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# URANIUM HEXAFLUORIDE: HANDLING PROCEDURES AND CONTAINER CRITERIA

MASTER

U. S. ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION



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Revision 4

## URANIUM HEXAFLUORIDE: HANDLING PROCEDURES AND CONTAINER CRITERIA

April 1977

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# URANIUM HEXAFLUORIDE: HANDLING PROCEDURES AND CONTAINER CRITERIA

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## Foreword

The U.S. Energy Research and Development Administration's (ERDA) procedures for packaging, measuring, and transferring uranium hexafluoride ( $UF_6$ ) have been undergoing continual review and revision for several years to keep them in phase with developing agreements for the supply of enriched uranium. This report, first issued in 1966, was reissued in 1967 to make editorial changes and to provide for minor revisions in procedural information. In 1968 and 1972, Revisions 2 and 3, respectively, were issued as part of the continuing effort to present updated information. This document, Revision 4, includes primarily revisions to  $UF_6$  cylinders, valves, and methods of use.

This revision supersedes all previous issues of this report. The procedures will normally apply in all transactions involving receipt or shipment of  $UF_6$  by ERDA, unless stipulated otherwise by contracts or agreements with ERDA or by notices published in the Federal Register.

Any questions or requests for additional information on the subject matter covered herein should be directed to the United States Energy Research and Development Administration, P. O. Box E, Oak Ridge, Tennessee, 37830, Attention: Director, Uranium Enrichment Operations Division.



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## 1. INTRODUCTION

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This report has been prepared to better acquaint the nuclear industry with UF<sub>6</sub> shipping containers and handling procedures. The information contained herein covers the essential aspects of packaging, cylinder filling and emptying, and the general principles of weighing and sampling. Shipping methods are discussed in very general terms. All UF<sub>6</sub> shipments to or from the ERDA facilities are f.o.b. the ERDA facilities. It is the responsibility of industry to provide the necessary shipping containers and transportation.

It should be noted that equipment and procedures described are general and may vary at different ERDA facilities. As a specific example, weighing devices are not identical at all sites; however, basic operating principles are implemented at all sites. More detailed information regarding weighing, sampling, and analytical procedures is contained in Report ORO-671, *Procedures for the Handling and Analysis of Uranium Hexafluoride*, Volumes 1 and 2.

The quality of feed material is important to the safe and efficient operation of ERDA enriching facilities. The purity of product UF<sub>6</sub> from ERDA enriching facilities is also important to product users. These considerations have been the impetus for an aggressive effort by ERDA and its contractors to improve the accuracy of chemical and isotopic analytical techniques. Also, a quality control program is maintained to ensure that the required accuracy and precision for the various ERDA measurements are obtained.

It is important that weights and related analytical data be reported in a similar manner by both shipper and receiver. Appropriate material transfer forms on which the data may be reported are available from ERDA.

Considerable effort has been made by the nuclear industry to standardize UF<sub>6</sub> cylinders and has culminated in the issuance of Standard N14.1-1971, *Packaging of Uranium Hexafluoride for Transport*, issued by the American National Standards Institute (ANSI). A revised standard, N14.1-1977, is to be issued by ANSI, and excerpts, including drawings of standard cylinders, are contained in Section 7.1 of this document.

A discussion of safety considerations and a brief description of the physical and chemical properties of UF<sub>6</sub> are given in Sections 7.2 and 7.3.



## 2. STANDARD PACKAGING INFORMATION



### 2.1 CYLINDER PACKAGING LIMITS

The UF<sub>6</sub> supplied by ERDA is packaged in cylinders which vary in shape and size, depending on the total quantity and/or the uranium-235 assay (wt % uranium-235) involved. The packaging limits for each standard cylinder are given in Table 3, Section 7. The UF<sub>6</sub> shipped to ERDA facilities in the standard cylinders must conform to the fill limits and maximum uranium-235 assay listed in the table.

A charge is made by ERDA for withdrawing UF<sub>6</sub> from the enriching facilities and packaging it. These charges are published in the Federal Register and may be revised from time to time.

### 2.2 INSPECTION, CLEANING, TESTING, AND REPAIRING OF PRIVATELY OWNED CYLINDERS

#### 2.2.1 General

It is the policy of ERDA to inspect externally all UF<sub>6</sub> cylinders at the time of their delivery to and receipt from the carrier. Both the shipper and receiver should inspect the cylinders and record the necessary data to facilitate the resolution of any claims for damage. These inspections are designed to minimize risks associated with filling, emptying, or shipping damaged cylinders. Examples of acceptable and unacceptable cylinder damage are given in Figure 1. A typical cylinder inspection data sheet is shown in Figure 2.

Occasionally, UF<sub>6</sub> cylinders require cleaning to remove excessive buildup of hydrogenous materials and other impurities. In addition, it may be desirable to remove the *heel*\* when UF<sub>6</sub> of a different isotopic assay is to be added to the cylinder. ERDA does not normally perform such cleaning services for privately owned cylinders.

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\**Heel* refers to the residual quantity of uranium material which remains in a cylinder after routine evacuation procedures have been followed.

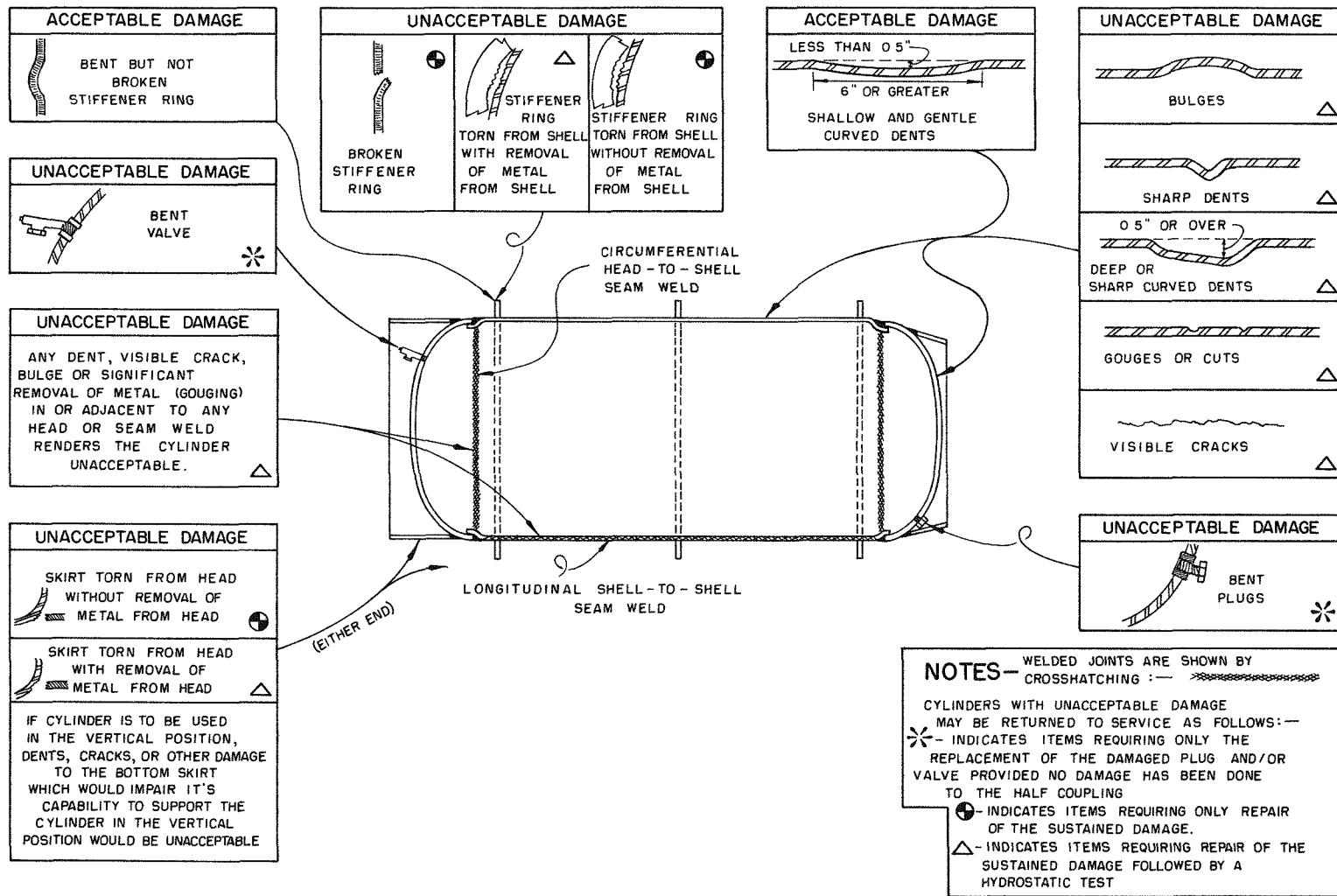


Figure 1  
EXAMPLES OF  
ACCEPTABLE AND UNACCEPTABLE DAMAGE TO  $UF_6$  CYLINDERS

UF <sub>6</sub> CYLINDER INSPECTION DATA SHEET																																																																																																																																																																									
CYLINDER NUMBER		CYLINDER MODEL		CYLINDER BEING INSPECTED																																																																																																																																																																					
		<input type="checkbox"/> 30A (2½-ton) <input type="checkbox"/> 48A (10-ton) <input type="checkbox"/> 48G (14-ton) <input type="checkbox"/> 30B (2½-ton) <input type="checkbox"/> 48F (14-ton HW) <input type="checkbox"/> LW		<input type="checkbox"/> Date Shipped _____ <input type="checkbox"/> Date Received _____																																																																																																																																																																					
OWNER		CYLINDER STATUS		Hydrostatic Pressure Test Date of																																																																																																																																																																					
		<input type="checkbox"/> Full <input type="checkbox"/> Empty, Heel of _____ Pounds is <input type="checkbox"/> Acceptable <input type="checkbox"/> Not Acceptable		<input type="checkbox"/> is <input type="checkbox"/> Acceptable <input type="checkbox"/> Not Acceptable <input type="checkbox"/> Carrier _____																																																																																																																																																																					
Cylinder is Code Stamped		<input type="checkbox"/> Yes <input type="checkbox"/> No		Cylinder's Contents Are Solidified																																																																																																																																																																					
				<input type="checkbox"/> Yes <input type="checkbox"/> No																																																																																																																																																																					
Cylinder Is Overfilled:		<b>CONDITION</b> <input type="checkbox"/> No <input type="checkbox"/> Yes, Net Weight is _____ pounds, Maximum Allowable Fill Limit is _____ pounds.																																																																																																																																																																							
		<table border="1"> <thead> <tr> <th></th> <th>Acceptable</th> <th>Un-acceptable</th> <th>Not Applicable</th> </tr> </thead> <tbody> <tr> <td>A. VALVE:</td> <td></td> <td></td> <td></td> </tr> <tr> <td>  1. Physical Damage _____</td> <td></td> <td></td> <td></td> </tr> <tr> <td>  2. Thread Engagement _____</td> <td></td> <td></td> <td></td> </tr> <tr> <td>  3. Valve Cap - Present and in Place _____</td> <td></td> <td></td> <td></td> </tr> <tr> <td>B. VALVE PORT:</td> <td></td> <td></td> <td></td> </tr> <tr> <td>  1. Plugged with UF<sub>6</sub> _____</td> <td></td> <td></td> <td></td> </tr> <tr> <td>  2. Contaminated with Other U-Salts or Foreign Material _____</td> <td></td> <td></td> <td></td> </tr> <tr> <td>C. PLUGS:</td> <td></td> <td></td> <td></td> </tr> <tr> <td>  1. Physical Damage _____</td> <td></td> <td></td> <td></td> </tr> <tr> <td>  2. Thread Engagement _____</td> <td></td> <td></td> <td></td> </tr> <tr> <td>D. VALVE PROTECTOR - PRESENT AND PROPERLY POSITIONED _____</td> <td></td> <td></td> <td></td> </tr> <tr> <td>E. SEAL _____</td> <td></td> <td></td> <td></td> </tr> <tr> <td colspan="4">Description of Damage (if any): _____</td> </tr> <tr> <td colspan="2">I. CYLINDER VALVE, VALVE PORT AND PLUGS</td> <td colspan="4"></td> </tr> <tr> <td colspan="2">II. CYLINDER WELDS</td> <td colspan="4"> A. CIRCUMFERENTIAL HEAD SEAM WELD - VALVE END _____  B. CIRCUMFERENTIAL HEAD SEAM WELD - PLUG END _____  C. LONGITUDINAL SEAM WELD _____       </td> </tr> <tr> <td colspan="2"></td> <td colspan="4">Description of Damage (if any): _____</td> </tr> <tr> <td colspan="2">III. CYLINDER SHELL AND HEADS</td> <td colspan="4"> A. SHELL _____  B. HEAD-VALVE END _____  C. HEAD-PLUG END _____       </td> </tr> <tr> <td colspan="2"></td> <td colspan="4">Description of Damage (if any): _____</td> </tr> <tr> <td colspan="2">IV. STIFFENING RINGS</td> <td colspan="4"> A. VALVE END _____  B. CENTER _____  C. 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PERSONNEL</td> </tr> <tr> <td colspan="2">SECTION B</td> <td colspan="4">The following damage has been inspected and approved (with the indicated limitations, if any) _____</td> </tr> <tr> <td colspan="3">DAMAGE APPROVED BY</td> <td colspan="2">TITLE</td> <td>DATE</td> </tr> <tr> <td colspan="3">DISTRIBUTION</td> <td colspan="3"> White - Uranium Control (KYRC)  Blue - Inspection (When Section A is Completed)  Buff - Originator </td> </tr> <tr> <td colspan="6">CONDITION LEGEND A - Acceptable U - Unacceptable NA - Not Applicable</td> </tr> </tbody> </table>					Acceptable	Un-acceptable	Not Applicable	A. VALVE:				1. Physical Damage _____				2. Thread Engagement _____				3. Valve Cap - Present and in Place _____				B. VALVE PORT:				1. Plugged with UF <sub>6</sub> _____				2. Contaminated with Other U-Salts or Foreign Material _____				C. PLUGS:				1. Physical Damage _____				2. Thread Engagement _____				D. VALVE PROTECTOR - PRESENT AND PROPERLY POSITIONED _____				E. SEAL _____				Description of Damage (if any): _____				I. CYLINDER VALVE, VALVE PORT AND PLUGS						II. CYLINDER WELDS		A. CIRCUMFERENTIAL HEAD SEAM WELD - VALVE END _____ B. CIRCUMFERENTIAL HEAD SEAM WELD - PLUG END _____ C. LONGITUDINAL SEAM WELD _____						Description of Damage (if any): _____				III. CYLINDER SHELL AND HEADS		A. SHELL _____ B. HEAD-VALVE END _____ C. HEAD-PLUG END _____						Description of Damage (if any): _____				IV. STIFFENING RINGS		A. VALVE END _____ B. CENTER _____ C. PLUG END _____						Description of Damage (if any): _____				V. SKIRTS		A. VALVE END _____ B. PLUG END _____						Description of Damage (if any): _____				DATE AND TIME INSPECTED			INSPECTED BY			THIS SECTION TO BE COMPLETED BY A QUALIFIED INSPECTOR (FOR DAMAGE REFERRED TO THE INSPECTION DEPT.)						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Figure 2  
TYPICAL CYLINDER INSPECTION DATA SHEET

A standard for UF<sub>6</sub> cylinders has been established by ANSI. This standard, N14.1, includes only those cylinders which meet all of the acceptance criteria for UF<sub>6</sub> handling. Cylinders not meeting the requirements of this standard, but now in use and having necessary regulatory approval, are considered to be acceptable for continued use provided they are inspected, tested, and maintained within the intent of the ANSI standard. A 1977 revision of this standard is in preparation.

*Cylinders and/or valves not covered by the standard must receive appropriate approval from ERDA and the Department of Transportation (DOT) before the cylinders are accepted for shipments to ERDA facilities.*

#### 2.2.2 Feed Cylinders

Cylinders of feed material are inspected externally upon receipt and cold pressure checked to determine that the internal pressure is 10 psia (52 cm Hg), or less. If there is evidence of UF<sub>6</sub> leakage, leak-control measures are taken, and the shipper is notified immediately. If the leakage is caused by a structural defect, the shipper is requested to provide instructions for the disposition of the cylinder. If the leakage is caused by a faulty valve, the shipper must provide authorization for valve repair by teletype or letter. If the internal pressure is greater than 10 psia, the shipper is requested to provide instructions either to return the cylinder or cold burp the cylinder at the receiving site. The costs incurred for valve repair and/or cold burping are billed to the shipper.

The net weight of UF<sub>6</sub> feed accepted by ERDA shall be that determined to be the difference between the weights of the cylinder before and after emptying (gross full weight minus gross empty weight). A reasonable effort is made to evacuate the feed cylinders so that heel weight is minimized. After routine evacuation has been accomplished, the heel weight should not exceed the following:

<u>UF<sub>6</sub> Cylinder Model</u>	<u>Heel Weight</u>	
	<u>lb</u>	<u>kg</u>
5A	0.1	0.05
8A	0.5	0.23
12A or 12B	1	0.45
30A or 30B	25	11.34
48A, 48X, 48F, or 48Y	50	22.68

Heels weighing in excess of the above values may require removal by cylinder cleaning.

### 2.2.3 Product and Tails Cylinders

Empty clean cylinders which are received for filling with product or *tails*\* material are cold pressure checked to assure a pressure less than 5 psia (26 cm Hg), inspected, weighed, and/or leak rated. The inspection may also include a borescopic examination of the interior of the cylinder. The empty cylinders must be free of impurities. These impurities, particularly hydrogenous materials, could contaminate or react with UF<sub>6</sub> added to the cylinder.

In leak rating, the empty cylinders are pressured with air to 100 psig and soap tested. Cylinders should then be evacuated to 5 psia, or less. Cylinders failing to meet this criterion are rejected until proper repairs are effected. If the cylinder is rejected because of a faulty valve or plug, the shipper may verbally authorize repair and payment of incurred cost, and confirm this authorization by teletype. Unacceptability for any reason other than a faulty valve or plug may be cause for returning the cylinder to the shipper unused.

### 2.2.4 Cylinder Heel Recycle (Model 30A or 30B)

Normally, before a cylinder is filled with product UF<sub>6</sub>, ERDA requires a clean, dry cylinder. However, frequent and routine movement of UF<sub>6</sub> from the uranium enriching plants to a fuel fabricator presents a technically and economically attractive alternative in the recycle of cylinders containing small quantities of heels.

Approval to recycle cylinders with ERDA facilities must be requested by the UF<sub>6</sub> processor. There are three criteria basic to the recycle of cylinders. The first is positive assurance that the cylinder does not contain extraneous contaminants and noncondensables (a guarantee, in essence, that the heel is composed of nothing but UF<sub>6</sub>). The second is an as-received cylinder pressure of less than 5 psia (26 cm Hg) vacuum, and the third is a heel weight of 25 lb (11.3<sup>1/4</sup> kg) of UF<sub>6</sub>, or less. Further, cylinders received for recycle must meet all specifications as shown in the Appendix, meet cleanliness standards, and have a current hydrostatic test and inspection date. Failure to meet these criteria will require decontamination of the cylinder before filling with product.

Since the only safety check on cylinder and valve condition available to plant personnel is a cold pressure check upon receipt of the recycle cylinders, it is necessary to have a high degree of confidence and assurance in the integrity of the UF<sub>6</sub> processor's procedures and equipment. Hence, recycle with a UF<sub>6</sub> processor is entirely at ERDA's option and is not only contingent on adequate procedures, but also on their continued implementation.

---

\**Tails* material refers to the uranium-235-depleted waste UF<sub>6</sub> from ERDA enriching facilities.

Under a recycle program for product cylinders, it should be noted that:

1. Recycle cylinders containing heels are filled from a parent cylinder previously filled and sampled and not directly from a withdrawal position in the enriching plant.
2. No warranty is made for the UF<sub>6</sub> after it has been transferred from the parent cylinder into a cylinder containing a heel. Any questions relating to the properties or specifications of ERDA-furnished material are resolved by recourse to the official ERDA sample taken from the parent cylinder.
3. Billing for enriching services is based on the quantity of UF<sub>6</sub> transferred to the cylinder containing the heel.

## 3. CYLINDER FILLING AND EMPTYING PROCEDURES

---

### 3.1 GENERAL

Systems and procedures used by ERDA are designed to accommodate the physical and chemical properties of UF<sub>6</sub> and to provide maximum safety and efficiency. The efficient transfer of UF<sub>6</sub> is made through a leaktight, adequately heated system. Safety considerations require compound pressure indicators and temperature control throughout the system.

### 3.2 TYPICAL PLANT SYSTEMS

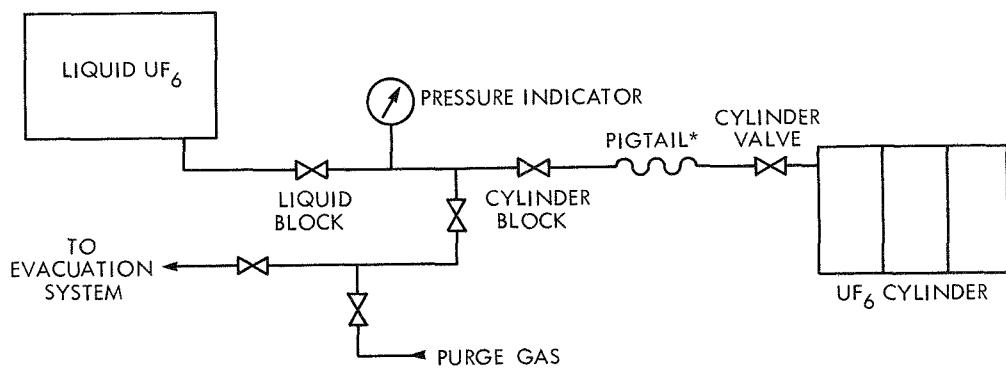
The systems shown in Figure 3 are typical of those used to fill or empty UF<sub>6</sub> cylinders. All lines are heated to maintain a temperature in the range of 175 to 250°F (79 to 121°C). Uranium hexafluoride undergoes large density changes in the liquid state presenting situations capable of leading to hydraulic rupture. Therefore, systems and operating procedures are designed to avoid trapping material without room for expansion. Conditions of this nature exist in an overfilled container; between two closed valves; or between two plugs in a line formed by wet air inleakage (UO<sub>2</sub>F<sub>2</sub>), solid UF<sub>6</sub> at a cold spot, or any other obstruction.

Evacuation systems are designed to preclude backflow of oil into the system or into a cylinder.

Because of their frequent use and the importance of their integrity, system pigtails are afforded particular attention. Only engineered, inspected pigtails should be used with UF<sub>6</sub> systems. Fabrication of pigtails according to drawing and specification, use of new virgin Teflon gaskets, and suitable pretesting and inspection are mandatory to assure quality pigtails for connections between UF<sub>6</sub> systems and UF<sub>6</sub> feed and withdrawal cylinders. Typical specifications and drawing references can be found in Goodyear Atomic Corporation documentation:

Material Specifications	GSP-6.21A
Drawing Specification	DX-761-892M
Brazing Specifications	GSP-4.330
Test and Inspection	QC-C307
Quality Assurance Plan	QA-761-005

## FILLING SYSTEM



## EMPTYING SYSTEM

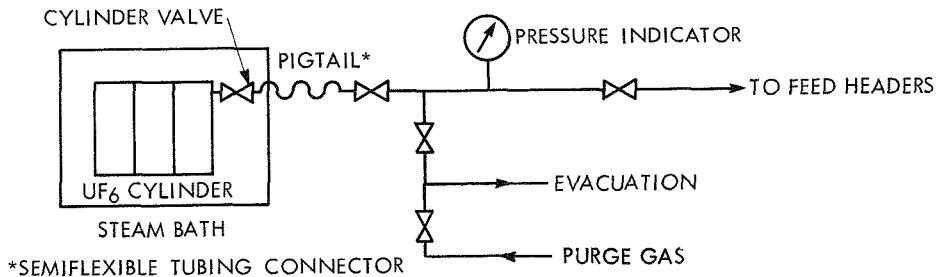


Figure 3  
TYPICAL UF<sub>6</sub> CYLINDER FILLING AND EMPTYING SYSTEMS

Additionally, continual field inspections must be conducted to ensure that the pigtails have not been damaged during use. Kinks, damaged threads, or insufficient heaters are cause for discontinuing use of the defective pigtail.

### 3.3 CYLINDER FILLING PROCEDURE

Liquid UF<sub>6</sub> is drained by gravity through heated lines and valves into evacuated cylinders. The liquid is controlled in a temperature range of 175 to 250°F (79 to 121°C). After the UF<sub>6</sub> has solidified, the cylinder is vented, if necessary, to a low-pressure system to remove contaminants which are volatile at room temperature.

The following procedural steps are commonly used for filling UF<sub>6</sub> cylinders by liquid transfer:

1. The valve protector and other attachments to the cylinder, as well as foreign material which could cause shipper-receiver weight discrepancies, are removed before the cylinder is weighed (see Section 4.1).
2. The evacuated cylinder is cold pressure checked, weighed, leak-rated, and connected to the withdrawal system.

