	400000	0	0	0	0	0	0	0	1	7.55E+03
5	500000	0	0	0	0	0	0	0	1	9.44E+03
6	600000	0	0	0	0	0	0	0	0	1.13E+04
7	700000	0	0	0	0	0	0	0	0	1.32E+04
8	800000	0	0	0	0	0	0	0	0	1.51E+04
9	900000	0	0	0	0	0	0	0	0	1.70E+04
10	1000000	0	0	0	0	0	0	0	0	1.89E+04
20	2000000	0	0	0	0	0	0	0	0	3.77E+04
30	3000000	0	0	0	0	0	0	0	0	5.66E+04
40	4000000	0	0	0	0	0	0	0	0	7.55E+04
50	5000000	0	0	0	0	0	0	0	0	9.44E+04
60	6000000	0	0	0	0	0	0	0	0	1.13E+05
63.2	**6320000**	0	0	0	0	0	0	0	0	1.19E+05

NOTE: Kanne Monitors Overrange at 63.2 uCi/cc or 6,320,000E-5 uCi/cc

5Q Limits: <10 rem Recover Victim, <25 rem Protect Health & Safety, <50 rem Reasonable Chance to Save a Life, 50 - 100 rem Strong Probability to Save a Life, >100 rem Protect Life & Public Safety

Maximum Exposure Time Limits - 12 mil PVC Suit

4/19/93 Rev. 2

Airborne Concentration uCi/cc	Airborne Concentration x E-5 uCi/cc	Time (minutes) To Receive (mrem or rem) From HTO Exposure ~5 mrem	~26 mrem	~53 mrem	~100 mrem	~500 mrem	~1 rem	~5 rem	~10 rem	mrem/min
0.001	100	899	4476	8953	17024	84660	169320	847500	1695440	5.90E-03
0.005	500	180	895	1789	3402	16920	33841	169384	338856	2.95E-02
0.01	1000	90	447	894	1700	8453	16906	84619	169283	5.91E-02
0.02	2000	45	223	446	848	4219	8438	42237	84496	1.18E-01
0.03	3000	30	148	297	565	2808	5616	28110	56235	1.78E-01
0.04	4000	22	111	222	423	2102	4205	21046	42104	2.37E-01
0.05	5000	18	89	178	338	1679	3358	16808	33625	2.97E-01
0.06	6000	15	74	148	281	1397	2794	13983	27973	3.57E-01
0.07	7000	13	63	126	240	1195	2390	11965	23936	4.18E-01
0.08	8000	11	55	110	210	1044	2088	10451	20908	4.78E-01
0.09	9000	10	49	98	186	926	1853	9274	18553	5.39E-01
0.1	10000	9	44	88	167	832	1665	8332	16669	6.00E-01
0.2	20000	4	22	43	82	409	818	4095	8193	1.22E+00
0.3	30000	3	14	28	54	268	536	2684	5369	1.86E+00
0.4	40000	2	10	21	40	198	395	1979	3959	2.53E+00
0.5	50000	2	8	16	31	155	311	1556	3113	3.21E+00
0.6	60000	1	7	13	26	127	255	1275	2550	3.92E+00
0.7	70000	1	6	11	22	107	215	1074	2149	4.65E+00
0.8	80000	1	5	10	19	92	185	924	1848	5.41E+00
0.9	90000	0	4	9	16	81	161	807	1615	6.19E+00
1	100000	0	4	8	14	71	143	714	1429	7.00E+00
2	200000	0	1	3	6	30	60	301	602	1.66E+01
3	300000	0	0	1	3	17	34	169	338	2.96E+01
4	400000	0	0	1	2	11	21	107	214	4.68E+01
5	500000	0	0	0	1	7	14	72	144	6.94E+01
6	600000	0	0	0	1	5	10	51	101	9.89E+01
7	700000	0	0	0	0	4	7	36	73	1.37E+02
8	800000	0	0	0	0	2	5	27	54	1.86E+02
9	900000	0	0	0	0	2	4	20	40	2.48E+02
10	1000000	0	0	0	0	1	3	15	31	3.27E+02
20	2000000	0	0	0	0	0	0	1	3	3.63E+03
30	3000000	0	0	0	0	0	0	0	0	3.02E+04
40	4000000	0	0	0	0	0	0	0	0	7.55E+04
50	5000000	0	0	0	0	0	0	0	0	9.44E+04
60	6000000	0	0	0	0	0	0	0	0	1.13E+05
63.2	**6320000**	0	0	0	0	0	0	0	0	1.19E+05

