Air Products and Chemicals, Inc.
7201 Hamilton Boulevard
Allentown, PA 18195-1501

Telephone (610) 481-4911

AIR PRODUCTS

3 May 1996

Mr. Keith Brown
Nuclear Regulatory Commission
Legion 1
Division of Nuclear Materials Safety
475 Allendale Road
King of Prussia, PA 19406

Dear Mr. Brown:

This letter confirms our telephone conference of 2 May 1996 concerning Air Products and Chemicals, Inc. letter to the NRC, dated 25 March 1996. NRC may keep all documents in Air Products and Chemicals letter, including those pages labeled "attorney-client privilege", on file in the NRC Public Document Room.

Yours truly,

Steven L. Feldman

Steven L. Feldman
Manager,
Gases and Equipment Group Safety

dls
xc: S. Ferrara, Law Dept.
nrcfiles

MAY 13 1996

Law Group - Litigation
Air Products and Chemicals, Inc.
7201 Hamilton Boulevard
Allentown, PA 18195-1501
Telephone (610) 481-7447
Fax (610) 481-7572

AIR PRODUCTS

25 March 1996

VIA FEDERAL EXPRESS

Mr. Charles W. Hehl, Director
Division of Nuclear Materials Safety
U.S. Nuclear Regulatory Commission
475 Allendale Road
King of Prussia, PA 19406

Dear Mr. Hehl:

The purpose of this letter is to request a waiver of Nuclear Regulatory Commission (NRC) regulations at 10 C.F.R. Part 30 for our krypton gas operations, facilities, and products. We recently received laboratory analyses of our pure krypton product which indicates it contains 23.5 x 10^{-6} microcuries/cm^3 of krypton-85, which is greater than the 3 x 10^{-6} microcuries/cm^3 concentration that is automatically exempted from regulation in the applicable NRC regulations. A full product cylinder of pure krypton gas would also contain more than 100 microcuries of krypton 85, which exceeds the NRC "exempt quantity" in the same regulations. Representatives of Air Products and NRC Region I discussed this matter by telephone on January 19 and again on February 12, 1996, and agreed that our production and distribution operations need <u>not</u> be stopped pending a regulatory decision. Attached is a copy of a memorandum of both telephone conversations, the laboratory reports of analyses of the pure krypton and crude krypton gas, and a report of our consultant evaluating the radiological aspects of the krypton-85.

The concentrations in the crude krypton and some krypton gas products also exceed that which the Department of Transportation (DOT) defines as a "radioactive material." Presently, all containers of our products containing krypton gas which are subject to the DOT regulations qualify for the limited quantity exemption in 49 C.F.R., 173.421. We are currently meeting all requirements to comply with this regulation. We are marking the containers as "radioactive" as required by the DOT limited quantity exemption. Based on the need to mark the cylinders, we informed our customers of this action by letter; attached is a copy of our customer notice and fact sheet.

Attachment (1)

Following our initial notification of NRC staff, we conducted additional surveys for radiation at our Cleveland, Ohio facility and additional laboratory analyses of the crude krypton intermediate produced at that facility. We determined that some radon naturally occurring in the atmosphere is drawn into our process there and results in measurable radiation levels on our crude krypton cylinders which quickly decays to background levels. Our assessments indicate no significant dose to personnel in normal operations and no significant radon is present in the final products.

We discussed the results of these additional surveys with your staff in our second telephone conference call on February 12, 1996. Also attached is a copy of a memorandum of that conversation. This letter was understandably delayed pending the completion of these additional assessments.

As a courtesy, we contacted state officials in Pennsylvania and Ohio to apprise them of these developments. A copy of this letter and its attachments is being sent to them simultaneously.

We are hereby requesting a waiver by the NRC of its licensing requirements for our krypton products and our operations in Cleveland and Hometown based on the limited potential for exposure to radiation posed by the extremely low radiation levels from the krypton-85 involved. We also would like to emphasize that this radioactivity is not added to our products, but is a natural result of concentrating the gases from levels that are normally present in the world's atmosphere, and is not the kind of situation to which NRC regulatory jurisdiction has been applied. The NRC decision in this matter will have a significant impact on an extensive and longstanding product line.

We would be pleased to meet with NRC representatives to discuss this request and to answer any questions that may arise. Please contact Mr. Steve Feldman, Gases and Equipment Group Safety Manager, Air Products, at 610-481-5132 to arrange such a meeting.

Respectfully Submitted,

Joseph J. Munley
Director, Specialty Gases
Air Products Incorporated

MEMORANDUM

TO: **File**

FROM: **Steve Feldman, Air Products**

DATE: **January 30, 1996**

RE: **Telephone Conversation with the Nuclear Regulatory Commission Region I -- January 19, 1996**

==========

On January 19, 1996, personnel representing Air Products Incorporated, at Hometown, Pennsylvania, telephoned the Nuclear Regulatory Commission staff at Region I offices in King of Prussia, Pennsylvania. The following individuals were present on the call:

Air Products

David Leone, Operations Manager, Specialty Gases
Don Maseley, Plant Manager, Hometown
Steve Feldman, Gases and Equipment Group Safety Manager
Dan Evans, Senior Safety Specialist, Hometown
Glen Sjoblom, Consultant

NRC

Jim Joyner, Project Manager
John Kinneman, Chief, R&D Licensing/Inspection
Frank Costello, Chief, Commercial Licensing/Inspection

Mr. Feldman described the background of the situation. During an internal company environmental audit, the question was raised whether the Krypton gas product line of Air Products might contain any radioactivity. Since the company does not have significant in-house radiation health expertise at present, they initially contacted Keller and Heckman of Washington, D.C., who, with technical assistance from Glen Sjoblom, provided assistance. Promptly after Air Products began investigating the situation, it was determined that the levels of radiation likely would be far below background and that no health hazard would exist.

