May 28, 1986

MEMORANDUM FOR: Roger A. Fortuna, Deputy Director
Office of Investigations

James G. Partlow, Director
Division of Inspection Programs

FROM: Donald R. Chapell, Deputy Director
Division of Fuel Cycle and Material Safety

SUBJECT: REQUEST FOR COMMENTS/CONCURRENCE ON VOLUME II OF NUREG-1179, "RUPTURE OF MODEL 48Y UF_6 CYLINDER AND RELEASE OF URANIUM HEXAFLUORIDE"

Enclosed for your review is a copy of Volume II of NUREG-1179. I would appreciate receiving your telephonic comments/concurrence no later than June 3, 1986.

Original Signed by
D. R. Chapell

Donald R. Chapell
Deputy Director
Division of Fuel Cycle
and Material Safety

Enclosure: As stated

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NUREG-1179
Vol. 2

Rupture of Model 48Y UF_6 Cylinder and Release of Uranium Hexafluoride

Cylinder Overfill, March 12-13, 1986
Investigation of a Failed UF_6 Shipping Container

U.S. Nuclear Regulatory Commission

NUREG-1179, Vol. 2

RUPTURE OF MODEL 48Y UF_6 CYLINDER AND RELEASE OF URANIUM HEXAFLUORIDE

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Augmented Investigation Team

U.S. Nuclear Regulatory Commission
Uranium Recovery Field Office
Region IV
Denver, CO 80225

ABSTRACT

NUREG-1179, Volume 1, reported on the rupture of a Model 48Y uranium hexafluoride (UF_6) cylinder and the subsequent release of UF_6. At the time of publication, a detailed metallurgical examination of the damaged cylinder was under way and results were not available.

Subsequent to the publication of Volume 1, a second incident occurred at the Sequoyah Fuels Corporation facility. On March 13, 1986, a Model 48X cylinder was overfilled during a special one-time draining procedure; however, no release of UF_6 occurred. An Augmented Investigation Team investigated this second incident.

This report, NUREG-1179, Volume 2, presents the findings made by the Augmented Investigation Team of the March 13 incident and the report of the detailed metallurgical examination conducted by Battelle Columbus Division of the cylinder damaged on January 4, 1986.

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PREFACE

The U.S. Nuclear Regulatory Commission Augmented Investigation Team, which conducted the investigation of the March 13, 1986, incident at the Sequoyah Fuels Corporation facility, consisted of the following members:

R. Dale Smith, Leader
Charles L. Cain
Justin T. Long
Gary F. Sanborn

1 INTRODUCTION

1.1 Background of Events

On January 4, 1986, a filled Model 48Y uranium hexafluoride (UF_6) cylinder ruptured while it was being heated at the Sequoyah Fuels Corporation (the licensee) conversion facility near Gore, Oklahoma. The accident sequence and resulting analysis are described in Volume 1 of NUREG-1179. This report, Volume 2 of NUREG-1179, describes events that occurred on March 12-13, 1986, as the licensee drained UF_6 from process cold traps to shipping cylinders.

1.1.1 Cylinder Overfill

On March 12, 1986, the Sequoyah Fuels Corporation began draining UF_6 from process cold traps to shipping cylinders. This operation was necessary to enable modification of facilities and equipment at the plant, which had been shut down since January 4, 1986. A secondary objective was to attempt to determine, by inventory accountability, the amount of UF_6 in the cylinder that had ruptured on January 4, 1986. (NUREG-1179, Volume 1, presented engineering estimates of the probable amount, but actual data were not yet available.)

During the course of the draindown process on March 13, 1986, a Model 48X cylinder was filled with 26,017 pounds of UF_6, an amount that was 4,987 pounds more than the cylinder's maximum shipping weight specification of 21,030 pounds. This weight exceeded the maximum amount of liquid UF_6 capacity for the cylinder, indicating that some solidification had occurred during the filling process. The draindown process was to have been conducted in accordance with special licensee procedures (Appendix A), which further limited each cylinder to be filled with no more than 20,000 pounds of UF_6.

