Facility operations with the 30B-X Cylinder

0045-BSH-2020-001-Appendix 1.7.3, Rev. 0

Prepared	Checked	Released
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05.09.2022	06.09.2022	06.09.2022

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1 Introduction

The operation of the 30B-X cylinder in facilities (e.g. enrichment plants, fuel fabricators) is generally described and reglemented in site specific operating handbooks not part of the DN30-X SAR. Chapter 2 of this appendix provides general information on these operations and demonstrates that they do not have any possible impact on the safe transport of the DN30-X package. Chapter 3 describes the introduction of 30B-X cylinders in UF_6 facilities via prototype testing.

2 Filling, Emptying, and Washing of the 30B-X Cylinder

Filling with UF_6, emptying and washing of 30B-X cylinders is described in site-specific operating handbooks that are not part of this SAR. This section discusses general aspects relevant to the transportation of 30B-X cylinders, and presents the design features that have been incorporated in the 30B-X cylinder to ensure that the presence of the interior CCS within the 30B-X cylinder does not adversely affect its operations.

A central point is that both the temperature and the total weight of the cylinder are controlled during filling and emptying. Generally, the cylinder is cooled during filling (to expediate condensation/sublimation of the incoming UF_6 gas) and heated during emptying.

2.1 Filling of 30B-X Cylinders

With regard to the filling of 30B-X cylinders, the following has been considered in the design of the 30B-10 and 30B-20 cylinders:

Filling of the 30B-X cylinder is generally identical to the process for the standard 30B cylinder.

Today's standard filling procedures for UF_6 cylinders use gaseous UF_6. Prior to filling, the pressure within a UF_6 cylinder is close to vacuum so that a stable gaseous flow of UF_6 is entering the cylinder through the valve. Distribution of the gaseous UF_6 within the 30B-X cylinder is not significantly hindered by the interior CCS, since the minimal effective cross section of the cavity of the 30B-10 and 30B-20 cylinder still amounts to 48 % and 40 % of the standard 30B cylinder, respectively (see Table 1-13 of the main SAR).

During filling, the surfaces of the 30B-X cylinder are cooled from the exterior to a temperature T_1 (around room temperature), while the instreaming gaseous UF_6 is at temperatures above the triple point, i.e. above 64.1 °C. Accordingly, the CCS will be at a higher temperature T_2 than the 30B-X cylinder walls, since it is continually heated by the instreaming UF_6 and has very little thermal contact to the rest of the cylinder (see Figure 1). It follows that the gaseous UF_6 will change to its solid form preferably at the colder cylinder walls, gradually building up a layer of UF_6 primarily at the 30B-X cylinder walls and not at the CCS.

Nevertheless, the two CCRs that are located in front of the valve and the plug have been shortened by 60 mm, respectively, to optimize the flow of gaseous UF_6 into the 30B-X cylinder. Even if a blockage of solidified UF_6 were to occur, it would be resolved by increasing the temperature to slightly above the melting point, so that the blockage changes into the liquid phase and collects at the cylinder bottom.

Overfilling of 30B-X cylinders is avoided by measuring the 30B-X cylinder weight during filling, using a calibrated scale. As long as the gross weight is not exceeded, the 30B-X cylinder is compliant with its fill limits (see Table 1-13 of the main SAR). If a 30B-X cylinder has been found to be overfilled, the same procedures as for a standard 30B cylinder can be used to remove the excess in UF_6.

