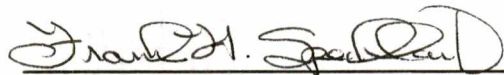


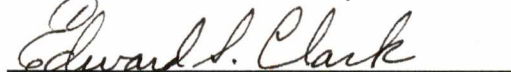
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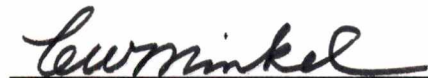


Frank H. Speckhart, Major Professor

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DEC 91

**AUTOMATION OF A TOOTHBRUSH
PACKAGING PROCESS**

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

Brian Dale Cook

December 1991

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Many people supported and contributed to this project and my academic progress in various ways. I wish to recognize and thank the people I feel contributed the most to the success of both my thesis project and my Master of Science education.

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Finally, I would like to thank my wife, Pamela Cook, for her support and understanding during the extent of my graduate career.

ABSTRACT

Today's global market place demands that companies incubate and implement innovative and unique ideas in order to survive. Meeting this demand motivated a local company to seek to reduce the labor content of a certain packaging process.

The packaging process involved stripping blister-packed toothbrushes from a molded set and placing the toothbrushes on a conveyor belt that feeds an automatic boxing device. The process required that a color assortment of brushes be placed on the belt at a rate of approximately thirty-six brushes per minute.

The device developed, named the Separator, picks up the brush sets from a serving tray and loads them into a punch device which separates the brushes from the molded set while simultaneously placing the brushes on the conveyor belt. The desired color assortment is made possible by the use of several Separators serving the same conveyor belt. Each Separator can place thirty-six brushes on the conveyor per minute, meeting the required speed of the belt.

This thesis presents the design methodology, the prototype, results of a product evaluation, and recommendations that may be implemented to improve the present design. The appendices contain the required documentation to manufacture, assemble, and operate the Separator devices.

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CHAPTER 1

INTRODUCTION

In April 1990, representatives of Anchor Brush Incorporated of Morristown, Tn. contacted the University of Tennessee's Center for Industrial Service and requested for assistance in reducing the labor content of an existing packaging operation. This center contacted Dr. Frank Speckhart of the Mechanical Engineering department.

Requirements

The meeting and tour of the plant outlined the problem as follows. Anchor Brush manufactures and packages a set of assorted color toothbrushes for a national company. First, each color of brush is sealed in sets of twelve, in a thermoformed polyvinyl chloride (PVC) package, called a blister pack set, see Figure 1.1. After a set of brushes is sealed, they are separated and stored in a random orientation in large boxes, while other brush colors are being blister packed. Figure 1.2 shows blister packed toothbrushes separated from the blister pack frame. Before the brushes are shipped, they are manually removed from their large boxes and placed on a conveyor belt in a specific orientation and color combination to create a color assortment of six different colors. The brushes are laid on the belt in groups of six, with the first three toothbrushes laid side-by-side, face-down and the next three brushes laid side-by-side, face up on top of the first three brushes. In turn, a pusher on the conveyor belt feeds

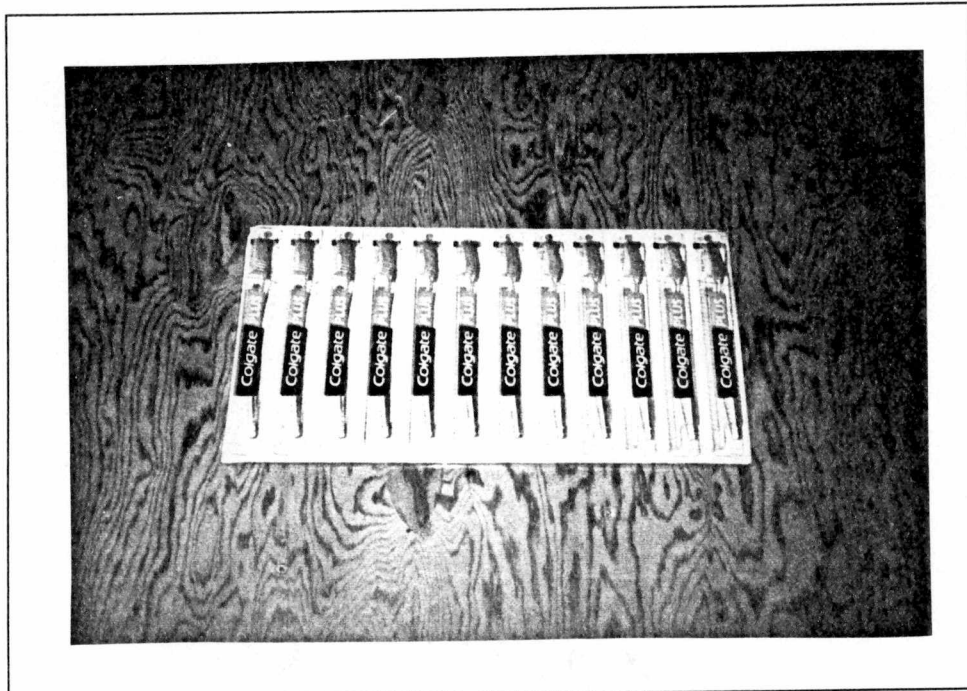


Figure 1.1: Blister pack set.

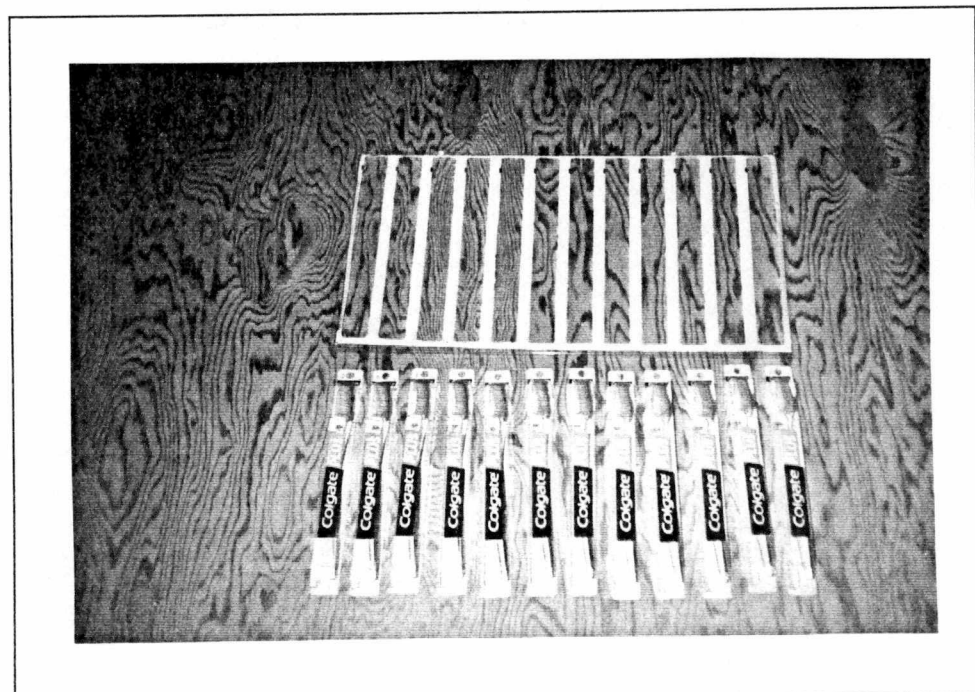


Figure 1.2: Blister packed toothbrushes separated from the set frame.

the brushes to an automatic packaging machine that boxes the brushes in groups of six called a redi-pak. Approximately thirty-six redi-paks are made each minute. The task of sealing and separating the sets of brushes is performed by one employee while the job of removing the brushes from the bulk box and placing the brushes on the conveyor belt is performed by four employees. Presently, Anchor Brush Inc. plans to automate all or part of the process described above in order to reduce the labor content, and consequently, the cost of packaging this particular toothbrush.

Conceptual Design

After the meeting, Dr. Speckhart and I discussed possible methods that may be incorporated to automate the packaging process. The discussion helped Dr. Speckhart and me develop a conceptual design which we felt could perform the required task. This design was presented to Anchor Brush at an informal meeting to gain acceptance and to receive recommendations. After further iterations, Dr. Speckhart and I put together a proposal to Anchor Brush which described a device to reduce the labor content of the packaging process of the blister packed toothbrushes by automating part of the packaging process previously described. The conceptualized device required that the blister packed brushes not be separated from each other as before, but should remain as a set and be boxed as a set. Boxing the brushes in this manner would keep the brushes oriented while in storage. Keeping the brushes oriented while in storage would aid automation and eliminate the need to orient the brushes as required when the brushes are randomly boxed. The device would consist of a pick-and-place unit

which would remove the brush sets from the storage box and place the set on a tray. The tray would then index the brush set such that a brush would be correctly positioned and oriented over the existing conveyor belt. A punch would then separate the brush from the set and deliver the brush to the conveyor belt. The tray would once again index and the next brush would be separated from the set. This process would continue until all twelve brushes of the set had been placed on the conveyor belt. To meet the speed and color assortment requirements, six pick-and-place devices and six punch devices would be used simultaneously. The scrap, the remaining part of the set, would then be removed and the tray would return to a home position where it would be reloaded and the process repeated.

Design Overview

The completed prototype is called the Separator and is illustrated in Figure 1.3. The Separator operates as a single unit, but actually consists of two individual devices: the Punch device and the Pick/Place device as shown in Figure 1.4 and Figure 1.5, respectively. The Punch device separates the toothbrushes from the set of twelve and disposes of the scrap. The Pick/Place device picks up brush sets from a stack and loads the set into the Punch device. Each device was built as a stand alone unit to aid in the development process of the devices and the control scheme.

A personal computer was chosen to control the devices since the control scheme is complex and the design incorporated stepping motors. The versatility of the computer also proved to be beneficial during the development of the devices.

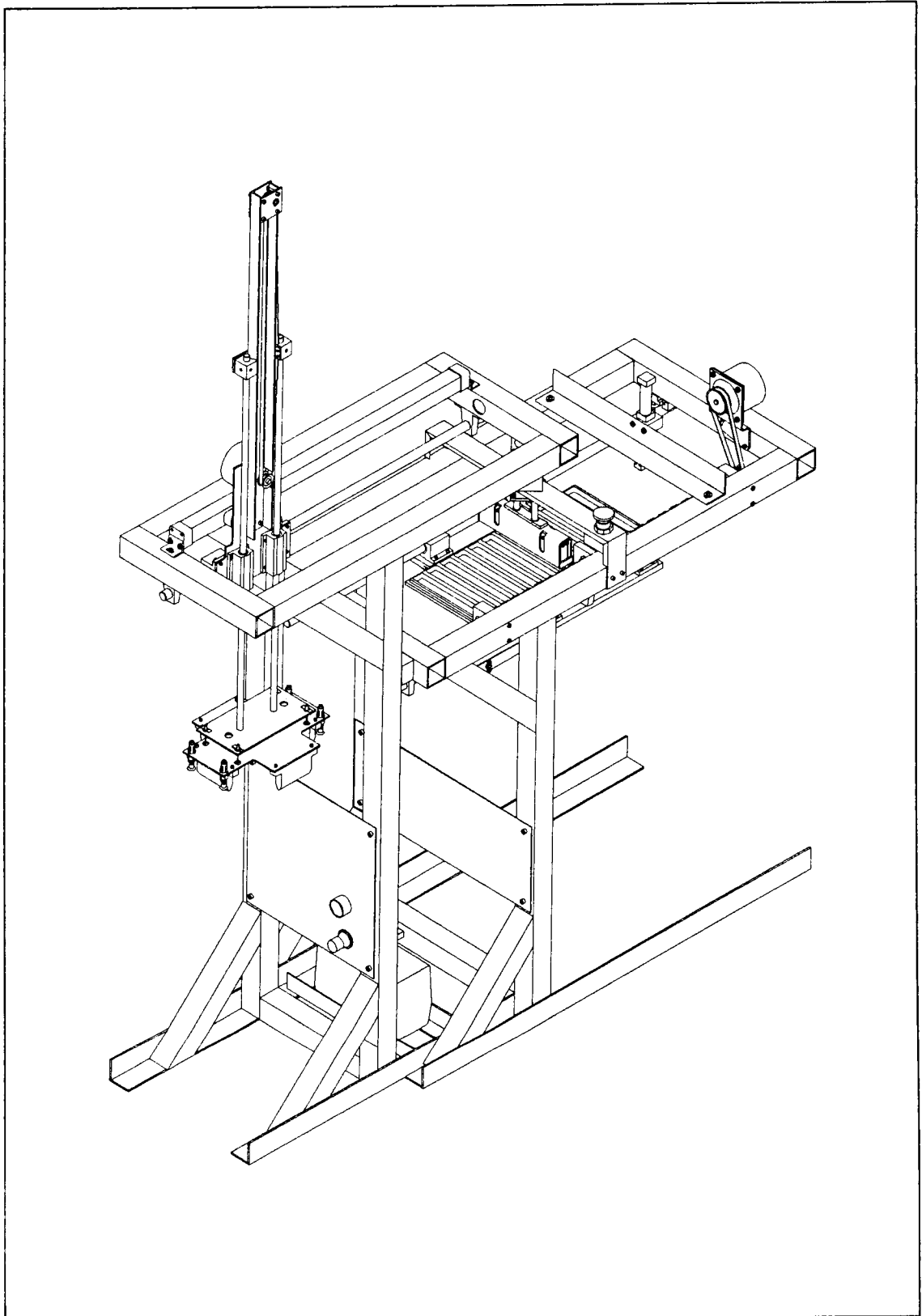


Figure 1.3: The Separator.

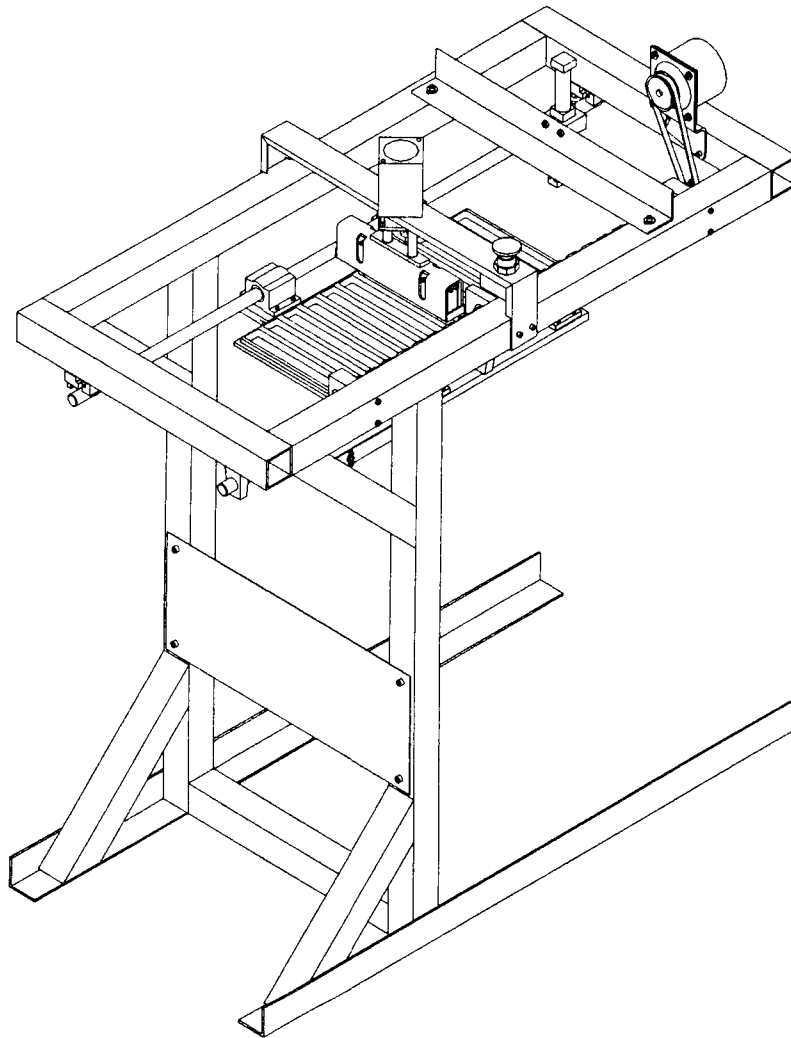


Figure 1.4: The Punch device.

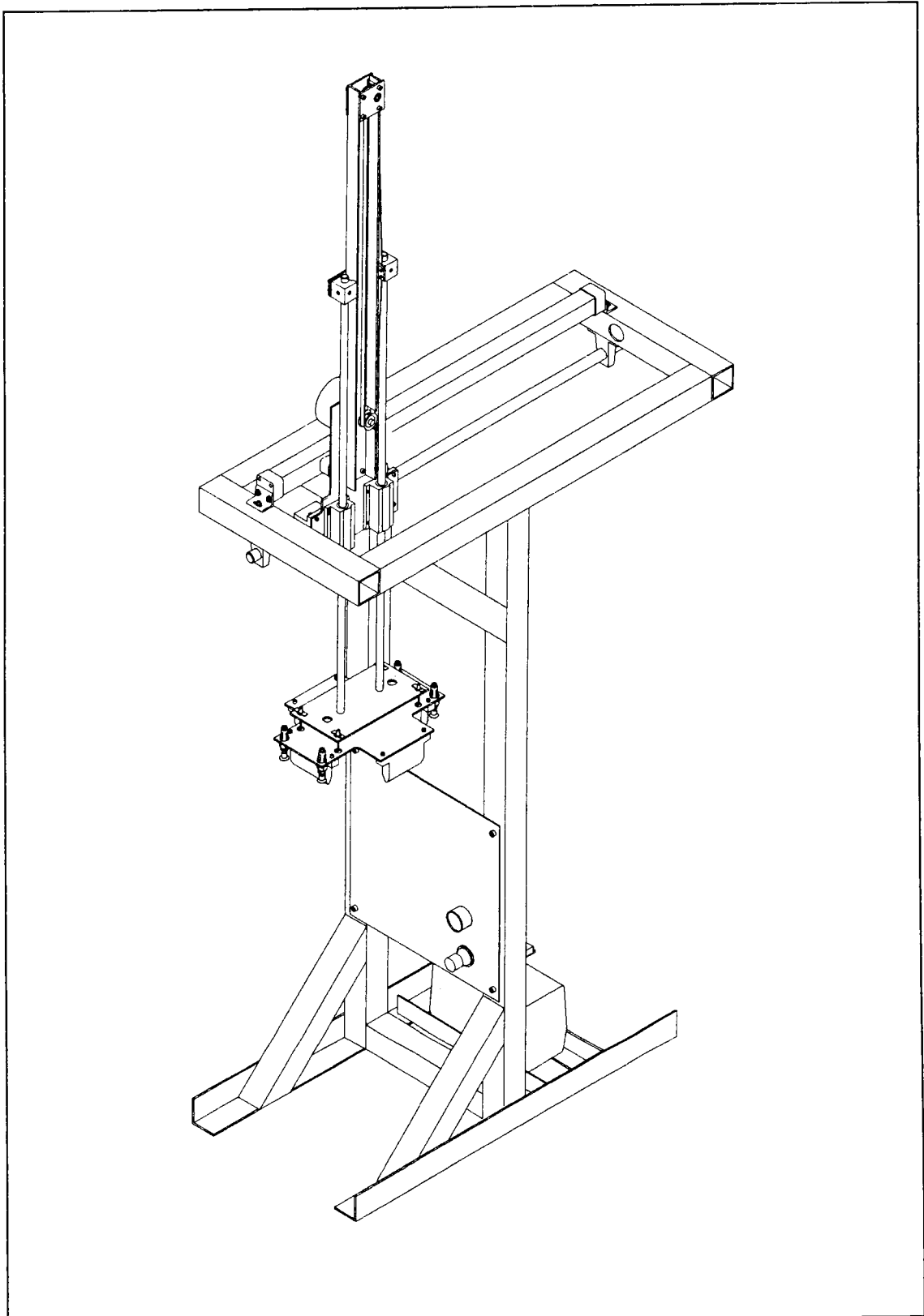


Figure 1.5: The Pick/Place device.

The design methodology was to use standard parts and components whenever possible to expedite the completion of the project. Bending operations were avoided whenever possible, due to the inaccuracies involved in low volume bending jobs. The components of each device were mounted on similarly styled welded frames of 2 inch square steel tubing. The large square tubing provided ample mounting surface for the components as well as stiff frame members. In addition, welding the frame members together provided sufficient stiffness for the entire structure. The control panel of each device was designed such that the control components could be mounted to the panel before the panel is mounted to the frame. Plug-in connectors were also used to aid in the assembly, debugging, and possible disassembly procedures.

CHAPTER 2

PROTOTYPE DESIGN

The first two sections of this chapter, describe the design and construction of the devices that make up the Separator. The third section describes the consolidation of the devices.

Punch Device

The Punch device separates a blister packed brush from the set and places the brush on the conveyor belt. The Punch device is illustrated in Figure 2.1. The device consists of an indexing tray, a horizontal motion system, a clamp-punch assembly, and a scrap removal system. The device can place twelve brushes on the conveyor belt and dispose of the frame in approximately twenty seconds. The base model of the Punch device accommodates the requirement of placing the brushes face-up on the conveyor belt. With the addition of four parts to the base model, the Punch device can remove brushes from the frame and place the brushes on the conveyor belt in a face-down orientation.

Operation

The device incorporates a stationary clamp-punch assembly positioned above a moving die called the indexing tray. The punch consists of flat metal shears bolted to

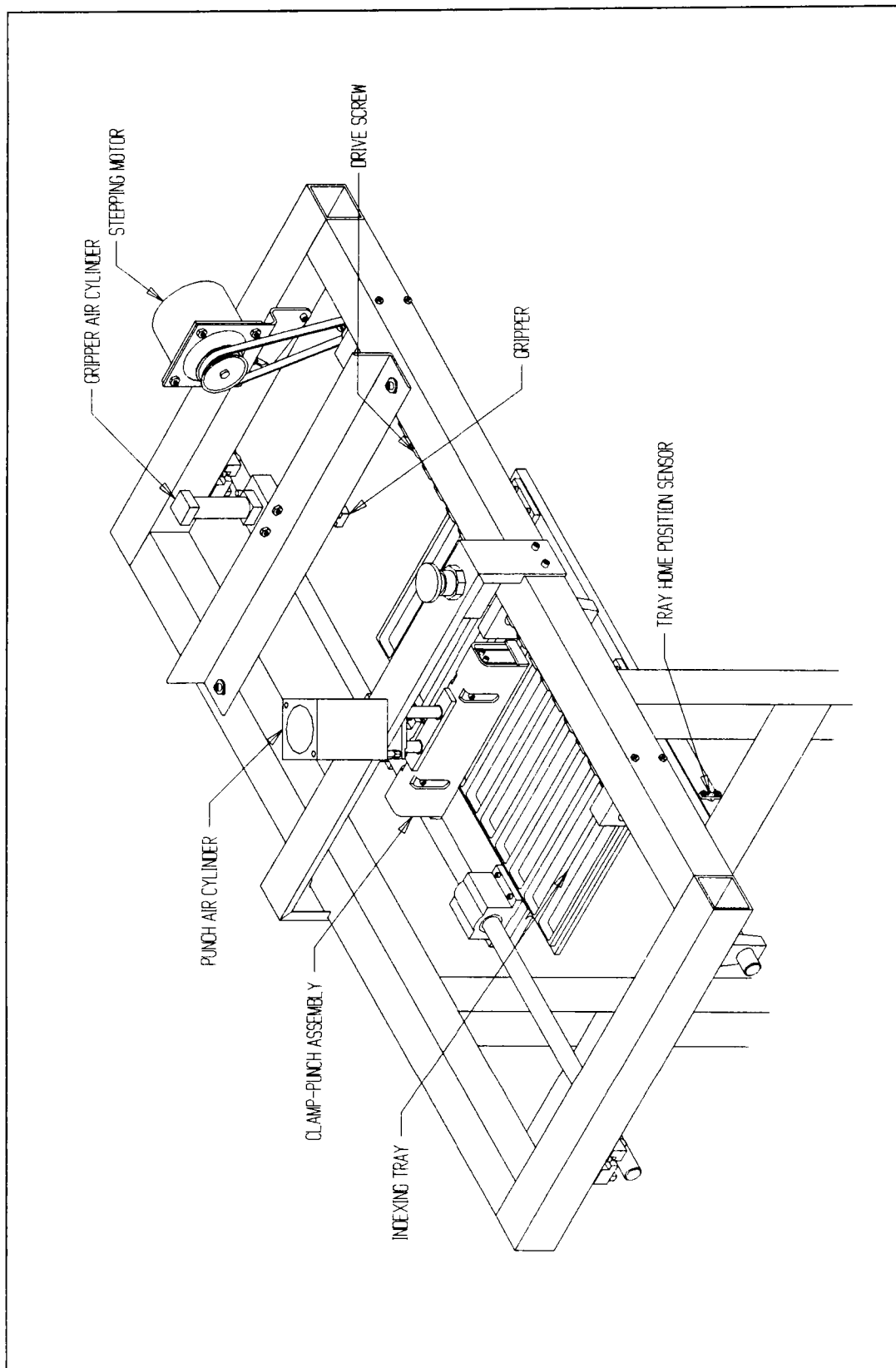


Figure 2.1: Major components of the Punch device.

a base. Figure 2.2 shows the punch without the clamp. During operation, the brushes are ripped from the frame by the punch. Ripping the brushes from the frame is the method presently used at Anchor Brush and, by using this method, the clearance between the tray and the punch is not critical; it should not be greater than 0.100 inches. However, the positional deviation between the punch and the indexing tray requires that the punch be precisely placed under the tray to ensure proper operation. To meet this required tolerance, a lead screw is employed, powered by a stepping motor via an indirect drive. By using a stepping motor as the prime mover, the tray is positioned to within ± 0.0056 inches, without the use of a feedback system.

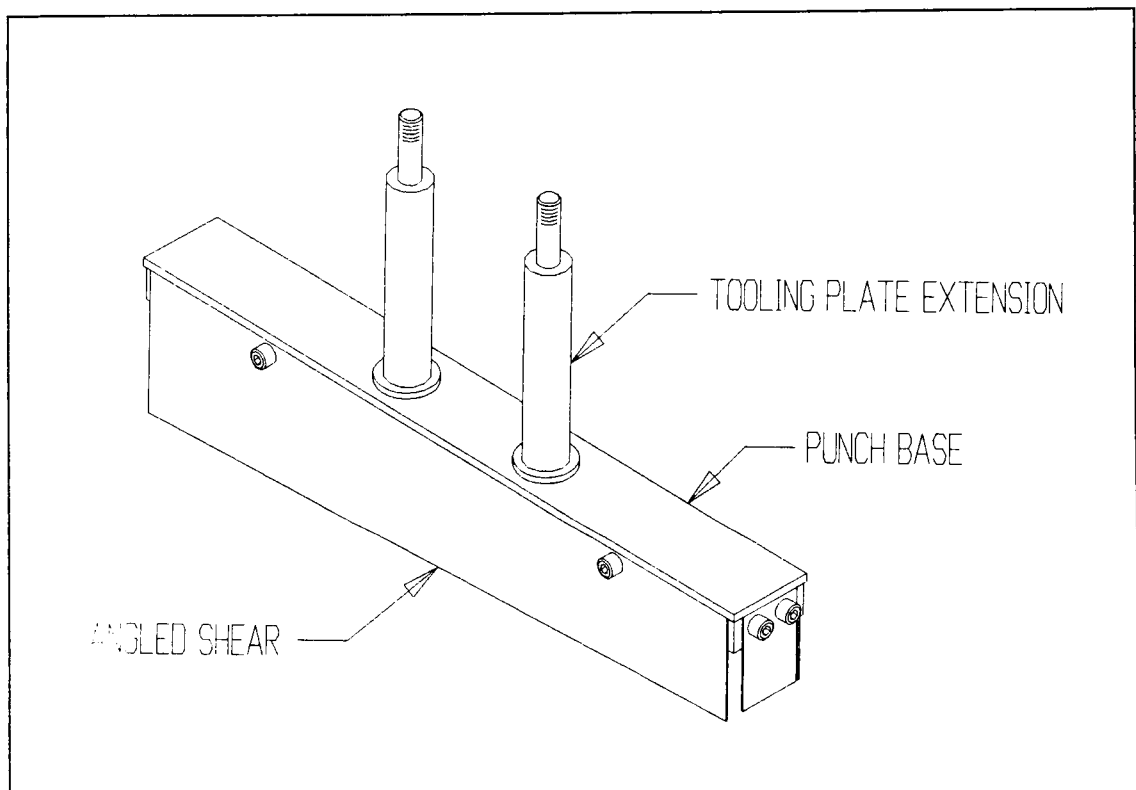


Figure 2.2: The punch.

Controlling the tray with a stepping motor also provides the positional flexibility required in this operation. Before starting each cycle the tray is "homed" with an optical sensor to define an exact starting position. The tray is mounted on steel shafts with ball bushings to minimize friction losses.

The brush set is held in place on the tray by the raised surface of the indexing tray, which mates with the frame of the brush set. Firmly holding the brush set during the punching operation is achieved by the spring loaded clamp of the clamp-punch assembly. When the clamp-punch assembly is extended, the clamp holds the frame as the punch separates the brush from the frame. The clamp-punch assembly is one unit and is activated by a single non-rotating air cylinder.

After the brushes have been removed, the frame is removed from the tray by a gripper located on the end of a non-rotating air cylinder. The gripper fingers are spaced slightly larger than the ribs of the tray but smaller than the ribs of the scrap. The scrap removal system is placed above the tray and is centered above one of the ribs of the tray. Initially, the air cylinder is retracted and the gripper is open. When activated by the computer, the air cylinder extends the gripper down and the gripper is closed against the scrap. The cylinder then retracts and the scrap is lifted above the tray. After the tray is moved back to its loading position, the gripper opens and the scrap is dropped into a trash bin.

Design Criteria

The tolerance of the mounting holes in the frame is held to ± 0.010 inches by locating and drilling the holes after the frame is assembled. This process properly locates the components on the frame relative to one another. In addition, adjustable pillow blocks are used, when necessary, to ensure the tray support shafts are parallel.

The angled shears of the punch are used to remove the brushes from the frame because the angled shear is more reliable and requires a smaller operating force, then a straight punch. This fact and the angle of the shear were determined experimentally.

Since the force applied to move the indexing tray is not in the geometrical center of the mechanism, a binding analysis was performed to ensure free motion of the tray during operation. As the tray is moved it is subjected to a horizontal binding force as shown in Figure 2.3. The analysis indicates that the coefficient of friction (μ) between the horizontal shafts and the bearings must be less than .14 to prevent binding. This is accomplished by employing Thomson ball bushings as the support bearings which have a coefficient of friction of less than 0.01. The complete binding analysis is presented in detail in Appendix C.

A torque analysis was performed to estimate the minimum size of the stepping motor. The analysis was simplified by neglecting friction and other possible losses. To compensate for this simplification, a safety factor of four was used. The analysis indicates that a stepping motor with a holding torque as small as 85.2 oz-in can run the device as desired. A 150 oz-in, size 34 stepping motor is used. The torque requirement analysis is documented in Appendix B.

