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# Crack Control and Rectification in Spray Powder Separator

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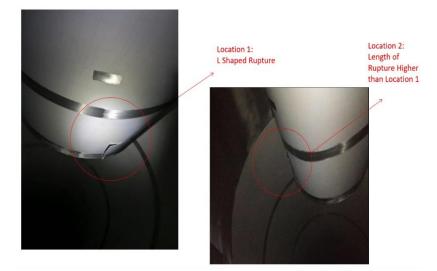
**ABSTRACT:** A gas-solid cyclone separator is a separation device that separates solid particles from a gas phase using a centrifugal force field. In traditional spray drying a cyclone separator is often included in a succeeding separation step, after a spray drying chamber. This thesis a study and analyzing crack propagation in Cyclone Insert cone, it includes brainstorming, collection of data, finding solutions by verification of parameters, material & FEM.

**KEYWORDS**: Spray Drying, Powder separation, cracks in process equipment's, cyclone, Material Testing, Autodesk Inventor, Fatigue analysis, Static Analysis, CFD output, ANSYS WORKBENCH

#### I. INTRODUCTION

Cyclone separators are used in food powder manufacturing industries to separate solid particles by cyclonic effect. There are change in velocities and pressure at inlet and outlet of cyclones and Air in with fine powder form cyclonic effect and move outward from small opening cone called Insert cone which gives change in velocity.

Here we are studying & analyzing various reasons for crack propagation on Cyclone separator Insert cone.



#### Figure 1: Crack on cyclone insert cone.

- 1. Particles hit the wall of the cyclone, decelerate, and separate from the air stream.
- 2. Particles fall under gravity towards catch-pot at the base of the cyclone.
- 3. Clean air passes to extraction source.
- 4. Captured particles in the catch-pot are removed for batch loss reconciliation, disposal, or reintroduction to the process (subject to QA and validation).

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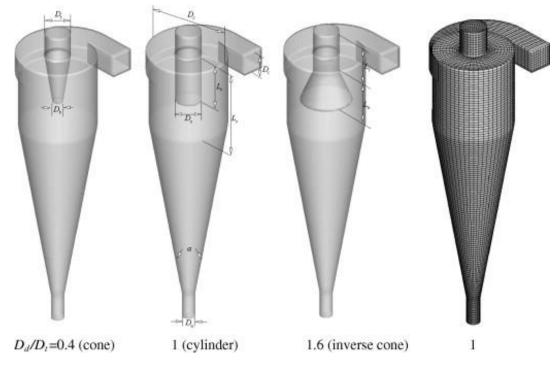


Figure 2: Various types in Cyclone

Purpose The purpose for this thesis is to investigate how spray drying is possible in cyclone separators. The changes of pressures Involved, Material study, Factors involved at time of production at customer site, FEM Analysis

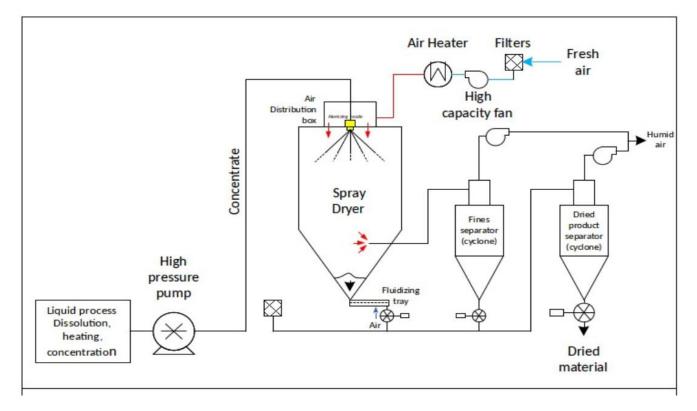


Figure 3: Working principle of Spray drying with Process flow diagram

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The following drawing is a simplified flowsheet of a common spray drying process with co-current air / product flow in the spray dryer chamber and open-air cycle. There are more complicated and performant spray drying technologies, but the representation below somehow constitutes a minimum for an industrial line. Independently of the degree of complexity of the factory, the spray drying process is made of 5 main steps described thereafter.

Here various process are involved such as;

- 1. Wet Process
- 2. Atomization
- 3. Drying
- 4. Solid separation

Here as we are going to analyze Separator lets concentrate on that.

#### Separation

Industrial spray dryers can reach several tons / h and have typically large drying chambers and several nozzles. However, there is also on the market laboratory spray dryers (mini spray dryers) that are very useful for research work, or simply to get a 1st idea of a product and its easiness of drying before scaling up to the industrial line.

## **II. PROBLEM STATEMENT & BRAIN STORMING**

 Crack in Insert cone. – When? What? How? When these cracks observed? What must be reason? What parameters to be check? How to analyze?

2. Parameters such as Pressure difference between Inlet and outlet of cyclone, Temperature need to be verified.

3. Brainstorming with technical team at site, Internal technical team, Quality team and design team performed, and various possibilities are generated, and action will be taken.

## **Results OF Brainstorming**

- Focus of study will be to study and analyses the reason for cracks and how it can be optimized. These can be divided on following ways.
- Data for operating parameters; Pressure, Temperature etc.
- Study on data for any shocks observed.
- Testing material.
- Is dried product is corrosive?
- If all above stages are ok, then focus on;

# III. FEM ANALYSIS WITH RESPECT TO OPERATIONAL DATA AND CFD INPUTS

CFD Analysis will be performed by CFD team & FEM Analysis will be done by me. Upon solution achievement; fabrication methods at site.

# **IV. OPERATING PARAMETERS**

#### Data for operating parameters; Pressure, Temperature etc.

As mentioned in Manufacturing process Chapter. Pressure drop across cyclone is between 1000 to 2000 Pa. Mostly cyclones are calculated using design parameters which are above operational parameters. Design Temp; 120- 150 DegC\*\* Pressure Shock Approx. 0.2 to 0.5 Bar\*\* Vacuum. 1500 Pa\*\* Pressure difference between Inlet and outlet depending on type of product. | ISSN: 2582-7219 | www.ijmrset.com | Impact Factor: 7.521 | Monthly Peer Reviewed & Referred Journal |



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Against above standard data; Verification has been done for component in operation. At check point it seems correct values, but real time analysis to be performed when crack is observed. For real time analysis, I made a checklist to discuss with peoples involved on verification of parameters to understand how crack was detected, time and change in parameters observed.

# Study on data for any shocks observed Recent Article from Bharti Vidyapeeth Technology, Mumbai on crack propagation & Process study from K. Masters Handbook.

Any defect or crack on the surface of process equipment like pressure vessel can lead to a fatal accident during operation, so it needs to be crack analysis. The present work has done to review the methods and techniques to analyze the process equipment like pressure vessel. Hence procedure could be developed to analyze or to test process equipment like pressure vessel based on operating parameters by using techniques like SIFs by validate the results with the FEA results.

## From discussion and brainstorming with inside stake holders of my company.

As our components are designed as per process parameters and validated with FEA analysis. It was time to study different approach for parameter which cause a crack. Crack in any process equipment can occur if process parameter goes beyond design parameters, Sudden shock waves, large pressure differences. Crack can occur also, if material selection is incorrect or used material is not as per requirement which may corrode if not stainless steel.

#### Testing material.

Chemical and Mechanical test has been performed for fractured material. Test report snaps are shown in fellow figures,

Our Reference: Z-12986			
	Test Certificate		Page 1 of
COMPANY NAME :	Your Reference		
SATYAM FABRICATORS PLOT NO-177/3.NO-7, PCNTDA BHOSARI	Your Reference Our Receipt Dat		/01/2022
PLOT NO-17773.NO-7, PCNTDA BHOSARI PCNTDA BHOSARI	Report Date :		
PUNE-MS-411026			
dentification :50 X 5MM THK , Material Specification : ASME Se 30400	ction II Part A SA 240:2017:TYPE 30	I - UNS	-
Sample Description : Flat			
Chemical Analysis : Test Method : ASTM E 1086 : 2014			ting Date: 14/07/2018
Sr.No Element	Min Value	Max Value	Observed Value
1 % C (Carbon)		0.0700 2.0000	0.033
2 % Mn (Manganese)		0.7500	0.41
3 % Si (Silicon)		0.0300	< 0.00050
4 % S (Sulphur) 5 % P (Phosphorous)		0.0450	0.029
6 % Cr (Chromium)	17.5000	19.5000	18.22
7 % Ni (Nickel)	8.0000	10.5000	8.10
8 % N (Nitrogen)		0.1000	0.045
\$30400 For Chemical Analysis Only.			-
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#### Chemical for 5mm thick Material.

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# Chemical for 3mm thick Material.

