
43rd Turbomachinery
30th Pump SYMPOSIA
GEORGE R. BROWN CONVENTION CENTER
HOUSTON, TX | SEPT. 22 - 25, 2014
COUPLING FAILURE DUE TO A MOTOR FAULT
Chevron
KOP-FLEX
EMERSON
Industrial Automation
TEXAS A&M
UNIVERSITY
TEES
TURBOMACHINERY
LABORATORY
TEXAS A&M ENGINEERING EXPERIMENT STATION

# *COUPLING FAILURE DUE TO A MOTOR FAULT*

*Clay McClinton*
*Rotating Equipment Reliability Analyst, Chevron*

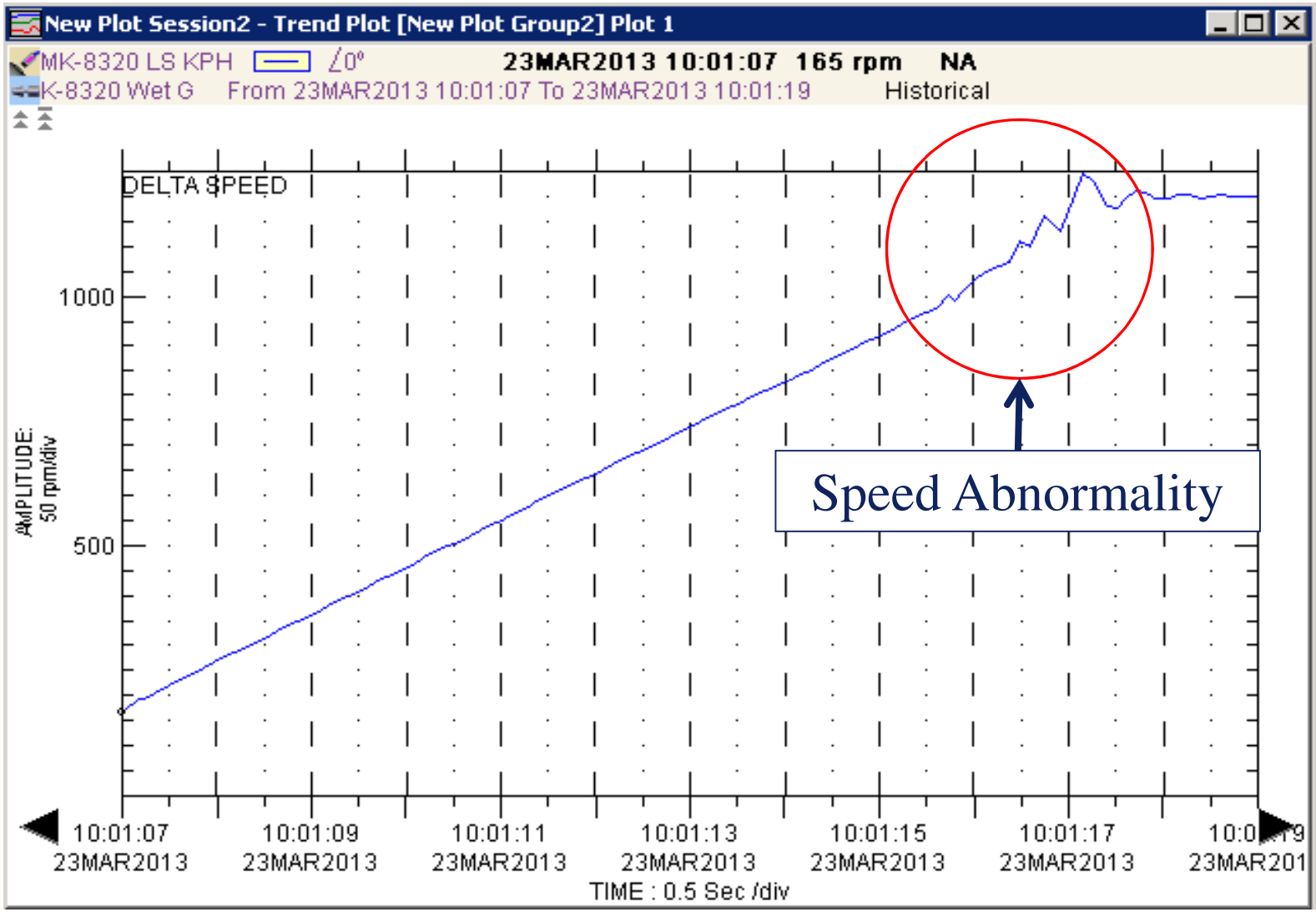
*Dan Phillips*
*Manager Global Field Services, Kop-Flex*

