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Design & Analysis of Iso-Flow Valve

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Abstracts: The Iso-Flow valve delivers improved sealing performance, extended service life, and greater reliability. The Iso-Flow valve is for vessel isolation service in high-pressure pneumatic conveying of dry ash and other abrasive materials. The Ash Handling dense phase system designed to convey large quantities of material, up to 200 TPH, over distances of 1,600m (5,200ft). The automated control system maintains constant conveying air mass flow in the pipeline at low velocities, which helps prevent plugging while minimizing abrasion, maintenance, and power consumption. With hundreds of installations globally, our Iso-Flow technology is a proven solution for continuously conveying ash from pulverized-coal boilers, and oil-fired boilers. The upgraded design improvements made to the Iso-Flow valve significantly reduce valve maintenance resulting in increased system reliability, even in the most demanding and severe-duty applications.

Keyword: - Ash handling system, Iso-Flow Valve, Isolation Services, Pneumatic conveying system

I. INTRODUCTION:

An Iso-Flow valve is a valve in a Ash handling system that stops the flow of process media to a given location, usually for maintenance or safety purposes. They can also be used to provide flow logic (selecting one flow path versus another), and to connect external equipment to a system. Vessel isolation is term used for temporary stopping of flow for maintenance purpose. Earlier there are many valves used for this temporary stopping of flow of ash in vessels but it has issue with size and sealing properties of valves also the life of those valves are very less when used in highly abrasive material condition.

II. OBJECTIVES:

Iso-Flow Valve is designed for vessel isolation service in high pressure pneumatic conveying applications of abrasive material such as dry ash. We are re-engineering this valve for improved sealing performance, extended service life, greater reliability and ease of maintenance over alternative valves. The Iso-Flow Valve comes fully assembled and can be shipped pre-piped to reduce field assembly and installation costs. The Iso-Flow valve is used during maintenance of big size vessels and its components when there was need of stopping flow of ash for a temporary period of time which has compact size and good sealing properties. A valve is classified as an isolation valve because of its intended function in a system, not because of the type of valve itself. Therefore, many different types of valves can be classified as isolation valves.

Table 2.1 Iso-Flow Valve Configuration

Sr. No.	**Parameter**	**Details**
1.	Valve Type	Iso-Flow Valve (Dense Phase Air Conveying Inlet Valve)
2.	Application	Ash handling systems in power plants, cement plants, and industrial operations
3.	Operation Mode	Pneumatically or electrically actuated
4.	Conveying Type	Dense-phase pneumatic conveying
5.	Material Handled	Fly ash, bottom ash, cement dust, other granular materials
6.	Design Configuration	Typically rotary, slide gate, or pinch valve
7.	Seal Type	Soft seals (elastomers), metal-to-metal seals, or advanced sealing technology for tight shut-off
8.	Flow Control Mechanism	Adjustable flow control through valve rotation or slide gate movement

9.	Wear Resistance Features	Wear-resistant coatings or alloys like chromium carbide, ceramic coatings
10.	Reliability	Designed for 24/7 operation with minimal downtime in harsh industrial environments

