TANK SHELL TOLERANCES

What are these, why are they important?

INSPECTION & MECHANICAL INTEGRITY SUMMIT

Inspection, Mechanical Engineering, Corrosion & Materials

API

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January 23 - 25, 2024 | Henry B. Gonzales Center | San Antonio, TX

PRESENTER

- **Andrew Yearwood, P.E.**
- PEMY Consulting
- Senior Engineer
- Years of Experience: 18
- Field of Expertise
  - Storage tank design, inspection, maintenance, and engineering
  - Failure investigations, root cause analysis, expert witness
  - API 653 Certified Inspector
- Industry Involvement/Recognition:
  - API SCAST:
    - Co-chair, API 2610 Tank Facilities Task Group
    - Member Sub-Group Fabrication

PRESENTER

- **Rama K. Challa, PhD., P.E., P.Eng**
- Director of Projects & Business Unit Director, Atmospheric and Cryogenic Storage Business Unit
- Years of Experience: 30+
- Fields of Expertise:
  - Project Engineering & Management; Project Development; Operations management;
  - Design & detailing; Estimating, Planning, and Scheduling of Turnkey Industrial Facilities
  - Steel Plate Structures; Structural Engineering; Stress Analysis & Fitness for Service
- Industry Involvement/Recognition:
  - API SCAST:
    - Chair, Refrigerated Tank Task Group &
    - Member Sub-Group Fabrication

PRESENTER

- **Sam Verulkar, P.E.**
- Engineering Manager, ASTs, R&M, ASME
- Matrix PDM Eng.
- (Matrix Service Company, parent company, is publicly traded under the NASDAQ symbol **MTRX**)
- Years of Experience: 25+
- Fields of Expertise:
  - Above ground storage tank design, Repair & Maintenances, ASME Spheres & Vessels, FFS evaluations.
  - Structural Analysis and Designs, Foundations
  - Estimating, Planning, and Scheduling of Turnkey Industrial Facilities
- Industry Involvement/Recognition:
  - Member – AISC, ACI

OBJECTIVE

FRAME	The Issue of Tolerances
COMMUNICATE	Role of Tolerances in (1) Design (2) Construction and (3) Function
IDENTIFY	Potential Issues
PROPOSE	Mitigation Measures

WHY ARE SHELL TOLERANCES IMPORTANT?

API 650

7.5 Dimensional Tolerances

7.5.1 General

The purpose of the tolerances given in 7.5.2 through 7.5.7 is to produce a tank of acceptable appearance and to permit proper functioning of floating roofs.

…

7.5.2 Plumbness

…

7.5.3 Roundness

…

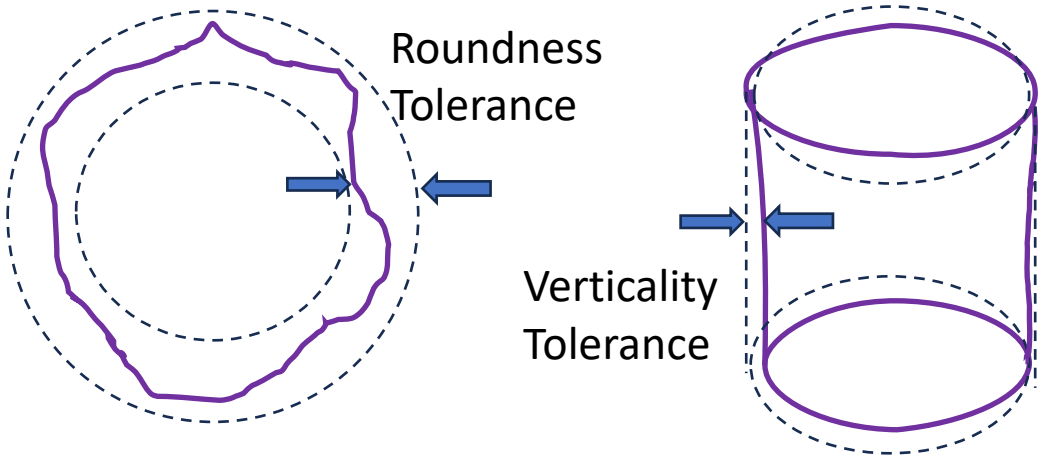
7.5.4 Local Deviations

- Stress increase when full of product
- Fatigue
- Lesser buckling strength for wind, vacuum
- Serviceability of floating roof
  - Binding
  - Seal gaps
- Strapping?

SO MANY CODES, SO MANY DIFFERENT GUIDELINES?

- API 650
- API 653
- ASME Section VIII
- UL 142
- API 12
- Etc. ….

Typical Tolerance Types in Codes and Standards



API 650 SHELL TOLERANCE V SEALS

- **Shell vs seal tolerances**

- API 650
  - 7.5.2 Plumbness
    - a) The maximum out-of-plumbness of the top of the shell relative to the bottom of the shell shall not exceed 1/200 of the total tank height…
  - 7.5.3 Roundness…
  - H.4.4.3 All peripheral seals and their attachment to the floating roof shall be designed to accommodate ±100 mm (±4 in.) of local deviation between the floating roof and the shell.

- **Example**

- A 250’ x 60’ tank can have +1.25” radial tolerance + 3.6” out-of-plumb = 4.85”.
- The tank shell is within tolerance but exceeds +/-4” seal capabilities.
- Floating roof rim space tolerance?

