Qualification and Application of Ultrasonic Technology for Power Plant Component Fouling Control

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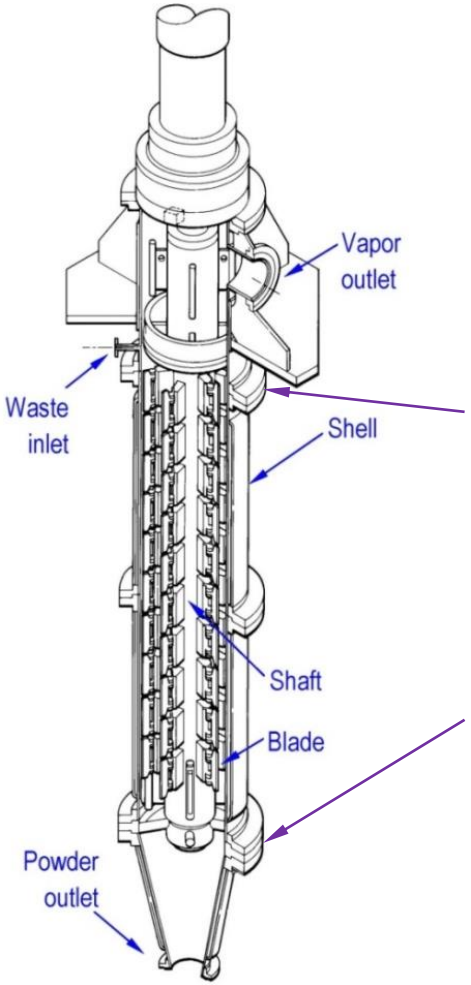
Topics

- Cement solidification system (CSS) overview
- Ultrasonic energy cleaning (UEC) systems developed for CSS
- Structural analyses and laboratory validation
- Material integrity testing
- Effectiveness testing
- Field results

CSS Background

- Wiped-film evaporator (dryer) is used in a nuclear power station to treat liquid low-level radwaste
  - Calcium borate particulates generated by chemical treatment
  - Particulates isolated through evaporation and then packaged for disposal
- Buildup of deposits on surfaces throughout the dryer led to off-normal thermal-hydraulic conditions and reduced dryer efficiency
- Manual / water-jet cleaning were initially implemented: labor-intensive with risk of personnel contamination

Cement Solidification System Dryer



Four upper UEC transducers mounted on top flange

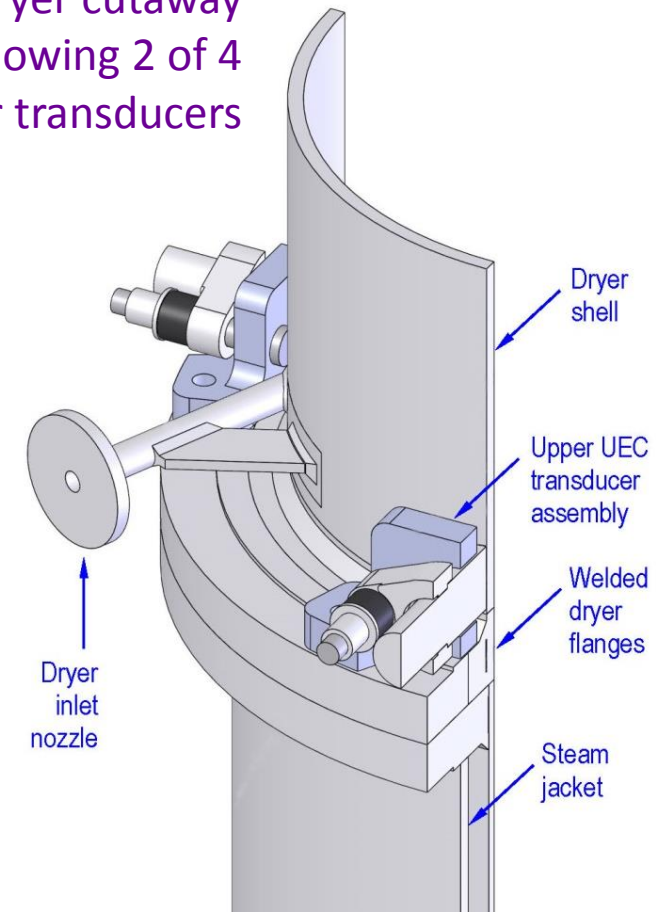
Powder outlet cone removed during UEC and replaced with lower UEC transducer assembly