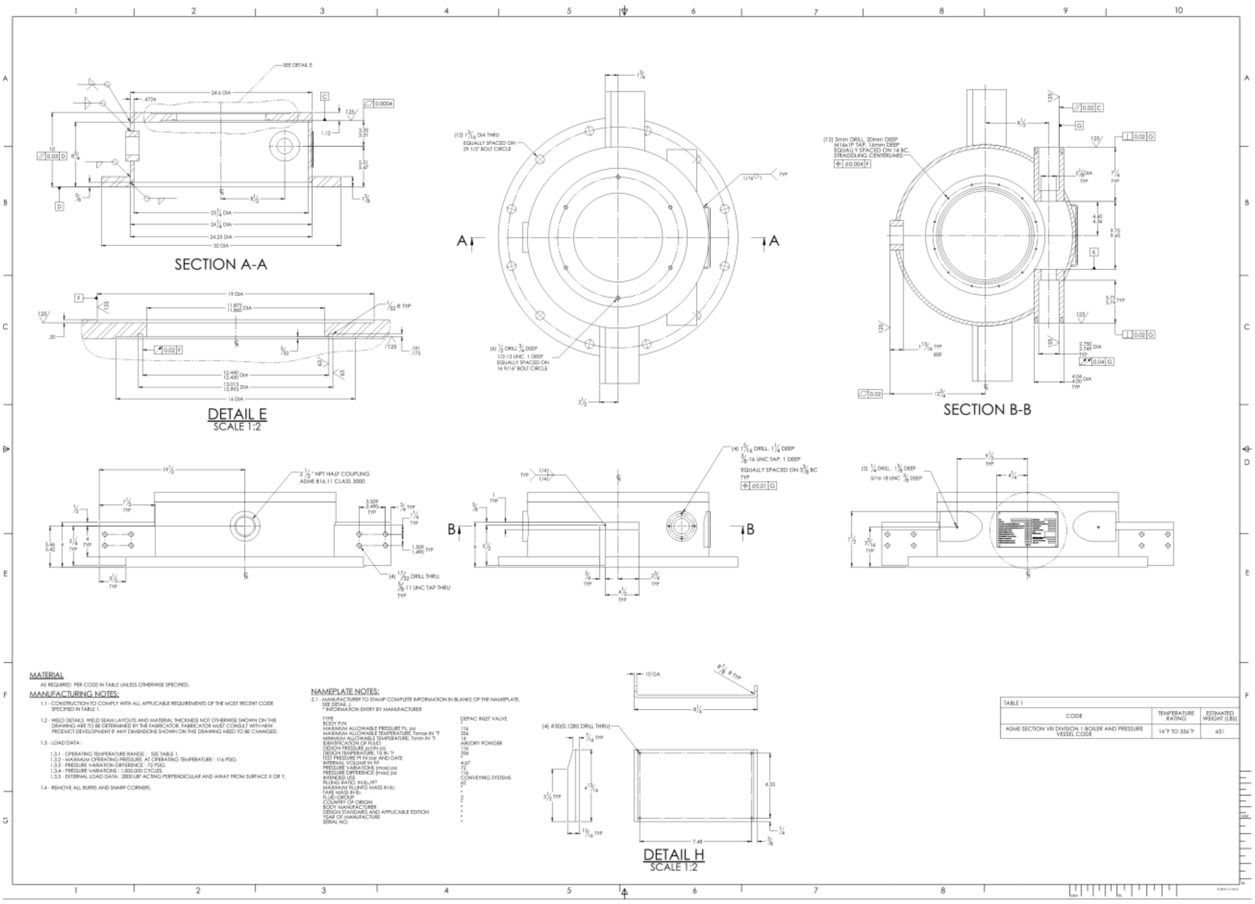

Fig -2.1 Details of Iso-Flow Valve

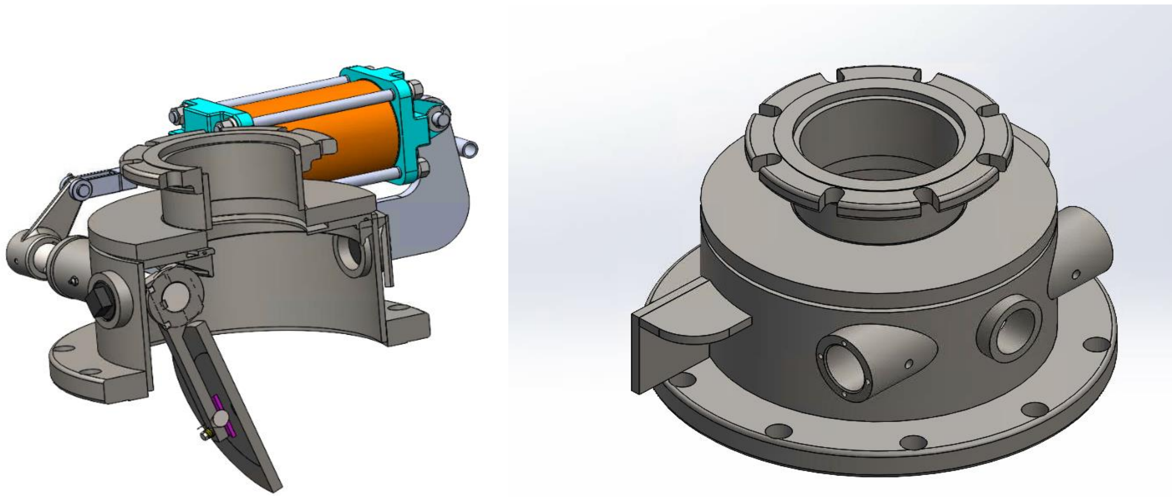

Fig 2.2 – 3D model view of Iso-Flow valve

III. Material Properties of Iso-Flow Valve:

Material properties used in this report are obtained from ASME IID Table 1A (materials for VIII-1 designs). [1] Stress classification limits are set in accordance with ASME VIII-2.
For Finite Element Analysis following material properties are considered at operating temperature 180 deg C Or shown in Table 3.1.