The causes of the overfill were identified as (1) a malfunctioning scale, (2) failure to include procedures to test the functioning of the scale, and (3) failure to recognize indications of malfunction.

The licensee's procedure prohibited the cylinders from being heated in the steam chests. Because this procedure was followed, the cylinder did not rupture and no material was released. Most of the excess material was evacuated back to the process equipment before the temperature and vacuum equilibrated with the vapor pressure of the material, causing flow to cease. The cylinder is in storage pending future plans for removing the excess UF_6 (172 pounds above the maximum shipping weight specification, and 1,202 pounds over the limit set by the one-time procedures). Reviews by the licensee and NRC concluded that storage of the overfilled cylinder poses no greater risk than storage of properly filled cylinders.

1.1.2 Investigation of a Failed UF_6 Shipping Container

At the time of publication of Volume 1, a detailed metallurgical examination of the damaged cylinder was under way and results were not yet available.

Battelle Columbus Laboratory conducted an investigation of the failed UF_6 shipping container to determine the cause of failure. The investigation consisted of (1) an onsite inspection of the failed vessel, (2) laboratory evaluations of appropriate sections removed from the failed container, and (3) stress analyses to estimate the pressures required to cause failure.

The investigation revealed (Appendix B) that the failure initiated in the region of the valve end stiffener ring. It appears that cracking of the butt weld in that stiffener ring occurred first. Cracking in the vessel wall appeared to be an extension of the stiffener ring crack. Upon rupture, the cracks propagated axially in a shear mode. Stress analyses indicated that the crack in the vessel shell may have initiated at an internal pressure of 1250 psig and that final rupture occurred at an internal pressure of approximately 1800 psig. There was no indication that the failure was related to material deficiencies.

1.2 Investigation of Cylinder Overfill

An Augmented Investigation Team (AIT) was assembled to review the activities relating to the draindown of the cold traps and the resultant overfilling of a Model 48X cylinder that occurred on March 12-13, 1986. The team consisted of the team leader and one investigator from the AIT who had investigated the January 4, 1986, incident, and was supplemented by representatives from Region IV and the Office of Nuclear Material Safety and Safeguards. The investigation was conducted in accordance with the draft "Procedure for AIT Response to Operational Events." Accordingly, the objectives of the investigation were to

- conduct an onsite fact-finding investigation of the March 13, 1986, incident
- identify and communicate any generic and specific safety concerns related to this event
- document the findings and conclusions of the onsite investigation

Furthermore, the scope of this investigation did not include

- an examination of proposed licensee actions to correct the cause of the event
- licensee actions taken or planned to be taken before resumption (or continuation) of draindown operations
- NRC staff review of the licensee's one-time special procedures for draindown.

2 CONDUCT OF THE ONSITE INVESTIGATION

2.1 Personal Interviews

On March 16-17, 1986, members of the AIT conducted personal interviews with Sequoyah Fuels Corporation employees who had firsthand knowledge of the events leading up to, during, and immediately following the incident that occurred on March 12-13. The team also interviewed an employee from the McElhaney Scale Company (Fort Smith, Arkansas) who had serviced the scales on the day after the incident. Seventeen persons were interviewed during this period. All of the interviews were recorded by a certified shorthand reporter, and transcripts were prepared.

The transcripts of these interviews are not presented separately; instead, they form much of the basis for the observations and descriptions contained in the investigation team's report.

2.2 Examination of Scale

On March 17, 1986, the team members examined the scale that had malfunctioned. The team was accompanied by the scale service technician who demonstrated the condition of the scale before and after he had serviced them on March 14, 1986.

3 FACTS SURROUNDING THE INCIDENT

3.1 Background Information

Further background information regarding facility description, management organization, and process description may be found in Section 3 of Volume 1 of NUREG-1179.

3.2 Recent History of Scale Use and Service

Section 2.3 of Volume 1 of NUREG-1179 describes the tests that were performed on the two drain station scales and the final product scale on January 28-29, 1986. These tests were observed by a representative of the National Bureau of Standards (NBS), and the scales were found to perform within expected tolerances. Because no mechanical abnormalities were observed at the south drain station scale, comprehensive testing was not performed on the matching north drain station scale. However, test weights were applied to this scale on January 29, and the scale was found to register accurately after approximately 25,000 pounds were applied.

