MCGILL UNIVERSITY – VELAN

Redesign and Value Engineering of Velan R-Type Ball Valve

MECH 497

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Executive Summary

The value analysis process was applied on the Velan R-type high pressure forged metal seated ball valve. After value and cost analysis of different implementations, the design changes to be proposed are:

1- Switch from forging to casting of bracket, body, and body-end to reduce cost and redesign the bracket to cut down on material.
2- Instead of the large bracket currently used, it is suggested to remove this piece in its entirety to incorporate the mounting of the actuator on the body itself. An example of this model is shown below.
3- Incorporate chevron packing rings instead of the existing ring design using a hinge like action that immediately reacts to change in pressure on the rings to block the fluid.
4- Incorporate TFM material for packing rings instead of graphite to reduce friction.

From the following proposals the following combinations were evaluated to determine the scenario with the best value/cost advantage:

- Switch from forging to casting of bracket, body, and body-end and change the design of the bracket.
- Switch from forging to casting of bracket, body, and body-end, change the design of the bracket and incorporate chevron packing rings.
- Switch from forging to casting of bracket, body, and body-end , change the design of the bracket , incorporate chevron packing rings and incorporate TFM material for packing rings/
- change the design of the bracket and Incorporate TFM material for packing rings

After evaluating these scenarios our primary final recommendation is: Switch from forging to casting of bracket, body, and body-end and change the design of the bracket because it resulted in the highest value (function/cost) with a substantial cost reduction of 2582 $ per valve (25% cost reduction).

Suggested changes pertaining to Trunnion seat design and a tilt-and-turn mechanism were discarded due to feasibility issues.

Acknowledgments

Our value engineering team would like to thank Velan Inc. for providing us with the opportunity to work on their product and providing us with the information necessary for our work. We would also like to thank Gerti Bajraktari and Luc Vernhes of Velan Inc. for their help and constructive input in achieving our result throughout the value analysis process. Finally, we would like to show our appreciation to Lucie Parrot and Paul Zsombor-Murray for providing us with the tools and knowledge and for sharing with us their experience in value engineering.

Introduction

Velan is a company based out of Montreal, which designs and manufactures industrial valves. The eminent inventor A.K. Velan founded the company in 1950. Today, the company boasts a global network of 16 specialized manufacturing plants in Europe, Asia, Canada and the US. Velan's products are used in a variety of industries ranging from the petrochemical industry to pulp and paper. Velan's market reputation is that of producing high quality, reliable products in an efficient and timely manner. It is because of this that their company motto claims: Velan, quality that lasts.

Velan has worked with McGill University in the past during a project involving the optimization of the design of a model of their butterfly valves. Since the result attained by this value engineering project were innovative, and were able to shed a new light on an old problem, Velan has returned to McGill to apply the same process to their ball valves.

The goal of the project is to apply the value engineering process in order to both increase the quality and reliability of the product while controlling cost. It is important in such a process to understand the state of mind and overarching goal of the company. After various meetings with representatives from Velan including a visit to a factory site, it became clear that Velan is a company that prioritizes quality. This means that cost increases are accepted, but must be justified by an increase in overall value of the product. Design changes that are able to greatly reduce cost but eliminate essential functions of the product will not be welcomed. Velan manufactures to specific orders rather than market trends. As well as providing great flexibility to the client, this somewhat compromises the company in terms of manufacturing time as well as cost. Velan has expressed their interest in a solution, which is able to standardize certain components of their product without sacrificing the client's needs and the companies' reputation.

"honed" or "homed on", not "honed on"

By following certain value engineering methodologies, the team has honed on those factors that can be modified, and those which shall remain constant according to ASME standards as well as company regulations and vision.

Information

In order to implement Value Engineering methods, it was essential to understand how the valve is manufactured. Time was spent with Velan engineers to understand what each component of the valve does. We also reviewed a lot of literature to grasp the functions of each component as quickly as possible. A visit to the manufacturing facility was also organized to deepen our understanding of the valve and the manner in which it is manufactured.

Understanding the valve

The metal seated ball valve is a special type of valve that is installed in severe service applications (high temperature and pressure). It is not used to regulate flow, but rather its function is to either allow complete flow or none at all. In this aspect it can be seen as an on/off switch. Different valve sizes are available depending on the application and sizes typically range from ½" to 24" IPS valves.

Key design features and specifications of the valve:

- **Bi-directional sealing** with preferred direction
- **Advanced HVOF** or Plasma Spray custom trim coating technology with hardness in excess of 70 RC
- **Superior ball/seat finish** to 2-4 RMS
- **Unique ball/seat spring loading** technology to assure tight shutoff at low differential pressures and/or when fines are present
- **Complete ball/seat** set individually vacuum tested to verify sealing integrity
- **Robust blowout-proof system**
- **Low emission stem seal with advanced live-loaded packing arrangement**
- **Stem bearing** reduces side thrust effect on packing and prevents stem wobbling
- **All valves are inherently fire safe**
- **Designed to ASME B16.34**
- **Flow relief** is incorporated into both the upstream and downstream ball lips increasing the area exposed to flow and thus reducing erosion due to velocity upon initial valve opening
- **Downstream and upstream** body-seat lapped contact

The figure below shows the design of the ball valve, with the material associated with each part. It can be seen here that the valve is very complex to ensure a tight seal under high pressures.

STANDARD MATERIALS

PART		CARBON STEEL		CHROME MOLY STEEL		STAINLESS STEEL		
		To 600°F To 315°C	600°F to 850°F 315°C To 454°C	To 1,100°F To 593°C	To 1,200°F To 649°C	To 600°F To 315°C	600°F to 1,000°F 315°C to 538°C	To 1,200°F To 649°C
1	Body	A105		F22	F91	F316		F316H or F347H
2	Body end	A105		F22	F91	F316		F316H or F347H
3	Stem	SS 410 Cond.2		SS 616[1]	Inconel 718 PH[2]	SS 630[1]	Inconel 718 PH[2]	Inconel 718 PH[2]
4	Ball	SS 410 Cond.2/CC[3]			Inconel 718/CC[3]	SS 410 Cond.2/CC[3]		Inconel 718/CC[3]
5	Thrust washer	Stellite 6						
6	Thrust bushing	Bronze						
7	Stem bushing	Nitrided SS 410 Cond.2 / Alt: Nitronic 60						
8	Seat	SS 410 Cond.2/CC[3]			Inconel 718/CC[3]	SS 410 Cond.2/CC[3]		Inconel 718/CC[3]
9	Packing flange	SS 304[4]		SS 304				
10	Gland bushing	SS 304						
11	Packing ring	Graphite						
12	Anti-extrusion ring	Braided Graphite						
13	Stud (body)	B7		B16		B8M CL.2	B16	
14	Stud (bracket)	B7		B7		B8M CL.2		
15	Stud (packing flange)	B7		B7		B8M CL.2		
16	Nut (body)	Gr. 2H		Gr. 4		Gr. 8M	Gr. 4	
17	Nut (bracket)	Gr. 2H		Gr. 2H		Gr. 8M		
18	Nut (packing flange)	Gr. 2H		Gr. 2H		Gr. 8M		
19	Socket head cap screw	A574 Alloy Steel						
20	Gasket (spiral-wound)	SS 347 / Graphite						
21	Snap ring	Carbon Spring Steel (SAE 1060-1090)						
22	Belleville washer	H11 / H13						
23	Load ring	SS 630	SS 630 (to 600°F/315°C) or SS 660 (to 1000°F/593°C) or Inconel 718 PH[2] (above 1000°F/593°C)					
		Inconel 718 PH[2]						
24	Spring guide bushing	SS 304						
25	Lock washer	Commercial Zinc Plated						
26	Bracket	CS c/w Aluminum High Temperature Paint						
27	Driver	SS 410 Cond.2						

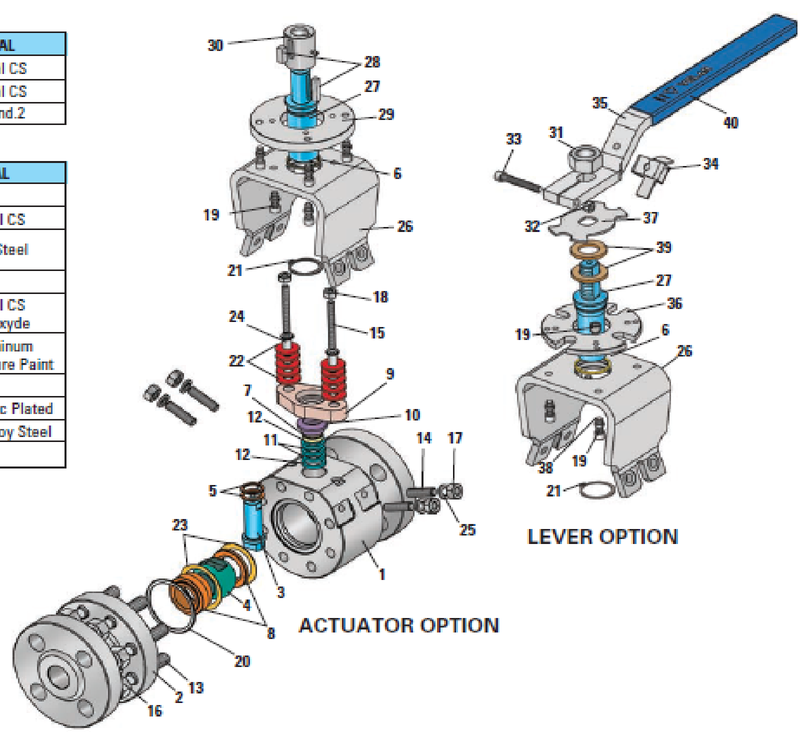
ACTUATOR OPTION

PART		MATERIAL
28	Key	Commercial CS
29	Adapter plate	Commercial CS
30	Coupling	SS 410 Cond.2

LEVER OPTION

PART		MATERIAL
31	Lock nut	SS 304
32	Nut	Commercial CS
33	Socket head cap screw	A574 Alloy Steel
34	Lock clip	SS 302
35	Lever	Commercial CS c/w Black Oxyde
36	Adapter plate (lever)	CS c/w Aluminum High Temperature Paint
37	Stopper plate	SS 302
38	Lock washers	Commercial Zinc Plated
39	Thrust washer	Commercial Alloy Steel
40	Plastic cover	Plastic

(1) Alt: SS 660
(2) PH=Precipitation Hardened
(3) CC=Chrome Carbide Coated
(4) Alt: A105 c/w Aluminum High Temperature Paint



Function and Existing Cost Analysis

Functional Analysis

The functional analysis phase lies at the very heart of Value Engineering. During this phase, the needs of the user are explained in terms of the requirements of a product or process while disregarding planned solutions. By understanding how a component works and what it contributes to the overall product or process on a deeper level, the value engineering team can better identify areas of value improvement. In order to define functions, an organized system was used whereby the action of the product was related to user needs.

The function could then be characterized where it was determined whether it was a basic service, a secondary or support service, or a constraint. Basic functions describe an action that the product is designed to perform. Without the basic functions, the product's ultimate goals cannot be realized. On the other hand, support functions are internal actions that support the basic functions of the product. Finally, constraints are requirements that the product must conform to, and they may be imposed by: the environment, technology, corporate demand, regulation, etc.

The identification of functions generally utilizes 6 methods: intuitive research, environmental analysis, sequential analysis, movement and effort analysis, reference product analysis, and standards and regulation analysis. However, for this project, our value engineering team focused on intuitive research, environmental analysis, and reference product analysis. Standards and regulations were briefly covered by our company representatives.

Next, the functions were logically organized in a Function Analysis System Technique (F.A.S.T) diagram

Identification Section

1) Intuitive research

In this approach, using common sense and intuition in conjunction with some direction from Velan representatives, the following items were found:

> Main Functions

- Maintain Product
- Maintain Fluid-Flow
- Avoid Explosion
- Prevent Leakage
- Allow Maintenance
- Allow Rotation
- Seal Valve
- Open Valve
- Prevent Partial-Opening

> Component Functions

> **Ball**

- Seal Flow
- Prevent Leakage (pipe and atmosphere)
- Allow Rotation
- Protects seal in open/closed position

- Controls Flow

> Stem

- Drive Ball
- Transmit Torque (determines the diameter of stem)
- Seal Flow
- Prevent Leakage

> Body

- Maintain Pressure
- Hold Stem (in position)
- Constrains Flow
- Prevent Leakage

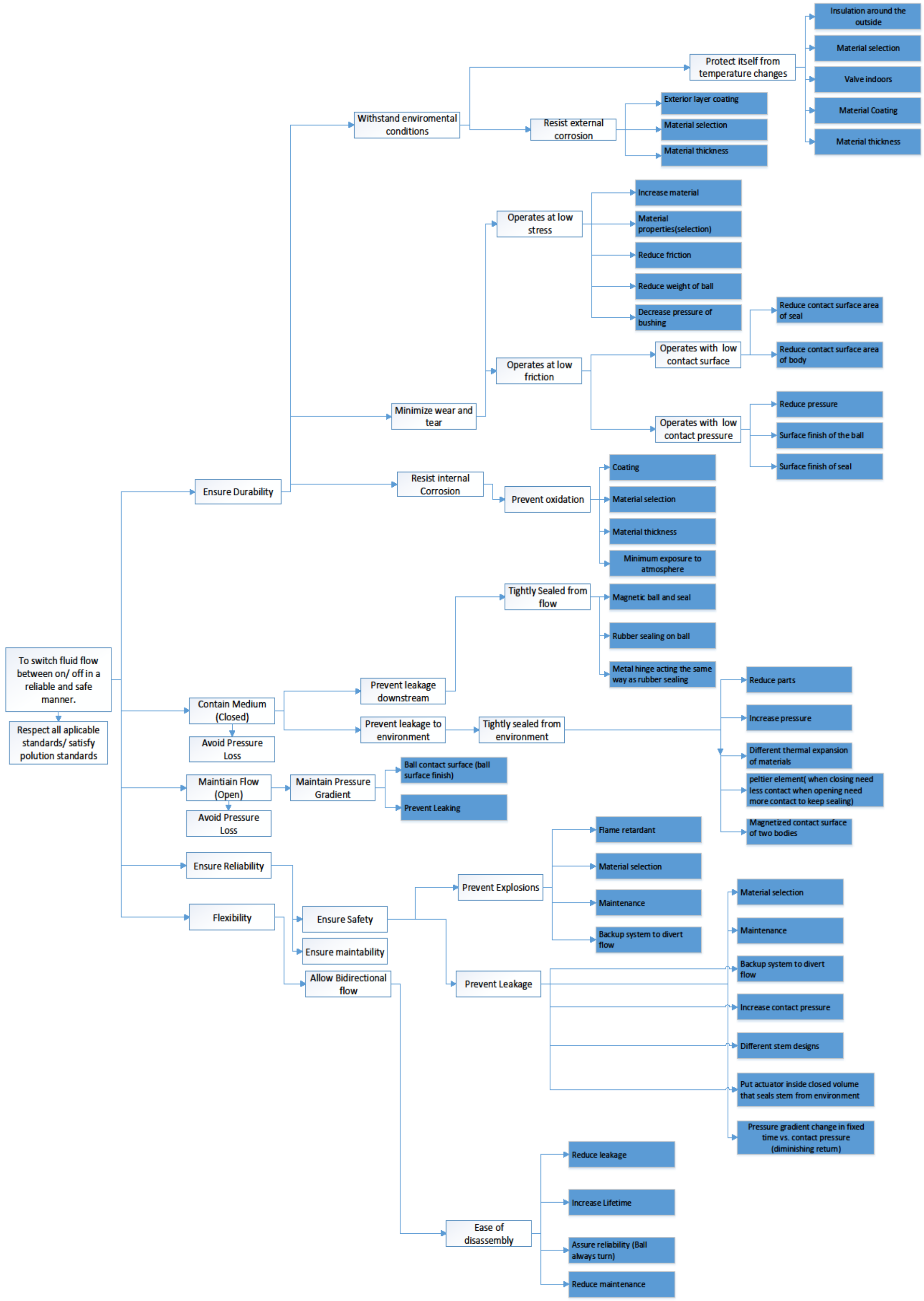
> **Truss Washer**

- Reduce Friction
- Prevent Leakage

> Constraints

- Maintain the two piece valve design
- Maintain pressure class
- Do not increase stem length
- Do not violate ASME ASME B16-34 and B16-10 standards

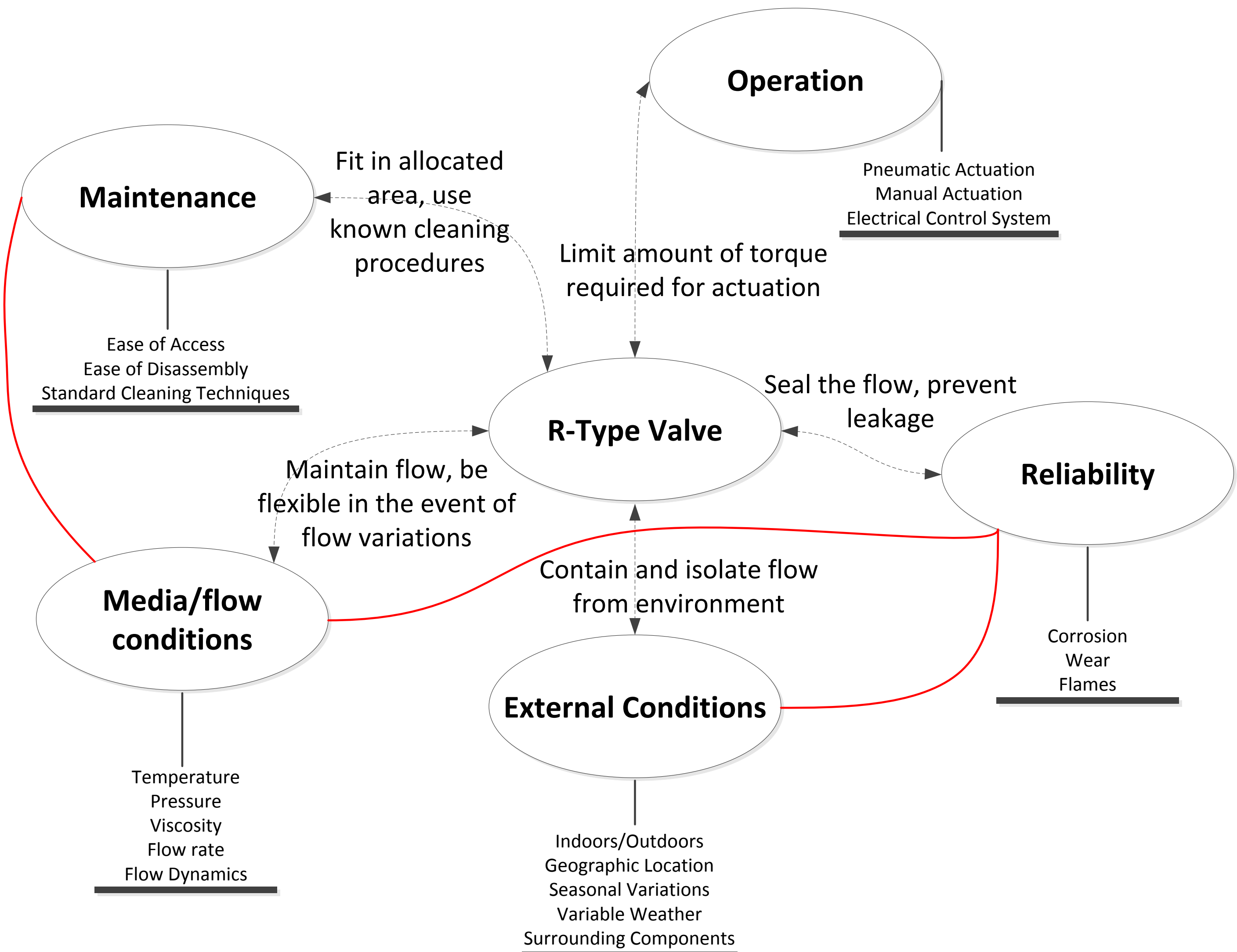
Functional Analysis Diagram



For full view of this diagram please see Appendix C

2) Environmental Analysis

The purpose of the environmental analysis was to find the external and the internal fluid flow elements that potentially interact with the valve. On the following page is the compiled environmental analysis diagram. It should be noted that the dotted lines between elements and the product represent connections they have to one another. A verbal description of the relations in terms of function is provided with these dotted lines. Furthermore, the red lines connecting separate elements represent interaction functions between respective elements. It could be stated that all the elements interact with one another; however, we highlighted the interactions found to be most significant. Finally, it is important to mention that the elements are strictly external influences, and do not belong to the product itself.