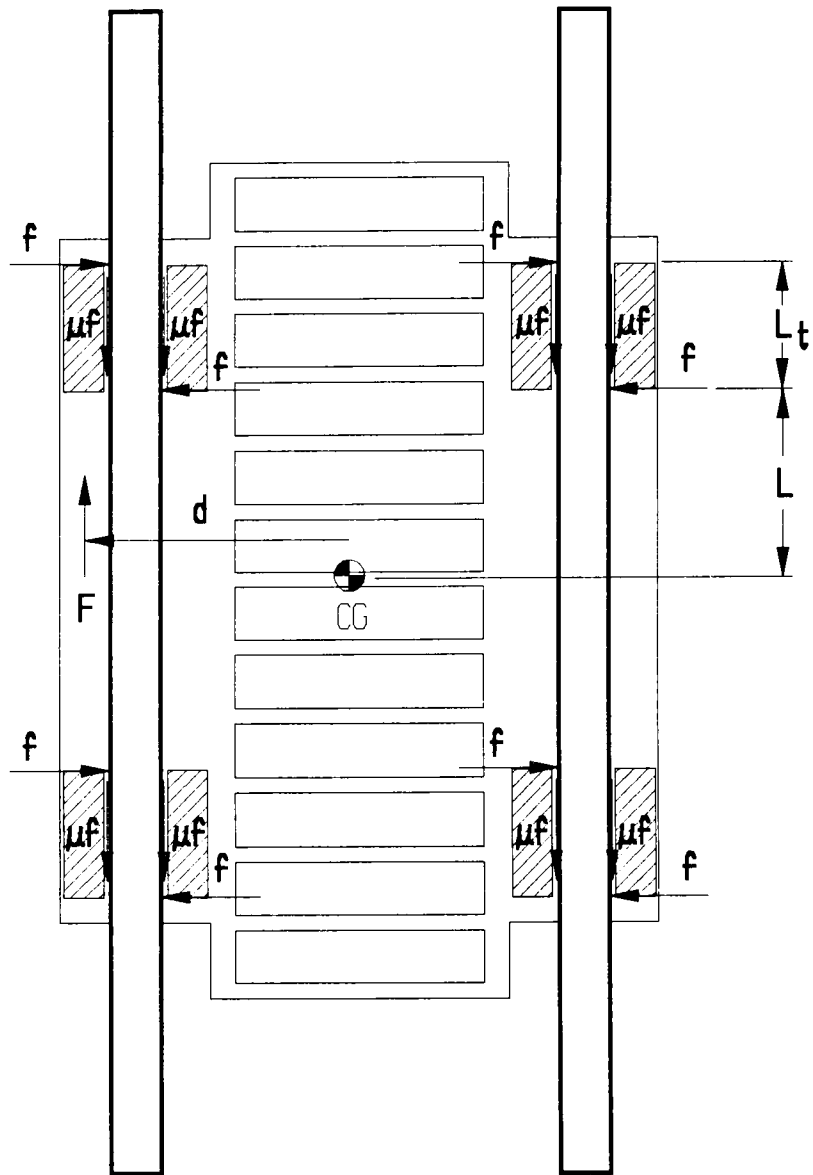


Figure 2.3: Free body diagram of the indexing tray.

A list of the parts required to manufacture the Punch device is included in Appendix D. Appendix E is comprised of detailed drawings of the custom manufactured parts. The part numbers that include the suffix "A" are parts that may be added to the base model to accommodate the face-down brush sets. Appendix F contains the assembly drawings for the device. The Punch device's pneumatic and electrical circuits are shown in Appendices G and H, respectively.

Pick/Place Device

The Pick/Place device accurately loads the Punch device with blister-packed toothbrush sets. The Pick/Place device is illustrated in Figure 2.4. The device consists of an end effector, a vertical motion system, and a horizontal motion system. The device picks up the brush sets from a custom made serving tray (not shown in Figure 2.4), where the sets are stacked, and loads the sets onto the indexing tray of the Punch device.

Operation

The end effector is made up of four major components, the upper support plate, the lower support plate, the guides, and the vacuum cups. The upper support plate is a horizontally mounted aluminum plate which mounts directly to the vertical

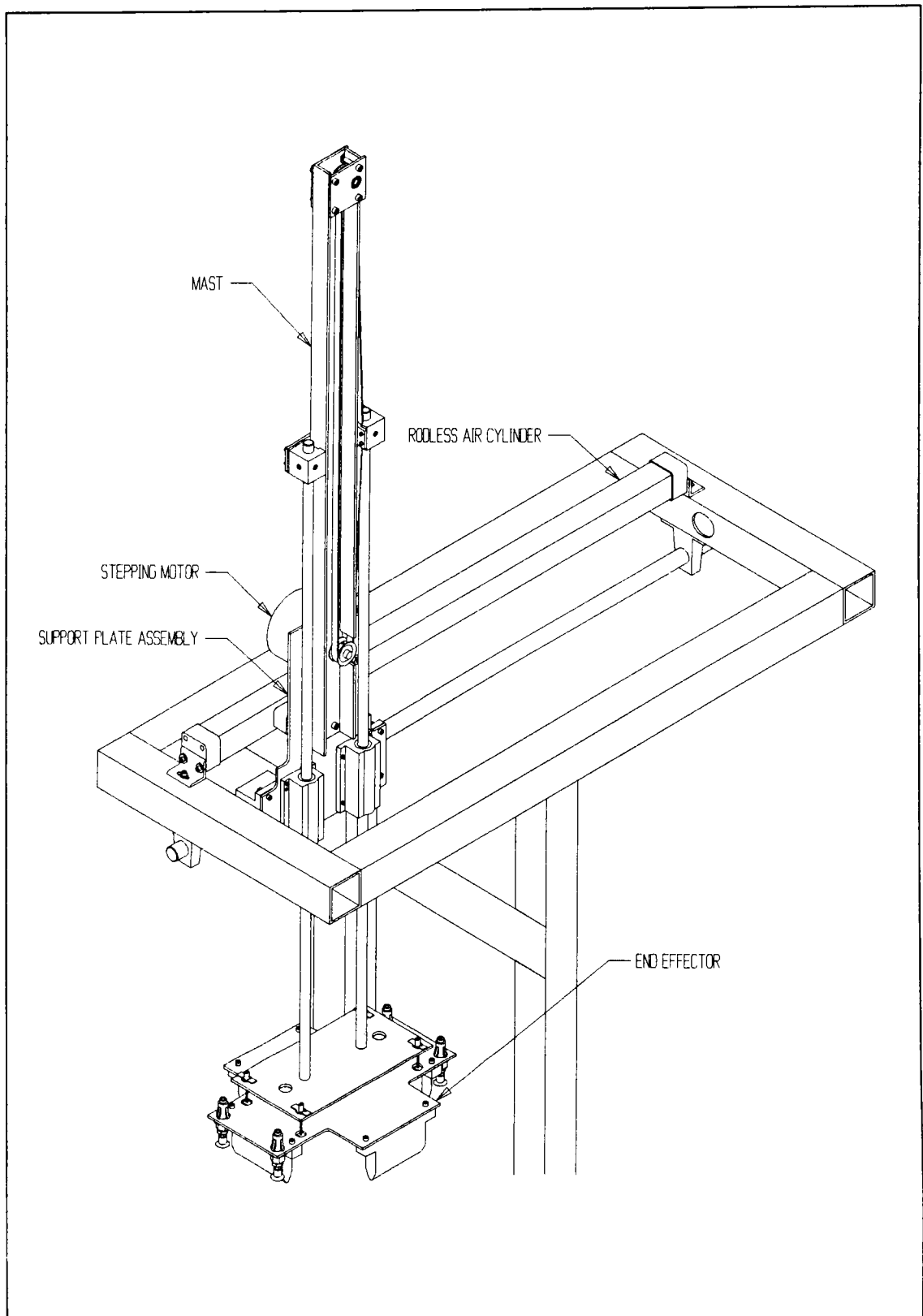


Figure 2.4: Major components of the Pick/Place device.

motion system. The lower support plate hangs from the upper support plate by four 1 inch long cables attached at the corners of the plates. This method of mounting the plate gives the plate freedom to move relative to the upper plate. This freedom is important when the end effector is picking up the brush sets from a tall stack, because, the toothbrush blister pack is slightly taller on the brush head end than on the brush handle end. This small difference becomes a significant tilt when the brush sets are stacked on top of one another as shown in Figure 2.5. To fully set the vacuum cups, not only should the end-effector match the tilt of the brush set, but the downward force of the vertical motion system must be transmitted to the vacuum cups as well. This required force is transmitted by a spring positioned between the upper and lower support plates. The spring restrains the movement of the lower support plate in the horizontal plane while allowing movement in the vertical direction for the plate to tilt. The lower support plate serves as a mount for the nylon guides and the vacuum cups. The nylon guides slide the brush sets into the correct position as they are picked up. The brush sets are then gripped by the vacuum cups. The vacuum supply is routed from a tube manifold mounted on the upper support plate to the lower support plate via custom coiled tubes. The tubes were coiled to prevent any additional restraining forces, other than the spring, on the movement of the lower support plate.

The vertical motion system consists of two vertical shafts rigidly connected to each other, as well as the end effector, sliding in double length ball bushings. Using two shafts prevents the possible rotation of the end effector. The vertical system is

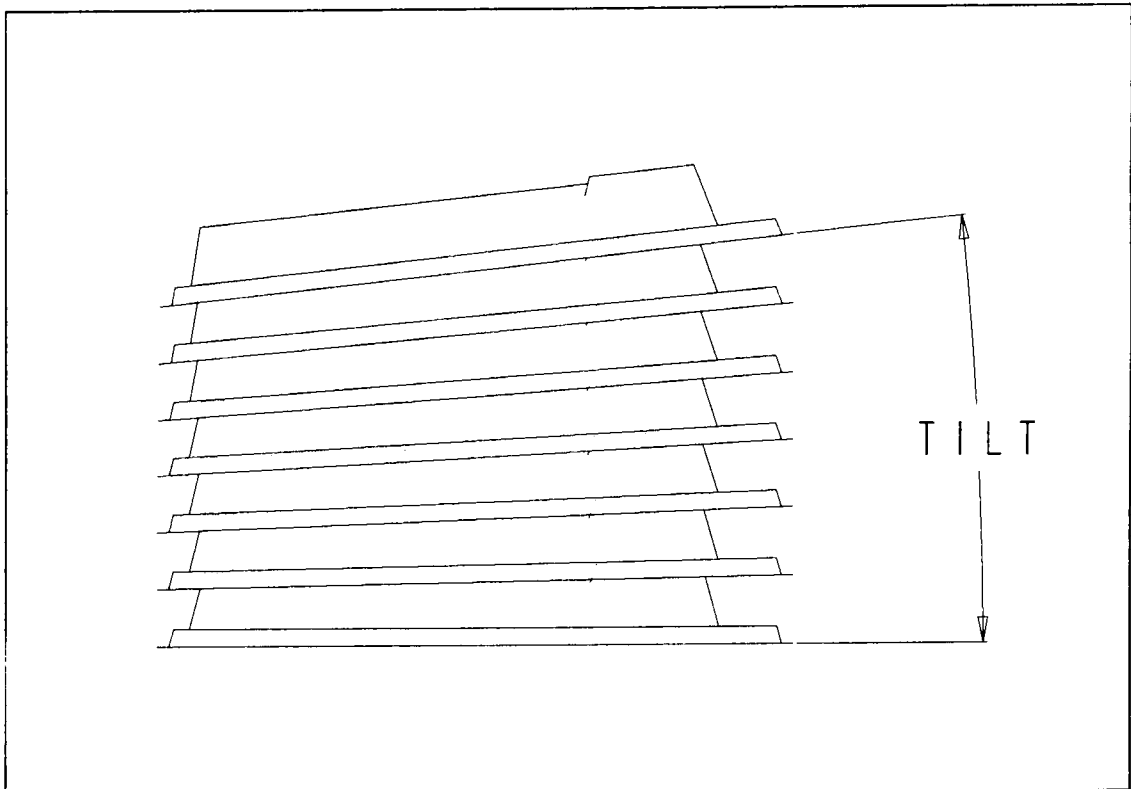


Figure 2.5: Tilt of stacked blister packed brush sets.

powered by a stepping motor. A stepping motor was chosen over a dc motor for two reasons, first, a holding torque is required when the end-effector is in the home position, and secondly, the end-effector had to be capable of placing the brush sets on the indexing tray accurately without any type of feedback system. The stepping motor drives the vertical shafts by a timing belt. A counterweight was added to protect the end effector assembly from damage in the event of a power failure. With the counterweight and the residual torque of the stepping motor, the end effector assembly still falls during a power failure, but the final impact is not detrimental.

The horizontal motion system is a rodless air cylinder which moves the end-effector and the vertical motion system from the pick position to the place position as

required. The air cylinder length is such that the pick and place positions are at the end of the piston travel.

Design Criteria

The tolerance of the mounting holes in the frame is held to ± 0.010 inches by locating and drilling the holes after the frame was assembled. Adjustable air cylinder brackets are also incorporated to ensure the rodless air cylinder is parallel to the horizontal shaft, as required for proper operation.

Since the force required to move the end effector-shaft assembly is not in the geometrical center of the mechanism, a binding analysis was performed to ensure free motion of the assembly during operation. As the assembly is moved, the vertical shafts are subjected to a horizontal binding force as illustrated in Figure 2.6. The analysis indicates that the coefficient of friction (μ) between the vertical shafts and the bearings must be less than 1.13 to prevent binding. This is easily accomplished by employing Thomson ball bushings as the support bearings which have a coefficient of less than 0.01. The complete binding analysis is presented in detail in Appendix C.

As in the development of the Punch device, a torque analysis was performed to estimate the minimum size of the stepping motor. The analysis was performed neglecting friction and other losses. To compensate for this simplification, a safety factor of four was used. The analysis indicated that a stepping motor with a holding torque as small as 37.2 oz-in can run the device as desired. A 150 oz-in, size 34

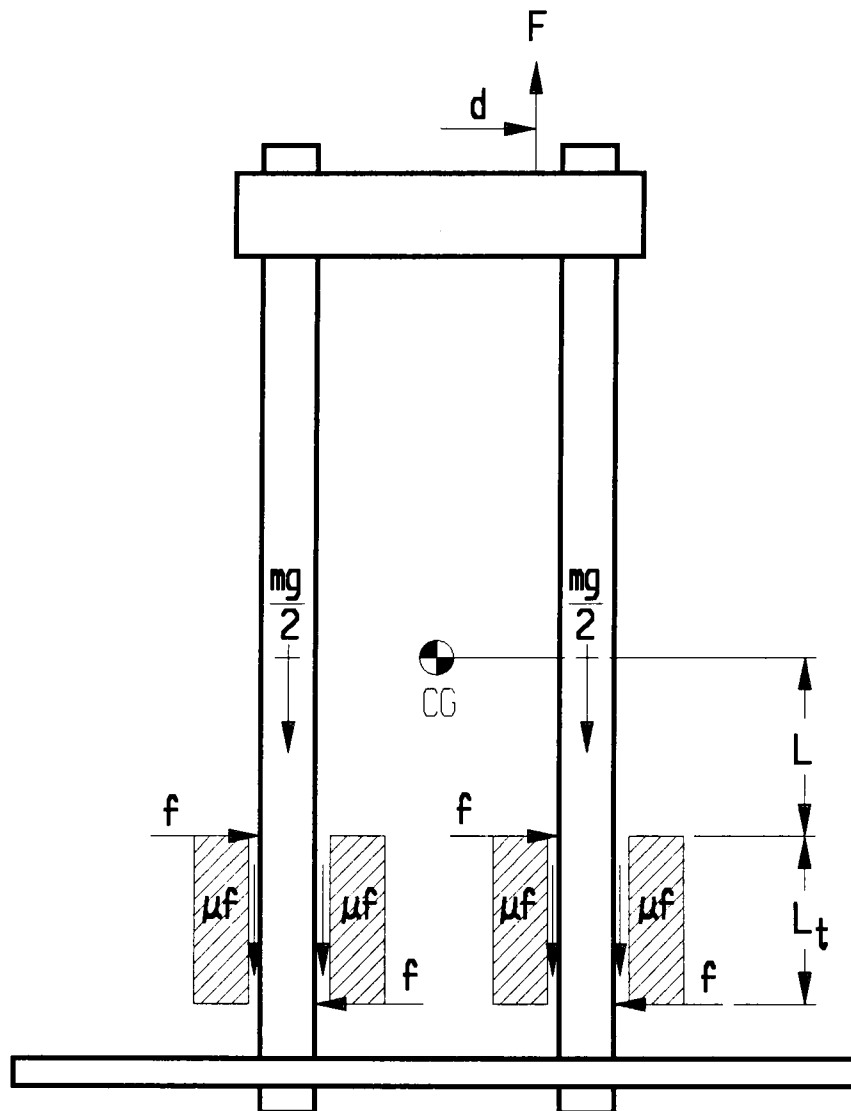


Figure 2.6: Free body diagram of the end effector-shaft assembly.

stepping motor is used. The torque requirement analysis is documented in Appendix B.

A list of the parts required to manufacture the Pick/Place device is included in Appendix D. Appendix E is comprised of detailed drawings of the custom manufactured parts. The part numbers that include the suffix "A", are parts that may be added to the base model to accommodate the face-down brush sets. Appendix F contains the assembly drawings for the device. The Pick/Place device's pneumatic and electrical circuits are shown in Appendices G and H, respectively.

Consolidation

Before the devices could operate as a single unit, the devices had to be consolidated mechanically and electrically.

The mechanical consolidation required connecting the frames of the devices together such that both frames act as one. This process involved bolting the vertical support member of the Pick/Place frame to the upper tie of the Punch frame. See assembly drawing ASM212 in Appendix F. It is not necessary to connect the lower portions of the frame together since the base of each frame will be anchored to the floor when installed in a manufacturing environment.

The electrical consolidation was accomplished by installing an additional parallel port controller in the computer. This approach allows both devices to be plugged into the computer simultaneously and permits the computer to access either device as required.

CHAPTER 3

CONTROL SCHEME AND OPERATION

A computer was chosen as the controller for the Separator because of its versatility and speed. The versatility of the computer made design changes and additions easy to accommodate, consequently playing a very important role in the development of the devices. The speed of the computer allows the hardware to operate at its maximum design speed.

Hardware

An IBM compatible computer, manufactured by the Intelec Corporation, controls the Separator. The computer consists of an Intel 80286 processor with a 16 MHz clock, 1 megabyte RAM, a 3-½ inch 1.44 megabyte diskette drive, and a monochrome monitor. The computer contains a 50 megabyte hard drive, but this drive was not required to run the Separator. A parallel port card was added to the computer's configuration, in addition to the original parallel port card. This addition was required to provide computer access to both the Punch and the Pick/Place devices.

The computer controls the Separator by sending information through the parallel port cables connected to the parallel port cards. Each cable contains 25 independently controlled wires or pins. The computer controls the components of each

device by turning certain parallel port pins on or off and monitoring the status of certain other pins.

Development

The computer program was developed in BASIC with the final version written in the "C" programming language. "C" provides significant speed advantages over BASIC. Due to the complexity of the control scheme, a time sharing procedure is implemented to run both the Pick/Place and the Punch devices as required. Each device only runs when the other device is not running, but, because of relatively high computer speeds, it appears that both devices run simultaneously.

The program increased the reliability of the devices by making decisions based on the status of certain sensors/switches, and because of the computer's speed, no noticeable time delays are incurred. Therefore, any check that increased the reliability of the Separator was incorporated into the program.

Operation

The following paragraphs describe how the Separator operates as controlled by the computer. Refer to Figure 2.1 and Figure 2.4 to identify the parts described.

During initial start-up, the end effector of the Pick/Place device and the tray of the Punch device will home sequentially. The stepping motor of the Pick/Place will index the end effector up until its home position switch is depressed. The home position switch for the end effector is located on the support plate assembly. The

stepping motor of the Punch device will index the tray forward up to one inch while the computer monitors the status of its home position sensor. If the home position sensor is not triggered, the motor will reverse and the tray will move backward until the home position sensor is triggered. Once the switch is triggered, the stepping motor will index $1/200^{\text{th}}$ of a revolution further in order to fully trip the home position sensor. At this time the operator loads brush sets onto the serving tray. As indicated on the menu of the program, the operator presses key #3 on the computer keyboard to start the devices.

After the computer receives the signal to begin, the Pick/Place and Punch devices start performing their designated task independently, hence, the following descriptions of the operation of the Pick/Place and Punch devices are given independently.

The rodless air cylinder control valve of the Pick/Place will switch and the end effector will be moved to the pick position (over the stack of brush sets). Once in this position the Pick/Place stepping motor will index the end effector down while the computer monitors the status of the brush set position switch. The brush set switch is located on the end effector. When the brush set position switch is depressed by a brush set, the end effector will be indexed down approximately $1/8$ inch further to ensure good contact between the vacuum cups and the brushes. Now the vacuum control valve is activated followed by a $1/2$ second delay which allows ample time for the vacuum to build in the tubing. The end effector will now index up approximately $1/4$ inch and again the computer will check the status of the brush position switch. If

the switch is not still depressed this indicates the brush set has been dropped or was never picked up. In either case the end effector will once again index down searching for a brush set. The program will search for a brush set up to three times, after the third attempt the program stops and a error message is given along with a list of possible problems. If the brush set switch is still depressed after the 1/4 inch increment, the end effector will be quickly indexed up until its home position switch is depressed. Now the rodless air cylinder control valve is deactivated and the end effector is moved to the place position. Here, the Pick/Place device will wait until the home position sensor for the indexing tray of the Punch device is triggered.

While the Pick/Place is performing the operation described, the Punch device's stepping motor will index the tray to the first brush position and wait for a signal before punching out the first brush. When a pusher of the conveyor belt depresses the pusher position switch, the punch air cylinder control valve will be activated and the clamp-punch assembly will extend down and separate the first brush from the set. After a short time delay, the punch control valve will be deactivated and the clamp-punch assembly will return to its home position. Once the clamp-punch home position switch is triggered the stepping motor will index the tray to the next brush position and again wait for the pusher position microswitch to be depressed. This procedure is repeated for the remaining brushes. It is important to note that the program will not move the indexing tray unless the home position sensor of the punch air cylinder is activated, hence, preventing a possible collision between the two.

During the separation of the last brush the scrap removal system is initiated. This process involves activating the scrap removal air cylinder control valve which moves the gripper within reach of the scrap. The gripper control valve is then activated in order to close the gripper and grip the scrap followed by the deactivation of the air cylinder control valve which retracts the scrap removal air cylinder. By this time the clamp-punch assembly has been returned to the home position. Once the clamp-punch assembly is in the home position, the stepping motor will reverse direction and return the tray to its home position. The gripper control valve will then be deactivated and the gripper will drop the scrap.

Now, with the tray in the home position, the brush set switch of the Pick/Place is again checked. If the switch is not depressed, it indicates that the brush set has been dropped; the program stops and an error message is displayed. However, if the brush set switch is still depressed the end effector of the Pick/Place will index down a prescribed distance so that the brush set is in the desired position on the tray. The vacuum control valve is then deactivated to release the brush set and the end effector is indexed up until it's home position switch is depressed. At this time both the end effector and the tray is in the home position and both the Pick/Place and the Punch will begin another cycle.

Multiple Separators

To perform the required task of placing different color toothbrushes on the conveyor belt simultaneously, it is necessary to build several Separator devices and

operate them simultaneously. To illustrate the manner in which the devices perform the required task and how the computer controlled Separator will work with the Programmable Logic Controller (PLC) controlled conveyor belt, the operation of six Separators is described below.

Description of Operation

The devices should be positioned side by side with the first three devices separating face-down brush sets and the next three devices separating face-up brush sets. Since each device can only place a brush in one specific place, it is important that the devices are staggered such that the first and fourth Separators place a brush on the left of the conveyor belt, the second and fifth devices place a brush on the center of the conveyor belt, and the third and sixth devices place a brush on the right of the conveyor belt. The Separators are timed with the conveyor belt by the punch belt synchronization microswitch which locates the position of the conveyor belt pusher.

The start-up procedure is described in Appendix J. After receiving the signal from the computer, the end effectors of all six Pick/Place devices will home simultaneously. Once the end effectors are homed, the computer program will home the indexing trays of the Punch devices sequentially. This process is accomplished by disabling the stepping motors of all but one of the punch devices as the indexing tray of this device is homed. The program will then disable the motor of this device, while the indexing tray of one of the remaining Punch devices is homed. When all the end effectors and the indexing trays are homed, the program will wait for the start

command as before. After the start command is received, all six Separators work simultaneously as the Pick/Place device begins to pick up the first brush set. During the first cycle the punch devices do not contain brush sets, therefore, no brushes will be punched out. And since the redi-pak boxer requires a toothbrush in order to make a box, no boxes will be made. However, during the second cycle each machine is loaded with a brush set and the brushes will be placed one at a time on the conveyor belt. The Separators will not place a full set of brushes on the conveyor belt for the redi-pak boxer until the sixth brush of the second cycle is punched. Therefore, it is suggested that the first five incomplete sets be removed by hand to prevent incomplete redi-paks. Figure 3.1 illustrates the position of the toothbrushes as placed on the conveyor belt during the first six punches of the second cycle. In the illustration, an arrow is placed by one of the conveyor pushers to show the position of this pusher as the belt moves and the brushes are laid on the conveyor belt. Over the position of each brush will be the Separator devices. As shown in the figure, during the first punch a toothbrush is laid in front of the pushers of the conveyor belt. The first three brushes are placed face-down and the next three brushes are placed face-up. The brush placed in front of the pusher with the arrow beside it during the first punch, will be in the first complete set during the sixth punch. Since the computer will stop the belt when the punch is not working, only complete redi-pak sets will be made after the sixth punch of the second cycle.

The computer controls the PLC of the conveyor belt by sending data, or a signal, to the PLC. Currently, the computer sends a negative twenty-four volt signal

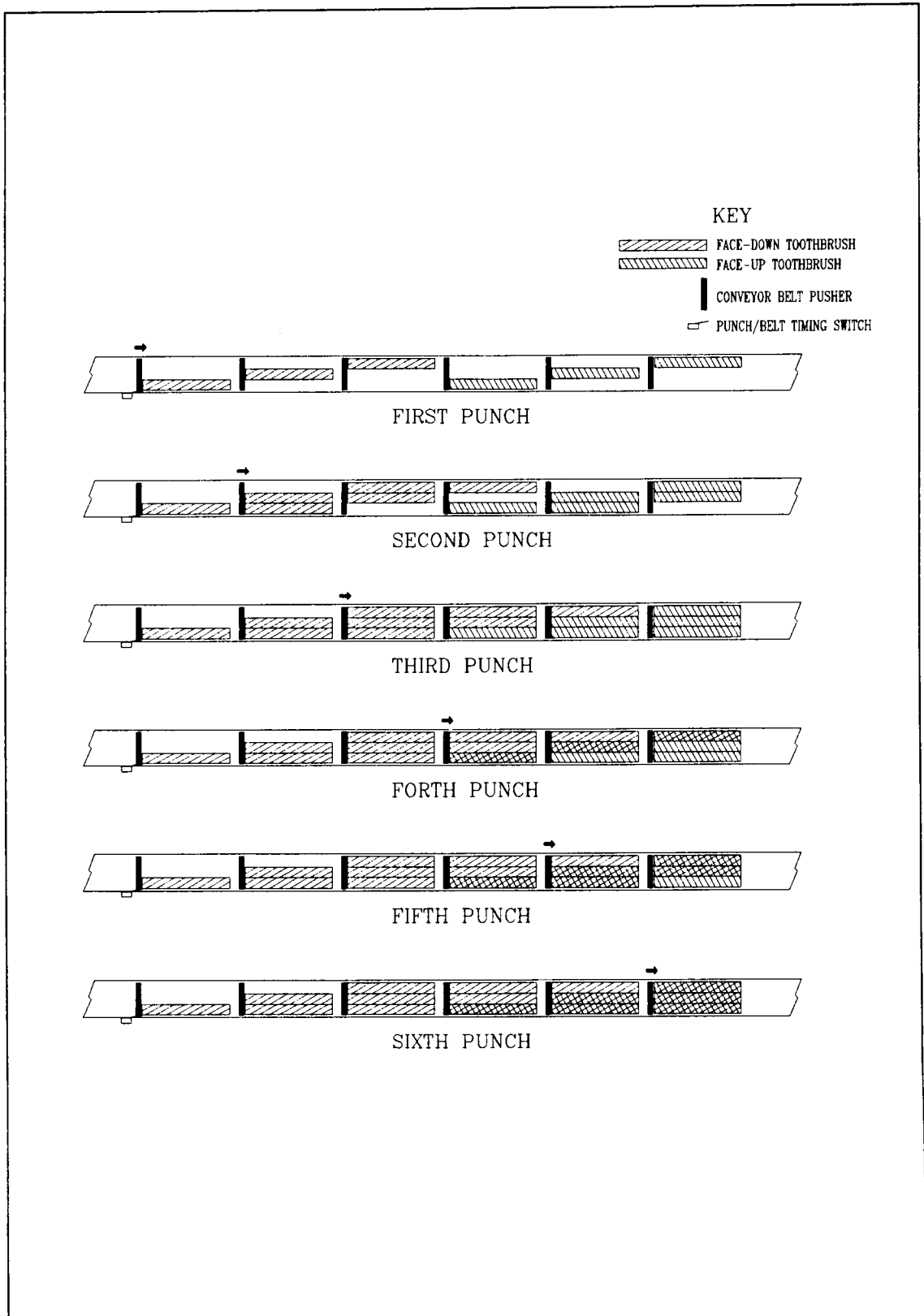


Figure 3.1: Brush placement on conveyor belt during start-up; second cycle.

to the PLC as an indication to run the belt. The absence of voltage on the same line indicates that the belt should stop.

CHAPTER 4

COST ANALYSIS

The total cost of the Separator is recorded in Table 1. See Appendix K for itemized lists of the cost. The cost is based on the construction of the prototype during the development of the machine. Both the manufactured parts costs and the assembly costs of the devices are only estimates. These costs could not be accurately assessed during prototyping due to design changes and re-working manufactured parts.

The computer shown on the cost summary table, which controls up to six separator devices simultaneously, would not need to be purchased for each Separator built. Thus, the total cost of additional Separators is reduced to the sub total of Table 1.

The cost of the purchased parts, for both the Punch and Pick/Place devices, may be reduced by ordering parts for more than one Separator at a time. For example, the set-up cost included in the cost of the Thomson class "L" shafting only applies to the first shaft manufactured, consequently, this cost will not be added to additional identical shafts ordered at the same time.

The cost of the manufactured parts may also be considerably reduced by purchasing the materials for multiple Separators at the same time. Building multiple Separators concurrently will also reduce the processing cost of the manufactured items, since most of the processing time is spent in the set-up of the machines. A significant

TABLE 1: COST SUMMARY

ITEM	COST
PURCHASED PARTS	
PUNCH DEVICE	\$1,608.44
PICK/PLACE DEVICE	\$1,508.52
MANUFACTURED PARTS	
PUNCH DEVICE	\$1,241.50
PICK/PLACE DEVICE	\$953.00
ASSEMBLY	
PUNCH DEVICE	\$400.00
PICK/PLACE DEVICE	<u>\$400.00</u>
SUB TOTAL	\$6,111.46
COMPUTER	<u>\$905.00</u>
TOTAL	\$7,016.46

portion of the indexing tray processing cost may also be saved by milling the tray with a Computer Numerical Controlled mill.

CHAPTER 5

CONCLUSIONS AND RESULTS

After the prototype was completed, a performance evaluation was conducted on the Separator. The evaluation consisted of separating approximately 2,400 blister packed toothbrushes from the frame as well as performing a reliability study on the device. The results of the evaluation are documented below in the three categories: prototype problems and solutions, issues not addressed, and recommendations.

Prototype Problems and Solutions

The Separator proved the validity of the conceptual design. However, it is a first generation prototype and has imperfections. The significant problems are presented below with viable solutions.

Problem: The blister packed set of toothbrushes does not always remain accurately positioned on the indexing tray during the punching operation. The design requires the formed sides of the blister pack set to hold the set in place, but because of possible damage that occurs in the sealing process, the sides may be deformed. Consequently, the set may not be held in place as required.

Solution: Damage of the blister-pack frame during the sealing process must be prevented.

Problem: The edges on the blister pack toothbrushes often have a rough or jagged edge after the punching operation. This condition is attributed to a poor or uneven seal around the blister packed toothbrush.

Solution: For best results during the punching operation, the sealing process parameters should be better controlled to consistently produce even and transparent seals.

Problem: When multiple Separators are operating at the same time, each Pick/Place device must be capable of making decisions independent of the other Pick/Place devices. For example, the stack of brush sets may vary in height from one serving tray to another. Hence, it is apparent that the program and the control circuit presently used is inadequate to control multiple Separators.

Solution: Each Pick/Place device could be controlled by a PLC, thereby, separating the control of the Pick/Place device from the Punch device. This solution involves two new computer programs and a hardware modification as outlined below.