The testing was performed before any decontamination of the scales occurred to ensure that the decontamination would not disturb in any way the condition of the scales that existed at the time of the accident on January 4, 1986. The scales were then released for decontamination, which was completed on January 31, 1986. The scales were not retested or recalibrated after decontamination.

All three scales had been previously checked and serviced by McElhaney Scale Company on September 17, 1985, and earlier on March 6, 1985. The invoice for the March 1985 service call recorded that one of the scales was found to be sticking and to have a minor weighing error that was corrected by the technician. This is consistent with earlier accounts by employees that the north scale had been sticking and had been repaired. The September 1985 invoice noted only that the scales were calibrated and serviced where necessary. Both invoices advised a regular service inspection every 90 days. Records show that the scales were routinely serviced three times a year over the past 7 years.

After the scale malfunctioned during the filling of the cylinder on March 12-13, 1986, a scale technician was summoned to the site to examine the north drain station scale on the morning of March 14. The invoice for this service stated that the main lever to the nose iron had been moved out of place. This caused the pivot, which is mounted on the lever, to be out of the bearing block, which is supported in the bottom of the scale pit (see Figure 3.1). The invoice further stated that the lever had been realigned, the scale calibration had been checked, and the scale was found to be in good working order.

The AIT interviewed the scale technician during the morning of March 17, 1986, and the technician accompanied the team members to the north drain station scale. The floor grating was removed to gain access to the scale pit midway between the catwalk located near the fill header and the scale platform. The

technician then demonstrated the condition in which he had found the scale on the previous Friday when he entered the scale pit. He then dislodged the lever to demonstrate how it could have been done and replaced it to its normal position. A member of the AIT then entered the pit and repeated these actions. The scale technician rechecked the positioning of the lever. The dislodgement of the lever was noted to take minimal effort. Thus, the lever could have been unnoticeably and unintentionally jarred out of position by decontamination workers working in the pit.

The AIT interviewed employees who had decontaminated the scale on January 31, 1986, to determine if anyone recalled stepping on or otherwise coming in contact with the lever. Although several employees recalled entering the pit to clean it out, none were able to recall whether the lever had been touched during the work. These employees also indicated that this was the only occasion since the January accident that they had observed the grating removed from above the scale pit and, thus, the only task likely to have caused the lever dislodgement. The day shift health physics technician also acknowledged that he had not been aware of any other work involving removal of the scale grating.

AIT interviews of plant employees who had participated in the filling of the cylinder disclosed that some operators had observed that the scale tare poise was in an unusual position during the filling. One employee had notified his supervisor of this condition and was told by the supervisor that the change in scale operation was likely caused by the recent calibration performed on the scale. (An erroneous assumption; no actual calibration of the north scale had occurred.)

3.3 Draindown Procedure Development and Review

After the January 4, 1986, accident, Sequoyah Fuels Corporation wanted to completely empty (drain) the UF_6 remaining in the cold traps to enable modification of facilities and equipment at the plant and to attempt to determine, by inventory accountability, the amount of UF_6 in the cylinder that ruptured during the accident. For this purpose, the licensee had drafted a procedure, "Special One-Time Instructions for Draining Cold Traps," to be followed during the operation (Appendix A).

The procedure was prepared jointly by four managers at Sequoyah Fuels Corporation, none of whom was assigned ultimate responsibility for the task. Final review and approval of the procedure was performed by the plant manager. One of the four managers had recommended that the filling of the cylinders be performed only on the south drain station scales. This recommendation had been rejected by the team preparing the procedures in favor of the greater operating flexibility provided by using both drain stations. — why?

An initial draft of the procedure was sent for approval to NRC's Region IV office (letter from S. D. Emerson, Sequoyah Fuels Corp., to R. D. Martin, NRC, dated February 13, 1986), and NRC responded with recommendations in a memorandum dated February 28, 1986 (memorandum from R. D. Martin, NRC, to S. D. Emerson, Sequoyah Fuels Corp.). The revised procedure was transmitted to Region IV on March 5, 1986 (letter from W. L. Utnage, Sequoyah Fuels Corp., to R. D. Martin, NRC), and the NRC responded with a memorandum dated March 10, 1986 (memorandum from R. D. Martin, NRC, to S. D. Emerson, Sequoyah Fuels

Corp.), stating that the revised procedure was approved and that the licensee could proceed with the cold trap draining.

