FE2:

IMPROVED DESIGN OF A FALLING-FILM TUBULAR EVAPORATOR

WITH MAINTENANCE-FRIENDLY NOVEL JUICE DISTRIBUTOR

Speaker

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BACKGROUND

- There are about 550 operating sugar factories in India, out of these, 70 are backend refineries and 6 are standalone refineries.

- Almost 40% sugar factories including sugar refineries are using falling film tubular evaporators with tube size 35/45 mm & tube length ranging 8.0 m to 12.0 m.

- Worldwide about 300 sugar factories and refineries are working with various design of falling film evaporators.

- Isgec has developed an improved design of falling film evaporator with a Novel juice distributor.

BACKGROUND

- We all know that juice distributor is the most important part of FFE. A faulty design can be a disaster, leading to chocking of tubes due to caramelisation of sugar, which is a huge sugar & efficiency loss.

This presentation gives details of the novel juice distributor, that is the one of its kind design, which provides 100% distribution of juice in tubes and also takes care of maintainability by providing sufficient head room between top tube sheet and juice distributor.

OBJECTIVE OF THE STUDY

- To develop a reliable and maintenance friendly juice distributor for falling film tubular evaporator.

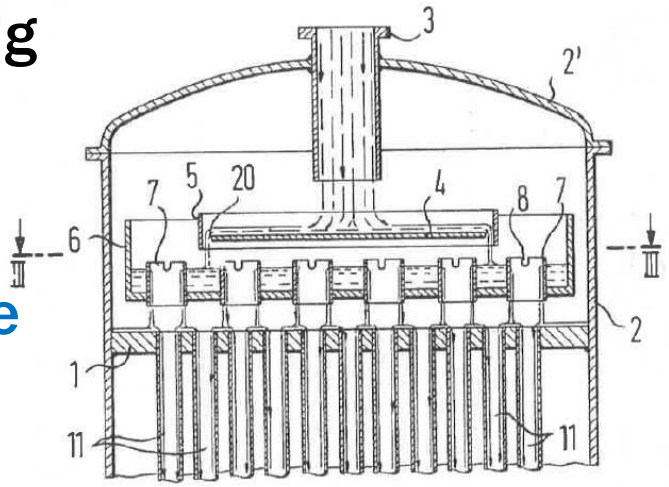
- To develop sturdy, reliable and thermally stable design of long tube falling film evaporator vessel.

CONVENTIONAL DISTRIBUTOR

DRAWBACKS

- Conventional distributors are prone to tube choking due to uneven distribution of juice.

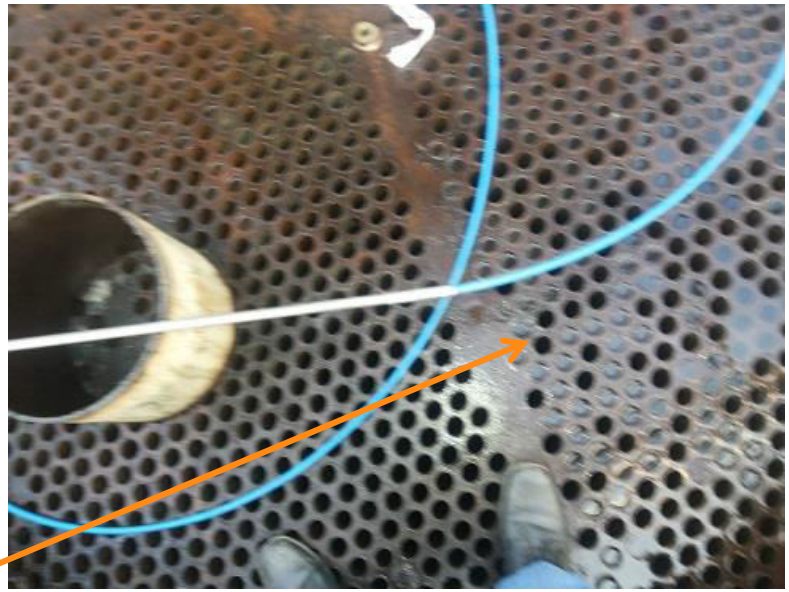
- Absence of head-room between top tube sheet and juice distributor, necessitates its dismantling for mechanical de-scaling of tubes



Hence there has been a need for a reliable and maintenance friendly new juice distributor.

