NATIONAL TRANSPORTATION SAFETY BOARD
Office of Research and Engineering
Materials Laboratory Division
Washington, D.C. 20594

December 14, 2005

MATERIALS LABORATORY FACTUAL REPORT — Report No. 05-133

A. ACCIDENT

Place	:	Wilmer, Texas
Date	:	September 23, 2005
Vehicle	:	MCI Motorcoach
NTSB No.	:	HWY05MH035
Investigator	:	James E. Henderson, RPH-30

B. COMPONENTS EXAMINED

Pieces from four medical oxygen cylinder assemblies.

C. DETAILS OF THE EXAMINATION

An overall view of the submitted cylinder assembly pieces is shown in figure 1. All cylinders in the assemblies were identified as Department of Transportation 3AL 2015 cylinders. The four cylinder assembly pieces shown in figure 1 had number identifiers on the red tags attached to each cylinder assembly, and the numbers shown in figure 1 correspond to the numbers on the tags. According to the tags, the aluminum-alloy cylinders of cylinder assemblies 1 and 3 were manufactured by Catalina Cylinders, and the aluminum-alloy cylinders of cylinder assemblies 2 and 4 were manufactured by Luxfer, Inc.

All submitted pieces were sooted and had deformation consistent with exposure to heat. The base ends of cylinder assemblies 1, 2, and 3 were missing, and the lengths of the submitted pieces from cylinder assemblies 1, 2, and 3 were similar. The valve and part of the neck area was missing from cylinder assembly 4, and a hole was present in the cylinder wall near the neck.

Valves for cylinder assemblies 1 and 2 were marked “Sherwood”, and the valve for cylinder assembly 3 was marked “YD”. Each valve for cylinder assemblies 1 to 3 was equipped with a pressure relief device (PRD). According to a representative of the manufacturer for the Sherwood valves, the PRD’s for cylinder assemblies 1 and 2 were a CG-4 style PRD. The CG-4 style Sherwood PRD includes a burst disk backed on its nonpressure side by a fusable metal plug that is specified to melt at a nominal temperature of 165 degrees Fahrenheit. According to the Sherwood representative, the activation of the PRD requires both temperature sufficient to melt the fusable metal plug and pressure sufficient to rupture the burst disk. According to literature obtained from Sherwood valves,

the specified gage pressure range for activating the CG-4 style Sherwood valve PRD at 160 degrees Fahrenheit is 3025 pounds per square inch to 3360 pounds per square inch.

A group examination of the submitted components was conducted at the Safety Board's Materials Laboratory in Washington, DC, on December 1, 2005. Party representatives from Sherwood and the United States Department of Transportation participated in the examination.

Cylinder Assembly 1

A fracture surface was present at the lower end of the submitted piece of cylinder for cylinder assembly 1. Cylinder assembly 1 had the least sooting of all cylinder assemblies. On this piece, the sooting was least near the neck end and at an area closest to the base end that was whitened consistent with high heat exposure.

A view of the fracture surface of the cylinder for cylinder assembly 1 is shown in figure 2. Chevron fracture features indicated fracture propagation directions emanating from an area shown at the lower side of figure 2 as indicated with unlabeled arrows. As the fracture propagated toward the neck, the fracture was oriented at an angle to the longitudinal axis and circumferential plane, turning more circumferential as the fracture moved closer to the cylinder neck. At the location from which the fracture emanated, the cylinder wall was deformed outward, and the surface was whitened, consistent with high heat exposure. The fracture surface in that area was relatively rough, consistent with overstress fracture under local tension stress. As the fracture turned more circumferential, the fracture features were smoother, and a lip was present at the outer surface, consistent with overstress fracture under local shear stress with the base side of the fracture moving outward relative to the neck side of the fracture. An abrupt change in the fracture orientation was observed at the location indicated in figure 2, consistent with an intersection between two fracture fronts.