Neither the initial nor final drafts of the procedure contained requirements for testing the scales before beginning the draining operation. The licensee routinely uses two special cylinders of certified weight to test the response of the final product scale, (see Procedure N-280-1, Appendix D, NUREG-1179, Volume 1) but these had not been used in conjunction with either of the drain station scales. The cylinders have been previously certified off site and weigh 4,503 and 25,509 pounds, respectively. The accuracy of these weights was confirmed during the January 28-29, 1986, tests. If these cylinders had been used to test the drain scales before their use, the inaccuracy of the north scale would have been identified.

The NBS report prepared for the scale testing performed at the site during January 1986 (NUREG-1179, Volume 1, Appendix A) recommended that the test cylinders be used after a scale had been serviced. This recommendation was not made by NRC during its review of the licensee's draindown procedures, since the scales were not serviced after the tests performed during January. In its memorandum dated February 28, 1986, NRC recommended that the licensee clearly identify in the procedure that no cylinder was to be heated in the steam chests. The procedure also included a requirement that the filled cylinders undergo weighing on the final product scale before being stored.

3.4 Training of Employees in Regard to the Draindown Procedure

The licensee implemented training for the specific procedures that were to be used for draining the cold traps on Tuesday, March 11, 1986, one day before the draining operation was to begin. According to information gained from interviews of the employees who were involved, the two shift supervisors and four chemical operators who had been selected to perform the draining of the cold traps met in the control room and reviewed in detail not only the one-time draindown procedure but also each of the standard operating procedures referenced in the special procedure. Following this discussion, which took about 3 hours, they went into the process plant to walk through the procedures and check equipment at their respective work stations. Testing of the scales at the drain stations was not discussed during the training session.

The licensee had designed and begun implementing a retraining program that included both orientation and job-related training for all shift supervisors and chemical operators. Among the individuals assigned to the draining operation, only the chemical operators had officially entered this program before the beginning of the cold trap draining. These employees were in the initial stages of the orientation phase of the program when they were withdrawn from training to participate in the draindown operation. The retraining program would not have addressed the special draindown procedures. Therefore, temporary withdrawal of the operators from the program had no effect on the conduct of the special draindown operations.

3.5 Sequence of Events for the First Day of Draining

The draindown operation began at 6:00 a.m. on Wednesday, March 12. The first shift crew, consisting of a supervisor and two chemical operators, was to work

until 2:00 p.m. A similar second shift crew was to arrive at 11:00 a.m. and work until 7:00 p.m. Thus, the two shifts were to overlap by 3 hours.

A simplified flow diagram illustrating the draindown equipment is shown in Figure 3.2.

Cylinder No. 1033 was moved to the north drain station and cylinder No. 637 was placed in the south drain station. Both cylinders had passed quality inspections performed on March 10 separately by a design engineer and an area supervisor. The cylinders were again inspected by the shift supervisor on the morning of March 12. After the cylinders were placed on the scales, the tare poise on each scale was set to cancel exactly the tare weight of each cylinder and its associated cart. It was at this time that one of the operators who noticed the abnormal position of the tare poise informed his supervisor that the north scale tare poise required positioning at a point different from what he was accustomed to encountering. The supervisor stated that he believed that this resulted from the testing and calibration of the scales that had occurred in January. He instructed the operator to continue with the draining procedures.

Tempering (heating to approximately 75°F) of two cold traps began at 6:00 a.m. These traps were identified in the shift log book as #1P (primary trap No. 1) and #1S (secondary trap No. 1). Traps #2P, #4P, #6C (cleanup reactor trap No. 6), and #3S were placed on line with the fluorination towers and were refrigerated to provide vacuum and backup capacity for the contents of the heated cold traps. Traps #1P and #1S were switched to the heat cycle (to allow heating to about 210°F in order to liquify the UF_6) at approximately 7:00 a.m. The #5C trap was switched to temper cycle at 8:45 a.m. The licensee reported that heating of the traps was normal and system pressures were within prescribed parameters.

