DESIGN OF A SCREW CONVEYOR SYSTEM

ME 4331/ ME 5327: DESIGN FOR MANUFACTURING

DATE OF COMPLETION: 12/15/2017

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1. PROBLEM STATEMENT/ DESIGN REQUIREMENTS:

Martin Sprocket & Gear Inc. is investigating a design change in a conveyor system that is used to move silica sand from a recycling operation into a foundry. There are currently two (2) mobile belt conveyors moving the sand into the foundry. Plant management wishes to replace the two belt conveyors with a single permanent fixed screw conveyor assembly. The screw conveyor must be designed to be cost effective while maintaining efficiency and performance.

A rotary airlock is currently metering 400 cubic feet of silica sand per hour onto the existing conveyors leading to the foundry. The distance from the center of the inlet to discharge is 19 feet and the conveyor is at an incline of 10 °. The temperature of the sand discharged from the airlock is heated in the previous process to a maximum of 1000° Fahrenheit. Additionally, plant personnel have reported that additives in the sand have caused corrosion to conveyor equipment fabricated in mild steel.

The design of the uniformly fed screw conveyor(s) should include but not be limited to the following:

- Motor (HP)
- Screw speed (RPM)
- Trough loading (%)
- Screw size (dia.)
- Pipe size (dia. & schedule)
- Screw pitch (full, half, etc.)
- Trough/cover type (U-trough, tubular, etc.)
- Shaft sizes, bolt drilling, bolt pads
- Hangers/bearings (intermediate screw supports, if applicable)
- Material thickness and type (Mild steel, stainless steel, AR steel, etc.)

The overall process must be considered in order to produce a practical cost-efficient design. Engineers are encouraged to modify standard designs should they feel a benefit in the performance/longevity of the equipment.

The following resources will be provided as a design guideline for this project:

- CEMA 350 Standards Book – A comprehensive design guideline that dictates existing industry standards
- Martin Sprocket & Gear, Inc. Material Handling Catalogue – Includes parts and design information
- General arrangement drawing for a basic screw conveyor – Use as reference to understand std. assemblies.

2. CUSTOMER REQUIREMENTS:

1. **Cost:** The cost of the conveyor system must be as minimal as possible.

2. **High Performance:** The system must be high performance system with good durability and lifespan.

3. **High Efficiency:** The overall efficiency of the system should be good.

4. **Corrosion Resistant:** The material used to be transported from one end of the conveyor to the other end is Silica Sand which may cause corrosion to the blades and the internal parts of the trough. Hence the material should be corrosion free or there is a need to get a corrosion resistive film on the parts.

5. **Abrasion Resistant:** The system should have high Abrasion Resistance.

6. **Controlled Screw Temperature:** The silica sand entering in the conveyor has a temperature of about 1000° F. Hence while designing the Screw temperature and the thermal properties of the materials needs to be considered.

7. **Controlled Driver Temperature:** The loading conditions and the effect on the motor loading needs to be low.

8. **Reduced Thermal Expansion:** While selecting the material for screw and the trough, thermal properties of the material needs to be considered.

9. **No Shaft Expansion:** Shaft material should have good thermal resistance to the withstand the high temperature silica sand.

10. **No Spilling:** Design should be spill free.

11. **Feed Rate:** Design should be done considering the rate at which the silica sand is entering the conveyor. In our case it is 400 cubic feet per hour.

12. **Inclination:** The inclination of the conveyor must be 10°.

3. IMPORTANCE OF THE WEIGHTING FACTOR:

Customer Requirement	Wants	Needs	Relative Importance
Cost		✓	5
High Performance		✓	5
High Efficiency		✓	5
Corrosion Resistant	✓		5
Abrasion Resistant	✓		4
Controlled Screw Temperature		✓	4
Controlled Driver Temperature		✓	2
Reduced Thermal Expansion		✓	3
No Shaft Expansion	✓		3
Long Lasting Expansion	✓		2
No Spilling	✓		4
Feed Rate		✓	4
Inclination	✓		2

Table 3.1. Importance or the weighting factor.

4. HOUSE OF QUALITY:

- The House of Quality develops the relationships between what the customer wants from a product and which of the product's features and overall performance parameters are most critical to fulfilling those wants.

- The House of Quality translates **Customer Requirements** into generally quantifiable design variables, called **Engineering Characteristics.**

- The HOQ process will identify a set of essential features and product performance measures that will be the target values to be achieved by the design team.

- The House of Quality can also be used to determine which engineering characteristics should be treated as constraints for the design process and which should become decision criteria for selecting the best design concept.

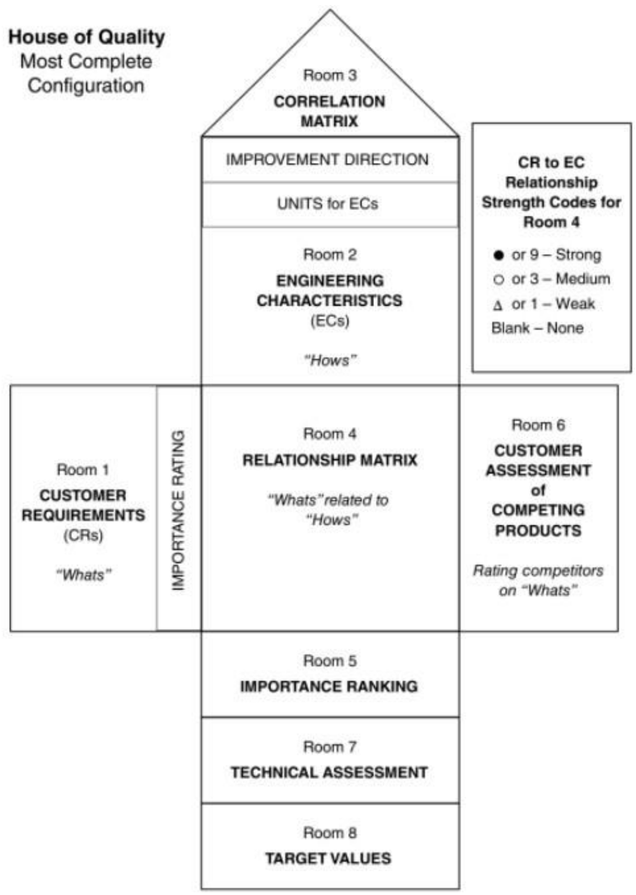
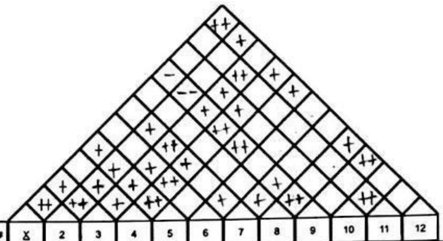


Figure 4.1: Configuration of House of Quality



Row #	Max Relationship Value in Row	Relative Weight	Weight / Importance	Demanded Quality (0,1,3,6,9)	MOTOR (HP)	SCREW SPEED (RPM)	TROUGH LOADING (cubic ft / hr)	SCREW SIZE (in)	PIPE SIZE (in)	SCREW PITCH (in)	TROUGH TYPE (FLANGE TUBULAR/TUBULAR)	BOLT SIZE (in)	HANGER BEARINGS (INTERMEDIATE - HANGING ROLL / SLIDE)	MATERIAL THICKNESS (in) (SCREW)	MATERIAL	SHAFT SIZE (in)	0 KWS Manufacturing	1 FMC Technologies	2	3	4	5
				Column #	X	2	3	4	5	6	7	8	9	10	11	12	Competitive Analysis (1,3,5)					
				Direction of Improvement:		▲	▲	▲	▼	▼				▼		▼						
1	9	10.4%	5	COST	6	3	9	9	6	6	1	1	6	6	9	3	5	5				
2	9	10.4%	5	HIGH PERFORMANCE	9	9	9	9	3	6	6	0	6	1	9	0	5	3				
3	9	10.4%	5	HIGH EFFICIENCY	6	9	9	9	3	6	6	1	6	1	9	0	3	5				
4	9	10.4%	5	CORROSION RESISTANT	0	0	6	0	0	0	1	0	0	9	9	0	3	3				
5	9	8.3%	4	ABRASION RESISTANT	0	0	6	6	0	0	1	0	0	9	9	0	3	3				
6	9	8.3%	4	CONTROLLED SCREW TEMPERATURE	0	6	9	3	0	6	9	0	0	3	9	0	1	3				
7	9	4.2%	2	CONTROLLED DRIVER TEMPERATURE	9	9	6	0	0	0	6	0	6	0	0	3	1	1				
8	9	6.3%	3	REDUCED THERMAL EXPANSION	3	6	6	9	3	6	1	0	1	9	9	1	1	1				
9	9	6.3%	3	NO SHAFT DEFLECTION	6	9	9	3	9	6	0	9	9	0	6	9	5	5				
10	9	4.2%	2	LONG LASTING PAINT	0	3	6	0	0	0	3	0	0	0	9	0	1	1				
11	9	8.3%	4	NO SPILLING	0	6	1	3	1	3	9	0	1	0	0	0	3	5				
12	9	8.3%	4	FEED-RATE	6	9	9	6	3	3	3	0	0	0	0	0	3	5				
13	9	4.2%	2	INCLINATION (10°)	9	6	3	9	6	6	6	0	6	0	0	3	3	5				
				Target or Limit Value	5	40	400	24	6	24	FLANGE TUBULAR	0.75	HANGING	1/4	SS316	5.5						
				Difficulty	7	9	0	8	5	8	2	1	6	8	10	5						
				Max Relationship Value in Column	9	9	9	9	9	6	9	9	9	9	9	9						
				Weight / Importance	192	270	340	261	124	186	191	37	148	160	315	30	Total = 2254					
				(%) Relative Weight	8.52	11.9	15.1	11.6	5.5	8.3	8.5	1.6	6.6	7.1	13.9	1.3						
							(V.Imp)									(Least Important)						

Figure 4.2: House of Quality for our Project.

5. PRODUCT DESIGN SPECIFICATION:

5.1 Product Identification:

- Product name: Single Fixed Screw Conveyor System.
- Basic functions of the product: move silica sand from a recycling operation into a foundry, accommodation of material of varied lump size.
- Special features of the product: screw is inclined at an angle (10 degrees) for better efficiency and increased speed.
- Key performance targets (power output, efficiency, accuracy): 5HP, 40% less spilling so accurate output.

5.2 Service Environment:

- Use conditions: Very hot temperatures (1000° Fahrenheit), abrasive and highly corrosive environment.
- Storage: In a closed environment to avoid contaminant.
- Use and predictable misuse: for transporting material in safe conditions, overloading situations.
- User training required: Yes. Skilled labor needed.

5.3 Market Identification:

- Description of target market and its size: Foundries, smelting factories, processing industry, cement industry, food & beverage industry.
- Anticipated market demand (units per year): 150 units in a year.
- Competing products: Continental Screw conveyor, FMC technologies, KWS Manufacturing.
-

5.4 Key Project Deadlines:

- One and half year required to finalize the Design.
- Two years to manufacture and setup the execution of product.

5.5 Physical Description:

- Design variable values that are known or fixed prior to the conceptual design process (e.g. external dimensions): Length= 19 ft., Screw size= 24in, shaft size= 5.5in, RPM= 40
- Constraints that determine known boundaries on some design variables (e.g., upper limit on acceptable weight): The volume can be exceeded from the limit of 400 cubic feet/hr.

5.6 Financial Requirements:

- Pricing policy over life cycle:
- Target manufacturing cost: $12,000

- Estimated retail price: $20,000
- Discounts: 5% (If the cost exceeds $25,000)
    - Warranty Policy: 5 years complete product warranty
    - Expected financial performance or rate of return on investment: 20% in one year
    - Level of capital investment required: $50 million.

5.7 **Life Cycle Targets:**

- Useful life/shelf life: 10-12 years (depending on the use, this number shows average expectancy of the system)
- Cost of installation and operation (energy costs, crew size, etc.): 20% handloading, 12.5% installation cost, 100-120 (including helpers and designers)
- Maintenance schedule and location (user-performed or service centered): Service centered with engineering technicians required and on-site repairs and maintenance.
- Reliability (mean time to failure):
  Hanging bearings and seals (2.5 years)
  Conveyor screws (4 years)
  Fasteners, flange, trough (2 years)
  Shaft (8 years)
- End-of-life strategy:
  % and type of recyclable components: 80% recycled, metal parts & rubber components.
  Company take back: Yes (only for recycling and repairs)
  Remanufacture of the product: Possible
  Upgrade policy: Yes

5.8 **Manufacturing Specifications:**

- Most of the parts for the assembly will be manufactured in-house (Complete manufacturing of screw conveyor, shafts, couplings, trough, hopper, etc.)
- Outsourced parts include (Motor, gearbox, bearings, fasteners)
- Suppliers: ABB Inc, Siemens, SKF, SC fastening systems.

5.9 **Social, Political, and Legal Requirements:**

- ANSI safety code obtained from ASME, CEMA, Screw conveyor safety operation and maintenance manual, Standard no: 352-2012, approved September 19th, 2012, ISBN: 978-1-891171-43-7.
- Intellectual property: It will be patented eventually as per more research.

6. FUNCTIONAL DECOMPOSITION:

- A common strategy for solving any complex task or describing any complex system is to decompose it into smaller units that are easier to manage. Decomposing must result in units that meaningfully represent the original entity.
- Functional decomposition is a top-down strategy where a general description of a device is refined into more specific arrangements of functions and sub-functions.

6.1 MORPHOLOGICAL CHART:

- Morphological analysis is a method for representing and exploring all the relationships in multidimensional problems.
- Morphological methods help structure the problem for the synthesis of different components to fulfill the same required functionality.
- The general morphological approach to design is summarized in the following three steps:
  1. Divide the overall design problem into simpler subproblems.
  2. Generate solution concepts for each subproblem.
  3. Systematically combine subproblem solutions into different complete solutions and evaluate all combinations.

Concept	**Conveyor Trough** (To convey the powders or granules and coarse materials)	**Drive Arrangement** (Drive the conveyor Screw, further to push material forward towards outlet)	**Hanger** (Used to provide a bearing surface to support a screw section when multiple screw sections are used in a screw conveyor)	**Material of Screw** (To provide the necessary performance in service and the processing methods used to create the correct part)
1	Formed Flange U Trough	Screw Driver Reducer	Style 220-	AL-6XN
2	Formed Flange Tubular Trough	Gear Motor Drive	Style 316	316 SS
3	Flared Trough	Shaft Mounted Reducer	Style 326	A36 Steel
4	Angle Flange U-Trough	Base Type Reducer Drive	Style 230	Mild Steel (MS)

Table 6.1.1: Morphological Chart

7. CONCEPT DESIGNS:

7.1 CONCEPT 1:

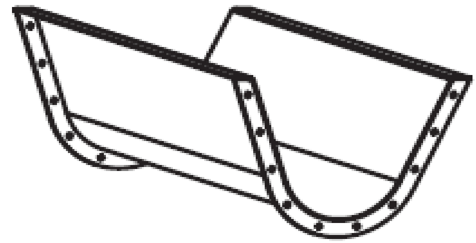
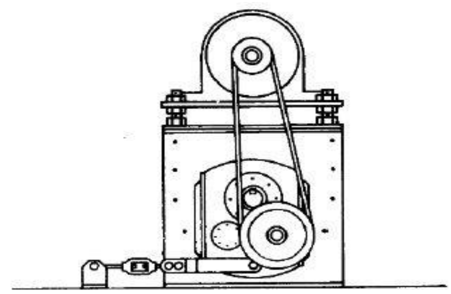
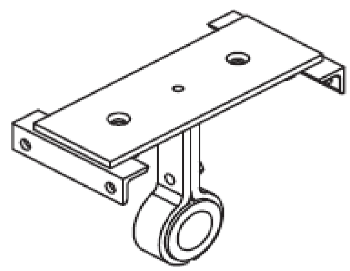
Conveyor Trough	Flared Trough	
Drive Arrangement	Shaft Mounted Reducer	
Hanger	Style 326	
Material of Screw	A36 Steel	

Table 7.1: Concept 1

7.2 **CONCEPT 2:**

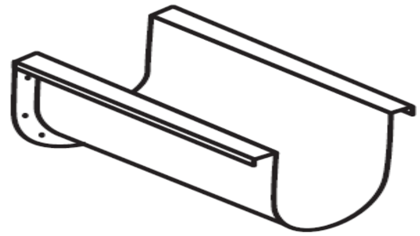
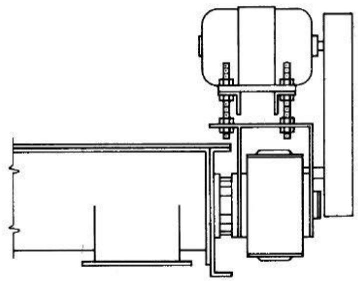
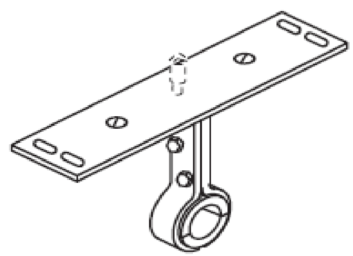
Conveyor Trough	Formed Flange U-Trough	
Drive Arrangement	Screw Driver Reducer	
Hanger	Style 220	
Material of Screw	AL-6XN	

Table 7.3: Concept 2

7.3 **CONCEPT 3:**

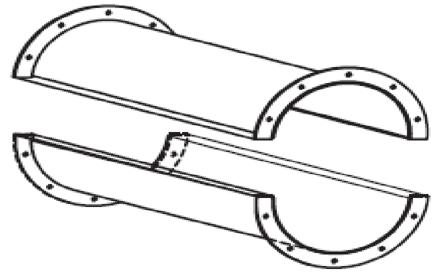
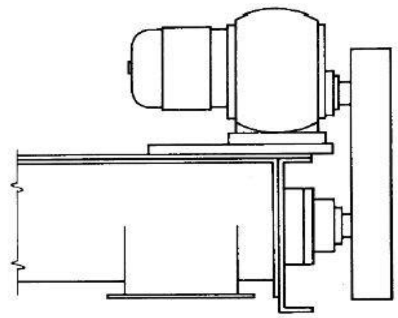
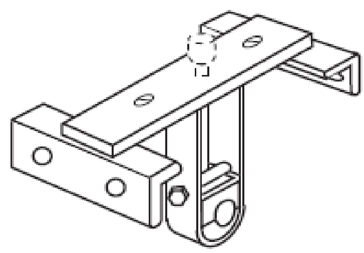
Conveyor Trough	Formed Flange Tubular Trough	
Drive Arrangement	Gearmotor Drive	
Hanger	Style 316	
Material of Screw	316 SS	

Table 7.4: Concept 3

7.4 CONCEPT 4:

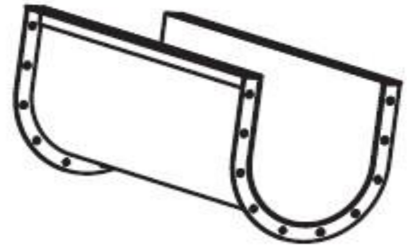
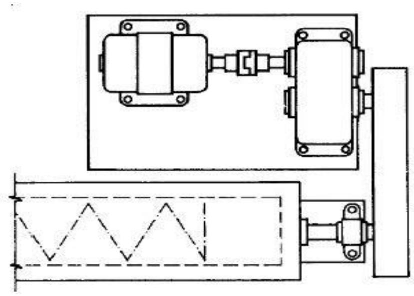
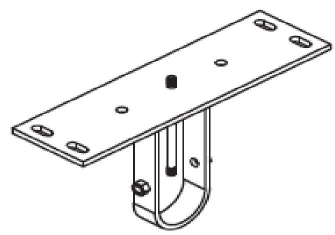
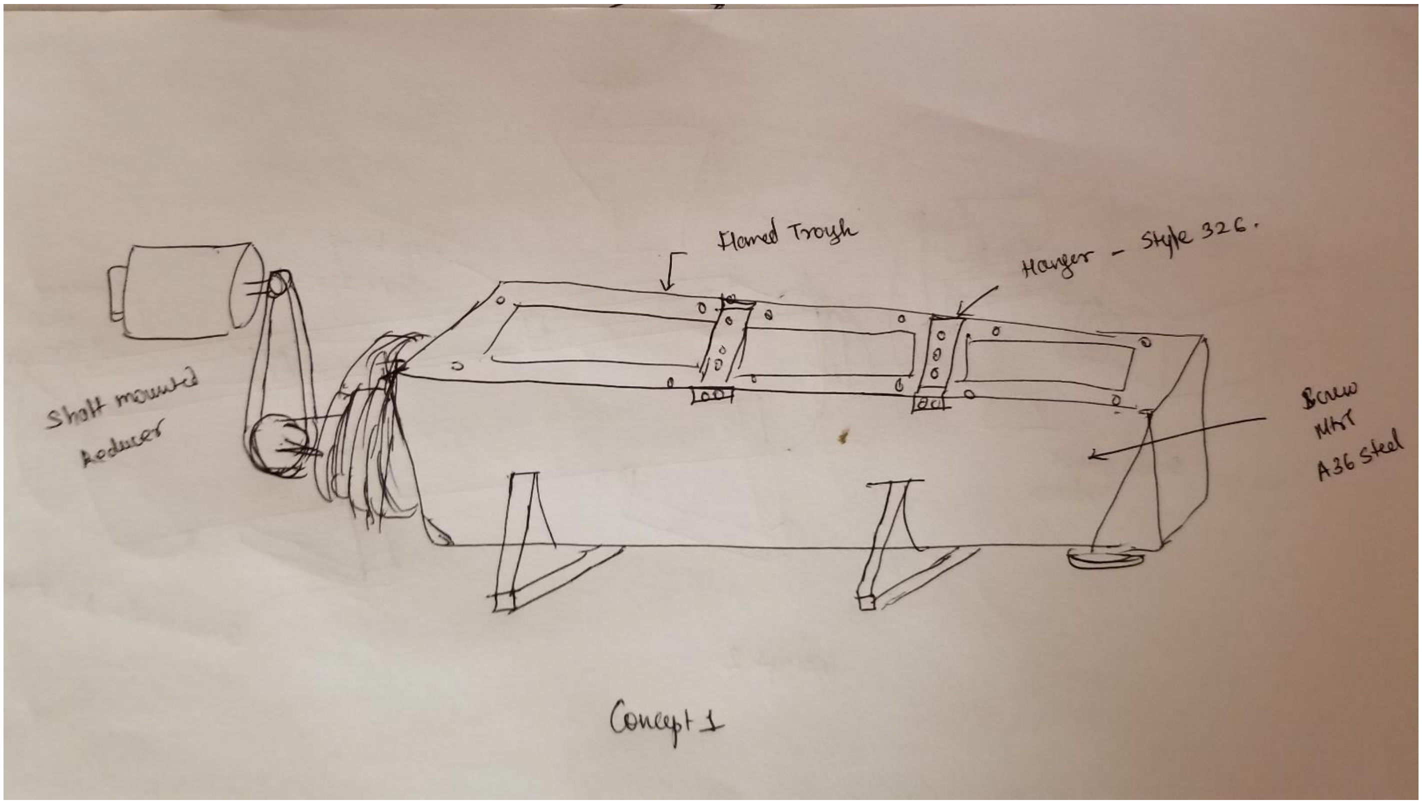
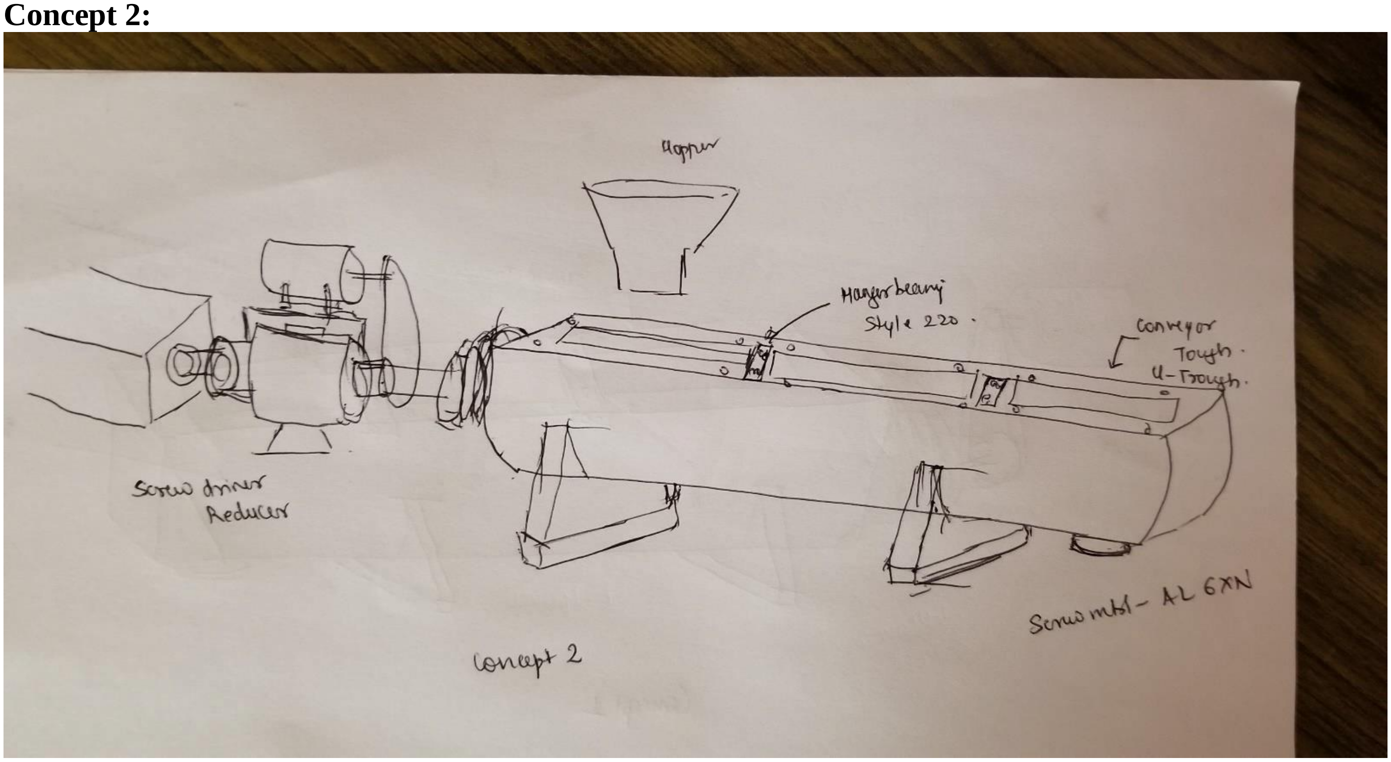
Conveyor Trough	Angle Flange U-Trough	
Drive Arrangement	Base Type Reducer Drive	
Hanger	Style 230	
Material of Screw	Mild Steel (MS)	