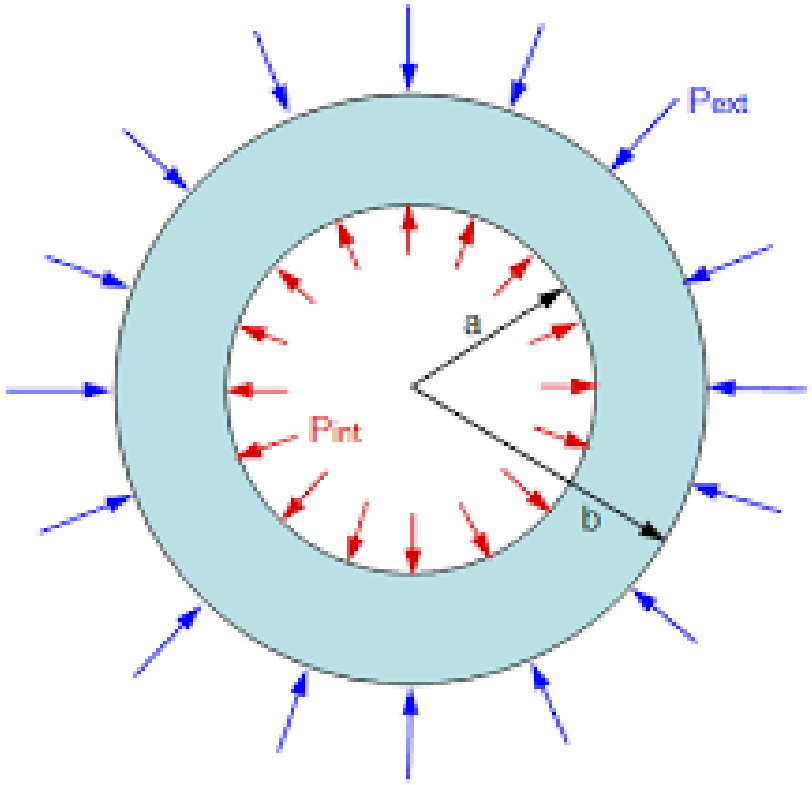
API 650 LOCAL TOLERANCES

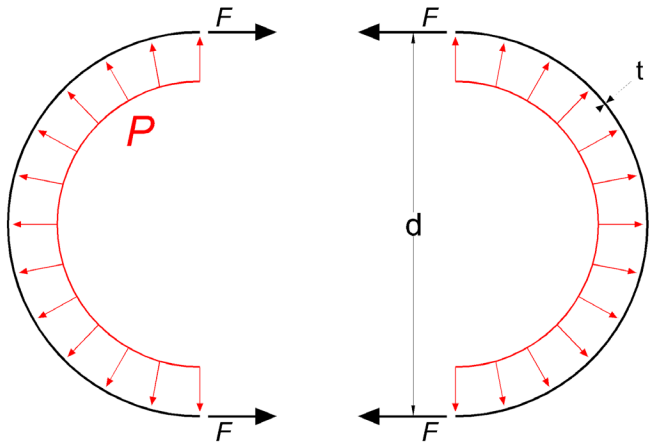
- API 650 7.5.2
  - …The out-of-plumbness in one shell course shall not exceed the permissible variations for flatness and waviness as specified in ASTM A6M/A6, ASTM A20M/A20, or ASTM A480M/A480, whichever is applicable.

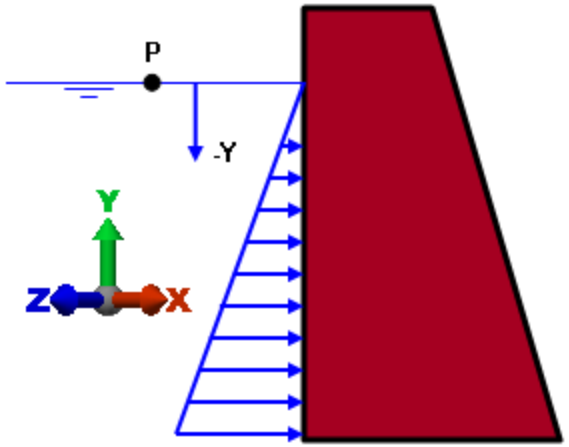
TABLE 13
PERMITTED VARIATIONS FROM A FLAT SURFACE FOR STANDARD FLATNESS CARBON STEEL PLATES

Specified Thickness, in.	Specified Weight, lb/ft^2	Permitted Variations from a Flat Surface for Specified Widths Given in Inches, in.[A,B]										
		To 36, excl	36 to 48, excl	48 to 60, excl	60 to 72, excl	72 to 84, excl	84 to 96, excl	96 to 108, excl	108 to 120, excl	120 to 144, excl	144 to 168, excl	168 and Over
To 1/4, excl	To 10.2, excl	9/16	3/4	15/16	1 1/4	1 3/8	1 1/2	1 5/8	1 3/4	1 7/8	...	...
1/4 to 3/8, excl	10.2 to 15.3, excl	1/2	5/8	3/4	15/16	1 1/8	1 1/4	1 3/8	1 1/2	1 5/8	...	...
3/8 to 1/2, excl	15.3 to 20.4, excl	1/2	9/16	5/8	5/8	3/4	7/8	1	1 1/8	1 1/4	1 7/8	2 1/8
1/2 to 3/4, excl	20.4 to 30.6, excl	7/16	1/2	9/16	5/8	5/8	3/4	1	1	1 1/8	1 1/2	2
3/4 to 1, excl	30.6 to 40.8, excl	7/16	1/2	9/16	5/8	5/8	5/8	3/4	7/8	1	1 3/8	1 3/4
1 to 2, excl	40.8 to 81.7, excl	3/8	1/2	1/2	9/16	9/16	5/8	5/8	5/8	11/16	1 1/8	1 1/2
2 to 4, excl	81.7 to 163.4, excl	5/16	3/8	7/16	1/2	1/2	1/2	1/2	9/16	5/8	7/8	1 1/8
4 to 6, excl	163.4 to 245.1, excl	3/8	7/16	1/2	1/2	9/16	9/16	5/8	3/4	7/8	7/8	1
6 to 8, excl	245.1 to 326.8, excl	7/16	1/2	1/2	5/8	11/16	3/4	7/8	7/8	1	1	1
8 to 10, excl	326.8 to 409.0, excl	1/2	1/2	5/8	11/16	3/4	13/16	7/8	15/16	1	1	1
10 to 12, excl	409.0 to 490.1, excl	1/2	5/8	3/4	13/16	7/8	15/16	1	1	1	1	1
12 to 15, excl	490.1 to 613.0, incl	5/8	3/4	13/16	7/8	15/16	1	1	1	1	1	...