3. To ascertain system tightness, all connections are leak-rated to 0.5 psia, or less, and pressure tested to a level equal to, or greater than, the UF<sub>6</sub> working pressure.
4. The scale is zeroed to take into account the cylinder tare weight.
5. The cylinder valve and pigtail are heated to prevent the solidification of UF<sub>6</sub>.
6. When the connecting lines are sufficiently hot to maintain the UF<sub>6</sub> in the liquid phase, the valves to the liquid system are opened.
7. The valves are closed when the cylinder contains the required amount of UF<sub>6</sub>, as determined by the observed weight gain.
8. All connections are evacuated to 0.5 psia (2.6 cm Hg), purged, and reevacuated.
9. The evacuated section is brought to atmospheric pressure with dry purge gas and the pigtail is cautiously disconnected.
10. The cylinder is weighed to determine the gross weight, and allowed to cool with the valve in the 12 o'clock position.
11. The cylinder is not shipped until the UF<sub>6</sub> has solidified and the vapor pressure in the cylinder is less than atmospheric pressure.

It is sometimes desirable to condense gaseous UF<sub>6</sub> directly into a cylinder. This method is applicable only to two-valve cylinders such as Models 5A, 8A, and 12B. The source of gaseous UF<sub>6</sub> is connected to the valve with the dip-pipe, and the other valve is connected to a low-pressure system. The cylinder is cooled in a trichloroethylene-dry ice slush bath or a mechanically refrigerated system cooled to approximately -25°F (-32°C). Gaseous UF<sub>6</sub> is then routed into the cylinder for condensation.

### 3.4 CYLINDER EMPTYING PROCEDURE

Uranium hexafluoride is removed from cylinders by vaporization or liquid transfer. The procedure for liquid draining is similar to that described in Section 3.3 and will not be discussed here.

Uranium hexafluoride is usually vaporized from cylinders with either steam heat or electrically heated air. High heat sources should never be applied directly to the cylinder surface because of the hydraulic rupture hazard associated with localized heating. Heat must be controlled to prevent temperatures in excess of 250°F (121°C). To determine when vaporization from a cylinder is complete, the system block valve is closed and the cylinder pressure observed. The absence of a pressure rise indicates that the vaporization of volatile material is complete. The following procedural steps are commonly used for emptying UF<sub>6</sub> cylinders by vapor transfer:

1. After the cylinder is gross weighed, cold pressure checked, and sampled, it is placed in the vaporizing position and connected to the feed system.
2. To ascertain system tightness, all connections are leak-rated to 0.5 psia, or less, and pressure tested to a level equal to, or greater than, the UF<sub>6</sub> working pressure.
3. The cylinder is valved to a continuous pressure indicator, preheated as necessary to liquefy the UF<sub>6</sub>, and the system valves are opened to start feeding.
4. Feeding is stopped when the desired amount of UF<sub>6</sub> has been vaporized or when the cylinder is empty. The latter is indicated by flow instruments or lack of pressure rise as described above.
5. Valves are closed and all connections are evacuated, purged, and leak-rated.
6. The evacuated section is brought to atmospheric pressure with purge gas and the pigtail is cautiously disconnected.
7. The cylinder is weighed to determine the actual amount removed.

Section 2.2.2 lists maximum allowable heels for standard cylinders.

## 4. WEIGHING PROCEDURES

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### 4.1 GENERAL

Accurate measurements of gross, tare, and net weights, percent uranium, and weight uranium are required. The individual measurements are important because the uranium and uranium-235 weights are obtained as follows:

Gross weight minus the tare weight provides the net weight.

Net weight multiplied by the percent uranium provides the uranium weight.

Uranium weight multiplied by the weight percent uranium-235 provides the uranium-235 weight.

Thus, careful attention is given in ERDA facilities to the type, capacity, precision, and maintenance of scales used for weighing the various sizes of UF<sub>6</sub> cylinders. Table 1 provides information regarding ERDA scales. Figures 4 through 7 are examples of typical scales and standard weights used by ERDA. The development of more precise weighing devices may result in replacement of the scales presently used.

All scales used for official weighing, except the fan scale and the equal-arm balance, are equipped with a printweigh attachment which provides a permanent record for audit and weight verification. A preliminary weight is obtained on a platform scale equipped with a printweigh attachment to provide a printed verification of the official weight obtained on an equal-arm balance.

Scales are normally enclosed or covered to ensure cleanliness and to prevent damage to the instrument. Scale pans, tare and weigh beams, platforms, cars, etc., are cleaned, and all building doors are closed to reduce drafts before any weighing operations are initiated.

Scales and balances are locked out while they are being loaded or unloaded to prevent damage to the weighing system. Special devices, such as lifting

Table 1

## WEIGHING CRITERIA

Cylinder Model No.	Typical Scale Type	Nominal Capacity of Scale	Scale Precision	Allowable Deviation(a)
1S, 2S	Fan	5 kg	$\pm 0.5$ g <sup>(b)</sup>	$\pm 0.5$ g
5A	Equal-Arm	60 kg	$\pm 0.5$ g <sup>(b)</sup>	$\pm 0.5$ g
8A, 12A, 12B	Platform	800 lb	$\pm 0.25$ lb	$\pm 0.25$ lb
30A, 30B	Platform	10,000 lb	$\pm 2$ lb	$\pm 2$ lb
48A, 48F, 48X, 48G, 48Y	Platform	40,000 lb	$\pm 2$ lb	$\pm 2$ lb

(a) From the established value during check weighing operations.

(b) ERDA gross, tare, and net weights are reported to the nearest gram.

mechanisms and scale cars operating on and off the scale platform on a steel track, are frequently used to load and center the cylinders on the scale platform to protect the scale from damage and to attain maximum weighing precision.

The tare weight for a cylinder is established only after the completely cleaned cylinder has been evacuated, thus eliminating the weight of contained air which would affect the tare weight. At least two independent weighings are obtained to establish the tare weight.

Cylinders are always weighed *without* valve protectors, skids, saddles, or other removable appurtenances. Valve protectors vary in weight and are not identified with a specific cylinder.

When a significant shipper-receiver difference is observed, the cylinder in question is subjected to the following check:

1. After the weight is rechecked, the cylinder is removed from the scale and the zero is checked.
2. The appropriate check weight is placed on the scale to verify the reliability of the scale.
3. The cylinder in question is again placed on the scale and weighed. If the two weights agree within the allowable deviation, as shown in Table 1, the first weight is considered to be acceptable.

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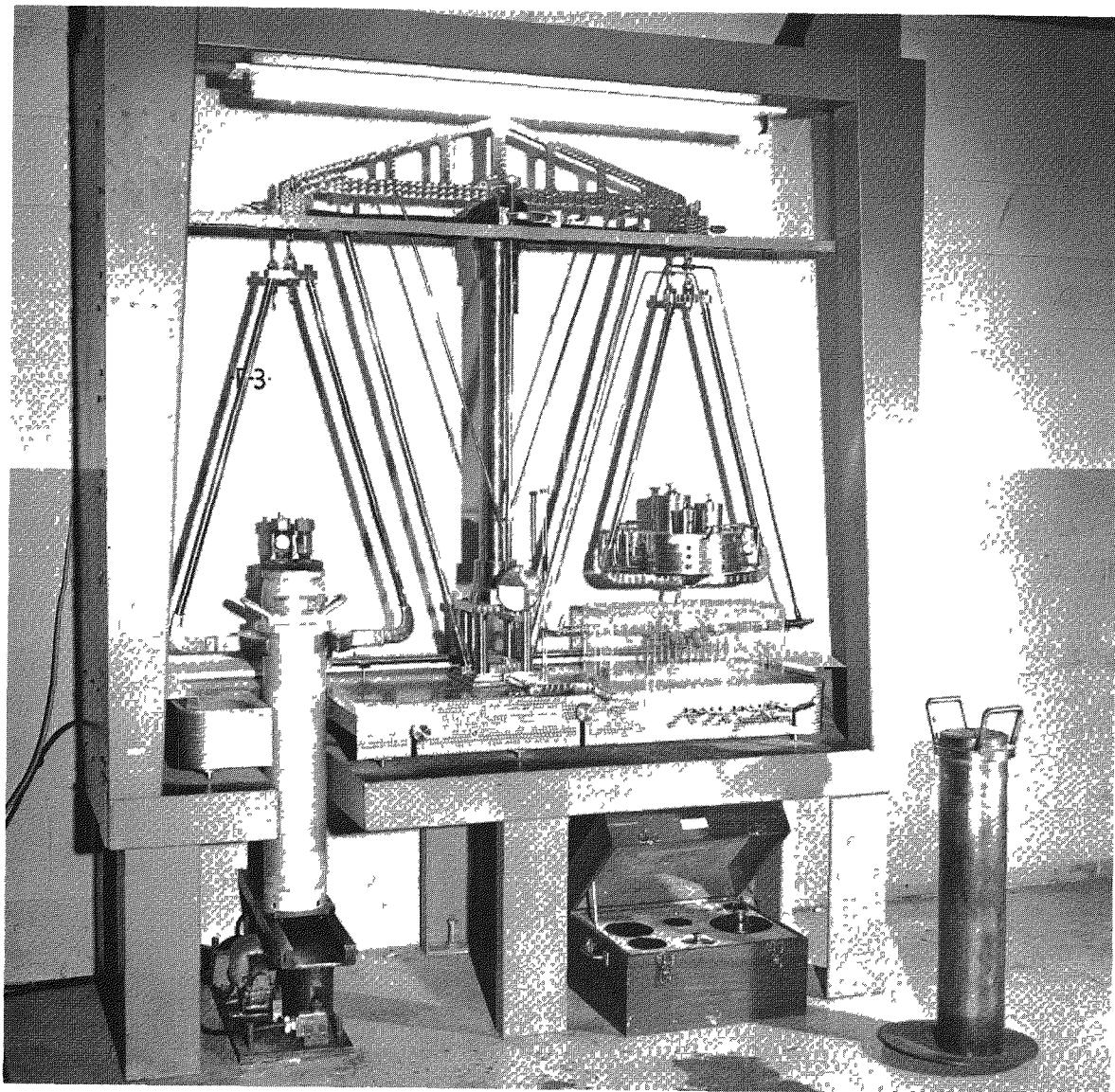


Figure 4  
TYPICAL EQUAL-ARM BALANCE FOR WEIGHING  $UF_6$  CYLINDER MODEL 5A

GAT PHOTO NO. 27-72-1

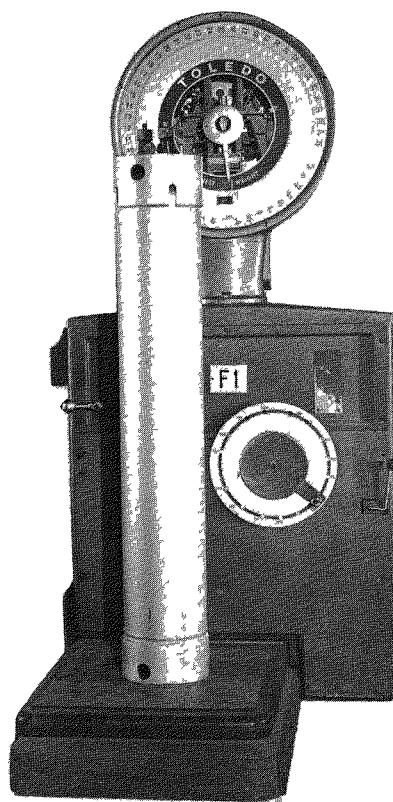


Figure 5

TYPICAL PLATFORM SCALE FOR  
WEIGHING  $UF_6$  CYLINDER MODELS 8A, 12A, AND 12B

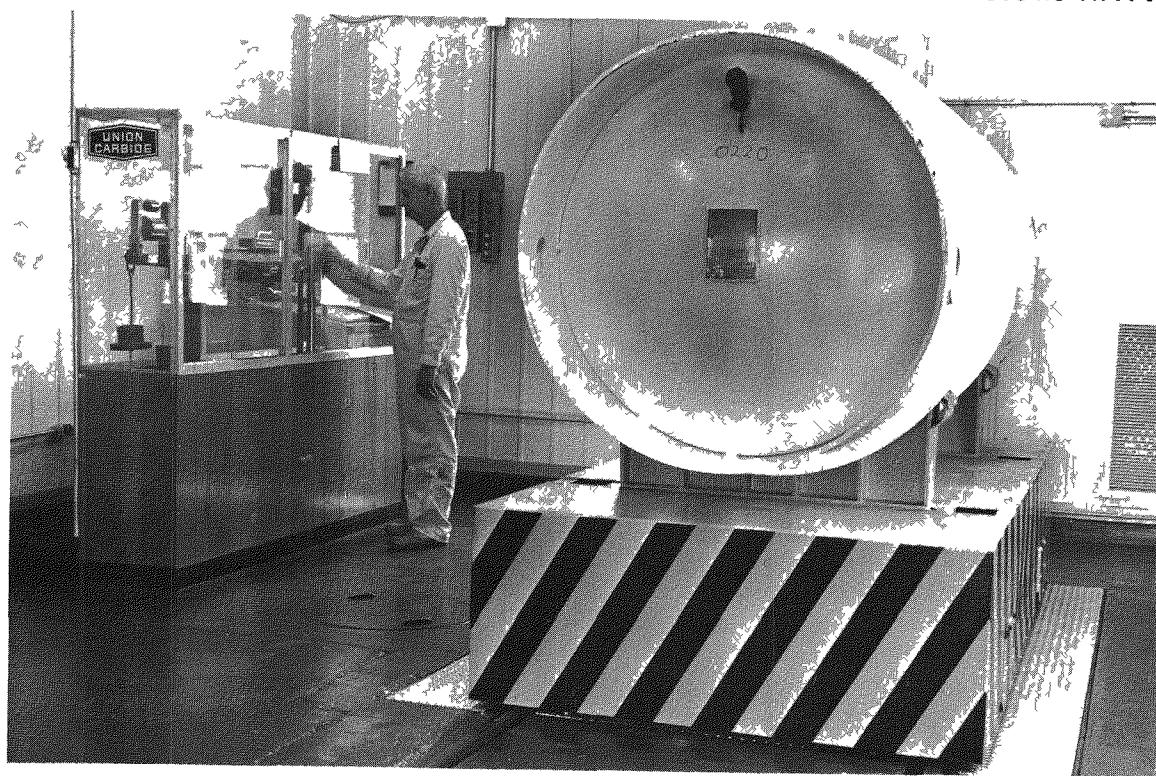


Figure 6  
TYPICAL PLATFORM SCALE FOR WEIGHING  
UF<sub>6</sub> CYLINDER MODELS 30A, 30B, 48X, 48G, AND 48Y

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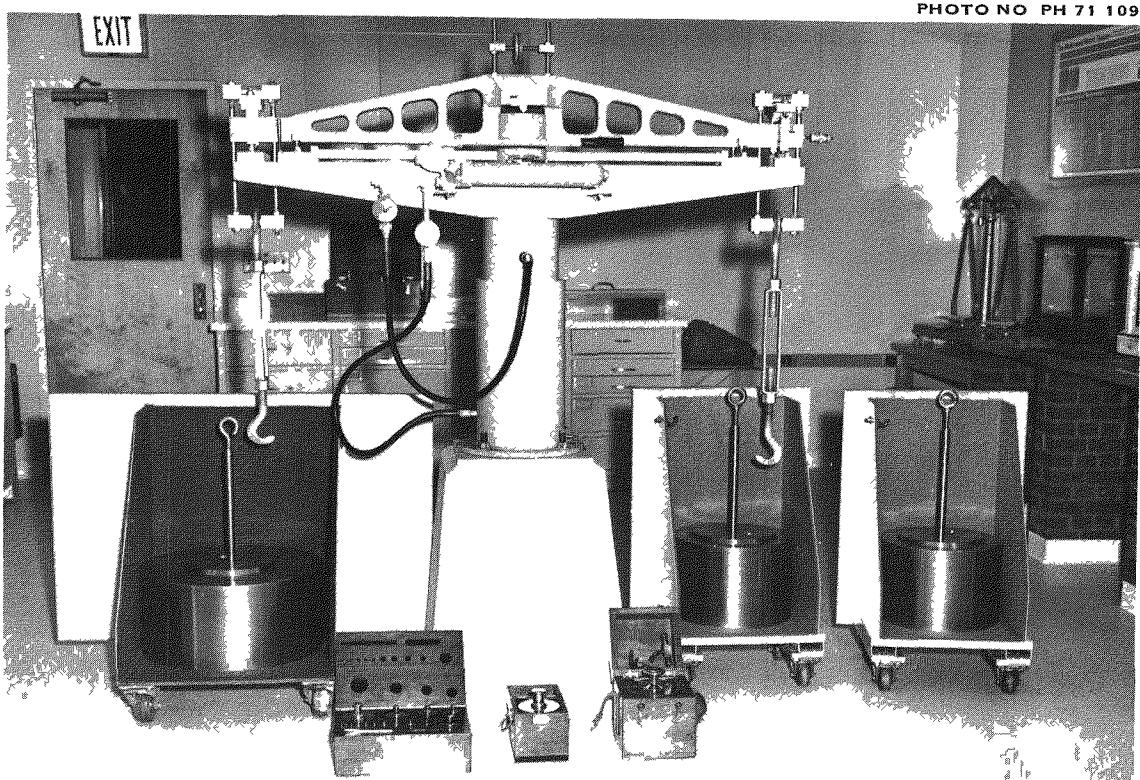


Figure 7  
TYPICAL EQUAL-ARM BALANCE FOR CALIBRATING TEST WEIGHTS

#### 4.2 GENERAL WEIGHING PRINCIPLES

The primary equipment required includes certified standard weights, test weights, check weights (or known weights), and scales or balances of appropriate capacity. The check weights, which are commensurate with the weight levels of both full and empty containers being weighed, are provided to verify that the scale is in proper working order. To facilitate handling, check weights are normally of the same size and shape as the UF<sub>6</sub> cylinders being weighed. If the weight obtained for a check weight differs from its established weight by more than the scale precision, the scale is rezeroed and the check weight reweighed. If the indicated weight still differs from the established weight by more than the allowable deviation, the scale is recalibrated.

The appropriate check weight is weighed either (1) prior to the first weighing and after the last weighing of any group of empty or full cylinders, or (2) on a periodic time schedule determined by the frequency of use of the scale. The procedure for weighing the check weight (to verify scale performance) is the same as for weighing UF<sub>6</sub> cylinders. The value assigned to each check weight is verified by comparison with a like mass of standard test weights.\* The weight is reestablished at any time that the container is altered, e.g., by painting.

All certified primary standard weights used in the calibration of standard test weights (working standards) are submitted to an acceptable standards laboratory (National Bureau of Standards or the equivalent State agency) prior to use. Recertification of these primary standards is performed per ANSI 15.18-1975. Test weights are calibrated using certified standards on an annual basis or using a weight control program based on the guidelines in ANSI 15.18.

All scales are calibrated with test weights at least annually and at other times as the need arises. Prior to beginning the calibration, the scale is inspected for damage and thoroughly cleaned. All poises are set at zero and the platform inspected for levelness and freedom of movement. If any increment checked is found to deviate by more than the scale precision (as shown in Table 1) from the value assigned to the weights on the scale, an adjustment to the scale is made. The scale is not considered to be in calibration until either the addition or subtraction of the test weights in prescribed increments has been completed throughout the usable weighing range without any adjustments to the scale or deviation greater than that allowable at each weight increment checked.

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\*As outlined in ANSI 15.18-1975, Mass Calibration Techniques for Nuclear Material Control.

## 5. SAMPLING PROCEDURES

### 5.1 GENERAL

An acceptable sample of  $UF_6$  must represent both the chemical and isotopic content of a defined quantity of  $UF_6$ . Experience has shown the most representative sample of the  $UF_6$  in a cylinder is one withdrawn from the liquid phase after complete homogenization. Achieving isotopic homogeneity is not difficult since the convection currents generated in the liquid  $UF_6$  during the heating of the cylinder for sampling will perform the necessary homogenization. However, achieving chemical homogeneity is more difficult, particularly in the presence of insoluble particles or excessive volatile impurities. If the presence of excessive volatile impurities is indicated, cylinders being prepared for shipment from ERDA facilities are vented to reduce such impurities to an acceptable level.

Prior to heating for sampling, a vapor pressure measurement (cold pressure check) is made which does not involve the withdrawal of a sample. The cylinder is heated (heating time is shown in Table 2) with the valve open and in the 12 o'clock position. Pressure instrumentation is attached and the pressure monitored throughout the required heating period to assure that the pressure does not exceed 75 psia at 200°F (93°C) or 125 psia at 235°F (113°C).

Sampling techniques may be classified into those applicable to cylinders which may be composited and to those cylinders which are sampled individually. A tabulation of sampling data applicable to each cylinder model number is presented in Table 2. A typical sampling system is shown schematically in Figure 8. The development of improved equipment and/or procedures may result in modification of ERDA sampling practices.

### 5.2 GENERAL SAMPLING PRINCIPLES

Models 30A, 30B, and larger cylinders are sampled in a horizontal position with the valve below the liquid level in the 3-5 o'clock or the 7-9 o'clock positions. Models 12A, 12B, and smaller cylinders are inverted for sampling.

Table 2

## SAMPLING INFORMATION

Cylinder Model No.	Sample Cylinders Normally Used			Maximum No. of Cylinders Composited	Approximate Sample Size/Cylinder, g UF <sub>6</sub>		Minimum Heating Time at 200°F (93°C), hr
	Model No.	Fill Limits	lb		Single Cylinders	Composited Cylinders	
5A	1S	1.0	450	6	400	65	2
8A	1S	1.0	450	6	400	65	3
12A, 12B	1S	1.0	450	10	400	65	4
30A, 30B	2S	4.9	2,200	4	1,700	340	8
48A, 48F, 48X, 48Y	2S	4.9	2,200	1	1,700	No Composite	12

## NOTES:

1. Steam or electrically heated air is used as the heating medium. Saturated steam is considered the safest medium for maximum temperature control. However, nuclear safety must be considered for enrichments above 1.0% uranium-235. When steam is used, provision must be made to drain the condensate and prevent the accumulation of an unsafe uranium mass in event the UF<sub>6</sub> cylinder should rupture.
2. Overfilled sample cylinders are not used for analytical purposes. In the event a sample cylinder is overfilled, a new sample is obtained.
3. UF<sub>6</sub> may be withdrawn into a large ERDA-owned container, sampled and then transferred into smaller customer-owned cylinders. Such transfers may involve the filling of up to ten Model 12A or 12B cylinders from one Model 30A or 30B cylinder, filling up to four Model 30A or 30B cylinders from one Model 48A or 48X cylinder.

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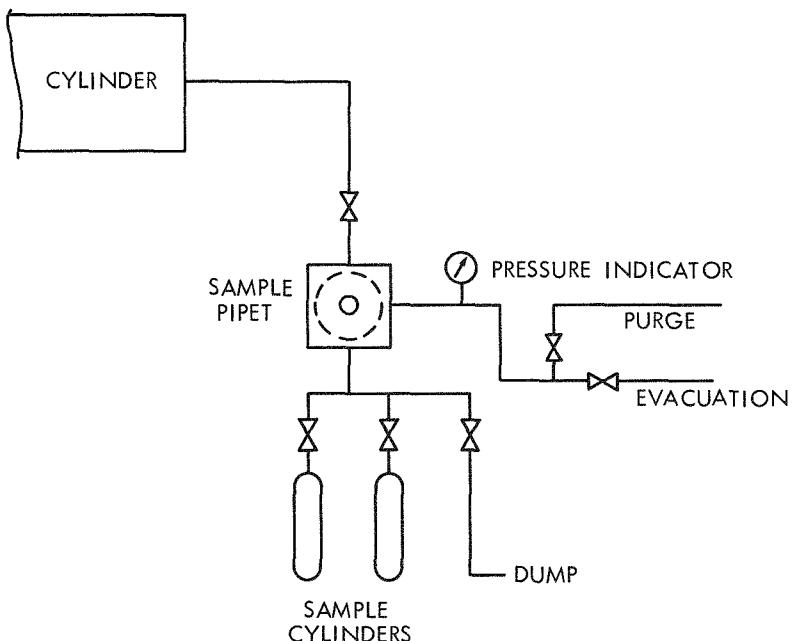


Figure 8  
TYPICAL SAMPLING SYSTEM

The temperature of the cylinder and contents is maintained at 200-235°F (93-113°C) throughout the required heating period (Table 2) and during the actual sample withdrawal procedure. The entire sampling system, including the sample cylinder valves, is maintained at approximately the same temperature to assure liquid flow.

The cylinder is connected to the fixed sampling volume with a length of Monel, nickel or copper tubing. If the cylinder has two valves, one of which is attached to a dip-pipe, the tubing is connected to the other valve. The fixed sampling volume permits the metering of a measured aliquot of UF<sub>6</sub> from the cylinder. New virgin Teflon gaskets are used at all connections. Prior to admission of UF<sub>6</sub>, the sampling system, including the sample cylinders, is evacuated to 0.5 psia (2.6 cm Hg) or less and leak rated. Additionally, the system is pressure tested, using dry air, to a level equivalent to or greater than the UF<sub>6</sub> working pressure.

