

Centrifugal Impeller Failure via a Thermite Reaction

Author: Mike Stanko
Praxair Inc.
Engineer
Turbomachinery Group

CASE STUDY ABSTRACT

A 2500 HP integral gear compressor in an air separation plant experienced an **impeller failure** in the first stage of compression. The failure was extensive and took the dry air compressor off-line. Plant production was curtailed for several weeks.

Initial investigation focused on the 1st stage centrifugal compressor impeller and upstream dust filter. Most of the aluminum impeller was missing and portions of the air filter element had melted. With the sequence and cause unclear, a formal root cause analysis (RCA) was undertaken.

The RCA process ultimately revealed that an unexpected **thermite reaction** occurred and consumed most of the aluminum impeller. During compressor shutdown, products of the intensely exothermic thermite reaction backflowed into the upstream dust filter causing the element to partially melt. The thermite reaction initiated in the impeller back disk seal area where metal oxides and fuel (debris) had collected. Viscous heating and temperatures greater than expected allowed the rotating labyrinth seal to **creep**. Contact with the babbitted stationary seal generated additional heat and further accelerated the creep process. Frictional heating in the impeller back disk seal initiated the reaction.

Corrective actions to prevent reoccurrence included a creep resistant impeller back disk seal and a **passive debris removal** system to prevent debris particles from collecting in the impeller back disk seal area. This compressor and a twin have operating reliably since 2003. Recent inspection revealed neither back disk seal creep nor the collection of debris particles. These facts have verified the effectiveness of the solution.

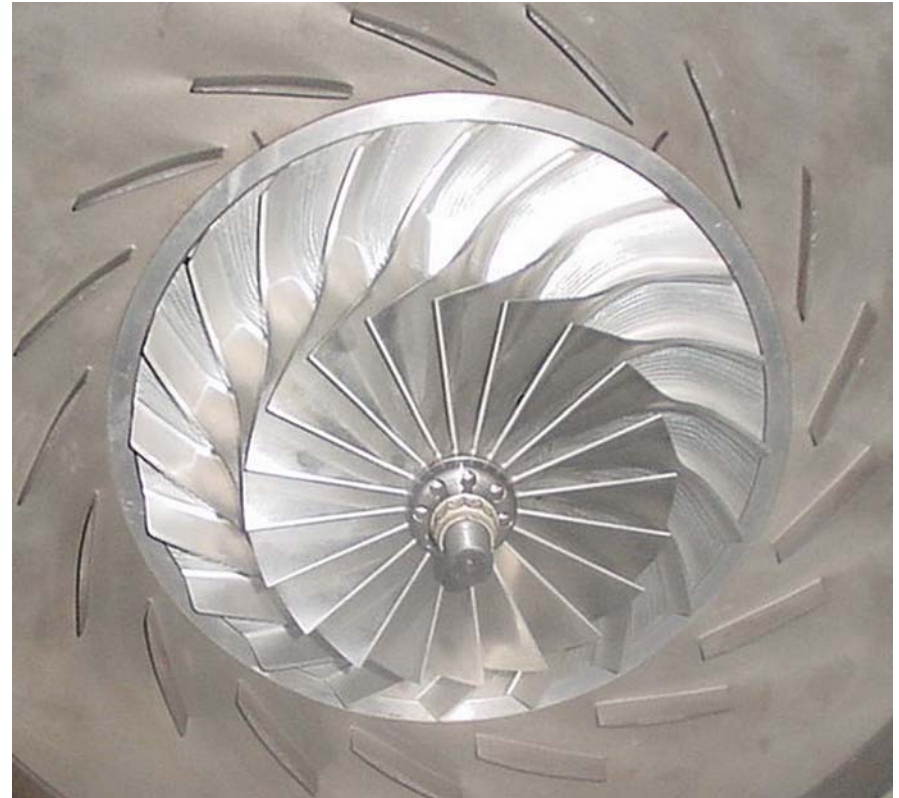
Mike Stanko
Praxair Inc.
175 East Park Drive
Tonawanda, NY 14150
mike_stanko@praxair.com
(716) 879-7454