At 10:30 a.m., trap #1P began to be drained into cylinder No. 1033, which was positioned on the north scale. By 12:15 p.m., the north scale indicated that 13,710 pounds of UF_6 was in the cylinder. The log noted at this time that draining to cylinder No. 1033 had slowed and had therefore been switched to cylinder No. 637 on the south scale. Apparently, cylinder No. 1033 had already been filled almost full at this point, which would explain the reduced flow rate. At the time, however, the shift crew suspected that the filter to the north cylinder had partially clogged, because they were aware that the product being drained was likely to have a high chromium content. (At the time of the January 4 accident, a cylinder with high chromium content was being evacuated back to the cold traps.)

Draining continued into cylinder No. 637 until 2,100 pounds of UF_6 was in the cylinder and trap #1P was empty. Trap #5C was then heated, and the contents of trap #1S began draining into the cylinders, starting with cylinder No. 1033. Cylinder No. 1033 received 980 pounds (indicated), and cylinder No. 637 received 540 pounds. At 3:30 p.m., a second draining of #1S added 480 pounds to cylinder No. 637. At 3:40 p.m., draining of trap #5C began, and the north scale indicated that an additional 1,150 pounds of product was drained into cylinder, No. 1033. Slow flow required changing the flow to the south cylinder, which received 3,690 pounds before trap #5C was emptied. At 5:15 p.m., traps #1P, #1S, and #5C had been emptied and were returned to a

refrigerated state. The operation was then terminated for the day. The north scale indicated that cylinder No. 1033 had a net weight of 15,840 pounds. Cylinder No. 637 on the south scale contained 6,810 pounds for a total of 22,650 pounds of product presumably drained for the day. These summary data were recorded on a "Cold Trap and Product Status" log sheet.

3.6 Sequence of Events for the Second Day of Draining

The second day of the operation began at 6:00 a.m. with the same shift schedules as for the first day. The #2P and #2S traps were started on the tempering cycle. The #1P, #1S, and #5C traps, which were emptied on the first day, were placed on line and refrigerated to provide vacuum and backup trap capacity. Heating was begun on #2P and tempering was begun on #6C at 6:45 a.m. Trap #2S was heated at 7:30 a.m., but the trap was found to be empty, as indicated by the absence of pressure gain. This trap was then cooled and refrigerated. The #3S trap was tempered at 8:30 a.m. and heated at 9:00 a.m.

At 11:00 a.m. draining commenced using trap #2P. The flow stopped after 750 pounds (indicated) were drained into cylinder No. 1033 on the north scale. Draining was diverted to cylinder No. 637, to which 4,890 pounds of UF_6 were added. Draining of trap #3S began at 1:50 p.m., and 3,630 pounds were drained into cylinder No. 637. At this point, the south scale indicated that cylinder No. 637 contained 15,330 pounds. Trap #3S remained heated so that another attempt to drain this trap could be made later in the day.

One of the assigned chemical operators was also the operator who, during the midnight shift of January 4, 1986, had filled the 14-ton cylinder that later ruptured when it was heated in the steam chest. This operator remarked that cylinder No. 1033 was behaving just like the 14-ton cylinder had before. He suggested that No. 1033 be disconnected from the north fill bay and moved to the final product scale for a check weighing. At about 3:20 p.m., the cylinder was transferred to this scale, which indicated that the gross weight (of the cylinder and its contents) was 30,568 pounds. The net weight was determined to be 26,017 pounds after deducting the tare weight of the empty cylinder.

The maximum net shipping weight specification for the Model 48X 10-ton cylinder is 21,030 pounds. However, the special procedure for this operation called for the cylinder to be filled to only 20,000 pounds. Thus, the cylinder was filled to 4,987 pounds in excess of the maximum shipping weight specification and 6,017 pounds in excess of the amount specified in the special procedure. This quantity exceeded, by 1-7% (depending on temperature), the maximum amount of liquid UF_6 capacity for the cylinder, indicating that some solidification had occurred during the filling process.

