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THE PATTERN OF EXPLOSIVE REACTION BETWEEN URANIUM HEXAFLUORIDE AND HYDROCARBON OILS

Karl E. Rapp

Oak Ridge Gaseous Diffusion Plant

March 21, 1986

OPERATED BY
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FOR THE UNITED STATES
DEPARTMENT OF ENERGY

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The Pattern of Explosive Reaction Between Uranium Hexafluoride and Hydrocarbon Oils

Karl E. Rapp

[Keywords: Explosive Reactions, Uranium Hexafluoride--Impurities--Reactions--Releases--Temperature Effects; Hydrocarbons]

Examination of uranium hexafluoride release incidents occurring over the past three decades of ORGDP experience has identified only four which apparently involved an explosion of a container resulting from reaction between uranium hexafluoride and an impurity. These four incidents exhibit a certain degree of commonality. Each has involved (a) condensed phase uranium hexafluoride, (b) a moderately elevated temperature, (c) a sufficient quantity of uranium hexafluoride for a significant partial pressure to be maintained independently above that which can be consumed by chemical reaction, and (d) an organic liquid (probably hydrocarbon oil) accidentally present in the container as a contaminant.

The purpose of this investigative search was to establish some conditional pattern for these four incidents to which their violent consequences could be attributed. Fortunately, the number of such incidents is relatively small, which emphasizes even more pointedly the unfortunate fact that documentation ranges from thorough to very limited. Documented sources of information are given in the bibliography. Copies of those which are not readily available are contained in six appendices. Descriptively, the incidents are identified chronologically as follows:

<u>1949</u>
This incident of March 7 involved explosion of a laboratory cold trap in which a quantity of UF_6 apparently had been collected. The explosion took place as the trap was being heated preparatory to vapor transferring its accountable contents to a larger trap for condensed UF_6. Material recovered after the release consisted of a black carbonaceous smoke which settled rapidly to give maximum surface readings of 20,000 cpm.[1]

<u>1953</u>
On May 25, personnel were using a hot water bath in K-413 to heat a cold trapping cylinder (300-lb capacity) containing 123 lb of UF_6 preparatory to making a vapor transfer of the contents to a larger cylinder. Shortly after the cylinder was placed in the hot water it ruptured explosively.[2] Analysis revealed carbon and reduced uranium in the residue found at the explosion scene.[3]

<u>1955</u>
On March 10, a type 12A feed cylinder of UF_6 exploded as it was being heated in the vaporization room of K-33 allowing over 500 lb of UF_6 to be released from this and another cylinder. About 100 lb of the released

material was recovered. Analyses of samples of various residues found in the room afterward showed part of the uranium in the reduced state and an elevated carbon content.[4,5]

1975

On September 17, shortly after being filled with liquid UF_6 at K-1423, a 30A cylinder (Nukem-8) suffered detonation which caused both concave ends of the cylinder to bulge. Cracks were developed in both the valve body and the cylinder wall at the opposite end resulting in the release of 18 lb of UF_6. Solid residues found in the cylinder after the unreacted UF_6 had been fed to the gaseous diffusion cascade consisted of β UF_5 containing about 4% U_2F_9 in association with a small amount of fluorinated carbonaceous material.[6] About 200 lb of U were recovered from the residues.

Although the four elements of commonality are not so readily apparent, one would be remiss should he fail to consider a fifth explosive release incident which predated these four. On May 8, 1947 at K-131 during a transfer of liquid UF_6 from a 12A cylinder to one with a capacity of 4500 lb, a piece of heated, flexible metal hose being used for pressure equalization exploded while supposedly in contact with only the vapor phase in a heated cylinder filled with liquid UF_6. Several pounds of UF_6 was released before the cylinder valves could be closed. The investigation which followed the incident revealed evidence that the flexible hose was contaminated with hydrocarbon oil. The presence of a copious residue of reduced uranium fluoride indicated liquid UF_6 may have been involved in the explosive oxidation-reduction reaction[7].

Experimental and Related Incidents

That a significant quantity of an organic contaminant was present and contributed to the explosion is indicated in each of these incidents by the carbonaceous residues. Because its introduction was unintentional, its presence remained unsuspected until the explosion. In the last and most completely documented incident a test was conducted to simulate the Kinney pump failure which occurred during evacuation of the 30A cylinder after a new valve was installed. This test dramatically demonstrated that over 1300 g of hydrocarbon oil could have backed up into the cylinder from the failed pump.[6] Although no such demonstration was conducted to simulate conditions which prevailed before any of the other explosion incidents, the very fact that a hydrocarbon oil pump had been used preparatory to filling each of the containers provided a necessary opportunity for organic contamination of the container.

Several experimental reactions with UF_6 and hydrocarbon oils were conducted relative to two of these incidents. A separate non-explosive release incident was brought to light during this survey and is discussed here because of the insight it provides to the fundamental reaction between UF_6 and hydrocarbon oil.

The experiments performed by A. V. Faloon and the author to which Rhees alludes in his analysis of the residues from the 1953 incident[3] indicated that "reaction between uranium hexafluoride and hydrocarbon oil becomes vigorous at 70-90°C, forming UF_4, carbon, and low molecular weight fluorinated compounds (CF_4, C_2F_6, C_3F_8, C_4F_{10})." These experiments were carried out in a high pressure reactor with liquid hydrocarbon oil and initially condensed (solid) UF_6. The temperature and pressure were observed remotely behind a barricade while heat was applied to the reactor at a constant rate. When an increase in the reaction rate became obvious from the accelerated rates of temperature and pressure rise, the reactor heater was turned off, and water cooling was applied. A mass spectrometer scan of the gaseous products of the reaction indicated complete fluorination of the fragmented hydrocarbon chain. The residue in the reactor consisted of UF_4 and carbon. Had the UF_6 been present in sufficient supply, the reaction could probably have been represented by the following simplified equation:

$$H\text{-}(CH_2)_n\text{-}H + [2(n+1)+x]\ UF_6 \rightarrow [2(n+1)+x]\ UF_4$$

$$+\ F\text{-}(CF_2)_m\text{-}F + 2(n+1)\ HF$$

where x represents the number of C-C bonds broken and fluorinated during the reaction to produce the mixture of low molecular weight fluorocarbons represented by $F\text{-}(CF_2)_m\text{-}F$. Where excess UF_6 is involved the reduced uranium most probably would consist of some UF_5, U_2F_9 and/or U_4F_{17} in amounts stoichiometrically equivalent to the UF_4 shown.

On December 29, 1974 a K-33 electrical transformer and substation failure occurred. In connection with the subsequent investigation of the incident a sluggishly operating seal exhaust pump was discovered.[8] Although the pump was not responsible for the electrical fault, the related analytical findings seem to confirm the smooth reaction projected above. A comparatively high seal leak rate apparently escaped detection until the traps protecting the hydrocarbon oil pumps became saturated with UF_6. The gas then passed unchecked into the oil. There it was intimately mixed by the pump action and reacted smoothly at the normally elevated operating temperature of the pump. Continued unobserved reaction was favored by the constant removal of gaseous reaction products <u>via</u> the pump exhaust to the roof.

By way of contrast, negligible reaction was observed in the two laboratory studies described in the analytical results section of the 1975 release incident report.[6] In these experiments UF_6 <u>vapor</u> at a maximum pressure of 500 torr in contact with the surface of hydrocarbon oil at 200°F was insufficient to initiate a sustained reaction even though the oil was thinly distributed to expose a relatively high surface area to the gas.