Table 7.5: Concept 4

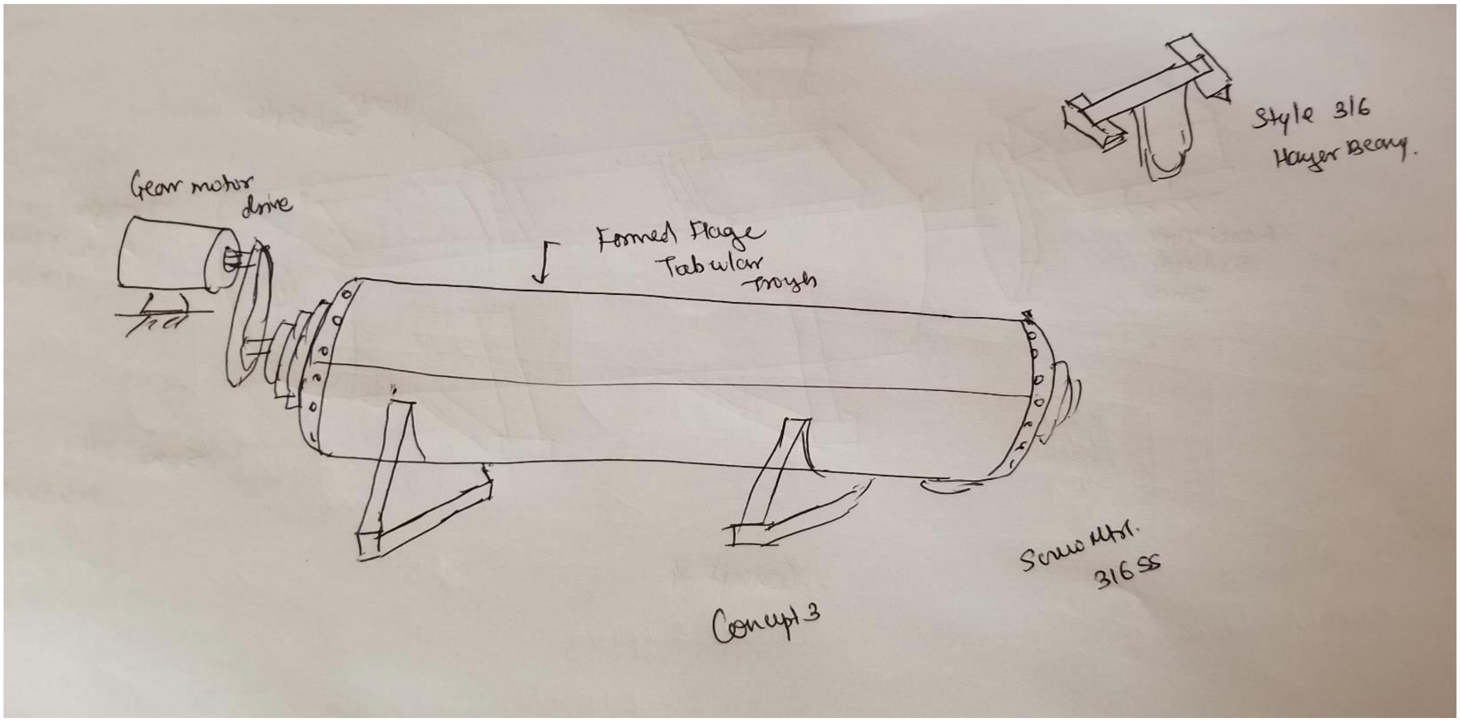
Concept 1:



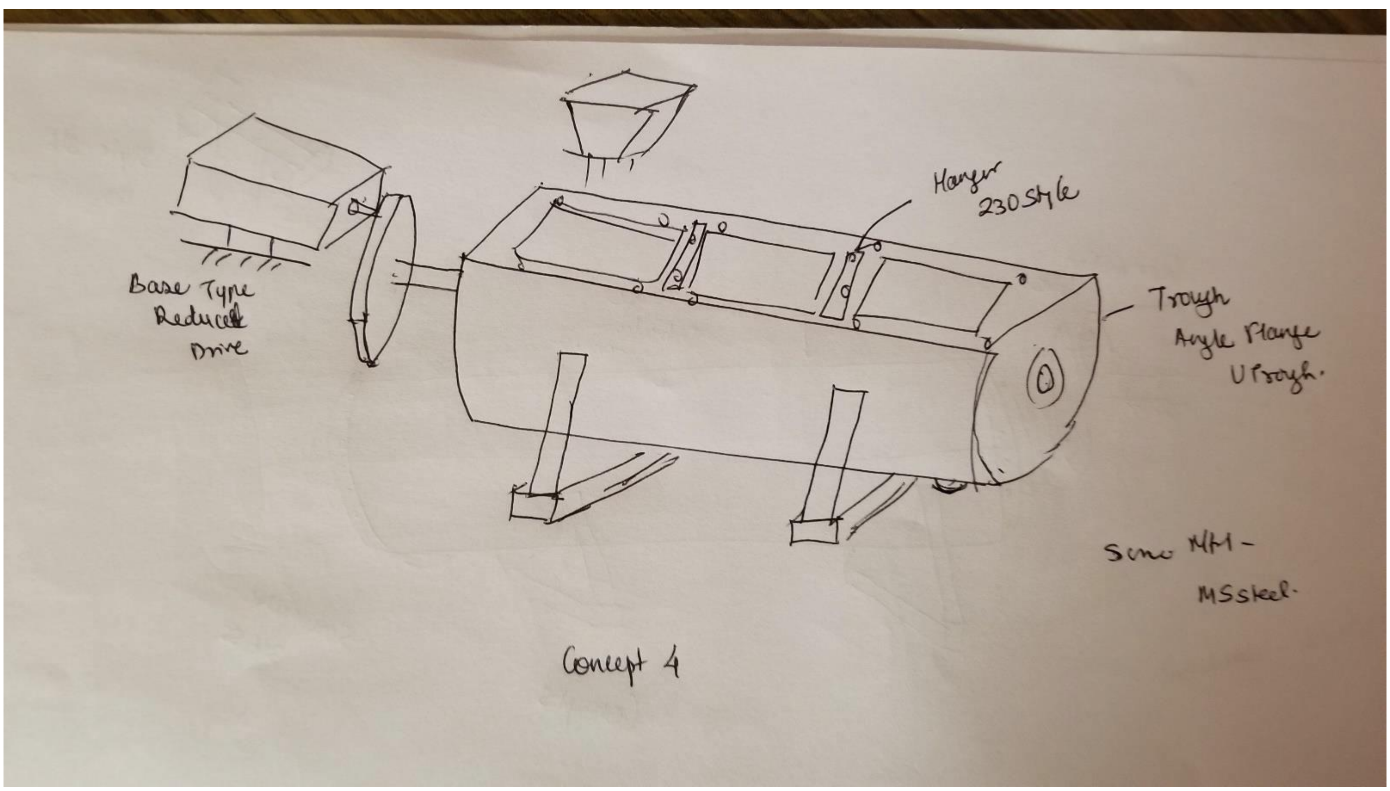
Concept 2:



Concept 3:



Concept 4:



8. WEIGHTED DECISION MATRIX:

- A decision matrix is a method of evaluating competing concepts by ranking the design criteria with weighting factors and scoring the degree to which each design concept meets the criterion.

- Objective Tree: Weighting factors can be determined by using a hierarchical objective tree. Better decisions regarding preferences will be made when the comparisons are made at the same level in the hierarchy, because you will be comparing “apples with apples and oranges with oranges”. Again, this method relies on some experience with the importance of the criteria in the design process.

- The simplest procedure in comparing design alternatives is to add up the ratings for each concept and declare the concept with the highest rating the winner. A better way to use the decision matrix is to examine carefully the components that make up the rating to see what design factors influenced the result.

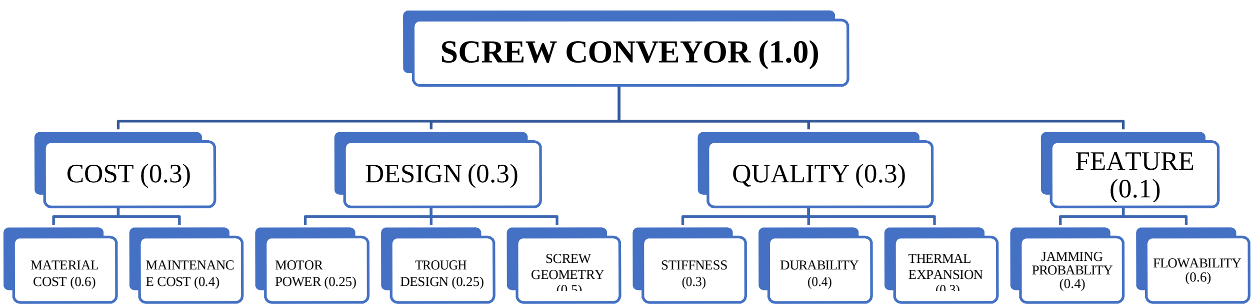


Figure 8 Objective Tree for the Screw Conveyor

Weighted Matrix for Concepts

Design Criteria	Weight Factor	Units	Concept-1			Concept-2			Concept-3			Concept-4		
			Magnitude	Score	Rating	Magnitude	Score	Rating	Magnitude	Score	Rating	Magnitude	Score	Rating
Motor Power	0.075	HP	Good	7	0.525	V Good	8	0.6	Good	7	0.525	Good	7	0.525
Jamming Probability	0.04	%	Good	8	0.32	Excellent	9	0.36	Good	7	0.28	Good	7	0.28
Flowability	0.06	Cubic ft /hr	Good	7	0.42	Excellent	9	0.54	Good	7	0.42	Good	6	0.36
Thermal Expansion	0.09	1/°C	Good	7	0.63	Good	7	0.63	Good	7	0.63	Good	7	0.63
Screw Geometry	0.15	N/A	Average	4	0.6	V. Good	8	1.20	V. Good	8	1.20	V.Good	8	1.20
Trough Design	0.075	N/A	F-F U-trough	7	0.525	A-F U-Trough	9	0.675	Flared Trough	8	0.6	Angle Flange U trough	7	0.525
Stiffness	0.09	lb/in	Good	7	0.63	V.Good	8	0.72	Average	6	0.54	Average	5	0.45
Material Selection	0.18	N/A	Good	7	1.26	V Good	8	1.44	Good	7	1.26	Good	7	1.26
Durability	0.12	%	Good	6	0.72	Excellent	9	1.08	Good	7	0.84	Good	6	0.72
Maintenance	0.12	N/A	Good	7	0.84	V Good	8	0.96	Good	7	0.84	V Good	8	0.96
	Total				**6.47**			**8.205**			**7.135**			**6.91**

Table 8 Weighted Decision Matrix for Screw conveyor

8.1 **FINAL CONCEPT SELECTION:**

• The Final Concept Selected is Concept-B (Rating 8.205) Design as per Weighted Decision Matrix. It is a Formed Flange U-Trough Product Architecture.

• The Concept-B Design Has Formed Flange U-Trough with Hanger Bearings at intermediate distance on the screw which can be disassembled with ease for maintenance and serviceability.

• The provided Geared Motor is foot mounted fixed with bolting which again can be disassembled with ease for maintenance and serviceability.

• Each Component has a specific function to accomplish.

9. **PRODUCT ARCHITECTURE:**

- Product subsystems, called modules or chunks, are defined and details of integration with each other are determined.
- To establish a product's architecture, a designer defines the geometric boundaries of the product and lays out the proposed elements of the design within its envelope.
- The design elements are both functional elements and physical elements.
- The functional elements are the functions that the product must perform to conform to its PDS. The physical elements are components, either standard parts or special-purpose parts, needed to achieve the functions.

The Product architecture for the following are:

- **Overall System: Modular** (The Conveyor system is adapted as per the needs of customers and it has specific set of functions to perform)
- **Hanger Bearing: Modular** (This bearing will be specifically used for screws for a specific role and the load that it will be handling at the specified length)
- **Trough: Modular** (The Trough will have certain limit of volumetric transfer from one end to the other end and hence it has been designed as per customers requirement)
- **Support Saddle: Modular** (It has been designed for a specific angle of 10^0 inclination)
- **Screw: Modular** (It makes it easier to evolve a design over a period. Also, it doesn't perform any other functions)

9.1 **SCHEMATIC DIAGRAM OF FLOW IN SCREW CONVEYOR:**

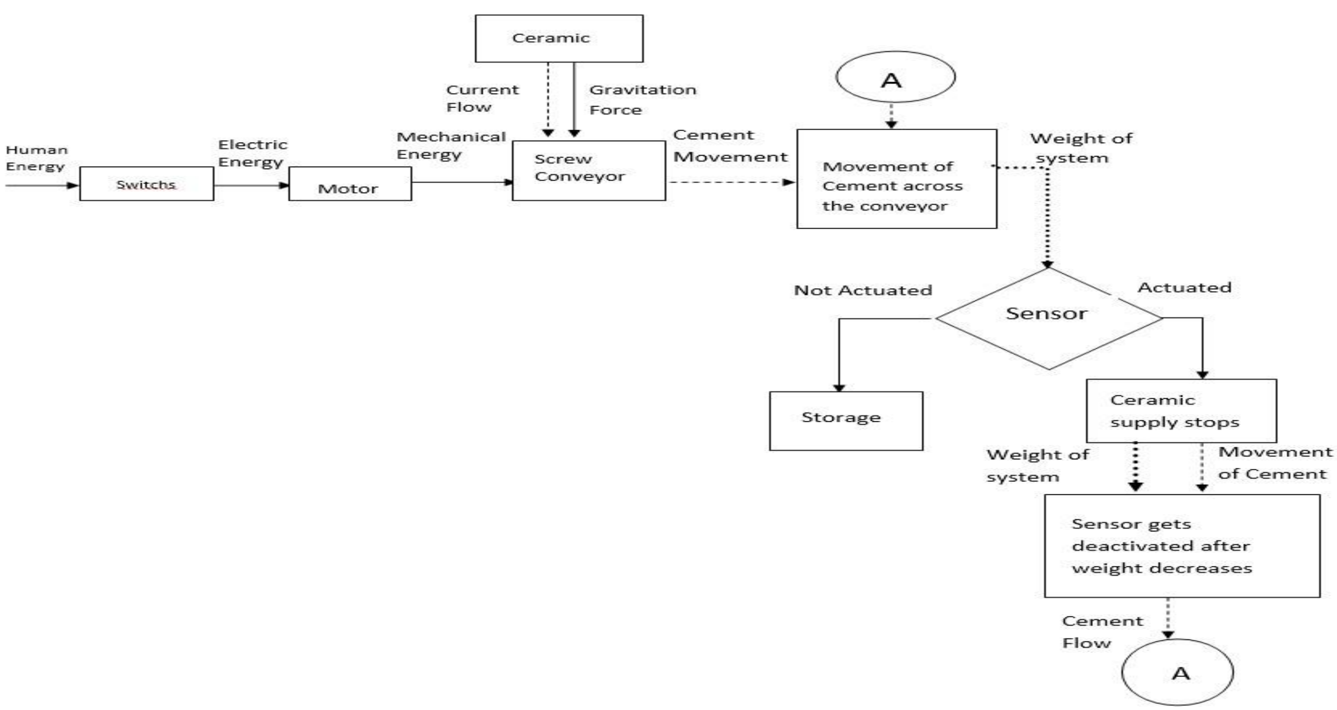


Figure 9.1 Schematic diagram of Screw Conveyor showing flow between components

9.2 **PHYSICAL DECOMPOSITION:**

9.2.1 BLOCK DIAGRAM:

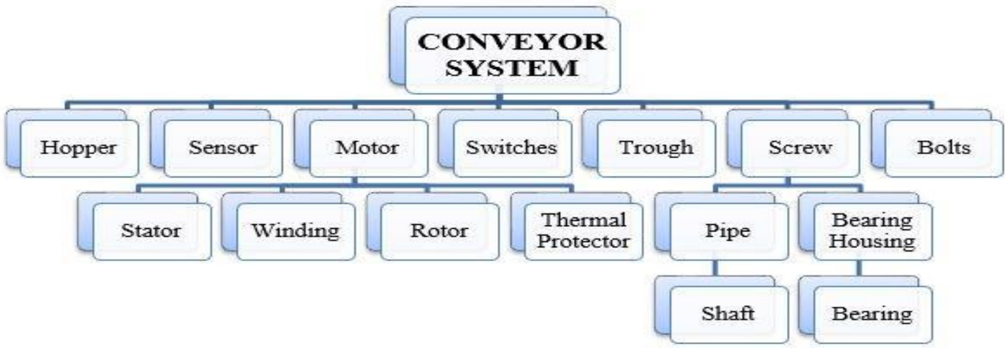


Figure 9.2.1 Block Diagram: Physical Decomposition of the Conveyor system

9.2.2PHYSICAL DECOMPOSITION:

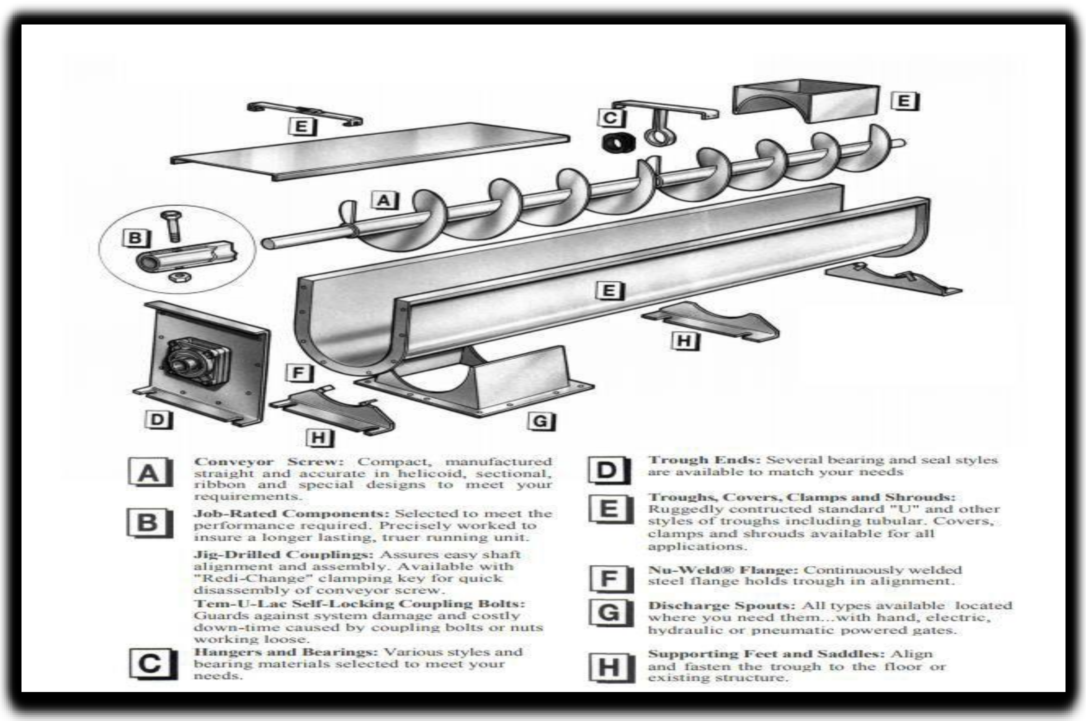


Figure 9.2.2 Physical Decomposition: Screw Conveyor

10. MANUFACTURING PROCESSES AND MATERIAL SELECTION

For manufacturing process, it is important to select material for a part that has the properties to provide the necessary performance in service and the processing methods used to create the correct part.

The General criteria for selection are as follows:

- Performance Characteristics (properties)
- Processing (Manufacturing) characteristics
- Environmental profile
- Business considerations

For material selection process we take four parts of screw conveyor as other parts like bearing, fasteners, motor and high & low speed coupling are of standard material which are bought instead of manufacturing in-house.

The parts of the screw conveyor system which are considered for selection process are:

- Conveyor Screw
- Trough
- Trough Saddle
- Hanger

We use Weighted decision matrix for evaluating concepts by ranking the design criteria and weighting factors.

11. MATERIAL SELECTION AS PER ASHBY/ASME STANDARDS

Material	SS304	SS316	MS (MILD STEEL)	SS904L	ALUMINIUM	COPPER	TITANIUM
Properties							
HARDNESS (BHN)	123	149	86	192	95	89	334
TENSILE STRENGTH (Ksi)	31.2	42.1	20.3	71.07	40	4.83	128
YOUNG'S MODULUS (x10^6 Psi)	28	28	18	28.4	10	13.7	16.8
MAX. SERVICE TEMPERATURE (°F)	1696.73	1696.73	750	2010	752	790	2800
THERMAL EXPANSION (x10^-6/°F)	32.4	32.4	13	8.5	13.1	9.8	4.8
CORROSION RESISTANT	YES (LOW)	YES (MEDIUM)	VERY LOW	YES (HIGH)	YES	YES (HIGH)	YES (HIGH)
COST	LOW	LOW	VERY LOW	VERY HIGH	LOW	LOW	VERY HIGH

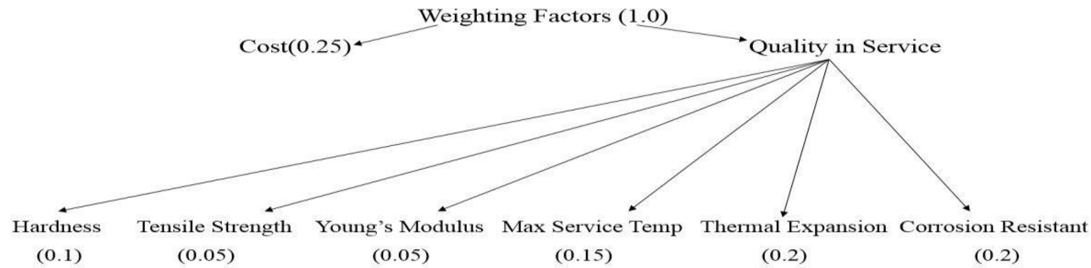
Material Required	SS304	SS316	MS (MILD STEEL)	ALUMINIUM
Properties Required				
HARDNESS (BHN)	123	149	86	95
TENSILE STRENGTH (Ksi)	31.2	42.1	20.3	40
YOUNG'S MODULUS (x10^6 Psi)	28	28	18	10
MAX. SERVICE TEMPERATURE (°F)	1696.73	1696.73	750	752
THERMAL EXPANSION (x10^-6/°F)	32.4	32.4	13	13.1
CORROSION RESISTANT	YES (LOW)	YES (MEDIUM)	VERY LOW	YES
COST	LOW	LOW	VERY LOW	LOW

12. WEIGHTED DECISION MATRIX FOR MATERIAL SELECTION

12.1 SCREW CONVEYOR

WEIGHTED DECISION MATRIX FOR MATERIAL SELECTION

- SCREW CONVEYOR

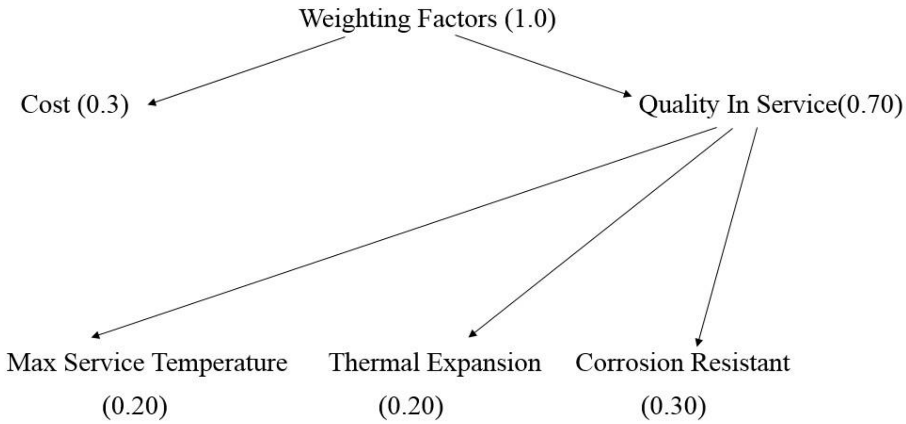


Design Criteria	Weight Factor	Units	SS304			SS316			MS			ALUMINIUM		
			Magnitude	Score	Rating	Magnitude	Score	Rating	Magnitude	Score	Rating	Magnitude	Score	Rating
HARDNESS	0.1	BHN	123	8	0.8	149	10	1	86	5	0.5	95	6	0.6
TENSILE STRENGTH	0.05	Ksi	31.2	7	0.35	42.1	9	0.45	20.3	4	0.2	40	8	0.4
YOUNG'S MODULUS	0.05	x106 Psi	28	8	0.4	28	8	0.4	18	5	0.25	10	3	0.15
MAX. SERVICE TEMPERATURE	0.15	^{0} F	1696.73	9	1.35	1696.73	9	1.35	750	2	0.3	752	2	0.3
THERMAL EXPANSION	0.2	x10^{-6} /^{0}F	32.4	8	1.6	32.4	8	1.6	13	4	0.8	13.1	4	0.8
CORROSION RESISTANT	0.2	NA	YES (LOW)	7	1.4	YES (MEDIUM)	9	1.8	NO	1	0.2	YES	5	1
COST	0.25	$	LOW	8	2	LOW	8	2	VERY LOW	10	2.5	LOW	9	2.25
	Total			7.9			8.6			4.75			5.5	

The Material selected for Conveyor screw is **SS316**

12.2 TROUGH

- TROUGH :

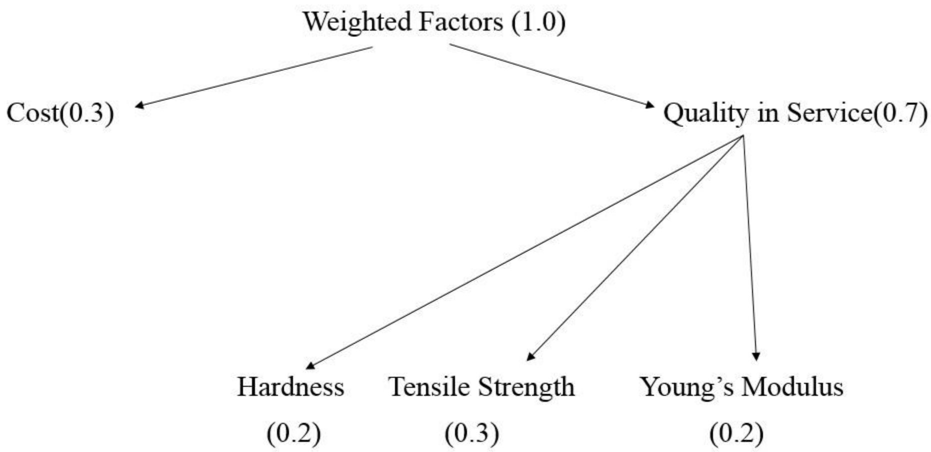


Design Criteria	Weight Factor	Units	SS304			SS316			MS			ALUMINIUM		
			Magnitude	Score	Rating	Magnitude	Score	Rating	Magnitude	Score	Rating	Magnitude	Score	Rating
MAX. SERVICE TEMPERATURE	0.2	^{0} F	1696.73	9	1.8	1696.73	9	1.8	750	2	0.4	752	2	0.4
THERMAL EXPANSION	0.2	$x10^{-6}$ $/^0F$	32.4	8	1.6	32.4	8	1.6	13	4	0.8	13.1	4	0.8
CORROSION RESISTANT	0.3	NA	YES (LOW)	7	2.1	YES (MEDIUM)	9	2.7	NO	1	0.3	YES	5	1.5
COST	0.3	$	LOW	8	2.4	LOW	8	2.4	VERY LOW	10	3	LOW	9	2.7
	Total			7.9			8.5			4.5			5.4	

The material selected for Trough is **SS316**

12.3 **SADDLE**

- SADDLE :

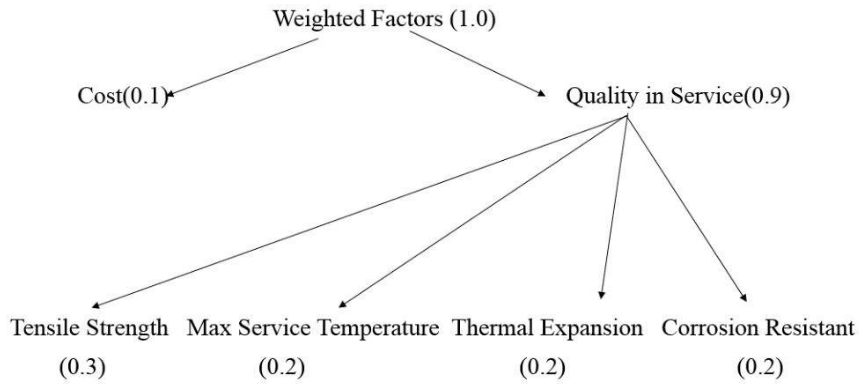


Design Criteria	Weight Factor	Units	SS304			SS316			MS			ALUMINIUM		
			Magnitude	Score	Rating	Magnitude	Score	Rating	Magnitude	Score	Rating	Magnitude	Score	Rating
HARDNESS	0.2	BHN	123	8	1.6	149	6	1.2	86	5	1	95	6	1.2
TENSILE STRENGTH	0.3	Ksi	31.2	7	2.1	42.1	9	2.7	20.3	4	1.2	40	8	2.4
YOUNG'S MODULUS	0.2	$x10^6$ Psi	28	8	1.6	28	8	1.6	18	5	1	10	3	0.6
COST	0.3	$	LOW	4	1.2	LOW	1	0.3	VERY LOW	10	3	LOW	6	1.8
	Total			5.9			5.8			6.2			6	

The material selected for Trough Saddle is **MS**

12.4 **HANGER**

- HANGER:



Design Criteria	Weight Factor	Units	SS304			SS316			MS			ALUMINIUM		
			Magnitude	Score	Rating	Magnitude	Score	Rating	Magnitude	Score	Rating	Magnitude	Score	Rating
TENSILE STRENGTH	0.3	Ksi	31.2	7	2.1	42.1	9	2.7	20.3	4	1.2	40	8	2.4
MAX. SERVICE TEMPERATURE	0.2	^{0}F	1696.73	9	1.8	1696.73	9	1.8	750	2	0.8	752	2	0.4
THERMAL EXPANSION	0.2	x10^{-6} /^{0}F	32.4	8	1.6	32.4	8	1.6	13	4	0.8	13.1	4	0.8
CORROSION RESISTANT	0.2	NA	YES (LOW)	7	1.4	YES (MEDIUM)	9	1.8	NO	1	0.2	YES	5	1.0
COST	0.1	$	LOW	8	0.8	LOW	8	0.8	VERY LOW	10	2.4	LOW	9	0.9
	Total			7.7			8.7			5.4			5.5	

13. MANUFACTURING PROCESS SELECTION

➢The factors that influence the selection of a process are:

- Quantity of parts required
- Complexity - shape, size, features
- Material
- Quality of part
- Cost to manufacture
- Availability, lead time, and delivery schedule

➢For designing a Screw Conveyor, we took quality of part as an important factor.