NOTE: Kanne Monitors Overrange at 63.2 uCi/cc or 6,320,000E-5 uCi/cc

5Q Limits: <10 rem Recover Victim, <25 rem Protect Health & Safety, <50 rem Reasonable Chance to Save a Life, 50 - 100 rem Strong Probability to Save a Life, >100 rem Protect Life & Public Safety

Maximum Exposure Time Limits - 9 mil Saran Chloropel Suit

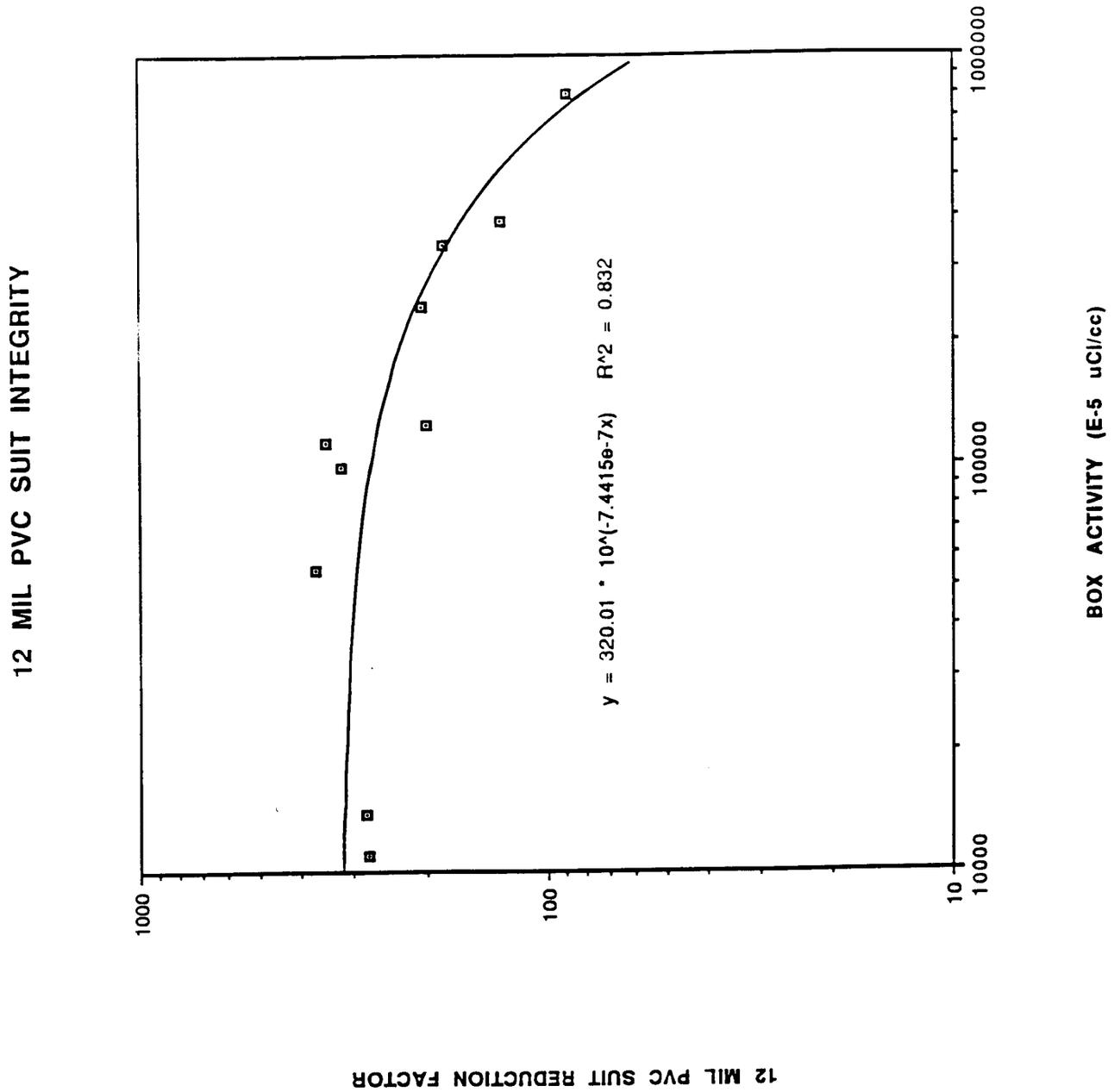
4/19/93 Rev. 2

Airborne Concentration uCi/cc	Airborne Concentration x E-5 uCi/cc	Time (minutes) To Receive (mrem or rem) From HTO Exposure ~5 mrem	~26 mrem	~53 mrem	~100 mrem	~500 mrem	~1 rem	~5 rem	~10 rem	mrem/min*
0.001	100	2447	10676	20971	39534	195098	389816	1949629	3899893	9.36E-04
0.005	500	793	2438	4495	8205	39297	78214	389963	779748	4.68E-03
0.01	1000	565	1408	2436	4289	19822	39264	195005	389730	9.38E-03
0.02	2000	282	893	1406	2331	10084	19789	97526	194722	1.88E-02
0.03	3000	188	721	1063	1679	6838	13297	65033	129719	2.82E-02
0.04	4000	141	636	891	1352	5216	10051	48787	97219	3.77E-02
0.05	5000	112	559	788	1157	4242	8104	39039	77718	4.72E-02
0.06	6000	93	465	720	1026	3593	6805	32541	64718	5.67E-02
0.07	7000	80	398	671	933	3129	5878	27899	55433	6.63E-02
0.08	8000	70	348	634	863	2781	5183	24418	48469	7.59E-02
0.09	9000	62	309	605	808	2511	4642	21711	43052	8.55E-02
0.1	10000	56	277	555	765	2294	4209	19545	38719	9.52E-02
0.2	20000	27	136	273	518	1321	2262	9800	19224	1.94E-01
0.3	30000	18	89	179	340	997	1613	6553	12729	2.96E-01
0.4	40000	13	66	132	250	835	1289	4931	9485	4.01E-01
0.5	50000	10	52	104	197	738	1095	3959	7540	5.10E-01