THE IMPELLER

37000 RPM
7.5 IN OD
1300 HP
7XXX ALUMINUM
DRY AIR

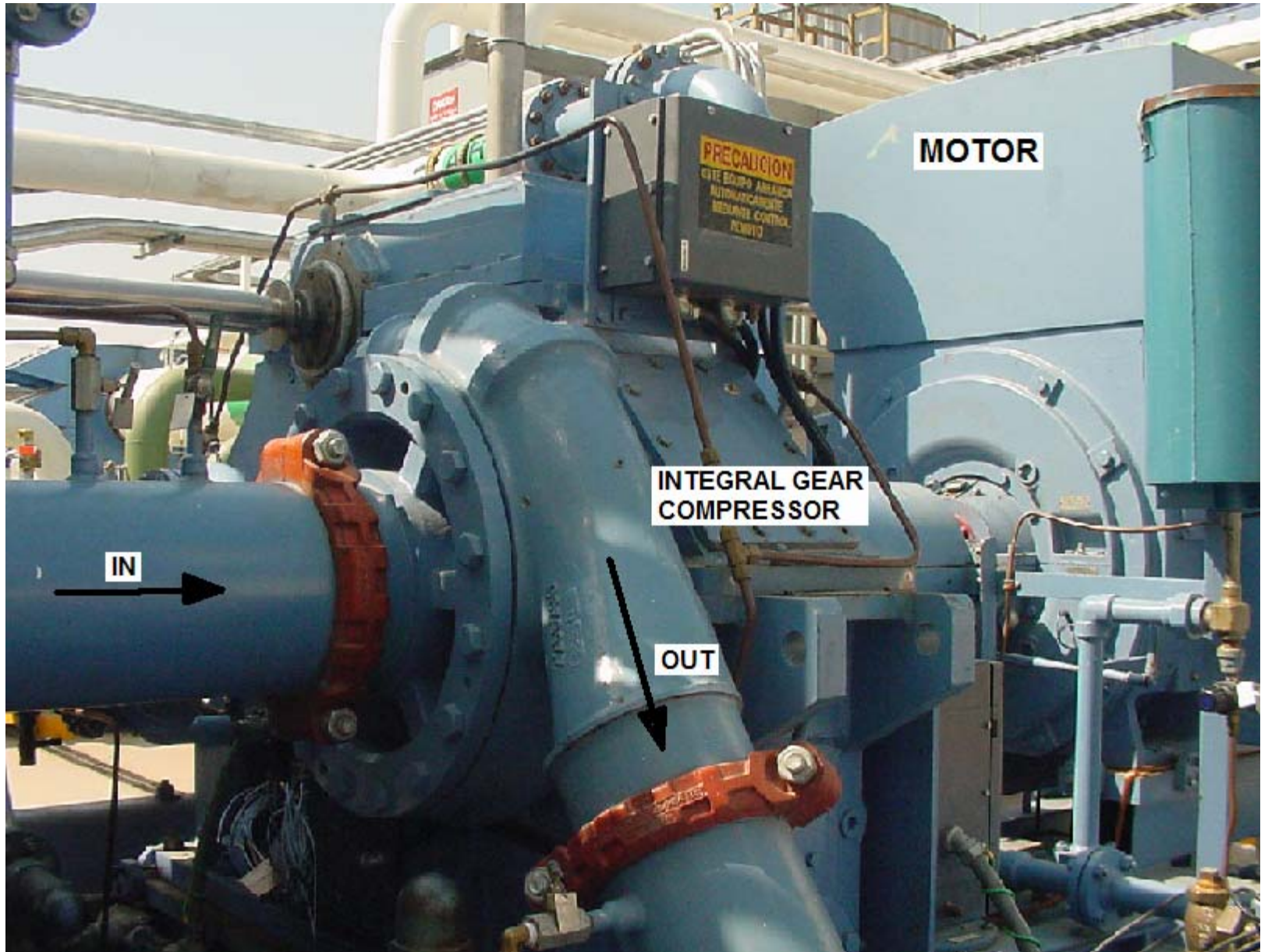


FAILED



NEW

THE COMPRESSOR