CONVENTIONAL DISTRIBUTOR

TUBE CHOCKING



Chocked Tubes

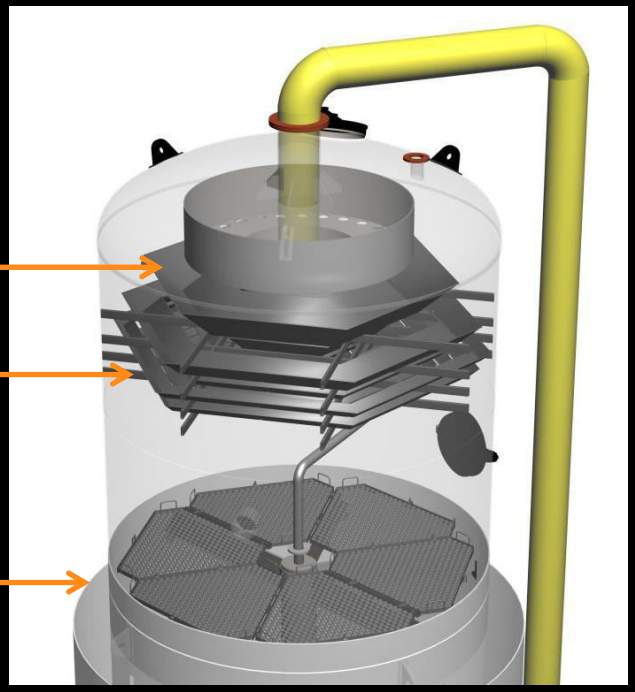
NOVEL JUICE DISTRIBUTOR

NOVEL JUICE DISTRIBUTOR:
INTERNAL 3D VIEW

Inlet weir box

Cascade distributor

Segmented tray plate

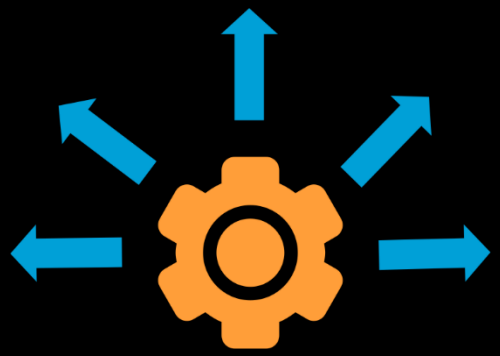


Click for video

NOVEL JUICE DISTRIBUTOR: FEATURES

- 5-stage cascading system that forms a uniform shower of juice across the entire cross section

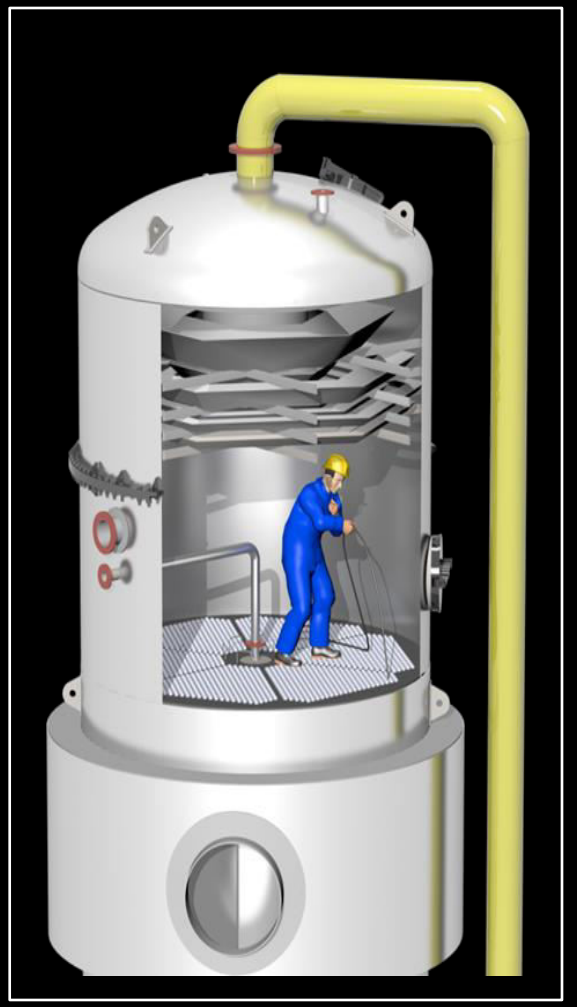
- Segmented tray plate with individual tripod umbrellas located over each tube. These prevent short circuiting and also ensure equal and uniform wetting of each and every tube.



NOVEL JUICE DISTRIBUTOR:

FEATURES

- Design vetting rate: 20-22 l/cm-h
- Laser assisted leveling of top of the tubes to ensure equitable distribution of juice into the tubes.
- 2 m head room over top tube sheet for easy maintenance/cleaning.
- Foldable segmented tray plate, bolted to tube sheet for quick access to tubes.



Several falling film evaporators with this distributor are in successful operation in various sugar mills around the Globe.

