Investigation and Resolution of Intermittent Loss of Flow in a Diaphragm Metering Pump

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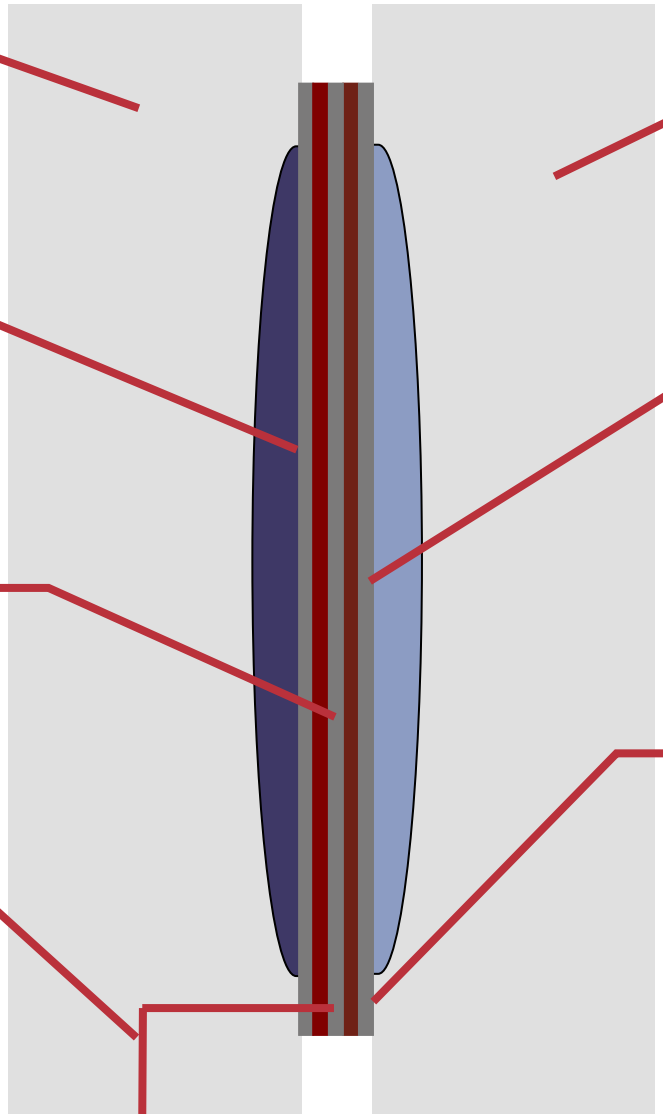
Background

- Pump adds an ingredient to a reaction vessel.
- Both short periods of loss of flow and long periods of excessive flow variation will impact product quality.
- Correct performance of this pump is critical to uptime and first pass / first quality yield.
- PROBLEM STATEMENT: Pump would experience intermittent loss of flow during operation, resulting in process upsets and poor quality material.
- A reliability improvement effort was initiated. This presentation covers the findings and improvements made to the pump.

Pump Details

- Hydraulically Actuated Diaphragm Metering Pump.
  - Triple Metal Diaphragm w/ Leak Detection
  - Variable Stroke Length
  - Variable Frequency Drive
- Operating Pressure:
  - Suction: 15 PSIG
  - Discharge: Up to 4000 PSIG
- Operating Temperature: Minus 35°C
- Viscosity: 2 cP @ Minus 35°C
- Duty: 24 / 7 / 365