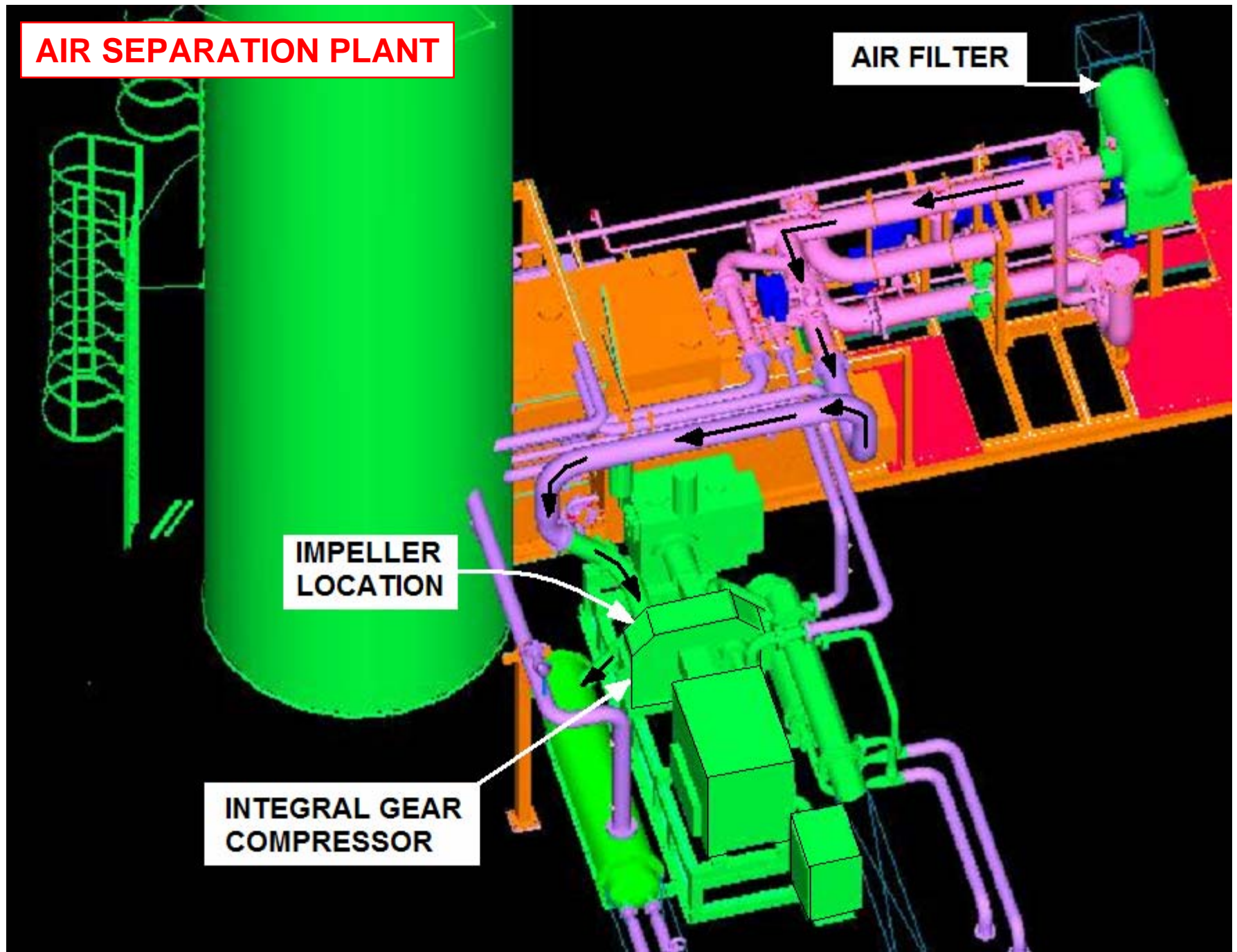


AIR SEPARATION PLANT

AIR FILTER

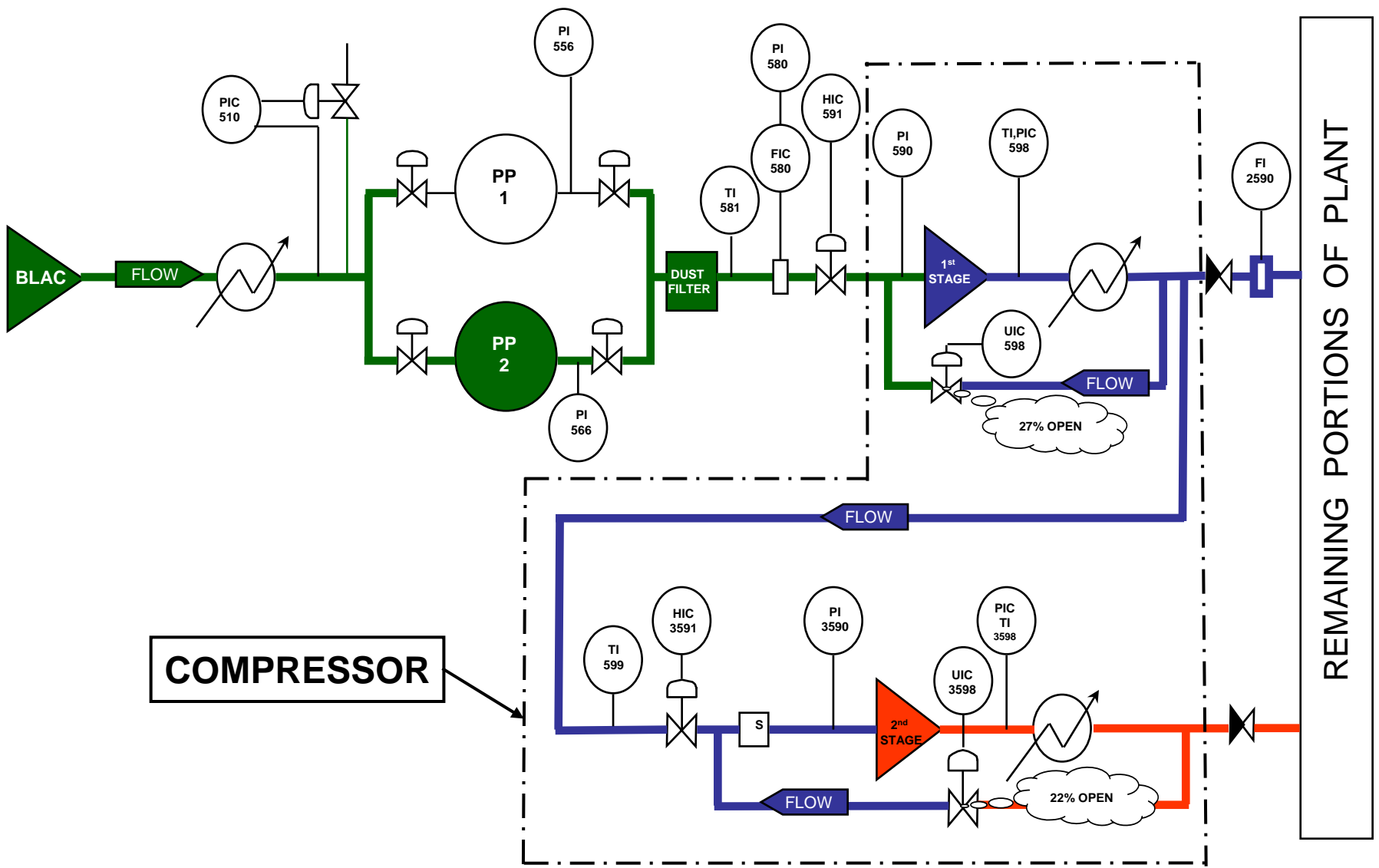
IMPELLER LOCATION