- A new computer program would have to be written to control the Punch devices and to send/receive signals from the PLC

controlling the Pick/Place device. Since this program would only control the Punch devices, the program would be simpler than the existing program and could be derived from the existing program.

- The Pick/Place device must be modified before it can be controlled by a PLC. This modification may be performed by one of the following two methods. One method would involve the addition of a frequency generator to the existing stepper motor circuit. The frequency generator should operate at approximately 190 Hz. By using this method, the PLC will simply turn on the stepping motor driver and the frequency generator will step the motor at the specified rate until the driver is turned off. The second method would involve replacing the stepping motor with a dc motor. A motor "brake" would be necessary because a holding torque is required to support the end effector while in the home position. Implementing this method would involve design changes on the vertical support plate, the stepping motor adapter, and various other mechanical parts due to the increased size and weight of the dc motor. In either case, a PLC program would have to be developed to control the Pick/Place devices and to communicate with the computer controlling the Punch devices.

Problem: Often, when the blister packed toothbrush is already partially ripped from the frame, the toothbrush will stick in the brush slot of the indexing tray after it is separated from the frame.

Solution: The blister-pack brush sets must be in excellent condition for the Separator to work properly. The corners of the frame must not be distorted and the complete circumference of each brush must be attached to the frame. Storage cartons should be designed in which the brushes may be placed and stored to minimize damage which may occur during handling.

Problem: In the event of a power failure the four-way control valve that controls the rodless air cylinder may or may not be activated. Consequently, the support plate-end effector assembly of the Pick/Place device may be at the pick end or the place end of the cylinder. If the valve is activated, the power failure will deactivate the valve and the end effector may be rammed into the Punch device.

Solution: The weight of the end effector counterweight of the Pick/Place device should be increased such that the end effector is in the home position (up against the vertical support plate) when the power is off. This change will eliminate the possibility of damage to the vertical shafts/end effector in the event of a power failure.

Problem: The scrap removal system sometimes fails due to the present design of the scrap removal system.

Solution: The reliability of the scrap removal system may be improved by adding an additional gripper or utilizing wider gripper jaws than presently used.

Issues Not Addressed

The following list is made up of items that were not addressed during the development of the Separator, but require attention to complete the project.

- The components to pick-up, place, and punch toothbrush sets that are oriented face-down are only conceptual and have not been tested .
- Appropriate guards/shields must be designed and installed to meet OSHA and other applicable standards to ensure the safety of the operator and other plant personnel.

Recommendations

The following recommendations are given to enhance and improve the safety, performance, and reliability of the Separator. Many of the reliability enhancement recommendations for the Pick/Place device come directly from a reliability study. The

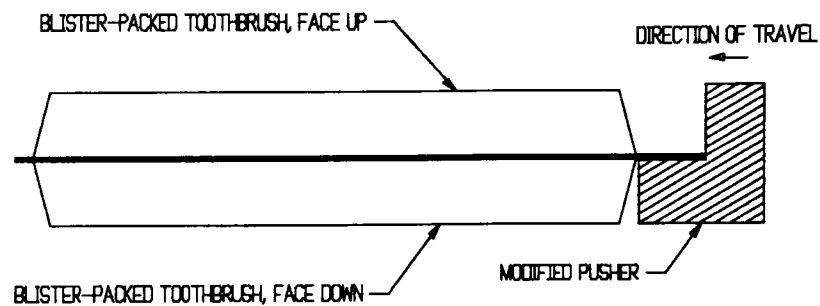
study employed the Failure Modes and Effects Analysis (FMEA) Program¹. The study involved documenting the implemented reliability improvements, looking for possible failure modes, and qualitatively evaluating the reliability of each component. The Pick/Place maintenance requirements and quality control guidelines are also documented in the study. The complete study is documented in Appendix L.

- Use one power supply for both devices and mount this power supply on the Separator control panel. Two power supplies were initially used to aid in the development of the devices. Using one power supply will simplify the electrical wiring on and to the devices. To accommodate a single larger power supply make a new larger control panel for the punch device. The elimination of the Pick/Place power supply will allow the length of its control panel to be smaller.
- Place an actual size, top view drawing of the blister-packed brush set on the serving tray to illustrate the loading orientation of the brush sets. This illustration will aid in the proper loading of the device.
- If the Separator experiences an electrical interference problem the following items should be implemented.

¹ FMEA Program is a product of the Superior Engineering Design Program of the Mechanical and Aerospace Engineering Dept. of the University of Tennessee based on work by David A. Walker.

- Use shielded wires on all circuitry, including the RS232 parallel port cables.
 - Completely enclose the control panels with a metal shield.
- A pressure limiting air pressure regulator should be installed to prevent over-pressurization, which could result in hardware damage.
- Decreasing the width of the lower support plate and the lower support plate guides on the end effector will allow the Pick/Place device to pick up brush sets directly out of a box. This modification will simplify the design of the serving tray because the tray no longer holds a stack of brush sets, but holds a box of brush sets. Note that the distance between the mounted support plate guides must not be changed from the original dimension.
- Design and build a serving tray to accurately hold a stack of brush sets. The end effector of the Pick/Place device will pick-up the brush sets from this tray. The tray must be capable of holding the brush set within $\pm 1/8$ inch in the "x" and "y" directions of the horizontal plane. The tray should match the contour of the brush sets to avoid damaging the blister pack frame.
- Space the pushers of the conveyor belt, upon which the brushes are delivered, to equal the spacing between the punches on the Punch devices.

- The pushers on the conveyor belt, upon which the brushes are delivered, should be modified to prevent the blister-packed toothbrushes, which are delivered face down, from tipping over. The modified pusher should have a step built on it such that the top tab of the blister-packed toothbrush will lay on this step when the brush is face down. This concept is illustrated below.



- A "hot box" or a "heated indexing tray" should be designed and built in an attempt to prevent the rough edges that occur on some brushes as they are separated from the blister-pack frame.

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BIBLIOGRAPHY

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APPENDICES

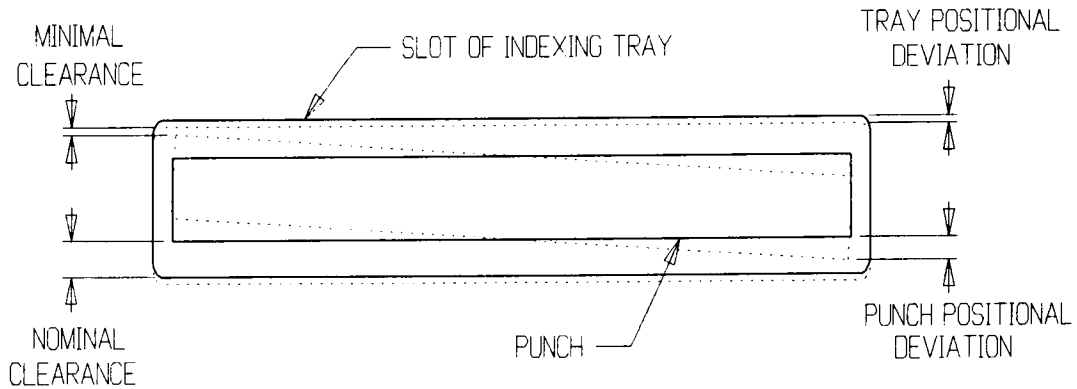
APPENDIX A

Positional Deviation Analysis

POSITIONAL DEVIATION ANALYSIS

The following calculations were performed in order to confirm adequate clearance between the punch and the indexing tray during operation. The calculations represent the worst possible case. The calculated dimensions have been exaggerated in the figure.

POSITIONAL DEVIATION ANALYSIS



Punch/Tray configuration

Maximum Tray Positional Deviation

$$\text{TRAY}_{\text{PD}} = (\text{STEP TOL.}) + (\text{SCREW LEAD TOL.}) + (\text{SCREW PLAY})$$

$$\text{TRAY}_{\text{PD}} = (.09^\circ) \left(\frac{1 \text{ rev}}{360^\circ} \right) \left(\frac{28 \text{ teeth}}{14 \text{ teeth}} \right) \left(\frac{.2 \text{ in}}{\text{rev}} \right) + \left(\frac{.004 \text{ in}}{\text{ft}} \right) (2.3 \text{ ft}) + (.002 \text{ in})$$

$$\text{TRAY}_{\text{PD}} = .0113 \text{ in}$$

Maximum Punch Positional Deviation

$$\text{PUNCH}_{\text{PD}} = \left(\frac{\text{PUNCH LENGTH}}{2} \right) \times \tan(\text{ANGULAR PUNCH TOL.})$$

$$\text{PUNCH}_{\text{PD}} = 4.15 \text{ in} \times \tan(1/2^\circ)$$

$$\text{PUNCH}_{\text{PD}} = .036 \text{ in}$$

Minimal Tray/Punch Clearance

$$\text{CLEARANCE}_{\text{MIN}} = (\text{SLOT WIDTH}_{\text{MIN}} - \text{TRAY}_{\text{PD}}) - (\text{PUNCH WIDTH}_{\text{MAX}} + \text{PUNCH}_{\text{PD}})$$

$$\text{CLEARANCE}_{\text{MIN}} = (1.095 \text{ in} - .0113 \text{ in}) - (1.035 \text{ in} + .036 \text{ in})$$

$$\text{CLEARANCE}_{\text{MIN}} = .0127 \text{ in}$$

APPENDIX B

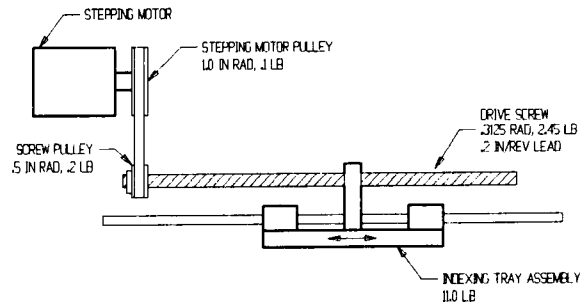
Stepping Motor Torque Requirements

STEPPING MOTOR TORQUE REQUIREMENTS

The following analysis estimated the minimum size stepping motor that would operate the device in question. The analysis was performed neglecting friction and other losses. To compensate for this simplification a safety factor of 4 was used.

PUNCH DEVICE STEPPING MOTOR TORQUE REQUIREMENTS

The following calculations specify the minimum torque requirements of the Punch device stepping motor. Many of the values used are estimates.



Punch device's drive train

Given

Safety Factor = $SF = 4$

Time to reach full speed = $\Delta t = .1 \text{ sec}$

Maximum rotational velocity = $\omega = 79.5 \text{ rad/sec}$

Summing up the kinetic energy of the system

$$KE = \frac{1}{2} I_e \omega_m^2 = KE_{mr} + KE_{mp} + KE_{sp} + KE_s + KE_{ta}$$

where

KE = kinetic energy

I = interia

ω = angular velocity

with subscripts

e = equivalent
m = stepping motor
mr = stepping motor rotor
mp = stepping motor pulley
sp = screw pulley
s = screw
ta = indexing tray assembly

expanding the kinetic energy terms

$$\frac{1}{2} I_e \omega_m^2 = \frac{1}{2} I_{mr} \omega_m^2 + \frac{1}{2} I_{mp} \omega_m^2 + \frac{1}{2} I_{sp} \omega_s^2 + \frac{1}{2} I_s \omega_s^2 + \frac{1}{2} m_{ta} \omega_s^2 \left(\frac{\text{lead}}{2\pi} \right)^2 \quad (1)$$

where

m = mass

with no belt slippage

$$\omega_m r_{mp} = \omega_s r_{sp}$$

or

$$\omega_s = \frac{r_{mp}}{r_{sp}} \omega_m$$

by squaring both sides of the above equation we obtain

$$\omega_s^2 = \left(\frac{r_{mp}}{r_{sp}} \right)^2 \omega_m^2 \quad (2)$$

substitution of equation 2 into equation 1 yields

$$I_e = I_{mr} + I_{mp} + I_{sp} \left(\frac{r_{mp}}{r_{sp}} \right)^2 + I_s \left(\frac{r_{mp}}{r_{sp}} \right)^2 + m_{ta} \left(\frac{r_{mp}}{r_{sp}} \right)^2 \left(\frac{\text{lead}}{2\pi} \right)^2$$

the inertia of the rotating components is approximated by

$$I = \frac{1}{2}mr^2$$

substitution yields

$$I_e = I_{mr} + \frac{1}{2}m_{mp}r_{mp}^2 + \frac{1}{2}m_{sp}r_{mp}^2 + \frac{1}{2}m_s r_s^2 \left(\frac{r_{mp}}{r_{sp}} \right)^2 + m_{ta} \left(\frac{r_{mp}}{r_{sp}} \right)^2 \left(\frac{\text{lead}}{2\pi} \right)^2$$

substitution of the given values yield

$$I_e = .05 \text{ lb-in}^2 + \frac{1}{2}(.11 \text{ lb})(1.0 \text{ in})^2 + \frac{1}{2}(.21 \text{ lb})(.5)^2 \\ + \frac{1}{2}(2.45 \text{ lb})(.3125 \text{ in})^2 \left(\frac{1.0 \text{ in}}{.5 \text{ in}} \right)^2 + 11.0 \text{ lb} \left(\frac{1.0 \text{ in}}{.5 \text{ in}} \right)^2 \left(\frac{.2 \text{ in}}{2\pi} \right)^2$$

$$I_e = .05 \text{ lb-in}^2 + .05 \text{ lb-in}^2 + .025 \text{ lb-in}^2 + .478 \text{ lb-in}^2 + .044 \text{ lb-in}^2$$

$$I_e = .647 \text{ lb-in}^2$$

calculating the required torque

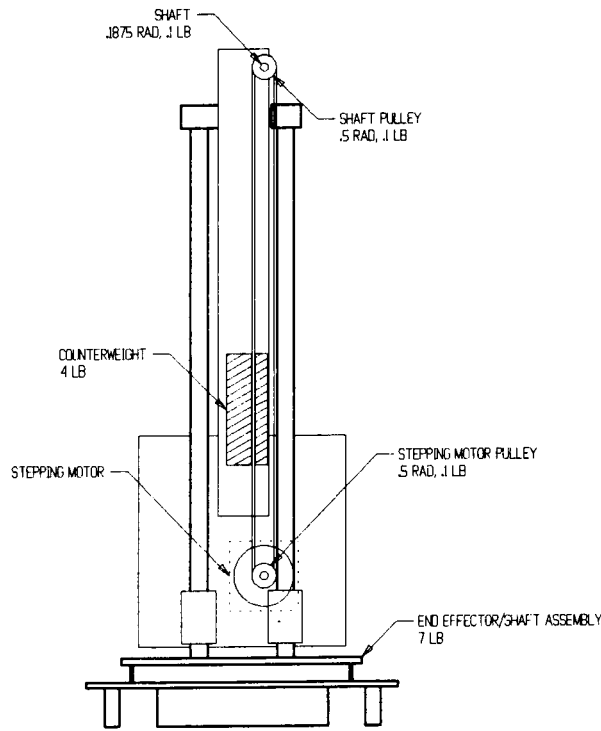
$$T = (SF)I_e \alpha = (SF)I_e \frac{\omega}{\Delta t}$$

$$T = 4(.647 \text{ lb-in}^2) \left(\frac{79.5 \frac{\text{RAD}}{\text{SEC}}}{.1 \text{ SEC}} \right) \left(\frac{\text{lbf s}^2}{386.4 \text{ lbin}} \right)$$

$$T = 5.32 \text{ lb-in} = 85.2 \text{ oz-in}$$

TORQUE REQUIREMENTS OF THE PICK/PLACE STEPPING MOTOR

The following calculations specify the minimum torque requirements of the Pick/Place device stepping motor. Many of the values used are estimates.



Pick/Place device's drive train

Given:

Safety Factor = $SF = 4$

Time to reach maximum speed = $\Delta t = .1 \text{ sec}$

Maximum rotational velocity = $\omega = 2.8 \text{ rad/sec}$

Required torque to overcome the gravity forces

$$T_g = fr$$

$$T_g = (112 \text{ oz})(.5 \text{ in}) - (64 \text{ oz})(.5 \text{ in})$$

$$T_g = 24 \text{ oz-in}$$

Summing up the kinetic energy of the system

$$KE = \frac{1}{2} I_e \omega_m^2 = KE_{mr} + KE_{mp} + KE_{sp} + KE_s + KE_{cw} + KE_{eea}$$

where

KE = kinetic energy

I = inertia

ω = angular velocity

with subscripts

e = equivalent

m = stepping motor

mr = stepping motor rotor

mp = stepping motor pulley

sp = shaft pulley

s = shaft

eea = end effector/shaft assembly

Expanding the kinetic energy terms

$$\frac{1}{2} I_e \omega_m^2 = \frac{1}{2} I_{mr} \omega_m^2 + \frac{1}{2} I_{mp} \omega_m^2 + \frac{1}{2} I_{sp} \omega_m^2 + \frac{1}{2} I_s \omega_m^2 + \frac{1}{2} I_{cw} \omega_m^2 + \frac{1}{2} I_{eea} \omega_m^2$$

the inertia of the rotating components is approximated by

$$I = \frac{1}{2} m r^2$$

for the linear motion components

$$I = m r^2$$

substitution yields

$$I_e = I_{mr} + \frac{1}{2}m_{mp}r_{mp}^2 + \frac{1}{2}m_{sp}r_{sp}^2 + \frac{1}{2}m_s r_s^2 + m_{cw} r_p^2 + m_{eea} r_p^2$$

substitution of the given values yield

$$I_e = .05 \text{ lb-in}^2 + \frac{1}{2}(.1 \text{ lb})(.5 \text{ in})^2 + \frac{1}{2}(.1 \text{ lb})(.5 \text{ in})^2 \\ + \frac{1}{2}(.1 \text{ lb})(.1875 \text{ in})^2 + (4 \text{ lb})(.5 \text{ in})^2 + (7 \text{ lb})(.5 \text{ in})^2$$

$$I_e = .05 \text{ lb-in}^2 + .0125 \text{ lb-in}^2 + .0125 \text{ lb-in}^2 \\ + .0018 \text{ lb-in}^2 + 1.0 \text{ lb-in}^2 + 1.75 \text{ lb-in}^2$$

$$I_e = 2.83 \text{ lb-in}^2$$

calculating the required torque

$$T - T_g = (SF)I_e \alpha = (SF)I_e \frac{\omega}{\Delta t}$$

$$T = (SF)I_e \frac{\omega}{\Delta t} + T_g$$

$$T = 4(2.83 \text{ lb-in}^2) \left(\frac{2.81 \frac{\text{rad}}{\text{sec}}}{.1 \text{ sec}} \right) \left(\frac{1 \text{ lbf sec}^2}{386.4 \text{ lb-in}} \right) \left(\frac{16 \text{ oz}}{1 \text{ lbf}} \right) + 24 \text{ oz-in}$$

$$T = 37.2 \text{ oz-in}$$

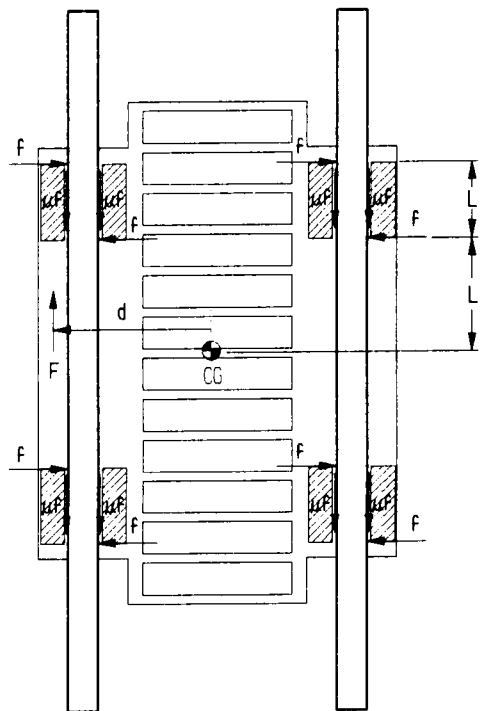
APPENDIX C

Binding Analysis

BINDING ANALYSIS

A binding analysis was performed on two separate linear motion systems of the Separator to ensure the free movement of the components in question before the design was finalized. Each analysis is presented with a free body diagram of its particular system.

Binding analysis for the indexing tray on horizontal shafts of the Punch device.



Free body diagram.

d = distance from center of gravity
 f = friction force
 F = applied force
 μ = coefficient of friction

Summing forces in the vertical direction

$$+\uparrow \sum F_y = ma = F - 8\mu f$$

Solving for the friction force

$$f = \frac{(F - ma)}{8\mu}$$

Summing moments about the center of gravity

$$\sum M = 0 = 4f(L+L_t) - 4FL - Fd$$

Solving for the friction force

$$f = \frac{Fd}{4L_t}$$

Equating the two friction equations

$$\frac{Fd}{4L_t} = \frac{(F-ma)}{8\mu}$$

Solving for acceleration

$$a = \frac{F}{m} \left(1 - \frac{2\mu d}{L_t} \right)$$

No binding will occur as long as the acceleration remains positive, or as long as

$$\left(1 - \frac{2\mu d}{L_t} \right) > 0$$

in other words, as long as

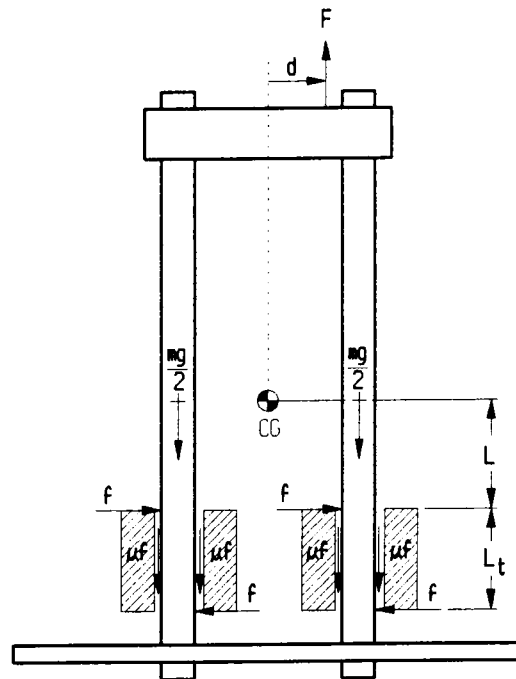
$$\mu < \frac{L_t}{2d}$$

Substitution yields ($L_t = 2.00$, $d = 7.00$)

$$\mu < .14$$

This can be easily accomplished by the use of Thomsom ball bushings.

Binding analysis for vertical shafts in vertical ball bushings of the Pick/Place device.



Free body diagram

d = distance from center of gravity
 f = friction force
 F = applied force
 μ = coefficient of friction

Summing forces in the vertical direction

$$+\uparrow \sum F_y = ma = F - 2\left(\frac{mg}{2}\right) - 4\mu f$$

Solving for the friction force

$$f = \frac{(F - ma - mg)}{4\mu}$$

Summing moments about the center of gravity

$$\sum M = 0 = 2fL - 2f(L + L_t) + Fd$$

Solving for the friction force

$$f = \frac{Fd}{2L_t}$$

Equating the two friction equations

$$\frac{Fd}{2L_t} = \frac{(F - ma - mg)}{4\mu}$$

Solving for acceleration

$$a = \frac{F}{m} \left(1 - \frac{2\mu d}{L_t} \right) - g$$

No binding will occur as long as the acceleration remains positive, or as long as

$$\frac{F}{m} \left(1 - \frac{2\mu d}{L_t} \right) > g$$

or, since F must be greater than mg to initiate motion

$$\left(1 - \frac{2\mu d}{L_t} \right) > 0$$

in other words, as long as

$$\mu < \frac{L_t}{2d}$$

Substitution yields ($L_t = 3.25$, $d = 1.437$)

$$\mu < 1.13$$

This can be easily accomplished by the use of Thomsom ball bushings.

APPENDIX D

Parts Lists

PARTS LISTS

The parts required to build the Separator are documented on three individual lists, a vendor parts list, a manufactured parts list, and a fasteners list. The vendor parts list contains the vendors part number, the vendors name, the manufacturers name, the quantity required, and a description of each purchased part. The manufactured parts list is a list of the parts fabricated. It contains the part number, which directly corresponds to the number on the part's drawing, the quantity required, and a description of all the fabricated parts. The fasteners list is comprised of the fasteners required to assemble the separator. This list contains each fastener's part number, the quantity required, and a description. Miscellaneous parts, such as tube fittings, tubing clamps, etc., are not included on the following list and should be purchased as required.

VENDORS PARTS LIST

(ARRANGED ALPHANUMERICALLY BY VENDOR PART NUMBER)

<u>PART NO.</u>	<u>VENDOR</u>	<u>MANUFACTURER</u>	<u>QTY</u>	<u>NAME/DESCRIPTION</u>
04604-0004	BERTLEKAMP AUTOMAT	SCHRADER BLLWS	1	1/4" PIPE PNEUMATIC EXH. MUFFLER
04606-0006	BERTLEKAMP AUTOMAT	SCHRADER BLLWS	1	3/8" PIPE PNEUMATIC EXH. MUFFLER
05430-0160	BERTLEKAMP AUTOMAT	SCHRADER BLLWS	1	PRESSURE GUAGE
05852-3042	BERTLEKAMP AUTOMAT	SCHRADER BLLWS	1	PRESSURE REGULATOR
08DU06	BEARINGS, INC.	GARLOCK BEARINGS	2	BUSHINGS
10250T5	ELECTRIC SUPPLY	CUTLER-HAMMER	1	SWITCH CONTACT BLOCK
10250T51	ELECTRIC SUPPLY	CUTLER-HAMMER	1	PUSH/PULL SWITCH OPERATOR
10250TC53	ELECTRIC SUPPLY	CUTLER-HAMMER	1	EMERGENCY SWITCH LENS
1105	SLOAN FLUID ACCESS	ADI	4	THREAD ADAPTER
130X037	BEARINGS, INC.	GATES	1	TIMING BELT
1/16 ADF	VOLUNTEER WIRE ROPE	-	8	CABLE STOPS FOR 1/16" DIA CABLE
1/16 GAC	VOLUNTEER WIRE ROPE	-	3	1/16" DIA CABLE
1/2" DIA X 35"	BEARINGS, INC.	THOMSON	2	CLASS "L" SHAFTING
2020/20-25MMX23	BERTLEKAMP AUTOMAT	ORIGA	1	RODLESS AIR CYLINDER
20806-3	BERTLEKAMP AUTOMAT	ALKON	1	3 STATION CONTROL VALVE MANIFOLD
2200PDE-2AP	BERTLEKAMP AUTOMAT	AIR PAC	1	1/8" PIPE BRASS ELBOW W/MOUNT
241S	BERTLEKAMP AUTOMAT	ALKON	1	CONTROL VALVE BASE W/1/8" PIPE NPT
242S	BERTLEKAMP AUTOMAT	ALKON	1	CONTROL VALVE BASE W/1/4" NPT
270-627	RADIO SHACK	RADIO SHACK	2	ELECTRICAL CIRCUIT BOX
276-168	RADIO SHACK	RADIO SHACK	2	CIRCUIT BOARD
278-356	RADIO SHACK	RADIO SHACK	1	RECOIL 4 CONDUCTOR CABLE
286 16MHZ	INTELEC	INTELEC	1	IBM COMPATIBLE COMPUTER
2Z866	GRAINGER	DAYTON	1	VACUUM PUMP
2-40R2-24/DC	BERTLEKAMP AUTOMAT	ALKON	5	4 WAY CONTROL VALVES
3088A233	McMASTER-CARR	McMASTER-CARR	AS REQ'D	SHAFT SHIM

VENDORS PARTS LIST

(ARRANGED ALPHANUMERICALLY BY VENDOR PART NUMBER)

<u>PART NO.</u>	<u>VENDOR</u>	<u>MANUFACTURER</u>	QTY	<u>NAME/DESCRIPTION</u>
3136-54-11	BERTLEKAMP AUTOMAT	LEGRIS	4	SNAP-IN BULKHEAD FITTING
3304-56-54	BERTLEKAMP AUTOMAT	LEGRIS	1	MULTIPLE TEE TUBE MANIFOLD
34D106S	MINARIK	ANAHEIM AUTOMAT	2	SIZE 34 STEPPING MOTOR
3/4" DIA X 36"	BEARINGS, INC.	THOMSON	1	CLASS "L" SHAFTING
3/4" DIA X 42"	BEARINGS, INC.	THOMSON	2	CLASS "L" SHAFTING
5168-008	BERTLEKAMP AUTOMAT	PHD	1	AIR CYLINDER RETURN SPRING
5966K16	McMASTER-CARR	NOOK INDUSTRIES	1	BALL NUT FOR 5/8" DIA SCREW
5966K999	McMASTER-CARR	NOOK INDUSTRIES	1	5/8" DIA DRIVE SCREW X 28" LONG
6A3-16H3710	STOCK DRIVE PROD	STOCK DRIVE PROD	2	1/5" PTCH X 16 GRVE HUBLESS PULL
6F3-14DF037	STOCK DRIVE PROD	STOCK DRIVE PROD	1	1/5" PTCH X 14 GRVE PULL
6R3-277037	STOCK DRIVE PROD	STOCK DRIVE PROD	1	1/5" PITCH X 3/8" WIDE TIM. BELT
6Z3-28DF03712	STOCK DRIVE PROD	STOCK DRIVE PROD	1	1/5" PTCH X 28 GRVE PULL
7765-56-11	BERTLEKAMP AUTOMAT	LEGRIS	4	PNEUMATIC FLOW CONTROL VALVE
8410-01-001	BERTLEKAMP AUTOMAT	PHD	1	GRIPPER
9656K29	McMASTER-CARR	McMASTER-CARR	2	CLAMP SPRINGS
AWHE	BERTLEKAMP AUTOMAT	COMPACT AIR PROD	1	AIR CYLINDER PISTON POSITION SNSR
CH119-ND	DIGI-KEY	CHERRY	2	MICROSWITCH
E10	BEARINGS, INC.	CONSOLIDATED	2	ANGULAR CONTACT BEARING
F15	SLOAN FLUID ACCESS	PIAB	4	VACUUM CUP
GC22X2BTP	BERTLEKAMP AUTOMAT	COMPACT AIR PROD	1	NON-ROTATING AIR CYLINDER
H21A1GE	DIGI-KEY	HARRIS	1	OPTICAL INTERRUPT. MOD. (HOME SNSR)
IB463	IMS	IMS	2	STEPPING MOTOR DRIVER
NAV3/4X2-P	BERTLEKAMP AUTOMAT	PHD	1	POWER SLIDE (NON-ROTATING AIR CYL)
PS2502-4NEC	DIGI-KEY	NEC	2	ELECTRONIC OPTICAL ISOLATOR
R140-04-07-9	BERTLEKAMP AUTOMAT	LEGRIS	1	5/32" MINI RECOIL TUBING

VENDORS PARTS LIST

(ARRANGED ALPHANUMERICALLY BY VENDOR PART NUMBER)

<u>PART NO.</u>	<u>VENDOR</u>	<u>MANUFACTURER</u>	QTY <u>REQ'D</u>	<u>NAME/DESCRIPTION</u>
RS232 M/F	UT COMPUTER STORE	EASYCOM	2	PARALLEL PORT CABLE, ALL LINES EXT.
SB12	BEARINGS, INC.	THOMSON	4	3/4" SHAFT SUPPORT BLOCK
SPB12	BEARINGS, INC.	THOMSON	6	3/4" LINEAR BALL BUSHING
SSL-1680ZZ	SOUTHERN BEARING	NMB	2	FLANGED BALL BEARING
TS6	IMS	IMS	2	MOTOR DRIVER TERMINAL STRIP
TWN8	BEARINGS, INC.	THOMSON	2	1/2" TWIN LINEAR BALL BUSHING
U24Y350	ACOPIAN	ACOPIAN	2	24 VOLT POWER SUPPLY
WM16	BEARINGS, INC.	THOMSON	2	ADJUSTABLE SHAFT SUPPORT
-	HOME DEPOT	-	8	5/16" SHANK ADJUSTABLE FRAME FEET
-	RADIO SHACK	RADIO SHACK	AS REQ'D	1/4 WATT RESISTOR