Two independent samples are removed from each cylinder or composite group. One of the samples is analyzed immediately. The second sample is retained for potential umpire use.

Prior to opening the sampling system to atmosphere, the system is purged, evacuated to 0.5 psia (2.6 cm Hg) and back filled with dry air or nitrogen to atmospheric pressure.



## 6. SHIPPING

### 6.1 GENERAL

Essentially all UF<sub>6</sub> shipments made to and from ERDA facilities are by rail or truck. For repetitive bulk shipments, particularly of the larger cylinders, transportation safety is promoted through the use of specially designed trucks. Rail cars have been equipped to accommodate four Model 48 (A, X, F, or Y) cylinders. Heavy-duty tie-down devices and saddles are utilized. Typical examples of appropriate equipment are shown in Figures 9 through 12. Examples of lifting fixtures are shown in Figures 13 through 15. Each full cylinder must either be shipped in a protective shipping package or it must be equipped with a valve protector. Each protective overpack containing a UF<sub>6</sub> cylinder and/or each cylinder valve is secured with a numbered seal. Uranium hexafluoride is shipped only after it has solidified and the vapor pressure of the cylinder is below atmospheric pressure. For the 48- and 30-in. cylinders, respectively, a cooling time of 5 days and 3 days is required to achieve subatmospheric pressures.

### 6.2 REGULATIONS

Various agencies have rules and regulations pertaining to the packaging and transportation of radioactive materials. In addition, many states and localities have their own regulations. The regulatory agencies include ERDA, DOT, the Nuclear Regulatory Commission (NRC), the U.S. Postal Service, the International Atomic Energy Agency (IAEA), and the International Air Transport Association (IATA). Detailed information regarding the packaging and transportation of UF<sub>6</sub> may be found in publications of these agencies. The regulations of the agencies are referenced as follows:

<u>Agency</u>	<u>Regulations</u>
ERDA	ERDAM 0529, 5201
NRC	10 CFR 71
DOT	49 CFR 85, 170-189
U.S. Postal Service	39 CFR 123
IAEA	Safety Series No. 6
IATA	Restricted Articles Regulations (latest edition)



Figure 9  
FOUR 10-TON CYLINDERS

PHOTO NO. PH-70-1189



Figure 10  
TWO 10-TON CYLINDERS



Figure 11  
FIVE 2-1/2-TON CYLINDERS IN PROTECTIVE OVERPACKS

PHOTO NO. PH-4570 (P)



Figure 12  
FOUR 10-TON CYLINDERS IN PROTECTIVE OVERPACKS



Figure 13  
STIFF BACK FOR CYLINDER MODELS 30A AND 30B

PHOTO NO. PH-76-1483

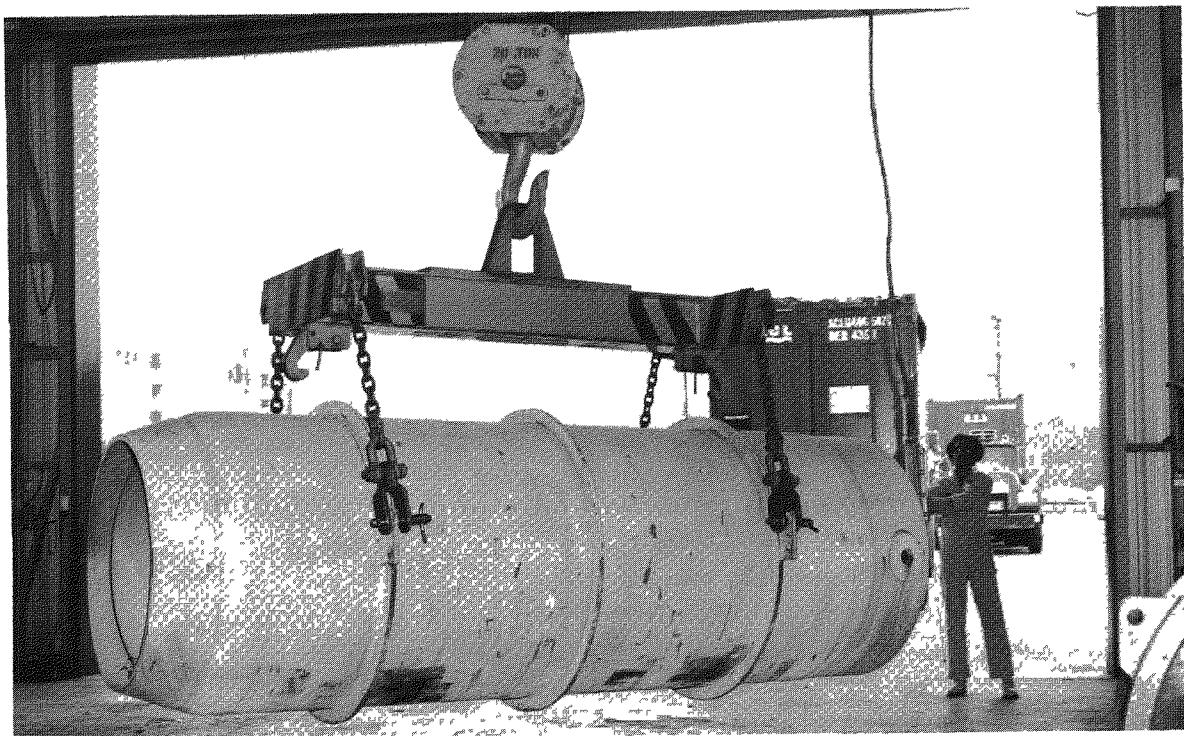


Figure 14  
H FRAME FOR CYLINDER MODELS 30A, 30B, 48X, 48G, AND 48Y

PHOTO NO. PH-76-637

27



Figure 15  
RAYGO WAGNER CYLINDER STACKER

### 6.3 PROTECTIVE OVERPACKS FOR FULL CYLINDERS

Except for exempt quantities of fissile material, cylinders containing UF<sub>6</sub> enriched to greater than 1.0 wt % uranium-235 must be shipped in protective overpacks. Provisions to adequately space, protect against accident conditions, and assure criticality prevention have been incorporated in the designs of the protective overpacks. Protective overpacks which have been designed and tested in accordance with applicable ERDA and DOT regulations for UF<sub>6</sub> cylinder Models 5A, 8A, 12A, 30A, and 30B are shown in Figures 16 through 19. A protective overpack for the 48A and 48X cylinders is shown in Figure 20. A series of drawings and specifications for these protective packages, except for the 48A and 48X cylinders, are available as CAPE PACKAGE No. 1662 from the National Technical Information Service, U.S. Department of Commerce, 5285 Port Royal Road, Springfield, Virginia 22161. The 48A and 48X overpacks are described in USERDA Report KY-665, *Safety Analysis Report on Paducah Tiger Protective Overpack for 10-Ton Cylinders of Uranium Hexafluoride*, and Supplement 1 to KY-665.

### 6.4 PROTECTIVE OVERPACK INSPECTION

Protective overpacks shall be visually inspected by the shipper prior to each use. The following shall be cause for further investigation or removal from service until the defective condition is satisfactorily corrected: excessive warping, distortion or other damage of liner or shell which prevents a tight closure of the package; excessive clearances for inner container within the liner; fastener damage; reduction in thermal insulation thickness in any area; or any other damage or condition which would otherwise make the integrity of the protective overpack questionable as a fire- and shock-resistant housing. The vent holes should be inspected and resealed with an epoxy, if necessary, and the gaskets replaced or resealed, as required. The 30-in. protective overpack should be weighed periodically to determine if water has leaked into the overpack causing a weight gain. Overpack tie-downs should be inspected to assure that they are not damaged and are adequate for their intended use. Figure 20 shows a typical overpack; Figure 21 shows a typical overpack inspection sheet.

### 6.5 EMPTY CYLINDERS

Empty cylinders with valve protection may be shipped without protective overpacks, provided the residual heel does not exceed the following:

Cylinder Model No.	Heel		Maximum Uranium-235, %
	lb	kg	
5A*	0.1	0.05	100.00
8A*	0.5	0.23	12.50
12A or 12B*	1.0	0.45	5.00
30A or 30B*	25.0	11.34	5.00
48A, 48X, 48F, or 48Y**	50.0	22.68	4.50

\*49-CFR-173.396(b)(8) covers these cylinders without a protective overpack.  
\*\*Certificate of compliance USA/6273/AF.

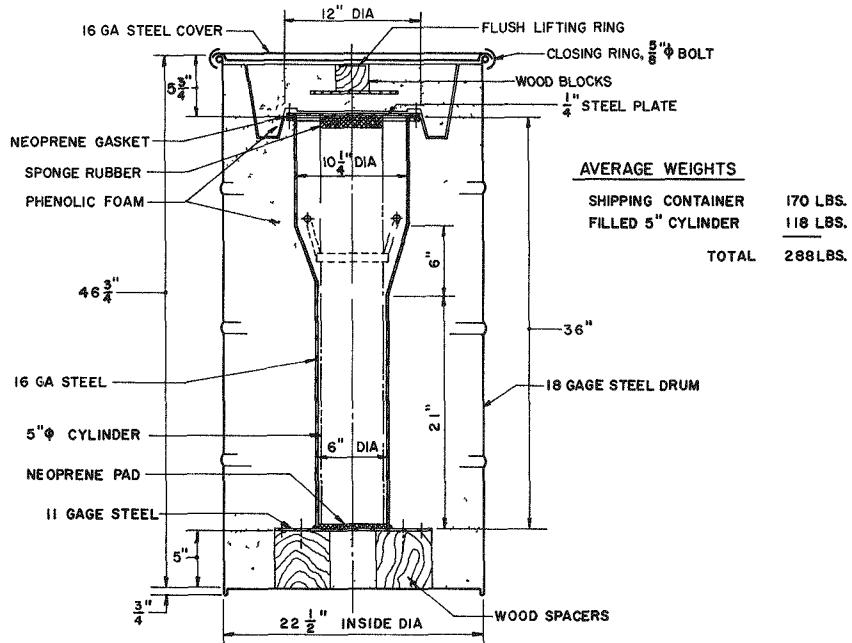


Figure 16  
PROTECTIVE OVERPACK FOR UF<sub>6</sub> CYLINDER MODEL 5A  
DOT SPECIFICATION 20-PF-1

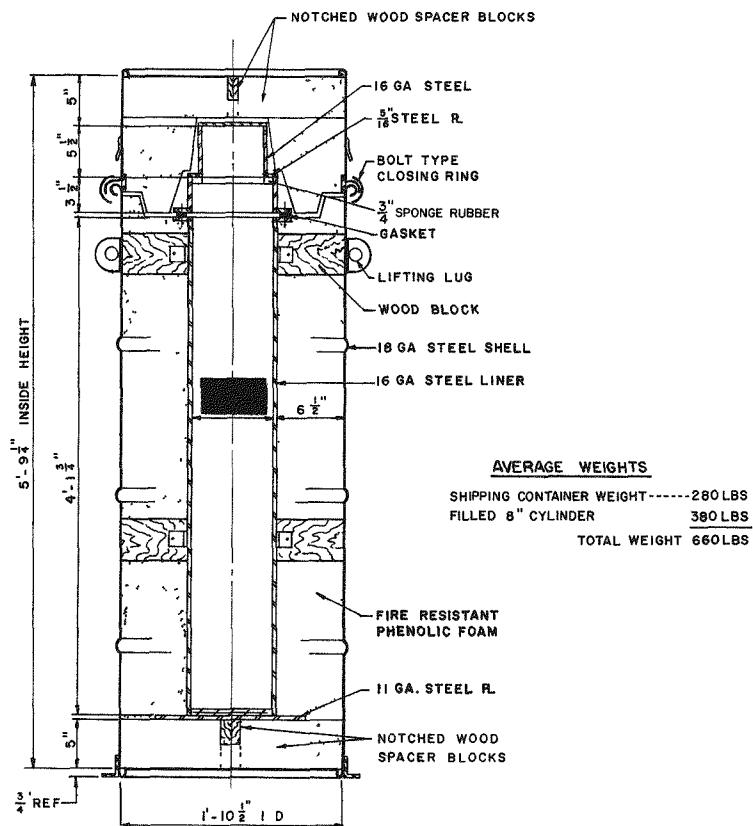


Figure 17  
PROTECTIVE OVERPACK FOR UF<sub>6</sub> CYLINDER MODEL 8A  
DOT SPECIFICATION 20-PF-2

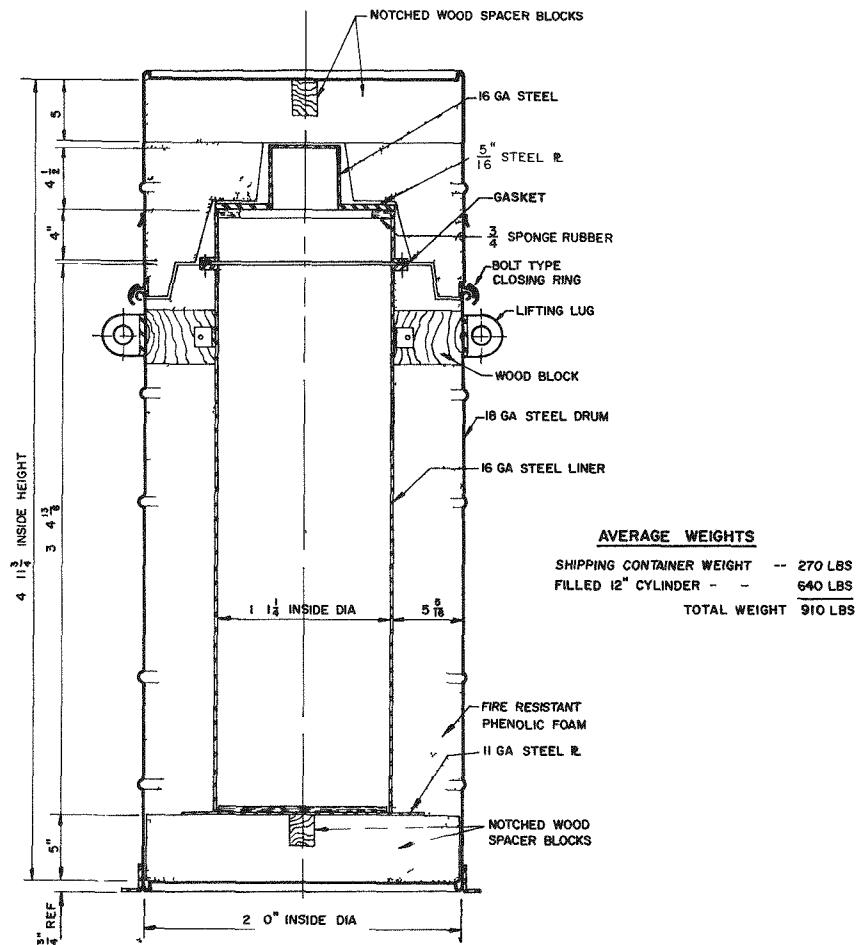
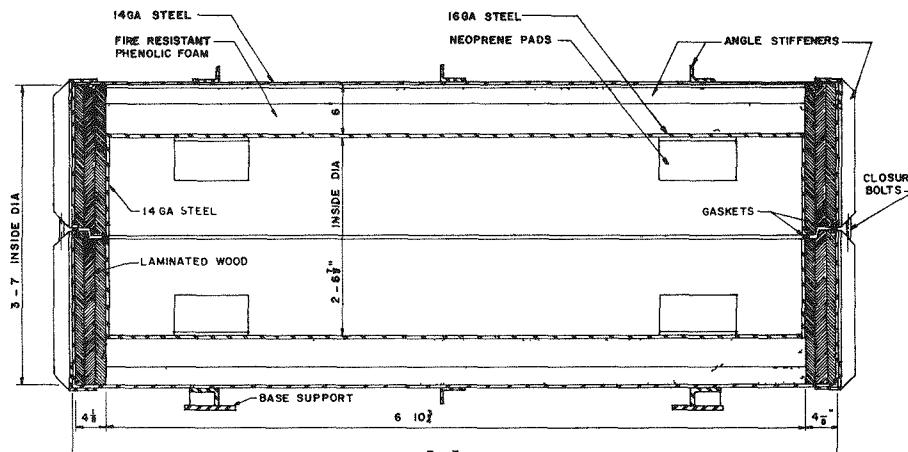
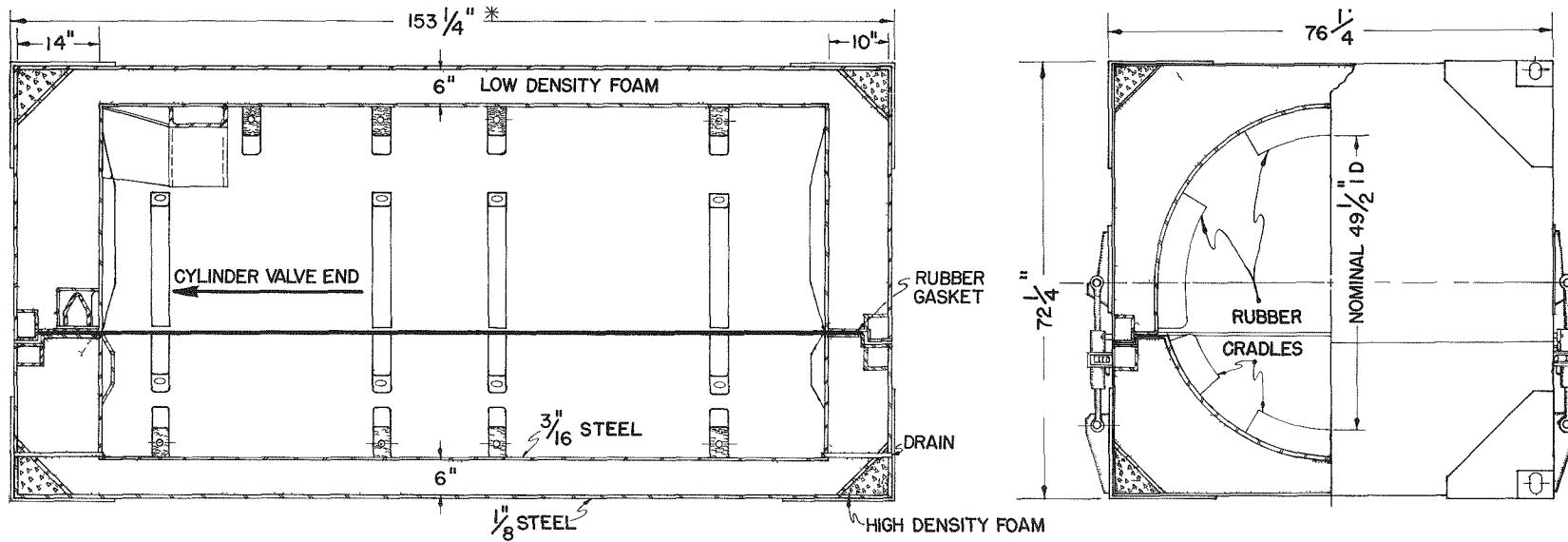


Figure 18  
PROTECTIVE OVERPACK FOR  $UF_6$  CYLINDER MODEL 12A  
DOT SPECIFICATION 20-PF-3



AVERAGE WEIGHTS  
SHIPPING CONTAINER WEIGHT 1750 LBS  
FILLED 30 CYLINDER 6400 LBS  
TOTAL WEIGHT 8150 LBS

Figure 19  
HORIZONTALLY-LOADED PROTECTIVE OVERPACK  
FOR  $UF_6$  CYLINDER MODELS 30A AND 30B  
DOT SPECIFICATION 21-PF-1



\* PROJECTED OVERALL LENGTH OF FUTURE PACKAGES TO ACCOMMODATE MODEL 48X TYPE CYLINDER

APPROXIMATE WEIGHT

SHIPPING CONTAINER FILLED CYLINDER	10,500 LBS 25,500 LBS
TOTAL	36,000 LBS

Figure 20  
PROTECTIVE OVERPACK FOR UF<sub>6</sub> CYLINDER MODEL 48X

<b>PADUCAH TIGER OVERPACK INSPECTION SHEET</b>							
UCN-10633 (5 10-74)							
VEHICLE NO		RECEIVED	DATE	TIME	INSPECTED BY		OVERPACK MODEL NO
SHIPPED							
POSITION NO 1	OVERPACK NO	SEAL NO	CYLINDER NO	POSITION NO 3	OVERPACK NO	SEAL NO	CYLINDER NO
POSITION NO 2	OVERPACK NO	SEAL NO	CYLINDER NO	POSITION NO. 4	OVERPACK NO	SEAL NO	CYLINDER NO
ITEM INSPECTED		SKETCH CODE	CONDITION				REMARKS (CIRCLE LOCATION OF UNACCEPTABLE ITEM ON ABOVE SKETCH INDICATE REPAIR REQUIRED AND/OR ACTION TAKEN BELOW.)
			POS. NO. 1	POS. NO. 2	POS. NO. 3	POS. NO. 4	
RUBBER BUMPERS-LID AND BASE		<input type="checkbox"/> R					
SKIN-INSIDE AND OUTSIDE							
GASKET							
LIFTING LUGS		<input type="checkbox"/> L					
TIE DOWN LUGS, BOLTS, AND RETAIN'S		<input type="checkbox"/> O					
TIE DOWN NUTS		<input type="checkbox"/> N					
TOEPLATES AND SHIMS		<input type="checkbox"/> T					
PINS IN PLACE		<input type="checkbox"/> P					
RATCHETS		<input type="checkbox"/> R					
D.O.T. LABELS							
PERMIT NUMBER							
PACKAGE PLACARDS							
HAZARDOUS INFO. AND EMERG. INSTR. SIGNS							
VEHICLE PLACARDS							
EMERGENCY NOTIFICATION SIGNS							
THIS SECTION TO BE COMPLETED BY A QUALIFIED INSPECTOR (For Damage Referred to the Inspection Dept.)							
Remarks (indicate number of overpack involved): _____							
SECTION A							
THE ABOVE ITEM(S) IS <input type="checkbox"/> ACCEPTABLE <input type="checkbox"/> UNACCEPTABLE DATE QUALIFIED INSPECTOR							
THIS SECTION TO BE COMPLETED WHEN THE DAMAGE INDICATED ABOVE IS INSPECTED AND APPROVED BY OTHER THAN INSPECTION DEPARTMENT PERSONNEL							
The following damage has been inspected and approved (with the indicated limitations, if any) (indicate number of overpack involved): _____							
SECTION B							
DAMAGE APPROVED BY				TITLE		DATE	
DISTRIBUTION				CONDITION LEGEND			
WHITE - URANIUM CONTROL (KYRC) BLUE - INSPECTION (WHEN SECTION A IS COMPLETED) BUFF - ORIGINATOR				A - ACCEPTABLE U - UNACCEPTABLE NA - NOT APPLICABLE			

Figure 21  
OVERPACK INSPECTION FORM

## 7. APPENDIX

### 7.1 STANDARD CYLINDER INFORMATION

#### 7.1.1 Introduction

This appendix contains information on standard ERDA UF<sub>6</sub> cylinders. The information included for each cylinder is as follows:

1. Photograph of cylinder and valve.
2. General data sheet.
3. Fabrication drawing of cylinder and valves including references to available up-to-date drawings, specifications, quality assurance plans, and inspection procedures.

All privately owned cylinders which are utilized must meet the specifications described herein unless deviations have been approved by ERDA and DOT prior to use. All cylinders must be certified for structural integrity, as described in Section 2.2. Details on cylinders, valves, and valve protectors are presented in this appendix.

All cylinders and valves which do not meet the described standards will be categorically rejected from use at the ERDA facilities unless approved by ERDA in writing.

#### 7.1.2 Cylinder Valves

The choice of valves used on UF<sub>6</sub> cylinders is very important. The valves described herein have been used by ERDA and have proved satisfactory. Requirements for valves are discussed below and included in this appendix.

7.1.2.1 Hoke Nos. 4618N4M and 4628N4M (or Approved Equal). These valves may be used on the Model 1S sample cylinder. Both the angle type, 4628N4M, and the straight-through type, 4618N4M, are of Monel construction. The composition and low internal volume make these valves suitable for

critical gas analysis applications. Each type has a screw handle, an Inconel diaphragm welded to the body, 1/4-in. OD tube connectors, and 1/8-in. orifice.

7.1.2.2 Hoke No. 2422L64M2 (or Approved Equal). This valve may be used on the Model 2S sample cylinder. It is an angle type valve of Monel construction. The metal plug stem is also of Monel construction and is packed with Teflon. The inlet port is 3/8-in. male pipe and the outlet port is 1/4-in. female type.

7.1.2.3 Three-Quarter-Inch Valve. Two each of these valves are used on Models 5A, 8A, and 12B cylinders. A single valve is used on the 12A cylinder. The body, packing gland, and collar are aluminum-silicon-bronze alloy. The stem is Monel and the packing is virgin Teflon. The ports are 3/8-in. diameter.