The krypton gas is used in a product line which has existed for over twenty years. Any radioactivity present would result from krypton-85, an isotope present in the earth's atmosphere.

The Air Products facility outside Hometown, Pennsylvania, handles many industrial and specialty gases. The feedstock for the Hometown plant is crude Krypton gas; a mixture of krypton, xenon, and oxygen. Crude krypton gas is produced in the Air Products air separation plant in Cleveland, Ohio. Krypton-85 is not added to the product at any step and serves no useful purpose, but is an unwanted natural contaminant. The crude krypton gas arrives at the Hometown facility in standard DOT gas cylinders and is processed in a cryogenic distillation column to purify it to product specifications. The pure krypton is then placed in gas cylinders of various sizes, and, for some products, is mixed with other gases to send to customers.

The krypton products have many commercial uses, including medial and other lasers, high intensity light bulbs of many sizes, in basic and applied research in academe, industry and government. Reportedly, the Department of Energy has been encouraging the use of lighting devices containing krypton gas, to enhance energy conservation and the useful life of the devices.

Mr. Sjoblom described the radiological aspects of krypton-85, the radioactive isotope of krypton present in the atmosphere. Since non-radioactive krypton exists in the earth's atmosphere at a concentration of 1.14 parts per million of air, producing pure (nominal 100%) krypton by the cryogenic air separation process concentrates both the non-radioactive and radioactive isotopes equally by a factor of nearly one million. Samples of the pure krypton from the Hometown plant were analyzed by a commercial laboratory and results were reported on January 17, 1996.

The reported concentrations in two analyses of pure krypton gas averaged 23.5×10^{-6} microcuries/cm^3 at atmospheric pressure. This compares well with the calculated specific activity of krypton 85 in air, based on the reported results of analyses by the U.S. Environmental Protection Agency at its Las Vegas, Nevada laboratory.

Krypton-85 principally emits beta radiation, but does produce a gamma emission in approximately 4 decays out of 1000. Since the Hometown, Pennsylvania and Cleveland, Ohio production process and the products are contained largely by relatively thick, metal-walled piping and cylinders, no

significant beta radiation is likely to be detectable. Calculated gamma radiation levels outside a full, large size, compressed pure krypton cylinder are a fraction of background radiation levels. One would not expect to be able to detect a change using simple portable survey instruments, and, as expected, measurements made using a GM type meter and a pressurized ion changer confirmed these predictions. No detectable beta radiation or any increase in ambient gamma radiation over background could be detected immediately outside cylinders of pure Krypton.

Glen Sjoblom calculated estimated doses that would result in the event of release of the entire contents of the largest available, completely full, pure krypton gas cylinder into an occupied area. A very small dose, primarily to the skin and well below background levels, could result.

The concentration of radioactivity in pure krypton exceeds the exempt concentration threshold, 3×10^{-6} microcurie per cubic centimeter (mCi/cm^3), established by the NRC in 10 C.F.R. § 30.70, Schedule A. A full product cylinder, containing approximately 8700 liters of pure Krypton gas, contains 200 microcuries of radiation; this exceeds the NRC exempt quantity, 100 microcuries, listed in Schedule B. There is no health hazard from the cylinders, however, in light of the very small radiation doses involved.

Air Products offered to meet with NRC Region I staff to discuss the information in more detail. Mr. Sjoblom stated that he saw no reason for the operations at the two facilities to stop pending such a meeting. NRC representatives (Joyner and Kinneman) stated they also saw no reason to stop the operations.

NRC (Joyner) requested that Air Products submit a letter requesting an NRC decision on whether NRC regulation of the Krypton operations is needed, and that, following receipt of such a letter a meeting would be held if considered necessary. Air Products representatives agreed to submit such a letter.

With these agreements, the telephone call ended.

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Table I
Results of Radiological Gas Testing - Krypton

Cylinder Data				Results, microcurie per cubic centimeter ($\mu Ci/cm^3$)	
Date of Test	Cylinder Designation	Date Filled	Composition	First Run	Second Run
1/3/96	DCD563		Pure Krypton product	0.000024	0.000023
1/23/96	DGA540		Crude Krypton, Cleveland[1]	0.000023	0.000021
1/23/96	DGA541		Cryodyne (Airgas), purchased	0.000018	0.000016
1/24/96	DGA543		Pure krypton (Stub from Dec. run)	0.000023	0.000024
1/23/96	DEG991		Nitrogen blank	<0.0000016	<0.0000013
2/12/96	DGS538, H-7309	1/1/96	Crude Krypton, Cleveland[2]	0.0000039	-
2/12/96	DMW788, H-7263	1/15/96	Crude Krypton, Cleveland[2]	0.0000030	-
2/12/96	DGA534, H-7321	2/1/96, 12:30 PM	Crude Krypton, Cleveland[2]	0.0000042	0.0000026
2/12/96	DGS537, H-7270	2/1/96, 1:00 PM	Crude Krypton, Cleveland[2]	0.0000030	0.0000035
2/12/96	DMW780, H-7310	2/1/96, 1:45 PM	Crude Krypton, Cleveland[2]	0.0000037	-
2/12/96	DMW787, H-7414	2/1/96, 2:00 PM	Crude Krypton, Cleveland[2]	0.0000042	-

Results from GPU Nuclear Environmental Radiation Laboratory, Harrisburg, Pennsylvania.

[1] Crude krypton: Approximately 90% krypton, balance xenon and oxygen.

[2] Approximately 1 part crude krypton gas to 9 parts nitrogen. Each sample cylinder prepared at the Cleveland facility was filled initially to approximately 50 psig with the crude krypton gas, then filled to a final pressure of 500 psig with pure nitrogen.

