# MIE 221: Manufacturing Engineering
# Final Proposal

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**Recommendation for reading this proposal:** Closely follow the references to the Appendix and the Drawings/redesign section to visualize the manufacturing devices while reading the Assembly Process and the Materials Handling sections of this proposal.

## 1.0 Assembly Process

Assembly is a cost operation [1]. Therefore, the main objective of the proposed assembly system is to have a time and cost efficient process. For the ¼ ball valve assembly process, all the parts being used are metallic. Observing the ¼ ball valve structure, threaded fastening is the only possible type of Mechanical fastening that can be utilized to assemble individual parts. The joints between the individual parts, therefore, would not be permanent. Assembly techniques of adhesive bonding, welding, brazing, and soldering are eliminated since all individual parts are supposed to have temporary joints. There are 7 different required parts in an assembled ¼ ball turn valve- that will be referred to by the names labelled in [**Appendix 1.1]** for this proposal. Given the required 7 parts for assembling the ball valve, assembly cost cannot be cut by reducing the number of parts; instead, an attempt to reduce the cost of the assembly process will be done in the selection/decision-making process of the appropriate manufacturing machines for a given task.

### 1.1 Sorting and Orientation

Even though all the individual parts are small/compact, the most viable sorting device for all 7 parts will be a vibratory feeder [**Appendix 1.2]** [1].. The usage of a vibratory feeder over a non-vibratory one is justified considering the inefficiencies of a non-vibratory feeder. Adding on, the common usage of vibratory feeders for complex geometries (for 95% of the time) further reinforces the justification [1].

Each part must be oriented in a way that enables the positioners (placement devices discussed later in this report) to be used effectively (at the highest possible speed) in order to reduce the assembly time. The stable orientations for all parts are illustrated in [**Appendix 1.3]** . The selected stable orientations for all parts are illustrated in **Figure 3.1** of the Drawings/Redesign section. The following are the descriptions of the selected orientations, justifications for these orientations, and the orientation devices used to obtain these orientations:

**Main Body**: There are 8 possible stable orientations of the main body, and the selected orientation (an unstable one) is for the part to horizontally lay flat on the ground, with the needle facing upwards. To eliminate the tall (vertical standing) orientations, a wiper blade will be used; to eliminate the vertical wide orientations, a narrowed track will be used; an edge riser will be used to ensure that the main-body needle faces upwards(vertical) as it is about to enter the feedtrack. **Figure 3.3** shows the orientation device for the main body.

**Big Nut & Small Nut :** Both parts having the same shape (different sizes), have 4 stable orientations (each). The interior region of these nuts has a threaded part through which the sleeves enter and a non-threaded part where the sleeves fix. Our desired orientation will be to have the non-threaded interior region below the threaded interior region. As explained in the next few steps of the assembly process (proposed in this report), the sleeves will be inserted into the nuts prior to their fastening with the main body. An off-the-shelf device, explained later in this report, will be used to acquire this desired orientation. As of now/this stage, the only orientation device that is being used in the vibratory feeder is the wiper, in order to eliminate the vertically oriented nuts.

**Big Sleeve & Small Sleeve**: Both these parts having the same shape (different sizes), have 2 stable orientations (each). The orientation of sleeves being horizontally flat on the ground was selected for making the process of positioners (to lift them and place them inside the nut) more efficient. The only orientation device being used in the vibratory feeder is the wiper, in order to eliminate the vertically oriented sleeves.

**Valve & the screw**: Both, the value and the screw have similar exterior geometries. A valve has 3 possible stable orientations. The desired orientation for the valve for its easy/efficient pickup by the positioner is the vertical orientation with the small radius region of the part as the base. Undesired orientations will be rejected by the means of first attachment (wiper blade mechanism), and second attachment (pressure brake mechanism). The third attachment is the combination of a dishout to eliminate the remaining unstable orientations, and a discharge hole to guide the parts (valve and the screw in separate feeders) to the feedtrack. **Figure 3.4** shows the orientation devices for the Valve & the screw.

There are 7 individual feeders of the respective parts (with their features discussed above). Considering that some parts are assembled prior (pre-assembled) to the final assembly (with the main body), the vibratory feeders will be positioned in a way that is time-efficient for the positioners to pre-assemble parts such as small-nut and small sleeve; big-nut and big-sleeve. [**Appendix B]** in the Drawing/Redesign section illustrates the proposed positioning of vibratory feeders for a space and time-efficient assembly process.