The valve for cylinder assembly 1 was unscrewed from the cylinder during the group examination. The valve was loose in the cylinder and could be unscrewed by hand. After removal, black deposits were observed at the seal location on the valve appearing consistent with charred remnants of seal material.

The threaded plug for the PRD was unscrewed from the valve body for cylinder assembly 1. The plug was loose and could be unscrewed by hand. After removing the plug, the burst disk for the PRD dropped out of the hole in the PRD when the valve body was tipped over with the hole for the PRD threaded plug facing downward. Some charred material also dropped out of the hole appearing consistent with seal material.

The burst disk from the PRD for cylinder assembly 1 was intact, as shown in figure 3. The center of the burst disk was dome shaped with the convex side of the dome facing outward when installed in the PRD. The manufacturer's representative indicated that the burst disk is flat when installed but will form a dome shape once the cylinder is pressurized. The thickness of the burst disk was 0.0038 inch as measured with a micrometer at the

flange around the dome. The measured thickness was nearly equal to the specified thickness of the sheet from which the burst disks are manufactured. The flange area of the burst disk was examined using energy dispersive x-ray spectroscopy (EDS), and the resulting spectrum showed peaks of nickel with no other significant peaks, consistent with the specified disk material.

Cylinder Assembly 2

The neck end of the cylinder from cylinder assembly 2 was sooted. The end closest to the missing base for the cylinder was deformed and had a hazy, light gray appearance, consistent with exposure to heat at or near the melting point for the aluminum alloy cylinder material. Some areas of fracture were observed, however fracture features were relatively sharp in the areas of deformation and high heat exposure, indicating that fracture occurred after exposure to high heat.

The valve for cylinder assembly 2 was unscrewed from the cylinder during the group examination. A wrench was required to unscrew the valve. The seal between the valve and cylinder neck was present, but the seal was deformed.

The threaded plug for the PRD was unscrewed from the valve body for cylinder assenbly 2. A Torx wrench was required to remove the threaded plug. The burst disk was retained in the body of the valve, and the seal remained intact around the edge of the burst disk as shown in figure 4.

The burst disk from the PRD for cylinder assembly 2 was intact, as shown in figure 4. The center of the burst disk was dome shaped with the convex side of the dome facing outward when installed in the PRD. The seal was cut from around the burst disk and removed with tweezers to facilitate removal of the burst disk from the valve body. The thickness of the burst disk was 0.0036 inch as measured with a micrometer at the flange around the dome. The measured thickness was nearly equal to the specified thickness of the sheet from which the burst disks are manufactured. The flange area of the burst disk was examined using energy dispersive x-ray spectroscopy (EDS), and the resulting spectrum showed peaks of nickel with no other significant peaks, consistent with the specified disk material.

Cylinder Assembly 3

The neck end of the cylinder for cylinder assembly 3 was sooted. The end closest to the missing base for the cylinder was deformed and had a hazy, light gray appearance, consistent with exposure to heat at or near the melting point for the aluminum alloy cylinder material. Some areas of fracture were observed, however fracture features were relatively sharp in the areas of deformation and high heat exposure, indicating that fracture occurred after exposure to high heat.

The valve for cylinder assembly 3 was unscrewed from the cylinder during the group examination. A wrench was required to unscrew the valve. The seal between the valve and cylinder neck was present, but the seal was deformed.

The threaded plug for the PRD was unscrewed from the valve body for cylinder assembly 3. An Allen wrench was required to remove the threaded plug. The burst disk remained adherent to the inner end of the threaded plug. Tweezers and a scalpel were used to pry the burst disk from the end of the threaded plug.

The burst disk from the PRD for cylinder assembly 3 was ruptured, as shown in figure 5. The center of the burst disk was fractured, and the fractured ends were deformed outward consistent with PRD activation. The thickness of the burst disk was 0.0057 inch as measured with a micrometer at the flange around the dome. The flange area of the burst disk was examined using energy dispersive x-ray spectroscopy (EDS), and the resulting spectrum showed highest peaks of nickel with smaller peaks of chromium and copper.