Parameter         Min Value         Max Value         Observation           Test Temperature (°C)         Test Specimen Type         Severage Victorian         Severage Victorian<	Your Reference Date :           Our Receipt Date :         06/01/2022           Report Date :         06/01/2022           In II Part A SA 240:2017: TYPE 304L - UNS \$30403         5           Size : 3.00(Thickness)         5           Section II-A:SA 370 : 2015         Testing Date:08/07/2018           Min Value         Max Value         Observed Value           Ambient.         Flat           12:.50         2.96           37:.00         50:.00           50:.00         12:.48           79:.11         70:.00           37:.00         337:.30           50:.00         628.11           0xr MPa)         485:.00         628.11           0xr MPa)         0.0300         0.029           0xr MPa)         0.0300         0.029           0xr MPa)         0.0300         0.029           0xr MPa) <th>ATYAM FABRICATORS         Your Reference Date :         Our Receipt Date :         Decempt Date:         Decempt Date :         Decemp</th> <th>r Reference: Z-12068</th> <th>Test C</th> <th>ertificate</th> <th>1 States</th> <th>Page 1 of 4</th>	ATYAM FABRICATORS         Your Reference Date :         Our Receipt Date :         Decempt Date:         Decempt Date :         Decemp	r Reference: Z-12068	Test C	ertificate	1 States	Page 1 of 4
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Test Temperature (%C)         Test Specimen Type         Average Width (mm)         Average Width (mm)         Average Mickness (mm)         Average Area (\$G, mm)         Gauge Length (mm)         Yield Load (KN)         Ultimate Load (KN)         Yield Stress (N/mn2 or MPa)         Yield Stress (N/mn2 or MPa)         Test Stress (N/mn2 or MPa)         Yield Stress (N/mn2 or MPa)         Test Stress (N/mn2 or MPa)         Test Stress (N/mn2 or MPa)         Yield Stress (N/mn2 or MPa)         Test Test Stress (N/mn2 or MPa)	Ambient Flat Flat 12:50 12:50 12:50 12:50 37:00 37:00 12:48 37:00 12:48 12	Test Temperature (%C)       Amblent         Test Spectrimen Type       Flat         Average Width (mm)       12.50         Average Width (mm)          Average Width (mm)          Average Michkenes (mm)          Gauge Length (mm)          Yield Load (KN)          Yield Load (KN)          Yield Load (KN)          Yield Sauge Length (mm)				Tes	ting Date:08/07/2018
Test Temperature (%C)         Test Specimen Type         Average Width (mm)         Average Width (mm)         Average Mickness (mm)         Average Area (\$G, mm)         Gauge Length (mm)         Yield Load (KN)         Ultimate Load (KN)         Yield Stress (N/mn2 or MPa)         Yield Stress (N/mn2 or MPa)         Test Stress (N/mn2 or MPa)         Yield Stress (N/mn2 or MPa)         Test Stress (N/mn2 or MPa)         Test Stress (N/mn2 or MPa)         Yield Stress (N/mn2 or MPa)         Test Test Stress (N/mn2 or MPa)	Ambient Flat Flat 12:50 2.96 37:00 50:00 12:48 50:00 12:48 12:48 52:24 79:11 170:00 337:30 79:11 170:00 337:30 628:11 0.00 56:22 W.G.L Ductle To ASME Section II Part A SA 240:2017:TYPE 304L - UNS 530403 ASTM E 1086 : 2014 Min Value 0.0300 0.029 2.0000 1.07 0.030 0.029 2.0000 1.07 0.030 0.029 2.0000 1.07 0.030 0.029 0.030 0.029 0.030 0.029 0.030 0.029 0.030 0.029 0.030 0.029 0.030 0.029 0.030 0.029 0.030 0.029 0.030 0.029 0.030 0.029 0.030 1.07 0.045 0.030 1.07 0.030 0.029 0.030 0.04 0.030 0.04 0.030 0.055 0.04 0.055	Test Temperature (%C)       Amblent         Test Spectrimen Type       Flat         Average Width (mm)       12.50         Average Width (mm)          Average Width (mm)          Average Michkenes (mm)          Gauge Length (mm)          Yield Load (KN)          Yield Load (KN)          Yield Load (KN)          Yield Sauge Length (mm)	Parameter		Min Value	Max Value	Observed Value
Average Width (mm)         Average Thickness (mm)           Average Thickness (mm)         Average Thickness (mm)           Average Thickness (mm)         Image Lengt (mm)           Yield Load (KN)         Image Lengt (mm)           Yield Load (KN)         Image Lengt (mm)           Yield Stress (N/mm2 or MPa)         170.00           Ultimate Tensile Stress (N/mm2 or MPa)         485.00           % Elongation         40.00           Fracture Load In         Testing Date:0           Fracture Type         Image Lengt (mm)           Streamer - Tensile Test Conforms To ASME Section II Part A SA 240:2017:TYPE 304L - UNS 530403         Image Lengt (mm)           Str.No         Element         Min Value         Max Value         Observa           1         % C (carbon)         0.0300         Image Lengt (mm)         Image Lengt (mm)         Image Lengt (mm)           2         % Mn (Manganese)         2.0000         Image Lengt (mm)         Image Lengt (mm)         Image Lengt (mm)           3         % S (Sillcon)         0.0300         Image Lengt (mm)         Image Lengt (mm)         Image Lengt (mm)           2         % Mn (Manganese)         0.0430         Image Lengt (mm)         Image Lengt (mm)         Image Lengt (mm)         Image Lengt (mm)           3	12.50           2.96           37.00           50.00           12.48           23.24           79.11           170.00           337.30           50.00           12.48           23.24           79.11           170.00           337.30           50 MPa)         485.00           40.00         58.22           W.G.L         Ductile           50 ASME Section II Part A SA 240:2017:TYPE 304L - UNS \$30403         Ductile           ASTM E 1086 : 2014         Testing Date:06/07/2018           Min Value         Max Value         Observed Value           0.0300         0.029           2.0000         1.07           0.7550         0.24           0.0300         <0.0010	Average Width (mm)       12.50         Average Thickness (mm)       2.96         Average Thickness (mm)       37.00         Average Area (Sq. mm)       37.00         Gauge Length (mm)       12.48         Uttimate Load (KN)       12.48         Uttimate Load (KN)       233.20         Uttimate Tensile Stress (N/mm2 or MPa)       170.00       337.30         Uttimate Tensile Stress (N/mm2 or MPa)       485.00       628.11         % Elongation       40.00       58.22         Fracture Type       W.G.I.       53040J         emmark - Tensile Test Conforms To ASME Section III Part A SA 240:2017:TYPE 304L - UNS 5304UJ       0bserved Value         1       % C (carbon)       0.0300       0.029         2       % Am (Manganese)       2.0000       1.070         3       % I (Sillcon)       0.0300       <0.0010					Contraction of the second s
Average Thickness (mm)           Average Area (Sq. mm)           Gauge Length (mm)           Yield Load (KN)           Tinal Gauge Length (mm)           Yield Stress (N/mm2 or MPa)           Tinal Gauge Length (mm)           Yield Stress (N/mm2 or MPa)           Tinal Gauge Length (mm)           Yield Stress (N/mm2 or MPa)           Timal Gauge Length (mm)           Yield Stress (N/mm2 or MPa)           Testile Test (N/mm2 or MPa)           Testile Test (N/mm2 or MPa)           Testile Test Conforms To ASME Section II Part A SA 240:2017:TYPE 304L - UNS S30403           Testile Test Conforms To ASME Section II Part A SA 240:2017:TYPE 304L - UNS S30403           Testile Test Conforms To ASME Section II Part A SA 240:2017:TYPE 304L - UNS S30403           Sr.No         Element         Min Value         Max Value         Observalue           Sr.No         Element         Min Value         Max Value         Observalue           1         % C (arbon)         0.03300         0         0           2         % Mn (Maganese)         0.03300         0         0           3         % S (Sulphur)         0.0430         0         0           5         % P (Phosphorous)         0.0450         0         0.0450 <tr< td=""><td>2.96           37.00           50.00           12.48           23.24           79.11           170.00           337.30           or MPa)           485.00           628.11           40.00           58.22           W.G.L           Ductlle           50.300           ASTM E 1086 : 2014           Testing Date:06/07/2018           Min Value         Max Value           0.0300         0.029           2.0000         1.07           0.7500         0.24           0.0300         &lt;0.010</td>           0.0450         0.030           17.5000         18.25           8.0000         12.0000           8.0000         12.0000           0.1000         0.661</tr<>	2.96           37.00           50.00           12.48           23.24           79.11           170.00           337.30           or MPa)           485.00           628.11           40.00           58.22           W.G.L           Ductlle           50.300           ASTM E 1086 : 2014           Testing Date:06/07/2018           Min Value         Max Value           0.0300         0.029           2.0000         1.07           0.7500         0.24           0.0300         <0.010	Average Area (Sq. mm)       2.96         Average Area (Sq. mm)       37.00         Gauge Length (mm)       50.00         Final Gauge Length (mm)       23.24         Final Gauge Length (mm)       77.01         Yield Stress (N/mn2 or MPa)       170.00       337.30         Uttimate Tensile Stress (N/mn2 or MPa)       445.00       58.22         Fracture Location       40.00       58.22         Fracture Type       W.G.L       W.G.L         Etemark - Tensile Test Conforms To ASME Section II Part A SA 240:2017:TYPE 304L - UNS S30403       00served Value         1       % C (arbon)       0.0300       0.029         2       % Mn (Manganese)       0.0300       0.029         2       % Mn (Manganese)       0.0300       <0.010	Test Specimen Type				