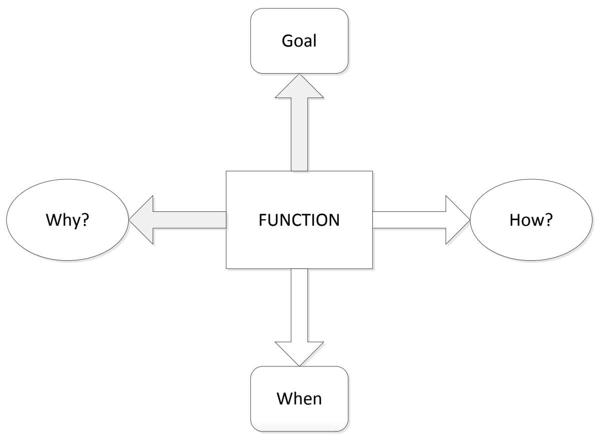


3) Reference Product Analysis

In this phase, each member individually did research on competitors' valves of different companies. This was a very helpful phase in terms of further understanding the function of Velan's product, and how different companies solved various design constraints in unique ways.

Organizational Section

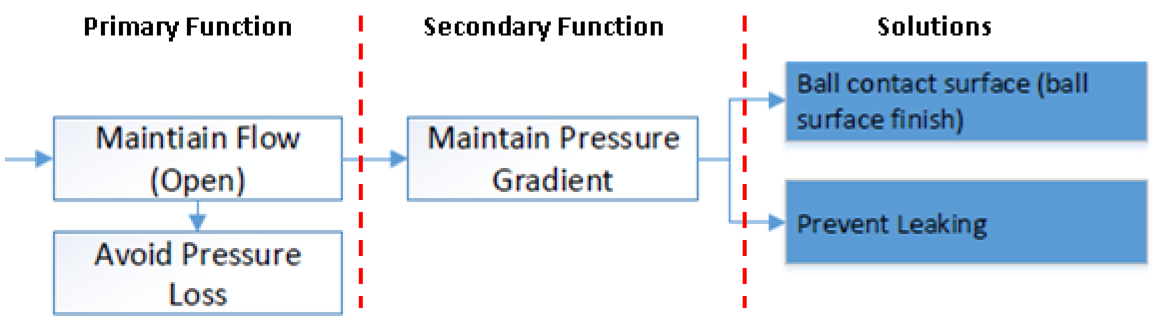
One of the major goals of the functional analysis phase was to create a functional diagram in the style of a classical FAST model. This model displays the how-why logic of every function, and provides a visual aid of the functional hierarchy of the product as follows:



This diagram asks the questions: Why is the function necessary? How is the function accomplished? When is the function accomplished, and what is the goal of the function? In doing so, logical relations are developed, and an organizational flow chart is formed.

Farthest to the left on the diagram is the mission of the product, and its overall goal. Branching from here are the primary basic functions. We found these to be: ensure durability, contain medium, maintain flow, avoid pressure loss, ensure reliability, and flexibility. Next, we began to ask how these functions could be performed, and came up with secondary and tertiary functions. At the far right of the diagram lie potential solutions that became clear after organizing the different level functions.

To summarize, the functional diagram is the result of organization. It moves to higher levels of abstraction as we move to the left, and becomes more detailed as we move to the right. Below is an example of a major logic path.



Characterization Section

This phase involved stating which functions would be measured in terms of performance. Criteria, level, and flexibility of each function were clearly labeled so as to clearly specify the characteristics of each function. In other words, each function was assigned a quantitative measurement that would describe it (characterize it,) and an allowable tolerance in performance was suggested by our company representatives. Criteria, level, and flexibility were defined as follows:

Criteria → How are function accomplished, and measured on a numeric scale?
Level → What is the acceptable result, or numeric tolerance for each criterion?
Flexibility → To what extent can the level be negotiated based on the client?

Below is the functional performance specification (FPS) table we came up with:

FUNCTION	**CRITERIA**	**LEVEL**	**FLEXIBILITY**
Ensure durability	• Average Lifetime (Yrs) • Corrosion Resistance (PPM)	5,000 cycles/5 years No inside	F1 F1
Contain Medium	• Pressure level (psi) • Temperature of medium (degrees Celsius) • Fluid loss (L/yr)	2.5 X Class (6,250 psi) ambient temperature Downstream:?? Atmosphere: 0	F0 F0 F1
Maintain Flow	• Control volume • Torque • Stem sizing • Wall thickness	Pipe diameter *Flow Velocity *Density → further depth required	F0 F0 F0 F0
Flexibility	• Variation in flow speed (m/s) • Mass (kg)		F1 F2
Ensure Reliability	• Ease of assembly/ disassembly (min) • Torque • Actuator sizing	Number of components: 28	F1 F0 F0

It should be noted that F0 represents no flexibility, F1 represents little flexibility, and F2 represents some flexibility.

Existing Cost Analysis

Cost Breakdown

[And for which value size is this?]

The cost breakdown of the valve by components was the first document we requested from our clients, Velan. As we received the cost of each individual component, it was very simple for us to realize where the elevated cost tag came from. The following Table 1 Cost Breakdown shows the list of components along with their respective cost. It also color-codes the prices and places them into four different categories, with the red color representing the components with the greatest contribution to the total cost and the green color representing the components with the lowest contribution.

DESCRIPTION	DWG N°	PRICE ($)
BODY	401-6240	3030
BODY END	403-6038	2270
STEM	404-9387	180
BALL	405-5194	542.4
THRW	406-007	406.3
SBSH	407-9296	35.26
TRBS	408-5046	107.78
SEAT A	409-9518	333.86
SEAT B	409-9698	237.62
PFLG	411-9350	165
GLBG	412-9332	97.29
PKRG	9079-040	28.78
STUD	S0B0-JD0	3.42
STUD	S0BF-F00	12.44
STUD	S0BL-JL0	98.4
NUTS	N0B0-XX0	2.2
NUTS	N0BF-XX0	19.16
NUTS	N0BL-XX0	37.2
SHCS	BDB0-DD0	31.52
GSKT	8977-023	5.71
RTRG	R0FD-XX0	9.35
KEYS	7939-202	10.5
BWSH	436-3341	83.44
BWSH	9554-095	132
BWSH	9555-331	44.1
WSHR	WA0L-NX0	2.76
WSHR	WABF-RX0	2.76
BRKT	478-5430	1816.9
DRVR	479-5535	625
TOTAL COST		**10371.15**

Table 1 Cost Breakdown

Furthermore, we calculated the percentage cost of each component as well as their volumes, densities and weights as illustrated in Table 2 Cost Percentage. It was observed that **69%** of the valve cost came from only three components: the body, the body end and the bracket. This can be better visualized Figure 1 Price Distribution. Thus we decided that we would focus on reducing the cost and weight of the three before-mentioned main components to try and reduce the overall cost of the valve and increase its value. The reason why we considered reducing the weight was to cut down on material usage, which would consequently reduce the cost.

Units? Units? excessive precision

excess. prec. up to 1 part in 10^9!

Description	DWG N°	Price ($)	Percent	Part Volume	Density	Part Weight	Percent
BODY	401-6240	3,030.00	29.22	59,782,999.79	7.86E-06	469.954	48.933
BODY END	403-6038	2,270.00	21.89	38,990,606.47	7.86E-06	306.505	31.914
STEM	404-9387	180.00	1.74	1,323,197.43	7.75E-06	10.255	1.068
BALL	405-5194	542.40	5.23	966,739.64	7.75E-06	7.492	0.780
THRW	406-007	406.30	3.92	8,888.08	8.44E-06	0.075	0.008
SBSH	407-9296	35.26	0.34	24,794.93	7.75E-06	0.192	0.020
TRBS	408-5046	107.78	1.04	54,934.52	8.70E-06	0.478	0.050
SEAT A	409-9518	333.86	3.22	703,249.85	7.75E-06	5.450	0.567
SEAT B	409-9698	237.62	2.29	216,734.64	7.75E-06	1.680	0.175
PFLG	411-9350	165.00	1.59	1,480,609.29	8.00E-06	11.845	1.233
GLBG	412-9332	97.29	0.94	86,075.13	8.00E-06	0.689	0.072
PKRG	9079-040	28.78	0.28	25,263.73	2.23E-06	0.056	0.006
STUD	S0B0-JD0	3.42	0.03	105,809.39	7.85E-06	0.831	0.086
STUD	S0BF-F00	12.44	0.12	121,146.25	7.85E-06	0.951	0.099
STUD	S0BL-JL0	98.40	0.95	344,218.92	7.85E-06	2.702	0.281
NUTS	N0B0-XX0	2.20	0.02	27,120.29	7.86E-06	0.213	0.022
NUTS	N0BF-XX0	19.16	0.18	64,267.87	7.86E-06	0.505	0.053
NUTS	N0BL-XX0	37.20	0.36	126,232.34	7.86E-06	0.992	0.103
SHCS	BDB0-DD0	31.52	0.30			0.000	0.000
GSKT	8977-023	5.71	0.06	12,136.66	8.00E-06	0.097	0.010
RTRG	R0FD-XX0	9.35	0.09			0.000	0.000
KEYS	7939-202	10.50	0.10	30,725.74	7.78E-06	0.239	0.025
BWSH	436-3341	83.44	0.80	7,009.31	7.78E-06	0.055	0.006
BWSH	9554-095	132.00	1.27	31,002.30	7.78E-06	0.241	0.025
BWSH	9555-331	44.10	0.43	57,507.15	7.78E-06	0.447	0.047
WSHR	WA0L-NX0	2.76	0.03	1,750.77	7.78E-06	0.014	0.001
WSHR	WABF-RX0	2.76	0.03	13,177.35	7.78E-06	0.102	0.011
BRKT	478-5430	1,816.90	17.52	14,285,500.48	7.78E-06	111.113	11.569
DRVR	479-5535	625	6.03	3,514,405.32	7.75E-06	27.237	2.836
TOTAL COST ($)		10371.15			TOTAL WEIGHT (kg)		960.41

Table 2 Cost percentage

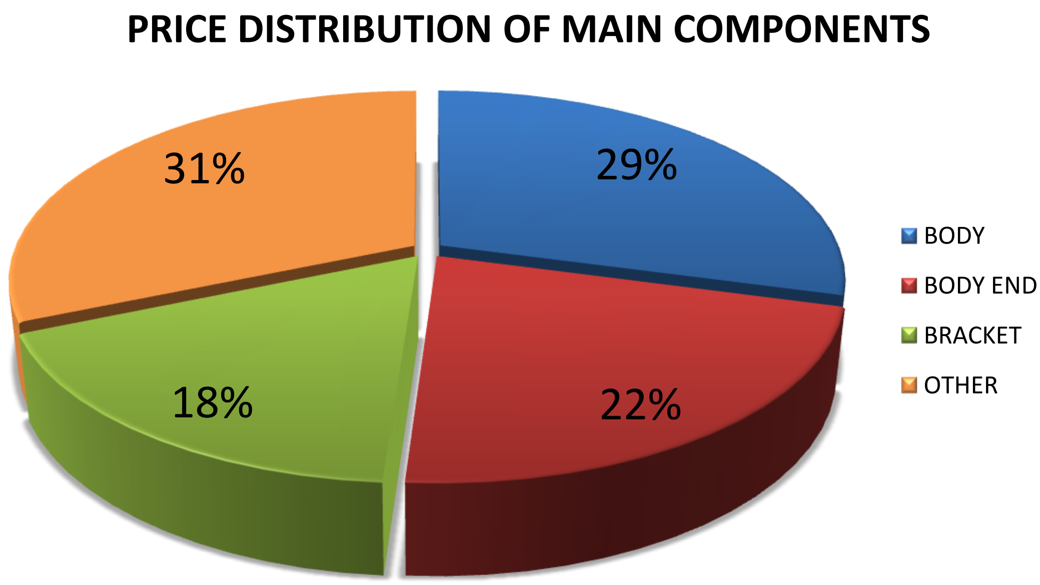


Figure 1 Price Distribution

Creativity Session

Once the problem statement and customer requirements were understood by the team the next phase was to move to the creative process of brainstorming potential solutions. Both value and cost functions were considered when generating new creative solutions for the customer's problem. The brainstorming session was used to come up with creative ideas without criticising any of them or questioning their feasibility. Each brainstorming idea emerged from the basic functions of the product: Ensure durability, Contain medium, Avoid pressure loss, maintain flow, and ensure reliability and flexibility. In order to provide solutions that is in line with what the customer values and requirements.

Ideas Proposed During Brainstorming

1. **Protect from temperature changes**

   1.1 Insulation around the outside
   1.2 Material selection
   1.3 Valve indoors
   1.4 Material Coating
   1.5 Material thickness

2. **Resist external corrosion**

   2.1 Exterior layer coating
   2.2 Material selection
   2.3 Material thickness

3. Operate at low stress

3.1 Increase material
3.2 Material properties (selection)
3.3 Reduce friction
3.4 Reduce weight of ball
3.5 Decrease pressure of bushing

4. Reduce contact surface

4.1 Reduce contact surface area of seal
4.2 Reduce contact surface area of body

5. Operates at low contact pressure

5.1 Reduce pressure
5.2 Surface finish of the ball
5.3 Surface finish of seal

6. Prevent oxidation

6.1 Coating
6.2 Material selection
6.3 Material thickness
6.4 Minimum exposure to atmosphere

7. Tightly sealed from flow

7.1 Magnetic ball and seal
7.2 Rubber sealing on ball
7.3 Metal hinge acting the same way as rubber sealing

8. Tightly sealed from environment

8.1 Reduce parts
8.2 Increase pressure
8.3 Different thermal expansion of materials
8.4 peltier element (when closing need less contact when opening need more contact to keep sealing)
8.5 Magnetized contact surface of two bodies

9. Maintain Pressure Gradient

9.1 Ball contact surface (ball surface finish)
9.2 Prevent Leaking

10. Prevent Explosions

10.1 Flame retardant
10.2 Material selection
10.3 Maintenance
10.4 Backup system to divert flow

11. Prevent Leakage

11.1 Material selection
11.2 Maintenance
11.3 Backup system to divert flow
11.4 Increase contact pressure
11.5 Different stem designs
11.6 Put actuator inside closed volume that seals stem from environment
11.7 Pressure gradient change in fixed time vs. contact pressure (diminishing return)

12. Ease of Disassembly

12.1 Reduce number of components
12.2 Reduce number of bolt
12.3 Reduce weight
12.4 Reduce distance of height of stem which reduce height of bracket (reduce size of bracket also)
12.5 Keep two-piece design
12.6 Reduce number of parts for assembly

Brainstorming session Evaluation

After discussion with the team, the following ideas were short listed for the subsequent reasons:

1. Nickel electrodes: Do not seem very reasonable as too expensive to implement
2. Trunnion seat: Investigate the idea further
3. Peltier tube: Not feasible at all
4. Machine Bracket in valve body: Can result in major reductions of cost
5. Conduct cost benefit analysis of casting
6. Coating application analysis
7. Compare components with competitors to investigate which components can be reduced
8. Chevron packing shape
9. Change graphite packing to TFM
10. Have seat A as part of body: Very interesting idea to explore
11. External thrust roller bearings: Idea seems to be very expensive and not easy to implement
12. Reduce bracket length

Brainstorming Session Evaluation

Feature	Yousuf	Jonathan	Joseph	Omar	Gerti	Iyad	%
Protect itself from temperature changes							
Insulation around the outside	3	1	1	1	1	1	13.33
Material selection	5	7	7	7	5	6	61.67
Valve indoors	1	1	1	1	1	1	10
Material coating	1	5	4	6	7	10	55
Material thickness	3	6	5	6	3	4	45
Resist external corrosion							
Exterior layer coating	1	1	4	1	3	2	20
Material selection	8	6	8	7	9	8	76.67
Material thickness	2	3	5	3	7	1	35

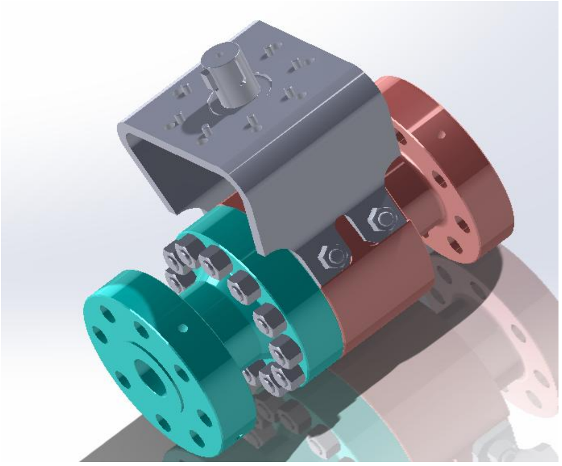
Table 3 Brainstorming Sample

The full Brainstorming Session evaluation is found in Appendix A

Proposals

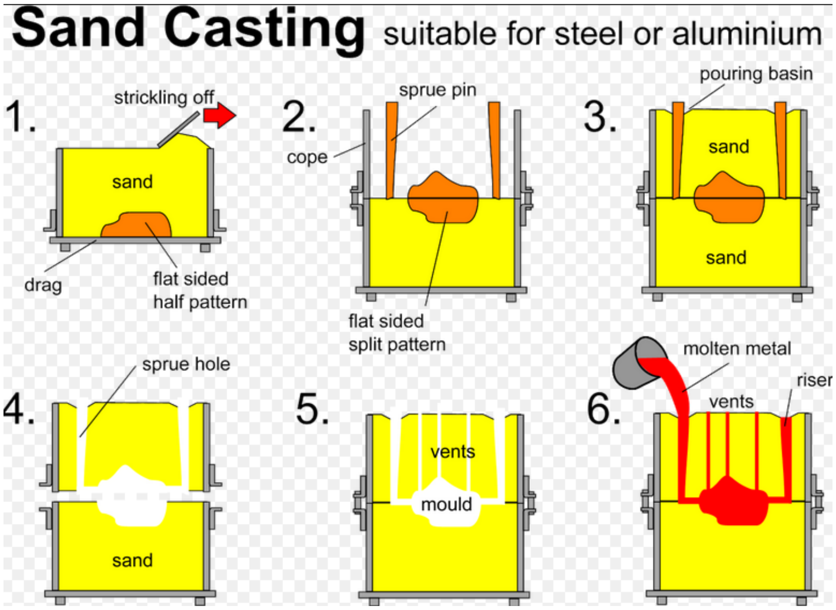
Project: Cast Manufacturing		**Prepared by:** McGill Value Engineering Team	
Proposal No: 1	**Date:** Nov. 21st, 2013	**Presented to:** Velan	**Page:** 1 of 3

Actual Situation: The Type R Valve is a high pressure forged metal-seated ball valve designed to permit multi-directional fluid flow through it. Some characteristics of the Valve are: Bi-Directional Sealing, All components are forged, Additional material on some components to reduce machining costs, Superior ball/seat finish, Requires large amounts of torque due to friction between ball and seat, Designed to ASME B16.34, Downstream and upstream body-seat lapped contact.



Through the value engineering workshops, we have identified that the bracket attached to the top of the valve it is overpriced. In terms of function, it only connects the valve to the actuator. However, it is approximately, 20% of the cost of the valve. We aim to reduce the costs of the bracket by changing the machining process of the bracket. The design above shows that the bracket attached to the top of the body is very large. Furthermore, bolts are required on the edge of the body to attach it rigidly. This explains why the cost is relatively high.

Proposed Design: The sand casting technique used for manufacturing will greatly reduce costs. It will also allow us to remove unwanted material in parts of the body and therefore reduce the weight of the valve as well. This is because the molds required to manufacturing the components can be designed in such a way that the



Valve body has the least amount of material. The figure below highlights the main features of the sand casting process.

Another very important factor to consider is that the sand casting process can adversely affect the finishing of numerous components. Therefore, it is recommended that only a few components of the valve are sand casted and the rest are forged as before. Internal components of the valve such as the seats and thrust washers will need to be forged as the quality of the surface finish is very important for these components. This is because a rough surface can increase the amount of friction and this will mean a lot more force will need to be applied when closing and opening the valve.

Discussion:

Feasibility: Similar manufacturing processes already exist and are used by some of Velan's competitors. Furthermore, we have discussed this option with Velan and they are very confident the casting process is very feasible and can be implemented with the current expertise that they have. In fact, Velan believes that these changes in the manufacturing process can be implemented in the near future as this technique does not affect the main functions of the valve.

