Metal Media Filters, AG-1 Section FI

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ABSTRACT
One application of metal media filters is in various nuclear air cleaning processes including applications for protecting workers, the public and the environment from hazardous and radioactive particles. To support this application the development of the ASME AG-1 FI Standard on Metal Media has been under way for more than ten years. Development of the proposed section has required resolving several difficult issues associated with operating conditions (media velocity, pressure drop, etc.), qualification testing, and quality acceptance testing. Performance characteristics of metal media are dramatically different than the glass fiber media with respect to parameters like differential pressures, operating temperatures, media strength, etc. These differences make existing data for a glass fiber media inadequate for qualifying a metal media filter for AG-1.

In the past much work has been conducted on metal media filters at facilities such as Lawrence Livermore National Laboratory (LLNL) and Savannah River National Laboratory (SRNL) to qualify the media as High Efficiency Particulate Air (HEPA) Filters. Particle retention testing has been conducted at Oak Ridge Filter Test Facility and at Air Techniques International (ATI) to prove that the metal media meets or exceeds the 99.97% particle retention required for a HEPA Filter. Even with his testing, data was lacking to complete an AG-1 FI Standard on metal media.

With funding secured by Mississippi State University (MSU) from National Nuclear Security Administration (NNSA), a research test stand is being designed and fabricated at MSU's Institute for Clean Energy Technology (ICET) Facility to obtain qualification data on metal media. This in turn will support required data needed for the FI Standard. The paper will discuss in detail how the test stand at MSU will obtain the necessary data to complete the FI Standard.

Background

Conventional disposable glass-fiber HEPA filters are used throughout the nuclear industry in various process systems. These HEPA filters must exhibit a particle removal efficiency of 99.97% when challenged by thermally generated di-octyl phthalate (DOP) aerosol with a diameter of 0.3 microns. The pleated glass fiber HEPA filter media has approximately 240 ft^2 (22.3 m^2) of surface area and is typically contained in a 2 ft x 2 ft x 1ft (0.6 m x 0.6 m x 0.3 m) housing and exhibits a 1" of water column (wc) (250 Pa) differential pressure across the filter media when clean. A conventional HEPA filter remains in service until the filter media reaches a predetermined maximum pressure drop (approximately 5" wc or 1250 Pa) or a high source term due to radioactive buildup, and then the filter is replaced. The contaminated HEPA filter is removed and disposed of. This process is not only expensive, but also subjects personnel to radiation exposure and adds to an ever-growing waste disposal problem.

The conventional HEPA filters have safety concerns in the areas of filter media strength, water damage, and operation in environments with elevated temperatures. In 1999 the Defense Nuclear Facility Safety Board issued a report titled "HEPA Filters used in the Department of Energy Hazardous Facilities", DNFSB/TECH-23 that documents these and other concerns pertaining to conventional HEPA filters.[1] To address most of the safety issues associated with the glass fiber filters, the Department of Energy (DOE) invested in the development of robust HEPA filters that could be regenerated or cleaned in situ. Previous research has been conducted at US DOE sites, such as Lawrence Livermore National Laboratory (LLNL) and Oak Ridge National Laboratory, to develop in situ cleanable or regenerative HEPA filters with high media strength. W. Bergman, *et al* conducted research on various filter media, such as steel fibers, and sintered metal.[2] Work was also conducted at the Savannah River National Laboratory (SRNL) on metal media as robust HEPA filters that could be cleaned insitu.[3,4]

An American Society of Mechanical Engineers (ASME) Peer Review of the metal media filtration system was conducted in FY2000 on a metal media HEPA system being designed at SRNL. The Peer Review Panel was complementary of the research and the promise of the new technology. However the peer review found the program was lacking due to the metal media was not being covered in the ASME AG-1 Manual.[5] This finding slowed the progress of the metal media HEPA system at SRNL. Due to the lack of funding this program has been on the back burner at SRNL since FY2001. This lack of funding has also, impacted the completion of the standard on metal media (FI) due to the lack of qualification data.

For the first time in over a decade funding has come available to support metal media HEPA filter technology. Funding was made available in FY2011 to Mississippi State University (MSU) to build a test stand to obtain qualification data needed to complete the ASME AG-1 FI standard. Additional information on the MSU metal media test stand will also be presented at the 32nd Nuclear Air Cleaning Conference.