Average Area (Sq. mm)         Science           Gauge Length (mm)	37.00         50.00         12.48         23.24         79.11         170.00       337.30         or MPa)       485.00       628.11         40.00       58.22         W.G.L       Ductile         Double       0.0300       0.029         2.0000       1.07         0.7500       0.24         0.0300       0.029         2.0000       1.07         0.7500       0.24         0.0300       0.029         2.0000       1.07         0.7500       0.24         0.0450       0.030         17.5000       18.25         8.0000       15.900         0.1000       0.61	Average Area (Sq. mm)       37.00         Gauge Length (mm)       50.00         Yield Load (KN)       12.48         Utimate Load (KN)       79.01         Yield State (Mm)       79.01         Yield State (Mm)       79.00         Utimate Tensile Stress (N/mm2 or MPa)       170.00       337.30         Utimate Tensile Stress (N/mm2 or MPa)       485.00       628.11         K Elongation       40.00       58.22         Fracture Topic       40.00       58.22         Fracture Topic       40.00       58.22         Fracture Topic       90.01       90.01         Tracture Topic       90.01       90.02         Str.No       Element       Min Value       Max Value       Observed Value         1       % C (Carbon)       0.0300       0.029         2       % Min Kanganese)       0.0300       0.029         3       % S (Sulphur)       0.0450       0.0300         5       % P (Phosphorous)       0.0450       0.0300         6       % Cr (Chromium)       17.5000       19.5000       18.25         8       N (Nikrogen)       0.0450       0.0300       <0.0300					
Gauge Length (mm)            Yield Load (KN)            Ultimate Load (KN)            Final Gauge Length (mm)         170.00           Yield Stress (N/mm2 or MPa)         170.00           Ultimate Tensile Stress (N/mm2 or MPa)         485.00           & Elongation         40.00           Fracture Torsile Stress (N/mm2 or MPa)         40.00           Fracture Tope         Fracture Location           Fracture Tope         Fracture Location           Fracture Location         Testing Date:0           Sr.No         Element         Min Value         Max Value         Observante:0           1         % C (Carbon)         0.0300         2         2         Min Value         Max Value         Observante:0           2         % Min (Manganese)         2.0000         2         3         % Si Silicon)         0.0300         2           3         % Si Silicon)         0.0300         0         2         0.0450         0           5         % P (Phosphorous)         0.0450         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0	50.00           12.48           23.24           79.11           170.00           337.30           65.00           628.11           40.00           485.00           628.11           40.00           485.00           628.11           40.00           40.00           56.11           40.00           40.00           56.11           40.00           56.12           W.G.L           Ductile           70.00           50.300           0.0300           0.0300           0.0300           0.0300           0.0300           0.0300           0.0300           0.0300           0.0300           0.0300           0.0300           0.0300           0.0300           0.0300           0.0300           17.5000           18.25           8.0000           0.1000           0.061	Gauge Length (mm)         50.00           Yield Load (KN)         12.48           Ultimate Load (KN)         73.10           Gauge Length (mm)         77.11           Yield Stress (N/mm2 or MPa)         170.00         337.30           Ultimate Tensile Stress (N/mm2 or MPa)         485.00         628.11           X Elongation         40.00         58.22           Fracture Location         485.00         628.11           rencile Tensile Test Conforms To ASME Section II Part A SA 240:2017:TYPE 304L - UNS 530403         Testing Date:06/07/2018           Sr.No         Element         Min Value         Max Value         Observed Value           1         % C (Carbon)         0.0300         0.029         0.0450         0.0300           2         % Min Value         Max Value         Observed Value         0.107         0.7500         0.224           3         % Si (Silicon)         0.7500         0.0300         0.0300         0.0010           5         % P (Phosphorous)         0.0450         0.0300         0.0010         0.859           8         % N (Nitrogen)         0.1000         0.061         8579         8         N (Nitrogen)         0.1000         0.061           1         L-UNF S30403 <td></td> <td></td> <td></td> <td></td> <td></td>					
Yield Load (KN)       Uttimate Load (KN)       Final Gauge Length (mm)       Yield Stress (N/mm2 or MPa)     170.00       Uttimate Tensile Stress (N/mm2 or MPa)     485.00       & Elongation     40.00       Fracture Load in     Fracture Load in       Fracture Load in     Testing Date:0       Sr.No     Element     Min Value     Max Value     Observa       1     % C (Carbon)     0.0300     2       2     % Mn (Manganese)     2.0000     2       3     % S (Sillcon)     0.7500     0.0300       5     % P (Phosphorous)     0.0450     0.0450       6     % C (Chromium)     17.5000     19.500       7     % Ni (Nickel)     8.0000     12.0000	12.48           23.24           79.11           170.00           337.30           or MPa)         485.00           40.00         58.22           W.G.L           Ductile           50 ASME Section II Part A SA 240:2017:TYPE 304L - UNS 530403           ASTM E 1086 : 2014         Testing Date:06/07/2018           Min Value         Max Value         Observed Value           0.0300         0.029         2.0000         1.07           0.7550         0.24         0.0300         <0.010	Yield Load (KN)       12.48         Ultimate Load (KN)       23.24         Final Gauge Length (mm)       79.11         Yield Stress (N/mm2 or MPa)       170.00       337.30         Ultimate Tensile Stress (N/mm2 or MPa)       485.00       628.11         % Elongation       40.00       58.22         Fracture Type       W.G.L       W.G.L         remark - Tensile Test Conforms To ASME Section II Part A SA 240:2017:TYPE 304L - UNS \$30403       W.G.L         temmark - Tensile Test Conforms To ASME Section II Part A SA 240:2017:TYPE 304L - UNS \$30403       Observed Value         1       % C (carbon)       0.0300       0.029         2       % Mn (Maganese)       2.0000       1.077         3       % S (Sillphur)       0.0300       <0.010					
Millmate Load (KN)           Final Gauge Length (mm)           Yield Stress (N/mn2 or MPa)           1700.00           Witimate Tensile Stress (N/mn2 or MPa)           485.00           % Elongation           40.00           Fracture Iocation           Fracture Type           mark - Tensile Test Conforms To ASME Section II Part A SA 240:2017:TYPE 304L - UNS S30403           remark - Tensile Test Conforms To ASME Section II Part A SA 240:2017:TYPE 304L - UNS S30403           remark - Tensile Test Conforms To ASME Section II Part A SA 240:2017:TYPE 304L - UNS S30403           remark - Tensile Test Conforms To ASME Section II Part A SA 240:2017:TYPE 304L - UNS S30403           Sr.No         Element           Min Value         Max Value           Observin         0.0300           1         % C (arbon)         0.0300           2         % Mn (Maganese)         0.0300           3         % S (Sulphur)         0.0430           5         % P (Phosphorous)         0.0450           6         % C (Chromium)         17.5000         19.5000           7         % Ni (Nickel)         8.0000         12.0000	23.24           79.11           170.00         337.30           or MPa)         485.00         628.11           40.00         58.22         W.G.L           W.G.L         Ductile         Ductile           To ASME Section II Part A SA 240:2017;TYPE 304L - UNS \$30403           ASTM E 1086 : 2014         Testing Date:06/07/2018           Min Value         Max Value         Observed Value           0.0300         0.029         2.0000         1.07           0.7500         0.24         0.0300         <0.010	Ultimate Load (KN)       23.24         Final Gauge Length (mm)       79.11         Yield Stress (N/mn2 or MPa)       170.00       337.30         Ultimate Tensile Stress (N/mn2 or MPa)       485.00       682.11         % Elongation       40.00       58.22         Fracture Location       40.00       58.22         Fracture Location       40.00       58.22         Barrier Tensile Test Conforms To ASME Section II Part A SA 240:2017:TYPE 304L - UNS S30403       Ductile         semark - Tensile Test Conforms To ASME Section II Part A SA 240:2017:TYPE 304L - UNS S30403       005erved Value         1       % C (carbon)       0.0300       0.029         2       % Mn (Manganese)       0.0300       0.029         3       % S (Sulphur)       0.0300       <0.0010					and the first state of the second state of the
Final Gauge Length (mm)         Yield Stress (N/mm2 or MPa)       170.00         Uttimate Tensile Stress (N/mm2 or MPa)       485.00         & Elongation       40.00         * Elongation       40.00         Fracture Location       ************************************	79.11           170.00         337.30           or MPa)         485.00         628.11           40.00         58.22         W.G.L           Ductile         W.G.L         Ductile           fo ASME Section II Part A SA 240:2017:TYPE 304L - UNS \$30403         Testing Date:06/07/2018           ASTM E 1086 : 2014         Min Value         Max Value         Observed Value           0.0300         0.029         2.0000         1.07           0.7500         0.24         0.030         <0.010	Final Gauge Length (mm)       79.11         Final Gauge Length (mm)       170.00       337.30         Uttimate Tensile Stress (N/mm2 or MPa)       485.00       628.11         K Elongation       40.00       58.22         Fracture Location       40.00       58.22         Fracture Type       W.G.L       W.G.L         emical Analysis : Test Method : ASTME Section II Part A SA 240:2017:TYPE 304L - UNS 530403       Testing Date:06/07/2018         Sr.No       Element       Min Value       Max Value       Observed Value         1       % C (Carbon)       0.0300       0.029         2       % Min (Anganese)       0.0300       <0.010					