*Joe Corcoran*
*Manager Global Services & Training, Kop-Flex*

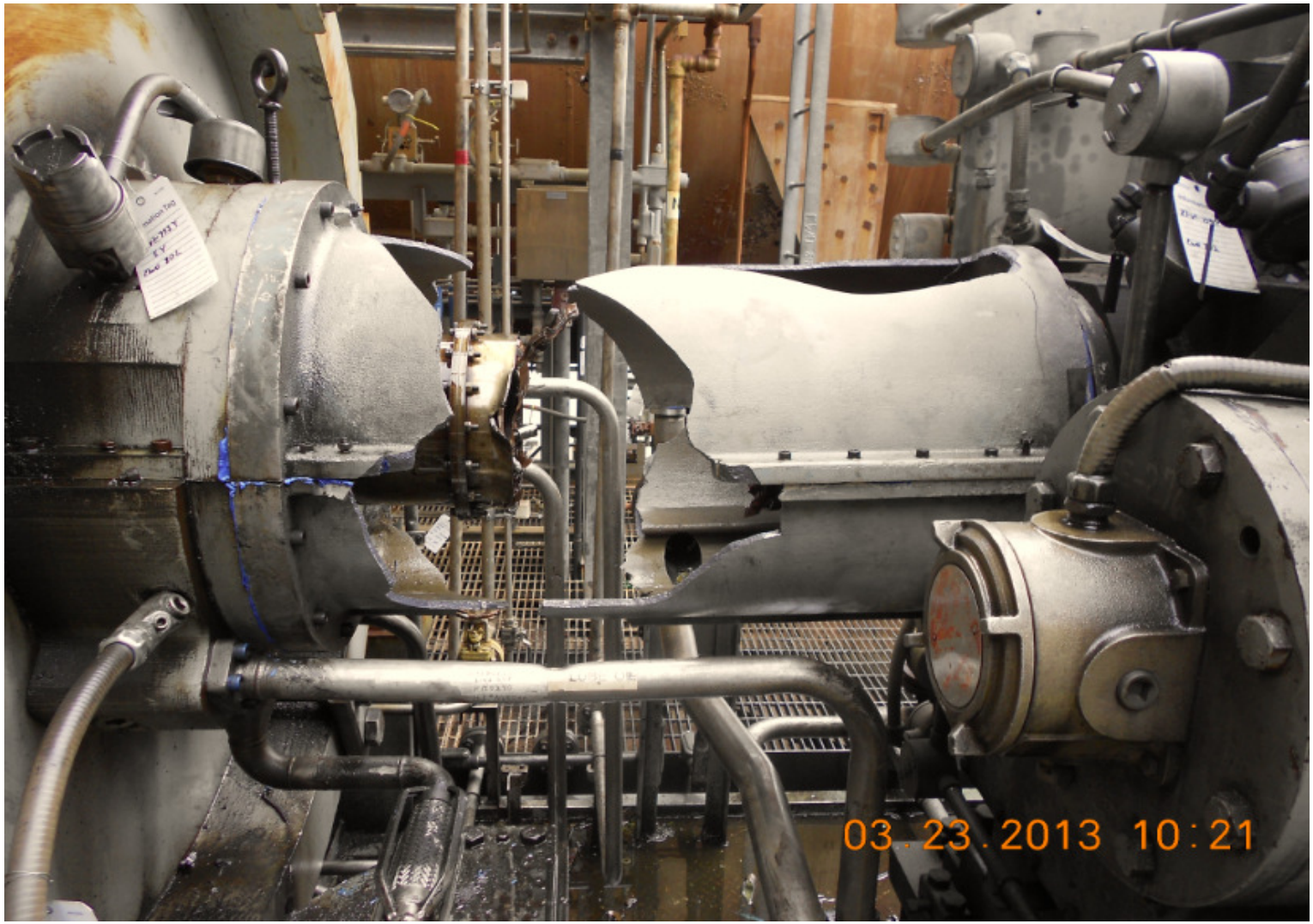
# *Incident Description*

- Soft Start Synchronous Electric Motor driving a Speed Increasing Gearbox to a Centrifugal Compressor
- Running since 2003 with no significant issues; Last shutdown in 2008
- Motor / Diaphragm Coupling /Gearbox
  - 15,000 hp @ 1,200 rpm (682,800 lb-in)
- Gearbox/ Disc Coupling / Compressor
  - 10,790 hp @ 6,662 rpm (102,100 lb-in)
- During start-up following 2013 turnaround, speed of motor dropped several times coming up to speed
  - Some electrical maintenance performed on motor during turnaround
- Failure and ejection of high speed coupling occurred 12 seconds after start (main part went 70 yards)
  - No injuries

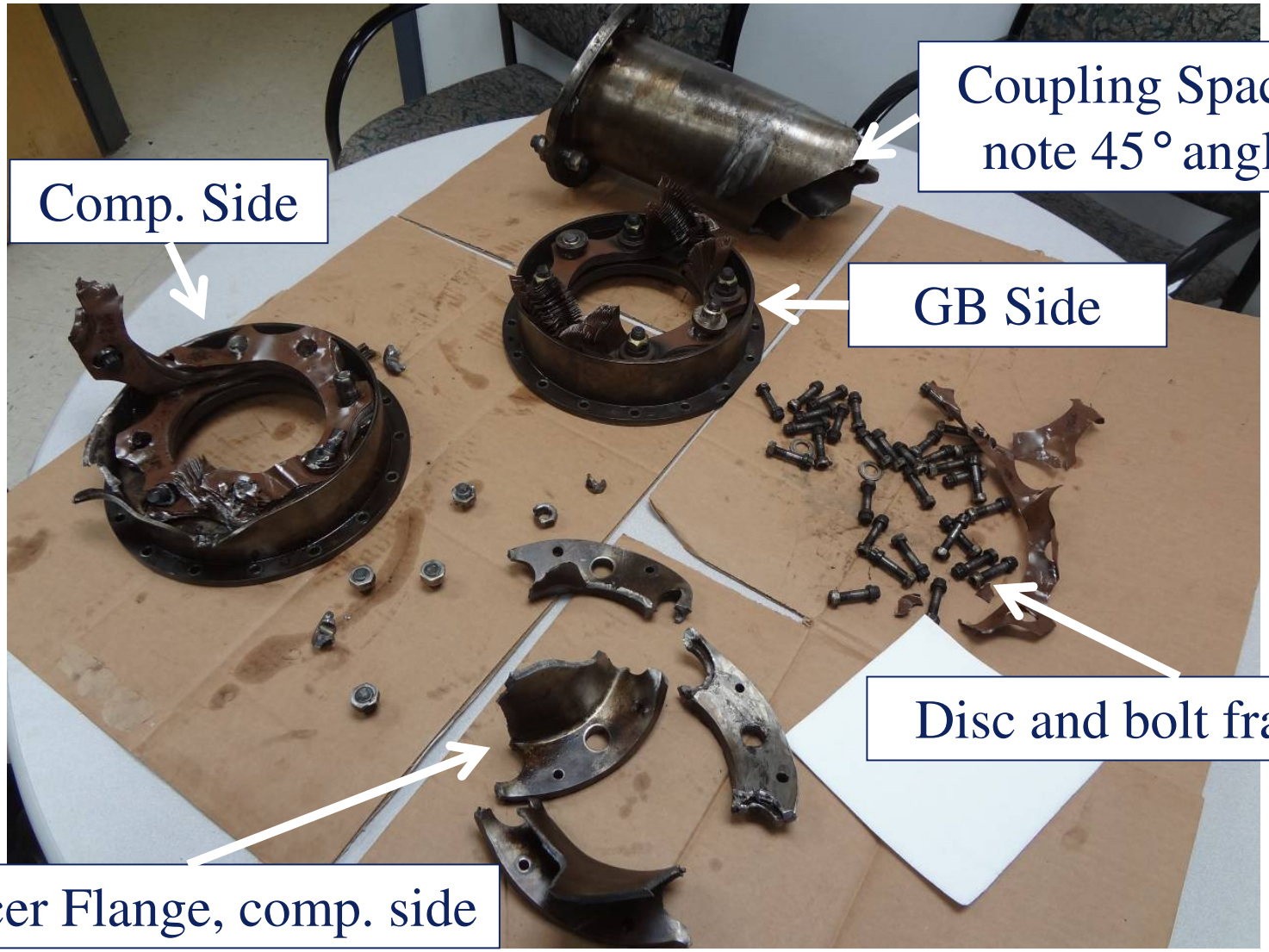
# Motor Speed Data from LS Speed Pick-up