INSTALLATIONS OF FFE

NOVEL JUICE DISTRIBUTOR

Sugar plant capacity : 5400 TCD

Location : AgroImos, Peru

Configuration : Quintuple

HSA of FFE : m^2 3500/3500/
3500/1200/800
with 1 spare of each size

INSTALLATIONS OF FFE

NOVEL JUICE DISTRIBUTOR

Sugar plant capacity: 12000 TCD

Location: Jawahar SSK, India

HSA of FFE : 2 x 6000 m2

(The largest FFE in India)

INSTALLATIONS OF FFE

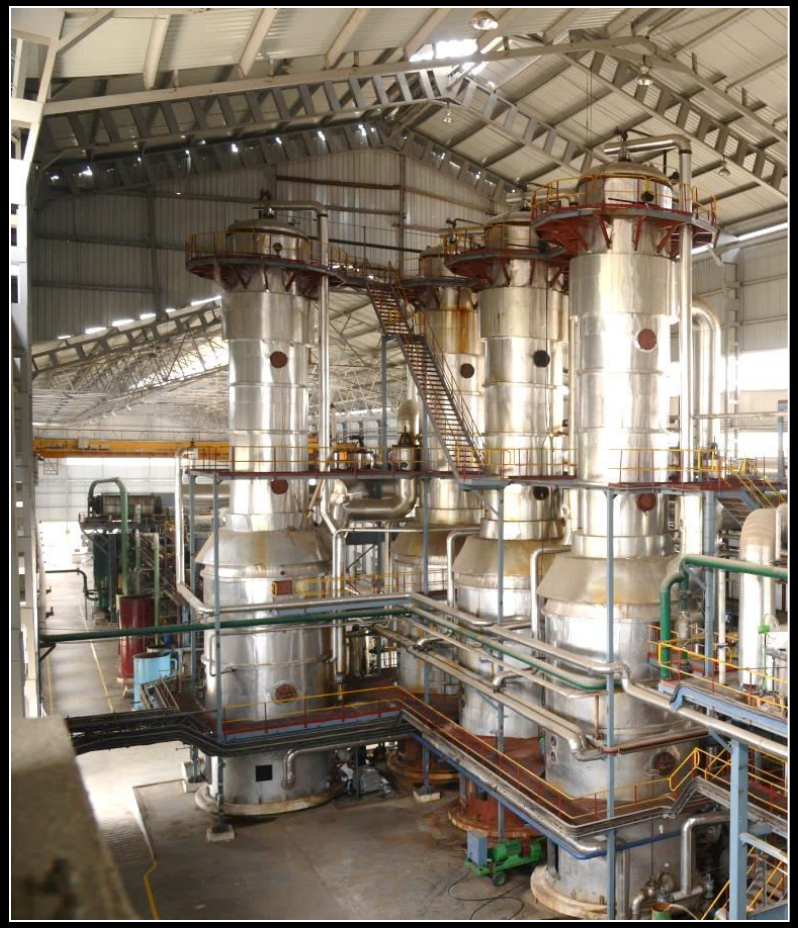
NOVEL JUICE DISTRIBUTOR

Sugar plant capacity: 5500 TCD

Location: Sar Senapati Santaji Ghorpade Sugar Factory, India

HSA of FFE: 3000 m2

INSTALLATIONS OF FFE



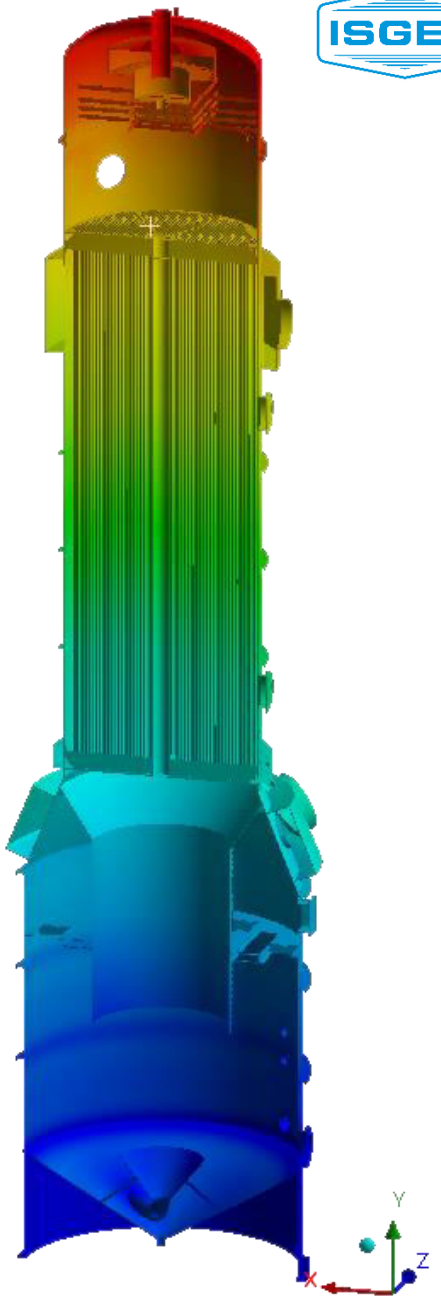
Sugar plant capacity: 6000 TCD

Location: KPR sugar, India

HSA of FFE: 4 x 3000 m2

DEVELOPMENT OF A THERMALLY STABLE DESIGN

OF FALLING FILM TUBULAR EVAPORATE



THERMAL STABILITY:
BACKGROUND

Falling film evaporator generally comprise of carbon steel calandria fitted with 10 /12 m long austenitic grade SS 304 or ferritic grade SS 439 tubes.

- Coeff. of linear expansion of SS 304 is 1.43 times that of carbon steel resulting in higher thermal stresses, particularly at temp. 100-120^{0}C.

- Coefficient of linear expansion of SS 439 is 0.87 times that of carbon steel and hence the thermal stress are much lower even at temp. 100-120^{0}C

PROPERTIES OF SS TUBES BODY

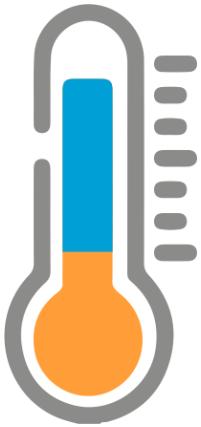