MANUFACTURED PARTS LIST

<u>PART NO.</u>	<u>QTY REQ'D</u>	<u>NAME/DESCRIPTION</u>
101	1	CLAMP
102	1	PUNCH BASE
103	2	PUNCH SIDE SHEAR
104	1	SHORT PUNCH END SHEAR
105	1	LONG PUNCH END SHEAR
106	1	MODIFIED AIR CYLINDER TOOLING PLATE
107	1	AIR CYLINDER TOOLING PLATE EXTENSION
108	2	SCREW BEARING SUPPORT BLOCK
109	1	DRIVE SCREW
111	1	BALL-NUT/TRAY INTERFACE
112	1	RIGHT-SIDE-UP TRAY
113	1	TRAY HOME POSITION INDICATOR
114	1	LEFT TRAY BEARING SHAFT
115	1	RIGHT TRAY BEARING SHAFT
116	2	PILLOW BLOCK SPACER
117	1	FRAME, PHASE I
118	1	GRIPPER BRIDGE
119	1	PUNCH BRIDGE
120	1	HOME POSITION SENSOR MOUNTING BRACKET
121	1	CONTROL PANEL, PHASE I
122	1	STEPPING MOTOR BRACKET
123	2	GRIPPER FINGER
124	1	DRIVE SCREW TIMING PULLEY
125	2	ADJUSTABLE PILLOW BLOCK SPACER
126A	2	INDEXING TRAY END GUIDE
127A	2	INDEXING TRAY SIDE GUIDE
201	1	VERTICAL SUPPORT PLATE
202	1	STEPPING MOTOR ADAPTER
203	1	LOWER SUPPORT PLATE
204	1	UPPER SUPPORT PLATE
206	1	MAST
207	1	BELT CLIP
208	1	BELT CONNECTOR
209	1	BELT CONNECTOR TIE
210	2	BELT CONNECTOR TIE SPACER
211	1	LEFT COUNTERWEIGHT FOR END EFFECTOR
212	1	RIGHT COUNTERWEIGHT FOR END EFFECTOR
213	1	FRAME, PHASE II
214	2	VACUUM PUMP SHELF

MANUFACTURED PARTS LIST

<u>PART</u> <u>NO.</u>	<u>QTY</u> <u>REQ'D</u>	<u>NAME/DESCRIPTION</u>
215	2	RODLESS AIR CYLINDER MOUNTING BRACKET
216	2	FRAME SPACER
217	1	CONTROL PANEL, PHASE II
218	2	VERTICAL SHAFT
219	2	PULLEY SHAFT BEARING RETAINER
220	1	PULLEY SHAFT
221	2	MODIFIED TWIN BALL BUSHING
222	2	SHORT SUPPORT GUIDE
223	2	LONG SUPPORT GUIDES
224	4	SUPPORT PLATE HANGER
225	1	MODIFIED VACUUM FITTING
226	1	HOME POSITION SWITCH BRACKET
227	1	BRUSH SET POSITION SWITCH
228	2	TIMING PULLEY
229A	4	SUPPORT STOP

FASTENERS LIST

<u>PART NO</u>	<u>QTY</u> <u>REQ'D</u>	<u>DESCRIPTION</u>
4-40NC-3/8	2	SOCKET HEAD BOLT
4-40NC-1/2	8	SOCKET HEAD BOLT
6-32NC-3/8	8	SOCKET HEAD BOLT
6-32NC-1/2	10	SOCKET HEAD BOLT
8-1/2	2	ROUND HEAD WOOD SCREW
8-32NC-3/4	4	SOCKET HEAD BOLT
8-32NC-3/4	4	FLAT HEAD BOLT
8-32NC-1	16	SOCKET HEAD BOLT
10-32NF-1/2	32	SOCKET HEAD BOLT
10-32NF-3/4	16	SOCKET HEAD BOLT
10-32NF-1 1/4	2	SOCKET HEAD BOLT
10-32NF-1 1/2	4	SOCKET HEAD BOLT
10-32NF-1 3/4	2	SOCKET HEAD BOLT
10-24NC-1/2	4	SOCKET HEAD BOLT
1/4-28NF-3/8	4	HALF DOG-POINT SET SCREW
1/4-28NF-1/2	14	SOCKET HEAD BOLT
1/4-28NF-1 1/4	2	HEX HEAD BOLT
1/4-28NF-2 1/2	10	SOCKET HEAD BOLT
1/4-28NF-3 3/4	4	SOCKET HEAD BOLT
5/16-24NF-3/4	2	SOCKET HEAD BOLT
5/16-18NC-1	2	HEX HEAD BOLT
3/8-16NC-4 1/4	2	T-BOLT
4-40NC	6	HEX NUT
6-32NC	10	HEX NUT
8-32NC	24	HEX NUT
10-32NF	36	HEX NUT
1/4-28NF	30	HEX NUT
3/8-16NC	2	HEX NUT
10	6	FLAT WASHERS
1/4	10	FLAT WASHERS
5/16	2	FLAT WASHERS
3/8	2	FLAT WASHERS
4	6	LOCK WASHERS
6	16	LOCK WASHERS
8	20	LOCK WASHERS
10	60	LOCK WASHERS
1/4	30	LOCK WASHERS
5/16	4	LOCK WASHERS
3/8	2	LOCK WASHERS

APPENDIX E

Parts Drawings

PARTS DRAWINGS

The drawings of the parts that were manufactured for the Separator prototype are presented after the Drawing Title-Part Number list. Drawings beginning with part number 101 and 201 refer to the parts of the Punch device and Pick/Place device respectively. The drawings were initially drawn and scaled on either "C" size (17 X 22 inches) or "D" size (22 X 34 inches) paper, therefore, the following copied reductions are not scaled as noted.

DRAWINGS LIST

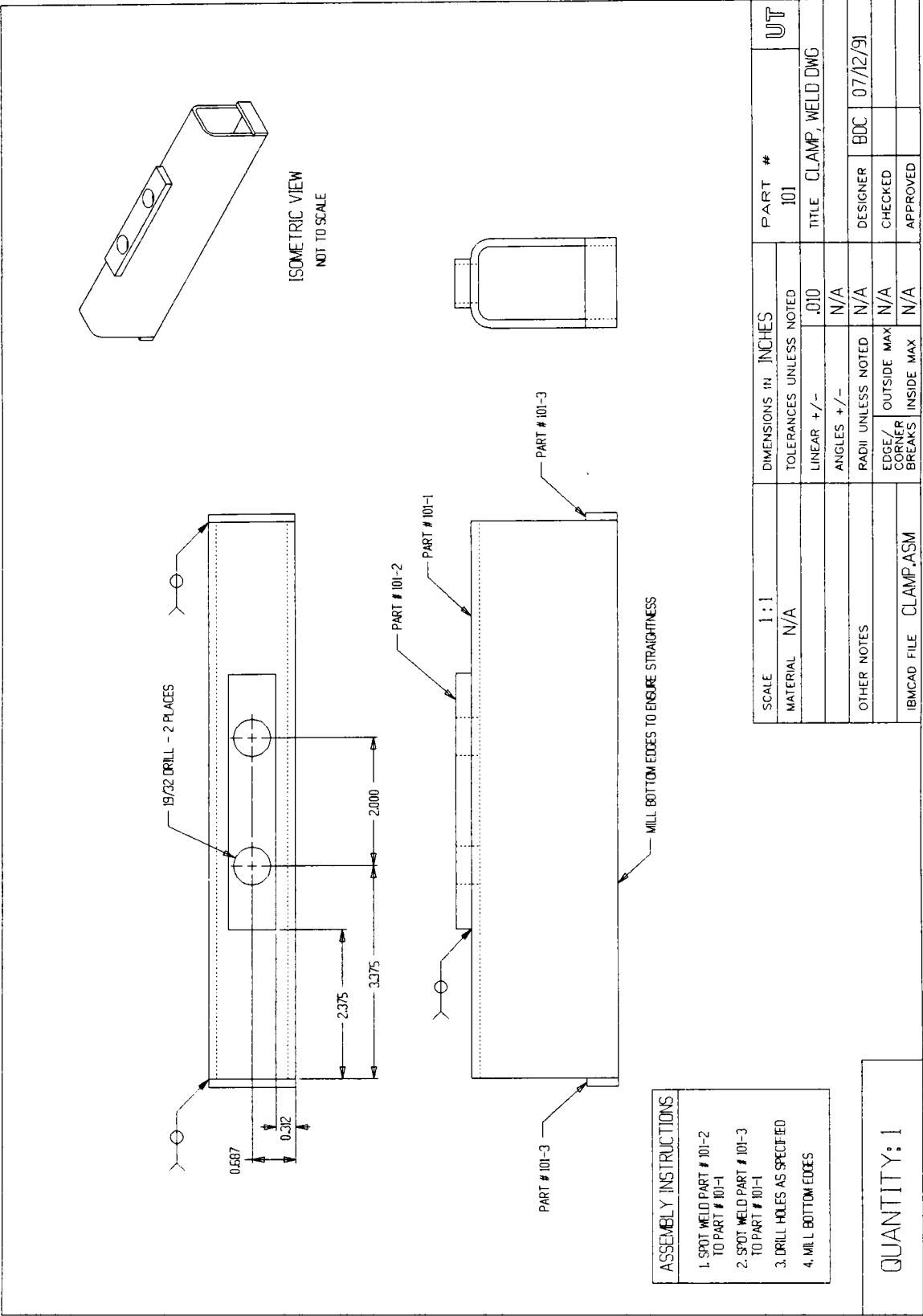
<u>DRAWING TITLE/DESCRIPTION</u>	<u>PART NO.</u>
ADJUSTABLE PILLOW BLOCK SPACER	125
AIR CYLINDER TOOLING PLATE EXTENSION	107
BALL-NUT/TRAY INTERFACE	111
BASE OF FRAME, PHASE I	117-5
BASE OF FRAME, PHASE II	213-5
BELT CLIP	207
BELT CONNECTOR	208
BELT CONNECTOR TIE	209
BELT CONNECTOR TIE SPACER	210
BRUSH SET POSITION SWITCH BRACKET, BEND DWG	227
BRUSH SET POSITION SWITCH BRACKET, MCH DWG	227
CLAMP, BEND DWG	101-1
CLAMP, MCH DWG	101-1
CLAMP, MOD DWG	101
CLAMP, WELD DWG	101
CLAMP ASSEMBLY MODIFICATION	101
CLAMP BUSHING ADAPTER	101-2
CONTROL PANEL, PHASE I	121
CONTROL PANEL, PHASE II	217
DRIVE SCREW	109
DRIVE SCREW TIMING PULLEY	124
END CLAMP	101-3
FRAME, PHASE I, SHEET 1 OF 2	117
FRAME, PHASE I, SHEET 2 OF 2	117
FRAME, PHASE II, SHEET 1 OF 2	213
FRAME, PHASE II, SHEET 2 OF 2	213
FRAME SPACER	216
GRIPPER BRIDGE	118
GRIPPER FINGER	123
HOME POSITION SENSOR MOUNTING BRACKET, BEND DWG	120
HOME POSITION SENSOR MOUNTING BRACKET, MCH DWG	120
HOME POSITION SWITCH BRACKET	226
INDEXING TRAY END GUIDE	126A
INDEXING TRAY SIDE GUIDE	127A
LEFT COUNTERWEIGHT FOR END EFFECTOR	211
LEFT TRAY BEARING SHAFT	114
LOC. OF MNTING HOLES, PHASE I, SHEET 1 OF 2	117
LOC. OF MNTING HOLES, PHASE I, SHEET 2 OF 2	117
LOC. OF MNTING HOLES, PHASE II	213
LONG PUNCH END SHEAR	105

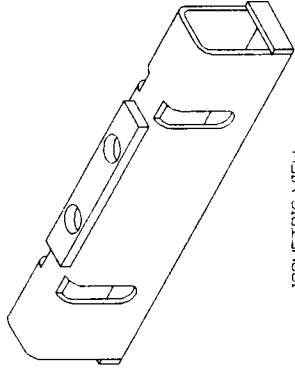
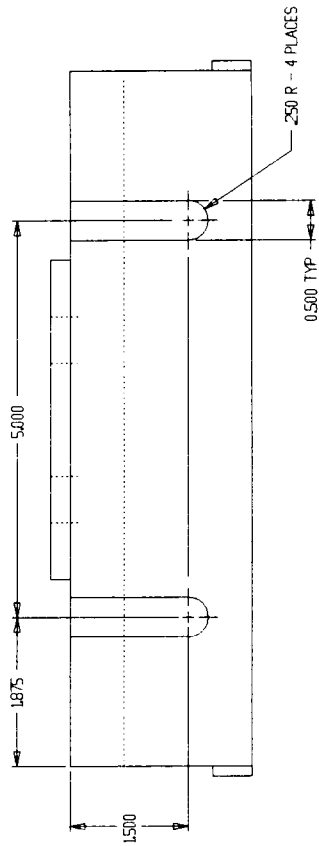
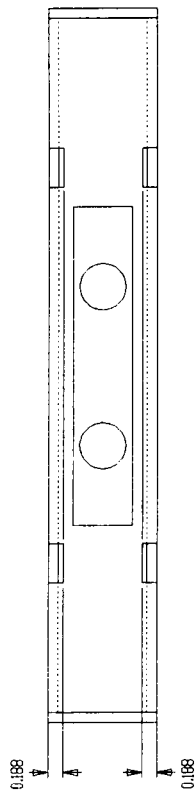
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<u>DRAWING TITLE/DESCRIPTION</u>	<u>PART NO.</u>
LONG SUPPORT GUIDE	223
LOWER SUPPORT PLATE	203
LOWER TIE OF FRAME, PHASE I	117-6
LOWER TIE OF FRAME, PHASE II	213-6
MAST	206
MODIFIED AIR CYLINDER TOOLING PLATE	106
MODIFIED TWIN BALL BUSHING	221
MODIFIED VACUUM FITTING	225
PILLOW BLOCK SPACER	116
PULLEY SHAFT	220
PULLEY SHAFT BEARING RETAINER	219
PUNCH BASE	102
PUNCH BRIDGE	119
PUNCH BRIDGE HORIZONTAL MEMBER	119-1
PUNCH BRIDGE VERTICAL MEMBER	119-2
PUNCH SIDE SHEAR	103
REINFORCING MEMBER OF FRAME, PHASE I	117-3
REINFORCING MEMBER OF FRAME, PHASE II	213-3
RIGHT COUNTERWEIGHT FOR END EFFECTOR	212
RIGHT TRAY BEARING SHAFT	115
RIGHT-SIDE-UP TRAY	112
RODLESS AIR CYLINDER MOUNTING BRACKET	215
SCREW BEARING SUPPORT BLOCK	108
SHORT PUNCH END SHEAR	104
SHORT SUPPORT GUIDE	222
STEPPING MOTOR ADAPTER	202
STEPPING MOTOR BRACKET, BEND DWG	122
STEPPING MOTOR BRACKET, MCH DWG	122
SUPPORT PLATE HANGER	224
SUPPORT PLATE HANGER CABLE	224-1
SUPPORT PLATE HANGER STOP, BEND DWG	224-2
SUPPORT PLATE HANGER STOP, MCH DWG	224-2
SUPPORT STOP	229A
TIMING PULLEY	228
TRAY HOME POSITION INDICATOR	113
UPPER MEMBER OF FRAME, PHASE I	117-1
UPPER MEMBER OF FRAME, PHASE II	213-1
UPPER SUPPORT PLATE	204
UPPER TIE OF FRAME, PHASE I	117-2
UPPER TIE OF FRAME, PHASE II	213-2

DRAWINGS LIST

<u>DRAWING TITLE/DESCRIPTION</u>	<u>PART NO.</u>
VACUUM PUMP SHELF	214
VERTICAL SHAFT	218
VERTICAL SUPPORT OF FRAME, PHASE I	117-4
VERTICAL SUPPORT OF FRAME, PHASE II	213-4
VERTICAL SUPPORT PLATE	201

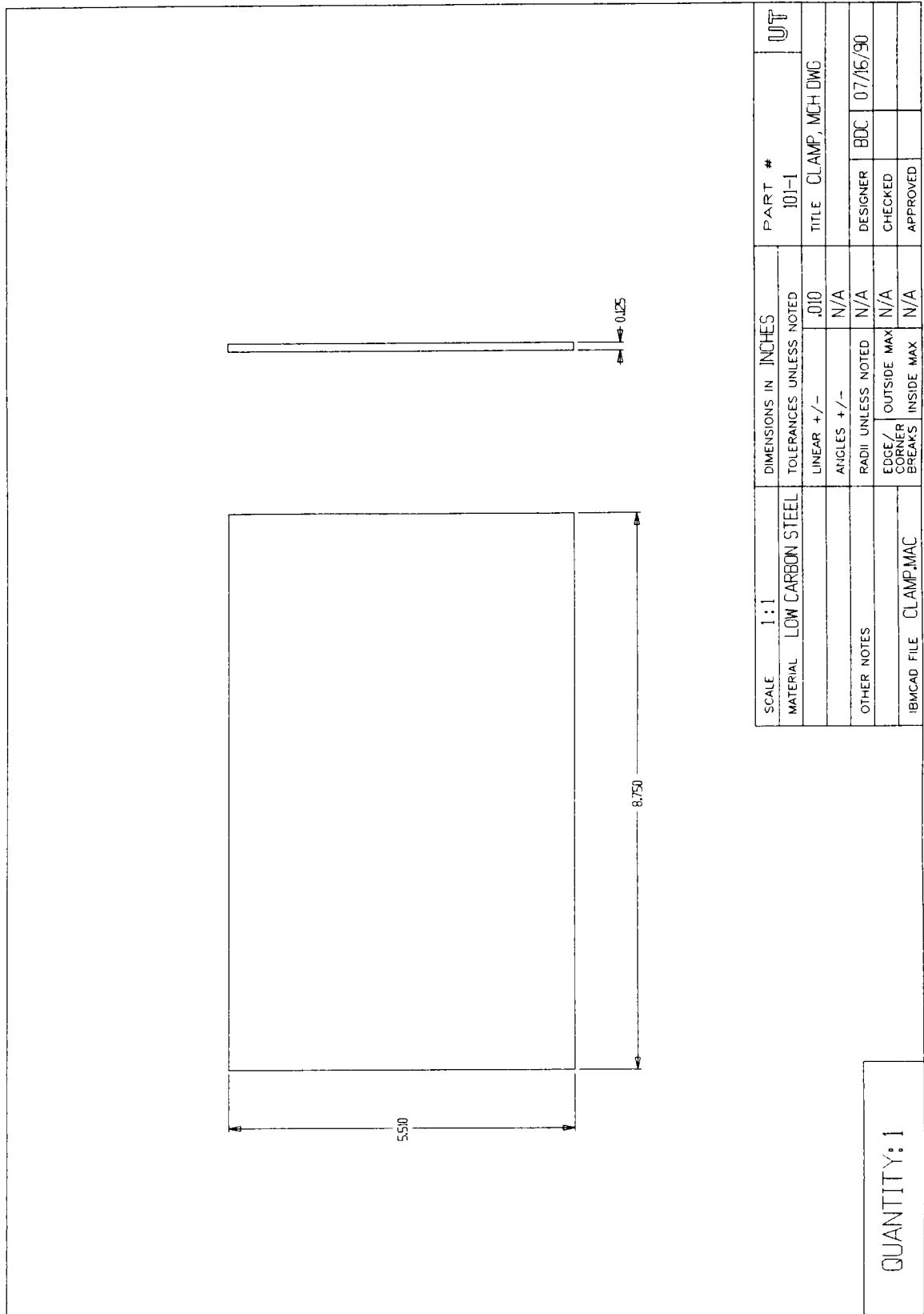


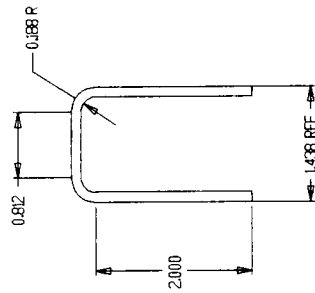
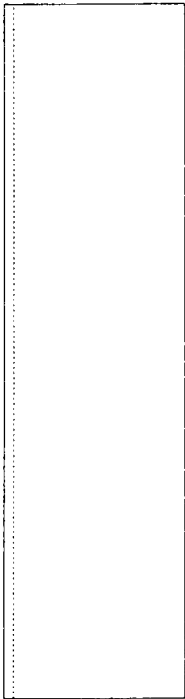


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1/2 SCALE

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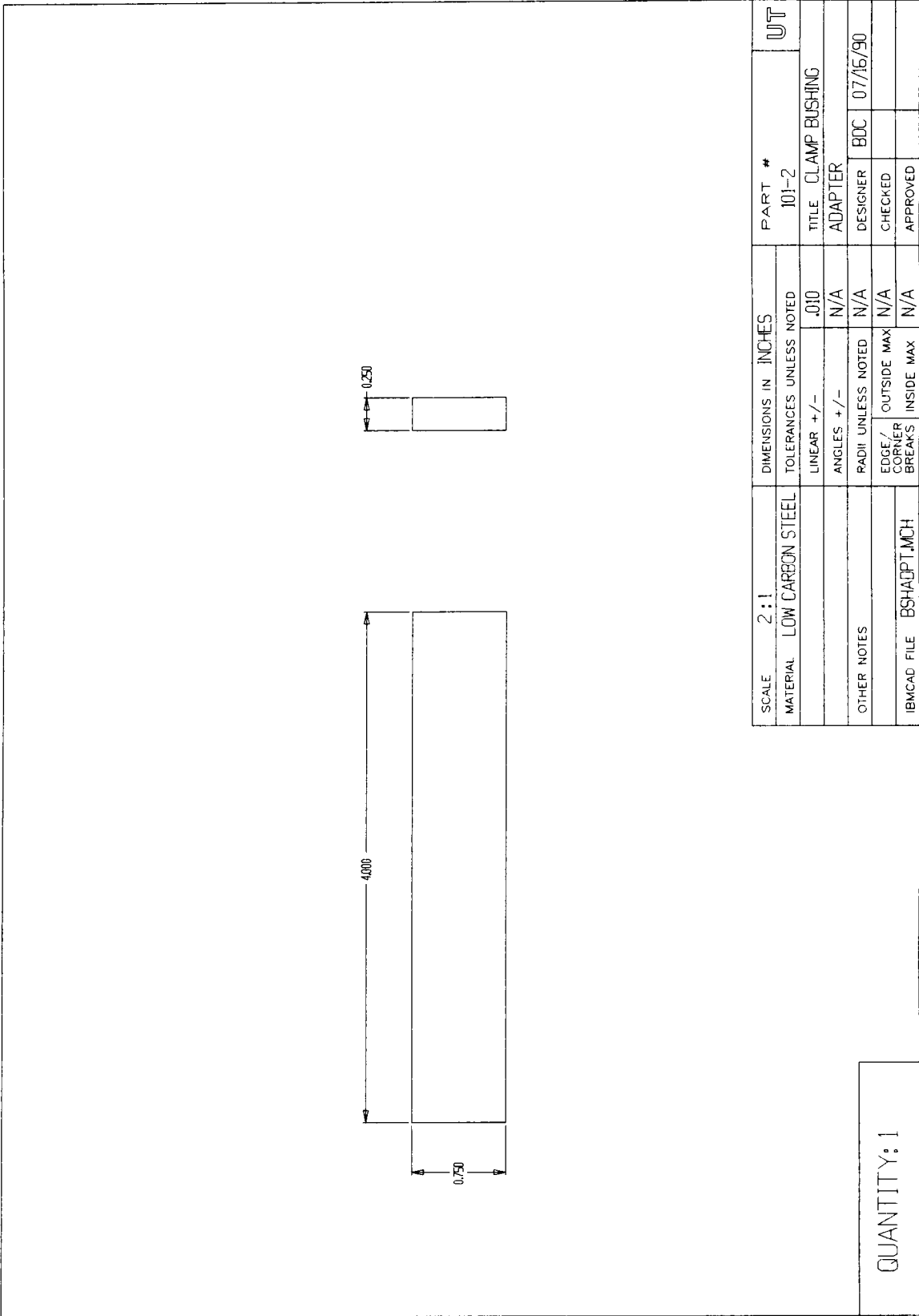
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		ANGLES +/-		
OTHER NOTES		RADI UNLESS NOTED	DESIGNER	BOC 09/20/90
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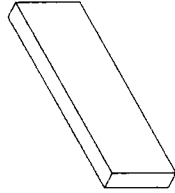
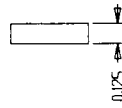
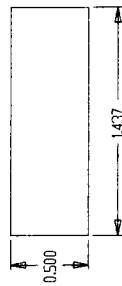




SCALE	1:1	DIMENSIONS IN INCHES	PART #	UT
MATERIAL	N/A	TOLERANCES UNLESS NOTED	101-1	
		LINEAR +/-	TITLE	CLAMP, BEND DWG
		ANGLES +/-		
OTHER NOTES		RADI UNLESS NOTED	DESIGNER	BDC 07/16/90
		EDGE / CORNER BREAKS	CHECKED	
IBMCAD FILE	CLAMP.BND	OUTSIDE MAX	APPROVED	
		INSIDE MAX		

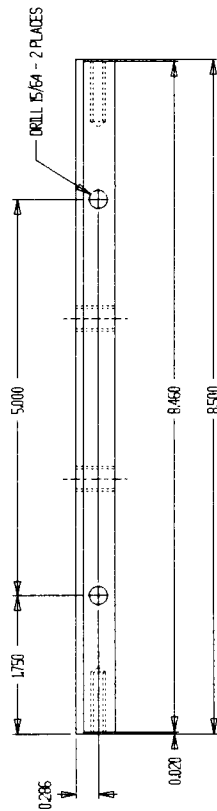
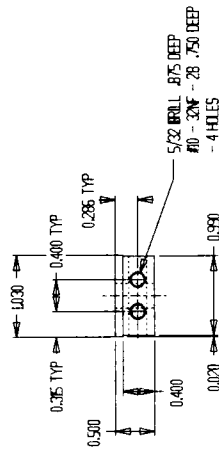
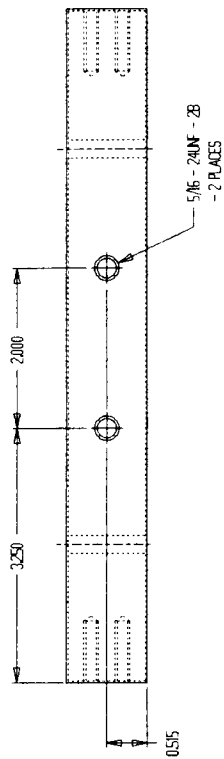
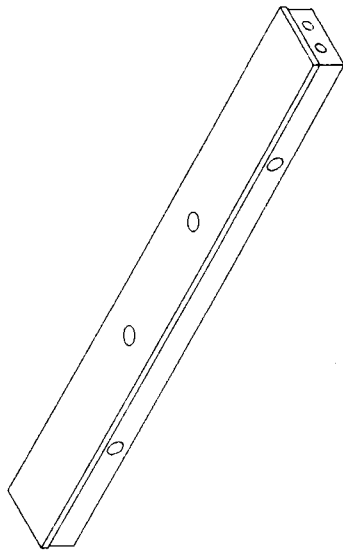
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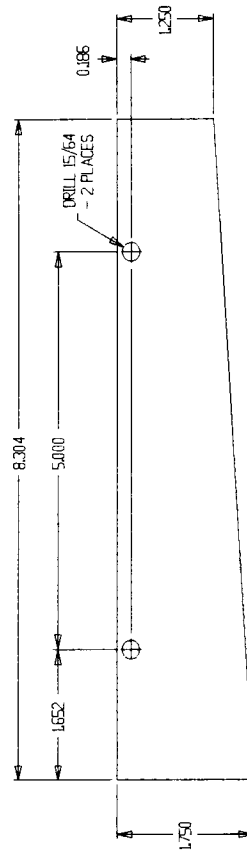
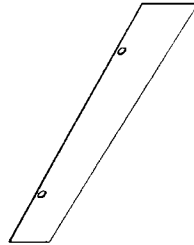
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SCALE	2:1	DIMENSIONS IN INCHES		PART #	UT
MATERIAL	LOW CARBON STEEL	TOLERANCES UNLESS NOTED		101-3	
		LINEAR +/-	.010	TITLE	END CLAMP
		ANGLES +/-	N/A		
OTHER NOTES		RADIO UNLESS NOTED	N/A	DESIGNER	BDC 07/12/91
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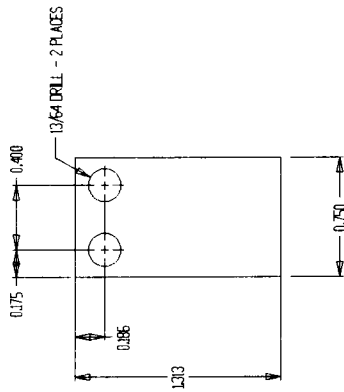
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MATERIAL	FREE MACHINING	TOLERANCES UNLESS NOTED	102	
ALLUMINUM		LINEAR +/-	TITLE	PUNCH BASE
OTHER NOTES		ANGLES +/-		
IBMCAD FILE	PUNBASER.MCH	RADII UNLESS NOTED	DESIGNER	BDC
		EDGE/CORNER BREAKS	CHECKED	
			APPROVED	
				10/10/90

QUANTITY: 1

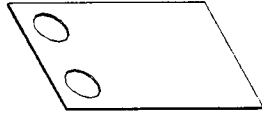


SCALE	1:1	DIMENSIONS IN INCHES	PART #	UT
MATERIAL	.020 INCH THICK	TOLERANCES UNLESS NOTED	103	
FLAT STEEL SHIM STOCK		LINEAR +/-	TITLE	PUNCH SIDE SHEAR
		ANGLES +/-		
OTHER NOTES		RADI UNLESS NOTED	DESIGNER	BDC
		EDGE/CORNER BREAKS	CHECKED	
IBMCAD FILE	PUNCH.MCH	OUTSIDE MAX	APPROVED	
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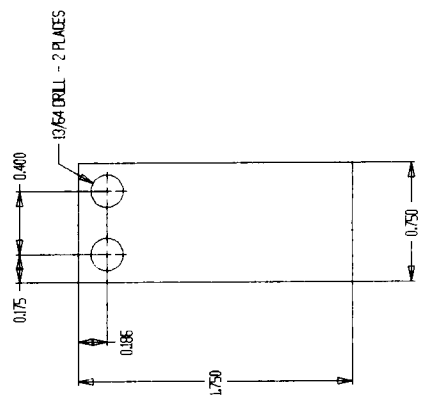