Yield Stress (N/mm2 or MPa)         170.00           Uttimate Tensile Stress (N/mm2 or MPa)         485.00           % Elongation         40.00           Fracture Location         Fracture Location           Fracture Type         Fracture Location           Emmel Analysis : Test Method : ASTM E 1086 : 2014         Testing Date:0           Sr.No         Element         Min Value         Max Value         Observe           1         % C (Carbon)         0.0300         -         -           2         % Mn (Manganese)         2.0000         -         -           3         % S (Silicon)         0.7500         -         -           4         % S (Sulphur)         0.0300         -         -           5         % P (Phosphorous)         0.0450         -         -           6         % C (Chromium)         17.5000         19.500         -	170.00         337.30           or MPa)         485.00         628.11           40.00         58.22           W. G.L         Ductile           To ASME Section II Part A SA 240:2017:TYPE 304L - UNS 530403         Juctile           ASTM E 1086 : 2014         Testing Date:06/07/2018           Min Value         Max Value         Observed Value           0.0300         0.029           2.0000         1.07           0.7500         0.24           0.0300         < 0.0010	Yield Stress (N/mm2 or MPa)       170.00       337.30         Uttimate Tensile Stress (N/mm2 or MPa)       485.00       628.11         % Elongation       445.00       58.22         Fracture Location       58.22       Testing Date:06/07/2018         Fracture Location       Testing Date:06/07/2018       Testing Date:06/07/2018         Sr.No       Element       Min Value       Max Value       Observed Value         1       % C (Carbon)       2.0000       0.029         2       % Min (Manganese)       2.0000       0.024         3       % Si (Silicon)       0.0450       0.0300         5       % P (Phosphorous)       0.0450       0.0300         5       % P (MinSphorous)       0.0450       0.0300         6       % C (Chromium)       17.5000       19.5000       18.25         7       % Ni (Nitrogen)       0.1000       0.0450       0.0300         6       % C (Chromium)       17.5000       19.5000       18.25         7       % Ni (Nitrogen)       0.1000       0.061         8       % Nitrogen)       0.1000       0.061         9       8       % Nitrogen)       0.1000       0.661         9       % Nitro					
Minute Tensile Stress (N/mm2 or MPa)         485.00           % Elongation         40.00           Fracture Location         Fracture Type           semical Analysis : Test Method : ASTM E 1086 : 2014         Testing Date:0           Sr.No         Element         Min Value         Max Value         Observa           1         % C (Carbon)         0.0300         Carbon         0.0300           2         % Min (Manganese)         2.0000         0.7500         Carbon         0.0300         Carbon         0.0300         Carbon         0.0300         Carbon         0.0450         Carbon	AB5.00         628.11           40.00         58.22           W.G.L         W.G.L           Ductile         Ductile           Fo ASME Section II Part A SA 240:2017:TYPE 304L - UNS \$30403         Testing Date:06/07/2018           ASTM E 1086 : 2014         Testing Date:06/07/2018           0.0300         0.029           2.0000         1.07           0.7500         0.24           0.0300         <0.030	Ultimate Tensile Stress (N/mm2 or MPa)       485.00       628.11         % Elongation       40.00       58.22         Fracture Location       W.G.L       W.G.L         reacture Type       Ultimate Tensile Test Conforms To ASME Section II Part A SA 240:2017:TYPE 304L - UNS 53040J       Untime Testing Date:06/07/2018         Sr.No       Element       Max Value       Observed Value         1       % C (Carbon)       2.0000       0.029         2       % Mn (Manganese)       2.0000       0.024         3       % S (Sillcon)       0.0300       <0.0010			170.00		
K Elongation         40.00           Fracture Location         Fracture Location           Fracture Location         Fracture Type           smark - Tensile Test Conforms To ASME Section II Part A SA 240:2017:TYPE 304L - UNS \$30403         Testing Date:0           semical Analysis : Test Method : ASTM E 1086 : 2014         Min Value         Max Value         Observing           1         % C (carbon)         0.0300         0.0300         0           2         % Mn (Maganese)         0.0300         0         0           3         % S (Skilphur)         0.0300         0         0           5         % P (Phosphorous)         0.0450         0         0           6         % C (Chromium)         17.5000         19.5000         0           7         % Ni (Nickel)         8.0000         12.0000         0	40.00         58.22           W.G.L         Ductile           50 ASME Section II Part A SA 240:2017;TYPE 304L - UNS S30403         Testing Date:06/07/2018           ASTM E 1086 : 2014         Min Value         Max Value         Observed Value           0.0300         0.029         2.0000         1.07           0.7550         0.24         0.0300         <0.010	% Elongation         40.00         58.22           Fracture Location         W. G. L.         W. G. L.           Fracture Location         U.C. II         DuctIle           Fracture Type         DuctIle         DuctIle           mark - Tensile Test Conforms To ASME Section II Part A SA 240;2017:TYPE 304L - UNS 530403         Testing Date:06/07/2018           Sr.No         Element         Min Value         Max Value         Observed Value           1         % C (Carbon)         0.0300         0.029           2         % Mn (Manganese)         0.0300         0.029           3         % S (Sulphur)         0.0300         <0.010					
Min Value         Max Value         Observe           3         % Si (Silicon)         0.0300         -           3         % Si (Silicon)         0.0300         -           5         % P (Phosphorous)         0.0300         -           6         % C (Chromium)         17.5000         19.500	Min Value         Max Value         Observed Value           0.0300         0.029         2.0000         1.07           0.0300         0.029         0.0300         0.029           0.0300         0.029         0.0300         0.029           0.0300         0.029         0.0300         1.07           0.0300         0.0300         0.030         1.24           0.0300         < 0.0010	Fracture Location       W. G. Location         Fracture Type       Juct like         emark - Tensile Test Conforms To ASME Section II Part A SA 240:2017:TYPE 304L - UNS 530403       Testing Date:06/07/2018         Sr. No       Element       Min Value       Observed Value         1       % C (Carbon)       0.000       0.0029         2       % Min (Manganese)       0.000       0.0010         3       % S (Sulphur)       0.000       0.0029         4       % S (Sulphur)       0.000       0.0020         5       % P (Phosphorous)       0.0100       0.0030         6       % C (Chromium)       17.5000       12.0000       0.024         7       % N (Nitrogen)       0.000       12.0000       0.0101         7       % N (Nitrogen)       0.1000       0.061         memark - Themical Analysis by Spectror Metrof Conforms To ASME Section II Part A SA 240:2017:TYPE       0.0001         7       % N (Nitrogen)       0.1000       0.061         94L - UNS 330403       Stest Test Method : ASME Section II-A:SA 370 : 2015       Testing Date:07/07/2018         Reminitering Lacation       Scale       Ander Malu       Max       R1       R2       R3         804					
Armark - Tensile Test Conforms To ASME Section II Part & SA 240:2017:TYPE 304L - UNS \$30403           termical Analysis : Test Method : ASTM E 1086 : 2014         Testing Date:0           Sr.No         Element         Min Value         Max Value         Observa           1         % C (Carbon)         0.0300         0.0300         0.0300           2         % Mn (Manganese)         2.0000         0.7500         0.0300           3         % S (Siulphur)         0.0300         0.0450         0.0450           5         % P (Phosphorous)         0.0450         0.0450         0.0450           6         % C (Chromium)         17.5000         19.5000         0.12.0000         0.12.0000         0.12.0000         0.12.0000         0.12.0000         0.045	To ASME Section II Part A SA 240:2017;TYPE 304L - UNS 530403 ASTM E 1086 : 2014 Testing Date:06/07/2018 Min Value Max Value Observed Value 0.0300 0.029 2.0000 1.07 0.7500 0.24 0.0300 < 0.0010 0.0450 0.030 17.5000 19.5000 18.25 8.0000 12.0000 8.59 0.1000 0.061	emark - Tensile Test Conforms To ASME Section II Part A SA 240:2017:TYPE 304L - UNS 530403           Testing Date:06/07/2018           Sr.No         Element         Min Value         Max Value         Observed Value           1         % C (Carbon)         0.0300         0.029           2         % Mn (Manganese)         2.0000         1.07           3         % SI (Silicon)         0.7500         0.244           4         % S (Sulphur)         0.0300         <0.0010					
Min Value         Max Value         Observing           Sr. No         Element         Min Value         Max Value         Observing           1         % C (Carbon)         0.0300         0.0300           2         % Min (Maganesc)         0.0300         0.0300           3         % S (Skilphur)         0.0300         0.0300           5         % P (Phosphorous)         0.0450         0.0450           6         % C (Chornium)         17.5000         19.5000           7         % NI (Nickel)         8.0000         12.0000	ASTM E 1086 : 2014 Testing Date:06/07/2018 Min Value Max Value Observed Value 0.0300 0.029 2.0000 1.07 0.7500 0.24 0.0300 <0.0010 0.0450 0.030 17.5000 19.5000 18.25 8.0000 12.0000 8.59 0.1000 0.061	Analysis : Test Method : ASTM E 1086 : 2014         Testing Date:06/07/2018           Sr. No         Element         Min Value         Max Value         Observed Value           1         % C (Carbon)         0.0300         0.029           2         % Mn (Maganese)         0.0300         0.029           3         % S (Sillcon)         0.7500         0.244           4         % S (Sulphur)         0.0450         0.0300         <0.0010	Fracture Type				Ductile