Table -3.1 Material Properties

	Material	**Allowable stress (MPa)**	**Young's modulus (MPa)**	**Poisson's Ration**	**Yield stress (MPa)**	**Density (Kg/m3)**
Valve Body	IS 2062 (E250A)	117	193.2E3	0.3	200.2	7850

Allowable Stress Limits for Stress Categories:

Stress limits are considered as per Part 5 of ASME SEC. VIII, DIV.2 [Ed. 2021] as shown in table 3.2.
Allowable stresses (MPa) of Iso-Flow Valve:

Table -3.2 Allowable Stress Limit

Sr. No.	**Stress Category**	**Stress Limit**	**IS 2062 (E250A)**
1	**General Primary Stress**	**Pm< S**	117
2	**Local Primary Stress**	**PL< 1.5S**	175.5
3	**Membrane+ Primary Bending Stress**	**PL+Pb<1.5S**	175.5
4	**Primary + Secondary Stress**	**PL+Pb+Q<3S**	351

IV. RESULTS & VALIDATION:

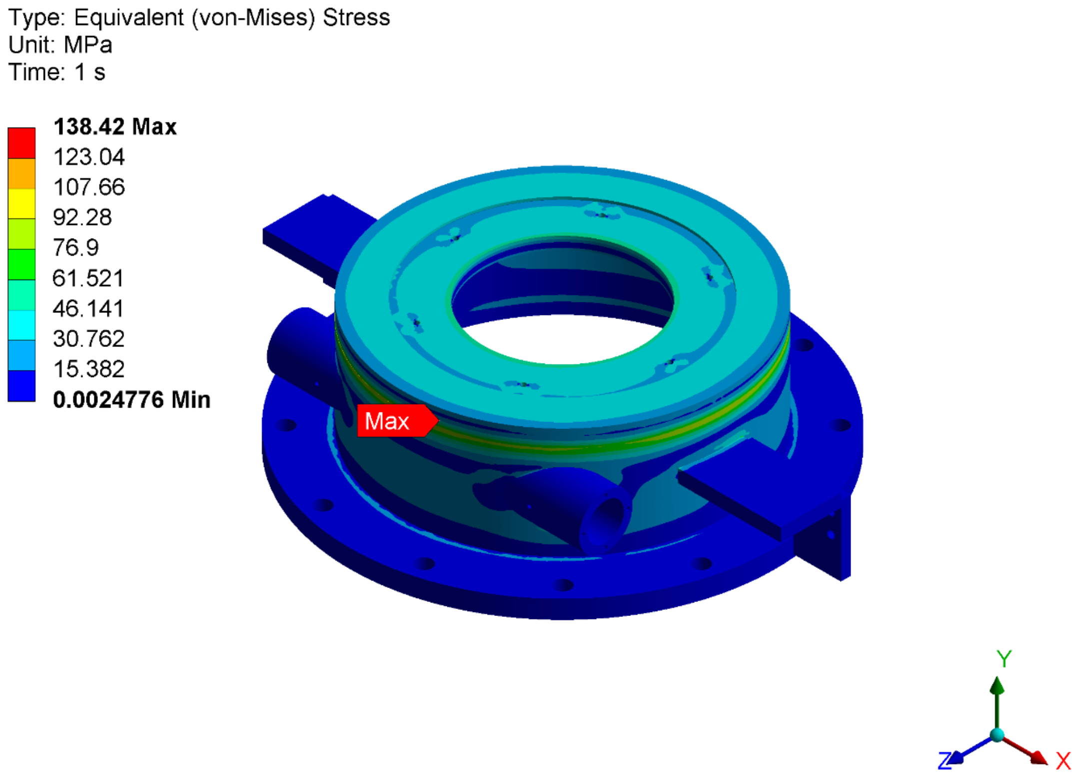

Fig 4.1 – Equivalent Von-mises stresses

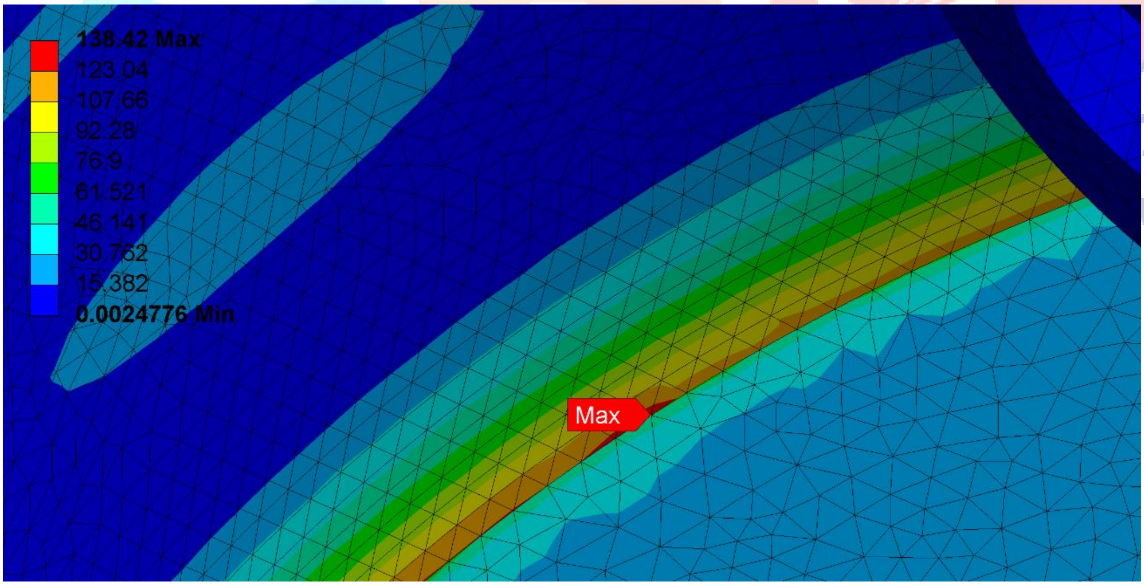

Fig 4.2 –Maximum Von-mises stresses

The above results indicate that the maximum von Mises stress of 138.42 MPa generated in nozzle to shell junction, while the minimum von Mises stress of 0.0024776 MPa is observed at the mounting flange.

