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RFP-2469
October 29, 1976

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**RADIOLYTIC GAS GENERATION IN PLUTONIUM
CONTAMINATED WASTE MATERIALS**

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PRODUCT INTEGRITY AND SURVEILLANCE GROUP

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U.S. ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
CONTRACT EY-76-C-04-3533

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Printed
October 29, 1976

RFP-2469
UC-70 NUCLEAR WASTE
MANAGEMENT
TID-4500-R64

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SUBJECT DESCRIPTORS

Waste Storage
Radioactive Wastes
Radiation Effects
Plutonium Residue

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Prepared under Contract EY-76-C-04-3533
for the
Albuquerque Operations Office
U. S. Energy Research and Development Administration

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ACKNOWLEDGMENTS

The author greatly appreciates the work done by Harold O. Pitts and Richard E. Schlupp in obtaining all of the analyses by mass spectrometry.

RADIOLYTIC GAS GENERATION IN PLUTONIUM CONTAMINATED WASTE MATERIALS

Armen R. Kazanjian

Abstract. Many plutonium contaminated waste materials decompose into gaseous products because of exposure to alpha radiation. The gases generated (usually hydrogen) over long-storage periods may create hazardous conditions. To determine the extent of such hazards, knowing the gas generation yields is necessary. These yields were measured by contacting some common Rocky Flats Plant waste materials with plutonium and monitoring the enclosed atmospheres for extensive periods of time. The materials were Plexiglas, polyvinyl chloride, glove-box gloves, machining oil, carbon tetrachloride, chlorothene VG® solvent, Kimwipes® (dry and wet), polyethylene, Dowex-1 resin, and surgeon's gloves. Both plutonium-239 oxide and plutonium-238 oxide were used as radiation sources. The gas analyses were made by mass spectrometry and the results obtained were the total gas generation, the hydrogen generation, the oxygen consumption rate, and the gas composition over the entire storage period. Hydrogen was the major gas produced in most of the materials. The total gas yields varied from 0.71 to 16 cubic centimetres (standard temperature pressure) per day per curie of plutonium. The oxygen consumption rates varied from 0.0088 to 0.070 millimoles per day per gram of plutonium oxide-239 and from 0.0014 to 0.0051 millimoles per day per milligram plutonium 238.

INTRODUCTION

A large variety of radioactive waste materials is produced relative to plutonium operations at Rocky Flats Plant. Many of these materials are organic compounds which decompose into gaseous products when exposed to the alpha radiation from plutonium. Although the gas yields are relatively small, the amounts produced over long-storage periods could be considerable. The storage times are presently projected for 20 years so that the gas formation in the 55-gallon storage drums is of concern. The information required to predict

the gas formation has been obtained by contacting a number of common Rocky Flats Plant waste materials with plutonium and monitoring the gas quantities and compositions over an extensive period of time. The materials were Plexiglas, polyvinyl chloride, glove-box gloves, machining oil, carbon tetrachloride, chlorothene® solvent, Kimwipes® (dry and wet), polyethylene, Dowex-1 resin, and surgeon's gloves.

The experiments were made up of two series. The first series, consisting of 6 materials in contact with plutonium 239 (Pu-239), has continued for 470 days. The second series, consisting of 6 materials in contact with plutonium 238 (Pu-238), has continued for 267 days.

DISCUSSION

Materials:

The description and amounts of material used, the plutonium weights, and the free volume in the containers are listed in Table I.

Experimental Procedures:

The experiments were conducted to obtain the maximum gas yields by maximizing the contact between plutonium and material. This was achieved by using a large surface area of material and small plutonium oxide particles. The plutonium-239 oxide (PuO₂-239) was passed through a 30-micrometre mesh screen. Almost all of the alpha radiation would escape from these particles since the range of an alpha particle in plutonium dioxide is about 10 micrometres. The plutonium-238 oxide was not screened, but a particle size analysis showed that essentially all of the particles were less than 20 micrometres and most were in the 2-micrometre range.

Most of the materials, originally in sheet form, were cut into small pieces by repetitively passing them through a mechanical shredder. The glove-box

TABLE I. Materials in Contact with Plutonium.

Material	Plutonium Oxide 239 Weight (grams)	Free Volume cubic (centimetres)
1. Plexiglas, rod stock, 12.8 grams	1.0	208
2. Polyvinyl Chloride, standard O-ring bags at Rocky Flats, 37.3 grams	1.0	190
3. Glove-box Gloves, 30-mil lead-lined Neoprene- Hypalon gloves used at Rocky Flats, 82.8 grams	1.0	186
4. Texaco Regal-A machining oil (30 cubic centimetres)	1.0	185
5. Carbon Tetrachloride (30 cubic centimetres)	1.0	185
6. Chlorothene-VG® solvent- 1,1,1-trichloroethane (30 cubic centimetres)	1.0	185
Material	Plutonium 238 Weight (milligrams)	Free Volume cubic (centimetres)
7. Kimwipes® (Dry), cellulosic material used at Rocky Flats for cleaning, 4.87 grams	7.3	181
8. Kimwipes® (Wet), water added to dry Kimwipes, 11.85 grams, dry weight 4.80 grams	5.5	155
9. Polyethylene, 3-mil thick bags used at Rocky Flats, 3.61 grams	9.0	180
10. Polyvinyl Chloride, standard O-ring bags at Rocky Flats 18.30 grams	13.5	145
11. Ion Exchange Resin, Dowex 1x4 in nitrate form, 50 to 100 mesh, contains about 20 percent water, 28.08 grams	6.9	136
12. Surgeon's Gloves, natural latex gloves used at Rocky Flats, 15.81 grams	9.7	162

gloves were cut up with a scissors and the Plexiglas was prepared by generating turnings on a lathe and crushing all by hand. A well-dispersed mixture was obtained by adding the plutonium oxide (PuO_2) to the material in increments and shaking or stirring the mixture in a container.

The three liquids were prepared by mixing one gram of plutonium dioxide with 5 grams of *Microcell*® (calcium silicate that is used for a liquid absorbent at Rocky Flats) and then admixing 30 cubic centimetres (cm^3) of the liquid to form a paste. The alpha radiation in these liquids would be well distributed and completely absorbed. The fraction (about 15 percent) of the energy absorbed by the *Microcell*® must be discounted and does not contribute significantly to the gas generation because calcium silicate is relatively radiation stable.

The plutonium-239 oxide appeared to be well-dispersed, although some of the oxide in the Plexiglas and glove-box gloves was on the bottom of the container and not on the surface of the material. Even with these materials, most of the radiation is probably absorbed by the material. With plutonium 238, approximately 10-milligram amounts of oxide were used so that it was not visible.