Kr.No         Element         Min Value         Max Value         Observent           1         % C (Carbon)         0.0300         0.0300         0.0300           2         % Mn (Manganese)         2.0000         0.7500         0.0300           3         % Si (Silicon)         0.07500         0.0300         0.0300           4         % S (Sulphur)         0.0300         0.0450         0.0450           5         % P (Phosphorous)         0.0450         0.0450         0.0450           6         % C (Chromium)         17.5000         19.5000         0.0450           7         % Ni (Nickel)         8.0000         12.0000         0.0450	Min Value         Max Value         Observed Value           0.0300         0.029           2.0000         1.07           0.7500         0.24           0.0300         < 0.0010           0.0450         0.030           17.5000         18.25           8.0000         12.0000         8.59           0.1000         0.061	Kr. No         Element         Min Value         Max Value         Observed Value           1         % C (Carbon)         0.0300         0.029           2         % Mn (Manganese)         2.0000         1.07           3         % SI (Silicon)         0.7500         0.244           4         % S (Sulphur)         0.0300         <0.0010           5         % P(Posphorous)         0.0450         0.0300           6         % Cr (Chromium)         17.5000         19.5000         18.25           7         % NI (Nickel)         8.0000         12.0000         8.59           8         % N (Nitrogen)         0.1000         0.061           emark - Chemical Analysis by Spectro Method Conforms To ASME Section II Part A SA 240:2017:TYPE         Vel-UMS 30403           rdness Test : Test Method : ASME Section II-A:SA 370 : 2015         Testing Date:07/07/2018           ype         Identification         Location         Scale         Indentor Ball Dia         Load(Kg)         Min         Max         R1         R2         R3           RBW          Surface         B (Red)         Ball 1/16 " 100         92.00         86.0         86.0         87.0	mark Tensile Test Conforms To ASHE See	tion II Part & SA 240-201		103	
1         % C (Carbon)         0.0300           2         % Mn (Manganese)         2.0000           3         % Si (Silicon)         0.7500           4         % S (Sulphur)         0.0300           5         % P (Phosphorous)         0.0450           6         % C (Chromium)         17.5000           7         % Ni (Nickel)         8.0000	0.0300         0.029           2.0000         1.07           0.7500         0.24           0.0300         < 0.0010           0.0450         0.030           17.5000         18.25           8.0000         12.0000         8.59           0.1000         0.061	1         % C (Carbon)         0.0300         0.029           2         % Mn (Manganese)         2.0000         1.07           3         % S1 (Silicon)         0.7500         0.24           4         % S (Sulphur)         0.0300         <0.0010           5         % P(Prosphorous)         0.0450         0.0300           6         % Cr (Chromium)         17.5000         19.5000         18.25           7         % NI (Nickel)         8.0000         12.0000         8.59           8         % N (Nitrogen)         0.1000         0.061           emark - Chemical Analysis by Spectro Method Conforms To ASME Section II Part A SA 240:2017:TYPE         0.1000         0.061           vick - L WKS SJ0403         rdssodd3         rdssodd3         rdstod7/07/2018           ype         Identification Location ICacation II-A:SA 370: 2015         Testing Date:07/07/2018           ype         Identification Location Scale Indentor Ball Dia Load(Kg) Min Max R1 R2 R3         R8         R8         8.6.0         87.0	mark - rensile rest conforms to Asme sec	1011 11 Fait A 3A 240.201	7:TYPE 304L - UNS 5304	403	
2         % Mn (Manganese)         2.0000           3         % Si (Silicon)         0.7500           4         % S (Sulphur)         0.0300           5         % P (Phosphorous)         0.0450           6         % Cr (Chromium)         17.5000           7         % Ni (Nickel)         8.0000	2.0000         1.07           0.7500         0.24           0.0300         <0.0010	2         % Mn (Manganese)         2.0000         1.07           3         % Si (Silicon)         0.7500         0.24           4         % S (Sulphur)         0.0300         <0.0010			7:1YPE 304L - UNS 5304		ting Date:06/07/2018
3         % Si (Sillcon)         0.7500           4         % S (Sulphur)         0.0300           5         % P (Phosphorous)         0.0450           6         % C (Chromium)         17,5000           7         % Ni (Nickel)         8.0000	0.7500         0.24           0.0300         < 0.0010	3       % Si (Silicon)       0.7500       0.24         4       % S (Sulphur)       0.0300       <0.0010	emical Analysis : Test Method : ASTM E 108			Tes	
4         % S (Sulphur)         0.0300           5         % P (Phosphorous)         0.0450           6         % Cr (Chromium)         17.5000         19.5000           7         % NI (Nickel)         8.0000         12.0000	0.0300         < 0.0010           0.0450         0.030           17.5000         19.5000           8.0000         12.0000           0.1000         0.061	4       % \$ (Sulphur)       0.0300       < 0.0010	emical Analysis : Test Method : ASTM E 108 Sr.No Element			Tes Max Value	Observed Value
5         % P (Phosphorous)         0.0450           6         % Cr (Chromium)         17.5000         19.5000           7         % NI (Nickel)         8.0000         12.0000	0.0450         0.030           17.5000         19.5000         18.25           8.0000         12.0000         8.59           0.1000         0.061	5         % P (Phosphorous)         0.0450         0.030           6         % Cr (Chromium)         17.5000         19.5000         18.25           7         % NI (Nickel)         8.0000         12.0000         8.59           8         % NI (Nitrogen)         0.1000         0.061           mark - Chemical Analysis by Spectro Method Conforms To ASME Section II Part A SA 240:2017:TYPE         0.1000         0.061           04L - UNS \$30403         Tresting Date:07/07/2018         Testing Date:07/07/2018           ype         Identification         Location         Scale         Indentor Ball Dia         Load(Kg)         Min         Max         R1         R2         R3           RBW          Surface         B (Red)         Ball         1/16 * 100         92.00         86.0         87.0	emical Analysis : Test Method : ASTM E 108 5r.No Element 1 % C (Carbon) 2 % Mn (Manganese)			Tes Max Value 0.0300 2.0000	Observed Value 0.029 1.07
6 % Cr (Chromium) 17.5000 19.5000 7 % Ni (Nickel) 8.0000 12.0000	17.5000         19.5000         18.25           8.0000         12.0000         8.59           0.1000         0.061	6         % Cr (Chromium)         17.5000         19.5000         18.25           7         % NI (Nickel)         8.0000         12.0000         8.59           8         % NI (Nitrogen)         0.1000         0.061           emark - Chemical Analysis by Spectro Method Conforms To ASME Section II Part A SA 240:2017:TYPE         0.1000         0.061           ut - UMS 50403         rdness Test : Test Method : ASME Section II-A:SA 370 : 2015         Testing Date:07/07/2018           ype         Identification         Location         Scale         Indentor Ball Dia         Load(Kg)         Min         Max         R1         R2         R3           RBW          Surface         B (Red)         Ball         1/16 " 100         92.00         86.0         86.0         87.0	emical Analysis : Test Method : ASTM E 108 Sr.No Element 1 % C (Carbon) 2 % Mn (Manganese) 3 % Si (Silicon)			Tes Max Value 0.0300 2.0000 0.7500	Observed Value 0.029 1.07 0.24
7 % Ni (Nickel) 8.0000 12.0000	8.0000 12.0000 8.59 0.1000 0.061	7         % NI (Nickel)         8.0000         12.0000         8.59           8         % N (Nitrogen)         0.1000         0.061           emark - Chemical Analysis by Spectro Method Conforms To ASME Section II Part A SA 240:2017:TYPE         20000         0.000           0.1.000         0.000         0.001         0.000         0.001           0.1.000         0.001         0.000         0.001           emark - Chemical Analysis by Spectro Method Conforms To ASME Section II Part A SA 240:2017:TYPE         2000         2000           del UNS 350403	emical Analysis : Test Method : ASTM E 108 5r.No Element 1 % C (Carbon) 2 % Mn (Manganese) 3 % Si (Silicon) 4 % S (Sulphur)			Tes Max Value 0.0300 2.0000 0.7500 0.0300	Observed Value 0.029 1.07 0.24 < 0.0010
	0.1000 0.061	8         % N (Niltrogen)         0.1000         0.061           emark - Chemical Analysis by Spectro Method Conforms To ASME Section II Part A SA 240:2017:TYPE         5         5         5         5         5         5         7	emical Analysis : Test Method : ASTM E 108 Sr.No Element 1 % C (Carbon) 2 % Mn (Manganese) 3 % Si (Silicon) 4 % S (Sulphur) 5 % P (Phosphorous)		Min Value	Tes Max Value 0.0300 2.0000 0.7500 0.0300 0.0450	Observed Value           0.029           1.07           0.24           < 0.0010
8 % N (Nitrogen) 0.1000		emark - Chemical Analysis by Spectro Method Conforms To ASME Section II Part A SA 240:2017:TYPE           O4L - UNS \$30403           Testing Date:07/07/2018           Testing Date:07/07/2018           ype Identification Location Scale Indentor Ball Dia Load(Kg) Min Max R1 R2 R3           RBW ··· Surface B (Red) Ball 1/16 * 100	emical Analysis : Test Method : ASTM E 108 5r.No Element 1 % C (Carbon) 2 % Mn (Manganese) 3 % Si (Sillcon) 4 % S (Sulphur) 5 % P (Phosphorous) 6 % Cr (Chromium)		Min Value 17.5000	Tes <u>Max Value</u> 0.0300 2.0000 0.7500 0.0300 0.0450 19.5000	Observed Value           0.029           1.07           0.24           < 0.0010