Conclusions and Recommendations

In each of the four explosive release incidents the handling of UF_6 as a condensed phase was intentional and in three of them the application was a necessary part of the operation being performed. The container involved in the fourth incident would normally have been heated at a later date had detonation not occurred when it did. In this sense the fourth explosive release fortunately took place prematurely, where the facilities and skill to dispose of the unreacted UF_6 safely were more readily available than might have been the case later. The only condition prevailing in all these incidents which was neither intentional nor a necessary part of the operation was the introduction of hydrocarbon oil. It is significant that recognition of the explosion potential demonstrated in three or four incidents occurring over an 8-year period resulted in the development of precautionary measures which proved effective for the next 20 years. Obviously the scrupulous exclusion of such contamination in the future offers the most reliable way of avoiding a recurrence of these hazardous and potentially costly incidents. In addition to the normal care exercised to maintain condensed UF_6 containers free of contamination, it is recommended that the following precautions be taken irrespective of the scale of the operation:

(A) A hydrocarbon oil pump used to evacuate a container prior to the admission of UF_6 should be connected to the container through a cold trap of sufficient volume that the entire hydrocarbon oil inventory of the pump can be contained. A cold trap is specified because it will prevent back diffusion of oil vapor to the container. An uncooled trap may suffice when only a rapid pump down operation is involved.

(B) In any transfer system subject to a possible transfer of UF_6 vapor which can be condensed in the evacuation equipment, a means of evacuation should be employed which avoids use of hydrocarbon oil or other reactant fluid, e.g., an air ejector or a Krytox filled mechanical vacuum pump.

(C) Whenever and wherever the possibility exists that condensed UF_6 may have inadvertently become contaminated with a reactive material such as hydrocarbon oil, a vapor phase transfer of the UF_6 should be made at room temperature from the potentially contaminated container.

Karl E. Rapp

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Appendix A

CARBIDE AND CARBON CHEMICALS CORP.
OAK RIDGE, TENNESSEE

FOREMAN'S ACCIDENT REPORT

EMPLOYEE'S NAME ______ PAYROLL NUMBER ______ AGE ______ SEX ______ RACE ______

OCCUPATION Chemist DIVISION Laboratory DEPARTMENT Works Lab

DATE OF ACCIDENT 3-7-49 TIME 3:29 A.M. P.M. BUILDING OR LOCATION K-1004-A-19

DESCRIPTION OF ACCIDENT See attachments.

CAUSE OF ACCIDENT 75 percent 3-1
25 percent 3-2

WHAT HAS BEEN DONE TO PREVENT A RECURRENCE? See attachments.

TYPE OF INJURY Exposure to UF_6, uranium bearing dusts, burns and abrasion on face and
PART OF BODY AFFECTED left forearm and inflammation of right eye.

Date 3-11-49 ______ Foreman

This Report to be submitted for all Accidents regardless of extent of Injury and for all Occupational Diseases.

WCX-103-5
Revised 11-1-46

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FOREMAN'S ACCIDENT REPORT

EXPLOSION AND MATERIAL RELEASE

K-1004-A Room 19 March 7, 1949

Description of Accident

had been sampling on the system shown in Figure 1. During the sampling the system had been evacuating sluggishly. Thinking that trap 2 was getting full of UF_6, he closed valve 9, removed the dryice-trichlorethylene slush, and started warming the trap with a pyrofax-oxygen torch to transfer the UF_6 to trap 1. He had started warming the trap at the top and was about halfway to the bottom when it exploded with a flash and a loud noise.

was standing about two feet from the explosion and was covered from his waist up with a sooty material. He incurred slight thermal burns on the right forearm and his face and appeared to have some particles imbedded in his skin. His eyes were protected from the full force of the blast by safety glasses, but some dirt did go around the glasses and caused a slight inflammation of his right eye.

The tube part of the trap blew loose from the top and was driven downward with considerable force. It appeared to have stretched in diameter and then to have buckled as it struck a four legged stand that had been used to support the dewar of cooling medium. It was found against the wall as shown in Fig. 2.

The legs of the dewar stand were buckled. One leg which was resting on a piece of half inch thick plywood was driven completely through the plywood, cutting out a plug.

A heavy black dust settled rapidly over two thirds of the room with maximum surface readings of 20,000 c.p.m. The material being sampled was approximately normal. The dust was readily cleaned up with damp mops and sponges. Surfaces showed no count after cleaning.

Three other people were in the room at the time as shown on Figure 2. None of these suffered any injury. One had to pass through the dust and smoke as he made his way to the front door and may have been exposed. left immediately through the front door and were not exposed.

An electrician, was in the attic of the building and said he passed through some smoke as he made his way to the trap door exit. Another electrician, , was in the elevator pit in the basement.

The evacuation alarm was sounded within ten seconds after the explosion at 3:29 PM. donned an assault mask immediately, covered the floor vents that exhaust air into the basement and opened some windows.

Air samples were taken in the basement, room 70, and in room 19 before anyone reentered without a mask. These samples taken 30-40 minutes after the explosion showed the air contamination to be below tolerance.

Causes:

1. The black sooty dust that covered the room after the explosion indicates that an incomplete combustion of pump oil occurred. Pump oil could have diffused into the trap while the pump was running or could have been sucked into the trap after the pump was stopped if someone had failed to break the vacuum by opening valve 10 in Figure 1.

2. The reaction probably took place between the pump oil and fluorine or some compound of fluorine. The material being sampled was UF_6 manufactured at K-1301. It is known that this material contains fluorine, HF and possibly chromium oxyfluoride. A sample taken from one of the cylinders previous to the explosion was about 50% liquid at room temperature. In vapor sampling such material these volatile compounds are present in relatively large amounts in the first gas that comes off.

3. Heating the trap probably started the reaction. However, the temperature at which such a reaction would start is not known although it is known that hydrocarbons and fluorine may react violently at liquid nitrogen temperature.

Remedies:

The following precautions are under consideration:

1. Find some fool-proof way to prevent oil from getting into the trap.
2. Use a fluorinated oil.
3. Install shielding around equipment.
4. Purify fluorinated material before sampling.
5. Liquid sample these cylinders.