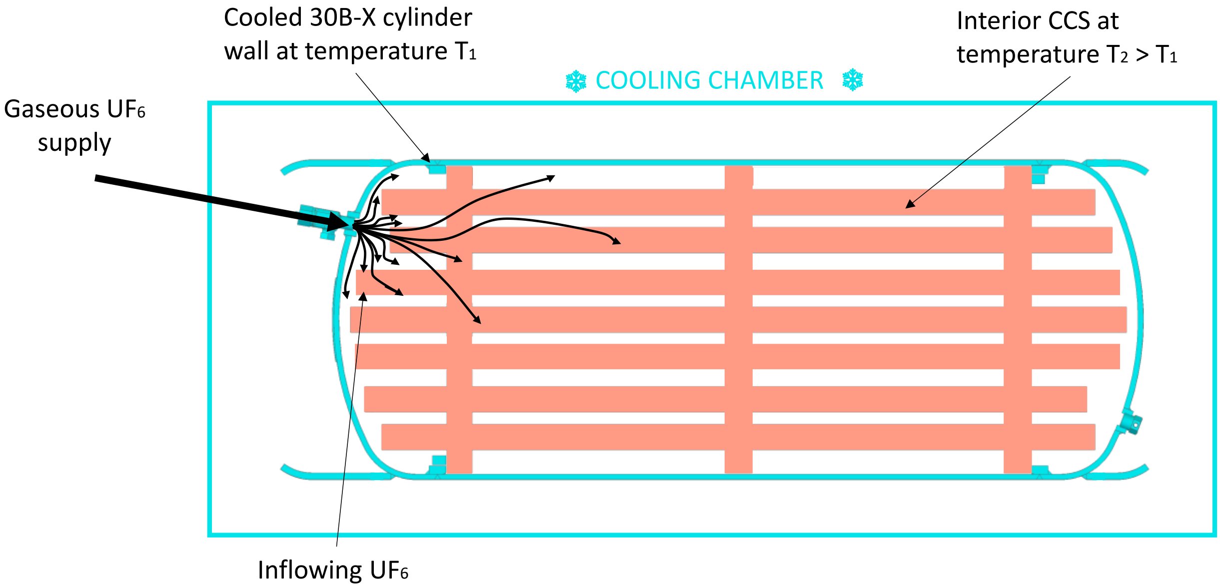

Figure 1: Schematic view of the 30B-X cylinder during UF_6 filling

2.2 Emptying of 30B-X Cylinders

With regard to the emptying of 30B-X cylinders, the following has been considered in the design of the 30B-10 and 30B-20 cylinders:

Emptying of the 30B-X cylinder is generally identical to the process for the standard 30B cylinder.

For emptying, the 30B-X cylinder is heated to a temperature T_1 so that the UF_6 within the cylinder changes to its gaseous form. Due to the duration of the emptying process (typically a few days) and the good thermal connection of CCS and cylinder walls due to the UF_6 filling, the temperature T_2 of the CCS can be expected to be approximately the same as T_1 (see Figure 2). As all parts of the emptying system are insulated and heated, the UF_6 remains in the gas phase during emptying. Hence, the reduced effective cross sections of the 30B-10 and 30B-20 cylinder in comparison to a standard 30B cylinder have not significant effect on the emptying operation.

