Centrifugal Impeller Failure via a Thermite Reaction

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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.

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THE IMPELLER

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

FAILED

NEW
THE DUST FILTER

Outlet

AIR FILTER ELEMENT

"SLAG"
"Normal" T=0

THE FLOW DIAGRAM

REMAINING PORTIONS OF PLANT

FLOW

FLOW

FLOW

FLOW

FLOW

FLOW

FLOW

FLOW

FLOW

FLOW
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

TE581 is located between the Dust Filter and CB1 of the BriM.

Upstream Side (Dust Filter)

Downstream Side (BriM)

![Graph showing pressure and flow dynamics after CB1 and BriM with specific data points and time stamps.]

- Pressure After CB1
- Pressure After Strainer
- Temperature After Dust Filter
- Bed 2 Pressure
- Pressure at Flow Meter
- CO2 After Dust Filter
- Bed 2 DP
- Valves HV519A Closes & PV599A Opens
- Time: 8:38:52

PP reach max pressure and start blowdown through CB1.

![Image of a circular strainer with a hand holding it.]
PRESSURES AND TEMPS

• BULK FLOW DIRECTIONS
• PRESSURES AND TEMPERATURES

195°F
230 PSIA

85°F
125 PSIA

210°F est
145 PSIA

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!
FEA OF FAILED
INSTRUMENTED BACK DISK SEAL, ACTUAL OPERATION

85°F
95°F
195°F
205°F
210°F est
250°F

STRESS + TIME + TEMP = CREEP

4 RTD'S LOCATED HERE
CREEP AND COMPARISON

7075-T6 (10000 hrs)

7XXX Aluminum at 250 deg F
Approximate Creep Rupture Curve

0.1% Creep
0.5% Creep
Rupture

34 KSI
24 KSI
18 KSI

FAILED
QUICK FIX
FINAL FIX
FINAL SOLUTION

DEBRIS FREE AREA

LOWER STRESS, CREEP FREE B’DISK