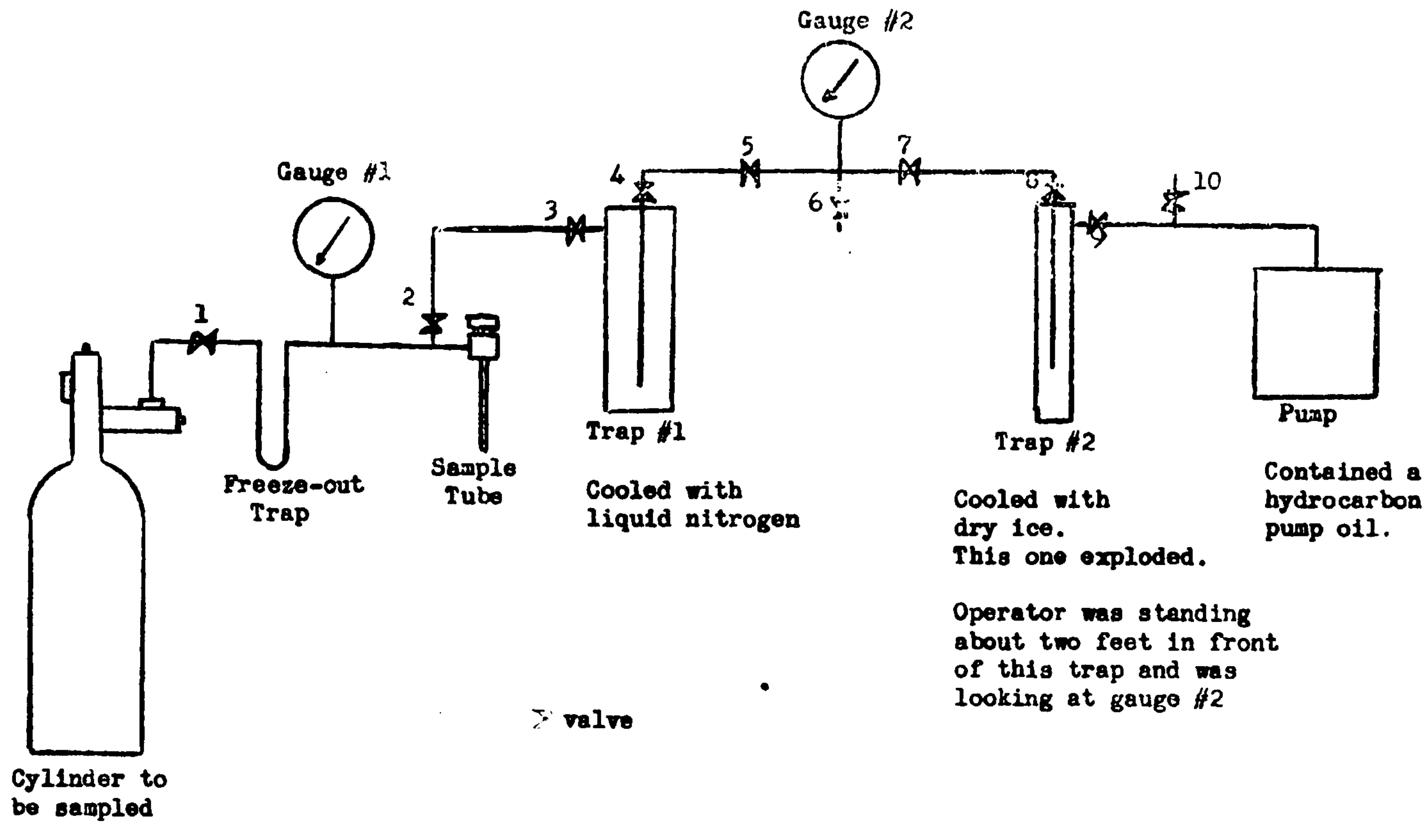
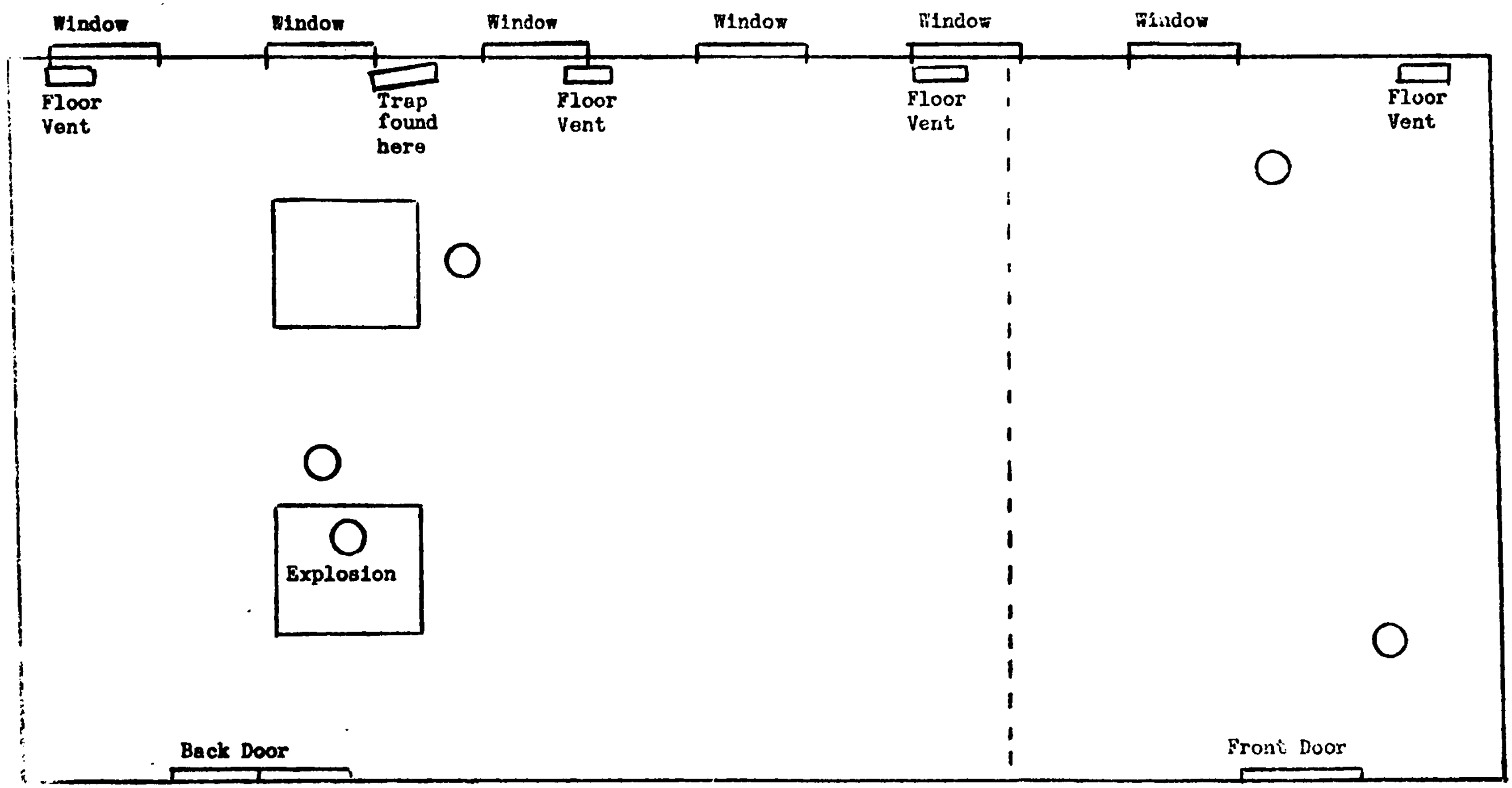


DIAGRAM OF SAMPLING SYSTEM ON WHICH EXPLOSION OCCURRED

Figure 1

3-10-49



Scale: ¼" = 1'

DIAGRAM OF ROOM 19, K-1004-A SHOWING LOCATION OF PERSONNEL AT TIME OF EXPLOSION
All surfaces to left of dotted line were contaminated

Figure 2 3-10-49

Appendix B

INVESTIGATING COMMITTEE REPORT

OF EXPLOSION AT K-25

PRD-2

KS-379

Description of Damaged Property: One cold-trap type cylinder, capacity 300 lb. UF_6 at 300°F., completely destroyed.

End of water bath, 3 ft. x 4 ft. x 5 ft., knocked off.

One wooden door knocked off its hinges.

Glass in one door removed and door itself damaged.

One set of chemical balances demolished.

Damage to miscellaneous measuring instruments.

Step knocked out of expanded steel stairs and other damage done to stairs.

Hole broken in cyclone fencing.

Five window frames demolished.

Miscellaneous damage done to piping and interior walls of building.

Amount of Material Released: 123 lb. of normal UF_6.

Extent of Damage to Government Property: Estimated $2,650.

Time of Incident: 11:45 a.m., May 25, 1953.

Location of Incident: Building K-413, Carbide and Carbon Chemicals Company, K-25 Plant, Oak Ridge, Tennessee.

Description of Incident: A cylinder, presumably containing only UF_6, was placed in a hot water bath for the purpose of transferring its contents to a larger container. A few moments later, as 2 employees were connecting it to the system, they noted that the cylinder wall was expanding and ran from the building. As they reached the door, a violent explosion occurred which ruptured the cylinder, blew out the building windows, and wrecked items of equipment in the room. Other than a ruptured eardrum sustained by 1 of the employees, injuries were confined to cuts and bruises but it was necessary to remove small imbedded particles from both men. A third employee working outside the building received a cut on his head from flying debris.

Findings:

1. The contents of several small cylinders which had been in storage since having been obtained from various locations throughout the plant over an extended period of time, were being combined in 1 large cylinder. The transfer was accomplished in the normal manner of vaporizing the UF_6 by heating the small cylinder, passing the UF_6 through a condenser, and then freezing it out again in the larger unit.
2. Ten cylinders of the same type as the one which exploded had previously been emptied in this manner.
3. According to the statements of the employees concerned as well as other evidence, the events leading up to the accident were as follows:

   a. This cylinder was the second of 2 such cylinders placed in the hot water bath.
   b. The first cylinder had not been connected to the transfer manifold, it being normal practice to place both cylinders in the bath before connecting either one.
   c. The employees were connecting the second cylinder to the manifold when they heard a small internal explosion and noted that the cylinder had expanded sufficiently to rise to the surface of the water.
   d. The 2 employees had reached the door and turned to observe the cylinder when the principal explosion occurred. Although they were knocked to the ground, they escaped from the building unaided.