INTEGRAL GEAR COMPRESSOR



THE FLOW DIAGRAM

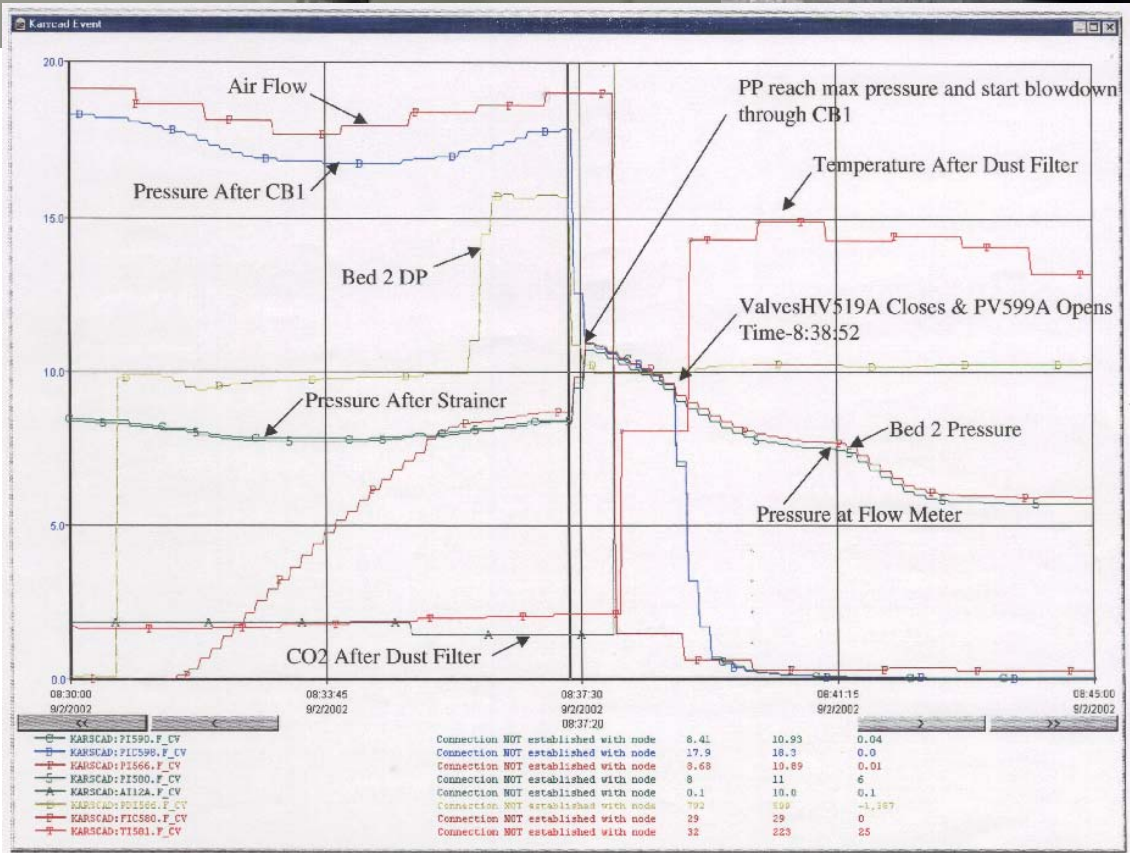
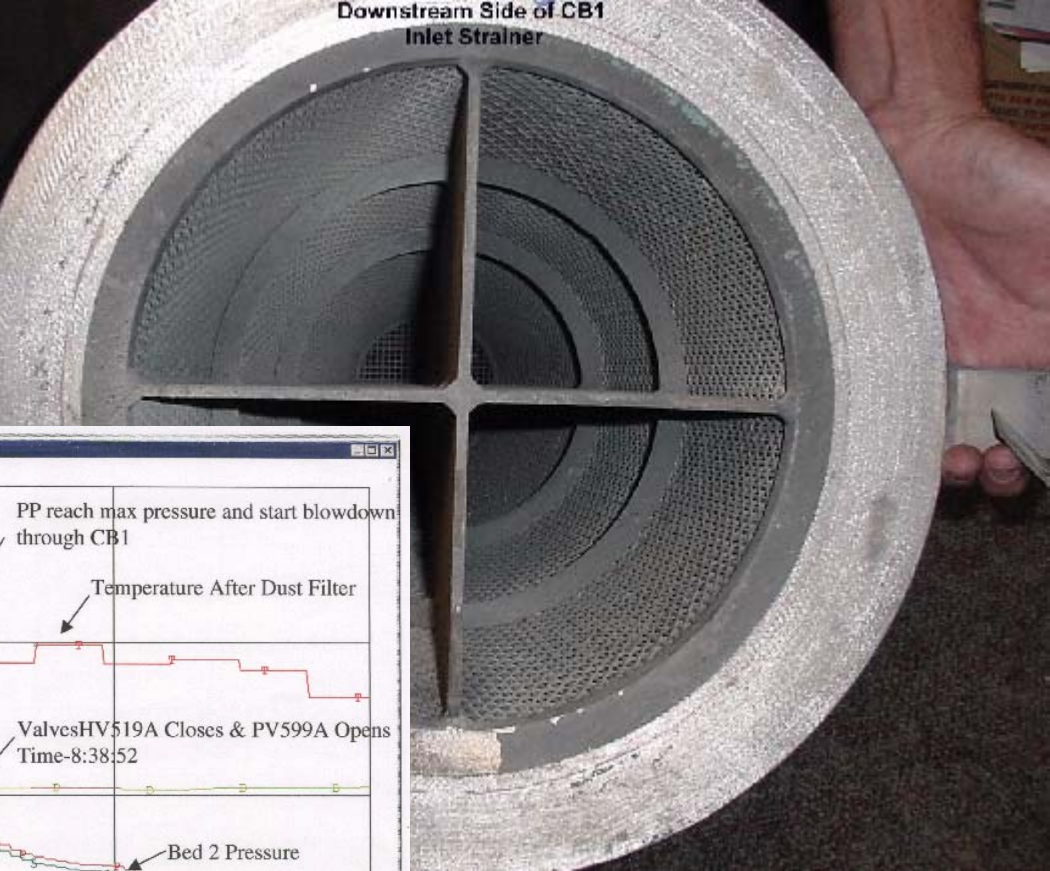
"Normal" T=0



