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Design of the suction table for plasma and oxy-fuel CNC cutting machine

Diplomová práce

Studijní program: N2301 – Mechanical Engineering
Studijní obor: 2302T010 – Machines and Equipment Design

Autor práce: **Sakthi Sai Thamizhchelvan**
Vedoucí práce: Ing. Petr Zelený, Ph.D.

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Master thesis

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Supervisor: Ing. Petr Zelený, Ph.D.

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(PROJECT, ART WORK, ART PERFORMANCE)

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[1] BUDYNAS, R. G. and J. K. NISBETT. Shigley's Mechanical Engineering Design (in SI Units). 10th ed. Asia: McGraw-Hill, 2015, 1104 p. ISBN 978-981-4595-28-5.

[2] MAREK, J. et al. Design of CNC Machine Tools. Praha: MM publishing, 2015, 730 p. ISBN 978-80-260-8637-6.

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Abstract

The Thesis is about various works carried out to design an exhausted table for Plasma and Oxy-cutting CNC machines for the company VANAD s.r.o. This modular table concept primarily serves three machines manufactured by the company. The whole document is a summary of analysis of existing solutions, market trend, feasible design, improvement of design on manufacturing basis, designing a mechanism for exhaust vent, designing a proper switching based on position of the gantry.

Currently the company Vanad uses tables manufactured by the companies KEMPER and TIGEMMA as per customer request. This thesis is to help them build their own table in modular form, so that the tables can be coupled together for required sizes. The whole design work is carried out in SOLIDWORKS and the mechanism is designed in FLUIDSIM as required by the company.

Key words:

Suction table, Extraction table, Oxy and Plasma cutting, Vanad table, Modular table for extraction, table design.

Abstrakt :

Tato diplomová práce se zabývá několika návrhy odsávaných stolů pro CNC stroje pro řezání plazmou a kyslíkem firmy VANAD s.r.o. Navržený koncept modulárních stolů je vhodný především pro tři typy strojůvyráběnýchfirmou VANAD.Práce obsahuje analýzy stávajících řešení, tržních trendů, proveditelnosti návrhu, zlepšení návrhu pro výrobu, návrh mechanismu pro odsávání a návrh spínání odsávání na základě polohy portálu. V současné době společnost Vanad používá stoly vyráběné firmami KEMPER a TIGEMMA podle požadavků zákazníka. Výsledek této diplomové práce firmě VANAD umožňuje sestavovat vlastní stoly v modulární podobě tak, aby stoly mohly být vzájemně propojeny do požadovaných velikostí. Celá konstrukční práce byla provedena v software SOLIDWORKS a mechanismus je navržen v FLUIDSIM podle požadavků společnosti.

Klíčová slova:

Sacístůl, Odsávacístůl, Kyslíkové a Plazmovéřezání, Modulovýstůl pro odsávání, návrhstolu.

Contents

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Foreword

This thesis is mainly focused on providing an optimal solution for plasma and oxy-cutting CNC machines, in suction of the exhaust gases and fumes. The thesis also explains the design concepts used and the mechanisms for sectional suction of the fumes.

The introduction part briefly talks about the prevailing situation which needs the solution. Which is then followed by the research work to travel through the right path for solution. The research work greatly breaks down the time for starting from scrap and to gather the knowledge from existing solutions.

The research work is then followed by an explanation to the work done and the design concepts for effective and optimal solution for the company.

The complete work is then justified and provided with assembly drawings and manufacturing drawings in order to help better understanding.

1 Introduction

The most often missed fourth state of matter – PLAMSA, can't be missed out from metal cutting, for this being the most popular method in manufacturing shops for steel or any other metal. This method primarily involves forcing out inert gas through nozzle at very high velocity to create an electric arc. This electric arc turns this gas into plasma.[1]

Plasma cutting creates a brand of smoke which is highly hazardous. This is called Hex Chrome. This element is recognized to be cancer causing agent. Inhaling of this increases the probability of lung cancer, damages to kidneys and intestines. Exposure to this element creates throat and nose irritations, rashes, eye damages.[2]

This hexavalent chromium, also known as hex chrome, is not only a by-product of plasma cutting, but are exposed even from welding, thermal cutting and laser cutting.

Because of these hazards, it is mandatory that the workers get proper protection from hex chrome. People working with plasma should be given proper protective gears. Apart from this, following standard OSHA safety guides[3], these dangerous gases should be properly ventilated. Proper dust and fume collector should be set up to dispose plasma dust. This should be done in a controlled environment.

This is the primary need for the exhausted table for plasma and oxy cutting CNC machines. The table is designed such that it also acts as the work bed for the machines. Apart from these functionalities, the table is designed in a modular form, so that it can match any dimensions required by the customer. This table design is mainly going to be used for three machines in Vanad.[4]

Aim of the thesis:

The main aim of the thesis is to provide an optimal solution for the company Vanad in extraction of the fumes and smoke for their plasma and oxy-fuel CNC cutting machine. The thesis is focused in a way that it also solves the problem effectively and cost efficiently, along with a scope for future improvement. The design of mechanism for separated suction of fumes and gases is highly focused along with a modular design in order to match different dimensions as required by the customer.

The design is to be made such that the solution is obtained from available resources from the company and dismissing the need for any new resources.

The whole design is to be completed along with a fully functional mechanism within the time constrain.

2 Description of CNC system for which the table is to be designed

2.1 VANAD SUPREMA:

SUPREMA is designed basically considering small and mid-sized companies for plasma cutting. Thanks to several torches which facilitate processing large metal sheets quick and precise without any downtime. With a possibility of manual bevelling, this machine is suitable for general two-shift operation[5]. Suprema is ultimately the commercially most needed machine of the three and therefore needs a varied range of customization in the table dimensions.

- The dynamic properties of the machine is boosted by the high torque of the motor.
- The front panel got a big touch screen, control of ignition and working height of torch, which all sums up to increase in productivity.
- Ready to install plasma system.

Features:

- Movement of the torches facilitated by linear guides on all axes.
- Sheet thickness that can be cut: 175mm.
- Data transfer done via LAN, USB. [5]
- Suprema can be equipped with Vanad RotCUT, for precise tube and profile processing.
- Working width of the machine: 3134 mm (max), for variant 30.
- Working length of the machine: 12580 mm (max), variant 30.[6]

Fig 1 Vanad Suprema[7]

2.2 Vanad arena

Vanad ARENA is designed considering the mid-sized companies. With high accuracy and high reliability, this is more suited for metal cuttings. This can be equipped with both plasma and oxy-fuel torches. ARENA uses B&R control system. This helps achieve greater efficiency and makes the machine more user friendly.[8]

- Equipped with bilateral longitudinal drive.
- High reliable control system.
- Data transfer via USB and LAN.
- Ignition and work height of torch can be controlled precisely.

Additional equipment:

- Laser pointer for locating cut position.
- CAD/CAM software for cutting data preparation.
- Ignition of torch by electrical method.

Features:

- Suited for longer operational time.
- Can be used with both plasma and oxy-fuel technology for metal cutting.
- Working width of the machine: 2134mm (max), for variant 20.
- Working length of the machine: 6230mm (max), for variant 20.[9]
- Can be used for cutting metals up to 150mm thickness.[8]

Fig 2 Vanad Arena[10]

2.3 Vanad MIRA:

This CNC cutting machine is the little brother of the previous machines. This is built mainly considering small industries and small operations in mind. Mainly suitable for new startups of thermal material cutting industries, Mira, can easily machine standard metal sheet formats.[11]

- This CNC machine can couple with standard air plasma systems, since it shares the concept of the cutting machines designed for oxy-fuel and plasma cutting of materials.
- The oxy-fuel can be used for cutting thicker metal sheets.
- This machine got two axis longitudinal drive.
- This is equipped with user friendly B&R control system.
- Mira got flexible energy chains.[11]

Features:

- Completely user friendly and compact.
- Equipped with POWER PANEL 500 along with technological keyboard for smoother and easier operation.
- Versatile, cuts materials up to standard thickness of 100mm.
- Working width of the machine: 2134mm (max), for variant 20.
- Working length of the machine: 6280m (max), for variant 20.[12]

Fig 3 Vanad MIRA [13]

3 Possible solutions for suction of fumes and smokes containing Hex chrome:

The removal of fumes and smoke can be achieved by various methods. On analysing Industrial trends and market, we can come to conclude over four feasible solutions to meet the needs.[14]

A. Range hood ventilation over the top
B. Separate fume extractor system
C. Water table
D. Exhaust table

- The above solutions are takes as case studies and will be researched extensively over the pros and cons of the same.
- Upon reaching the maximum level of research needed, all solutions will be justified based on the most feasible and most appropriate method.
- The study of these solutions opens up the gateway to the important factors to be considered while designing an optimal solution.

The **main factors** that are going to influence the suitable solution are as follows:

- The suitability to the cutting condition, should withstand elevated temperature.
- Should not react with the cutting material.
- Should not alter the cutting procedure.
- The efficiency in extraction
- Cost effectiveness.
- Degree of customization.
- Maintenance frequency and reduced downtime.

3.1 Range hood ventilation over the top:

This system is as simple as having an overhead ventilation system to extract fumes and smokes[15]. Ready to operate provided electrical supply and a duct to connect the table to the blower.

- Range hoods are capable of capturing 70 – 80 % of total smoke and dust.[16]
- The remaining smoke and fumes escapes to the ambience.
- This also leads to heating up of the work environment.
- Mostly the contaminants are pushed outside to the environment, which in our case, is not advisable.[17]
- Proper dust collector can be installed to filter out the contaminating particles before releasing the air out.
- This can be set up both vertically and horizontally, based on the requirement.
- A little difficulty is faced if the tube is placed vertically as it should be climbed for any kind of servicing.[18]

Fig 4 Range hoods [19]

3.2 Fume extractor system:

This is the method of capturing smokes and fumes by means of nozzles and extraction guns right at the source or over and around the work area. The method of extraction differs with each manufacturer but the operation level principle remains the same – either by “mass flow” or by “movement of material”.

- This movement of the material is achieved by a vacuum chamber, which sucks through the extraction gun.
- This gun is connected to the filtration system through flexible hose.
- The level of suction can be varied as required.
- Few manufacturers provides adjustable suction via control regulators at the gun handle, whereas few provide this function internally.
- The big advantage of this method is that the gun remove the fumes right at the source, reducing the amount of fumes being exposed to operator’s immediate breathing.

Fig 5 Fume extractor [20]

3.3 Water table:

This method is well known for its smoke arresting capability as this captures 98% of the smoke and dust.[21] This level is adjusted by adjusting the height of the water level at the table during the cutting process.[22]

- The water level can be controlled by compressed air, eliminating the usage of separate pumps for the process.
- Normal plant air pressure, at 120 PSI, is used to raise or lower the water level.
- This is done by hand operated valve.
- This air is used to force the water out of the air chamber and to raise it to the upper deck.
- This trapped air is again released through the hand operated valve in order to lower the water level in the table.[23]
- This can also be achieved with installation of proper electric solenoids.
- However, this needs extensive maintenance and few won't prefer it.
- Moreover, water cannot be used with all materials being cut as some may lead to corrosion.
- This may get even worse with freezing conditions.
- The initial set up is going to be much difficult with water table.
- Some cutting conditions may not prefer cooling up of the material immediately when being cut.
- The water might sometime spoil the blow torch, leading to series of failures in machines.

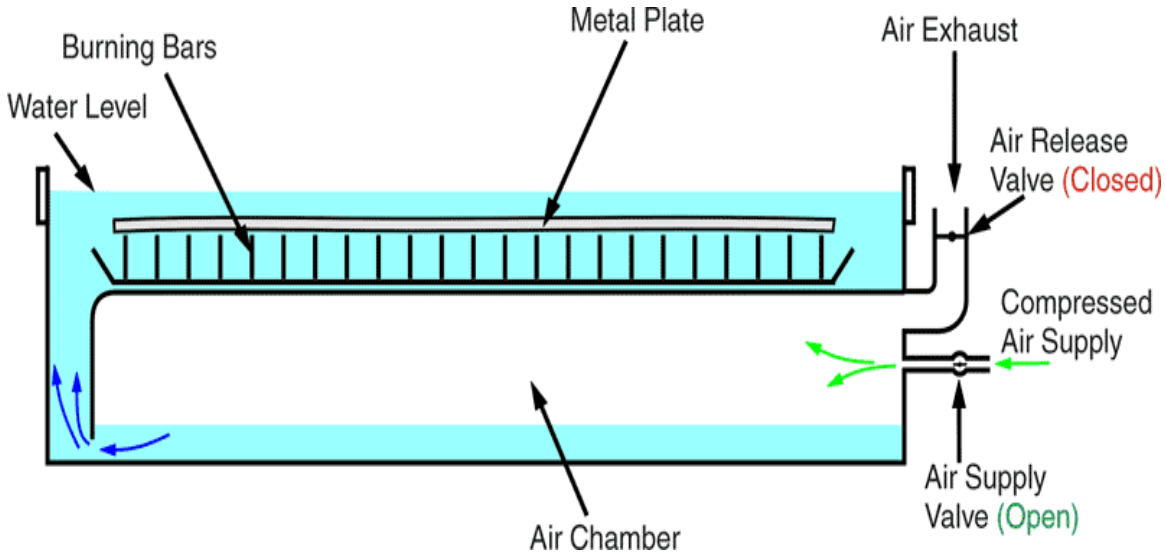

Fig 6 Water table 1 [22]

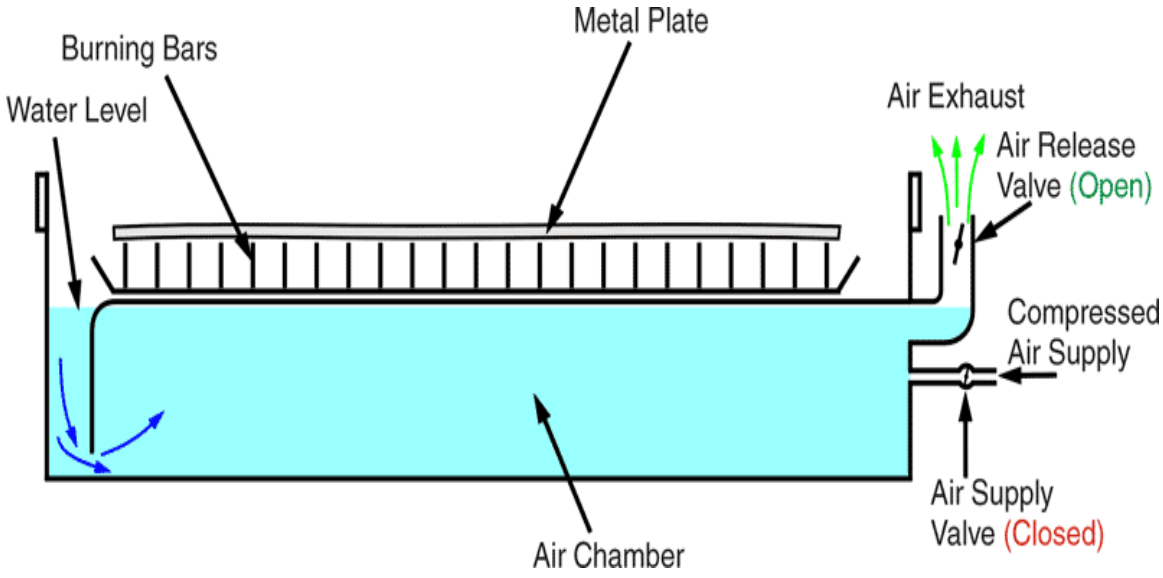

Fig 7 Water Table 2 [22]

3.4 Exhaust table:

Exhaust tables are simply the tables for extraction of fumes which also couples as the work bed for the cutting machine.[24] This method is commonly practised over various machine shops owing to its advantages and efficiency.

- This is as simple as placing a table right below the work piece and the cutting machine.
- Exhaust tables are highly preferred in places where the left overs should be removed easily without much efforts.[25]

- **Extraction segments:**
    - The table is segmented so that the extraction can be kept at very effective and low level.
    - This segmentation also helps in extracting fumes as well as leftovers only at the place where the cutting process is taking place.[24]
- **Fire safety:**
    - The cutting process leads to sparks being spit out from the material being cut. This might lead to serious fire.
    - This is prevented in tables as the sparks will be sucked up
- **Cleaning:**
    - Regular maintenance is important for the table for smoother and effective functioning.
    - This table got chambers which can be removed to clean the leftovers that are collected over the period of cutting process.
    - These chambers often comes with crane hooks for easier lifting.[26]
- **Work bed:**
    - This also provides the proper rigid support to the workpiece that is being cut.
    - Slats can be used to rest the work piece which do not react with the material during the cutting process.
    - These slats can be changed over a period of time.

Fig 8 Extraction table [27]

4 Justification on most feasible solution:

Evaluating all the possible solutions carefully for their merits and demerits, the solution that more suits Vanad is Exhaust table. This is justified as follows.

- Usage of range hood and fume extractor guns are good in removing smoke and dust, but they don't provide a support to the work piece like water table or exhaust table. Also the smoke that escapes through this system is still going to be hazardous to the operator.[17]
- While considering water table, it is ideal in trapping smoke and even keeps the work piece cool, yet it is not suited for all materials.
- Water table got its own maintenance methods which are not quite easy, moreover things gets more difficult with winter.[23]
- Exposure to water might result in easy oxidation of the material being cut.
- So analysing all possibilities, it seems exhaust table is the most suited method for smoke and fumes extraction while providing support for the work piece as well.
- Whereas, maintenance and construction are much simpler with exhaust table since it got separate segments and compartments.
- Exhaust tables can be built as modular setup to match the need for different lengths of the work area as required by Vanad.

5 Market trend in exhaust table:

Upon selecting exhaust table to be used for cutting machines, the existing market trends are analyzed and documented for the study purpose and improvements.

The various variants from different manufacturers are as follows.

5.1 Downdraft table wt by Tama Aeronova

This table is mainly designed for plasma and oxy-cutting machines which allows supporting of the work piece and this facilitates capturing of the fumes, dust and swarf [28].

- The cutting table can be activated part by part in the areas where the cutting process is taking place by the cutting machine itself in order to utilize a reduced air flow in particular zone for better efficiency.
- This got better aspiration due to higher capacity tanks.[28]
- The compartments can be removed easily from the machine without the need for removal of entire machine, facilitating to easier cleaning and disposal of the waste materials collected.
- This got an adjustable feet which helps in easy leveling up of the work height of the bed.
- It is easy to replace the venting panels.
- Got rigid pipe connections and controls with pneumatic valves for exhaust vent.

Fig 9 Downdraft Table by Tama Aeronova[29]

5.2 Tigemma

Tigemma is another successful table manufacturer in the market and they got two variants that are suitable for vanad machines. They are explained as follows.[30]

5.2.1 Light series with capacity up to 390 kg / m²:

The light series tables are known for its low weight and cost. This is mainly designed for plasma cutting process and the maximum weight of cut material is 390 kg/m^2. Even being light, these tables are rigid and stable.

- The tables are designed with ergonomics in mind.
- Work area and the compartment spaces are high so that the workpieces got the comfortable working conditions.
- The table is completely made with high quality finish RAL steel sheets.[31]

Optimal design of the table ensures high suction efficiency, safety and ease of access. With comparison with conventional extraction tables, they do have more efficient suction per unit area.Even though the table is designed as single unit, separate sections can be activated for the exhaust purpose.

- This table uses mechanical method, as well as electro-pneumatic switching for above purpose.
- The size of the container ensures longer period of operation before next cleaning, cutting maintenance costs.