4. A third employee was working about 30 ft. from the outside wall of the building. He heard the explosion and simultaneously was hit by flying debris.
5. The violence of the explosion is attested by the attached photographs which are identified as follows:

   a. Photograph No. 1. Outside of the building. The third employee was working at a point beyond the lower left edge of the photograph.
   b. Photograph No. 2. Broken windows in the interior of the building, taken from the overhead pipe gallery.
   c. Photographs Nos. 3 and 4. General views of room.
   d. Photograph No. 5. Damage done to stairway by piece of metal. Metal had broken a hole in a length of cyclone fencing before striking these stairs which were about 30 ft. from the heating bath.
   e. Photograph No. 6. Largest piece of cylinder found; it had looped itself in the insulated piping as shown.
   f. Photograph No. 7. Damage done to transfer piping. The feed bath is also shown; the cylinder which did not explode was immediately frozen down with dry ice.

6. The water in the feed bath was at a temperature of about 200°F.
7. The history of the cylinder in the plant is as follows:

   a. Prior to 1951, it was used for miscellaneous UF_6 trapping in the cascade.
   b. In September, 1951, the cylinder was decontaminated and a revised valve arrangement was welded to it.
   c. On October 1, 1951, it received a hydrostatic test at 400 psig. and an air test at 100 psig.
   d. After being stored, it was sent to the Barrier Pilot Plant in K-1401 on June 11, 1952, and was installed in a freeze-out system there on July 17, 1952.
   e. In service, the cylinder was normally kept at a temperature of about -30°F. in a mechanically refrigerated system. At one time during its use, the mechanical refrigeration system failed, but the cylinder had been valved from the remainder of the system at the time and the system temperature had been reduced with dry ice.
   f. A Beach-Russ pump using hydrocarbon oil was a part of the freeze-out system; however, a cold trap was installed between the pump and this particular cylinder.
   g. Part of the time that this cylinder was in service, it was used as a part of a system separating freon-114 and UF_6.
   h. On August 29, 1952, the cylinder was removed from the system and returned to storage with approximately 125 lb. of UF_6 reported as being contained therein.
   i. On April 28, 1953, this cylinder was one of more than a score sent to the K-413 Building for transfer of their contents to a large cylinder. This transfer procedure was also used as a part of experiments to determine the heating and cooling cycle of UF_6 in these particular containers.
   j. The transfer started on May 21, and 10 cylinders had been emptied before this unit was placed in the system.

8. The cylinder, made of 1/4-in. monel, had a rated capacity of 300 lb. of UF_6 at 300°F.
9. Calculations indicate that a pressure of approximately 1,250 psig. inside the cylinder would be necessary to produce the rupture observed.
10. Analysis of the material spread throughout the building indicated that most of the uranium found was in the tetravalent state, this indicating strong reduction of the originally hexavalent uranium. In addition, significant amounts of carbon and iron were found.
11. Although the interior of the building was heavily contaminated, no significant problem from contamination was noted outside.

Conclusions:

The committee could reach no definite conclusion of the cause of the explosion other than that it resulted from the reaction of UF_6 and some unknown substance. It is suspected that this substance was hydrocarbon oil which had gotten into the cylinder in some way.

Recommendations:

Although it is obviously difficult to establish procedures for preventing similar incidents when the cause of the accident in question is unknown and no significant operating faults are apparent, the implementation of the following recommendations of the investigating committee appears to encompass the major practicable actions which the plant should take in attempting to prevent similar occurrences in the future:

1. In identifying the contents of UF_6 cylinders sent to storage, employees should list possible contaminants.
2. Permanent barricaded facilities should be established for transfer or sampling operations and their use should be specified for those cases where the possibility of a dangerous reaction is suspected or the employees concerned are unfamiliar with the properties of the materials being handled.
3. Locations where miscellaneous sampling throughout the plant is done should be reduced and sampling operations thus be more centralized.
4. A thorough investigation, both of the literature and by experiment if necessary, should be made of the potential explosion hazards of mixtures of materials available at K-25.
5. All systems used to fill cylinders with UF_6 should use fluorocarbon oil in their vacuum pumps rather than hydrocarbon oil.

INVESTIGATING COMMITTEE

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J. W. Arendt, Member, SF-Materials Control Supervisor, Production Division

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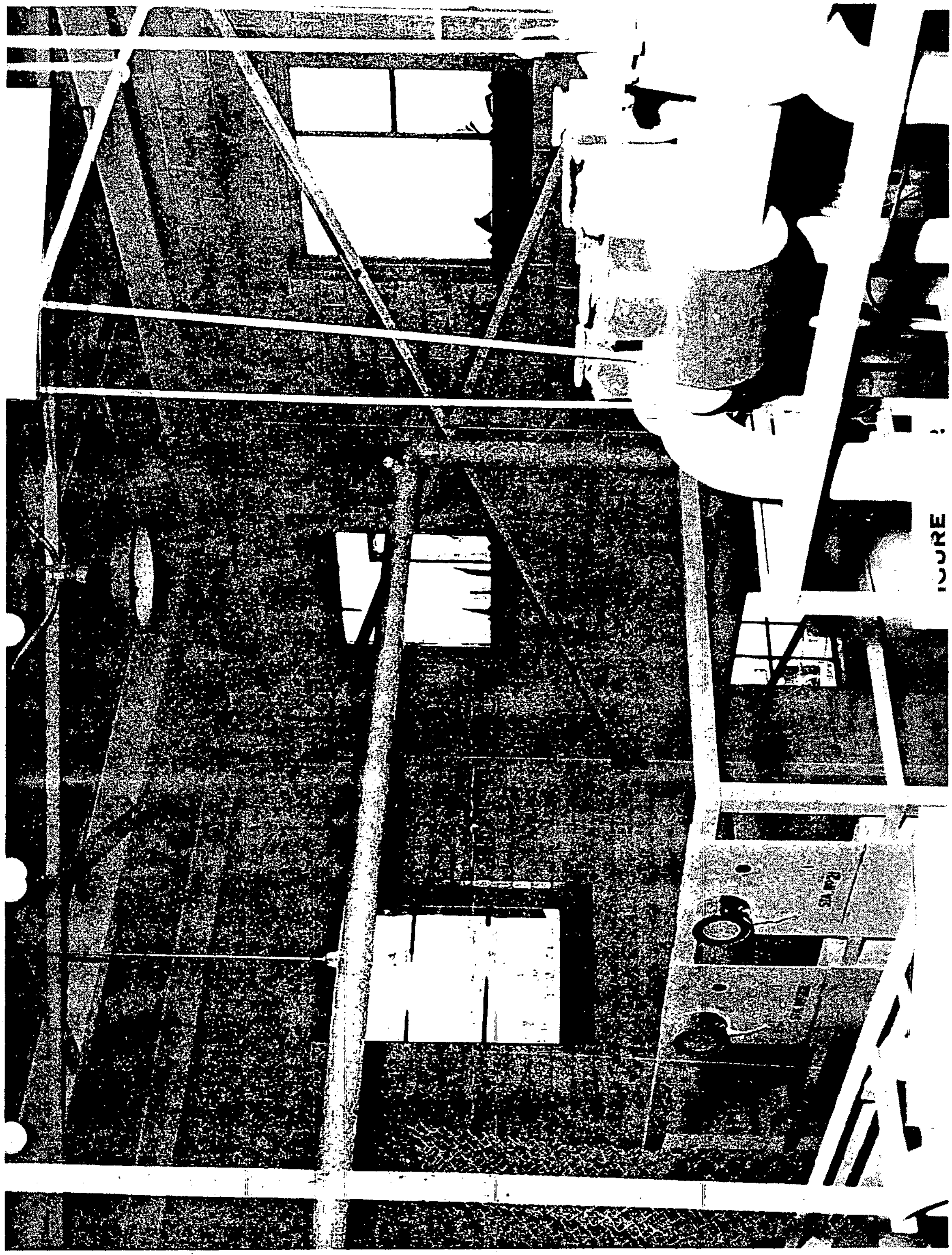
A. S. Sabin, Member, Associate Development Engineer, Laboratory Division