7.1.2.4 One-Inch Valve. This valve is used on Models 30A, 30B, 48A, 48F, 48X, 48Y, and 48G cylinders and is referred to as a 1-in. valve. The body, packing nut, packing ring, and packing follower are aluminum-silicon-bronze alloy, while the stem is Monel. The packing and cap gasket are virgin Teflon.

### 7.1.3 Requirements for UF<sub>6</sub> Cylinders

7.1.3.1 Design and Fabrication. Design, fabrication, inspection, testing, and cleaning of UF<sub>6</sub> cylinders are specified in the reference documents shown on the drawings in this section. Design conditions and materials specified on the drawings for pressure-containing portions of the cylinders shall be adhered to. However, non-pressure parts, such as skirts, may be fabricated from the materials listed or from equivalent ASME Code-approved materials which are compatible with fabrication of the cylinders involved.

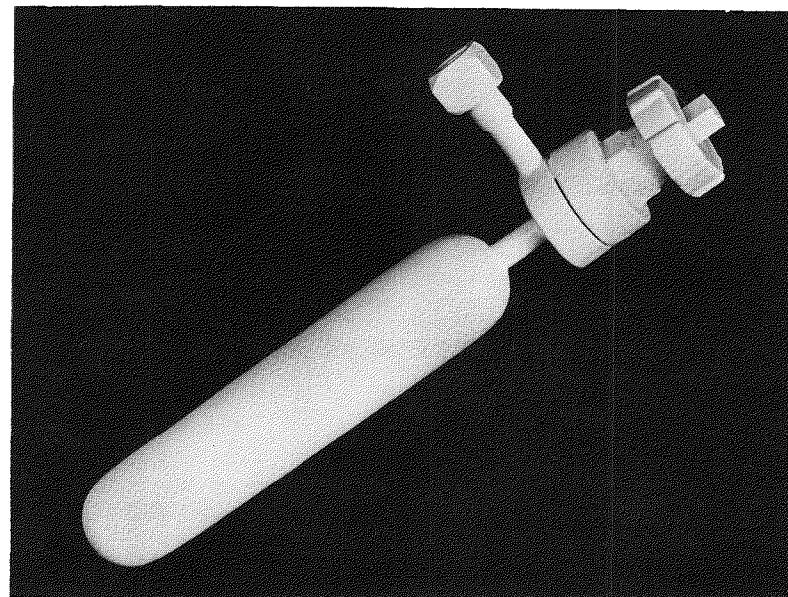
In order to minimize points of leakage, it is desirable to install only one valve and one plug. However, if additional valves and/or plugs are deemed necessary by the purchaser, they may be provided if approved by ERDA and installed and tested in the manner specified in the applicable drawings.

7.1.3.2 Reports, Certification, and Records. For each cylinder fabricated, the manufacturer shall supply to the purchaser and to the National Board of Boiler and Pressure Vessel Inspectors, copies of the Manufacturer's Data Report, ASME Code Form U-1 or U-1A.

The manufacturer shall provide to the purchaser a copy of the *as-built* drawing pertaining to the cylinder or cylinders involved. The manufacturer shall also provide to the purchaser one copy of each radiograph, properly identified with the cylinder and the location to which it applies.

The manufacturer shall measure the actual water capacity of each cylinder and certify to the purchaser the water weight at a temperature of 60°F (16°C). This weight shall be accurate to  $\pm 0.10\%$ . For a cylinder

## UF<sub>6</sub> CYLINDER MODEL 1S



### GENERAL DATA

Other Descriptive Terminology Used - None

#### ENGINEERING DRAWING REFERENCE

Nominal Diameter

Nominal Length

Wall Thickness

Nominal Tare Weight

Maximum Net Weight

Nominal Gross Weight

Minimum Volume

Basic Material of Construction

Service Pressure

Hydrostatic Test Pressure

Isotopic Content Limit

#### GOODYEAR ATOMIC CORPORATION DRAWING CX-761-M2009

1-1/2 in.

11 in.

1/16 in.

1-3/4 lb (0.79 kg)

1 lb (0.45 kg)

2-3/4 (1.25 kg)

0.0053 ft<sup>3</sup> (150 cm<sup>3</sup>)

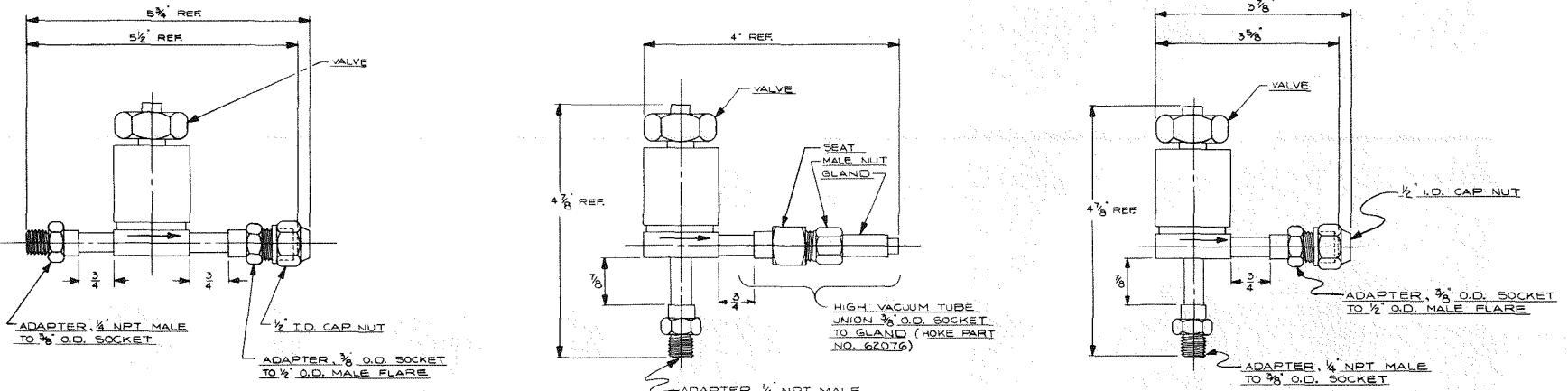
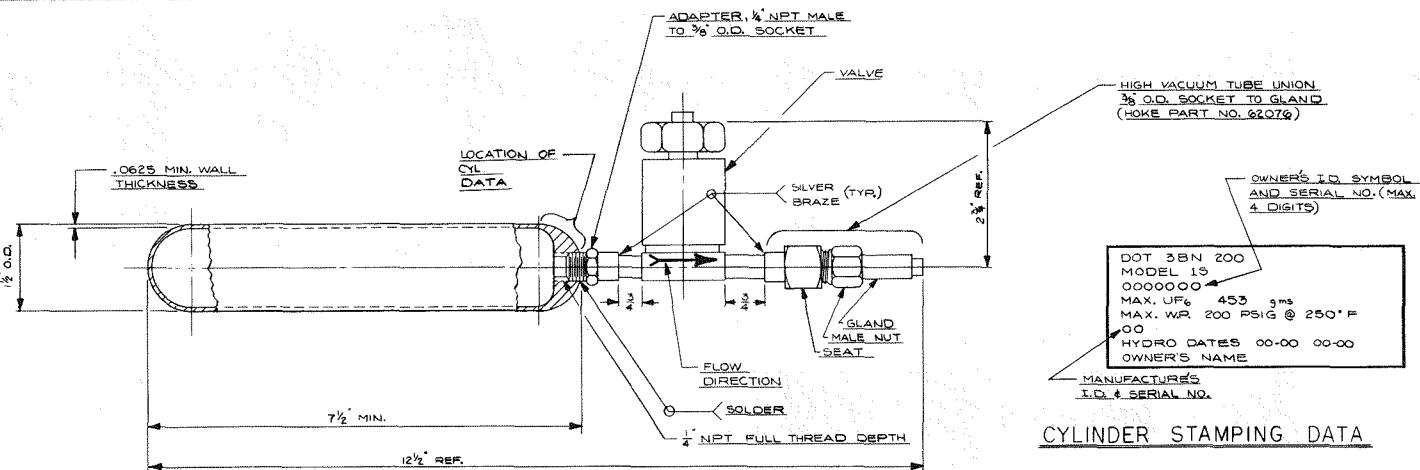
Nickel

200 psig

400 psig

100% U-235 max.

Valve Used - Hoke No. 4618N4M, 4628N4M, or equal.



OPTIONAL VALVE AND ADAPTER DETAIL

NOTE:

DIMENSIONAL TOLERANCE  $\pm \frac{1}{16}$   
UNLESS OTHERWISE SPECIFIED  
ANGULAR TOLERANCE  $\pm 2^\circ$ .

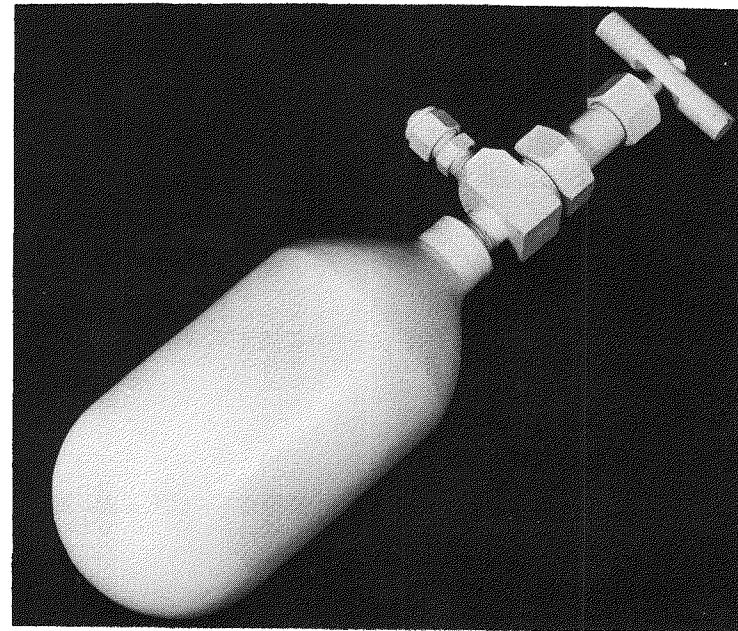
\*GOODYEAR ATOMIC CORPORATION DOCUMENTS.

#### **REFERENCE DOCUMENTS\***

**Drawing:** CX-761-M2009  
**Specification:** ES-M-191  
**Inspection:** IPM-3  
**QA Plan:** QA-601-001

## UF<sub>6</sub> CYLINDER MODEL 1S

## UF<sub>6</sub> CYLINDER MODEL 2S



### GENERAL DATA

Other Descriptive Terminology Used - Harshaw Type

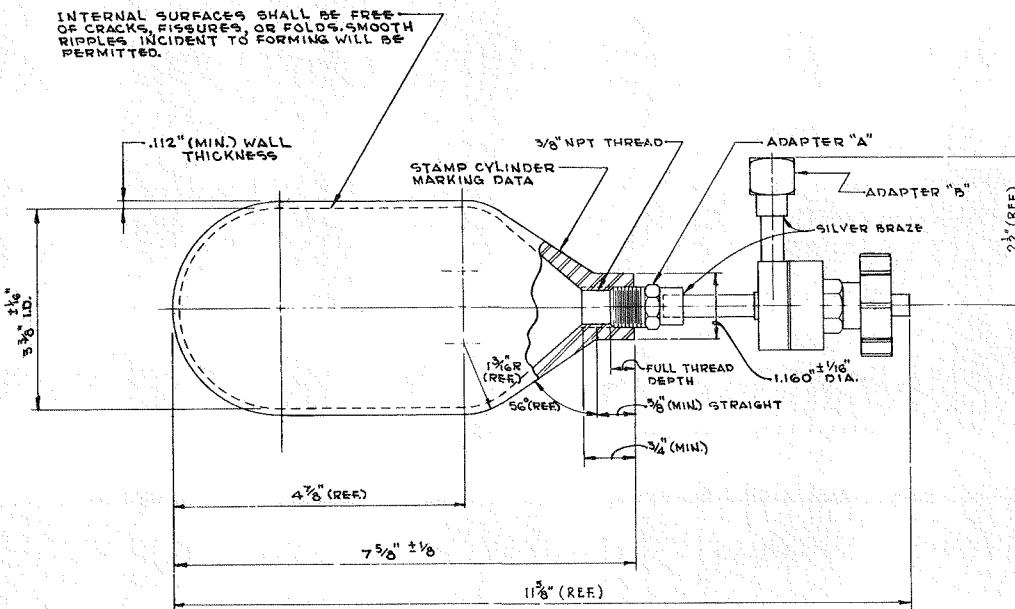
#### ENGINEERING DRAWING REFERENCE

#### GOODYEAR ATOMIC CORPORATION DRAWING CX-761-M2010

**Nominal Diameter**  
**Nominal Length**  
**Wall Thickness**  
**Nominal Tare Weight**  
**Maximum Net Weight**  
**Nominal Gross Weight**  
**Minimum Volume**  
**Basic Material of Construction**  
**Service Pressure**  
**Hydrostatic Test Pressure**  
**Isotopic Content Limit**

3-1/2 in.  
 11-1/2 in.  
 0.112 in. (min)  
 4.2 lb (1.91 kg)  
 4.9 lb (2.22 kg)  
 9.1 lb (4.13 kg)  
 0.026 ft<sup>3</sup> (736 cm<sup>3</sup>)  
 Nickel  
 200 psig  
 400 psig  
 100% U-235 max.

Valve Used - Hoke No. 2422L64M2, or equal.



300

#### REFERENCE DOCUMENTS\*

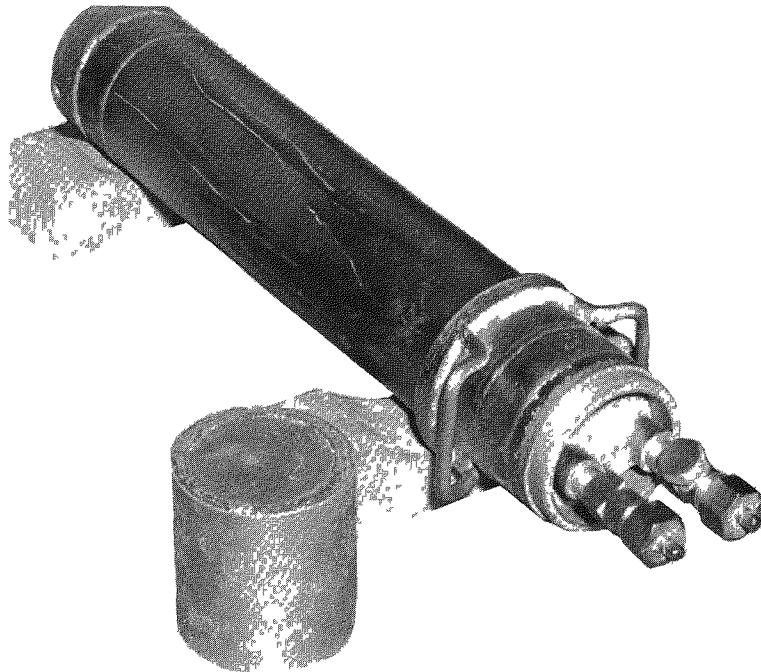
Drawing: CX-761-2010  
 Specification: ES-M-192  
 Inspection: IPM-3  
 QA Plan: QA-601-001

\*GOODYEAR ATOMIC CORPORATION DOCUMENTS.

NOTE: REFER TO SPECIFICATION FOR VALVE DESIGN.

UF<sub>6</sub> CYLINDER MODEL 2S

## UF<sub>6</sub> CYLINDER MODEL 5A



### GENERAL DATA

Other Descriptive Terminology Used - 5-in. product

#### ENGINEERING DRAWING REFERENCE

GOODYEAR ATOMIC CORPORATION  
DRAWING CX-761-M2011

Nominal Diameter

5 in.

Nominal Length

36 in.

Wall Thickness

1/4 in.

Nominal Tare Weight

55 lb (24.95 kg)

Maximum Net Weight

55 lb (24.95 kg)

Nominal Gross Weight

110 lb (without cap) (49.9 kg)

Minimum Volume

0.284 ft<sup>3</sup> (8.04 liters)

Basic Material of Construction

Monel

Service Pressure

200 psig

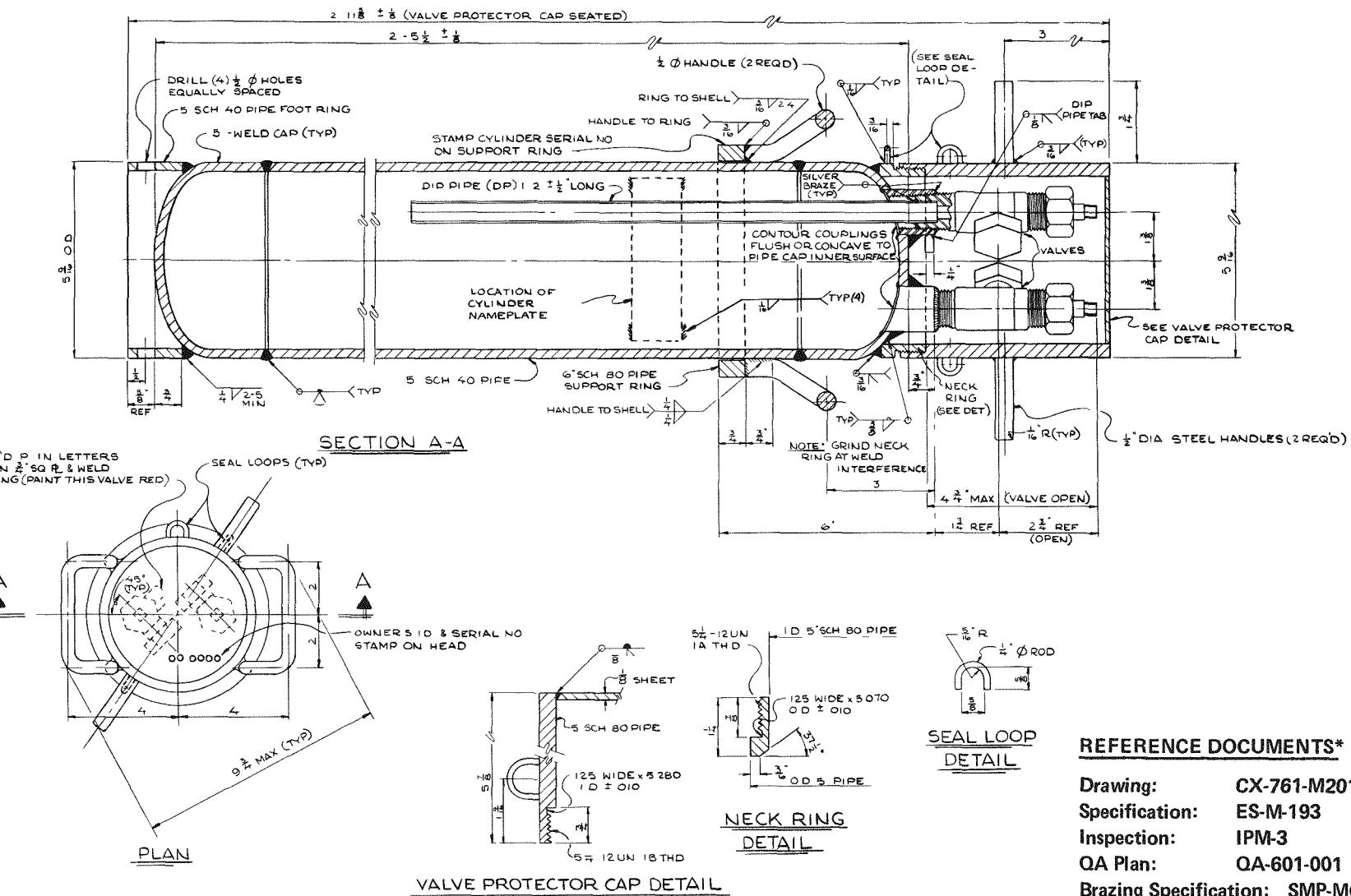
Hydrostatic Test Pressure

400 psig

Isotopic Content Limit

100% U-235 max

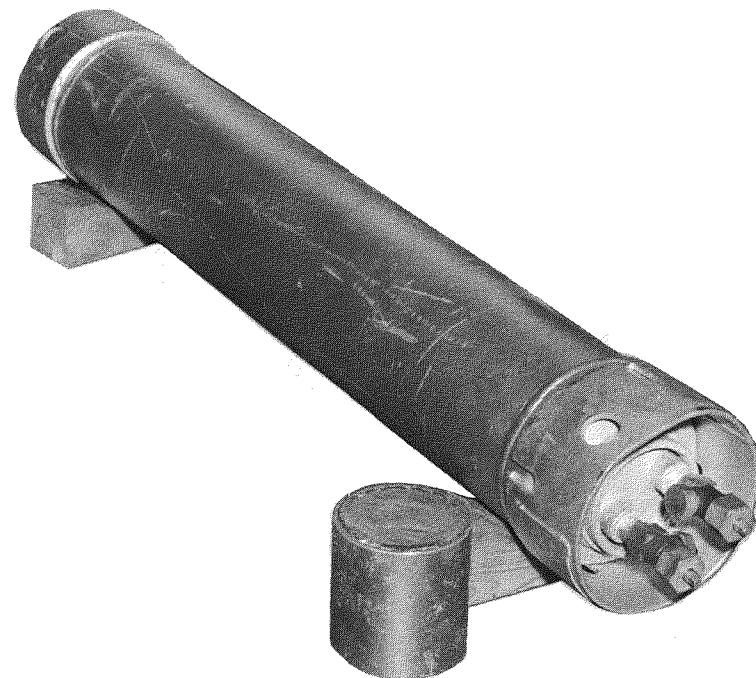
Valve Used - 3/4-inch Valve



\*GOODYEAR ATOMIC CORPORATION DOCUMENTS.

UF<sub>6</sub> CYLINDER MODEL 5A

## UF<sub>6</sub> CYLINDER MODEL 8A



### GENERAL DATA

Other Descriptive Terminology Used - 8-in.

#### ENGINEERING DRAWING REFERENCE

GOODYEAR ATOMIC CORPORATION,  
DRAWING CX-761-M2012

Nominal Diameter

8 in.

Nominal Length

56 in.

Wall Thickness

3/16 in.