SHELLS – INTERNAL PRESSURE VS EXTERNAL PRESSURE

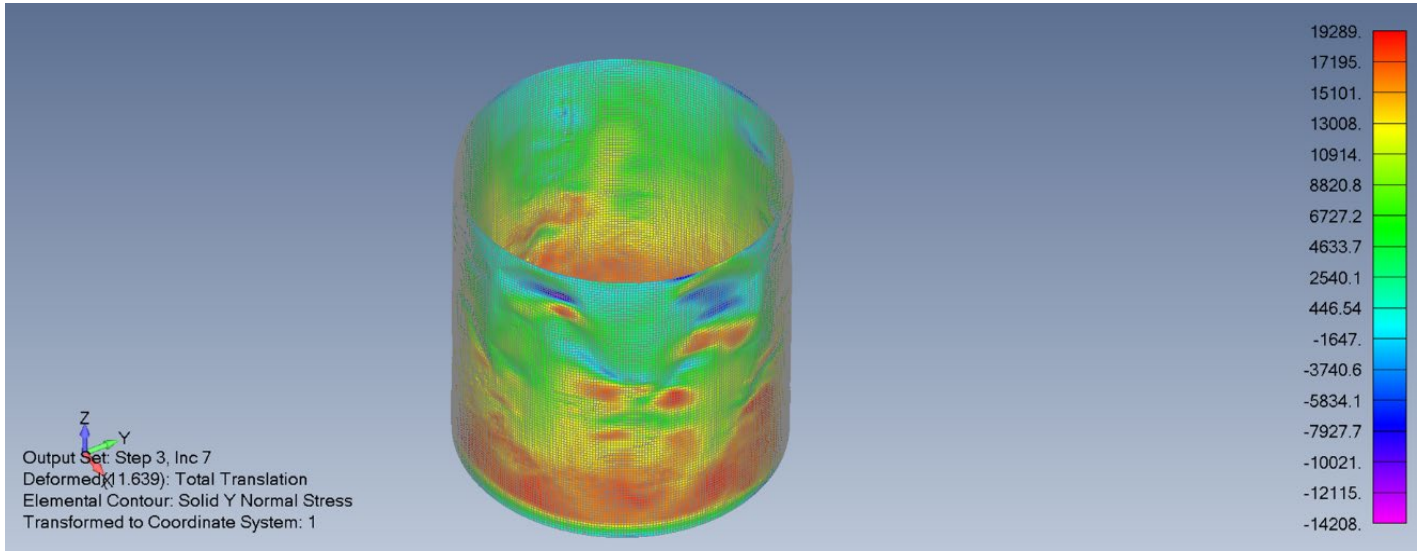




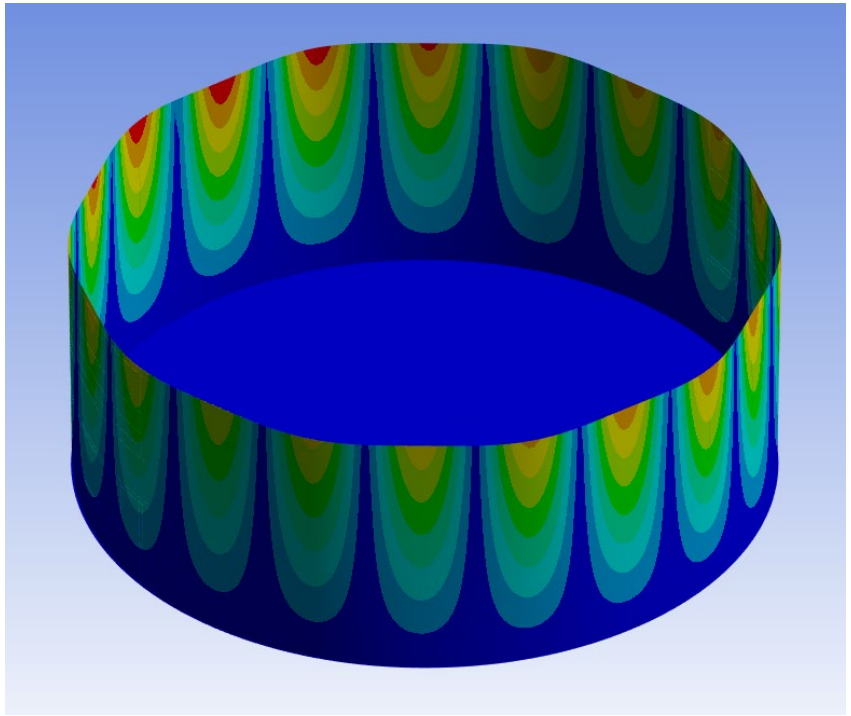


[external pressure design thickness calculation for pipe with an example – The piping talk]

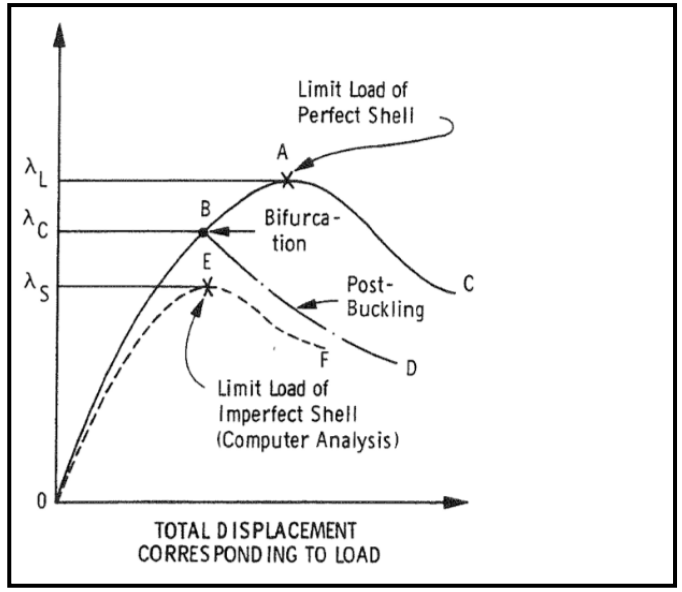
WHAT DO DENTS DO TO THE VESSELS?