Pump Head Details



Pump Cover

Hydraulic Head

Cover Diaphragm

Hydraulic Diaphragm

Intermediate Diaphragm

Metal to Metal Seal

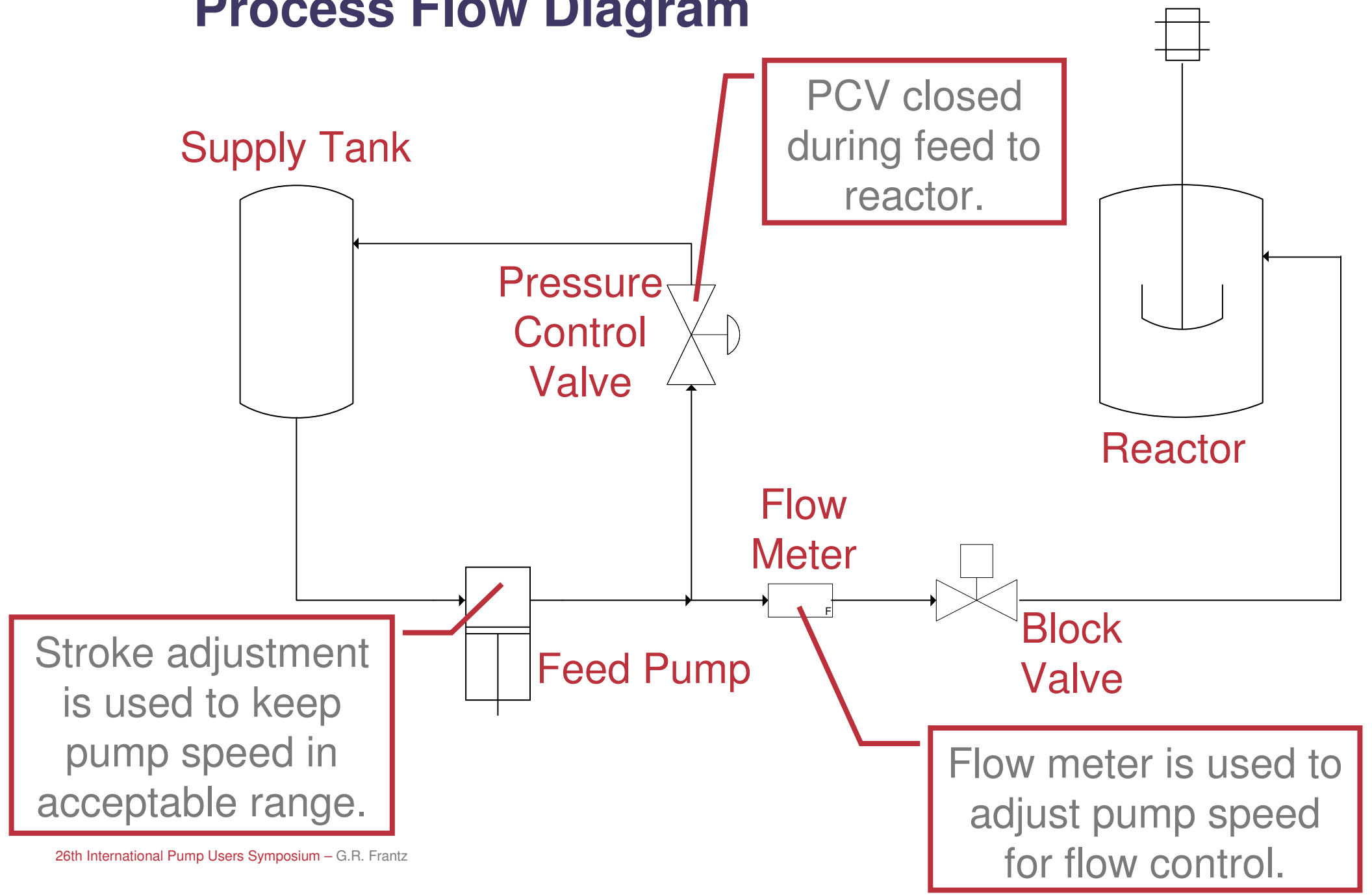
Leak Detection Port

– Process Fluid

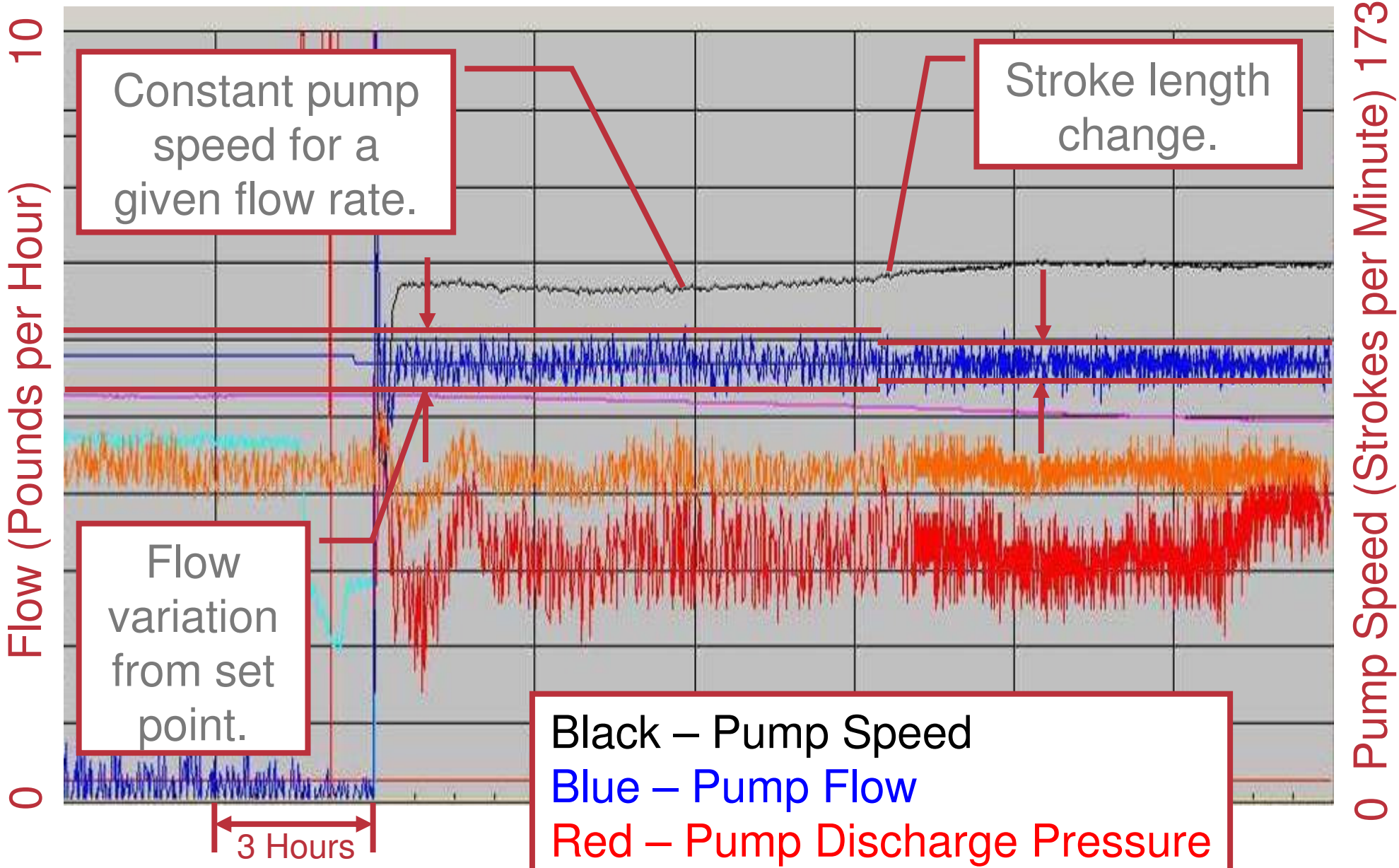
– Intermediate Fluid

– Hydraulic Fluid

