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Proposal for Monitoring Within the Centrifuge Cascades of Uranium Enrichment Facilities

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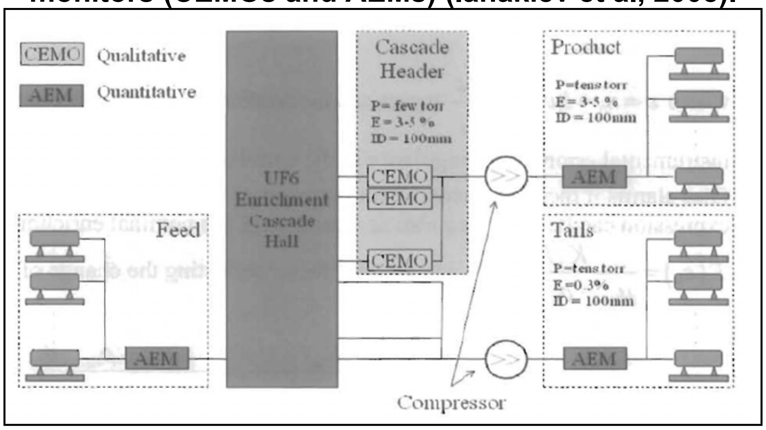
CONTENTS

FIGURES

1. Introduction

Safeguards are technical measures implemented by the International Atomic Energy Agency (IAEA) to independently verify that nuclear material is not diverted from peaceful purposes to weapons (IAEA, 2017a). Safeguards implemented at uranium enrichment facilities (facilities hereafter) include enrichment monitors (IAEA, 2011). Figure 1 shows a diagram of how a facility could be monitored.

Figure 1 - Example of monitoring a uranium enrichment system with enrichment monitors (CEMOs and AEMs) (Ianakiev et al, 2008).



However, enrichment monitors are based on the high purity germanium detector (Ianakiev et al, 2008), which is expensive technology, and require relatively high pressure of uranium hexafluoride (UF_6) in the flow (Ianakiev et al, 2008). The interior of a centrifuge enrichment system consists of a large number of centrifuges (World Nuclear Association, 2016), in which the pressure of UF_6 in the flow is relatively low (Ianakiev et al, 2008). Therefore, enrichment monitors are not applicable for the interior.

The use of a system for monitoring within centrifuge cascades is proposed. The monitoring system would be designed to detect diversion of centrifuges away from a facility's monitored enrichment system. After design, the system would need to be built and tested in order to assess its capability. If its capability is sufficient for detecting diversion of centrifuges, then it would need to be customized for feasible use by the IAEA as a part of their safeguards. This customization may need to be facility-specific.

2. Additional Benefits of Monitoring System Within Cascade

A monitoring system within centrifuge cascades could provide benefits to the IAEA in addition to detecting secondary enrichment capability that is separate from a monitored enrichment system. The monitoring system could find diversion of small amounts of uranium occurring from within the monitored enrichment system. Nuclear material accountancy by the IAEA is based on counting containers of material, weighing them, and measuring their emitted radiation (IAEA, 2011). Due to IAEA's limited resources, it may perform accountancy only at locations where accumulation of material is the largest. It is plausible that small amounts of material may be missing from these locations without the IAEA's knowledge. If the diversion of material occurs within the centrifuge cascade, a monitoring system within the cascade could catch it.

Also, a monitoring system within centrifuge cascades could determine the amount of centrifuges within a facility. This amount can be checked against the facility's declared amount of centrifuges. If there is a mismatch, this could indicate unauthorized export of nuclear technology, or enrichment beyond what was declared to the IAEA.

3. Arguments Against Monitoring System Within Cascade

One argument against a monitoring system within centrifuge cascades is the IAEA performs site inspections of facilities on a routine basis (IAEA, 2017b), and these inspections would catch any diversion of centrifuges. A centrifuge consists of one input and a few outputs pipes (shown in Figure 2), centrifuges are placed close together in a facility (example shown in Figure 3), a centrifuge cascade consists of a large number of centrifuges, and many parallel centrifuge cascades make up a facility (World Nuclear Association, 2016). These result in large amounts of pipes that inspectors would have to examine visually in order to find diversion of centrifuges. The limits on inspectors' time during an inspection prevent detailed examination of this magnitude.

Figure 2 - Diagram of gas centrifuge (Ulmer-Scholle, 2016).