Parameters	Unit	SS439 tubes	SS304 tubes	Carbon steel vessel
Fabrication Procedure		Laser welded	Electric resistance welded	Arc welded
Type of steel		Ferritic	Austenitic	Ferritic
UTS	MPa	450	586	410
0.2 % YS	Mpa	370	350	250
Coeff. of linear expansion	μ/m/°K	9.8	16.1	11.3

- SS439 has higher yield strength & thermal conductivity Vs SS 304
- SS439 requires laser welding for tubes
- SS304 can be easily manufactured by electric resistance welding.

THERMAL STRESS

ANALYSIS: ASSUMPTIONS

- The 1st effect of evaporator is subjected to the highest thermal and pressure loading so we selected 1st effect with 10 m long, 45 mm dia tubes for study.
- Solid works software version 2016 and ANSYS Workbench R15 software were used for the 3D modeling and thermal stress analysis, respectively.
- The assembly is constrained (fixed) at bottom support skirt. The pressure and temperature were applied simultaneously in full body
- Thermal stress analysis is carried out for 2 grades of SS tubes i.e. 439 and 304, fitted in carbon steel calandria without expansion joints in the calandria shell.



THERMAL STRESS ANALYSIS: OPERATING PARAMETER

- Tube side pressure 2.2 bar (a) and temp. 115°C
- Shell side pressure 2.8 bar (a) and temp. 130°C
- Ambient temp. 30°C

THERMAL STRESS ANALYSIS:

DETAIL OF ITERATIONS

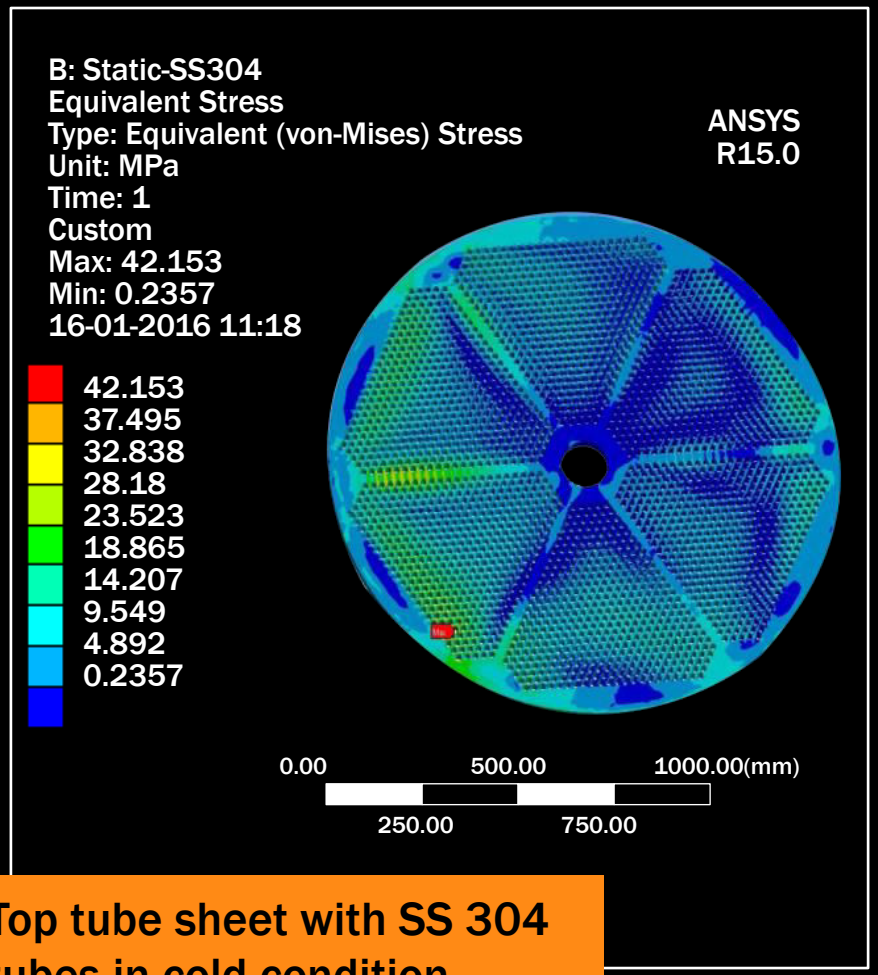
Three iterations were done for FEA of falling film evap.