Fig 10 Light series table [32]

5.2.2 Exhausted tables for mid-range capacity up to 1800 kg / m²:

These tables are designed mainly for plasma and thermal cutting of the metal weighing up to a maximum of 1800 kg/m^2.[33]

- These tables are designed for a higher level of safety and optimum extraction.
- This again uses the surface suction technique as above which is more efficient and uniform than conventional methods.
- The Mid- range table normally implies three to four standard section modules.
- Any desired size of the table can be achieved by combination of modules.
- Bigger size of the table make sure a prolonged interval of cleaning, which also facilitates lesser maintenance cost.
- Sectional activation of the exhaustion is made possible through electro-pneumatic switching from feed input from position of gantry on rail guide.
- A sheet of thickness of 220mm maximum can be cut.
- Grid frame like structure prevents falling of bigger pieces of cut materials into the container.
- Work height of the table is 700mm.[34]

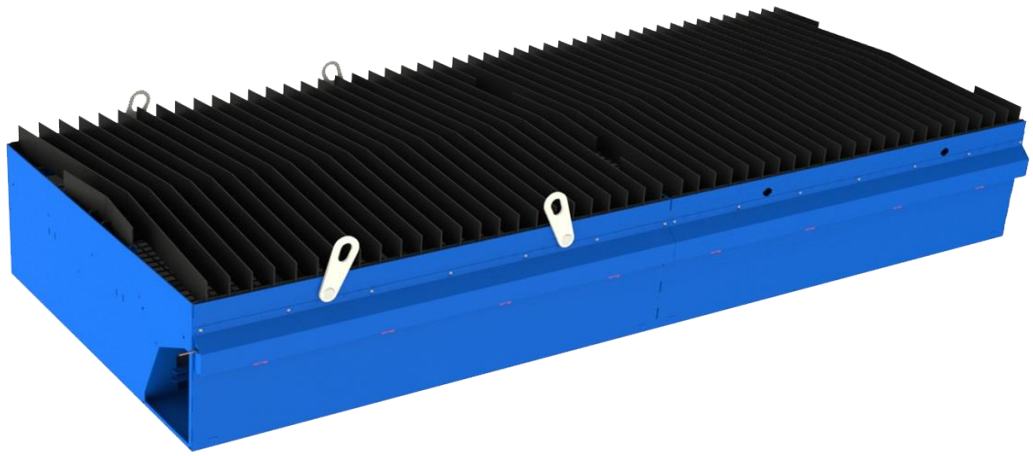

Fig 11 Mid-range series table [35]

5.2.3 Heavy series table:

This heavy series table is mainly designed for demanding applications in terms of heat and mass, having a maximum loading capacity of 2400 kg/m^2.[33]

- The researched and developed design makes sure higher grade of safety coupled with optimum extraction of fumes and comfort.
- This also uses the same principle as suction surface as its smaller versions of tables, which is proven to be more efficient and uniform.
- Generally composed of three to four modules of standard sections, still any desired size can be achieved by combination of the same.
- The sectional opening of the flaps is controlled by electro-pneumatic switch which will be operated by the gantry depending on its position on the rail guide.
- Have a very less maintenance cost, owing to rigidity and reliability of the device in toughest environments.
- The tables are designed to cut metals of thickness 300mm maximum.
- The work height of the table is 738 mm.[36]

Fig 12 Heavy series table [37]

5.3 Kemper Extraction tables

5.3.1 KemTab Basic Extraction Table

The most basic version of extraction table available with kemper. However this is capable of cutting materials up to 75 mm thick. This handles a cutting current up to 150 A.[38]

- Even though this is designed for 150 A current, this can handle short peaks of 250 A.
- Uses their own easyFRAME technique for the material support.
- The material support frame can be easily replaced upon wear due to cutting.
- High volume containers helping less maintenance downtime and cost.
- Modular table design.
- The slats can be made easily with provided drawing for the same or even any custom design can be made.
- Pointed slats can be used in case of cutting of very minute dimensions in order to make sure the cutting metal don’t take up any shrugs or pieces of material from the slats.

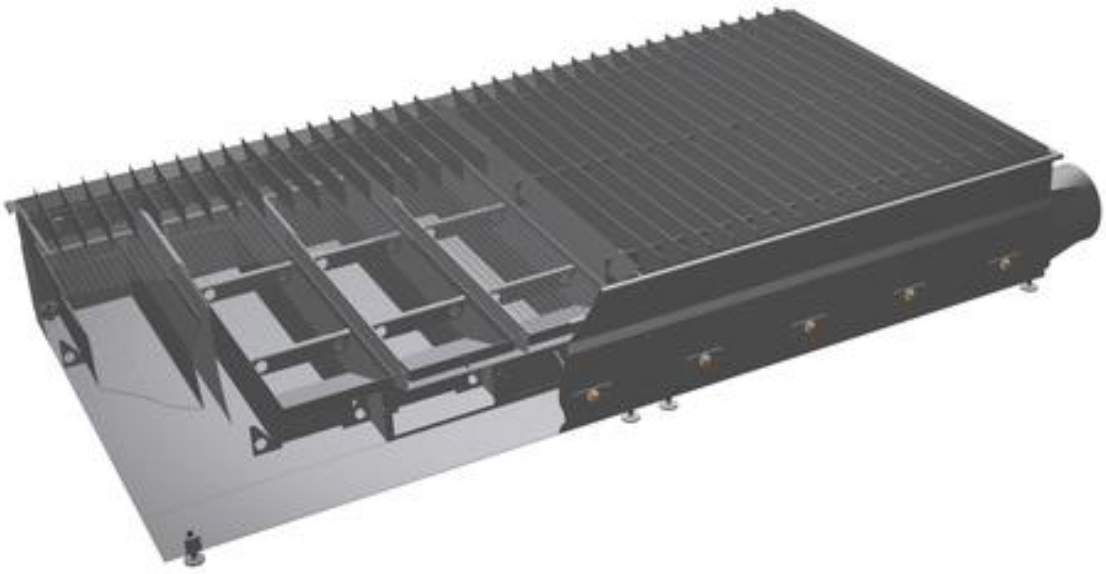

Fig 13 KemTab Basic [39]

5.3.2 KemTab Advance Extraction Table

This is designed as a solid and a flexible cutting table. This variant of the table handles up to 300 A of cutting current and a thickness of up to 150mm.[40]

- This again uses easyFRAME technique to separate the container and the material support which improves the life and the rigidity of the table.
- Very high container volume and lesser extraction volume adds up to lesser maintenance and efficient exhaustion.
- Separate modules can be activated with the help of various pneumatic control option.
- Modular design to match any dimensions required.

Fig 14 KemTab Advance [41]

5.3.3 KemTab Vibro Extraction Table

Kemtab Vibro is mainly designed for solid needs of the cutting process ranging from medium to high requirements. This is equipped with an automatic discharge system. This is designed to handle a cutting current of 400 A and can handle short peaks of 450 A. This can withstand cutting materials up to 150 mm thick.[42]

- Claims automatic slag discharge system which eliminates the regular break down of the process to clean the containers.
- The material support system and the table frame are distinctively separate ensuring a better rigidity of the table.
- Very rare or lesser maintenance procedures required, cutting the maintenance costs.
- Better utilization of the compartment area along with automatic slag removal.

Fig 15 KemTab Vibro [43]

5.3.4 KEMPER KemTab HiEnd Extraction Table

Kemper is another successful extraction table manufacturer which got different variants depending on the capacity.[44]

The Kemtab Hiend version is more suitable for heavy demanding operations such as cutting metals up to 300mm thick and a capacity of 600 A.

- This variant got larger slag trays for very less downtime and less maintenance, both in terms of cost and occurrence.
- Most suitable for applications with high cutting amperages.
- This is being more rigid owing to that the material support surface and the table construction being separate.
- The pneumatic system is placed externally.
- No mechanical system for switching of flaps which is replaced by electro pneumatic system provides lesser mechanical failure.
- Wear on the pneumatic system is comparatively lesser as it is placed separately from the exhaust air stream.
- Available for various dimensions of requirement.

Fig 16 KemTabHiEnd table [45]

5.4 Vicon HVAC 510 Plasma Cutting Table

This table got a very rigid design yet flexible design and acts as optimal solution for extraction system. The table is made as a one piece downdraft table.[46]

- Got separate controller for activation of exhaust flaps for segmented exhaust system.
- Matches with basic to mid-range tables of its competitors.
- For cutting process of metals up to 200mm.
- Got a table height of 35''.
- This variant is available along with the cutting machines and additional torches for combined usage.
- The controller can be customized with the needs of the customer.
- Got a bigger variant as well for demanding conditions and performance, but this variant falls along our category.

Fig 17 Vicon HVAC 510 [47]

6 Basic design of the assembly:

The basic design layout got four main assemblies as follows:

1. The main framework
    a. The shell assembly
    b. The exhaust vent assembly
    c. Separator assembly
    d. Support to the cutting material
2. Bucket assembly
    a. Bucket frame
    b. Side plates and support
    c. Bucket lift
3. Mesh plate assembly
4. Frame with slats
    a. Support frame
    b. Slotted guides
    c. Slats

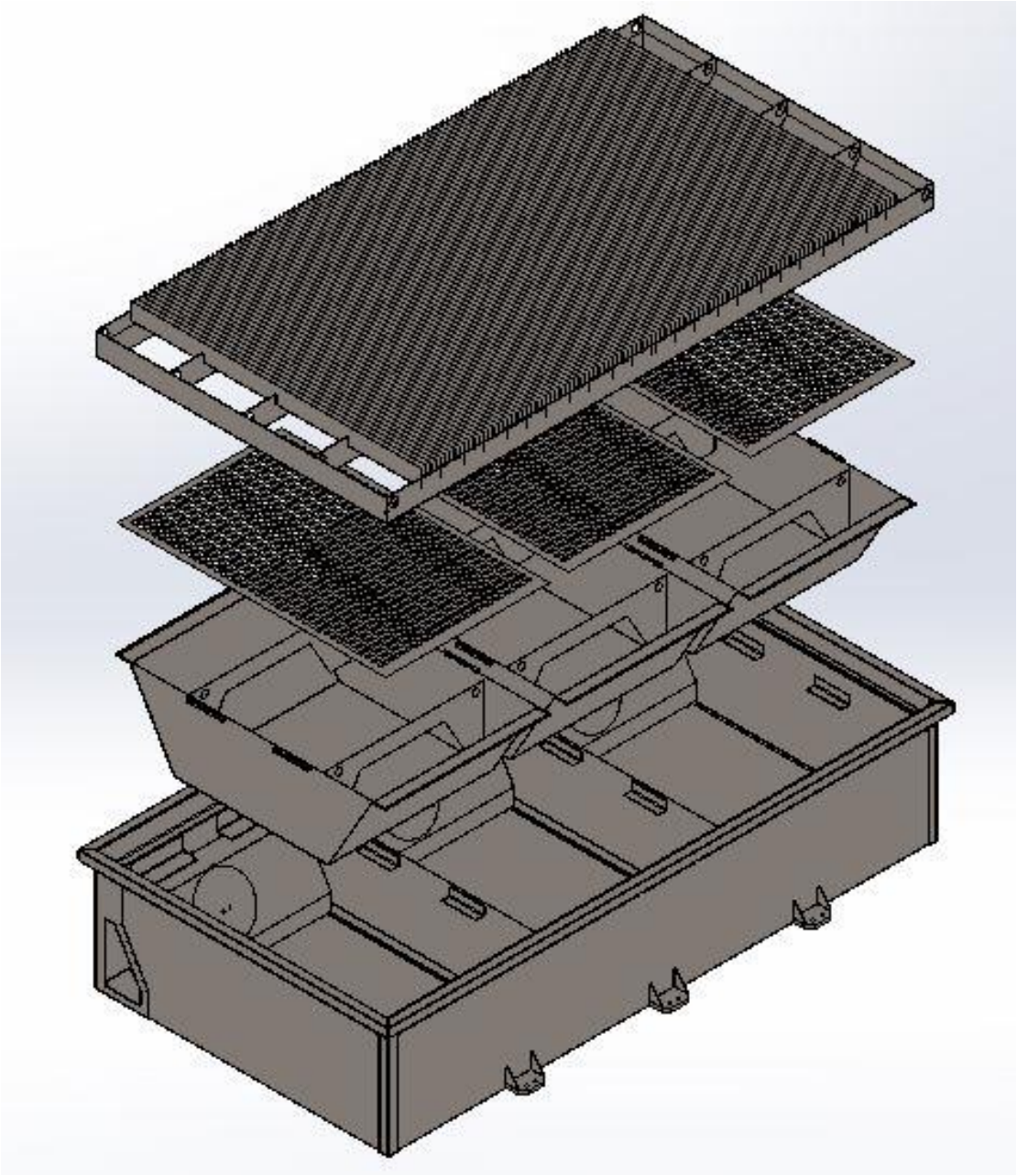

Fig 18 Exploded view of sub-assemblies

6.1 The main framework:

The main framework is designed in a way that it acts as the base as well as the support for the entire table. The main frame is built in a way that it separates the support for the cutting material and the containers. Thus improving the rigidity of the design. [Refer appendix A]

6.1.1 The shell assembly:

The shell assembly is the skeleton of the suction table. The shell got the baseplate where the containers are made to rest. Sides of the shell assembly got the fixtures for attaching the table firmly to the ground. In case of increasing the work height of the bed, which is not currently needed, is also possible by adding screws to the same and adjusting.

The side walls got the L-flange at the first layer over the top to provide support for the frame with slats, over which the work piece is going to be placed. L-flanges over any other methods provide more rigidity and makes sure the support is strong enough for robust design.

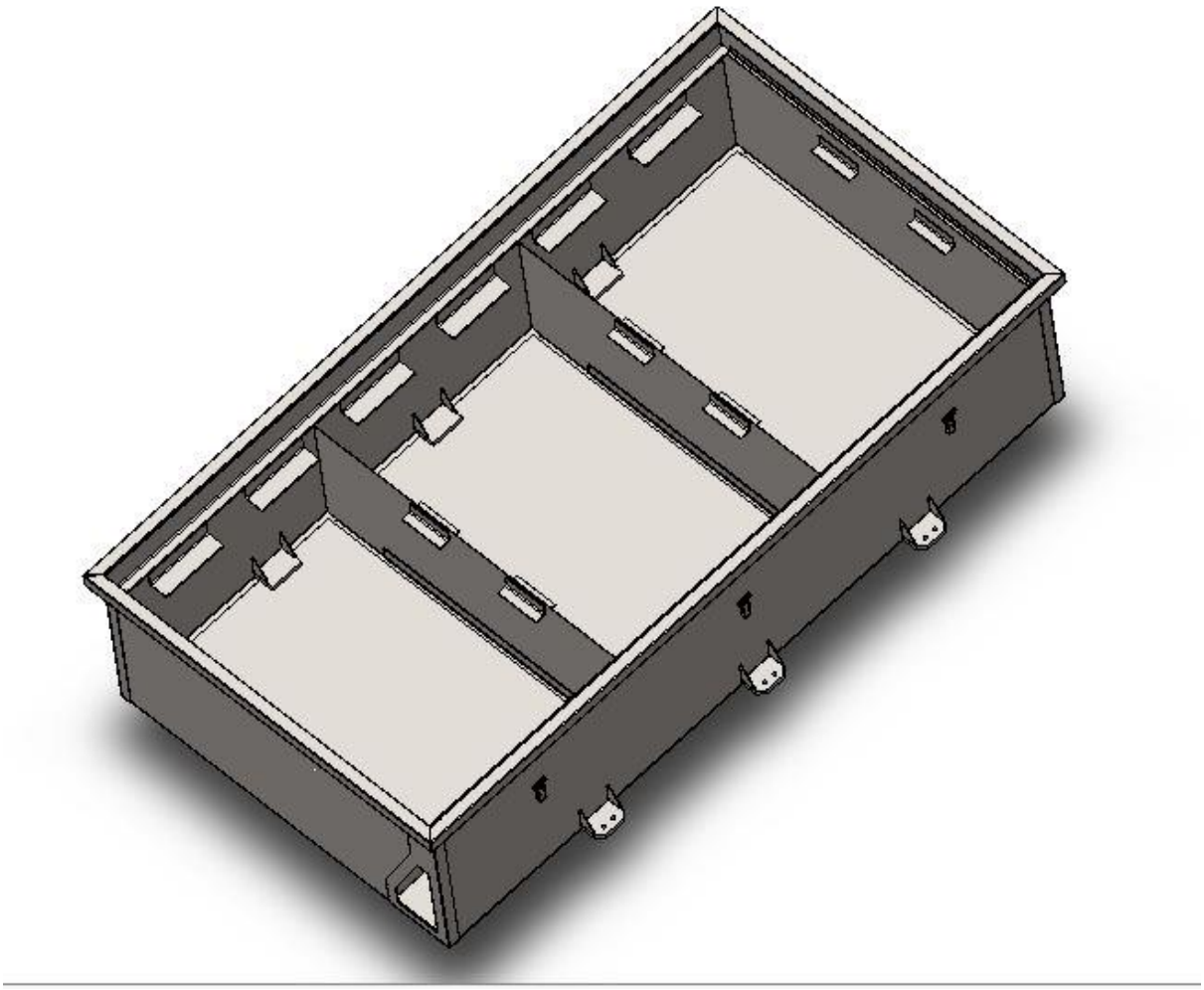

Fig 19 Shell assembly

6.1.2 The exhaust vent assembly

This is the most important and prominent sub assembly of the table. The main interest of design being the suction of gases and fumes, exhaust went also got more complications in designing. As a designer part of view, the vent made as a long tube over the length of the table, makes it simpler for manufacturing.

The vent is again made of two parts, each being sheet metal, bent to form the required shape and are then riveted. The base part of the vent subassembly got cuts running through the structure to allow the fixing plate of the table. The upper part of the vent subassembly got an opening that is covered by a flap. [Refer appendix H]

- This flap covered passage is going to suck the gases out of the table during the cutting process. This flapping mechanism is achieved through electro pneumatic switching.
- The switch which is going to be activated by the position of the gantry, will initiate the actuation of a double acting pneumatic cylinder.
- This is done by using a 5/2 valve, which is acts as the controller in between the pneumatic supply and the cylinder.
- The double acting cylinder, 5/2 control valve, roller switch G 1/8 – all are purchased from PNEUMAX s.r.o,
- The mechanism is made with Simulink and is executed in real time in the vent sub-assembly.
- Inside the subassembly, runs the support plates for the pistons. Since the whole table is sub divided into three different modules, three pistons are positioned such that it separates the modules at an equal distance.
- Short double acting pneumatic cylinders are used whose stroke length do not exceeds 20mm. This stroke length lies within the clearance range of the vent from the bucket containers.
- Capsuling the pistons within the vent sub assembly increases the complications in the design.
- The pistons are constantly supplied with normal industrial air pressure and is enough for the actuation of the cylinders.