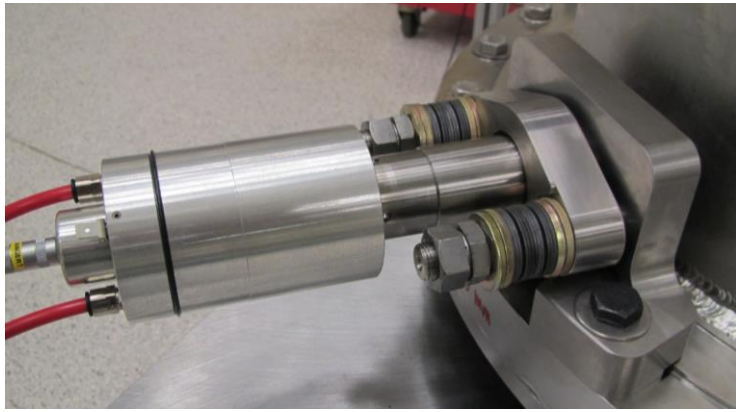
Development of CSS UEC Systems

- Two ultrasonic systems constructed:
  - The first ("upper system") consists of four externally mounted transducers focused on cleaning the liquid distribution ring (fouling leads to flow maldistribution and performance problems)
  - The second ("lower system") targets cleaning the lower dryer internals, including central shaft and wiper blades
- Upper system may be operated online and offline (deposit prevention and cleaning)
- Lower system requires flooding of the dryer and may only be operated offline

Upper UEC Transducer Assemblies

CSS dryer cutaway showing 2 of 4 upper transducers





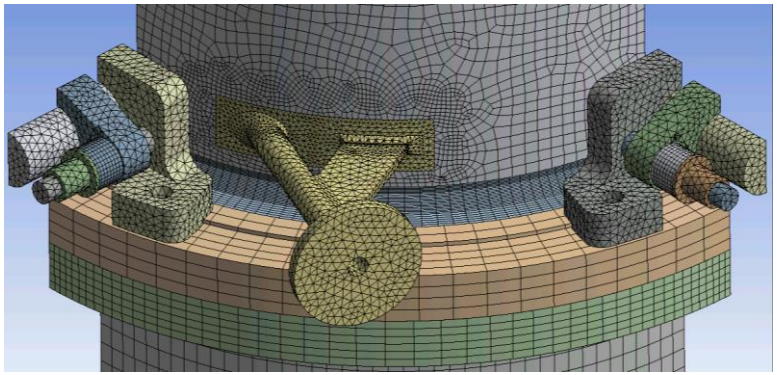
Upper transducer installed on dryer mockup