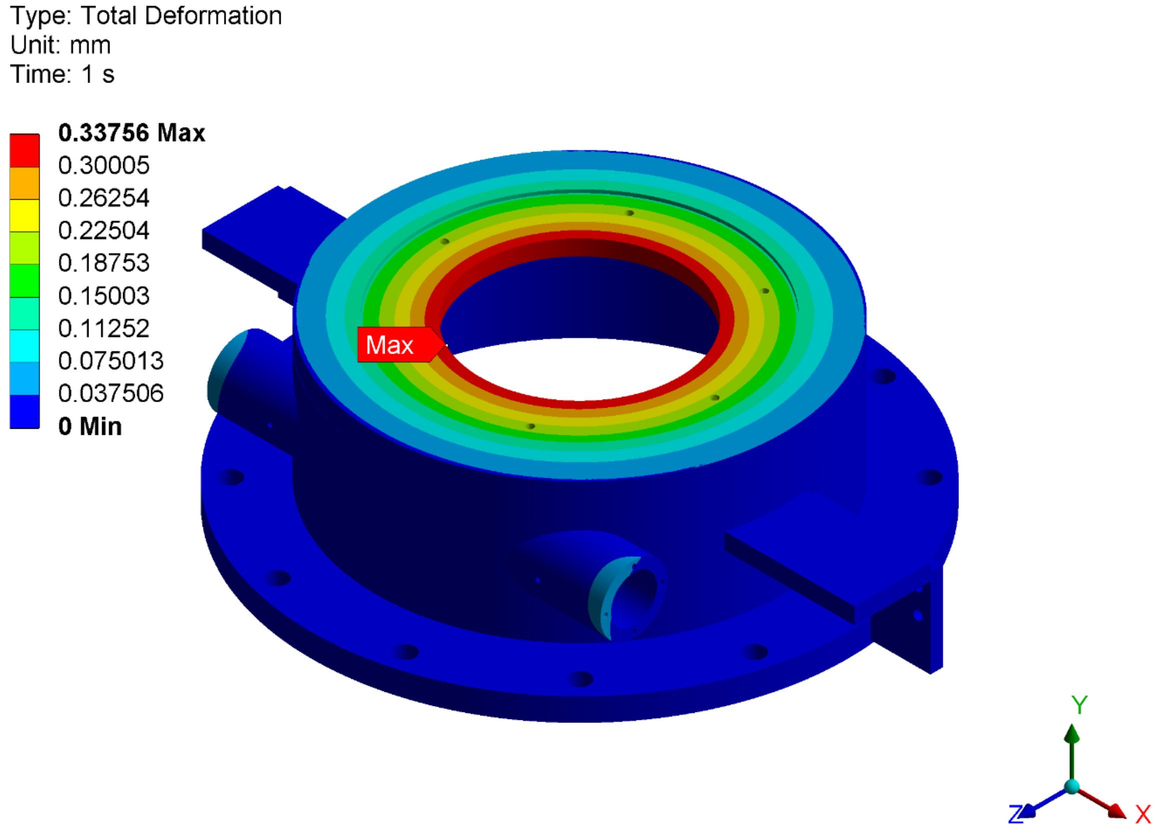

Fig 4.3 – Total Deformation

The above results indicate that the maximum deformation of 0.33756 mm generated at top of vessel body, while the no deformation is observed at the mounting flange and body.

V. FATIGUE LIFE CALCULATION

The Fatigue assessment is carried out by Elastic stress analysis and equivalent stresses – Effective total equivalent stress amplitude is used to evaluate the fatigue damage for results obtained from a linear elastic stress analysis. The controlling stress for the fatigue evaluation is the effective total equivalent stress amplitude.

The maximum von mises stress for the Load Case 1 (Design condition) is observed in valve body which is 138.42 MPa

So, the effective total maximum stress

$S\Delta pk = 138.42$ MPa

As the local notch or effect of weld is not accounted for in Finite Element model, therefore the fatigue strength reduction factor (Kf) for weld is selected from table 5.12 of Section VIII Div. [2] Kf = 1.2 (As welded weld that receives full volumetric examination and a surface that receives MT/PT examination and a VT examination (visual))

As the induced equivalent stress (138.42 MPa) is less than the three times the allowable stress value (3 X 117 MPa = 351 MPa) i.e. $\Delta Sn,k < \Delta Sps$, the fatigue penalty factor Ke, k = 1

The Poisson Correction Factor need not be used as the fatigue penalty factor Ke, k is used for entire stress.

Therefore, the alternating equivalent stress for the kth Cycle is calculated as follows

$S\ alt,k = (Kf \cdot Ke,k \cdot \Delta S\_P,k) / 2$

$S_{alt,k} = 1.2 * 1 * 138.42/2$

$S_{alt,k} = 83.052$ MPa

Based on the alternating equivalent stress the permissible stress number of cycles are calculated according to Annex 3.F as follows –

Number of allowable stress cycles = $N = 10^X$

And the Stress factor used to compute $Y = \log [28.3 \times 10^3 \times (S_a / E_t)]$

Y = 1.085

Exponent used to calculate permissible number of cycles as the σuts is < 552 MPa.
For 10^Y ≥ 20:
X = -4706.5245 + 1813.6228Y + 6785.5644/Y - 368.12404Y^2 - 5133.7345/Y^2 + 30.708204Y^3 + 1596.1916/Y^3
For 10^Y < 20:
X = (38.1309 - 60.1705Y^2 + 25.0352Y^4) / (1 + 1.80224Y^2 - 4.68904Y^4 + 2.26536Y^6)

X = 6.2392
$N = 10^{X} = 10^{6.2392} = 1734506$ cycles
Allowable cycles = 1734506 cycles

Designed life of equipment is 1000000cycles
Fatigue Damage Factor = Design Number of Cycle / Calculated Number of Cycle
= 1000000 / 1734506
Fatigue Damage Factor = 0.576

VI. VALIDATION

FEA Result Validation (Software Validation):
Results are verified for stress due to pressure as follows
Hook stress away from discontinuity =

$$\frac{Px\ D}{2xt} = 19.73\ MPa$$

The stresses in tangential directions match with calculated value as shown in figure 6.1.