Assumptions: The casting procedure would cost Velan 1.37$/pound of the component. We will use this price for all the components we evaluate. The surface finish and material properties will not be significantly compromised when using casted model. Labor costs will remain the same for casted and forged components. There are no hidden costs when switching from casted to forged components. The new bracket design will be able to withstand the weight of the actuator

Pros:	Cons:
• Considerably lower delivery time	• Strength might be reduced
• Reduced weight	• Surface finish will not be as good and additional polishing may be required
• Less costs	• Tests to ensure structural integrity with new design may take time

Impacts and Risks: Changing the design of an existing product always has risks associated to it. The main risks that Velan needs to be aware of include:

- Velan has always relied on producing high quality valves and does not see itself as a low cost producer. A lower quality in surface finish can make some customers unhappy
- Once installed, the valves function for a long time. It is therefore essential to study the effects of the new design after years in operation. Since there is so much competition in this industry, even slight failure in valves can drastically reduce customer confidence
- The complex geometry of the design might increase the casting costs. This would mean that the initial estimate of 1.37$/pound will need to be revised

Implementation Conditions: Given the risks associated with the product, we recommend Velan to conduct customer reviews before significantly changing their design. It should ask customer whether a lower surface finish would be acceptable to them given that the new design would cost much lower and would be easier to install. A small pilot program can be run to understand customer sentiments about this new product. Also, instead of completely shifting to the casted design, we would recommend Velan to cater to all customers by keeping both the options. This would allow the company to have more customers and the demands of each type of customer can be specifically met. This would allow Velan to remain a leader in the valve industry.

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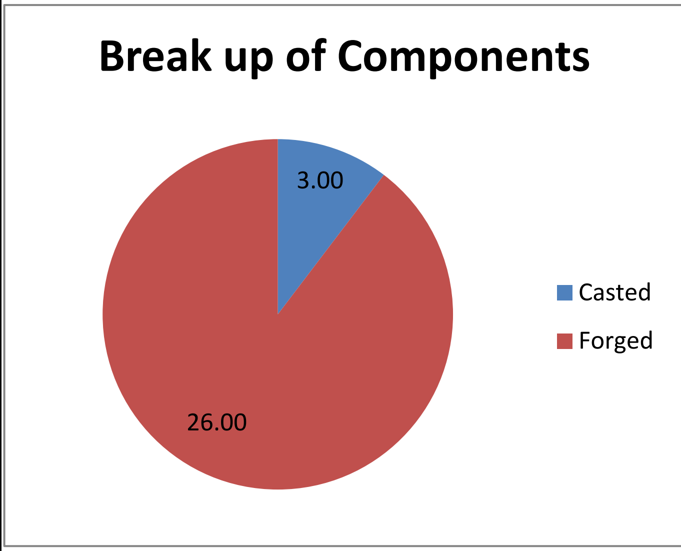
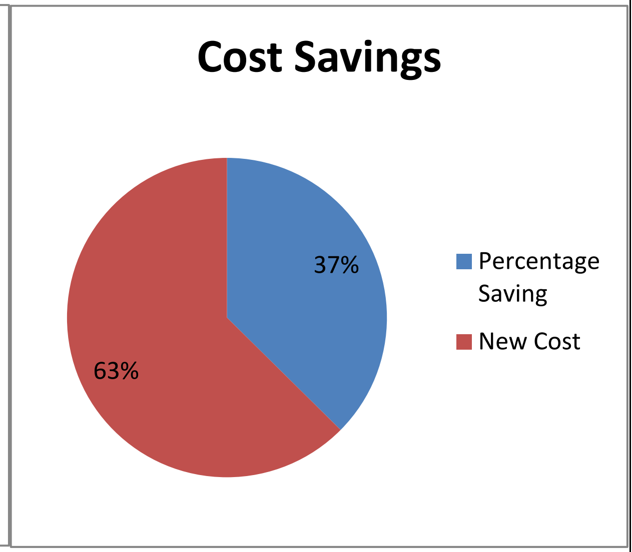


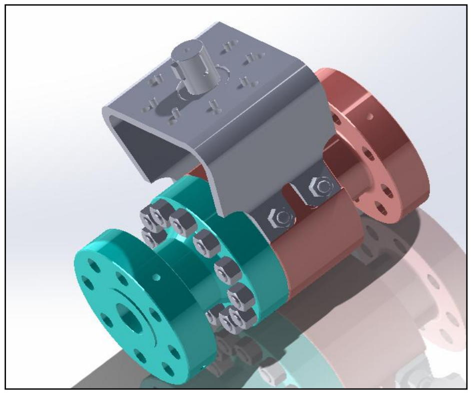


Desc.	DWG N°	Part Weight (kg)	Part Weight (lb)	Casted/Forged	Price ($) (Forging)	Price ($) (Casting)
BODY	401-6240	469.95	1036.07	Part is Casted	3030.00	1419.42
BODY END	403-6038	306.51	675.73	Part is Casted	2270.00	925.75
STEM	404-9387	10.25	22.61	Part is Forged	180.00	180.00
BALL	405-5194	7.49	16.52	Part is Forged	542.40	542.40
THRW	406-007	0.08	0.17	Part is Forged	406.30	406.30
SBSH	407-9296	0.19	0.42	Part is Forged	35.26	35.26
TRBS	408-5046	0.48	1.05	Part is Forged	107.78	107.78
SEAT A	409-9518	5.45	12.02	Part is Forged	333.86	333.86
SEAT B	409-9698	1.68	3.70	Part is Forged	237.62	237.62
PFLG	411-9350	11.84	26.11	Part is Forged	165.00	165.00
GLBG	412-9332	0.69	1.52	Part is Forged	97.29	97.29
PKRG	9079-040	0.06	0.12	Part is Forged	28.78	28.78
STUD	S080-JD0	0.83	1.83	Part is Forged	3.42	3.42
STUD	S08F-F00	0.95	2.10	Part is Forged	12.44	12.44
STUD	S08L-JL0	2.70	5.96	Part is Forged	98.40	98.40
NUTS	N080-XX0	0.21	0.47	Part is Forged	2.20	2.20
NUTS	N08F-XX0	0.51	1.11	Part is Forged	19.16	19.16
NUTS	N08L-XX0	0.99	2.19	Part is Forged	37.20	37.20
SHCS	BD80-DD0	0.00	0.00	Part is Forged	31.52	31.52
GSKT	8977-023	0.10	0.21	Part is Forged	5.71	5.71
RTRG	R0FD-XX0	0.00	0.00	Part is Forged	9.35	9.35
KEYS	7939-202	0.24	0.53	Part is Forged	10.50	10.50
BWSH	436-3341	0.05	0.12	Part is Forged	83.44	83.44
BWSH	9554-095	0.24	0.53	Part is Forged	132.00	132.00
BWSH	9555-331	0.45	0.99	Part is Forged	44.10	44.10
WSHR	WA0L-NX0	0.01	0.03	Part is Forged	2.76	2.76
WSHR	WABF-RX0	0.10	0.23	Part is Forged	2.76	2.76
BRKT	478-5430	111.11	244.96	Part is Casted	1816.90	335.60
DRVR	479-5535	27.24	60.05	Part is Forged	625.00	625.00
		960.41	2117.34		10371.15	6303.93

FEASIBLE

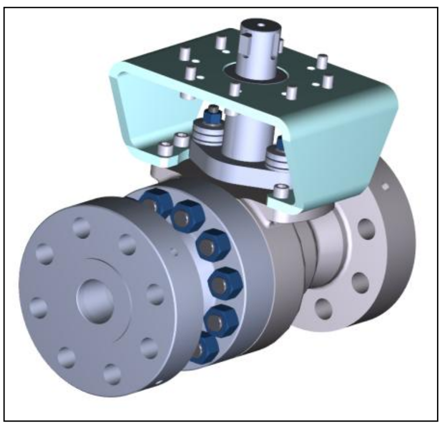
Project: Redesign of the bracket		**Prepared by:** McGill Value Engineering Team	
Proposal No: 2	**Date:** Nov. 21st, 2013	**Presented to:** Velan	**Page:** 1 of 2

Actual Design: The following CAD model depicts the current bracket implemented to keep the driver in place, and hold the actuator.

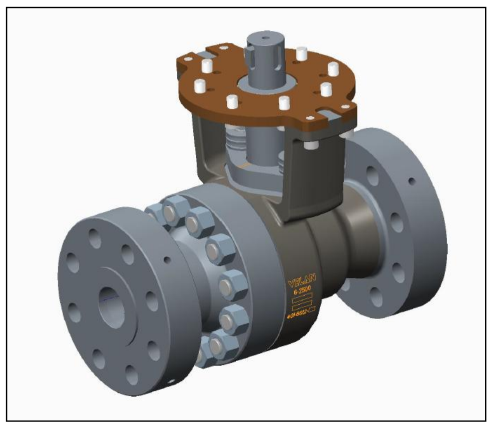


As can be seen from the diagram, the bracket is bolted tangentially to the body.

Proposed Design: Instead of the large bracket currently used, two alternatives have been designed to reduce the weight of the bracket, and thereby the cost. The two designs are shown below:



Flat Mounting Top



Integral Mounting Top

Discussion:

Feasibility: The changes in design required by the alternative proposals are not too rigorous. However, some considerations will have to be made to ensure that the stem protrudes far enough out of the body (if the driver is removed completely), and that the bracket can be properly mounted to the actuator. Furthermore, simulations to ensure that the weight of the actuator can be sustained will have to be considered.

Assumptions: The first assumption is that the cost of the body and bracket are fixed at an average of \$2.97/lb. This was assumed because in the original bracket, the cost of manufacturing per pound for the bracket and the body were not the same. The value for the body was selected because it was the lower of the two options. Further follow-up should be done to determine why the cost to manufacture the bracket was greater, per pound, than the cost to manufacture the body. It was also assumed that, for the cost analysis, the material for the bracket and the body would be the same, and they would both be manufactured in the same way (forging). The option of changing the manufacturing process is examined in a proceeding proposal.

<u>Pros:</u>

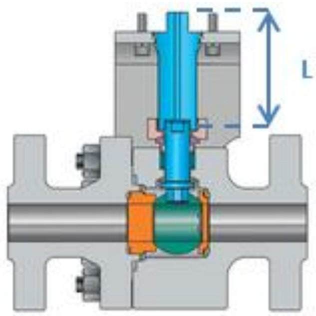
- Fewer components
- Less weight
- Lower cost
- Potentially easier to maintain

<u>Cons:</u>

- Initial R&D investment might be required
- No prior experience with this design
- More torque needs to be applied by actuator

Risks: The research and development costs required to explore this design are virtually unknown. As a result, the initial investment costs may outweigh the benefits in cost due to the reduction in volume of the proposed alternatives.

Alternative: Consider simply decreasing the length of the current bracket and driver as shown below (labeled "L.") The increase in torque necessary to turn the stem will be less dramatic than that of the above proposal.



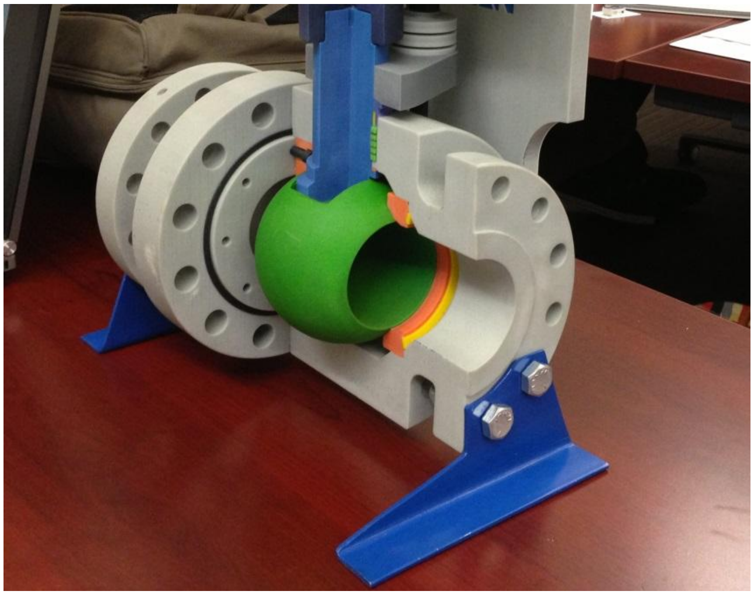
Design	Bracket Cost + Body Cost ($)	Total Savings/Valve ($)
Current	4850.00	-
Integral Mounting Top	3875.00	975.00
Flat Mounting Top	4000.00	850.00

By the assumptions made, the substantial decrease in cost due to reduction in volume is worth exploring. Since the initial research and development cost is impossible to estimate, an idea the payback period cannot be given. However, these assumptions do not include the potential for more valves to be sold due to lower sale prices and better design, so this estimate is solely an exploration of the worst possible scenario.

FEASIBLE

Project: Trunnion Mounted Ball		**Prepared by:** McGill Value Engineering Team	
Proposal No: 3	**Date:** Nov. 21st, 2013	**Presented to:** Velan	**Page:** 1 of 3

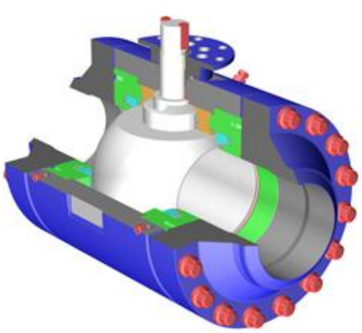
Actual Design: The original design of the ball valve consists of a fixed seat and a floating seat; The sealing from the medium during on and off configurations relies on the downstream pressure of the flow; The higher the downstream pressure, the greater the force of the ball valve pushing against the seat; The high surface contact between the ball and the seat requires a large torque from the actuator to switch the valve from on and off and vice versa**.**

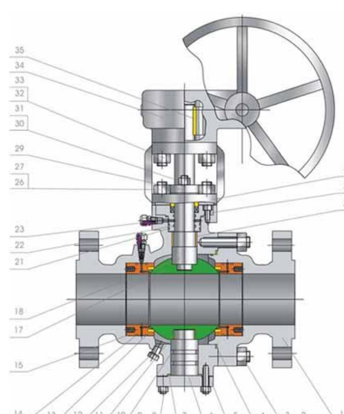


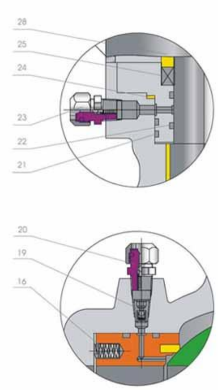
Proposed Design: The name of the type of seat proposed is a Trunnion seat based on the seat used to support a cannon; In this configuration the line seal between the ball and the upstream seat is maintained by a spring mechanism or line pressure assistance rather than the use of upstream pressure by the fluid; Bearings and a Trunnion plate would be placed on the top and bottom shafts which achieve lower operational torque**;** Amendments would be made to top and bottom of the ball in order to accommodate the new design.

Discussion:

Feasibility: The Trunnion design will be more expensive than the floating seat design as there are more parts needed to manufacture. The ball also needs to turn on carefully engineered bearings which may be







costly

to manufacture. The increase in cost is justified by the increase in quality of the product.

Assumptions: The increase in cost of changing to a Trunnion design in terms of manufacturing time and cost will be over shadowed by the greater reductions in operational torque required and thus the cost of the actuator.

Pros:

- Valve is able to withstand much higher pressures
- The lifetime of the seats is longer as the ball is fixed and is not exposed to as much upstream pressure
- The operational torque is lower since the fixed ball moves on carefully engineered seats
- The design is not as prone to blockages as the possibility of pressure welding the materials is eliminated
- Up to ASME class 2500
- 25% reduction in cost

Cons:

- Shaft maintenance is not possible while valve is operational
- There are more components in the design, thus increasing its complexity and cost
- The tendency of the floating seat design to allow the ball to float downstream
- provides a more reliable seal
- Up to ASME class 800

Risks: Development costs will not be justified by the increase in value. Design will be more vulnerable to leakages to the environment through the shaft section. According to the Velan representatives, the cost estimate made was too conservative. The Trunnion option is in fact much more expensive. In order to make this design successful more input must be put into research and development.

Implementation Conditions:

- New machining required of ball to allow for Trunnion seat
- Additional Trunnion seats and thrust bearings
- New sealing design between bearings and shaft

	Material + Labor Cost/Year	Initial Investment	Total
Current	~35,000$	N/A	35,000$
Proposed	~45,000$	5,000$	50,000$

The initial investment cost is based on 20 hours of machining, and 2 week of design work in order to make a fully functional prototype. The material and labor cost is based on 10 ball valves being produced per year. According Velan representatives, a Trunnion design will reduce friction and thus actuator torque by 30%. If this is in fact true, then the reduction in actuator cost will be around 3000$. This is a significant saving in cost. The estimate was made in this manner, as quotations from competitors could not be ascertained for research purposes. After learning that Velan does in fact have a Trunnion design for a different type of valve, it seems that an in house cost analysis could be more feasible for this project and more accurate.

Page: 3 of 3

Conclusion: This proposal was finally deemed unfeasible. First, it aims to change too much of the current design: something that Velan is not prepared to do immediately. Similar to the tilt and turn mechanism, the final price of such a design could not be determined accurately through research. Although the general consensus is that the Trunnion design is expensive, the predicted costs in actuator costs are substantial. The biggest worry for Velan is that the Trunnion design will pose problems in sealing, due to the existence of bearings and the replacement of the packing between the body and the shaft. More research could determine whether an efficient compromise between torque required and acceptable sealing can be made.

Discarded

Project: Tilt-and-Turn Closing Mechanism		**Prepared by:** McGill Value Engineering Team	
Item: 4	**Date:** Nov. 21st, 2013	**Presented to:** Velan	**Page** 1 of 2

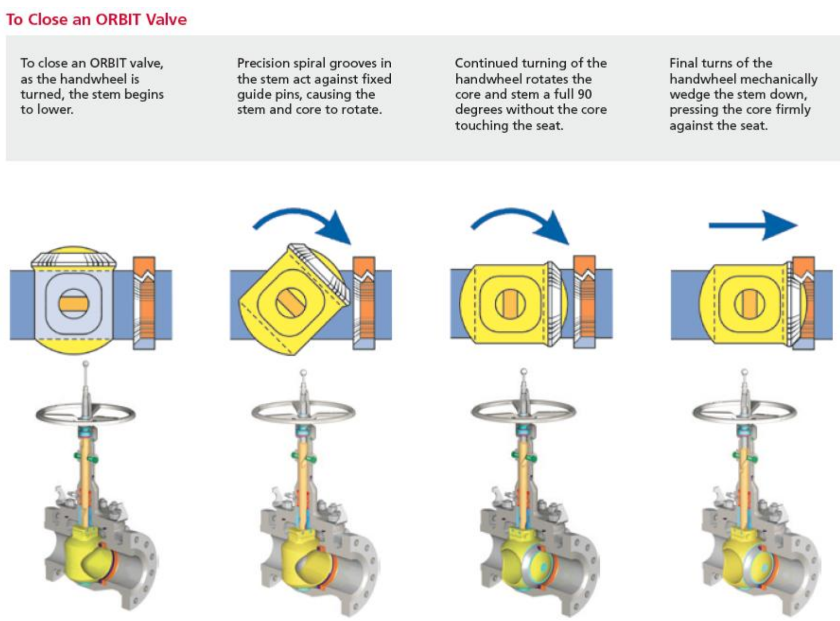
Actual Design: The Type R Valve is a high pressure forged metal-seated ball valve designed to permit multi-directional fluid flow through it. Some Characteristics of the Valve are: Bi-Directional Sealing; Two seats (1 fixed, 1 loose); Superior ball/seat finish; Requires large amounts of torque due to friction between ball and seat; Designed to ASME B16.34; Downstream and upstream body-seat lapped contact.

Improvements: The following proposed design solution focuses on reducing the friction between the ball and the seats, and on improving sealing. By decreasing the friction, the required torque automatically decreases, which also leads to the reduction in size of the actuator and consequently the supporting bracket as well. Overall, the changes should reduce the price of the mechanism drastically.