- Assembly with tubes at the time of hydro test
- Assembly with 304 tubes at operating parameter
- Assembly with 439 tubes at operating parameter

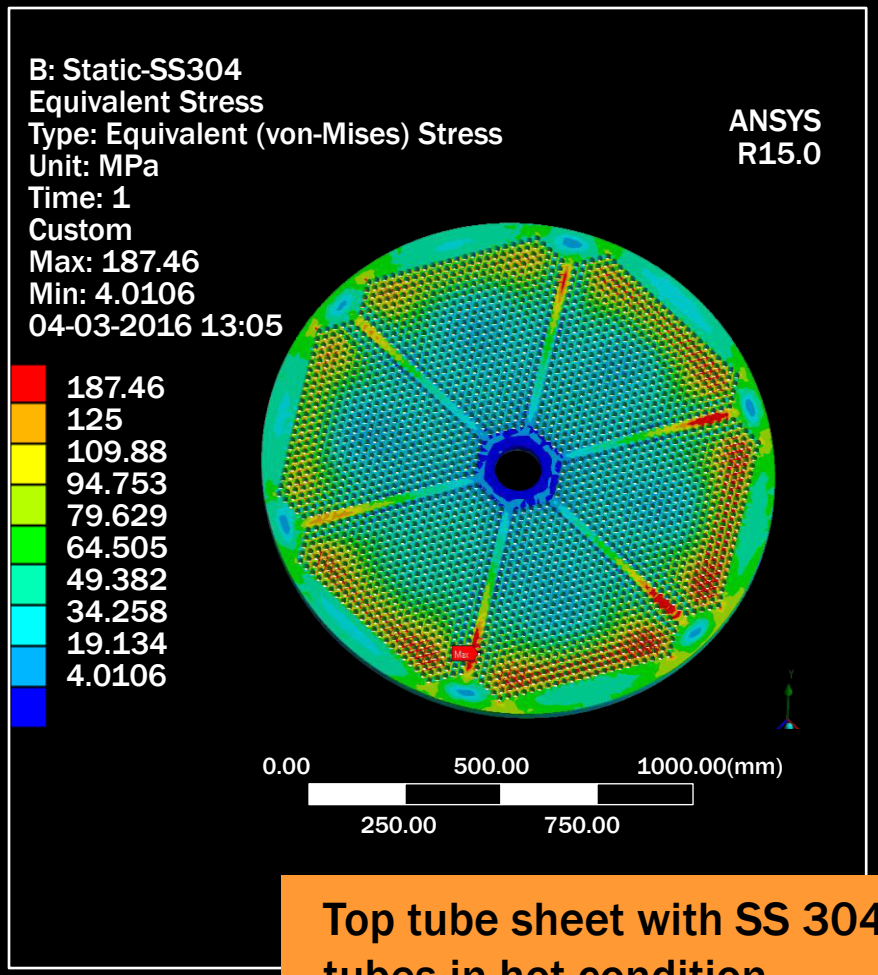
Outputs of stress values and deflection pattern in respect of following are shown in subsequent slides

