Mechanically Cooled Large-Volume Germanium Detector Systems for Nuclear Explosion Monitoring

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Brief introduction (only included in this first report)

Compact maintenance free mechanical cooling systems are being developed to operate large volume ($\sim 570 \text{ cm}^3$, $\sim 3 \text{ kg}$, 140% or larger) germanium detectors for field applications. To accomplish this we are utilizing a newly available generation of Stirling-cycle mechanical coolers to operate the very largest volume germanium detectors with no maintenance. The user will be able to leave these systems unplugged on the shelf until needed. The flip of a switch will bring a system to life in ~ 1 hour for measurements. The maintenance-free operating lifetime of these detector systems will exceed 5 years. These features are necessary for remote long-duration liquid-nitrogen free deployment of large-volume germanium gamma-ray detector systems for Nuclear Explosion Monitoring. The Radionuclide Aerosol Sampler/Analyzer (RASA) will greatly benefit from the availability of such detectors by eliminating the need for liquid nitrogen at RASA sites while still allowing the very largest available germanium detectors to be reliably utilized.

Three important factors affect the operation of mechanically cooled germanium detectors: temperature, vacuum, and vibration. These factors will be studied in the laboratory at the most fundamental levels to insure a solid understanding of the physical limitations each factor places on a practical mechanically cooled germanium detector system. Using this knowledge, mechanically cooled germanium detector prototype systems will be designed and fabricated. Our collaborators at PNNL will evaluate these detectors on the bench top and eventually in RASA systems to insure reliable and practical operation. By the end of this project, we will be able to supply maintenance-free large volume mechanically cooled germanium detector systems to RASA manufacturers.

Description of activities conducted this Reporting Period:

1. Contract details have been worked out to the extent that work can begin at PHDs Co. in Oak Ridge, TN.
2. System for vacuum analysis was purchased. This turbo molecular pumping station, complemented by a residual gas analyzer will allow careful study of

accumulating gasses in sealed vacuum chambers over time. Residual gases accumulate to the extent that they provide a thermally conductive path that often warms the germanium detector to an intolerably high temperature. A Pfeiffer Turbo-Molecular TSU521 vacuum pumping station purchased and delivered. An Ametek 100-AMU LC100M Residual Gas Analyzer (RGA) purchased and delivered. Vacuum hardware including valves, seals, and chamber parts were purchased and delivered. A Dell Laptop PC to control RGA was purchased and delivered. The vacuum system was assembled. Measurements have been started to establish operating parameters for sensitive gas accumulation measurements. Figure 1 shows a photograph of the system operating at our Oak Ridge, TN facility.

Figure 1 The photograph shows the turbo molecular pump in with the RGA operating over the pump. A histogram of the RGA output can be seen on the laptop computer on the bench to the left.

3. The design for MCO-a has started. MCO-a is to be the first prototype mechanically cooled detector system. It will be used initially for cool down tests incorporating the vacuum strategies originating from RGA measurements of accumulating gasses. MC0-a is being designed to hold a very large germanium detector. Initially it will hold a large brass cylinder in

place of the germanium detector for cool-down tests. The system will be optimized to cool the germanium detector to as cold a temperature as possible as quickly as possible. The system is being designed to house the largest possible p-type germanium coaxial detector; 10-cm diameter and 10-cm long. The system is being designed for rugged field operation. Allowance is being made for variable tap into ~ 120 K portion of cooler for maximum efficiency and coldest possible detector operating temperature. The conductivity of the cooling path is being maximized to provide most rapid possible cool down times. The copper block at the cold tip can contain molecular sieve for vacuum gettering.

Figure 2 The assembly drawing shows the status of the design of MC0-a, our first prototype mechanically cooled system to be built. The system is large enough to accommodate the largest germanium detector available; a 10-cm diameter, 10-cm long detector.

4. Abstracts and papers were submitted for September 2006 SRR in Orlando, FL.
5. A trip was arranged to visit PNNL in early August to meet with Product Integrator Ted Bowyer and collaborator Harry Miley.

Progress/Deliverables Required By this Reporting periods Per Contract:

The highlighted items a, b, and c required attention during the first two months of the Phase 1 (year 1) of the program.

PHASE 1 (12 months)

- a. Build Vacuum—RGA system (months 1-2) Acquire equipment including turbo-molecular vacuum system, RGA, and computers to operate RGA and cooler.
- b. Establish operation parameters for sensitive accumulated gas measurements (month 2).
- c. Design and build first test cryostat (MC0-a) using Cryotel CT cooler from Sunpower with brass detector dummy (months 1-3).
- d. Measure cooler performance as a function of time and vacuum quality (month 3).
- e. Make measurements of accumulated gases in test cryostat (months 4-5).
- f. Attend SRR.
- g. Address predominant accumulated gases (months 6-8).
- h. Design and fabricate MC1 (months 8-10).
- i. Load planar detector into MC1 and evaluate microphonics (month 11).
- j. Load 50% coaxial detector into MC1 at Ortec and deliver to PNNL (month 12).
- k. Meetings with Product Integrator.

Reason for Differences in Cooperative Agreement Statement of Objectives/Deliverables

No differences, everything is on schedule.