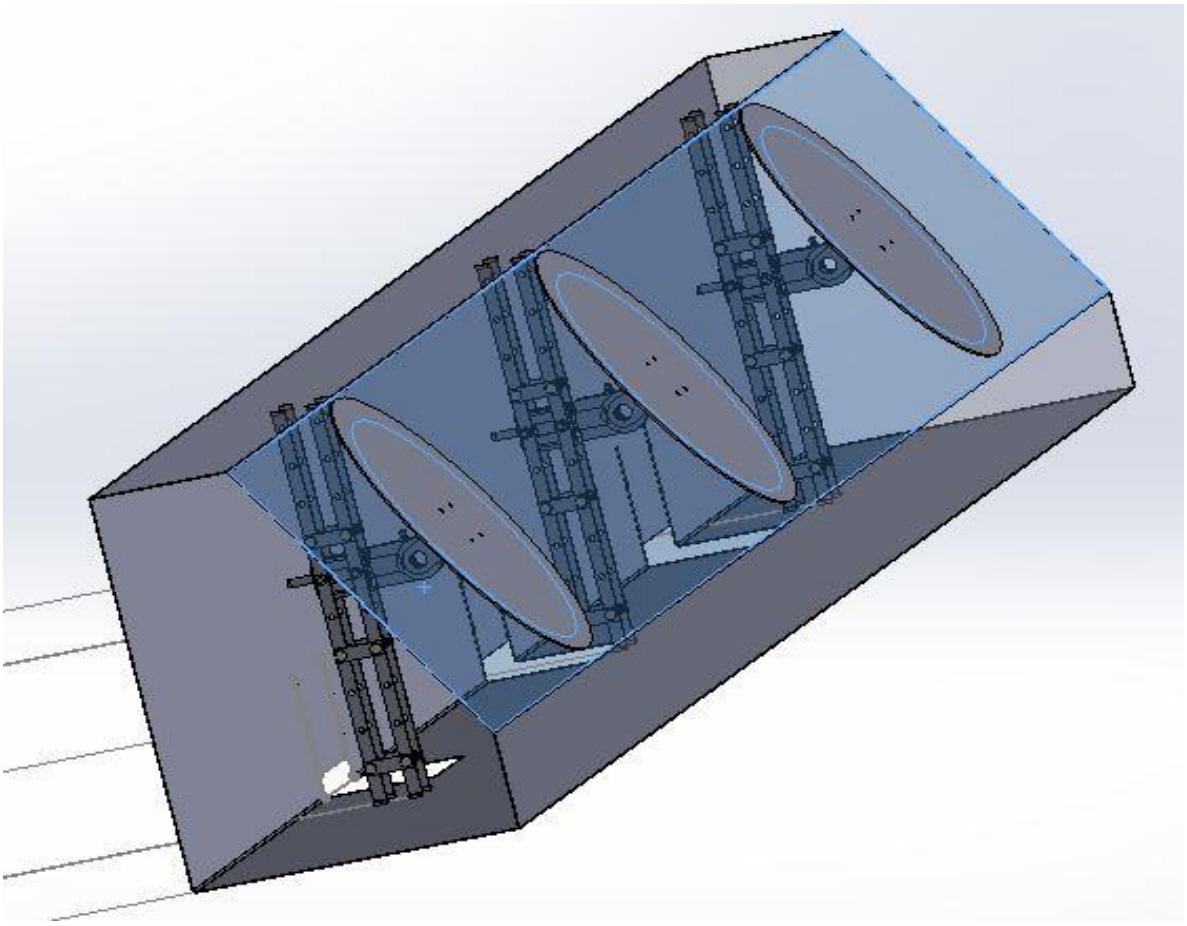

Fig 20 Exhaust vent sub assembly

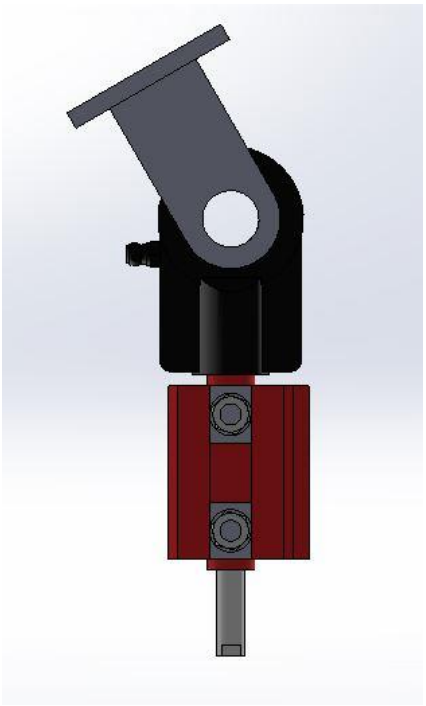

Fig 21 Cylinder with clevis attachment

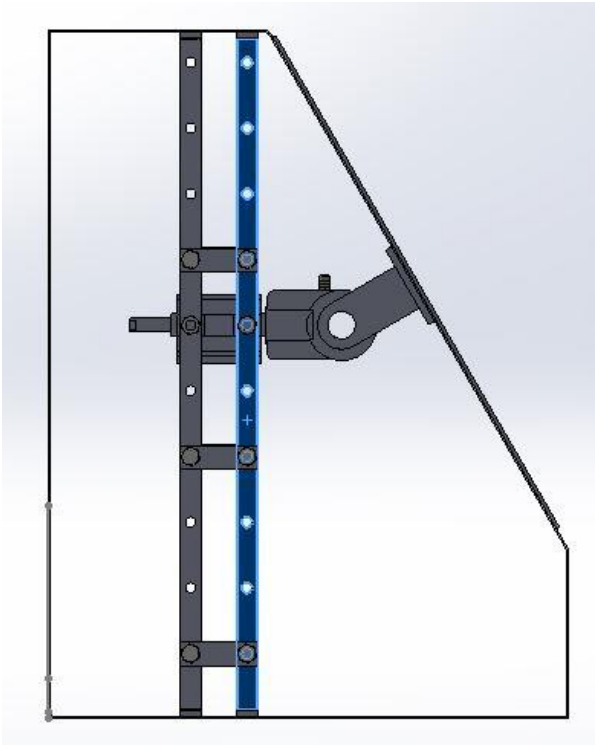

Fig 22 Exhaust vent side view - pistons

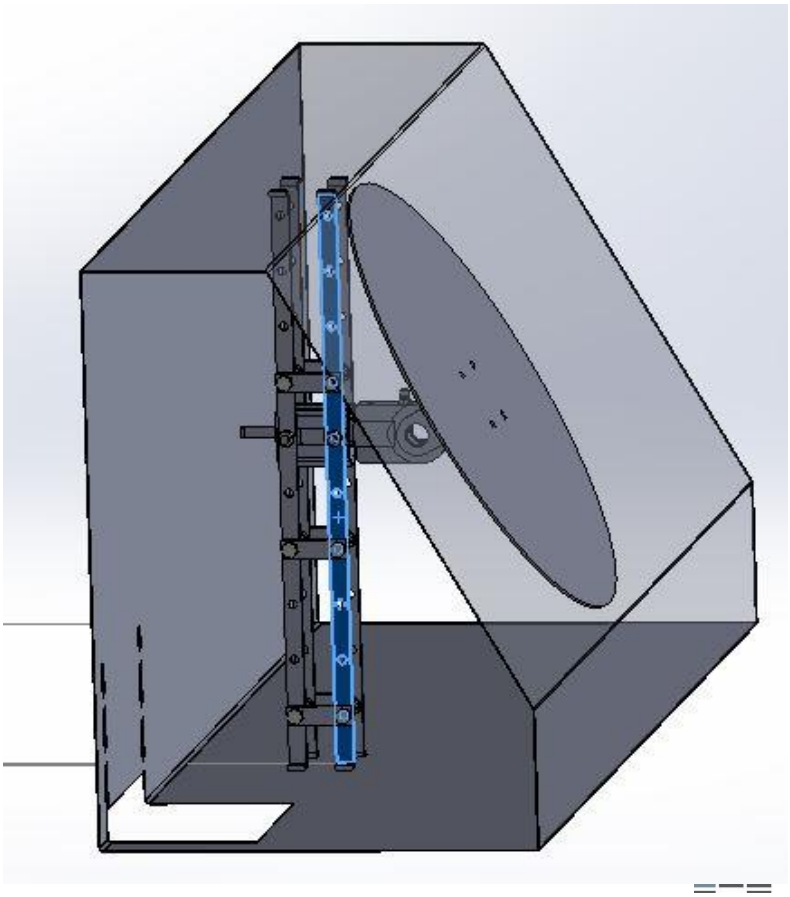

Fig 23 Exhaust vent flap view

6.1.3 The separator assembly:

This subassembly is essentially nothing but a screen between the modules and they primarily separates the whole table into three modules.

- The base plate of the subassembly is designed in the way that it also withholds the base plate of the main frame, which acts as the support for the bucket.
- This subassembly is completed by merging three parts by means of welding.
- This also got the L flanges on either side to provide support to the containers.
- The screen part is made in such a way that it do not interfere with the vent subassembly not breaking it from being a single long tube.

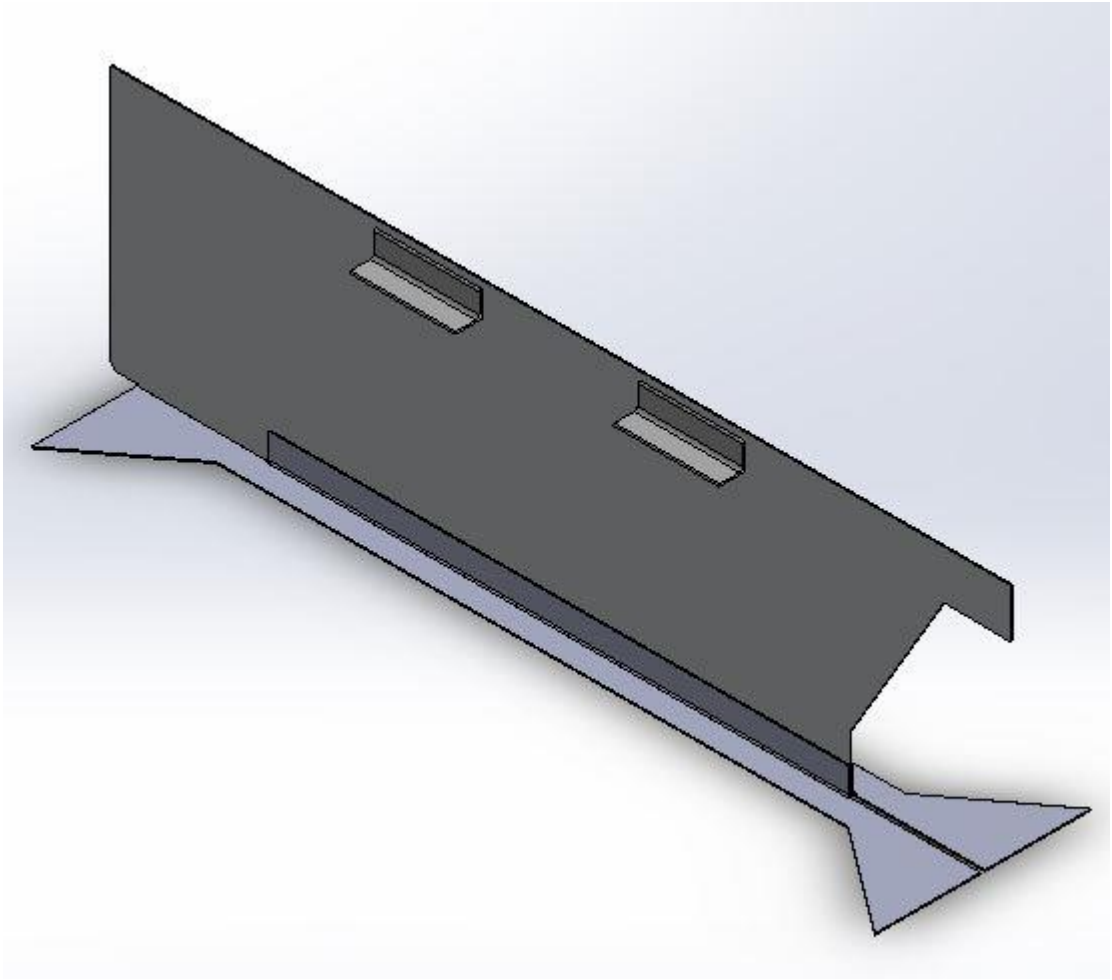

Fig 24 Separator assembly

6.1.4 Support to the cutting material

The side walls and the whole subassembly is provided with L flanges which are positioned by small triangular supports at the bottom. L flanges are used whenever possible to make sure the table is made as the robust design at a minimal usage of resources.

A thick fixing plate with screw holes are provided at the bottom as a part of support system. This is then screwed to the ground to make the table completely constrained. This thick plate is again supported by small triangles on both sides.

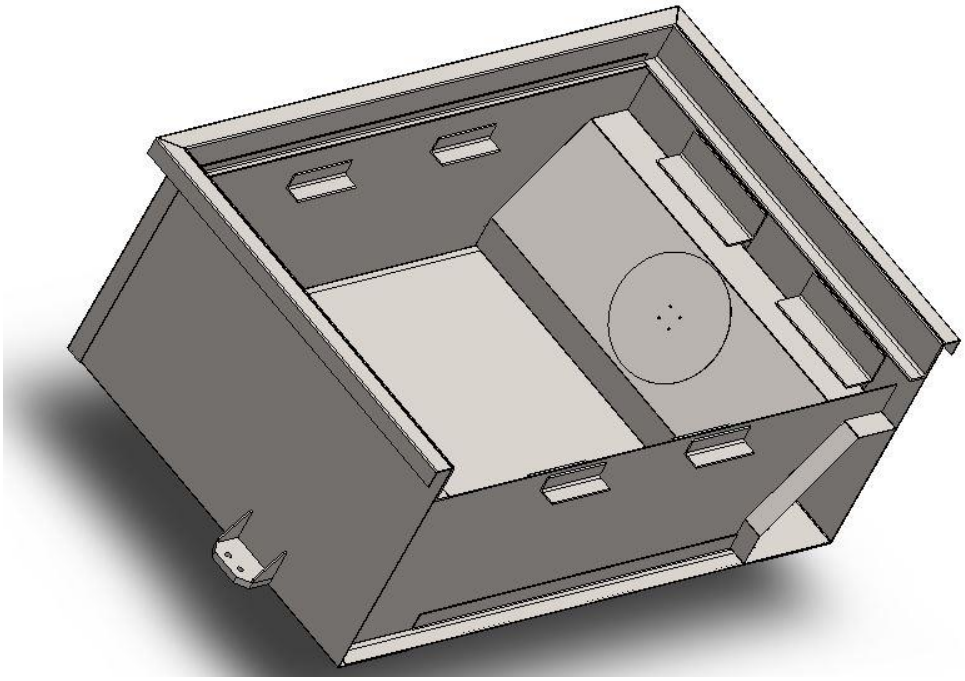

Fig 25 L flanges and side supports

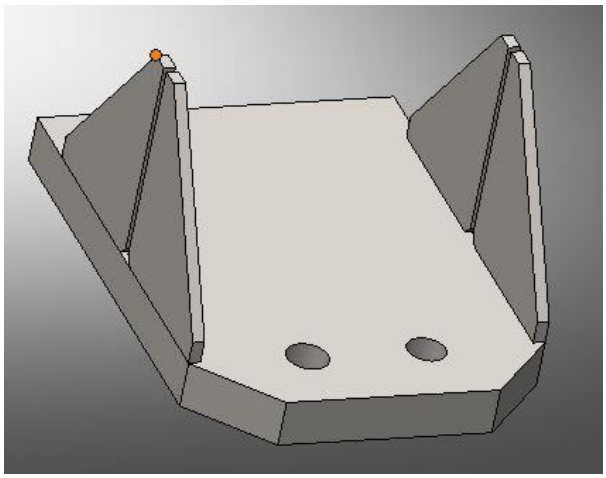

Fig 26 Fixing plate with screw holes

6.2 Bucket assembly

This subassembly contains the container part of the table. This is essentially where the leftovers are going to be collected. [Refer appendix C]

6.2.1 The bucket frame:

- The bucket frame is drawn from sheet metal to form the shape and then welded with the remaining parts.
- Frame is designed in a way such that it gives the maximum volume for the given dimensions.
- Higher volume leads to collection of more leftovers.
- This in turn cuts down the occurrence of maintenance downtime. Also reducing the maintenance costs.
- The sides are kept at maximum angle to make sure the slags and the swarfs do not accumulate on the sides.

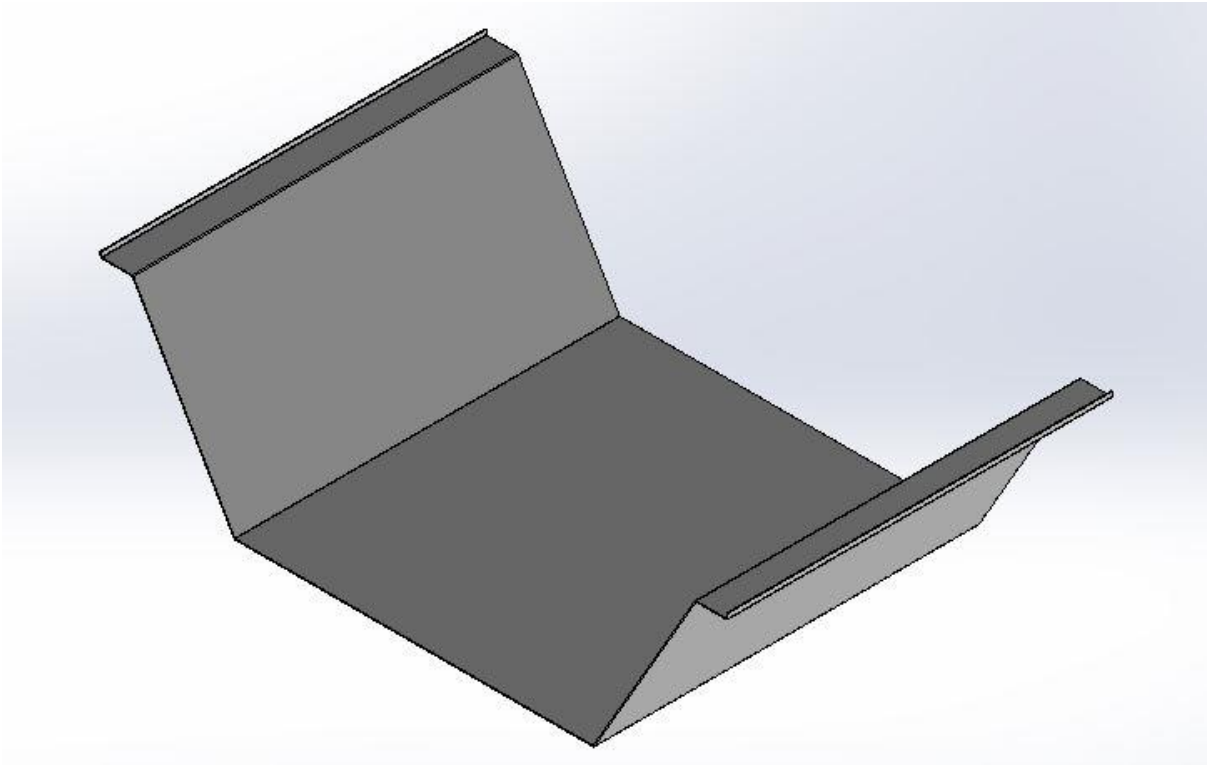

Fig 27 Bucket frame

6.2.2 Bucket lift

- The bucket is provided with a beam like support which not only acts a supporting system to the bucket, but also got the holes for the crane hooks.
- The holes are ergonomically placed such that the mass center lies in between the crane hooks when lifted.
- This highly avoids the toppling of the container when lifting and easy disposal of the contaminants.

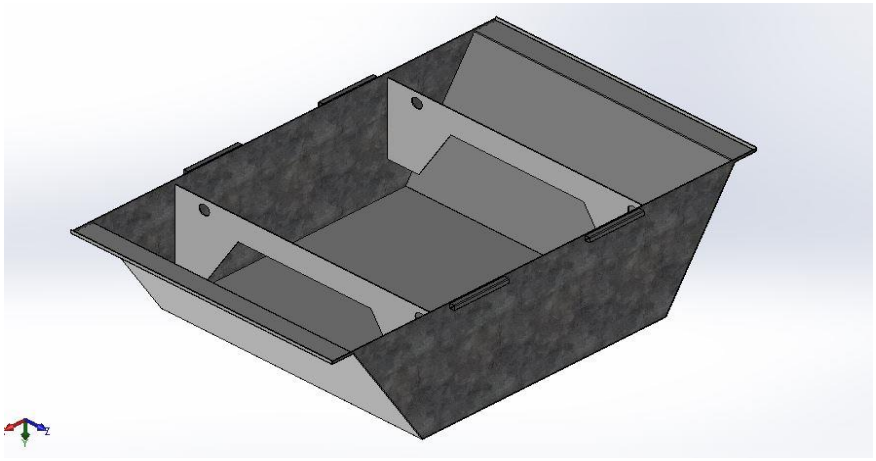

Fig 28 Bucket with lift

6.2.3 Side plates and supports

- The side plates are drawn from sheet metals and are then welded to the bucket frame.
- Apart from that, the side plates got the support system for the bucket assembly.
- The hollow box structures at the sides of the subassembly, constrains itself to the separator assembly making sure the subassembly stays in place.
- The top part of the whole subassembly is made in a way that it holds the grid plate.
- Enough support is given to the grid plate and is made sure that the removal of the latter be easy.