➢The quality of a part is defined by related sets of characteristics

- Freedom from external and internal defects.
- Surface finish.
- Dimensional accuracy and tolerance.

➢To a high degree, the achievement of quality in these areas is influenced by the workability or formability of the material. For selection of Manufacturing process for material we are using PRIMA selection matrix highlights materials and processes that are usually used together, based on common practice.

QUANTITY \ MATERIAL	IRONS	STEEL (carbon)	STEEL (tool, alloy)	STAINLESS STEEL	COPPER & ALLOYS	ALUMINIUM & ALLOYS	MAGNESIUM & ALLOYS
VERY LOW 1 TO 100	[1.5] [1.6] [1.7] [4.M]	[1.5] [1.7] [3.10] [4.M] [5.1] [5.5] [5.6]	[1.1] [1.5] [1.7] [3.10] [4.M] [5.1] [5.5] [5.6] [5.7]	[1.6] [1.7] [3.7] [3.10] [4.M] [5.1] [5.5] [5.6]	[1.5] [1.7] [3.6] [4.M] [5.1]	[1.5] [1.7] [3.7] [3.10] [4.M] [5.5]	[1.6] [1.7] [3.10] [4.M] [5.1] [5.5]
LOW 100 TO 1,000	[1.2] [1.5] [1.6] [1.7] [4.M] [5.3] [5.4]	[1.2] [1.6] [1.7] [3.10] [4.M] [5.1] [5.3] [5.4] [5.5]	[1.1] [1.2] [1.7] [4.M] [5.1] [5.3] [5.4] [5.5] [5.6] [5.7]	[1.2] [1.7] [3.7] [3.10] [4.M] [5.1] [5.3] [5.4] [5.5]	[1.2] [1.3] [1.5] [1.7] [1.8] [3.3] [3.6] [4.M] [5.1] [5.3] [5.4]	[1.2] [1.5] [1.7] [1.8] [3.7] [3.10] [4.M] [5.3] [5.4] [5.5]	[1.6] [1.7] [1.8] [3.10] [4.M] [5.5]
LOW TO MEDIUM 1,000 TO 10,000	[1.2] [1.3] [1.5] [1.6] [1.7] [3.11] [4.A] [5.2]	[1.2] [1.3] [1.5] [1.7] [3.1] [3.3] [3.10] [3.11] [4.A] [5.2] [5.3] [5.4] [5.5]	[1.2] [1.5] [1.7] [3.1] [3.4] [3.11] [4.A] [5.2] [5.3] [5.4] [5.5]	[1.2] [1.5] [1.7] [3.1] [3.2] [3.7] [3.10] [3.11] [4.A] [5.2] [5.3] [5.4] [6.0]	[1.2] [1.3] [1.6] [1.8] [3.1] [3.2] [3.10] [3.11] [4.A] [5.2] [5.3] [5.4]	[1.2] [1.3] [1.4] [1.5] [3.1] [3.3] [3.7] [3.10] [3.11] [4.A] [5.3] [5.4] [5.5]	[1.3] [1.5] [1.8] [3.1] [3.3] [3.4] [3.10] [4.A] [5.5]
MEDIUM TO HIGH 10,000 TO 100,000	[1.2] [1.3] [3.11] [4.A]	[1.3] [2.1] [3.3] [3.4] [3.5] [3.11] [3.12] [4.A] [5.2] [5.5]	[3.1] [3.4] [3.5] [3.11] [3.12] [4.A] [5.2]	[1.3] [3.1] [3.3] [3.4] [3.5] [3.11] [3.12] [4.A]	[1.2] [1.4] [1.8] [3.1] [3.3] [3.4] [3.5] [3.11] [3.12] [4.A]	[1.2] [1.3] [1.4] [1.8] [3.1] [3.3] [3.4] [3.5] [3.11] [3.12] [4.A] [5.5]	[1.3] [1.4] [3.1] [3.3] [3.4] [3.5] [3.12] [4.A]
HIGH 100,000+	[1.2] [1.3] [3.11] [4.A]	[1.8] [3.1] [3.2] [3.3] [3.4] [3.5] [3.12] [4.A]	[4.A]	[1.8] [3.2] [3.3] [4.A]	[1.2] [1.4] [3.1] [3.2] [3.3] [3.4] [3.5] [3.7] [3.8] [3.11] [3.12] [4.A]	[1.2] [1.3] [1.4] [1.6] [3.1] [3.2] [3.3] [3.4] [3.5] [3.8] [3.12] [4.A]	[1.3] [1.4] [3.1] [3.3] [3.4] [3.8] [3.12] [4.A]
ALL QUANTITIES	[1.1]	[1.1] [1.5] [3.6] [3.8] [3.9]	[1.6] [3.8]	[1.1] [1.6] [3.6] [3.8] [3.9]	[1.1] [1.6] [3.6] [3.8] [3.9] [5.5]	[1.1] [1.6] [3.4] [3.5] [3.6]	[1.1] [3.5] [3.6] [3.8]

QUANTITY \ MATERIAL	ZINC & ALLOYS	TIN & ALLOYS	LEAD & ALLOYS	NICKEL & ALLOYS	TITANIUM & ALLOYS	THERMOPLASTICS	THERMOSETS	FR COMPOSITES	CERAMICS	REFRACTORY METALS	PRECIOUS METALS
VERY LOW 1 TO 100	[1.1] [1.7] [3.10] [4.M] [5.5]	[1.1] [1.7] [3.10] [4.M] [5.5]	[1.1] [3.10] [4.M] [5.5]	[1.5] [1.7] [3.10] [4.M] [5.1] [5.5] [5.6]	[1.1] [1.6] [3.7] [3.10] [4.M] [5.1] [5.5] [5.6] [5.7]	[2.5] [2.7]	[2.5] [2.7]	[2.2] [2.6] [5.7]	[1.5] [5.1] [5.5] [5.6] [5.7]	[1.1] [5.7]	[5.6]
LOW 100 TO 1,000	[1.1] [1.7] [1.8] [3.10] [4.M] [5.5]	[1.1] [1.7] [1.8] [3.10] [4.M] [5.5]	[1.1] [1.8] [3.10] [4.M] [5.5]	[1.2] [1.5] [1.7] [3.10] [4.M] [5.1] [5.3] [5.4] [5.5] [5.6]	[1.1] [1.6] [3.7] [3.10] [4.M] [5.1] [5.3] [5.4] [5.5] [5.6] [5.7]	[2.3] [2.5] [2.7]	[2.2] [2.3]	[2.2] [2.3] [2.6] [5.7]	[5.1] [5.3] [5.5] [5.6] [5.7]	[5.7]	[5.5]
LOW TO MEDIUM 1,000 TO 10,000	[1.3] [1.8] [3.3] [3.10] [4.A] [5.5]	[1.3] [1.5] [3.2] [3.10]	[1.3] [1.5] [3.3] [3.10]	[1.2] [1.3] [1.5] [1.7] [3.1] [3.2] [3.11] [4.A] [5.1] [5.3] [5.4] [5.5] [3.10]	[3.1] [3.7] [3.10] [3.11] [4.A] [5.2] [5.3] [5.4] [5.5]	[2.3] [2.5] [2.6] [2.7]	[2.2] [2.3] [2.4]	[2.1] [2.2] [2.3]	[5.2] [5.3] [5.4] [5.5]		[5.5]
MEDIUM TO HIGH 10,000 TO 100,000	[1.3] [1.4] [3.3] [3.4] [3.5] [3.12] [4.A]	[1.3] [1.4] [3.3] [3.4] [3.12]	[1.3] [1.4] [3.3] [3.4] [3.8] [3.12] [4.A]	[3.1] [3.3] [3.5] [3.4] [3.11] [3.12] [4.A] [5.2] [5.5]	[3.1] [3.4] [3.11] [3.12] [4.A] [5.2] [5.5]	[2.1] [2.3] [2.6] [2.7] [2.8]	[2.1] [2.3] [2.8]	[2.1] [2.3]	[3.11]	[3.12]	[3.5]
HIGH 100,000+	[1.4] [3.2] [3.3] [3.4] [3.5] [4.A]	[1.4] [3.3] [3.4] [4.A]	[1.4] [3.2] [3.3] [3.4] [4.A]	[3.2] [3.3] [4.A]	[4.A]	[2.1] [2.6] [2.8]	[2.1] [2.3] [2.4] [2.9]		[3.7] [3.11]		[3.5]
ALL QUANTITIES	[3.6] [3.8] [3.9]		[3.5]	[1.1] [1.6] [3.4] [3.5] [3.6]	[3.8] [3.9]				[5.5]	[1.5]	[1.6]

KEY TO MANUFACTURING PROCESS PRIMA SELECTION MATRIX:

CASTING PROCESSES
[1.1] SAND CASTING
[1.2] SHELL MOULDING
[1.3] GRAVITY DIE CASTING
[1.4] PRESSURE DIE CASTING
[1.5] CENTRIFUGAL CASTING
[1.6] INVESTMENT CASTING
[1.7] CERAMIC MOULD CASTING
[1.8] PLASTER MOULD CASTING
[1.9] SQUEEZE CASTING

PLASTIC & COMPOSITE PROCESSING
[2.1] INJECTION MOULDING
[2.2] REACTION INJECTION MOULDING
[2.3] COMPRESSION MOULDING
[2.4] TRANSFER MOULDING
[2.5] VACUUM MOULDING
[2.6] BLOW MOULDING
[2.7] ROTATIONAL MOULDING
[2.8] CONTACT MOULDING
[2.9] CONTINUOUS EXTRUSION (PLASTICS)

FORMING PROCESSES
[3.1] CLOSED DIE FORGING
[3.2] ROLLING
[3.3] DRAWING
[3.4] COLD FORMING
[3.5] COLD HEADING
[3.6] SWAGING
[3.7] SUPERPLASTIC FORMING
[3.8] SHEET-METAL SHEARING
[3.9] SHEET-METAL FORMING
[3.10] SPINNING
[3.11] POWDER METALLURGY
[3.12] CONTINUOUS EXTRUSION (METALS)

MACHINING PROCESSES
[4.A] AUTOMATIC MACHINING
[4.M] MANUAL MACHINING

(THE ABOVE HEADINGS COVER A BROAD RANGE OF MACHINING PROCESSES AND LEVELS OF CONTROL TECHNOLOGY. FOR MORE DETAIL, THE READER IS REFERRED TO THE INDIVIDUAL PROCESSES.)

NTM PROCESSES
[5.1] ELECTRICAL DISCHARGE MACHINING (EDM)
[5.2] ELECTROCHEMICAL MACHINING (ECM)
[5.3] ELECTRON BEAM MACHINING (EBM)
[5.4] LASER BEAM MACHINING (LBM)
[5.5] CHEMICAL MACHINING (CM)
[5.6] ULTRASONIC MACHINING (USM)
[5.7] ABRASIVE JET MACHINING (AJM)

FIGURE 13.9
PRIMA selection matrix showing which materials and processes are usually used together, based on common practice. (From K. G. Swift and J. D Booker, *Process Selection*, 2nd ed., p. 23. Copyright Elsevier, 2003. Used with permission.)

From **PRIMA Selection Matrix** the process selected for **Carbon Steel** and **Stainless Steel** are as follows:

- Sand Casting
- Centrifugal Casting
- Ceramic Mold Casting
- Spinning, Bending
- Manual Machining
- Electrical Discharge Machining (EDM)
- Chemical Machining
- Ultrasonic Machining
- Abrasive Jet Machining
- Investment Casting
- Sheet Metal Shearing
- Sheet Metal Forming

14. RATING OF CHARACTERISTICS OF COMMON MANUFACTURING PROCESS

Processes	Shape	Cycle Timing	Flexibility	Material Utilization	Quality	Equipment Tool costs
Centrifugal casting	3-D Hollow	2	3	5	3	3
Spinning , Bending	3-D	2	1	3	4	1
Manual Machining	3-D	2	5	1	5	4
Electrical Discharge Machining	3-D	1	4	1	5	1
Sand Casting	3-D	2	5	2	2	1
Investment casting	3-D	2	4	4	4	3
Sheet metal shearing	3-D	3	1	3	4	1
Sheet metal Forming	3-D	3	1	3	4	1

Rating Scale for Ranking Manufacturing Processes

Rating	Cycle Time	Flexibility	Material Utilization	Quality	Equipment Tooling Costs
1	>15 min	Changeover very difficult	Waste >100% of finished part	Poor quality	High machine and tooling costs
2	5 to 15 min	Slow changeover	Waste 50 to 100%	Average quality	Tooling and machines costly
3	1 to 5 min	Avg changeover and setup time	Waste 10 to 50%	Average to good quality	Tooling and machines relatively inexpensi
4	20 s to 1 min	Fast changeover	Waste < 10% finished part	Good to excellent	Tooling costs low
5	<20 s	No setup time	No appreciable waste	Excellent quality	Equip. and tooling very low

Rating scale: 1, poorest; 5, best

15. INITIAL SCREENING OF CANDIDATE PROCESSES

	SS316		MS		REASON
	YES/NO	REJECT	YES/NO	REJECT	
SAND CASTING	Y		N		
CENTRIFUGAL CASTING	N		N		
CERAMIC MOLD CASTING		R	N		Heavy Investment considering it is required only for flight, since we are using metal, ceramic material is not required.
SPINNING, BENDING	Y		Y		
MANUAL MACHINING	Y		Y		
ELECTRICAL DISCHARGE MACHINING (EDM)	Y		N		
CHEMICAL MACHINING	N		N		
ULTRASONIC MACHINING	N		N		
ABRASIVE JET MACHINING	N		N		
INVESTMENT CASTING	N		N		
SHEET METAL SHEARING	Y		Y		
SHEET METAL FORMING	Y		Y		

From Initial screening, we eliminated the following processes:

- Centrifugal Casting
- Investment Casting
- Chemical Machining
- Ultrasonic Machining
- Investment Machining
- Ceramic Mold Machining

Processes	Shape	Cycle Timing	Flexibility	Material Utilization	Quality	Equipment tool costs	Total	Economic batch size
Spinning, Bending	3D	2	1	3	4	1	11	
Manual Machining	3D	2	5	1	5	4	17	1-6000
Electrical Discharge machining	3D	1	4	1	5	1	12	1-900
Sheet metal Shearing	3D	3	1	3	4	1	12	
Sheet metal Forming	3D	3	1	3	4	1	12	2000-12000

- Now, second screening table was constructed from data given in Process selection. The rating for each criterion is totaled for each process.
- The results of this process ranking are not very discriminating. All casting processes rank are between 12 or 17.
- The ranking for spinning and bending is slightly lower, 11. Moreover, spinning and bending process is more difficult than others, as they require more material and equipment as compare to others and has less flexibility.
- Whereas manual machining is more flexible and high-quality process. Thus, from second screening we eliminated the process sheet metal shearing and sheet metal forming.

16. COMPARISION OF CHARACTERISTICS

Process Requirement	Screw Conveyor Design	Spinning, Bending	Manual Machining	EDM
Size range, Mass (kg)	2500	90	10,000	900
Section Thickness max. (mm)	51	10	1000	9
Section Thickness min. (mm)	3	0.3	0.1	0.2
Tolerance (+/-mm)		0.008-0.1	0.0001-0.1	0.012-0.1
Economic batch size	1	2000	< 6000	< 1000

By using either casting or molding we expect to be able to manufacture a component. This will eliminate assembling the parts, although there may be a requirement for a balancing step.

Each of the candidate processes are capable of producing symmetrical 3-D shapes. The screening parameter examined first was the economic batch size.

Now that we have narrowed the selection of a manufacturing process down to three alternatives, the final selection is based on the estimated cost to make the cost model.

The final decision on a manufacturing process is usually made on the basis of the cost to make a part, called the unit cost.

17. DETERMINING UNIT COST FOR THREE PROCESSES BASED ON COST MODEL

Cost element	Spinning, Bending	Manual Machining	Electrical Discharge Machining (EDM)
Material cost ($/lb)	0.6	1.2	1.8
Fraction of process that is Scrap	0.08	0.06	0.08
Mass of part, m	800	750	850
C_M, Unit cost of material ($)	**521.74**	**957.45**	**1663.05**
Labor cost, C_W	25	25	25
Production Rate, n	6	3	8
C_L, Unit cost of Labor ($)	**4.17**	**8.33**	**3.13**
Tooling Cost, C_T	800	700	900
Total production run	1	1	1
Tooling Life	1	1	1
Sets of tooling required, k	1	1	1
C_T, Unit cost of Tooling ($)	**800**	**700**	**900**
Capital Cost, C_E	250,000	200,000	350,000
Capital write off-time	5	5	5
Load fraction, L	1	1	1
Load Sharing fraction, q	1	1	1
C_E, Unit cost of capital equipment ($)	**2.85**	**4.57**	**2.99**
Factory overhead	60	60	60
Production Rate, n	1	1	1
C_{OH}, Unit cost of factory overhead ($)	**60**	**60**	**60**
Total unit cost ($) = **$C_M + C_L + C_T + C_E + C_{OH}$**	**1388.76**	**1730.35**	**2629.17**

18. DESIGN FOR MANUFACTURING

Design for manufacture represents an awareness of the importance of design as the time for thoughtful consideration of all steps of production.

DFM Guidelines:

DFM guidelines are statements of good design practice that have been empirically derived from years of experience.

- **Minimize total number of parts:** Eliminating parts results is great savings. The best way to eliminate parts is to make minimum part count a requirement of the design at the conceptual stage of design.
- **Standardize components:**
- **Use common parts across product lines:** It is good business sense to use parts in more than one product. Specify the same materials, parts, and sub-assemblies in each product as much as possible.
- **Standardize design features:** Standardizing on design features like drilled hole sizes, screw thread types, and bend radii minimizes the number of tools that must be maintained in the tool room. This reduces manufacturing overhead cost
- **Aim to keep designs functional and simple:**
- **Design parts to be multifunctional:** A good way to minimize part count is to design such that parts can fulfill more than one function, leading to integral architecture.
- **Design parts for ease of fabrication:** The least costly material that satisfies the functional requirements should be chosen.
- **Avoid excessively tight tolerances:** Specifying tolerances that are tighter than needed, results in increased cost. Before selecting a manufacturing process, be sure that it is capable of producing the needed tolerance and surface finish.
- **Minimize secondary and finishing operations:** Minimize secondary operations such as heat treatment, machining, and joining and avoid finishing operations such as deburring, painting, plating, and polishing. Use only when there is a functional or safety reason for doing so.
- **Utilize the special characteristics of processes**

18.1DESIGN FOR MANUFACTURE (DFM) ANALYSIS FOR MACHINING, BENDING

	1	3	4	5	6	7	
PART(ID or Description or features)	Hanger	End Seal	Conveyor Screw	Trough Saddle	Drive Shaft	Trough Assembly	
Step-1(Part Details)							
Quantity	2	1	1	4	1	1	
Primary operation on the part	Use to hold shaft and bearing together, and allows mounting on top of the trough	Reduce Bulk material leak	Impart smooth positive motion to the material as it rotates within the trough	Support the trough at trough connection	Connect and transmit motion to subsequent screw conveyors	To completely enclose the material being conveyed and the rotating parts	
Secondary operation on the part	1) Allow dust, light and weather proof operation, 2) Allow minimum obstruction to material flow, 3) Serve as bearing surface	1) Reduce product loss, 2) Reduce Contamination, 3) Reduce bearing failure		1) Align and fasten the trough to the floor or an existing structures, 2)Accurately maintain trough height, 3) Permit easy removal of a trough end without disturbing the entire unit		1) Allow flow of material, 2) Provide cover to screw	
Instances of tolerances							
Step-2(DFM analysis)							
							Sum
Number of secondary operations on the part (+1 for each operation)	3	3	0	3	0	2	11
Shape of the machined part(+1 if taper, +1 if complex contour,-1 if rectangular)	1	1	2	2	2	1	9
Can the part withstand forces of clamping? (-1 if yes and +1 if no)	-1	-1	-1	-1	-1	-1	-6
Presence of secure holding and fixturing (-1 if yes and +1 if no)	-1	-1	-1	-1	-1	-1	-6
Number of sharp corners(+1 for each occurance)	16	0	2	2	0	4	24
Presence of stock dimensions(-2 if present)	0	-2	-2	-2	-2	-2	-10
Presence of undercuts (+1 for each occurance)	0	4	0	2	1	1	8

Presence of parting lines or draft surface for clamping (+1 for each occurance)	2	2	2	1	2	1	10	
Presence of shoulders and overruns (+1 for each occurance)	0	0	0	2	0	1	3	
Type of cutter (+1 if small and -1 if large)	1	1	1	1	1	1	6	
Enough access for cutters, bushing s and fixture elements(-1 if present and +1 if not present)	-1	-1	1	-1	-1	-1	-4	
Interrupted cuts for single ponit cutting tools (+1 for each occurance)	0	0	0	0	1	1	2	
Space for burr relief (-1 if present or +1 if not present)	-1	-1	-1	-1	-1	-1	-6	
							41	
Step-3. Miscellenous checklist								
Presence of finishing stock(+1 if less than 0.0 15 in)	0	0	1	0	1	0	2	
Can quanity of parts be reduced?(-1 for each quantity reduced)	-1	0	-1	-1	-1	0	-4	
Can the instances of tolerances be reduced?(-1 for each occurance reduced)	0	0	0	-1	0	-1	-2	(0 is ideal)
Is the material difficult to machine? (+1 if yes)	0	0	1	0	0	0	1	
Is the cutting tool standard? (-1 if yes and +1 if no)	-1	-1	1	-1	-1	-1	-4	
							-7	
								(0 is ideal)

18.2 DESIGN FOR MANUFACTURE (DFM) ANALYSIS FOR EDM

PART(ID or Description or features)	Trough Saddle	Trough Assembly		
Step-1(Part Details)				
Quantity	4	1		
Primary operation on the part	Support the trough at trough connection	To completely enclose the material being conveyed and the rotating parts		
Secondary operation on the part	1) Align and fasten the trough to the floor or an existing structures, 2)Accurately maintain trough height, 3) Permit easy removal of a trough end without disturbing the entire unit	1) Allow flow of material, 2) Provide cover to screw		
Instances of tolerances				
Step-2(DFM analysis)				
			Sum	
Number of secondary operations on the part (+1 for each operation)	3	3	6	
Shape of the machined part(+1 if taper, +1 if complex contour,-1 if rectangular)	2	2	4	
Can the part withstand forces of clamping? (-1 if yes and +1 if no)	-1	-1	-2	
Presence of secure holding and fixturing (-1 if yes and +1 if no)	-1	-1	-2	
Number of sharp corners(+1 for each occurance)	2	2	4	
Presence of stock dimensions(-2 if present)	-2	-2	-4	
Presence of undercuts (+1 for each occurance)	2	2	4	
Presence of parting lines or draft surface for clamping (+1 for each occurance)	1	1	2	
Presence of shoulders and overruns (+1 for each occurance)	2	2	4	
Type of cutter (+1 if small and -1 if large)	1	1	2	
Enough access for cutters, bushing s and fixture elements(-1 if present and +1 if not present)	-1	-1	-2	
Interrupted cuts for single ponit cutting tools (+1 for each occurance)	0	0	0	
Space for burr relief (-1 if present or +1 if not present)	-1	-1	-2	
			14	(0 is ideal)

Step-3. Miscellenous checklist				
Presence of finishing stock(+1 if less than 0.0 15 in)	0	0	0	
Can quanity of parts be reduced?(-1 for each quantity reduced)	-1	0	-1	
Can the instances of tolerances be reduced?(-1 for each occurance reduced)	-1	-1	-2	
Is the material difficult to machine? (+1 if yes)	0	0	0	
Is the cutting tool standard? (-1 if yes and +1 if no)	-1	-1	-2	
			-5	(0 is ideal)

19. DESIGN FOR ASSEMBLY

PART(ID or Description or features)	Trough Saddle	Trough Assembly		
	Step-1(Part Details)			
Quantity	4	1		
Primary operation on the part	Support the trough at trough connection	To completely enclose the material being conveyed and the rotating parts		
Secondary operation on the part	1) Align and fasten the trough to the floor or an existing structures, 2)Accurately maintain trough height, 3) Permit easy removal of a trough end without disturbing the entire unit	1) Allow flow of material, 2) Provide cover to screw		
Instances of tolerances				
	Step-2(DFM analysis)			
			Sum	
Number of secondary operations on the part (+1 for each operation)	3	3	6	
Shape of the machined part(+1 if taper, +1 if complex contour,-1 if rectangular)	2	2	4	
Can the part withstand forces of clamping? (-1 if yes and +1 if no)	-1	-1	-2	
Presence of secure holding and fixturing (-1 if yes and +1 if no)	-1	-1	-2	
Number of sharp corners(+1 for each occurance)	2	2	4	
Presence of stock dimensions(-2 if present)	-2	-2	-4	
Presence of undercuts (+1 for each occurance)	2	2	4	
Presence of parting lines or draft surface for clamping (+1 for each occurance)	1	1	2	
Presence of shoulders and overruns (+1 for each occurance)	2	2	4	
Type of cutter (+1 if small and -1 if large)	1	1	2	
Enough access for cutters, bushing s and fixture elements(-1 if present and +1 if not present)	-1	-1	-2	
Interrupted cuts for single point cutting tools (+1 for each occurance)	0	0	0	
Space for burr relief (-1 if present or +1 if not present)	-1	-1	-2	
			14	(0 is ideal)
	Step-3. Miscellenous checklist			
Presence of finishing stock(+1 if less than 0.0 15 in)	0	0	0	
Can quanity of parts be reduced?(-1 for each quantity reduced)	-1	0	-1	
Can the instances of tolerances be reduced?(-1 for each occurance reduced)	-1	-1	-2	
Is the material difficult to machine? (+1 if yes)	0	0	0	
Is the cutting tool standard? (-1 if yes and +1 if no)	-1	-1	-2	
			-5	(0 is ideal)

➢The cost of assembly is determined by the number of parts in the assembly and the ease with which the parts can be handled, inserted, and fastened.