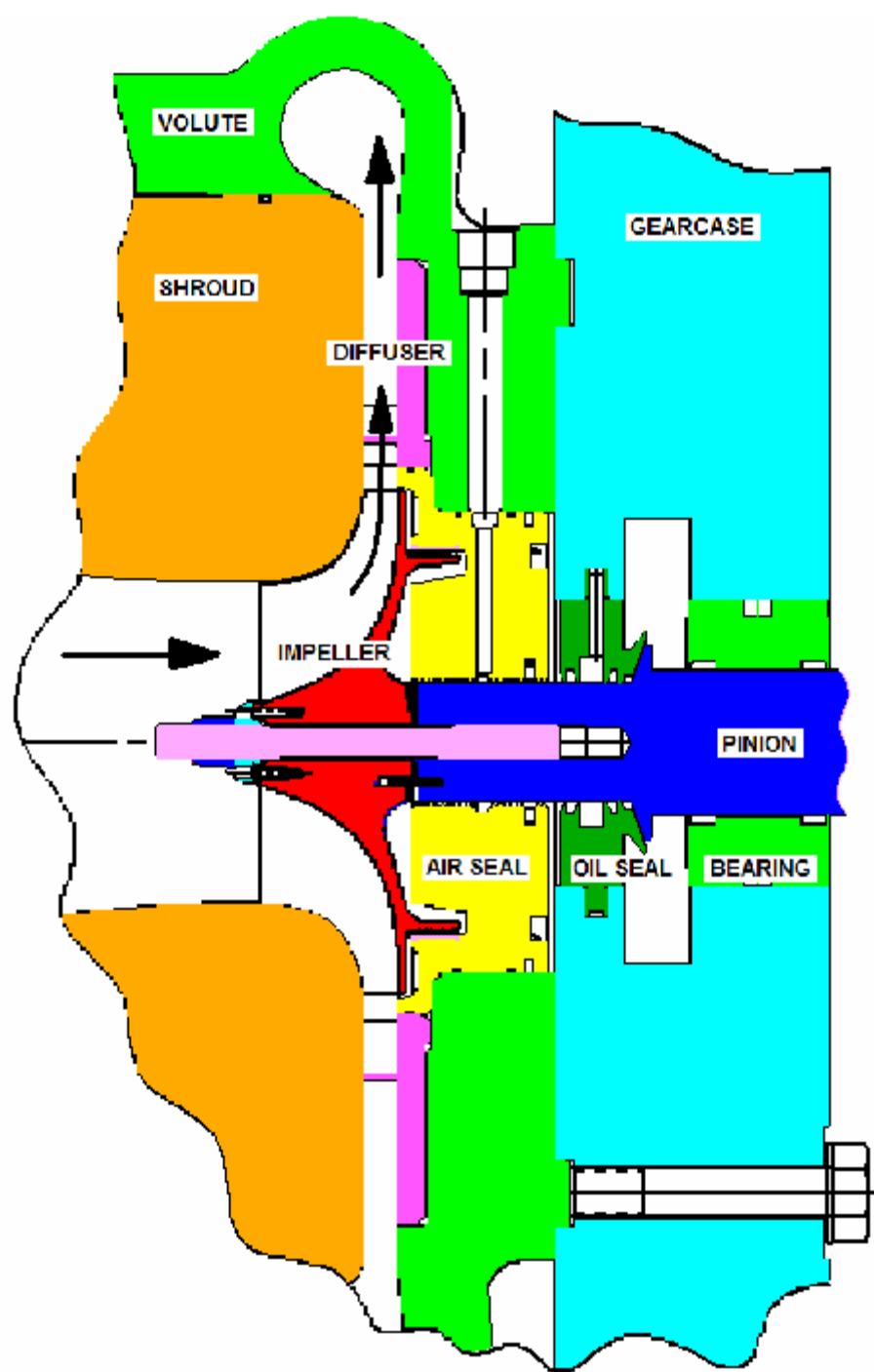
THERMITE REACTION

- REACTION BETWEEN METAL AND METAL OXIDE WITH A HIGH HEAT OF FORMATION
- ALUMINUM + METAL OXIDE IS THE MOST COMMON
- FRICTION CAN CREATE IGNITION
- TEMPERATURES OF 4000°F TYPICAL