Nominal Tare Weight

120 lb (54.43 kg)

Maximum Net Weight

255 lb (115.67 kg)

Nominal Gross Weight

375 lb (without cap) (170.10 kg)

Minimum Volume

1.319 ft<sup>3</sup> (37.4 liters)

Basic Material of Construction

Monel

Service Pressure

200 psig

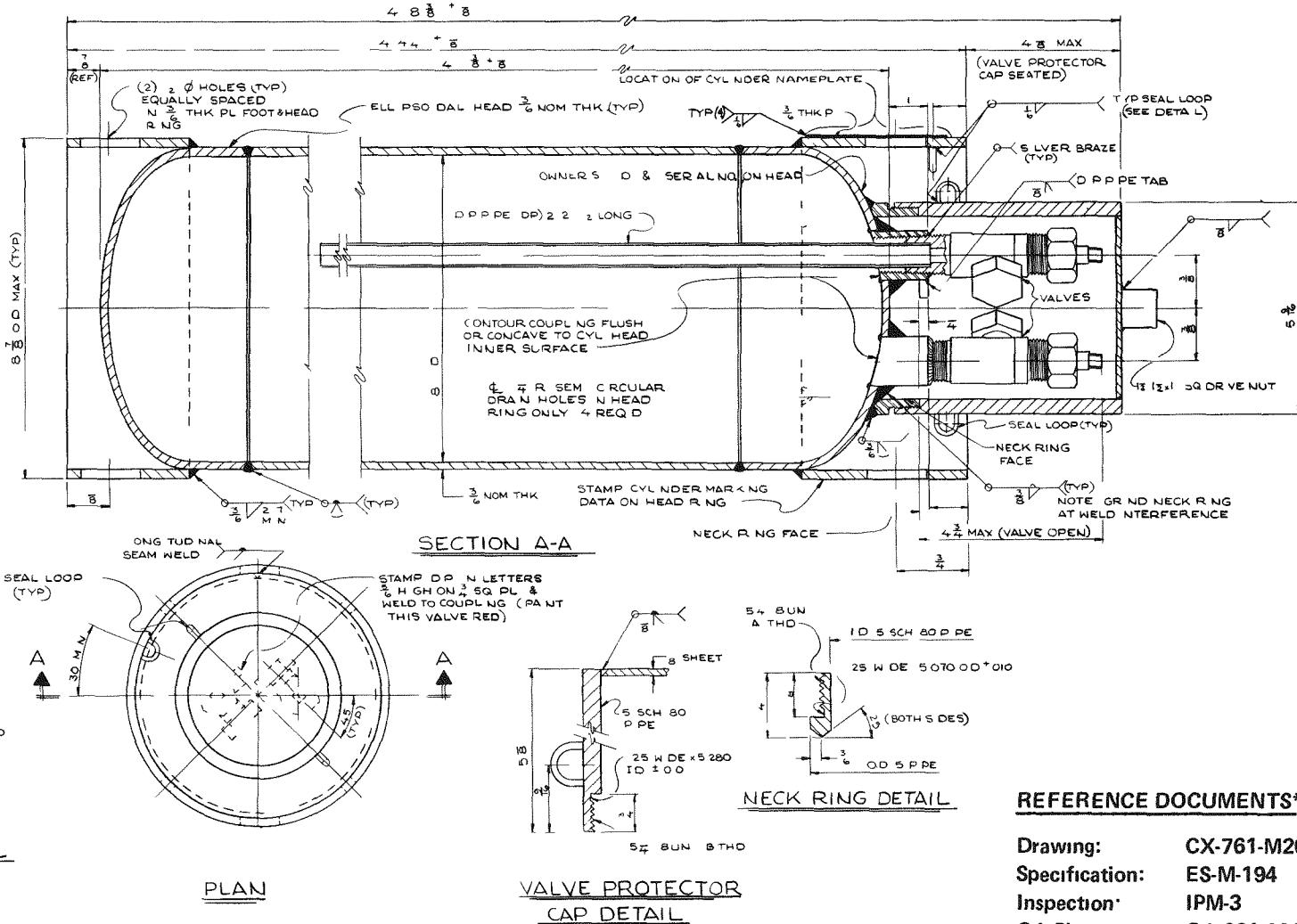
Hydrostatic Test Pressure

400 psig

Isotopic Content Limit

12.5% U-235 max

Valve Used - 3/4-in. Valve



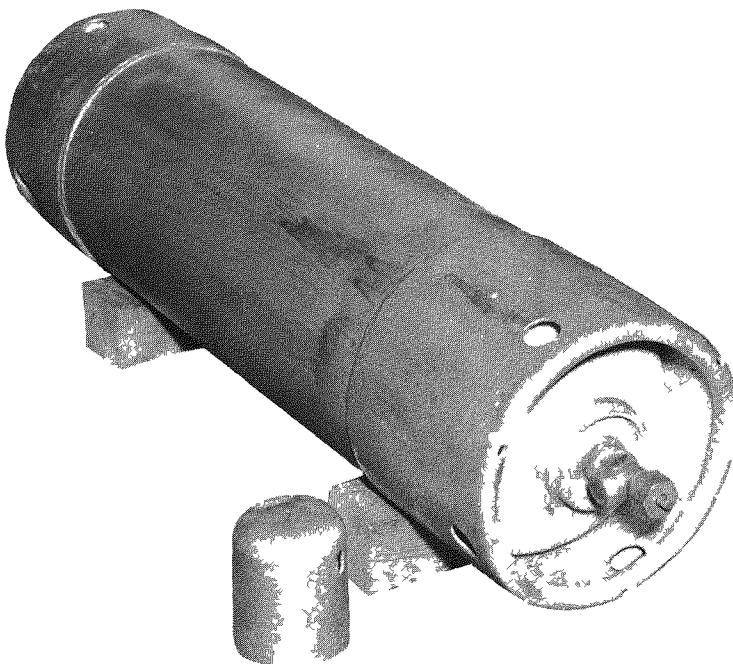
UF<sub>6</sub> CYLINDER MODEL 8A

#### **REFERENCE DOCUMENTS\***

**Drawing:** CX-761-M2012  
**Specification:** ES-M-194  
**Inspection:** IPM-3  
**QA Plan:** QA-601-001  
**Brazing Specification:** SMP-MCS-

**\*GOODYEAR ATOMIC CORPORATION DOCUMENTS.**

# UF<sub>6</sub> CYLINDER MODEL 12A\*



## GENERAL DATA

Other Descriptive Terminology Used - 12-in., MD

### ENGINEERING DRAWING REFERENCE

### GOODYEAR ATOMIC CORPORATION, DRAWING CX-761-M2013

Nominal Diameter

12 in.

Nominal Length

54 in.

Wall Thickness

0.200 in.

Nominal Tare Weight

185 lb (84 kg)

Maximum Net Weight

460 lb (208.7 kg)

Nominal Gross Weight

645 lb (without cap)(293 kg)

Minimum Volume

2.38 ft<sup>3</sup> (67.4 liters)

Basic Material of Construction

Nickel

Service Pressure

200 psig

Hydrostatic Test Pressure

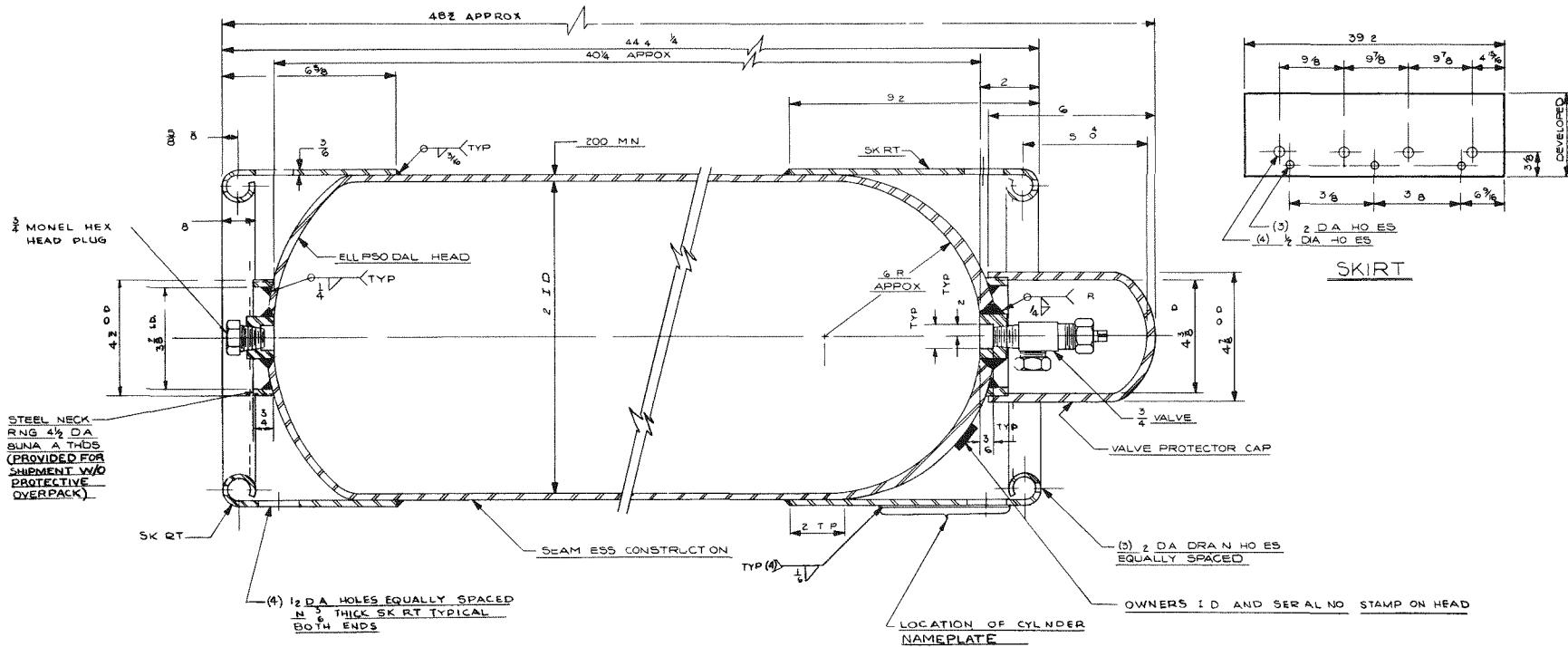
400 psig

Isotopic Content Limit

5.0% U-235 max

Valve Used - 3/4-in. Valve

\*OBSOLETE – SUBSTITUTE MODEL 12B



NOTE

0 MENSINAL TOLERANCE 16  
UNLESS OTHERWISE SPECIFIED  
ANGULAR TOLERANCE 2

CYLINDER STAMPING DATA

NATL BD NO 000000  
 MODEL 12A  
 000000 ← OWNERS D AND SERIAL NO (MAX 40 G T:  
 TARE WT 00 000 KG  
 WATER CAP 00 000 KG  
 MAX NET UF 200 KG  
 MAX W P 200 PS G @ 250°F  
 15 PS G @ 250°F  
 00 ← MANUF D  
 HYDRO DATES 00 00 00 00  
 00 00 00 00 00 00  
 00 00 00 00 00 00  
 OWNERS NAME

NOTE: MODEL 12A CYLINDER IS OBSOLETE. SUBSTITUTE MODEL 12B.

## REFERENCE DOCUMENTS\*

Drawing: CX-761-M2013

Specification: ES-M-195

Inspection: IPM-3

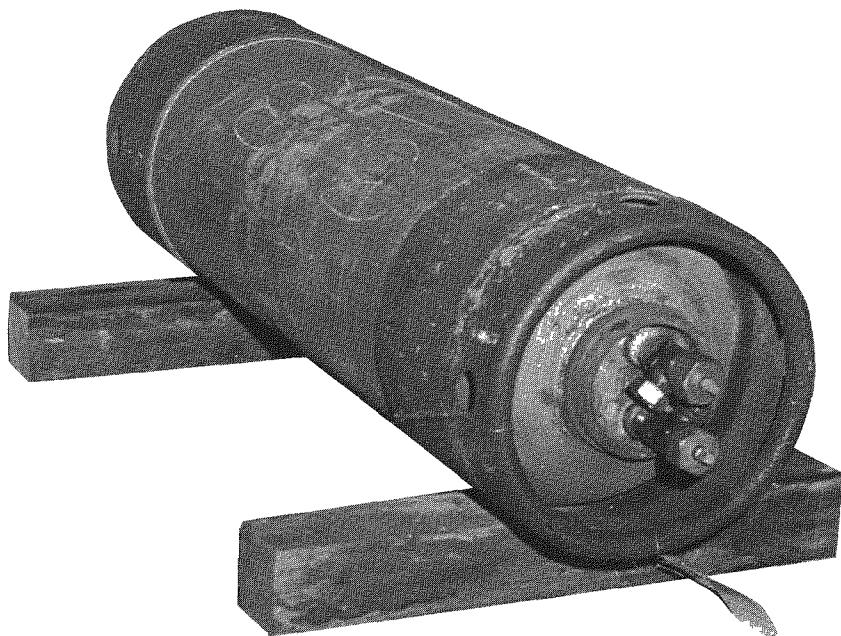
QA Plan: QA-601-001

## Valve Tinning Specification. SMP-MCS-1

\*GOODYEAR ATOMIC CORPORATION DOCUMENTS.

## UF<sub>6</sub> CYLINDER MODEL 12A

## UF<sub>6</sub> CYLINDER MODEL 12B



### GENERAL DATA

Other Descriptive Terminology Used - 12 in. - 2 Valves.

ENGINEERING DRAWING  
REFERENCE

GOODYEAR ATOMIC CORPORATION,  
DRAWING CX-761-M2014

Nominal Diameter

12 in.

Nominal Length

49.5 in.

Wall Thickness

0.250 in.

Nominal Tare Weight

185 lb (84 kg)

Maximum Net Weight

460 lb (208.7 kg)

Nominal Gross Weight

645 lb (without cap)(293 kg)

Minimum Volume

2.38 ft<sup>3</sup> (67 liters)

Basic Material of Construction

Monel

Service Pressure

200 psig

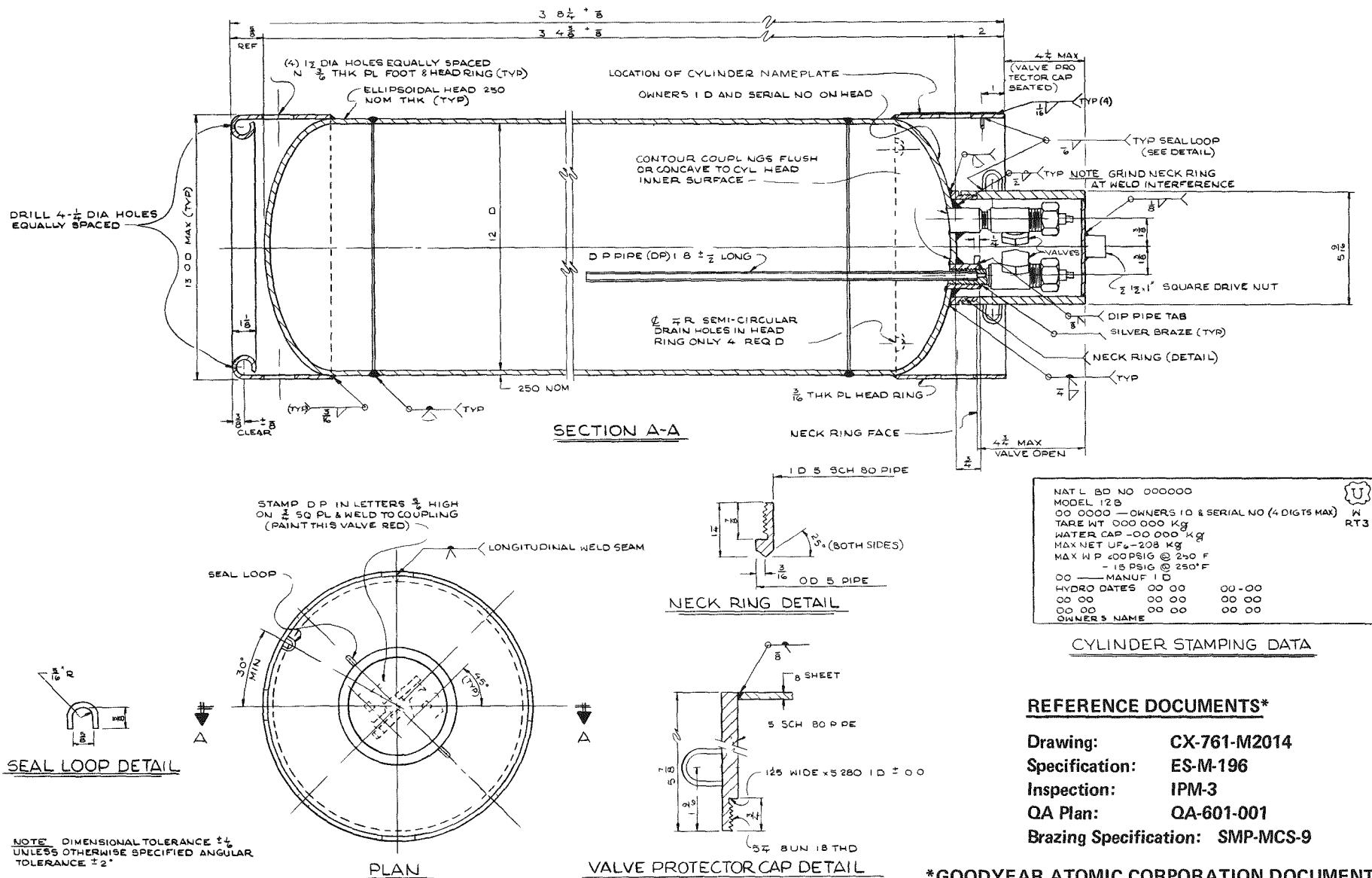
Hydrostatic Test Pressure

400 psig

Isotopic Content Limit

5.0% U-235 max

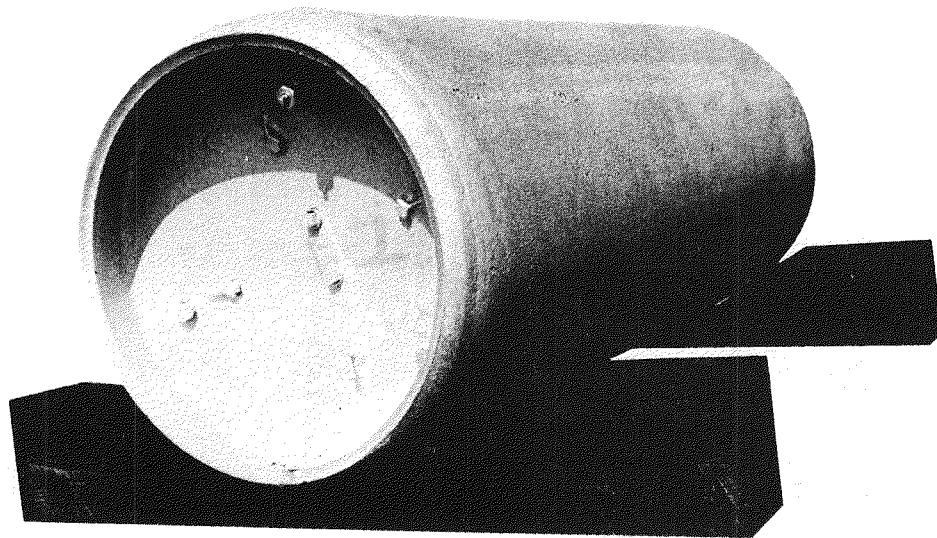
Valve Used - 3/4-in. Valve



UF<sub>6</sub> CYLINDER MODEL 12B

**\*GOODYEAR ATOMIC CORPORATION DOCUMENTS.**

# UF<sub>6</sub> CYLINDER MODEL 30A\*



## GENERAL DATA

Other Descriptive Terminology Used - 2-1/2-ton UF<sub>6</sub>, 1-ton chlorine

### ENGINEERING DRAWING REFERENCE

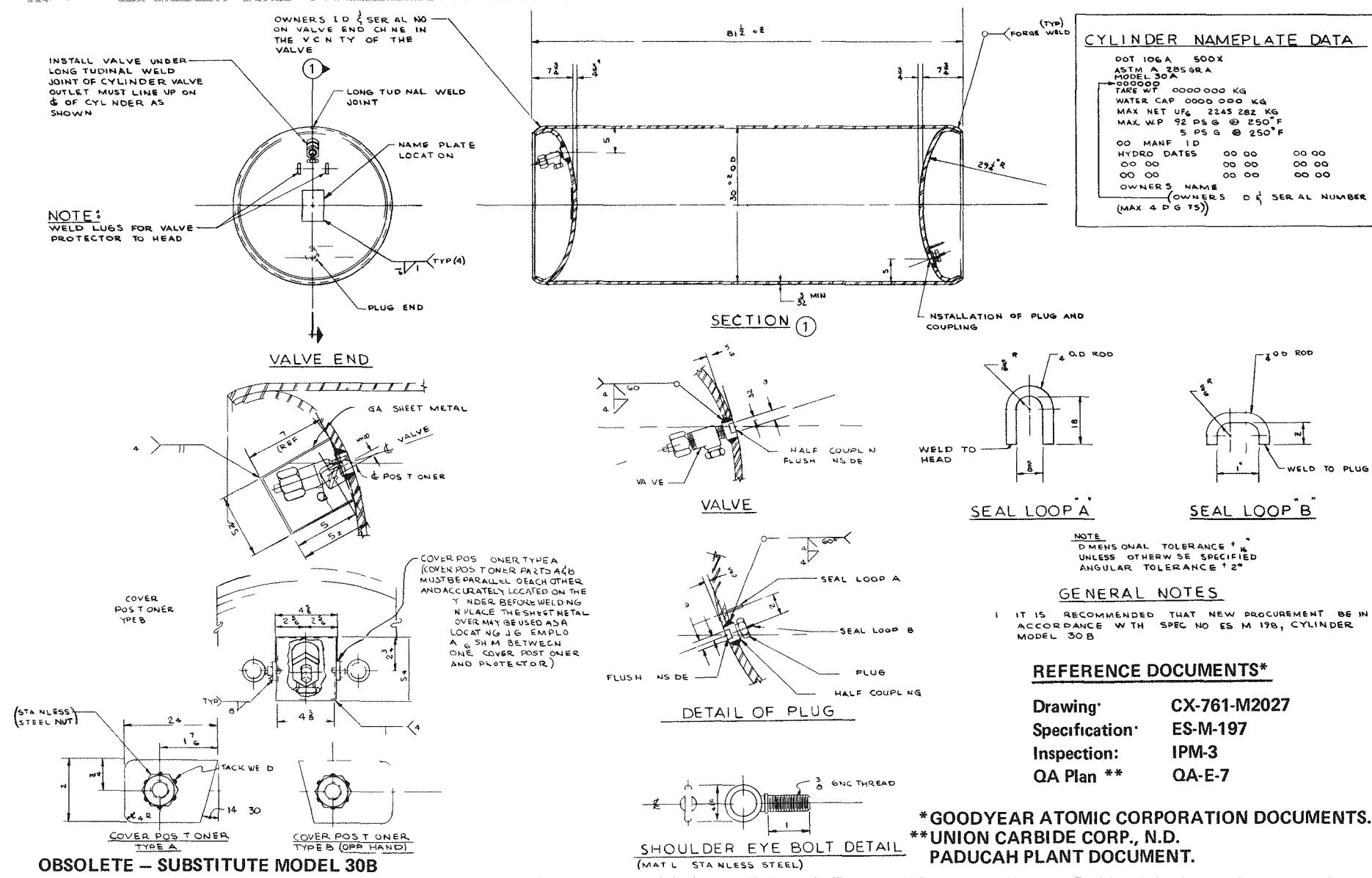
Nominal Diameter  
Nominal Length  
Wall Thickness  
Head Thickness  
Nominal Tare Weight  
Maximum Net Weight  
Nominal Gross Weight  
Minimum Volume  
Basic Material of Construction  
Service Pressure  
Hydrostatic Test Pressure  
Isotopic Content Limit

### GOODYEAR ATOMIC CORPORATION, DRAWING CX-761-M2027

30 in.  
81 in.  
13/32 in.  
3/4 in.  
1,400 lb (635 kg)  
4,950 lb (2,245 kg)  
6,350 lb (2,880 kg)  
25.65 ft<sup>3</sup> (726 liters)  
Steel  
192 psig (approximately)  
500 psig  
5.0% U-235 max with  
moderation control

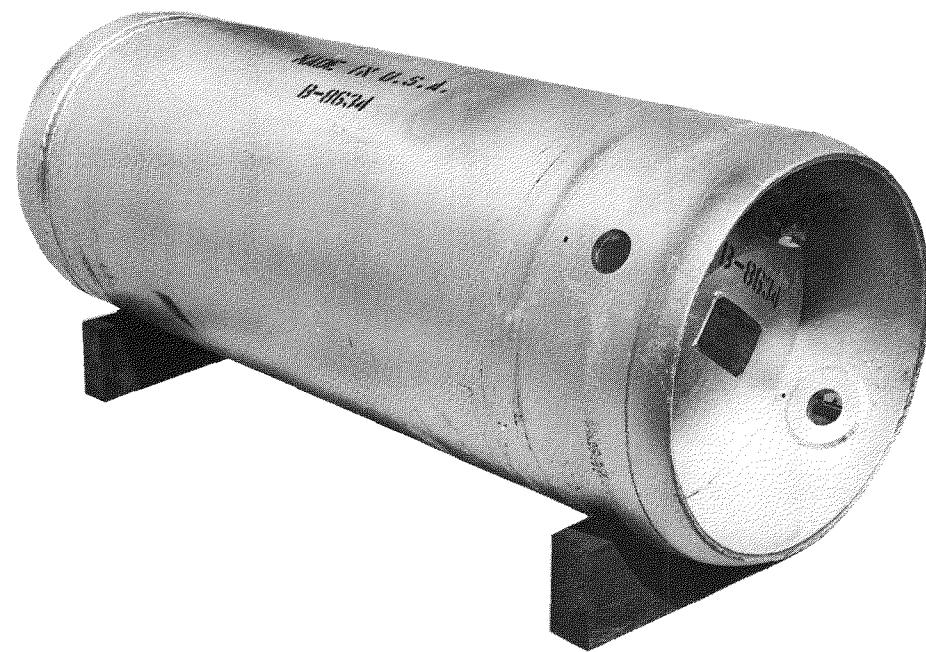
Valve Used - 1-in Valve.