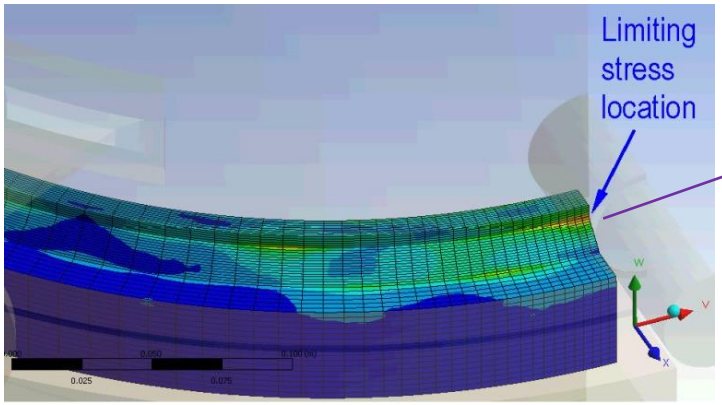
Lower UEC Equipment

Field installation of lower UEC transducer assembly

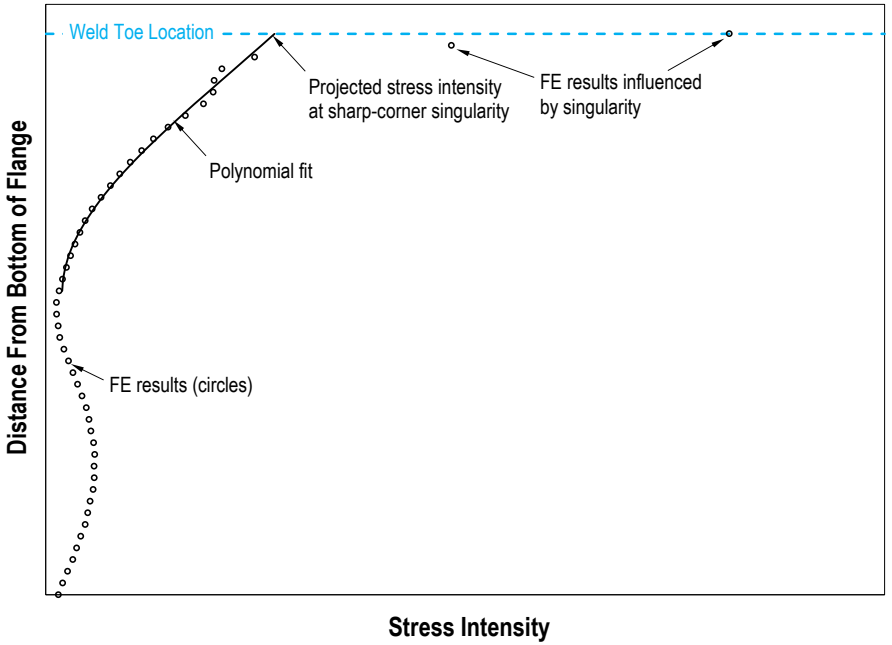
Lower UEC controls:
level, temperature, dissolved gas, particle filtration, transducer on/off

Upper UEC Structural Analysis



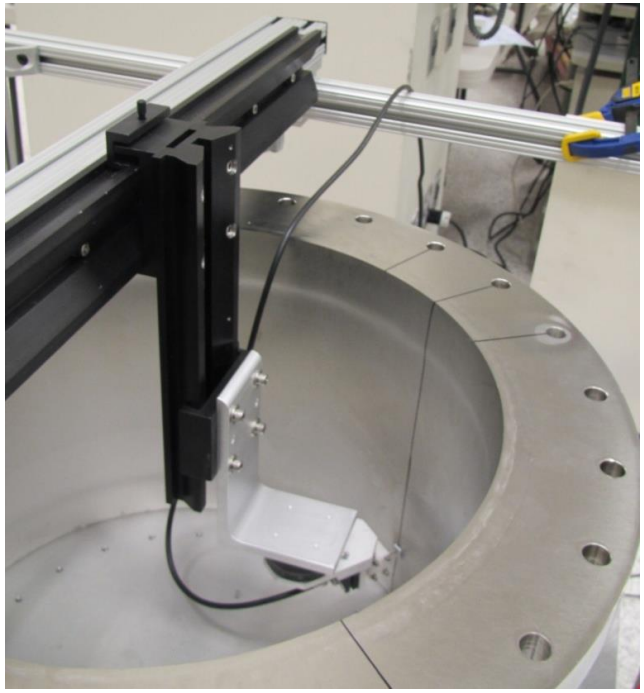


Upper UEC finite element mesh (top)
Harmonic stress intensity during UEC (bottom)