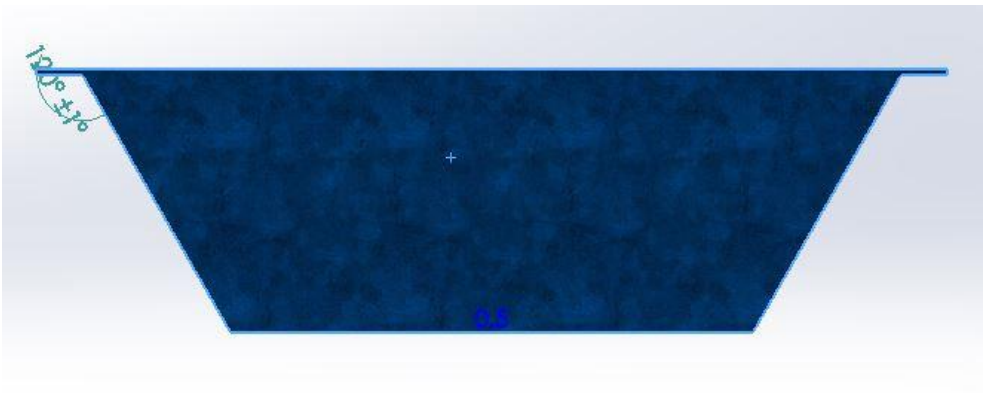

Fig 29 Side plate

6.2.4 Mesh plate assembly:

- Mesh plate assembly is as simple as a plate with punched holes all over the surface. [Refer appendix D]
- The grid plate is made to rest over the top of the container.
- This grid plate make sure that no bigger particles, being cut from the material, escapes into the container.
- This basically acts as a top level of filter from contaminants.

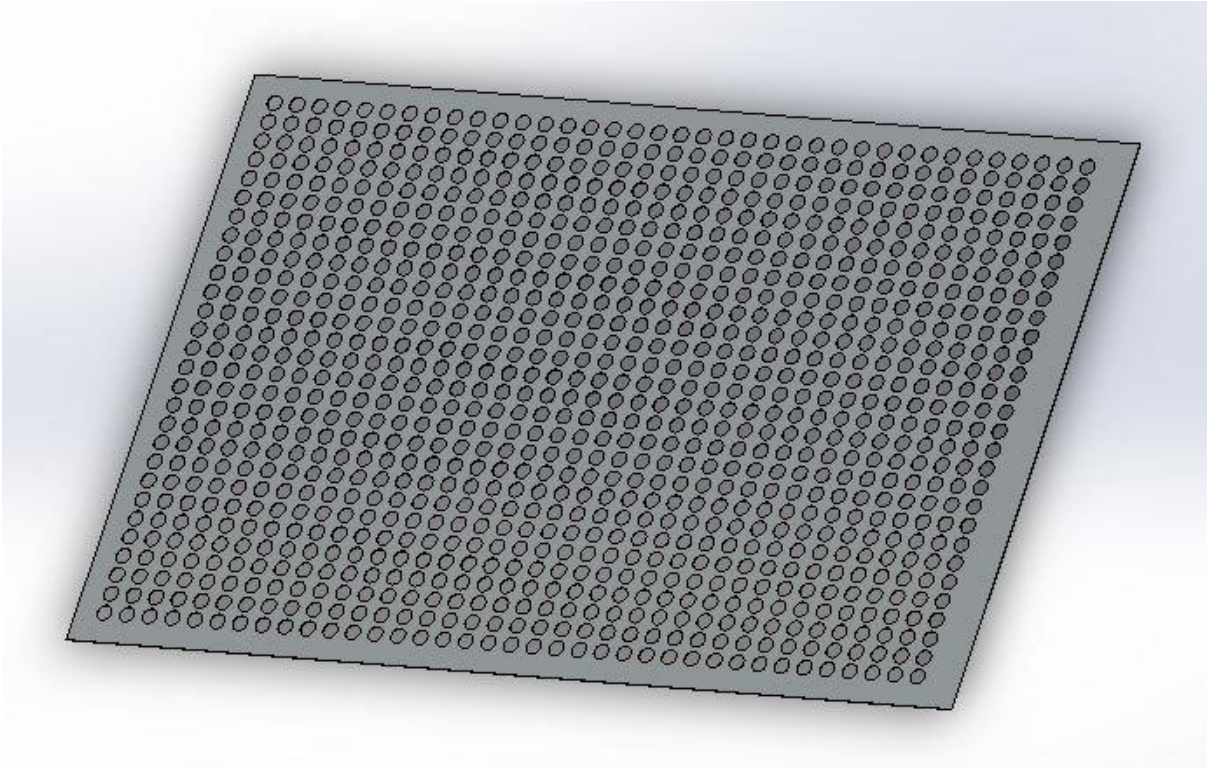

Fig 30 Mesh plate

6.3 Frame with slats:

This subassembly is mainly where the workpiece is going to be placed for cutting process and acts with direct contact with the metal cutting process. [Refer appendix E]

6.3.1 Support frame

- The four outer plates forms the skeletal frame for the subassembly.
- These plates are designed in a way that they are welded to each other.
- Not only that it rests comfortably over the supports provided at the sides of main frame, but also that it is embedded with L brackets so that this don't dismiss its form during demanding applications.
- Welded to the inner side of the frame are plates at an angle, to make sure the swarfs from the cutting process do no accumulate, but slides down the plates to the container.
- These angular welded plates are provided at all four sides and also in the middle where there is going to be the separator plate at its immediate bottom. [Refer appendix F]

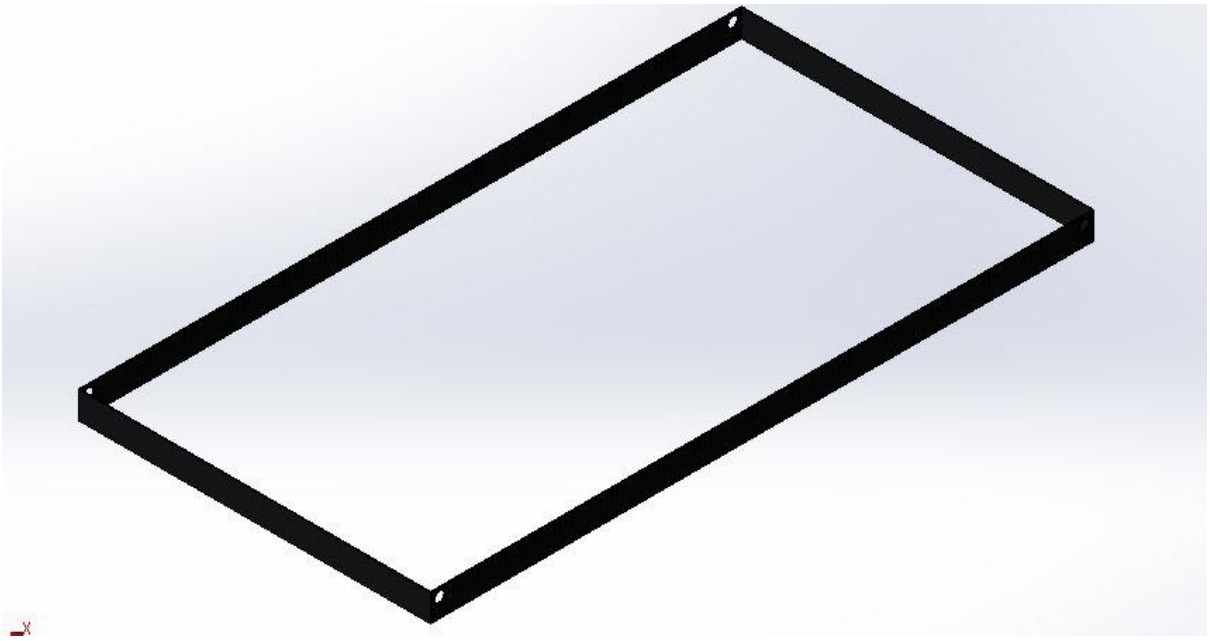

Fig 31 Support frame

6.3.2 Slotted guides

- The subassembly got three slotted guides running in between the frame.
- This is designed to keep insert the slats into the assembly.
- The slots are made at regular intervals at an optimum distance to reduce the contact with the cutting material as well as not compensating the rigidity of the frame to withstand the mass.
- The guides got standard holes for crane lifts at the corners to be lifted with ease.
- Since this acts as the top layer of the entire assembly, the robust design of this subassembly greatly influence the overall rigidity of the suction table.

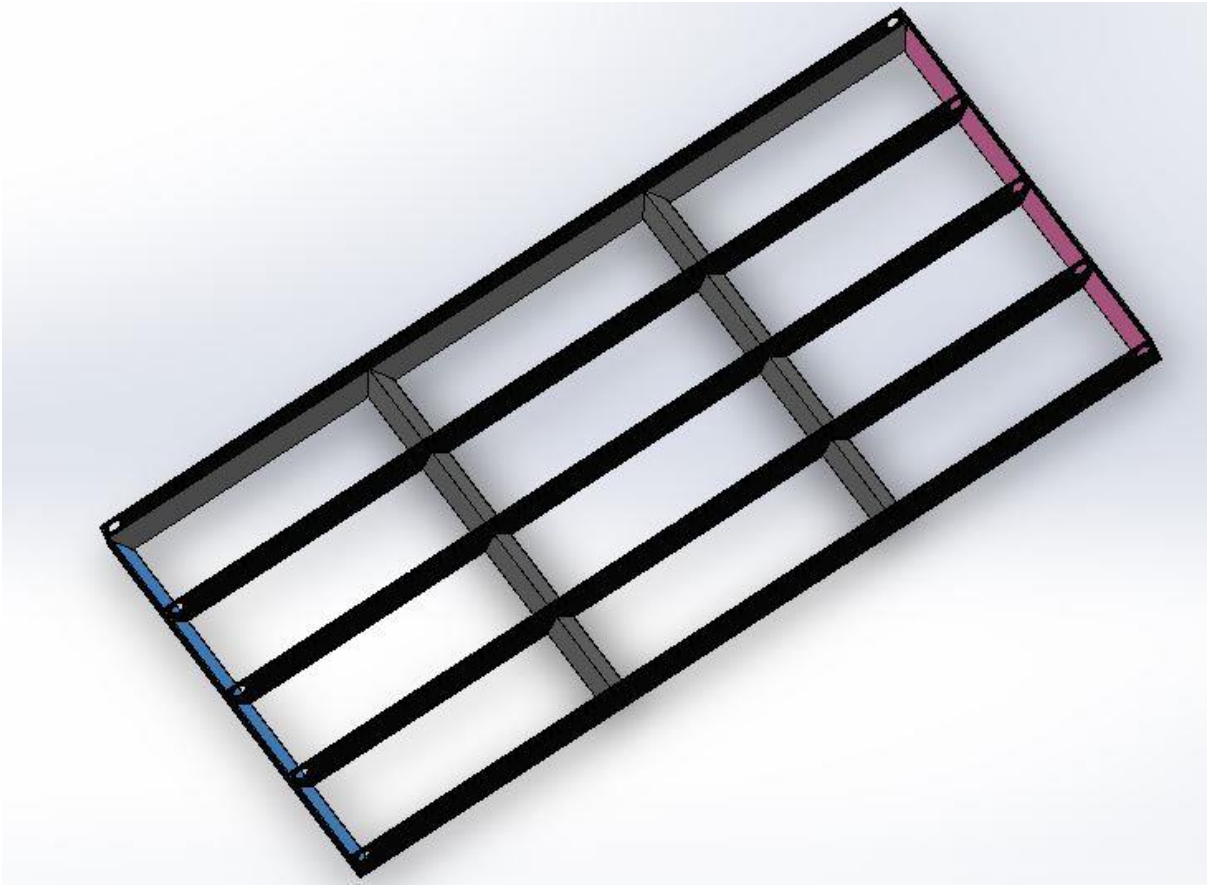

Fig 32 Slotted guides

6.3.3 Slats

- The slats are where the cutting material is to be placed for the cutting purposes.
- To ensure the slats do no react with the metal during the cutting process, the contact area between both are greatly reduced.
- The distances between the slats facilitates the proper ventilation for the fumes to escape freely.
- These slats wears due to the exposure to plasma and oxy-fuel cutting flame.
- Once the slats wears down, it can easily be replaced with a new one.
- The slats can be designed as per the requirement for the cutting process and material.
- In order to reduce the contact area even more, pointed slats can be used.
- The pointed slats are preferred in case of cutting process with very minute dimensions. [Refer appendix G]

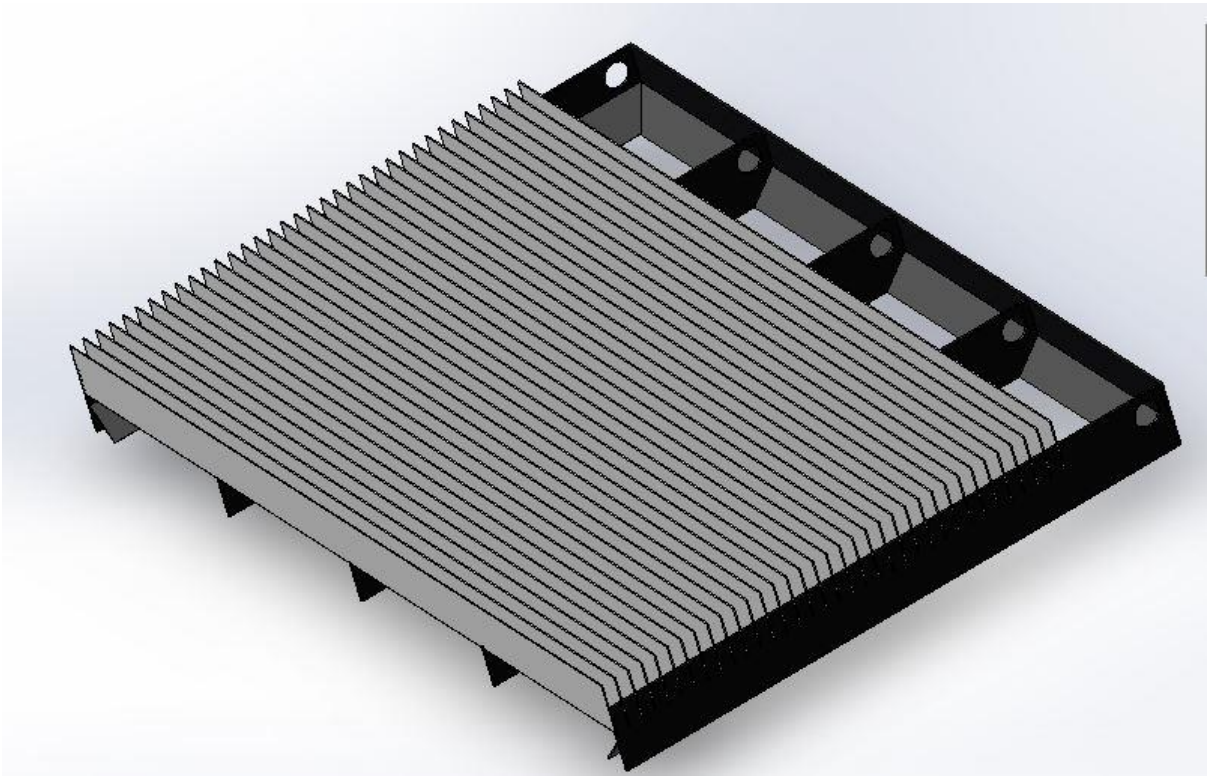

Fig 33 Slats arrangement

7 Mechanism for the opening and closing of exhaust flap:

The activation of exhaust in one particular module is achieved by means of a flap opening at one particular module during the cutting process based on the gantry position. This system can be achieved by two different methods:

1. By means of mechanical linkages.
2. By means of pneumatic operation.

7.1 Mechanical linkage for opening and closing of the exhaust flap:

In order to choose the wiser method and more practically feasible system, both methods are studied extensively and analysed.

- Mechanical linkages can be used in case of our table since there is going to be only few linkages and movable parts.
- Mechanical system don't need any external supply such as electricity or air supply for the operation but depends only on the force exerted due to the gantry movement.
- In case the opening is covered by flap outside the vent, then it should be designed within the limit of 30mm, since that's the clearance between vent and the container.
- If the flap is made to move inside the vent, the only constraint is that it do not sucks in any smaller pieces of leftovers.

7.2 Pneumatic operation of opening and closing of flap:

This method essentially uses industrial air supply of 120 PSI for operation and depends on a roller switch for activation.

- A short double acting pneumatic cylinder from Pneumaxs.r.o[48] is bought for the process of actuation.
- This is supplied with pneumatic industrial air supply
- The stroke length of the cylinder is 20mm which is in the range of our clearance distance.
- The pneumatic method got a good repeatability.
- For switching, a roller switch from Pneumax[48] is selected.

7.3 Justification of more feasible solution:

On comparing carefully both the methods, it is found that pneumatic activation of the flap seems more suitable and is justified as below:

- The mechanical linkage wears more than the pneumatic links, this leads to more maintenance downtime and costs.
- The sedimentation of fumes over the linkages are possible which leads to accumulation of dust over the linkages increasing the wear.
- Where in other hand, the pneumatic system got only the actuator present inside.
- Lesser the moving parts inside the system, more stable the system will be.

8 Pneumatic scheme for the opening and closing of exhaust flap:

The scheme basically implies the following parts for the operation.

1. Short stroke double acting cylinder.
2. 5/2 pneumatic valve.
3. 3/2 roller valve, normally closed.

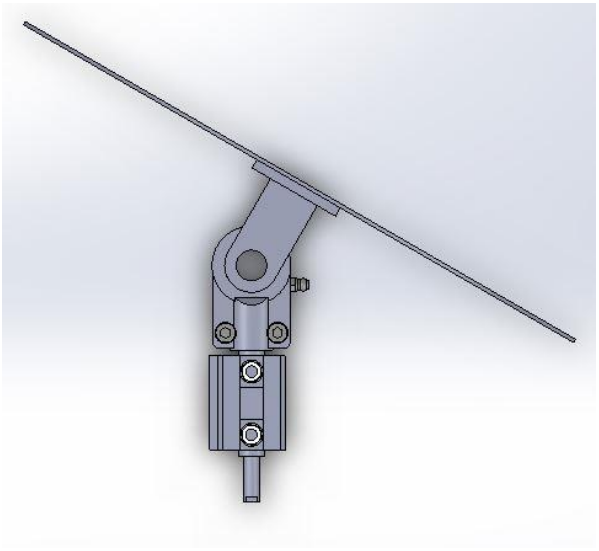

Fig 35 Piston with flap

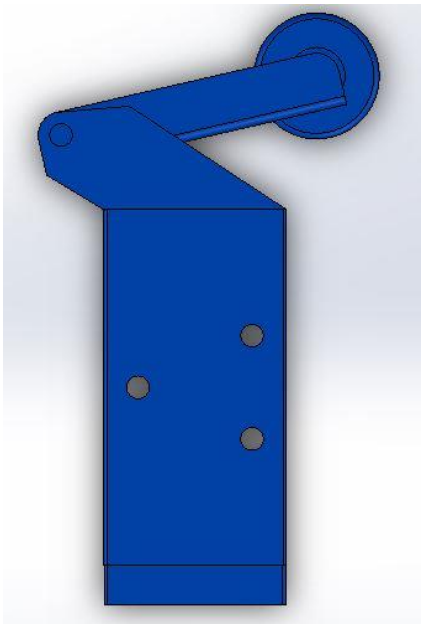

Fig 34 Roller switch

The following scheme explains the basic connection.