Cylinder Assembly 4

The cylinder from cylinder assembly 4 was the most heavily sooted of the four cylinder assemblies, and the greatest amount of sooting on this piece was at the base end of the cylinder. An orange surface coating was observed at the base end of the cylinder under the soot.

Close views of the neck end of the cylinder from cylinder assembly 4 are shown in figures 6 and 7. The shoulder of the cylinder near the neck was deformed and flowed, consistent with local heating above the melting point of the cylinder material. A hole in the cylinder wall was present in the deformed and flowed area, and deformation around the hole was inward consistent with no internal pressure at the time of deformation. The valve hole in the neck of the cylinder was deformed to an elliptical shape, and portions of the neck around the hole were missing. Surfaces where material was missing were rounded consistent with heat exposure. Threads were observed in the neck around approximately half of the hole at one end of the major axis of the elliptically-shaped valve hole as indicated with unlabeled brackets in figures 3 and 4. The location of these threads was outside the normal range of thread engagement for the valve. The threads appeared intact, but were somewhat thinned and degraded consistent with heat exposure. Several thread remnants were observed on the portion of the hole within the range of normal valve thread engagement as indicated in figure 4.

Matthew R. Fox
Senior Materials Engineer

Image No.:0510A00142, Project No.: 2005100006

Figure 1. Overall view of the as-received cylinder assembly pieces. Assemblies 1 and 2 had valves labeled “Sherwood”. Assembly 3 had a valve labeled “YD”, and assembly 4 had a missing valve.

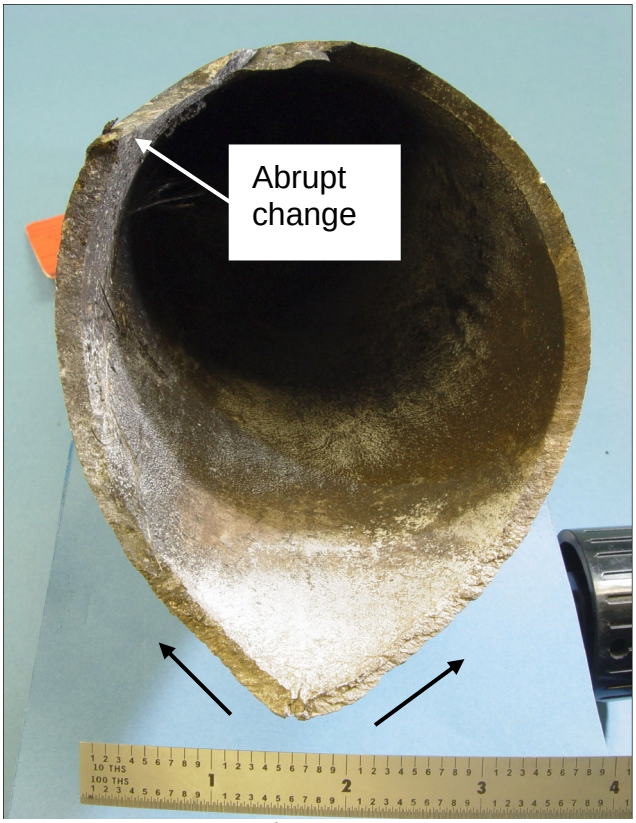

Image No.:0510A01271, Project No.: 2005100006

Figure 2. Closer view of the fracture surface on the cylinder from cylinder assembly 1. Unlabeled arrows indicated fracture directions, and a location is indicated where the fracture abruptly changed between nearly circumferential and nearly longitudinal.

Image No.:0512A00198, Project No.: 2005100006

Figure 3. View of the intact burst disk for cylinder assembly 1 after removal from the valve body.