Hugh F. Henry

H. F. Henry, Member, Safety and Radiation Hazards Department Head, Safety and Protection Division

H. F. Henry:lja
June 9, 1953



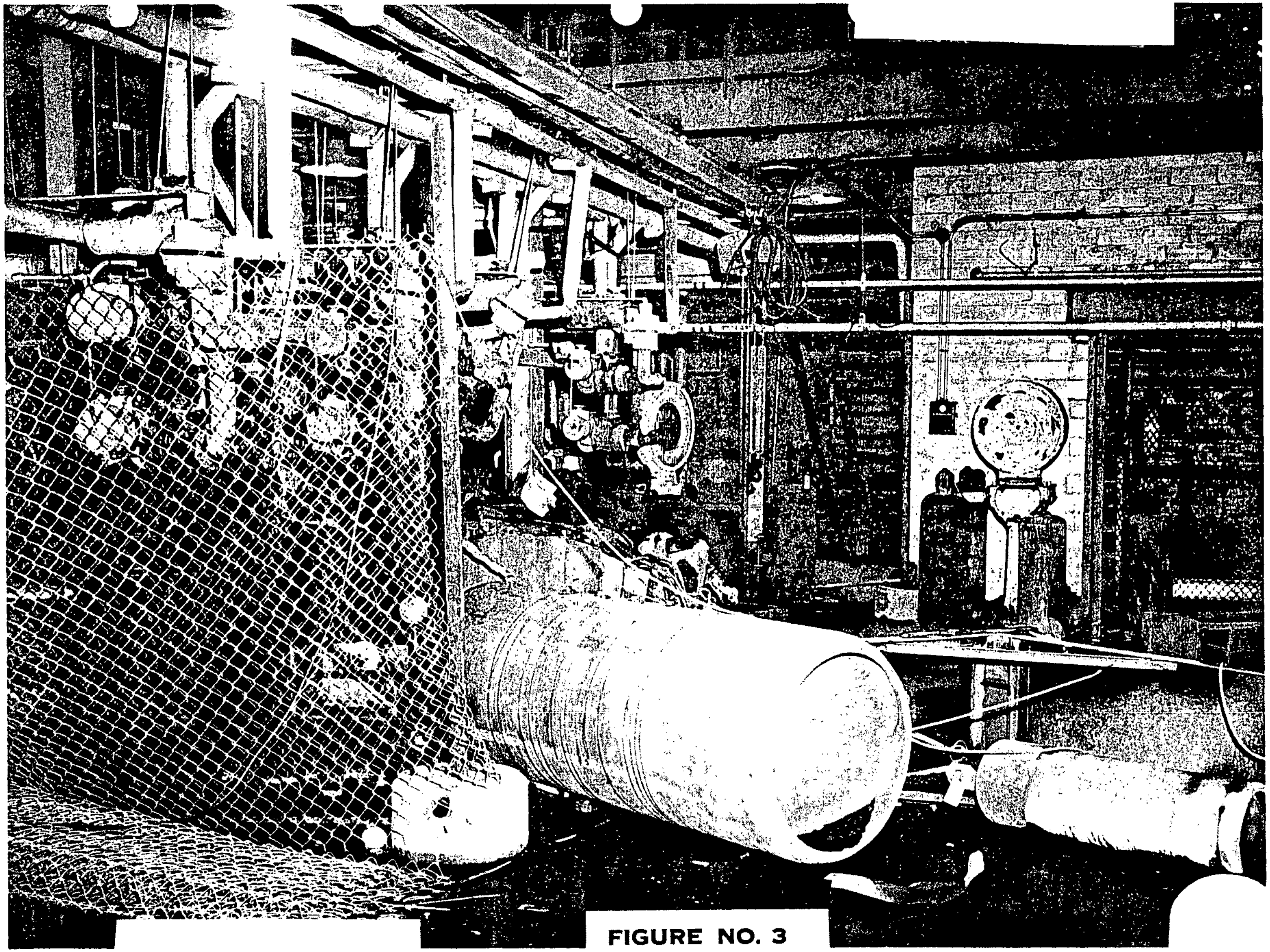
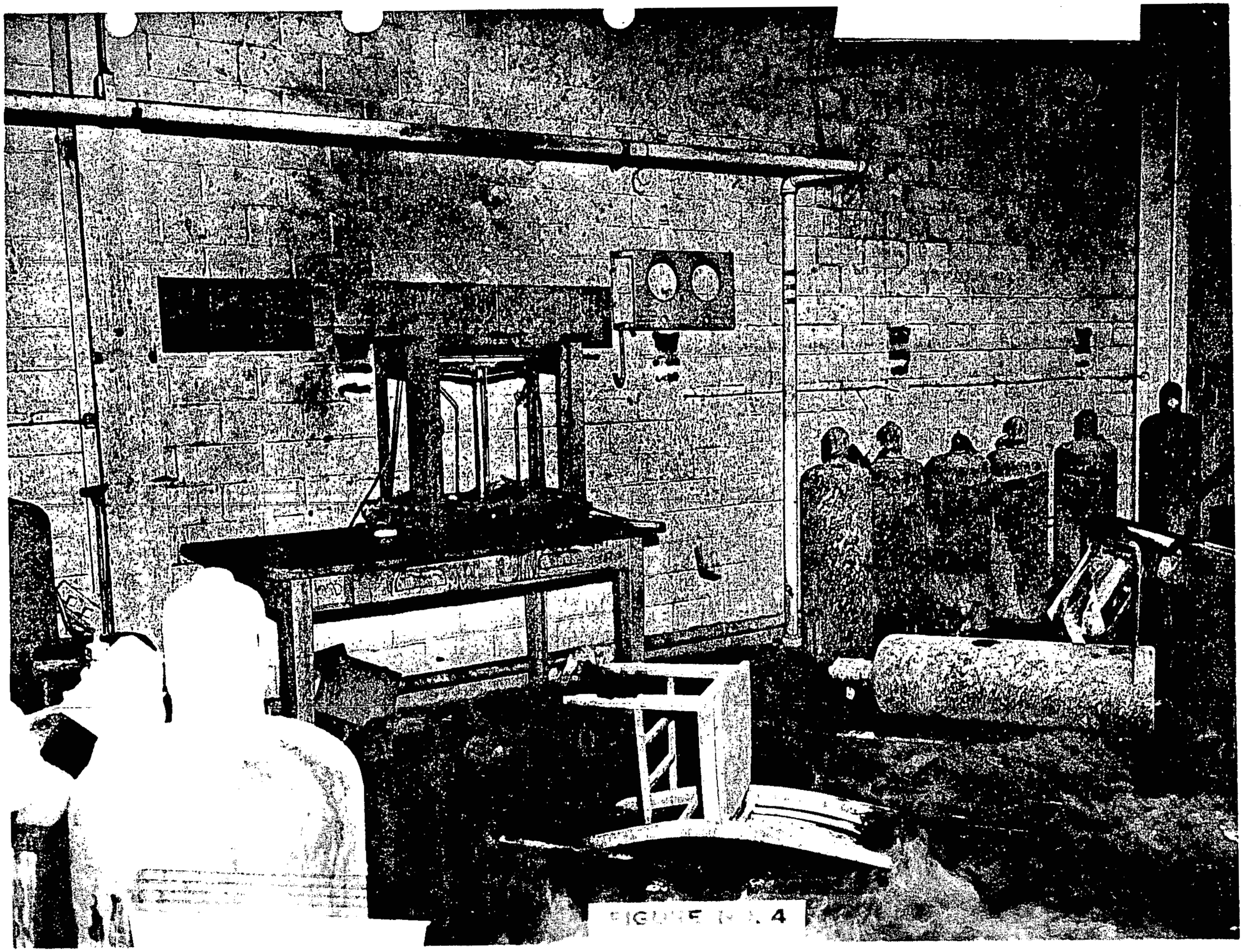