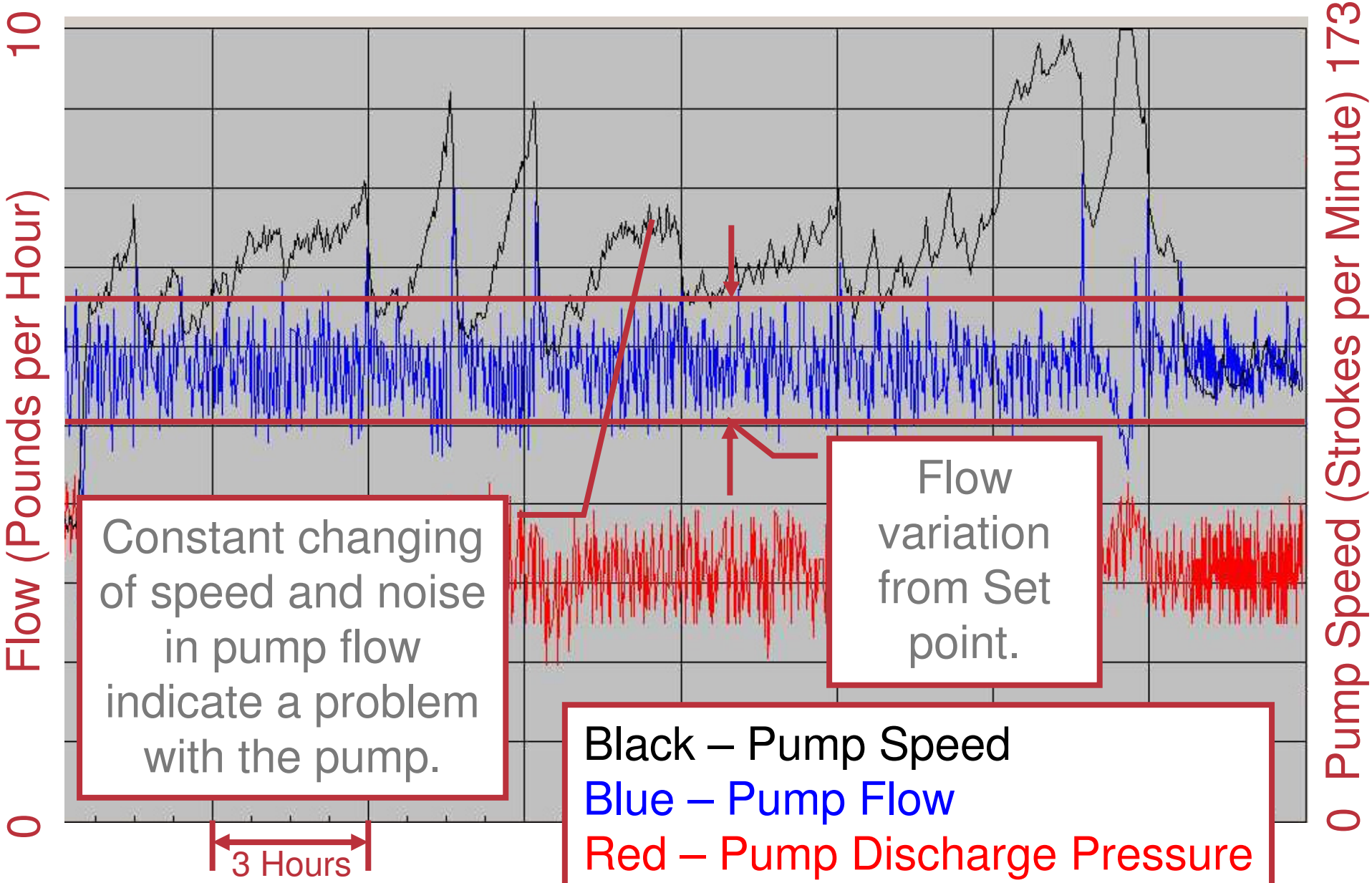
Process Flow Diagram



Acceptable Flow Variation



Unacceptable Flow Variation



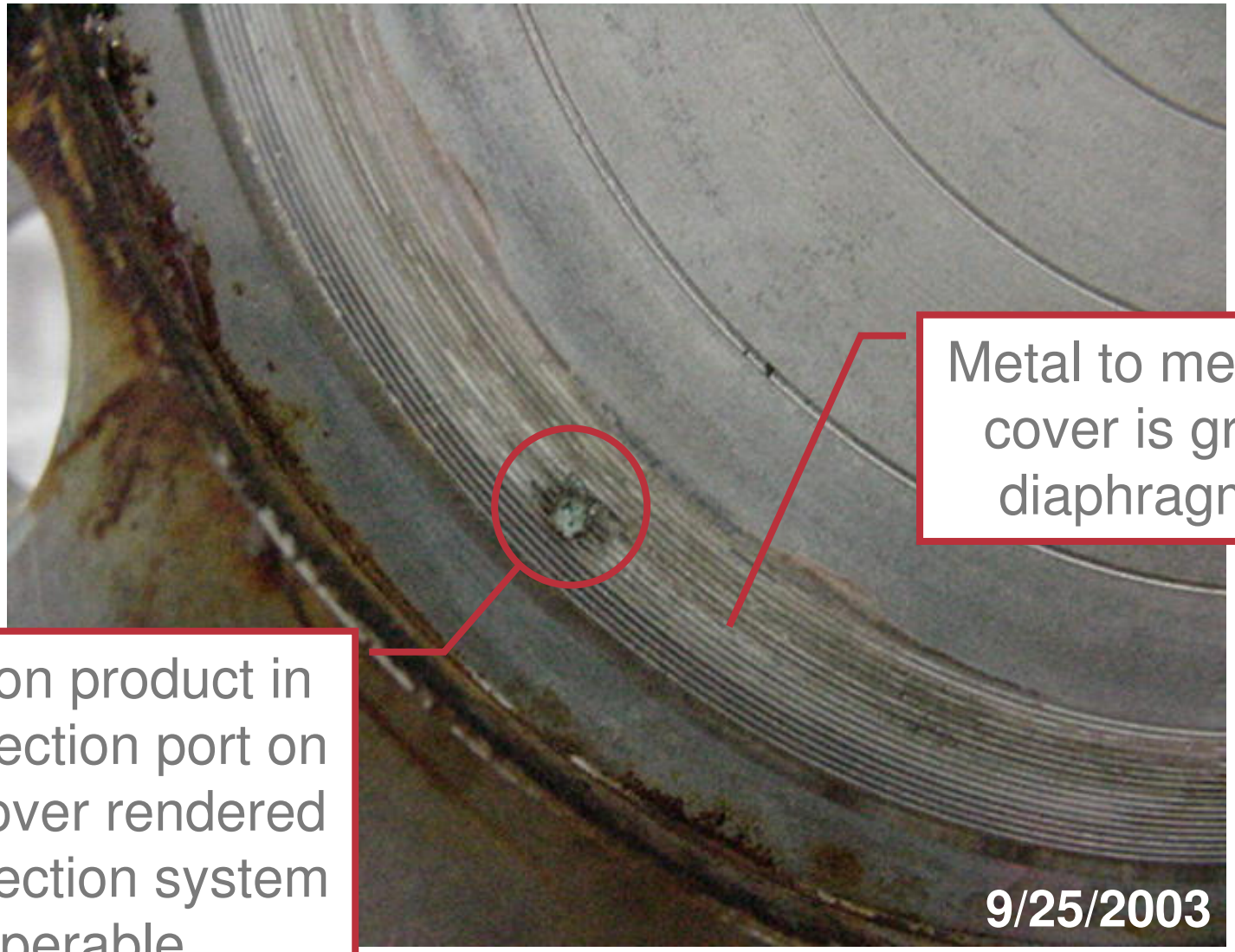
Failure Analysis

- Focus had been on system problems but system is robust.
- Began investigating potential problems with pump design.
- Proposed that metal to metal seal between the cover and cover diaphragm was leaking, allowing process liquid to migrate between the diaphragms via the leak detection system.
- Three potential causes were identified:
  - Cold temperatures relaxing the seal on the pump head.
  - Damage to seal from repeated maintenance.
  - Similar hardness of cover and cover diaphragm materials did not allow for adequate “bite” of the cover into the diaphragm.

Cover Diaphragm – Process Side

Port for communication between leak detection system and intermediate diaphragm.