Discussion

Metal media HEPA filters would not be a good choice for all applications in the nuclear industry. But the applications that metal media filters can be applied to are diverse. The metal media can be designed for direct replacement a conventional gas fiber filter in the exiting filters housing, not impacting the parameters of the existing system. Figure 1 from the draft FI Standard is an example of a direct replacement metal media filter for a 2 ft x 2 ft x 1ft (0.6 m x 0.6 m x 0.3 m) glass fiber filter.

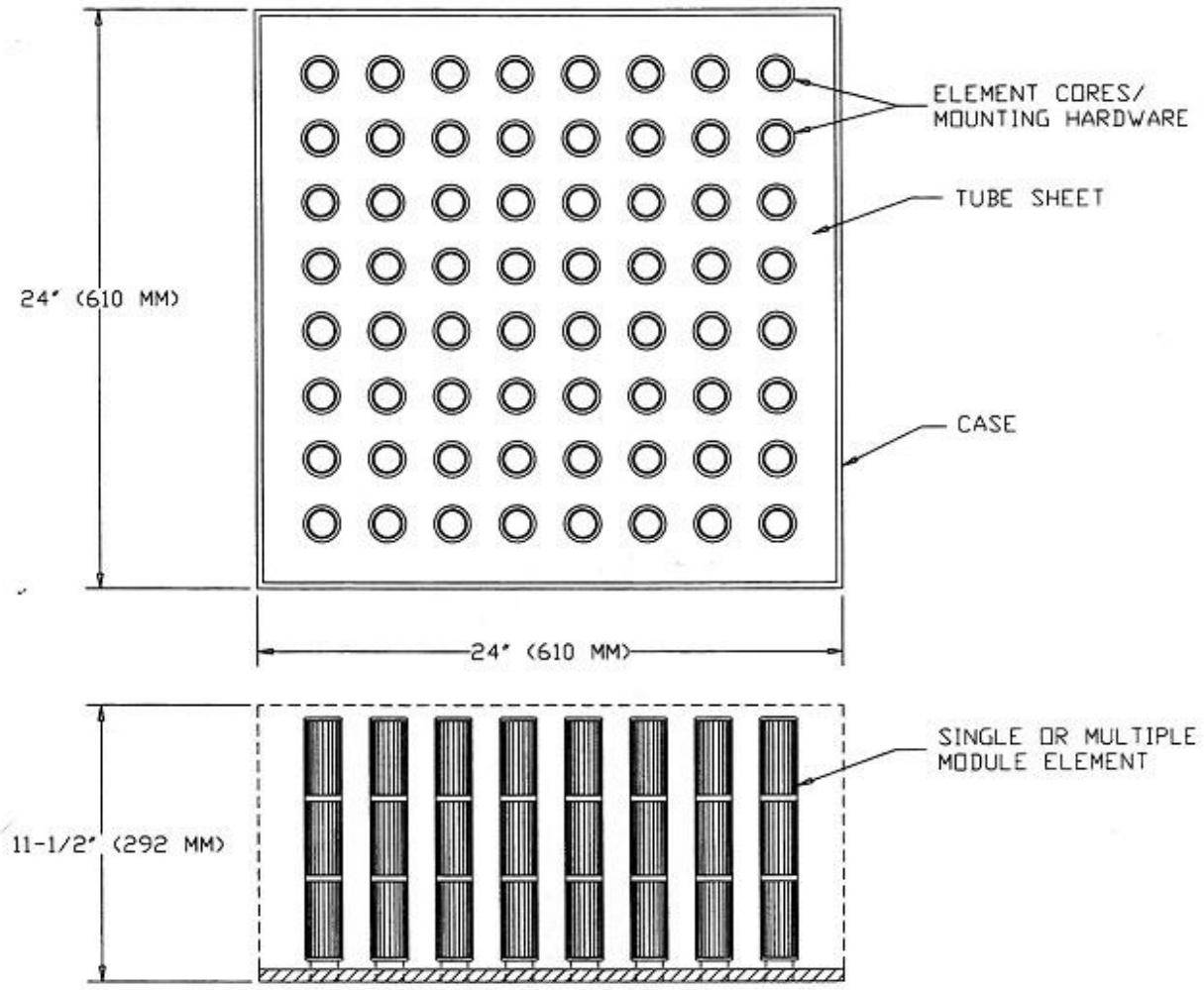

Figure 1: Metal Media 2x2x1 Direct Replacement for Standard HEPA Filter

The metal media filter in Figure 1 was built by W. Bergman, *et al* as a direct replacement of a conventional glass fiber filter over a decade ago, proving the concept of metal media. With the improvements made in the metal media industry over the last ten years, this design can be improved drastically in media surface area and pressure drop.