\*OBSOLETE – SUBSTITUTE MODEL 30B



## UF<sub>6</sub> CYLINDER MODEL 30A

## UF<sub>6</sub> CYLINDER MODEL 30B



### GENERAL DATA

Other Descriptive Terminology Used - 2-1/2-ton

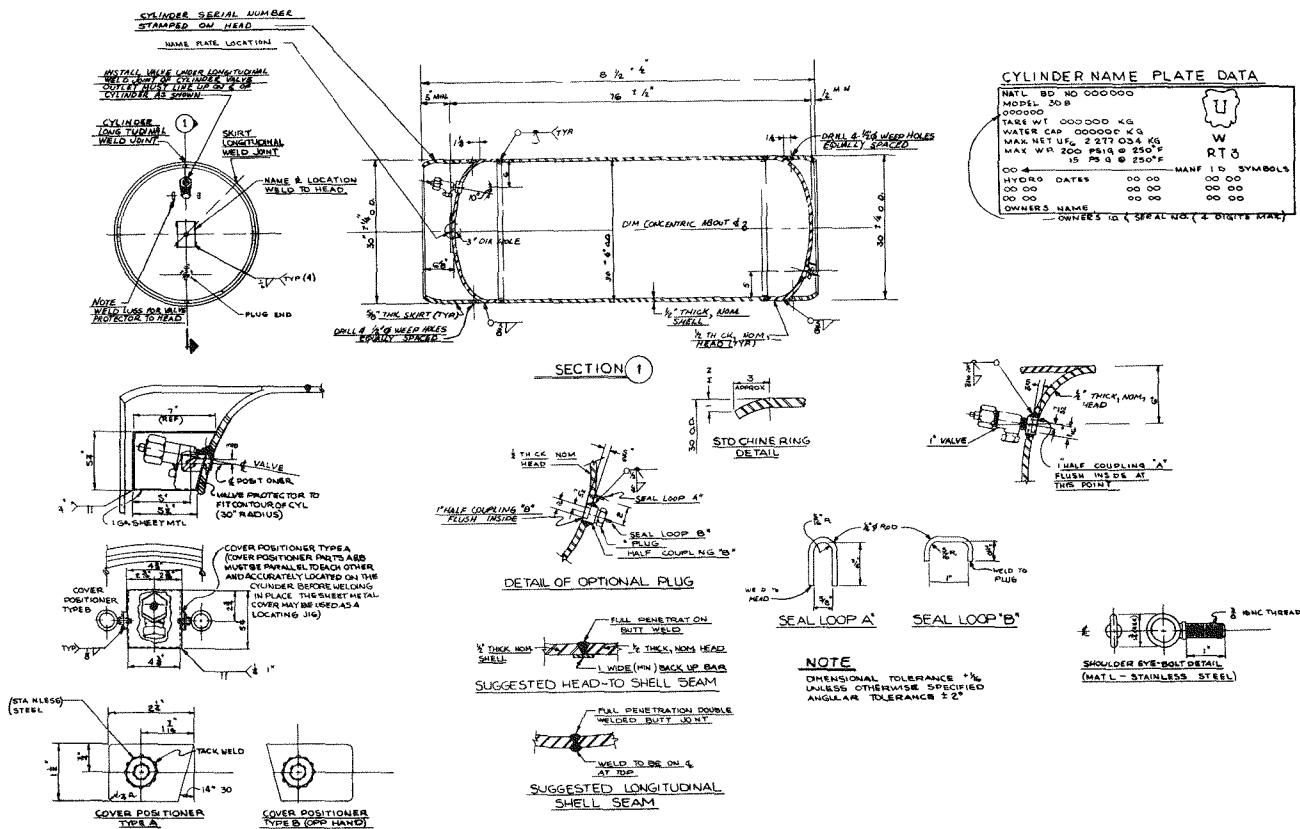
#### ENGINEERING DRAWING REFERENCE

GOODYEAR ATOMIC CORPORATION  
DRAWING: CX-761-M2028

**Nominal Diameter**  
**Nominal Length**  
**Wall Thickness**  
**Nominal Tare Weight**  
**Maximum Net Weight**  
**Nominal Gross Weight**  
**Minimum Volume**  
**Basic Material of Construction**  
**Service Pressure**  
**Hydrostatic Test Pressure**  
**Isotopic Content Limit**

**30 in.**  
**81 in.**  
**1/2 in.**  
**1,400 lb (635 kg)**  
**5,020 lb (2,277 kg)**  
**6,420 lb (2,912 kg)**  
**26 ft<sup>3</sup> (736 liters)**  
**Steel**  
**200 psig**  
**400 psig**  
**5.0% U-235 max with moderation control**

Valve Used - 1-in Valve.



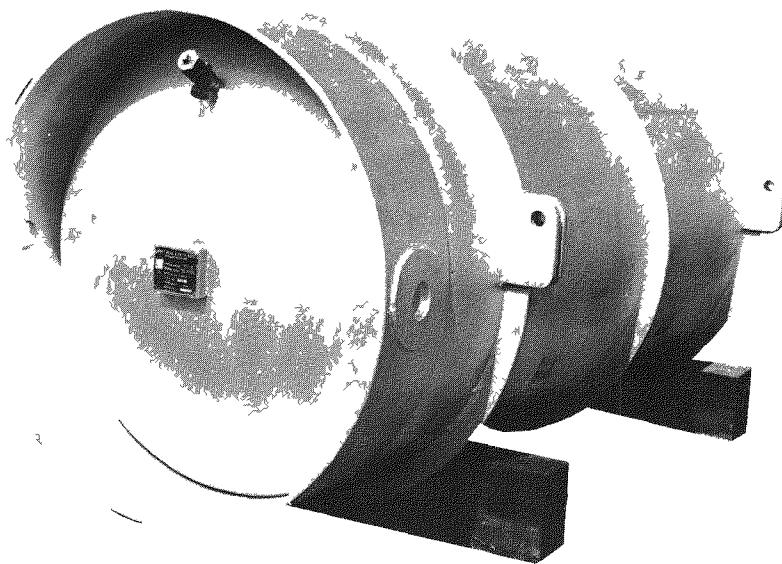
## REFERENCE DOCUMENTS\*

**Drawing:** CX-761-M2028  
**Specification:** ES-M-198  
**Inspection:** IPM-3  
**QA Plan:\*\*** QA-E-7

\*GOODYEAR ATOMIC CORPORATION DOCUMENTS.  
\*\*UNION CARBIDE CORP., N.D. PADUCAH PLANT.

UF<sub>6</sub> CYLINDER MODEL 30B

## UF<sub>6</sub> CYLINDER MODEL 48X



### GENERAL DATA

Other Descriptive Terminology Used - 10-ton

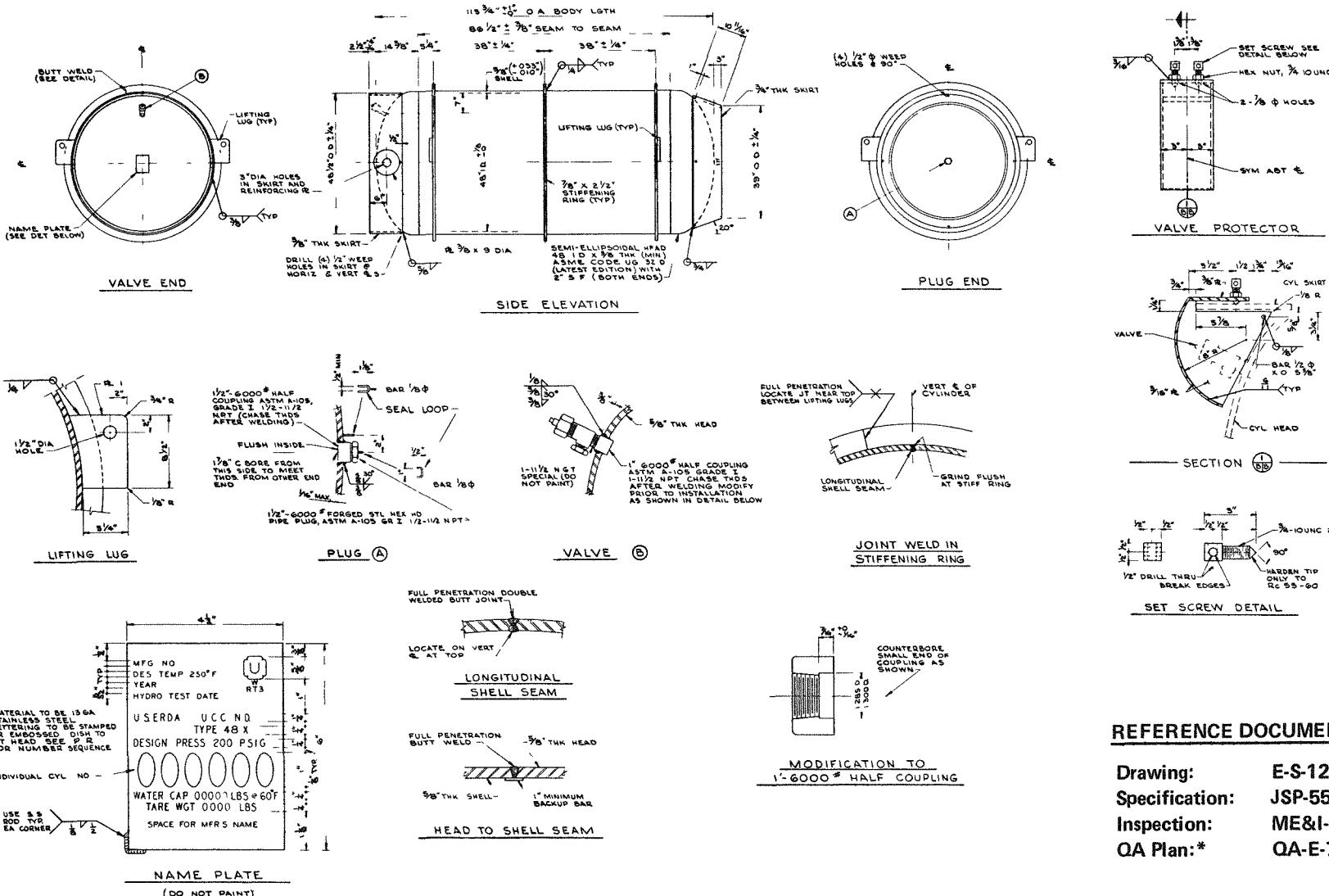
ENGINEERING DRAWING  
REFERENCE

UNION CARBIDE CORPORATION  
PGDP: E-S-12292-B

Nominal Diameter	48 in.
Nominal Length	121 in.
Wall Thickness	5/8 in.
Nominal Tare Weight	4,500 lb (2,041 kg)
Maximum Net Weight	21,030 lb (9,539 kg)
Nominal Gross Weight	25,530 lb (11,580 kg)
Minimum Volume	108.9 ft <sup>3</sup> (3.084 m <sup>3</sup> )
Basic Material of Construction	Steel
Service Pressure	200 psig
Hydrostatic Test Pressure	400 psig
Isotopic Content Limit	4.5% U-235 max with moderation control

Valve Used - 1-in Valve.

NOTE: Previously built 48A cylinders are similar in design, but do not have certified volumes; refer to Table 3 for fill limits and other data applicable to this cylinder.



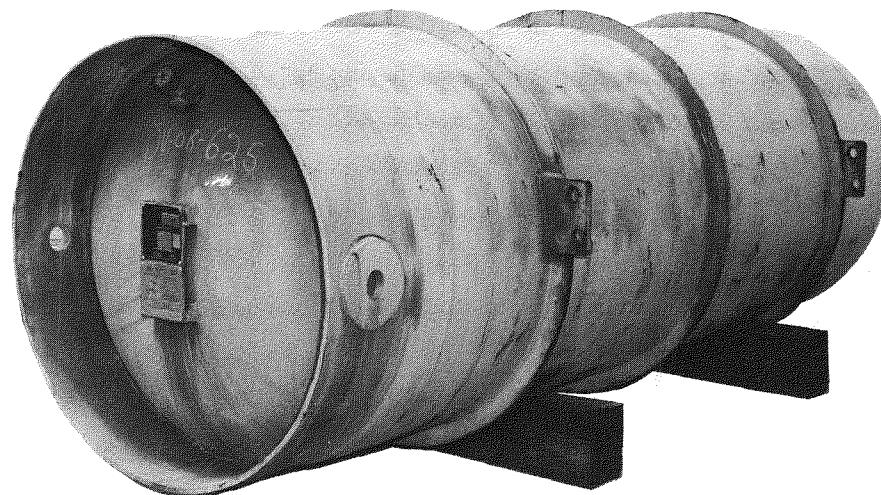
## REFERENCE DOCUMENTS \*

**Drawing:** E-S-12292-B  
**Specification:** JSP-554-R-O  
**Inspection:** ME&I-11C  
**QA Plan:\*** QA-E-7

\*UNION CARBIDE CORP., N.D. PADUCAH PLANT DOCUMENT.

## UF<sub>6</sub> CYLINDER MODEL 48X

## UF<sub>6</sub> CYLINDER MODEL 48Y



### GENERAL DATA

Other Descriptive Terminology Used - 14-ton

#### ENGINEERING DRAWING REFERENCE

UNION CARBIDE CORPORATION,  
PGDP: E-S-12292-C

Nominal Diameter

48 in.

Nominal Length

150 in.

Wall Thickness

5/8 in.

Nominal Tare Weight

5,200 lb (2,359 kg)

Maximum Net Weight

27,560 lb (12,501 kg)

Nominal Gross Weight

32,760 lb (14,860 kg)

Minimum Volume

142.7 ft<sup>3</sup> (4.04 m<sup>3</sup>)

Basic Material of Construction

Steel

Service Pressure

200 psig

Hydrostatic Test Pressure

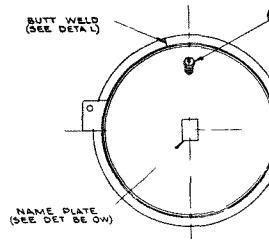
400 psig

Isotopic Content Limit

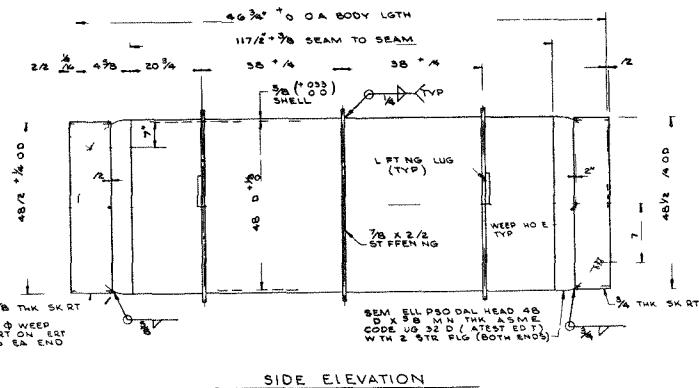
4.5% U-235 max with  
moderation control

Valve Used - 1-in. Valve.

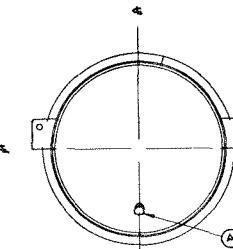
NOTE: Previously built 48F cylinders are similar in design, but do not have certified volumes; refer to table 3 for fill limits and other data applicable to this cylinder.



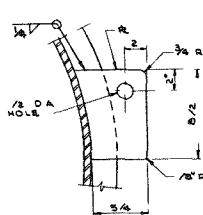
VALVE END



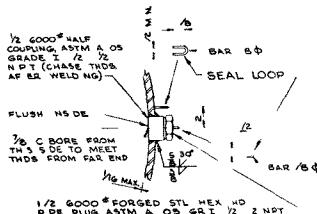
SIDE ELEVATION



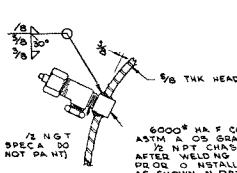
PLUG END



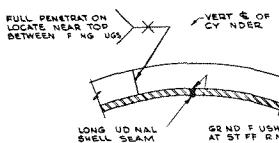
LIFTING LUG



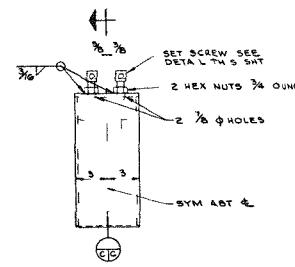
PLUG A



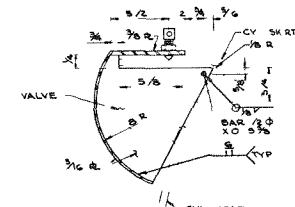
VALVE B



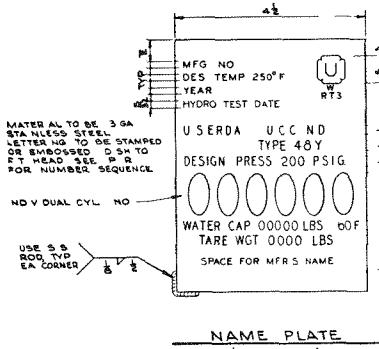
JOINT WELD N  
STIFFENING RING



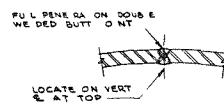
VALVE PROTECTOR



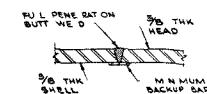
SECTION C



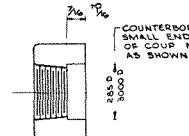
NAME PLATE  
(DO NOT PA HT)



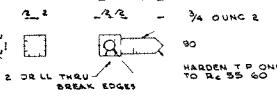
LONGITUDINAL  
SHELL SEAM



HEAD TO SHELL  
SEAM



MODIFICATION TO  
1 6000# HALF COUPLING



SET SCREW DETAIL

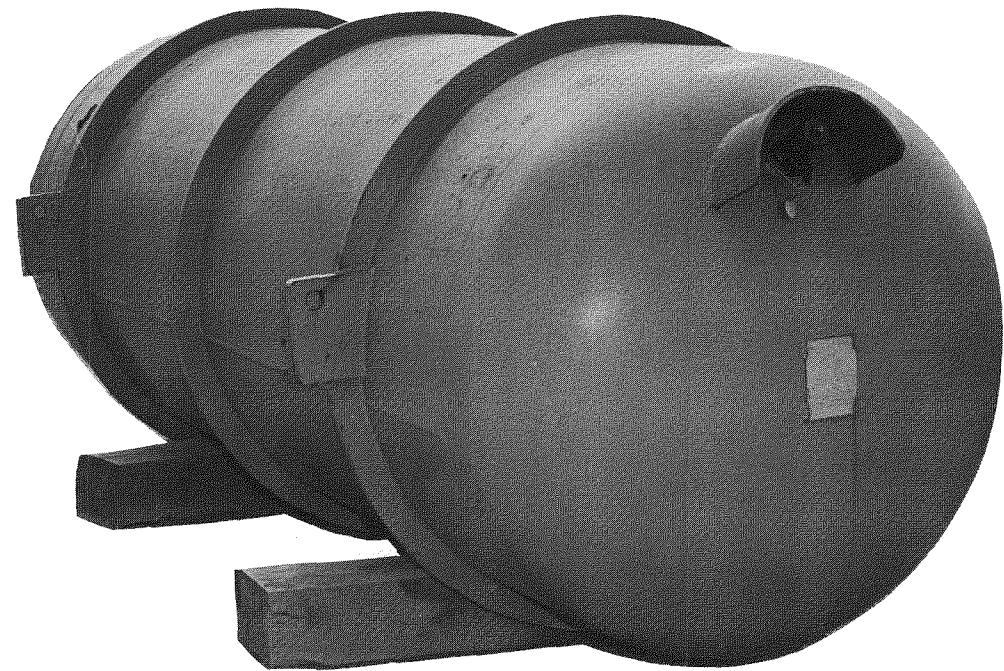
\*UNION CARBIDE CORP., N.D. PADUCAH PLANT DOCUMENTS.

UF<sub>6</sub> CYLINDER MODEL 48Y

## REFERENCE DOCUMENTS\*

Drawing: E-S-12292-C  
 Specification: JSP-555  
 Inspection: ME&I-11C  
 QA Plan: QA-E-7

## UF<sub>6</sub> CYLINDER MODEL 48G



### GENERAL DATA

#### ENGINEERING DRAWING REFERENCE

**Nominal Diameter**  
**Nominal Length**  
**Nominal Wall Thickness**  
**Nominal Tare Weight**  
**Maximum Net Weight**  
**Nominal Gross Weight**  
**Minimum Volume**  
**Basic Material of Construction**  
**Service Pressure**  
**Hydrostatic Test Pressure**  
**Isotopic Content Limit**

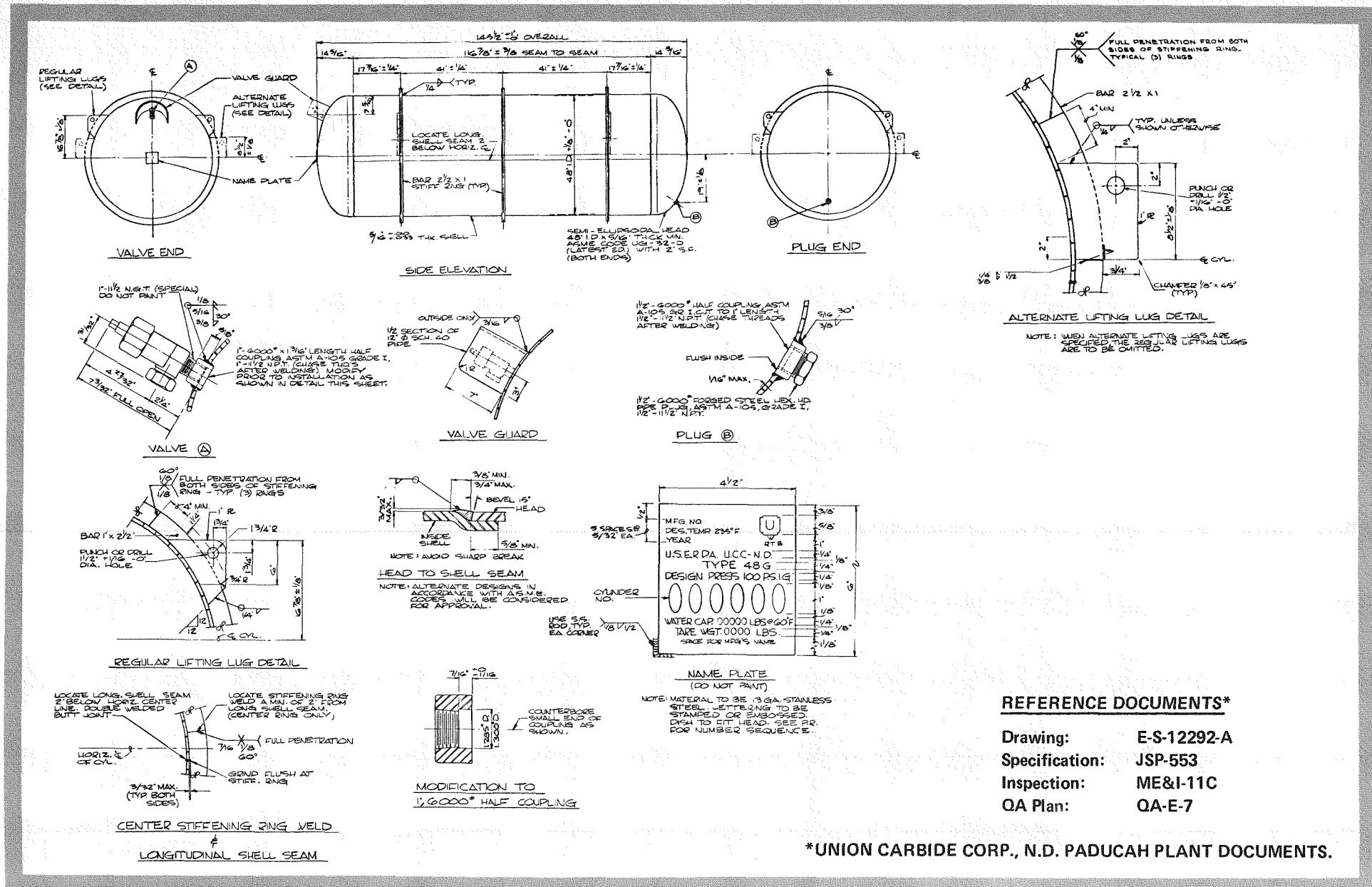
#### UNION CARBIDE CORPORATION PGDP: E-S-12292-A

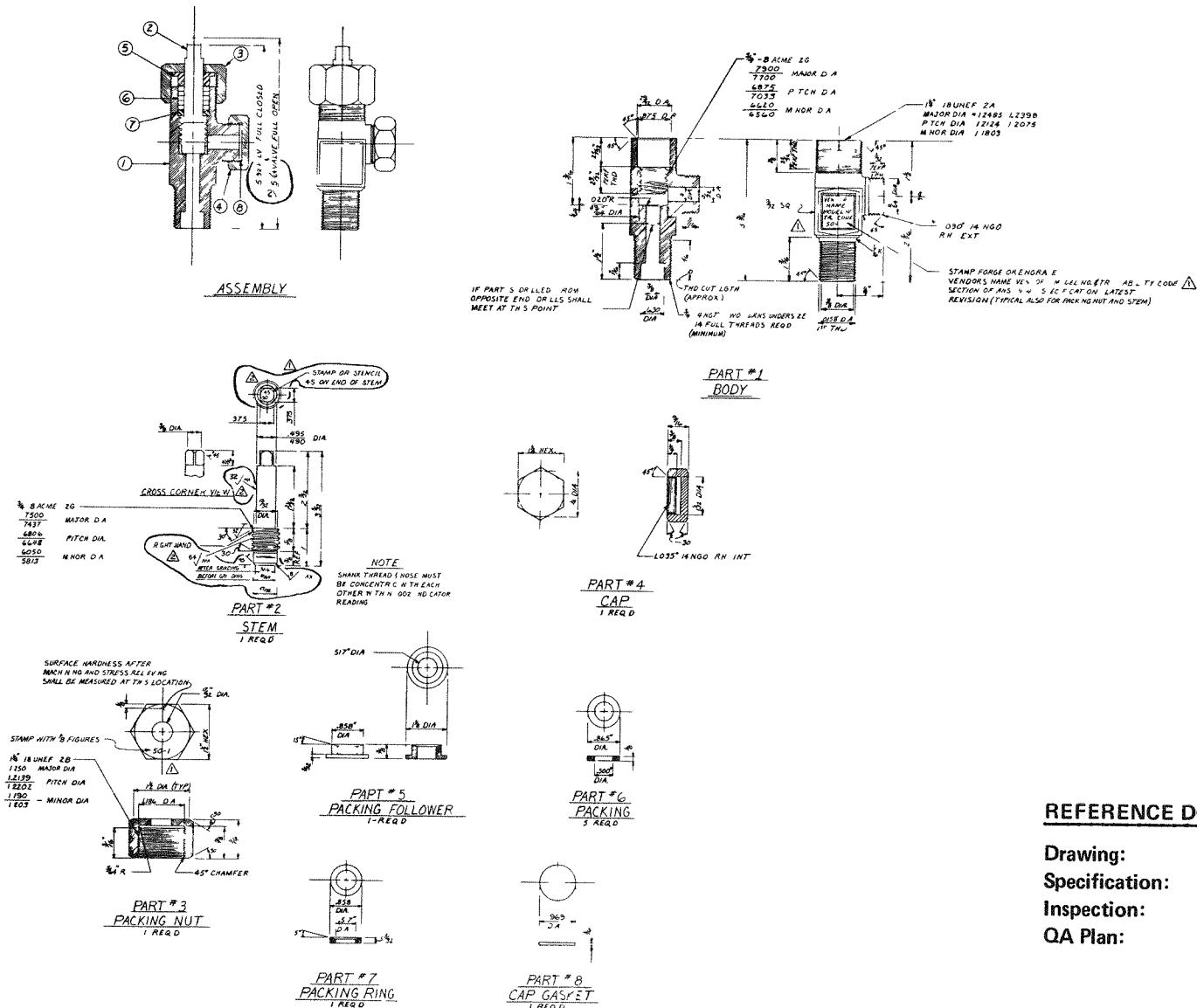
**48 in.**  
**146 in.**  
**5/16 in.**  
**2,600 lbs (1,179 kg)**  
**28,000 lb (12,701 kg)\***  
**30,600 lb (13,880 kg)**  
**139 ft<sup>3</sup> (3.94 m<sup>3</sup>)**  
**Steel**  
**100 psig**  
**200 psig**  
**Tails**

Valve Used - 1-in. Valve.