## 1.2 Feeding and Escaping- Part transportation

After being released from the vibratory feeders, all parts must be led to the conveyors (discussed in 1.4). Feed tracks are paths for these parts that ensure the parts exiting the vibratory feeders are maintained in a single line with the obtained desired orientation [1]. These feedtracks must be wide enough to avoid jamming and narrow enough for maintaining the part orientations. All the feed tracks in our assembly system use gravity (no other external forces) to drive the parts ahead. The optimal feed track designs catering to the geometry of the individual parts are illustrated in **Figure 3.2** in the Drawings/Redesign section.
After following the feed-track paths, the parts need to be stopped, and exact quantities need to be presented to the main assembler [1]. Event-based (rather than time-based) gate controls for the escapements are required in order to release the part at the exact instant -to be picked up by the positioner[1]. As the positioners prompt signals to the escapement (the event), the gate control releases the oriented part[1]. All the parts use ratchet escapements for their release to the positioners [**Appendix 1.4**][1]. The following is the justification for the devised gate control mechanisms for the respective parts according to their consumption by the presentation device:

**Main Body**

The gate control mechanism for the main body will be triggered by the first off-the-shelf device used in our assembly line. This off-the-device is a clamping device illustrated in **Figure 3.5** in the Drawings/Redesign section. From the escapement, the main body is directly released inside the open clamp. This clamp is placed on the assembly (presentation) line. The contact of the main body with the interior base of the clamp leads it to close its walls (closed clamp). Note that, the appearance of the subsequent open clamp in the presentation assembly line, is the trigger for releasing the main body (into the clamp). The use of the above discussed gate-control mechanism rather than the traditional use of positioners enables cost reductions. The justification of this cost reduction is on the basis of these (clamping) devices being clamps for the main body in the assembly line as well as a gate-control trigger.

**Nuts and Sleeves**

Note that, since the geometrical structure (not size) of the Big-nut and Small-nuts are the same, the same gate-control mechanism will be utilized. Adding on, the Big-sleeve and Small-sleeve will also use the same gate control mechanism.

**Nuts:** Recall (from the discussion of **Big Nut & Small Nut** in **1.2**) that the vibratory feeder was not equipped to orient the nuts in the desired orientation of the non-threaded interior region to be below the threaded interior region. Therefore, both the horizontal orientations come out of the escapement. The second off-the-shelf device used as an escapement gate control trigger and an orientation device is illustrated in **Figure 3.6** in the Drawings/Redesign section. This off-the-shelf device is a 3dof positioner. These positioners (1 for the small nut and the big nut, each) have compressible sleeve structures with accurate dimensions that go inside their nut of the respective sizes- Small/Big. As these nuts are released from the escapement, the positioner rod thrusts inside half the depth of the nut. After the rod has been thrust inside the nut, the nut being attached to the compressive sleeve structure indicates that the non-threaded interior is above the threaded interior (undesirable) . If the nut attaches to the compressive sleeve structure, the positioner places it back inside the vibratory feeder of the respective nut size. If the nut does attach to the compressive sleeve structure, the sleeve positioners (discussed next) place the sleeves inside the nut (through the threaded region). The trigger for the escapement gate-control to release the nut occurs when the nut attaches to the compressive sleeve structure of the off-the-shelf positioner.

**Sleeves:** Simple, 2dof positioners will be used to place the sleeves inside their respective nuts (according to their sizes). [**Appendix 1.5]** shows the possible 2dof positioners that can be used for this task. The pick-up of the sleeves will trigger the escapement gate control for the next sleeve to be released.

**Valve and Screw**

Considering their similar geometrical structures and orientations, same escapement gate-control mechanism and. Both these parts will be directly consumed by the presentation line for assembly with the help of a 3dof positioner (for screw) and a 2dof positioner (for valve) similar to the ones shown in **[Appendix 1.5].**

## 1.3 Presentation

Pallet conveyors will be used as presentation devices for the assembly location [**Appendix 1.5**][1]. The main body will be attached to clamps on a pallet that will traverse across the various stations where different parts will be assembled to the main structure. Pallet conveyors have been selected over rotary tables as all the parts will be assembled onto the main body one after the other in a straight line and pallet conveyors work best in transferring equipment across the assembly process in a straight line. Additionally, as all the individual parts will be assembled to the main body sequentially, the vibratory feeders for the different parts will be placed on either side of the conveyor to allow better space optimization.

## 1.4 Assembly using positioners

Reaching this phase of the assembly process, the main body is in the clamp on the pallet conveyor; sleeves and the nuts have been pre-assembled (and ready to be attached to the main body); valves and screws are ready to be picked and attached to the main body. The following are the positioner types to be used for the final assembly at the presentation line (pallet conveyor):

**Nut & sleeve to the main body-** 3dof positioners to screw the pre-assembled Nuts & Sleeves to the main body.

**Valve:** As discussed in 1.2, the valve will be placed on the needle of the main body with the use of a 2dof positioner. The joint will be fastened utilizing the screw.

**Screw**: The screw will fasten the valve with the main body. Therefore, a 3dof positioner with a specific gripper (used for screwing) will be used. The gripper type will be discussed in the Materials Handling Section of this report.

## 2.0 Materials Handling

Materials Handling will deal with on-time delivery and transfer of the individual parts of the assembly. Packaging and moving the assembled ¼ ball valve will also be handled as a part of the entire materials handling process. Ensuring an efficient flow of materials is necessary to reduce handling costs.