The mixtures were placed in valved stainless steel containers whose volumes were approximately 215 cubic centimetres. Air at approximately 81.1 kilopascals (610 torr) pressure was the original atmosphere. The atmospheres in the containers were sampled periodically for pressure and gas composition. The pressure measurements were made with a Wallace and Tiernan differential pressure gage. The gas analyses were made with a CEC-104 mass spectrometer. Each sampling removed 3.0 and 2.5 cm^3 , for the first and second series, respectively. The corrected pressures are included in Tables II through XVIII appearing at the end of text, see Page 7. The first series of tests (Pu-239) were carried out in two stages. After 120 days, the containers were partially evacuated to obtain the free volumes. The containers were then backfilled with helium to varying degrees as indicated in Tables VIII through XII. The sampling and analyses were then continued for another 347 days. The change in atmosphere should not and did not appear to affect the radiolytic gas generation. The free volumes in the second series (Pu-238) were measured after the last sample was taken.

These tests were continued for long periods to determine if the gas generation rates remained constant. After a given time, depending on the

material and the size of the plutonium particle, the gas generation will slow down as the material around each particle becomes depleted through radiolytic decomposition. Since movement of the particles would eliminate this effect, disturbance of the samples was held to a minimum. The samples had to be transported across a room for every analysis so that it is unknown whether the plutonium particles were moved. For the last two analyses, the samples had to be transported between buildings so there was a greater possibility for movement.

RESULTS

The data obtained are reported in Tables II through XVIII. The amounts of total gas, hydrogen, and oxygen are plotted as function of time in Figures 1 through 17 appearing at the end of text following the tables, Page 17. The first series of samples were evacuated after 120 days of contact time so that an additional set of curves (Figures 7 through 11) was required for the new pressures. The results on each material will be discussed individually, followed by some general observations and conclusions.

Plexiglas:

The total pressure decreased the first 17 days as a result of oxygen depletion and then increased linearly for about 200 days. The gas generation rate then declined slowly over the remaining 250 days. This appears to be an example of material depletion. The main radiolysis product is carbon monoxide, and carbon dioxide is produced at about the same rate as hydrogen. The hydrogen rate is the only one plotted in all the figures because there is the greatest concern about the amount of hydrogen produced on long storage. The hydrogen rate is essentially linear up to about the last 50 days so that most of the decrease in rate of total pressure must be attributed to the other gaseous components. The higher rate shown in the second column (100-200 days) of Table XIX (Page 16) can be attributed to air leakage into the container.

Polyvinyl Chloride:

The total pressure (using Pu-239) decreased the first 35 days as a result of oxygen depletion and

then increased linearly for the remainder of the test period. Hydrogen, the predominant product, increased at a constant rate. Although it is known that hydrogen chloride is a main radiolysis product,¹ it has not been detected analytically probably because of prior reaction. With Pu-238 after an initial decrease for 15 days, the total pressure increased linearly up to 150 days, then appeared to begin leveling off. The gas generation rate obtained with Pu-238 is about one-half that obtained with Pu-239. The discrepancy is not clear, but it may be due to Pu-238 not well dispersed in the material.

Glove-Box Gloves:

The total pressure decreased the first 60 days as a result of oxygen depletion and then increased almost linearly from then on. The rate appears to be slowly declining over the entire range. Hydrogen and carbon dioxide are the main radiolysis products.

Texaco Regal-A Oil:

The total gas pressure increases linearly over the entire test period. The last point indicates a decrease in rate, but more data would be required to confirm this. No decrease in initial pressure was noted because the radiolytic reaction of oxygen is too slow to offset the relatively large rate of hydrogen production. Hydrogen, the main product, increases linearly after a somewhat slower rate for the first 50 days.

Carbon Tetrachloride:

The only gaseous product analyzed in carbon tetrachloride was carbon dioxide, and after the oxygen was completely depleted in about 40 days the production rate became essentially nil. The source of the carbon dioxide is puzzling because previous studies² have shown that chlorine and phosgene are the only gaseous products. Chlorine was not detected, probably because of its reactivity. Phosgene reacts with water to form carbon dioxide but the source of so much water (greater than one millimole) is unknown.

¹ A. A. Miller. "Radiation Chemistry of Polyvinyl Chloride." *Journal of Physical Chemistry* 63:1755. 1959.

² J. W. T. Spinks and R. J. Woods. *An Introduction to Radiation Chemistry*. John Wiley and Sons, New York. 1964. Page 233. (Also same article by Zd. Spurny and I Janovsky in *Nature* 190:624. 1961.)

Chlorothene®:

The total pressure declined for the first 30 days because of oxygen depletion, then increased. There appears to be air leakage at some points [note nitrogen (N₂) and argon (Ar) concentrations in Table XII, Page 12] after 150 days, so that the total pressure increase thereafter is questionable. The main products are hydrogen, carbon dioxide, and dichloroethylene. The formation of this last compound infers the production of hydrogen chloride, which was not detected probably because of its reactivity.

Kimwipes®, Dry:

The total pressure increased almost linearly throughout the test period. The rate for the first 50 days is somewhat slower because of oxygen depletion and the rate is starting to fall off after 200 days probably because of material depletion. Hydrogen and carbon dioxide are the main products. The rate of hydrogen production starts to decrease after about 130 days.

Kimwipes®, Wet:

The total pressure increased linearly throughout the test period. The rate is significantly lower than that from dry Kimwipes because of the high water content. Water is relatively radiation stable.³ Hydrogen and carbon dioxide are the main products. The rate of hydrogen production starts to decline after 120 days.

Polyethylene:

The total pressure decreased for the first 10 days because of oxygen depletion. The rate of increase shows a slight decline for the next 100 days and then appears constant for the remainder of the test period. Hydrogen, the main product, shows a slowly declining rate.

Ion Exchange Resin:

The total pressure decreased the first 50 days because of oxygen depletion and then increased

linearly over the entire range. Hydrogen and carbon dioxide are the main products. The rate of hydrogen production is constant except for a slight decline over the last 50 days.

Surgeon's Gloves:

The total pressure decreased the first 30 days because of oxygen depletion. The pressure then increases at a gradually decreasing rate over the entire range. Hydrogen, the main product, follows the same pattern.