		UPUEL - UNS \$30403           Testing Date:07/07/2018           Testing Date:07/07/2018           ype         Identification         Location         Scale         Indentor Ball Dia         Load(Kg)         Min         Max         R1         RBW         ···         Surface         B (Red)         Ball         1/16 °         100         92.00         86.0         87.0	emical Analysis : Test Method : ASTM E 108 5r.No Element 1 % C (Carbon) 2 % Mn (Manganese) 3 % S (Sillcon) 4 % S (Sulphur) 5 % P (Phosphorous) 6 % Cr (Chromium) 7 % Ni (Nickel)		Min Value 17.5000	Tes <u>Max Value</u> 0.0300 2.0000 0.7500 0.0300 0.0450 19.5000 12.0000	Observed Value 0.029 1.07 0.24 < 0.0010 0.030 18.25 8.59
		ype Identification Location Scale Indentor Ball Dia Load(Kg) Min Max R1 R2 R3 RBW Surface B (Red) Ball 1/16 * 100 92.00 86.0 86.0 87.0	emical Analysis : Test Method : ASTM E 108 5r.No Element 1 % C (Carbon) 2 % Mn (Manganese) 3 % Si (Silcon) 4 % S (Sulphur) 5 % P (Phosphorous) 6 % Cr (Chromium) 7 % Ni (Nickel) 8 % N (Nitrogen)	86 : 2014	Min Value 17.5000 8.0000	Tes Max Value 0.0300 2.0000 0.7500 0.0300 0.0450 19.5000 12.0000 0.1000	Observed Value 0.029 1.07 0.24 < 0.0010 0.030 18.25 8.59
rdness Test : Test Method : ASME Section II-A:SA 370 : 2015 Testing Date:0	E Section II-A:SA 370 : 2015 Testing Date:07/07/2018	RBW Surface B (Red) Ball 1/16 " 100 92.00 86.0 86.0 87.0	emical Analysis : Test Method : ASTM E 108 Sr.No Element 1 % C (Carbon) 2 % Mn (Manganese) 3 % SI (Silicon) 4 % S (Sulphur) 5 % P (Phosphorous) 6 % Cr (Chromium) 7 % NI (Nickel) 8 % N (Nitrogen) smark - Chemical Analysis by Spectro Metho	86 : 2014	Min Value 17.5000 8.0000	Tes Max Value 0.0300 2.0000 0.7500 0.0300 0.0450 19.5000 12.0000 0.1000	Observed Value 0.029 1.07 0.24 < 0.0010 0.030 18.25 8.59
ype Identification Location Scale Indentor Ball Dia Load(Kg) Min Max R1 R2			emical Analysis : Test Method : ASTM E 108 Sr. No Element 1 % C (Carbon) 2 % Mn (Manganese) 3 % Si (Silicon) 4 % S (Sulphur) 5 % P (Phosphorous) 6 % Cr (Chromium) 7 % NI (Nickel) 8 % N (Nitrogen) mark - Chemical Analysis by Spectro Metho 94L - UNS \$30403	86 : 2014 od Conforms To ASME Sec	Min Value 17.5000 8.0000	Tes Max Value 0.0300 2.0000 0.7500 0.0300 0.0450 19.5000 12.0000 0.1000 017:TYPE	Observed Value           0.029           1.07           0.24           < 0.0010
RBW Surface B (Red) Ball 1/16 " 100 92.00 86.0 86.0	ocation Scale Indentor Ball Dia Load(Kg) Min Max R1 R2 R3	emark - Hardness Test Conforms To ASME Section II Part A SA 240:2017:TYPE 304L - UNS S30403	emical Analysis : Test Method : ASTM E 108 Sr.No Element 1 % C (Carbon) 2 % Mn (Manganese) 3 % SI (Silicon) 4 % S (Sulphur) 5 % P (Phosphorous) 6 % Cr (Chromium) 7 % Ni (Nickel) 8 % N (Nitrogen) smark - Chemical Analysis by Spectro Methode ML - UNK 530403 rdraess Test : Test Method : ASME Section II	86 : 2014 od Conforms To ASME Sec I-A:SA 370 : 2015	Min Value 17.5000 8.0000 tion II Part A SA 240:20	Tes <u>Max Value</u> 0.0300 2.0000 0.7500 0.0300 0.0450 19.5000 19.5000 19.5000 0.1000 0.1000 D17:TYPE Tes	Observed Value           0.029           1.07           0.24           <0.0010
amark - Hardness Test Conforms To ASME Section II Part & S& 240:2017:TVPE 3041 - LINS \$30403			emical Analysis : Test Method : ASTM E 108 Sr.No Element 1 % C (Carbon) 2 % Mn (Manganese) 3 % S (Silcon) 4 % S (Sulphur) 5 % P (Phosphorous) 6 % Cr (Chromium) 7 % Ni (Nickel) 8 % N (Nitrogen) semark - Chemical Analysis by Spectro Methi VAL - UNK S30403 rdness Test : Test Method : ASME Section II ype Identification Location S	od Conforms To ASME Sec I-A:SA 370 : 2015 cale Indentor, Ball Di	Min Value 17.5000 8.0000 tion II Part A SA 240;20 a Load(Kg) Min	Tes <u>Max Value</u> 0.0300 2.0000 0.0300 0.0450 19.5000 12.0000 0.1000 0.1000 0.1000 0.17:TYPE Tes <u>Max</u> R1	Observed Value           0.029           1.07           0.24           < 0.0010
	urface B (Red) Ball 1/16" 100 92.00 86.0 86.0 87.0		emical Analysis : Test Method : ASTM E 108 Sr.No Element 1 % C (Carbon) 2 % Mn (Manganese) 3 % SI (Sillicon) 4 % S (Sulphur) 5 % P (Phosphorous) 6 % Cr (Chromium) 7 % Ni (Nickel) 8 % N (Nitrogen) mmark - Chemical Analysis by Spectro Methold UNS \$30403 rdmess Test : Test Method : ASME Section II ype Identification Location S RBW ··· Surface B	od Conforms To ASME Sec -A:SA 370 : 2015 cale Indentor, Ball Di (Red) Ball 1/16 <sup>-</sup>	Min Value 17.5000 8.0000 tion II Part A SA 240:20 a Load(Kg) Min 100	Tes           Max Value           0.0300           2.0000           0.7500           0.0300           0.0450           19.5000           0.1000           0.1000           0.17:TYPE           Tes           Max         R1           92.00         86.0	Observed Value           0.029           1.07           0.24           < 0.0010
	urface B (Red) Ball 1/16" 100 92.00 86.0 86.0 87.0		emical Analysis : Test Method : ASTM E 108 Sr.No Element 1 % C (Carbon) 2 % Mn (Manganese) 3 % SI (Sillicon) 4 % S (Sulphur) 5 % P (Phosphorous) 6 % Cr (Chromium) 7 % Ni (Nickel) 8 % N (Nitrogen) mmark - Chemical Analysis by Spectro Methold UNS \$30403 rdmess Test : Test Method : ASME Section II ype Identification Location S RBW ··· Surface B	od Conforms To ASME Sec -A:SA 370 : 2015 cale Indentor, Ball Di (Red) Ball 1/16 <sup>-</sup>	Min Value 17.5000 8.0000 tion II Part A SA 240:20 a Load(Kg) Min 100	Tes           Max Value           0.0300           2.0000           0.7500           0.0300           0.0450           19.5000           0.1000           0.1000           0.17:TYPE           Tes           Max         R1           92.00         86.0	Observed Value           0.029           1.07           0.24           < 0.0010
			emical Analysis : Test Method : ASTM E 108 Sr.No Element 1 % C (Carbon) 2 % Mn (Manganese) 3 % SI (Silicon) 4 % S (Sulphur) 5 % P (Phosphorous) 6 % Cr (Chromium) 7 % Ni (Nickel) 8 % N (Nitrogen) smark - Chemical Analysis by Spectro Methode ML - UNK 530403 rdraess Test : Test Method : ASME Section II	86 : 2014 od Conforms To ASME Sec I-A:SA 370 : 2015	Min Value 17.5000 8.0000 tion II Part A SA 240:20	Tes <u>Max Value</u> 0.0300 2.0000 0.7500 0.0300 0.0450 19.5000 19.5000 19.5000 0.1000 0.1000 D17:TYPE Tes	Observed Value           0.029           1.07           0.24           <0.0010
			emical Analysis : Test Method : ASTM E 108 Sr.No Element 1 % C (Carbon) 2 % Mn (Manganese) 3 % S (Silcon) 4 % S (Sulphur) 5 % P (Phosphorous) 6 % Cr (Chromium) 7 % Ni (Nickel) 8 % N (Nitrogen) semark - Chemical Analysis by Spectro Methi VAL - UNK S30403 rdness Test : Test Method : ASME Section II ype Identification Location S	od Conforms To ASME Sec I-A:SA 370 : 2015 cale Indentor, Ball Di	Min Value 17.5000 8.0000 tion II Part A SA 240;20 a Load(Kg) Min	Tes <u>Max Value</u> 0.0300 2.0000 0.0300 0.0450 19.5000 12.0000 0.1000 0.1000 0.1000 0.17:TYPE Tes <u>Max</u> R1	Observed Value           0.029           1.07           0.24           < 0.0010
	urface B (Red) Ball 1/16" 100 92.00 86.0 86.0 87.0		emical Analysis : Test Method : ASTM E 108 Sr.No Element 1 % C (Carbon) 2 % Mn (Manganese) 3 % SI (Sillicon) 4 % S (Sulphur) 5 % P (Phosphorous) 6 % Cr (Chromium) 7 % Ni (Nickel) 8 % N (Nitrogen) mmark - Chemical Analysis by Spectro Methold UNS \$30403 rdmess Test : Test Method : ASME Section II ype Identification Location S RBW ··· Surface B	od Conforms To ASME Sec -A:SA 370 : 2015 cale Indentor, Ball Di (Red) Ball 1/16 <sup>-</sup>	Min Value 17.5000 8.0000 tion II Part A SA 240:20 a Load(Kg) Min 100	Tes           Max Value           0.0300           2.0000           0.7500           0.0300           0.0450           19.5000           0.1000           0.1000           0.17:TYPE           Tes           Max         R1           92.00         86.0	Observed Value           0.029           1.07           0.24           < 0.0010
Remark - Hardness resc contorns to Asme section in Parch SA 240.2017.11PE 504E - 013 550405	urface B (Red) Ball 1/16 " 100 92.00 86.0 86.0 87.0		emical Analysis : Test Method : ASTM E 108 Sr.No Element 1 % C (Carbon) 2 % Mn (Manganese) 3 % SI (Sillicon) 4 % S (Sulphur) 5 % P (Phosphorous) 6 % Cr (Chromium) 7 % Ni (Nickel) 8 % N (Nitrogen) mmark - Chemical Analysis by Spectro Methold UNS \$30403 rdmess Test : Test Method : ASME Section II ype Identification Location S RBW ··· Surface B	od Conforms To ASME Sec -A:SA 370 : 2015 cale Indentor, Ball Di (Red) Ball 1/16 <sup>-</sup>	Min Value 17.5000 8.0000 tion II Part A SA 240:20 a Load(Kg) Min 100	Tes           Max Value           0.0300           2.0000           0.7500           0.0300           0.0450           19.5000           0.1000           0.1000           0.17:TYPE           Tes           Max         R1           92.00         86.0	Observed Value           0.029           1.07           0.24              0.010           0.030           18.25           8.59           0.061           ting Date:07/07/2018           R2         R3
	urface B (Red) Ball 1/16" 100 92.00 86.0 86.0 87.0		emical Analysis : Test Method : ASTM E 108 Sr.No Element 1 % C (Carbon) 2 % Mn (Manganese) 3 % SI (Sillicon) 4 % S (Sulphur) 5 % P (Phosphorous) 6 % Cr (Chromium) 7 % Ni (Nickel) 8 % N (Nitrogen) mmark - Chemical Analysis by Spectro Methold UNS \$30403 rdmess Test : Test Method : ASME Section II ype Identification Location S RBW ··· Surface B	od Conforms To ASME Sec -A:SA 370 : 2015 cale Indentor, Ball Di (Red) Ball 1/16 <sup>-</sup>	Min Value 17.5000 8.0000 tion II Part A SA 240:20 a Load(Kg) Min 100	Tes           Max Value           0.0300           2.0000           0.7500           0.0300           0.0450           19.5000           0.1000           0.1000           0.17:TYPE           Tes           Max         R1           92.00         86.0	Observed Value           0.02/           1.01           0.22           < 0.0011

