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RPV Threaded Hole Lubrication Device

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ABSTRACT

Adequate lubrication of RPV stud bolts is crucial for regular RPV head area maintenance. A newly developed specialized device for lubricating RPV threaded holes is presented. The device is designed in order to allow adjustments of all variables, i.e. travel and speed of stroke, lubricant supply and spray pressure. Besides that it comprises also plug seat surface sealing and constant lubricant stirring and circulation function. It is lightweight and operates using compressed air only. The device offers automatic lubrication cycles, high productivity, repeatability and reliability while also remaining ergonomic and user friendly.

1 INTRODUCTION

The lubrication of threaded holes in the Reactor Pressure Vessel (RPV) holds profound significance for several compelling reasons. Among these reasons, one of paramount importance lies in the mitigation of friction during the assembly process. When two metal surfaces come into contact, they generate friction which, if unchecked, can lead to abrasion, distortion, or even cold welding of the threads. Lubricating these threads diminishes friction and serves as a bulwark against the emergence of such adversities. Another virtue of RPV lubrication lies in its capacity to enhance the integrity of the threaded connection. Application of lubrication facilitates the controlled tightening of threads to prescribed torque values, thereby ensuring a tight and secure seal. This proves especially pivotal in scenarios where the risk of leaks or pressure loss is imminent. Furthermore, lubrication acts as a safeguard, shielding the threads against corrosion and other forms of deterioration. Exposed to harsh working environments, such as saline solutions or corrosive chemicals, threads can undergo damage that imperils the structural soundness of the connection. Lubricating the threads becomes a preventative measure that not only averts such damage but also extends the longevity of the connection. In summation, the lubrication of threaded boreholes within the RPV holds multifaceted significance. It attenuates friction, enhances sealing efficacy, and safeguards threads against potential harm. By employing appropriate lubrication agents, we ensure that threaded connections remain steadfast, secure, and reliable, even under the duress of challenging operational conditions.

2 DEVICE OPERATION

The device can operate in two distinct operational modes. The first mode is automatic, wherein the device begins operating automatically upon pressing a button. In this mode, the piston with the attached spray head extends (moves downward). Upon reaching the preset stroke length, it activates a limit switch, which triggers the opening of the pilot air (nozzle on the spray head opens for the supply of atomizing air), initiates the lubricant flow, and causes the retraction of the piston (movement upward). The spray head continuously emits a mist of lubricant onto the thread until it reaches the limit switch in the upper position of the stroke. The device is then extracted from the threaded bore and moved to the adjacent bore.

The second mode is the manual operating mode, primarily designed for variable adjustments and the final cleaning of the device.

The operation of the lubrication device is based on compressed air. Compressed air is supplied to the preparation unit through a quick coupling. The pressure is adjusted to the required value, thereby providing the necessary energy for the device to operate. All necessary variables on the lubrication device are adjustable.

These include:

- The working stroke of the cylinder (the stroke must remain within the maximum stroke of the cylinder).
- The speed of the cylinder's movement.
- The amount of sprayed lubricant.
- The quantity of the returning lubricant flow.

The RPV lubrication device can be broadly divided into two distinct components (see Figure 1): the main unit and the portable unit. The main unit embodies a transport cart (constructed from stainless steel) and encompasses everything placed upon it, while excluding the portable unit (crafted from aluminum).

Within the main unit, one can discover:

- The foundational structure that supports all pivotal components.
- A cabinet housing a logical pneumatic circuit and a convenient assembly.
- A lubricant reservoir complete with a mixer.
- A pump for dispensing the lubricant.
- A connecting conduit between the reservoir and the pump.

The portable unit consists of:

- Base plate for component attachment.
- Pneumatic cylinder (bidirectional).
- Limit switches (pneumatic).
- 360° adjustable spray head.
- Protective sleeve.
- Protective cone with an o-ring seal.
- Leveling screws for precise centering adjustment.
- Distribution connector for lubricant/air supply and discharge. The units are interconnected with supply/discharge pipes.