\*Based on 235° F (113° C).

NOTE: For tails storage only. Cylinders with serial numbers below 111601 do not have certified volumes.



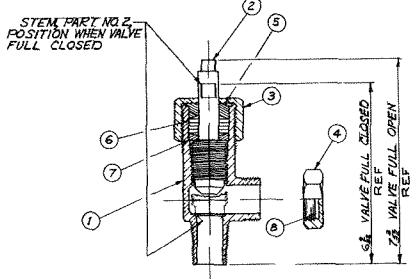


## REFERENCE DOCUMENTS\*

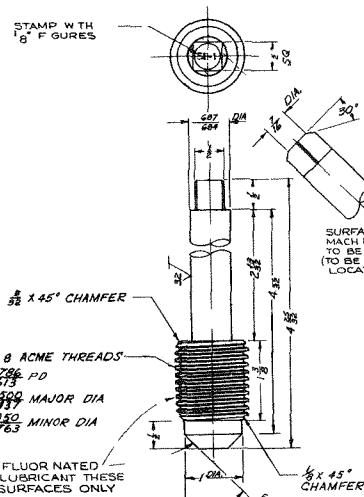
**Drawing:** DX-761-M980  
**Specification:** ES-M-176  
**Inspection:** IMP-2  
**QA Plan:** QA-600-002

**\*GOODYEAR ATOMIC CORPORATION DOCUMENTS.**

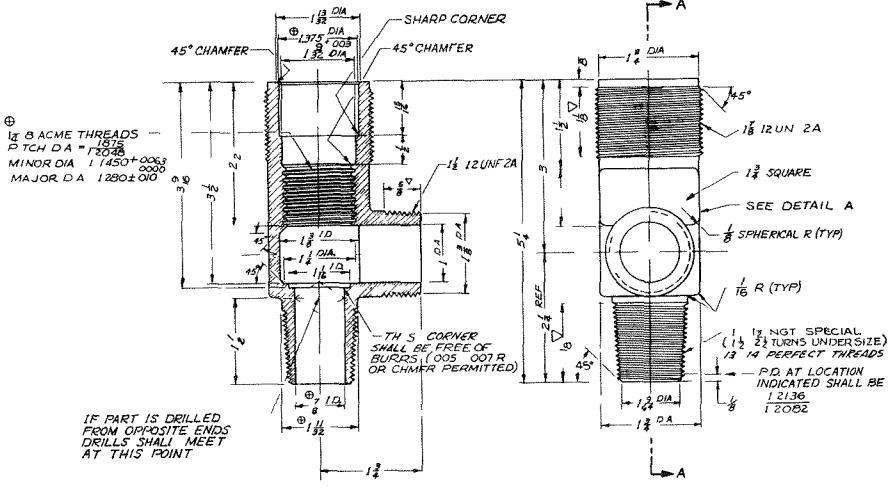
### **3/4-INCH CYLINDER VALVE**



ASSEMBLY

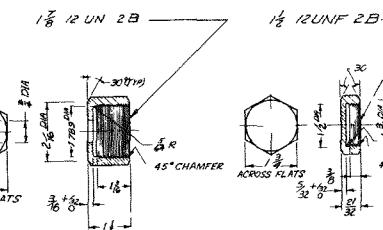


PART 2  
STEM



SECTION A A

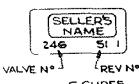
NOTE  
DIAMETERS INDICATED BY SYMBOL  $\oplus$  SHALL  
BE CONCENTRIC WITH EA OTHER TO WITHIN  
020 TIR  
DIMENSIONS INDICATED BY SYMBOL  $\nabla$   
INDICATES THE LENGTH OF PERFECT THDS



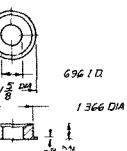
PART 3  
PACKING NUT



FORGE STAMP OR ENGRAVE  
SELLER'S NAME VALVE NUMBER  
AND REVISION NUMBER

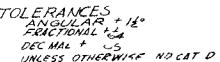
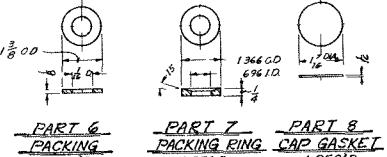


**DETAIL "A"**



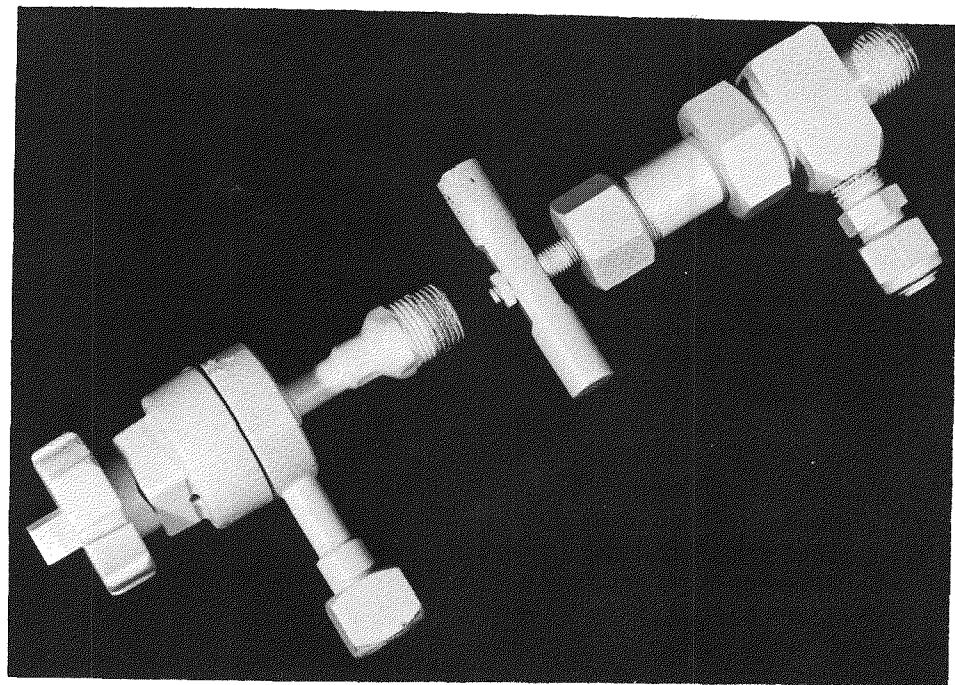
## REFERENCE DOCUMENTS\*

**Drawing:** E-J-11246  
**Specification:** JSP-532  
**Inspection:** ME&I-11A  
**QA Plan:** QA-E-4

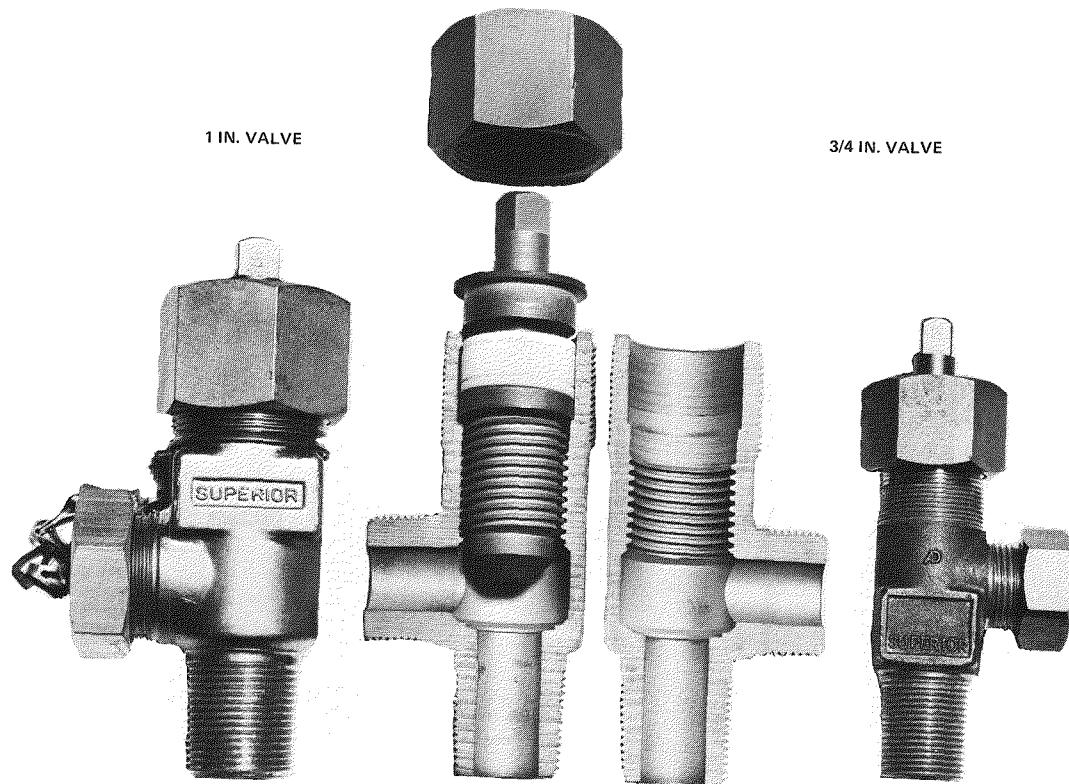


\*UNION CARBIDE CORP., N.D. PADUCAH PLANT DOCUMENTS.

## SAMPLE CYLINDER VALVES



## SHIPPING CYLINDER VALVES



to be acceptable, the quotient of the certified water weight divided by 62.37 [pounds of water in 1 ft<sup>3</sup> at 60°F (16°C)] shall not be less than the minimum cubic foot capacity specified in the design conditions stated on the applicable specification. The certified water capacity and hydrotest date shall also be stamped on the cylinder as part of the nameplate data.

The manufacturer shall retain fabrication and inspection records in accordance with ASME Code requirements. The purchaser shall retain his copies of the Manufacturer's Data Report, drawings, certifications, radiographs, and other related papers on file throughout his use or ownership of the cylinder.

7.1.3.3 Certification of Cylinders and Valves of Non-U.S. Origin. Users of non-U.S.-made cylinders shall be required to certify that the design, fabrication, tests, cleanliness, and volume of their cylinders are in compliance with requirements specified herein and in ANSI N14.1 *Packaging of Uranium Hexafluoride for Transport*, before they are accepted for sampling, filling, or material transfer in ERDA facilities. This certification shall be in the English language. The nameplate markings on such cylinders shall either be in metric units or in English units. Translations of the descriptive non-English markings for each cylinder shall be required. In all instances where the certification data was not generated by the originator of the certification, a copy of the manufacturer's or vendor's data shall accompany the certification.

Users of valves of non-U.S. origin shall be required to certify that the design, fabrication, materials, and testing meet the requirements specified herein and as described in ANSI N14.1 (ANSI N14.1-50 and ANSI N14.1-51).

Allowable deviations from established standards for valves and/or cylinders require written ERDA approval with concurrence from ERDA operating facilities before the deviating equipment will be used.

#### 7.1.4 Cleanliness

7.1.4.1 New Cylinders. The inside of the cylinder shall be thoroughly cleaned of all grease, oil, scale, slag, oxides, dirt, moisture, and other foreign matter. The surfaces shall be left clean, dry, and free of all contamination.

*The cleanliness of UF<sub>6</sub> cylinders is of serious concern to the nuclear industry, since the reaction of UF<sub>6</sub> with hydrocarbon oils, even in small quantities, and some other impurities is quite vigorous and can result in serious explosions. The purity of the UF<sub>6</sub> contained can also be appreciably affected.*

7.1.4.2 In-Service Cylinders. Cylinders containing residual quantities of UF<sub>6</sub> may require cleaning prior to refilling to assure product purity, and when maintenance or hydrostatic testing is performed.

7.1.4.3 Cylinder Outer Surfaces. Cylinder surfaces shall be monitored and cleaned of surface contamination when required to meet applicable radiation requirements.

7.1.4.4 Cylinder Cleaning and Decontamination. A typical cleaning procedure for new cylinders and a method for large cylinder decontamination are included in the appendixes of ANSI N14.1.

#### 7.1.5 Service Inspections, Tests, and Maintenance

7.1.5.1 Routine Inspections. All UF<sub>6</sub> cylinders shall be routinely inspected as-received, and prior to sampling, emptying, filling, or shipping to assure that they remain in a safe, usable condition.

7.1.5.2 Periodic Inspections and Tests. All cylinders shall be periodically inspected and tested throughout their service lives at intervals not to exceed five years, except that full cylinders need not be emptied specifically for this inspection and test. However, cylinders which have not been inspected and tested within the required five-year period shall not be refilled until properly reinspected, retested, and restamped on the nameplate.

The periodic inspection shall consist of an internal and external examination of the cylinder by a qualified inspector, an ASME Code-type hydrostatic strength test, and an air-leak test. The hydrostatic test shall be applied at a pressure equal to the original test pressure. The air test shall be at a pressure of 100 psig, and it shall be applied after the cylinder has been dried and after all valves and fittings have been reinstalled. Cylinders which pass the periodic inspection and tests shall be restamped, on the nameplate, with the month and year that the inspection and tests were performed. This restamping shall be placed close to the previous or original stamping. Records of periodic inspections and tests shall be retained by the cylinder owner for a period of five years or until a subsequent periodic inspection and test has been performed and recorded.

A UF<sub>6</sub> cylinder shall be removed from service (for repair or replacement) when it is found to have leaks, excessive corrosion, cracks, bulges, dents, gouges, defective valves, damaged stiffening rings or skirts, or other conditions which, in the judgment of the qualified inspector, render it unsafe or unserviceable in its existing condition. A qualified inspector is one who has passed the written examination sponsored by the National Board of Boiler and Pressure Vessel Inspectors, or other competent inspector designated by the owner's inspection authority. Cylinders shall no longer be used in UF<sub>6</sub> service when their shell and/or head thicknesses have decreased below the following values:

<u>Cylinder Model</u>	<u>Minimum Thickness, in.</u>
1S	1/16
2S	7/64
5A	1/8
8A	1/8
12A, 12B	3/16
30B	5/16
48A, 48F, 48X, 48Y	1/2

A tagging system will be used to identify defective cylinders or valves. Presence of such a tag is intended to prevent use of cylinders with defective components until satisfactory repairs are made. Additionally, a *Hydro Date Expired* tag will be used to identify cylinders exceeding the five-year test date limit.

**7.1.5.3 Cylinder Maintenance.** Cylinder repairs and alterations are authorized provided (1) they meet the approval of a qualified inspector, and (2) they comply with the design, material, fabrication, and welding qualification requirements of the ASME Code for Unfired Pressure Vessels.

Welded repairs or alterations to pressure parts shall require the use of ASME Code-qualified welding procedures, welders, and inspectors.

Repairs or alterations to pressure parts shall be followed by the hydrostatic strength test. Plug or valve replacements should be checked for proper insertion and tightness, and should be followed by air-leak tests, when possible. Repairs to structural attachments will not require pressure or leak tests of the cylinder unless repair of torn or deformed areas of pressure-containing materials are involved.

A careful inspection of cylinders and valves is an important prerequisite to any operation. Filled cylinders are easily dented or otherwise damaged; therefore, all cylinder movements must be performed carefully and slowly.

**7.1.5.4 Cylinder Valve and Plug Replacement.** Replacement of brazed 3/4-in. valves can only be successfully accomplished by following the brazing specifications referenced with each type of cylinder using this method of installation. Field replacement should not be attempted, since the valve coupling will likely crack due to the presence of contaminant materials.

Replacement of tinned valves in cylinders containing UF<sub>6</sub> is accomplished by first assuring that the cylinder has cooled the required number of days, and, if possible, by obtaining a cold pressure measurement to determine that the pressure is subatmospheric. With adequate safety equipment, slowly loosen the valve. No outgassing should occur, and inleakage should become audible. A newly tinned valve, previously inspected, should be positioned for insertion as soon as the defective valve is removed. The replacement valve is then torqued into the cylinder to not more than 400

ft-lb for the 1-in. valve and the 3/4-in. valve. After insertion, the number of threads inserted should not be less than seven (7) nor more than twelve (12) for either valve size. If possible, the seal at the valve coupling should be soap tested at 5 psig, or as an alternative, the vacuum after the valve change should be recorded and if unchanged after five days, the seal was successfully made. Cold burping may be required after a valve change to remove air and preclude high pressures during subsequent heating of the repaired cylinder.

Plug changes are accomplished in a similar manner. Specification components are required to obtain proper thread engagement for both valves and plugs.

**7.1.5.5 Three-Quarter-Inch Valve Wear Inspection.** Because of the brazed joint required of the 3/4-in. valve, these valves cannot be easily replaced; therefore, if possible, the 3/4-in. valve is rebuilt in-place following decontamination and inspection. In addition to the inspection of the internal and external cylinder surfaces, the valve body is visually inspected for adverse corrosion, erosion, distortion, or other damage which would make it unserviceable. This inspection is supported by two 100-psig air tests and a helium leak test. Other tests, such as radiographic examination, may be conducted prior to use.

## 7.2 SAFETY CONSIDERATIONS

### 7.2.1 General

The variations of density, vapor pressure, and physical state with temperature and the chemical and nuclear properties of  $\text{UF}_6$  require the development and use of safe handling procedures. Procedures incorporating the safety considerations presented in this appendix have been developed and evaluated in ERDA facilities during the more than 25 years of handling vast quantities of  $\text{UF}_6$ . Aside from nuclear considerations,  $\text{UF}_6$  can be safely handled in essentially the same manner as any other corrosive and/or toxic chemical.

Gaseous  $\text{UF}_6$ , when released to the atmosphere, reacts with the atmospheric moisture to form HF gas and particulate  $\text{UO}_2\text{F}_2$  which tends to settle on surfaces. The corrosive properties of  $\text{UF}_6$  and HF are such that exposure to a severe release can result in skin burns and temporary lung impairment. The inhalation of fumes from very large releases for more than a few breaths may result in temporary lung impairment quite soon after the exposure and, in some instances, mild but repairable kidney damage within a few days. Water-soluble uranium compounds such as  $\text{UO}_2\text{F}_2$ , like most heavy metal compounds, are toxic to the kidneys when inhaled or ingested in large quantities. For uranium of uranium-235 enrichment less than 10%, the chemical toxicity is more important than the radiotoxicity.

The  $\text{UO}_2\text{F}_2$  and HF which form quickly during a release to the atmosphere is readily visible as a white cloud. A concentration of 1 mg of  $\text{UO}_2\text{F}_2$  per cubic meter of air is visible and the cloud from large releases may obscure vision.

### 7.2.2 Hazards and Precautions

Some of the hazards of UF<sub>6</sub> handling and the precautions used to control or eliminate the hazards are listed below:

7.2.2.1 Handling Cylinders of Liquid UF<sub>6</sub>. Liquid UF<sub>6</sub> is hot, pressurized, and very mobile. Movements of partially filled cylinders result in surges of the dense liquid which can upset handling equipment and cause loss of control. Therefore, movement of large cylinders containing liquid UF<sub>6</sub> should be minimized. A 3-day cool-down period should be observed for 30-in. cylinders and a 5-day period for 48-in. cylinders whenever possible.

Leaks in a cylinder containing liquid UF<sub>6</sub> are difficult to control. Caution should be exercised in handling cylinders until the contents have solidified. A cylinder should not be shipped until its contents have completely solidified.

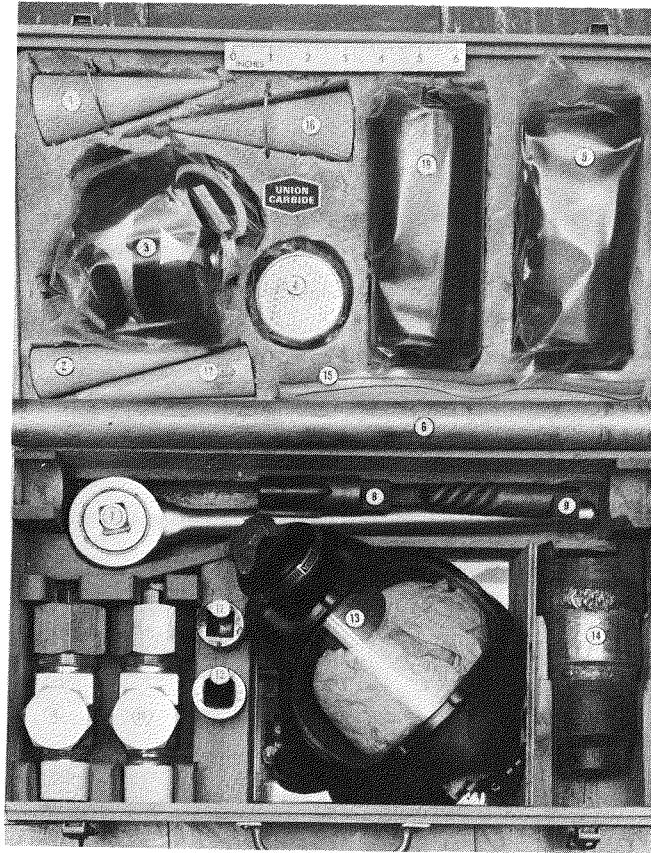
7.2.2.2 Overfilling Cylinders. Cylinders may be overfilled by completely filling with liquid, by condensing the UF<sub>6</sub> as a solid in the cylinder from a gaseous system, and by condensing lightweight contaminants into the UF<sub>6</sub> cylinder. If the cylinder is heated after overfilling, it may be hydraulically ruptured. Overfilling is prevented by adhering to weight limitations, maintaining a high purity in the UF<sub>6</sub> system, and taking the necessary precautions to have the contents of the cylinder at a temperature above the condensation temperature of gas systems to which it is connected. If overfilling occurs, the cylinder should be connected to an evacuation system and the excess UF<sub>6</sub> removed, without heating the cylinder, until the correct fill limit is obtained.

7.2.2.3 Overheating Cylinders. The fill limits for cylinders are established for a maximum temperature of 250°F (121°C). Heating cylinders above this temperature may result in liquid expansion to a volume exceeding that of the cylinder, which could result in hydraulic rupture.

7.2.2.4 Localized Heating. Localized heating of a manifold system to remove a UF<sub>6</sub> plug is very hazardous. Liquefying a quantity of UF<sub>6</sub> in a restricted space, such as between two solid UF<sub>6</sub> sections or between two valves, can readily result in hydraulic rupture of the system and UF<sub>6</sub> release. Since the valve packing and plastic gaskets used soften at elevated temperatures, localized heating should be avoided.

7.2.2.5 Damaged Cylinder Valves. Occasionally, valves are damaged in handling full cylinders of UF<sub>6</sub> which require immediate action. It is recommended that any installation handling significant quantities of liquid UF<sub>6</sub> have available an emergency kit containing equipment similar to that shown in Figure 22.

7.2.2.6 Manifold Connection Leaks. Leaking connections can result in serious UF<sub>6</sub> releases. All connections, especially flexible connectors, should be checked for kinking, abrasion and other damage prior to use. After cylinder hookup, all connections should be leak rated and pressure tested.