EVALUATION OF RESULTS

The rates of gas generation are listed in Tables XIX through XXII (Page 16) using three types of units. The gas yields listed in Tables XX (Page 16) and XXI and the first column of Table XIX are maximum yields obtained from the slopes of the curves after oxygen depletion. The rates have been calculated using 0.0692 curies per gram Pu-239, 0.00211 watts per gram Pu-239, 17.1 curies per gram PU-238, and 0.567 watts per gram Pu-238 as conversion factors. The factors for Pu-239 are high because of the presence of other plutonium isotopes.

The G-values (Table XXI) are the numbers of molecules produced per 100 eV of absorbed energy. These values are approximately the same as those obtained previously using gamma radiation⁴ indicating that the plutonium was fairly well-dispersed and the maximum yields have probably been reasonably achieved. Exact comparisons are not given because of the variation in these types of materials and the difference between alpha and gamma radiation.

The rates of radiation induced oxygen consumption are shown in Table XXII. The oxygen is reacted to form carbon dioxide, carbon monoxide, and non-volatile oxidation products from the various materials. Comparison of the oxygen consumption rates with the gas generation rates indicates the extent to which the total pressure will decrease before becoming larger. For example, the gas production rate in Texaco oil is so much larger than the rate of oxygen depletion that the overall

³J. W. T. Spinks and R. J. Woods. *An Introduction to Radiation Chemistry*. John Wiley and Sons, New York. 1964. Page 250.

⁴R. O. Bolt and J. G. Carroll, editors. *Radiation Effects on Organic Materials*. Academic Press, New York. 1963. Page 239.

pressure increases linearly from the start. The total pressure over the Kimwipes (dry and wet) increases from the start, even though gas production and oxygen depletion are essentially the same because almost all of the oxygen is utilized to form carbon dioxide so that there is no net loss in pressure. Each experiment must be analyzed individually. The time for complete oxygen depletion is, of course, dependent on the free volume of air. In storage drums with free volumes on the order of 100 litres, exceptionally long times would be required for the total pressure to decrease and then increase to atmospheric pressure, assuming carbon dioxide or carbon monoxide were not major products.

These tests were continued for a long period to determine whether the rates would decrease because of material depletion. In many cases the rates had decreased as shown in the figures. The rates shown in the second and third columns of Table XIX are approximate measurements of the slopes at the specified periods. Unfortunately, definite conclusions can not be drawn because of three factors. One, there is no assurance that the oxide particles were stationary throughout the test period. This was discussed in the experimental section. Movement of the particles can decrease the rates by falling to the bottom of the container as well as increase the rates by contacting fresh material. Two, the exact dispersion of the oxide particles in the solid materials is not known. Particles in close proximity will contribute radiation to the same volume and hasten the decomposition. The extent of this is unknown so that it is difficult to make predictions from the data that have been obtained. Three, the results obtained from Pu-238 and Pu-239 radiation are inconsistent. The main reason Pu-238 was used in the second series was that its dosage is about 200 times that of Pu-239. Therefore, the material around each Pu-238 oxide particle should be depleted 200 times faster. There should have been more indication of this effect even though different materials were used in each series. Polyvinyl chloride was irradiated by both sources and does show some evidence. The gas generation rate from polyvinyl chloride is constant for the entire period of irradiation with Pu-239, whereas the rate appears to decrease after about 6 months of irradiation with Pu-238.

Calculations show that the material around a 10-micrometre size particle of Pu-238 should be completely decomposed in a few months. This duration with regard to gas generation depends on the decomposition rate of the radiolysis products, as well as that of the starting material. With 10-micrometre size Pu-239 particles, the material would not be depleted for many years. These results are not in accord with the observations that some of the rates with Pu-239 were decreasing and some of the rates with Pu-238 were constant. More experiments irradiating the same materials with both sources are required to determine the extent of this dose rate effect.

The most important factor in material depletion is the size of the plutonium particle. If the sizes are on the order of atomic dimensions and there is the usual excess of material, the material would never be depleted. If the particle sizes are greater than about 30 micrometres, the depletion times would not be much less than a few months because an appreciable fraction of the radiation is then absorbed by the plutonium.

CONCLUSIONS

The gas generation rates produced by exposure of Rocky Flats Plant waste materials to alpha radiation from plutonium have been obtained in two series of tests. In one series, materials were contacted with plutonium 239 for 470 days and in the other series, materials were contacted with plutonium 238 for 267 days. The gas yields, in units of standard cubic centimetres per day per curie of plutonium, varied from 16 for Texaco Regal-A machining oil to 0.71 for Dowex-1 ion exchange resin. The predominant gas in most of the materials was hydrogen.

Estimation of the hazards created in storage drums by the measured gas rates has not been made here because of its complexity. This topic should be the subject of another report. The results obtained here indicate that although significant over-pressurization is possible, the probability is low. The probability depends on the material and many other factors. Appreciable amounts of hydrogen are usually produced, but will not be accompanied by oxygen in a drum for most of the storage period.

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TABLES
II through XXII

TABLE II. Plexiglas, Gas Pressure and Composition, Irradiation from Plutonium 239.

Days in Contact	1	6	12	19	30	44	61	82	100
*Pressure (torr)	605	580	558	545	563	598	645	669	704
Corrected Pressure (torr)	613	596	581	576	604	650	711	747	798
Millimoles Gas	6.80	6.62	6.45	6.39	6.70	7.22	7.89	8.29	8.86
Percent Gas Composition									
Nitrogen (N ₂)	78.7	79.5	82.9	87.2	81.8	82.9	75.6	65.6	62.9
Oxygen (O ₂)	19.5	13.6	7.0	0.3	0.1	0.2	0.6	0.2	0.3
Argon (Ar)	0.9	0.9	0.9	1.0	1.0	0.9	0.7	0.8	0.7
Hydrogen (H ₂)	0.09	0.6	1.3	2.3	3.2	4.6	5.7	7.4	8.2
Carbon Monoxide (CO)	—	3.6	4.4	3.9	6.7	2.5	6.0	14.5	15.2
Carbon Dioxide (CO ₂)	0.2	1.2	2.4	4.1	5.6	6.3	7.2	7.8	8.3
Methane (CH ₄)	0.06	0.3	0.6	1.0	1.5	2.2	3.0	3.4	3.8
Ethane (C ₂ H ₆)	—	—	—	0.04	—	0.03	—	0.1	0.06
Other Hydrocarbons	0.04	0.05	0.3	0.2	0.1	0.3	1.0	0.2	0.5

*For SI (metric) use: 1 torr = 133 pascals.

TABLE III. Polyvinyl Chloride, Gas Pressure and Composition, Irradiation from Plutonium 239.