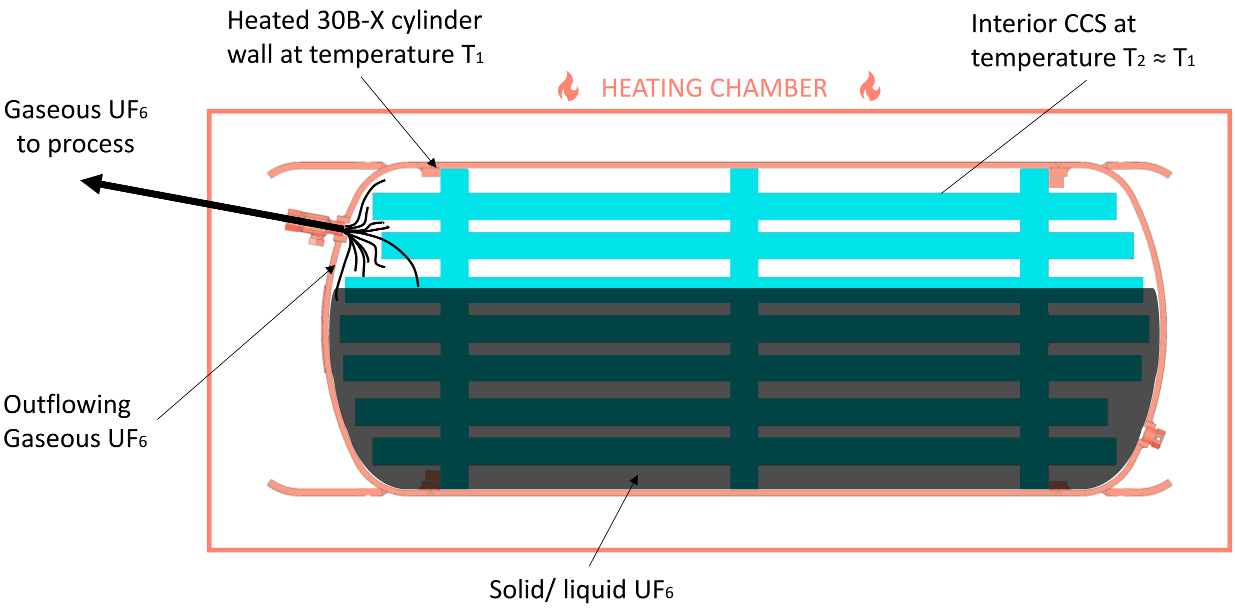

Figure 2: Schematic view of the 30B-X cylinder during UF_6 emptying

However, the established site-specific emptying process has to ensure that the 30B-X cylinder is heated appropriately taking into account the increased heat sink due to the interior CCS within the 30B-X cylinder. The 30B-X cylinder valve shall not be opened when solid UF_6 is still present within the 30B-X cylinder to avoid that solid UF_6 could plug the cylinder valve.

Furthermore, the established site-specific emptying process for the 30B-X cylinder may require lower evacuation speeds of the gaseous UF_6 in comparison to a standard 30B cylinder to avoid that the UF_6 changes to its solid form because of sudden pressure drops.

As the minimum ullage at 121 °C is significantly larger for 30B-X cylinders in comparison to the standard 30B cylinder, the safety margins against hydraulic rupture of the pressure envelope during heating are increased compared to a standard 30B cylinder.

The occurrence of a blockage from solidified UF_6 between the CCS and the plug during the emptying process is unlikely due to the shortened CCR in front of the plug. Even if a blockage of solidified UF_6 were to occur, it would be resolved by increasing the temperature to slightly above the melting point, so that the blockage changes into the liquid phase and collects at the cylinder bottom. This can under no circumstances lead to a pressure increase that would be safety relevant: any blockage can be definitely removed by increasing the temperature to above the UF_6 triple point of 64 °C. In section 2.3.1.4 of the main SAR, the calculated pressure for a temperature of 131 °C and 100% UF_6 filling ratio is 1.16 MPa, clearly below the maximum allowable working pressure (MAWP) of 1.38 MPa. Due to the lower filling ratios and temperatures during the emptying process, the safety margin to the MAWP will always be higher.

Reducing cylinder heels may also be accomplished as for standard 30B cylinders (e.g., by using cold traps).

2.3 Washing of 30B-X Cylinders

For washing of 30B-X cylinders, the same precautions apply as for standard 30B cylinders, but there are some additional aspects that need to be considered for washing of 30B-X cylinders:

For the standard 30B cylinder, several washing procedures exist, but for the 30B-X cylinder only the tilt-roll method is suitable, which is due to the presence of the interior CCS within the 30B-X cylinder. Rolling the 30B-X cylinder constantly changes the contact points between the 30B-X cylinder shell and the interior CCS so that the wash solution reaches all interior surfaces.

In contrast to the standard 30B cylinder, the amount of wash solution that can be used to clean a 30B-X cylinder is not limited by criticality safety aspects, as safe subcriticality is maintained even for optimal moderation with water. Accordingly, adding a boron solution into the 30B-X cylinder is not required to maintain safe subcriticality.

The amount of wash solution that can be added into the 30B-X cylinder might be limited by other aspects than criticality safety (e.g., the heavy reaction of UF_6 with water). Therefore, the amount of solution that can be added into a 30B-X cylinder shall be specified in the site-specific operating handbook.

Great care is required when syphoning the contaminated wash solution from the 30B-X cylinder into a container. Depending on the level of enrichment in ^{235}U, the amount of solution that can be syphoned into a container might have to be reduced. The size of the container shall be specified in the site-specific operating handbook.

Because of the presence of the interior CCS within the 30B-X cylinder, longer or more wash cycles might be required in comparison to the standard 30B cylinder to achieve the uranium concentration in samples specified in the site-specific operating handbook.

The same applies to the removal of oil within the 30B-X cylinder.