Proposed Design:

<u>Tilt-and-Turn Closing Mechanism (with Cam):</u>

The tilt-and-turn mechanism is a two stage closing mechanism that consists of first rotating the ball by 90 degrees and then pushing it firmly against the seat with the help of a mechanical cam. Hereunder is a detailed illustration which clearly represents how the mechanism functions. (*The illustration is taken from Cameron's ORBIT Valve Technology brochure.)*



The two stage closing mechanism offers:

- **Low torque operation.** Since the ball and the seat are not in contact during rotation, the rubbing is eliminated thus reducing friction forces.
- **Single-seat design.** The stationary seat seals in both directions and avoids the problems of trapped pressures between seals.
- **No rubbing between sealing surfaces.** The tilt-and-turn action eliminates seal abrasion, which is the major cause of seat wear in conventional ball valves.

Discussion:

Feasibility: Since Velan's competitors have previously implemented this type of mechanism then we can ensure that the two stage closing mechanism is in fact feasible. However, it must be noted that if Velan decides to implement the two-stage closing mechanism, it will be required to completely change its design since the "Orbit Valve" is a completely different design.

Assumptions: It is assumed that the value of the new design is equal or greater than that of the present valve design. It is also assumed that the increase in price in the valve is countered by a greater reduction in price in the actuator. Since the valve has sophisticated components, we assumed that its price might be greater than that of Velan's Type R Valve. However, since there will be a great reduction in friction due to the tilt-and-turn mechanism, we assumed that the torque requirement will decrease drastically, hence leading to a reduction in actuator size and price.

<u>Pros</u>

- Low-torque operation
- Single seat design
- Zero-tolerance leakage
- Lasts 2 to 5 times longer than conventional ball valves
- Avoids damage caused by scratching and tearing suffered by other valves
- Elimination of the localized high-velocity flow that typically creates uneven seat wear in ordinary ball, gate and plug valves.
- Available with both floating and Trunnion ball design

<u>Cons</u>

- Entire design of valve must change
- Maintenance is more difficult

Impacts and Risks: There is always a risk of losing customers with such a drastic change in design. Velan has no previous experience with this type of valve, and R&D will be required. Also, more moving parts in the tilt-and-turn mechanism can lead to some unforeseen difficulties

Conclusion: The tilt-and-turn mechanism is an excellent, if not the best, design for the reduction of friction. The overall price of the valve could not be determined throughout research, nor through direct communication with Cameron Valve suppliers. However, per unit price, it should not exceed the price of Velan's R-Valve by much. Nevertheless it does reduce the size and price of the actuator by a lot, since it reduces the friction by approximately 90%. If we assume that the price of the actuator is proportional to the friction exerted then we can see the extent to which this design can save on the actuator's cost.
The last point that should be mentioned is related to the R&D costs associated with the change in design. One must carefully note that in the short run, it would not be beneficial for Velan to change its design to a tilt-and-turn mechanism because the initial costs related to research and development will be very high. This means that it would take years before the company can break even and start making profit.
Therefore, this proposal, even though has many advantages, will be hard to implement by Velan and we will therefore disregard it as a possible solution. However Velan should not disregard the idea completely as it could be beneficial for them to implement the proposed mechanism in the future.

Discarded

Project: Chevron Packing Rings		Prepared by: McGill Value Engineering Team	
Proposal No: 5	**Date:** Nov. 21st, 2013	**Presented to:** Velan	**Page:** 1 of 1

Actual Design: The Type R Valve is a high pressure forged metal-seated ball valve designed to permit multi-directional fluid flow through it.

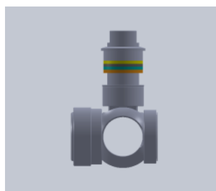
Packing Rings

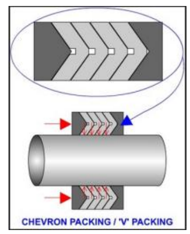
Some Characteristics of the packing are:

- Live loaded packing arrangement
- Graphite packing rings

Improvements: The following proposed design solution focuses on reducing torque requirement of packing. This is done by using a different design than the original packing ring design.

Proposed Design: The proposed design is to incorporate chevron packing rings instead of the packing ring design to block fluid from escaping through the packing rings using a hinge like action that immediately reacts to change in pressure on the rings to block the fluid.





Discussion:

Feasibility: Replacement of the O-rings is highly feasible requiring no modification in terms of components with low cost.

Assumptions: Assumptions are that the proposition of sealing flow is of more importance than reducing friction between the stem and the packing rings.

Pros:

- Automatic pressure distribution
- Immediate reaction to change in pressure
- Flexibility in terms of material used
- Reduced seal failure
- Reduction in installation cost
- Extended lifetime
- Flexibility in terms of exact seal specifications (accepts misalignment between gaps)

Cons:

- The design may cause an increase in friction in some conditions
- Increased number of rings depending on maximum pressure

Impacts and Risks: Extensive testing needs to be performed before application. Not suitable for low friction needs.

Implementation conditions: Must be implemented when the value of sealing flow outweighs the value of motor torque reduction since the chevron packing rings may increase friction with stem resulting in higher torque requirement to turn the valve.

FEASIBLE

Project: TFM Packing rings		**Prepared By:** McGill Value Engineering Team	
Proposal No: 6	**Date:** Nov. 21st, 2013	**Presented to:** Velan	**Page:** 1 of 1

Actual Situation: There exists a high pressure forged metal-seated ball valve designed to permit multi-directional fluid flow through it.

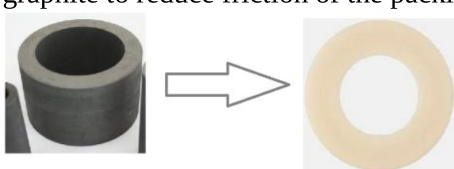
<u>Packing rings:</u>

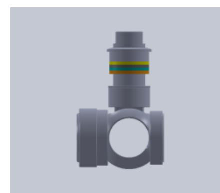
Some Characteristics of the packing are:

- Live loaded packing arrangement
- Graphite packing rings

Improvements: The following proposed design solution focuses on reducing the friction between the stem and the packing rings. Decreasing the friction leads to decrease in torque needed which leads to a decrease in size of the actuator and the bracket. Therefore the changes should reduce operating cost of the mechanism.

Proposed Design: The proposed design is to incorporate TFM material for packing rings instead of graphite to reduce friction of the packing rings with the stem.





Discussion:

Feasibility: Material replacement of the packing rings is highly feasible requiring no modification in terms of components.

Assumptions: Assumptions are that the fluid bulk temperature is in the range of -200 to 250 °C. Three major factors influence the desired characteristics of packing: sealing capability, low friction and lifetime. Working pressure is below 10MPa. Coating arrangements are not considered in this proposal.

<u>Pros:</u>

- Low friction coefficient
- Good abrasion resistance
- Good deformation and pressure recovery
- Chemical Resistivity
- Great surface characteristics

<u>Cons:</u>

- Failure at temperatures above 250°C
- Poor heat dissipation
- Low wear and tear properties compared to other alloys
- Lower strength than graphite

Impacts and Risks: Life cycle of packing may be reduced, risk of failure at high temperatures. PTFE has been used in packing rings but TFM is untested in this application.

Implementation conditions: The condition of implementation consist of implementation with only fluids that meet the temperature range requirement of -200°C to 250 °C.

FEASIBLE

Development

The development was done to the proposals that are deemed feasible. In this section, forging and casting, Redesign of the bracket, switching from graphite to TFM and switching from ring to chevron packing proposals are further developed. While the Trunnion seat and tilt and turn mechanism proposals are not, because they were unfeasible for this value analysis as mentioned in the proposal section.

Forging to Casting:

Cost Analysis

	Desc.	DWG N˚	Part Weight (kg)	Part Weight (lb)	Casted/Forged	Price ($) (Forging)	Price ($) (Casting)
	BODY	401-6240	469.95	1036.07	Part is Casted	3030.00	1419.42
	BODY END	403-6038	306.51	675.73	Part is Casted	2270.00	925.75
	STEM	404-9387	10.25	22.61	Part is Forged	180.00	180.00
	BALL	405-5194	7.49	16.52	Part is Forged	542.40	542.40
	THRW	406-007	0.08	0.17	Part is Forged	406.30	406.30
	SBSH	407-9296	0.19	0.42	Part is Forged	35.26	35.26
	TRBS	408-5046	0.48	1.05	Part is Forged	107.78	107.78
	SEAT A	409-9518	5.45	12.02	Part is Forged	333.86	333.86
	SEAT B	409-9698	1.68	3.70	Part is Forged	237.62	237.62
	PFLG	411-9350	11.84	26.11	Part is Forged	165.00	165.00
	GLBG	412-9332	0.69	1.52	Part is Forged	97.29	97.29
	PKRG	9079-040	0.06	0.12	Part is Forged	28.78	28.78
	STUD	S0B0-JD0	0.83	1.83	Part is Forged	3.42	3.42
	STUD	S0BF-F00	0.95	2.10	Part is Forged	12.44	12.44
	STUD	S0BL-JL0	2.70	5.96	Part is Forged	98.40	98.40
	NUTS	N0B0-XX0	0.21	0.47	Part is Forged	2.20	2.20
	NUTS	N0BF-XX0	0.51	1.11	Part is Forged	19.16	19.16
	NUTS	N0BL-XX0	0.99	2.19	Part is Forged	37.20	37.20
	SHCS	BDB0-DD0	0.00	0.00	Part is Forged	31.52	31.52
	GSKT	8977-023	0.10	0.21	Part is Forged	5.71	5.71
	RTRG	R0FD-XX0	0.00	0.00	Part is Forged	9.35	9.35
	KEYS	7939-202	0.24	0.53	Part is Forged	10.50	10.50
	BWSH	436-3341	0.05	0.12	Part is Forged	83.44	83.44
	BWSH	9554-095	0.24	0.53	Part is Forged	132.00	132.00
	BWSH	9555-331	0.45	0.99	Part is Forged	44.10	44.10
	WSHR	WA0L-NX0	0.01	0.03	Part is Forged	2.76	2.76
	WSHR	WABF-RX0	0.10	0.23	Part is Forged	2.76	2.76
	BRKT	478-5430	111.11	244.96	Part is Casted	1816.90	335.60
	DRVR	479-5535	27.24	60.05	Part is Forged	625.00	625.00
Totals			960.41	2117.34		10371.15	6303.93

Table 4 Cost Analysis

Assumptions:

- Cost per part remains the same as $1.37/lb. This value was given to us by Velan after discussion with their vendors.
- The labor costs will be 60% of the initial labor costs. This is because a large part of the valve is not casted and labor operations will no longer be required. Once again, this estimate was discussed with Velan to ensure that it is as realistic as possible.

Sample Calculations

- Price for Body

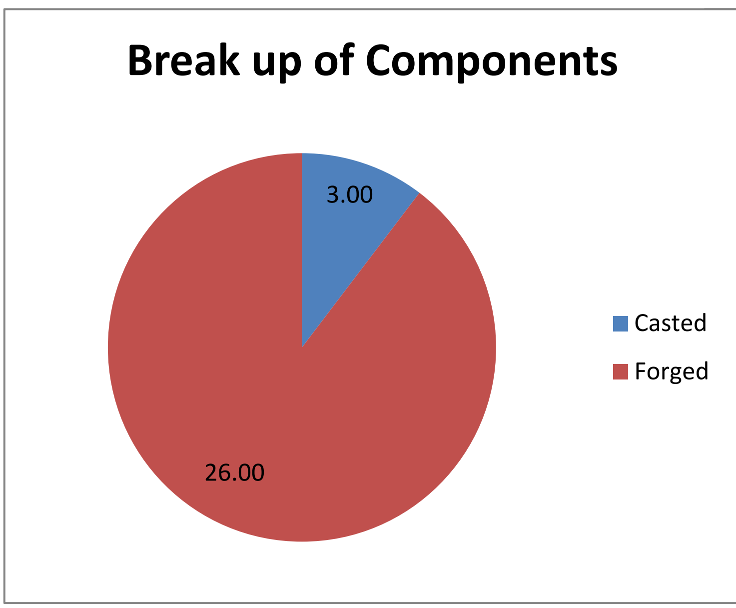
$P = 1036.07 * 1.37$

P= $\$\mathbf{1419.42}$

Results

Breakup of Components	
3.00	Casted
26.00	Forged

Saving in Cost	
29.89 %	Percentage Saving
70.11 %	New Cost



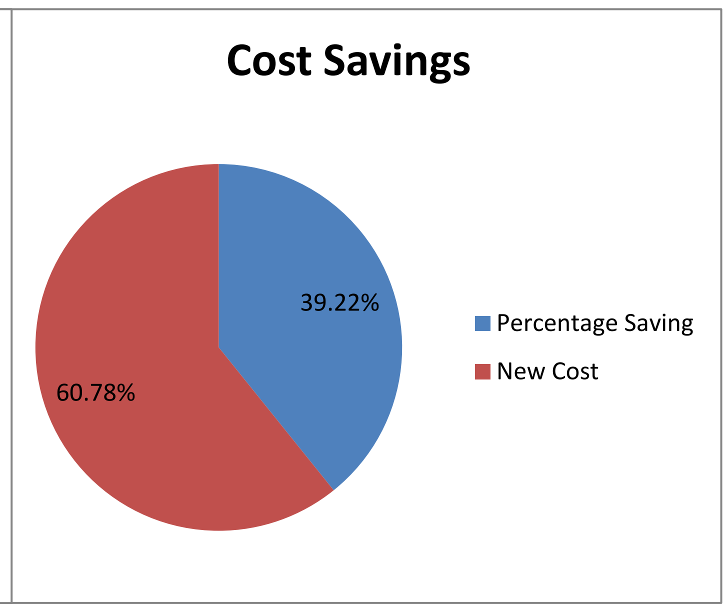


Figure 2 Breakups of Components

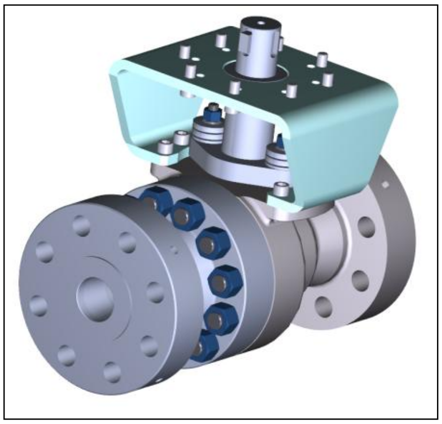
Figure 3 Cost Savings

Redesign of the bracket

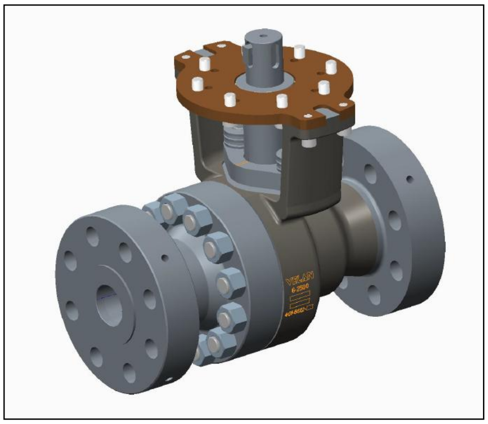
The bracket redesign presents the best options for reducing the volume and weight of the total valve. As a result of the reduction in material, there will be a proportional reduction in the cost of the valve thus improving the value of the valve. It should be noted that the cost reduction does not include potential clients added due to the cheaper overall price of the valve. An estimate of how many clients would be added would not be useful because of all the variables involved with such an estimation thus yielding poor approximations.

As can be seen from the table in the proposal section, both proposed alternative designs represent a reduction in material costs. We believe, however, that the better option is the integral mounting top. There are several reasons for this. First and foremost, the cost is reduced by a greater extent. Secondly, maintenance would be easier to perform on the integral mounting top than on the flat mounting top. This is because the geometry of the flat mounting top would make installation of the stem and driver more difficult. On the other hand, the flat mounting top has the advantage that it reduces the number of parts on the valve, whereas the integral mounting top does not. Ultimately, it was determined that this did not outweigh the other aspects mentioned previously.

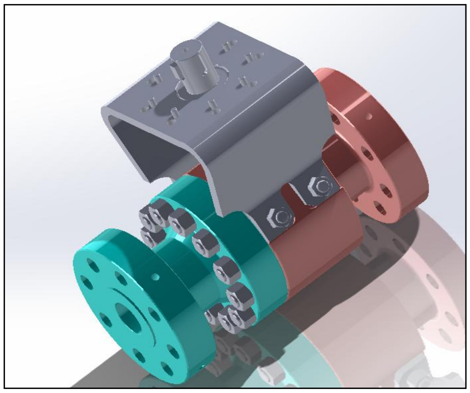
Research and development of this proposal will need to include rigorous studies of whether or not the new mounting piece can sustain the weight of the actuator, and whether or not the stem and driver will be kept in place to the tolerances required. Overall, this proposal is quite feasible.



Flat Mounting Top



Integral Mounting Top



Chevron packing

The proposed design is to incorporate chevron packing ring design instead of the graphite packing ring design to block fluid from escaping through the packing rings using a hinge like action that immediately reacts to change in pressure on the rings to block the fluid.

Benefits

- Automatic distribution of pressure
- V-rings automatically reacts to small increase or decrease of pressure
- V shape allows for Easy assembly (Lower assembly cost)
- Can be used with any material
- Reduces seal failure
- Flexibility in terms of seal specification

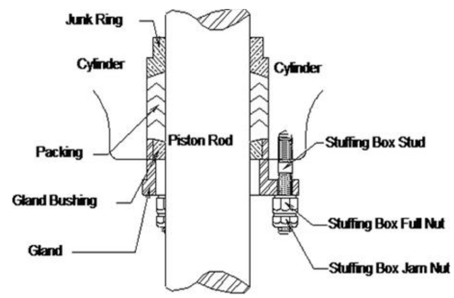


Figure 2 Chevron Design

The design is best suited for applications with small clearances, but the chevron packing design allows for varied clearance. Chevron packing can stand seal abrasion and is better suited for high pressure applications and its seal capabilities are pressure activated. However the risks associated with chevron packing is when gas rapid depressurizing occurs, temporary swelling of seal occurs which causes increase in drag. Another issue is that when fluid softens or swells failure is possible.

The hinge like action of the rings allows for an instantaneous reaction to small pressure changes and each ring reacts independently.

The Seal is made of three main components with a variable number of center rings: The base seal, Center V-Ring and pressure ring. The center rings are the main seal maintaining the pressure distribution. The base seal is the support for the center rings to prevent large extrusions caused by high pressure. Finally, the pressure rings holds the center rings.

Chevron packing rings are made of various materials such as PTFE.

Chevron rings are accepting low and high pressures and tolerate sealing gaps and the number of rings dictates the maximum pressure of the sealing.