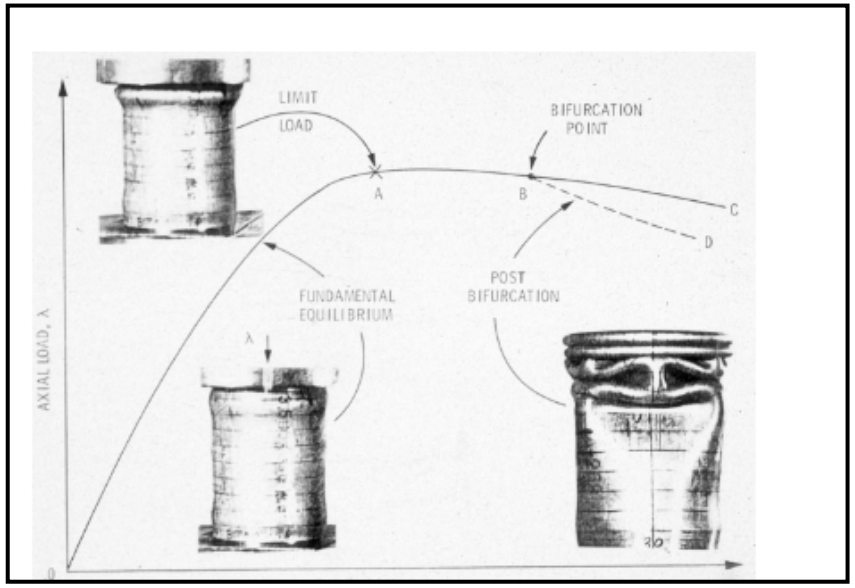


BUCKLING OF SHELLS UNDER EXTERNAL PRESSURE



SHELLS - Effect of imperfections on buckling capacity





Ref: https://shellbuckling.com/papers/bucklingcomments.pdf
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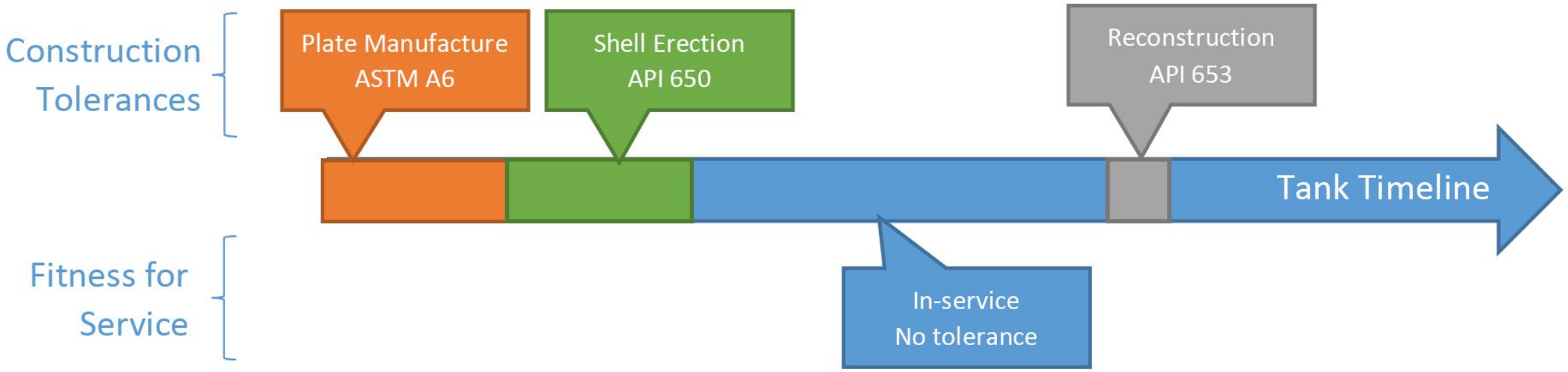
HOW DO YOU PREDICT BUCKLING CAPACITY

Crumpling Coke Cans
November 28, 2017• Physics 10, s131

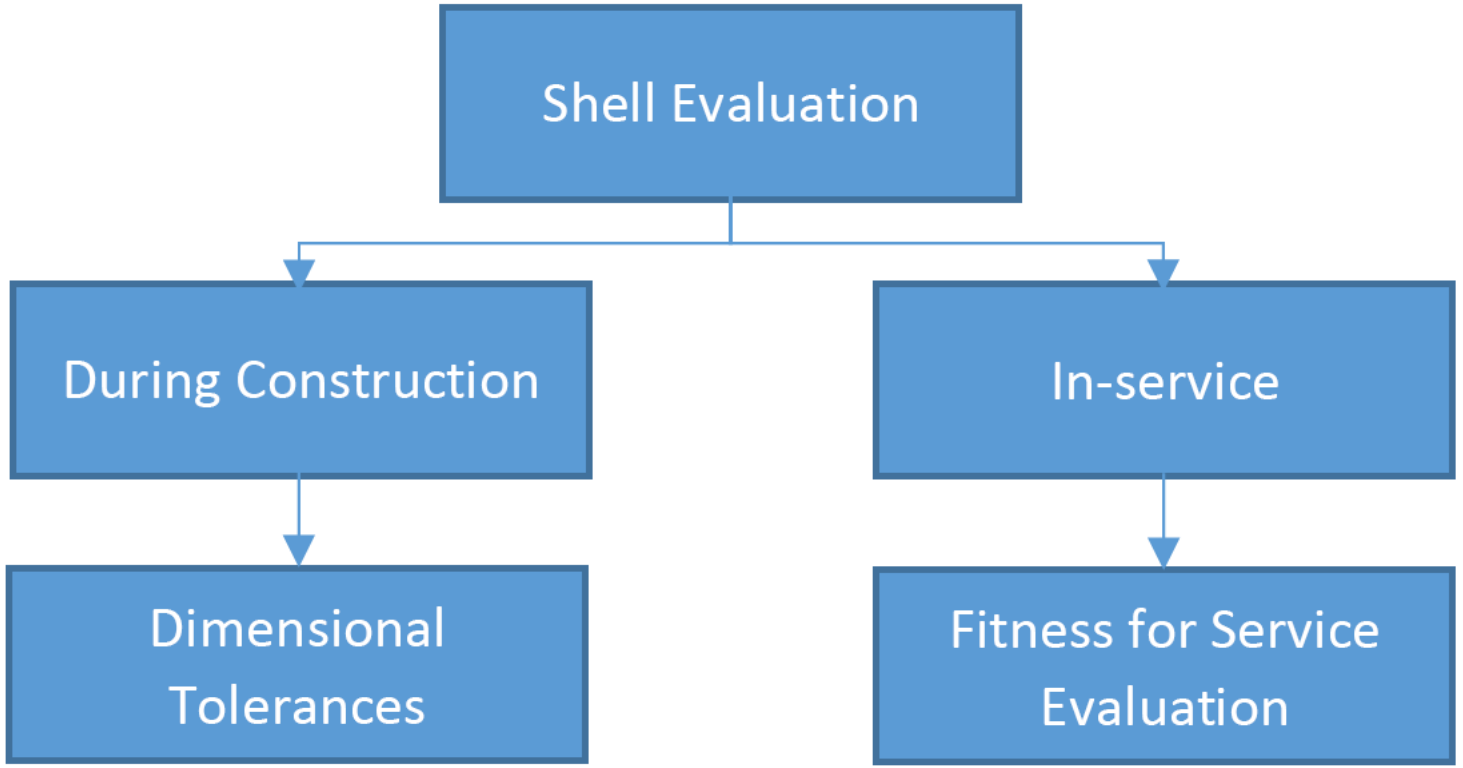
- $P_{CR} = P_{THEORETICAL} * \alpha * \eta$
- α = Geometric Reduction Factor
- η = Plasticity Reduction Factor