GPU Nuclear

5-JAN-96

Environmental Radioactivity Laboratory
2574 Interstate Drive
Harrisburg, PA 17110
Writer's Direct Dial Number: 717-948-8110

KELLER AND HECKMAN
Attn: David G. Sarvadi
1001 G Street, N.W.
Suite 500 West
Washington, D.C. 20001

* Note: If the counting error is less than 10 % of the activity then the total error is reported as 10 %. Only in this case it is not a true 2σ error.

R E P O R T O F A N A L Y S I S

Sample Type: **GAS SAMPLE**
Analysis Type: **Gamma Spectrometry of Gas Sample**

GPU ID	STATION ID	COLLECTION	RESULTS IN uCi/cc +/- 2σ *
085526	KH-KR-DCD563	Start: 122995 12:00 Stop: 122995 12:00	KR-85 0.000024 +/- 0.000002

Approved: J.P. Donnachie Jr. Date: JAN 04 1996
J.P. Donnachie Jr.
Environmental Radioactivity Laboratory Manager

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-JAN-96

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R E P O R T O F A N A L Y S I S

Sample Type: **GAS SAMPLE**
Analysis Type: **Gamma Spectrometry of Gas Sample**

GPU ID	STATION ID	COLLECTION	RESULTS IN uCi/cc +/- 2σ *
085525	KH-KR-DCD563	Start: 122995 12:00 Stop: 122995 12:00	KR-85 0.000023 +/- 0.000002

Approved: J.P. Donnachie Jr. Date: JAN 04 1996

J.P. Donnachie Jr.
Environmental Radioactivity Laboratory Manager

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Sample Type: **GAS SAMPLE**
Analysis Type: **Gamma Spectrometry of Gas Sample**

GPU ID	STATION ID	COLLECTION	RESULTS IN **uCi/cc** +/- 2σ *
085869	KH-KR-DGA540	Start: 011696 12:00 Stop: 011696 12:00	
			KR-85 0.000023 +/- 0.000002

Approved: J.P. Donnachie Jr. Date: JAN 24 1996
J.P. Donnachie Jr.
Environmental Radioactivity Laboratory Manager

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R E P O R T O F A N A L Y S I S

Sample Type: **GAS SAMPLE**
Analysis Type: **Gamma Spectrometry of Gas Sample**

GPU ID	STATION ID	COLLECTION	RESULTS IN **uCi/cc** +/- 2σ *
085792	KH-KR-DGA540	Start: 011696 12:00 Stop: 011696 12:00	
			KR-85 0.000021 +/- 0.000002

Approved: J.P. Donnachie Jr. Date: JAN 24 1996
J.P. Donnachie Jr.
Environmental Radioactivity Laboratory Manager

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Attachments:

1. Memorandum of January 19 telephone conversation
2. Laboratory results of Krypton analysis
3. Consultant report on Krypton-85
4. Customer notice and Fact Sheet
5. Memorandum of February 12 telephone conversation

cc: Dr. William Kirk
Bureau of Radiation Protection
400 Market Street
13th Floor
Harrisburg, PA 17101

Mr. Roger Supas
Ohio Department of Health
Bureau of Radiation Protection
246 North High Street
Columbus, OH 43215

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MEMORANDUM

TO: **File**

FROM: **Steve Feldman, Air Products** S. Feldman

DATE: **February 14, 1996**

RE: **Telephone Conversation With the Nuclear Regulatory Commission (Region I), February 12, 1996**

==========

On February 12, 1996, personnel representing Air Products and Chemicals, Incorporated, at Allentown and Hometown, Pennsylvania telephoned the Nuclear Regulatory Commission staff at Region I offices in King of Prussia, Pennsylvania. The following individuals were present on the call:

Air Products:

Steve Feldman, Gases and Equipment Group Safety Manager
Rick Wood, Corporate Industrial Hygiene Department
Dick Meiser, Hometown Plant Safety Manager
Mr. Glen Sjoblom, consultant

NRC:

Jim Joyner, Project Manager
Frank Costello, Chief, Commercial Licensing/Inspection

Mr. Feldman discussed the background for the call to the NRC, briefly reiterating the discovery and evaluation of krypton-85 present in the pure krypton products, described in Air Products letter to file dated January 30, 1996. He indicated that the purpose of this call was to report the results of additional radiological surveys related to the production of the crude krypton.

At the Air Products plant in Cleveland, Ohio, air is cryogenically separated into components, nitrogen, oxygen, argon and a mixture of krypton/xenon/oxygen which is referred to as "crude krypton". At the end of each month, the filled crude krypton cylinders (normally numbering from twelve to fifteen) are shipped to the

Hometown Specialty Gases facility in Pennsylvania where the mixture is further purified into finished gas products.

During the weeks of January 21 and 28, additional radiological surveys were conducted at the Cleveland facility. Mr. Sjoblom summarized the results of these additional surveys. Direct radiation levels of approximately 0.5 mrem/hr were detected on the surface of individual cylinders shortly after filling with crude krypton and levels up to 1 mrem/hr were found internal to an array of about a dozen cylinders in the sample room, where they are stored and sampled prior to shipment. Radiation levels on cylinders of different filling dates showed a drop off with a half-life consistent with that of Radon 222. The hypothesis that the source of the gamma radiation was from the short lived decay products of radon, namely Bismuth-214 and Lead-214 was confirmed by analysis of crude krypton gas samples sent to a laboratory.

Initial radiation dose assessments indicated that operating personal might receive approximately 10-38 mrem/year (later refined to be 4-15 mrem/year) of collective dose from the crude krypton operations, with doses to individual employees less than this maximum annual estimate. Overall, individual doses were estimated to be a small fraction of the approximately 100-300 mrem average dose to a member of the general public each year from natural background radiation. There was no detectable contamination on surfaces normally accessible to personnel, although there appeared to be some buildup of a longer lived decay product, believed to be lead-210, on the interior surfaces of the internal and inaccessible components of the crude krypton process equipment and the reusable crude krypton cylinders. It was noted that these cylinders are dedicated to shipment of the crude krypton between the Hometown facility and the Cleveland plant. They are returned empty, and at no time used for delivery of any other compressed gas product to customers. Due to the decay that occurs during normal processing and to the nature of the purification process at Hometown, any radon in the process would either have decayed away, or is released back to the atmosphere during purification at Hometown.