- Top tube sheet
- Tube bundle
- Complete assembly of the evaporator vessel

THERMAL STRESS ANALYSIS : TUBE PLATE

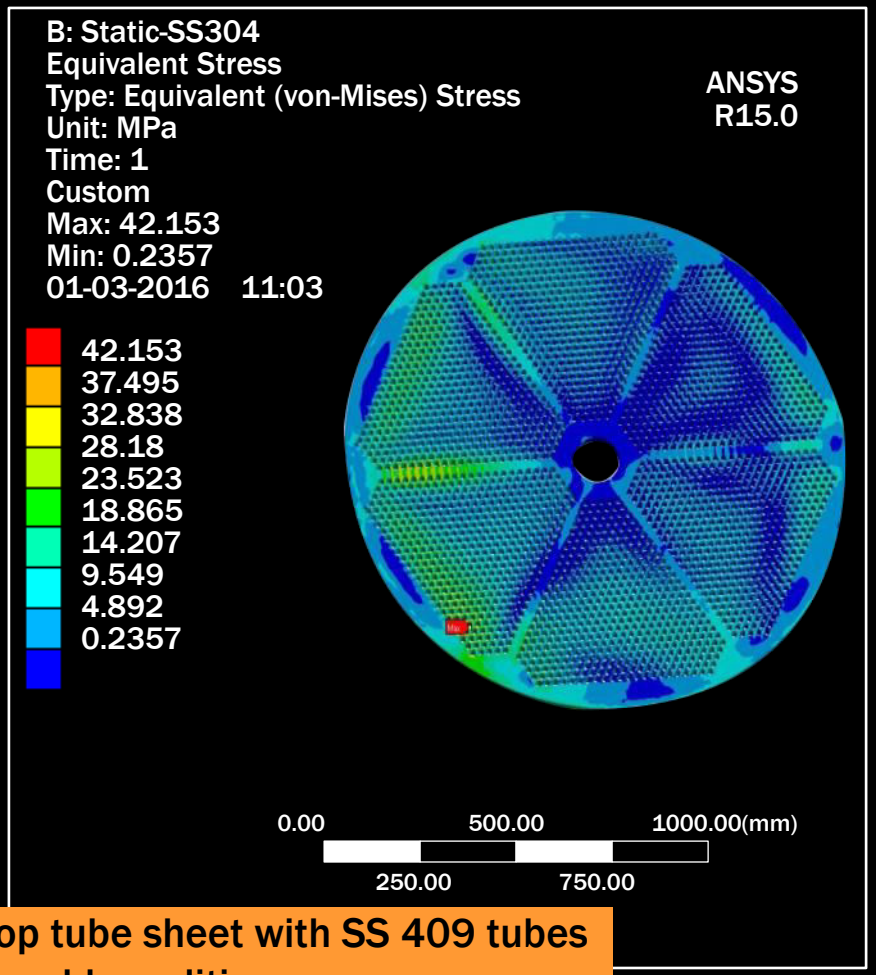


Top tube sheet with SS 304 tubes in cold condition

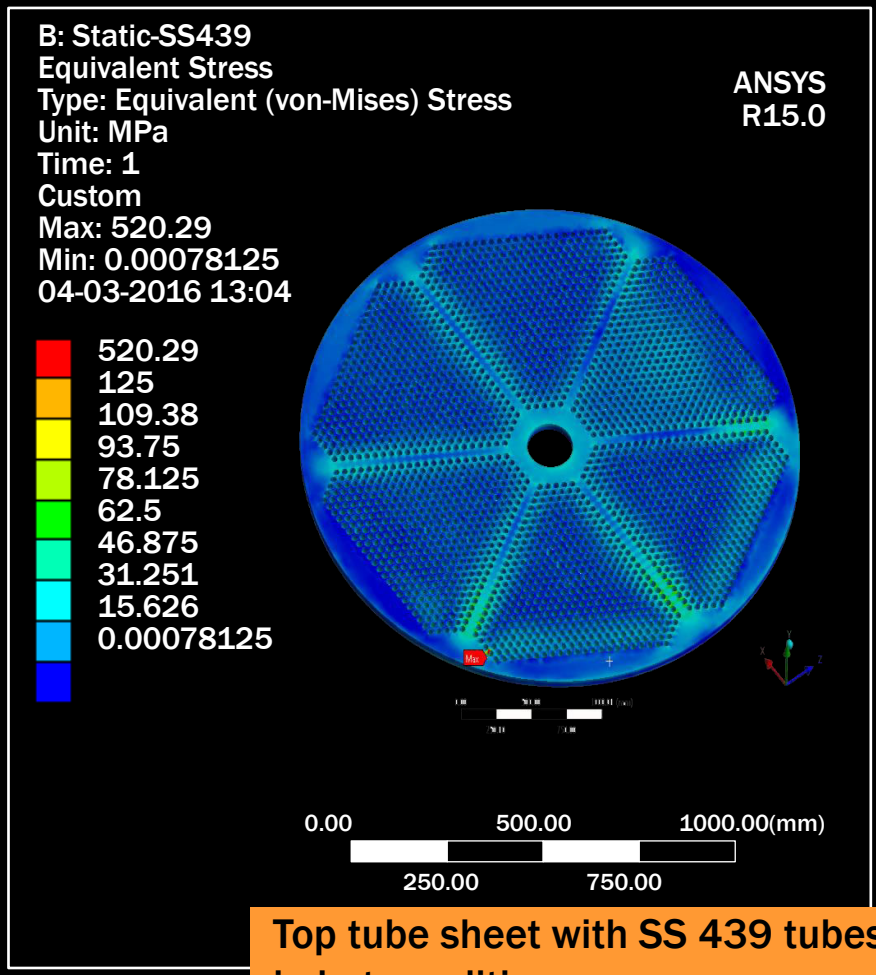


Top tube sheet with SS 304 tubes in hot condition

THERMAL STRESS
ANALYSIS : TUBE PLATE



Top tube sheet with SS 409 tubes in cold condition



Top tube sheet with SS 439 tubes in hot condition

THERMAL STRESS ANALYSIS: TUBE PLATE

- At cold condition i.e. hydro test, stress in top tube sheet is only 35-40 Mpa.

- Once the FFTE vessel is subjected to the operating temperature conditions, the stress level in the tube sheets increases substantially due to the difference in the coefficient of linear expansion between the calandria and the tubes.

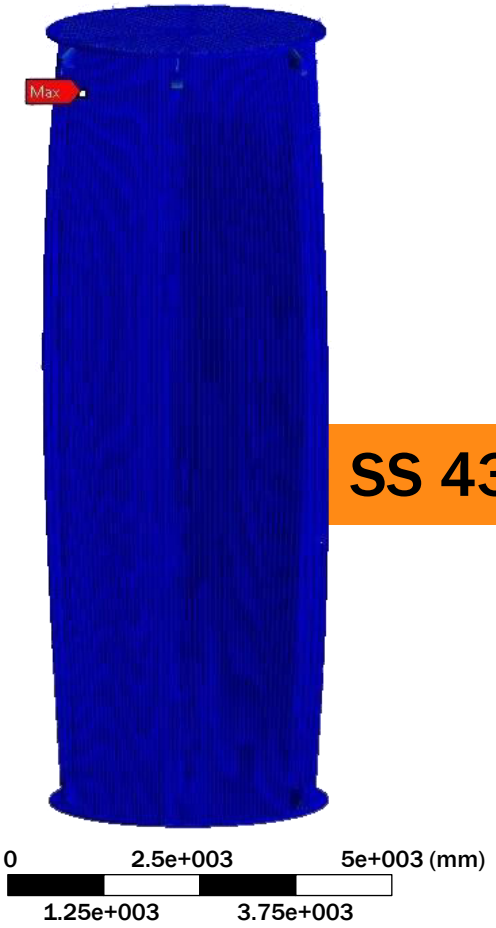
- At the operating pressure and temperature conditions, the top tube sheet (assembled with SS 304 tubes) develops a stress level of 130-150 MPa, which decreases to 100-120 MPa for tube sheet (assembled with SS 439 tubes).

THERMAL STRESS

ANALYSIS : TUBE BUNDLE