Configurations and dimensional requirements can also be customized for a given application. This leads to why the existing draft FI standard allows for owner/designer specification of metal durability, dimensional specifications, media velocity and differential pressure across the media. It is to be understood that this flexibility of specification is limited to filtration units that will be used in newly designed systems or restricted to operating ranges of existing systems.

The current draft of the FI standard takes into account that the conditions encountered by metal media filters may not be equivalent to those commonly used in testing conventional (glass fiber) filters. Sufficient specificity of testing methods for ranges of filtering efficiencies is provided to

establish a minimum set of test protocols, yet flexibility is provided to offer the owner/designer the ability to include test conditions necessary to ensure performance within the operational environment.

The tensile strength of fibrous glass media is very small when compared to the strength of the metal media. This current low tensile strength restricts the maximum operating differential pressure of HEPA Filters. Without qualification data, metal media falls under the same requirements as glass fiber. The current differential pressure restriction in AG-1 is much too small for metal media. This will be priority data to obtain from the testing at MSU. Past testing at Savannah River National Laboratory with metal filters proved that the filters can safely operate with a high differential pressure while providing the required particle retention efficiency.

The goal of the MSU Filter Project is the development of the test stand for the establishment of the qualification criteria posed upon the Section FI metal media filters. The primary objective for this test stand is to provide filter qualification data, with possible future use for examining loading characteristics and assesses the capabilities of a wide range of metal media elements.

FILTER QUALIFICATION

Qualification for the FI standard covers several different categories that are in conflict with the existing requirements of a conventional HEPA filter. The metal media is superior to the glass fiber media in many categories;

- Resistance to high humidity
- High tensile strength
- High temperature operation
- Increased safety in the event of a fire
- High differential pressure operation, resistant to pressure spikes
- Performance in a corrosive environment
- Ability to clean Filters in-situ

More than one committee member noted that infrastructure to qualify metal media filters does not exist during the last balloting of Section FI. This infrastructure must include the physical apparati and testing protocols to accomplish the qualification process. It is instructive to review each area of qualification testing to contrast performance capabilities of fibrous glass with those of metal media.

Humidity

The metal media is capable of withstanding 100% humidity without degrading the media. There are operational issues associated with challenging any filter with a gas stream containing liquid droplets. Through wetting of any filter medium can cause the release of droplets on the downstream side of the filter containing radiological material or solutes. It is therefore possible to achieve “failure” of any filter, as defined by a drop to less than 99.97% filtering efficiency, when the medium has become saturated with moisture even through there has not been a physical failure of the medium.

Wetting metal medium filters can produce the loss of filtering efficiency without physically degrading the filter. Additionally, high humidity can also reduce the capability of regenerating filtering capacity of metal medium filters by back pulsing with air. This can negate one of the frequent reasons for selecting metal medium filters, the ability to clean the filter and continue use under high loading conditions.

Tensile Strength

Metal media has dramatically superior tensile strength compared to glass fiber media. The functional unit of many, if not most metal media filter systems is a filter candle. These candles may or may not be pleated to increase surface area. Airflow in these systems is from the outside of the candle to the inside generating a compressive load as opposed to tension for fibrous medium filters. An appropriate test for metal medium filters is the crush pressure for filter candles. Metal media filter systems are currently in operation that withstands differential pressures greater than 10 psig (690 kPa).

Temperature and Fire

The metal media have much higher operating temperatures and Section FI will cover air streams temperatures up to 750°F (399°C). Metal media will improve safety in the event of a ventilation fire by not only having a high temperature tolerance but also be able to withstand differential pressures outside the range of most fan curves. During wild fires, heavy smoke and smoke borne particulates may plug the metal media filters, but test results indicate that the plugged condition will not cause filter failure and/or breakthrough causing a release to the environment.[3,4] A wild fire event such as this occurred at Las Alamos National Laboratory causing HEPA filter failures.