➢Reduction in the number of parts can be achieved by elimination of parts.

<u>DFA Guidelines</u>:

The guidelines for design for assembly can be grouped into three classes: General, Handling, and Insertion.

- **Minimize the total number of parts**
- **Minimize the assembly surfaces**
- **Use subassemblies**
- **Mistake-proof the design and assembly**
- **Avoid separate fasteners or minimize fastener costs**
- **Minimize assembly directions**
- **Provide unobstructed access for parts and tools**
- **Maximize compliance in assembly**

19.1 DESIGN FOR ASSEMBLY (DFA) ANALYSIS

Part	Retrieve	Handle	Insert	# Parts (P)	Asssembly Index	Part Required (PR)
Description or ID	Small < 12 mm +1 < 2 mm +2 Tangled +2 Flexible +2	No End Sym +2 or +1 if obvious No Insert Sym +2 Heavy or Tools Needed +2	Alignment Difficult +2 Resistance +2 Fasten Obstructed +2 Hold in Place +2 Twist +1 Not Top Down +2 Screw +3	Enter number of part instances	Sum all assembly scores	Enter code (1,2,3)
Screw Subassembly						
Screw assembly (Flight+pipe)	0	1	0	5	6	3
End lugs	0	1	0	2	3	2
Coupling Bolts	0	1	0	4	5	2
Internal Collars	0	1	0	2	3	2
Housing						
Trough End	0	0	1	2	3	3
Trough Flange	0	0	1	6	7	3
Inlet- Hopper	0	0	0	1	1	3
Cover Fasteners	0	0	1	32	33	3
End Seals	0	2	1	10	13	2
Shaft and bearing	0	1	1	4	6	2
Coupling Bolts	0	1	0	6	7	3
Hangers						
Hanger Bearing	0	0	1	1	2	3
Fasteners	0	0	0	8	8	3
Drive Assembly						
Motor	0	2	1	1	4	3
High Speed Coupling	0	0	1	1	1	3
Low Speed Coupling	0	0	1	1	1	3
Fasteners	0	0	1	4	4	3
			Total	90	107	46

Assembly Index =	107	(0 Ideal)
Part Reduction = (#P - #PR)/#P =	0.4888	(0 Ideal)

Part required if:
1 relative motion required
2 different material required
3 assembly/disassembly impossible without it

20. DIMENSIONS AND TOLERANCE FOR SCREW CONVEYOR

DIMENSIONS:

➢Dimensions are used on engineering drawings to specify **size, location, and orientation** of features of components.

➢ Dimensions are as important as the geometric information that is conveyed by the drawing.

Each drawing must contain the following information:

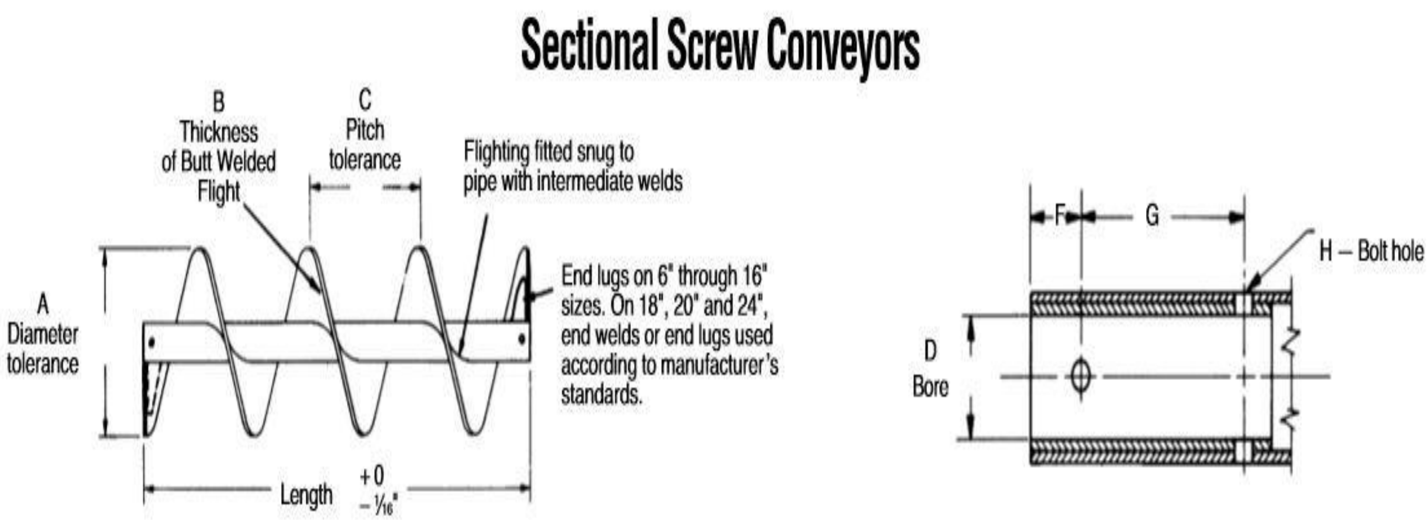
- The size of each feature
- The relative position between features
- The required precision (tolerance) of sizing and positioning features
- The type of material, and how it should be processed to obtain its expected mechanical properties.

TOLERANCE:

➢The tolerance on a part is the difference between the upper and lower allowable limits of a basic size dimension.

➢A tolerance is the acceptable variation in the dimension.

20.1 Screw Dimensions (CEMA Standard):

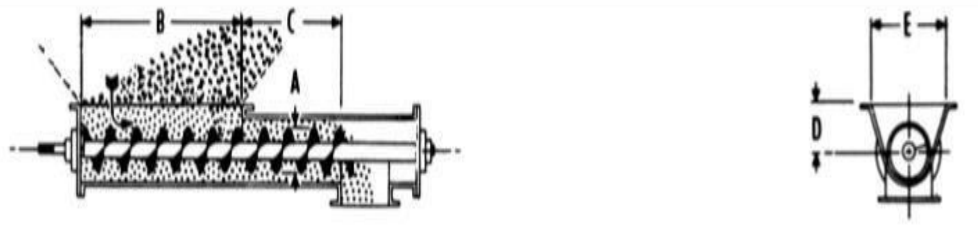


Listed Screw Diameter and Pitch	Cplng. Dia.	Size Designation	Pipe Size Schedule 40	Length Feet and Inches	A Diameter Tolerance		B Flight Thickness	C Pitch Tolerance		D Bushing Bore Inside Diameter		F Spacing 1st Bolt Hole	G Centers 2nd Bolt Hole	H Nominal Bolt Hole Size
					Plus	Minus		Plus	Minus	Minimum	Maximum			
24	$3\frac{7}{16}$	24S712	4	10	$\frac{3}{16}$	$\frac{3}{8}$	$\frac{3}{16}$	$\frac{7}{8}$	$\frac{1}{2}$	3.443	3.467	$1\frac{1}{2}$	4	$\frac{29}{32}$

20.2 Screw Feeder Dimension & Weight (CEMA Standard):

Feeder Type	Inlet Opening	Material Removal	Pitch	Feeder Screw Diameter	Extended Screw
SF2B	Long	Forepart Only of Inlet Opening	Short (⅔)	Uniform	None

SF2B



Feeder Diameter	Maximum Lump Size	Maximum Speed RPM	Capacity		B	C	D	E
			At One RPM	At Max RPM				
24	2½	30	224	6720	86	72	16 ½	40

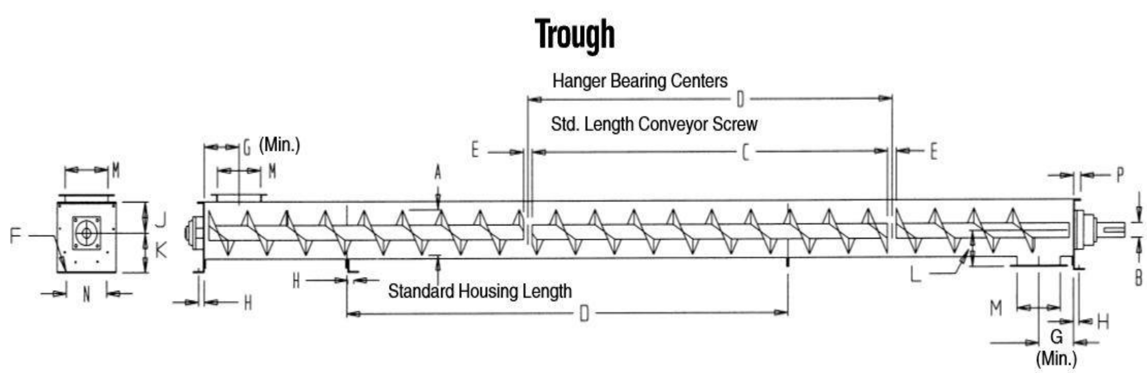
** All Dimensions are in inches

20.3 **Pipe Size Dimension and Weights:**

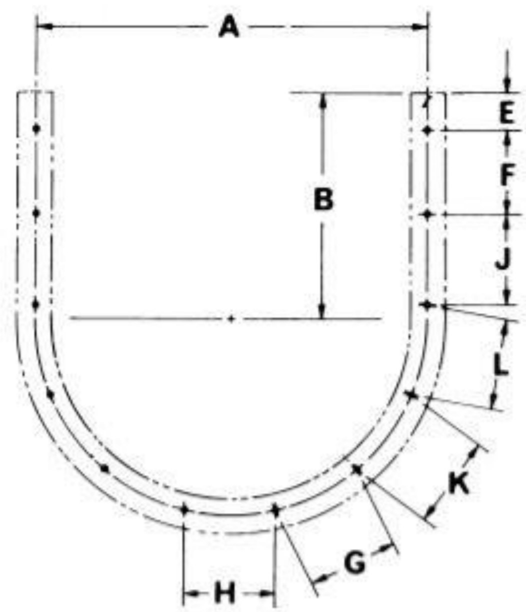
Nominal Pipe Size Inches	Outside Diameter Inches	I.P.S. Schedule	Wall Inches	Inside Diameter Inches	Wt./Ft. Pounds
4	4.5	5S	.083	4.334	3.915

20.4 **Trough Dimensions (CEMA Standard):**

A Screw Diameter	B Coupling Diameter	C Length (ft & in)	D	E	F	G (Min)	H	J	K	L	M	N	P	R
24	3 7/16	11-8	12	4	¾	17½	2¼	16½	18 1/8	15 3/8	25	20	2½	2½



20.4.1 Trough Type (CEMA Standard):



12 Bolts

Screw Diameter	Bolts		A	B	E	F	G	H	J	K	L
	No.	Dia									
24	12	$^{5}/_{8}$	28 ½	16 ½	$2^{25}/_{32}$	$6^{1}/_{8}$	$6^{5}/_{8}$	$6^{5}/_{8}$	$6^{5}/_{8}$	$6^{5}/_{8}$	$6^{5}/_{8}$

20.5 Tolerance Analysis:

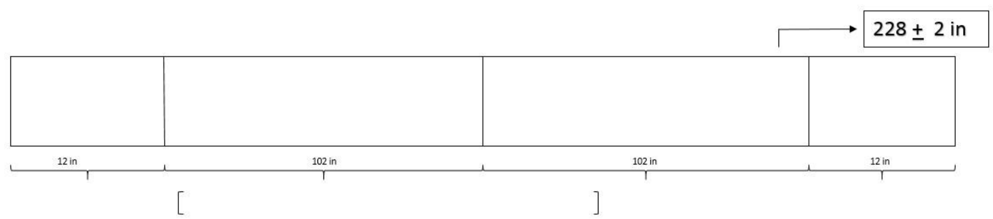
Screw Diameter A		Coupling Diameter B		Trough Length C (ft & in)		Hanger Bearing Distance D (only one hanger bearing)		Section Break E		Thickness of Base Plate F	
24		$3\,^{7}/_{16}$		11-8		0		4		$^{3}/_{4}$	
Plus	Minus	Plus	Minus	Plus	Minus	Plus	Minus	Plus	Minus	Plus	Minus
$^{3}/_{16}$	$^{3}/_{8}$	$^{1}/_{8}$	0	$^{3}/_{4}$	0	$^{1}/_{8}$	$^{3}/_{8}$	$^{1}/_{16}$	0	$^{1}/_{10}$	0

Pitch G		Hole Center Distance From End Plate H		Bearing Center Distance to Top J		Bearing Center Distance to Base K		Shaft Center Distance To Discharge L		Inlet, Outlet M	
16		$2\,^{1}/_{4}$		16 ½"		$18^{1}/_{8}$		$15^{3}/_{8}$"		25	
Plus	Minus	Plus	Minus	Plus	Minus	Plus	Minus	Plus	Minus	Plus	Minus
$^{3}/_{4}$	$^{1}/_{2}$	$^{1}/_{10}$	0	$^{3}/_{8}$	$^{1}/_{7}$	$^{3}/_{8}$	$^{1}/_{7}$	$^{3}/_{16}$	$^{3}/_{8}$	$^{3}/_{16}$	$^{3}/_{8}$

Trough Width E		Top Cover Extension		Screw Clearance At Trough End	
16 ½		2		2	
Plus	Minus	Plus	Minus	Plus	Minus
$3/16$	$3/8$	$3/16$	0	1/10	0

20.6 STACK UP TOLERANCE

STACK UP TOLERANCE



Lmax = 230 - ((3/8 + 3/8) * 12) + (3/8 *108) + (3/8 *12) = 176 – (7/8 * 8 *16) = 92 in

Lmin = 226 - ((1/8 + 3/16) * 12) + ((3/4 + 1/16 + 1/8) *102) + ((3/16 + 3/16 + 1/8)*102) = 78.17 in

Tolerance Range : Lmax – Lmin

= 92- 78.17

= 1.15Ft

Overall review of DFM

The **Preliminary Design review** illustrates about Manufacturing processes that could be used in the processing of screw conveyor system using PRIMA chart. Materials were selected as per Ashby chart and ASME standards. As per the standards and norms provided the suitable material selected for Screw conveyor system was **SS316**. This material was selected based on corrosion, abrasion and other related problems faced by Martin Sprocket. This material covers wide range of mechanical and physical properties which ensures smooth running of this system. SS316 was selected among other materials from weighted decision matrix.

Design for Manufacturing (DFM) methodology was used to select the best process among various other process using PRIMA chart. From this we inferred that machining and bending process are more feasible and economical as compared to EDM.

Design for Assembly (DFA) analysis was done to reduce time and cost associated with these processes during the assembly of all these components.

Finally, the **Tolerances and Dimensioning** were done using GD&T knowledge and CEMA standards.

21. RELIABILITY ANALYSIS

We have calculated reliability through Weibull Distribution Chart, in which a graph is plotted between Cumulative Probability of Failures with respect to Time. Based on the graph, the scale factor and shape factor were calculated. Using the formula:

$$R\{t\}= e^{-\left(t/\theta\right)^{m}}$$

We calculated the reliability of the system, which was 54.2% at 11680 hours.

Reliability Analysis for Screw Conveyor

Total No. of Components = 20

Expected life of Conveyor = 4 years (Life of conveyor screw)

Let's assume conveyor is used for 8 hours daily

∴ Screw conveyor will be running for $= 4 \times 365 \times 8$

$= 11680$ ~~years~~ hrs

① For reliability purpose all compo will be tested for <u>20000hrs.</u> in order to gain confidence

② from weibull distribution ⇒ following eqn will be used to calculate Reliability

$$R(t) = 1 - F(t) = e^{-(t/\theta)^m}$$

"t" = Time at which we have to calculate reliability of system.

Here $t = 11680$ hr.

θ = Scale factor ; get from graph

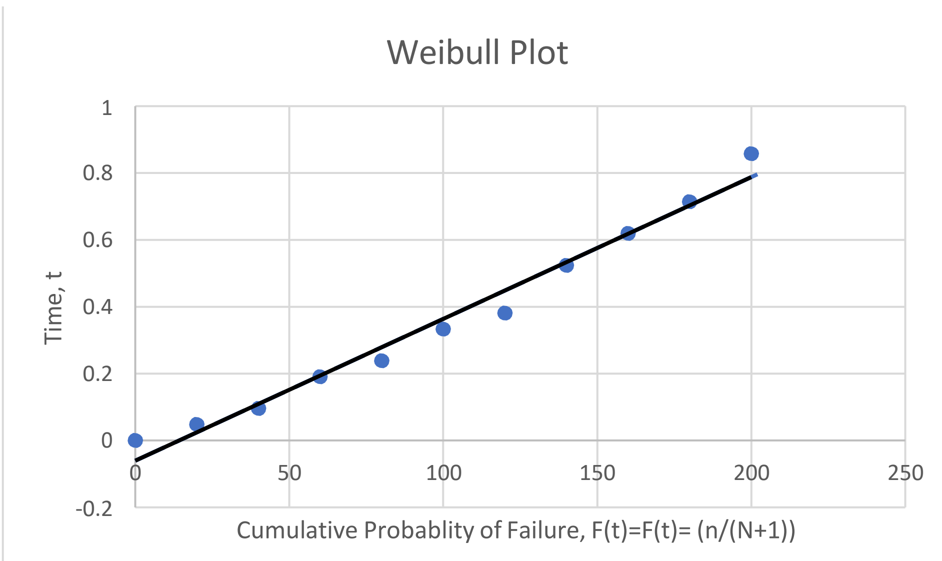
m = Shape factor/parameter = Slope of the line

Weibull distribution graph for Reliability analysis

Reliability Analysis

		Total Number of Hrs.
Total Components (N)	20	
Life cycle of screw conveyor	4 Years	35040
Operating time of screw conveyor	8 Hours	11680
Total Testing Time		20000

Time **(t)**, in number of hours,10^2	Cumulative tota number of failures, **n**	Cumulative total number of failures, **F(t)**= (n/(N+1))	Reliability **R(t)**=1-F(t)
0	0	0	1
20	1	0.047619048	0.952380952
40	2	0.095238095	0.904761905
60	4	0.19047619	0.80952381
80	5	0.238095238	0.761904762
100	7	0.333333333	0.666666667
120	8	0.380952381	0.619047619
140	11	0.523809524	0.476190476
160	13	0.619047619	0.380952381
180	15	0.714285714	0.285714286
200	18	0.857142857	0.142857143



X-Axis-Time, t
Y-Axis- Cumulative
Probability of Failure, F(t)

from Graph consider 2 datapoints:
(20, 0.04761), (180, 0.7143)

$$\therefore m = \frac{\ln\left(\ln\left(\frac{1}{1-0.7143}\right)\right) - \ln\left(\ln\left(\frac{1}{1-0.04761}\right)\right)}{\ln(80) - \ln(20)}$$

$$= \frac{3.2458}{2.19722}$$

$$\Rightarrow \boxed{m = 1.477}$$

In order to calculate scale factor (θ)
when $t = \theta$

$$R(t) = e^{-(t/\theta)^m}$$

$$= e^{-(1)^m} = e^{-1} = 0.3679$$

$$F(t) = 1 - R(t) = 0 - 0.3679 = 0.632$$

from graph at $F(t) = 0.632$

time $= 16273.68$ hrs

Reliability of system

$$R(t) = e^{-\left(\frac{11640}{16273.68}\right)^{1.477}} = 0.542$$

$$\Rightarrow \boxed{R(t) = 54.2\%}$$ (Reliability of system)

22. COST ANALYSIS

- The cost analysis requires a detailed report of all the components involved including brought-out items, manufactured products (in-house), labor cost, transportation, erection, material handling, assembly, testing, indirect, etc. All these details help us evaluate time required to complete the operation and detailed analysis of parts produced. At the outset of developing the cost estimate, the following information should be available:
  - **Detailed drawings (CAD files)**
  - **Bill of Material (BOM)**
  - **Production Schedule**
  - **Total quantity of products**
- The steps used to determine the manufacturing costs are:
  - **Material Costs**
  - **Preparation of operations route sheet**
  - **Performance of each operations conducted**
  - **Conversion of time to cost**
- We initially determine items that were produced in-house and those that were brought out items. Then we determined the cost of quality using parameters.
  - **Internal failure**
  - **External failure**
  - **Testing cost**
  - **Prevention of defects**
- Along with, the knowledge of textbook (Engineering Design, 5th Edition by Linda Schmidt), engineering and industrial experience following costs were determined:
  - **Manufacturing cost**
  - **Cost of Brought-out items**
  - **Activity Based costing**
- With all the data and cost analysis we finally generated the **Product Profit Model** to determine the profit percentage.

22.1 BILL OF MATERIAL

Sr. No.	Part	Material	Quantity
1	End Bearing	SKF/ EQUIVALENT MAKE	2
2	Bushing	SS316	[No Title]
3	Hanger Bearing	SS316	1
4	Screw	SS316	1
5	Hollow pipe (center)	SS316	2
6	Support Bracket	MS	3
7	Fasteners	SS316	150
8	Trough Cover (One end)	SS316	2
9	Trough	SS316	1
10	End Shaft Seals	RUBBER	2
11	Motor (5HP)	ABB/SIEMENS/EQUIVALENT MAKE	1
12	Reducer	SIEMENS/BONFIGLIOLI/CGL/ EQUIVALENT MAKE	1
13	High speed coupling	CAST STEEL	1
14	Inner Shaft	SS316	3
15	Hopper (Inlet)	SS316	1
16	Outlet	SS316	1
17	End Flange	SS316	2
18	End Plates	SS316	2
19	Hanger Bearing Bracket	SS316	1
20	Trough Cover with Inlet cutout	SS316	1
21	Bearing Spacer	SS316	2
	Total		**182**

22.2 MANUFACTURING COSTS

1. TROUGH		**MATERIAL: SS316**
Total No. of product units, n	1	
Unit Cost of Disposal, C_W	20.32	$
Factory Overhead, O_{HF}	22.62	$
Material Cost, C_M	253.44	$
Labor Cost, C_L	35	$
Cost of Ownership, C_E	42.35	$
Cost of Design, C_V	60	$
Manufacturer dependent lifecycle cost, C_{WR}	20	$
Warranty Cost, C_Q	20	$
Corporate Overhead, O_{HC}	30	$
Manufacturing Cost, C_{TM}	**$C_{TM} = n\,(C_M+C_L+C_E+C_W+O_{HF}) + C_V+C_{WR}+C_Q+O_{HC}$**	
C_{TM}	**504.73**	$

2. SCREW		MATERIAL: SS316
Total No. of product units, n	1	
Unit Cost of Disposal, C_W	76.53	$
Factory Overhead, O_{HF}	50	$
Material Cost, C_M	505.42	$
Labor Cost, C_L	100	$
Cost of Ownership, C_E	50	$
Cost of Design, C_V	80	$
Manufacturer dependent lifecycle cost, C_{WR}	50	$
Warranty Cost, C_Q	20	$
Corporate Overhead, O_{HC}	30	$
Manufacturing Cost, C_{TM}	**$C_{TM} = n\ (C_M+C_L+C_E+C_W+O_{HF}) + C_V+C_{WR}+C_Q+O_{HC}$**	
C_{TM}	**961.95**	**$**

3. HOLLOW PIPE		MATERIAL: SS316
Total No. of product units, n	1	
Unit Cost of Disposal, C_W	20	$
Factory Overhead, O_{HF}	25	$
Material Cost, C_M	1508.23	$
Labor Cost, C_L	50	$
Cost of Ownership, C_E	30	$
Cost of Design, C_V	50	$
Manufacturer dependent lifecycle cost, C_{WR}	30	$
Warranty Cost, C_Q	20	$
Corporate Overhead, O_{HC}	30	$
Manufacturing Cost, C_{TM}	**$C_{TM} = n\ (C_M+C_L+C_E+C_W+O_{HF}) + C_V+C_{WR}+C_Q+O_{HC}$**	
C_{TM}	**1,763.23**	**$**

4. END PLATES		MATERIAL: SS316
Total No. of product units, n	2	
Unit Cost of Disposal, C_W	10	$
Factory Overhead, O_{HF}	15	$
Material Cost, C_M	54.32	$
Labor Cost, C_L	30	$
Cost of Ownership, C_E	20	$
Cost of Design, C_V	50	$
Manufacturer dependent lifecycle cost, C_{WR}	50	$
Warranty Cost, C_Q	20	$
Corporate Overhead, O_{HC}	30	$
Manufacturing Cost, C_{TM}	**$C_{TM} = n\ (C_M+C_L+C_E+C_W+O_{HF}) + C_V+C_{WR}+C_Q+O_{HC}$**	
C_{TM}	**408.64**	**$**

5. HANGER BEARING BRACKET		MATERIAL: SS316
Total No. of product units, n	1	
Unit Cost of Disposal, C_W	10	$
Factory Overhead, O_{HF}	15	$
Material Cost, C_M	40	$
Labor Cost, C_L	20	$
Cost of Ownership, C_E	15	$
Cost of Design, C_V	40	$
Manufacturer dependent lifecycle cost, C_{WR}	30	$
Warranty Cost, C_Q	20	$
Corporate Overhead, O_{HC}	30	$
Manufacturing Cost, C_{TM}	**$C_{TM} = n\,(C_M+C_L+C_E+C_W+O_{HF}) + C_V+C_{WR}+C_Q+O_{HC}$**	
C_{TM}	**220**	**$**