### 2.1 Automated Guided Vehicles

Automated Guided Vehicles (AGVs) with robotic arms will be used for transferring the individual parts in bulk for assembling to the vibratory feeders. AGVs with robotic arms were selected for carrying out this process as they are driverless vehicles that help reduce costs as compared to other industrial self-powered vehicles. The onboard automatic-guided device will allow the vehicle to follow a pre-programmed path based on the weight of the parts. The big nut and sleeve packed boxes will be the heaviest followed by the small nut and sleeve, valve, main body, and finally, the screws. As the vibratory feeders of the big (and small) nut-sleeve parts will be located close to each other, the boxes of these two parts will be transported together to their respective feeders. The AGV will follow its pre-programmed path to transport the parts to their respective vibratory feeders based on their weight. This feature of using only one AGV to transport all the parts to the assembly process through reprogrammability will significantly reduce the handling costs. Optical passive tracking will be adopted for operating the AGV as it is one of the most economical methods of navigation.

Once all the individual parts are transported to their vibratory feeders, the AGV will travel to the end of the assembly process for transferring the final packed box to the dispatch site. A flow chart representing the path followed by the AGV and the machine positioning is represented in [**Appendix B**].

## 2.2 Robotic Arm of AGV

The AGV will be of a Unit-Load Carrying type with a robotic arm that will transport the boxes of the unassembled parts from one station to the other in an asynchronous manner [2]. The robotic arm will help in unloading the box containing the individual parts from the AGV to the vibratory feeder. The robotic arm will have a spherical geometry with 5 degrees of freedom that will allow fast loading/unloading of the parts [**Appendix 2.2**]. The robotic arm will be supported by parallelogram linkages to attain maximum stability and flexibility. The gripper type will be discussed in the next section.

## 2.3 Grippers

Grippers have been used in both the robotic arm for the AGV and the positioners in the assembly process. The gripper for the robotic arm will need to have 3 degrees of freedom at the wrist to allow free movement in the pitch, roll, and yaw directions. Free movement in these three directions will allow the robotic arm to turn the box containing the individual parts by 180° and into the vibrator. The mechanical gripper will have two rods wide and large enough to carry the box [**Appendix 2.2**]. Similarly, after the assembly process, the box filled with the assembled parts will have to be transferred to the AGV and this would require the same type of mechanical gripper.

For the positioners in the assembly process, there will be 2 main types of grippers that will be used for the different types of positioners. The first one is a 2 finger mechanical gripper with the wrist having 3 DOFs that will open wide enough to obtain the ¼ ball valve assembly from the palette conveyor to the roller conveyor which will then be transferred out for packaging [**Appendix 2.3.1**]. The gripper used for placing the valve over the assembly will also be a mechanical one with 2 fingers and the wrist having 3 DOFs [**Appendix 2.3.1**]. We will also be using this gripper type to screw the valve to the main body [**Appendix 2.3.2**]. The fingers will clamp the screw coming out of the escapement and perform the rotation for screwing by rotating the wrist of the gripper. The second type of gripper used will be a magnetic gripper that will attach the sleeves to the respective nuts [**Appendix 2.3.3**]. The gripper would obtain the sleeve from the escapement and directly attach it to the nut that comes out of the feedtrack. Finally, the third type of gripper will be a slightly modified version of the magnetic gripper that will obtain the nut-sleeve assembly and then rotate to screw the nut to the main body on the clamp.

### 2.4 Roller Conveyor

Roller conveyors will be used for transporting the final ¼ ball valve assembly from the clamp on the palette conveyor to individual boxes on the roller conveyor. The roller conveyor will allow the transportation of the final product from the assembly process for final packaging. The above-floor roller conveyors provide the manufacturers with a cost-effective option for transporting the materials from one place to another as compared to other alternatives. A Roller conveyor was selected over a belt conveyor as it is less expensive and is also easier to maintain as it experiences less wear. Roller conveyors can also be used for long distances which makes them more advantageous. As the assembled product has to travel in a straight line from the assembly process to the final packaging box, using a roller conveyor makes it easier to do so. All the individual ball valve assembly boxes would then be placed into a larger box on the AGV using the robotic arm. This will be an event-based process where the individual boxes will be placed for final packaging based on the number of boxes being packed and the weight of the larger box.

The entire assembly process along with materials handling has been presented in a flow chart format in [**Appendix A**].