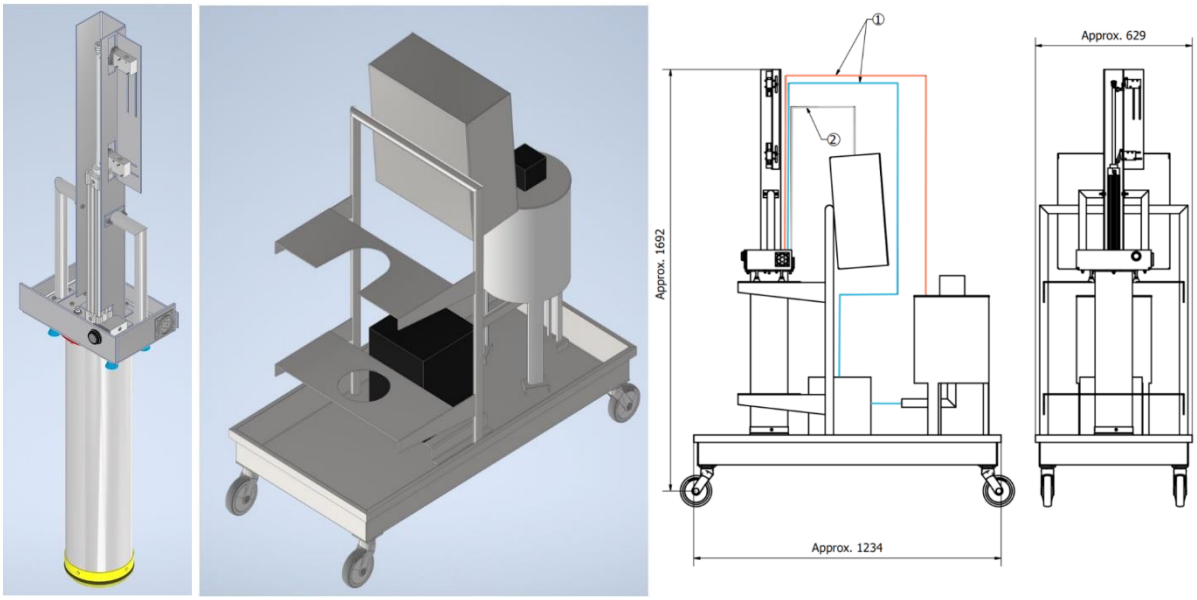

Figure 1: 3D model of portable unit (left), main unit (middle) and approximate dimensions (right).

In Figure 2, the arrangement of a portable unit within a threaded borehole is presented, as well as the approximate dimensions of the working area. The portable unit is placed into the threaded borehole through the upper part of the cover (flange of the RPV head). By using levelling screws, the desired depth and centrality on the borehole axis are adjusted. The tapered part at the end of the sleeve serves as a guiding pin, ensuring precise positioning of the unit at the center of the borehole, while the O-ring prevents lubricant from entering the flange joint.

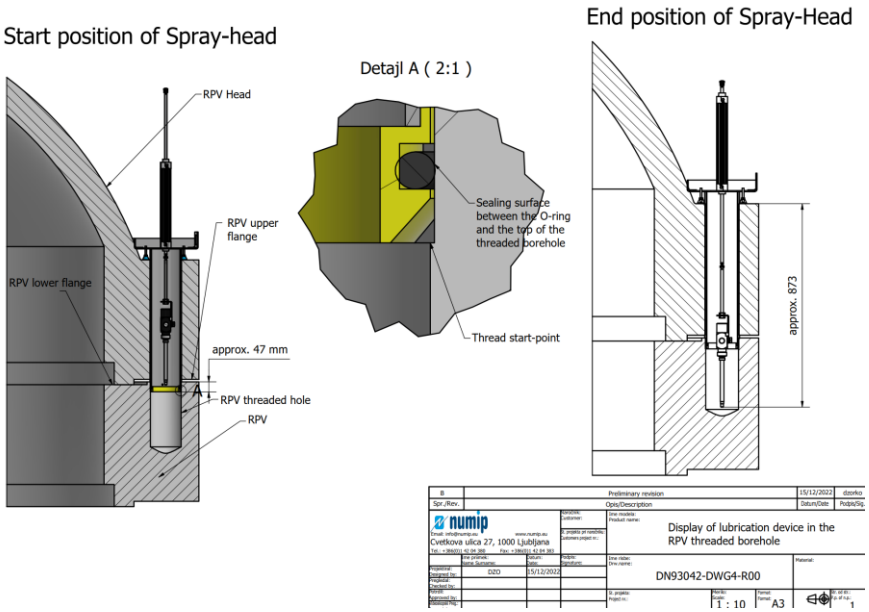

Figure 3: Installation of the device in the RPV threaded borehole with start position of spray head (left), end position of spray head (right) and sealing principle detail (middle).