Cover– Leak Detection Port

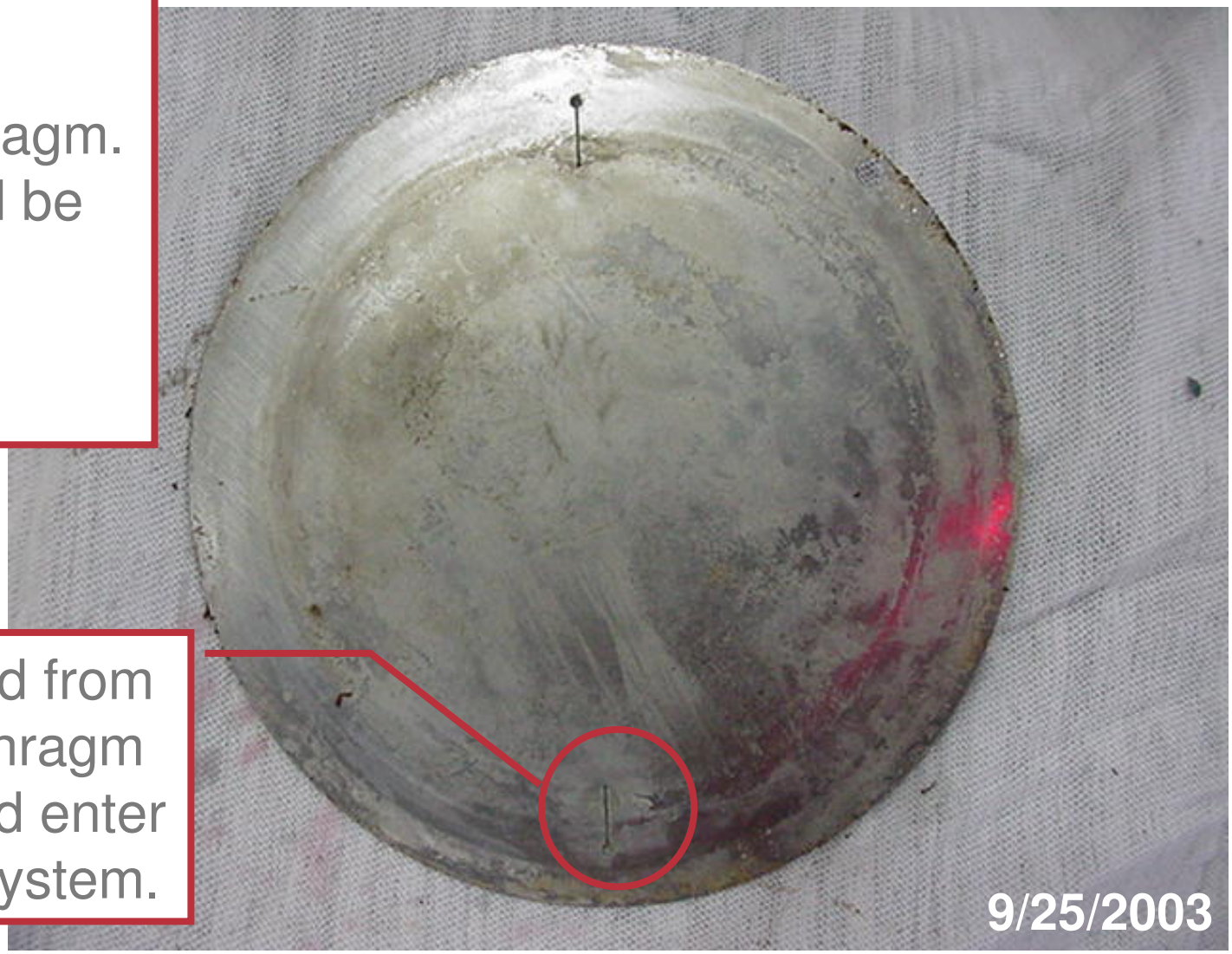


Metal to metal seal – cover is grooved / diaphragm is flat

Corrosion product in leak detection port on pump cover rendered leak detection system inoperable.

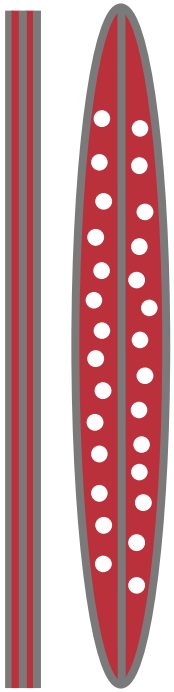
Intermediate Diaphragm – Process Side

Process liquid and contamination on intermediate diaphragm. This surface should be clean, with only the lubricant from initial assembly present.



Slots allow liquid from a cracked diaphragm to cross seal and enter leak detection system.

Root Cause



- It was determined that the cover to diaphragm seal was leaking, resulting in pumped liquid migrating between the diaphragms.
- As time passed, trapped liquid would start to generate gas, resulting in loss of the hydraulic link between the hydraulic fluid and the pumped liquid.
- Increased suction pressure would collapse the diaphragms, and allow the pump to work again for a period of time.
- It was felt that we had damaged the head due to the repeated disassembly of the pump. A new pump head was purchased.
- In service, the problem continued . . .
  - Implementing a cold re-torque did not have any impact.

– Diaphragm – Liquid – Liquid & Gas

Proving the Theory

- For the manufacturer to correct the problem, we needed to prove the material was leaking across the seal.
- A test was authorized to replace the cover diaphragm with a hydraulic diaphragm, eliminating the communication between the leak detection system and the diaphragm sandwich.
  - The hydraulic diaphragm is solid.
  - A perfluorinated polyether (PFPE) based grease was used in the grooves on the cover that seal to the diaphragm.
    - Water and hydraulic fluid will not breakdown the grease.
    - Pumped liquid will dissolve PFPE based greases.