 $\underline{\mathbf{F}}$ rom testing reports it seems that material used for fabrication is as per requirement, so crack is not due to wrong material.

As above scenario satisfies the requirement then next step will be verification of Cyclone worst condition scenario for crack propagation.

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# V.FEM ANALYSIS

We Myself and our Global design team has collected date for worst scenario for CFD as well as FEM analysis.

# **Reference documents.**

#### Regulations, Codes and Standards

No.	Document No.	Title
1	EN13445 PART-2	Design and Manufacturing Code
2	ASME SEC-II PART-D,2015	Materials (for yield strength and tensile stress values).

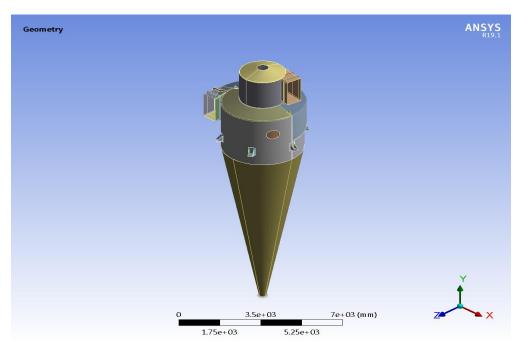
#### **Design Parameters**

- 1. Design Pressure (External and Internal) as per requirements.
- 2. Design Temperature as per requirements.
- 3. Pressure drops.
- 4. Material of construction.

# **Cyclone Model**

## Drawing No.- XXXXXXXXXX

# Model of Cyclone



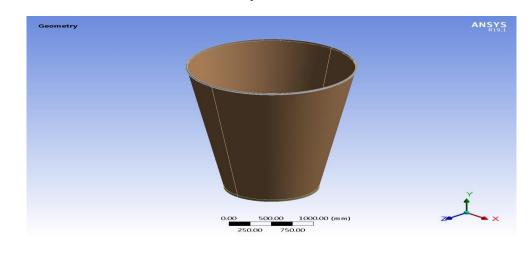
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#### Model of Cyclone Insert Cone



Component Name	Material	Young Modulus (MPa)	Poisson's Ratio	Allowable Stress (*S)(MPa)
Insert cone assembly	SS 304L	187.8 X 10 <sup>3</sup>	0.3	115

\*S: Allowable Stress of material at design temperature.

## **Acceptance Criteria**

	Stress Categories						
		Primary stress		Secondary			
	General membrane stress	Local membrane stress	Bending stress	membrane + bending stress	Peak stress		
Description (For practical examples, see Table C-2)	Primary mean stress calculated across the wall thickness without taking into account discontinuities and stress concentrations. Caused only by mechanical loads.	Primary mean stress calculated across the wall thickness taking into account large discontinuities, but not stress concentrations. Caused only by mechanical loads.	Primary stress component proportional to the distance from the centroid of the solid wall section. Doe will section. Doe on the section and stress concentrations. Caused only by mechanical loads	Self-equilibrating stress necessary to satisfy the continuity of the structure. Occurs at large discontinuities, but does not include stress concentrations. Can be caused by both mechanical loads and thermal effects.	<ul> <li>a) Addition to primary or secondary stress because of stress concentration.</li> <li>b) Certain thermal stresses which may cause fatigue, but not distortion.</li> </ul>		
Symbol	Pm	PL <sup>1)</sup>	Pb	$(= Q_m + Q_b)$	F		
assessment againts static loading	$(\sigma_{eq})_{P_{a}} \leq f$ $(oq. C.7.2-1)$ $(\sigma_{eq})_{P_{a}} \leq 1.5f$ $(oq. C.7.2-2)$ $(a_{eq})_{P_{a}} \leq 1.5f$ $(a_{eq})_{P_{a}} \leq 3.f$ $(a_{eq})_{P_{a}} \leq 1.5.f$ $(a_{eq})_{P_{a}} < 1.5.f$ $(a_{eq})_{P_{a}$						
fatigue assessment (only if required)	Assessment <sup>4)</sup> based on : $7$ $rac{(\Delta \sigma_{eq})P+Q}{max (\Delta \sigma_{p})}$ or $rac{(\Delta \sigma_{eq})P+Q+F}{(\Delta \sigma_{eq})P+Q+F}$						
<sup>1)</sup> $P_{L} = P_{m}$ does not occur at the point in question. <sup>2)</sup> In assessment criteria given in equations (C.7.2-1) to (C.7.2-3), the value of the nominal design stress <i>f</i> shall be that relevant for the loading condition under consideration (normal operation, exceptional operation, proof test), as defined in clause 6. <sup>3)</sup> If ( $\Delta \sigma_{eq}$ )P+Q is greater than 3 <i>f</i> , see C.7.6							
relevant stre fatigue asse <sup>의</sup> The primary	<sup>5</sup> Failgue assessment shall consider all the applied cycles of various types, each of them being characterised by their own relevant stress range (see footnotes 5 and 6), mean temperature and mean stress (if relevant). Clause 18 (detailed fatigue assessment) should normally be used. <sup>6</sup> The primary + secondary stress range (named "structural stress range" in clause 18 on detailed fatigue assessment)						
principal stre	ess range max( $\Delta \sigma_i$ ) m	ay be used.		ess range (∆σ <sub>eq</sub> )P+Q or th			
assessment	, applies to assessme	nt of unwelded parts.		nge" in clause 18 on detaile			
<sup>5</sup> It should be observed that, depending on the model used, the computer programs usually give directly the primary + secondary stresses (P + 0) or the primary + secondary + peak stresses (P + 0 + 7).							