Days in Contact	1	6	12	19	30	44	61	82	100
*Pressure (torr)	605	588	567	550	523	522	541	559	577
Corrected Pressure (torr)	615	607	594	586	566	574	604	634	665
Millimoles Gas	6.21	6.13	6.00	5.92	5.72	5.80	6.10	6.40	6.72
Percent Gas Composition									
Nitrogen (N ₂)	78.8	79.5	82.6	84.3	86.4	92.0	85.6	80.4	78.2
Oxygen (O ₂)	19.8	17.3	14.0	10.3	4.3	—	—	—	—
Argon (Ar)	0.8	0.9	0.9	1.0	1.0	1.0	0.9	0.9	0.9
Hydrogen (H ₂)	0.1	0.8	1.5	3.1	5.4	4.6	10.4	14.8	17.2
Carbon Monoxide (CO)	—	0.8	0.05	—	1.1	—	—	0.5	—
Carbon Dioxide (CO ₂)	0.1	0.2	0.3	0.6	1.0	1.5	2.2	2.3	2.4
Methane (CH ₄)	0.02	0.03	0.04	0.07	0.1	0.2	0.3	0.4	0.4
Ethane (C ₂ H ₆)	0.02	0.1	0.1	0.2	0.5	0.5	0.4	0.3	0.4
Other Hydrocarbons	0.04	0.05	0.2	0.2	0.2	0.2	0.3	0.4	0.4

*For SI (metric) use: 1 torr = 133 pascals.

TABLE IV. Glove-Box Gloves, Gas Pressure and Composition, Irradiation from Plutonium 239.

Days in Contact	1	6	12	19	30	44	61	82	100
*Pressure (torr)	608	591	580	567	546	524	491	492	496
Corrected Pressure (torr)	618	610	608	604	591	576	548	558	572
Millimoles Gas	6.14	6.06	6.04	6.00	5.87	5.73	5.45	5.55	5.69
Percent Gas Composition									
Nitrogen (N ₂)	77.9	78.1	79.0	80.8	82.4	87.0	91.3	88.8	87.0
Oxygen (O ₂)	20.7	19.6	17.6	15.7	12.5	6.9	0.3	—	—
Argon (Ar)	0.9	0.9	0.9	1.0	1.0	1.0	1.0	1.1	1.0
Hydrogen (H ₂)	0.05	0.4	0.7	1.3	2.0	2.7	3.8	5.6	6.7
Carbon Monoxide (CO)	—	0.4	0.8	—	0.3	—	—	—	—
Carbon Dioxide (CO ₂)	0.1	0.3	0.6	1.0	1.5	2.2	3.4	4.3	5.0
Methane (CH ₄)	0.02	0.02	—	0.03	0.04	0.06	0.08	0.1	0.2
Ethane (C ₂ H ₆)	—	0.02	—	—	0.05	—	—	—	—
Other Hydrocarbons	0.02	—	0.1	0.05	—	0.1	0.06	0.06	0.06

*For SI (metric) use: 1 torr = 133 pascals.

TABLE V. Texaco Regal-A Oil, Gas Pressure and Composition, Irradiation from Plutonium 239.

Days in Contact	1	6	12	19	30	44	61	82	100
*Pressure (torr)	656	664	678	698	724	769	824	888	951
Corrected Pressure (torr)	665	685	711	743	783	845	920	1008	1097
Millimoles Gas	6.58	6.77	7.03	7.35	7.74	8.36	9.10	9.97	10.85
Percent Gas Composition									
Nitrogen (N ₂)	76.9	75.6	74.8	71.6	68.4	65.5	60.7	53.0	48.8
Oxygen (O ₂)	20.8	19.9	18.1	17.0	13.9	11.3	8.3	6.3	4.6
Argon (Ar)	0.9	0.9	0.8	0.8	0.8	0.7	0.7	0.7	0.6
Hydrogen (H ₂)	0.3	2.5	5.6	9.7	15.6	20.8	28.3	37.5	43.2
Carbon Monoxide (CO)	0.7	0.7	—	—	—	—	—	—	—
Carbon Dioxide (CO ₂)	0.08	0.07	0.06	0.07	0.07	0.06	0.2	0.1	0.1
Methane (CH ₄)	0.02	0.03	0.1	0.1	0.2	0.3	0.4	0.5	0.5
Ethane (C ₂ H ₆)	0.02	0.1	0.2	0.4	0.6	0.9	1.3	1.4	1.6
Other Hydrocarbons	0.04	0.04	0.08	0.1	0.2	0.3	0.07	0.4	0.5

*For SI (metric) use: 1 torr = 133 pascals.

TABLE VI. Carbon Tetrachloride, Gas Pressure and Composition, Irradiation from Plutonium 239.

Days in Contact	1	6	12	19	30	44	61	82	100
*Pressure (torr)	695	682	679	670	670	674	672	664	661
Corrected Pressure	706	704	712	714	725	741	751	754	762
Millimoles Gas	6.98	6.96	7.04	7.06	7.17	7.33	7.43	7.46	7.54
Percent Gas Composition									
Carbon Tetrachloride (CCl ₄)	19.3	17.7	18.2	19.3	18.9	20.6	19.4	19.2	19.0
**Nitrogen (N ₂)	62.8	64.7	64.1	62.8	62.7	60.2	59.5	60.3	59.1
Oxygen (O ₂)	16.8	14.4	11.6	8.3	4.4	0.09	—	—	—
Argon (Ar)	0.7	0.7	0.7	0.8	0.8	0.7	0.7	0.7	0.7
Carbon Dioxide (CO ₂)	0.2	2.1	5.0	8.3	12.7	17.9	20.1	19.7	21.0

*For SI (metric) use: 1 torr = 133 pascals.

**The nitrogen and carbon monoxide gas analyses are indistinguishable in this case.

TABLE VII. Chlorothene®, Gas Pressure and Composition, Irradiation from Plutonium 239.