FIGURE NO. 3



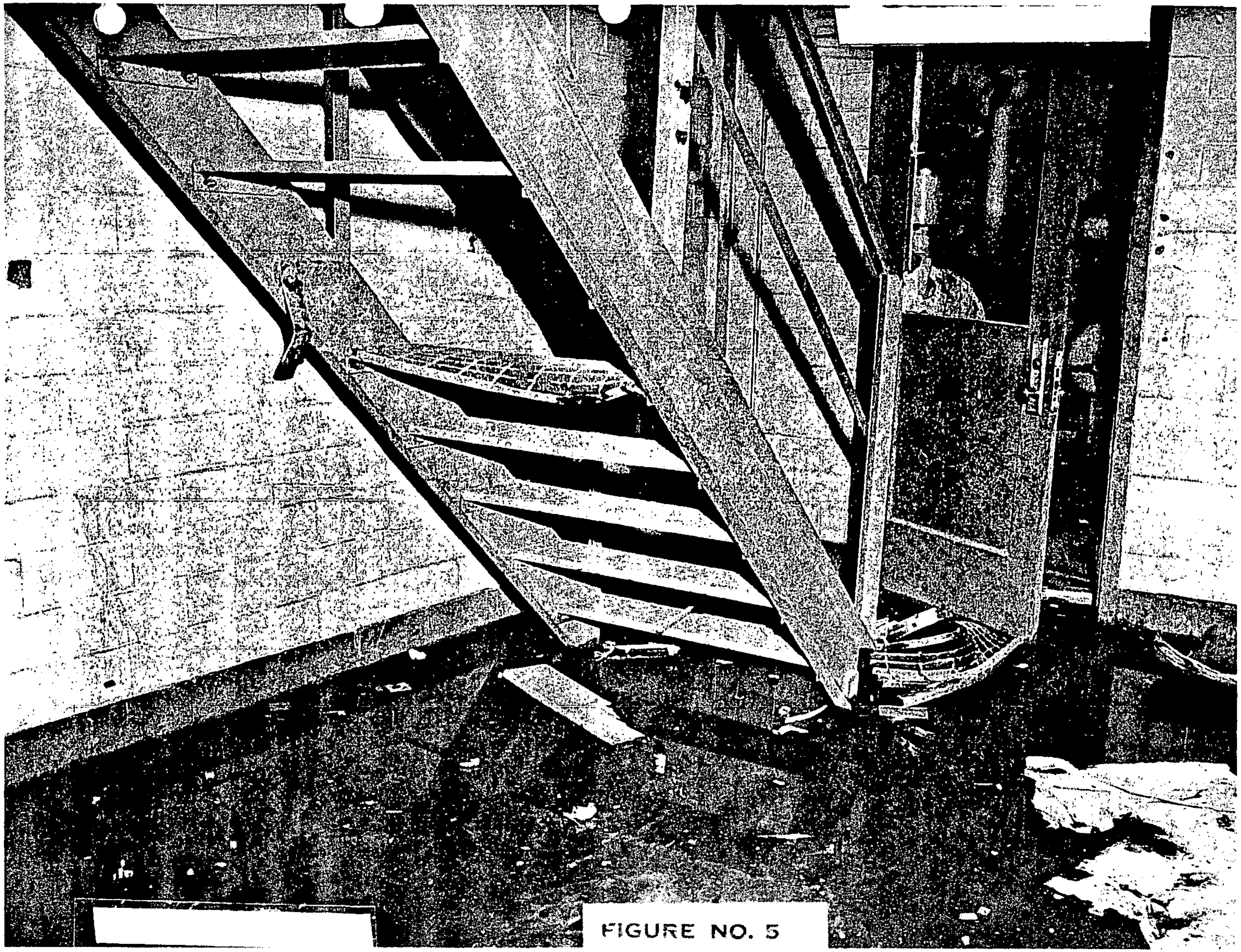


FIGURE NO. 5

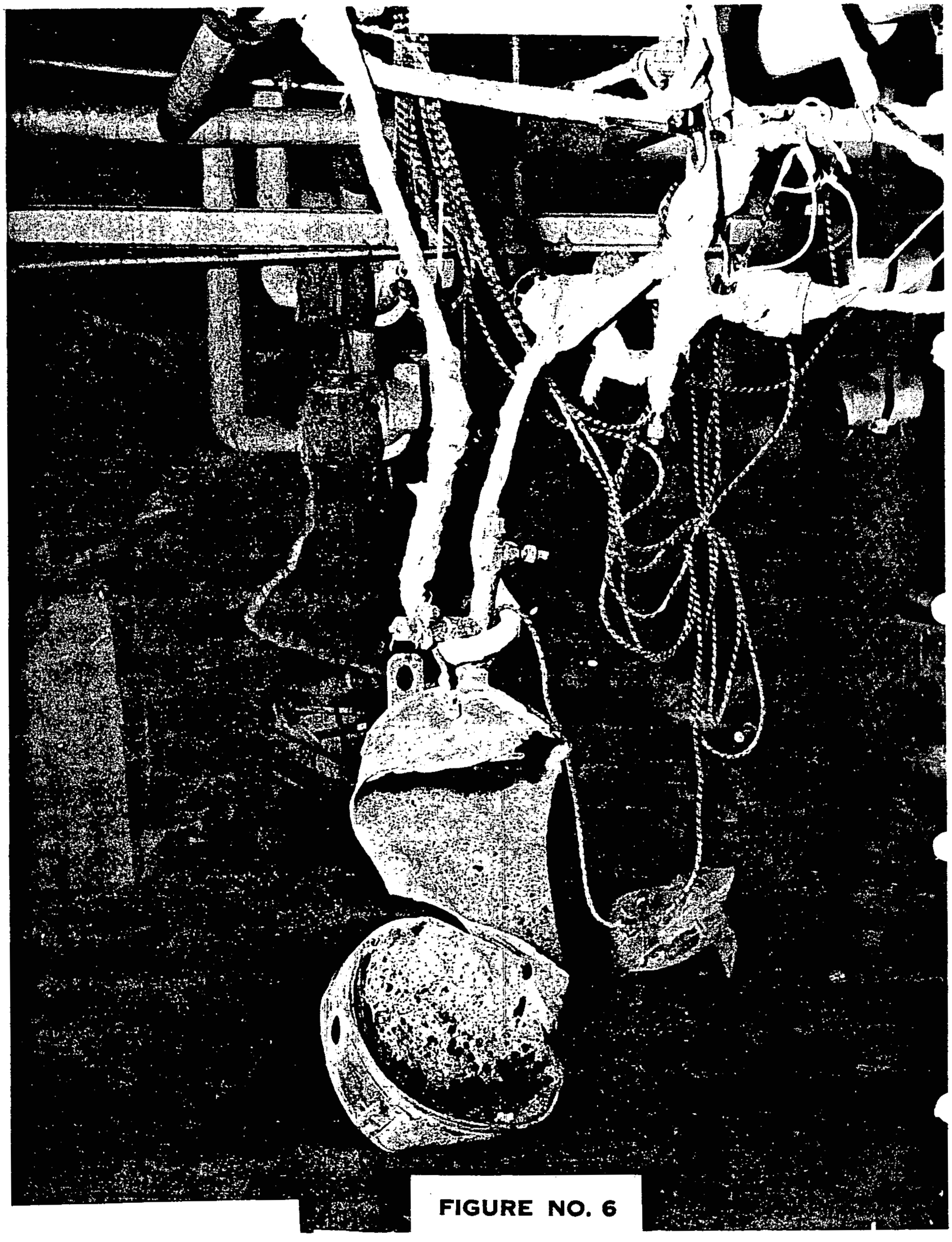
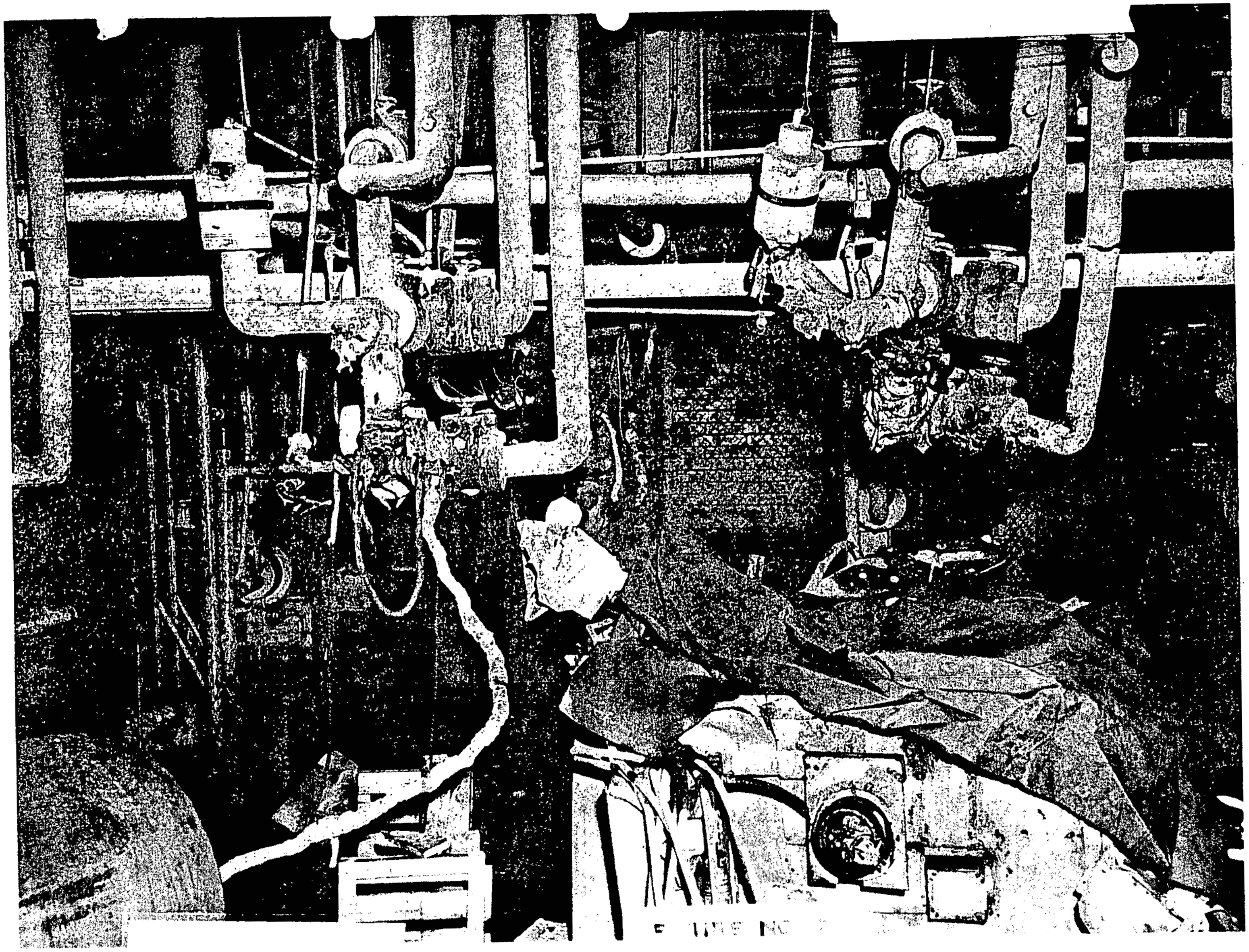