Deflection of tube bundle at operating parameter

SS 304



SS 439

THERMAL STRESS

ANALYSIS : TUBE BUNDLE

- For the SS 304 tube bundle, all the tubes have buckled-in to cater the relatively lower expansion of carbon steel calandria shell.

- However, for the SS 439 tube bundle, the tube sheets have sagged inwards marginally and the outer periphery tubes have followed the shell expansion.

- At the hydro-test condition, the stress in the tubes is only 6-12 MPa. At the operating conditions, SS 304 tubes develop a stress of 65-130 MPa, which decreases to 30-50 MPa if the tubes are SS 439.

THERMAL STRESS

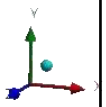
ANALYSIS : ASSEMBLY

Stress/deflection of assly at operating parameter

B: Static-SS439
Equivalent Stress
Type: Equivalent (von-Mises) Stress
Unit: MPa
Time: 1
Custom
Max: 235.29
Min: 0.00078125
04-03-2016 13:04

235.29
125
109.38
93.75
78.125
62.5
46.875
31.251
15.626
0.00078125

ANSYS
R15.0



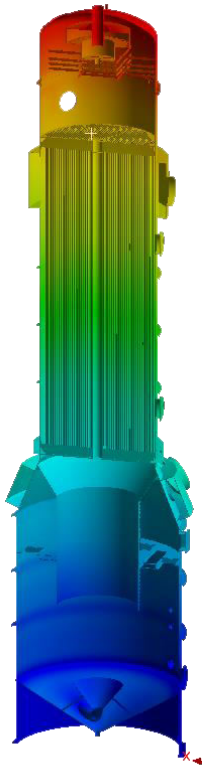
0 9e + 003 (mm)
4.5e +003

Stress pattern: SS 439

C: Static – SS739
Total Deformation
Unit: mm
Time: 1
Custom
Max: 27.24
Min: 0
04-03-2016 12:48