The shift supervisor notified the acting production manager at 3:30 p.m., who then immediately notified the plant manager. An NRC staff member, who was with the plant manager at the time of the notification, in turn notified NRC regional management. NRC headquarters management was subsequently notified.

The overfilled cylinder remained on the final weigh station scale, where it was connected to a vacuum line for evacuating the UF_6 to the process equipment. Evacuation of the overfilled cylinder to trap #1P began at 4:10. All other traps were returned to a refrigerated state later that evening.

The production manager moved the 25,509-pound test cylinder onto the north drain station scale. He later recounted to the AIT that the scale indicated only about 13,000 pounds.

Evacuation of the overfilled cylinder continued until Friday afternoon (March 14), at which time the contents had solidified to the extent that no further material could be removed using the plant vacuum (about 14 inches of mercury (Hg)). The net weight of the cylinder was then 21,203 pounds, 173 pounds above the maximum shipping weight specification of 21,030 and 1,203 pounds over the limit established by the one-time procedures.

Subsequently, the overfilled cylinder was disconnected and placed into storage pending future NRC approval of plans to further reduce the amount of the contained UF_6.

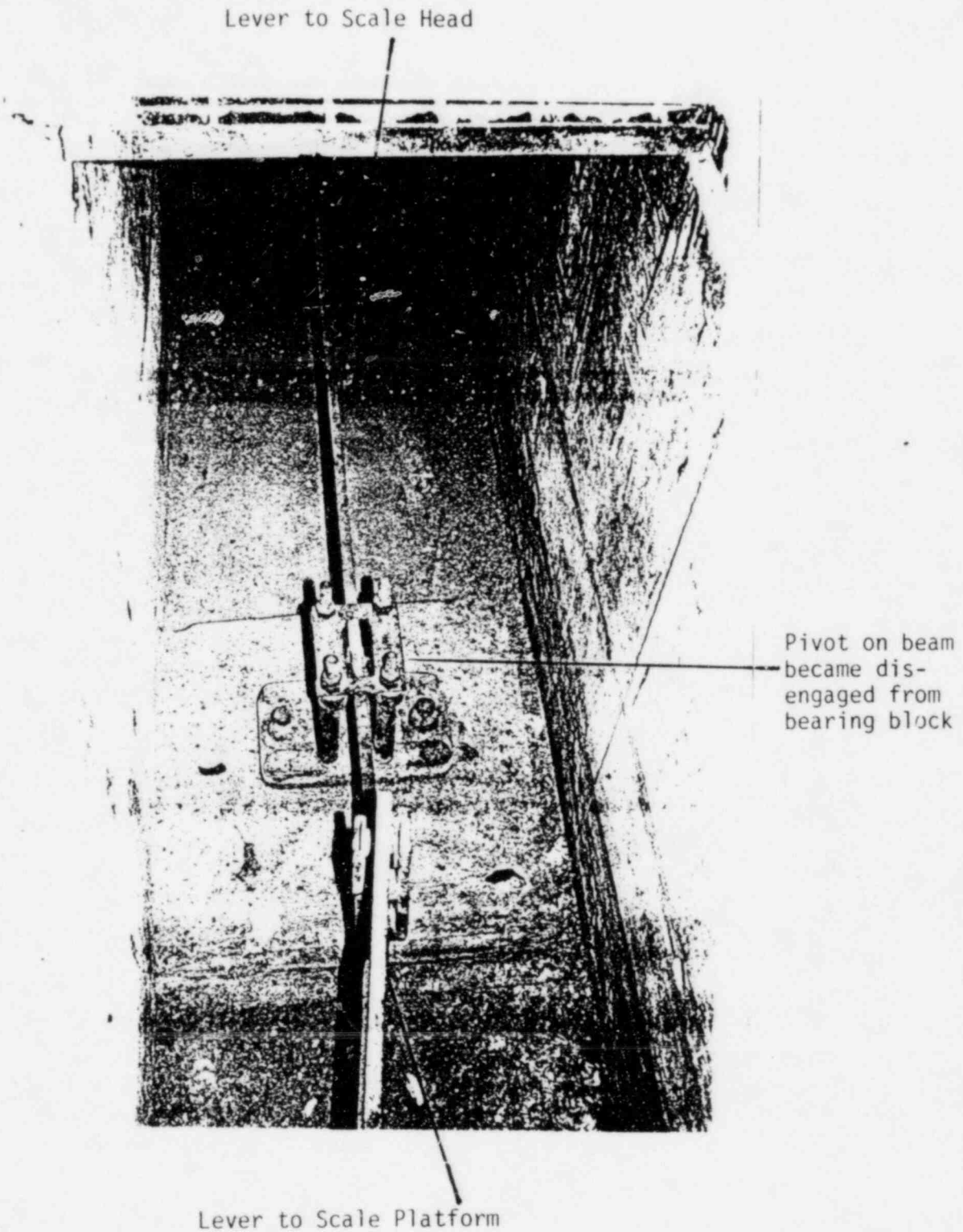


Figure 3.1 Beam and Pivot Assembly

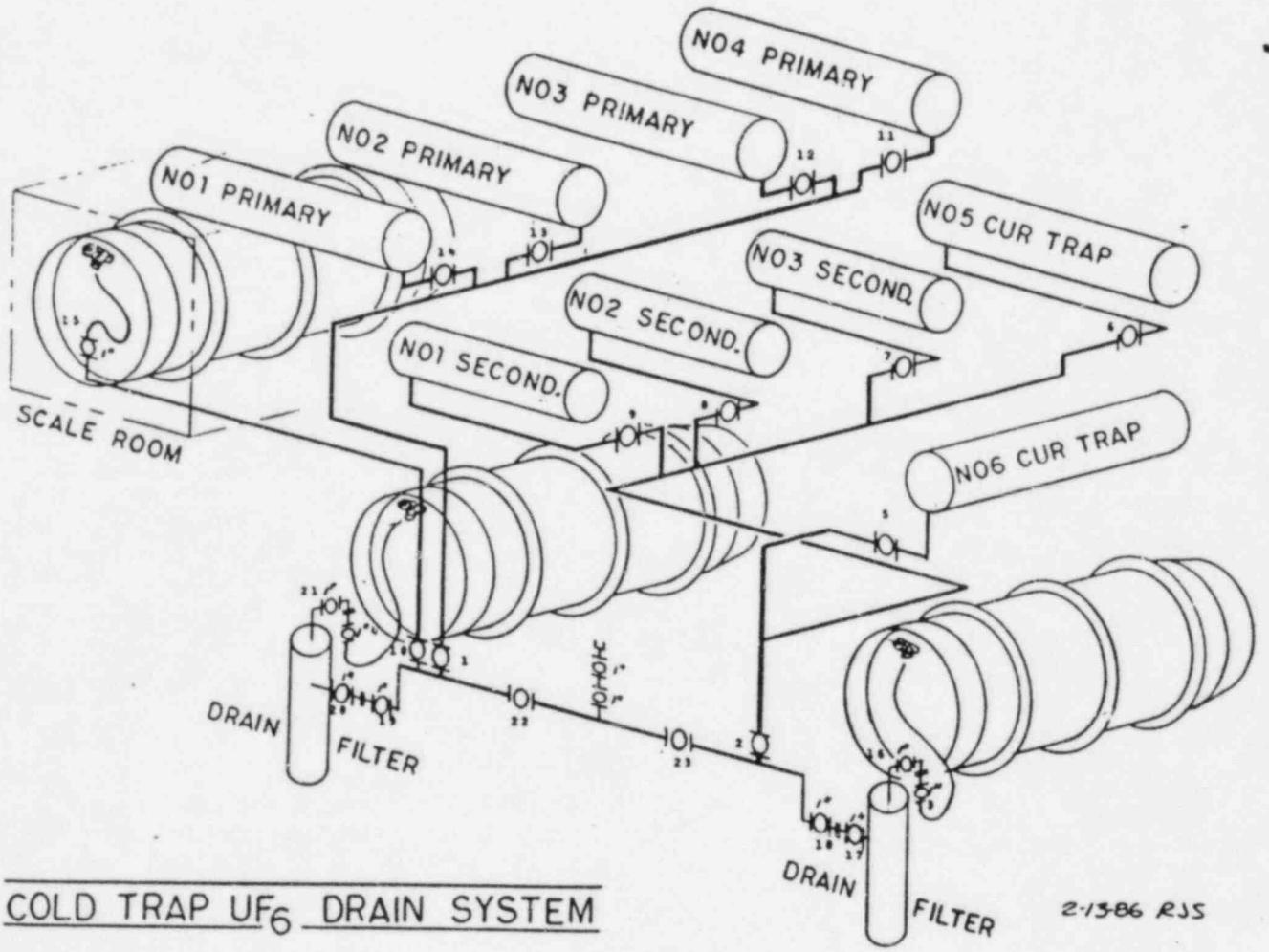


Figure 3.2 Cold Trap UF_6 Drain System

4 FINDINGS AND CONCLUSIONS

The Augmented Investigation Team has concluded that the overfilling of the cylinder had the following causes:

(1) The scale used for weighing the cylinder being filled was malfunctioning. It was determined that a beam linking the scale platform with the readout dial had become dislodged. With its pivot point displaced, the scale gave erroneously low indications of weight.

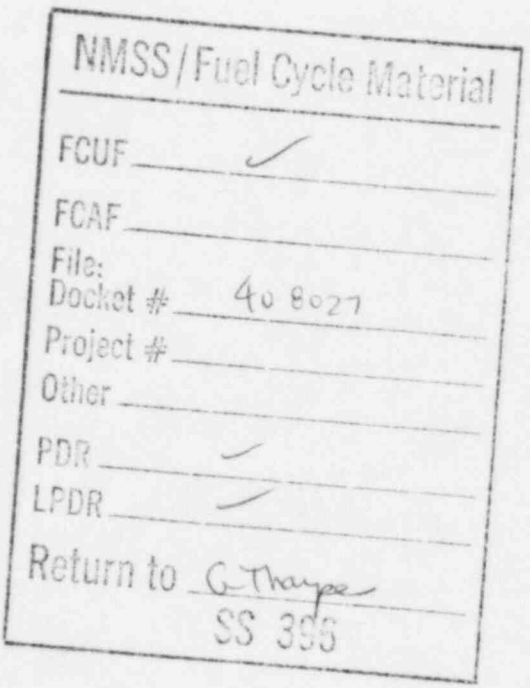
(2) The procedures for draindown did not include any provisions for ensuring proper scale functioning. Neither the one-time special procedure for conducting the draindown nor any of the regular procedures incorporated by reference required any use of check weights to determine the scales' accuracy and functioning. The procedure for filling UF_6 cylinders called only for cancelling out the tare weight by adjusting the uncalibrated tare poise.

(3) The supervision in charge of the operation did not recognize early indications of malfunction. When the chemical operator adjusted the tare poise to compensate for the empty cylinder weight, he reported to his supervisor that the poise was in an unusual position. The supervisor erroneously assumed that this resulted from the recent scale calibration activities, even though a detailed check of the north scale had not been performed. Later, a chemical operator observed that the flow rate, as indicated by the weight gain of the cylinder, was lower than anticipated. It was erroneously concluded that this was caused by contaminants clogging the newly replaced filters, even though this phenomenon was not observed on the south scale.

The Augmented Investigation Team further concluded that a serious accident was avoided by the following actions:

(1) The approved procedures prohibited the heating of any of the cylinders involved in the draindown operation. Even though the cylinder was overfilled, the special procedures precluded its heating. The workers appeared to have been adequately trained in these procedures. As long as the cylinder was not heated, it presented no danger.

(2) The overfilled cylinder was connected to a vent line and most of the overfill was removed to process equipment. In accordance with established procedures, the cylinder was vented to cold traps under vacuum. Nearly 4,800 pounds of UF_6 was removed from the cylinder before the temperature and applied vacuum equilibrated with the vapor pressure of the UF_6 and the vaporization ceased.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