Spot Flame

The Spot Flame Test is a staple for qualifying fibrous glass filters. The primary purpose of this test is to determine if medium and potting material used in these filters are self-extinguishing. Most metal medium is made of either stainless steel wire or metal powder. It is unclear if a Spot Flame Test is necessary for the metal media.

One of the issues associated with the spot flame test will be embrittlement of the medium or possibly rendering where the flame impinges on it much more resistant to airflow. While the spot flame test may not be necessary for metal media, it is important to recognize that welding the seams on metal medium candles can reduce the effective surface area and must be done in a manner that does not cause embrittlement or oxidation.

Pressure and Pressure Spikes

The metal media is designed to withstand a high differential pressure across the media. The media is different from glass fiber and unable to meet the low dP requirements of a HEPA filter in AG-1 manual. The metal media can withstand large pressure spikes, such as a small explosion in the ventilation system. The metal media can withstand a wide range of off gas corrosive environments while meeting the particle retention efficiency. Another advantage of metal media is the metallic construction of the media can be altered to provide superior performance for the corrosive environment.

In Situ Cleaning of Filters

The metal media can be cleaned in situ resulting in longer life of the filter and reducing disposal cost. Past work at Savannah River National Laboratory showed that the filters could be cleaned in situ with good success. Figure 2 is an aggressive loading and cleaning curve of a metal media filter, operated in a very hostile salt environment for 2,000 hours. The test environment represents a HLW salt tank found at Savannah River and Hanford. During, this 2,000 hour test the filter was cleaned in situ four times. Each time the filter essentially returned to clean filter dP status.

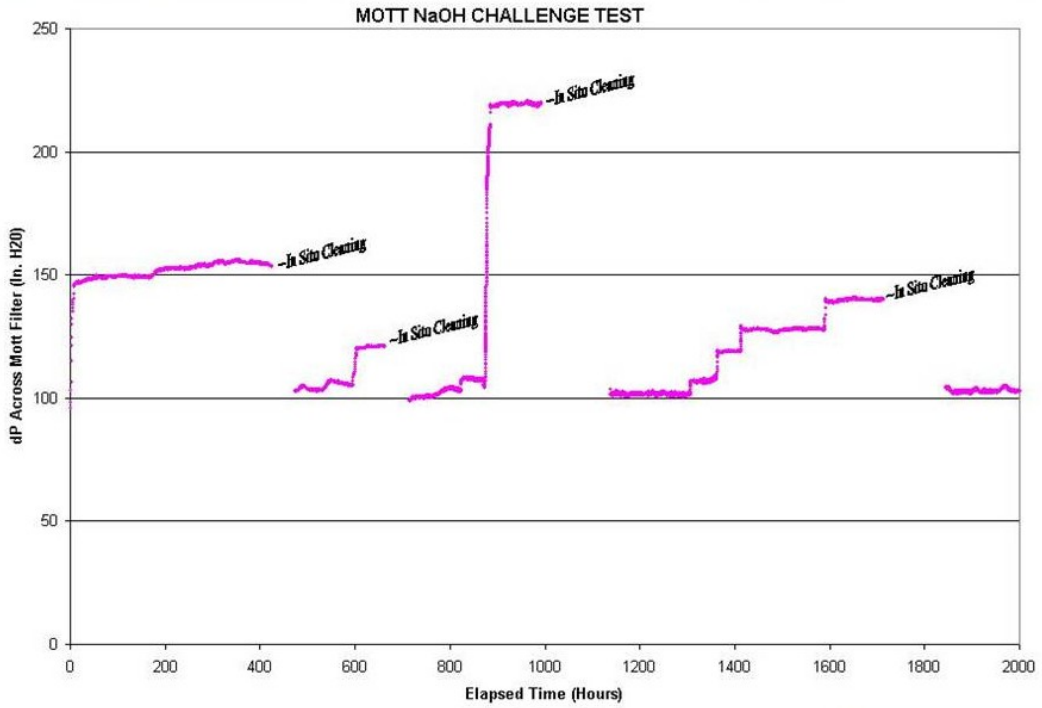

Figure 2: Example of Regenerating/Cleaning a Metal Media Filter In Situ

The filter used in this testing was a sintered metal powder medium filter. Figure 3 is a picture of the sintered metal filter showing the configuration. The filters have a cylindrical design for ease of cleaning the filter in situ. The filter was 3 inches (7.6 cm) in diameter and 24 inches (61 cm) long. The particle retention of the test filter was greater than 99.99% before testing. After the 2,000 hour test was completed the metal media test filter was returned to the Oak Ridge Filter Test Facility for posttest particle retention test. The particle retention of the test filter remained greater than 99.99% efficient when challenged by thermally generated di-octyl phthalate (DOP) aerosol with a diameter of 0.3 microns. [3]