Quality control sampling of the crude kryton product is performed at Cleveland using a flow-through gas chromatograph, with venting into the sample room. Slightly elevated radon levels were detected in the sample room during this operation. The assessment of these levels indicated that an operator would receive less than 1 mrem/year, which is very small compared to average doses due to radon in homes in the United States, approximately 200 mrem/year. In summary, while

radon is present in the intermediate crude krypton mixture manufactured at Cleveland, it does not represent any significant health hazard.

Mr. Sjoblom stated an understanding that the NRC was not involved in the regulation of radon but felt that the NRC should nevertheless be informed. Mr. Joyner expressed thanks, confirmed that there did not appear to be a hazard, and confirmed that the NRC was not authorized by the Atomic Energy Act to regulate such natural radioactivity, but that in certain situations, state organizations may have an interest in such matters. Air Products representatives indicated an intent to discuss this with appropriate individuals in Ohio and Pennsylvania, and the NRC suggested state contacts.

The Air Products representatives confirmed that having completed the additional assessments, Air Products would send the letter requesting an NRC regulatory decision on the small quantities of krypton-85 in its operations and products. With this, the conversation ended.

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2 -JAN-96

Environmental Radioactivity Laboratory
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KELLER AND HECKMAN
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* Note: If the counting error is less than 10 % of the activity then the total error is reported as 10 %. Only in this case it is not a true 2σ error.

R E P O R T O F A N A L Y S I S

Sample Type: **GAS SAMPLE**
Analysis Type: **Gamma Spectrometry of Gas Sample**

GPU ID	STATION ID	COLLECTION	RESULTS IN **uCi/cc** +/- 2σ *
085791	KH-KR-DGA541	Start: 011696 12:00 Stop: 011696 12:00	
			KR-85 0.000018 +/- 0.000003

Approved: _____ Date: JAN 24 1996
J.P. Donnachie Jr.
Environmental Radioactivity Laboratory Manager

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Sample Type: **GAS SAMPLE**
Analysis Type: **Gamma Spectrometry of Gas Sample**

GPU ID	STATION ID	COLLECTION	RESULTS IN **uCi/cc** +/- 2σ *
085868	KH-KR-DGA541	Start: 011696 12:00 Stop: 011696 12:00	
			KR-85 0.000016 +/- 0.000002

Approved: J.P. Donnachie Jr. Date: JAN 24 1996
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R E P O R T O F A N A L Y S I S

Sample Type: **GAS SAMPLE**
Analysis Type: **Gamma Spectrometry of Gas Sample**

GPU ID	STATION ID	COLLECTION	RESULTS IN **uCi/cc** +/- 2σ *
085870	KH-KR-DGA543	Start: 011696 12:00 Stop: 011696 12:00	
			KR-85 0.000023 +/- 0.000002

Approved: J.P. Donnachie Jr. Date: JAN 24 1996
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Sample Type: **GAS SAMPLE**
Analysis Type: **Gamma Spectrometry of Gas Sample**

GPU ID	STATION ID	COLLECTION	RESULTS IN **uCi/cc** +/- 2σ *	
085793	KH-KR-DGA543	Start: 011696 12:00 Stop: 011696 12:00	KR-85	0.000024 +/- 0.000002

Approved: J.P. Donnachie Jr. Date: JAN 24 1996
J.P. Donnachie Jr.
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R E P O R T O F A N A L Y S I S

Sample Type: **GAS SAMPLE**
Analysis Type: **Gamma Spectrometry of Gas Sample**

GPU ID	STATION ID	COLLECTION	RESULTS IN **uCi/cc** +/- 2σ *
085871	KH-N2-DEG991	Start: 011696 12:00 Stop: 011696 12:00	KR-85 Less Than 0.0000016

Approved: J.P. Donnachie Jr. Date: JAN 24 1996
J.P. Donnachie Jr.
Environmental Radioactivity Laboratory Manager

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R E P O R T O F A N A L Y S I S

Sample Type: **GAS SAMPLE**
Analysis Type: **Gamma Spectrometry of Gas Sample**

GPU ID	STATION ID	COLLECTION	RESULTS IN **uCi/cc** +/- 2σ *	
085794	KH-N2-DEG991	Start: 011696 12:00 Stop: 011696 12:00	KR-85	Less Than 0.0000013

Approved: _____ Date: JAN 24 1996
J.P. Donnachie Jr.
Environmental Radioactivity Laboratory Manager

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12-FEB-96

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KELLER AND HECKMAN
Attn: David G. Sarvadi
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Washington, D.C. 20001

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Sample Type: **GAS SAMPLE**
Analysis Type: **Gamma Spectrometry of Gas Sample**

GPU ID	STATION ID	COLLECTION	RESULTS IN **uCi/cc** +/- 2σ *
086135	KH-KR-DGA538	Start: 010196 12:00 Stop: 010196 12:00	
			KR-85 0.0000039 +/- 0.0000006

Approved: J.P. Donnachie Jr. Date: FEB 13 1996
J.P. Donnachie Jr.
Environmental Radioactivity Laboratory Manager

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12-FEB-96

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Sample Type: **GAS SAMPLE**
Analysis Type: **Gamma Spectrometry of Gas Sample**

GPU ID	STATION ID	COLLECTION	RESULTS IN **uCi/cc** +/- 2σ *
086142	KH-KR-DMW788	Start: 011596 12:00 Stop: 011596 12:00	
			KR-85 0.0000030 +/- 0.0000006
			RN-222 0.0000064 +/- 0.0000007

Approved: J.P. Donnachie Jr. Date: FEB 13 1996

J.P. Donnachie Jr.
Environmental Radioactivity Laboratory Manager

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Analysis Type: **Gamma Spectrometry of Gas Sample**

GPU ID	STATION ID	COLLECTION	RESULTS IN **uCi/cc** +/- 2σ *
086131	KH-KR-DGA534	Start: 020196 12:30 Stop: 020196 12:30	
			KR-85 0.0000042 +/- 0.0000012
			RN-222 0.0000018 +/- 0.0000002

Approved: J.P. Donnachie Jr. Date: FEB 13 1996
J.P. Donnachie Jr.
Environmental Radioactivity Laboratory Manager

Produced under the direction of attorney work product.
Privileged and Confidential.