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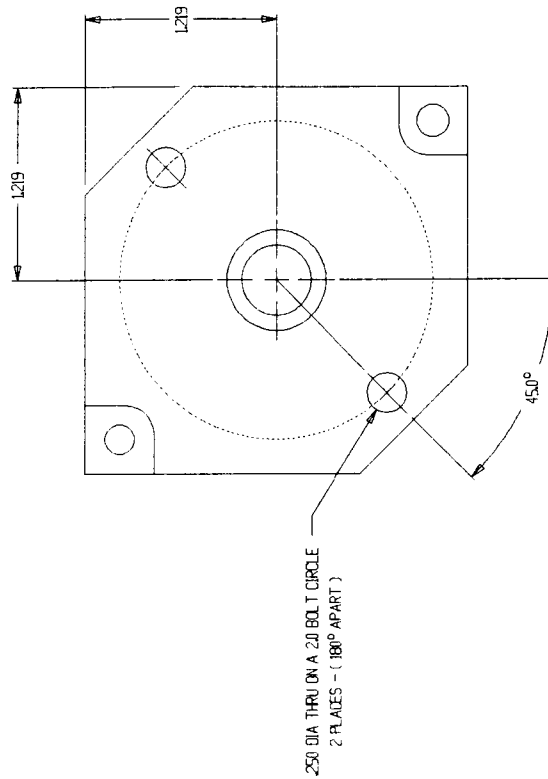
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MATERIAL	.020 INCH THICK	TOLERANCES UNLESS NOTED	104	
FLAT STEEL SHIM STOCK		LINEAR +/-	TITLE	SHORT PUNCH END
		ANGLES +/-	SHEAR	
OTHER NOTES		RADII UNLESS NOTED	DESIGNER	BDC 10/09/90
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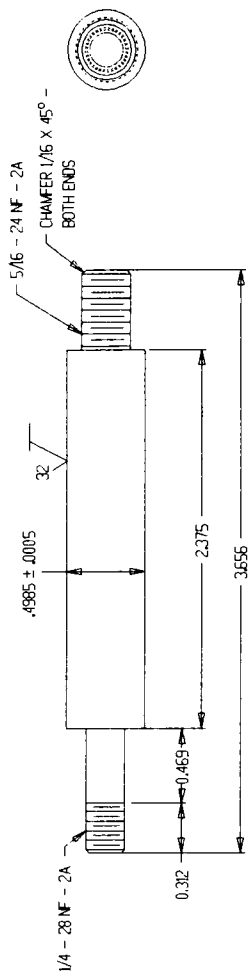
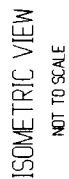
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SCALE	2:1	DIMENSIONS IN INCHES		PART #	UT
MATERIAL	.020 INCH THICK	TOLERANCES UNLESS NOTED			
FLAT STEEL SHIM STOCK		LINEAR +/-	.010	TITLE	LONG PUNCH END SHEAR
		ANGLES +/-	N/A		
OTHER NOTES		RADII UNLESS NOTED	N/A	DESIGNER	BDC
		EDGE/ CORNER BREAKS	OUTSIDE MAX	CHECKED	
			INSIDE MAX	APPROVED	
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					10/09/90



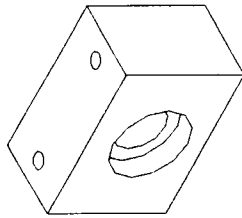
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SCALE	1:1	DIMENSIONS IN INCHES	PART #	UT
MATERIAL	TOOLING PLATE, COMPACT AIR PRODUCTS	TOLERANCES UNLESS NOTED	106	
PART #	BTP-2	LINEAR +/-	TITLE	MODIFIED AIR CYLINDER
OTHER NOTES		ANGLES +/-	TOOLING PLATE	
		RADII UNLESS NOTED	DESIGNER	BDC
		EDGE/ CORNER BREAKS	CHECKED	10/01/90
		OUTSIDE MAX	APPROVED	
		INSIDE MAX		
	IBMCAD FILE	PLATE.MCH		

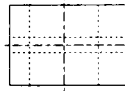
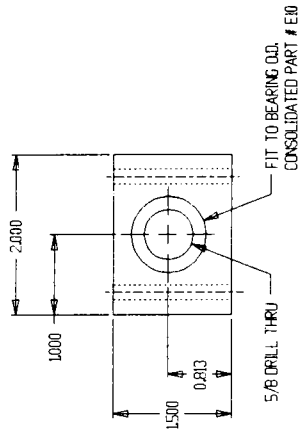
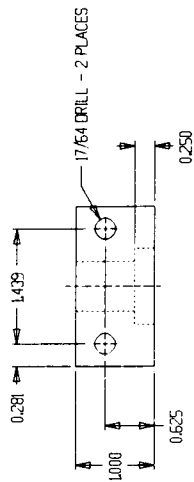


SCALE	2:1	DIMENSIONS IN INCHES		PART #	UT	
MATERIAL	LOW CARBON STEEL	TOLERANCES UNLESS NOTED				
		LINEAR	+/-	.010	TITLE	AIR CYLINDER TOOLING
		ANGLES	+/-	N/A	PLATE	EXTENSION
OTHER NOTES		RADIi UNLESS NOTED		.010	DESIGNER	BDC 11/06/90
		EDGE/ CORNER BREAKS	OUTSIDE MAX	N/A	CHECKED	
IBMCAD FILE	EXTENDMCH		INSIDE MAX	N/A	APPROVED	

QUANTITY: 2

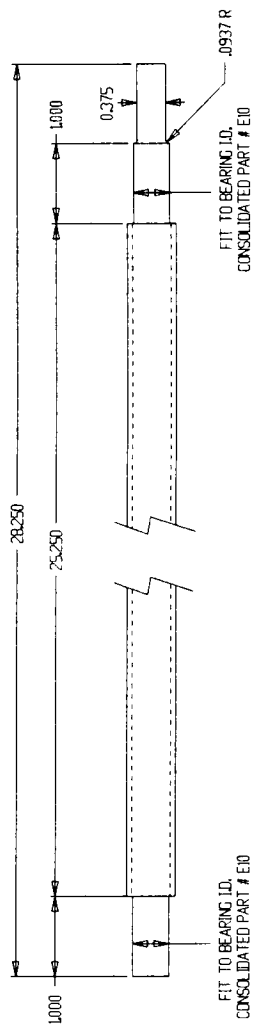


ISOMETRIC VIEW



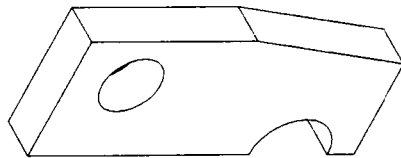
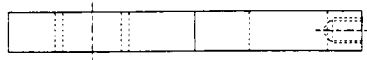
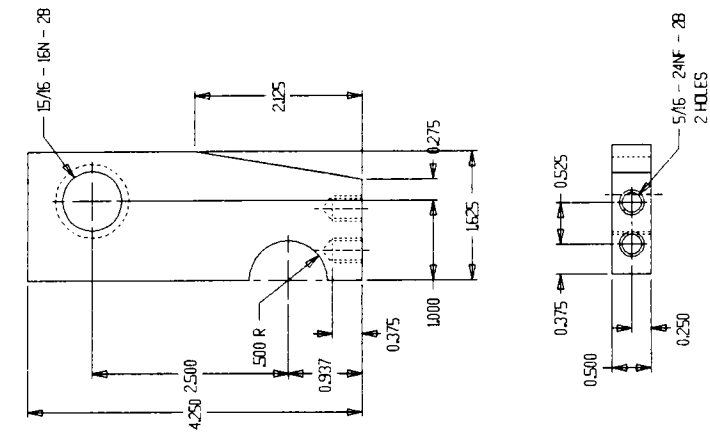
SCALE	1:1	DIMENSIONS IN INCHES	PART #	UT
MATERIAL	LOW CARBON STEEL	TOLERANCES UNLESS NOTED	108	
		LINEAR +/-	TITLE	SCREW BEARING SUPPORT
		ANGLES +/-	BLOCK	
OTHER NOTES		RADI UNLESS NOTED	DESIGNER	BDC
		EDGE/CORNER BREAKS	CHECKED	07/17/90
IBMCAD FILE	BLOCK.MCH	INSIDE MAX	APPROVED	

QUANTITY: 2



QUANTITY: 1

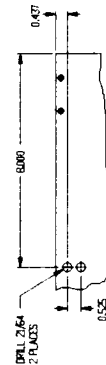
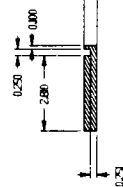
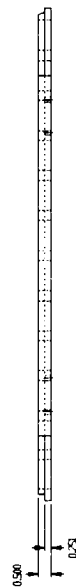
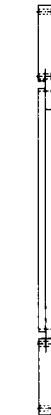
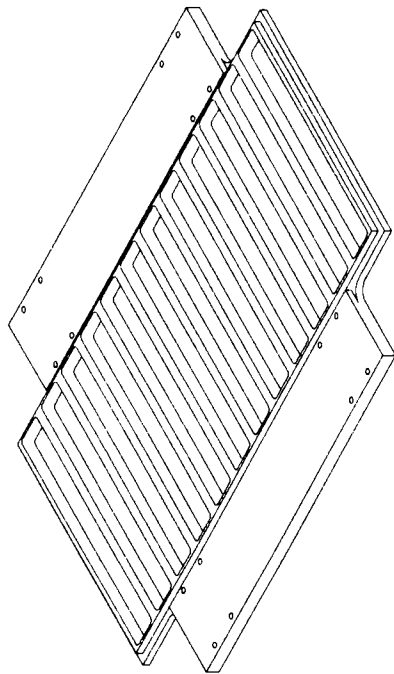
SCALE	1:1	DIMENSIONS IN INCHES	PART #	UT
MATERIAL	5/8 Ø X 28 IN	TOLERANCES UNLESS NOTED	109	
BALL SCREW, NOOK IND.		LINEAR +/-	TITLE DRIVE SCREW	
PART # 5966K26		ANGLES +/-		
OTHER NOTES		RADI UNLESS NOTED	DESIGNER BDC	08/31/90
		EDGE/ CORNER BREAKS	CHECKED	
			APPROVED	
IBMCAD FILE	SCREW.MCH			



ISOMETRIC VIEW

SCALE	1:1	DIMENSIONS IN INCHES	PART #	UT
MATERIAL	LOW CARBON STEEL	TOLERANCES UNLESS NOTED	III	
		LINEAR +/-		TITLE BALL-NUT/TRAY
		ANGLES +/-		INTERFACE
OTHER NOTES		RADI UNLESS NOTED		DESIGNER BDC 09/16/90
		EDGE/CORNER BREAKS		CHECKED
		OUTSIDE MAX		APPROVED
IBMCAD FILE	CONECTOR.MCH	INSIDE MAX		

QUANTITY: 1



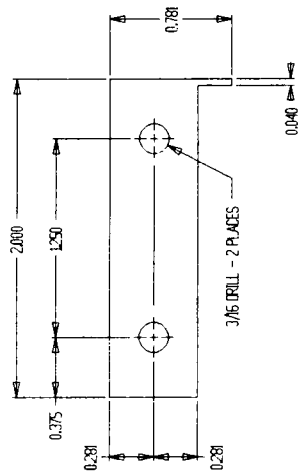
DETAIL C - C



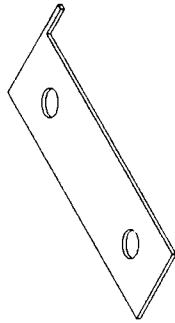
SECTION B - B

QUANTITY: 1

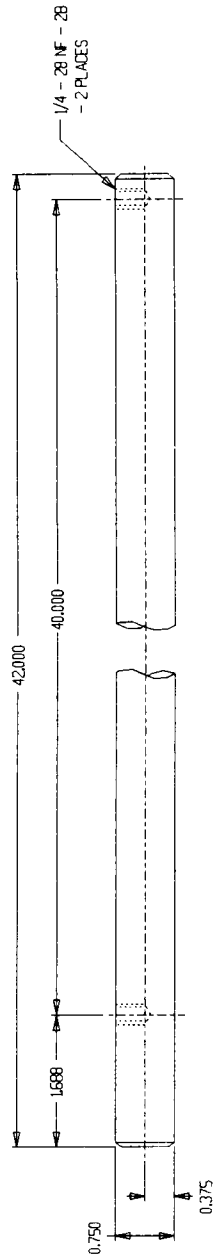
DETAIL C - C



ISOMETRIC VIEW
NOT TO SCALE

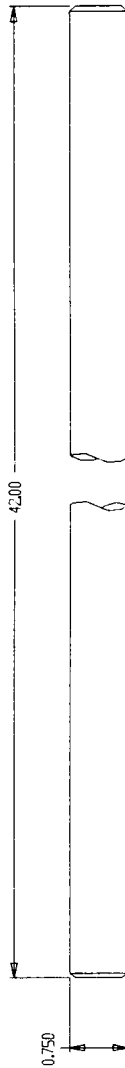


SCALE 2:1			DIMENSIONS IN INCHES		PART #	UT
MATERIAL 1/32 INCH THICK			TOLERANCES UNLESS NOTED			
FREE MACHINING ALUMINUM			LINEAR +/-	.010	TITLE TRAY HOME POSITION	
			ANGLES +/-		INDICATOR	
OTHER NOTES			RADI UNLESS NOTED		DESIGNER	BDC 07/17/91
			EDGE/ CORNER BREAKS	OUTSIDE MAX	CHECKED	
IBMCAD FILE HOMEIND.MCH				INSIDE MAX	APPROVED	
			N/A			
QUANTITY: 1						



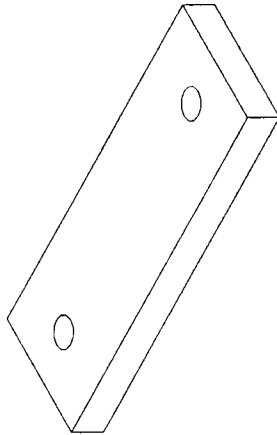
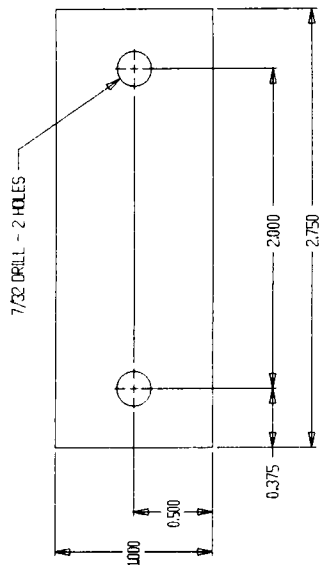
QUANTITY: 1

SCALE	1:1	DIMENSIONS IN INCHES	PART #	UT
MATERIAL	3/4" Ø X 42"	TOLERANCES UNLESS NOTED	114	
CLASS "L" SHAFT, THOMSON		LINEAR +/-	TITLE LEFT TRAY BEARING	
PART # 3/4" Ø X 42"		ANGLES +/-	SHAFT	
OTHER NOTES		RADII UNLESS NOTED	DESIGNER BDC	07/23/90
		EDGE/CORNER BREAKS	CHECKED	
			APPROVED	
IBMCAD FILE	SHAFT.DRL			



QUANTITY: 1

SCALE	1:1	DIMENSIONS IN INCHES	PART #	UT
MATERIAL	3/4" Ø X 42"	TOLERANCES UNLESS NOTED	115	
CLASS "L" SHAFT, THOMSON		LINEAR +/-	TITLE	RIGHT TRAY BEARING
PART # 3/4" Ø X 42"		ANGLES +/-	SHAFT	
OTHER NOTES		RADII UNLESS NOTED	DESIGNER	BDC 07/23/90
		EDGE / CORNER BREAKS	CHECKED	
		INSIDE MAX	APPROVED	
IBMCAD FILE	SHAFT.LNG			

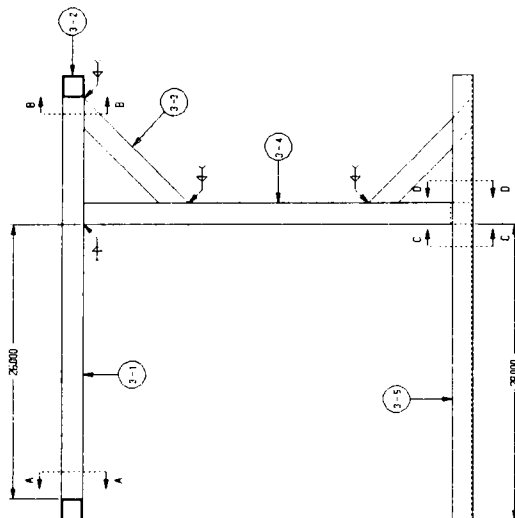


ISOMETRIC VIEW
NOT TO SCALE

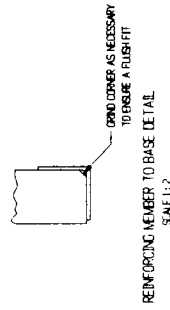


QUANTITY: 2

SCALE	2:1	DIMENSIONS IN INCHES		PART #	UT
MATERIAL	LOW CARBON STEEL	TOLERANCES UNLESS NOTED		116	
OTHER NOTES		LINEAR +/-	.010	TITLE	PILLOW BLOCK SPACER
		ANGLES +/-	N/A		
		RADI UNLESS NOTED	N/A	DESIGNER	BDC
		EDGE/ CORNER BREAKS	OUTSIDE MAX INSIDE MAX	CHECKED	06/29/91
IBMCAD FILE	BLKSPCR.MCH		N/A	APPROVED	



PART #	NAME	QTY
107-1	UPPER MEMBER	2
107-2	UPPER TE	2
107-4	REINFORCING MEMBER	4
107-5	VERTICAL SUPPORT	2
107-5	BASE	2
107-6	LOWER TE	1



SECTION A - A



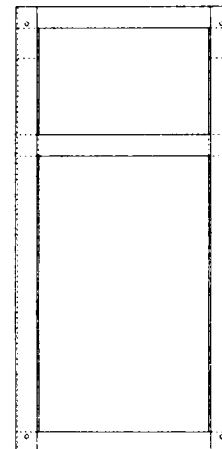
SECTION B - B



SECTION C - C

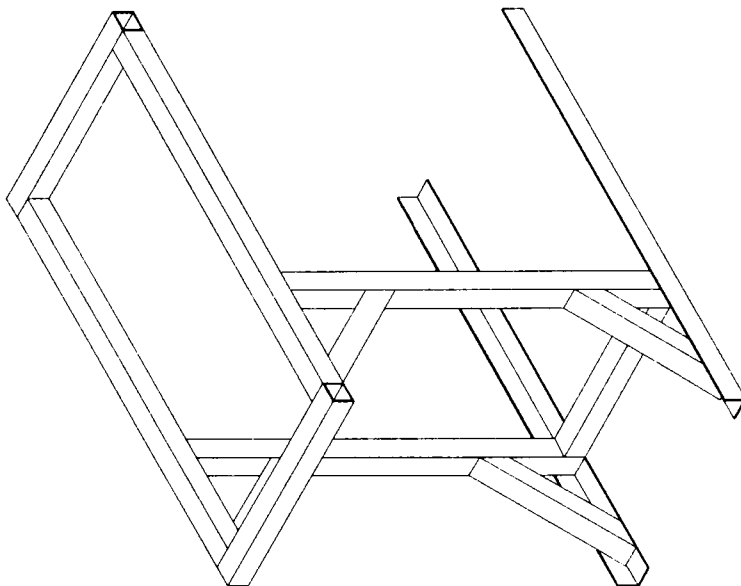


SECTION D - D



SCALE	1:5	DIMENSIONS IN INCHES	PART #	UT
MATERIAL	N/A	TOLERANCES UNLESS NOTED	117	
		LINEAR +/-	.020	TITLE FRAME PHASE I
		ANGLES +/-	N/A	
OTHER NOTES		RADII UNLESS NOTED	N/A	
		EDGE CORNER BREAKS	OUTSIDE MAX	
			INSIDE MAX	
IBMCAD FILE	FRAME.ASM		DESIGNER	BOC 08/10/90
			CHECKED	
			APPROVED	

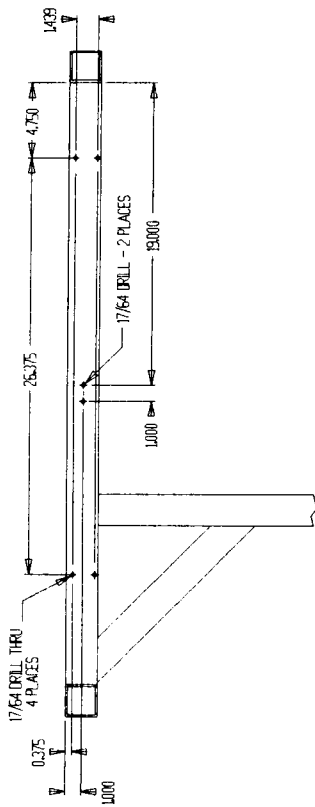
QUANTITY: 1



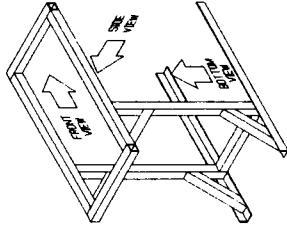
ISOMETRIC VIEW

SCALE	1:5	DIMENSIONS IN INCHES			PART #	UT
MATERIAL	N/A	TOLERANCES UNLESS NOTED			117	
		LINEAR +/-	N/A		TITLE FRAME, PHASE I	
		ANGLES +/-	N/A			
OTHER NOTES		RADI UNLESS NOTED	N/A		DESIGNER	BCC 08/05/90
		EDGE / CORNER BREAKS	N/A		CHECKED	
IBMCAD FILE	FRAME.ISO	OUTSIDE MAX	N/A		APPROVED	
		INSIDE MAX	N/A			

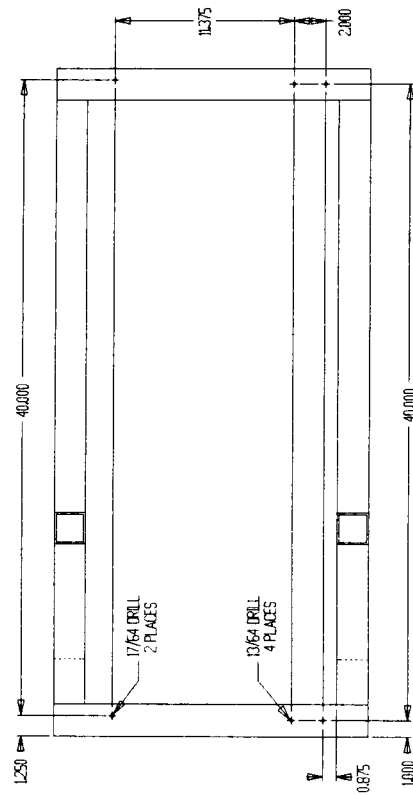
QUANTITY: 1



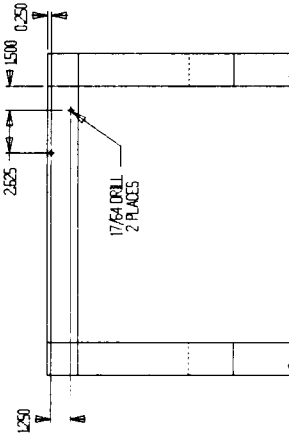
SIDE VIEW



ISOMETRIC VIEW
NOT TO SCALE



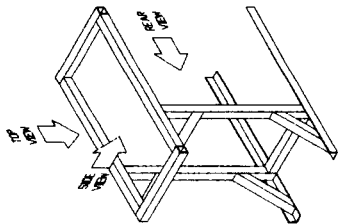
BOTTOM VIEW



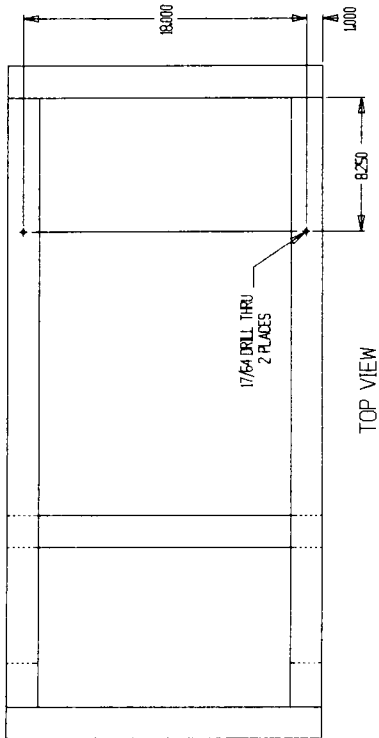
FRONT VIEW

SCALE	1:5	DIMENSIONS IN INCHES	PART #	UT
MATERIAL	N/A	TOLERANCES UNLESS NOTED	117	
		LINEAR +/-		TITLE LOCATION OF MOUNTING
		ANGLES +/-		HOLES, PHASE I
		RADIO UNLESS NOTED		DESIGNER BDC
OTHER NOTES HOLES ARE		EDGE/CORNER BREAKS		CHECKED
DRILLED TO CONTR UNLESS NOTED		OUTSIDE MAX		APPROVED
IBM/CAD FILE	FRMORL.MCH	INSIDE MAX		