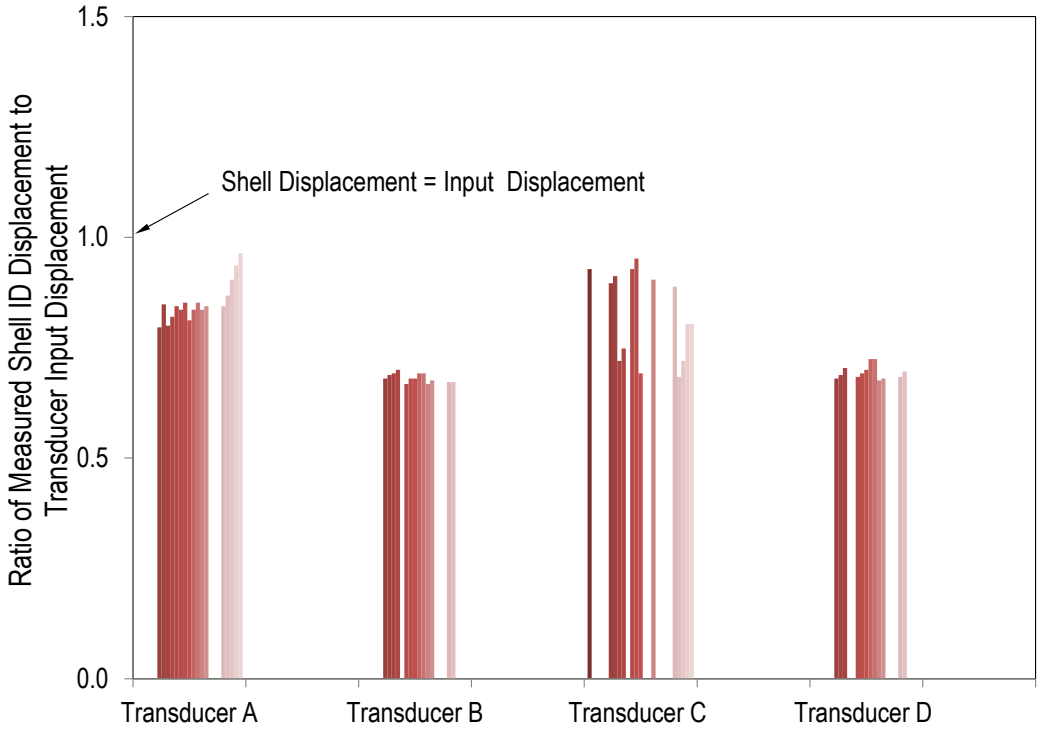


Determination of
limiting stress intensity

Upper UEC FE Model Validation

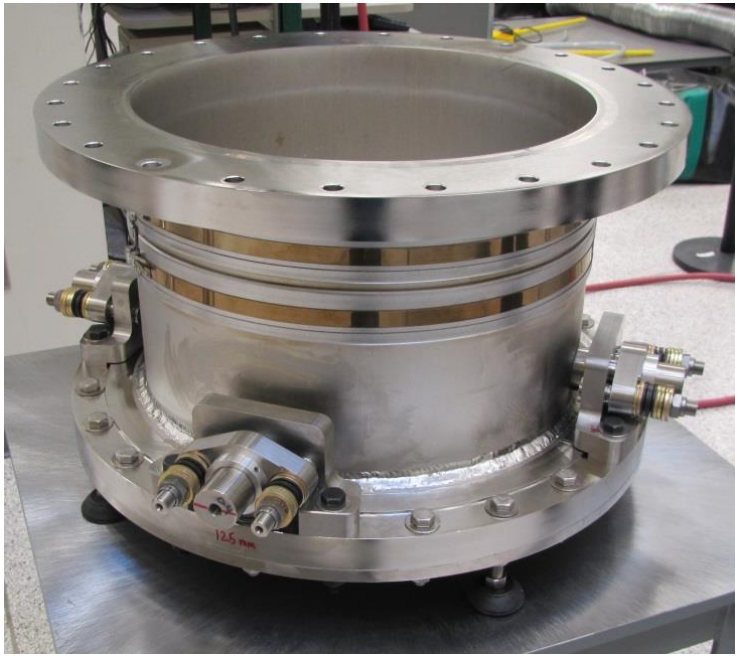


Laboratory measurement of dryer mockup shell displacements



Laboratory shell displacement measurement results

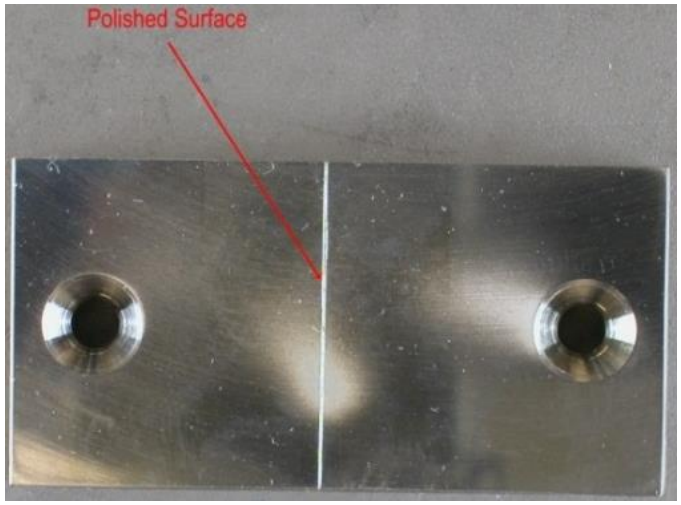
Material Integrity Testing Facilities



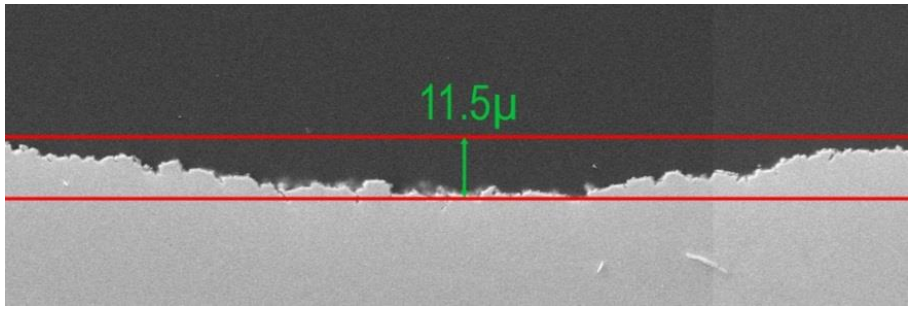
Upper UEC mockup

Lower UEC mockup

Material Integrity Testing Results



UEC cavitation erosion
on test coupon



Scaled microphotograph of
