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Assessment of an Oil Filtration System for a Helium Circulation Loop used for Accelerator Production of Mo-99

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PURPOSE & GOALS:

The objective of this project was to investigate the use of an oil filtration system to extend the operating life of the oil used in the helium circulation blower. This blower is a part of the cooling system used in the accelerator production of Mo-99. A goal of one oil change per year is desired.

INTRODUCTION:

In order to provide necessary cooling to the target, the helium must be circulated at high pressure (high density). This is accomplished by placing a rotary blower inside of a pressure vessel and charging the system to the required pressure. In this way, the blower only experiences a 15-20 psi differential while the system can operate at an elevated pressure (300 to 400 psi). The current design of the pressure vessel which houses the blower and motor is 63" in length with 30" diameter interior. A 43" outer flange contains 28 bolts that must be removed before opening the pressure vessel to perform maintenance on the blower and motor. A CAD model of the pressure vessel assembly is shown in Figure 1.

Figure 1-CAD model of current pressure vessel assembly

To change the blower's oil, the system must be depressurized and the pressure vessel must be disassembled; this process typically takes two maintenance workers a full day to accomplish or approximately 12 hours. In order to reduce the amount down time of the cooling system, oil filtration was investigated as a method of minimizing the frequency of oil changes by enhancing the life of the oil.

Tuthill Blower:

The original design of the system called for a Tuthill PD Plus 3200 series blower which could achieve 100 g/s flow and provide approximately 20 psi differential. The Tuthill blower has an expected oil life of approximately 1000 hours, which would require the system to be shut down for maintenance every 42 days (assuming continuous operation).

At one time, Tuthill offered an external lubrication system which featured a filter, reservoir, and circulating pump to be used with their blowers. The external lubrication system is shown in Figure 2.

Figure 2 –Tuthill external lubrication system

It was thought that the oil filter could be modified to fit inside of the pressure vessel or that the connections could be fed through the pressure vessel cap and the unit could be external to the

pressure vessel. However, Tuthill no longer sells this external lubrication system. Thus, while it is possible to implement an external oil system with this blower, a customized design would be required.

For the production scale system, it is necessary to increase the flow to 400 g/s while maintaining a 15-20 psi differential to achieve the required cooling. This required the use of a new, larger unit and an Aerzen GM 12.4 blower was chosen. Focus was then shifted away from the Tuthill blower and directed towards ensuring the Aerzen blower was capable of achieving the desired oil life.

Aerzen Blower:

The Aerzen blower has two independent oil reservoirs which must be treated individually. These reservoirs provide oil lubrication at the gear end and the drive end by splash lubrication. Oil level monitoring is done via sight glasses on the side of each reservoir. The total volume of oil for the GM 12.4 model is approximately 1.3 liters divided equally between the two reservoirs, and the recommended oil is a high quality synthetic which is supplied by Aerzen. The blower manual lists the oil lifetime at 8000 hours (approximately 1 year). Additionally, Aerzen has indicated that it is acceptable to change the oil between 1 and 2 years. Thus, a filter is not required to meet the desired maintenance schedule. Although the oil meets the desired life without the addition of a filtration system, a preliminary investigation of the requirements to install an oil filtration system was conducted.

FILTRATION DESIGNS:

Several possible designs were discussed including both internal and external systems to the pressure vessel. Both types of systems would require a filter housing, a filter differential pressure indication, a method of oil circulation, piping to and from each oil reservoir of the blower, and some method of oil level monitoring. It is important to note that the improvement in oil life provided by the use of a filter cannot be clearly identified at this point in time. To accurately determine the added benefit of using a filtration system, oil samples would need to be taken periodically from an operating unit. The analysis of the oil samples would provide an indication of the amount and the type of degradation that is occurring, and to what extent filtering would improve the life of the oil. Additional information regarding recommended oil analysis is contained in Appendix A.

Internal Solution:

An internal filtration system was desired so that the components would not have to penetrate the pressure vessel and thus would not necessarily need to be rated to 400 psia. However, this team could not find any suitable “off-the-shelf” circulation and filtration devices that would fit inside of the current pressure vessel. Additionally, even if a customized system could be designed for this particular application, the independence of the oil reservoirs must be maintained. To accomplish this, either two separate circulation and filtration systems could be implemented or perhaps a 3-way valve could be used to switch between the two reservoirs. For either internal situation, the available space inside of the pressure vessel severely limits the available options. A simple schematic of one possible internal configuration is shown in Figure 3.

Figure 3 – Pump and Filter housed internal to the pressure vessel

External Solution:

An external filtration system is not subject to the tight space requirements of the internal system, and thus the options for filtration and circulation methods are greater. However, since the components would be penetrating the pressure vessel, they must be rated for the maximum working pressure of the pressure vessel (currently 400 psia). Similar to an internal system, the independence of the oil reservoirs must be maintained. This would require additional penetrations to the pressure vessel cap or perhaps a 3-way binary valve could be used similar to the internal system description. A simple example of an external configuration is shown in Figure 4.

For both internal and external solutions, some method of oil level monitoring and control must be implemented. A sight glass is the current oil level indication for the Aerzen blower, and it is not easily adaptable to a remote monitoring/indication system.