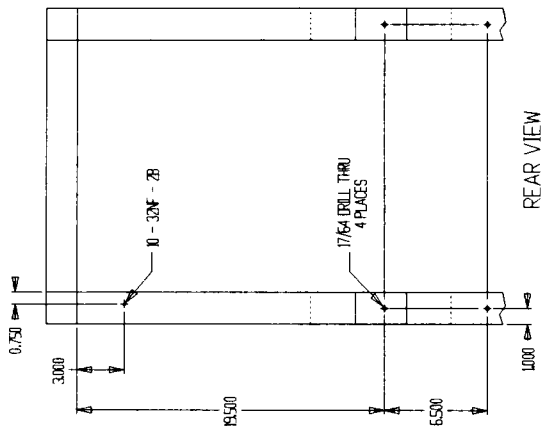
QUANTITY: 1



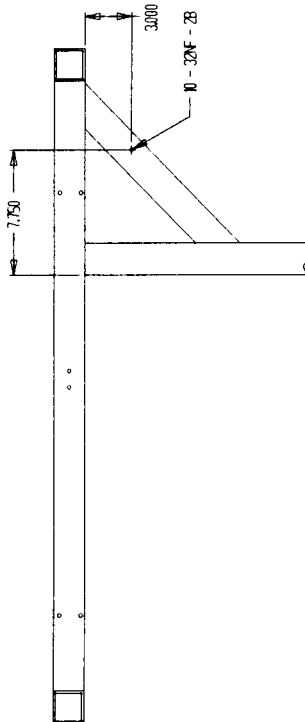
ISOMETRIC VIEW
NOT TO SCALE



TOP VIEW



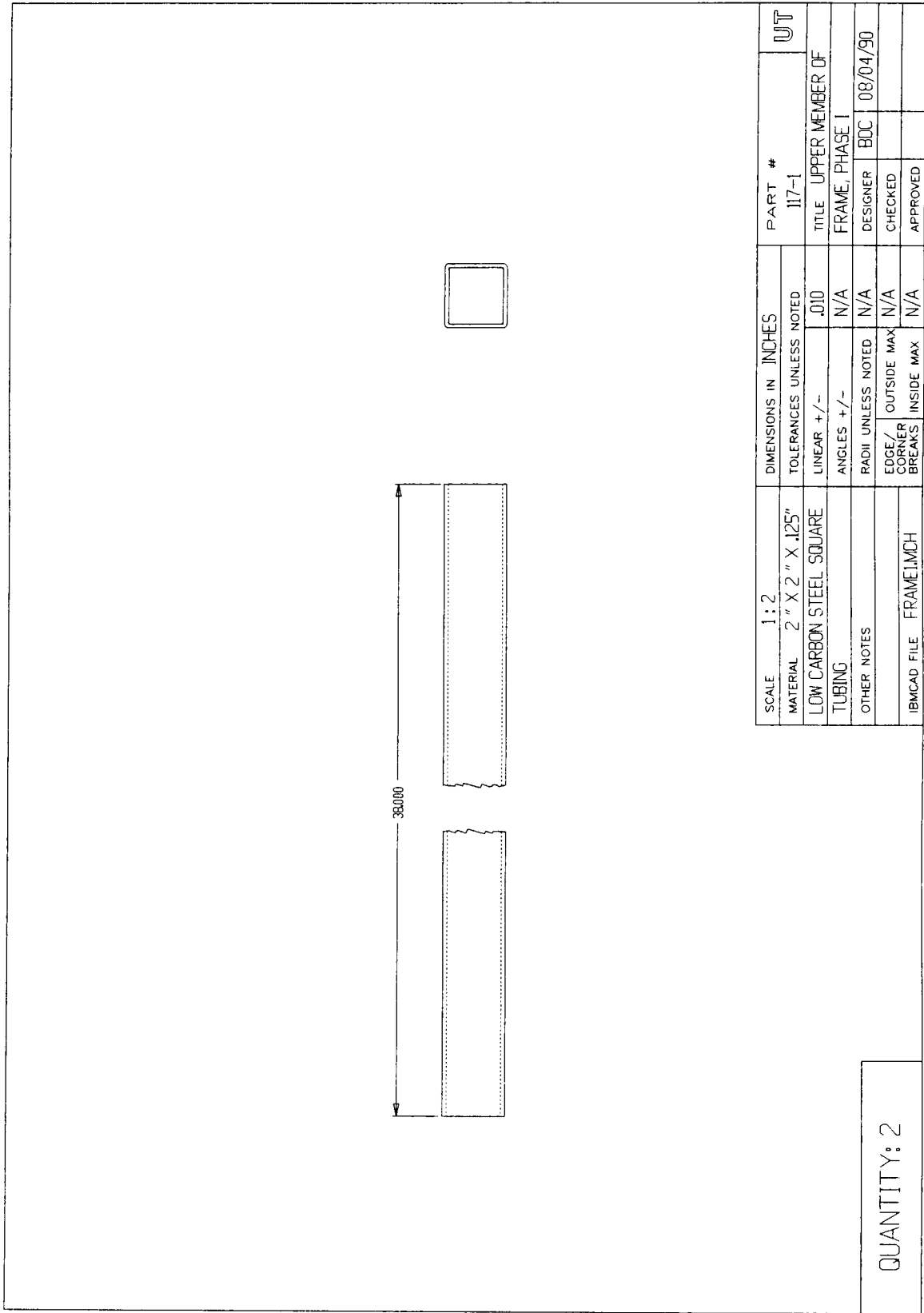
REAR VIEW

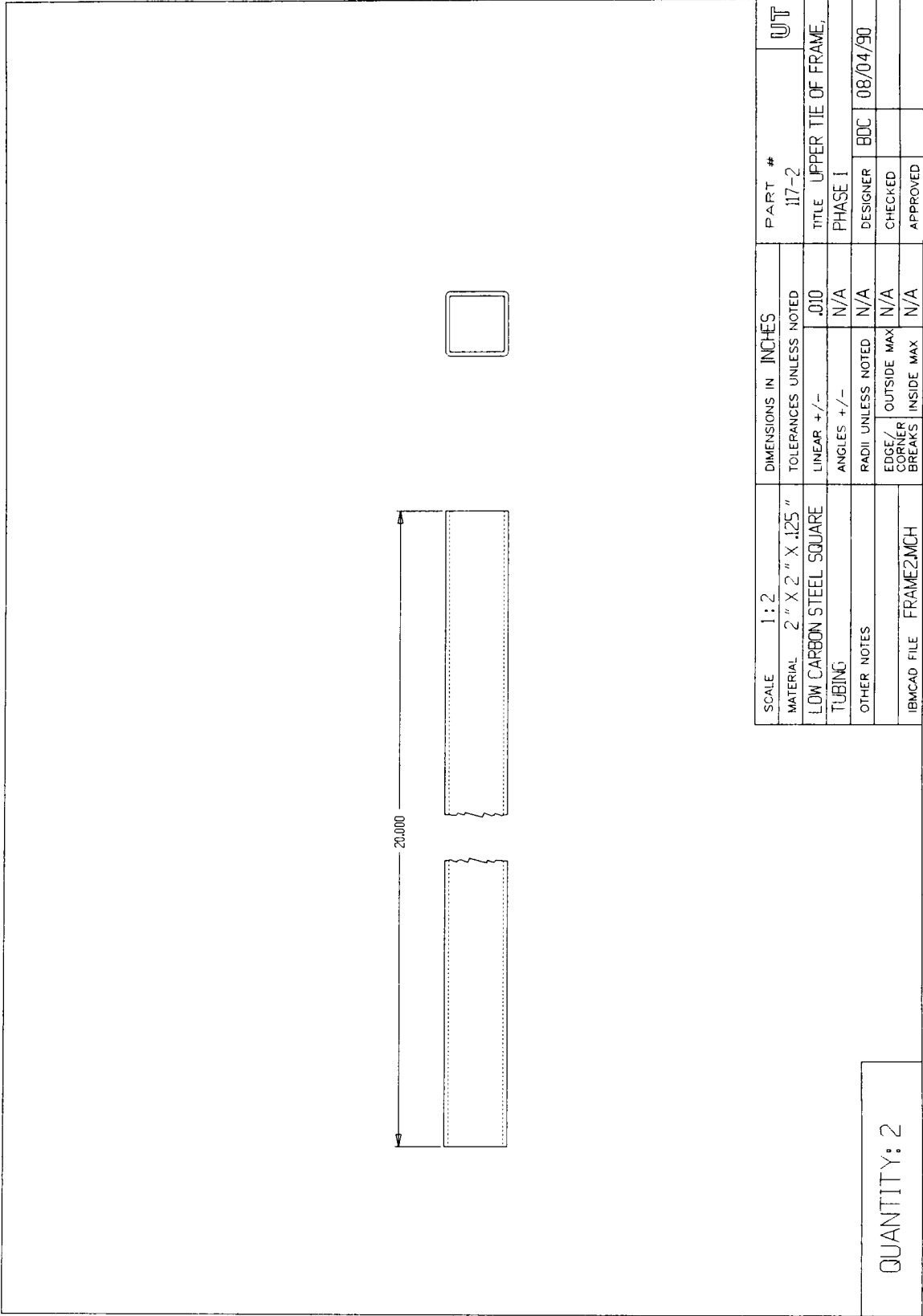


SIDE VIEW

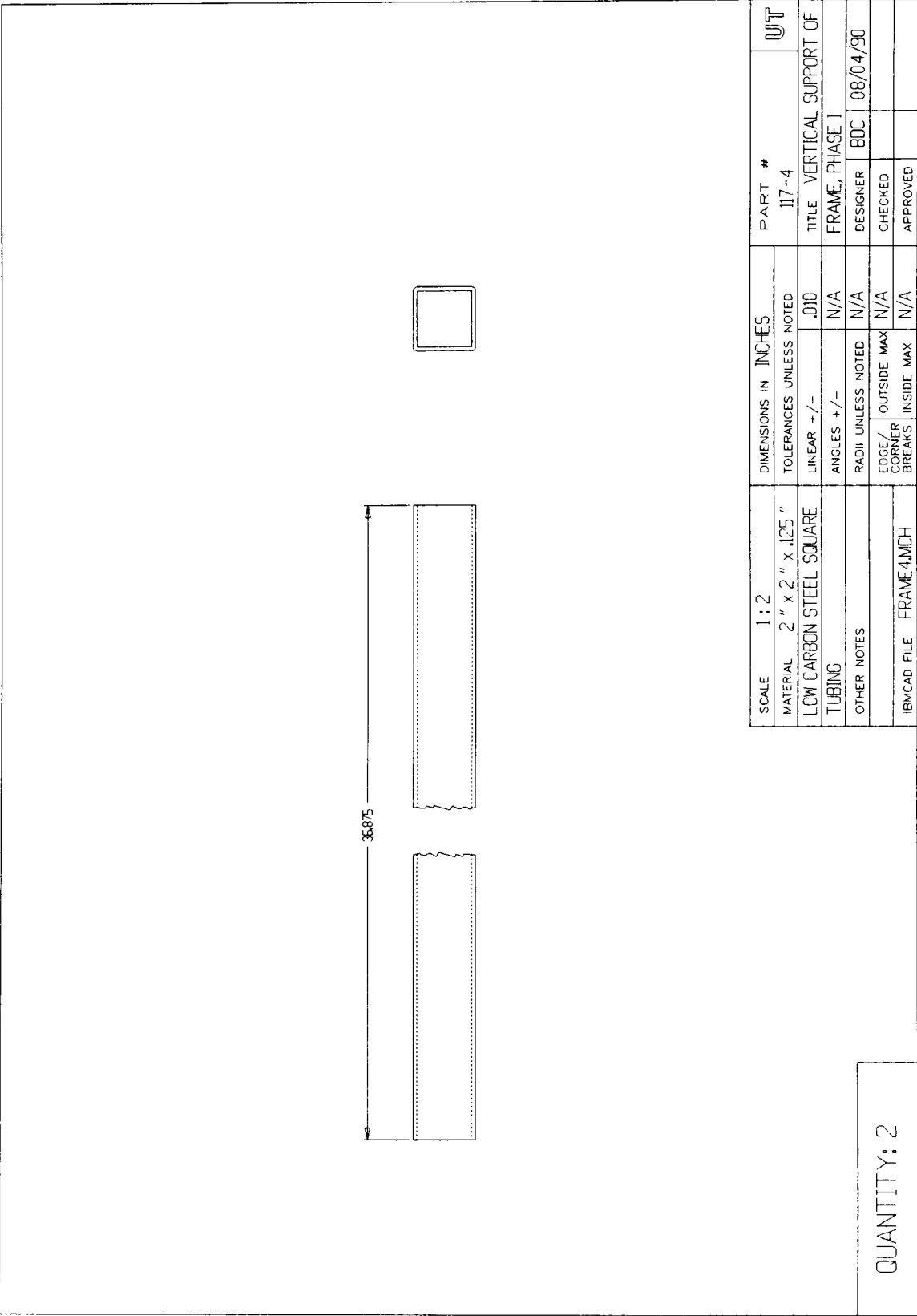
SCALE	1:5	DIMENSIONS IN INCHES		PART #	UT
		TOLERANCES UNLESS NOTED	.010		
MATERIAL	N/A	LINEAR +/-	N/A	TITLE	LOCATION OF MOUNTING
OTHER NOTES		ANGLES +/-	N/A	HOLES, PHASE I	
HOLES ARE		RADIUS UNLESS NOTED	N/A	DESIGNER	BOC
DRILLED TO OMT		EDGE/ CORNER BREAKS	N/A	CHECKED	
FILE		INSIDE MAX	N/A	APPROVED	

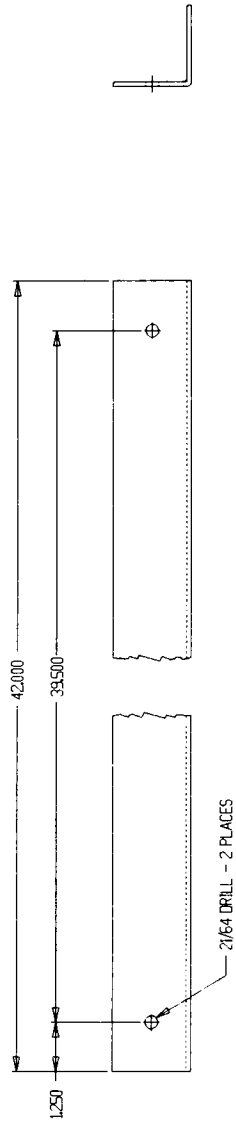
QUANTITY: 1





SCALE	1:2	DIMENSIONS IN INCHES	PART #	UT
MATERIAL	2" X 2" X .125"	TOLERANCES UNLESS NOTED	117-2	
LOW CARBON STEEL SQUARE TUBING		LINEAR +/-	TITLE	UPPER TIE OF FRAME,
		ANGLES +/-	PHASE I	
OTHER NOTES		RADI UNLESS NOTED	DESIGNER	BOC 08/04/90
		EDGE/CORNER BREAKS	CHECKED	
IBMCAD FILE	FRAME2.MCH	INSIDE MAX	APPROVED	





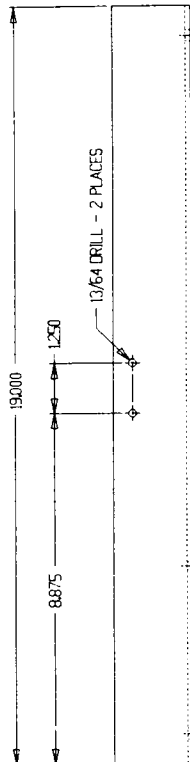
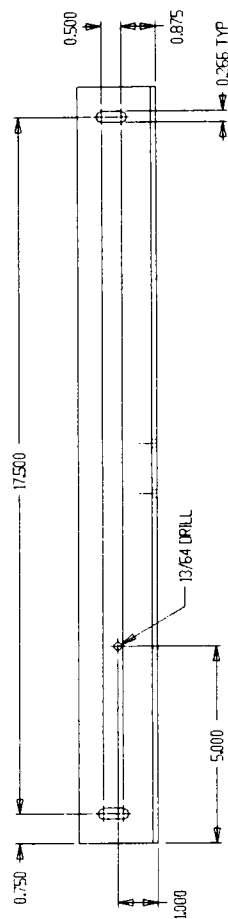
SCALE	1 : 2	DIMENSIONS IN INCHES		PART #	UT	
		TOLERANCES UNLESS NOTED				
MATERIAL	2 " X 2 " X .125 "	LINEAR +/-	.010	117-5	TITLE BASE OF FRAME, PHASE I	
LOW CARBON STEEL ANGLE		ANGLES +/-	N/A			
OTHER NOTES		RADI UNLESS NOTED	N/A	DESIGNER	BDC	08/10/90
		EDGE / CORNER BREAKS	OUTSIDE MAX	N/A	CHECKED	
IBMCAD FILE	FRAMES.MCH	INSIDE MAX	N/A	APPROVED		

QUANTITY: 2



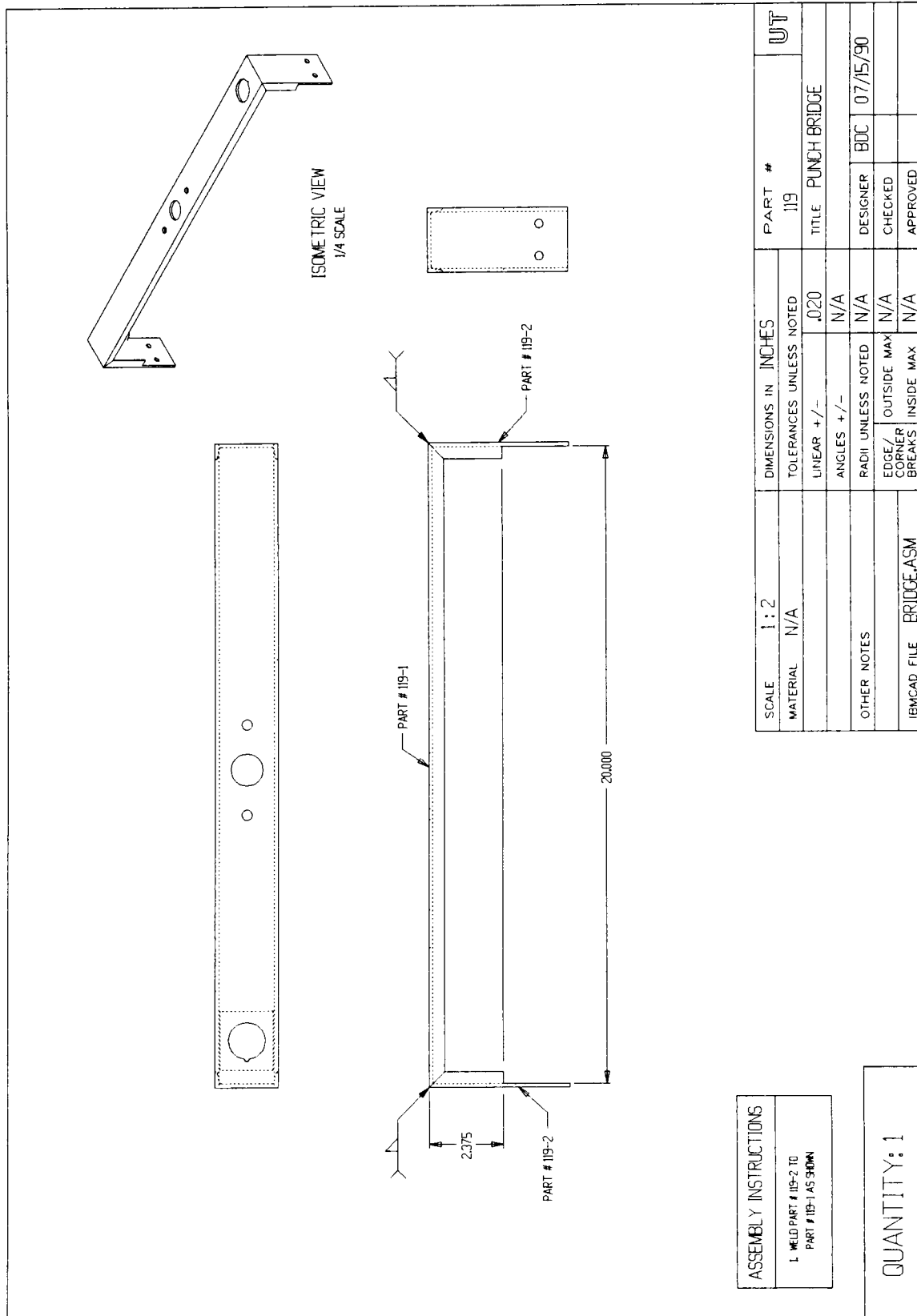
QUANTITY: 1

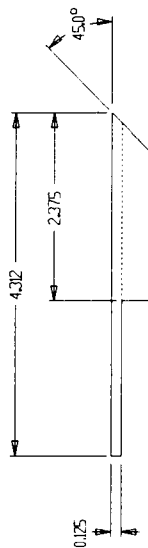
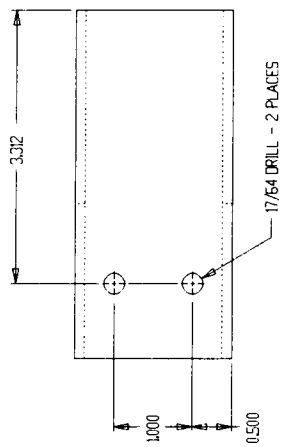
SCALE	1:1	DIMENSIONS IN INCHES	PART #	UT
MATERIAL	2" X 2" X .125"	TOLERANCES UNLESS NOTED	117-6	
LOW CARBON STEEL SQUARE		LINEAR +/-	TITLE LOWER TIE OF FRAME,	
TUBING		ANGLES +/-	PHASE I	
OTHER NOTES		RADI UNLESS NOTED	DESIGNER	08/04/90
		EDGE/CORNER BREAKS	CHECKED	
			APPROVED	
IBMCAD FILE	FRAME.MCH			



QUANTITY: 1

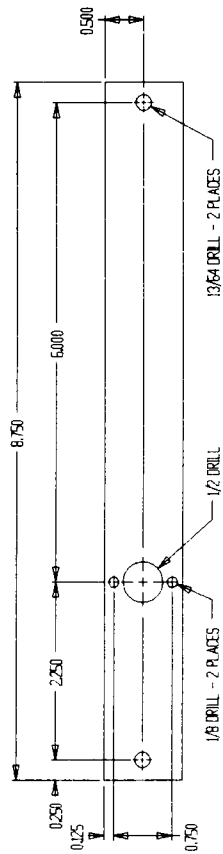
SCALE	1:2	DIMENSIONS IN INCHES		PART #	UT
MATERIAL	2" X 2" .125"	TOLERANCES UNLESS NOTED			
LOW CARBON STEEL ANGLE		LINEAR +/-	.010	TITLE	GRIPPER BRIDGE
		ANGLES +/-	N/A		
OTHER NOTES		RADI UNLESS NOTED	N/A	DESIGNER	BDC
		EDGE/ CORNER BREAKS	OUTSIDE MAX	CHECKED	
IBMCAD FILE		FRAME10.MCH	INSIDE MAX	APPROVED	
					06/26/91





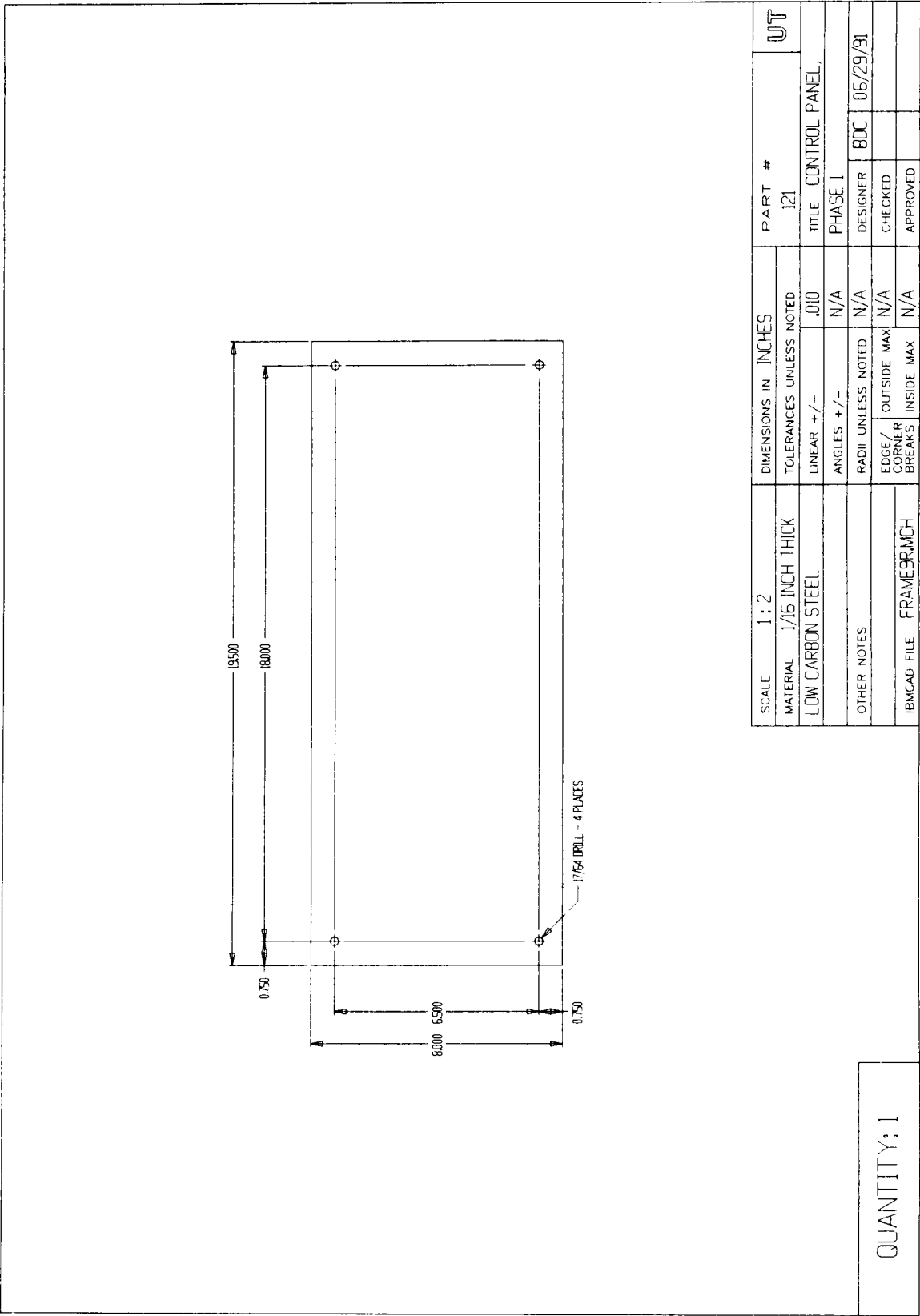
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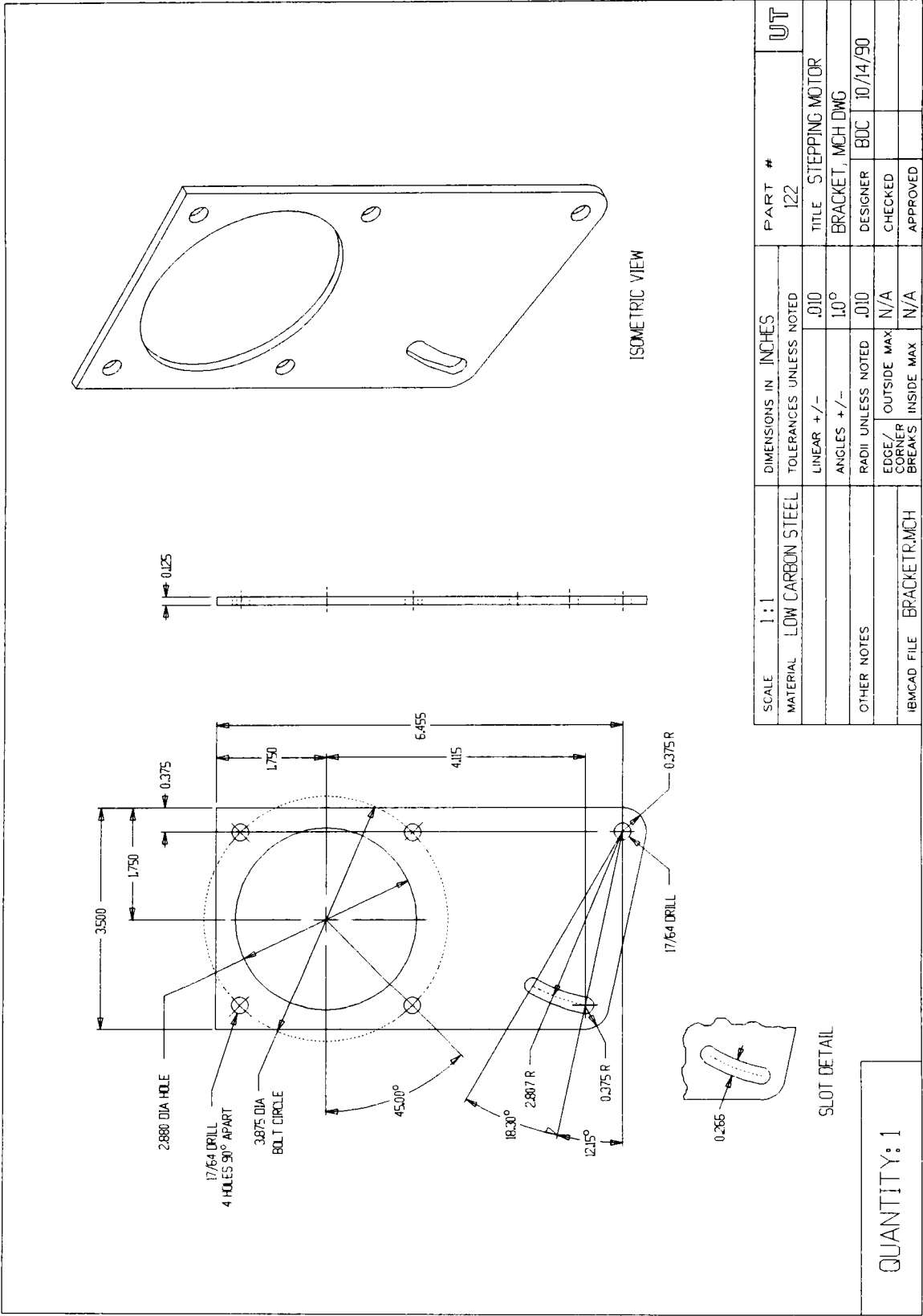
SCALE	1:1	DIMENSIONS IN INCHES	PART #	UT
MATERIAL	2" X 1/2" X 1/8"	TOLERANCES UNLESS NOTED	119-2	
LOW CARBON STEEL CHANNEL		LINEAR +/-	TITLE PUNCH BRIDGE	
		ANGLES +/-	VERTICAL MEMBER	
OTHER NOTES		RADII UNLESS NOTED	DESIGNER BOC	09/15/90
		EDGE/CORNER BREAKS	CHECKED	
IBMCAD FILE	FRAME8MCH	OUTSIDE MAX	APPROVED	
		INSIDE MAX		

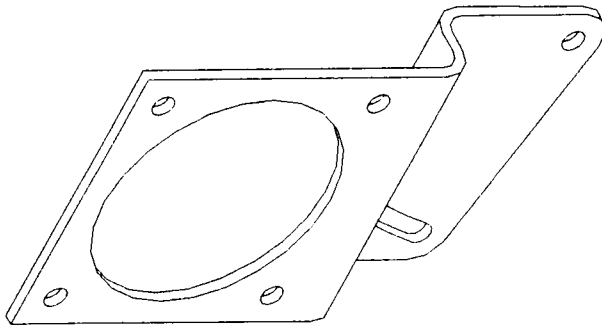
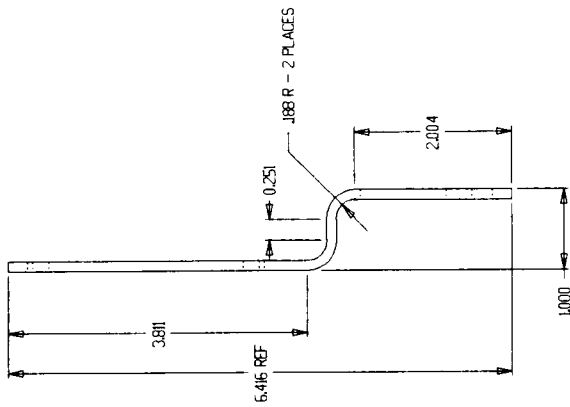
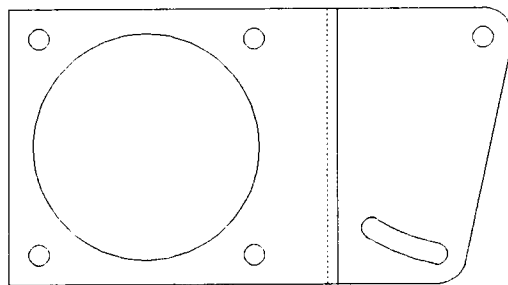


SCALE	1:1	DIMENSIONS IN INCHES	PART #	UT
MATERIAL	1/16 IN. THICK	TOLERANCES UNLESS NOTED	120	
LOW CARBON STEEL		LINEAR +/-		
		ANGLES +/-		
OTHER NOTES		RADI UNLESS NOTED		
		EDGE/CORNER BREAKS		
		OUTSIDE MAX		
		INSIDE MAX		
IBMCAD FILE	SNSRBRCK.MCH			

QUANTITY: 1





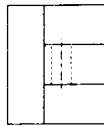


ISOMETRIC VIEW

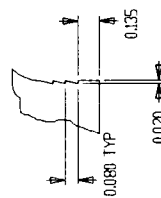
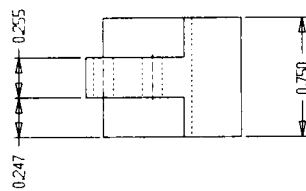
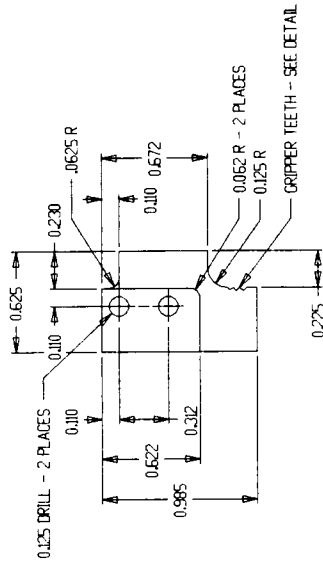
SCALE	1:1	DIMENSIONS IN INCHES	PART #	UT
MATERIAL	LOW CARBON STEEL	TOLERANCES UNLESS NOTED	122	
		LINEAR +/-		
		ANGLES +/-		
OTHER NOTES		RADI UNLESS NOTED		
		EDGE / CORNER BREAKS		
		OUTSIDE MAX		
		INSIDE MAX		
IBMCAD FILE	BRACKET.RBND			

TITLE	STEPPING MOTOR
DESIGNER	BDC
CHECKED	
APPROVED	

QUANTITY: 1



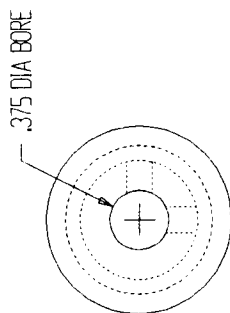
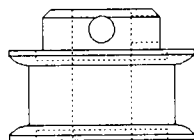
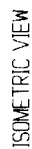
ISOMETRIC VIEW



TEETH DETAIL
4" SCALE

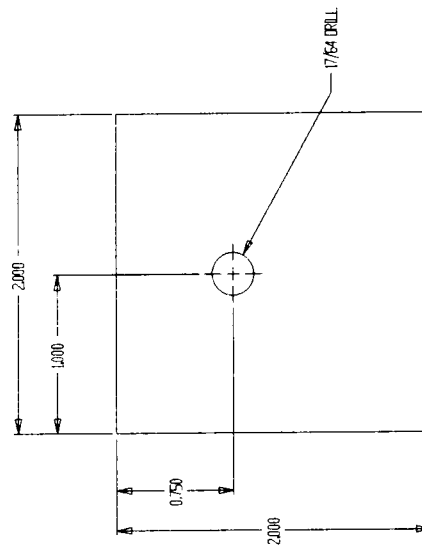
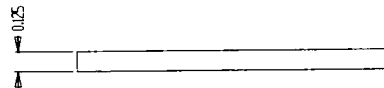
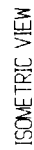
QUANTITY: 2

SCALE	2:1	DIMENSIONS IN INCHES		PART #	UT
MATERIAL	NYLON	TOLERANCES UNLESS NOTED			
		LINEAR	+/-	.010	TITLE GRIPPER FINGER
		ANGLES +/-		N/A	
OTHER NOTES		RADI UNLESS NOTED		.010	DESIGNER BDC 12/19/90
		EDGE/ CORNER BREAKS		N/A	CHECKED
BMCAD FILE	GRIPPER.MCH			N/A	APPROVED



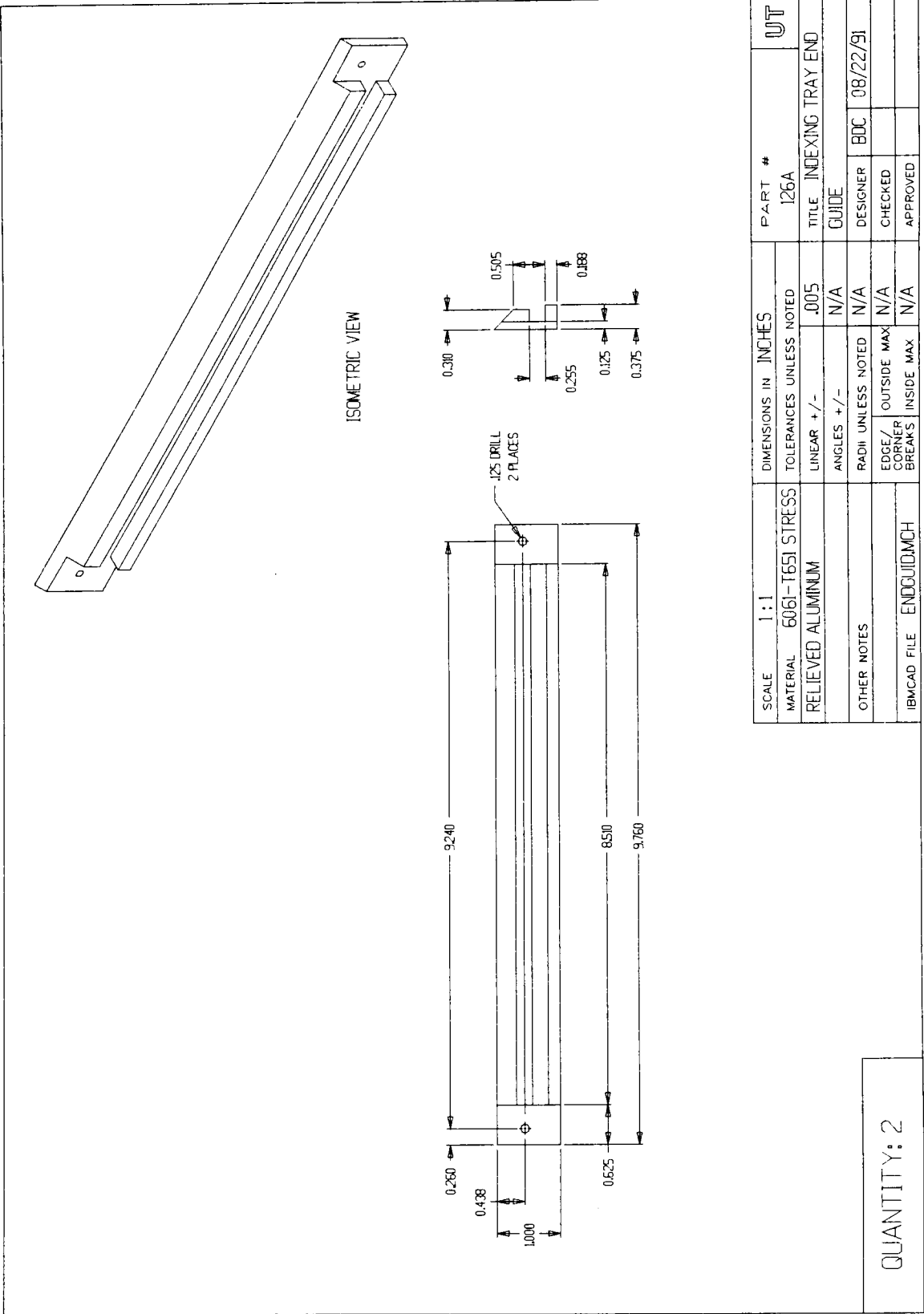
SCALE	2 : 1	DIMENSIONS IN INCHES		PART #	UT	
MATERIAL	1/4 GROOVE STEEL	TOLERANCES UNLESS NOTED		124		
TIMING PULLEY, STOCK		LINEAR + / -	.001			
DRIVE PART # 6F3-14DF037		ANGLES + / -	N/A			
OTHER NOTES		RADI UNLESS NOTED	N/A			
		EDGE / R OUTSIDE MAX	N/A			
FINISH FILE	DILL YSTL MTH	INSIDE MAX	N/A	CHECKED	APPROVED	
				DESIGNER	BDC	07/24/91