Days is Contact	1	6	12	19	30	44	61	82	100
*Pressure (torr)	692	662	642	625	607	623	634	646	661
Corrected Pressure (torr)	703	683	673	666	657	685	708	733	762
Millimoles Gas	6.95	6.75	6.66	6.59	6.50	6.77	7.00	7.25	7.54
Percent Gas Composition									
Chlorothene (C ₂ H ₃ Cl ₃)	22.4	22.3	20.6	22.2	22.9	24.4	22.9	21.5	20.6
**Nitrogen (N ₂)	60.7	63.4	66.3	68.0	69.8	65.7	63.8	62.8	61.2
Oxygen (O ₂)	15.9	13.0	9.8	5.1	—	—	—	—	—
Argon (Ar)	0.6	0.7	0.8	0.8	0.8	0.8	0.8	0.7	0.7
Hydrogen (H ₂)	0.06	0.3	0.6	1.1	1.7	2.3	3.2	4.4	5.5
Carbon Dioxide (CO ₂)	0.08	0.2	0.6	1.2	2.6	4.1	5.9	6.1	6.6
Methane (CH ₄)	—	—	0.1	0.2	0.2	0.2	0.3	0.4	0.6
Ethane (C ₂ H ₆)	—	—	0.6	0.4	0.4	0.4	0.4	0.3	0.2
Other Hydrocarbons	—	—	0.3	0.8	1.6	2.1	2.8	3.7	4.5

*For Si (metric) use: 1 torr = 133 pascals.

**The nitrogen and carbon monoxide gas analyses are indistinguishable in this case.

TABLE VIII. Plexiglas, Gas Pressure and Composition, Irradiation from Plutonium 239.

^a Days in Contact	0	31	80	116	157	200	252	300	347
^b Pressure (torr)	246	366	520	591	660	717	757	804	844
Corrected Pressure (torr)	250	377	543	626	709	781	836	901	960
Millimoles Gas	2.78	4.18	6.03	6.95	7.87	8.67	9.28	10.0	10.7
Percent Gas Composition									
Nitrogen (N ₂)	21.6	26.9	26.9	24.3	22.5	19.6	19.9	17.5	15.1
Oxygen (O ₂)	0.8	0.8	0.7	—	—	—	—	—	—
Argon (Ar)	0.07	0.2	0.3	0.3	0.3	0.2	0.2	0.2	0.2
Hydrogen (H ₂)	4.0	7.5	10.2	11.5	12.8	21.6	16.0	16.6	16.7
Carbon Monoxide (CO)	7.2	13.8	18.2	20.5	22.4	21.4	26.8	27.5	29.9
Carbon Dioxide (CO ₂)	7.4	8.0	12.0	10.8	12.0	11.7	13.5	14.2	14.8
Methane (CH ₄)	2.7	4.1	5.2	4.9	5.4	5.3	6.5	6.9	7.0
Ethane (C ₂ H ₆)	—	—	0.2	0.5	0.5	0.5	0.6	0.6	0.7
Other Hydrocarbons	1.8	1.5	0.3	^c 4.7	^c 4.1	^c 4.2	^c 2.5	^c 3.4	^c 3.8
Helium (He)	54.3	37.2	25.9	21.0	18.5	14.3	13.0	11.7	10.6

^a Plus 120 days before pump-out.^b For SI (metric) use: 1 torr = 133 pascals.^c Methanol (CH₃OH).

TABLE IX. Polyvinyl Chloride, Gas Pressure and Composition, Irradiation from Plutonium 239.

^a Days in Contact	0	31	80	116	157	200	252	300	347
^b Pressure (torr)	26.4	65	155	206	277	327	403	472	535
Corrected Pressure (torr)	26.8	67	162	219	299	359	449	535	616
Millimoles Gas	0.273	0.683	1.65	2.24	3.05	3.66	4.58	5.45	6.28
Percent Gas Composition									
Nitrogen (N ₂)	2.0	2.9	2.6	0.3	0.3	0.4	0.6	0.7	0.8
Oxygen (O ₂)	0.1	0.02	—	0.09	0.06	—	—	—	—
Argon (Ar)	—	0.1	—	0.02	—	—	—	—	0.1
Hydrogen (H ₂)	60.3	78.3	80.2	82.6	82.8	83.2	85.1	82.1	82.9
Carbon Monoxide (CO)	—	—	—	—	1.6	2.4	2.7	3.4	3.9
Carbon Dioxide (CO ₂)	6.3	5.6	5.0	5.1	5.0	4.9	4.6	4.7	5.0
Methane (CH ₄)	2.0	1.8	1.8	2.0	2.1	2.1	2.1	2.2	2.3
Ethane (C ₂ H ₆)	8.5	7.8	5.8	7.3	5.5	4.9	3.7	3.2	3.4
Other Hydrocarbons	19.8	3.3	4.6	2.2	2.4	2.1	1.1	1.9	0.6
^c Helium (He)	0.08	0.03	0.08	—	—	—	—	—	—

^a Plus 120 days before pump-out.^b For SI (metric) use: 1 torr = 133 pascals.^c Container evacuated after helium back-fill.

TABLE X. Glove-Box Gloves, Gas Pressure and Composition, Irradiation from Plutonium 239.

^a Days in Contact	0	31	80	116	157	200	252	300	347
^b Pressure (torr)	13.2	30	63	80	96	110	122	142	158
Corrected Pressure (torr)	13.4	31	66	85	104	121	136	161	182
Millimoles Gas	0.133	0.308	0.656	0.848	1.03	1.20	1.35	1.60	1.81
Percent Gas Composition									
Nitrogen (N ₂)	16.7	10.3	7.0	6.3	6.0	6.7	5.8	6.1	6.1
Oxygen (O ₂)	0.1	0.1	0.1	0.09	0.09	0.06	—	—	0.4
Argon (Ar)	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Hydrogen (H ₂)	23.1	44.6	52.6	56.3	60.3	64.0	65.8	67.6	67.5
Carbon Monoxide (CO)	1.1	2.7	4.5	5.0	5.8	3.4	6.1	5.8	6.5
Carbon Dioxide (CO ₂)	42.4	34.3	30.6	27.8	23.9	22.2	19.1	17.4	16.9
Methane (CH ₄)	0.6	0.8	1.0	1.2	1.3	1.4	1.4	1.4	1.6
Ethane (C ₂ H ₆)	0.8	1.1	0.6	0.6	0.4	0.3	0.2	0.2	0.1
Other Hydrocarbons	1.1	0.1	0.5	0.3	0.05	0.08	0.09	0.06	0.06
Helium (He)	13.8	5.7	3.0	2.3	1.9	1.6	1.3	1.1	1.0

^a Plus 120 days before pump-out.^b For SI (metric) use: 1 torr = 133 pascals.

TABLE XI. Texaco Regal-A Oil, Gas Pressure and Composition, Irradiation from Plutonium 239.