## 3.0 Drawings/Redesign

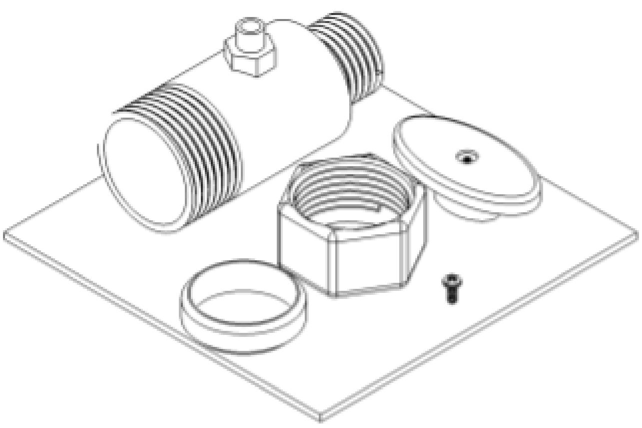

**Figure 3.1** Selected stable orientations (small nut and sleeve have same orientations as big)

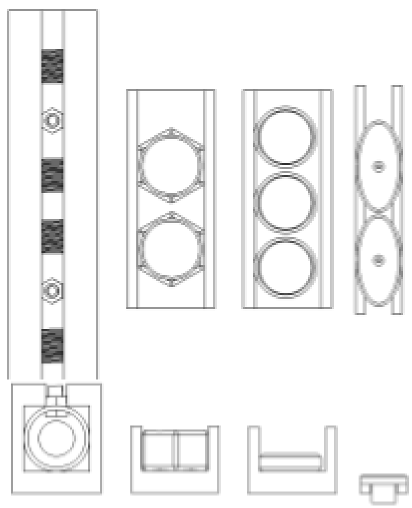

**Figure 3.2** Feedtracks for components (small nut and sleeve use same feedtracks as big but scaled down)(screw uses same feedtracks as valve but scaled down)

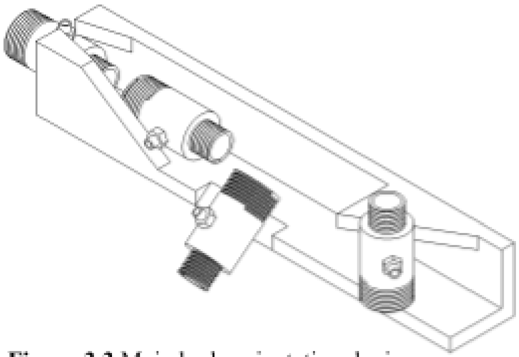

**Figure 3.3** Main body orientation device

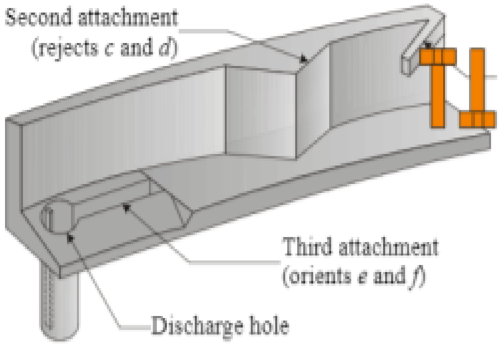


**Figure 3.4** Screw and valve orientation device[1]

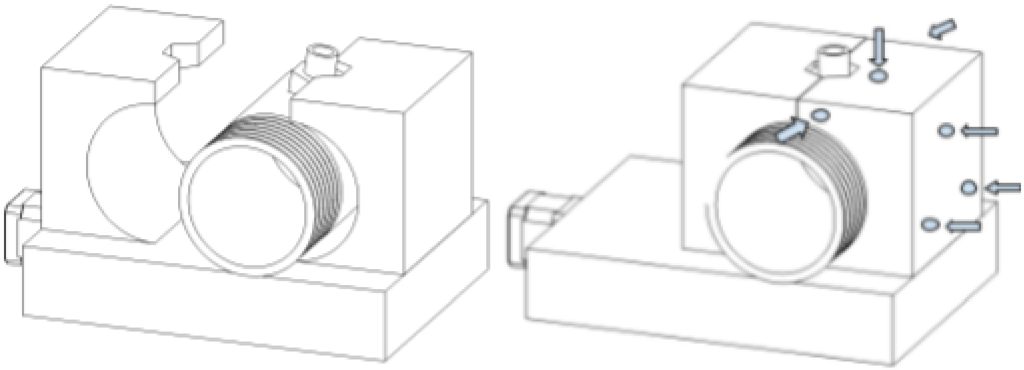

**Figure 3.5** Main body clamp with 3-2-1 clamping forces

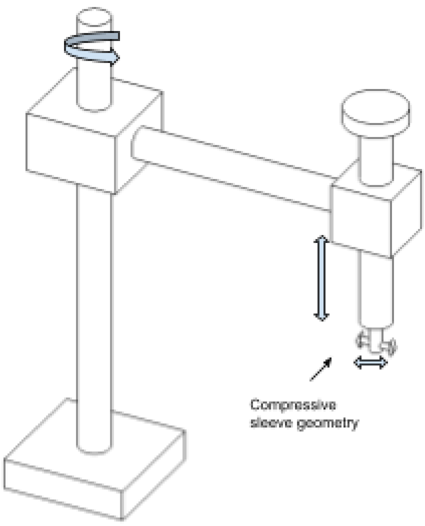


**Figure 3.6** Off-the-shelf positioner

# 4.0 Line-Evaluation/Maintenance/Economics

## 4.1 Economics

Estimated cost for the overall assembly system was created with online resources. Cost of some machinery was joined together including orientation devices are calculated in vibratory feeder cost and gripper cost calculated in positioner cost. Preventative maintenance cost was also calculated for each machinery. Some values were not available online so estimations were made. Calculations are shown in Appendix 3.

| | |
|---|---|
| Total Equipment cost estimation | $401,265.00 |
| Total yearly maintenance cost estimation | $119,847.00 |

## 4.2 Maintenance

Jamming or other forms of machine error can cause the whole assembly system to fail. While manual maintenance takes place because of a fixed machine the assembly system is not running. The objective of maintenance is to limit the amount of time the assembly system is not functioning. Therefore, preventative maintenance will be the focus of the ball valve assembly system. Though this may come with additional cost, this will prevent long periods of time with the assembly system not running where revenue is not being produced. Through analysis of all the machinery used in the assembly process including feeders, escapements, positions, and the assembly line. Maintenance check-ups on each of these machines will be scheduled appropriately. These preventative maintenance measures will stop machine failure from happening on a consistent basis. Jamming at times can not be prevented especially inside the vibratory feeders which are more prone to jamming. An on-site maintenance team will always be present to fix jamming and any other machine failure to limit the time spent without the assembly process in progress. The on-site maintenance team will also perform routine check-ups on machines for quality control.