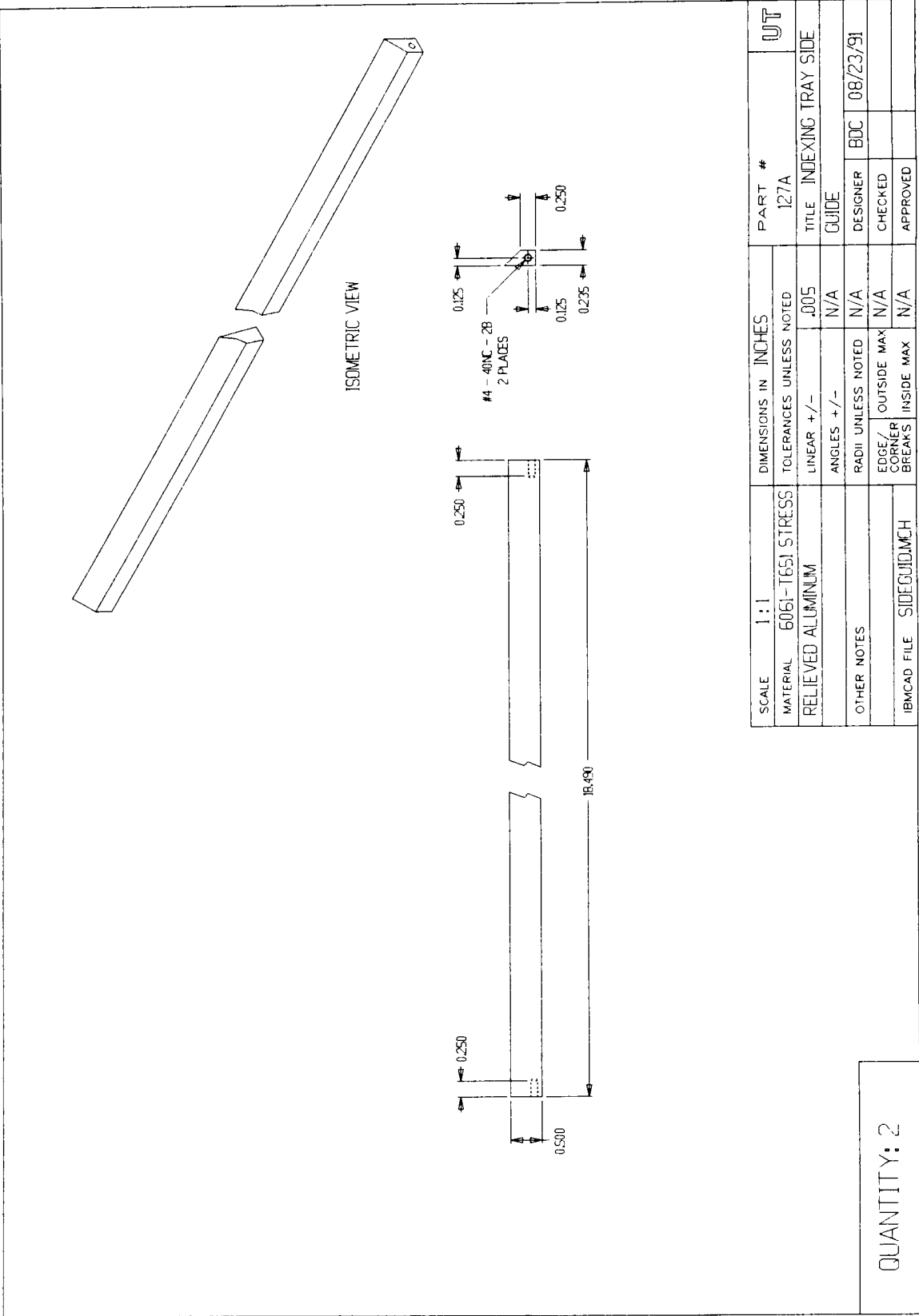
QUANTITY: 1

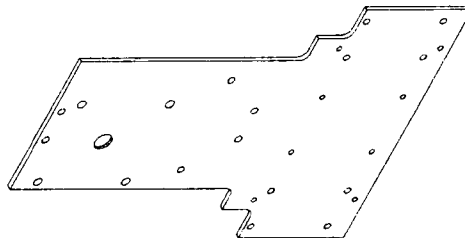


SCALE	2:1	DIMENSIONS IN INCHES		PART #	UT
MATERIAL	LOW CARBON STEEL	TOLERANCES UNLESS NOTED		125	
		LINEAR +/-	.010	TITLE ADJUSTABLE PILLOW	
		ANGLES +/-	N/A	BLOCK SPACER	
OTHER NOTES		RADIi UNLESS NOTED	N/A	DESIGNER	BDC
		EDGE/CORNER BREAKS	OUTSIDE MAX	CHECKED	
IBMCAD FILE	ADJSPC.RMCH		INSIDE MAX	APPROVED	
					08/01/91

QUANTITY: 2

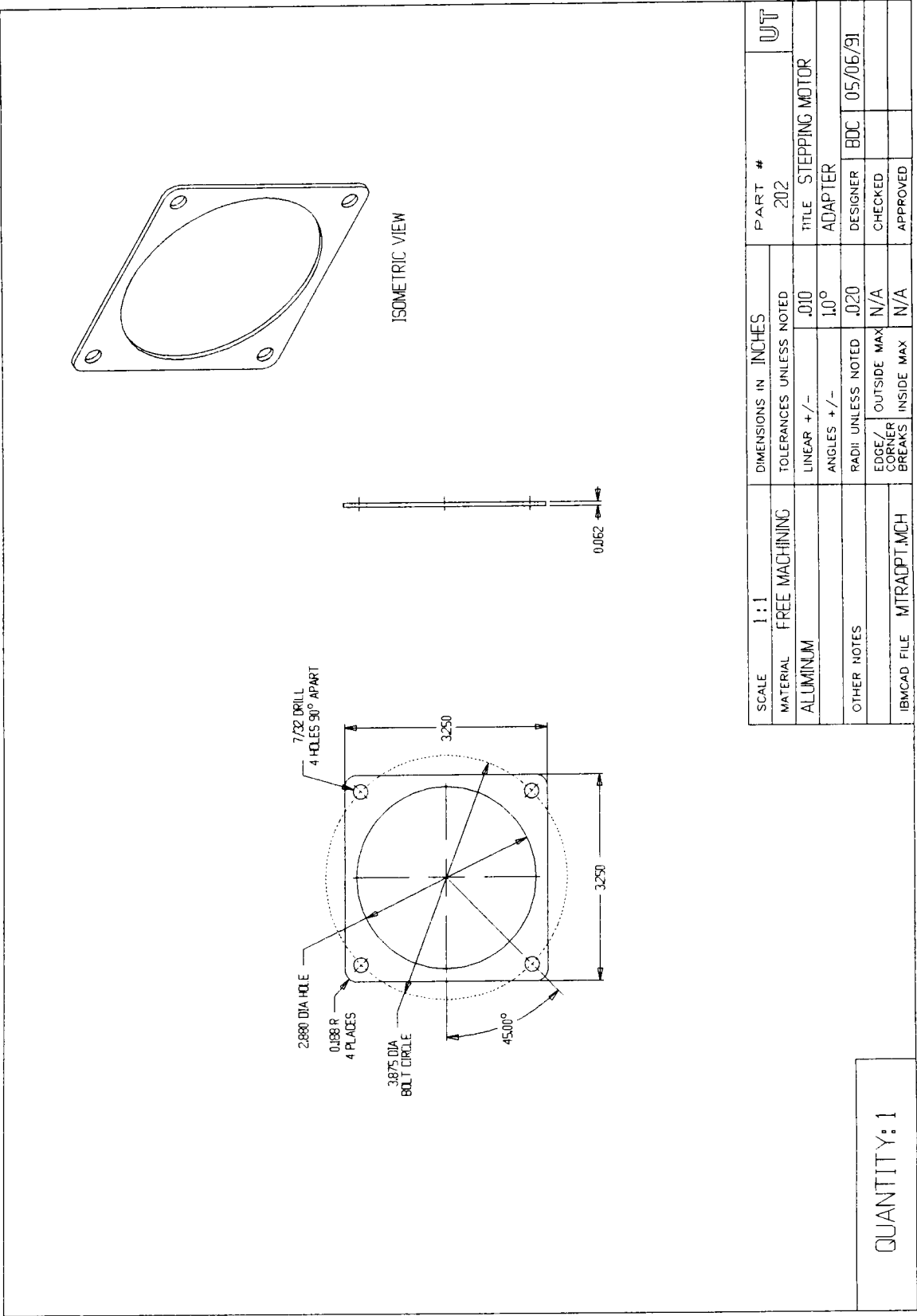


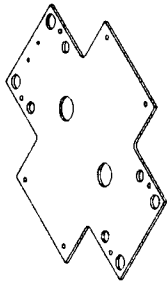




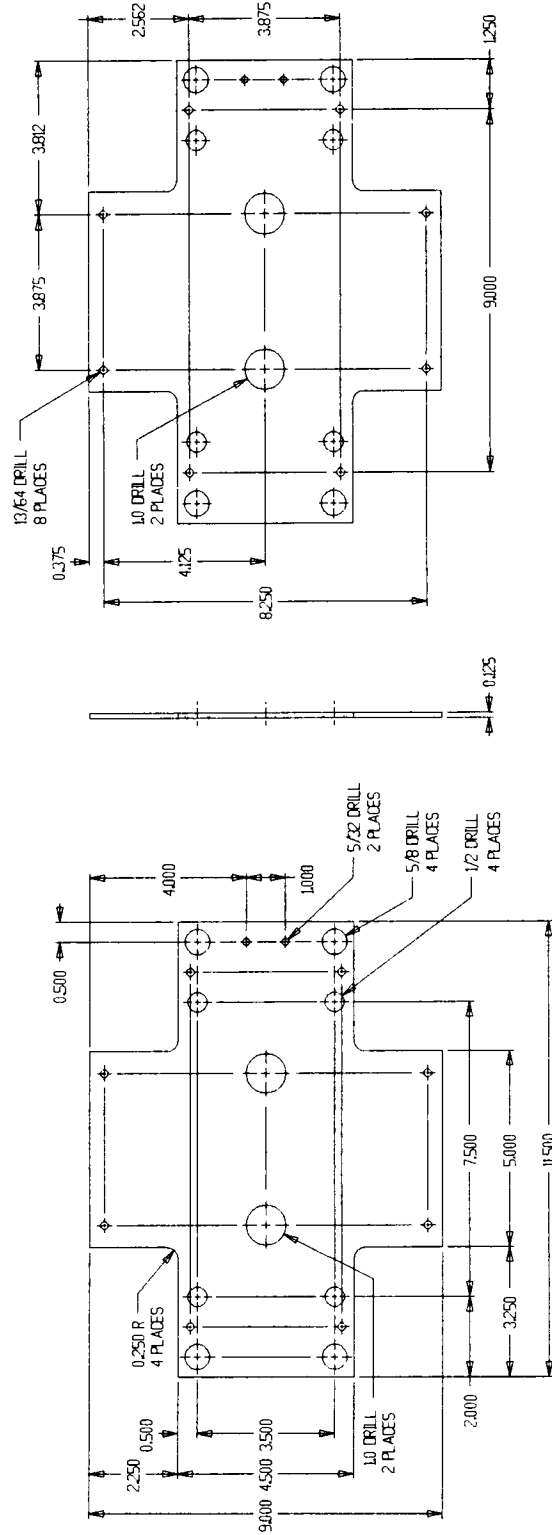
QUANTITY: 1

SCALE	1:2	DIMENSIONS IN INCHES		PART #	UT	
MATERIAL	FREE MACHINING	TOLERANCES UNLESS NOTED		201		
ALUMINUM		LINEAR + / -	.010	TITLE		VERTICAL SUPPORT
		ANGLES + / -	N/A	PLATE		
OTHER NOTES		RADII UNLESS NOTED	.010	DESIGNER	BDC	05/06/91
BMCAD FILE	MOUNT2.MCH	EDGE / CORNER BREAKS	OUTSIDE MAX	N/A	CHECKED	
			INSIDE MAX	N/A	APPROVED	



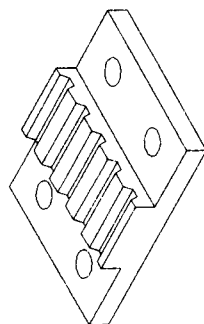
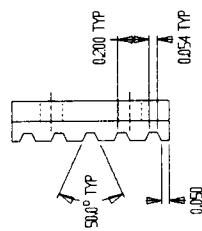


ISOMETRIC VIEW
1/4 SCALE



SCALE	1:2	DIMENSIONS IN INCHES	PART #	UT
MATERIAL	FREE MACHINING	TOLERANCES UNLESS NOTED	203	
ALUMINUM		LINEAR +/- .010	TITLE LOWER SUPPORT PLATE	
OTHER NOTES		ANGLES +/- N/A	DESIGNER BDC	04/24/91
		RADI UNLESS NOTED .020	CHECKED	
		EDGE/CORNER BREAKS OUTSIDE MAX N/A	APPROVED	
IBMCAD FILE	SUFORTIR.OPT	INSIDE MAX N/A		

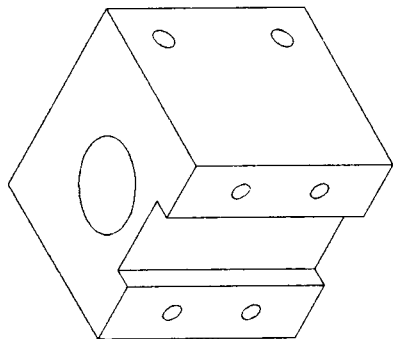
QUANTITY: 1



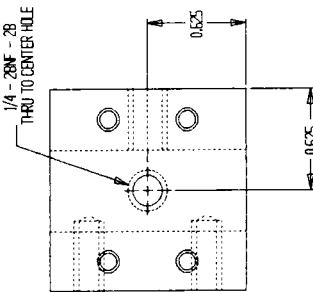
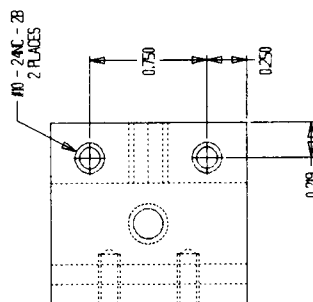
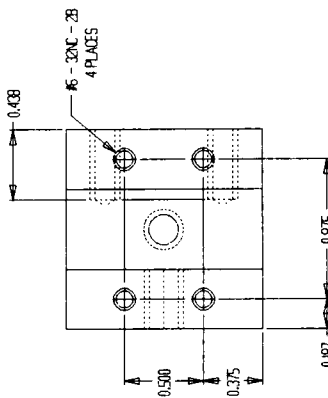
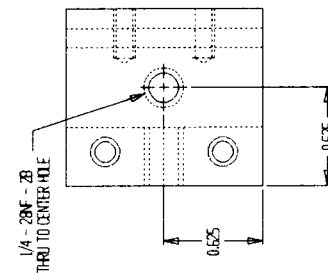
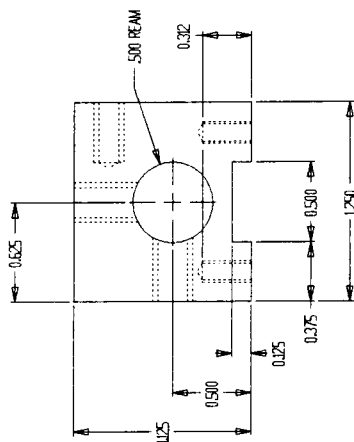
ISOMETRIC VIEW

SCALE	2:1	DIMENSIONS IN INCHES		PART #	UT
MATERIAL	FREE MACHINING	TOLERANCES UNLESS NOTED			
ALUMINUM		LINEAR +/-	.010	207	TITLE BELT CLIP
		ANGLES +/-	1°		
OTHER NOTES		RADII UNLESS NOTED	N/A	DESIGNER	BDC 07/17/91
REWORK FILE	BLOT PMCH	EDGE/ CORNER BREAKS	N/A	CHECKED	
			N/A	APPROVED	

QUANTITY: 1

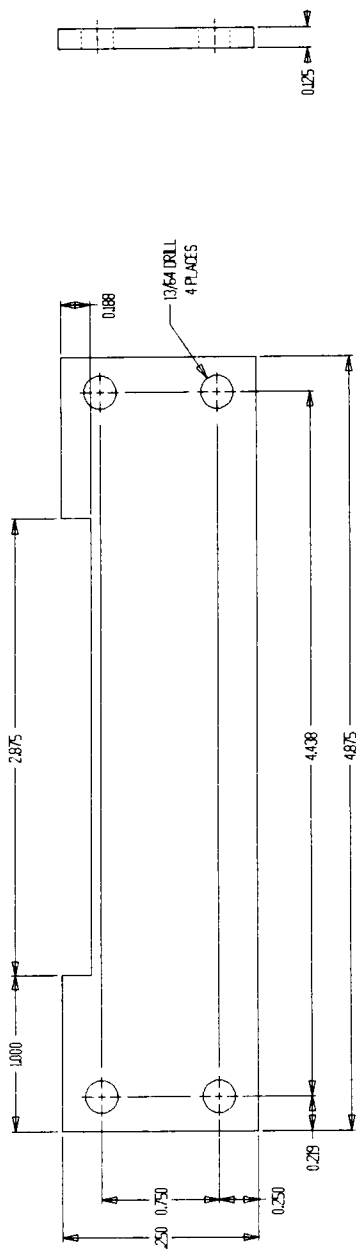
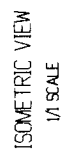


ISOMETRIC VIEW



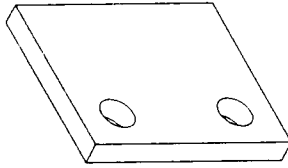
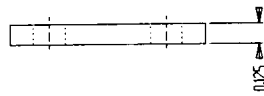
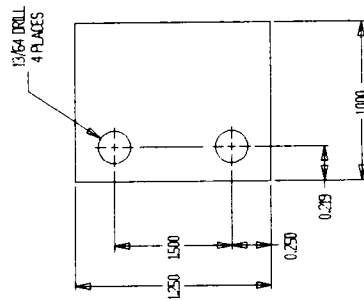
SCALE	2:1	DIMENSIONS IN INCHES	PART #	UT
MATERIAL	FREE MACHINING	TOLERANCES UNLESS NOTED	208	
ALUMINUM		LINEAR +/-	TITLE	BELT CONNECTOR
		ANGLES +/-		
OTHER NOTES		RADI UNLESS NOTED	DESIGNER	BOC 03/27/91
		EDGE/CORNER BREAKS	CHECKED	
IBMCAD FILE	CONNECT.MCH	OUTSIDE MAX	APPROVED	
		INSIDE MAX		

QUANTITY: 2



SCALE	2:1	DIMENSIONS IN INCHES		PART #	UT
MATERIAL	FREE MACHINING	TOLERANCES	UNLESS NOTED		
ALUMINUM		LINEAR	+/- .010	TITLE BELT CONNECTOR TIE	
		ANGLES	+/- N/A		
OTHER NOTES		RADIUS	UNLESS NOTED N/A	DESIGNER	BDC 03/27/91
		EDGE/CORNER BREAKS	OUTSIDE MAX N/A	CHECKED	
BMCAD FILE	CONPLAT.MCH		INSIDE MAX N/A	APPROVED	

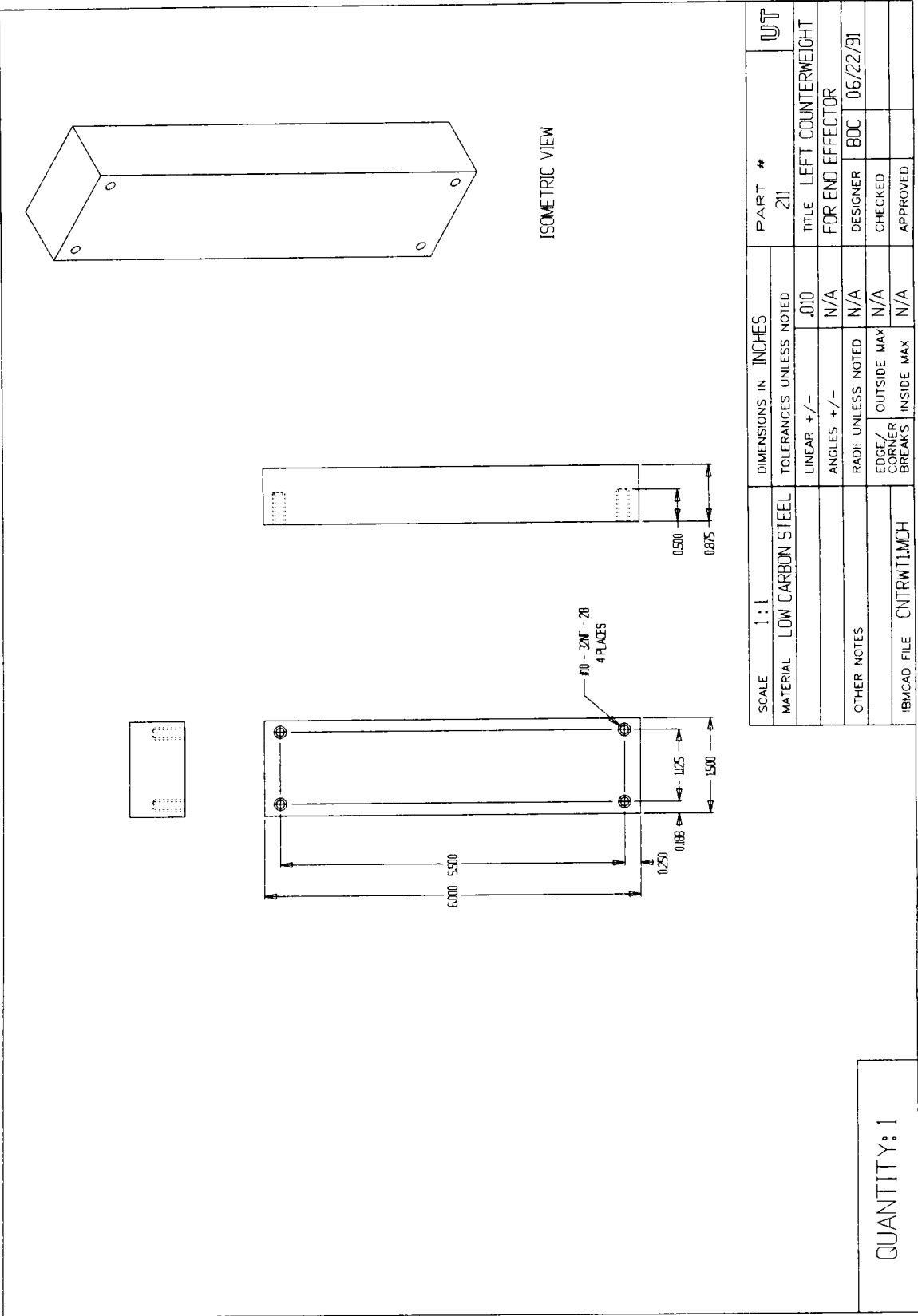
QUANTITY: 1

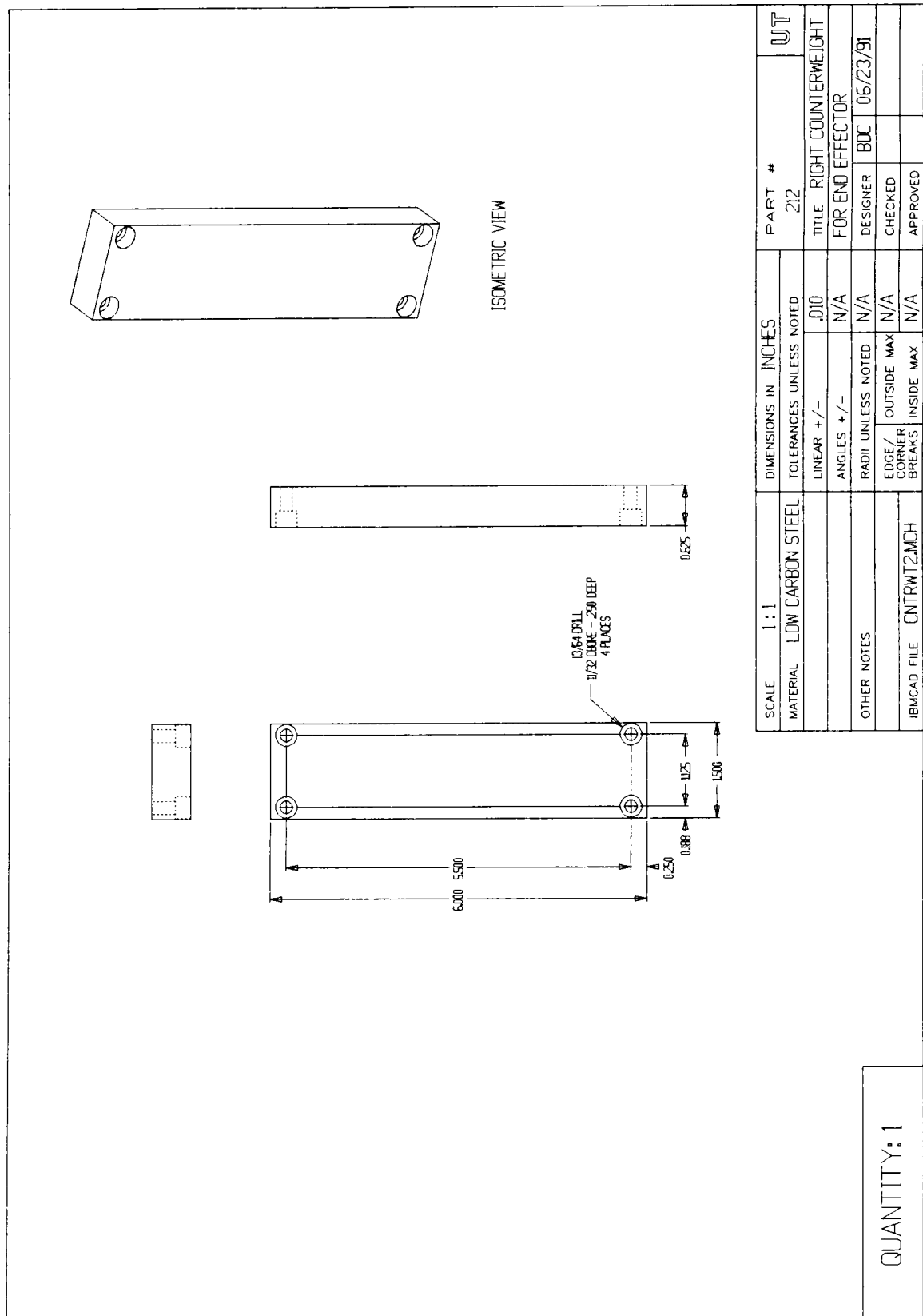


ISOMETRIC VIEW

SCALE	2:1	DIMENSIONS IN INCHES	PART #	UT
MATERIAL	FREE MACHINING	TOLERANCES UNLESS NOTED	210	
ALUMINUM		LINEAR +/-	TITLE	BELT CONNECTOR TIE
		ANGLES +/-	SPACER	
OTHER NOTES		RADI UNLESS NOTED	DESIGNER	BDC 07/05/91
		EDGE/CORNER BREAKS	CHECKED	
IBMCAD FILE	CNNSPCRMCH	OUTSIDE MAX	APPROVED	
		INSIDE MAX		

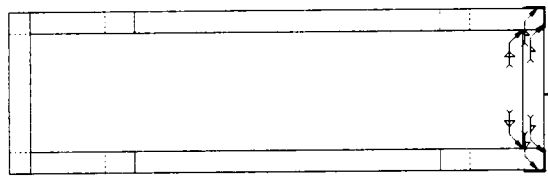
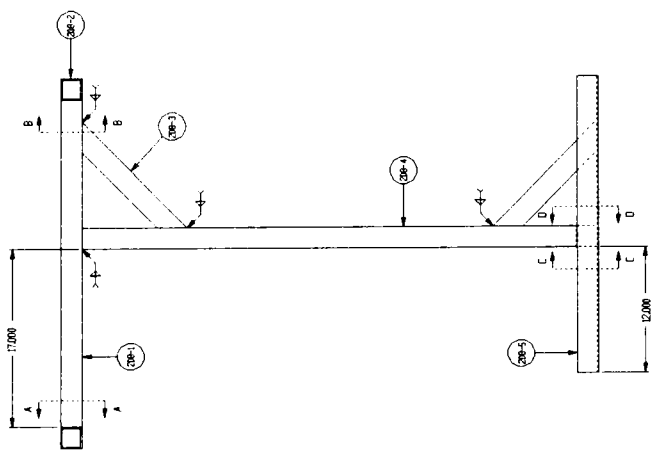
QUANTITY: 2



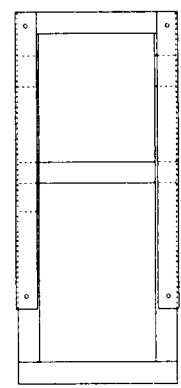
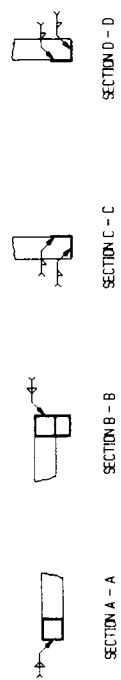
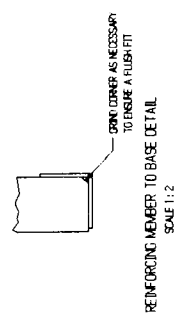


SCALE	1:1	DIMENSIONS IN INCHES	PART #	UT
MATERIAL	LOW CARBON STEEL	TOLERANCES UNLESS NOTED	212	
		LINEAR +/-		TITLE RIGHT COUNTERWEIGHT
		ANGLES +/-		FOR END EFFECTOR
OTHER NOTES		RADII UNLESS NOTED		DESIGNER BDC
		EDGE/CORNER BREAKS		CHECKED
				APPROVED
IBMCAD FILE	CNTRWT2.MCH			

QUANTITY: 1

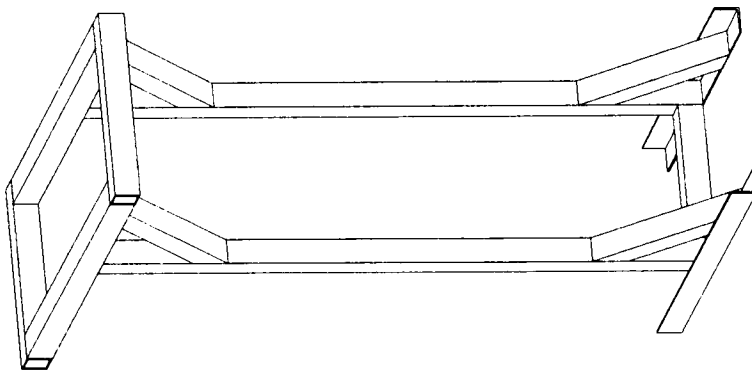


PART #	NAME	QTY
213-1	UPPER MEMBER	2
213-2	UPPER TIE	2
213-3	REINFORCING MEMBER	4
213-4	VERTICAL SUPPORT	2
213-5	BASE	2
213-6	LOWER TIE	1