0.6	60000	9	42	85	161	673	966	3312	6245	6.22E-01
0.7	70000	7	36	71	136	627	874	2850	5322	7.39E-01
0.8	80000	6	31	61	117	581	805	2505	4631	8.59E-01
0.9	90000	5	27	54	102	508	751	2237	4094	9.83E-01
1	100000	5	24	48	90	449	708	2023	3666	1.11E+00
2	200000	2	10	20	38	189	379	1072	1764	2.64E+00
3	300000	1	6	11	21	106	213	769	1158	4.69E+00
4	400000	0	4	7	14	67	134	626	871	7.43E+00
5	500000	0	2	5	9	45	91	453	711	1.10E+01
6	600000	0	1	3	6	32	64	318	613	1.57E+01
7	700000	0	1	2	5	23	46	230	460	2.17E+01
8	800000	0	1	2	3	17	34	169	339	2.95E+01
9	900000	0	0	1	2	13	25	127	254	3.94E+01
10	1000000	0	0	1	2	10	19	96	193	5.19E+01
20	2000000	0	0	0	0	0	1	9	17	5.76E+02
30	3000000	0	0	0	0	0	0	1	2	4.80E+03
40	4000000	0	0	0	0	0	0	0	0	1.20E+04
50	5000000	0	0	0	0	0	0	0	0	1.50E+04
60	6000000	0	0	0	0	0	0	0	0	1.80E+04
63.2	**6320000**	0	0	0	0	0	0	0	0	1.89E+04

NOTE: Kanne Monitors Overrange at 63.2 uCi/cc or 6,320,000E-5 uCi/cc

* - based on first hour of exposure

5Q Limits: <10 rem Recover Victim, <25 rem Protect Health & Safety, <50 rem Reasonable Chance to Save a Life, 50 - 100 rem Strong Probability to Save a Life, >100 rem Protect Life & Public Safety


12 MIL PVC SUIT INTEGRITY
y = 320.01 * 10^(-7.44156-7x) R^2 = 0.832
1000
100
10
10000
100000
1000000
12 MIL PVC SUIT REDUCTION FACTOR
BOX ACTIVITY (E-5 uCi/cc)

APRIL 19, 1993

ESH-HPT-93-0126
Rev. 1

TECHNICAL BASES FOR PLASTIC SUIT REDUCTION FACTORS AGAINST AIRBORNE TRITIUM EXPOSURE (U)

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