## 4.3 Line-Evaluation

The goal of the assembly process is to create a process that results in a product that satisfies the needs and expectations of the consumers. The assembly process should meet the specifications set for the design. This can be completed via two processes: on-line quality control and post-process sampling. As the assembly design is a cost-effective design cost of quality control methods such as inspection on 100% of products post-process is not economical. However, the cost of quality control must be considered with the cost of poor-quality products. The assembly process for the ball valve structure will implement both post-process sampling and online quality control.

Post-process sampling will be done with an off-line product inspection. This inspection will only be performed on a small percentage of products. The online quality control is designed to remove 99.9% of the products that do not meet the specifications. An important specification of the valve is the ability to not leak fluids when in use. API 598 Valve Inspection and Test will be performed to test for leaks[12]. Along with testing on the structure and dimensions of the valve. The offline product inspection will only be performed on 1 in every 1000 completed products by the assembly. The on-line quality control is designed to have the product meet design specifications. If the post process sampling were to fail this would be cause for manual inspection of the on-line quality control process.

On-line quality control will be performed on the assembly line. Before an additional part is added by a positioner at each station, automatic inspection of the product will take place. This inspection will test that the positioner at the previous station correctly added the new part while also utilizing an electro-optical system to measure the dimensions of the product, specifically the recently added part. If the product does meet the set specifications for that station the positioner will not add a new part and the product will continue down the assembly line and not receive any new parts at each station. At the end of the line, it will be separated from the finished products that pass specification. The automotive assembly process is to have less than 1% of the products being assembled fail on-line inspection. These products after failing on-line inspection will either be disposed of or disassembled for parts to be recycled into the assembly process.

In the valve automation assembly system, the on-line quality control process is to remove 99.99% of products that do not meet specifications. The post-process sampling will test the product for functionality that cannot be done. Along with being a safety net for the on-line control, identifying any possible error that could suddenly appear with the on-line quality control system.