American Society of Mechanical Engineers (ASME). (2007). “Case N-284: Metal Containment Shell Buckling Design Methods, Class MC,” Code Cases: Nuclear Components, New York.

TANK TIMELINE



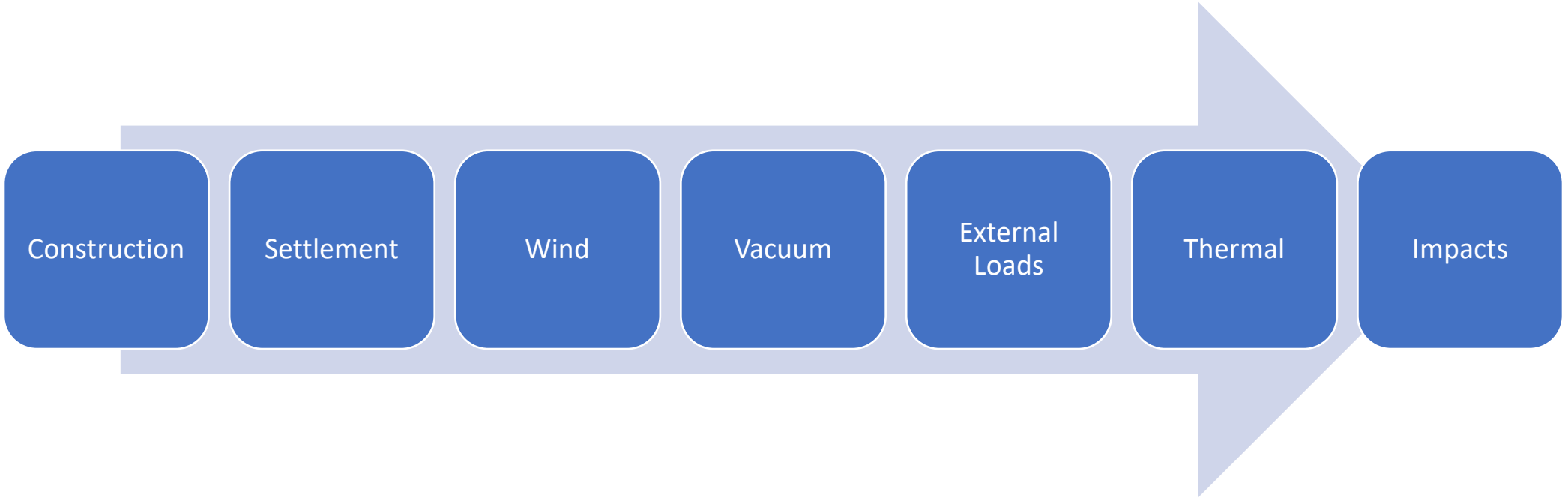
CONSTRUCTION V IN-SERVICE



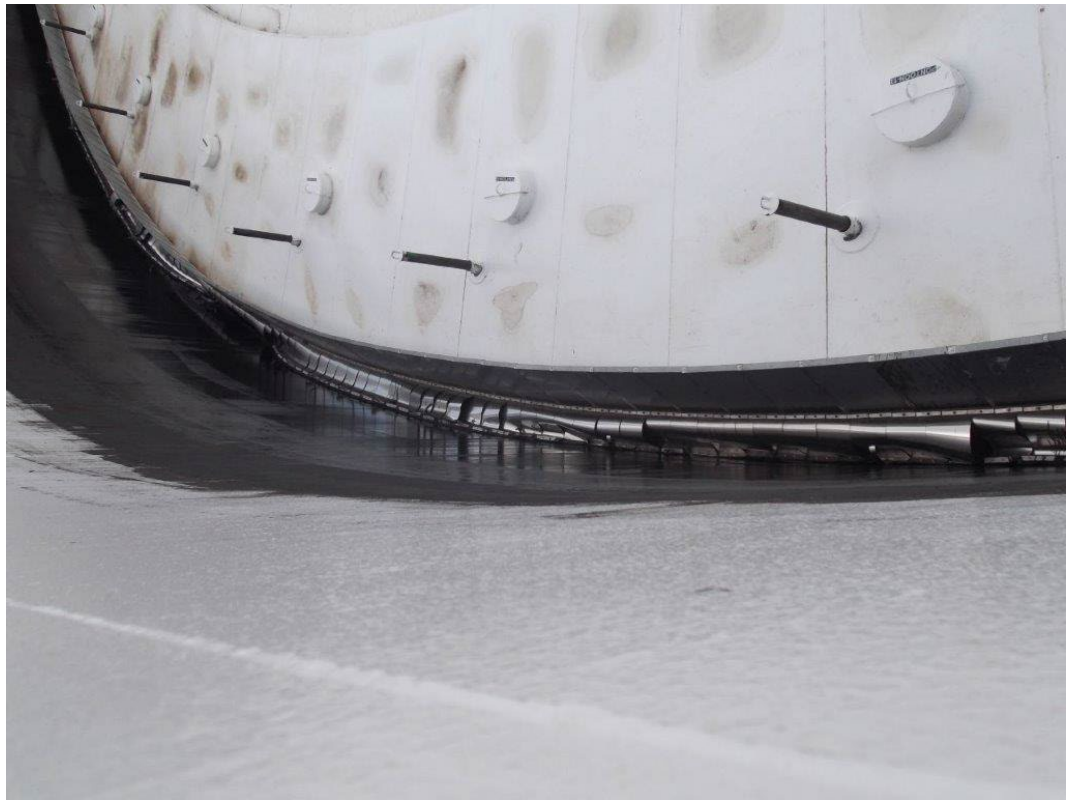
API 653 INSPECTIONS

- **4.3.5 Distortions**
- **4.3.5.1** Shell distortions include out-of-roundness, buckled areas, flat spots, and peaking and banding at welded joints.
- **4.3.5.2** Shell distortions can be caused by many conditions such as foundation settlement, over- or under-pressuring, high wind, poor shell fabrication, or repair techniques, and so forth.
- **4.3.5.3** Shell distortions shall be evaluated on an individual basis to determine if specific conditions are considered acceptable for continuing tank service and/or the extent of corrective action.