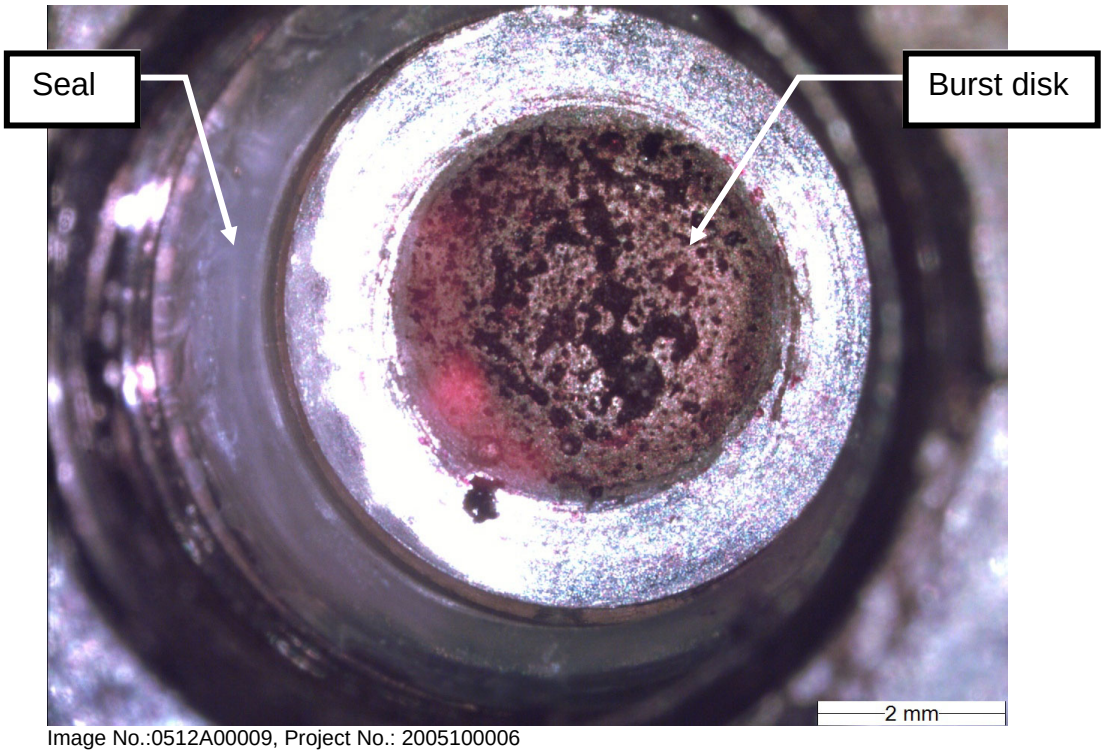

Image No.:0512A00009, Project No.: 2005100006

Figure 4. View of the intact burst disk for cylinder assembly 2 as viewed inside the valve body.

Image No.:0512A00195, Project No.: 2005100006

Figure 5. View of the outer side of the ruptured burst disk for cylinder assembly 3 after removal from the valve body.