## References:

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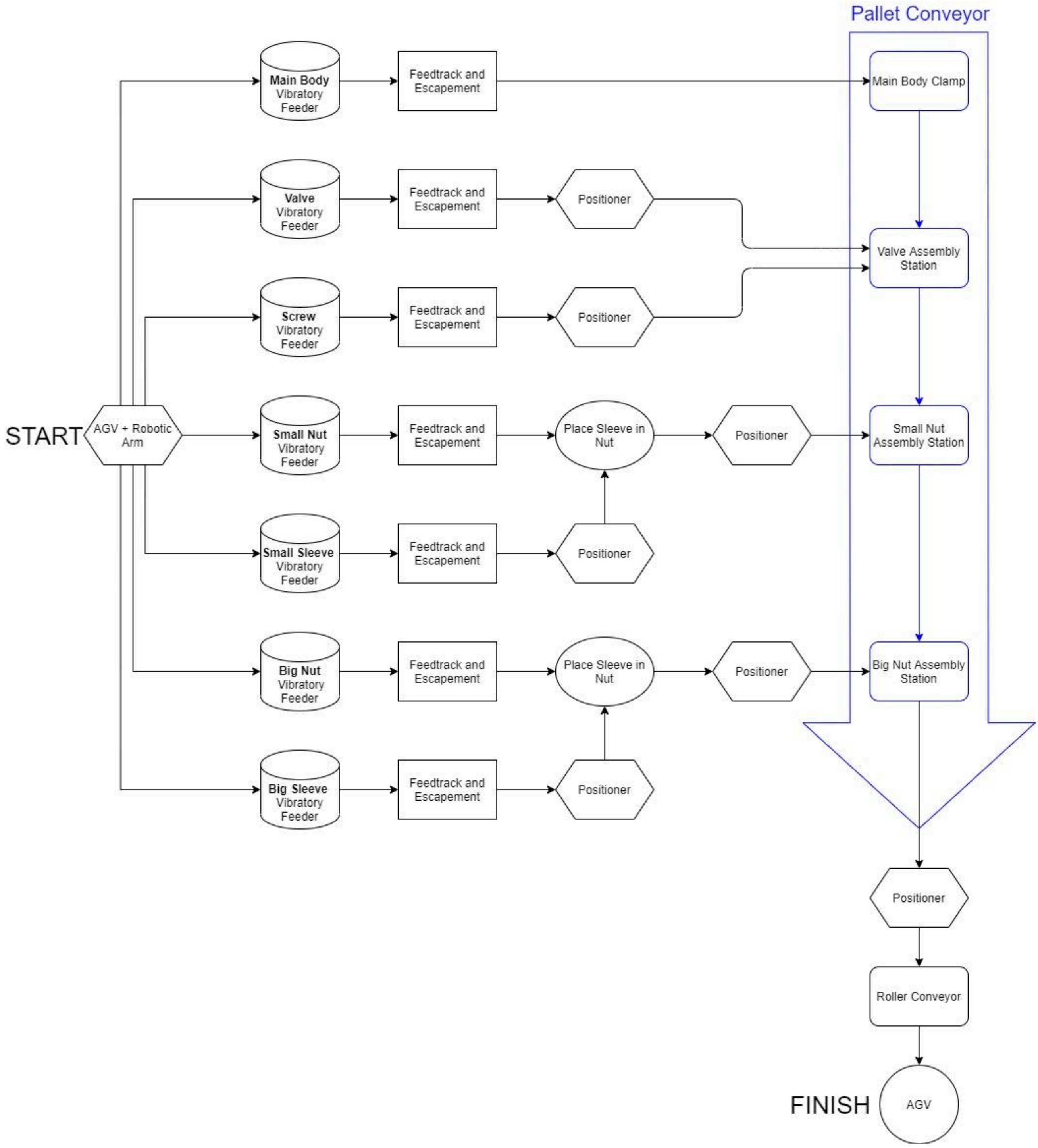
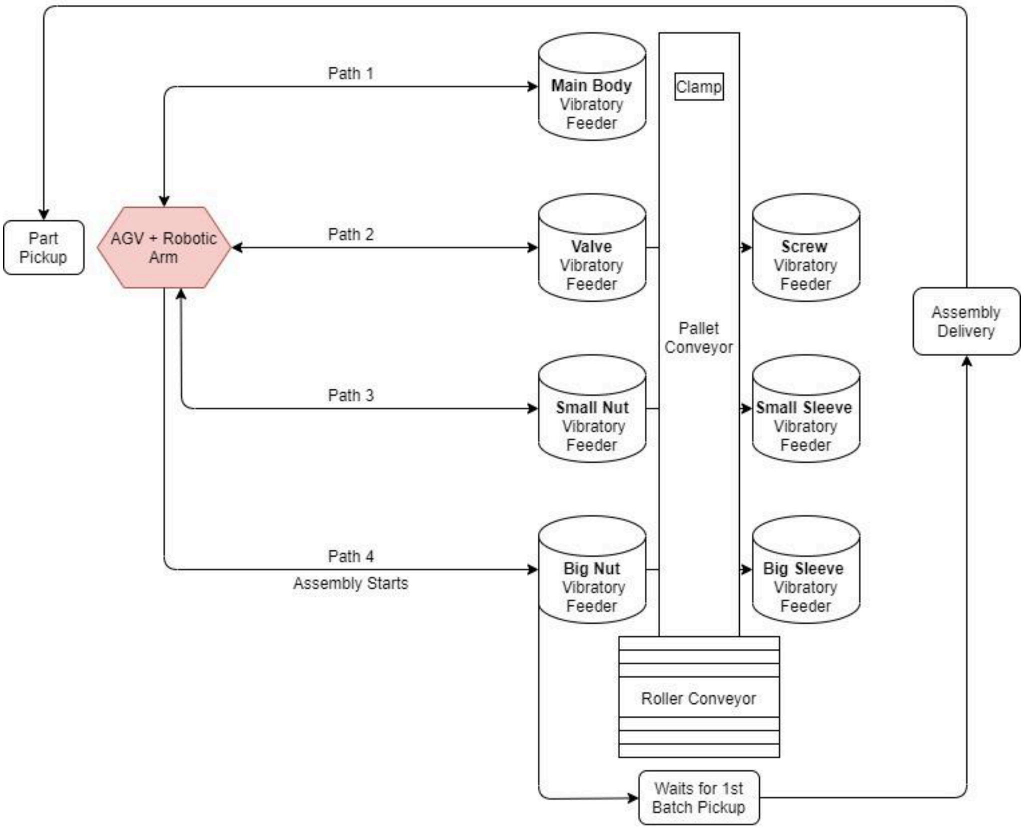
[12] “Valve Inspectoin Testing,”American Petroleum Institute. 2004. [Online]. Available: https://www.valve-world.net/pdf/API_598_Valves_Inspection_and_Testing.pdf.