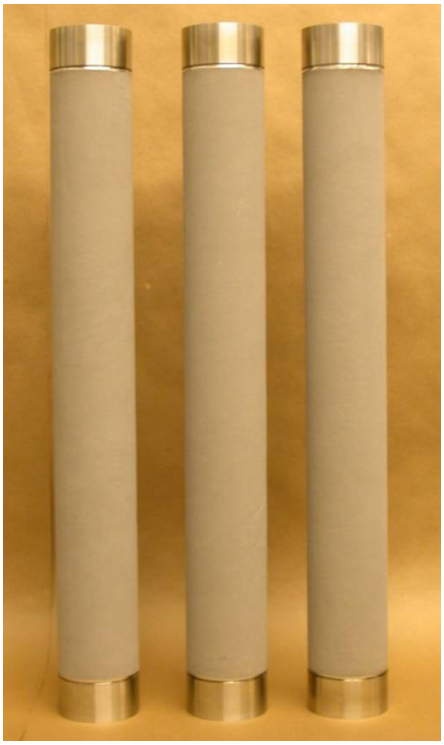

Figure 3: Picture of Sintered Metal Powder Medium Filter Candles

Path Forward

Figure 3 is a drawing of the Metal Media Test Stand being constructed at MSU. The system is being designed to supply volumetric airflows up to 250 ft^3/min (7.1 m^3/min) at 10 psig (690 kPa) across the metal media.