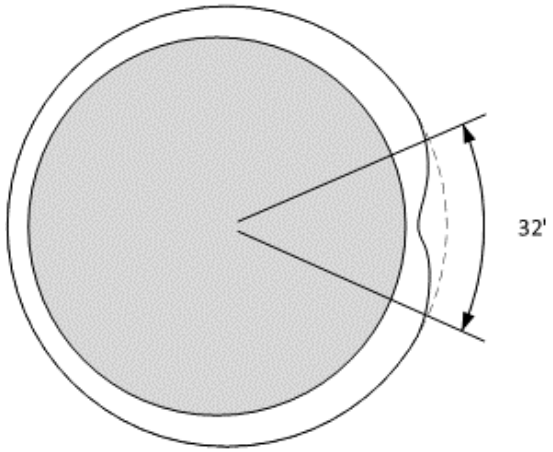
WHAT CAUSES SHELLS TO DISTORT

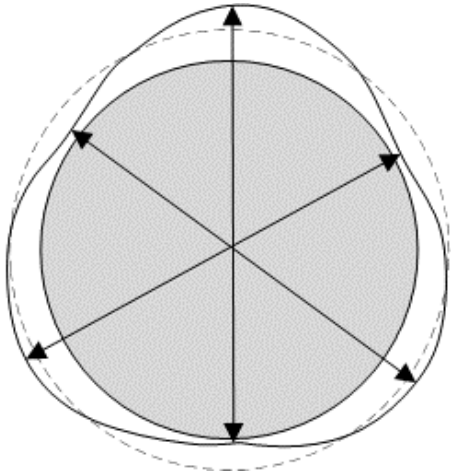


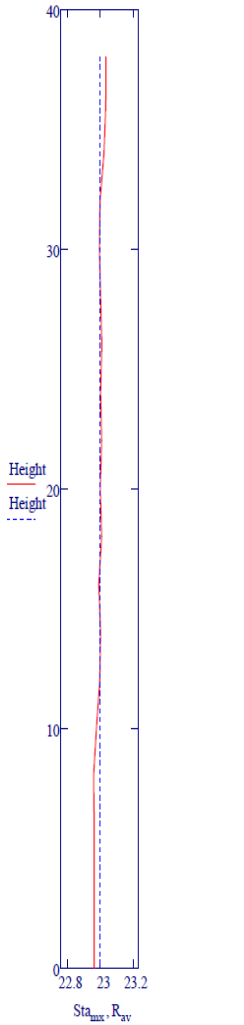
FUNCTIONAL EFFECT – SEAL FAILURES



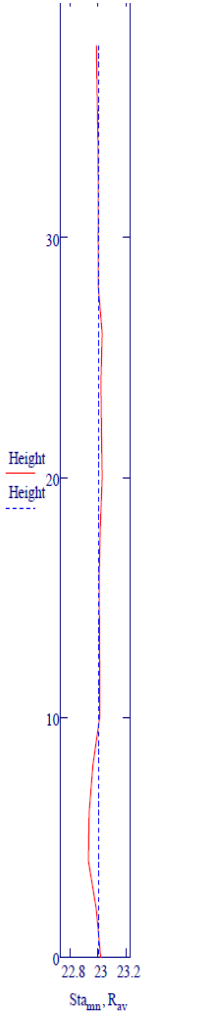
MEASUREMENT PROBLEMS







$S_{lmax} = 8.864 \cdot in$



$S_{lmin} = 6.956 \cdot in$

FUNCTIONAL EFFECT - SEISMICITY

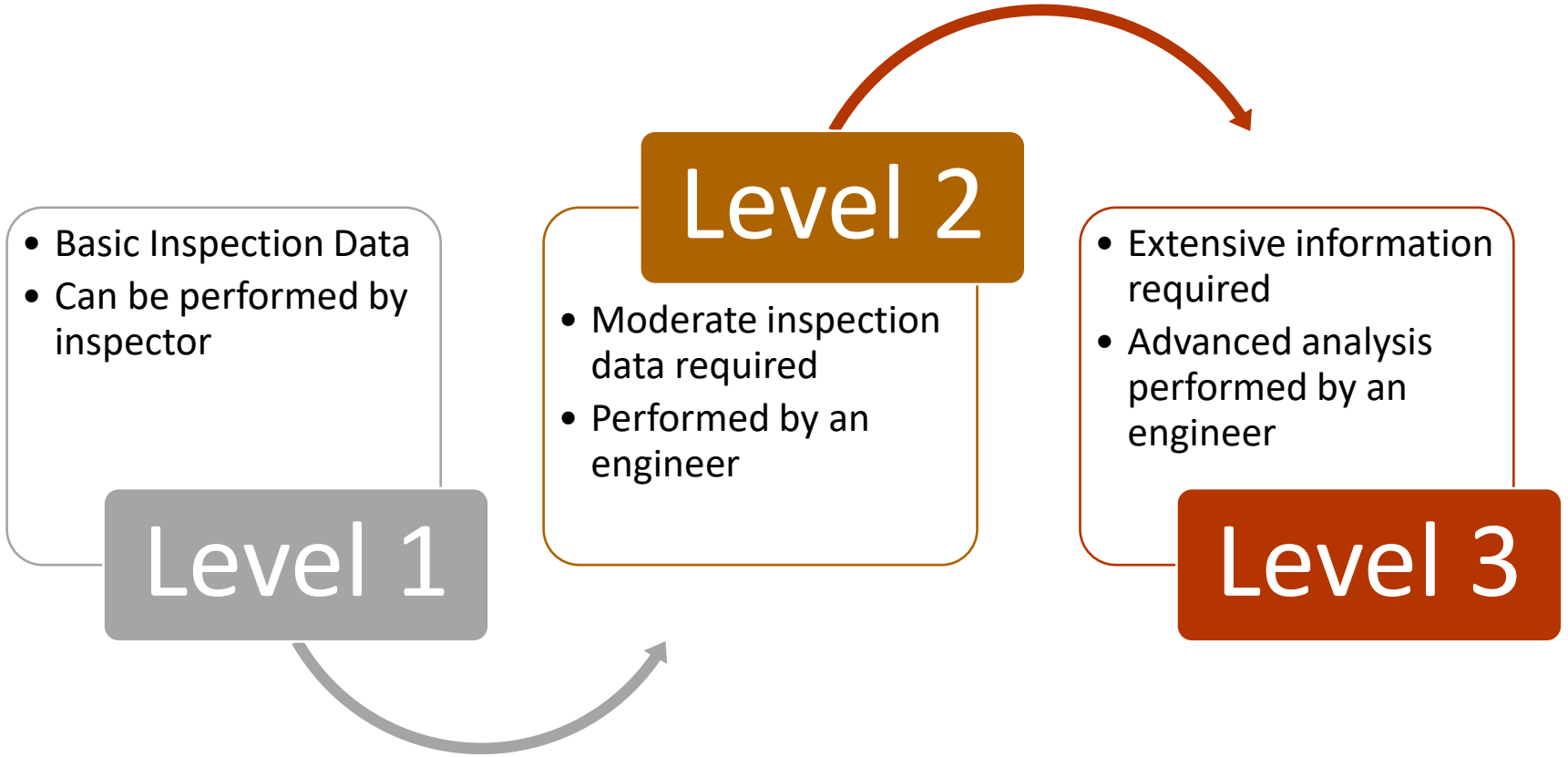
Shell Compression; Uplift

Hydrodynamic Hoop Stress

Lateral Stability

FITNESS FOR SERVICE ASSESSMENTS

ASSESSMENT OF EFFECTS BEYOND TOLERANCES

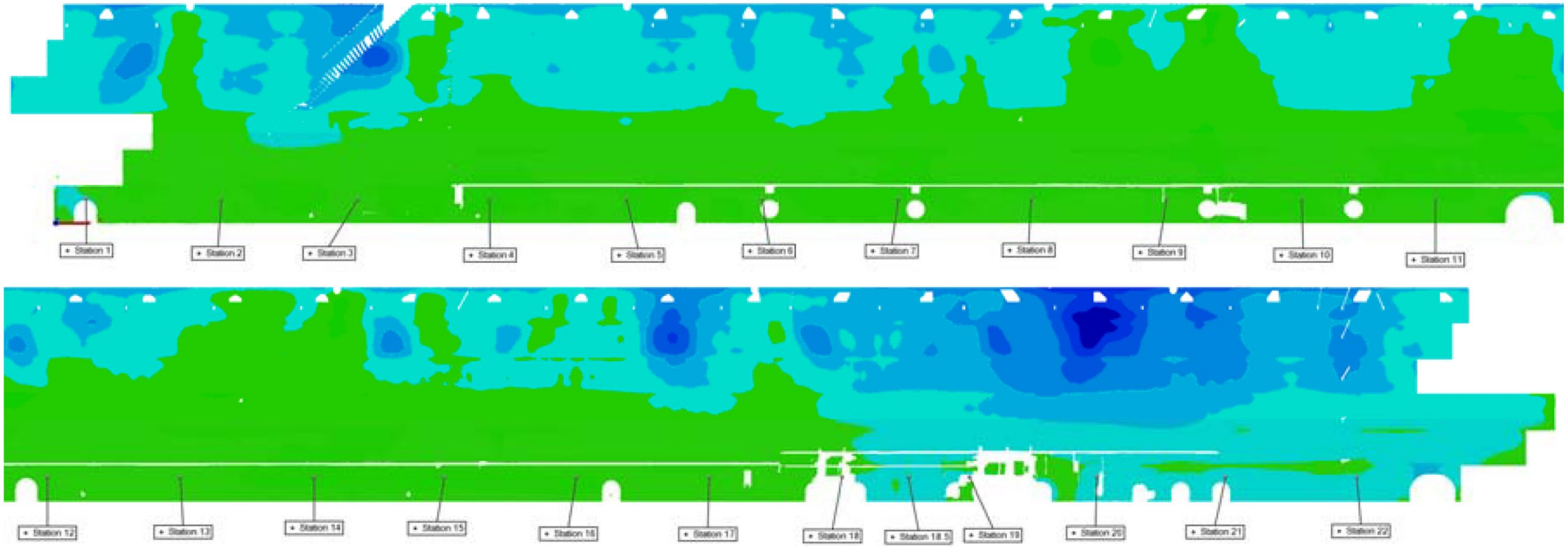


API RP 579-1/ASME FFS-1, " Fitness- for-Service (FFS)"

STANDARDS FOR WELDED STORAGE TANK REPAIRS

- API Standard 653 “Tank Inspection, Repair, Alteration, and Reconstruction”
  - Covers the maintenance, inspection, alteration and repair of steel, field-erected aboveground storage tanks (ASTs) built to API 650 or API 12C standards
  - API 653 9.2.3.4 To reduce the potential for distortion of an existing tank due to welding a replacement plate into an existing tank shell, fit-up, heat input, and welding sequence must be considered.
- API Standard 650,“Welded Tanks for Oil Storage”
  - Material Selection
  - Provides Nozzle details and elevations