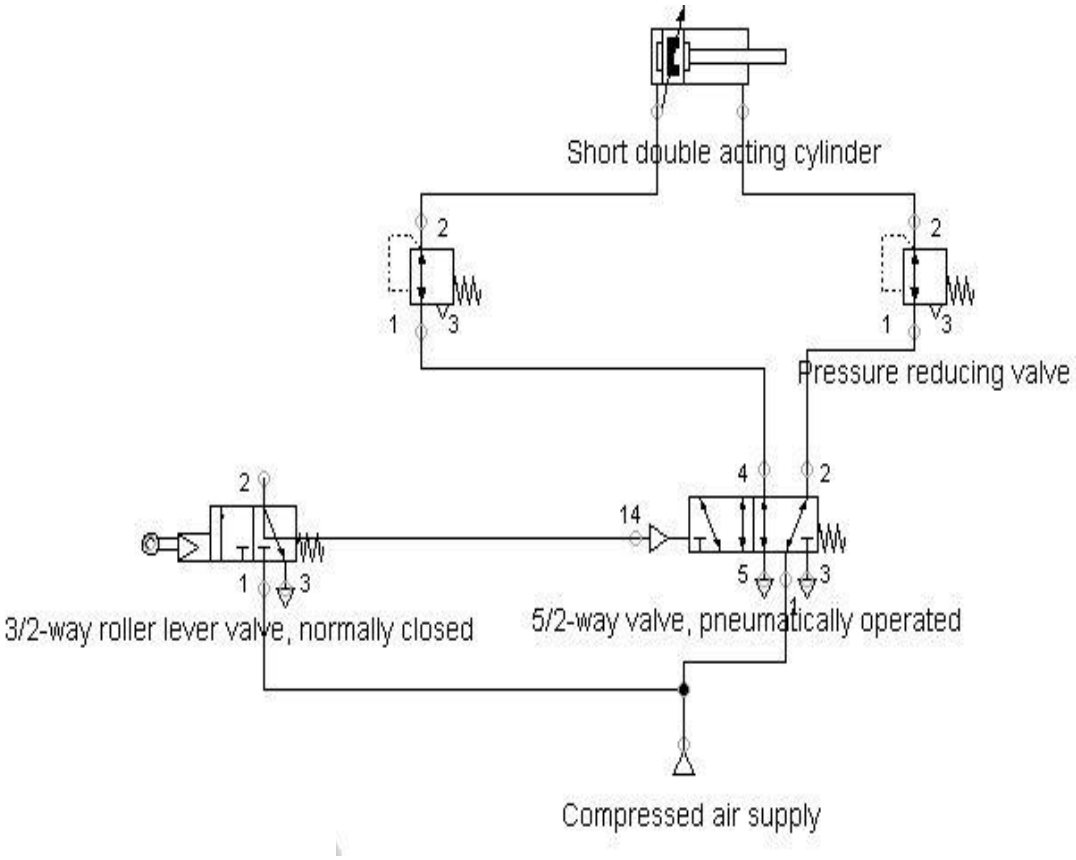

Fig 36 Pneumatic scheme using FLUIDSIM

- The roller swtich is normally closed, spring return.
- The whole set up is powered by compressed air supply.
- The supply of pressurized air to the cylinder will make it actuate at very high velocity, leading to vibration and more strain acting at the fixtures of the cylinder.
- In order to reduce this, the cylinders are provided with pressure regulators at each end, so that the velocity is controlled and the piston moves gradually.
- This highly reduces the vibration in the system.

The working of the whole system is illustrated through the images below:

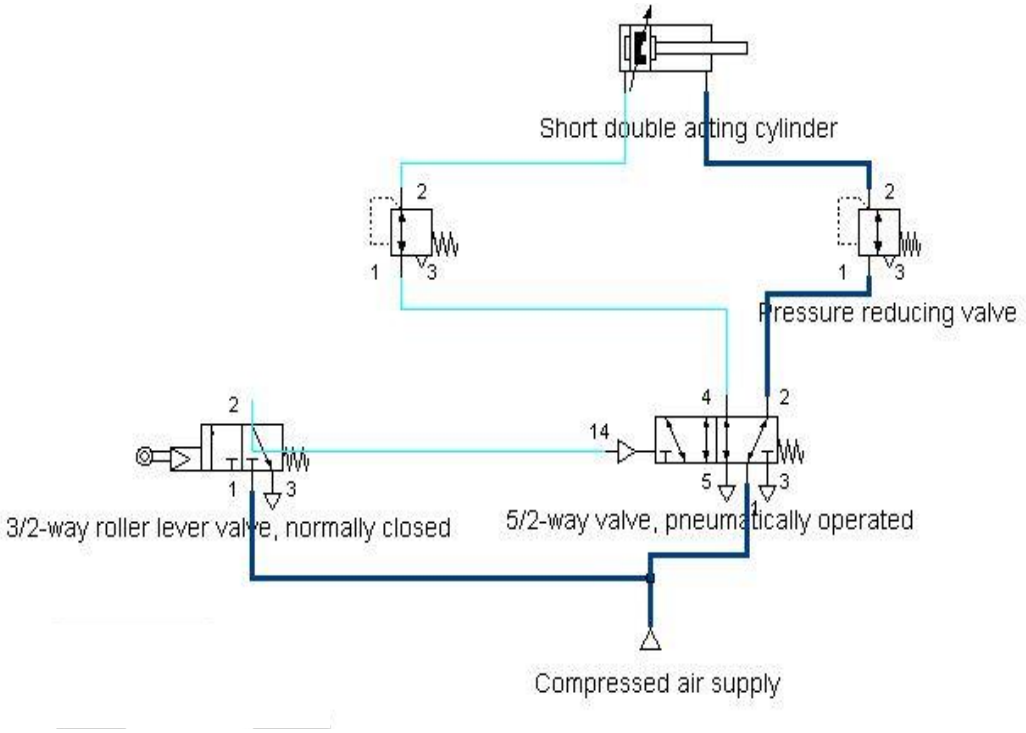

Fig 37 Pneumatic scheme representing normally closed condition

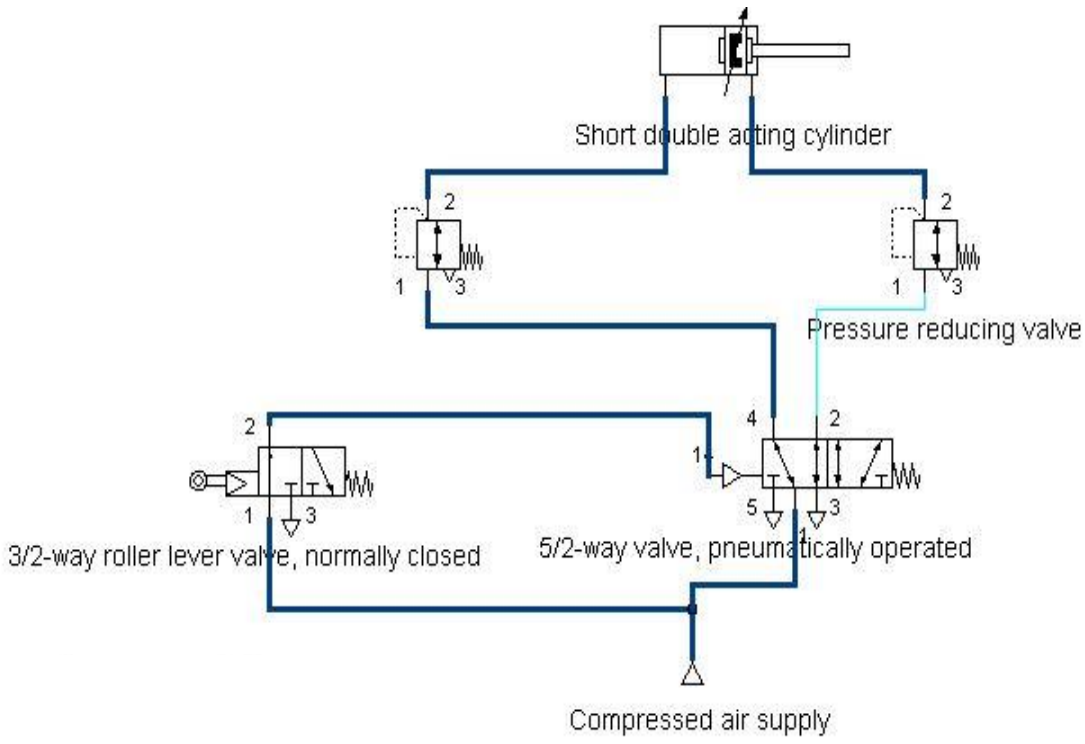

Fig 38 Pneumatic scheme representing the actuation of the piston.

8.1 Explanation of important parts and justification for the design:

The basic design started with the main frame work and is designed from sheet metals of 1.5m x 3m, 2m x 4m.

- Sheet metals are used so that the table is made as light weight as possible without compromising the robustness and rigidity.
- The fixing plate is made of solid plate with screw holes for proper fixing of the base to the floor.
- This fixing plate is strengthened on either side by means of angular supports.

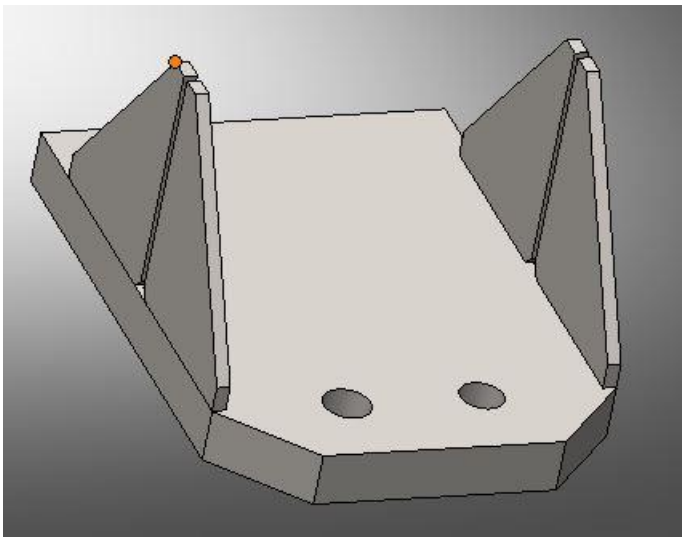

Fig 39 Fixing plate with screw holes and angular supports

- The piston is attached to the flap by means of a clevis in between. This clevis is then connected to an angularly positioned attachment plate to which the flap is actually screwed to.
- The pistons are supported at both sides to withstand the strain that will act on the pistons during the actuation process.
- The vent is made in a way that it can either be coupled with the exhaust tube or can be coupled with another table for extended dimensions.
- L flanges and L brackets are used whenever and wherever possible in order to make sure about the rigidity of the table,

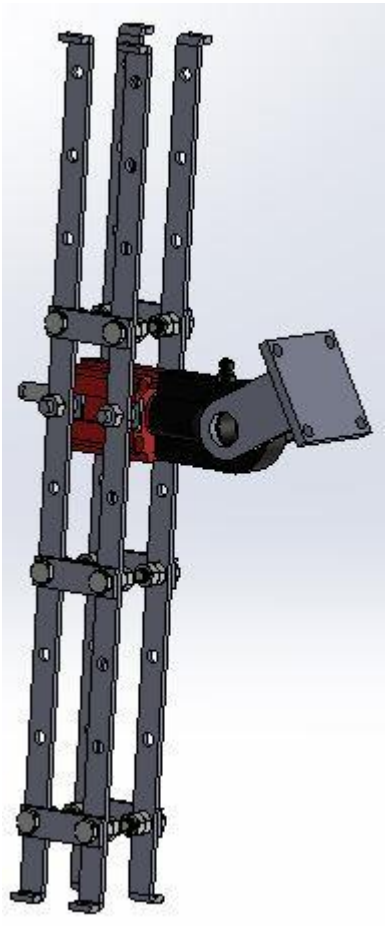

Fig 43 Piston with side support plates

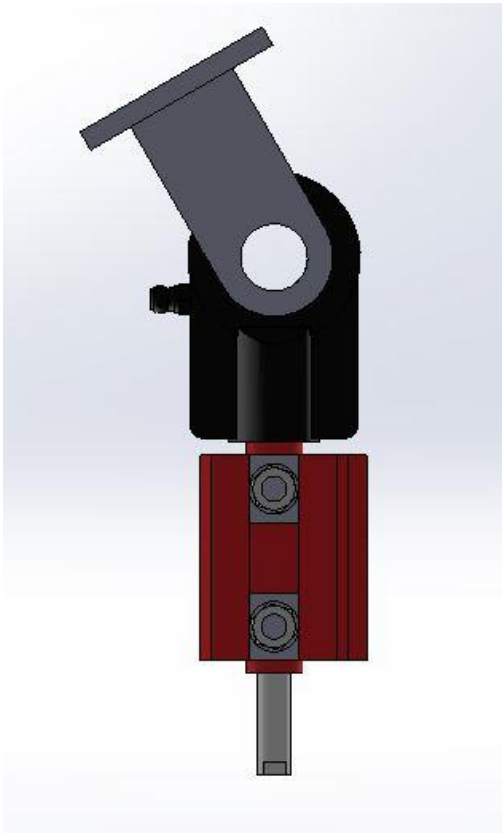

Fig 42 Piston with clevis

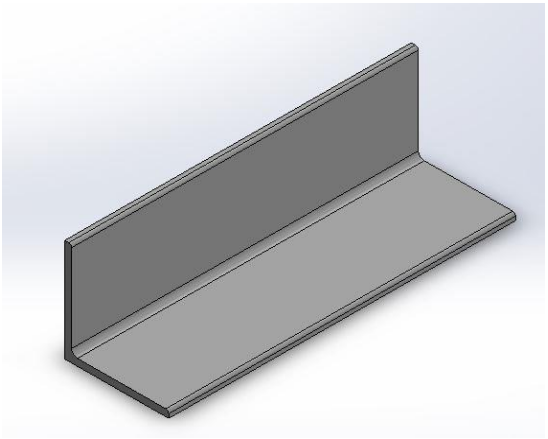

Fig 41 L flange

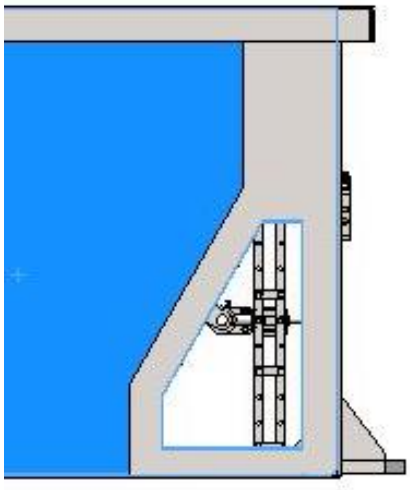

Fig 40 Vent view

9 Summary of the work done and results:

The beginning stages of the thesis started with understanding the core. For this, a long stay in the company is needed and the thesis began with a one month internship in Vanad. The exposure during this course gave a basic idea on how the plasma and oxy-fuel cuttings are done in real time and what kind of extraction methods are used. The real struggle to overcome during the cutting process is that the work bed should withstand the high cutting temperature and should not react with the material.

For this exact reason, resting the material on a planar surface is eliminated. This arose the use of slats which highly reduces the contact area with the material. However the use of slats reduces the rigidity by a bit, but at the same time providing a passage for the gases and fumes to escape.

In order to activate separate modules for suction during the cutting process, roller switches are used, which are activated by the gantry position. Pneumatics are used for better repeatability. The entire stretch of the table is composed of three modules each one housing a separate container for collecting leftovers. The vent is connected to the industrial extraction system to facilitate the suction of even finest particles.

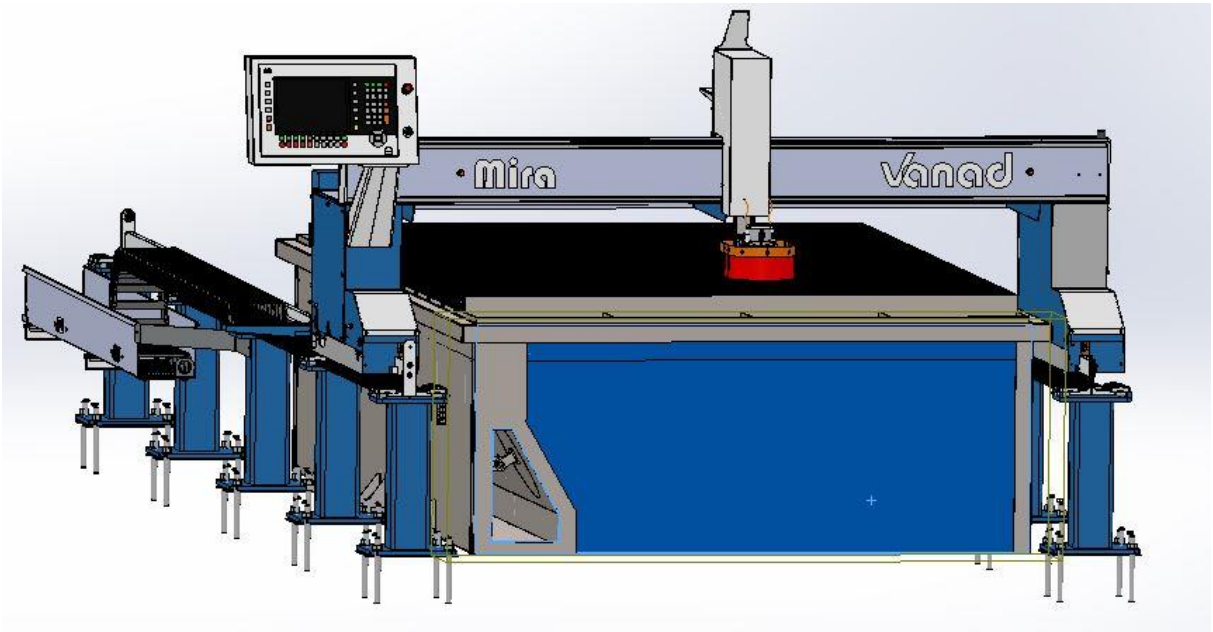

Fig 44 Table with Vanad Mira

10 Conclusion

The design of the table is drafted many times before arriving at the final design in order to achieve the optimal design with greater efficiency. The usage of pneumatics in the system highly added to the repeatability of the opening and closing of the flaps.

The final design is made according to the required dimensions successfully and is completely functional.

Scope for improvement:

- The flaps can be provided with a damping system in order to reduce the vibrations during operation.
- The roller switch can be eliminated and can be replaced with position sensors in order to achieve more accuracy.
- The table can be designed such that additional table can be added even along sideways to achieve the desired width.
- The pistons can be replaced with linear guides for smoother operations.
- Solution for removal of leftovers from the container without disassembling can be found.