# Appendix

**Appendix A:** Flow chart of the Assembly Process

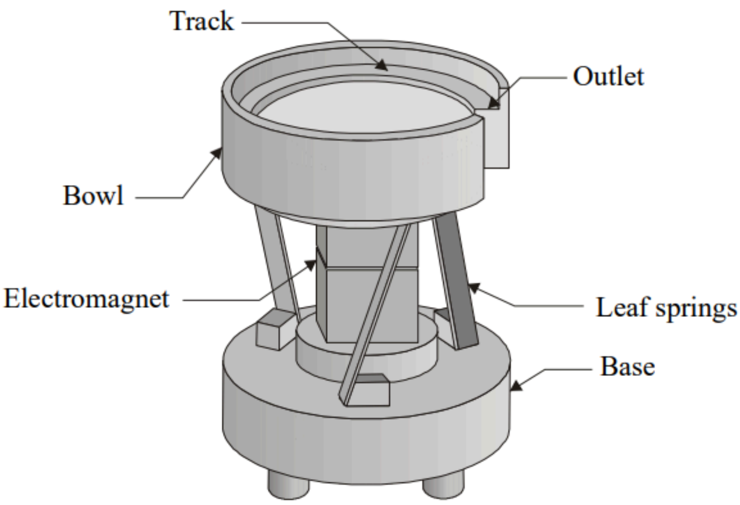



**Appendix B:** AGV path and machine positioning




**Appendix 1.1:** Individual Part Names


**Appendix 1.2:** Vibratory Feeder




**Appendix 1.3:** Stable orientations for all parts.

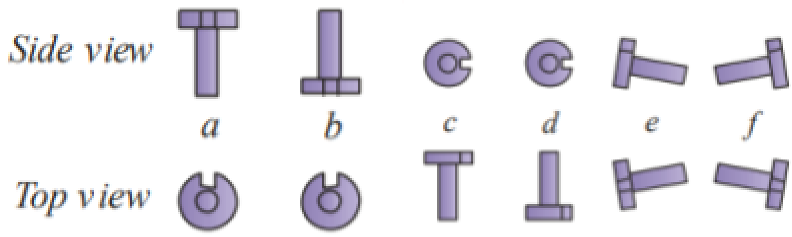
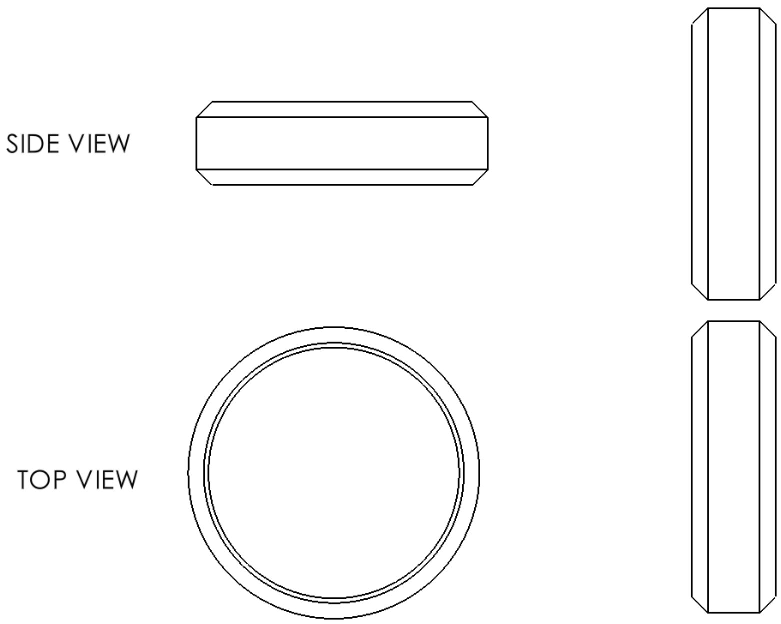
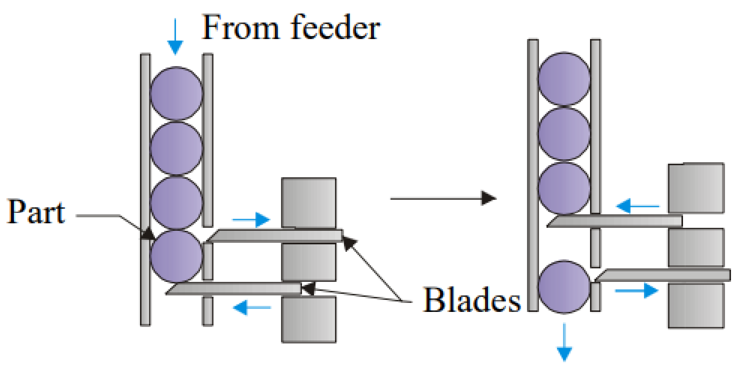