Work procedure:

- Visually check the settings for individual system components. They should match as follows (see Figure 3): Manual injection 0, Manual cylinder up, Mixer 0, Manual, Pump 0;
- Connect the compressed air and set the working pressure to 5 bar.
- Turn on the mixer and pour the lubricant mixture. Turn on the pump and open the return line for lubricant circulation.
- Switch to automatic mode.
- Adjust the air pressure of the pump (0.2 MPa) and the atomization pressure (0.1 MPa).
- Insert the device into the opening you want to lubricate. Ensure that the protective sleeve is deep enough in the threaded hole. Adjust if necessary with spacer feet.
- Press the green Start button for the automatic cycle on the device or control panel.
- After completing the work, switch the operation switch to manual mode.

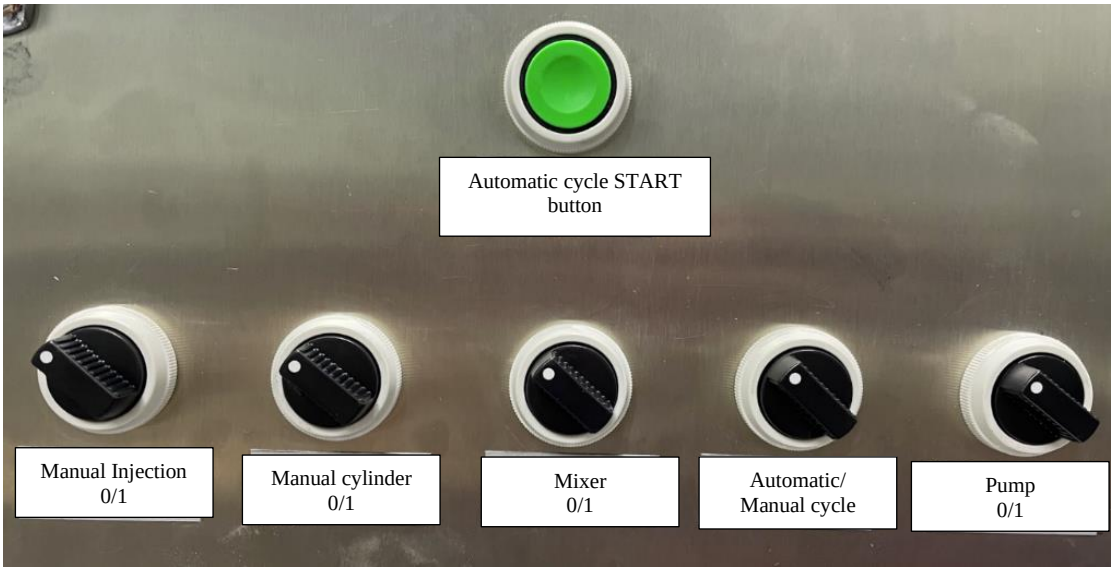

Figure 3: Control panel switches.

3 CONLUSION

The company demonstrates a strong commitment to sustainable development and environmental policies, evident through years of adherence to management system requirements aligned with the ISO 14001 environmental standard. It is important to emphasize that all reactor flange maintenance activities involve relatively high exposure to ionizing radiation. Through the utilization of our device, we have managed to reduce individual exposure significantly, as the lubrication cycle (positioning + lubrication) is now 20% shorter. This is crucial for conducting maintenance tasks critical to the timeline (any delay extends the maintenance, leading to electricity generation loss). The automated cycle also enables the operator to move away from the reactor flange after positioning the device and initiating the cycle, allowing the chamber to depressurize. Considering the inverse square law for dose reduction with distance, we can conclude that the dose received during lubrication activities for RPV threaded boreholes is reduced by 50% using the new device.

Furthermore, optimization efforts led to a 10% reduction in lubricant consumption, as our device ensures precise and optimal lubricant dosing at the required locations. This optimization also directly impacts waste reduction. The device can be operated by a single person, eliminating the need for multiple individuals to enter the reactor pool. Each entry or exit from the pool generates a significant amount of compacted radioactive waste due to protective equipment.

The development of such products bolsters the company's culture of innovation, fostering collaboration between departments and multidisciplinary engagement with high-tech product providers. The developed device has paved the way as the first in a series of RPV devices. In the future, we intend to create devices for cleaning RPV threaded boreholes, as well as cleaning and scanning devices for the RPV flange sealing surface. With these devices, we would offer a comprehensive package for inspecting and opening/closing RPV´s.

The development took place within a team framework in collaboration with users. After the initial practical application, users expressed great satisfaction with the device's simplicity and functionality, which eases at least one of the tasks in an exceptionally challenging working environment.