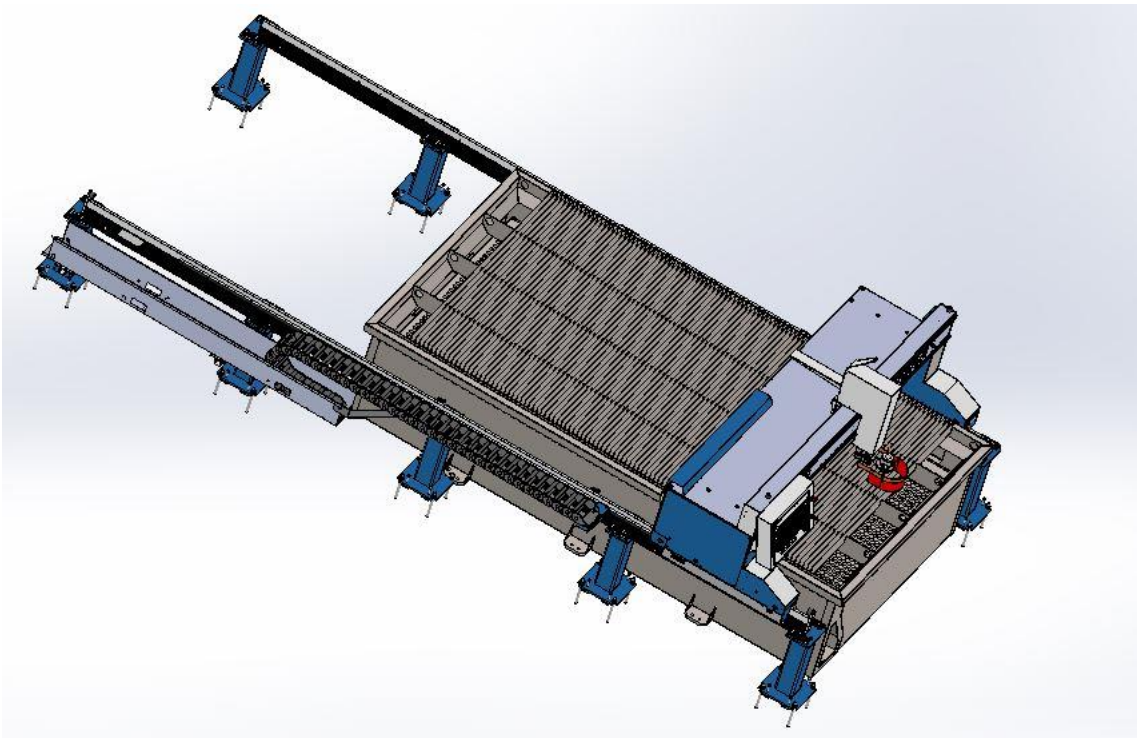

Fig 45 Table complete set up with machine.

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36. **Tigemma. *Exhausted tables middle row to load 2400 kg / m²*. [web] n.d n.d [cited 2016 29 Dec]; Available from: http://www.tigemma.cz/cisty-vzduch/odsavane-stoly-pro-termicke-paleni-kovu.**
37. **Tigemma, *Exhausted tables middle row to load 2400 kg / m²*, n.d, Tigemma s.r.o.: Bělotín, Tschechische Republik.**
38. **KEMPER. *KemTab Basic Extraction Table*. Fume Extraction Tables For Cutting Systems [web] n.d n.d [cited 2016 30 Dec]; Basic extraction table for many different cutting applications]. Available from: https://www.kemper.eu/en/products/kemtab-basic-extraction-table_p7609.**
39. **KEMPER, *KemTab Basic Extraction Table*, in *Fume Extraction Tables For Cutting Systems*n.d, KEMPER GmbH: Vreden**
40. **KEMPER. *KemTab Advance Extraction Table*. Fume Extraction Tables For Cutting Systems [web] n.d n.d [cited 2016 30 Dec]; Solid cutting bed for medium to high requirements]. Available from: https://www.kemper.eu/en/products/kemtab-advance-extraction-table_p7611.**
41. **KEMPER, *KemTab Advance Extraction Table*, in *Fume Extraction Tables For Cutting Systems*n.d, KEMPER GmbH: Vreden**
42. **KEMPER. *KemTab Vibro Extraction Table*. Fume Extraction Tables For Cutting Systems [web] n.d n.d [cited 2016 30 Dec]; Solid cutting bed for medium to high requirements with automatic slag removal]. Available from: https://www.kemper.eu/en/products/kemtab-vibro-extraction-table_p7615.**
43. **KEMPER, *KemTab Vibro Extraction Table*, in *Fume Extraction Tables For Cutting Systems*n.d, KEMPER GmbH: Vreden**
44. **VANAD. *Kemper extraction tables*. Sectional extraction tables [web] n.d [cited 2016 Dec 30]; Available from: http://www.vanad.cz/en/section-table.**
45. **KEMPER, *KemTab Hiend Extraction Table*, in *Fume Extraction Tables For Cutting Systems*n.d, KEMPER GmbH: Vreden**

46. **Vicon. *HVAC 510 Plasma Cutting Table*. Standard Sheet Metal Cutting System [web] n.d [cited 2016 31 Dec]; Available from: http://www.plasma-automation.com/Machinery/Plasma-Cutting/HVAC-510-Plasma-Cutter.php.**

47. **Vicon, *HVAC 510 Plasma Cutting Table*, in *Standard Sheet Metal Cutting System*n.d, Plasma Automation, Inc.: Meadville.**

48. **Pneumax, *Pneumax general catalogue*, 2007, Pneumax: Lurano.**

Appendix

Appendix A – Complete assembly of the table 1KSAVSTA0100

Appendix B – Table with detailed view and BOM 0KSAVSTA0200

Appendix C – Bucket assembly 3KSAVSTA0300

Appendix D – Mesh plate 3KSAVSTA0400

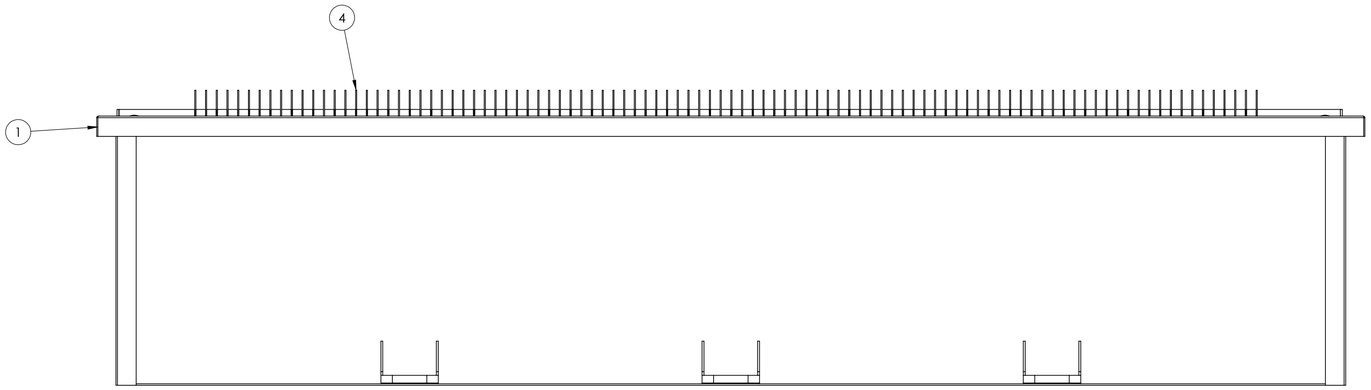
Appendix E – Frame with slats 0KSAVSTA0500

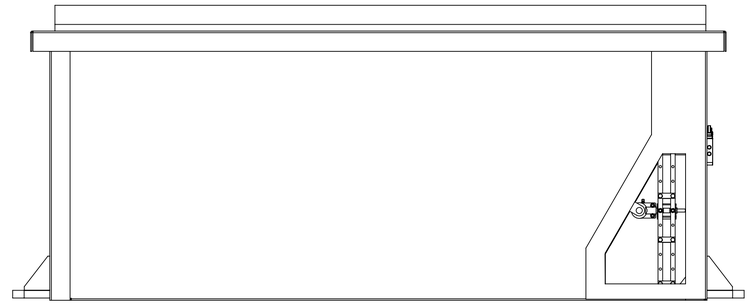
Appendix F – Side plate of the frame of slats 3KSAVSTA0502

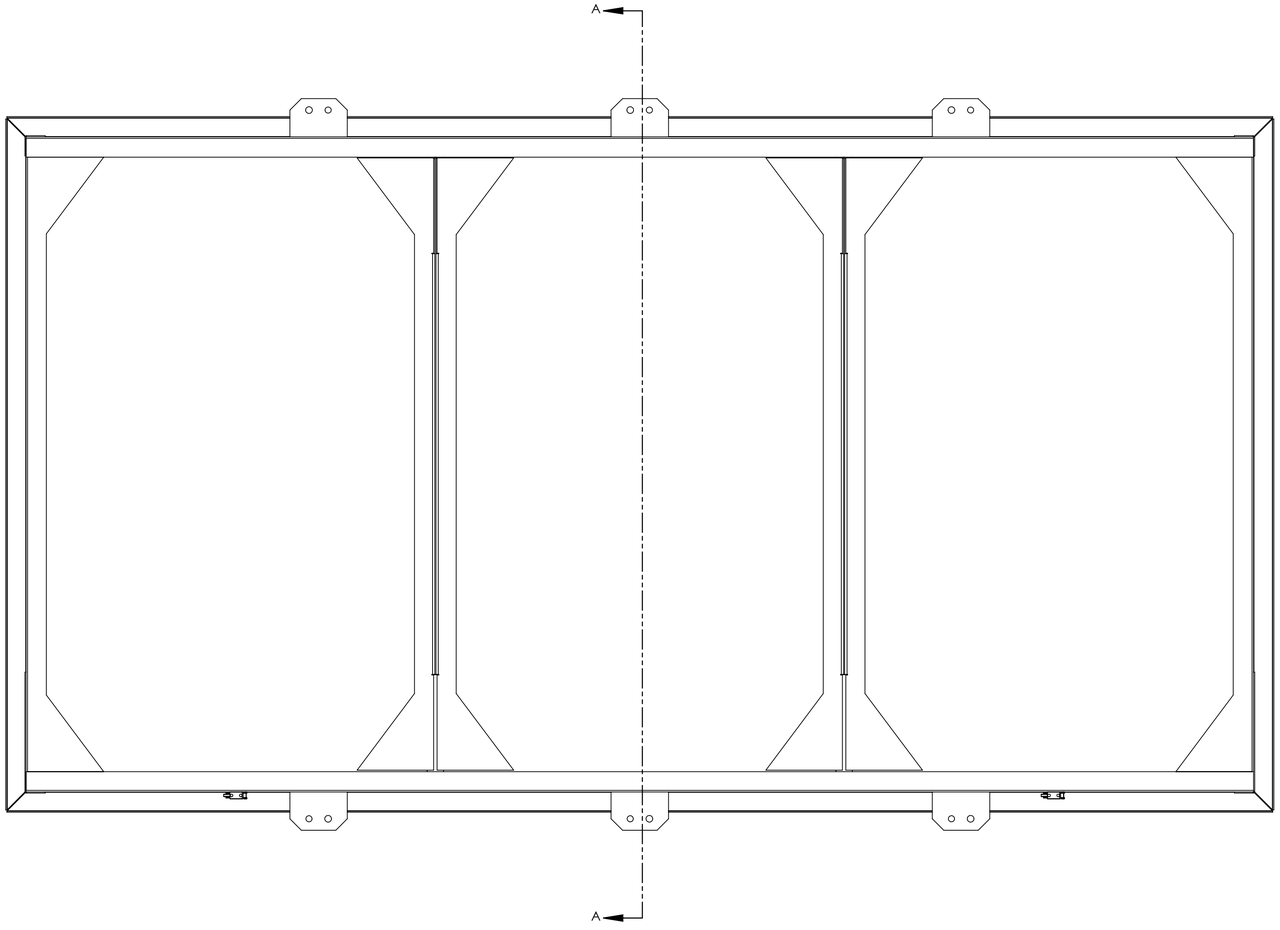
Appendix G – Slats 3KSAVSTA0507

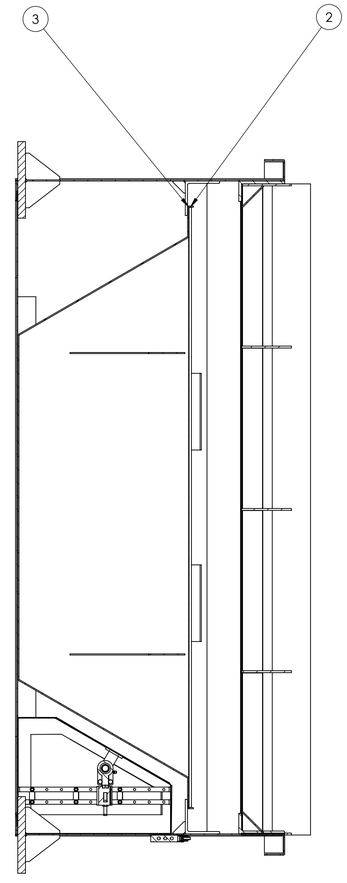
Appendix H – Detailed view of vent with pistons 3KSAVSTA0601

Attaching an electronic copy in the form of CD.









SECTION A-A
SCALE 1 : 8

ITEM NO.	ASSEMBLY NUMBER	ASSEMBLY NAME	QTY.
1	KSAVSTA0200	Assem1	1
2	KSAVSTA0300	bucket assembly	3
3	KSAVSTA0400	mesh plate assembly	3
4	KSAVSTA0500	frame with slats	1

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:

FINISH:

DEBURR AND BREAK SHARP EDGES

DO NOT SCALE DRAWING

REVISION

	NAME	SIGNATURE	DATE
DRAWN			
CHK'D			
APP'V'D			
MFG			
Q.A			

MATERIAL:

WEIGHT:

TITLE:

Complete

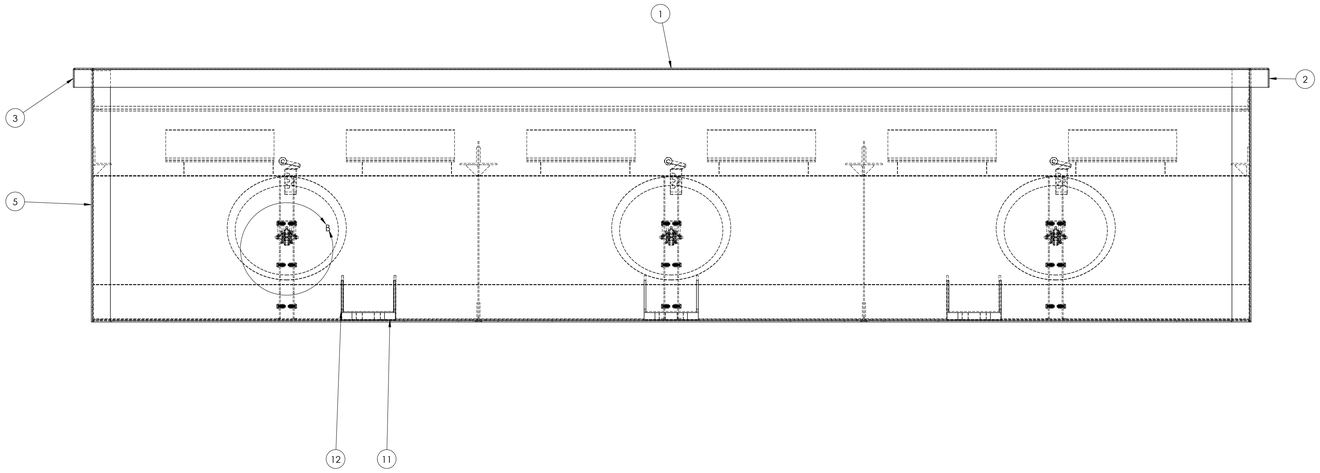
Design of Suction Table for Plasma and Oxy-fuel CNC Cutting Machine