^a Days in Contact	0	31	80	116	157	200	252	300	347
^b Pressure (torr)	142	280	500	625	792	947	1110	1265	1320
Corrected Pressure (torr)	144	289	525	666	858	1042	1241	1437	1523
Millimoles Gas	1.42	2.86	5.19	6.59	8.48	10.3	12.3	14.2	15.1
Percent Gas Composition									
Nitrogen (N ₂)	13.1	8.3	5.5	3.2	2.3	1.9	1.4	1.2	0.8
Oxygen (O ₂)	0.5	0.02	0.02	—	—	—	—	—	—
Argon (Ar)	0.4	0.4	0.2	0.3	0.7	0.2	0.1	0.2	0.2
Hydrogen (H ₂)	37.5	65.6	76.7	80.5	83.0	85.1	86.5	87.1	87.2
Carbon Dioxide (CO ₂)	0.3	0.2	0.04	0.09	0.2	0.04	—	—	—
Methane (CH ₄)	0.6	1.0	1.1	1.2	1.3	1.3	1.3	1.3	1.4
Ethane (C ₂ H ₆)	3.9	3.9	3.5	5.1	4.6	5.2	4.9	5.1	5.4
Other Hydrocarbons	7.7	1.5	1.7	1.1	1.3	1.1	1.7	1.3	1.2
Helium (He)	35.2	18.9	10.6	8.0	6.1	4.9	3.9	3.4	3.0

^a Plus 120 days before pump-out.^b For SI (metric) use: 1 torr = 133 pascals.

TABLE XII. Chlorothene-VG®, Gas Pressure and Composition, Irradiation from Plutonium 239.

^a Days in Contact	0	31	80	116	157	200	252	300	347
^b Pressure (torr)	322	338	450	504	552	585	588	671	785
Corrected Pressure (torr)	327	349	472	537	598	643	657	762	906
Millimoles Gas	3.24	3.45	4.67	5.31	5.91	6.36	6.50	7.54	8.96
Percent Gas Composition									
Nitrogen (N ₂)	4.0	9.1	7.4	7.4	10.7	14.2	17.7	11.6	11.8
Oxygen (O ₂)	—	—	—	—	—	—	—	—	—
Argon (Ar)	0.04	0.1	0.07	0.08	0.1	0.2	0.2	0.1	0.1
Hydrogen (H ₂)	2.0	5.8	5.9	7.8	13.0	14.8	18.2	16.4	15.9
Carbon Monoxide (CO)	—	—	0.3	1.2	2.6	3.4	0.4	2.3	0.08
Carbon Dioxide (CO ₂)	2.5	3.6	7.7	10.5	14.0	15.1	14.5	11.8	10.4
Methane (CH ₄)	0.4	0.6	0.6	0.7	1.0	1.5	1.7	1.6	1.5
Ethane (C ₂ H ₆)	0.6	0.3	0.6	0.8	0.3	0.3	0.4	0.7	1.1
Other Hydrocarbons	2.8	4.8	4.1	4.7	^c 7.1	^c 9.6	^c 9.9	^c 9.3	^c 10.2
Helium (He)	41.7	36.6	16.3	15.4	18.4	18.6	17.7	13.7	12.1
Chlorothene-VG	46.0	39.0	57.0	51.5	32.8	22.3	19.3	32.4	36.7

^a Plus 120 days before pump-out.^b For SI (metric) use: 1 torr = 133 pascals.^c Dichloroethylene (CH₂ = CCl₂).

TABLE XIII. Kimwipes®, Dry, Gas Pressure and Composition, Irradiation from Plutonium 238.

Days in Contact	0	2	8	21	36	77	120	175	220	267
*Pressure (torr)	624	607	619	629	644	739	838	933	1004	1068
Corrected Pressure (torr)	633	624	645	664	689	802	922	1041	1135	1224
Millimoles Gas	6.12	6.03	6.24	6.42	6.67	7.76	8.92	10.1	11.0	11.8
Percent Gas Composition										
Nitrogen (N ₂)	77.1	77.3	75.4	72.8	71.6	59.2	52.0	45.5	41.6	38.8
Oxygen (O ₂)	21.0	19.9	17.7	11.6	5.8	0.05	—	—	—	—
Argon (Ar)	1.0	1.0	0.9	0.8	0.8	0.7	0.6	0.6	0.5	0.5
Hydrogen (H ₂)	0.06	1.1	3.8	8.6	12.8	20.7	26.3	30.7	33.2	33.4
Carbon Monoxide (CO)	0.3	—	—	1.2	0.3	5.3	5.4	4.9	4.6	5.5
Carbon Dioxide (CO ₂)	0.1	0.4	1.4	3.6	7.2	12.4	14.4	16.8	17.9	19.4
Methane (CH ₄)	0.02	0.04	0.1	0.2	0.4	0.6	0.6	0.8	1.0	1.0
Ethane (C ₂ H ₆)	0.02	0.03	0.07	0.1	0.3	0.3	0.2	0.4	0.4	0.5
Other Hydrocarbons	—	0.05	0.4	0.8	0.4	0.7	0.5	0.3	0.6	0.4
Water (H ₂ O)	> 0.3	> 0.3	> 0.3	> 0.2	> 0.2	—	—	> 0.05	> 0.3	> 0.4

*For SI (metric) use: 1 torr = 133 pascals.

TABLE XIV. Kimwipes®, Wet, Gas Pressure and Composition, Irradiation from Plutonium 238.

Days in Contact	0	2	8	21	36	77	120	175	220	267
*Pressure (torr)	370	369	368	369	372	412	456	491	526	559
Corrected Pressure (torr)	376	381	386	393	403	453	510	558	607	655
Millimoles Gas	3.11	3.15	3.20	3.25	3.34	3.75	4.22	4.62	5.03	5.43
Percent Gas Composition										
Nitrogen (N ₂)	76.3	76.5	69.0	70.2	70.9	64.5	58.0	51.0	48.4	44.3
Oxygen (O ₂)	20.3	20.7	18.0	14.0	10.0	1.1	—	—	—	—
Argon (Ar)	0.9	1.0	0.9	0.9	0.9	0.8	0.7	0.6	0.6	0.6
Hydrogen (H ₂)	0.04	0.7	2.2	6.0	9.9	19.0	26.4	33.5	36.2	39.5
Carbon Monoxide (CO)	—	—	1.3	0.2	—	1.2	2.0	1.6	1.0	2.6
Carbon Dioxide (CO ₂)	0.1	0.3	1.1	2.7	5.7	10.6	11.2	11.2	11.4	11.7
Methane (CH ₄)	—	0.03	0.03	0.04	0.07	0.1	0.2	0.2	0.2	0.3
Ethane (C ₂ H ₆)	0.03	0.04	0.04	0.06	0.1	0.2	0.1	0.1	0.1	0.1
Other Hydrocarbons	—	—	—	—	0.3	0.06	0.1	0.1	0.2	0.05
Water (H ₂ O)	> 2.3	> 0.8	> 7.4	> 5.8	> 2.4	> 2.6	> 1.3	> 1.6	> 1.9	> 0.9

*For SI (metric) use: 1 torr = 133 pascals.