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#### Meshing

All the components have been meshed with SOLID186 elements. SOLID186 is used for the three-dimensional modelling of solid structures. The element is defined by eight nodes having three degrees of freedom at each node: translations in the nodal x, y, and z directions. The element has plasticity, stress stiffening, large deflection, and large strain capabilities.

SOLID186 Homogeneous Structural Solid is well suited to modeling irregular meshes (such as those produced by various CAD/CAM systems). The element may have any spatial orientation. It can be adjust itself in the required shape (Tetrahedral, pyramidal, prism etc.) depend upon the complex geometry of the part. Representation of solid 186 element with different shapes is given below in Fig.

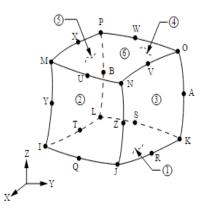
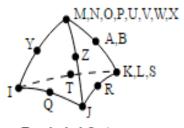
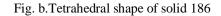


Fig. a.General representation of solid 186



Tetrahedral Option



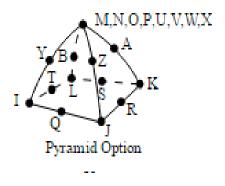


Fig. c. Pyramidal shape of solid 186

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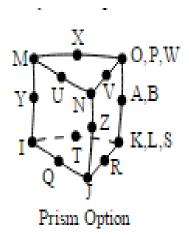
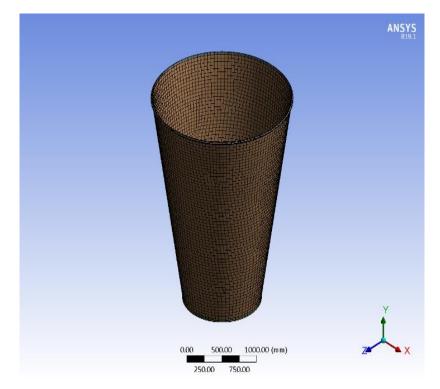


Fig. d. Prism shape of solid 186

Element Type Used: I) Tetrahedral Shape of Solid 186 II) Hexahedral Shape of Solid 186 Total No of Nodes = 52595 Total No of Elements = 9063

Meshing of model



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Equivalent Stress = 154.51 MPa (Max)

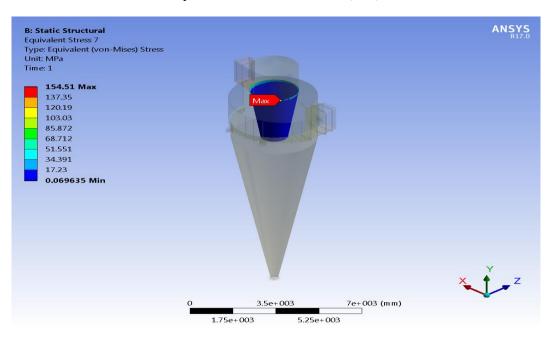
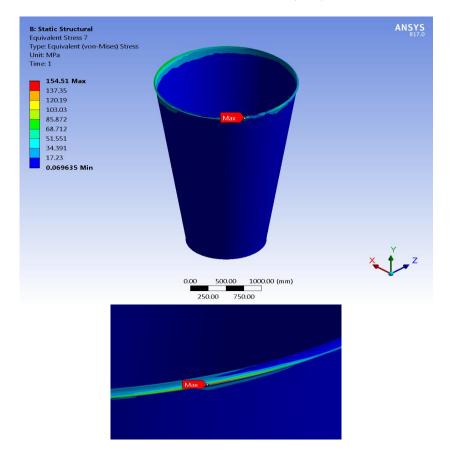


Figure 1 Equivalent stress.

Total Deformation = 3.07 mm (Max)



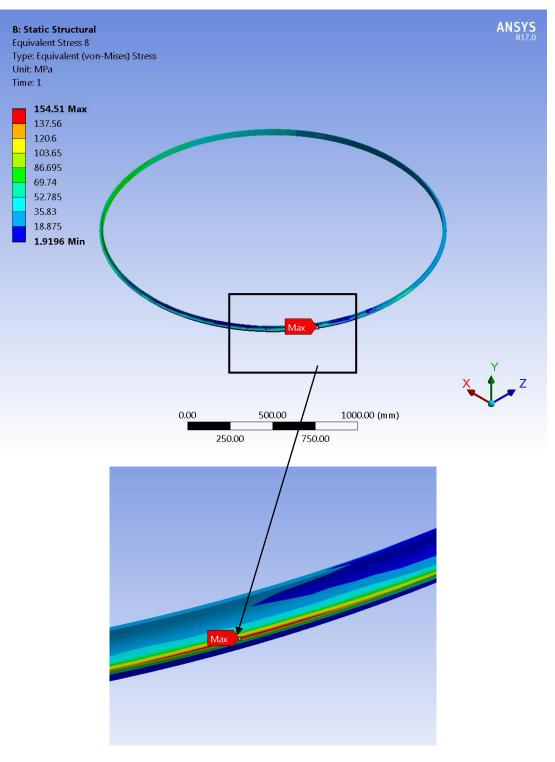
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• Equivalent Stress on Inert cone Ring = 154.51 MPa (Max)



Equivalent stress

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#### Linearized Equivalent stress.

Result-					
Classification	Material	Allowable Limit	Allowable Stress (MPa)	Actual Stress (MPa)	Remarks
P <sub>M</sub>	SS 304L	1.0 * S	115	19.94	SAFE
$P_M + P_B$	SS 304L	1.5 * S	172.5	36.61	SAFE

#### Refer, - Acceptance Criteria for allowable stress limit.

• Equivalent Stress on Cone Shell = 60.69 MPa (Max)

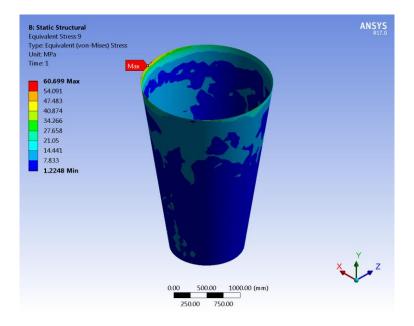


Figure5 Equivalent stress.

## **Result-**

Classification	Material	Allowable Limit	Allowable Stress (MPa)	Actual Stress (MPa)	Remarks
P <sub>M</sub>	SS 304L	1.0 * S	115	60.69	SAFE

#### **Result-**

Classification	Material	Remarks
Insert Cone Ring	SS 304L	SAFE
Insert Cone Shell	SS 304L	SAFE

## **Fatigue Life Calculations**

Given Condition for Operating condition is, Pvacuum = mmWG @  $T=^{\circ}C$ Pressure fluctuation level,  $\Delta p = mmWG$ 

From above we have plotted a different value for input pressure and applied on faces for determining the life of insert cone.

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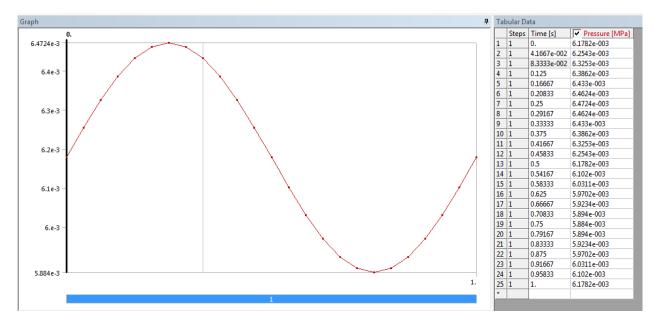


Figure 62 Fluctuation pressure graph and respective values.

The analysis is carried out and fatigue life is determined.

## VI. CONCLUSION

- 1. From above results, it is observed that all the induced stresses are within respective code limits mentioned above.
- 2. So, it Crack might be observed due to sudden shock in process and it seems from discussion there was a trigger of explosion sensors which witness the shock pressure which might be reason for crack propagation.
- 3. To safeguard the design on these kinds of unknown parameters; Separator's are made with stronger at certain critical areas.
- 4. Similar changes have been done and from last couple of months it has been observed the component is running smoother without any further cracks.
- 5. This Cyclone Insert cone is safe for specified boundary conditions.

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