C31 Analyzing Failure of Rubber O-Rings

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After attending this presentation, attendees will be able to identify common causes of o-ring failures, and to distinguish between installation problems and manufacturing problems.

This presentation will impact the forensic community and/or humanity by providing the forensic engineering community with methods of rubber failures and with the literature concerning those failures.

The use of o-rings is common in hydraulic systems to prevent leaking of fluid at connections. However, sudden failure of an o-ring under high pressure can result in loss of property and/or injury to the operator. The case covered here involved a sudden failure of an o-ring that sprayed hydraulic fluid on the operator and on the exhaust manifold, causing a fire and severe injury to the operator.

The operator was driving an earthmoving vehicle when a leak was detected and the o-ring was replaced. Within approximately an hour after replacing the o-ring, it failed catastrophically, allowing hydraulic fluid to spray into the cab and onto the hot exhaust manifold. The operator was severely burned by the resultant fire and a lawsuit was started against the o-ring manufacturer.

The author was retained by the plaintive attorney to analyze the o-ring and to determine the cause of the failure.

O-rings commonly used in hydraulic service are referred to as BUNAN, which is a co-polymer of butadiene and acrylonitrile. The material has a good resistance to hydraulic fluid and can operate at the elevated temperatures found in most hydraulic systems. The type of rubber is identified by FTIR analysis. Then, the application specification should match the hardness of the o-ring on the Shore D scale.

The common failure patterns of o-rings are listed in Reference #1. Other applicable standards are referenced below in Reference #s 2-6.

In addition, there are manufacturing causes for exceptionally short life and dramatic failure, such as backrinding and porosity.

The installation errors causing failure are:

- Extrusion and Nibbling: If the o-ring is too small or too soft, small nibbles are torn off during pressure fluctuations that force the o-ring into the downstream clearance area.
- Spiral Failure: A condition that causes the o-ring to slide and roll, resulting in a deep, spiral cut and is usually associated with piston seals.
- Abrasion: Occurs in systems where the o-ring is in motion.
  Usually, one side of the o-ring will be rough and slightly flattened. The metal surface is either too rough or there are contaminants in the system.
- Compression Set: A flat surface on the bottom and top of the o-ring indicate compression set. This is generally caused by the o-ring material exceeding its high temperature range.
- Weather and ozone cracking: This appears as many small cracks, generally perpendicular to the direction of stress. Typically found in o-rings exposed to atmospheres containing ozone and air pollutants
- Heat aging and oxidation: This condition is one of the temperatures being too high for the rubber, causing hardening by additional cross-linking in the rubber.
- Plasticizer extraction: Exhibited by small cracks due to the extraction of the plasticizer by the service fluid.
- Installation Damage: Appearance is short cuts or notches on the surface due to the mis-sizing of the o-ring in the application.
- Gas expansion Rupture: Exhibited by splits or ruptures due to absorption of gas under high pressure.

The manufacturer errors causing failure are:

- Backrind: Backrinding occurs when the mold is too hot for the specific formulation and the excess rubber that flows in the flash cavity is rapidly cured and pushed further in by the curing of the rubber behind it. When the mold is opened, the rubber in the flash cavity snaps back and makes a crack in the parting line.
- Porosity: Explosive decompression occurs when pressure varies and gas or liquid is absorbed into the o-ring.

The examination by Scanning Electron Microscope (SEM) clearly showed a great deal of backrinding and porosity in the o-ring.

Each time the hydraulic pressure cycled, the o-ring filled and emptied, causing tearing and rapid failure. It was clear that a manufacturing error caused the failure. In addition, the o-rings were mistakenly sized

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metrically, but marked and sold as English measure.

The case went to trial in Los Angeles County and resulted in a verdict for the plaintive.

References:

1. SAE Aerospace Information Report 1707, “Patterns of o-ring failure”
2. ASTM D2000-01 “Standard Classification System for Rubber Products in Automotive Applications.”
3. SAE Surface Vehicle Standard J515, “Specifications for Hydraulic o-ring Materials, Properties, and Sizes for Metric and Inch Stud Ends, Face Seal Fitting and Four-Screw Flange Tube Connections.”
4. ASTM 471-98, “Standard Test Method for Rubber Property—Effect of Liquids.”
5. ISO 3601-3 part 3, “Fluid systems—Sealing Devices—o-rings.”
6. ASTM D1414-94, “Standard Test Methods for Rubber o-ring.”

O-ring Failures, BUNA-N Rubber, Rubber Failures