GPU Nuclear

12-FEB-96

Environmental Radioactivity Laboratory
2574 Interstate Drive
Harrisburg, PA 17110
Writer's Direct Dial Number: 717-948-8110

KELLER AND HECKMAN
Attn: David G. Sarvadi
1001 G Street, N.W.
Suite 500 West
Washington, D.C. 20001

* Note: If the counting error is less than 10 % of the activity then the total error is reported as 10 %. Only in this case it is not a true 2σ error.

R E P O R T O F A N A L Y S I S

Sample Type: **GAS SAMPLE**
Analysis Type: **Gamma Spectrometry of Gas Sample**

GPU ID	STATION ID	COLLECTION	RESULTS IN **uCi/cc** +/- 2σ *
086132	KH-KR-DGA534	Start: 020196 12:30 Stop: 020196 12:30	
			KR-85 0.0000026 +/- 0.0000007
			RN-222 0.0000020 +/- 0.0000002

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R E P O R T O F A N A L Y S I S

Sample Type: **GAS SAMPLE**
Analysis Type: **Gamma Spectrometry of Gas Sample**

GPU ID	STATION ID	COLLECTION	RESULTS IN **uCi/cc** +/- 2σ *
086133	KH-KR-DGA537	Start: 020196 13:00 Stop: 020196 13:00	
			KR-85 0.0000030 +/- 0.0000006
			RN-222 0.0000020 +/- 0.0000002

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R E P O R T O F A N A L Y S I S

Sample Type: **GAS SAMPLE**
Analysis Type: **Gamma Spectrometry of Gas Sample**

GPU ID	STATION ID	COLLECTION	RESULTS IN **uCi/cc** +/- 2σ *
086134	KH-KR-DGA537	Start: 020196 13:00 Stop: 020196 13:00	
			KR-85 0.0000035 +/- 0.0000006
			RN-222 0.0000018 +/- 0.0000002

Approved: J.P. Donnachie Jr. Date: FEB 13 1996
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* Note: If the counting error is less than 10 % of the activity then the total error is reported as 10 %. Only in this case it is not a true 2σ error.

R E P O R T O F A N A L Y S I S

Sample Type: **GAS SAMPLE**
Analysis Type: **Gamma Spectrometry of Gas Sample**

GPU ID	STATION ID	COLLECTION	RESULTS IN **uCi/cc** +/- 2σ *
086137	KH-KR-DMW780	Start: 020196 13:45 Stop: 020196 13:45	
			KR-85 0.0000037 +/- 0.0000009
			RN-222 0.0000029 +/- 0.0000003

Approved: J.P. Donnachie Jr. Date: FEB 13 1996
J.P. Donnachie Jr.
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* Note: If the counting error is less than 10 % of the activity then the total error is reported as 10 %. Only in this case it is not a true 2σ error.

R E P O R T O F A N A L Y S I S

Sample Type: **GAS SAMPLE**
Analysis Type: **Gamma Spectrometry of Gas Sample**

GPU ID	STATION ID	COLLECTION	RESULTS IN **uCi/cc** +/- 2σ *
086139	KH-KR-DMW787	Start: 020196 14:00 Stop: 020196 14:00	
			KR-85 0.0000042 +/- 0.0000007
			RN-222 0.0000022 +/- 0.0000002

Approved: J.P. Donnachie Jr. Date: FEB 13 1996
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KRYPTON 85

The purpose of this brief report is to provide background information on Krypton-85 (^{85}Kr) in the environment and in relation to commercial extraction of Krypton gas from the atmosphere. Information is provided on (1) its radiological properties; (2) concentrations reported in ambient air by laboratories of the Environmental Protection Agency; (3) commercial laboratories which could analyze samples; (4) a discussion of historical agency approaches to regulatory issues; and (5) a brief assessment of the radiological significance for potential use by management.

Radiological Properties

^{85}Kr is a radioactive noble gas which is present in the atmosphere from uranium and plutonium fission reactions and release during reprocessing of spent nuclear fuel and, earlier, from atmospheric nuclear weapons tests. ^{85}Kr decays by a beta emission of 0.687 million electron volts (mev) 99.57 per cent of the time or by a beta emission of 0.173 mev followed by a gamma ray of 0.514 mev 0.43 per cent of the time. The half life of ^{85}Kr is 10.7 years.

Because most of the radiation from ^{85}Kr is beta radiation and only a small fraction of gamma radiation is produced, it penetrates solid objects, including human tissue, only to a small degree. The National Council on Radiation Protection and Measurements (NCRP) has published factors taking these characteristics into account which can be used to estimate the radiation dose from ^{85}Kr in air. Based on this information, the principal contributors to dose are beta radiation of the skin and gamma radiation of the total body. The beta emission results in a dose of 1.8 rem[1/] to the skin per year of exposure at a unit concentration of 1 microcurie per cubic meter ($\mu Ci/m^3$). The dose rate due to the gamma radiation to the total body is 0.015 rem per year of exposure at a unit concentration of 1 $\mu Ci/m^3$. Thus, estimates of doses can be made if the atmospheric concentration is known.