# Broken Guard Due to Ejected High Speed Coupling Center Section



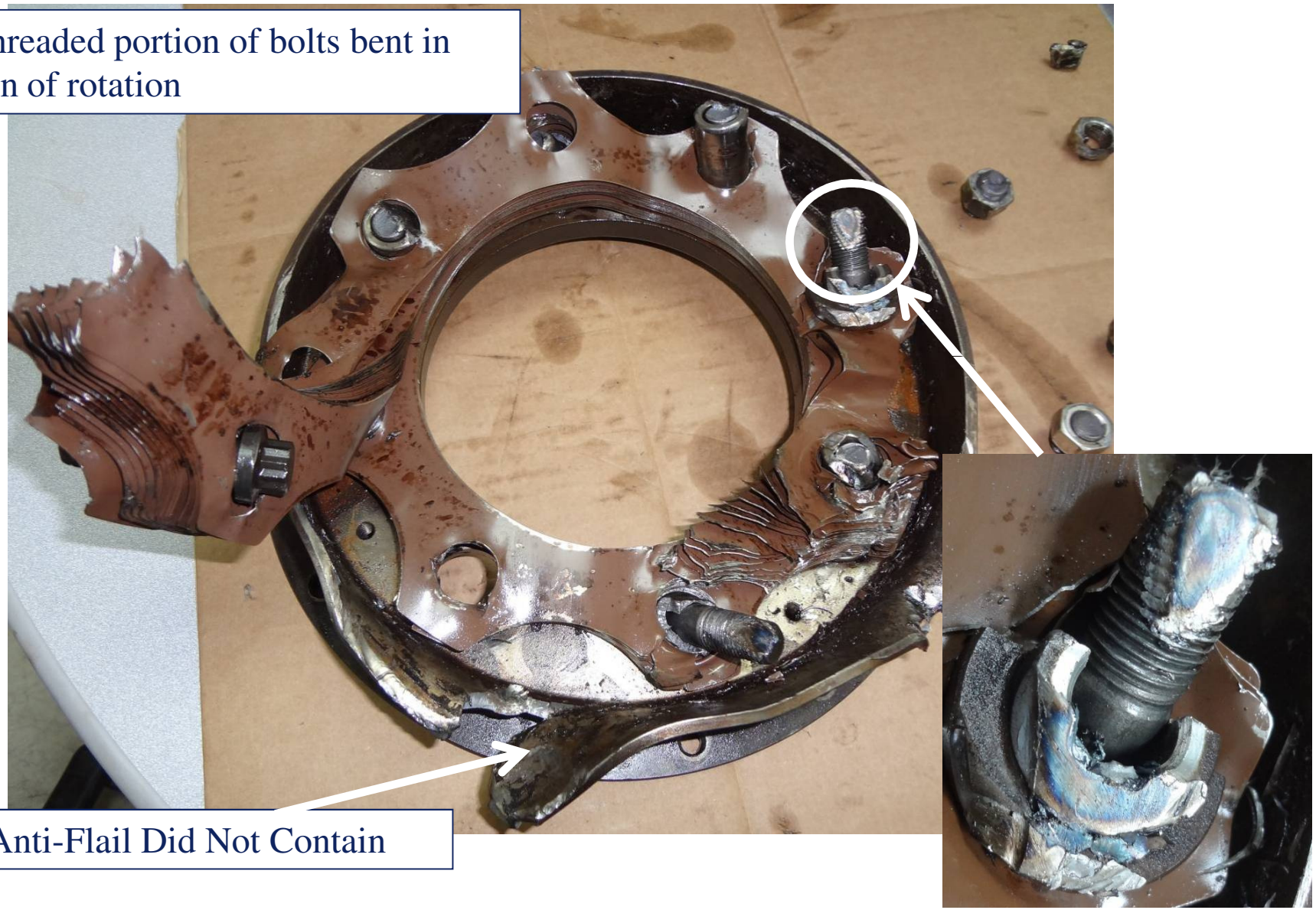
# *Failed Components Less Rigids*



# Spool Piece from Gearbox Side

# Spool Piece from Compressor Side

Note: threaded portion of bolts bent in direction of rotation

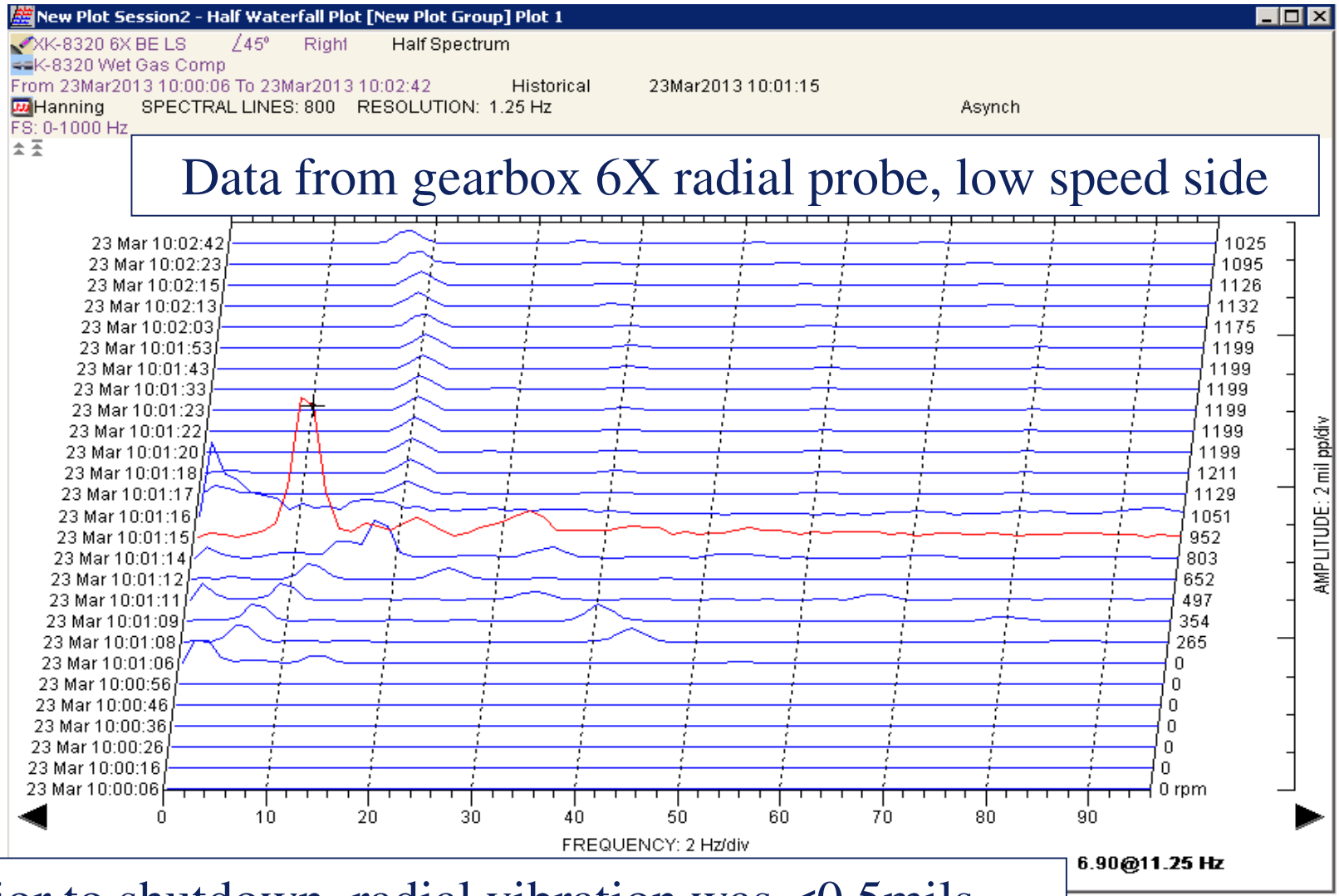


Note Anti-Flail Did Not Contain

# Driving End of Spacer with "Nut Broaching"

Nut/bolt pulled through flange

# Waterfall Plot from Start Up Reveals 6.9 Mils @ 11.25 Hz




Prior to shutdown, radial vibration was <0.5mils $_{p\text{-}p}$

# RCA

- No conclusive evidence of liquid slug
- High speed coupling flange bolts intact
  - Failure <5.8X normal torque, based on bolt strength with flange friction
- Shear Stress >84,000 psi on spacer tube
  - >6X normal torque to yield
  - Additional bending loads occurred as disc pack buckled
- Disc pack buckled, bolts bent
  - Max momentary rating of HS coupling 3.3X normal torque
- 3.3X normal torque < Failure Torque < 5.8X normal torque