Figure A1.3.1. Stable orientations for Valve and Screw structure




**Appendix 1.4**: Ratchet Escapement




Ratchet escapement

**Appendix 1.5:** Possible positioners for their respective parts .

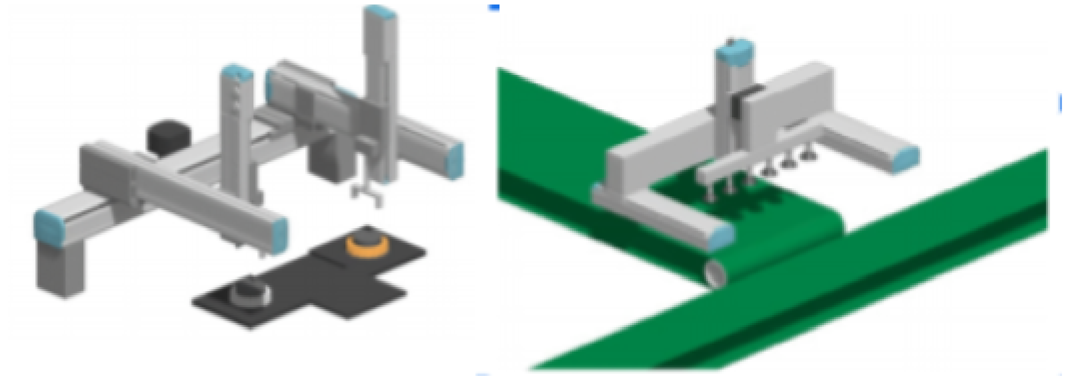


Figure A1.4.1: Possible 2dof positioners for sleeves and valves

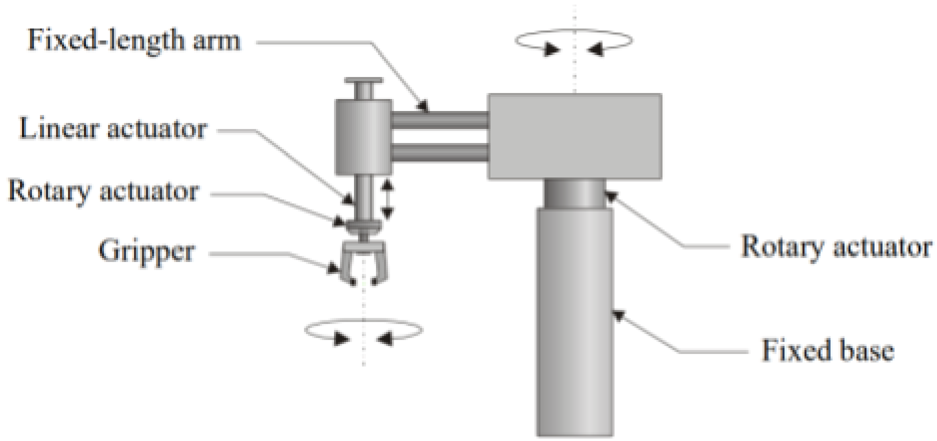
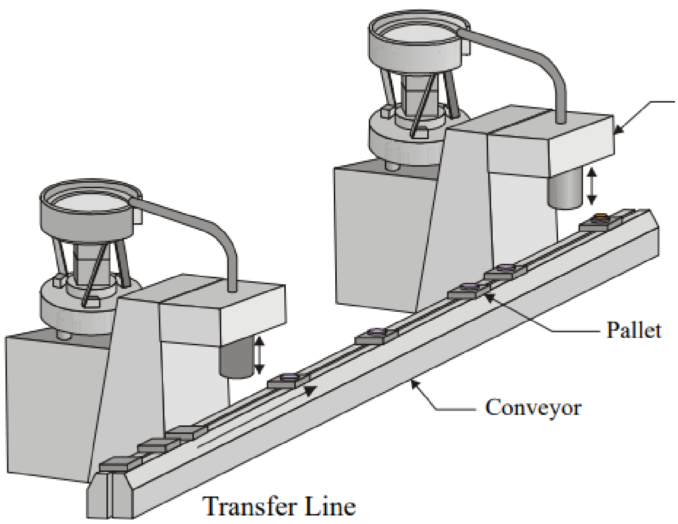



Figure A1.4.2: Possible 3dof positioners

**Appendix 1.6:** Pallet Conveyor



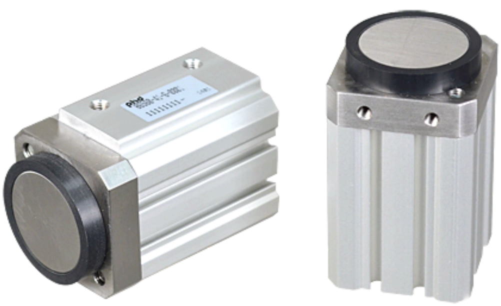
**Appendix 2.2:** Video for the AGV with Robotic Arm

https://www.youtube.com/watch?v=dsQsGGiojAI

**Appendix 2.3.1:** Two Finger Mechanical Gripper For Transporting the Main Body


**Appendix 2.3.2:** Two Finger Gripper for Attaching the Sleeve to the Nut


**Appendix 2.3.3:** Magnetic Grippers



**Appendix 3:** Table of Cost

| Machinery | Quantity | Equipment Cost | Maintenance Cost(yearly) |
|---|---|---|---|
| Vibratory Feeder | 7 | $30,000.00[3] | $12,000.00[3] |
| AGV | 1 | $20,000.00[4] | $15,000.00[5] |
| Pallet Conveyor | 1 | $1,980.00[6] | $300.00[6] |
| Positioner 3 DOF | 5 | $23,000.00[7] | $3,000.00 |
| UR 5 AGV Arm | 1 | $35,000.00[7] | $3,000.00 |
| Event-based escapement | 7 | $300.00[8] | $100.00 |
| AGV Gripper | 1 | $1,185.00[9] | $47.00[9] |
| RG2 Gripper | 1 | $4,000.00[10] | $300.00 |
| Positioner 2 DOF | 2 | $6,000.00[11] | $750.00 |