The NCRP has estimated that the average person is exposed to approximately 300 mrem/year from all sources (alpha, beta, and gamma radiation) in the environment, principally radon in the buildings, cosmic radiation, and terrestrial radiation. Occupational exposures for radiation workers in the nuclear industry are limited generally to levels as low as reasonably achievable, not to exceed 2000 mrem per year, set by the Nuclear Regulatory Commission. Limits for members of the general public from releases from various types of nuclear facilities are in the

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1/ These terms are defined in Appendix I. The symbol for a curie is Ci.

range of 10-25 mrem/year, set by the Environmental Protection Agency and the Nuclear Regulatory Commission.

Krypton 85 in the Atmosphere and Resulting Potential Radiation Exposure

Prior to the nuclear age, only relatively small concentrations of ^{85}Kr were present in the atmosphere from spontaneous fission of uranium in the earth's crust. Reprocessing of spent nuclear fuel and atmospheric nuclear weapons testing are the source of the larger proportion of ^{85}Kr in the atmosphere at current levels.

In the late 1960's and early 1970's, it was predicted that ^{85}Kr levels would increase dramatically due to nuclear fuel reprocessing. However, due to policy changes in the 1970's, the U.S. does not now commercially reprocess spent nuclear fuel and in recent years has not reprocessed spent fuel at government reactors. Some reprocessing continues in other countries.

The Environmental Protection Agency (EPA) has measured atmospheric levels at its Montgomery, Alabama and its Las Vegas, Nevada laboratories. In 1970, reported levels were approximately 14 picocuries per cubic meter (pCi/m^3).[2/] In 1979, levels were measured at 17-24 pCi/m^3. The most recent report for 1992 shows about 25 pCi/m^3 ($25 \times 10^{-6} \mu Ci/m^3$). Therefore, current dose rates can be estimated using the following calculation:

$$25\times10^{-6} \frac{\mu Ci}{m^3} \times \frac{1.8\ rem/yr}{\mu Ci/m^3} \times 10^3 \frac{mrem}{rem} = 0.045 \frac{mrem}{yr} \text{ to skin}$$

and

$$25\times10^{-6} \frac{\mu Ci}{m^3} \times \frac{0.015\ rem/yr}{\mu Ci/m^3} \times 10^3 \frac{mrem}{rem} = 0.000038 \frac{mrem}{yr} \text{ to whole body}$$

Based on the above NCRP estimates of background exposure of approximately 300 mrem/year from all sources in the environment, the contribution from ^{85}Kr in the atmosphere is not significant. These levels are well below the occupational limits for radiation workers of 2000 mrem per year and also below the limits for members of the general public from releases from various types of nuclear facilities of 10-25 mrem/year.

[2/] One million picocuries is equal to one microcurie. Thus, 14 picocuries per cubic meter (pCi/m^3) is equal to 14×10^{-6} microcuries per cubic meter ($\mu Ci/m^3$).

Expected ^{85}Kr Levels in Industrial Gases

Concentrating Krypton gas from the air for various industrial and commercial uses would also concentrate the ^{85}Kr. Isotopic abundance of non-radioactive Krypton isotopes is as follows:

Isotope	Atmospheric fraction, per cent
^{78}Kr	0.35
^{80}Kr	2.27
^{82}Kr	11.56
^{83}Kr	11.55
^{84}Kr	56.90
^{86}Kr	17.37

Knowing the ratio of ^{85}Kr to the other isotopes of Kr allows a prediction of the concentration of ^{85}Kr in gases extracted from the atmosphere. Unless the process of Krypton separation from other constituents in air results in a differential separation rate for different Krypton isotopes, the ^{85}Kr fraction in the concentrated Krypton would be the same as in the atmosphere. Since air contains about 1.1 parts of Krypton per million parts of air, the resulting ^{85}Kr concentrations in pure Krypton gas would be $10^6/1.1$ or 9.09×10^5 times that in air. Based on the current levels reported by the Las Vegas EPA laboratory, pure Krypton at standard pressure and temperature would be expected to contain:

$$9.09\times10^5 \times 25\times10^{-6}\ \mu Ci/m^3 \times \frac{m^3}{10^6\ cm^3} = \frac{2.3\times10^{-5}\ \mu Ci \text{ of } ^{85}Kr}{cm^3}$$

Radiological Assessment of Krypton Separation Facilities

A radiological assessment of ^{85}Kr in Krypton separation facilities would need to consider the amounts of inventory present and the degree of containment of the gases since the exposure is affected by the degree of contact possible with workers in the facility. It is assumed that the separation process occurs in essentially closed piping systems and containers, and therefore the exposure to beta emissions would only occur if the gas released or escaped from the system or a product container. Under the right circumstances, low level gamma radiation might be emitted from sections of process systems and product containers having significant concentrated Krypton inventory.

a. Hypothetical dose rate adjacent to a product cylinder

If a product cylinder contained 7,880 liters of Krypton derived at currently reported atmospheric levels, and the cylinder is assumed to be approximately one foot diameter and four feet high, in each cylinder, then, the amount of radioactive ^{85}Kr would be:

$$2.3\times10^{-5}\frac{\mu Ci}{ml} \times \frac{10^3 ml}{l} \times 7880\ l = 131\ \mu Ci$$

Gamma radiation levels could be calculated accurately using formulas in standard texts, but for purposes of a first order estimate, approximately one curie = Yield x 1 rem/hr at a distance of one meter from cylinders of this approximate size.[3/]

Beyond one meter, the radiation level would drop inversely with the square of the distance. Within one meter, the level would increase linearly at approximately a rate of 1/distance. At one meter, one could estimate gamma radiation levels from the contained ^{85}Kr, ignoring the steel shielding of the cylinder wall as follows:

$$131\times10^{-6}\ Ci \times \frac{0.0043 \times 1\ rem/hr}{Ci} \times \frac{10^6 \mu rem}{rem} = 0.56\ \frac{\mu rem}{hr}$$

where 0.0043 is the fractional yield of gamma radiation from ^{85}Kr decay. At ½ meter, radiation would be about 1 μrem/hr.