Finally, the interior inspection with a borescope might require more time due to the CCS.

Other than that, the washing procedure is similar to that for a standard 30B cylinder and, thus, consists of the following steps:

1. Check the weight of the 30B-X cylinder before the wash solution is added.
2. Transfer the 30B-X cylinder from the storage area to the tilt-roll stand.
3. Connect the 30B-X cylinder valve to a container, using appropriate hoses and fittings.
4. Add 20 liter of wash solution to the container.
5. Check the internal pressure by slightly opening the cylinder valve. If a positive pressure is experienced (appearance of bubbles in the hose), the cylinder valve must be closed, and the internal pressure must be reduced (e.g., by cooling the cylinder).
6. When no positive pressure is evident, the cylinder valve can be opened, allowing the wash solution to enter the 30B-X cylinder.
7. Close the cylinder valve and disconnect the hose.
8. Rotate and tilt the 30B-X cylinder for 10 minutes to hydrolyze the uranium compounds.
9. Remove the cylinder valve or plug.
10. Siphon the solution into a criticality safe container as specified by the site-specific operating handbook.
11. Repeat steps (4), (8), and (10) three times more and subsequently increase the amount of wash solution that is added into the 30B-X cylinder:
    - Add 50 liter of wash solution for the second wash cycle.
    - Add 100 liter of wash solution for the third wash cycle.
    - Add half the certified volume of the 30B-X cylinder plus 5 % $(1.05 \cdot V_{\text{certified}}/2)$ of wash solution for the fourth wash cycle.

    This procedure ensures that all CCRs are appropriately cleaned.
12. After the fourth wash cycle, sample the solution for total uranium concentration.
13. Repeat the water-solution wash, cylinder rotation, siphoning, and sampling until the uranium concentration is compliant with the site-specific operating handbook.
14. Using a borescope, visually inspect the interior of the 30B-X cylinder for any accumulations of uranium-bearing compounds.
15. Apply steam to the interior of the 30B-X cylinder for approximately 2 to 3 hours. Discard steam condensate solution. Provide local exhaust control to prevent atmospheric contamination.
16. Use the borescope to ascertain that the 30B-X cylinder has been completely cleaned.
17. Ensure that no hydrocarbons are present in the cylinder. If hydrocarbons are present in the cylinder remove those according to the site-specific operating handbook.
18. Steam the 30B-X cylinder for 10 to 20 minutes.
19. Rotate the 30B-X cylinder and siphon the condensate through the valve opening.
20. Dry the interior of the 30B-X cylinder with filtered dry air until the moisture content of the air in the 30B-X cylinder is less than -35 °C dew point.
21. Visually inspect the interior of the 30B-X cylinder with the borescope to ascertain that it is clean and dry.
22. Replace the valve, tag the 30B-X cylinder as being cleaned and washed, and transfer it to storage.

3 Introduction and Testing of 30B-X Cylinder Prototypes in UF_6 Facilities

As laid out in chapter 2 above, there is no possible impact of facility operations with the 30B-X cylinder (filling, emptying and washing) on the transportation safety of the DN30-X package. Even if UF_6 blockages were to occur during filling or emptying, they can be resolved via the temperature control of the cylinder without risk.

Since the duration and necessary effort for these facility operations is important information for the users of the 30B-X cylinder, they will be investigated and verified by simulating full operational cycles in UF_6 facilities with 30B-X cylinder prototypes manufactured for this task. The emphasis of these tests shall be:

- Filling procedure of the 30B-X cylinder, especially investigation whether freezing of UF_6 during filling can occur and, if necessary, evaluation of countermeasures. Use of depleted uranium is preferred for these tests.
- Emptying procedure of the 30B-X cylinder, especially investigation whether freezing of UF_6 during emptying can occur and, if necessary, evaluation of countermeasures. After emptying, the amount of heel quantities shall be determined.
- Washing procedure of the 30B-X cylinder (possibly carried out at a later stage as washing facilities are required to be qualified for such operation beforehand).

In addition, handling trials with the 30B-X cylinder prototypes in UF_6 facilities will be performed.

If these tests reveal that the facility operations require modifications (e.g. intermediate heating), this will be incorporated in a revision of this Appendix.