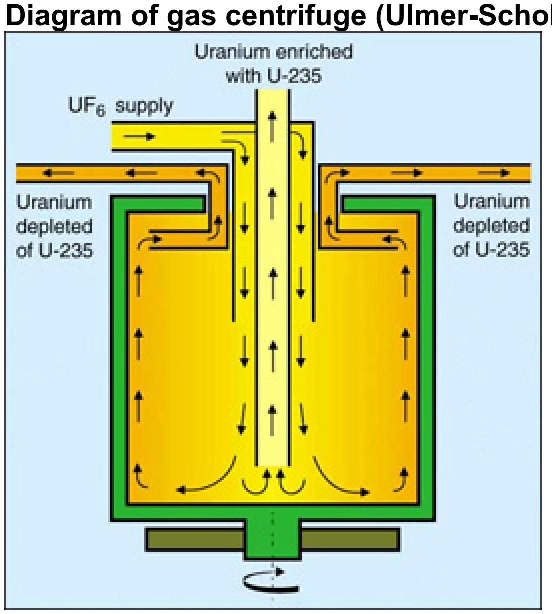
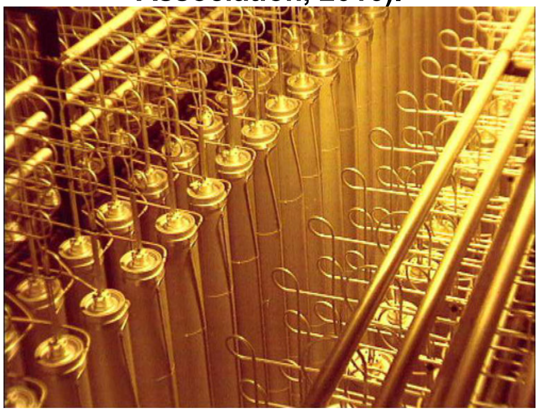


Figure 3 - Bank of centrifuges at a uranium enrichment facility (World Nuclear Association, 2016).



Another argument is that any monitoring system within centrifuge cascades would be too expensive for the IAEA to use. This is because any system would need to monitor multiple (possibly a lot) points within the centrifuge cascades of a facility. Not only would the system require purchasing lots of monitors, the costs associated with deploying, maintaining, and extracting data from the monitors would be prohibitive as well. The IAEA uses monitors based on radiation detection technology (IAEA, 2011). There is a wide range of radiation detection technology available. Some technologies do not require power sources or computers when measuring radiation, can be left unattended, are easy-to-use, are commercially available in bulk, have relatively easy processes for extracting data on radiation measured, and are in extensive use in many different applications. Examples of radiation detection technology that meet these criteria are thermoluminescent and optically-stimulated luminescent dosimeters ([Knoll, 2010], [Thermo Fisher Scientific, 2016], [Landauer, 2016]).

The last argument addressed is facility owners would be reluctant to allow monitoring systems within their centrifuge cascades. Some of their concerns may include intrusiveness in the enrichment process, potential to obtain proprietary information with such a system, and alarms due to shutdown/disconnection of centrifuges for valid reasons (like maintenance and repair). The flows of UF_6 within/between centrifuges are relatively low and current intrusive monitors used by the IAEA are not used in these low flows (Ianakiev et all, 2008). So it is possible that any viable monitoring within centrifuge cascades would have to be non-intrusive. For the potential of obtaining proprietary information, monitoring systems can be made to be qualitative in nature (like the cascade enrichment monitor [IAEA, 2011]). A monitoring system for centrifuge cascades can have a similar function, which may alleviate concerns of obtaining proprietary data. Finally, alarms by a monitoring system may only trigger an investigation by the IAEA, and not directly lead to immediate conclusions of non-compliance. The investigations would give facility owners chances to explain their valid reasons for shutdown/disconnection of centrifuges.

4. Conclusion

Monitoring within centrifuge cascades of facilities is not currently performed by the IAEA as a part of international safeguards. A monitoring system would need to be designed, tested, and tailored such that the IAEA can use it in their safeguards of facilities. It is possible that monitoring within centrifuge cascades could also serve to verify declared amounts of centrifuges in a facility. Monitoring systems in centrifuge cascades have a higher probability of finding diversion of centrifuges than visual inspections by the IAEA. Some technology that could be used in monitoring systems is economical in terms of material and operations. Monitoring systems within centrifuge cascades can be designed in such a way to alleviate concerns from facility owners.

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