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KEVLAR/MYLAR WINDOW FAILURE AT ACCELERATOR

On June 14, 1995, at Brookhaven National Laboratory, a Kevlar-Mylar window on a vacuum decay tank at the Alternating Gradient Synchrotron (AGS) failed catastrophically, causing air to rush into the tank and damaging equipment. Damage to facility equipment extended five feet downstream of the window and was estimated to be $20,000. There were no personnel injuries. Facility personnel removed all Kevlar windows from service pending a complete investigation of the failure. (ORPS Report CH-BH-BNL-AGS-1995-0003)

The failed vacuum window consisted of a 0.017-inch layer of Kevlar-29 woven cloth for strength and 0.005-inch layer of Mylar sheet to maintain the vacuum seal. The composite window was clamped between steel end-flanges and provided a 34-inch-high by 76-inch-wide opening. Before installing the window, AGS personnel tested it three times to 1.5 times atmospheric pressure and returned it to a no load condition.

Investigators observed that the Kevlar portion of the window was torn free of the frame along both sides, the bottom and 40 percent of the top and the Mylar portion was obliterated. Once started, the tear in the Kevlar quickly propagated until the window flapped open, allowing a large slug of air and adjacent detector equipment to enter the chamber. Investigators could not determine what caused the window to fail; however, preliminary data indicates that the age of the window may have been a major factor. The window was nearly two years old.

Investigators concluded that the direct cause of the failure was probably stress rupture, a sudden failure in a material that has been subjected to loads less than the nominal material tensile strength for long periods of time. AGS personnel performed a visual inspection of the window and noted a number of anomalies that could have caused localized high-stress points and contributed to a stress rupture. First, a 1/32-inch speck of metal or dirt was found jammed into the Mylar frame on the low pressure side of the window. The tear is near the speck and it is possible that the speck caused a localized increase in stress and started the tear. Second, the Kevlar weave was not parallel to the side of the window. It is possible that there were locations where some fibers were under greater stress than adjacent fibers. Finally, the epoxy that seals the Kevlar fabric around the ends of the frame was not consistently applied.

Event investigators determined that the root cause was "policy not adequately defined / disseminated / enforced." Little was known about the long-term load-bearing ability of the composite materials used in the window. Engineers raised this issue during the design review process and a plan to change the windows once a year was discussed and approved. However, the minutes of the design review meeting were not written, and the plan was not published or implemented.

Investigators also identified the following contributing causes:

- Defective or Inadequate Procedure - The assembly procedure for the window was not well defined. Assembly information was provided only as notes on the window drawing. The details of cutting material, laying out bolt holes, and applying epoxy were not governed by procedures.

- Inadequate Work Environment - The window was assembled in a mechanical equipment shop near metal cutting and machining tools, which could have been a source of the debris speck.

- Inadequate or Defective Design - Windows of this type are a new design for the AGS. A similar window was designed and tested extensively for another installation at about the same time as the failed window. Design reviews were performed for both windows. However, if computer analysis of the design had been used, high stress points may have been identified encouraging more testing or design modifications.

Facility personnel are conducting additional research of the failure, including (1) removal and testing of the similar window, (2) development of a computer model of the window to determine stresses and establish how near the material is to its yield stress point, and (3) micro-photographing and analyzing the speck of debris and surrounding window material.

This event is significant because catastrophic failure of composite windows could affect personnel safety and cause significant equipment damage. Composite windows, typically used at DOE facilities where high-energy physics is researched with an accelerator, are frequently located near valuable equipment and near detectors that could contain combustible gases. Hearing damage or other injury may occur if personnel are near the window when it fails. Personnel at DOE facilities where composite windows are used in vacuum applications should review the lessons learned from this event for applicability to their facility. More information on the event can be obtained by contacting Ed Lessard, Associate Chair for Safety for AGS, (516) 282-4250, or Jim Cullen, AGS Chief Mechanical Engineer, (516) 282-7544.