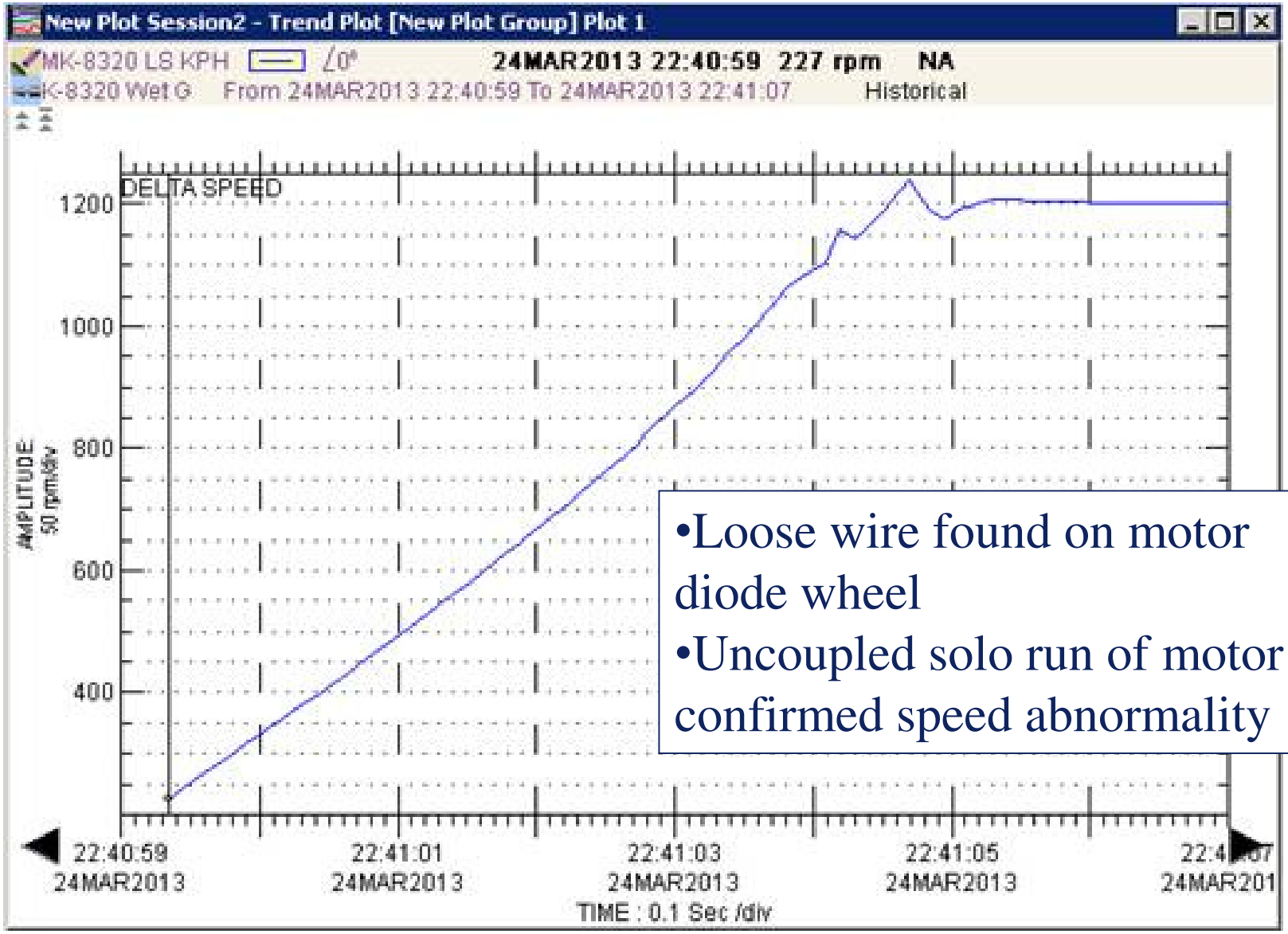
# Evaluation

- Location of initial failure was on compressor end of HS coupling center section
- Scenario
  - Comp. end disc pack buckles, disc pack bolts bend
  - Comp. end flange/Tube breaks due to torque + bending loads
  - Remaining portion of center section breaks through anti-flail
  - Unbalance forces (>30,000 lb) rip center section away from opposite end disc pack
  - Kinetic energy of broken center section (~4300 ft-$lb_f$) allows ejection through coupling guard

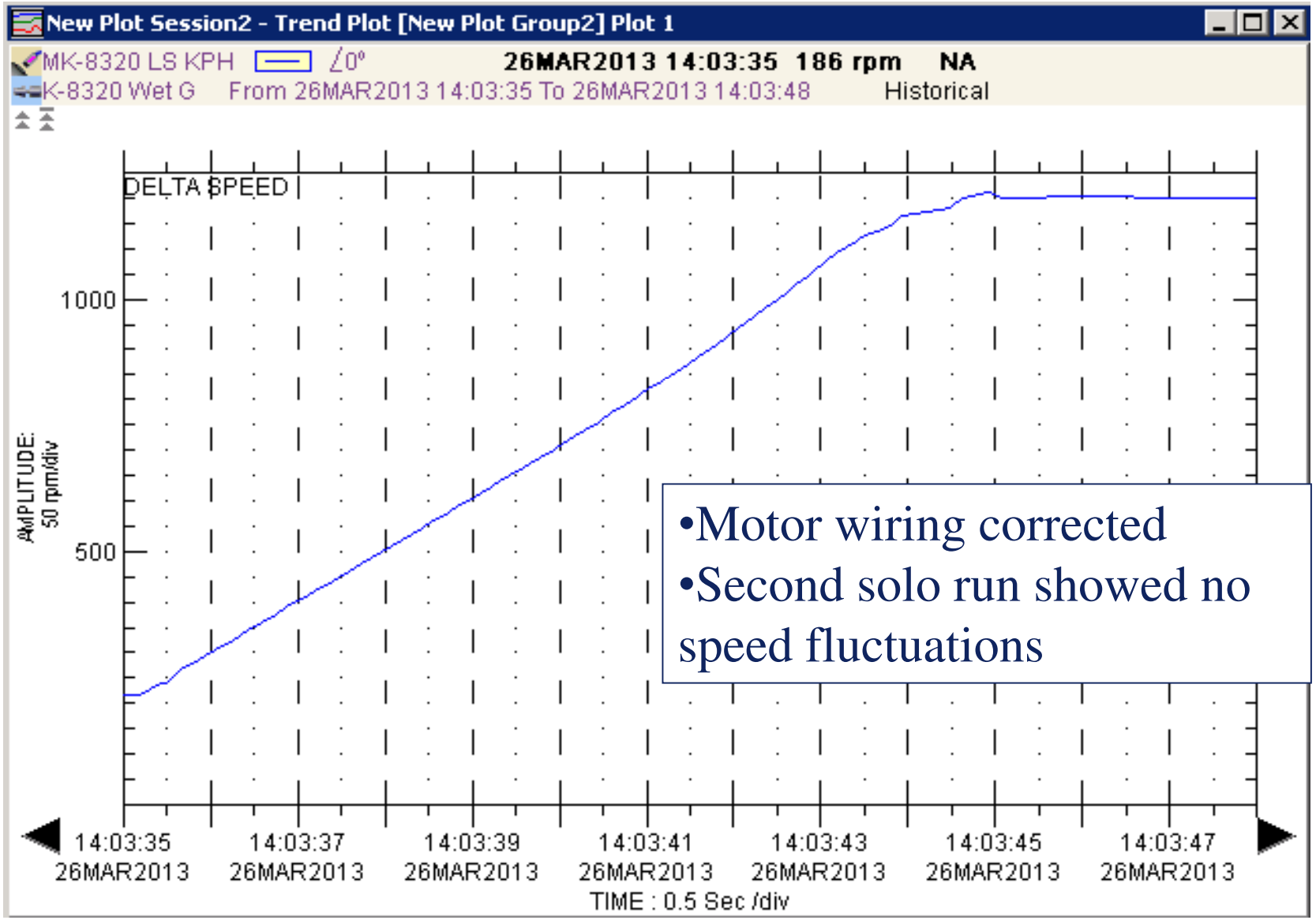
# Evaluation

- Low speed coupling looked good visually
  - Replaced as precautionary measure. Further inspection revealed no defects.
- Low speed coupling had higher torque capacity ratio
  - Max Momentary Torque was 8X vs. 3.2X
  - Not typical
  - Original Selection was a MAX-C Elastomeric Coupling
- So what caused the tremendous loads?
  - Speed fluctuations investigated
  - Torsional analysis reviewed