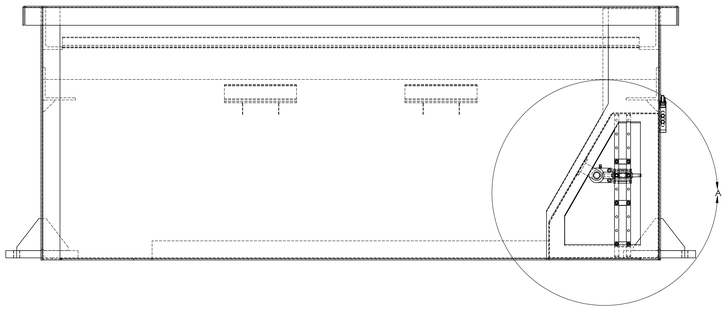
DWG NO. 1KSAVSTA0100

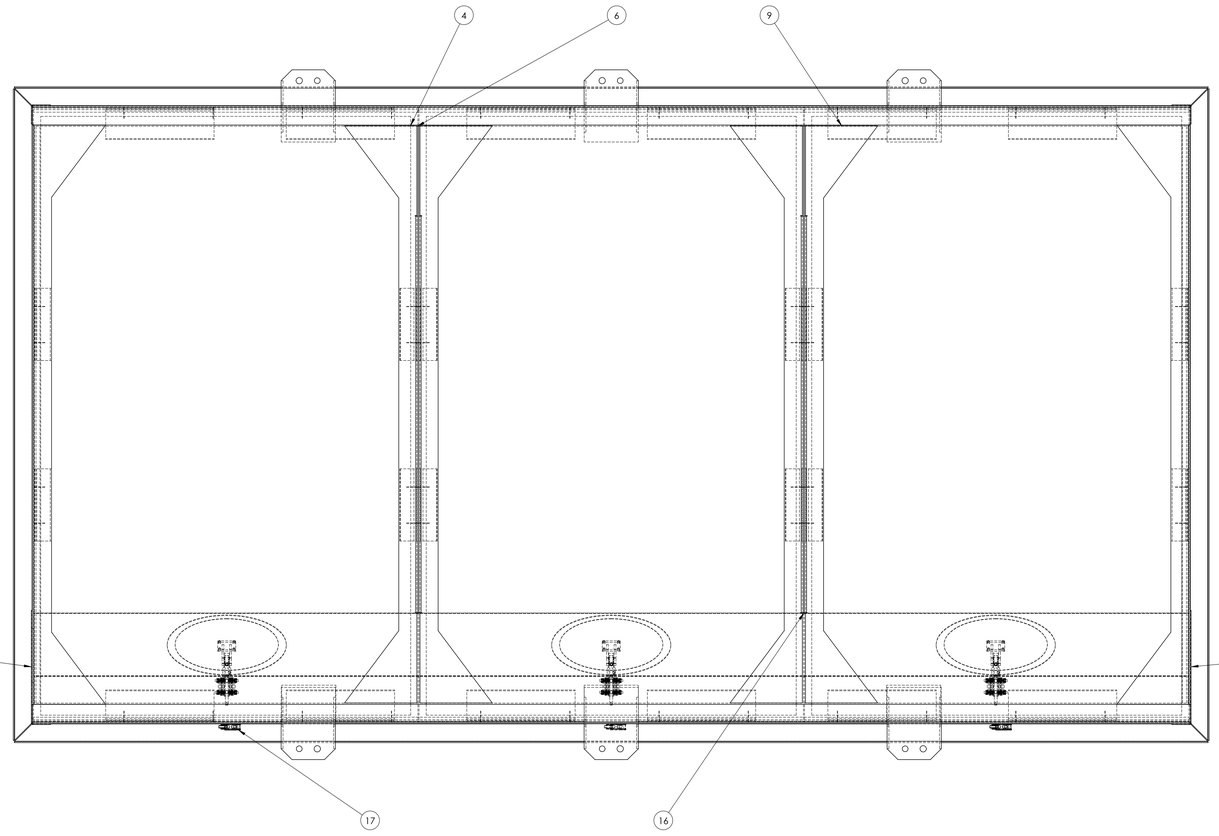
A1

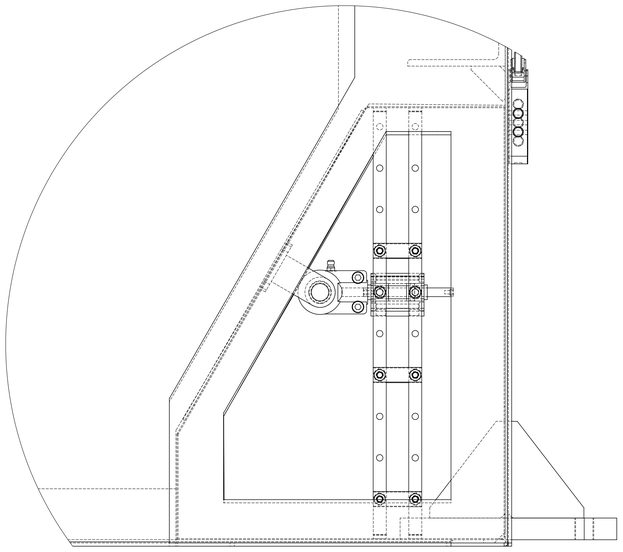
SCALE:1:10

SHEET 1 OF 1

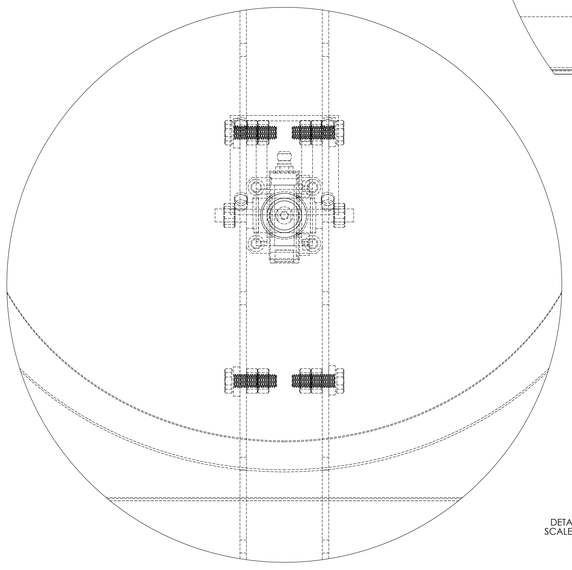








DETAIL A
SCALE 1 : 2



DETAIL B
SCALE 1 : 1

ITEM NO.	PART NUMBER	PART NAME	QTY.
1	KSAVSTA0201	main frame side plate	2
2	KSAVSTA0202	front plate sm	1
3	KSAVSTA0203	front plate sm 2 copy	1
4	KSAVSTA0204	base plate final	3
5	KSAVSTA0205	bracket support	2
6	KSAVSTA0206	L 3000	2
7	KSAVSTA0207	side L flanges for bucket support	12
8	KSAVSTA0208	L flange on support side plate assembly	4
9	KSAVSTA0209	support assembly inside	2
10	KSAVSTA0210	traingle welding support	48
11	KSAVSTA0211	mounting plate	6
12	KSAVSTA0212	triangle support for mounting plate	24
13	KSAVSTA0213	L flange for main assemble	2
14	KSAVSTA0214	bracket support near exhaust vent	1
15	KSAVSTA0215	bracket support 2 near exhaust vent	1
16	KSAVSTA0216	exhaust vent with pistons	1
17	KSAVSTA0217	roller valve switch	3

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:

FINISH:

DEBURR AND BREAK SHARP EDGES

DO NOT SCALE DRAWING | REVISION:

Assembly 1

	NAME	SIGNATURE	DATE
DRAWN			
CHK'D			
APPV'D			
MFG			
Q.A			

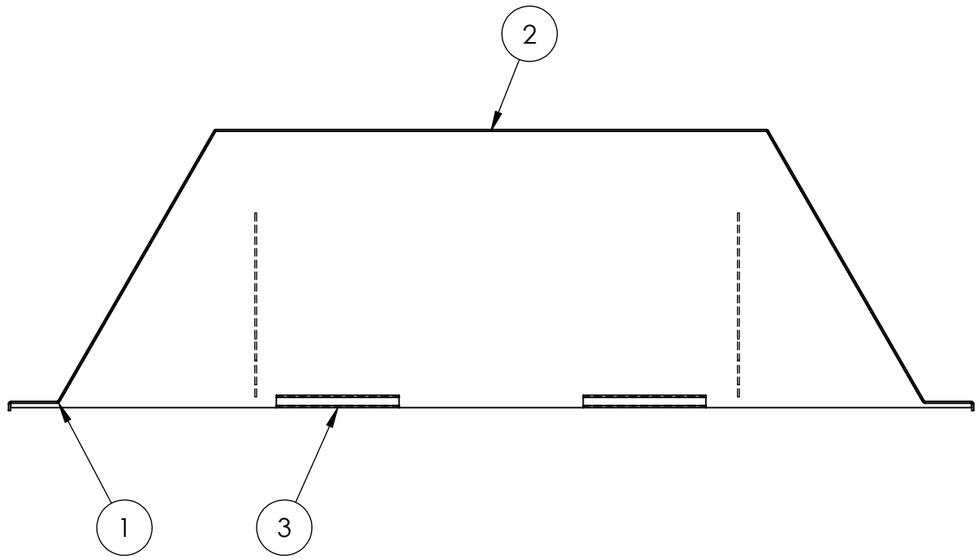
TITLE:

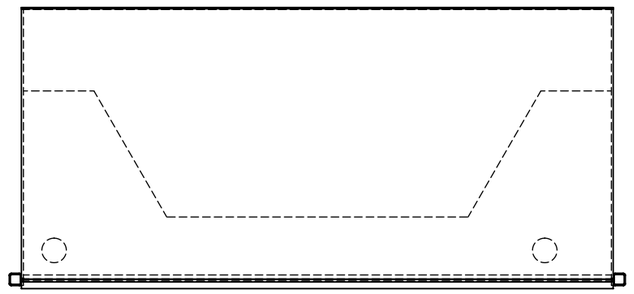
Design of Suction Table for Plasma and Oxy-Fuel CNC Cutting Machine

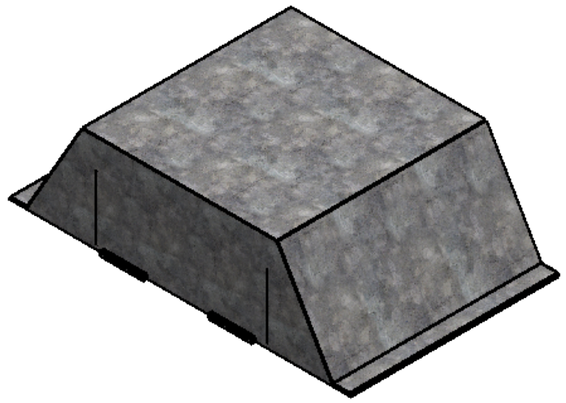
MATERIAL:

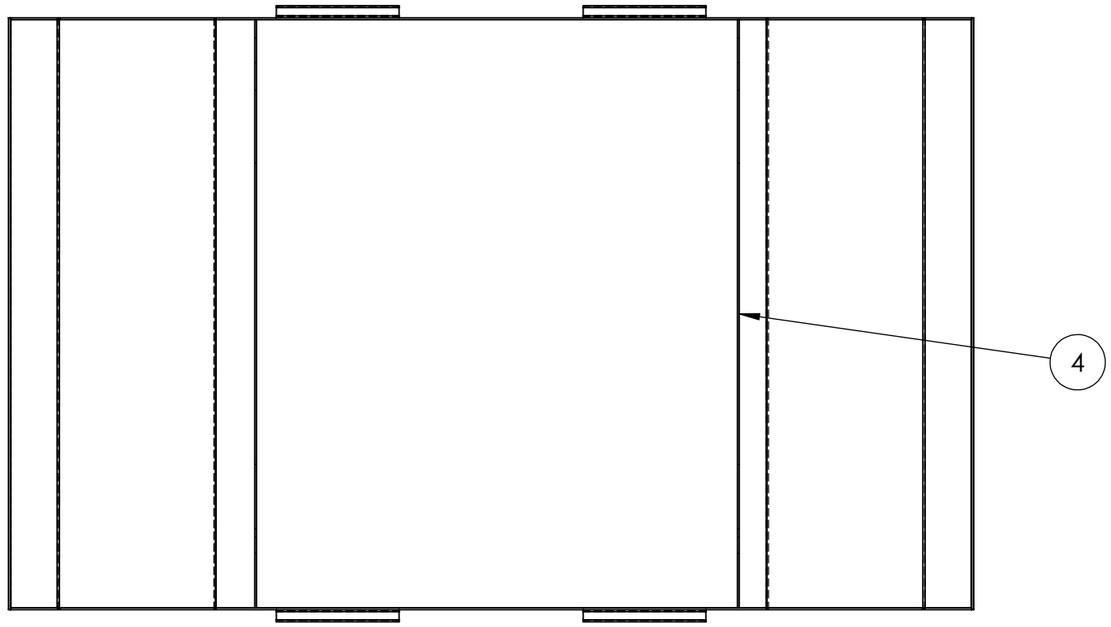
DWG NO. 0KSAVSTA0200 | A0

WEIGHT: | SCALE:1:6 | SHEET 1 OF 1









ITEM NO.	PART NUMBER	PART NAME	QTY.
1	KSAVSTA0301	bucket frame	1
2	KSAVSTA0302	bucket side	2
3	KSAVSTA0303	box support on side plate of bucket	4
4	KSAVSTA0304	BUCKET LIFT	2

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:

FINISH:

DEBURR AND BREAK SHARP EDGES

DO NOT SCALE DRAWING

REVISION

bucket assembly

	NAME	SIGNATURE	DATE
DRAWN	Sakthi Sai		
CHK'D			
APPV'D			
MFG			
Q.A			

TITLE:
Design of Suction Table for Plasma and Oxy-fuel CNC Cutting Machine

MATERIAL:

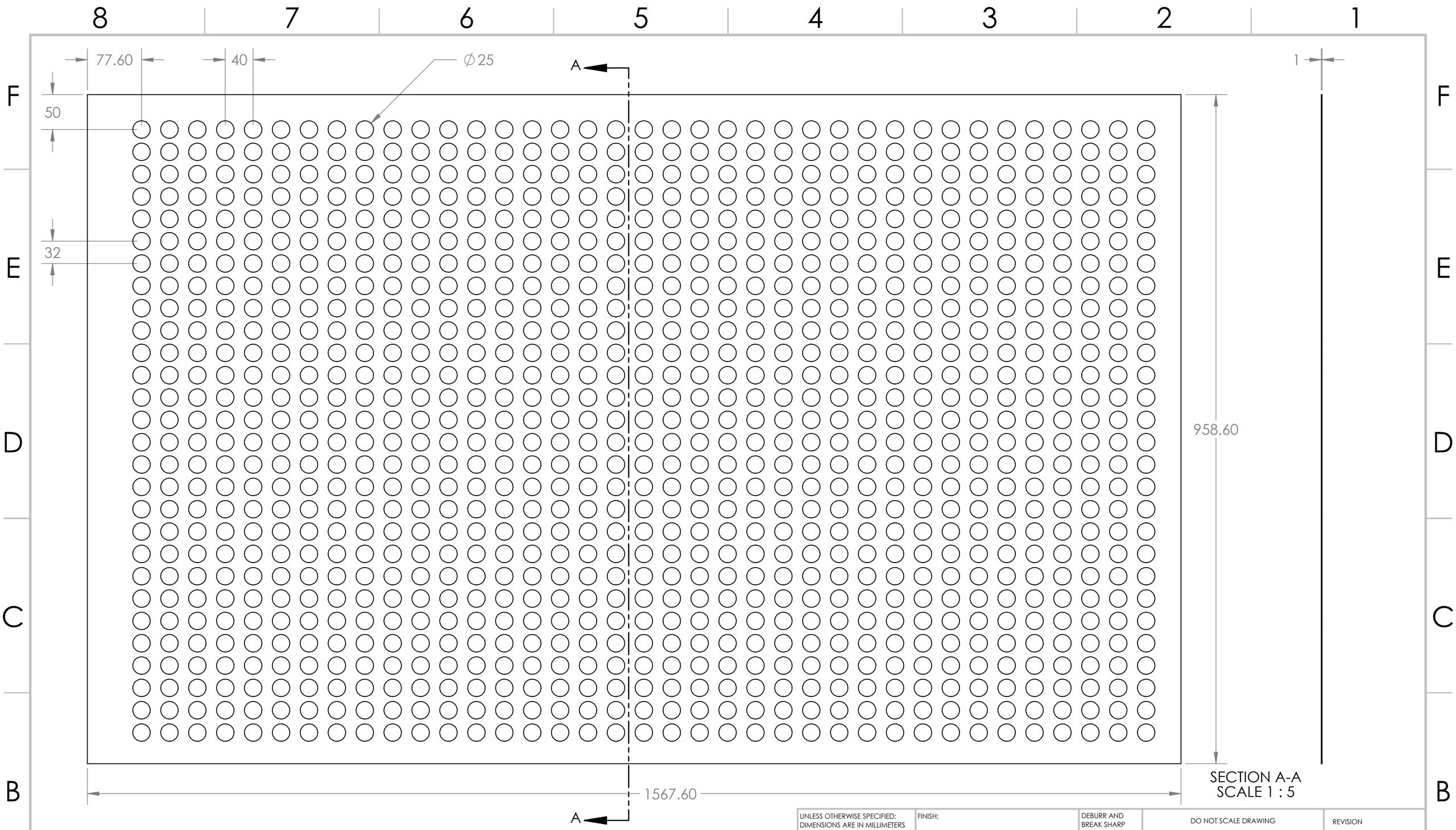
DWG NO.
3KSAVSTA0300

A3

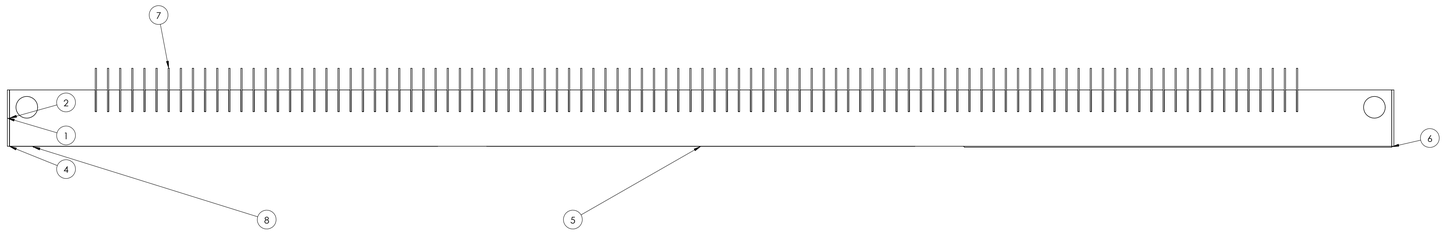
WEIGHT:

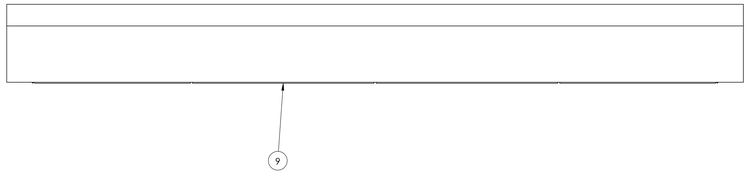
SCALE:1:20

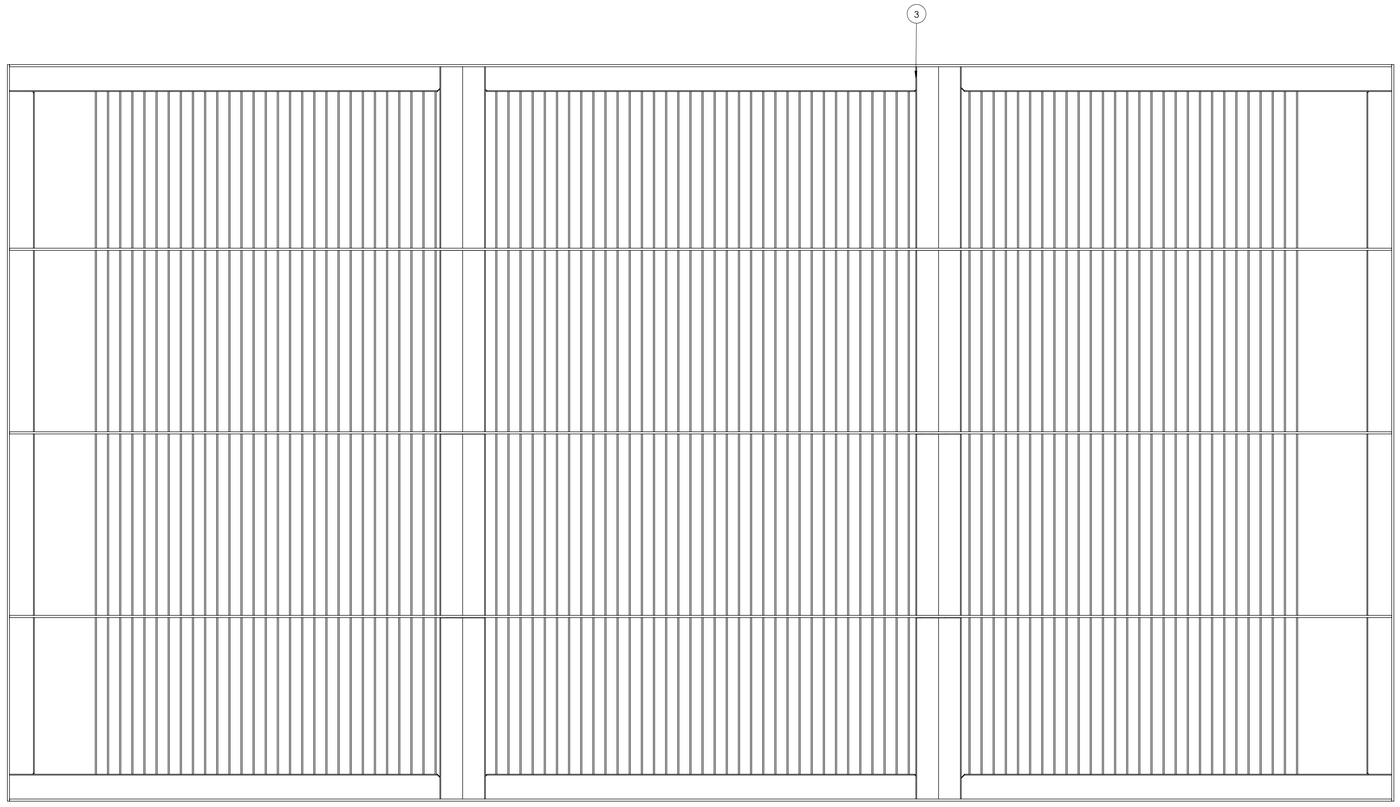
SHEET 1 OF 1



UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS SURFACE FINISH: TOLERANCES: LINEAR: ANGULAR:		FINISH:		DEBURR AND BREAK SHARP EDGES		DO NOT SCALE DRAWING	REVISION
						mesh plate assembly	
	NAME	SIGNATURE	DATE			TITLE:	
DRAWN	Sakthi Sai					Design of Suction Table for Plasma and Oxy-fuel CNC Cutting Machine	
CHK'D							
APPV'D							
MFG							
Q.A				MATERIAL:		DWG NO. 3KSAVSTA0400	A3
				WEIGHT:		SCALE:1:20	SHEET 1 OF 1







ITEM NO.	PART NUMBER	PART NAME	QTY.
1	KSAVSTA0501	slats frame side plate1	2
2	KSAVSTA0502	slats frame side plate2	5
3	KSAVSTA0503	L flange for frame with slats1	8
4	KSAVSTA0504	slats frame crossed plate 1	2
5	KSAVSTA0505	side plate2 for frame with slats	2
6	KSAVSTA0506	side plate3 for frame with slats	2
7	KSAVSTA0507	slats	100
8	KSAVSTA0508	slats short cross plate 2	4
9	KSAVSTA0509	slats short cross plate	4

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCE:
LINEAR:
ANGULAR:

FINISH:

DEBURR AND BREAK SHARP EDGES

DO NOT SCALE DRAWING

REVISION

frame with slats

	NAME	SIGNATURE	DATE
DRAWN	Sakhi Sai		
CHK'D			
APPV'D			
MFG			
Q.A			

TITLE:

Design of Suction Table for Plasma and Oxy-Fuel CNC Cutting Machine

MATERIAL:

DWG NO.