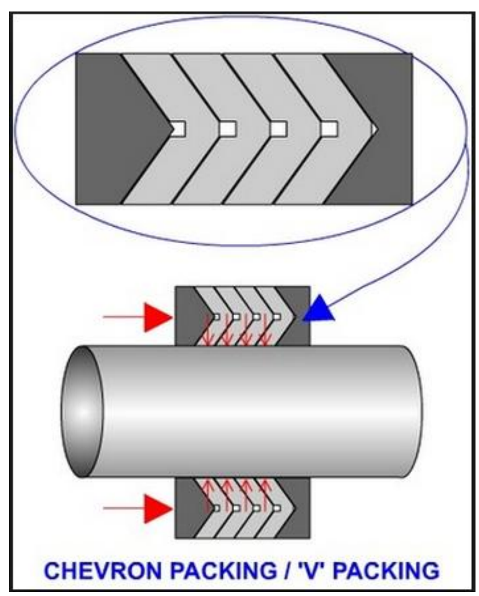


Figure 3 Chevron Design

100 bars applied:

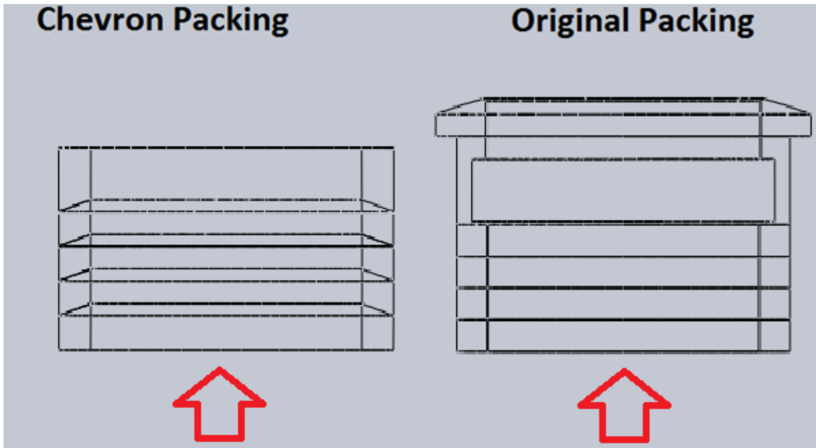


Figure 4 Packing Design

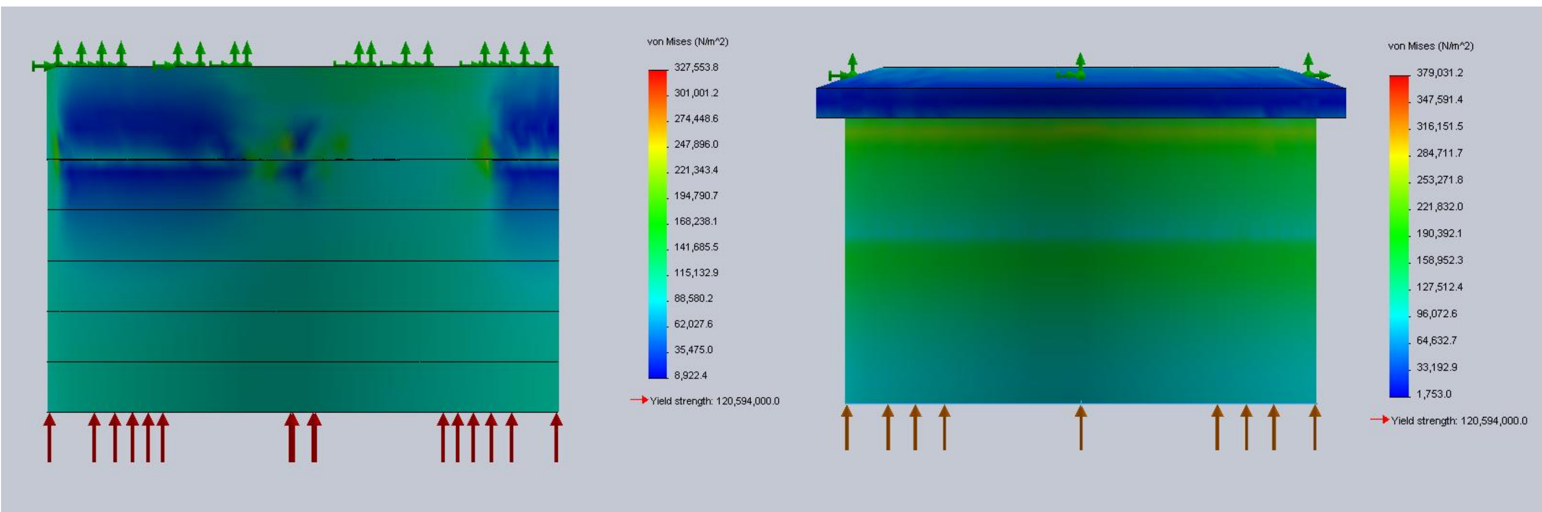


Figure 5 Stress Analysis

Cost Analysis

The original design packing ring cost was 28.78$ per set of graphite rings. The price estimate for the chevron packing ring set made from PTFE is 20$. Therefore there is a cost saving of 8.78$ by switching to chevron packing. However it is important to note that the specification and material of the chevron rings influence the price. Therefore the cost estimate is preliminary.

Conclusion

Therefore form the simple stress model it can be concluded that chevron packing rings are better at pressure distribution than standard packing ring as shown by the lower maximum stress on the FEA model. The chevron rings offer many advantages over o rings such as automation pressure reaction, better pressure distribution, long lifetime and ease of assembly. However the main befit of chevron pickings is the increase in the sealing function of the packing rings by their hinge like action that reacts to small changes in pressure with an increase in sealing.

It is important to note however that due to the v ring design there can be increase in friction with the stem in some conditions and the chevron rings are not best suited for fast depressurization applications.

However chevron rings are available in the market and the implementation cost is relatively low with a high increase in value.

TFM packing rings

Incorporation of TFM material for packing rings

The proposed design is to incorporate TFM material for packing rings instead of graphite to reduce friction of the packing rings with the stem.

The characteristics of packing rings

1) Sealing capability is influenced by the design, assembly and material type of packing.

Proper alignment, clearance, surface finish, the number of rings effect the sealing capability of a packing.

2) Low friction: The compression of the packing should not exceed the necessary value for sealing. Therefore low friction packing rings are preferred.

3) Life time: This aspect is important when choosing the material for the packing rings as choosing the right material and lowering friction increases the lifetime of the product as it reduces wear.

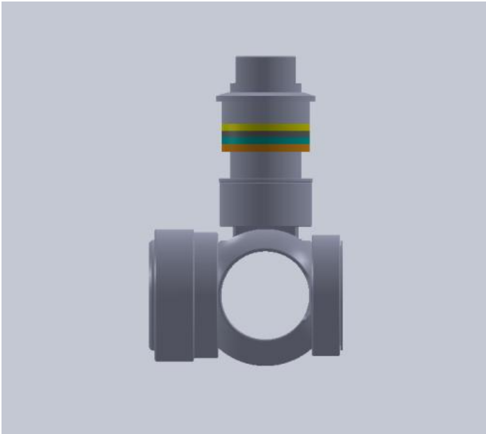


Figure 6 Packing Model

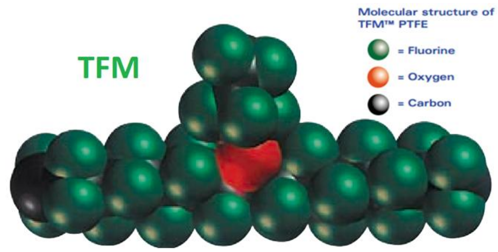
Material Selection for packing rings:

Temperature of fluid, fluid characteristics and working pressure all influence the material selection of the packing material.

The temperature is the most crucial factor that effects material selection of packing. For example PTFE can’t be used for temperature higher than 200 °C and graphite must be used for temperatures higher than 250 °C however for the type R valve the temperature range is acceptable. The characteristics of the fluid influence the coating and the material of the packing rings. Reinforced or coated packing rings must be used for Fluids that are abrasive or viscous

Working pressure that is higher than 10 MPa requires stiffer material to prevent fugitive emission.

What is TFM?



It is a modified PTFE material with a molecular weight five times lowers than PTFE.

TFM has a temperature range between -200 to 250 °C and is resistance to chemicals. The surface characteristics are also better than PTFE.

Graphite, PTFE, FTM:

Figure 7 TFM Composition

Graphite which is used for packing ring material doesn't seal flow but it restricts it. PTFE and FTM are better at blocking material however they decompose at high temperatures. PTFE and FTM are resistant to chemical and have lower coefficient of friction than graphite but they are poor dissipaters of heat.

TFM Characteristics:

- Low friction coefficient
- Good Abrasion and wear resistance
- Low cold flow deformation, better cold flow properties than PTFE
- Excellent Deformation and pressure recovery.
- Temperature resistant between -200° and +250°C
- Completely resistant to chemicals
- Better surface characteristics than PTFE

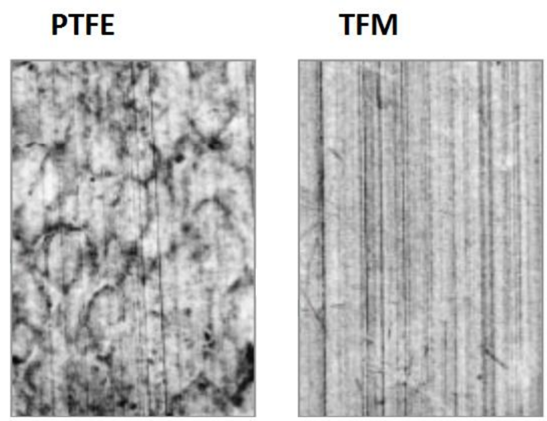


Figure 8 TFM vs. PTFE

Friction Test:

Testing of TFM (100% PTFE) against other alloys resulted in the following conclusions:

TFM has the lowest friction coefficient of all the alloys tested. The graphite coefficient of friction is between 0.5 - 0.8 and PTFE has coefficient of friction of 0.2

In terms wear and tear TFM scored low in this category

Average coefficient of friction at 66 N normal load and 7.9 m/min.

TFM	0.12	Chemloy 7584	0.19
Chemloy 7586	0.12	Chemloy 7520	0.19
Rulon-J	0.16	Vespel SP3	0.20
Chemloy Q18	0.17	Chemloy 7574	0.20
Chemloy 7558	0.17	Chemloy 7570	0.22
Chemloy 7589	0.17	Vespel SP211	0.23
Chemloy 7579	0.18	Chemloy 7569	0.24
Chemloy 7519	0.18	Vespel SP22	0.32
Chemloy 7575	0.18	Vespel SP21	0.35
Delrin	0.19	Carbon/PTFE Composite	No Test Due to Limited Number of Test Specimens

Overall ranking of self-lubricating materials based on coefficient of friction.

TFM	Chemloy 7584
Carbon/PTFE Composite	Chemloy 7570
Chemloy 7589	Chemloy 7520
Rulon-J	Chemloy 7574
Delrin	Chemloy 7519
Chemloy 7575	Vespel SP3
Chemloy 7558	Chemloy 7569
Chemloy Q18	Vespel SP211
Chemloy 7586	Vespel SP22
Chemloy 7579	Vespel SP21
Chemloy 7568	

Figure 9 Coefficient of Friction

Average wear rate at 66 N normal load and 7.9 m/min relative velocity.

Chemloy 7570	2.0E–7	Delrin	2.0E–6
Vespel SP211	4.6E–7	Chemloy 7589	2.4E–6
Chemloy 7558	6.3E–7	Chemloy 7579	3.9E–6
Vespel SP21	8.9E–7	Chemloy 7568	5.3E–6
Chemloy 7586	1.0E–6	Chemloy 7519	5.4E–6
Chemloy 7569	1.0E–6	Chemloy 7584	1.5E–5
Chemloy 7520	1.1E–6	Chemloy 7574	6.0E–5
Rulon-J	1.3E–6	Chemloy 7575	7.4E–5
Vespel SP22	1.4E–6	TFM	1.1E–4
Chemloy Q18	1.9E–6	Carbon/PTFE Composite	No Test Due to the Limited Number of Test Specimens

Overall ranking of self-lubricating materials based on lowest wear rate.

Vespel SP211	Chemloy Q18
Vespel SP21	Chemloy 7568
Chemloy 7570	Chemloy 7579
Vespel SP22	Chemloy 7519
Delrin	Chemloy 7586
Rulon-J	Chemloy 7584
Chemloy 7569	Chemloy 7574
Vespel SP3	Chemloy 7575
Chemloy 7520	TFM
Chemloy 7589	Carbon/PTFE
Chemloy 7558	

Figure 10 Wear and Tear Properties

Material toughness:

From the comparison of the stress and strain analysis of both the original graphite packing material and the proposed TFM packing material and understanding of the behavior of each material with similar conditions can be drawn.

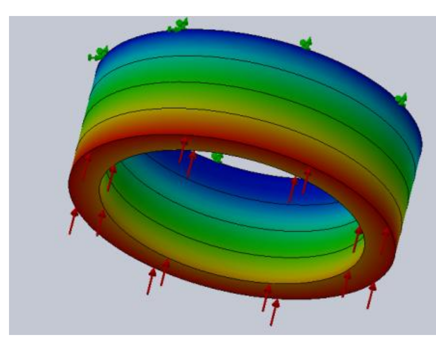
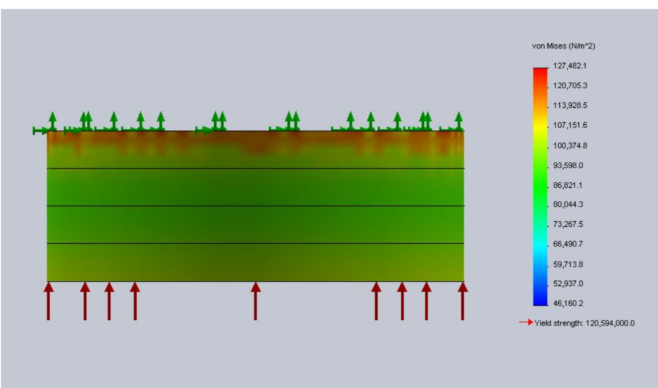


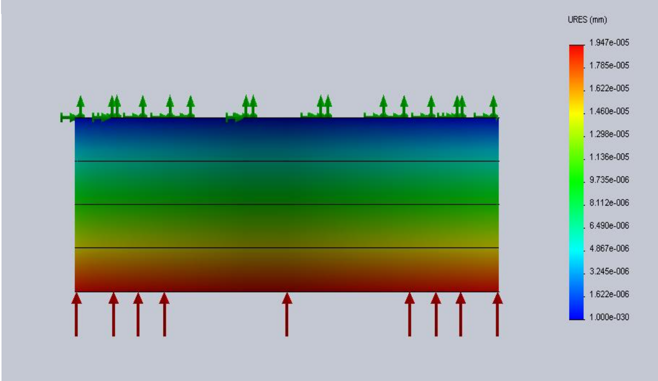
Figure 11 FEA

Graphite material with 10 MPa applied:

Graphite		
Elastic modulus	2.10E+11	N/m^2
Poisson's ratio	0.28	N/A
Shear Modulus in XY		N/m^2
Mass density	2240	kg/m^3
Tensile strength	100826000	N/m^2
Compressive Strength in X		N/m^2
Yield strength	120594000	N/m^2
Thermal expansion coefficient	1.30E-05	/K
Thermal conductivity	168	W/(m·K)
Specific heat	44	J/(kg·K)
Material Damping Ratio		N/A

Table 5 Graphite Properties

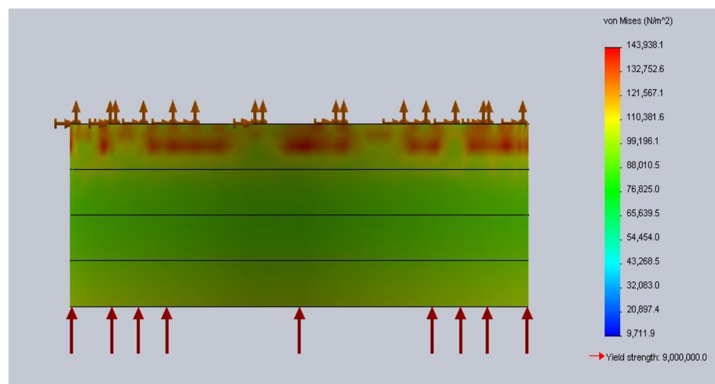


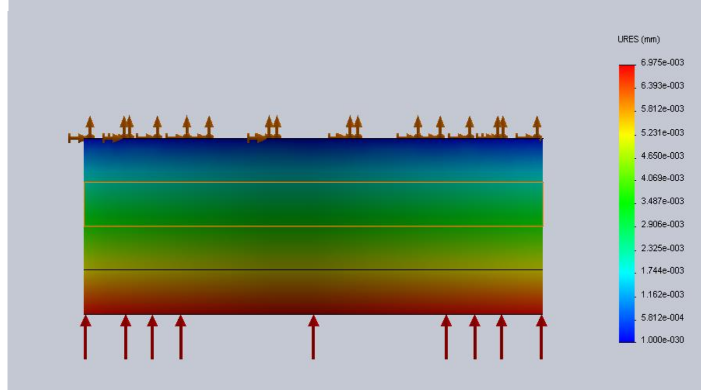


TFM material with 10 MPa applied:
Note: Minimum estimate of Yield strength of PTFE (9 MPa)

TFM		
Elastic Modulus in X	6.50E+08	N/m^2
Poisson's Ration in XY	0.46	N/A
Shear Modulus in XY	318900000	N/m^2
Mass Density	830	kg/m^3
Tensile Strength in X	30000000	N/m^2
Compressive Strength in X		N/m^2
Yield Strength	9000000	N/m^2
Thermal Expansion Coefficient in X		/K
Thermal Conductivity in X	0.2256	W/(m·K)
Specific Heat	1386	J/(kg·K)
Material Damping Ratio		N/A

Table 6 TFM Properties





Cost Analysis

An estimate of the cost of graphite material gives a value of 0.61kg/$ and the cost estimate of TFM is 1.05 kg/$. Therefore there is a slight increase in price by switching to TFM but it is negligible because of the light weight of the packing rings (0.056 kg). Therefore it can be assumed that there is no increase in price by switching to TFM assuming material is the only different factor that influences cost of modification.

Conclusion

It can be concluded from the analysis of friction, wear and tear and stress analysis that the TFM material for packing rings has an advantage over Graphite and PTFE in terms of having a lower friction coefficient. Graphite has a coefficient of friction 0.5 - 0.8 and PTFE is 0.2 while TFM has a coefficient of friction of 0.12. This means less friction between the driver and the packing rings allowing for low torque requirement hence saving on cost and weight of the motor.

However in terms of the wear and tear characteristics of TFM it has a lower lifespan than PTFE. But it's important to note that the reducing of friction would mean less abrasion, so that using TFM would mean wear and tear is less significant.

The stress and strain analysis on the other hand show that with the same applied pressure and same geometry of packing rings the stress concentration is higher on TFM compared to graphite. The maximum strain in TFM is also higher than the strain in graphite. This means that further analysis is needed to ensure TFM packing rings would not fail during high pressure applications.

Overall, the significant reduction of friction is a critical advantage in packing rings therefore the significantly lower coefficient of friction of TFM compared to graphite may justify the modification in certain applications while respecting the temperature, lifetime and strength limitations of TFM.

Proposal Evaluation

In order to create our scenarios, we started by weighing the merits of each proposal. After consulting the Velan representatives, we were able to choose the different merits and weight them. We then evaluated each proposal compared to the existing design. As you can see, we used 5 as the neutral point. A grade of 10 indicated a great d, and a 0 indicated an excessive decline in merit.

The results can be seen in Table 7.

Merits	Weight	Proposal 1	Proposal 2	Proposal 3	Proposal 4	Existing
Maintenance		5	4	5	7	5
	6	**30**	**24**	**30**	**42**	**30**
Installation		5	4	5	7	5
	6	**30**	**24**	**30**	**42**	**30**
Reliability		2	5	2	8	5
	8	**16**	**40**	**16**	**64**	**40**
Work to Implement		7	9	5	5	5
	8	**56**	**72**	**40**	**40**	**40**
Realization		7	9	5	5	5
	10	**70**	**90**	**40**	**50**	**50**
Total	**-**	**202**	**250**	**156**	**230**	**150**
Cost		**6303.93**	**9191.8**	**10371**	**10362.37**	**10371.15**

Table 7 Merit Cost Table

Furthermore, we plotted the results on a Radar chart to show how each proposal scored on each merit. The black polygon represents the existing scenario. Proposal 1, 2 and 3 have a greater area than the existing design and are promising solutions. Whereas, proposal 3 does not look very promising, especially with a total score neighboring that of the existing design.