CONFIRMING EVIDENCE

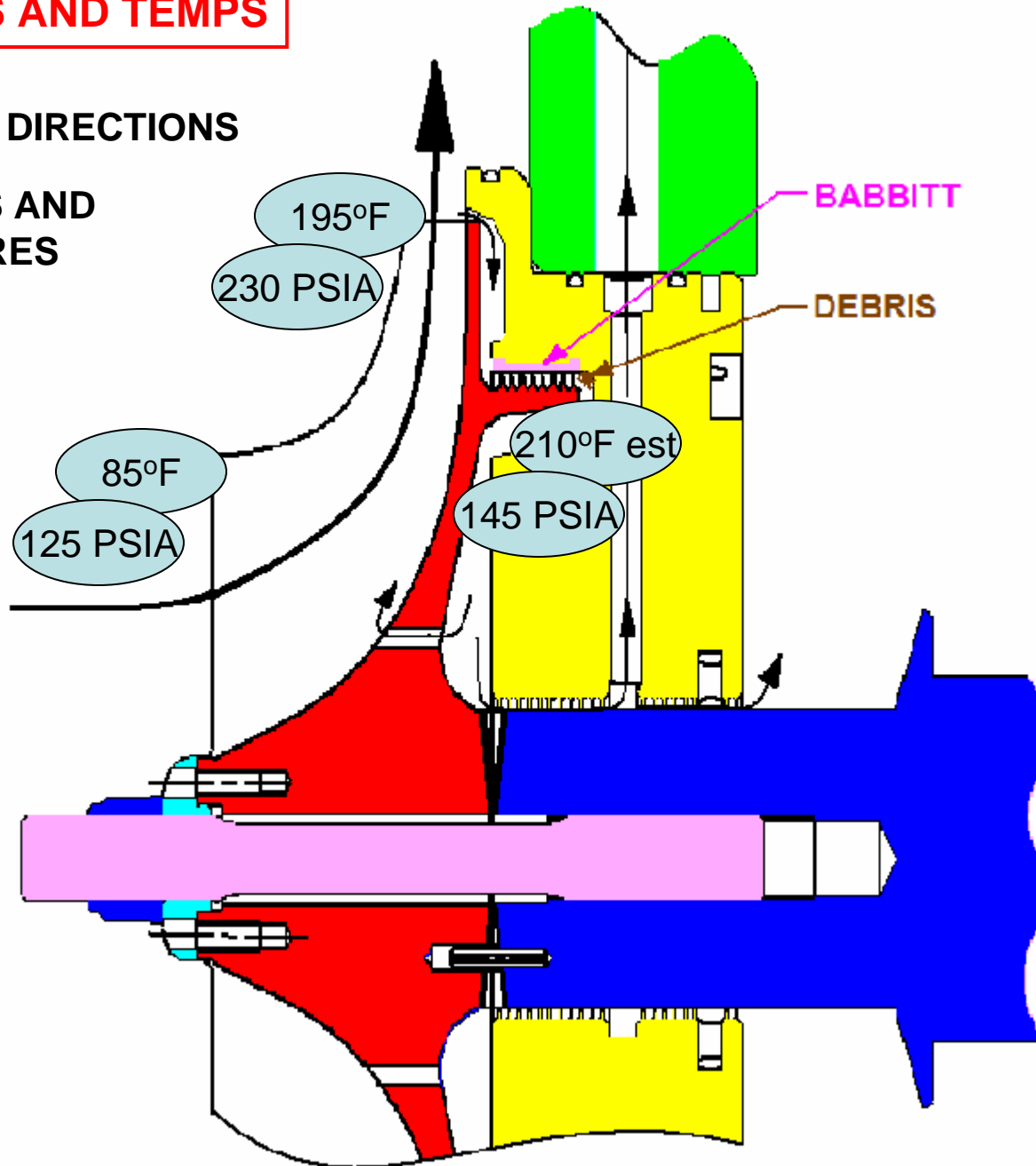


MAJOR PARTS



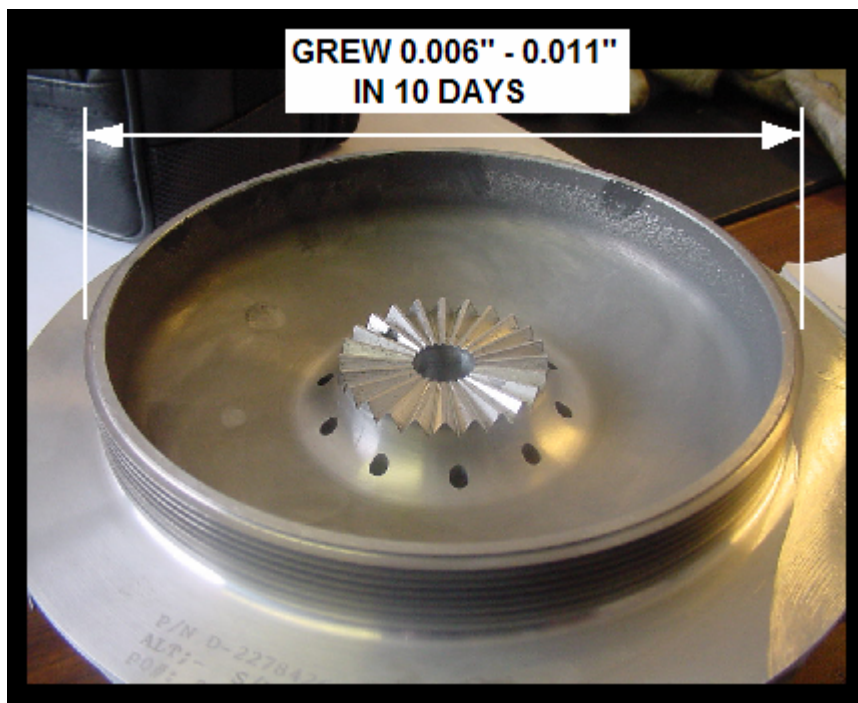
PRESSURES AND TEMPS

- BULK FLOW DIRECTIONS
- PRESSURES AND TEMPERATURES



NORMAL
OPERATION

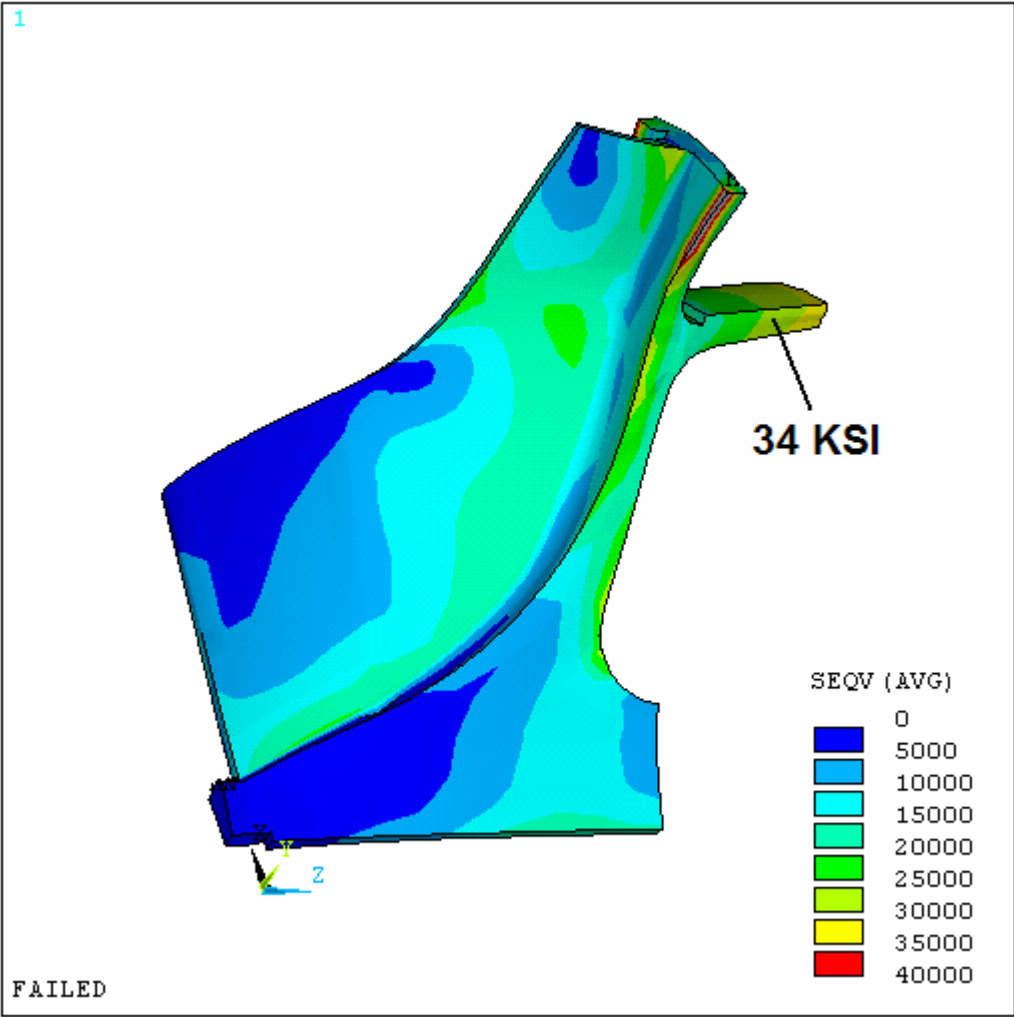
THE MISSING LINK IS FOUND !



- **CREEP IN THE ALUMINUM IMPELLER BACK DISK ROTATING LABYRINTH SEAL**
- **SHUTDOWN AND INSPECTED A “TWIN” IGC**
- **THE DISCIPLINE TO CHECK EVERYTHING YIELDED THIS KEY FINDING!**