6. SHAFT		MATERIAL: SS316
Total No. of product units, n	3	
Unit Cost of Disposal, C_W	10	$
Factory Overhead, O_{HF}	17	$
Material Cost, C_M	98.67	$
Labor Cost, C_L	20	$
Cost of Ownership, C_E	11	$
Cost of Design, C_V	35	$
Manufacturer dependent lifecycle cost, C_{WR}	32	$
Warranty Cost, C_Q	20	$
Corporate Overhead, O_{HC}	30	$
Manufacturing Cost, C_{TM}	**$C_{TM} = n\,(C_M+C_L+C_E+C_W+O_{HF}) + C_V+C_{WR}+C_Q+O_{HC}$**	
C_{TM}	**587.01**	**$**

7. SUPPORT BRACKET		MATERIAL: MS
Total No. of product units, n	3	
Unit Cost of Disposal, C_W	12.5	$
Factory Overhead, O_{HF}	27.3	$
Material Cost, C_M	87.7	$
Labor Cost, C_L	15	$
Cost of Ownership, C_E	15	$
Cost of Design, C_V	20	$
Manufacturer dependent lifecycle cost, C_{WR}	20	$
Warranty Cost, C_Q	20	$
Corporate Overhead, O_{HC}	30	$
Manufacturing Cost, C_{TM}	**$C_{TM} = n\,(C_M+C_L+C_E+C_W+O_{HF}) + C_V+C_{WR}+C_Q+O_{HC}$**	
C_{TM}	**562.5**	**$**

8. BUSHING		**MATERIAL: SS316**
Total No. of product units, n	2	
Unit Cost of Disposal, C_W	12	$
Factory Overhead, O_{HF}	23.5	$
Material Cost, C_M	52.36	$
Labor Cost, C_L	20	$
Cost of Ownership, C_E	15	$
Cost of Design, C_V	30	$
Manufacturer dependent lifecycle cost, C_{WR}	20	$
Warranty Cost, C_Q	20	$
Corporate Overhead, O_{HC}	30	$
Manufacturing Cost, C_{TM}	$C_{TM} = n\,(C_M+C_L+C_E+C_W+O_{HF}) + C_V+C_{WR}+C_Q+O_{HC}$	
C_{TM}	**345.72**	**$**

9. TROUGH COVER		**MATERIAL: SS316**
Total No. of product units, n	1	
Unit Cost of Disposal, C_W	23	$
Factory Overhead, O_{HF}	30	$
Material Cost, C_M	78.62	$
Labor Cost, C_L	50	$
Cost of Ownership, C_E	24	$
Cost of Design, C_V	30	$
Manufacturer dependent lifecycle cost, C_{WR}	20	$
Warranty Cost, C_Q	20	$
Corporate Overhead, O_{HC}	30	$
Manufacturing Cost, C_{TM}	$C_{TM} = n\,(C_M+C_L+C_E+C_W+O_{HF}) + C_V+C_{WR}+C_Q+O_{HC}$	
C_{TM}	**305.62**	**$**

10. HOPPER		**MATERIAL: SS316**
Total No. of product units, n	1	
Unit Cost of Disposal, C_W	15	$
Factory Overhead, O_{HF}	25	$
Material Cost, C_M	65.69	$
Labor Cost, C_L	30	$
Cost of Ownership, C_E	17	$
Cost of Design, C_V	40	$
Manufacturer dependent lifecycle cost, C_{WR}	20	$
Warranty Cost, C_Q	20	$
Corporate Overhead, O_{HC}	30	$
Manufacturing Cost, C_{TM}	$C_{TM} = n\,(C_M+C_L+C_E+C_W+O_{HF}) + C_V+C_{WR}+C_Q+O_{HC}$	
C_{TM}	**262.69**	**$**

11. OUTLET		MATERIAL: SS316
Total No. of product units, n	1	
Unit Cost of Disposal, C_W	25	$
Factory Overhead, O_{HF}	30	$
Material Cost, C_M	56.2	$
Labor Cost, C_L	20	$
Cost of Ownership, C_E	26	$
Cost of Design, C_V	31	$
Manufacturer dependent lifecycle cost, C_{WR}	35	$
Warranty Cost, C_Q	20	$
Corporate Overhead, O_{HC}	30	$
Manufacturing Cost, C_{TM}	**$C_{TM} = n\,(C_M+C_L+C_E+C_W+O_{HF}) + C_V+C_{WR}+C_Q+O_{HC}$**	
C_{TM}	**273.2**	**$**

12. END PLATES		MATERIAL: SS316
Total No. of product units, n	2	
Unit Cost of Disposal, C_W	15	$
Factory Overhead, O_{HF}	35	$
Material Cost, C_M	83.5	$
Labor Cost, C_L	30	$
Cost of Ownership, C_E	26	$
Cost of Design, C_V	31	$
Manufacturer dependent lifecycle cost, C_{WR}	15	$
Warranty Cost, C_Q	20	$
Corporate Overhead, O_{HC}	30	$
Manufacturing Cost, C_{TM}	**$C_{TM} = n\,(C_M+C_L+C_E+C_W+O_{HF}) + C_V+C_{WR}+C_Q+O_{HC}$**	
C_{TM}	**475**	**$**

13. BEARING SPACER		MATERIAL: SS316
Total No. of product units, n	2	
Unit Cost of Disposal, C_W	23	$
Factory Overhead, O_{HF}	30	$
Material Cost, C_M	69.7	$
Labor Cost, C_L	30	$
Cost of Ownership, C_E	42	$
Cost of Design, C_V	30	$
Manufacturer dependent lifecycle cost, C_{WR}	34	$
Warranty Cost, C_Q	20	$
Corporate Overhead, O_{HC}	30	$
Manufacturing Cost, C_{TM}	**$C_{TM} = n\,(C_M+C_L+C_E+C_W+O_{HF}) + C_V+C_{WR}+C_Q+O_{HC}$**	
C_{TM}	**503.4**	**$**

OVERALL COST, ENGINEERING (DESIGN AND MANUFACTURE) = $ 7173.69

Sr. No.	ITEMS	QUANTITY	UNIT COST ($)	TOTAL COST ($)
1	MOTOR	1	400	400
2	REDUCER	1	800	800
3	HIGH SPEED COUPLING	1	100	100
4	FASTNERS	150	1.45	217.5
5	SEALS	2	25	50
6	HANGER BEARING	1	47.08	47.08
7	END BEARINGS	2	95	190
8	BUSHING	2	80	160
	TOTAL			**1,964.58**

ACTIVITY BASED COSTING:

Sr. No.	ACTIVITIES	COST ($)
1	ENGINEERING (DESIGN & MANUFACTURE)	**7173.69**
2	BROUGHT-OUT ITEMS	**1964.58**
3	INDIRECT COSTS	**500**
4	R&D COSTS FOR FUTURE PRODUCTION	**700**
5	PRODUCTION SETUP	**1000**
6	MATERIAL HANDLING	**200**
7	COST OF ASSEMBLY	**1000**
8	COST OF TESTING	**500**
9	INSPECTION	**250**
10	TRANSPORTATION	**1000**
11	COST OF ERECTION	**700**
	TOTAL	**14,988.27**

22.3 PRODUCT PROFIT MODEL

Net Sale = (number of units sold) x (sales price)
Number of units sold = 1
Sales Price = $ 20,000
Net Sale = $ 20,000
Total Manufacturing cost = $ 14,988.27
Profit:
Profit = Net sale – Total Manufacturing cost
= 20000 – 14988.27
= $ 5,011.73
Profit percentage = (Profit / Total Manufacturing cost) x 100
= (5011.73 / 14988.27) x 100
= 33.44 %

23. **ERGONOMICS, SAFETY ANALYSIS**

- Recognize and Identify the potential hazards and design the product so that it doesn't affect the functioning of the screw conveyor.
- Make the prototypes and test the prototypes of the product to check and reveal any hazards overlooked in the initial design
- Design the product so that it is safe to use and easier to use than use unsafely.
- Design a user-friendly product. Realize that humans will do foolish things, allow it in your design. More product problem will arise with improper product use than from product defects.
- There exists a close relation between a safe design and a good ergonomic design.

For Example:

- Avoid sharp edges and corners.
- Arrange the controls so that operators do not have to move to manipulate them.
- Point-of-operation of guards should not interfere with the operator's movement.
- We need to make sure that fingers are not pinched in between levers or in between the screw.
- Design a product to avoid carpel tunnel syndrome. This means awkward position of hand, wrist and arm and repetitive motions, heavy weights and vibrations for a longer time should be avoided.
- Provide enough an adequate access for maintenance and repair without pinch or puncture hazards to the repairer.
- Minimize the use of flammable materials which might include packaging materials.
- Surface Finishing or paint materials should be chosen to comply with EPA and OSHA regulations as they might be toxic to the user or when recycled, discarded or burned.
- Provide electrical interlocks so that high-voltage circuits will not be energized unless guard comes to proper position to keep the electric products grounded to avoid shocks.

FIG: Shows various warning label as CEMA 352-2012

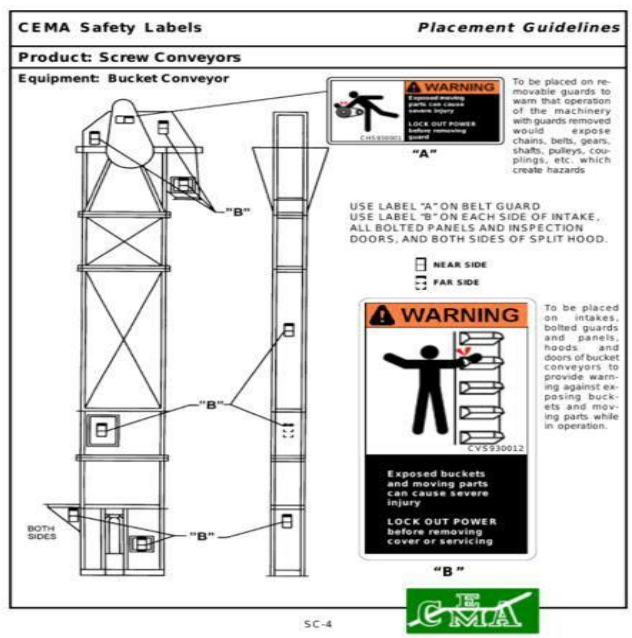


FIG: Shows various warning label placement guidelines as CEMA 352-2012

FIG: Shows some general Screw Conveyor Safety Labels as CEMA

24. Failure Modes and Effects Analysis (FMEA)

- Failure mode and effects analysis (FMEA) is a team-based methodology for identifying potential problems with new or existing designs.
- It was first used to identify and correct safety hazards. FMEA identifies the mode of failure of every component in a system and determines the effect on the system of each potential failure. By failure we mean inability to meet a customer's requirements as opposed to actual catastrophic material breakage or failure.
- Three factors are considered in developing a FMEA:
    1. The severity of a failure. Many organizations require that potential failures with a 9 or 10 rating require immediate redesign.
    2. The probability of occurrence of the failure. The probabilities given are very approximate and depend on the nature of the failure, the robustness of the design, and the level of quality developed in manufacturing.
    3. The likelihood of detecting the failure in either design or manufacturing, before the product is used by the customer. Clearly, the rating for this factor depends on the quality review systems in place in the organization.

Rating for Severity of Failure

Rating	Severity Description
1	The effect is not noticed by the customer
2	Very slight effect noticed by customer; does not annoy or inconvenience customer
3	Slight effect that causes customers annoyance, but they do not seek service
4	Slight effect, customer may return product for service
5	Moderate effect, customer requires immediate service
6	Significant effect, causes customer dissatisfaction; may violate a regulation or design code
7	Major effect, system may not be operable; elicits customer complaint; may cause injury
8	Extreme effect, system is inoperable and a safety problem; may cause severe injury
9	Critical effect, complete system shutdown; safety risk
10	Hazardous; failure occurs without warning; life-threatening

Rating for Occurrence of Failure

Rating	Approx. Probability of Failure	Description of Occurrence
1	$\leq 1 \times 10^{-6}$	Extremely remote
2	1×10^{-5}	Remote, very unlikely
3	1×10^{-5}	Very slight chance of occurrence
4	4×10^{-4}	Slight chance of occurrence
5	2×10^{-3}	Occasional occurrence
6	1×10^{-2}	Moderate occurrence
7	4×10^{-2}	Frequent occurrence
8	0.20	High occurrence
9	0.33	Very high occurrence
10	≥ 0.50	Extremely high occurrence

Rating for Detection of Failure

Rating	Description of Detection
1	Almost certain to detect
2	Very high chance of detection
3	High chance of detection
4	Moderately high chance of detection
5	Medium chance of detection
6	Low chance of detection
7	Slight chance of detection
8	Remote chance of detection
9	Very remote chance of detection
10	No chance of detection; no inspection

Usual practice is to combine the rating for the three factors into a *risk priority number* (RPN).

$$\text{RPN} = (\text{severity of failure}) \times (\text{occurrence of failure}) \times (\text{detection rating}) \quad (14.42)$$

24.1 FMEA Chart

1. The design is reviewed to determine the interrelations of assemblies and the interrelations of the components of each subassembly. Identify how each component might fail to perform its required function. A complete list of the components in each assembly and the function of each component is prepared. For each function ask, What if this function fails to take place? To further sharpen the point ask:
   - What if the function fails to occur at the right time?
   - What if the function fails to occur in the proper sequence?
   - What if this function fails to occur completely?
2. Now look more broadly, and ask what are the consequences to the system of each failure identified in step 1. It may be difficult to answer this question in systems for which the subsystems are not independent. A frequent cause of hazardous failures is that an apparently innocuous failure in one subsystem overloads another subsystem in an unexpected way.
3. For each of the functions, list the potential failure modes (see Sec. 14.7). There are likely to be several potential failure modes associated with each of the functions.
4. For each of the failure modes identified in step 3, describe the consequences or effects of the failure. First list the local effect on the particular component; then extend the effects analysis to the entire subassembly and to the total system.
5. Using the severity of failure table (Table 14.12), enter the numerical value. This is best done as a team using consensus decision methods.
6. Identify the possible causes of the failure mode. Try to determine the root cause by using a why-why diagram and interrelationship digraph. (see Sec. 4.7).
7. Using the occurrence of failure table (Table 14.13), enter a value for the occurrence of the cause of each failure.
8. Determine how the potential failure will be detected. This might be a design checklist, a specific design calculation, a visual quality inspection, or a nondestructive inspection.
9. Using Table 14.14, enter a rating that reflects the ability to detect the cause of failure identified in step 8.
10. Calculate the risk priority number (RPN) from Eq. (14.42). Those potential failures with the highest RPN values will be given priority action. In making decisions about where to deploy the resources, also consider Fig. 14.9.
11. For each potential failure, determine the corrective action to remove a potential design, manufacturing, or operational failure. One of the actions might be "no action required." Assign ownership for the removal of each potential failure.

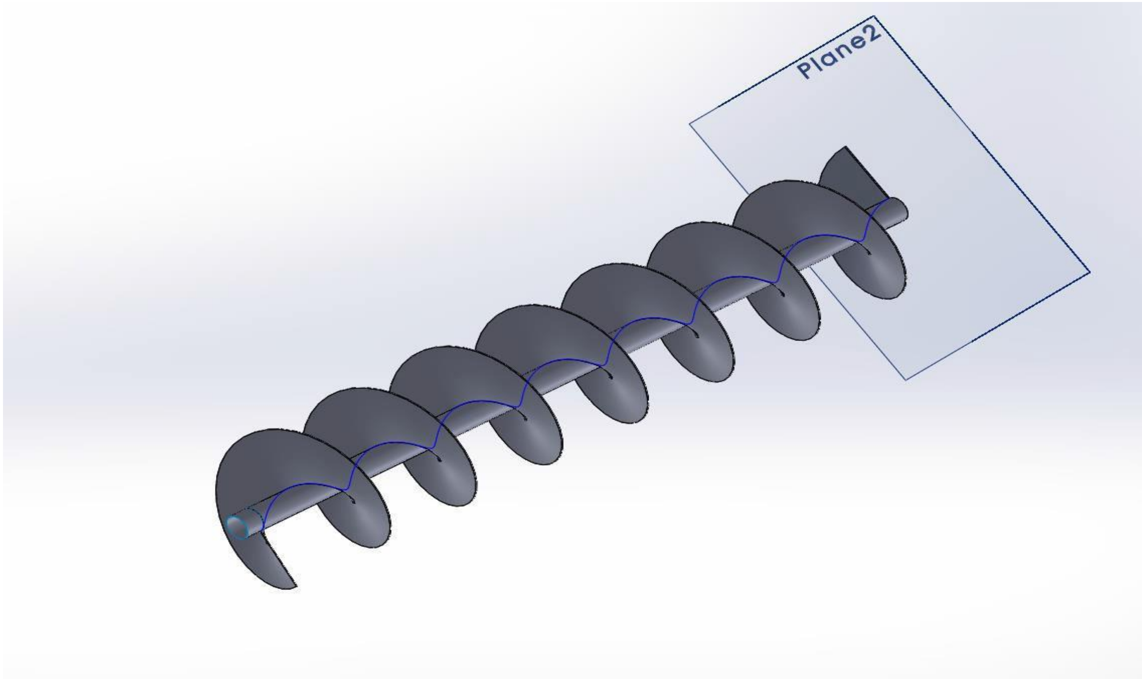
SR.NO	PART/PROCESS NAME	PART/PROCESS FUNCTION	FAILURE MODE	EFFECTS OF FAILURE	CAUSES OF FAILURE	O	S	D	RPN	RECOMMENDED CORRECTIVE ACTION
1.	HANGER BEARING	To support the screw	Hanger bearing Failure	Screw Damage	Excessive bearing wear	4	5	7	140	Check CEMA 350 book to check bearing for the required speed and trough loading
					Inappropriate material	4	6	7	168	Check for correct Bearing Material
					Incorrect Alignment	4	6	6	144	Realign the trough lining and hanger lining.
					Improper Speed and trough loading	3	5	7	105	Replace bearing hanger
				Conveyor Body Damage	Incorrect Alignment	5	8	3	120	Realign the required part
					Inappropriate material	3	5	8	120	Check for correct material
					Wrong design	2	7	5	70	redesign
					Excessive bearing wear	4	5	7	140	Check CEMA 350 book to check bearing for the required speed and trough loading
					Improper speed and trough loading	3	5	7	105	Replace hanger bearing
			Clamp failure	Screw Damage	Incorrect Alignment	5	7	5	175	Realign the required part
					Inappropriate material	3	5	8	120	Check for correct Material
					Wrong design	2	7	5	70	
					Excessive wear	4	5	7	140	Check CEMA 350 book to check bearing for the required speed and trough loading
					Improper speed and trough loading	3	5	7	105	Replace the hanger bearing
2.	FLIGHT	To transfer material from end to end	Accelerated flight wear	Loss in efficiency	Flight thickness too light	6	6	7	252	Increase flight thickness. Use abrasion resistant materials
					RPM too high or trough loading too high	2	6	6	72	Reduce the speed
3.	TROUGH	Handle the material	Premature Failure	Loss of Material	Less Thickness	4	7	5	140	Increase trough thickness. Use abrasion resistant material
					Screw bent	5	8	3	120	Replace screw
					Screw deflection	5	8	3	120	Determine proper pipe
4.	HANGER BEARING SHAFT	Reducer end to screw pipe to other part	Breakage of shaft or bending	Bearing damage	Insufficient no of coupling bolts	4	7	3	84	Increase number of bolts
					Conveyor subjected to frequent Start and Stop operation	3	8	4	96	Cease frequent stop/start
					Improper speed and trough loading	3	5	6	90	Replace the bearing shaft
				Loss of efficiency	Insufficient no of coupling bolts	3	7	4	84	Increase the numbers of bolt
					Conveyor subjected to frequent Start and Stop operation	2	8	4	64	Cease frequent stop/start
					Improper speed and trough loading	3	5	6	90	Replace the bearing
			Fatigue due to misalignment	Loss of efficiency	Insufficient no of coupling bolts	3	7	3	63	Increase the number of bolts
					Conveyor subjected to frequent Start and Stop operation	3	7	5	105	Cease frequent stop/start
					Improper speed and trough loading	3	5	6	90	Replace the bearing

5.	DRIVE BELT	Power transmission from motor to the shaft	Breakage of drive shaft	Movement stops	Excessive Torque	7	8	5	280	Consult CEMA 350 book to determine appropriate torque rating
6.	ELECTRIC MOTOR	To run the conveyor	Overloading	No operation	Upset loading	6	6	5	180	Empty trough, control feed and operate under design specification
					Undersized motor	3	5	6	90	Check for proper horsepower of the motor
7.	TROUGH END BEARING	Frictionless relative motion	Bearing Failure	Shaft wear	Bearing contamination	2	3	5	30	Upgrade or replace the seal
					Improper shaft alignment	2	3	6	36	Check screw straightness
					Insufficient lubrication	2	3	6	36	Lubricate it
		Support the shaft	Bearing Failure	Shaft wear	Bearing contamination	2	3	5	30	Upgrade or replace the seal
					Improper shaft alignment	2	3	6	36	Check the screw straightness
					Insufficient lubrication	2	3	6	36	Lubricate it
8.	END SHAFT	Support Screw ends	Coupling shaft breakage	Loss of efficiency	Insufficient no of coupling bolts	6	7	5	210	Increase the number of bolts
					Conveyor subjected to frequent Start and Stop operation	5	8	5	200	Cease frequent start/stop
					Improper speed and trough loading	3	7	5	105	Reduce the input speed and loading
				Coupling damage	Excessive Torque	3	8	4	96	increase number of coupling bolts
					Shaft wear	7	6	5	210	Increase the bearing capacity of the shaft
					Misalignment	6	6	4	144	Correct the alignment issue
				Bearing damage	Insufficient no of coupling bolts	6	7	5	210	Increase the number of bolts
					Conveyor subjected to frequent Start and Stop operation	5	8	5	200	Cease frequent start/stop
					Improper speed and trough loading	3	7	5	105	Reduce the speed and loading
		Transmit power from reducer to pipe	Coupling shaft breakage	Loss of efficiency	Insufficient no of coupling bolts	6	7	5	210	Increase the number of bolts
					Conveyor subjected to frequent Start and Stop operation	5	8	5	200	Cease frequent start/stop
					Improper speed and trough loading	3	7	5	105	Reduce the speed and loading
				Coupling damage	Excessive Torque	3	7	4	84	Increase the number of bolts
					Shaft wear	3	5	4	60	Cease frequent stop/start
					Misalignment	6	6	4	144	Correct the alignment issue
				Bearing damage	Insufficient no of coupling bolts	6	7	5	210	Increase the number of bolts
					Conveyor subjected to frequent Start and Stop operation	5	8	5	200	Cease frequent start/stop
					Improper speed and trough loading	3	7	5	105	Reduce the speed and trough loading

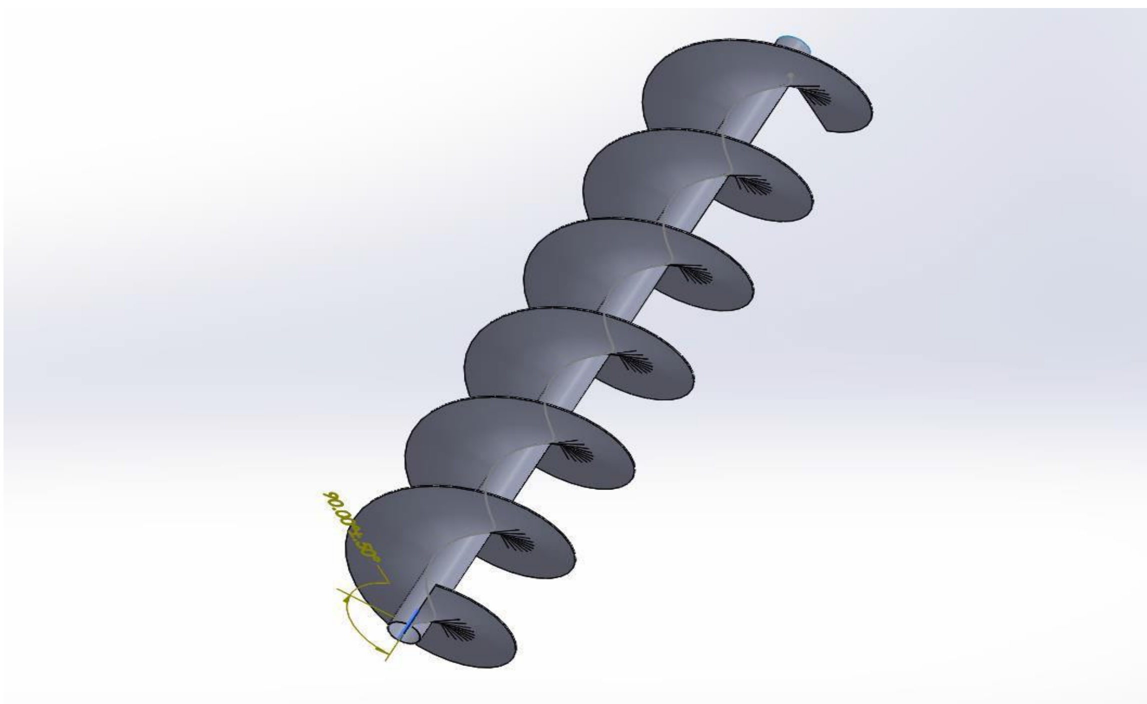
- Encircled RPNs are critical design parameters.
- In our design we have considered RPN>125 as a critical concern, which will be given top priority during concern resolution.