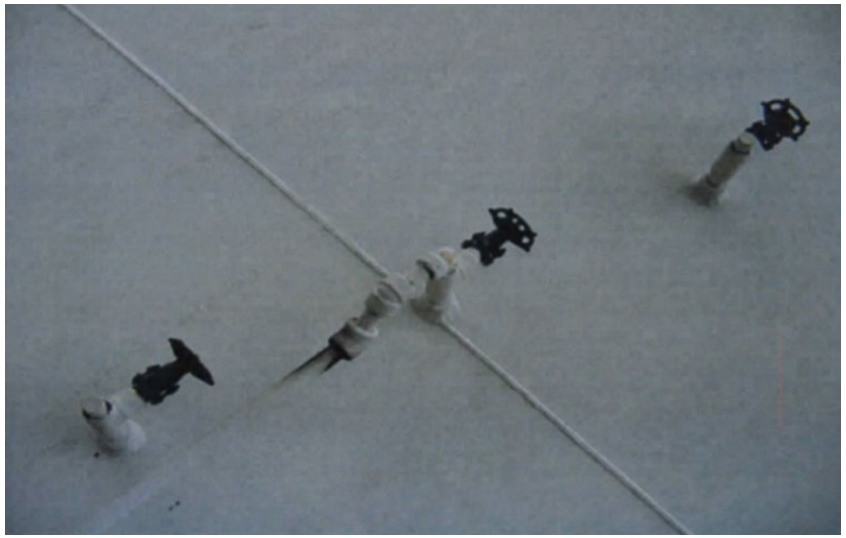
LASER SCAN MEASUREMENTS



SHELL DISTORTIONS

- Distortion from welded insert plate
- Coupling too close to weld seam
- Peaking and banding

Pic. 1 – Shell distortion at insert.

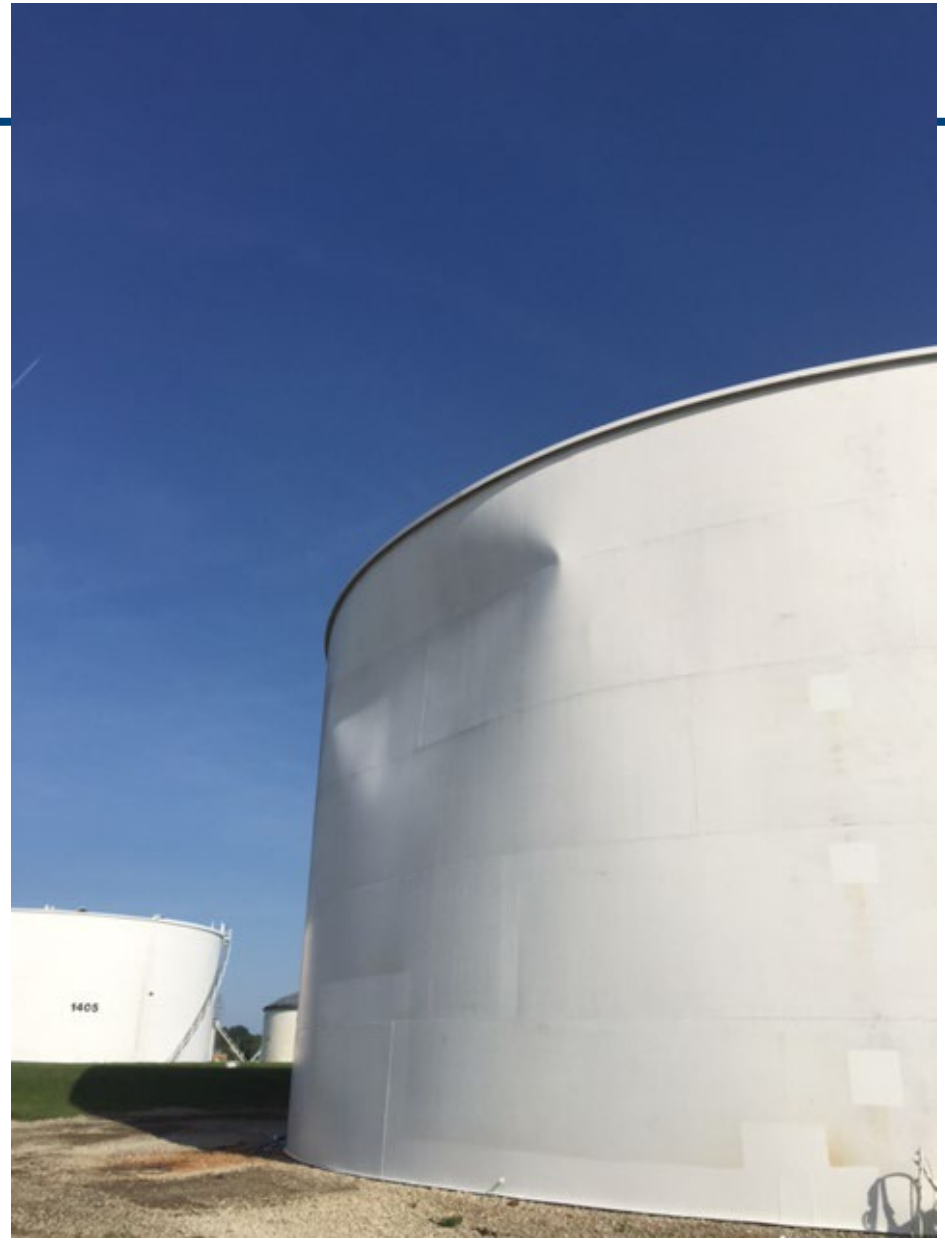


Coupling installed at a seam

Sweep board

SHELL BUCKLES

- Common Causes:
  - High Winds
  - Vent failure (vacuum)
  - (see video)



SHELL BUCKLE REPAIR

SHELL REPAIR : PARTIAL REPLACEMENT

EDGE SETTLEMENT

- Common Causes:
  - Foundation Issues
  - Poor site conditions

FOUNDATION REPAIR

New concrete ringwall foundation under existing tank

SUMMARY

- Tolerances are imposed by Codes and Standards
- Storage Tanks and Pressure Vessels Operating with distortions greater than code allowed will have issues both with the function and operation
- API 653 provides rules for Inspection Evaluation, Repair methods and NDE requirements
- Additional assessments can be performed using API 579 and other methods
- Assessment and repairs need to be performed in a logical manner