Test Results

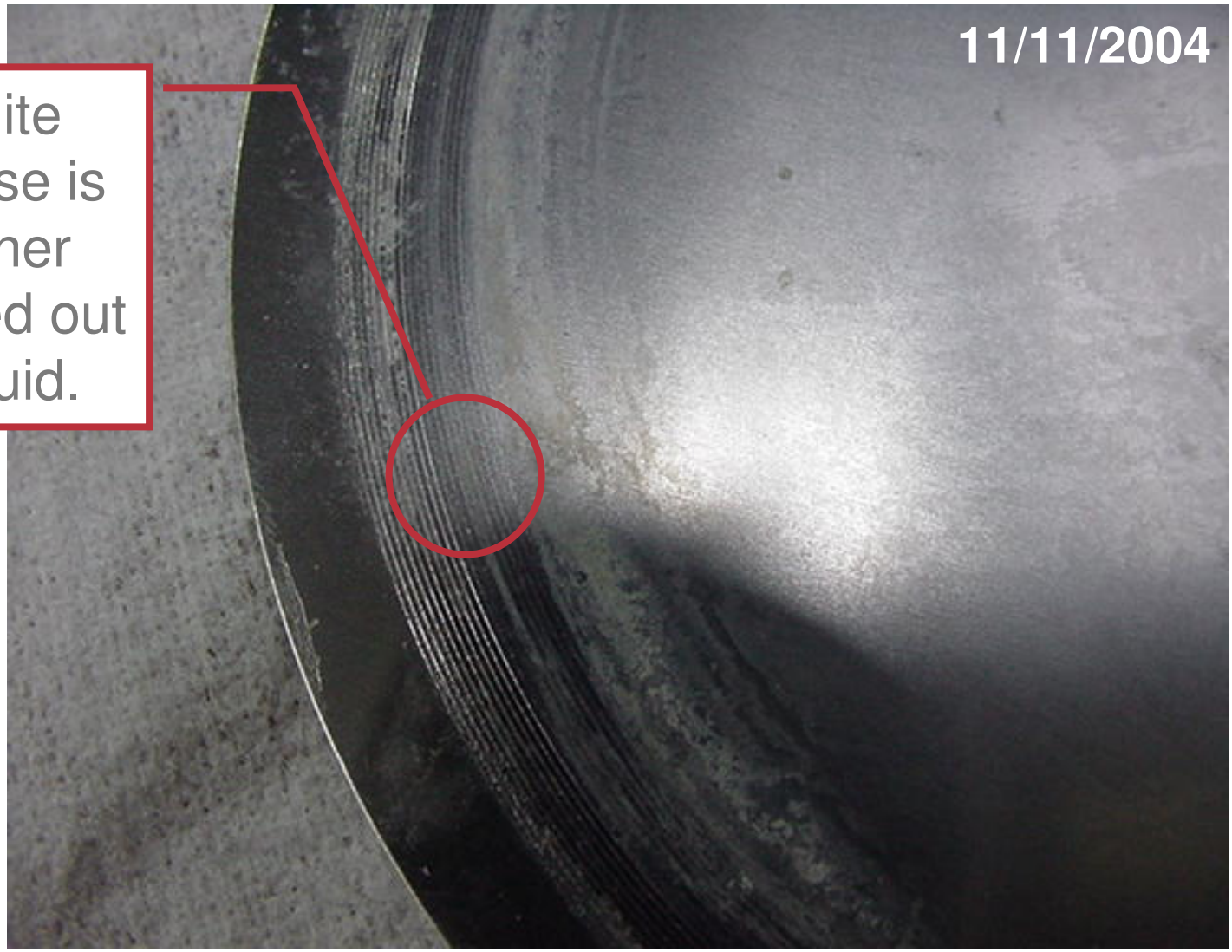
- The pump ran for one year with no operational issues.
- The pump was overhauled and inspected during planned maintenance.
- Unlike previous inspections, the intermediate diaphragm was clean.
- Pumped fluid was found in the leak indicator port.
- PFPE based grease was gone from the inner part of the seal.
  - Grease was still present beyond the leak detection port.

Hydraulic Diaphragm Used as Cover Diaphragm

Note the lack of ports for the leak detection system. This was the hydraulic diaphragm that was installed as the cover for the test.