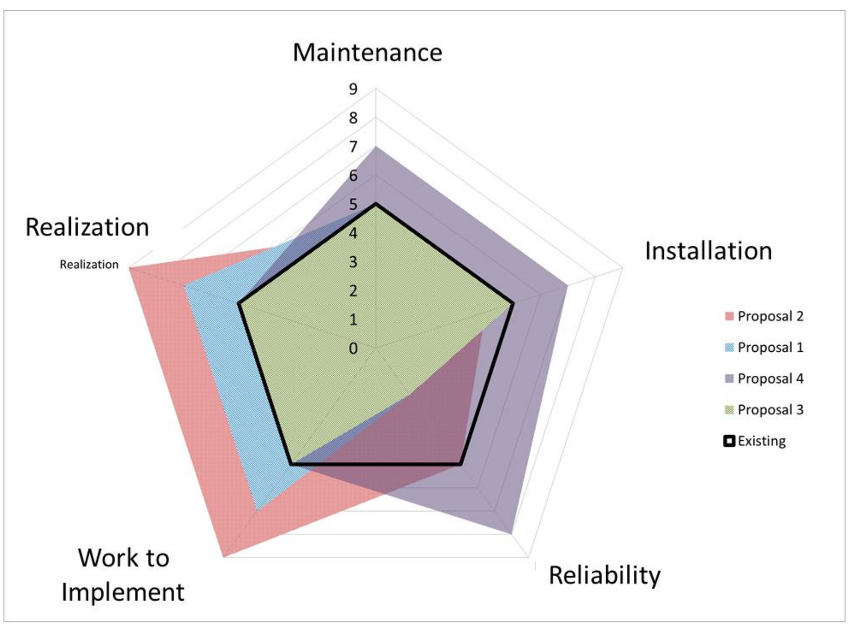


Figure 12 Merit diagram

Scenarios

From the proposals discussed earlier, we came up with four (4) scenarios to consider. Here is an explanation of each scenario:

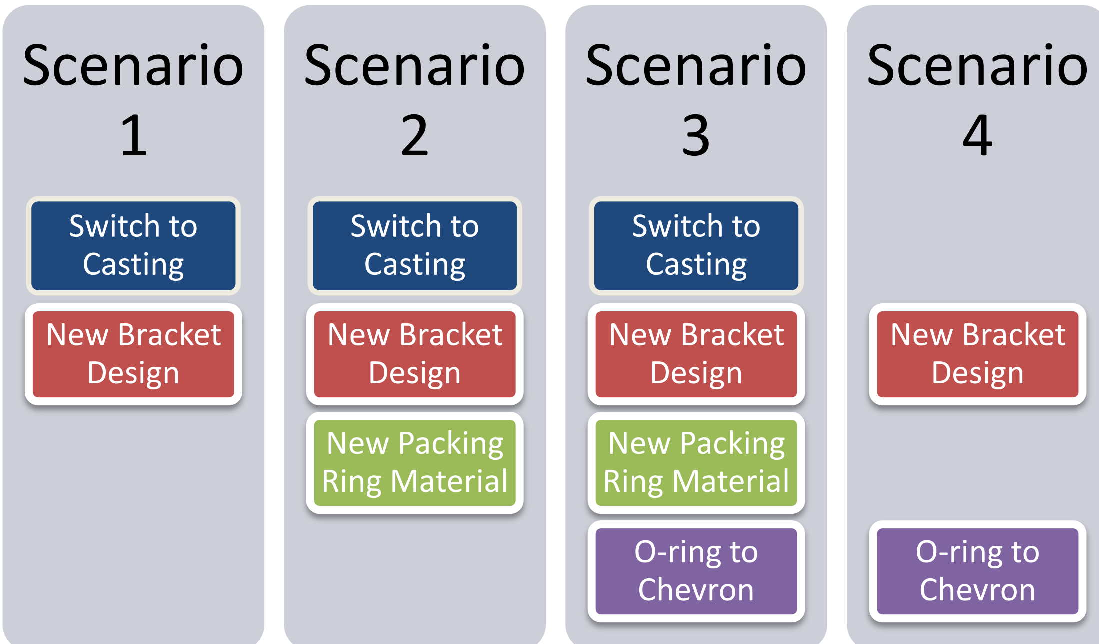


Figure 13 Scenarios

[What's this about O-rings?]

Scenario 1 Discussion:

This scenario combines the first and second proposals. The first proposal aims to change the manufacturing process of the body, body-end and bracket from forging to casting. Its maintenance and installations factors do not change across designs, as it is a relatively simple change aimed at changing a process. In terms of reliability, this proposal fares relatively poorly as casting will generally produce a weaker product. Its ease of implementation and realization factors, however, scores highly. This is because in comparison to the other proposals, this proposal can be directly implemented and has the most readily available data from suppliers. After the value engineering analysis, it can be seen that this proposal both increases the satisfaction of needs and reduces costs, which gives it the highest priority on the Value vs. Cost diagram. It also displays the largest area on the Merit vs. Cost saving graph. Thus it is apparent that any pairing with this proposal would fare quite well in terms of value.

The second proposal involves the change of the design of the bracket. It is integral to mention that this does not interfere with the first proposal, as the change in the design does not necessitate forging. The main objective of this design change is to reduce the total volume of material used for the bracket. Again, the product fares relatively the same as the original in terms of maintenance, installation and reliability, however is of great value when factors such as work to implement and realization are discussed. Of course the most attractive factor of this proposal is its cost saving advantages as illustrated by all three of the figures as well as the table.

Scenario 2 Discussion:

The same applies for this scenario in terms of the first two proposals; however this scenario suggests the addition of the third proposal: changing packing ring material from graphite to TFM. Although in the brainstorming phase, this seemed like a promising potential project, once the proposal comparison table was made with the consultation of Velan as well as the individuals of the value engineering team, the proposal did not change the value in all the relevant factors and even reduced its reliability by a factor of 3. It would seem that adding this proposal would only make the second scenario weaker in terms of value. Although implementing this value would generally increase the value of the product as the slope of the second scenario is steeper than that of the original design as illustrated in the Merit vs. Cost diagram, there are more promising avenues to explore without it. §

Scenario 3 Discussion:

Scenario three is the weakest scenario, but it still remains a better option than the existing design. It consists of combining the four feasible proposals into one potential option. The value graph indicates that the slope is not as steep as the other scenarios, but it is steeper than the existing design. It is important to remember that the steepness of the slope of the line translates into more value, so steeper slopes are desired. The reason that this slope is less steep is because the cost of this scenario is second highest, while the merit total is second lowest. From the cost savings graph it can be seen that scenarios one and two save more money than does this option. Namely, the cost of this scenario is a total of $8912.04.

Overall, this is not a very strong option, and may not even be worthwhile to consider over the existing design. This is because the unknown research and development costs associated with all the underlying proposals may outweigh the merits that could be gained from them. Furthermore, the risks associated with some of the proposals are quite high thus the overall risk of this scenario is the highest among all other scenarios.

Scenario 4 Discussion:

This scenario combined the proposals to change the packing ring to an o-ring, and to change the design of the bracket. It was found that the cost of this scenario would total $9,486.53, which was the largest cost among all the scenarios. As can be seen from the Value Graph (Merit/Cost) the slope of the line is steeper than that of the original design, scenario two, and scenario three, but less steep than that of scenario one. Furthermore, from the cost savings graph, the area under the curve is greater than the original design, but not greater than any other scenario. Both of these findings suggest that scenario four is not as good of an option in terms of value when compared to scenario one.

Based on the merit table, scenario four has the highest total in terms of increasing customer needs/satisfaction. Unfortunately, what reduces the value of this scenario as compared to the other scenarios is the cost. Because this is such a strong scenario, if Velan has sufficient interest, this scenario can be further improved by revisiting the proposals independently to see if costs could be cut in any other manner, thereby improving the value.

Scenarios Evaluation

From the proposals discussed earlier, we came up with four (4) scenarios to consider: Scenario 1 was designed to mainly reduce cost. Scenario 4 was designed to mainly increase the satisfaction of the need. Scenario 2 and 3 are a mixture of the 4 proposals aimed at reducing cost and increasing the satisfaction of the need. Here is an explanation of each scenario:

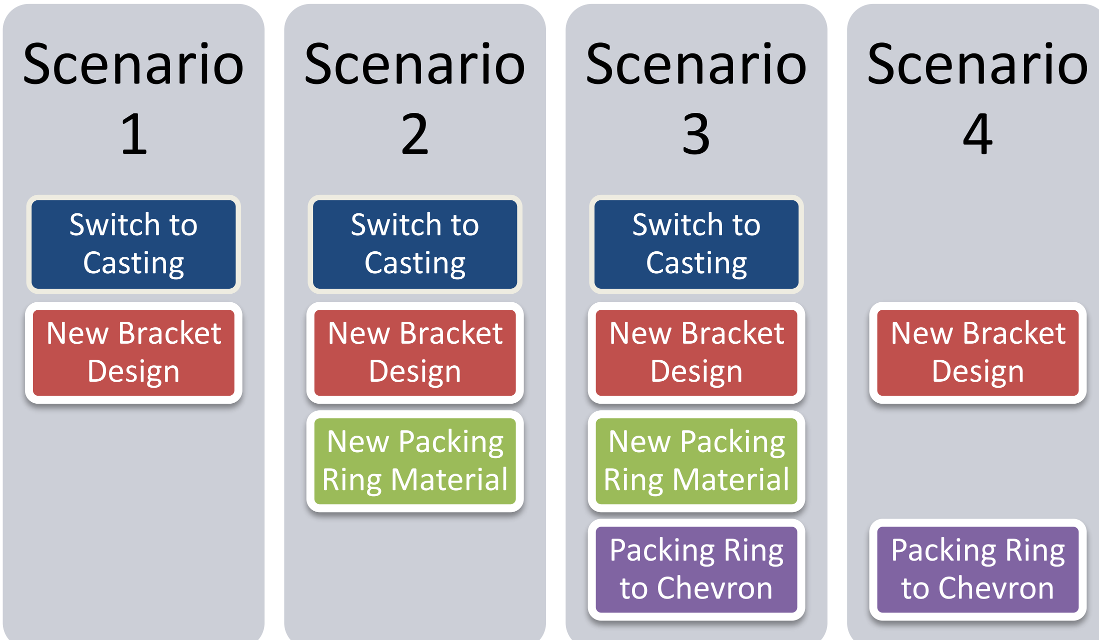


Figure 13 Scenarios

Scenario 1 Discussion:

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Scenario 2 Discussion:

The same applies for this scenario in terms of the first two proposals; however this scenario suggests the addition of the third proposal: changing packing ring material from graphite to TFM. Although in the brainstorming phase, this seemed like a promising potential project, once the proposal comparison table was made with the consultation of Velan as well as the individuals of the value engineering team, the proposal did not change the value in all the relevant factors and even reduced its reliability by a factor of 3. It would seem that adding this proposal would only make the second scenario weaker in terms of value. Although implementing this value would generally increase the value of the product as the slope of the second scenario is steeper than that of the original design as illustrated in the Merit vs. Cost diagram, there are more promising avenues to explore without it.

Scenario 3 Discussion:

Scenario three is the least strong scenario, but it still remains a better option than the existing design. It consists of combining the four feasible proposals into one potential option. The value graph indicates that the slope is not as steep as the other scenarios, but it is steeper than the existing design. It is important to remember that the steepness of the slope of the line translates into more value, so steeper slopes are desired. The reason that this slope is less steep is because the cost of this scenario is second highest, while the merit total is second lowest. From the cost savings graph it can be seen that scenarios one and two save more money than does this option. Namely, the cost of this scenario is a total of $8912.04.

Overall, this is not a very strong option, and may not even be worthwhile to consider over the existing design. This is because the unknown research and development costs associated with all the underlying proposals may outweigh the merits that could be gained from them. Furthermore, the risks associated with some of the proposals are quite high thus the overall risk of this scenario is the highest among all other scenarios.

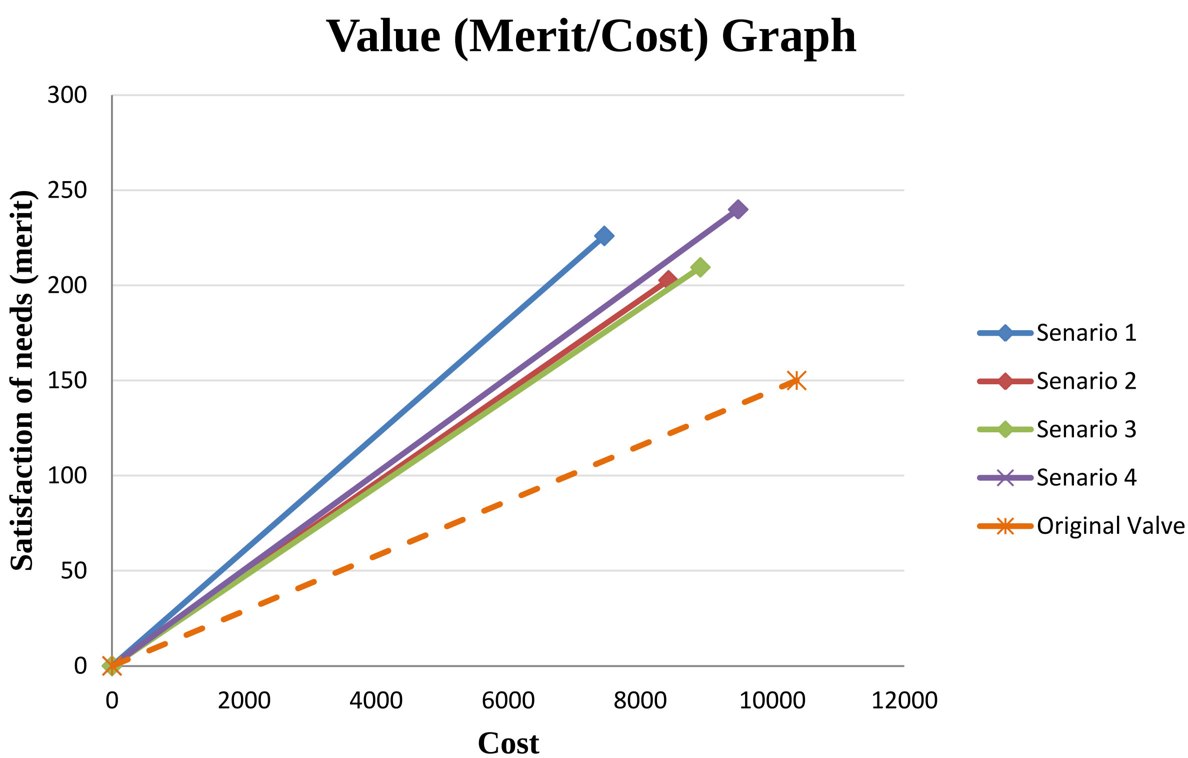
Scenario 4 Discussion:

This scenario combined the proposals to change the packing ring to Chevron packing, and to change the design of the bracket. It was found that the cost of this scenario would total $9,486.53, which was the largest cost among all the scenarios. As can be seen from the Value Graph (Merit/Cost) the slope of the line is steeper than that of the original design, scenario two, and scenario three, but less steep than that of scenario one. Furthermore, from the cost savings graph, the area under the curve is greater than the original design, but not greater than any other scenario. Both of these findings suggest that scenario four is not as good of an option in terms of value when compared to scenario one.

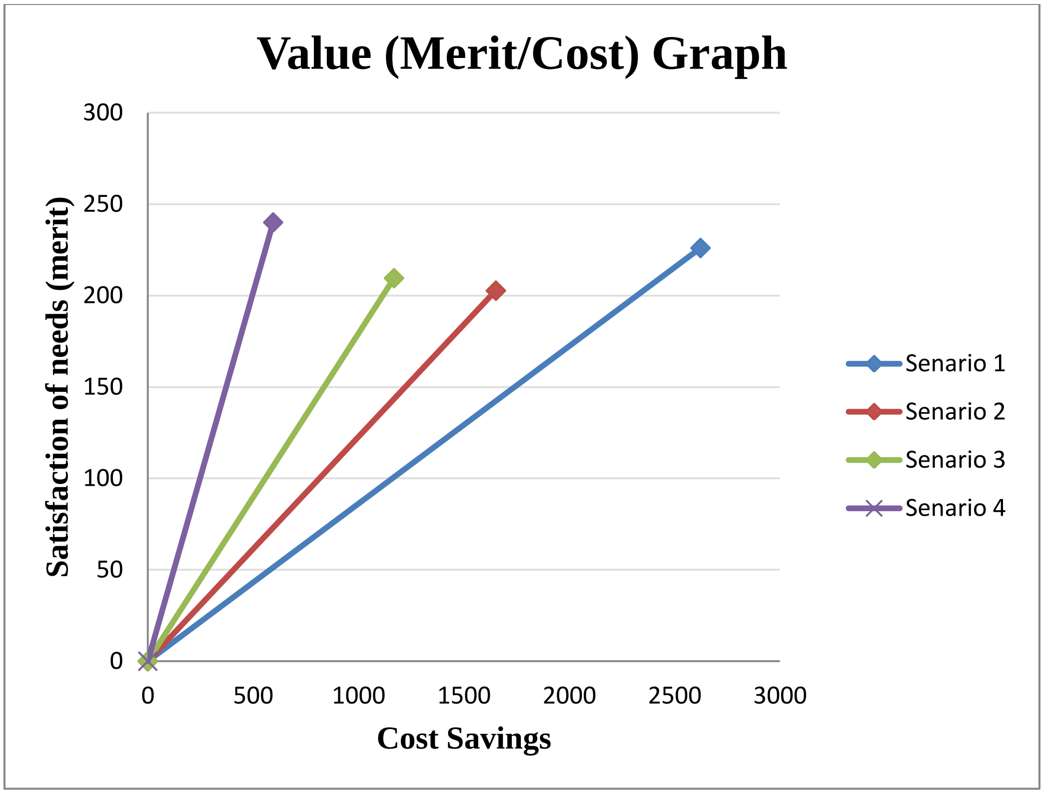
Based on the merit table, scenario four has the highest total in terms of increasing customer needs/satisfaction. Unfortunately, what reduces the value of this scenario as compared to the other scenarios is the cost. Because this is such a strong scenario, if Velan has sufficient interest, this scenario can be further improved by revisiting the proposals independently to see if costs could be cut in any other manner, thereby improving the value.

The following graphs give you a good summary of the results discussed above. Graph X first shows you the merit vs. the cost of the four scenarios compared to that of the original valve. As we can see, all four scenarios offer improvements since their costs are lower than that of the original valve, and all scenarios have higher merit. This, as explained previously, is represented by a line with a higher slope.

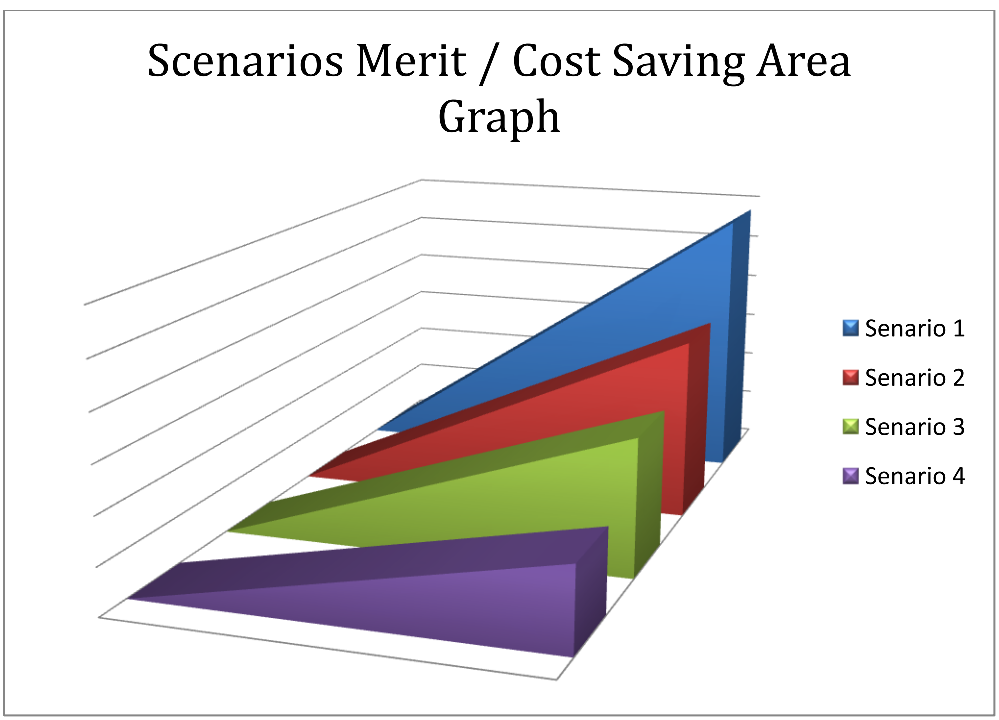
Graph XX plots the merit vs. the cost savings of each scenario. Here we were looking for the largest area under the curve. This is because the higher the merit the higher the area under the curve, and the higher the cost savings, the higher the area will be once again. As we can see, the scenario will the largest area under the curve is once again scenario 1. To better see this, we normalized the areas by taking a constant base and represented the areas on Graph XXX. On this graph we can clearly see that Scenario 1 is the one that gives the best results.