# Motor Speed Data from Solo Run

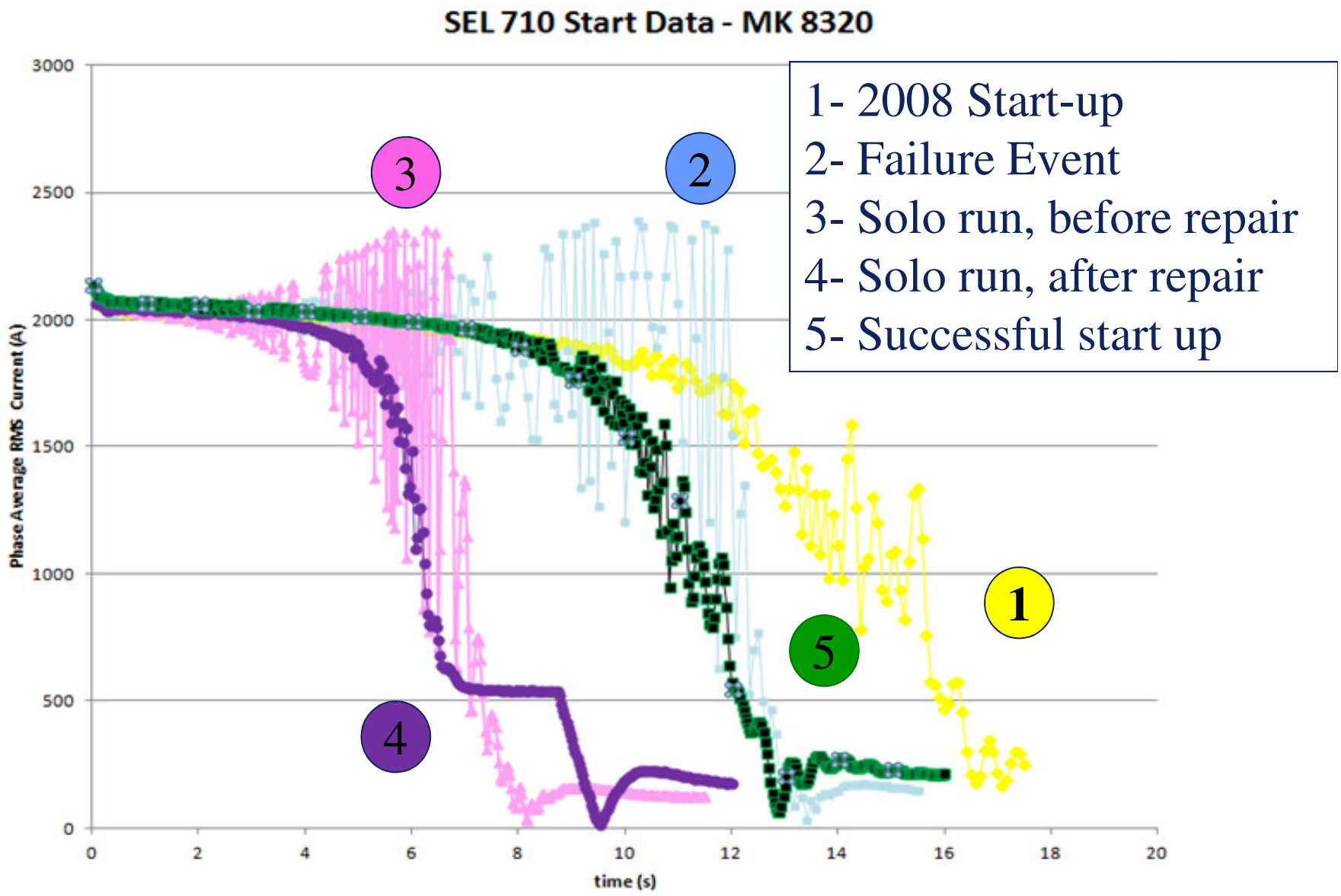


# Loose Wire Repaired; Motor Speed Data from Successful Start up 3/26




- Motor wiring corrected
- Second solo run showed no speed fluctuations

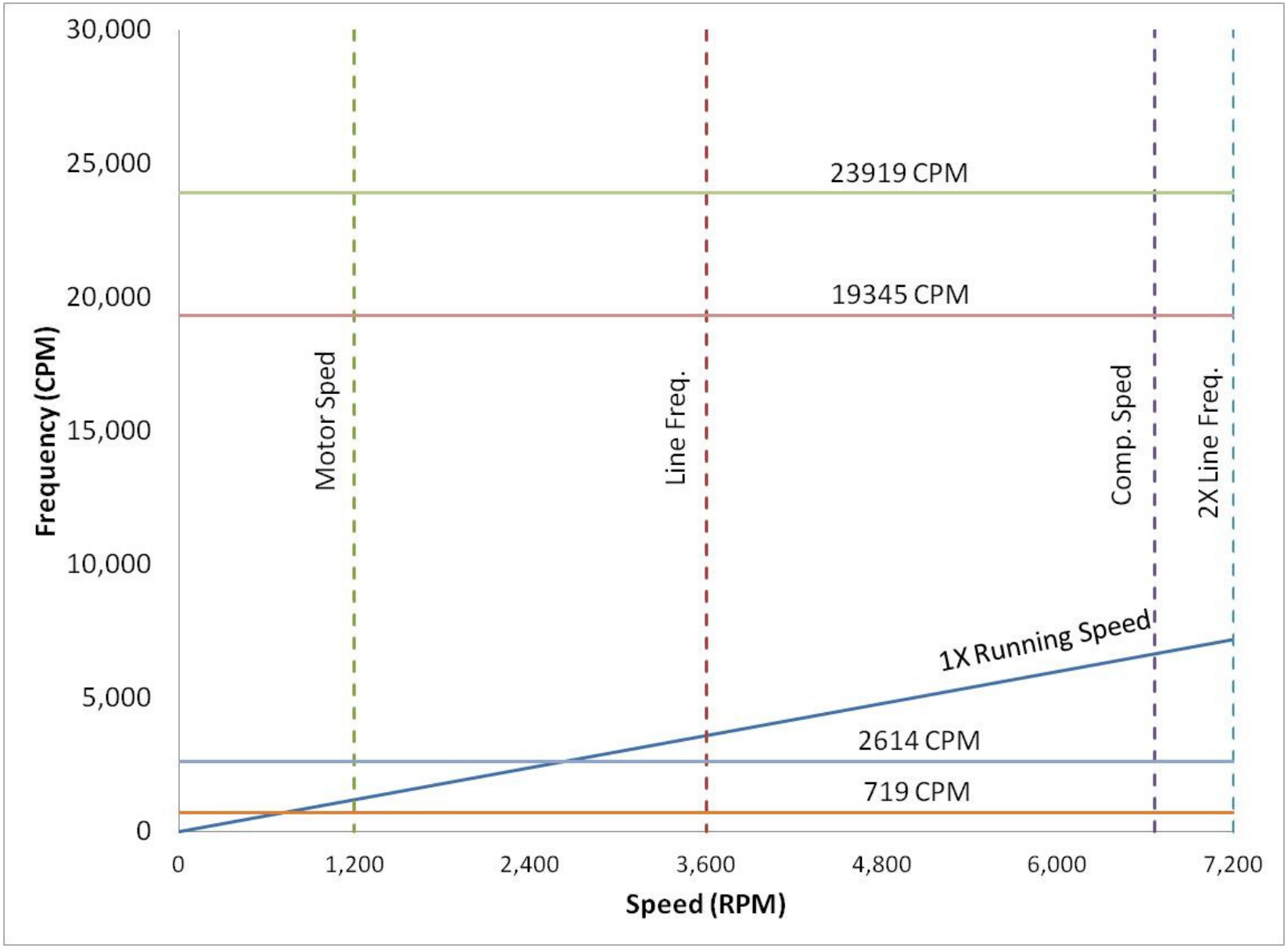
# Coupled and Solo Run Electrical Data – Current Fluctuations – Source of Excitation



# *Verification of Torsional Analysis*

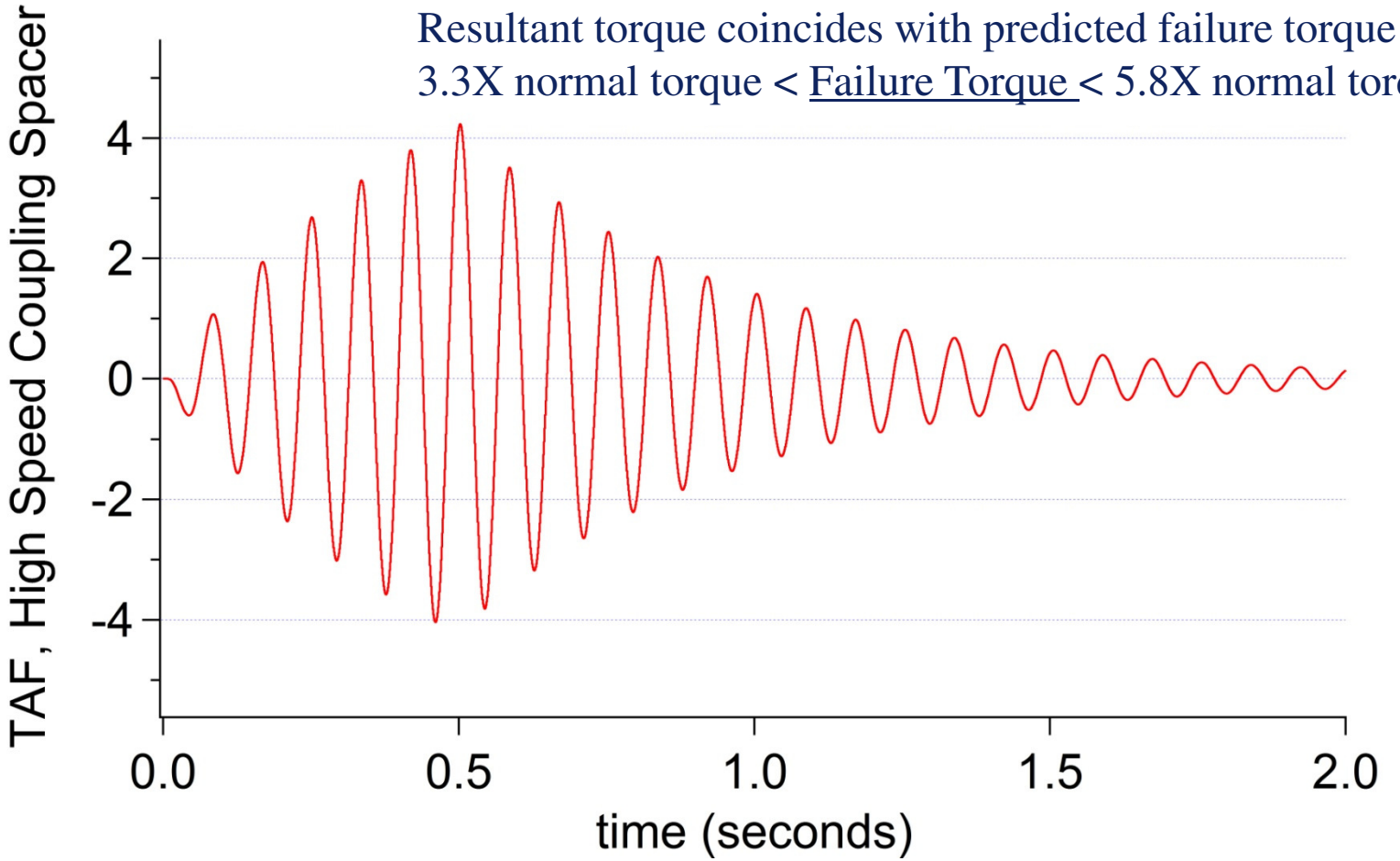
- Original torsional analysis reviewed
  - Frequency (11.25 Hz) of high radial vibrations found during start-up prior to failure appeared to be near a system torsional natural frequency
- New forced response analysis conducted
  - Wiring problem caused current fluctuations in motor, exciting torsional natural frequency
  - Need to determine effect of short duration torsional excitation at motor, resulting from diode wheel wiring