For comparison purposes, ambient background gamma radiation levels range from 5-25 μrem/hr in the United States, with a typical level being about 10 μrem/hr. Variations in background radiation levels in the vicinity of a product cylinder would be barely detectable using typical radiation survey instruments at their low range, but could be readily measured using sensitive instruments such as a pressurized ion chamber. In any event, radiation levels surrounding a single cylinder would not appear to represent a very significant increase above natural background ranging from four to twenty percent of typical U.S. levels. A

[3/] For purposes of calculating radiation levels, a rule of thumb is that, for objects of approximately the size given in this section, at a distance of one meter, the radiation levels can be approximated by assuming that the source is a point source. However, if the cylinder were substantially different in size, or if the source were a bank of 8-10 cylinders, the point source approximation is less valid.

more thorough assessment using actual amounts in multiple cylinders could be somewhat higher.

b. Hypothetical dose due to release of cylinder contents

In the event of venting of a system or a product container, the contents would return to the atmosphere from where it was obtained. If the venting occurred from a location outside the building, such as a rooftop vent, exposure would be negligible due to rapid dispersal. In the event of a significant release to occupied spaces such as a building, radiation exposure can be estimated. Assume for this purpose that the contents of a product cylinder were released quickly into a building space 30 meters x 30 meters x 3 meters high having a ventilation rate of 3 air changes per hour.

Initial ^{85}Kr levels would be

$$\frac{131\ \mu Ci}{30\ m \times 30\ m \times 3m} = 4.8 \times 10^{-2}\ \frac{\mu Ci}{m^3}$$

Krypton levels would dissipate roughly in the following fashion, assuming typical infiltration of fresh air into the space and dilution of the Krypton accordingly:

Time	Fraction of Krypton remaining
20 minutes	1/2
+20 minutes	1/4
+20 minutes	1/8
+20 minutes	1/16
+20 minutes	1/32
+20 minutes	1/64
+20 minutes	1/128

One could calculate the concentration more exactly but that would not be warranted for our purposes. An estimate of the dose received from an exposure of two hours at one-fourth the initial concentration would give an approximate answer. Then one can roughly estimate that the dose due to immersion in the air in the building would be:

For the skin dose:

$$\tfrac{1}{4} \times 4.8 \times 10^{-2}\ \frac{\mu Ci}{m^3} \times \frac{1.8\ rem/yr}{\mu Ci/m^3} \times 10^3\ \frac{mrem}{rem} \times \frac{2\ hr \times 1\ yr}{8760\ hr}$$

$$= 0.004\ mrem;$$

and for the whole body:

$$\frac{1}{4} \times 4.8\times10^{-2} \frac{\mu Ci}{m^3} \times \frac{0.015\ rem/yr}{\mu Ci/m^3} \times 10^3 \frac{mrem}{rem} \times \frac{2\ hr \times 1\ yr}{8760\ hr}$$

$$= 0.00003\ mrem.$$

Both these values represent insignificant doses compared to any limits for members of the public or workers or annual exposures due to natural background radiation.

Additional information on the terms and units used to describe radiation is contained in the attached Appendix.

Historical Agency Approaches to Regulatory Issues

The Nuclear Regulatory Commission regulates commercial applications of source material such as uranium and thorium, special nuclear material such as U235 and plutonium, which are used as fuel in nuclear reactors, and byproduct material. "Byproduct material" is defined in the NRC regulations, 10 C.F.R. § 30.4, as

> "any radioactive material yielded in or made radioactive by exposure to the radiation incident to the process of producing or utilizing special nuclear material."

^{85}Kr is a radioactive product of fissioning of special nuclear fuel. Normally, byproduct material that has been subject to NRC regulation has been obtained directly from the reactor facility located in the United States. In this case, the ^{85}Kr is obtained as an undesired contaminant by separation of Krypton from the ambient atmosphere.

Based on my experience at the agency, the NRC may possibly not want to exercise regulatory authority. For example, NRC does not exercise regulatory authority over naturally occurring radioactive material. Some states do exercise authority over naturally-occurring radioactive material, principally over isotopes such as radium which have been sources of radiation exposure significant enough to warrant regulatory control practices.

NRC exercises regulatory authority over byproduct material by requiring an application for a license to possess and/or to distribute products containing byproduct material. NRC regulations of 10 C.F.R. Part 30 apply. Section 30.70, Schedule

A lists an exempt concentration of $3x10^{-6}$ $\mu Ci/cm^3$[4]; Schedule B an exempt quantity of 100 μCi for ^{85}Kr; and Schedule C lists a value of 6,000,000 curies for requiring an emergency plan in the event of a release. Therefore, while a person possessing less than $3x10^{-6}$ $\mu Ci/cm^3$ or less than 100 μCi does not require a specific license, when a person has materials having radioactivity slightly above these values, in the past, consultation with the NRC has been appropriate to determine the need for a license. Prior to consultation, an assessment of the amount to be possessed should be made.

Sampling and Analyses

^{85}Kr can be analyzed by either a liquid scintillation analysis of emitted beta particles or by gamma spectral analysis. In the beta scintillation method, a known volume of the Krypton gas is dissolved in the liquid scintillating fluid, such as toluene, and counted in the detector. In the gamma counting method, a container such as a small sample cylinder about 4" diameter and 4" long containing the gas is placed in an analyzer and gamma emissions are directly counted. Many organizations could analyze using the direct counting method and many could set up to use the liquid scintillation method, but would need to set up to transfer known volumes of the gas into standard counting vials. One such laboratory is the offsite laboratory of General Public Utilities located outside Harrisburg, Pennsylvania, and another is at Georgia Tech University, near Atlanta. These laboratories are licensed by the NRC or by the state.