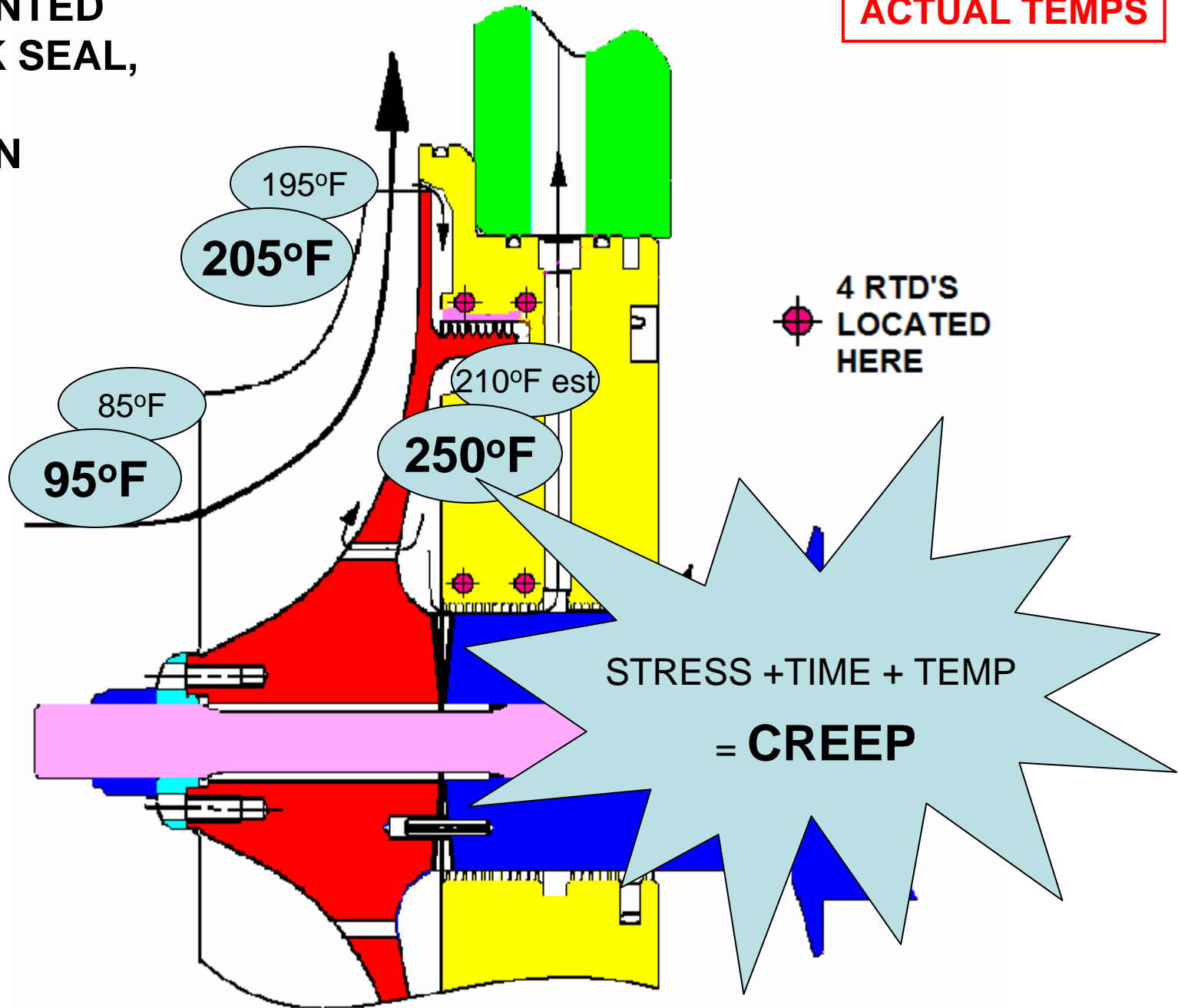
STRESS

FEA OF FAILED

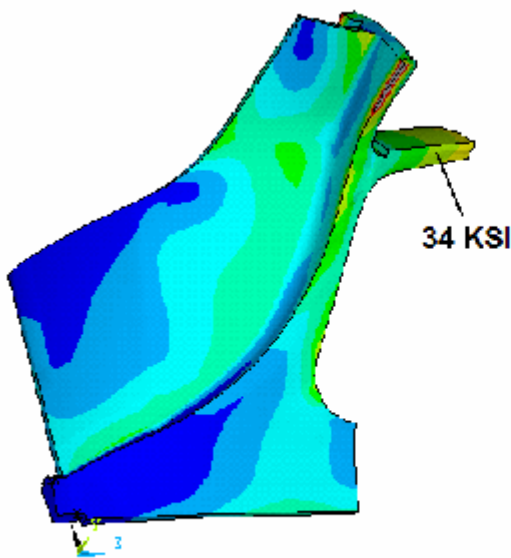
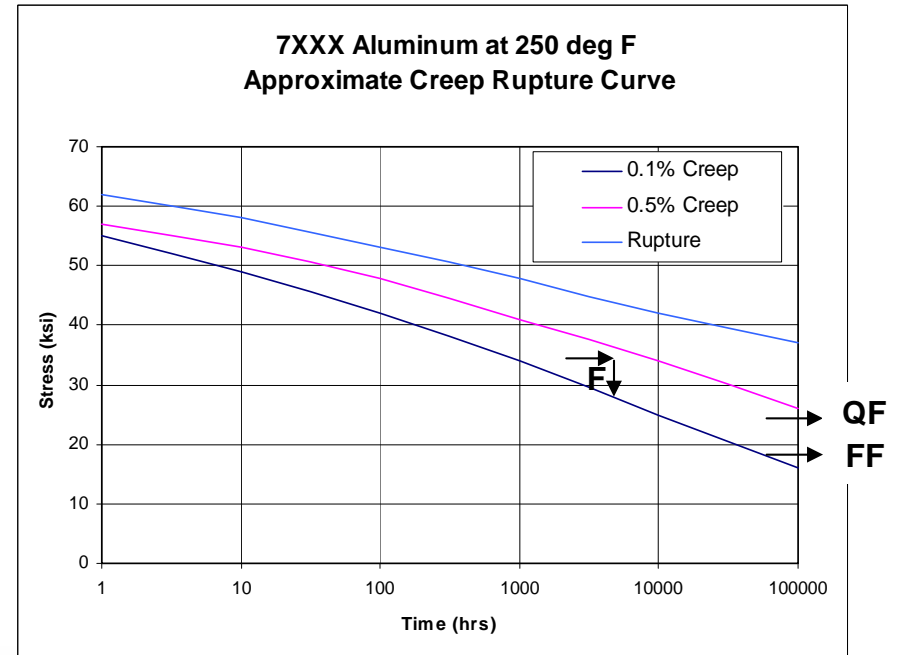
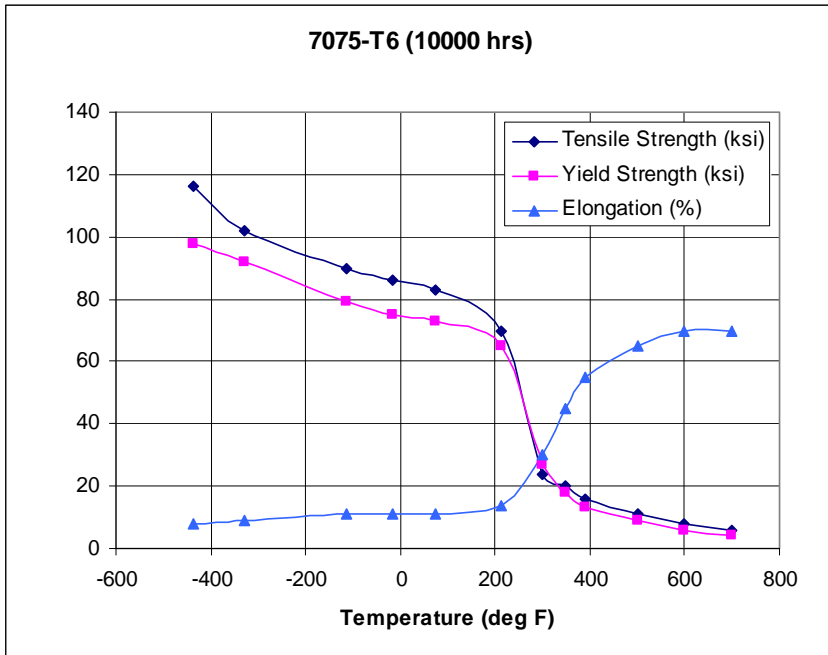