25. 3D PARTS AND ASSEMBLY

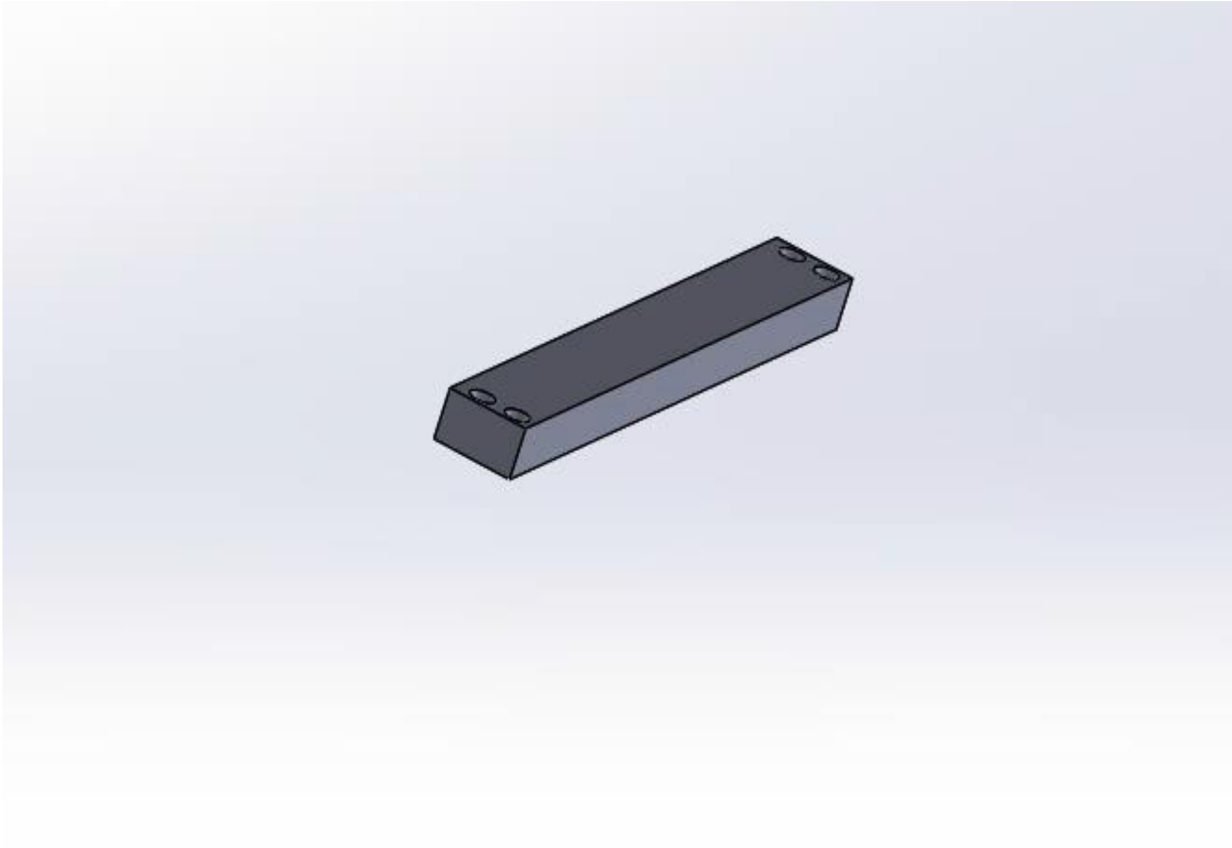
25.1 3D MODEL: SCREW- I



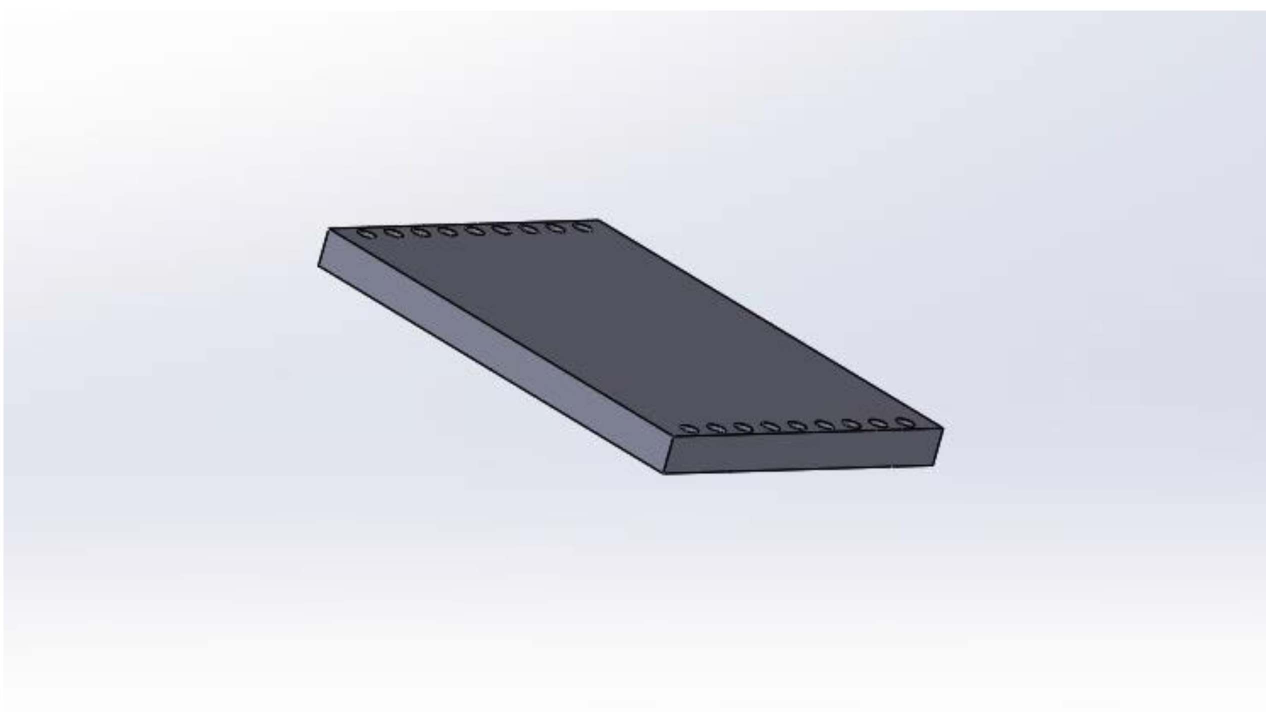
25.2 3D MODEL: SCREW-II



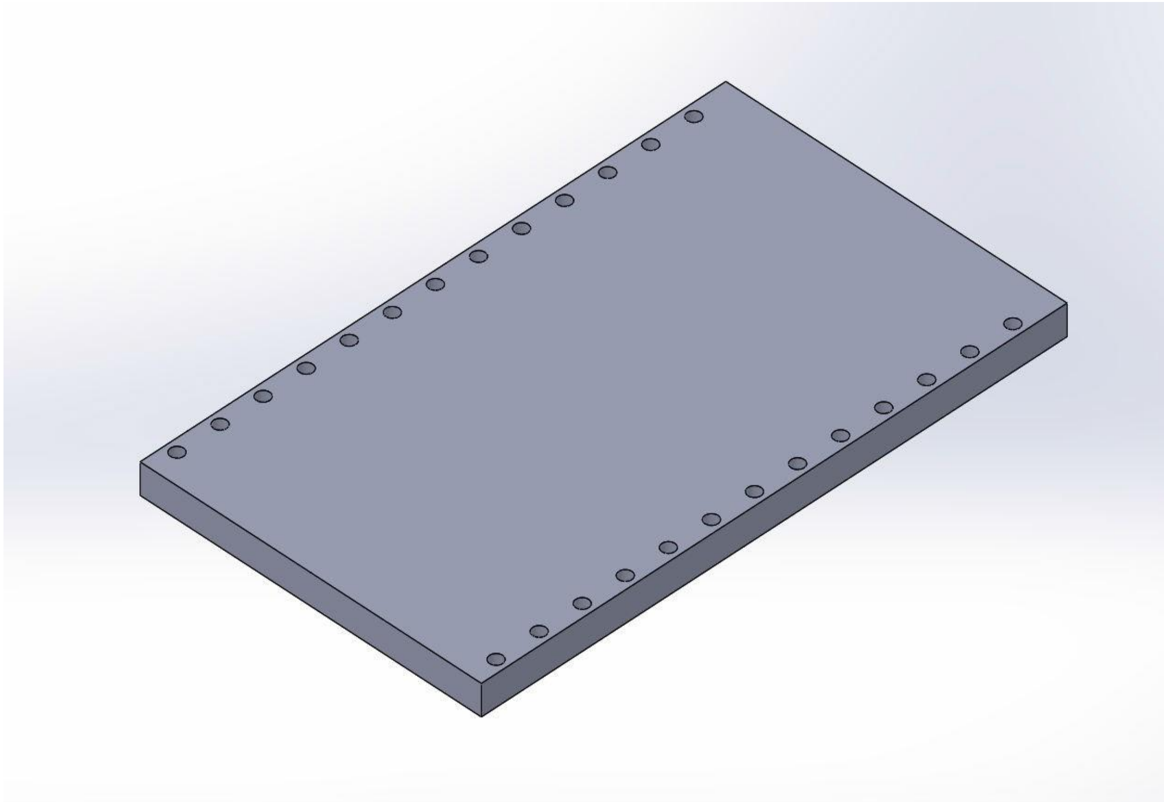
25.3 3D MODEL: 5 IN. TOP TROUGH 3D MODEL:



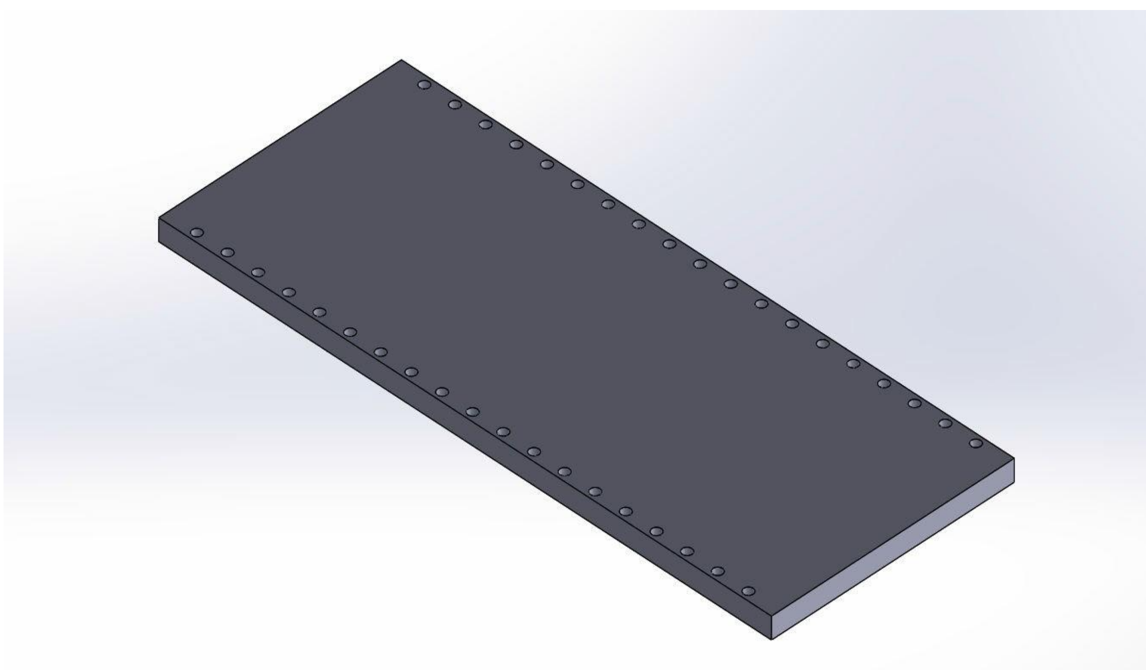
25.4 3D MODEL: 30 IN. TOP TROUGH



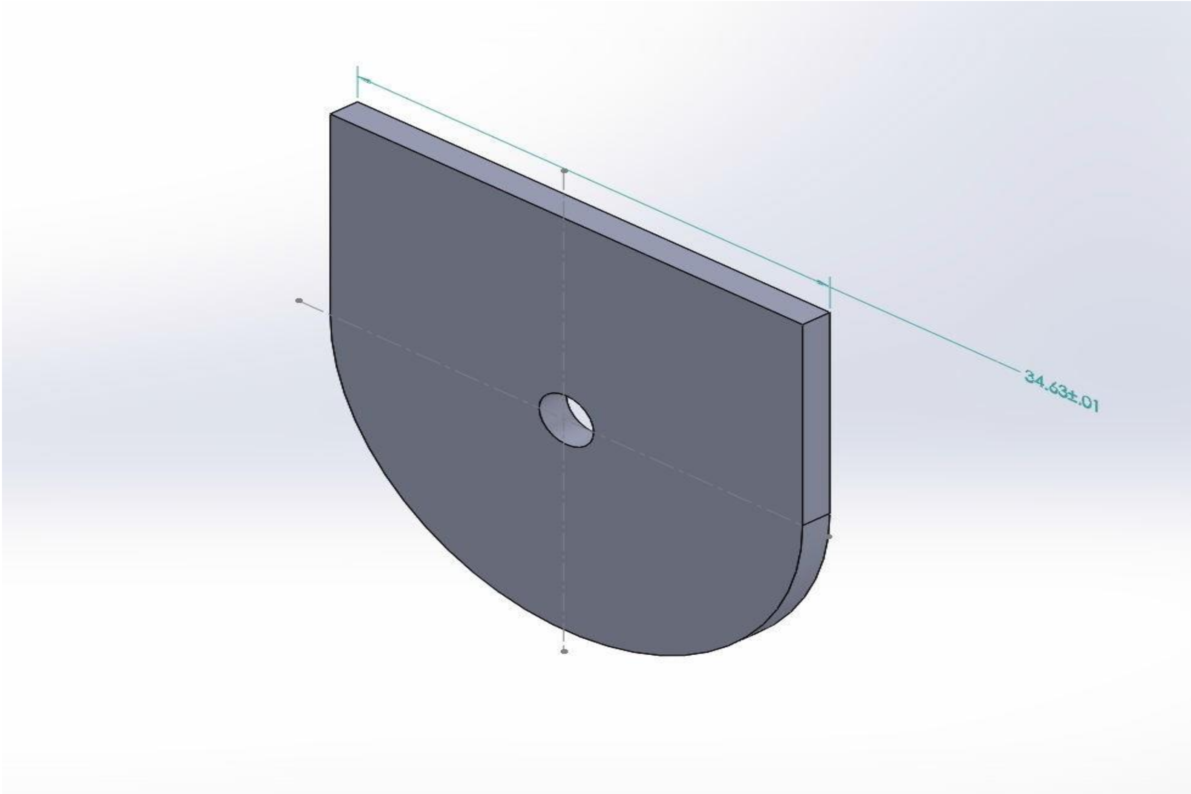
25.5 3D MODEL: 68 IN. TOP TROUGH



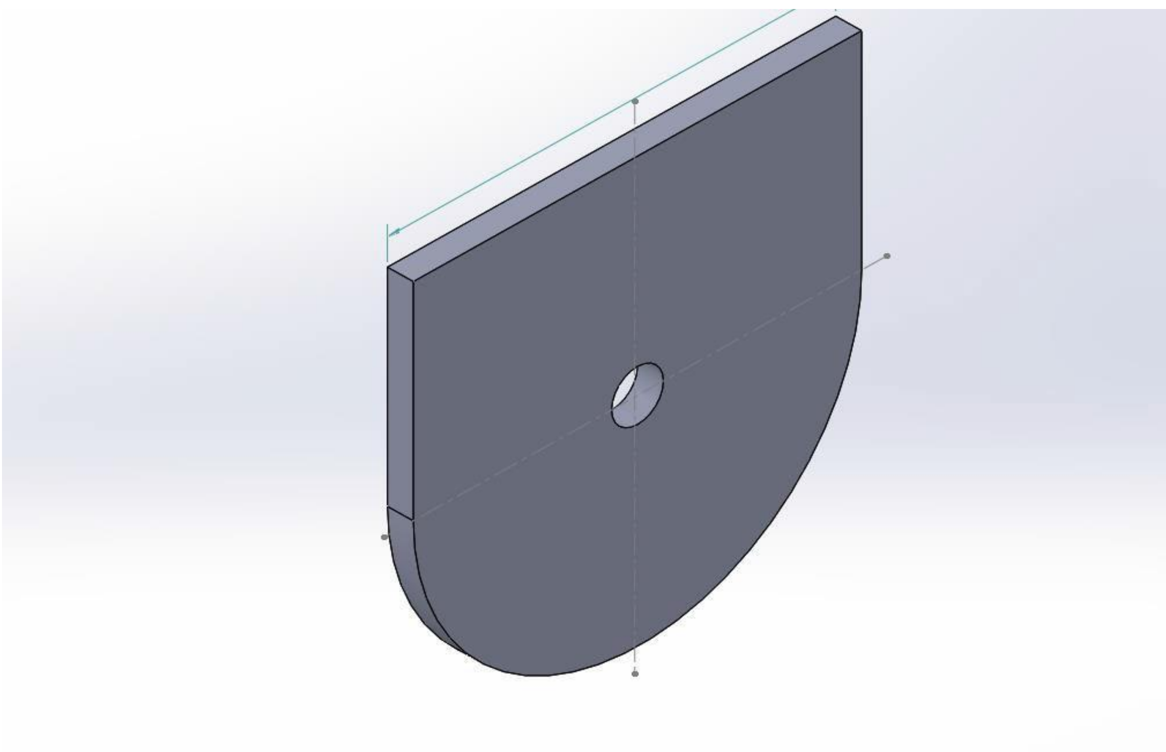
25.6 3D MODEL: 100 IN. TOP TROUGH



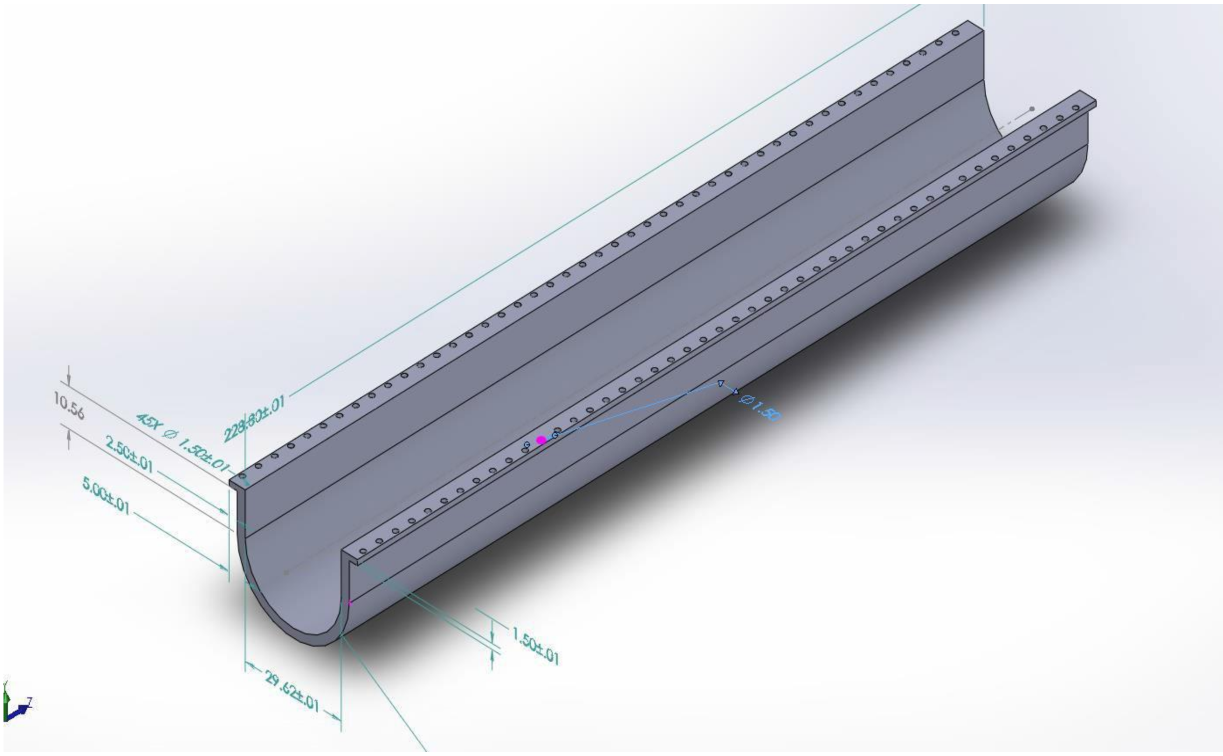
25.7 3D MODEL: END PLATE



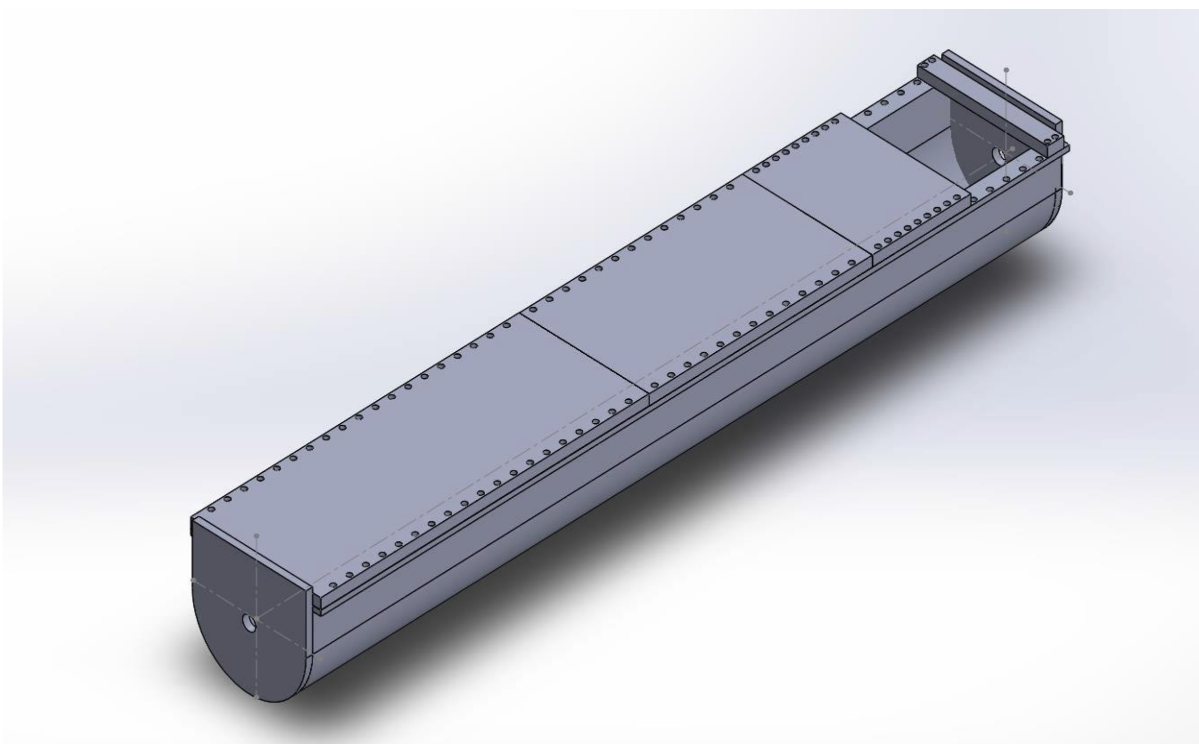
25.8 3D MODEL: END PLATE



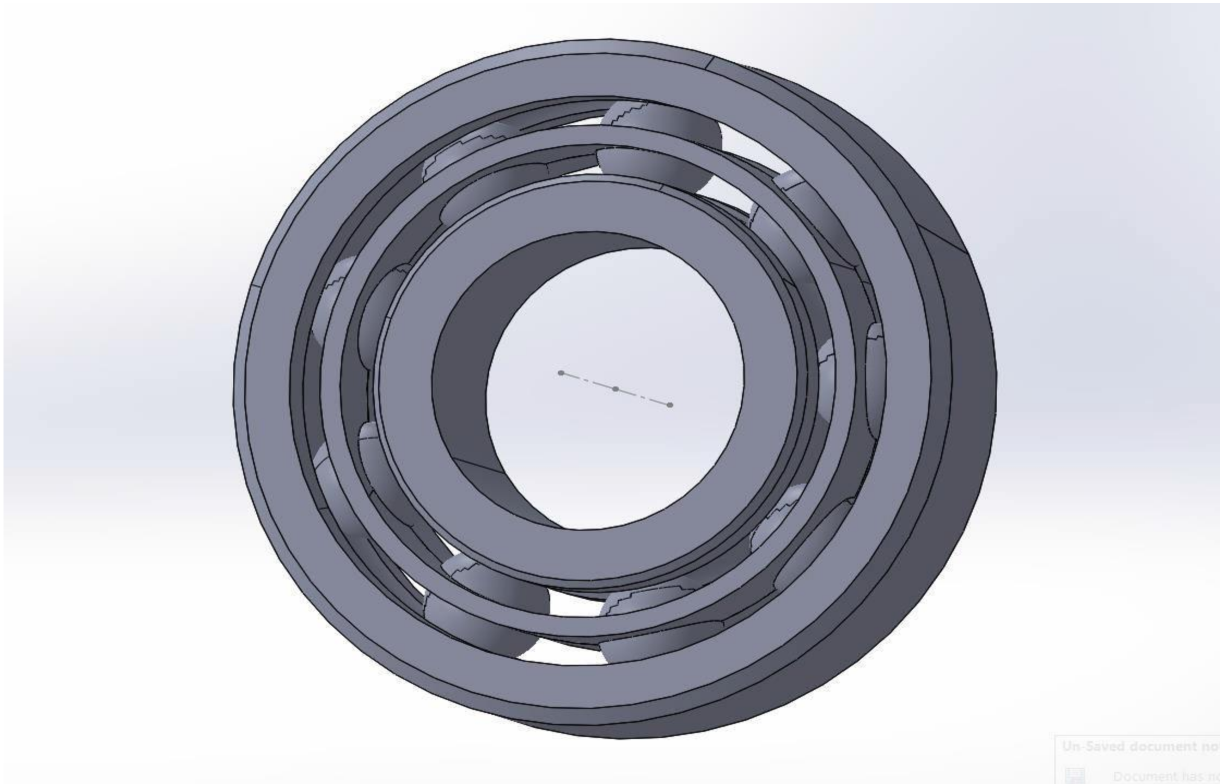
25.9 **3D MODEL: TROUGH**



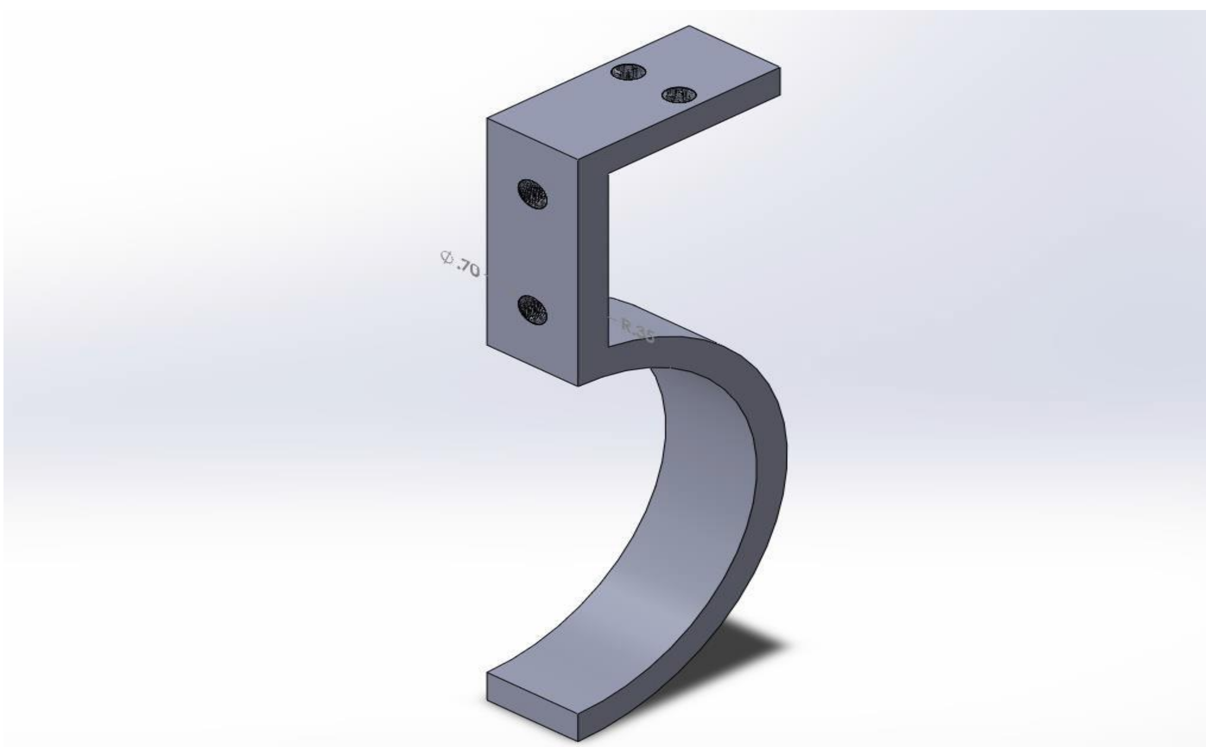
25.10 **3D MODEL: TROUGH ASSEMBLY**



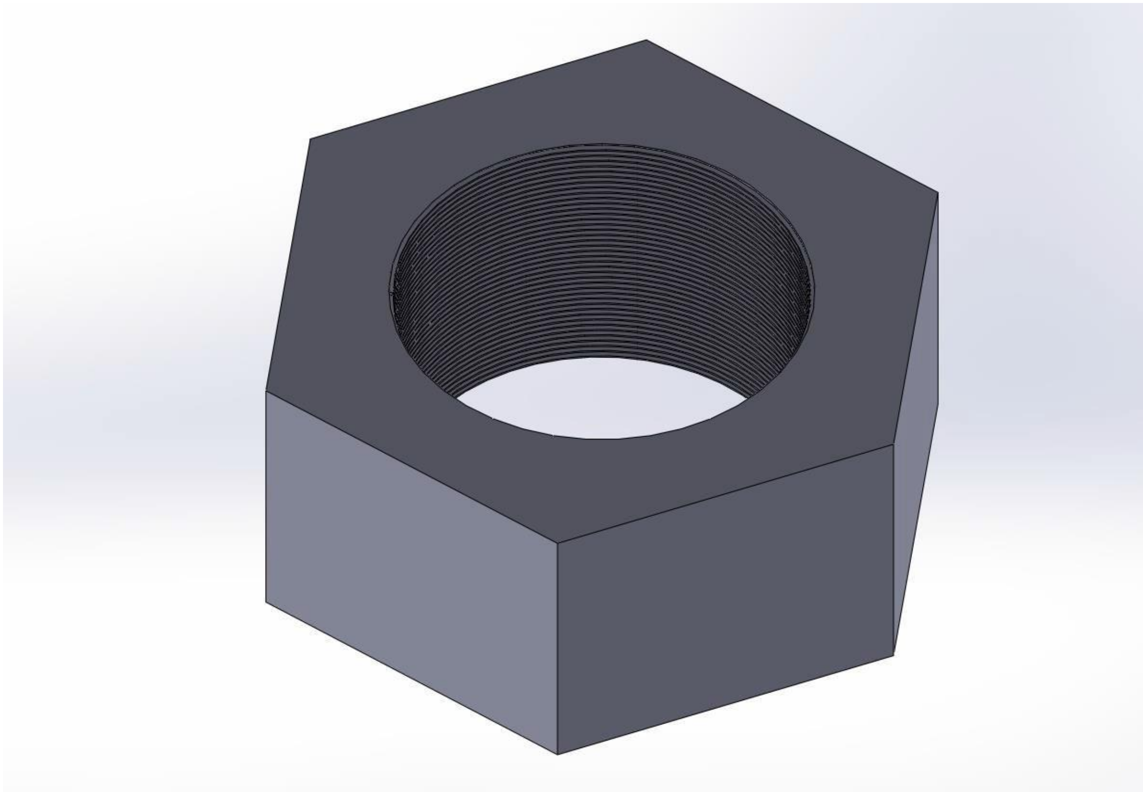
25.11 **3D MODEL: BALL BEARING**



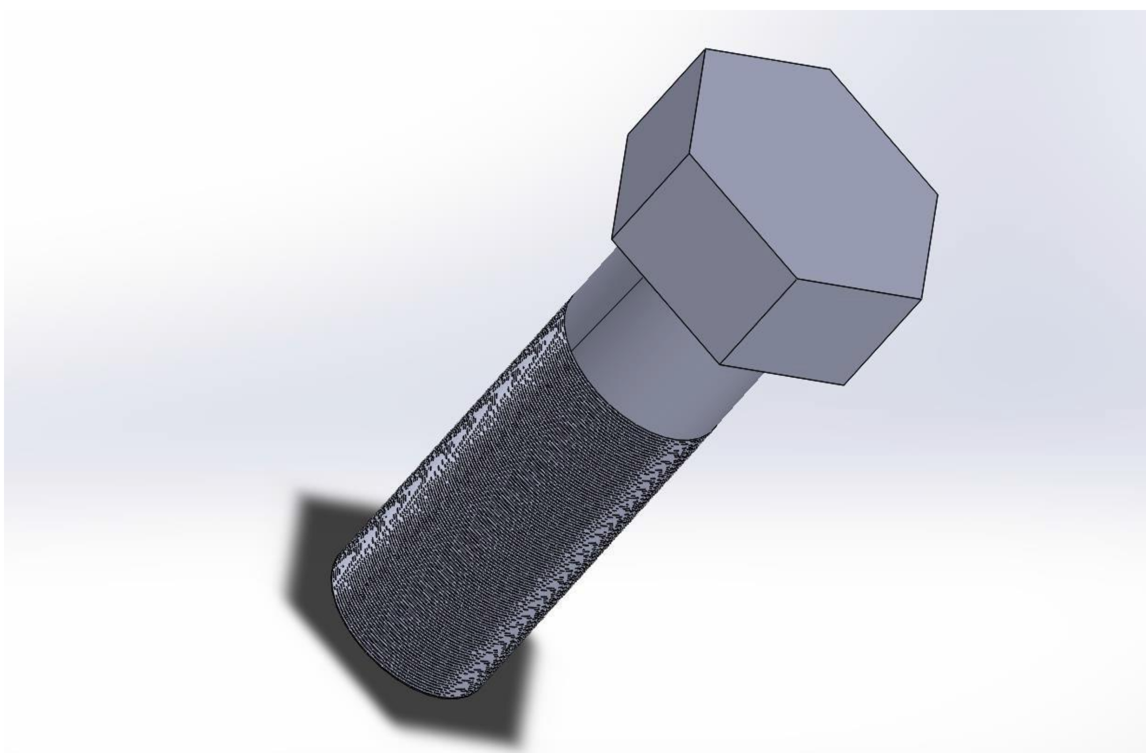
25.12 **3D MODEL: HANGER**



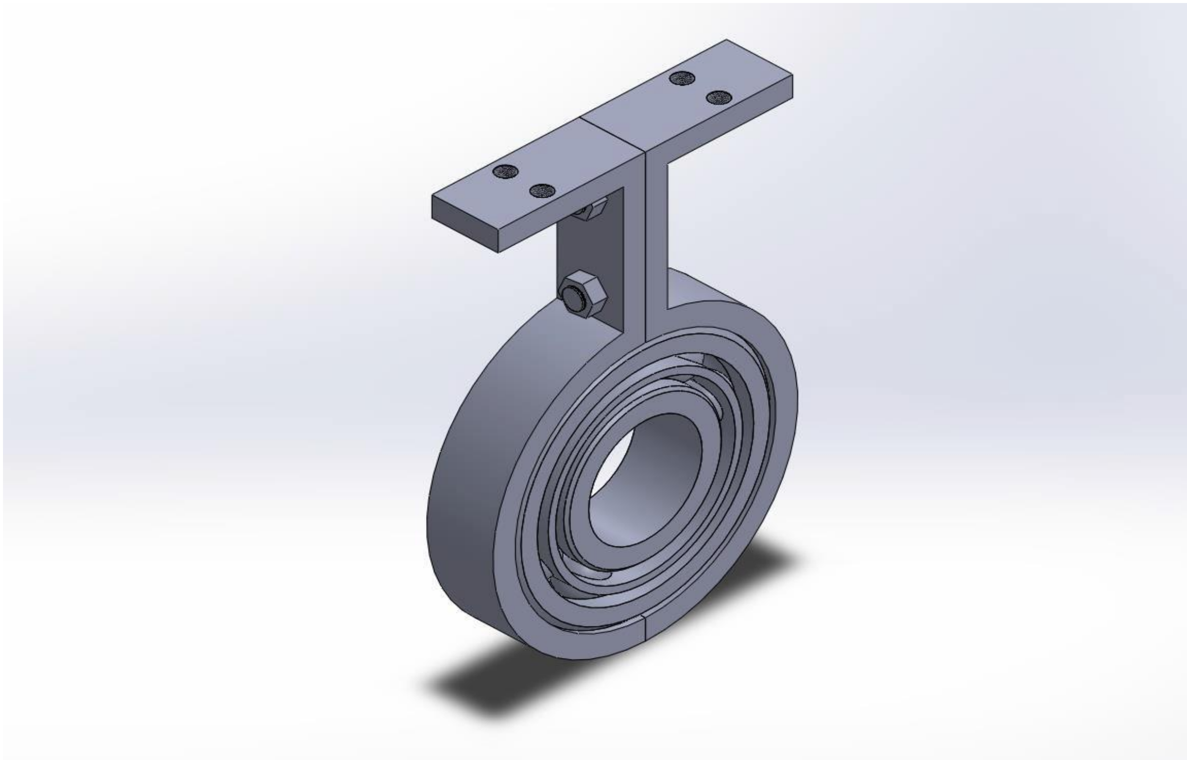
25.13 3D MODEL: NUT



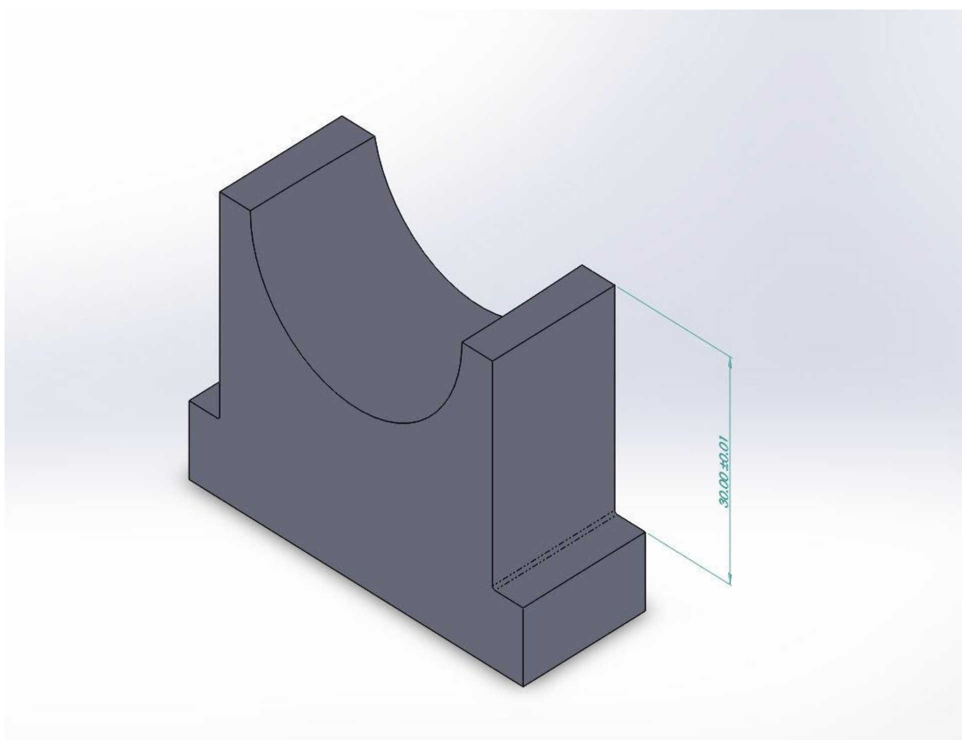
25.14 3D MODEL: BOLT



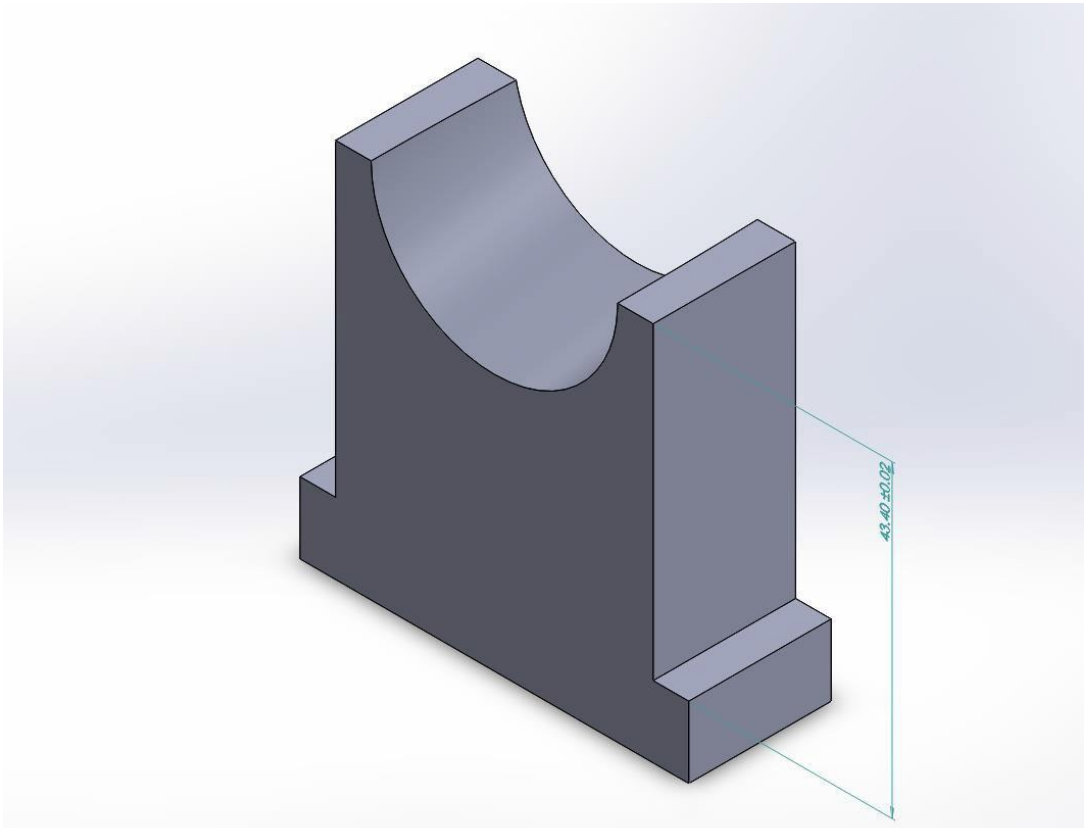
25.15 **3D MODEL: HANGER BEARING ASSEMBLY**



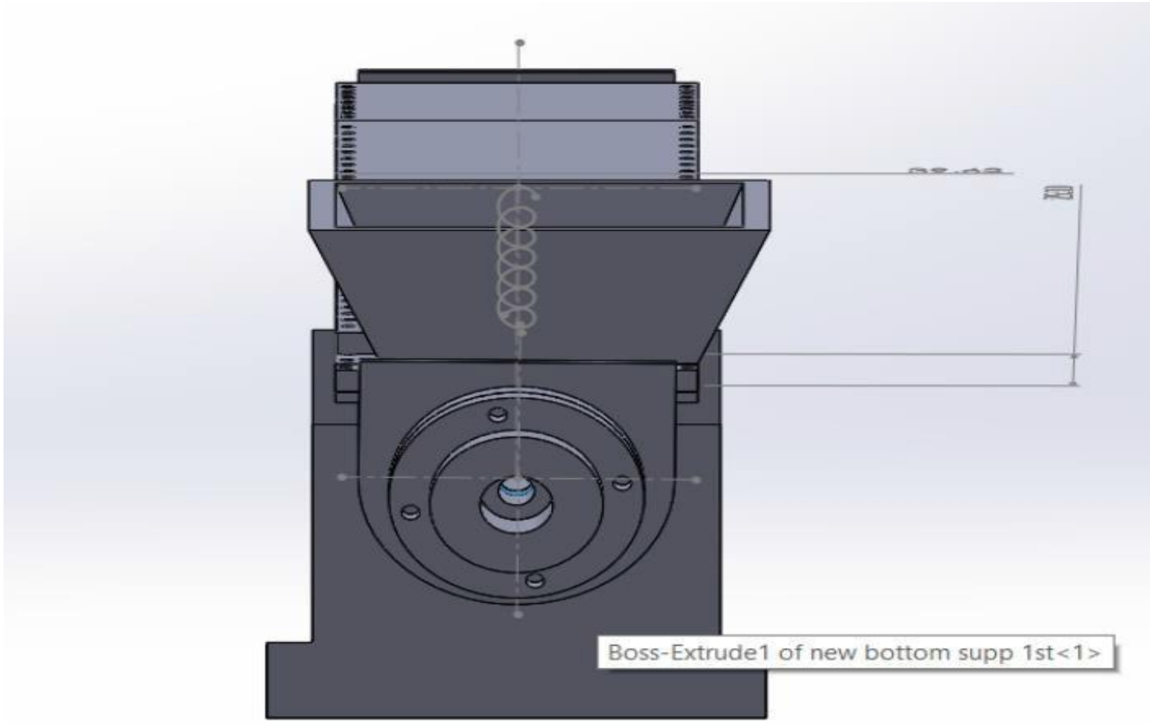
25.16 **3D MODEL: SMALL SADDLE**



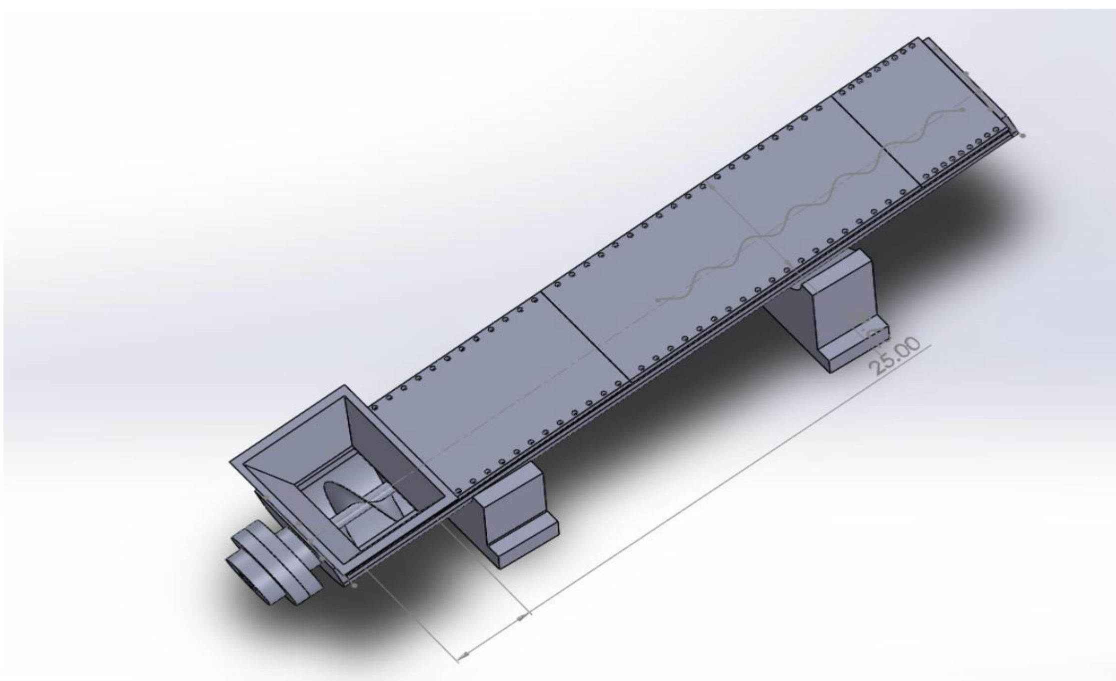
25.17 **3D MODEL: TALL SADDLE**



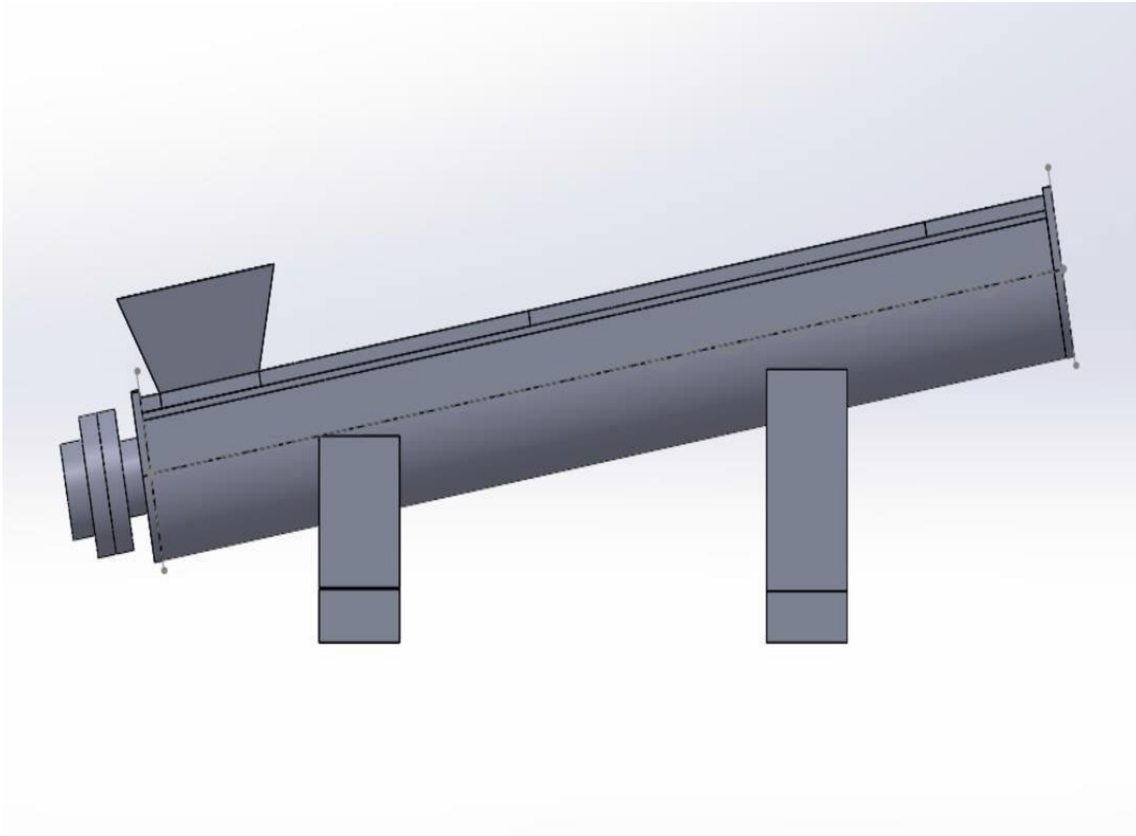
25.18 **3D MODEL: SCREW CONVEYOR ASSEMBLY- FRONT VIEW**



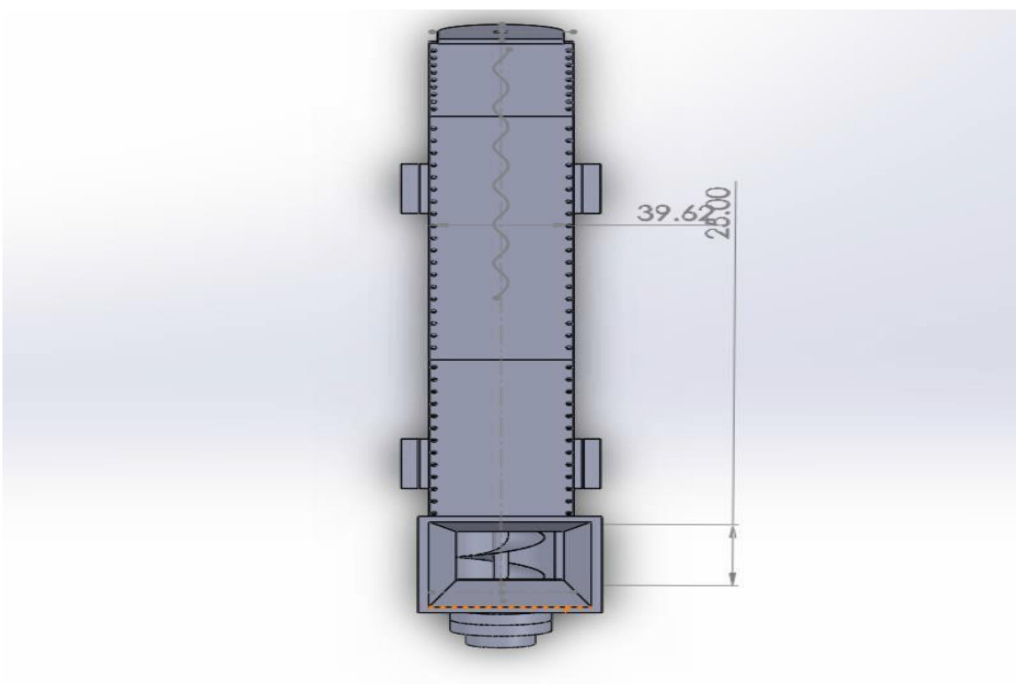
25.19 **3D MODEL: SCREW CONVEYOR ASSEMBLY- ISOMETRIC VIEW**