Graph X



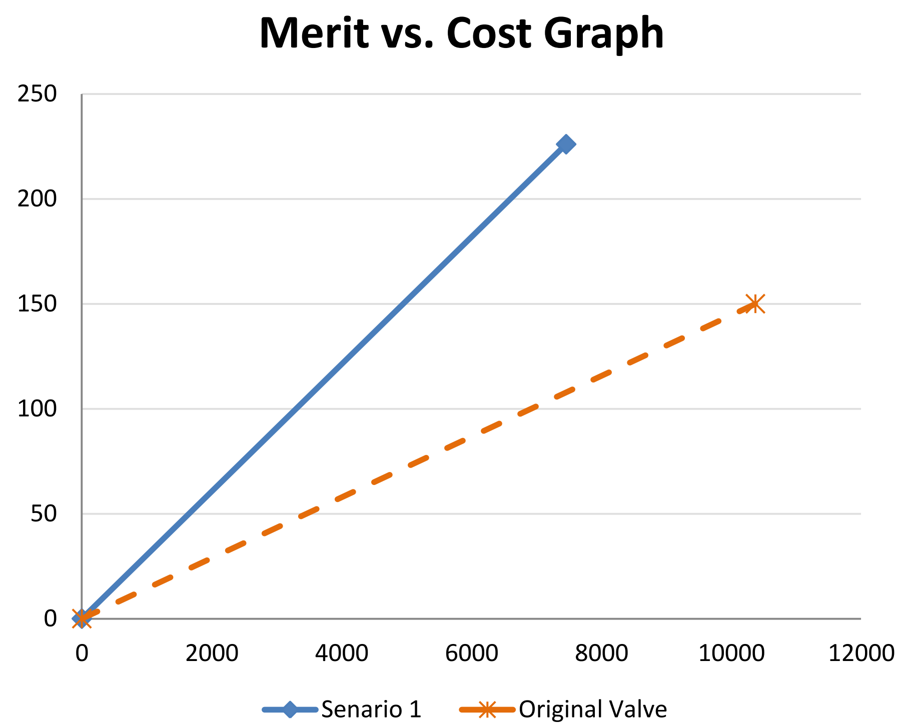
Graph XX



Graph XXX

Final Recommendation

From our thorough analysis, we have shown that scenario 1 is the best solution for our Clients. Graph XXXX is the same Merit vs. Cost Graph as Graph X but here we have only included the original valve and the winning scenario. We can clearly see here that there is substantial increase in merit as well as a worthy reduction in the overall cost.



Graph XXXX

To better illustrate the results, we have done a cost breakdown of how the $4070 are distributed. As we can see, $3770 is saved by switching from forging to casting. $3400 comes from savings on the production cost whereas $370 is saved on labor costs. This is approximately a reduction of 50% on the labor cost associated with the manufacturing of the body, body end and bracket.

Furthermore, the new bracket design helps reduce the overall cost by $300. This is a saving solely on production cost.

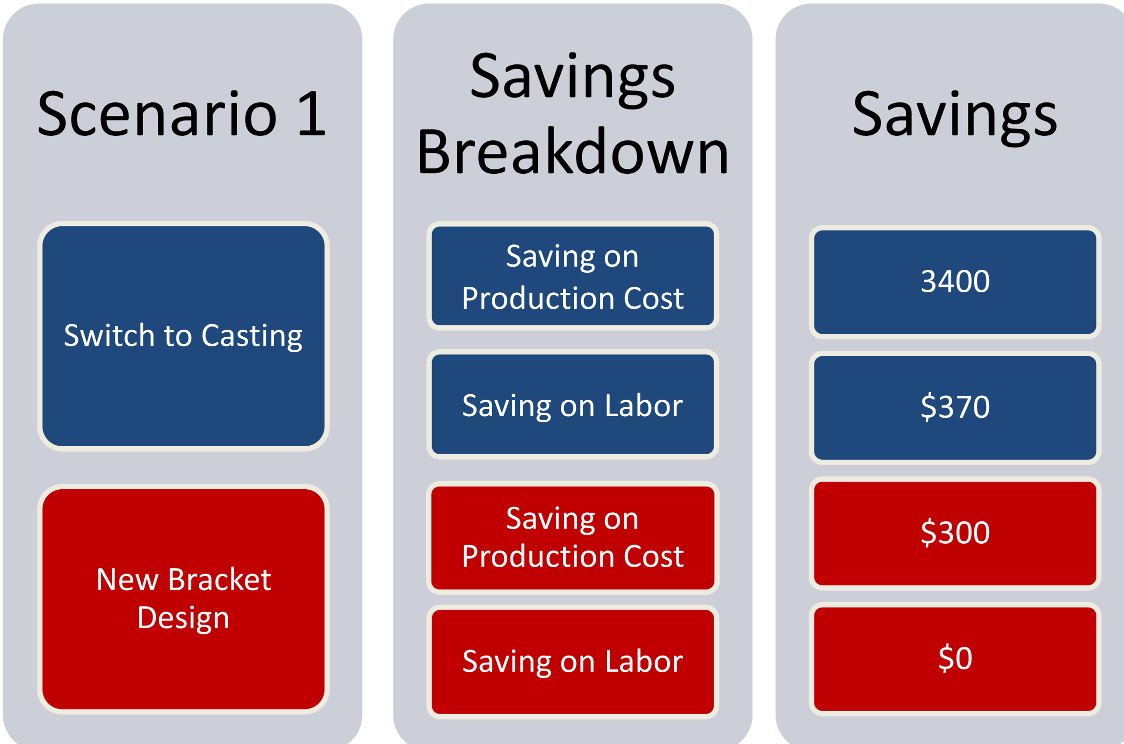
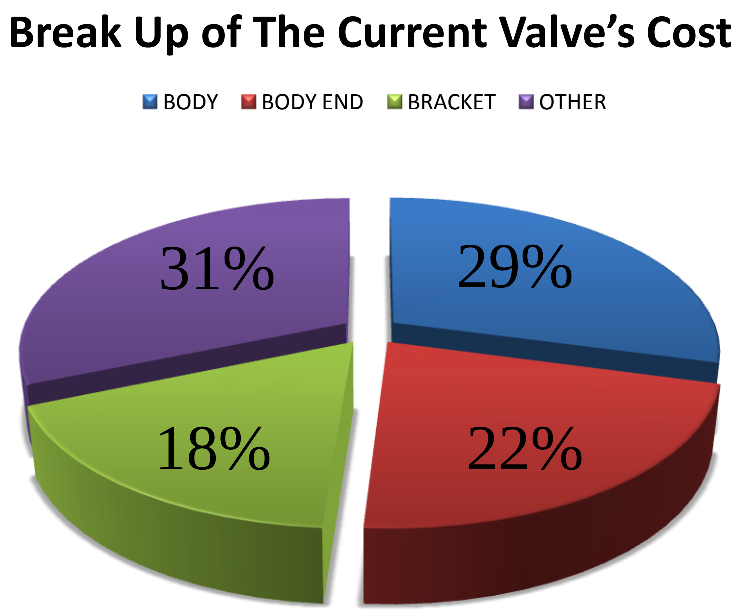


Figure 14 Final Scenario

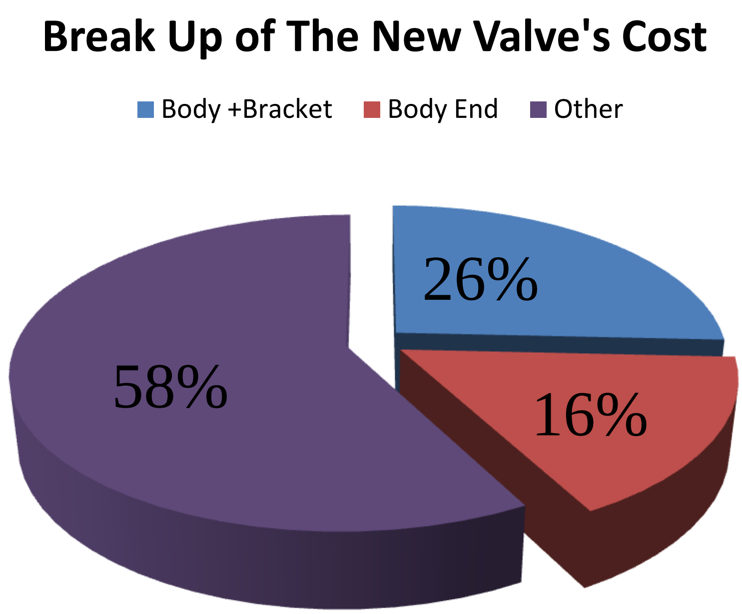
Total Cost Savings: $10070 - $6000 = $4070

Finally, we have created a new pie chart to represent the new distribution of the cost between the parts. As we can see on Graph XXXXX, the bracket, body and body end constituted of 69% of the total price, while the rest of the component only constituted of 31% of the total cost.

With the implementation of scenario 1, we can now see that the bracket, body and body end only constitute of 42% of the total cost. This can be seen on Graph XXXXXX



Graph XXXXX



Graph XXXXXX

Conclusion

Overall, the purpose of our value engineering analysis was accomplished. We progressed through each phase of the structured job plan performing the tasks required of us. From the collected research and discussion material, we obtained the results presented in the development and evaluation phases.

From our analysis during the evaluation phase, it is evident that scenario one is the best option. Because of this, our final recommendation to Velan is that this scenario be implemented. According to the merit versus cost graph as discussed in the development phase, the scenario with the steepest gradient or slope is desired indicating a greater value. All of the scenarios had a steeper slope than the current design whether it was because of cost reduction or merit augmentation, but the highest gradient was achieved by scenario one. To recap, scenario one involved the joint proposals of casting the bracket, body, and body-end, and redesigning the bracket, or proposals one and two respectively.

Again, the switch from forging to casting is significant in reduction of cost because the manufacturing process itself is much cheaper. This does have an effect on the surface finish of the components cast, but this is not important because the tolerances for these components do not need to be very high. The redesign of the bracket adds value because it reduces the material costs, and decreases the weight of the valve. However, some work will be required to identify the initial costs of research and development for the implementation of this valve. It was found that the total savings from the implementation of this scenario would be $4070, or approximately 40% of the total valve cost. With such a tremendous saving in cost, we believe that Velan will be able to remain the top company in this competitive industry.

Appendices

Appendix A – Brainstorming session evaluation

Feature	Yousuf	Jonathan	Joseph	Omar	Gerti	Iyad	%
Protect itself from temperature changes							
Insulation around the outside	3	1	1	1	1	1	13.33
Material selection	5	7	7	7	5	6	61.67
Valve indoors	1	1	1	1	1	1	10
Material coating	1	5	4	6	7	10	55
Material thickness	3	6	5	6	3	4	45
Resist external corrosion							
Exterior layer coating	1	1	4	1	3	2	20
Material selection	8	6	8	7	9	8	76.67
Material thickness	2	3	5	3	7	1	35
Operates at low stress							
Increase material	4	4	6	6	6	8	56.67
Material properties(selection)	6	5	7	7	9	7	68.33333
Reduce Friction	9	8	8	10	8	10	88.33333
Reduce weight of ball	8	7	9	9	9	8	83.33333
decrease pressure of bushing	3	4	9	9	7	6	63.33333
Reduce contact surface							
Reduce contact surface area of seal	4	6	7	8	8	6	65
Reduce contact surface area of body	1	1	1	1	1	1	10
Operates with low contact pressure							
Reduce pressure	3	4	2	5	6	1	35
Surface finish of the ball	5	6	7	8	9	9	73.33333
Surface finish of seal	6	7	7	7	3	7	61.66667
Prevent oxidation							
Coating(ie: boat coating)	3	7	7	3	5	5	50
Material selection	7	7	7	7	7	8	71.66667
Material thickness	3	2	2	3	3	3	26.66667
Minimum exposure to atmosphere	2	2	2	2	1	2	18.33333
Tightly sealed from flow							
Magnetic ball and seal	1	8	1	1	3	2	26.66667
Rubber sealing on ball	4	1	2	3	3	4	28.33333
Metal hinge acting the same way as rubber	2	2	1	2	3	2	20
Magnetic coil	1	1	1	9	2	2	26.66667
Seal from environment							
Reduce parts	3	1	1	1	1	1	13.33333

Increase pressure	1	1	8	9	9	9	61.66667
Different thermal expansion of materials	4	5	5	8	7	8	61.66667
Peltier element: closing need less contact	1	2	8	10	4	10	58.33333
Magnetized contact surface of two bodies	1	5	6	1	2	3	30
Maintain Pressure Gradient							
Ball contact surface (ball surface finish)	5	4	5	5	5	4	46.66667
Prevent Leakage	5	1	1	1	4	3	25
Prevent Explosions							
Flame retardant	6	7	1	1	3	7	41.66667
Material selection	4	4	5	2	6	6	45
Maintenance	6	3	2	7	5	8	51.66667
Backup system to divert flow	1	5	4	3	3	3	31.66667
Prevent Leakage							
Material selection	6	7	6	6	9	8	70
Maintenance	3	2	8	3	6	7	48.33333
Backup system to divert flow	1	5	4	3	3	1	28.33333
Increase contact pressure	4	6	7	7	9	9	70
Different stem designs	5	8	8	8	5	8	70
Put actuator inside closed volume	1	1	1	1	1	1	10
Pressure gradient (friction vs. contact pressure)	4	4	9	10	8	10	75
Mechanical solution to control friction	6	6	9	8	7	8	73.33333
Change the design of the bracket	9	10	10	10	10	9	96.66667
Different types of seats							
Bolted	6	3	5	4	5	6	48.33333
Press fit	6	4	7	6	8	7	63.33333
Welded	2	3	4	7	7	7	50
Shrink fit	4	7	7	7	8	9	70
Same part as body	6	2	3	3	6	8	46.66667
Ease of disassembly							
Reduce number of components	8	7	7	7	10	9	80
Reduce number of bolt	3	2	6	1	5	7	40
Reduce weight	9	8	7	1	3	7	58.33333
Reduce height of stem and driver which reduces	10	10	10	9	9	8	93.33333
height of bracket(reduce size of bracket also)							
Casting Vs Forging	-	-	-	-	-	-	-
Peltier tube	-	-	-	-	-	-	-

Appendix B – TFM Material

Comparison of Dyneon™ PTFE and Dyneon™ TFM™ PTFE

Property	Unit	Test Method	Dyneon™ TFM™ 1700 PTFE	Dyneon™ TF 1750 PTFE
Bulk Density	g/l	ASTM D 4894-98a	420	380
Specific Gravity	g/cc	ASTM D 4894-98a	2.165	2.155
Shrinkage	%	ASTM D 4894-98a	5.7	4.3
Tensile Strength	psi	ASTM D 4894	4000	4800
	psi	DIN53455	6400	6000
Elongation at Break	%	ASTM D 4894	350	450
	%	DIN53455	430	600
Deformation Under Load, 2175 psi	%	ASTM D 621		
		24 hours	8	15
		100 hours	9	17
		Permanent	4	11
Void Content	%	Dyneon Method	0.26	0.75
Permeability:				
SO_2 (@ 23°C)	$\frac{cm^3}{m^2 \times d \times bar}$	Based on ASTM D 3985 film thickness 1 mm	210	310
HCl (@ 54°C)			460	640
Cl_2 (@ 54°C)			160	320
Tensile Modulus	psi	ASTM D 638	94,250	87,000
Dielectric Strength	kV/mil	ASTM D 149-95a film thickness 100 μm	3.7	3.5

Typical values. Not for specification purposes.

	TFM™ 1600 PTFE	Reinforced PTFE	Graphite, Carbon, C
Physical			
Bulk Density (g/cc)	0.83	--	--
Density (g/cc)	2.16	2.3	2.25
Particle Size (µm)	450	--	--
Specific Surface Area (m^2/g)	--	--	1
Molecular Weight (g/mol)	--	--	12.011
Thickness (microns)	--	790, 1570, 3180	--
Deformation (%)	4 , 8, 9	--	--
Mechanical			
Hardness, Mohs	--	--	1.0 - 2.0
Tensile Strength, Ultimate (MPa)	31.7	82.7	--
Elongation at Break (%)	450	--	--
Modulus of Elasticity (GPa)	0.6498	--	4.8
Compression Set (%)	--	30	--
Thermal			
Heat of Fusion (J/g)	--	--	9741.07
CTE, linear (µm/m-°C)	--	--	0.600 - 4.30
Specific Heat Capacity (J/g-°C)	--	--	0.70768
Thermal Conductivity (W/m-K)	--	--	24
Melting Point (°C)	317 - 337, 332 - 352	--	3650
Sublimation Temperature (°C)	--	--	3650
Maximum Service Temperature, Air (°C)	260	245	--
Maximum Service Temperature, Inert (°C)	--	--	<= 3650 4492
Heat of Formation (kJ/mol)	--	--	0 716.7
Minimum Service Temperature, Air (°C)	-200	-200	--
Flammability, UL94	V-0	--	--
Shrinkage (%)	3.5	--	--

TFM™ 1600 PTFE

Typical properties (Data not for specification purposes)

Powder properties

Property	Value	Unit	Test Method
Bulk density	830	g/l	ASTM D 4894-98a
Average particle size	450	µ	ASTM D 4894-98a

Mechanical properties, measured at 23°C (73°F) on sintered moldings

Property	Value	Unit	Test Method
Tensile Strength	4600	psi	ASTM D 4894-98a
Elongation at break	450	%	ASTM D 4894-98a
Specific gravity	2.16	g/cc	ASTM D 4894-98a
Shrinkage	3.5	%	ASTM D 4894-98a
Tensile Modulus	94,250	psi	ASTM D 638
Deformation under Load		%	ASTM D 621
2175 psi – 24 hrs	8		
2175 psi – 100 hrs	9		
2175 psi – permanent	4		