FIGURE NO. 6



Appendix C

INTER-COMPANY CORRESPONDENCE

(INSERT NAME) COMPANY CARBIDE AND CARBON CHEMICALS COMPANY LOCATION Post Office Box P OAK RIDGE, TENN.

TO Mr. M. F. Schwenn
LOCATION K-303-8

DATE June 9, 1953
ANSWERING LETTER DATE

ATTENTION
COPY TO
Mr. J. W. Arendt
Mr. J. C. Barton
Dr. A. E. Cameron
Mr. R. H. Dyer
Mr. I. C. Flanders
Dr. H. F. Henry
Mr. W. B. Humes
Mr. A. P. Huber
Dr. F. W. Hurd
Mr. E. C. Johnson
Mr. R. G. Jordan
Mr. D. M. Lang
Mr. R. W. Levin
Mr. C. H. Mahoney
Mr. J. A. Marshall
Mr. J. P. Murray
Mr. J. A. Parsons
Dr. R. C. Rhees
Mr. W. L. Richardson
Mr. R. D. Shaffer
Mr. M. Schussler
Mr. H. G. P. Snyder
Mr. S. S. Stief
Mr. B. H. Thompson
Laboratory Central Files (K25RC)

SUBJECT Analysis of Residue from Cylinder Explosion in K-413

KLI-2310

The grey powder formed by the explosion of a cylinder containing uranium hexafluoride in K-413 has been analyzed with the hope of securing information concerning the cause of the explosion. The following results were obtained:

Chemical Analysis, %	
Reduced uranium (U^{+4})	57.7
Soluble uranium (0.1N HCl soln.)	4.7
Total uranium	61.4
Total carbon	2.1
Total fluoride	20.4
Chloride	none found
Iron	3.1
Nicke	[illegible].0

Mr. M. F. Schwenn -2- June 9, 1953

Spectrographic Analysis, %

Al	0.1
Ca	0.5
Cu	0.1
Fe	5.
Mg	0.2
Mn	0.1
Si	1.
U	Strong

X-ray analysis showed the sample to be principally UF_4.

The history of the cylinder and the nature of the explosion indicate that the reaction between UF_6 and the reducing agent is negligible at ordinary storage temperatures (25-35° C.), yet becomes violent at temperatures attainable in a water bath. Experiments performed by A. V. Falcon and K. E. Rapp showed that the reaction between uranium hexafluoride and hydrocarbon oil becomes vigorous at 70-90° C., forming UF_4, carbon, and low molecular weight fluorinated carbon compounds (CF_4, C_2F_6, C_3F_8, C_4F_{10}).

The findings of the laboratory strongly indicate that the cylinder which exploded contained hydrocarbon oil as well as UF_6.

We understand that precautions are being taken to greatly decrease the possibility of getting pump oil into cylinders which contain uranium hexafluoride.

R. C. Rhees
R. C. Rhees

RCR:ae

Special Analysis Laboratory
Works Laboratory Department
Laboratory Division

Appendix D

K5-478

CARBIDE AND CARBON CHEMICALS COMPANY

A DIVISION OF UNION CARBIDE AND CARBON CORPORATION

UCC

POST OFFICE BOX P

OAK RIDGE, TENNESSEE

March 18, 1955

United States Atomic Energy Commission
Post Office Box E
Oak Ridge, Tennessee

Attention: Mr. Ray C. Armstrong, Director, Production Division

Gentlemen:

Report of Explosion at K-25

The attached report of the formal investigation of an explosion occurring while a cylinder was being heated to feed its contents to the K-25 cascade has been prepared in accordance with Bulletin OR-SFP-5 (Serial No. 88). The investigating committee was composed of H. G. P. Snyder, J. A. Parsons, and L. L. Anthony of the Production Division, E. C. Johnson of the Technical Division, and H. F. Henry of the Safety and Protection Division. Action is being taken upon the recommendations of the committee which appears to encompass the major practicable steps for the prevention of a similar incident in the future.

Very truly yours,

CARBIDE AND CARBON CHEMICALS COMPANY

A P Huber

A. P. Huber, K-25 Plant Superintendent

HFH:mh:ved

Attachment

cc: Mr. C. E. Center
Mr. L. B. Emlet
Mr. W. L. Richardson
Mr. M. F. Schwenn
Safety Department - K25RC ✓

INVESTIGATING COMMITTEE REPORT

OF AN EXPLOSION AT K-25

KS-478

Description of Damaged Property:	One feed furnace, demolished. Minor damage to another feed furnace. Two platform scales heavily damaged. One 12" I.D. x 40" feed cylinder destroyed. Miscellaneous damage to lighting system.
Extent of Damage to Government Property:	$5800
Amount of Material Released: *	547 lb. of normal UF_6 maximum; of this, it is estimated that over 100 lb. will be recovered.
Value of Materials Lost: *	$5000
Time of Incident:	10:40 P.M., March 10, 1955
Location of Incident:	Feed Vaporization Room in Building K-902-5, Carbide and Carbon Chemicals Company, K-25 Plant, Oak Ridge, Tennessee

Description of Incident:

While a partially emptied cylinder from which UF_6 had been fed to the cascade was cooling down, it violently exploded without warning, severely damaging nearby equipment and releasing its contents to the atmosphere. Although there were 5 employees in the room at the time of the explosion, none were injured in any way, either by flying debris or by the UF_6 released. A previous release of material from a similar cylinder in another furnace had occurred at 4:03 P.M. of the same day in the same room when a connection suddenly ruptured during the normal feeding cycle.