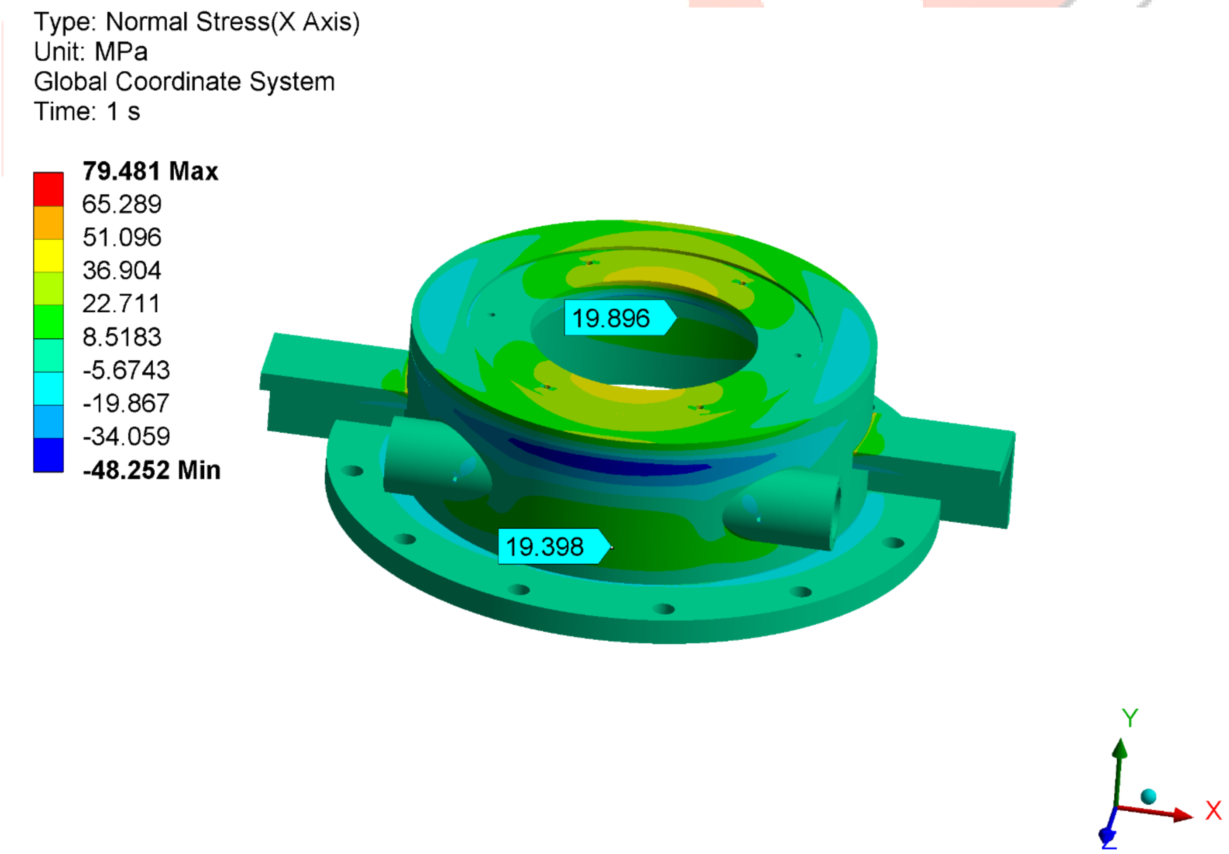

Fig 6.1 – Normal stress (X-Axis)

The theoretically calculated normal stress of 19.73 MPa closely aligns with the analytical result, which shows a stress value of 19.896 MPa.

VII. CONCLUSION:

Stresses induced in valve body are within allowable limit as per criteria specified in Part 5 methods of ASME SEC VIII DIV 2 Edition 2021 for given considerations and assumptions made in this report.
The fatigue life cycles are observed based on the Finite Element Analysis calculations are more than the design cycles of the equipment. The damage factor observed to be less than 1.

VIII. FUTURE SCOPE:

The Iso-Flow Valve has strong potential for future development through the use of advanced wear-resistant materials, integration with smart monitoring systems, and broader application across industries like mining, cement, and waste-to-energy. Further improvements in compact design, automation, and sustainability will enhance performance and ease of maintenance. Standardization and global market expansion will also drive its adoption in high-demand sectors.

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