TABLE XV. Polyethylene, Gas Pressure and Composition, Irradiation from Plutonium 238.

Days in Contact	0	2	8	21	36	77	120	175	220	267
*Pressure (torr)	622	609	570	598	648	766	875	970	1051	1128
Corrected Pressure (torr)	631	626	594	632	694	832	963	1083	1189	1294
Millimoles Gas	6.07	6.02	5.71	6.08	6.68	8.00	9.27	10.4	11.4	12.5
Percent Gas Composition										
Nitrogen (N ₂)	77.9	79.0	84.8	78.9	73.5	58.3	49.6	44.4	40.2	38.0
Oxygen (O ₂)	20.6	17.0	3.6	—	—	—	—	—	—	—
Argon (Ar)	1.0	1.0	0.9	1.0	0.9	0.7	0.6	0.5	0.5	0.5
Hydrogen (H ₂)	0.03	2.0	6.6	14.2	20.2	34.0	42.0	50.5	54.5	57.7
Carbon Monoxide (CO)	—	—	—	1.1	—	2.0	2.9	0.4	0.8	—
Carbon Dioxide (CO ₂)	0.1	0.5	2.5	3.5	4.2	3.9	3.5	3.0	2.7	2.6
Methane (CH ₄)	0.02	0.03	0.09	0.3	0.4	0.4	0.9	0.5	0.6	0.6
Ethane (C ₂ H ₆)	0.04	—	—	0.1	0.2	0.3	0.3	0.3	0.3	0.4
Other Hydrocarbons	—	0.2	1.3	0.6	0.5	0.4	0.1	0.4	0.4	0.1
Water (H ₂ O)	> 0.3	> 0.2	> 0.4	> 0.4	> 0.2	—	—	—	> 0.1	> 0.1

*For SI (metric) use: 1 torr = 133 pascals.

TABLE XVI. Polyvinyl Chloride, Gas Pressure and Composition, Irradiation from Plutonium 238.

Days in Contact	0	2	8	21	36	77	120	175	220	267
*Pressure (torr)	625	605	573	560	614	742	864	965	1060	1161
Corrected Pressure (torr)	636	626	603	599	668	822	973	1106	1235	1376
Millimoles Gas	4.93	4.85	4.67	4.65	5.18	6.37	7.54	8.57	9.57	10.7
Percent Gas Composition										
Nitrogen (N ₂)	76.6	78.8	82.6	83.8	77.4	61.1	53.1	45.3	40.0	36.4
Oxygen (O ₂)	20.8	18.1	10.3	—	—	—	—	—	—	—
Argon (Ar)	1.0	1.0	1.0	1.1	0.9	0.8	0.7	0.6	0.5	0.4
Hydrogen (H ₂)	0.1	1.0	4.4	10.7	16.5	28.2	36.6	45.4	49.9	52.8
Carbon Monoxide (CO)	1.0	0.4	—	1.1	0.9	5.0	4.1	3.0	3.3	4.0
Carbon Dioxide (CO ₂)	0.1	0.3	1.0	2.3	3.0	3.4	3.5	3.5	3.5	3.5
Methane (CH ₄)	0.02	0.04	0.1	0.3	0.6	1.0	1.2	1.5	1.6	1.7
Ethane (C ₂ H ₆)	0.03	0.05	0.2	0.3	0.5	0.6	0.5	0.5	0.5	0.4
Other Hydrocarbons	0.05	0.05	0.3	0.4	0.3	0.08	0.4	0.09	0.1	0.5
Water (H ₂ O)	> 0.3	> 0.2	> 0.2	—	—	—	—	—	> 0.5	> 0.3

*For SI (metric) use: 1 torr = 133 pascals.

TABLE XVII. Ion Exchange Resin, Gas Pressure and Composition, Irradiation from Plutonium 238.

Days in Contact	0	2	8	21	36	77	120	175	220	267
*Pressure (torr)	632	623	603	577	552	549	564	566	579	600
Corrected Pressure (torr)	644	646	637	621	605	612	641	655	682	720
Millimoles Gas	4.67	4.69	4.62	4.51	4.39	4.45	4.65	4.75	4.95	5.22
Percent Gas Composition										
Nitrogen (N ₂)	77.6	77.0	77.4	81.3	83.8	83.9	81.6	79.9	78.6	74.2
Oxygen (O ₂)	20.9	20.5	18.5	13.2	7.7	—	—	—	—	—
Argon (Ar)	1.0	1.0	1.0	1.1	1.0	1.0	1.0	1.0	0.9	0.9
Hydrogen (H ₂)	0.1	0.06	0.4	1.4	2.2	4.9	6.9	9.6	11.3	12.6
Carbon Monoxide (CO)	—	1.1	0.6	0.1	—	2.1	2.9	0.9	—	1.2
Carbon Dioxide (CO ₂)	0.1	0.9	0.4	1.4	3.3	6.7	7.0	7.0	7.4	7.9
Methane (CH ₄)	0.02	0.03	0.06	0.1	0.2	0.3	0.4	0.6	0.7	0.8
Ethane (C ₂ H ₆)	0.03	0.02	0.03	0.04	0.07	0.04	0.06	0.08	0.07	0.06
Other Hydrocarbons	0.05	—	—	0.04	—	—	—	—	—	—
Water (H ₂ O)	> 0.3	> 0.2	> 1.6	> 1.4	> 1.7	> 1.1	—	> 1.0	> 1.0	> 2.4

*For SI (metric) use: 1 torr = 133 pascals.

TABLE XVIII. Surgeon's Gloves, Gas Pressure and Composition, Irradiation from Plutonium 238.