cavitation erosion (cross section)

- Testing showed acceptably low levels of erosion compatible with planned periodic surface inspections

Upper UEC Effectiveness Testing

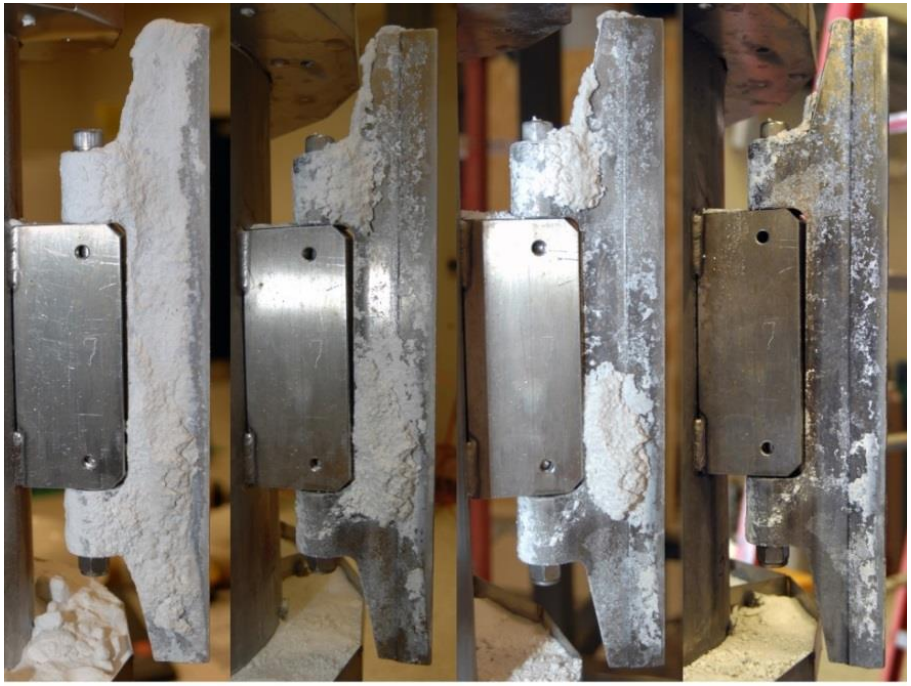
Initial deposits (t = 0)

t = 3 h

t = 5 h

- Testing demonstrated complete removal of tenacious calcium borate deposits after several hours of UEC

Lower UEC Effectiveness Testing



- Actual CSS dryer blades fouled in the vendor's test facility were 97–99% clean after <5 hours of UEC

Field Results (1/2)