25.20 **3D MODEL: SCREW CONVEYOR ASSEMBLY- RIGHT SIDE VIEW**

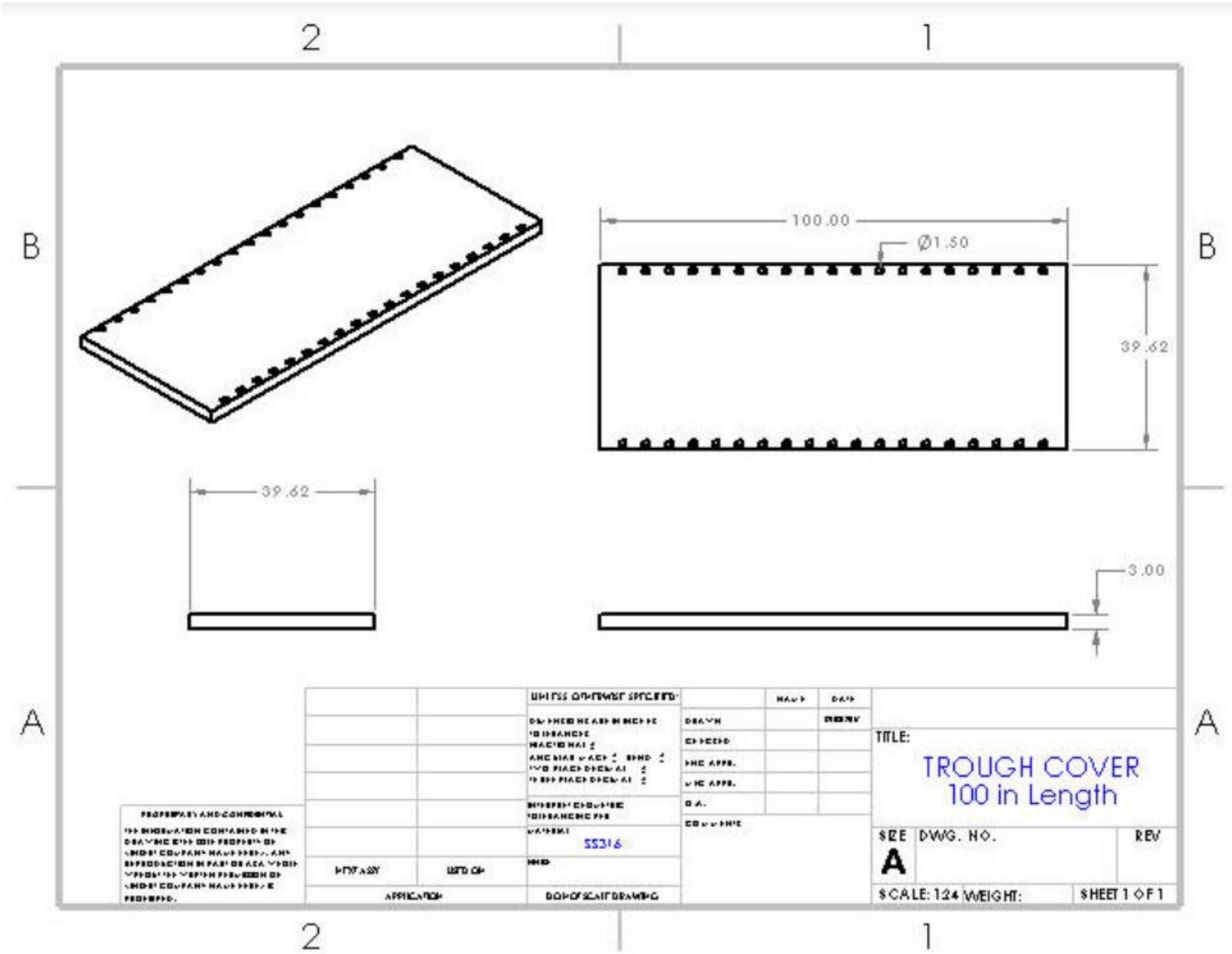


25.21 **3D MODEL: SCREW CONVEYOR ASSEMBLY- TOP VIEW**

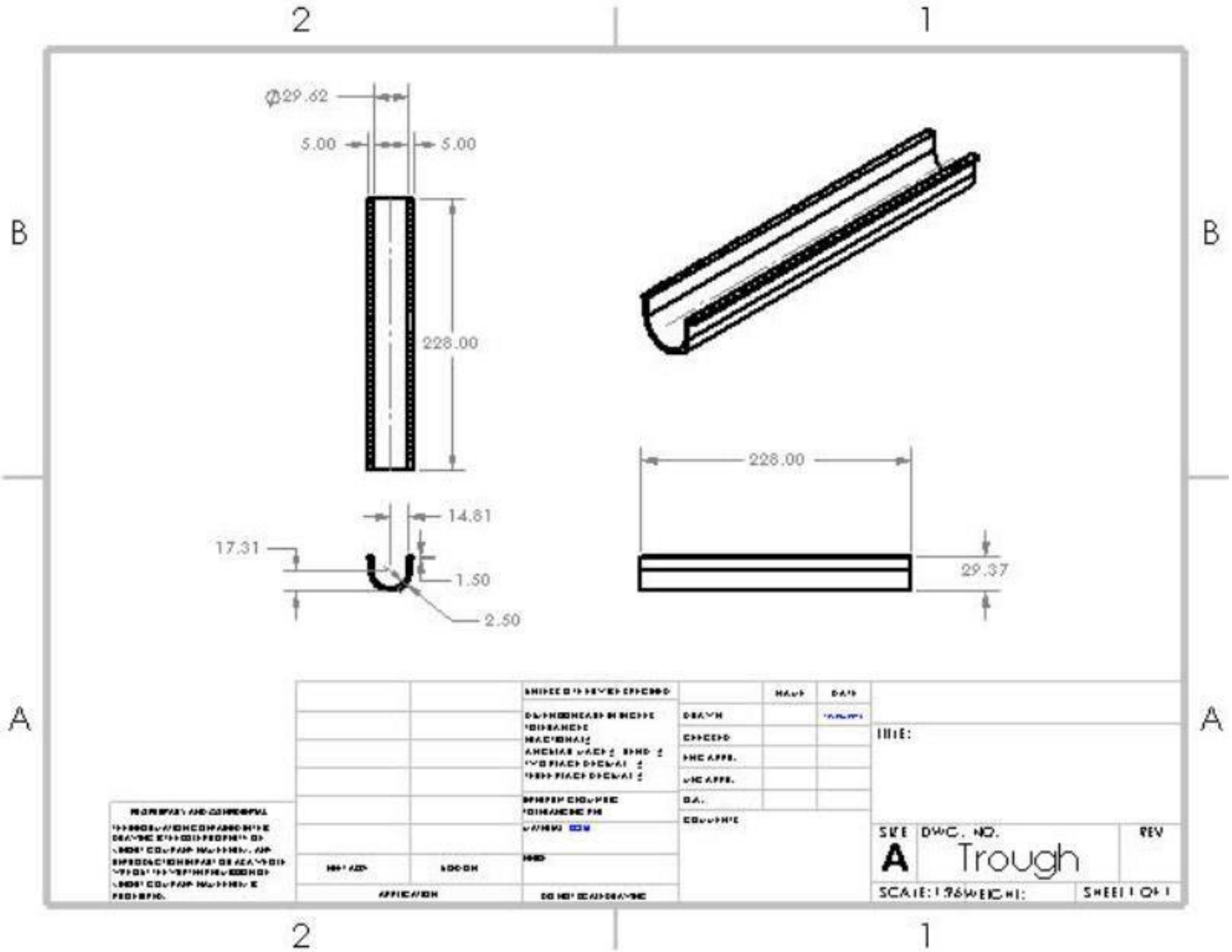


26. **2D DRAWINGS**

26.1 **TROUGH COVER**

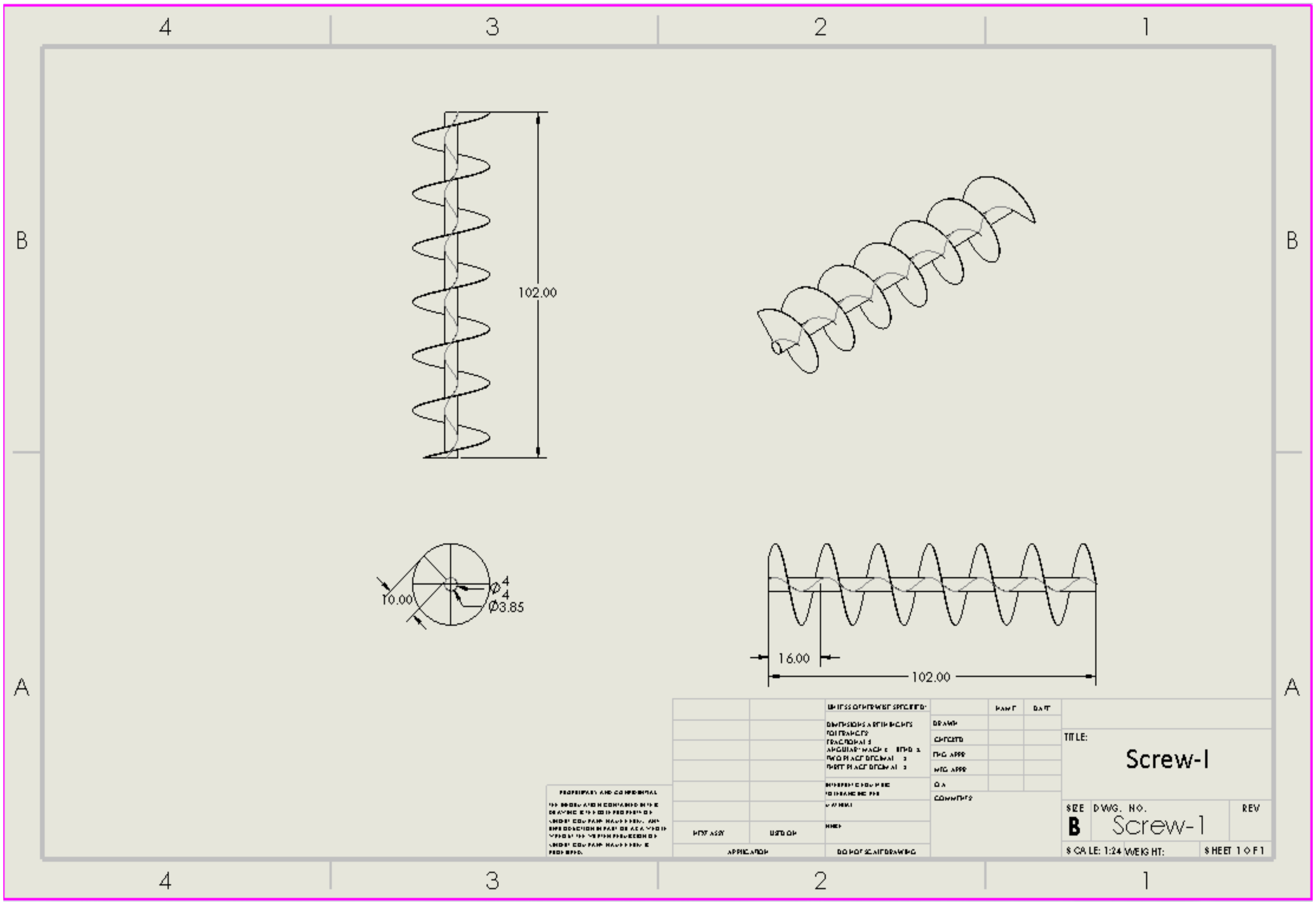


26.2 **TROUGH**



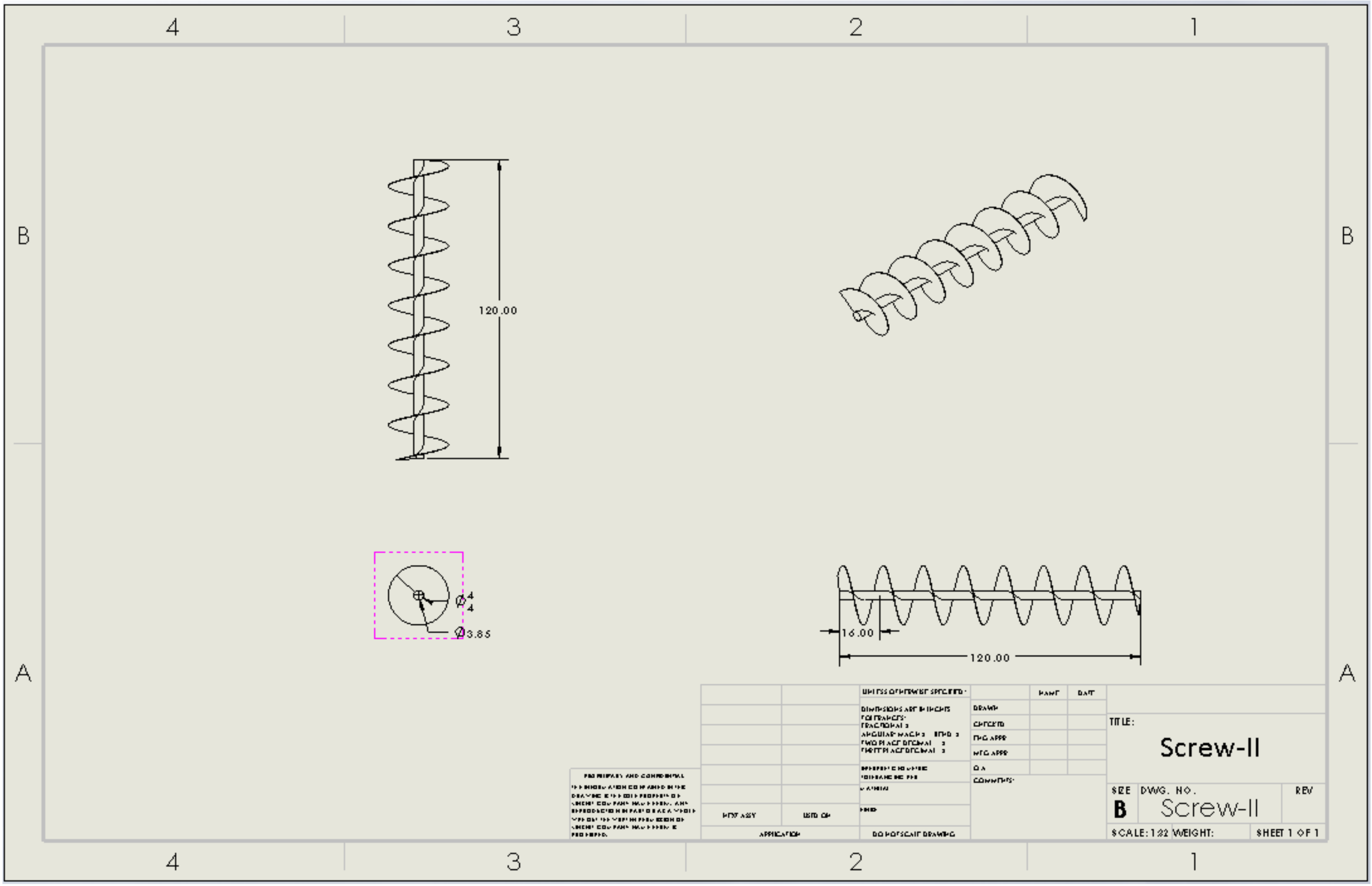
Ø29.62
5.00
5.00
228.00
228.00
14.81
17.31
1.50
2.50
29.37
DRAWN
CHECKED
TITLE:
SIZE
A
DWG. NO.
Trough
REV
APPLICATION

26.3 **SCREW-I**



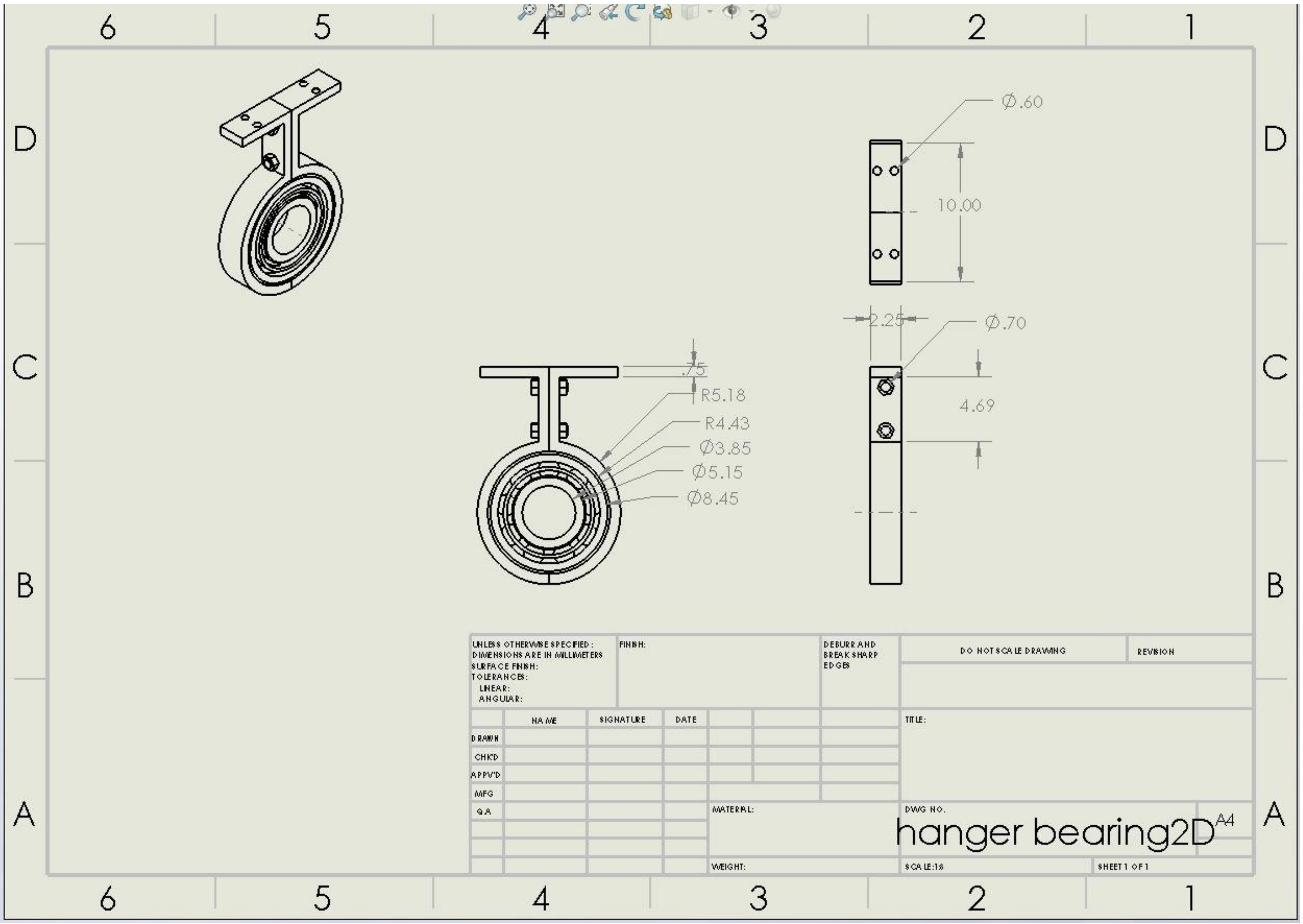
102.00
10.00
Ø4
4
Ø3.85
16.00
102.00
TITLE:
Screw-I
SIZE
DWG. NO.
REV
B
Screw-1
SCALE: 1:24
WEIGHT:
SHEET 1 OF 1

26.4SCREW-II

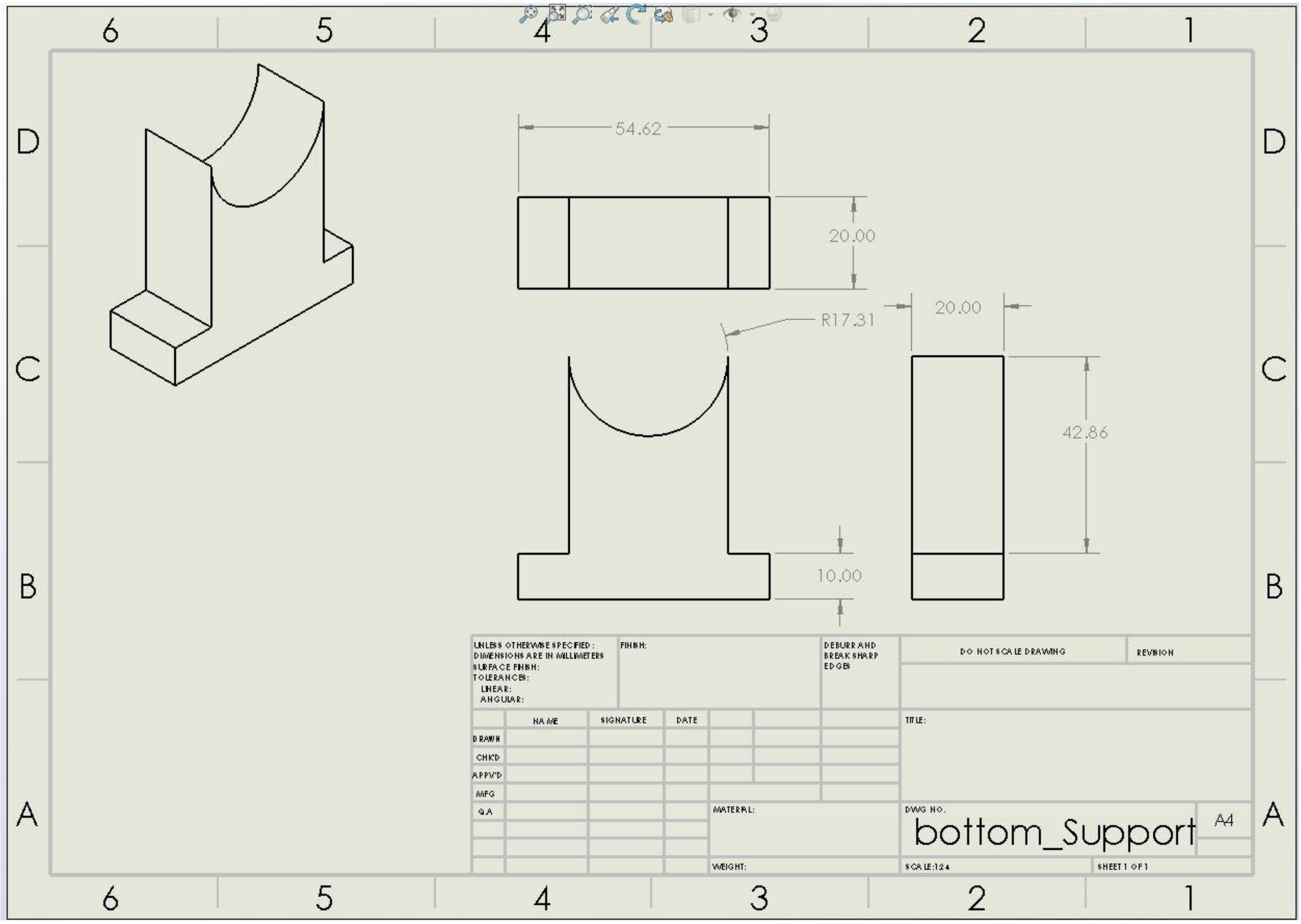


120.00
16.00
120.00
Ø3.85
TITLE:
Screw-II
SIZE
DWG. NO.
REV
B
Screw-II
SCALE: 1:2
WEIGHT:
SHEET 1 OF 1

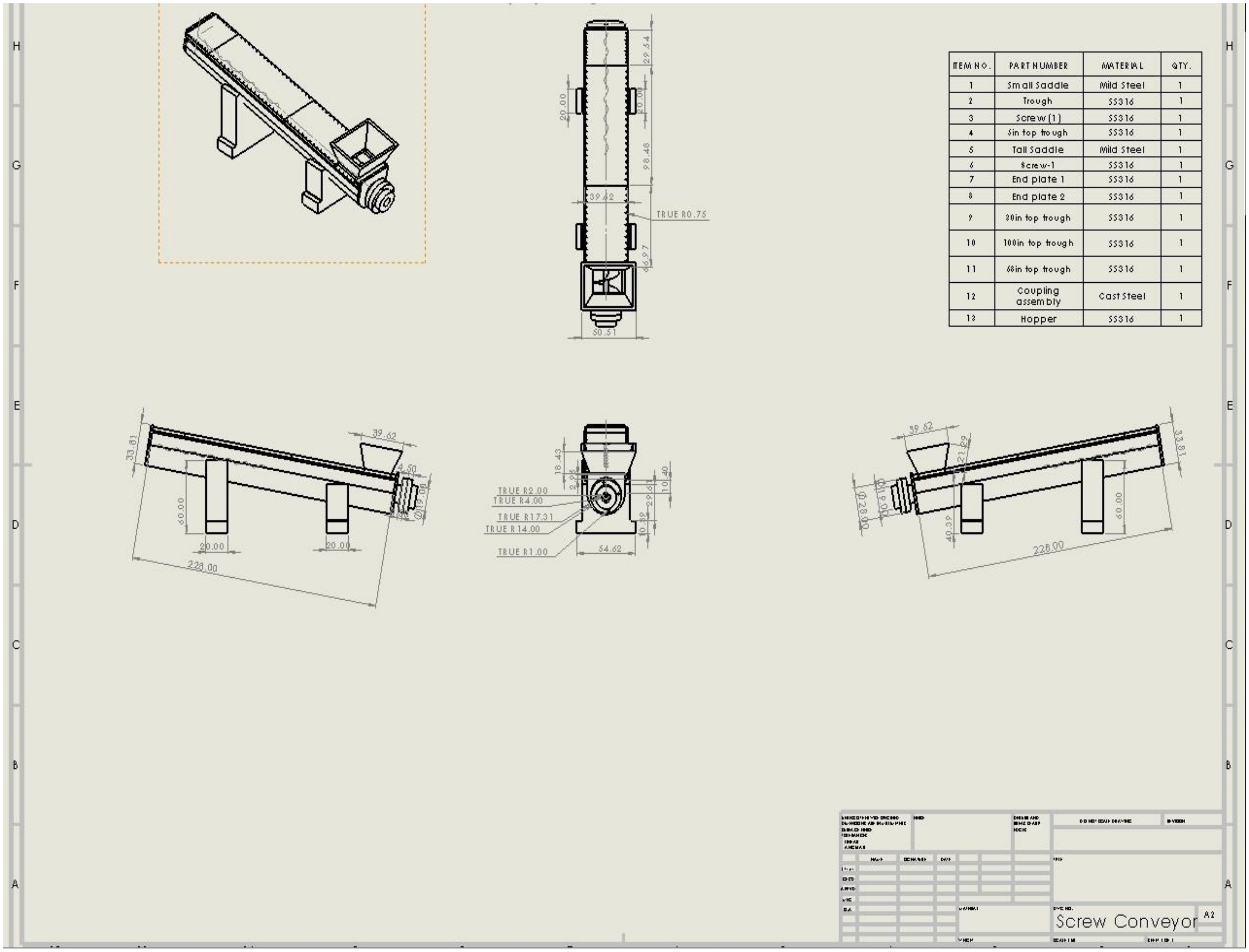
26.5: HANGER BEARING



26.6: BOTTOM SUPPORT



26.7 SCREW CONVEYOR ASSEMBLY



27. Final Design Review: Results and Discussions

1) The Concept Design Phase has all the initial decision which needs to be made so as to frame a general path to work on.

2) While designing a screw conveyor system many small yet important decisions were made. Our project started from getting all the inputs which the customer needs i.e., **Customer Requirements** and relate it to **Engineering Characteristics** to make **House of Quality** where all of these characteristics where laid down and general ranking was given based on importance rating.

3) The Second Part of Concept design was to formulate a **product specification** & accordingly perform a concept design configuration.

4) In our project **four concepts** were modeled keeping in mind the type of drive arrangement, trough shape, material used and the design of hanger bearing.

5) We later prepared a **Weighted Decision Matrix Chart** to weigh the requirements with the importance factor where all the other factors sum up to 1. Then using such a procedure for all the components, we selected **Concept 2** since it had maximum rating.

6) In the last for this phase **Physical Decomposition** of the Screw Conveyor was prepared to know the module of each component functioning in the Screw Conveyor and eventually decide to purchase it from outside or make it in house. The Screw Conveyor had a modular function but the function of each component varied.

7) **Reliability analysis** was carried out to calculate reliability of whole screw conveyor assembly. To calculate reliability, we used Weibull Distribution Chart. From this chart we calculated reliability of system= 54.2% for 11680 operational hours.

8) The **cost analysis** requires a detailed report of all the components involved including brought-out items, manufactured products (in-house), labor cost, transportation, erection, material handling, assembly, testing, indirect, etc
   - Overall cost Engineering, (Design and Manufacture): $ 7173.69
   - Total activity based costings: $ 14988.27
   - Net Profit: 33.4%

9) **Failure mode and effects analysis (FMEA)** is a team-based methodology for identifying potential problems with new or existing designs. In our design we have considered RPN>125 as a critical concern, which will be given top priority during concern resolution.