27.24
24.213
21.187
18.16
15.133
12.107
9.0799
6.0533
3.0266
0

ANSYS
R15.0



0 4e + 003 (mm)
2e +003

Deflection pattern: SS 439

SUMMARY OF FEA RESULTS

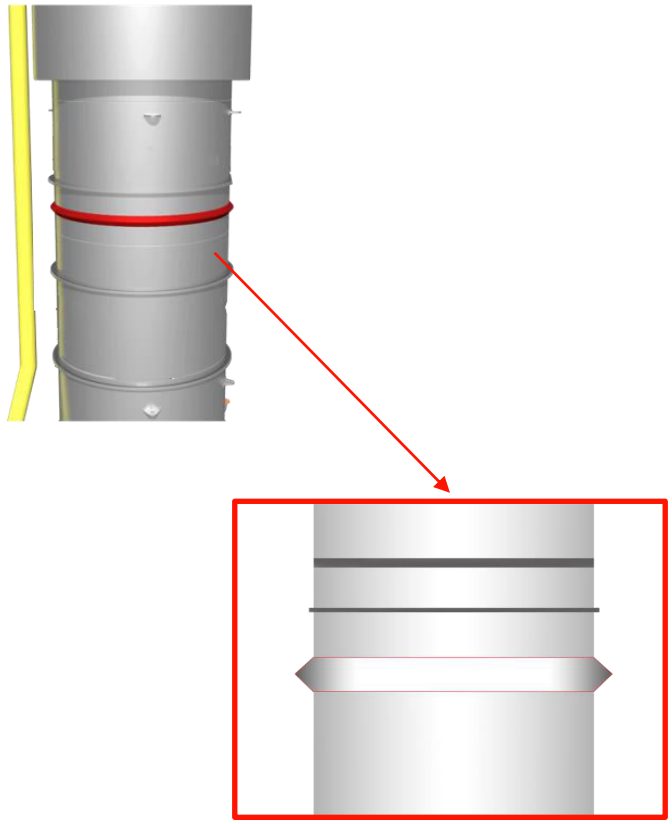
Description	Unit	Iteration-1 Hydro test	Iteration-2 SS 304 tube	Iteration-3 SS 439 tube
Max. stress in top tube sheet	MPa	35-40	130-150	100-120
Max. stress in SS tubes	Mpa	6-12	65-130	30-50
Max. stress in Evap. Body	Mpa	90-100	165-175*	140-150

*Study shows that at operating parameters, use of 304 tubes results in stress level higher than desired 1.5 to 1.6 safety factor and hence requires corrective action in design.

DESIGN IMPROVEMENT
FOR FFE WITH SS304 TUBE

- Sugar mills in most of countries prefer SS304 tubes because of easy availability from local supplier.

- For such requirement, we have improved the design of the carbon steel calandria by incorporating an expansion joint, to reduce the thermal stresses arising out of vastly dissimilar linear expansions between tubes and calandria.



INSTALLATIONS WITH SS 439 FERRITIC TUBES

Sugar plant capacity: 24000 TCD

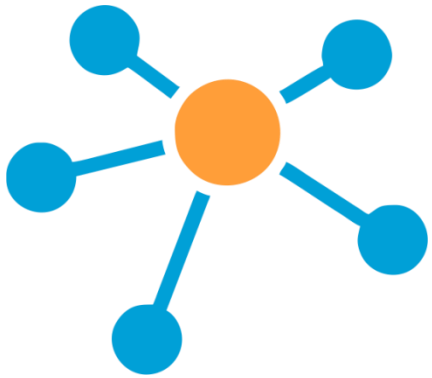
Location: WNSC, Sudan

Configuration: 5 quintuple sets

HSA of FFE: m^2 3340/1200

CONCLUSION: NOVEL JUICE DISTRIBUTOR

- Ensures uniform wetting of each and every tube.
- The cascade juice distributor, once assembled inside the FFE vessel, need not be disturbed or dismantled even during the off-season.
- As there is no need to dismantle the juice distributor, this facilitates faster mechanical de-scaling during the crop.



CONCLUSION: THERMALLY STABLE DESIGN

- The tubes and the tube sheets of a falling film evaporator fitted with SS 439 tubes, are subjected to 25% lower stresses.

- Falling film evaporators with SS 439 tubes installed in a green field 24,000 TCD sugar plant in Sudan, have completed 4 crushing seasons without any tube failure or structural deformity.

- Falling film evaporators with SS304 tubes and expansion joint in carbon steel calandria shell, are also working satisfactorily in several installations.

- FFE with SS304 calandria as well as tubes for sugar refineries, have no problem of thermal stress. Such FFE are working in a sugar refinery in Mexico supplied by ISGEC.

Click for video

Thank You

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