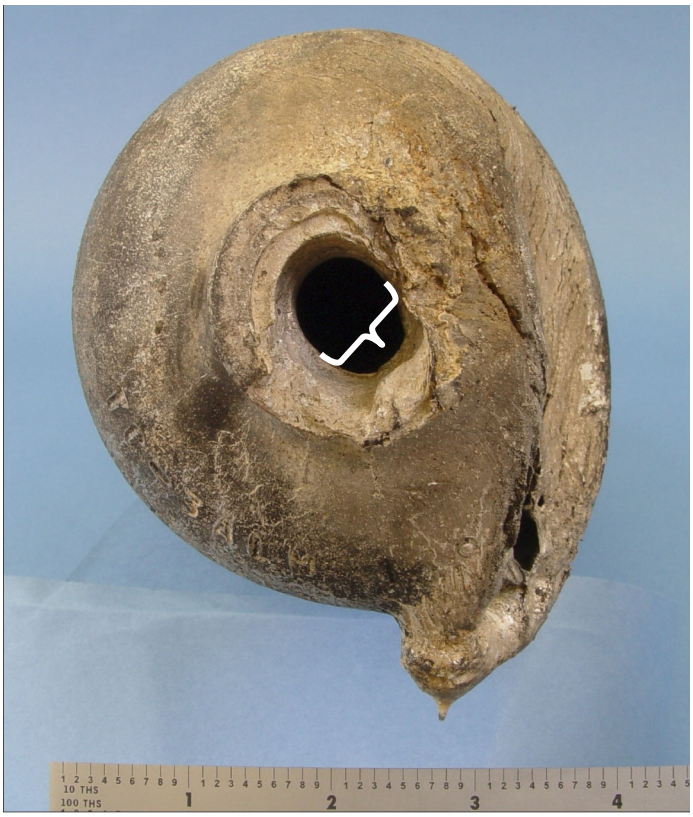

Image No.:0510A01188, Project No.: 2005100006

Figure 6. View of the neck end of the cylinder for cylinder assembly 4. The valve fitting was missing. An unlabeled bracket indicates the location of the intact threads shown in figure 7.

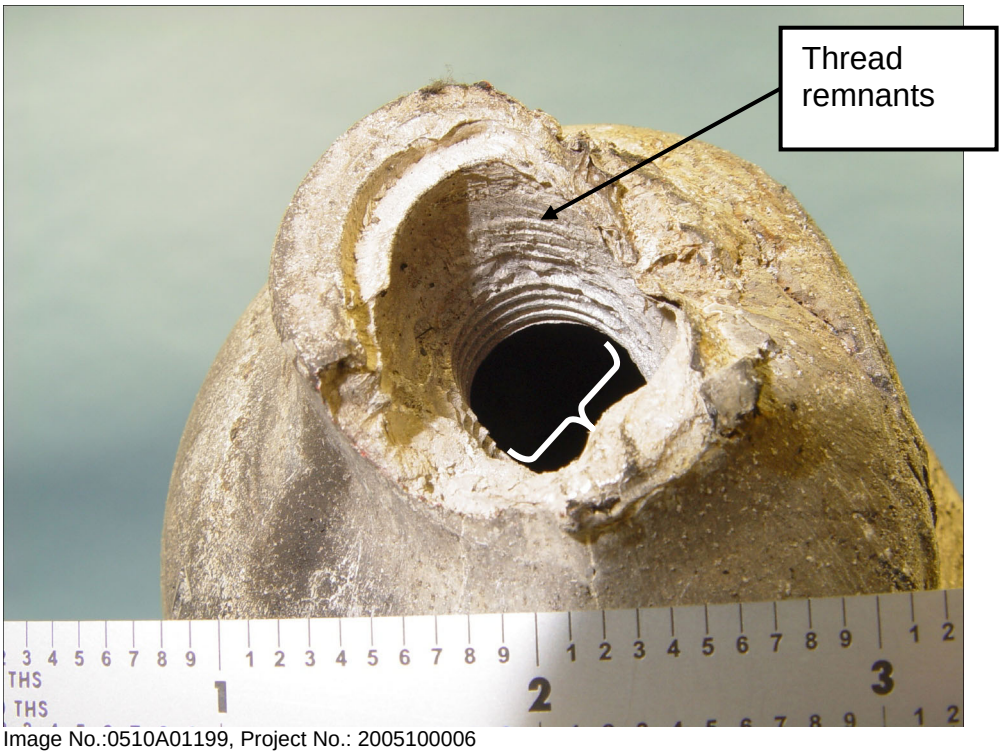

Image No.:0510A01199, Project No.: 2005100006

Figure 7. A closer view of the threaded area in the neck of the cylinder for cylinder assembly 4 showing intact threads indicated with a bracket and some thread remnants.