Days in Contact	0	2	8	21	36	77	120	175	220	267
*Pressure (torr)	625	616	602	575	573	654	725	784	842	893
Corrected Pressure (torr)	635	635	630	611	618	717	807	886	966	1040
Millimoles Gas	5.49	5.49	5.45	5.29	5.35	6.20	6.98	7.66	8.35	9.00
Percent Gas Composition										
Nitrogen (N ₂)	76.7	77.8	77.8	80.9	82.6	69.4	61.2	53.8	50.0	46.9
Oxygen (O ₂)	21.4	20.0	16.6	6.7	—	—	—	—	—	—
Argon (Ar)	1.0	1.0	1.0	1.1	1.0	0.8	0.7	0.7	0.6	0.5
Hydrogen (H ₂)	—	0.8	3.4	8.5	13.3	22.8	30.1	37.5	41.8	44.4
Carbon Monoxide (CO)	0.6	—	0.3	1.0	—	2.8	3.2	2.9	2.0	2.3
Carbon Dioxide (CO ₂)	0.09	0.2	0.4	1.2	2.4	3.2	3.5	3.8	3.9	3.9
Methane (CH ₄)	0.02	0.03	0.07	0.2	0.4	0.6	0.7	0.9	1.1	1.1
Ethane (C ₂ H ₆)	0.04	0.02	0.05	0.2	0.2	0.2	0.09	0.2	0.2	0.06
Other Hydrocarbons	—	—	0.2	0.05	0.09	0.1	0.4	0.2	0.1	0.6
Water (H ₂ O)	> 0.3	> 0.2	> 0.3	> 0.2	—	—	—	—	> 0.1	> 0.2

*For SI (metric) use: 1 torr = 133 pascals.

TABLE XIX. Gas Yields Generated by Plutonium 239.

	Millimoles Gas per Day per Gram Plutonium Dioxide		
	0 to 100 days	100 to 200 days	200 to 400 days
Plexiglas	0.031	* 0.040	0.016
Polyvinyl Chloride	0.016	0.017	0.017
Glove-Box Gloves	0.0061	0.0062	0.0040
Texaco Oil	0.043	0.043	0.043
Carbon Tetrachloride	0.009	—	—
Chlorothene-VG®	0.015	** 0.017	** 0.013

	Cubic Centimetres (standard temperature pressure) Gas per Day per Curie Plutonium		
	11	14	5.9
Plexiglas	11	14	5.9
Polyvinyl Chloride	5.9	6.2	6.2
Glove-Box Gloves	2.2	2.3	1.5
Texaco Oil	16	16	16
Carbon Tetrachloride	3.3	—	—
Chlorothene-VG®	5.5	6.2	4.8

*Refer to discussion under Plexiglas, Page 3.

**Refer to discussion under Chlorothene-VG, Page 4.

TABLE XX. Gas Yields Generated by Plutonium 238.

	Millimoles Gas per Day per Milligram Plutonium 238	Cubic Centimetres (standard temperature pressure) Gas per Day per Curie Plutonium
Kimwipes®, Dry	0.0032	4.2
Kimwipes®, Wet	0.0016	2.1
*Polyethylene	0.0037	4.9
*Polyvinyl Chloride	0.0022	2.9
Ion Exchange Resin	0.00054	0.71
*Surgeon's Gloves	0.0020	2.6

*Values calculated from initial slopes.

TABLE XXI. Gas Yields in Units of G-Values.

Plexiglas	1.9
Polyvinyl Chloride	0.96
Glove-Box Gloves	0.37
Texaco Oil	*2.6 (3.1)
Carbon Tetrachloride	*0.54 (0.60)
Chlorothene-VG®	*0.90 (1.0)
Kimwipes®, Dry	0.63
Kimwipes®, Wet	0.31
Polyethylene	0.73
Polyvinyl Chloride	0.43
Ion Exchange Resin	0.11
Surgeon's Gloves	0.40

*These calculations are based on total energy absorption. Values in parentheses are approximate yields obtained when energy absorbed by Microcell® is excluded.

The G-Values are equal to the number of molecules produced per 100 electron volts of absorbed energy.

TABLE XXII. Radiolytic Oxygen Consumption and Hydrogen Production.

	Millimoles Oxygen per Day per Gram Plutonium Dioxide 239	Millimoles Hydrogen per Day per Gram Plutonium Dioxide 239
Plexiglas	0.070	0.0073
Polyvinyl Chloride	0.034	0.012
Glove-Box Gloves	0.019	0.0038
Texaco Oil	0.0088	0.043
Carbon Tetrachloride	0.030	—
Chlorothene-VG®	0.042	0.0036
	Millimoles Oxygen per Day per Milligram Plutonium 238	Millimoles Hydrogen per Day per Milligram Plutonium 238
Kimwipes®, Dry	0.0034	0.0027
Kimwipes®, Wet	0.0014	0.0016
Polyethylene	0.0014	0.0037
Polyvinyl Chloride	0.0051	0.0017
Ion Exchange Resin	0.0026	0.00038
Surgeon's Gloves	0.0034	0.0019

ILLUSTRATIONS
Figures 1 through 17

FIGURE 1. Plexiglas, Gas Production and Oxygen Depletion, Irradiation from Plutonium 239.

FIGURE 2. Polyvinyl Chloride, Gas Production and Oxygen Depletion, Irradiation from Plutonium 239.

FIGURE 3. Glove-Box Gloves, Gas Production and Oxygen Depletion, Irradiation from Plutonium 239.

FIGURE 4. Texaco Oil, Gas Production and Oxygen Depletion, Irradiation from Plutonium 239.

FIGURE 5. Carbon Tetrachloride, Gas Production and Oxygen Depletion, Irradiation from Plutonium 239.

FIGURE 6. Chlorothene®, Gas Production and Oxygen Depletion, Irradiation from Plutonium 239.

FIGURE 7. Plexiglas, Gas Production after Evacuation at 120 Days, Irradiation from Plutonium 239.

FIGURE 8. Polyvinyl Chloride, Gas Production after Evacuation at 120 Days, Irradiation from Plutonium 239.

FIGURE 9. Glove-Box Gloves, Gas Production after Evacuation at 120 Days, Irradiation from Plutonium 239.

FIGURE 10. Texaco Regal-A Oil, Gas Production after Evacuation at 120 Days, Irradiation from Plutonium 239.

FIGURE 11. Chlorothene®, Gas Production after Evacuation at 120 Days, Irradiation from Plutonium 239.

FIGURE 12. Kimwipes®, Dry, Gas Production and Oxygen Depletion, Irradiation from Plutonium 238.

FIGURE 13. Kimwipes®, Wet, Gas Production and Oxygen Depletion, Irradiation from Plutonium 238.

FIGURE 14. Polyethylene, Gas Production and Oxygen Depletion, Irradiation from Plutonium 238.

FIGURE 15. Polyvinyl Chloride, Gas Production and Oxygen Depletion, Irradiation from Plutonium 238.

FIGURE 16. Ion Exchange Resin, Gas Production and Oxygen Depletion, Irradiation from Plutonium 238.

FIGURE 17. Surgeon's Gloves, Gas Production and Oxygen Depletion, Irradiation from Plutonium 238.

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