# Campbell Diagram – 1st Torsional Mode at 11.9 Hz (719 CPM)



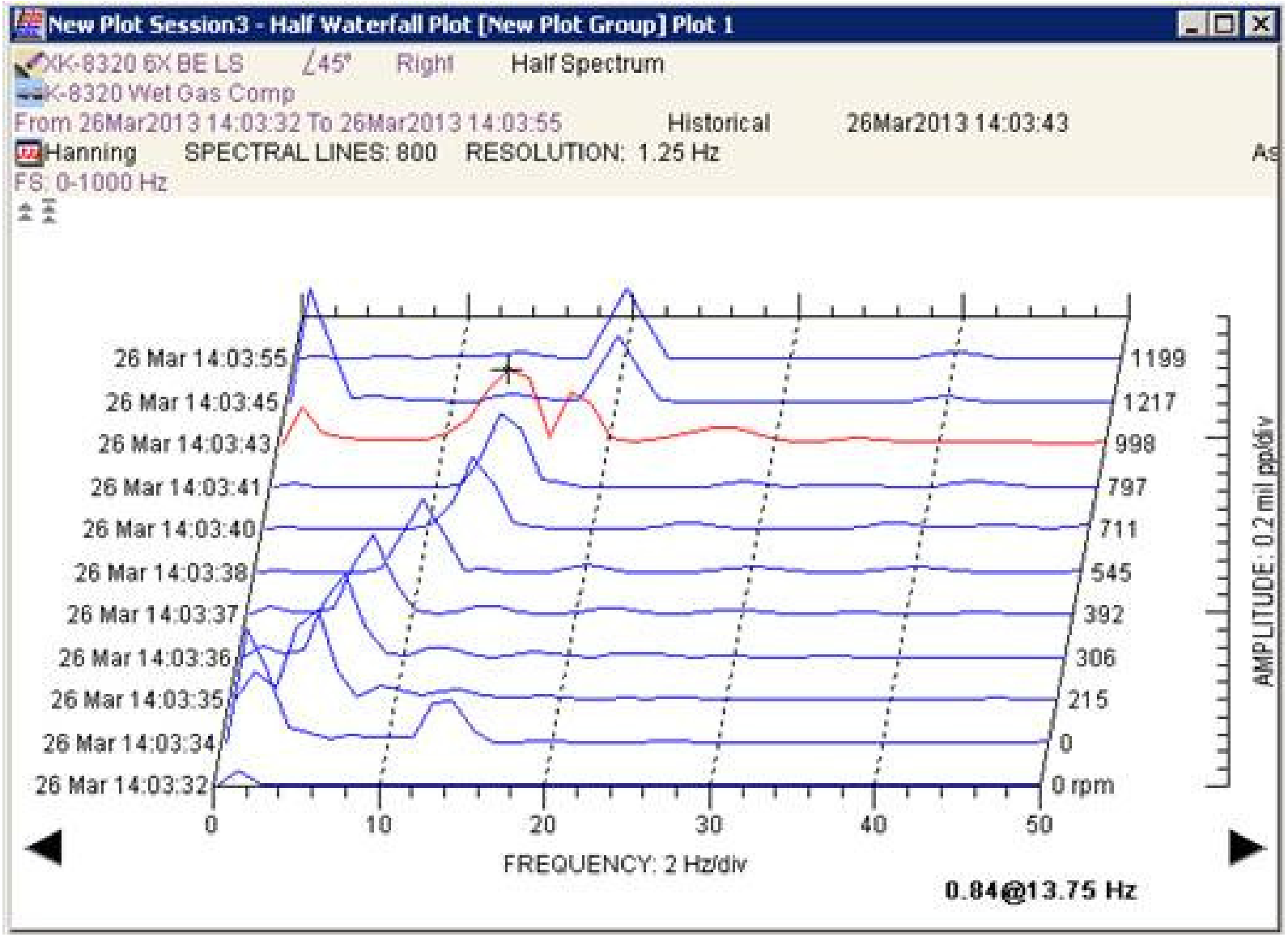
# Calculated Torque on Coupling During ~4X Rated

Resultant torque coincides with predicted failure torque levels
3.3X normal torque < Failure Torque < 5.8X normal torque




TAF response of high speed coupling with 0.5 sec excitation of first natural frequency applied at motor, .013% damping included.

# *Vibration Data from Successful Start-up 3/26*



# Lessons Learned and Recommendations

- This is a Very Rare Occurrence that Could Have Been Prevented
- Conduct Torsional Vibration Analysis- Forced Response
  - Faulty motor wiring excited torsional natural frequency during start-up
  - TVA concluded that peak torques exceed coupling rating and also
  - TVA provides critical information on location of weak point and can be used to evaluate necessary change (mass-elastic properties, overload protection, etc.)
- Wiring Checks
  - After any motor electrical maintenance, a full inspection of wiring connections is required
- Perform solo run on motor after major electrical maintenance completed
- Different couplings could have helped - Larger High Speed Coupling or Shear Section at High Speed (or Low Speed?)
- Unnecessary personnel should never be in close proximity to rotating equipment during start-up