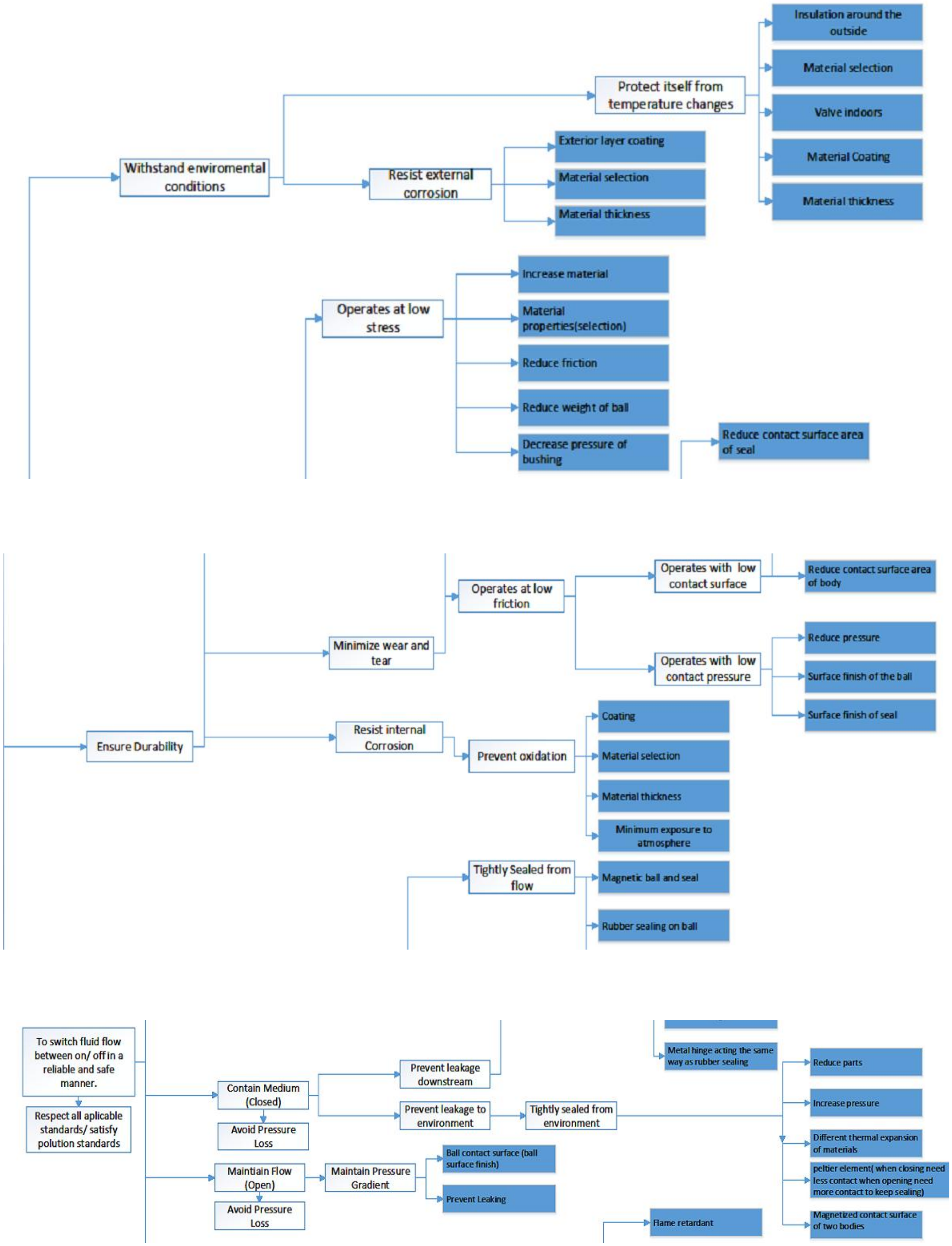
Thermal properties

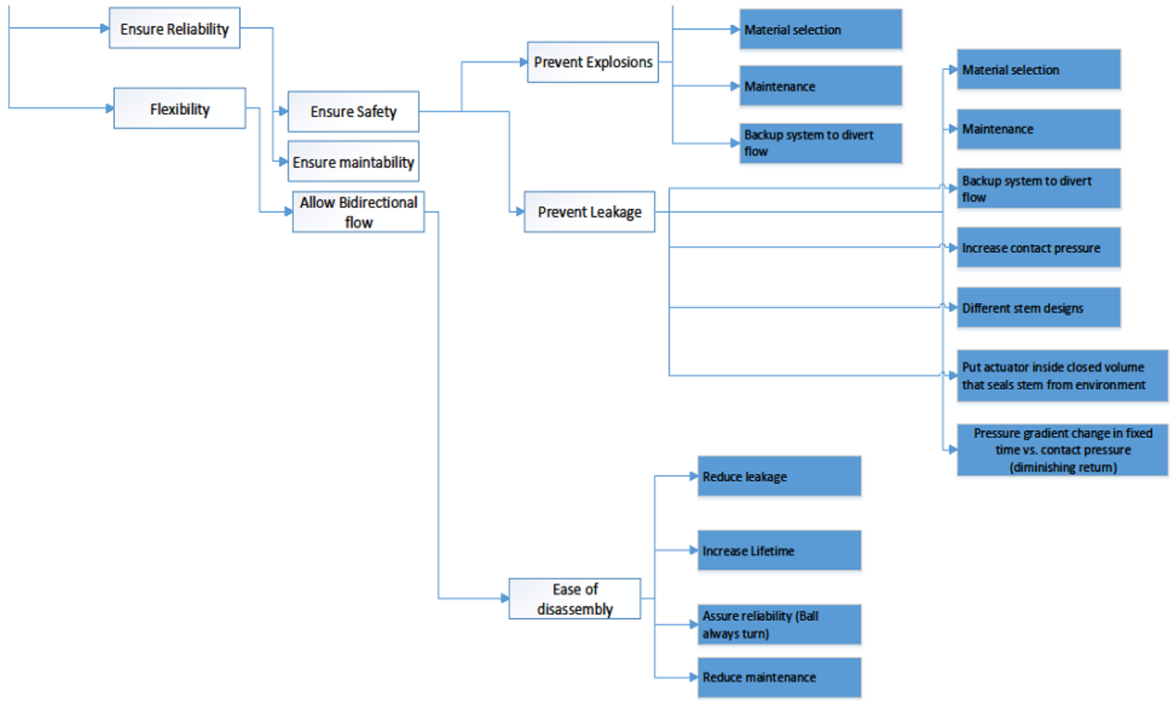
Property	Value	Unit	Test Method
Flammability	V-0		UL94
Melt point (initial)	342 ± 10	°C	ASTM D 4894-98a
(second)	327 ± 10	°C	ASTM D 4894-98a
Service Temperature Range	-200°C to 260°C (-328°F to 500°F)		

Electrical Properties

Property	Value	Unit	Test Method
Dielectric Strength	2.6	kV/mil	ASTM D149-95a

Appendix C – Functional Diagram





Appendix D –Research for casting

Manufacturing Processes

Sand Casting

- Most widely used casting process, accounting for a significant majority of total tonnage cast
- Nearly all alloys can be sand casted, including metals with high melting temperatures, such as steel, nickel, and titanium
- Parts ranging in size from small to very large
- Production quantities from one to millions

Shell Molding

Casting process in which the mold is a thin shell of sand held together by thermosetting resin binder

- Advantages:
  - Smoother cavity surface permits easier flow of molten metal and better surface finish on casting
  - Good dimensional accuracy
  - Machining often not required
  - Mold collapsibility usually avoids cracks in casting
  - Can be mechanized for mass production

- Disadvantages:

- More expensive metal pattern
- Difficult to justify for small quantities

Vacuum Molding

Uses sand mold held together by vacuum pressure rather than by a chemical binder

- Advantages:
  - Easy recovery of the sand, since binders not used
  - Sand does not require mechanical reconditioning normally done when binders are used
  - Since no water is mixed with sand, moisture-related defects are absent

- Disadvantages:
  - Slow process
  - Not readily adaptable to mechanization

Expanded Polystyrene Process

Uses a mold of sand packed around a polystyrene foam pattern which vaporizes when molten metal is poured into mold. Other names: are *lost-foam process*, *lost pattern process*, *evaporative-foam process*, and *full-mold process.* Polystyrene foam pattern includes sprue, risers, gating system, and internal cores (if needed). The mold does not have to be opened into cope and drag sections.

- Advantages:
  - Pattern need not be removed from the mold
  - Simplifies and expedites mold-making, since two mold halves (cope and drag) are not required as in a conventional green-sand mold

- Disadvantages:
  - A new pattern is needed for every casting
  - Economic justification of the process is highly dependent on cost of producing patterns

Investment Casting (Lost Wax Process)

A pattern made of wax is coated with a refractory material to make mold, after which wax is melted away prior to pouring molten metal. "Investment" comes from one of the less familiar definitions of "invest" - "to cover completely," which refers to coating of refractory material around wax pattern. It is a precision casting process - capable of castings of high accuracy and intricate detail

- Advantages:
  - Parts of great complexity and intricacy can be cast
  - Close dimensional control and good surface finish
  - Wax can usually be recovered for reuse
  - Additional machining is not normally required - this is a net shape process

- Disadvantages
  - Many processing steps are required

- Relatively expensive process

Plaster Mold Casting

Similar to sand casting except mold is made of plaster of Paris (gypsum - $CaSO_4$-$2H_2O$). In mold-making, plaster and water mixture is poured over plastic or metal pattern and allowed to set. Wood patterns not generally used due to extended contact with water. Plaster mixture readily flows around pattern, capturing its fine details and good surface finish

Advantages:
- Good dimensional accuracy and surface finish
- Capability to make thin cross-sections in casting

- Disadvantages:
  - Moisture in plaster mold causes problems:
  - Mold must be baked to remove moisture
  - Mold strength is lost when it is over-baked, yet moisture content can cause defects in the product
  - Plaster molds cannot stand high temperatures, so limited to lower melting point alloys

Ceramic Mold Casting

Similar to plaster mold casting except that mold is made of refractory ceramic materials that can withstand higher temperatures than plaster
- Ceramic molding can be used to cast steels, cast irons, and other high-temperature alloys
- Applications similar to those of plaster mold casting except for the metals cast
- Advantages (good accuracy and finish) also similar

Permanent Mold Casting Processes

Economic disadvantage of expendable mold casting: a new mold is required for every casting. In permanent mold casting, the mold is reused many times
- The processes include:
  - Basic permanent mold casting
  - Die casting
  - Centrifugal casting

Uses a metal mold constructed of two sections designed for easy, precise opening and closing. Molds used for casting lower melting point alloys are commonly made of steel or cast iron. Molds used for casting steel must be made of refractory material, due to the very high pouring temperatures.
- Advantages:
  - Good dimensional control and surface finish
  - More rapid solidification caused by the cold metal mold results in a finer grain structure, so stronger castings are produced

- Limitations:
  - Generally limited to metals of lower melting point
  - Simple part geometries compared to sand casting because of the need to open the mold
  - High cost of mold

Die Casting

A permanent mold casting process in which molten metal is injected into mold cavity under high pressure. Pressure is maintained during solidification, then mold is opened and part is removed. Molds in this casting operation are called *dies*; hence the name die casting. Use of high pressure to force metal into die cavity is what distinguishes this from other permanent mold processes

- Advantages:
  - Economical for large production quantities
  - Good dimensional accuracy and surface finish
  - Thin sections are possible
  - Rapid cooling provides small grain size and good strength to casting

- Disadvantages:
  - Generally limited to metals with low metal points
  - Part geometry must allow removal from die cavity

Centrifugal Casting

A group of casting processes in which the mold is rotated at high speed so centrifugal force distributes molten metal to outer regions of die cavity

- The group includes:
  - True centrifugal casting
  - Semi centrifugal casting
  - Centrifuge casting

True Centrifugal Casting

Molten metal is poured into rotating mold to produce a tubular part

- In some operations, mold rotation commences after pouring rather than before
- Parts: pipes, tubes, bushings, and rings
- Outside shape of casting can be round, octagonal, hexagonal, etc , but inside shape is (theoretically) perfectly round, due to radially symmetric forces

Semi centrifugal Casting

Centrifugal force is used to produce solid castings rather than tubular parts

- Molds are designed with risers at center to supply feed metal
- Density of metal in final casting is greater in outer sections than at center of rotation

- Often used on parts in which center of casting is machined away, thus eliminating the portion where quality is lowest
- Examples: wheels and pulleys

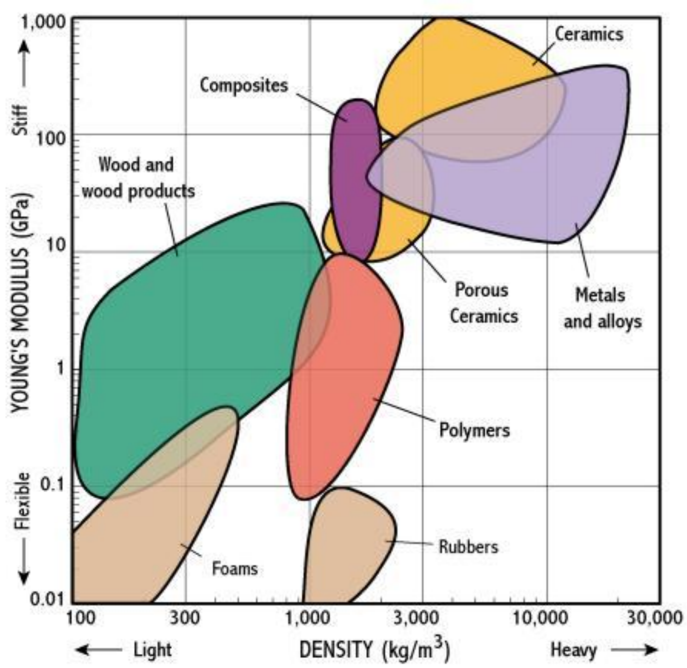
Centrifuge Casting

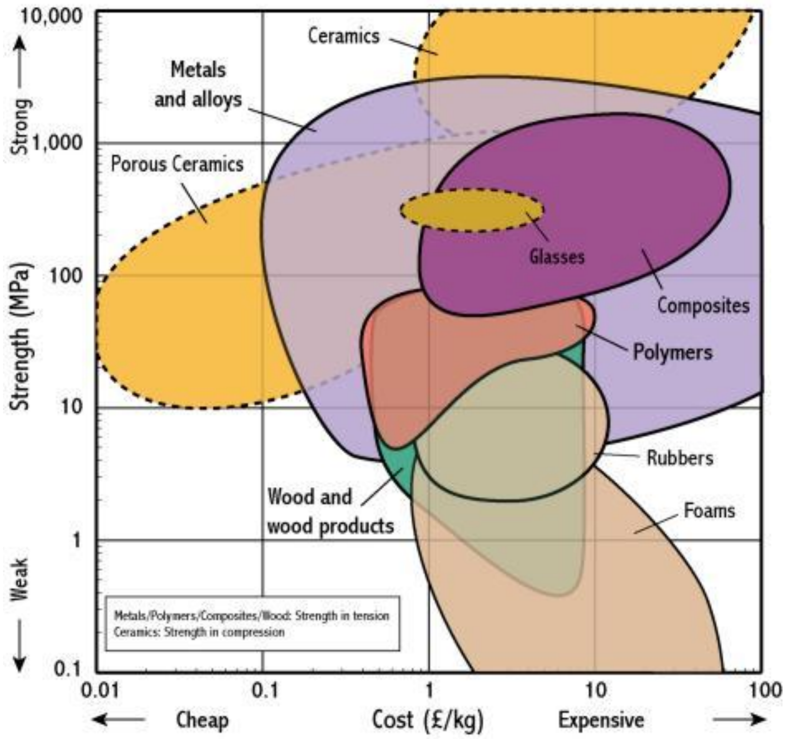
- Mold is designed with part cavities located away from axis of rotation, so that molten metal poured into mold is distributed to these cavities by centrifugal force
- Used for smaller parts
- Radial symmetry of part is not required as in other centrifugal casting methods

Material Selection

According to shown figure, the only materials that rival the stiffness of metals and alloys (currently used in the valve) are composites and ceramics. Unfortunately, these materials tend to be less inert than metals, and, particularly in the case of ceramics, more brittle. Furthermore, the thermal properties of metals are favorable over those of ceramics and composites.

Also, according to the chart below, the cost differences between composites, ceramics, and metals are not significant. From these conclusions, the materials to focus on for the scope of this project are composites and metals.





a. Metal Matrix Composites

In comparison with conventional polymer matrix composites, MMCs are resistant to fire, can operate in wider range of temperatures, do not absorb moisture, have better electrical and thermal conductivity, are resistant to radiation damage, and do not display outgassing (release of a gas that was trapped within the material.) On the other hand, MMCs tend to be more expensive, the fiber-reinforced materials may be difficult to fabricate, and the available experience in use is limited.

MMCs are nearly always more expensive than the more conventional materials they are replacing. As a result, they are found where improved properties and performance can justify the added cost. Today these applications are found most often in aircraft components, space systems and high-end or "boutique" sports equipment. The scope of applications will certainly increase as manufacturing costs are reduced.

b. Low Expansion Alloys

All of the alloys in this group are iron-nickel or iron-nickel-cobalt alloys with face-centered cubic crystal structure. As nickel content in the iron-nickel alloys increases from 36 percent, thermal expansivity and Curie temperature also increase. Curie temperature increases from 280°C (536°F) for 36 percent nickel to greater than 510°C (960°F) for 50 percent nickel. Thus, consideration in selecting an alloy also must be given the useful temperature range as might be limited by the Curie temperature.

**Note that the Curie point is the temperature where a material's permanent magnetism changes to induced magnetism. The force of magnetism is determined by magnetic moments. **

Any one of four other low expansion alloys may be particularly suitable for service at higher temperature ranges. For example, Low Expansion "39" alloy (ASTM B-753) has a useful low thermal expansivity extending to approximately 340ºC (644ºF). It has been used for tunable capacitors and as the low expansion element in thermostat bimetal products.

Low Expansion "42" alloy (ASTM B-753) has a virtually constant low rate of thermal expansion at temperatures up to about 380°C (716ºF), while Low Expansion "45" alloy (ASTM B-753) has a relatively constant rate of thermal expansion to about 440°C (824°F). Both metals have been used in thermostats and thermo switches. The thermal expansivity of the higher-nickel alloy approximates the thermal expansivity of some alumina ceramics over certain temperature ranges.

The alloy in this family with the highest nickel content, Low Expansion "49" alloy, has been used for glass sealing of fiber optics.

SOURCE: http://www.cartech.com/techarticles.aspx?id=1674

Reduce Friction

Option 1: Special coating for ball

-Superlow friction behavior of diamond-like carbon coatings

-low-friction TiB_2-based coatings by incorporation of C or MoS_2

- a trade-off between hardness and friction coefficient was found
- Coatings exhibiting a relatively high hardness of 20 GPa and friction coefficients as low as 0.05 could be obtained by choosing a suitable composition. Low friction could be obtained for temperatures as high as 400 °C for the TiB_2–MoS_2 coatings.

-Friction, wear and N_2-lubrication of carbon nitride coatings

- It was found that friction coefficient μ is high (μ=0.2–0.4) in air and O_2, and low (μ=0.01–0.1) in N_2, CO_2 and vacuum. The lowest friction coefficient (μ<0.01) was obtained in N_2. It was also found that N_2 gas blown to the sliding surfaces in air effectively reduced the friction coefficient down to $\mu \approx 0.017$.

Option 2: Lubricant

-friction-reducing properties of the lubricant additive, nanometer zinc borate

- compared with the base oil the wear resistance and load-carrying capacity of the oil were improved and the friction coefficient was decreased. There was an optimal content of zinc borate, and the corresponding oil gave the highest maximum nonseized load.

-CeF_3 nanoparticles as additives in lubricating oils

- The results show that CeF_3 nanoparticles are spherical and cylindrical in shape (size: 25 nm) and possess excellent extreme pressure and friction-reducing properties.
- However, CeF_3 nanoparticles cannot improve the anti-wear performance of lubricating oil effectively, and the reason may be that F^- ion generated by decomposing CeF_3 corrodes the rubbing surfaces.

-Room-temperature ionic liquids: a novel versatile lubricant

- Alkylimidazolium tetrafluoroborates are promising versatile lubricants for the contact of steel/steel, steel/aluminium, steel/copper, steel/SiO_2, Si_3N_4/SiO_2, steel/Si(100), steel/sialon ceramics and Si_3N_4/sialon ceramics; they show excellent friction reduction, antiwear performance and high load-carrying capacity.

Option 3: Improved Surface Finish

-Laser sintered rapid tools with improved surface finish and strength using plating technology

- Rapid tooling (RT) is a technology that can contribute greatly in reducing product development cycle. However, currently used RT methods permit smaller, pre-serial production runs to be conducted economically only in a limited number of cases.

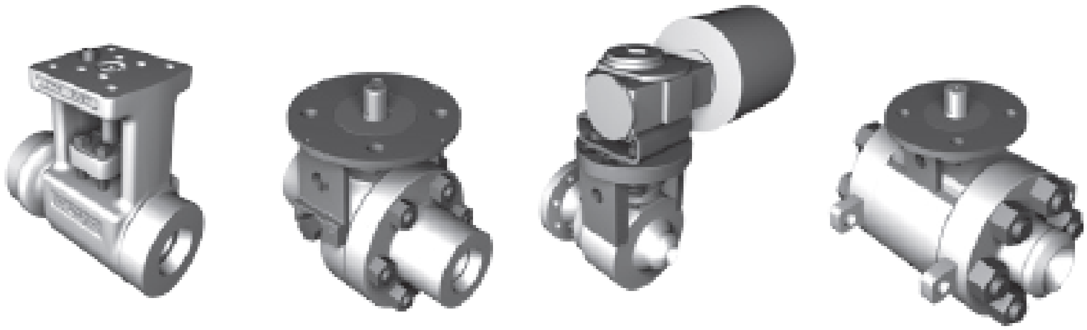
- Electroless nickel plating and semi-bright nickel electroplating have been chosen for their unique characteristics while they are applied either alone or combined with each other to achieve the best possible results. The investigated results demonstrate that the applied techniques possess enormous potential in developing rapid tools.

Change the design of the bracket

-Need to create a CAD

(Valvtechnologies)

(Argus)



(Mogas)

Bracket Price Reduction

- Reduce the height of the stem. By cutting down the height of the stem we can reduce the height and weight of the bracket.
- Connect the actuator directly to the bottom stem and eliminate the top stem.
- Replace the bracket with an X truss. This will automatically reduce the weight on the valve while withstanding that of the actuator. It will also reduce the cost if the X truss is standardized. (Look at the solid work design suggested on the next page)
- Connect the bracket to the top of the valve instead of to the side of the valve.

Appendix E-Chevron Packing

Operating limits

Pressure/Temperature/Speed	Combined sealing sets
Pressure	30 MPa
Temperature	–200 to 260°C
Linear velocity – Continuous operation – Intermittent operation	 0.5 m/s 1.2 m/s

* With vacuum or pressure reversal to 0.2 MPa, housing closed

Recommended number of chevron seals in sets

Pressure levels	DM 9403		DM 9406		DM 9409	
	Pure PTFE to 100°C	PTFE compound to 220°C	Pure PTFE to 100°C	PTFE compound to 220°C	Pure PTFE to 100°C	PTFE compound to 220°C
Vacuum					3	3
< 0.5 MPa			2	2	3	3
< 1.6 MPa			2	2		
< 5.0 MPa	3	3	3	3		
< 10.0 MPa	4	3	4	3		
< 20.0 MPa	5	4	5	4		
< 30.0 MPa		5		5		

The temperature range specified for pure PTFE can be greatly increased by including components made of PTFE compound.

FOB Price: US $1,000 - 1,500 / Ton

Minimum Order Quantity: 20 Ton/Tons

Supply Ability: 8000 Ton/Tons per Month

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