<u>ITEM NO.</u>	<u>EMERGENCY KIT EQUIPMENT</u>
1	2-in. Wooden Peg
2	1-1/2 in. Wooden Peg
3	Respirator
4	P.T. No. 92884 Respirator Filter
5	Neoprene Gloves
6	1-in. X 18-in. Pipe (To Increase Leverage on Valve Socket Handle)
7	3/4 in. Socket Wrench
8	1-in. Thread Tap
9	13/16-in. Extractor
10	1-in. Valve
11	1/2 in. Socket (To Operate 1-in. Valve Stem)
12	3/4 in. Socket (To Use on 1-in. Tap)
13	1-Ultravue Mask
14	1-in. Valve Wrench (To Remove Valve)
15	Six 10-in. X 10-in. Plastic Bags (For Contaminated Items)
16	Spare 2-in. Wooden Peg
17	Spare 1-1/2 in. Wooden Peg
18	Spare Neoprene Gloves
19	Spare 1-in. Valve

Figure 22

7.2.2.7 Releases of UF<sub>6</sub>. The control of UF<sub>6</sub> releases requires pre-planning with respect to emergency procedures and equipment. Respiratory protective equipment, wooden plugs, patches, a release detection and alarm system, and some type of cooling mechanism should be readily available in areas where UF<sub>6</sub> is processed. Entry into dense clouds from UF<sub>6</sub> releases requires use of breathing apparatus capable of preventing HF and particulate inhalation. Skin protection is necessary to prevent burns. It is essential that all persons not properly protected be evacuated from areas affected by the smoke of the release. The wooden plugs should be designed to be inserted into holes which might occur as a result of broken or defective valves, line breakage, etc. Patches should be shaped to fit contours of the UF<sub>6</sub> cylinders.

A UF<sub>6</sub> release may be terminated by *freezing off* the opening in the system with appropriate cooling. This cooling is usually provided by a water stream for low enrichment UF<sub>6</sub>. In no case should water be streamed directly into a cylinder opening. Dry ice or pressurized CO<sub>2</sub> from large-capacity fire extinguishers may be used safely with any enrichment to *freeze off* leaks. If the cylinder content is liquid, extended *freeze off* periods will be required. However, nuclear safety evaluations should be made beforehand to assure the absence of possible unsafe accumulations of uranium.

7.2.2.8 Radiation. The radioactivity of UF<sub>6</sub> produced from the unirradiated uranium varies with the uranium-235 enrichment. Naturally occurring uranium has a specific activity of 1.5 disintegrations per minute per microgram (d/m/ $\mu$ g). Of this activity the isotopes of uranium-238 and uranium-234 each contribute about half. As the enrichment in uranium-235 is increased, the activity from uranium-234, which enriches faster than uranium-235, increases very rapidly. Highly enriched uranium produced from natural uranium feed has a specific activity (SA) of about 200 d/m/ $\mu$ g which is almost entirely from uranium-234. While the exact specific activity of slightly enriched uranium depends on the history of the particular material, it may be approximated by:

$$SA(d/m/\mu g) = 0.75 + 1.06 (\text{wt \% uranium-235})$$

Alpha particles resulting from the primary disintegration of uranium present no external radiation problem, since they do not penetrate the skin. However, the decay products of uranium include isotopes which emit mildly penetrating beta rays and highly penetrating gamma rays. Beta radiation levels as high as 200 mrad/hr may be found at the surface of UF<sub>6</sub>. When UF<sub>6</sub> is vaporized from a cylinder, the decay products usually remain behind. Thus, the internal surfaces of an empty cylinder may have beta radiation levels up to several rad/hr. Similarly, the gamma radiation from an empty cylinder will be much higher than from a filled cylinder and may range up to 200 mrad/hr.

Radiation exposures of employees working around UF<sub>6</sub> cylinders are easily controlled at very low levels through conventional distance-time limitations.

NOTE: CONTRIBUTION OF THE RADIOACTIVITY FROM FISSION PRODUCTS AND TRANS-URANIUM ELEMENTS WHICH MAY BE PRESENT IN UF<sub>6</sub> PRODUCED FROM IRRADIATED URANIUM IS NOT CONSIDERED IN THIS REPORT.

7.2.2.9 Mechanical Hazards. The mechanical hazards of handling UF<sub>6</sub> cylinders are not unique. The surging of liquid in partially filled cylinders and the eccentric center of gravity of cooled cylinders add to the normal hazards of handling heavy loads.

### 7.2.3 Criticality Control

A paramount consideration in the handling and shipping of cylinders of UF<sub>6</sub> is the application of stringent controls to prevent an inadvertent nuclear chain reaction or criticality condition. This goal is accomplished by employing, individually or collectively, specific limits on uranium-235 enrichment, mass, volume, geometry, moderation and spacing, and, in some instances, utilizing the neutron absorption characteristics of the steel cylinder walls. Most of the above limitations, including temperature control to prevent cylinder rupture in process operations, are specified throughout this report. The amount of UF<sub>6</sub> which may be contained in an individual cylinder and the total number of cylinders which may be transported together are determined by the nuclear properties of the UF<sub>6</sub>. Spacing of cylinders of enriched UF<sub>6</sub> in transit is assured through the use of DOT specification packages or ERDA and/or NRC approved packages which also provide protection against impact and fire.

The use of Models 30 (A and B) and 48 (A, F, X, and Y) cylinders at uranium-235 enrichments of 5.0 and 4.5%, respectively, is dependent on moderation control, i.e., a hydrogen-to-uranium atomic ratio of less than 0.088, which is equivalent to the purity specification of 99.5% for UF<sub>6</sub> as given in the Federal Register. For shipments of UF<sub>6</sub> above the 5.0% uranium-235, geometric or mass limits are employed.

NOTE: THE SPECIFIC DETAILS GOVERNING CRITICALITY CONTROL ARE NOT COVERED IN THIS DOCUMENT SINCE SUCH INFORMATION IS GENERALLY AVAILABLE IN OTHER PUBLICATIONS.

## 7.3 CHEMICAL AND PHYSICAL PROPERTIES OF UF<sub>6</sub>

### 7.3.1 General

General information on the properties of UF<sub>6</sub> is presented below for convenient reference.

Sublimation Point (14.7 psia) 133.8°F (56.6°C)  
(76 cm Hg)

Triple Point 22 psia (114 cm Hg), 147.3°F (64.1°C)

Density, Solid (68°F) (20°C)	317.8 lb/ft <sup>3</sup> (5.1 g/cc)
Liquid (147.3°F) (64.1°C)	227.7 lb/ft <sup>3</sup> (3.60 g/cc)
Liquid (200°F) (93°C)	215.6 lb/ft <sup>3</sup> (3.5 g/cc)
Liquid (235°F) (113°C)	207.1 lb/ft <sup>3</sup> (3.3 g/cc)
Liquid (250°F) (121°C)	203.3 lb/ft <sup>3</sup> (3.3 g/cc)
Heat of Sublimation (147°F) (64°C)	58.2 Btu/lb
Heat of Fusion (147°F) (64°C)	23.5 Btu/lb
Heat of Vaporization (147°F) (64°C)	35.1 Btu/lb
Heat of Solution in Water (77°F) (25°C), Heat Evolves	258.2 Btu/lb
Critical Pressure	668.8 psia (3458 cm Hg)
Critical Temperature	446.4°F (230.2°C)
Specific Heat Solid (81°F) (27°C)	0.114 Btu/lb
Specific Heat Liquid (162°F) (72°C)	0.130 Btu/lb

### 7.3.2 Chemical Properties

Uranium hexafluoride is a highly reactive substance. It reacts chemically with water, ether, and alcohol forming soluble reaction products. It reacts with most organic compounds and with many metals. The reaction with hydrocarbon oil can be violent at elevated temperatures. Its reactivity with most saturated fluorocarbons is very low. It does not react with oxygen, nitrogen, or dry air. It is sufficiently inert to clean, dry aluminum, copper, Monel, nickel, and aluminum bronze that they can be exposed to UF<sub>6</sub> without excessive corrosion.

Uranium hexafluoride reacts very readily with H<sub>2</sub>O to form UO<sub>2</sub>F<sub>2</sub> and HF. A saturated solution of UO<sub>2</sub>F<sub>2</sub> in water has the following composition:

Temperature, °C	Wt % UO <sub>2</sub> F <sub>2</sub>
1	61.4
25	65.6
60	71.0
100	74.1

Conversion factors, or stoichiometric equivalents, for seven chemical forms of uranium enriched to 3 wt % uranium-235 are listed below. To compute the quantity of the compound named at the top of the column, a given quantity of the compound named in the left column is multiplied by the factor in the column and line indicated. Example, 1.4790 kg of  $\text{UF}_6$  contains 1 kg uranium; the uranium in 1.3037 kg of  $\text{UF}_6$  will produce 1 kg  $\text{UO}_2$ .

#### CONVERSION FACTORS

	<u>U</u>	<u><math>\text{UF}_4</math></u>	<u><math>\text{UF}_6</math></u>	<u><math>\text{UO}_2</math></u>	<u><math>\text{U}_3\text{O}_8</math></u>	<u><math>\text{UO}_3</math></u>	<u><math>\text{UO}_2\text{F}_2</math></u>
U	1.0000	1.3194	1.4790	1.1345	1.1793	1.2017	1.2941
$\text{UF}_4$	0.75794	1.0000	1.1210	0.8599	0.8938	0.9108	0.9809
$\text{UF}_6$	0.67612	0.8920	1.0000	0.7670	0.7973	1.0593	0.8750
$\text{UO}_2$	0.88147	1.1630	1.3037	1.0000	1.0395	1.0593	1.1408
$\text{U}_3\text{O}_8$	0.84796	1.1188	1.2542	0.9620	1.0000	1.0190	1.0974
$\text{UO}_3$	0.83215	1.0979	1.2308	0.9440	0.9814	1.0000	1.0769
$\text{UO}_2\text{F}_2$	0.77271	1.0195	1.1429	0.8766	0.9113	0.9286	1.0000

#### 7.3.3 Physical Properties

At room temperature,  $\text{UF}_6$  is a white, volatile solid. At a temperature of 147.3°F (64.1°C) and a pressure of 22 psia,  $\text{UF}_6$  melts to form a colorless liquid of high density.

The density-temperature, pressure-density, and pressure-temperature relations for  $\text{UF}_6$  are presented graphically in Figures 23, 24, and 25.

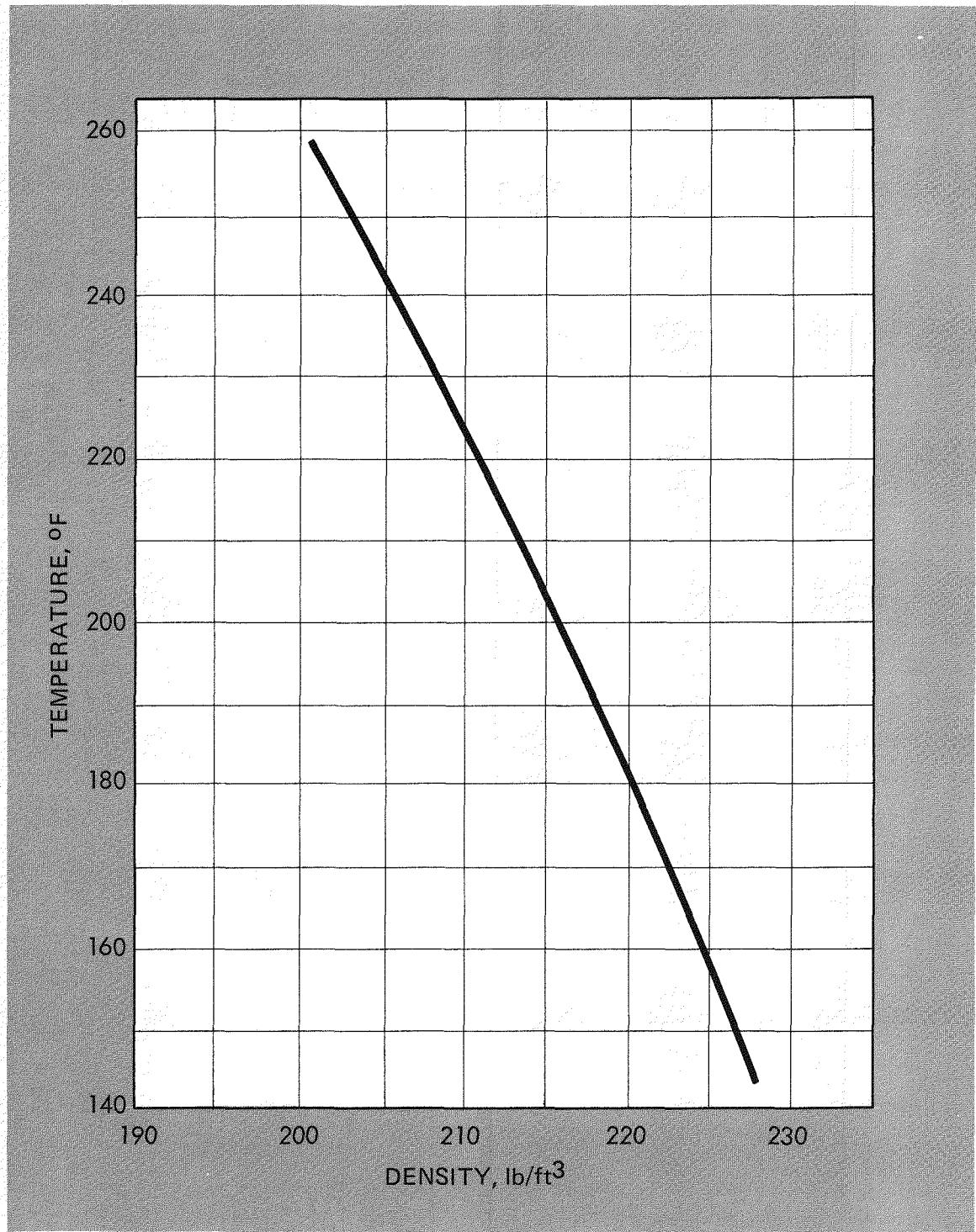


Figure 23  
DENSITY OF LIQUID  $\text{UF}_6$

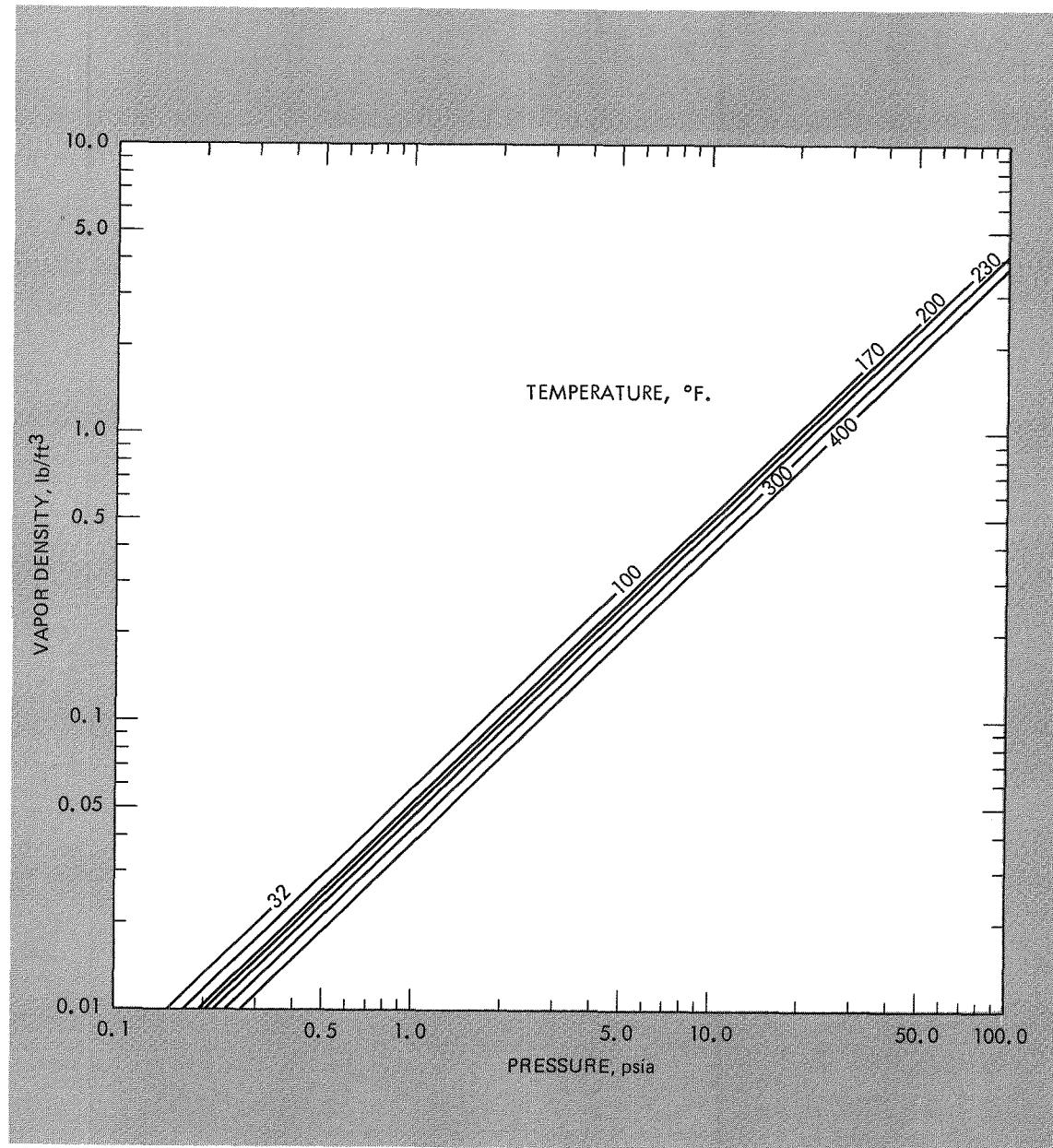


Figure 24  
DENSITY OF GASEOUS  $\text{UF}_6$

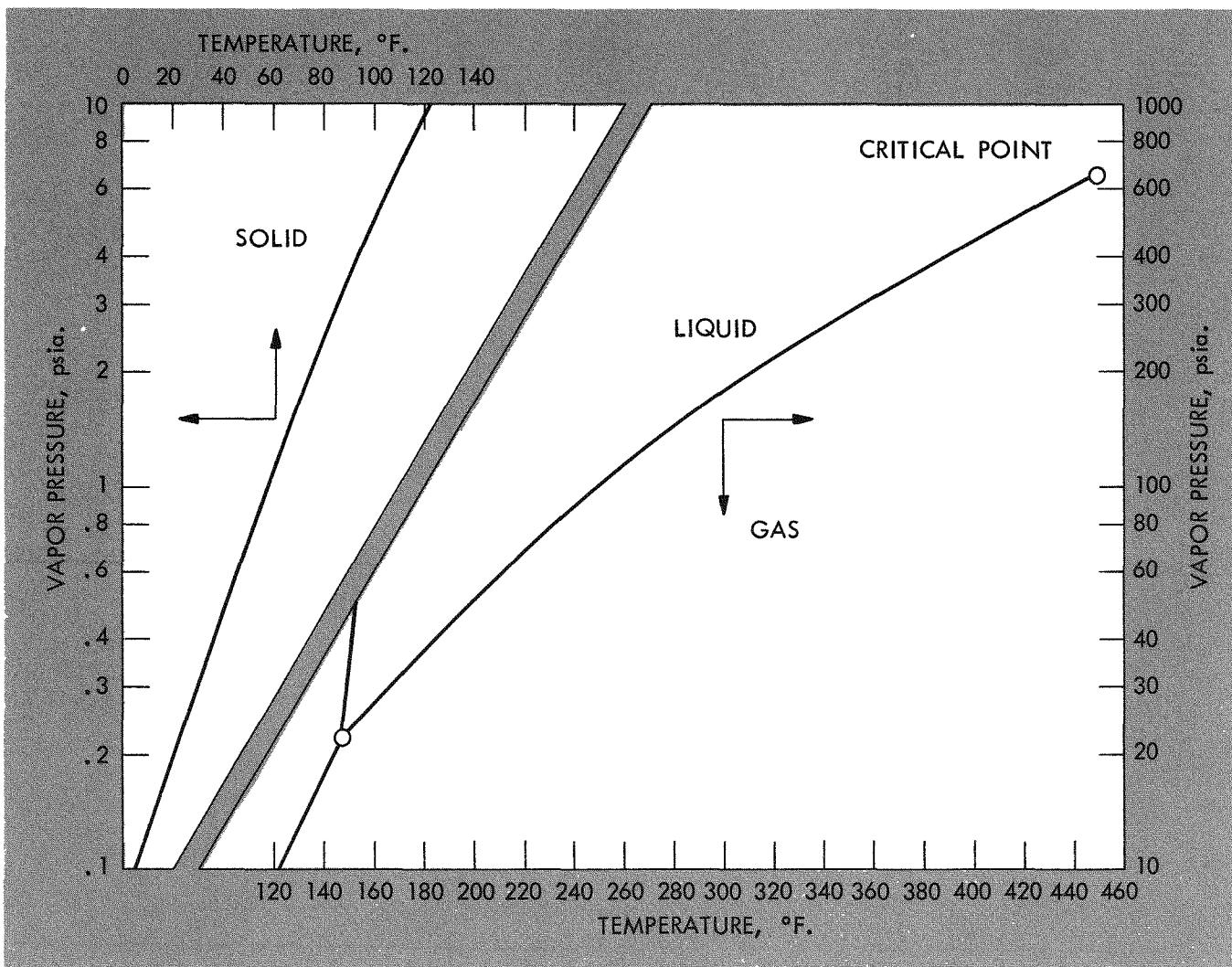


Figure 25  
PHASE DIAGRAM OF  $\text{UF}_6$

Table 3

ERDA UF<sub>6</sub> CYLINDER DATA

Cylinder Model No.	Nominal Diameter, in.	Material of Construction(a)	Minimum Volume		Approximate Tare Weight (Without Valve Protector)		Maximum Enrichment, wt % Uranium-235	Fill Limit Maximum,(b) UF <sub>6</sub>		Fill Limit Minimum, UF <sub>6</sub>	
			ft <sup>3</sup>	liters	lb	kg		lb	kg	lb	kg
1S	1.5	Nickel	0.0053	0.15	1.75	0.79	100.00	1.0	0.45	45 g	0.045
2S	3.5	Nickel	0.0254	0.72	4.2	1.91	100.00	4.9	2.22	1	0.45
5A	5	Monel	0.284	8.04	55	25	100.00	55	24.95	11	4.99
8A	8	Monel	1.319	37.35	120	54	12.5	255	115.67	55	25
12A	12	Nickel	2.38	67.4	185	84	5.0	460	208.7	55	25
12B	12	Monel	2.38	67.4	185	84	5.0	460	208.7	55	25
30A	30	Steel	25.65	726.0	1,400	635	5.0(c)	4,950	2,245	2,300(d)	1,043
30B(e)	30	Steel	26.0	736.0	1,400	635	5.0(c)	5,020	2,277	2,300(d)	1,043
48A	48	Steel	108.9	3,084	4,500	2,041	4.5(c)	21,030	9,539	14,000	6,350
48X(f)	48	Steel	108.9	3,084	4,500	2,041	4.5(c)	21,030	9,539	14,000	6,350
48F	48	Steel	140.0	3,964	5,200	2,359	4.5(c)	27,030	12,261	21,000	9,525
48G(g)	48	Steel	139.0	3,936	2,600	1,179	Tails	28,000	12,701	--	--
48Y(f)	48	Steel	142.7	4,041	5,200	2,359	4.5(c)	27,560	12,501	21,000	9,525

(a) For packaging normal and depleted UF<sub>6</sub>, cylinders of other materials, such as steel and Monel, may be substituted, provided they have equivalent strength.

(b) Fill limits are based on 250°F (121°C) maximum UF<sub>6</sub> temperature (203.3 lb UF<sub>6</sub>/ft<sup>3</sup>), certified minimum internal volumes for all cylinders, and a minimum safety factor of 5%. The operating limits apply to UF<sub>6</sub> with a minimum purity of 99.5%. More restrictive measures are required if additional impurities are present. The maximum UF<sub>6</sub> temperature must not be exceeded.

(c) Maximum enrichments indicated require moderation control equivalent to a UF<sub>6</sub> purity of 99.5%. Without moderation control, the maximum permissible enrichment is 1.0 wt % uranium-235.

(d) Shipments from ERDA and at the customer's request can be less than 2,300 lb (1,043 kg) in the 30A or 30B cylinders providing the UF<sub>6</sub> is transferred from a larger cylinder.

(e) This cylinder replaces the Model 30A cylinder.

(f) Models 48X and 48Y replace Models 48A and 48F.

(g) For UF<sub>6</sub> tails storage only. Fill limit is based on maximum UF<sub>6</sub> temperature of 235°F (113°C), certified minimum volumes and a minimum safety factor of 3%.