For Krypton-air mixtures, the same process could be used. The details of handling the gas and its analysis would need to be worked out in consultation with the laboratory facility. As a general matter of consideration, the concentrations and quantities in samples should be less than the exempt quantities and concentrations of 10 C.F.R. § 30 unless the specific laboratory license authorizes other amounts and concentration.

Based on conversations with the laboratories, the cost of the analysis is approximately $30 per sample, so that the total analytical cost will be small, unless a set-up charge were required.

---

[4] The values in the C.F.R. are listed in microcurie per milliliter (μcu/ml). A milliliter is equal to a cubic centimeter (cm^3). For consistency, we will use cm^3.

Krypton Customers

American Laser Corp
ARC Gas Products
Balzers Tool Coating Inc
Boeing Kent Space Cylinder
Capitol City Welding
Westinghouse Handford Co
Xerox Corp
Conductus
Coulter - Scientific Instrument
Welch Allyn
Agriculture Canada
Eastman Kodak
Extrell Corporation
General Electric Co
George W. Fowler Company
University of Laval
Integrated Systems Assemblies
Lockheed Eng & Mgmt Svcs
Martin Marietta Enrg Sys
NASA Goddard Space
Naval Surface Warfar Center
Neocera, Inc
North American Phillips
Ogden Logistic Service
Pennsylvania State University
Philips Lighting Corp
Reuter Stokes Elect. Inc
Roberts Oxygen Co
S- Cubed
Scott Gross Company
Spectralytics, Inc
Tessera Inc
Tulane University
UC Berkeley
University of Arizona
University of California
University of Delaware
University of Maryland
University of Minnesota
Urie & Blanton
Carnegie Mellon University
College of William and Mary
Soudair
Carleton Technologies, Inc
National Technical Systems
University of Toronto
University of Ottawa
CTF Systems, Inc
Intuco International
Pavillon Comtois
Georgia Institute of Technology

Specialty Gas Department - A5223
7201 Hamilton Blvd
Allentown, PA 18195-1501
(610)481-4911

AIR PRODUCTS

31 January 1996

Dear Customer,

Air Products and Chemicals, Inc. has recently identified a **regulatory** issue surrounding krypton gas which requires your close attention and understanding.

A recent product assessment performed by APCI Safety, Health and Environmental professionals, with the assistance of independent experts, indicates that our krypton gas, which is extracted from the earth's atmosphere, contains low concentrations of a radioactive isotope normally found in the environment, krypton 85.

However, the level of radioactivity found in some of our krypton products is above the activity level the U.S. Department of Transportation (DOT) uses to define a "radioactive material," and, as such, some of these krypton products require special package markings as outlined under Department of Transportation (DOT) regulations found in 49 CFR § 173.421.

With regard to the DOT requirements, we have determined that the DOT regulation requires us to mark (stencil) product cylinders containing krypton with the statement, "radioactive." Effective 1/19/96, all shipments from Air Products and Chemicals, Inc. of krypton gas and krypton gas mixtures containing more than 30% krypton, will be marked in accordance with DOT requirements.

Based on information presently available, we have established that the concentration of krypton 85 isotope in krypton gas is minimal **and presents no personal health hazard to users of our krypton gas products, our employees, or other persons who may come in contact with our krypton gas products in transportation or handling.** Indeed, preliminary measurements by our consultant in our Hometown, Pennsylvania Specialty Gases Products facility and at our Cleveland, Ohio transfill facility, show no detectable levels of radioactivity above background around product cylinders in storage.

In addition, this low level of radioactivity in some of our krypton products brings them within the regulatory authority of the U.S. Nuclear Regulatory Commission (NRC). We have contacted NRC staff to apprise them of this situation and to resolve any questions about the regulatory status of our products. NRC staff have verbally agreed with us - - that the products pose no appreciable health hazard - - and that we should continue normal operations.

ANSWER: We recommend that you consult with your own safety and health professionals to make sure that you have properly evaluated the information we are providing, in light of your own workplace conditions and practices. Based on our assessment of the concentration of radioactivity present in our krypton gas products, there would not be a significant or even measurable dose under normal conditions of use where the krypton gas is contained in processes, products, or other containers. Nor is there an appreciable hazard under conditions where the gas itself would be released. Therefore, no added controls appear warranted.

We have determined that the level of radioactive gas in the cylinders requires, under Department of Transportation (DOT) regulations, that cylinders of the products containing more than approximately 30% krypton gas must be marked (stenciled) "radioactive." Air Products has begun marking its products according to the terms of the DOT standards while we consider approaching the DOT for a waiver from these regulations.

4. QUESTION: Do products and processes using krypton gas require a license to continue operating?

   ANSWER: We are requesting the Nuclear Regulatory Commission (NRC) to waive regulation of krypton operations and products. In the meantime, Air Products has discussed this initially with the NRC staff and they saw no reason to stop our krypton gas operations. We will provide further information following a decision by the NRC.

5. QUESTION: How is krypton obtained and how is it used?

   ANSWER: Pure krypton gas is produced by cryogenic separation from other constituents of air, including oxygen, nitrogen, argon, and xenon. Krypton occurs naturally at a concentration of about one part krypton in a million parts of air; krypton-85 is an equally small fraction of the total krypton present. Krypton gas products are used in many different and important products, including lasers in medicine, high intensity lights, and research.

6. QUESTION: Why has this come to light now; hasn't krypton been used for such purposes for decades?

   ANSWER: Yes the uses of krypton gas go back over twenty years. In the course of an environmental audit, the question was asked - - no one can remember who or why the question was asked - - whether Air Products knew if there was any radioactivity in its krypton products. The company consulted with some knowledgeable individuals, including a radiation expert, to obtain laboratory analyses and assess the significance of any radiation detected. This work will continue until we have resolved all existing ambiguities with the responsible regulatory authorities.