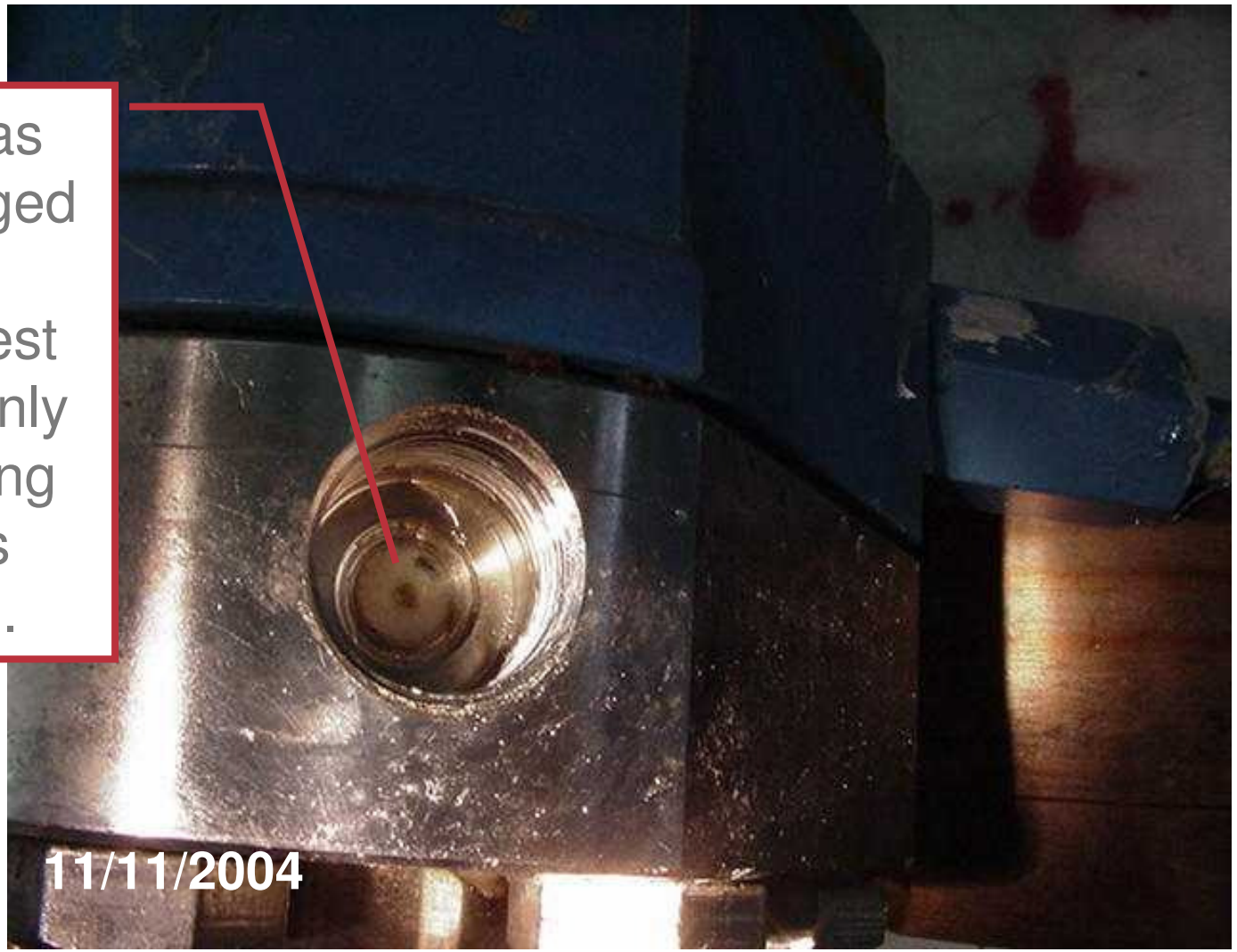
Test Diaphragm – Process Side

Note that the white PFPE based grease is gone from the inner seal. It was washed out by the pumped fluid.



Leak Indicator Port

Pumped fluid was found in the plugged leak detection system. In the test installation, the only means for entering this chamber is across the seal.



Resolution

- The original pump head was sent to the manufacturer for inspection.
  - It was determined that there may be a sealing issue with the pumped fluid and the existing pump head design.
- The proposal from the manufacturer was to make the cover out of a harder stainless steel alloy.
  - The harder alloy allowed the grooves in the cover to bite into the diaphragm better.
  - The manufacturer supplied this head at no cost.
- The problems have been eliminated. The pump can now easily run one year between scheduled maintenance outages.

Questions?