Typical CSS dryer shaft without cleaning

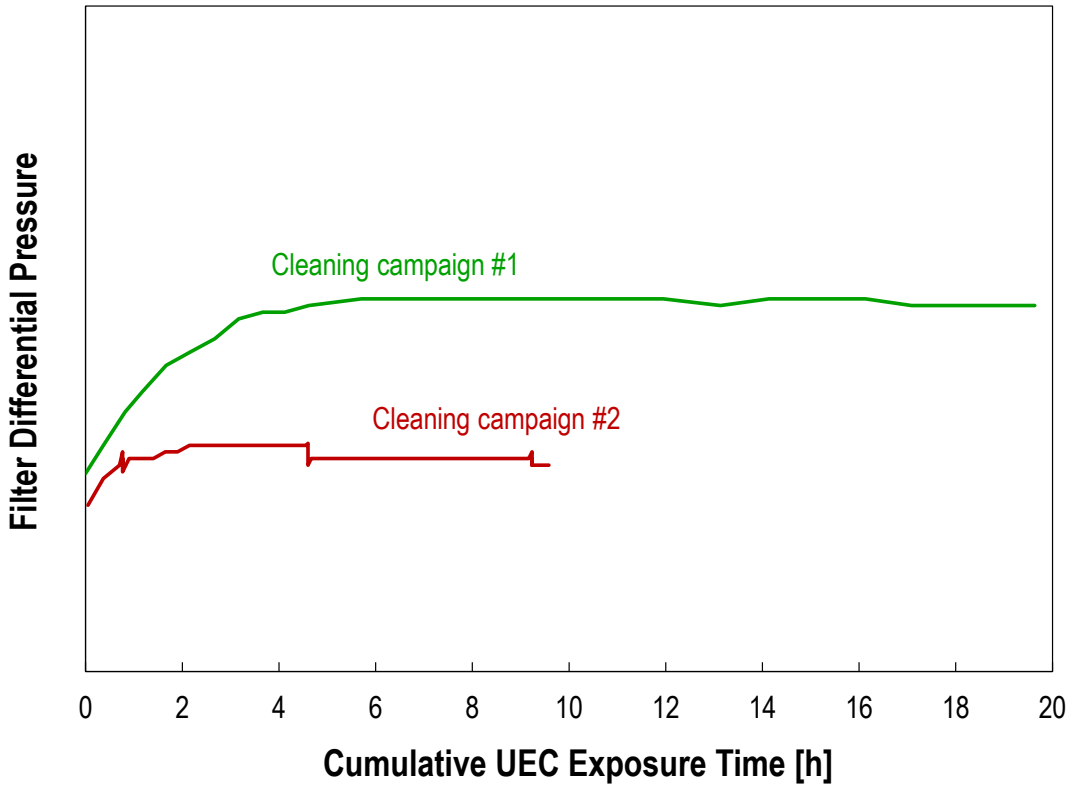
Without cleaning

After UEC

CSS dryer shaft after UEC

Internals removed only for inspection of cleaning efficiency after first-of-a-kind application.
Routine removal of internals not needed.

Field Results (2/2)



- Trends in differential pressure across particle filter elements suggested complete cleaning in <6 hours

Summary

- A wiped-film evaporator (dryer) used to process low-level radwaste in a nuclear station experienced rapid, extensive fouling with calcium borate deposits
- Two custom ultrasonic energy cleaning (UEC) systems were developed to remove these deposits
- Extensive testing and structural evaluations demonstrated that the UEC systems are:
  - Effective at removing tenacious calcium borate deposits
  - Safe for the dryer materials exposed to ultrasonic vibrations
- Key benefits of the UEC systems for this application:
  - Dryer performance was restored
  - Manual cleaning protocols were eliminated (time consuming, risk of personnel contamination)

Other DEI Cleaning Applications

- Fuel/reactor services
  - High efficiency ultrasonic fuel cleaning
  - Vacuum canister fuel sipping (fuel leak detection)
  - Ultrasonic jet pump cleaning
- Mechanical cleaning equipment
  - Sludge flush system (hydraulic)
  - Ultrasonic devices (SGs, piping, BWR jet pumps, filters/resin vessels, hot spot removal)
- Chemical cleaning/treatment processes
  - SG cleaning (ASCA, CODE, etc.)
  - Dose reduction/passivation (LT-ZP)