Findings:

1. Both the cylinder which exploded and the one from which a material release had occurred earlier had been placed in the vaporization furnaces earlier in the day, and, after normal handling, were valved into the cascade for feeding to the cascade at about 2:00 P.M. during the afternoon.

2. As a result of the material release which occurred at 4:03 P.M. and which was quickly brought under control by the use of dry ice, it was decided to turn off the furnaces, allow the second cylinder to cool down, and then to remove it from the feed bath; however,

* These figures apply both to this particular release and a previous release described in the report.

the cylinder connection to the cascade was left open while it was cooling. Thus, when this cylinder exploded, it had been cooling and venting for over 5 hours.

3. At the time of the explosion, the building operator was in the feed room along with 4 other employees who were cleaning up the area contaminated by the earlier release. No one recalls any suspicious circumstance which would have led him to believe the feed operation was abnormal in any way prior to the explosion.

4. None of the employees were struck by debris, and, despite the heavy yellowish "fog" which almost immediately filled the room, all quickly left the room.

5. The violence of the explosion is indicated by the photographs attached. No. 1 shows the feed bath shortly after the explosion where a similar undamaged one may be noted at the side of the photograph. No. 2 shows the remains of the cylinder compared to a similar undamaged one.

6. Pertinent items in the history of the cylinder are as follows:

   a. Both this cylinder and the one from which the earlier material release had occurred were units of a group of 33 similar cylinders from the K-1401 Barrier Pilot Plant, one of which had exploded on May 25, 1953, after 10 had been successfully emptied. (See KS-379, attached to a letter from Mr. A. P. Huber to Mr. R. C. Armstrong dated June 24, 1953.)

   b. Since the previous incident, all of these cylinders had been stored pending a final decision on the disposition of the group.

   c. As a result of a decision to reduce the inventory of stored UF_6 (approximately 300 cylinders) in the plant, the 2 cylinders concerned were inadvertently included in the group which was selected for emptying.

   d. Although adequate records of cylinder history were maintained, these records were not traced beyond the past year, and the significance of this pair of cylinders escaped detection.

   e. The potential hazards inherent in handling cylinders of this group were not identified except by the SF transfer record noted above.

7. Since it has been suspected that the previous explosion of May 25, 1953, was the result of hydrocarbon oil being mixed with the UF_6, experiments had been initiated to indicate the explosivity of such mixtures, and these had indicated that they would explode at temperatures in the range of 70° - 90°C. At the time of this explosion, it is estimated that at least some of the contents of the cylinder were probably well within this range.

8. As a result of the previous incident, the following steps had been taken in accord with the recommendations of the investigating committee and their later modifications:

   a. Standard Reference Information had been prepared and distributed on practically all of the potentially hazardous chemicals at K-25.

   b. A barricaded facility had been provided for UF_6 transfer operations; however, the committee doubts if the present facility would have withstood an explosion as violent as the one involved in this instance.

   c. A review of vacuum pumps used in UF_6 transfer systems was made and, where practicable, fluorocarbon oil was specified for use in those not already using it.

   d. The cylinders immediately concerned in the original explosion were removed to a separate storage location; however, as indicated above, they were not so marked that immediate identification of their hazards would be possible.

Conclusions:

Although the results of the explosion made positive identification of its cause difficult, it was the rather definite opinion of the committee that it did result from hydrocarbon oil having gotten into the cylinder of UF_6 during its usage in the K-1401 Barrier Pilot Plant.

Recommendations:

In addition to continued follow-up on the recommendations made at the time of the previous incident, the investigating committee suggests that:

1. A more positive method for immediate identification of container contents with specific attention given to potentially hazardous materials be developed and employed.

2. Pending a laboratory investigation to develop a method of safely disposing of cylinders from the involved facility, the subject cylinders should be segregated and individually identified until the ultimate method of disposal can be formulated.

3. It is recommended that a review be made of the adequacy of the existing sampling facility to determine whether the present barricades can be strengthened to provide adequate personnel protection in the event of an incident similar to this one.

4. Additional experimental investigation of the explosive properties of materials fed to the K-25 cascade be made where the advisability of such action is indicated.

H. F. Henry:mh:ved
3-18-55

Appendix E

INTER-COMPANY CORRESPONDENCE

(INSERT NAME) COMPANY CARBIDE AND CARBON CHEMICALS COMPANY LOCATION Post Office Box P OAK RIDGE, TENN.

TO Mr. M. F. Schwenn
LOCATION K-303-8

DATE April 6, 1955

ANSWERING LETTER DATE

ATTENTION

COPY TO Mr. A. P. Huber
Production & Chemicals Divisions
Central File
Mr. R. H. Dyer
Mr. J. A. Marshall
Mr. J. A. Parsons
Mr. R. D. Shaffer
Mr. H. G. P. Snyder
Mr. E. O. Sternberg
Mr. S. S. Stief
Mr. B. H. Thompson
Safety and Protection Division
Central File
Dr. H. F. Henry
Mr. W. L. Richardson
Technical Division, K-1005 File
Miss M. E. Adams (K25RC)✓
Mr. J. C. Barton
Mr. I. C. Flanders
Mr. E. C. Johnson
Mr. T. Kwasnoski
Mr. D. M. Lang
Mr. C. H. Mahoney
Mr. J. T. Mottern
Dr. R. C. Rhees
Mr. M. Schussler
Uranium Control Department
Central File
Mr. J. W. Arendt

SUBJECT Analysis of Residue from Cylinder Explosion in K-33

KLI-3451

Four samples of material collected from the K-33 vaporization room after the March 10th explosion of a cylinder containing uranium hexafluoride have been analyzed in an attempt to determine the cause of the explosion. Three different types of material were collected. The first was a finely divided, grey powder removed from equipment adjacent to the point of explosion; the second was lumps of green and black material taken from the floor in the area of maximum damage; the third was a resinous, black residue adhering to the manifold housing after the loose powder had been removed. The fourth sample received was a powder removed from the body of the valve from the ruptured cylinder. This material had the same appearance as the grey powder mentioned above. The following analytical results were obtained:

CHEMICAL ANALYSES (%)

	Grey Powder	Lump Material	Black Resinous Material*	Material from Body of Valve
Total uranium	65.8	70.1	----	----
Reduced uranium (U^{+4})	45.3	48.0	----	----
Total fluoride	22.0	24.7	----	----
Total carbon	2.85	2.46	----	1.86
Iron	1.98	----	----	----
Weight loss on ignition	----	----	31.3	----

*This material ignited and sustained a flame when heated. The residue after ignition was impure uranium oxides.

SPECTROCHEMICAL ANALYSES (PPM)**

	Grey Powder	Lump Material
Al	300	80
B	20	---
Cr	40	---
Cu	100	10
Fe	20000	100
Mg	2000	10
Mn	40	---
Na	2000	---
Si	100	60
Zn	2000	---

**Spectrochemical analysis was made only on the first two samples above.

The grey powder produced by this explosion is similar in appearance and analysis to that produced by the explosion of a cylinder in K-413 two years ago (KLI-2310). All samples analyzed indicate the uranium hexafluoride in the exploding cylinder was in contact with an organic substance, probably hydrocarbon oil, which resulted in violent reducing action on the uranium hexafluoride when the cylinder was heated.

J. T. Mottern

T. Kwasnoski
Special Analysis Department
Technical Division

/jd

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