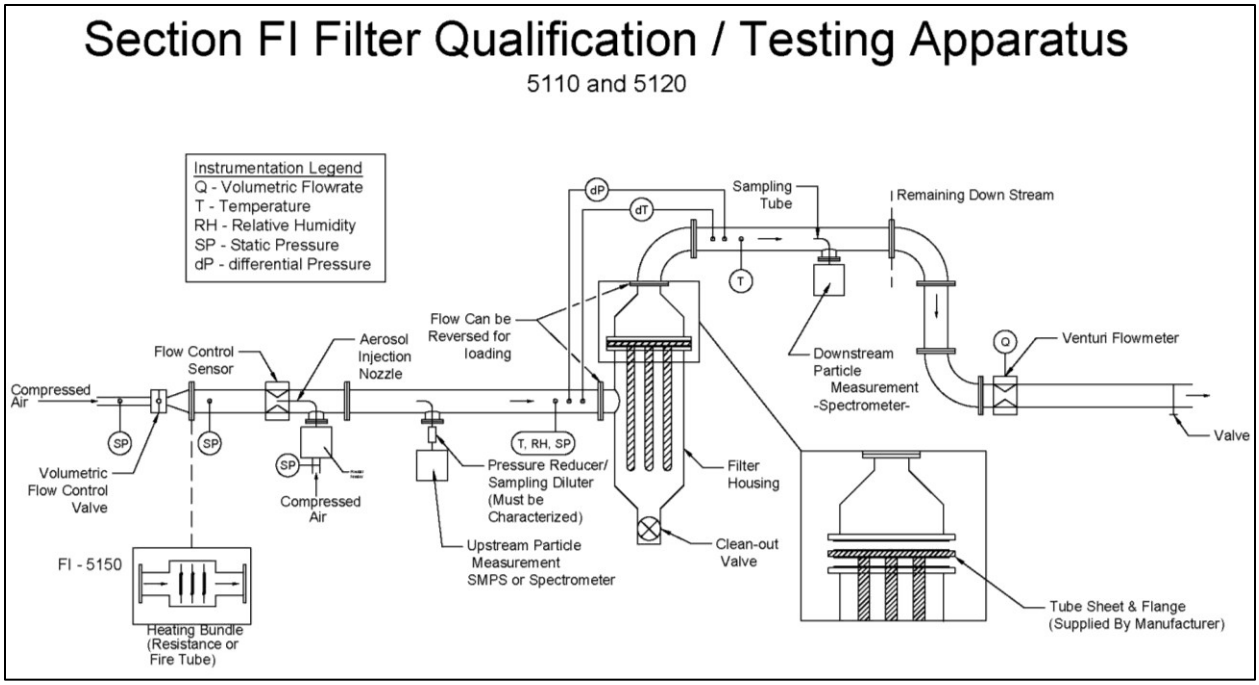

Figure 4: MSU Metal Media Filter Test Stand

Funding has been provided by International Society of Nuclear Air Treatment Technologies (ISNATT) and DOE-EM to fabricate this test stand and develop a set of testing protocols necessary for finalizing Section FI of the AG-1 standard. Activities conducted at Mississippi State University will be carried out in close consultation with members of the Section FI project team and are intended to directly contribute to providing work products necessary for completing Section FI. The test stand has been designed as a flexible research tool to evaluate parameters sufficiently for establishing testing protocols and target performance values for the qualification portions of FI. Data collected using this apparatus will also be employed in design of an effective unit for qualifying metal medium filters.

Section FI includes a broad range of filtering efficiencies, filter configurations, and types of metal media. The test stand depicted in Figure 4 can be used for evaluating all of the options available under Section FI except for filters designed as a direct replacement for Section FC fibrous glass filters. Qualifying Section FI filters as replacements for Section FC units will require an appropriate filter housing and ductwork designed to withstand positive or negative pressures to maximum differential pressures, potentially 10 psig (690 kPa).

There are a number of technical issues to be resolved in order to successfully characterize the test stand, develop test protocols, and collect data needed to complete the code section. The most significant hurdle deals with aerosol measurement against either a positive or negative pressure of greater than 100 in. wc (25 kPa). There is also the issue of measuring and controlling volumetric flow rates from 15 ft^3 (0.4 m^3) to 250 ft^3 (7 m^3) at pressures from 4 in. wc (1 kPa) to 100 psig (690 kPa). Other issues such as aerosol generation and injection, aerosol neutralization, and control of temperature and humidity need to be established to within acceptable limits. Finally, the work is to be completed consistent with NQA-1 requirements.

The test stand being developed at MSU is intended to serve a research role to provide data that are not currently available; the Section FI project team will serve an oversight role ensuring efficiency and applicability of the work. MSU will host a meeting of the project team upon completion of fabrication and characterization of the test stand. This will provide an opportunity for a peer review of the equipment and quality program employed.

The current time line for activities is for the test stand to be completed and characterized by August 2012. The project team will meet and approve the test plan for data collection. Mott Corporation has agreed to provide sintered metal powder elements and Porvair Filtration Group has agreed to provide sintered metal fiber elements for test stand characterization and for development of test protocols. Initial data collection is to be completed by the end of September 2012. This will include the following:

- Resistance to rated air flow
- Aerosol penetration at rated air flow and at 20% rated air flow
- Resistance to pressure
- Test housing/tube sheet leaks
- Filter loading
- Resistance to heated air flow

The activity completed by the end of calendar year 2012 will include protocols for conducting qualification testing and design of a test stand or test stands tailored for qualifying metal media filters. The priority will be obtaining qualification data for resistance to airflow, test aerosol penetration and resistance to heated air. MSU anticipates working with a manufacturer to modify the test stand for addition of back pulse cleaning. The test vessel has been designed to include the possibility of monitoring the effectiveness of back pulse cleaning.

Conclusion

Metal media holds great promise as an HEPA filter for many application across the DOE complex and commercially where the off gas environment is very hostile and corrosive to a conventional glass fiber filter. Metal media is robust which will reduce the potential of a catastrophic HEPA filter due to water damage, pressure surges, chemical erosion, and ventilation fire. But for metal media to be a candidate for offgas systems in many nuclear facilities, the design must have the backing of the AG-1 Manual with an approved FI Standard.

The Section FI project team has worked closely with DOE-EM representatives and with MSU researchers to map out testing capabilities that are needed to complete Section FI. Work is progressing under DOE-EM and NNSA funding. Talks can be enjoined between the FI project team, DOE-EM, NNSA, and the DoD qualification laboratory by the end of calendar year 2012 to determine the most appropriate design for a qualification test stand for metal media HEPA filters that will be compatible with the Edgewood, MD facility.

References

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