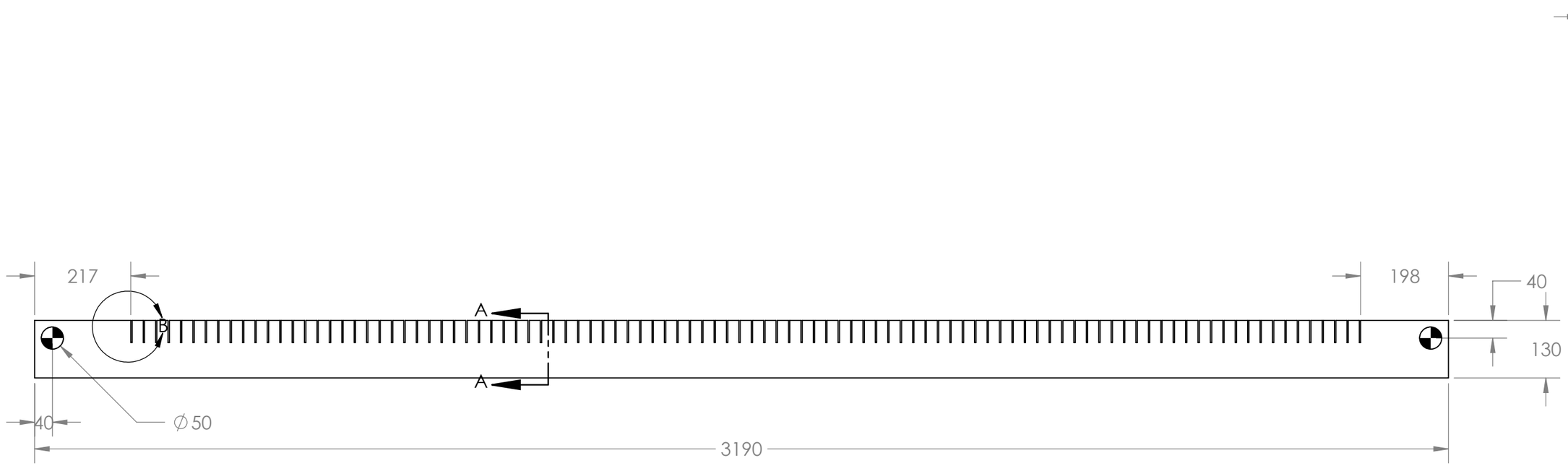
0KSAVSTA0500

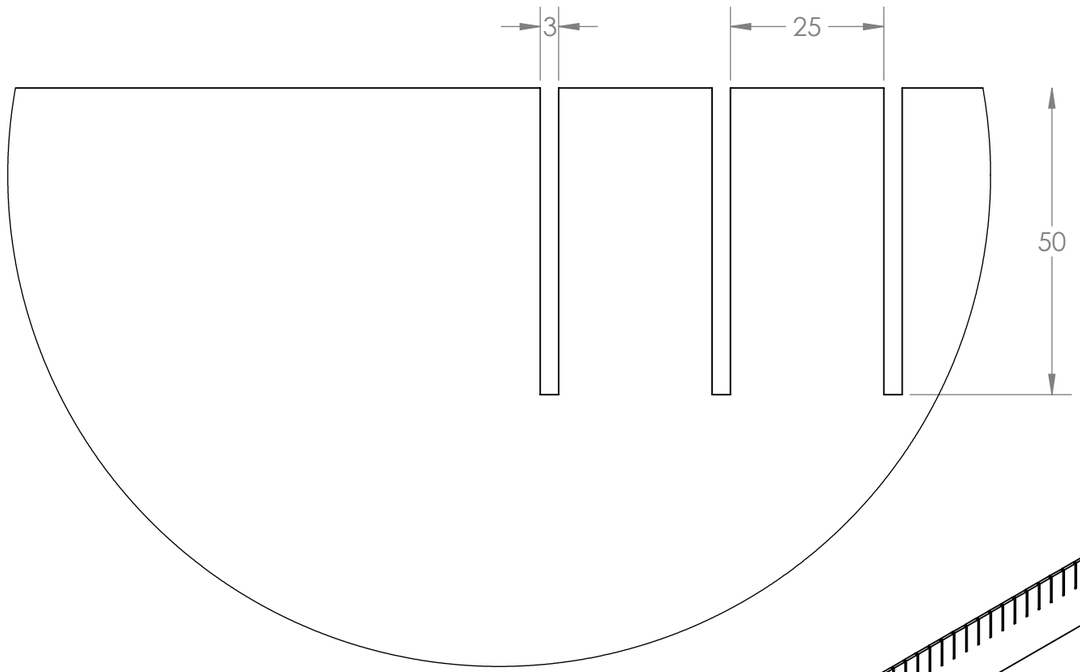
A0

WEIGHT:

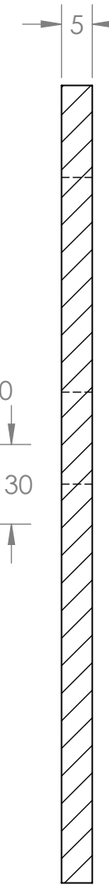
SCALE:1:10

SHEET 1 OF 1

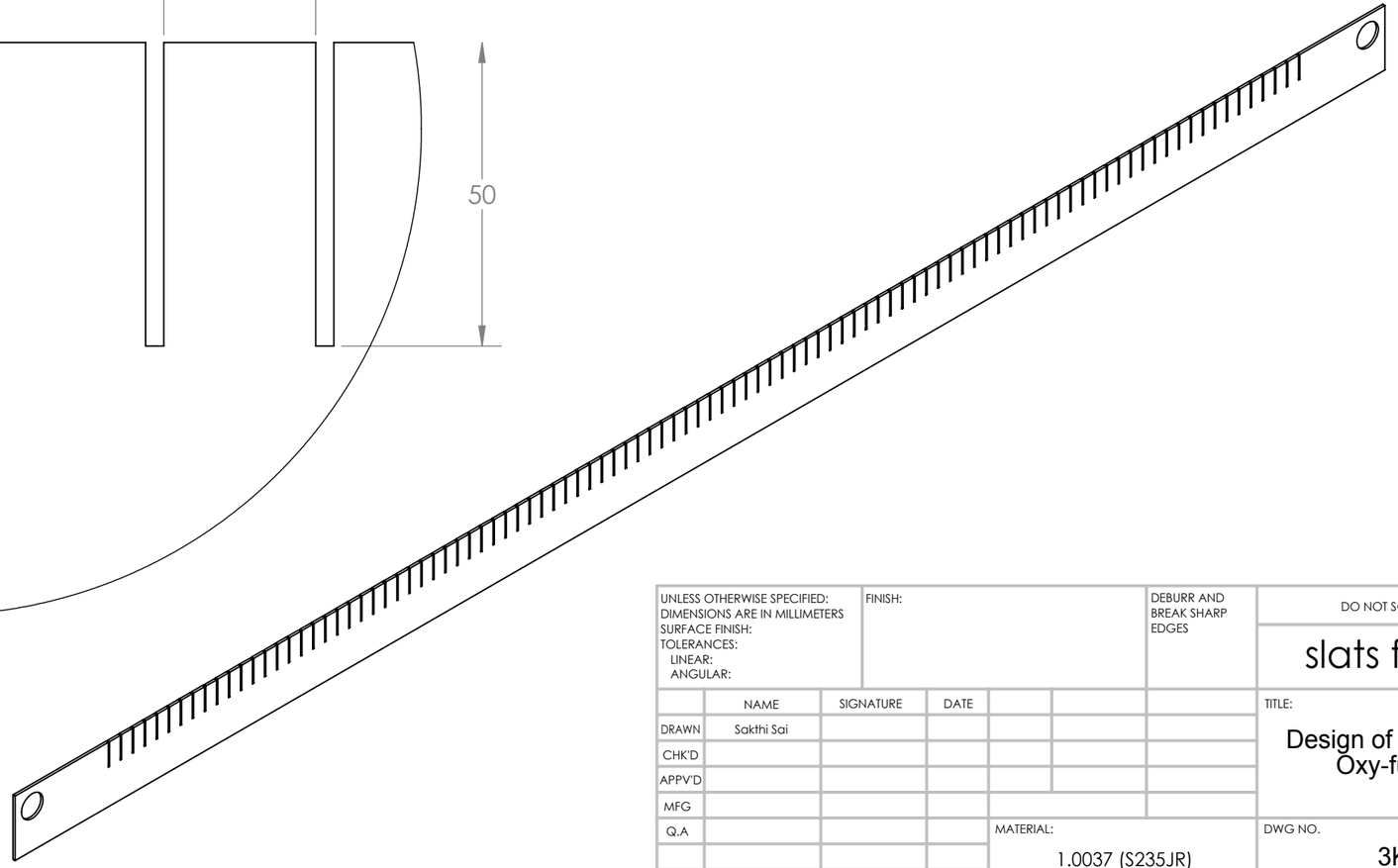




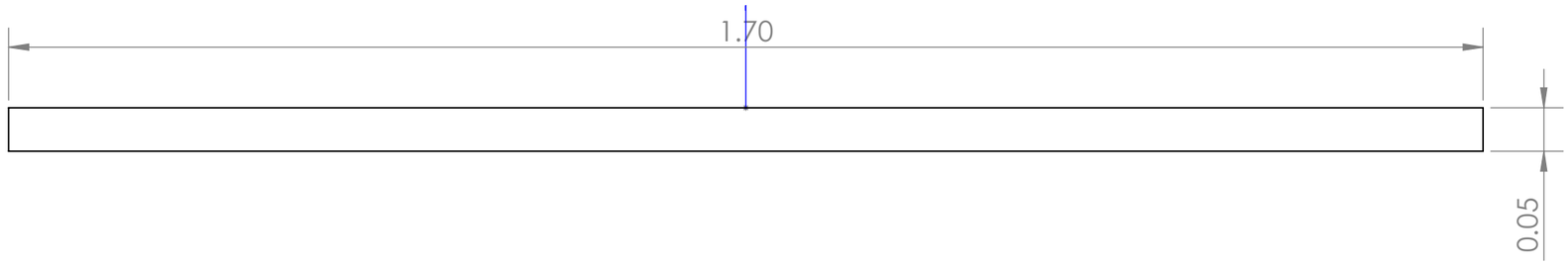
DETAIL B
SCALE 1 : 1

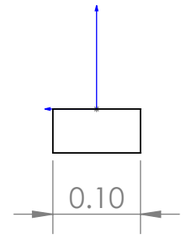


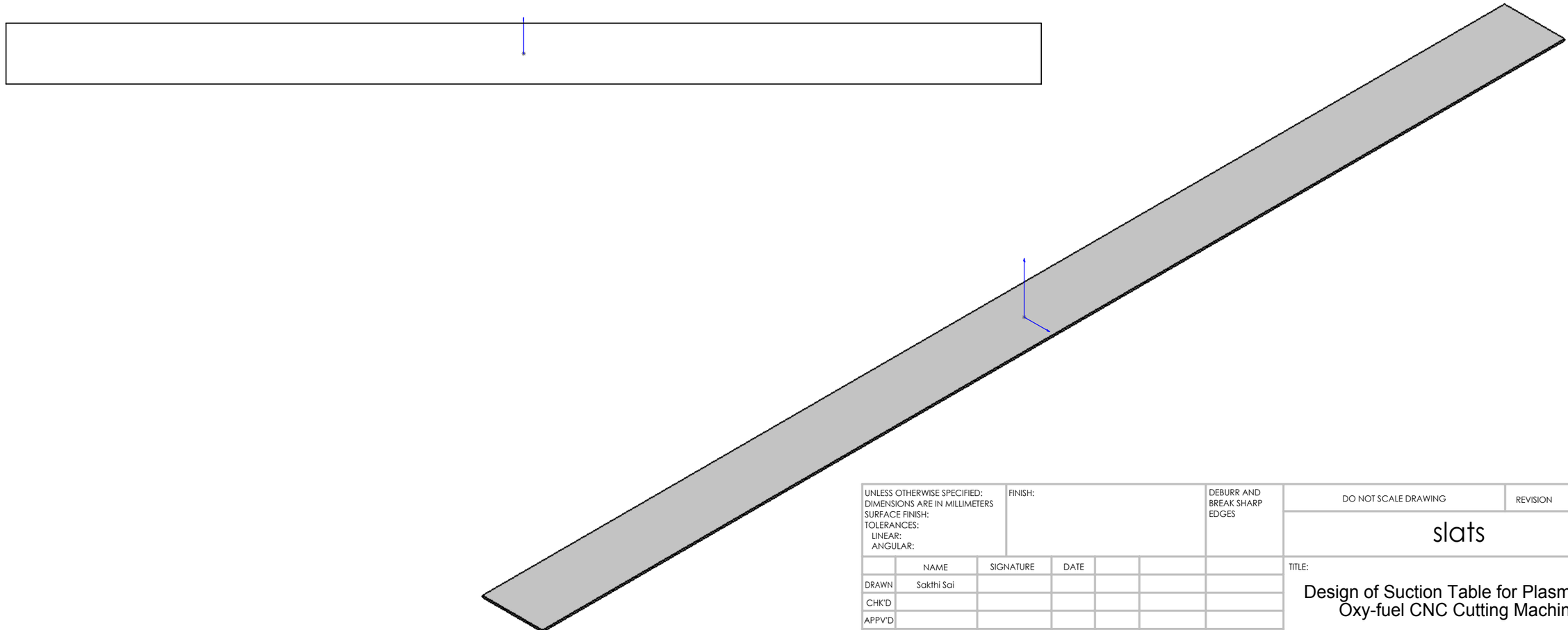
SECTION A-A
SCALE 1 : 1



UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS SURFACE FINISH: TOLERANCES: LINEAR: ANGULAR:		FINISH:				DEBURR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING / REVISION
							slats frame side plate2
	NAME	SIGNATURE	DATE				TITLE: Design of Suction Table for Plasma and Oxy-fuel CNC Cutting Machine
DRAWN	Sakthi Sai						
CHK'D							
APPV'D							
MFG							
Q.A				MATERIAL: 1.0037 (S235JR)			DWG NO. 3KSAVSTA0502 / A3
				WEIGHT:		SCALE:1:25	SHEET 1 OF 1







UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS SURFACE FINISH: TOLERANCES: LINEAR: ANGULAR:	FINISH:		DEBURR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING	REVISION		
				slats			
	NAME	SIGNATURE	DATE	TITLE:			
DRAWN	Sakthi Sai			Design of Suction Table for Plasma and Oxy-fuel CNC Cutting Machine			
CHK'D							
APPV'D							
MFG							
Q.A				MATERIAL:	DWG NO.		A3
				1.0037 (S235JR)	3KSAVSTA0507		
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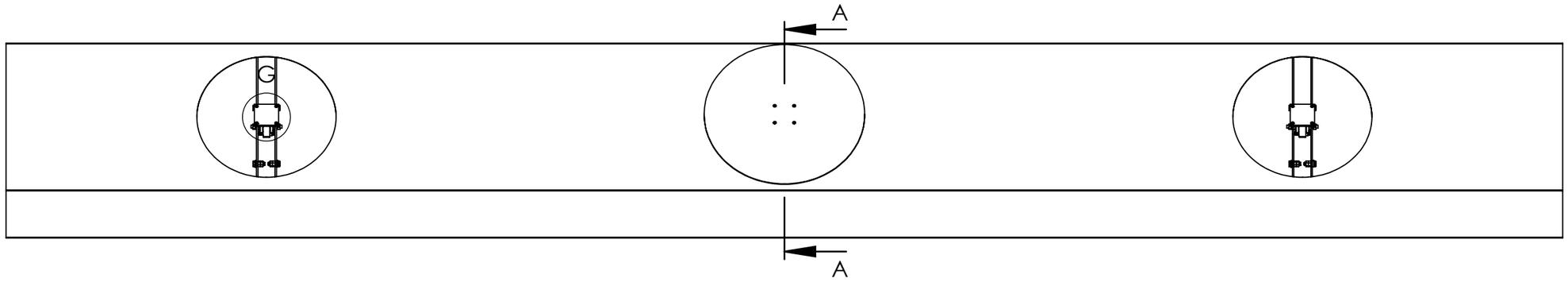
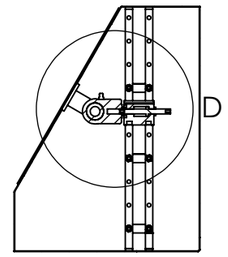
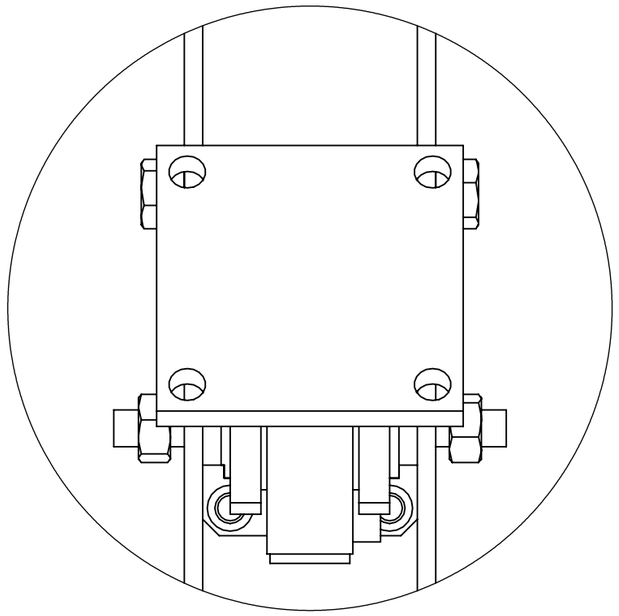
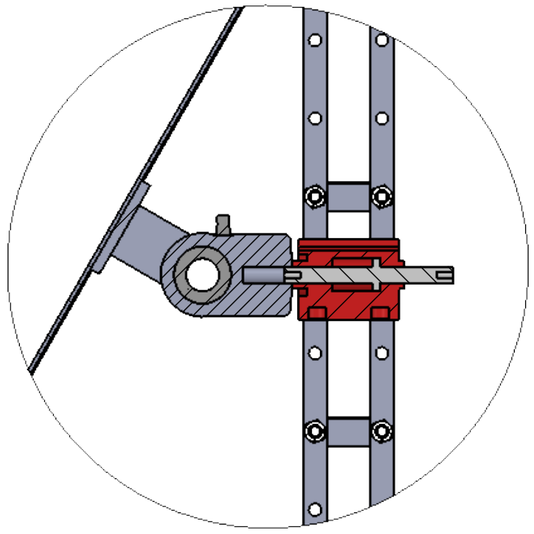




SECTION A-A
SCALE 1 : 10



DETAIL G
SCALE 1 : 1



DETAIL D
SCALE 1 : 3

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UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS SURFACE FINISH: TOLERANCES: LINEAR: ANGULAR:		FINISH:			DEBURR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING	REVISION
	NAME	SIGNATURE	DATE			TITLE: Design of the suction table for Plasma and Oxy-fuel CNC cutting machines	
DRAWN							
CHK'D							
APPV'D							
MFG							
Q.A				MATERIAL:		DWG NO. 3KSAVSTA0601	A3
				WEIGHT:		SCALE:1:50	SHEET 1 OF 1