INSTRUMENTED BACK DISK SEAL, ACTUAL OPERATION

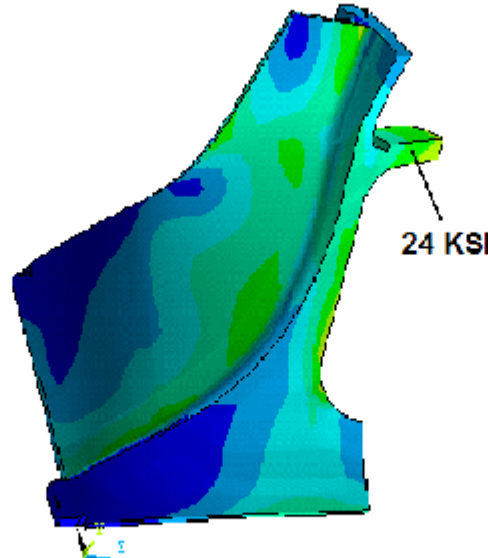
ACTUAL TEMPS



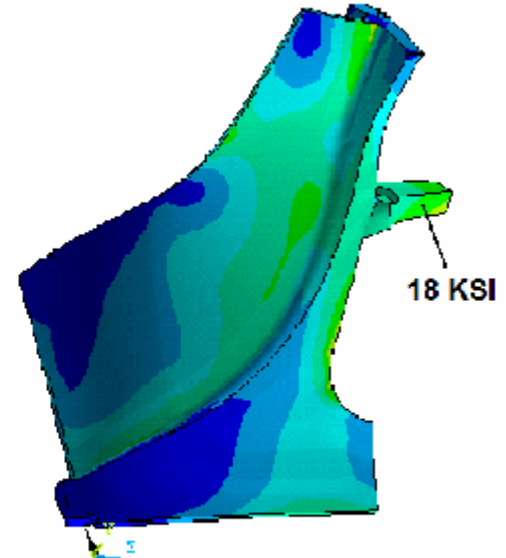
CREEP AND COMPARISON



FAILED



QUICK FIX

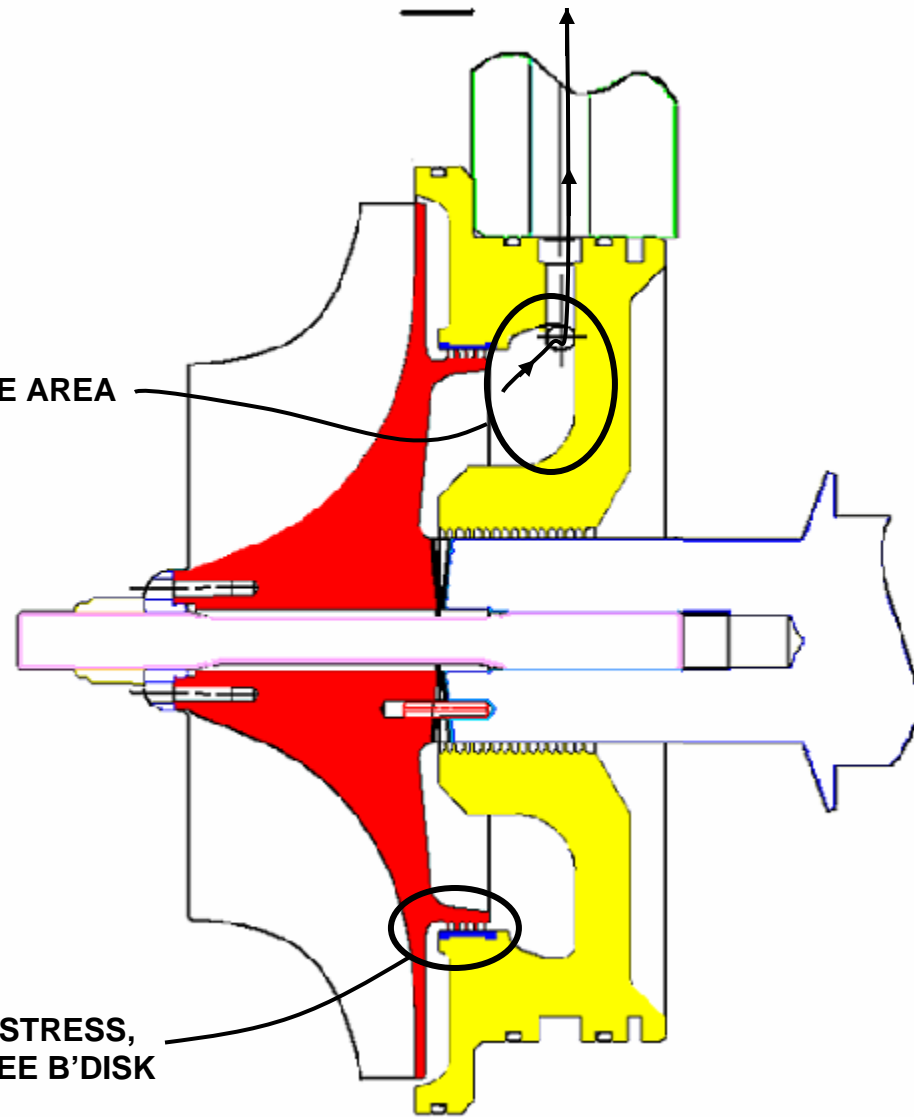
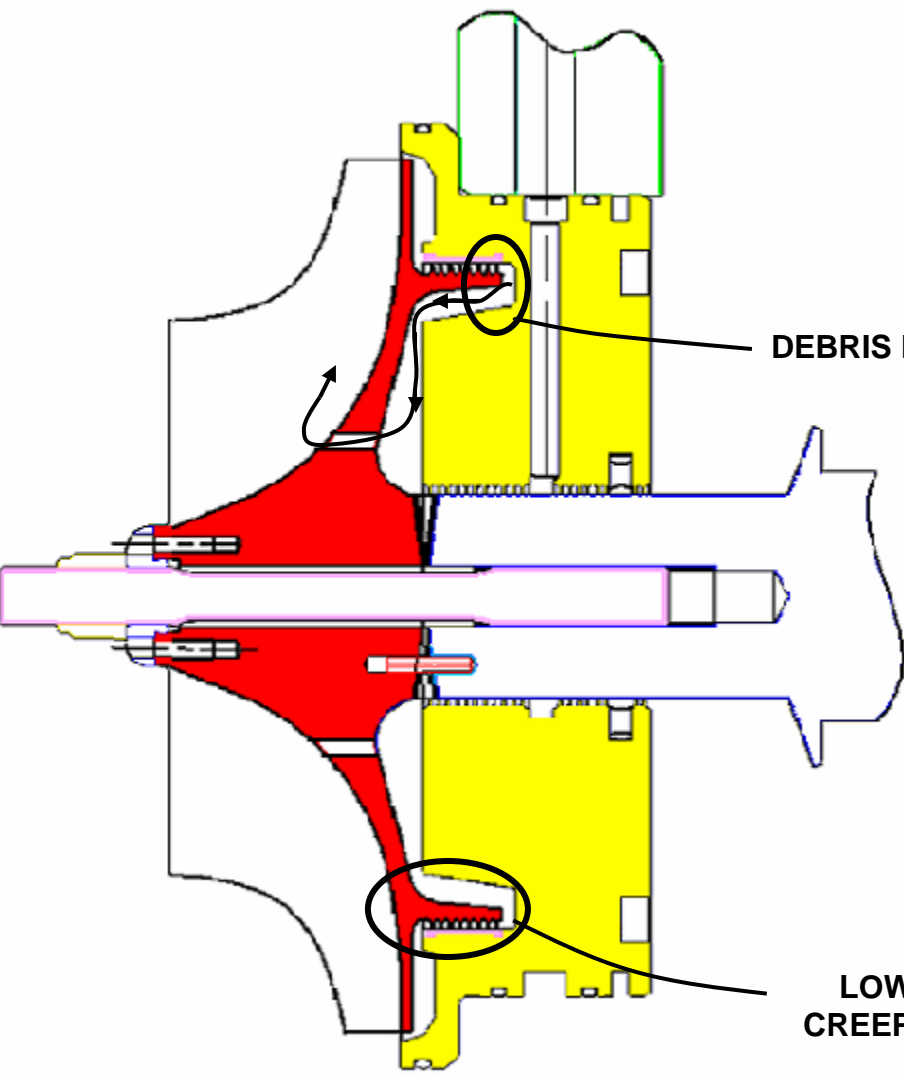


FINAL FIX

FINAL SOLUTION

FAILED

FIX



DEBRIS FREE AREA

LOWER STRESS,
CREEP FREE B'DISK