Figure 4 – Oil filtration system schematic external to the pressure vessel

CONCLUSIONS & RECOMMENDATIONS:

After weighing the available oil filtration and oil monitoring schemes, the following conclusions were drawn from this investigation:

1. The benefits of incorporating a filter cannot be determined at this time. Sampling the oil to analyze the degradation is recommended to assess the potential benefit of a filter. We are not able to recommend a specific oil filter at this time.
2. Oil level indication is a challenge in both internal and external designs. The current sight glass method is not easily adapted to a remote monitoring system.
3. There is a narrow range for an acceptable oil level. Due to the minimal quantity of oil in each reservoir (approximately 0.65L) and the design of the reservoirs, there is difficulty in accurately monitoring the oil level using a transducer.
4. Having two independent oil reservoirs doubles the amount of equipment required for remote oil monitoring. This increases equipment costs and adds further strain to the availability of space inside the pressure vessel. Moreover, this introduces a significant amount of added complexity to the system, which increases the potential failure modes and reduces the overall reliability of the system.

Considering the above conclusions and the fact that the oil for the Aerzen blower already meets the desired life, it is recommended that an oil filtration system not be implemented. Instead, other methods to reduce the time required to perform maintenance are recommended and are described in the Alternative Solutions section.

Alternative Solutions:

After evaluating multiple oil filtration designs with no stand-out solutions, the team decided to investigate the root of the problem: the amount of time required to open and close the pressure vessel. The main time requirement was dedicated to removing the 28 bolts and then torquing them to the required amount when closing the pressure vessel. One solution to minimize the time to open and close the pressure vessel without any redesign of the vessel is the use of hydraulic nuts. A sample schematic of a hydraulic nut is shown in Figure 5. Hydraulic nuts are screwed by hand onto the existing bolt (replacing the existing nut). Hydraulic pressure is applied through a nipple fitting on the nut body which forces the piston and the nut body apart, thus tensioning the bolt through the joint. A lock ring, which is mounted on the nut body, is then screwed against the flange face to retain the induced load on the bolt. Typical applications include pressure vessel closures and flanged connections which require precise tensioning in the nuclear, oil, and gas industries. An example of hydraulic nuts on a flanged connection is shown in Figure 6.

Figure 5-Sample Schematic of Hydraulic Nut

Figure 6-Hydraulic nuts mounted on flanged connection

The use of hydraulic nuts could be implemented to the current design without the need for a redesign of the pressure vessel allowing for a safe, quick, and reliable way to tension and de-tension the bolts on the pressure vessel.

Alternatively, a quick open/close pressure vessel closure could be implemented to completely eliminate the use of the bolts to secure the pressure vessel closure. An example would be a tool-less closure from Sypris Technologies Tube Turn division. This closure mechanism satisfies the appropriate ASME codes while opening in about a minute without the need for tools. An example of a tool-less quick open/close closure is shown in Figure 7:

Figure 7-Tool-less quick open/close closure

The closure design for our application would not be hinged. Instead, the front would be welded in place, similar to the current design, and the pressure vessel hub would again be mounted on a track. The current pressure vessel manufacturing prints were provided to Sypris Technologies Tube Turns Products and they returned a quotation of \$14,000 for the tool-less closure mechanism with the appropriate penetrations machined. This closure is able to be opened in under a minute by a single worker without the use of any specialized tools.

APPENDIX A: OIL ANALYSIS

The best way to control oil contamination is to prevent the contaminants from entering the system from the start. This requires all components to be clean and thoroughly flushed before beginning full operation. In addition, the oil must be properly stored and ideally pre-filtered before coming into contact with any machine component. Also, when oil needs to be added and/or samples taken, it is important to be careful not introduce any unnecessary contamination.

Water is a major source of contamination and degradation in oil systems. Below is an excerpt from a clean oil guide from CJC:

Water reduces the lubricity of the oil, due to the lower viscosity and poor load capacity of water. When water is exposed to the high pressures found in load zones in e.g. bearings and gears, the water droplets collapse (implode). The resulting micro-jets create micro-pitting in metal surfaces and can even result in metal-to-metal contact when water vapor pushes the oil away momentarily. Free hydrogen ions in the water can further worsen the situation, since they migrate into machine components making steel brittle and prone to crack. Water also results in corrosion and erosion leading to pitting damage.

Thus, it is desirable to prevent water from entering the oil both in storage and during operation.

Other types of degradation resulting from elevated temperatures, water, or chemical contamination include various acids, polymerized compounds, and varnish which typically precipitates onto colder machine components. Many of these contaminants can be removed from the oil with the use of a proper filter. However, it is difficult to predict the type of degradation that will occur. To understand the degradation of the oil, and choose the appropriate filter, an oil analysis program could be implemented.

If an oil analysis is conducted, the following are the typical and recommended quantities which should be obtained from the analysis:

- Viscosity @ 40 C and 100 C
- Spectrochemical Analysis in ppm
- Wear element concentration (per ISO 4406)
- Water Concentration in %
- Additives Listing
- TAN index
- Oxidation Index

With the above parameters, it is possible to get a better understanding of the type and amount of degradation that is taking place, and thus be able to recommend the appropriate actions.