SCALE	1:5	DIMENSIONS IN INCHES	PART #	UT
MATERIAL	N/A	TOLERANCES UNLESS NOTED:	213	
		LINEAR +/-	.020	
		ANGLES +/-	N/A	
OTHER NOTES		RADI UNLESS NOTED	N/A	
		EDGE CORNER BREAKS	OUTSIDE MAX	
			INSIDE MAX	
IBMCAD FILE	FRAME2.ASM		DESIGNER	BOC
			CHECKED	
			APPROVED	
				04/03/91

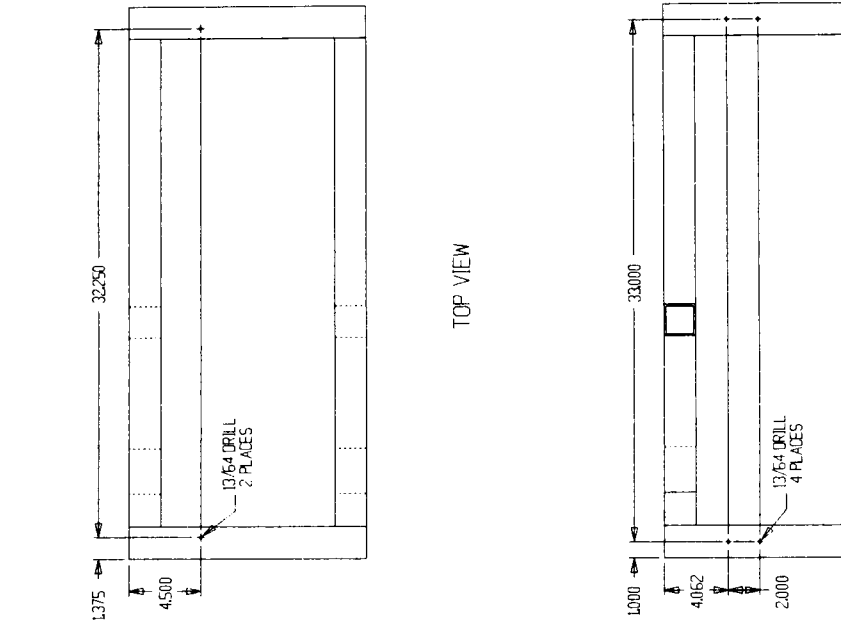
QUANTITY: 1



ISOMETRIC VIEW

SCALE	1:5	DIMENSIONS IN INCHES	PART #	UT
MATERIAL	N/A	TOLERANCES UNLESS NOTED	213	
		LINEAR +/-	TITLE FRAME, PHASE II	
		ANGLES +/-		
OTHER NOTES		RADI UNLESS NOTED	DESIGNER	BOC
		EDGE/CORNER BREAKS	CHECKED	
ENCAD FILE	FRAME2.ISO	OUTSIDE MAX	APPROVED	
		INSIDE MAX		04/03/91

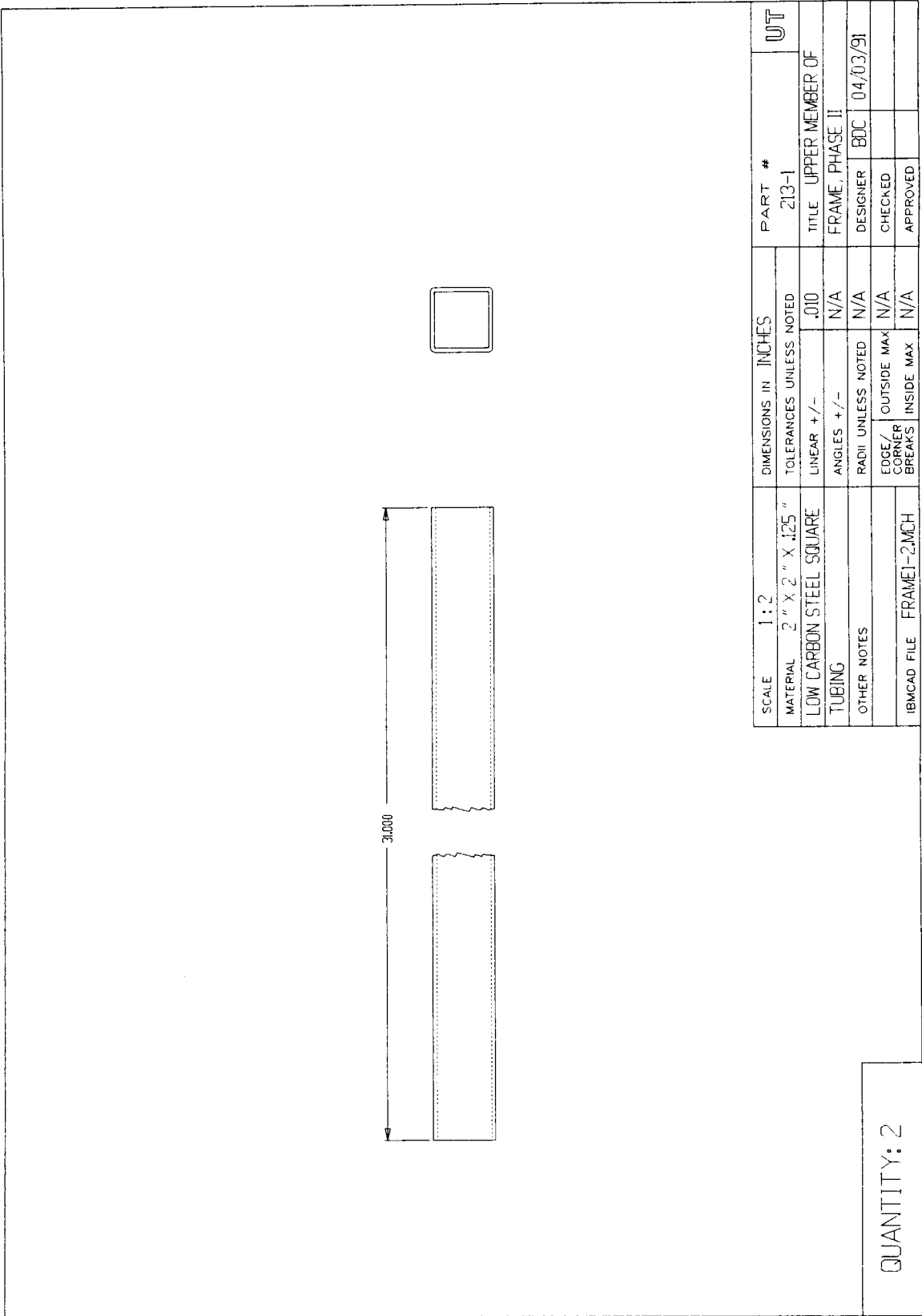
QUANTITY: 1



BOTTOM VIEW

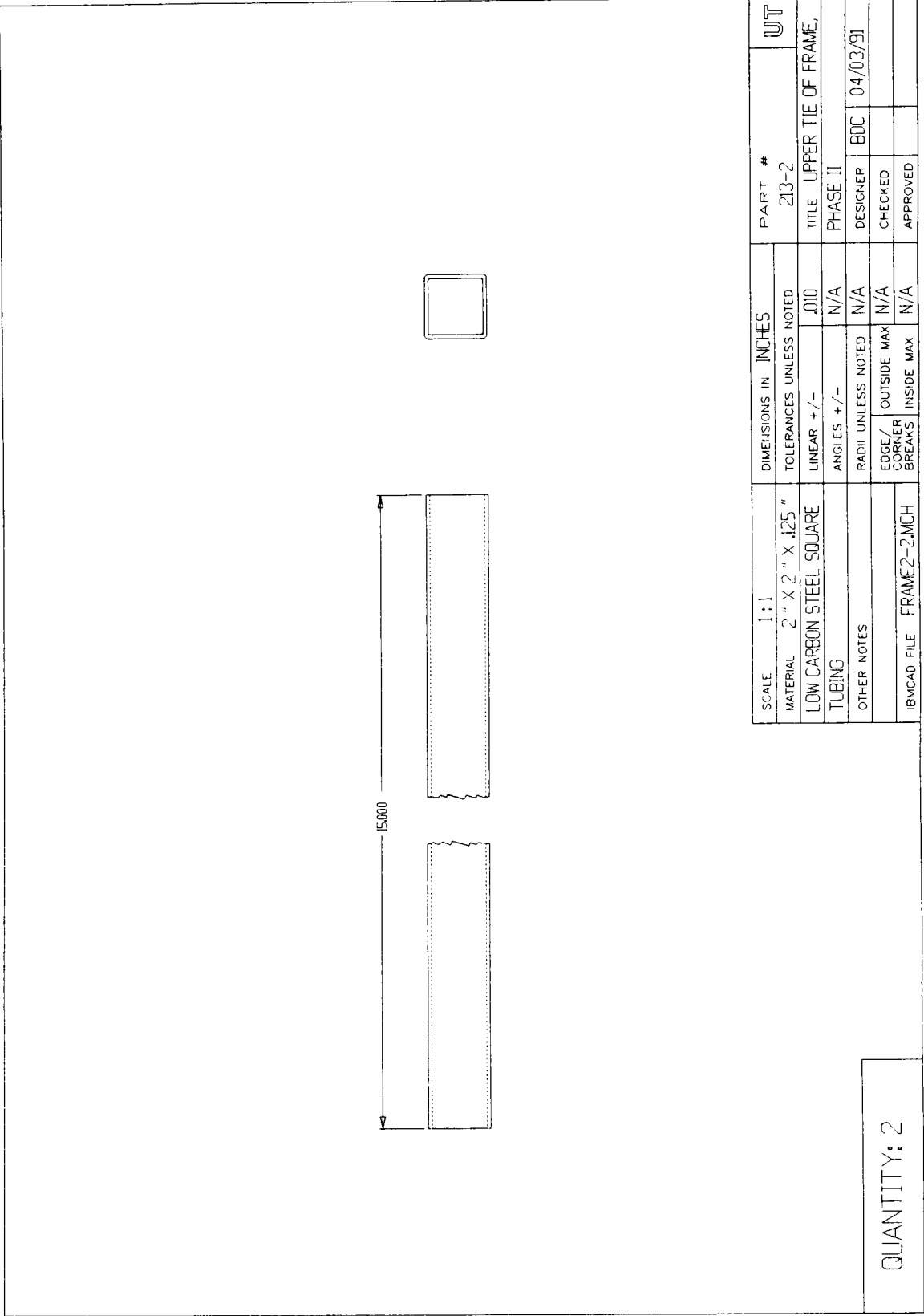
QUANTITY: 1

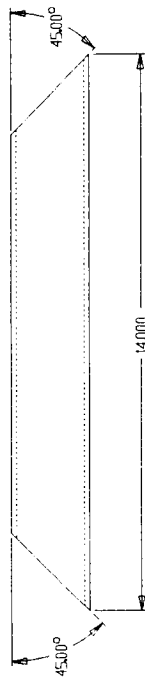
SCALE		DIMENSIONS IN INCHES		PART #	UT
MATERIAL		TOLERANCES UNLESS NOTED			
1:5		.010		213	LOCATION OF MOUNTING HOLES, PHASE II
N/A		LINEAR +/-			
		ANGLES +/-			
OTHER NOTES		RADIUS UNLESS NOTED		DESIGNER	BDC
Holes are		N/A		CHECKED	
Drilled to center		EDGE / OUTSIDE MAX			
UNLESS NOTED		CORNER BREAKS			
IBMCAD FILE		INSIDE MAX		APPROVED	
FEMAPL 2.MCH					



QUANTITY: 2

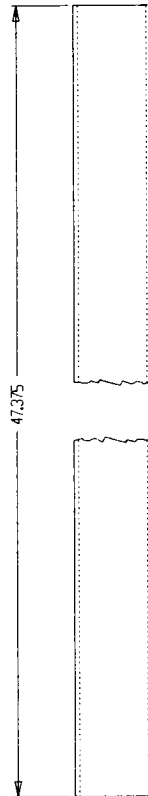
SCALE	1:2	DIMENSIONS IN INCHES		PART #	UT
MATERIAL	2" X 2" X .125"	TOLERANCES UNLESS NOTED		213-1	
LOW CARBON STEEL SQUARE		LINEAR +/-	.010	TITLE UPPER MEMBER OF	
TUBING		ANGLES +/-	N/A	FRAME, PHASE II	
OTHER NOTES		RADII UNLESS NOTED	N/A	DESIGNER	BUC 04/03/91
		EDGE / CORNER BREAKS	N/A	CHECKED	
IBMCAD FILE	FRAME1-2.MCH	INSIDE MAX	N/A	APPROVED	





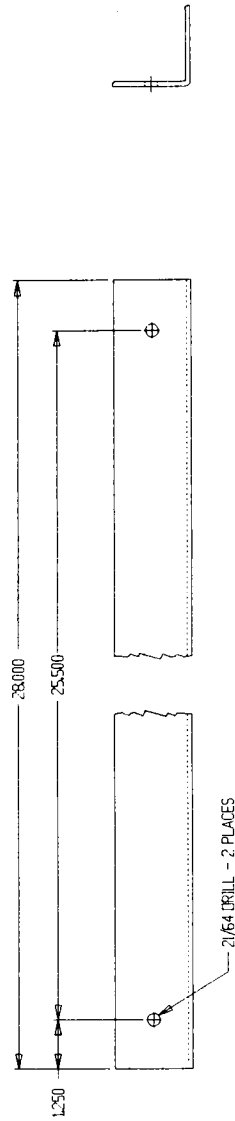
QUANTITY: 4

SCALE	1:2	DIMENSIONS IN INCHES	PART #	UT
MATERIAL	2" X 2" X .125"	TOLERANCES UNLESS NOTED	213-3	
LOW CARBON STEEL SQUARE TUBING		LINEAR +/-	TITLE REINFORCING MEMBER	
OTHER NOTES		ANGLES +/-	OF FRAME, PHASE II	
		RADI UNLESS NOTED	DESIGNER BDC	04/03/91
		EDGE/CORNER BREAKS	CHECKED	
		OUTSIDE MAX	APPROVED	
		INSIDE MAX		
IBMCAD FILE	FRAME3-2.MCH			



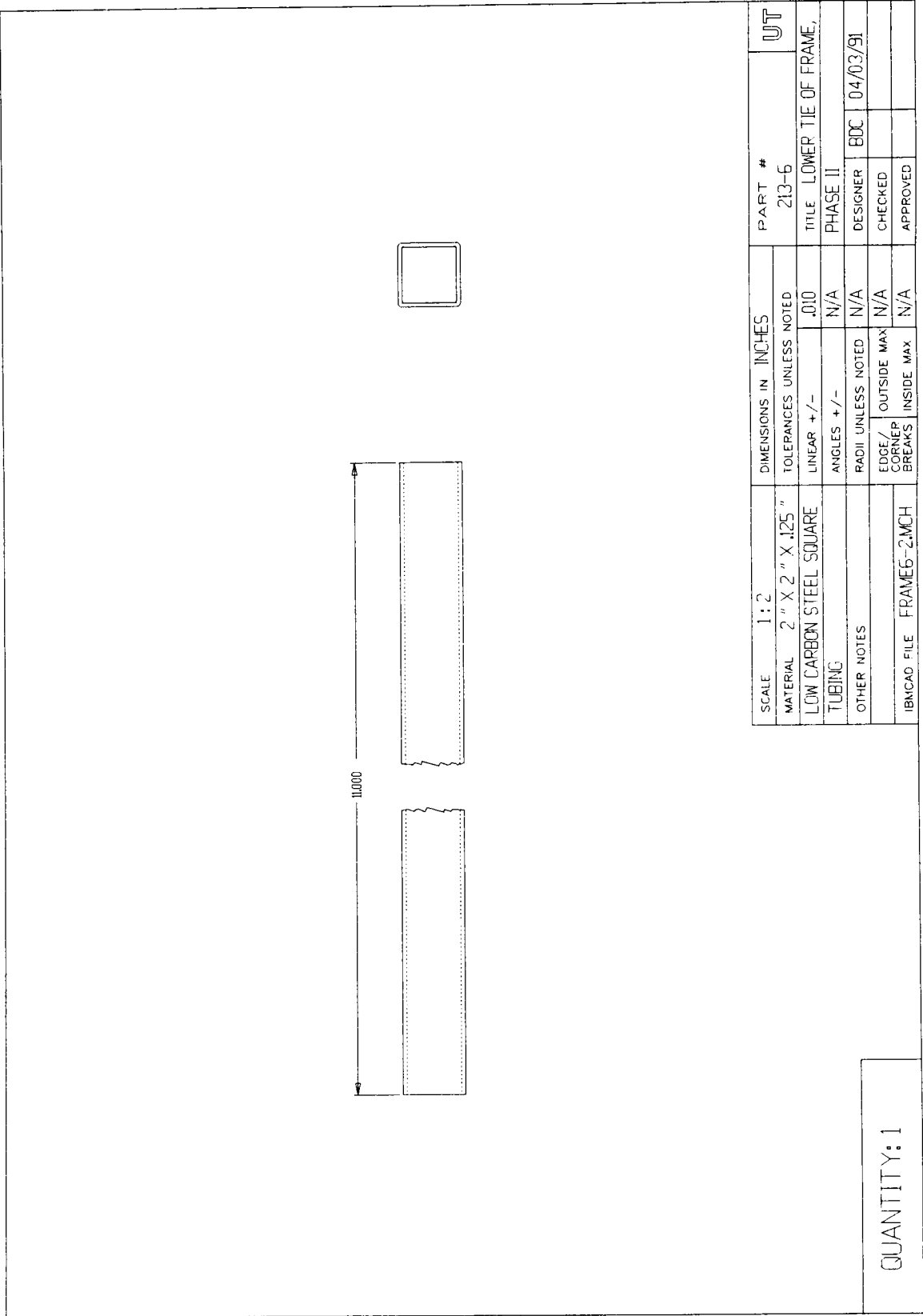
QUANTITY: 2

SCALE	1:2	DIMENSIONS IN INCHES		PART #	UT
MATERIAL	2" X 2" X .125"	TOLERANCES UNLESS NOTED		213-4	
LOW CARBON STEEL SQUARE		LINEAR +/-	.010	TITLE VERTICAL SUPPORT OF	
TUBING		ANGLES +/-	N/A	FRAME, PHASE II	
OTHER NOTES		RADI UNLESS NOTED	N/A	DESIGNER	BDC 04/03/91
		EDGE/CORNER BREAKS	OUTSIDE MAX	CHECKED	
IBMCAD FILE	FRAME4-2.MCH		INSIDE MAX	APPROVED	

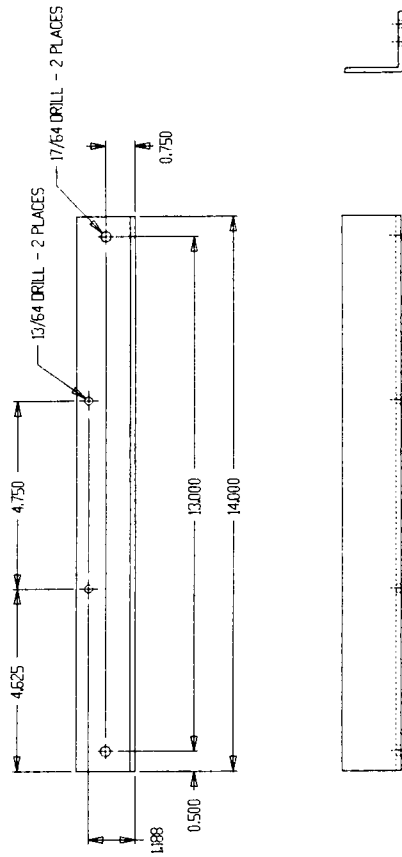


SCALE	1:2	DIMENSIONS IN INCHES		PART #	UT
MATERIAL	2" X 2" X .125"	TOLERANCES UNLESS NOTED		213-5	
LOW CARBON STEEL ANGLE		LINEAR +/-	.010	TITLE	BASE OF FRAME,
		ANGLES +/-	N/A	PHASE II	
OTHER NOTES		RADI UNLESS NOTED	N/A	DESIGNER	BDC 04/03/91
		EDGE/ CORNER BREAK'S	N/A	CHECKED	
IBMCAD FILE	FRAMES-2.MCH	INSIDE MAX	N/A	APPROVED	

QUANTITY: 2

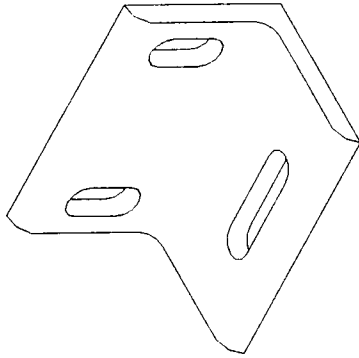
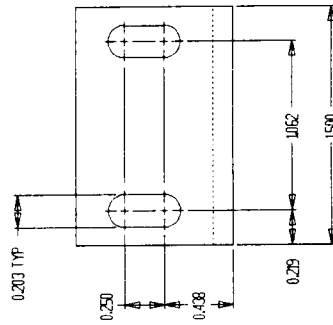
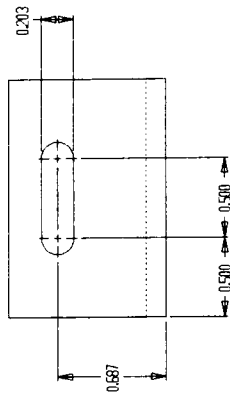


QUANTITY: 1

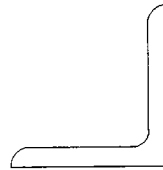


QUANTITY: 2

SCALE	1:2	DIMENSIONS IN INCHES		PART #	UT
MATERIAL	1.5" X 1.5" X .125"	TOLERANCES UNLESS NOTED		214	
LOW CARBON STEEL ANGLE		LINEAR +/-	.010	TITLE VACUUM PUMP SHELF	
		ANGLES +/-	N/A		
OTHER NOTES		RADI UNLESS NOTED	N/A	DESIGNER	BDC 07/07/91
		EDGE/CORNER BREAKS	N/A	CHECKED	
IBMCAD FILE PMPSHLF.MCH		INSIDE MAX	N/A	APPROVED	

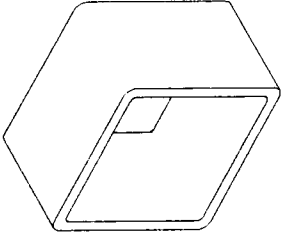
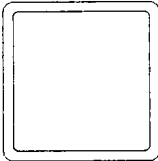


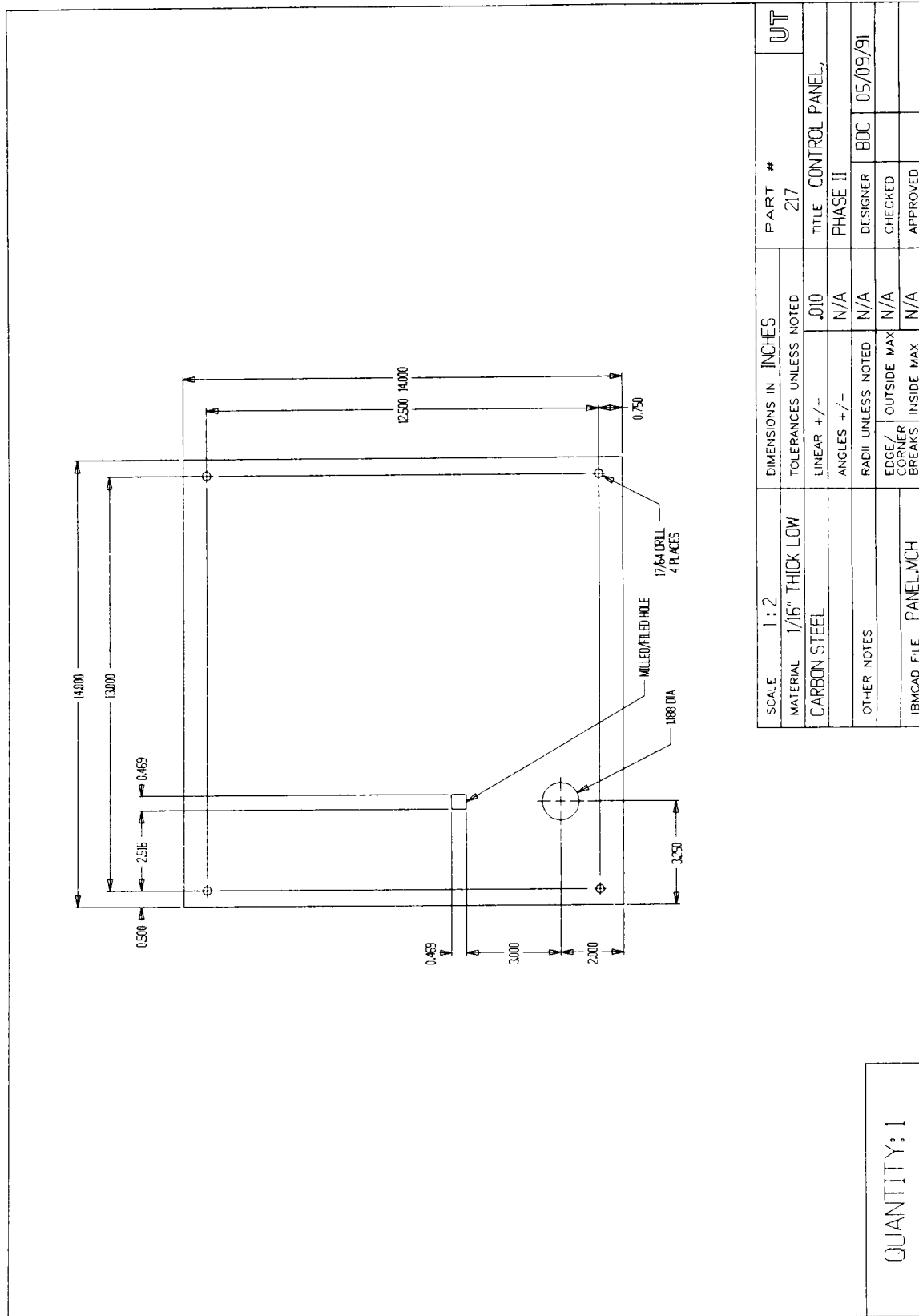
ISOMETRIC VIEW

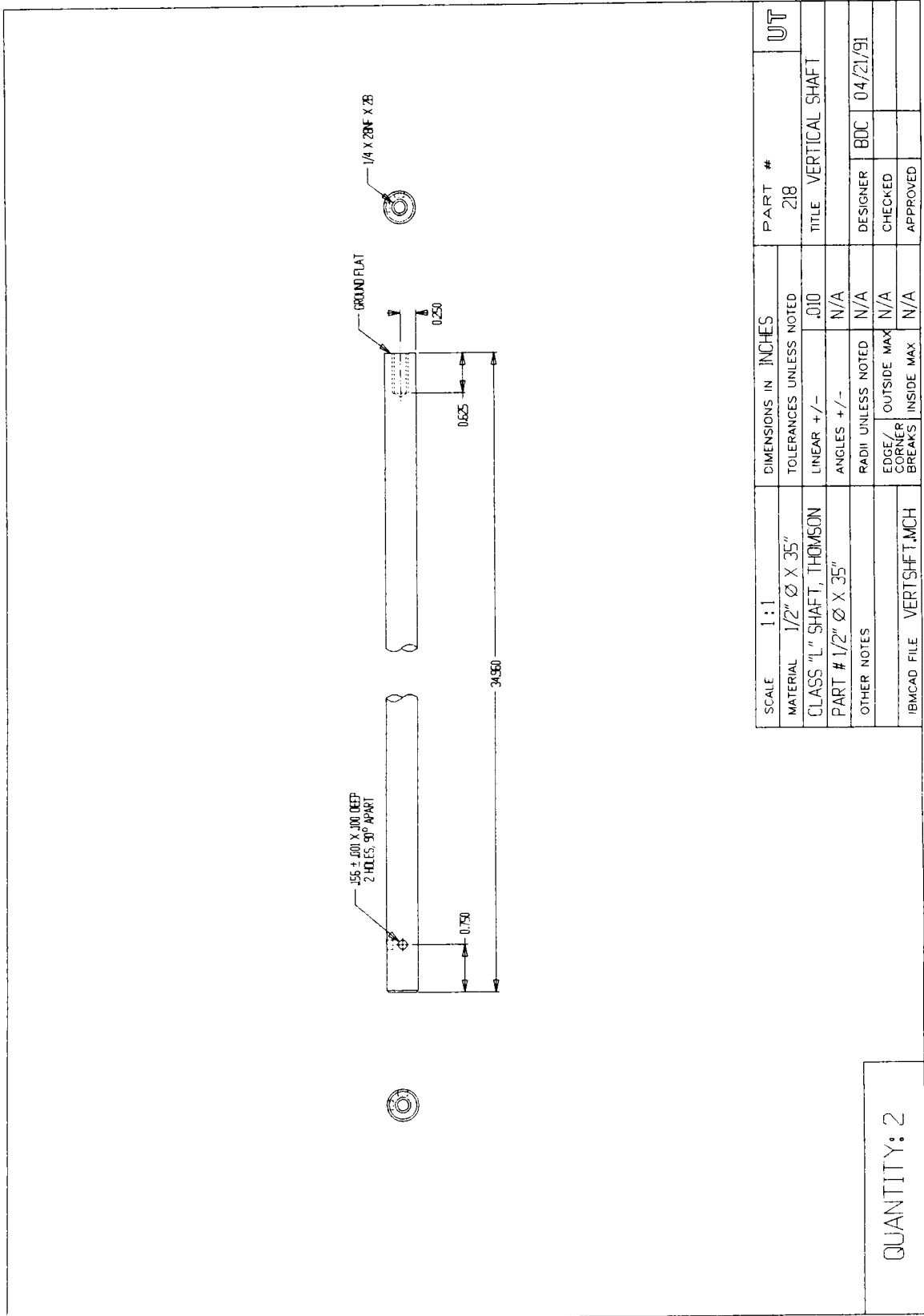


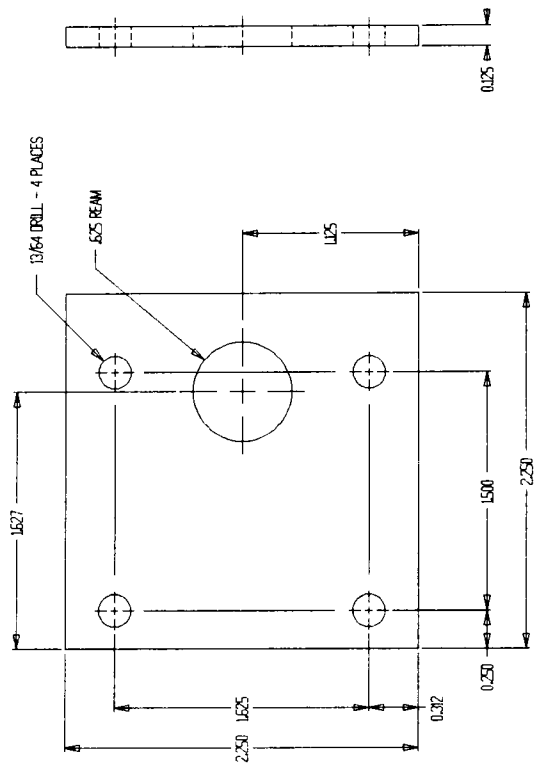
SCALE	2:1	DIMENSIONS IN INCHES	PART #	UT
MATERIAL	1" X 1" X .125"	TOLERANCES UNLESS NOTED	215	
LOW CARBON STEEL	ANGLE	LINEAR +/-	TITLE	RODLESS AIR CYLINDER
		ANGLES +/-		MOUNTING BRACKET
OTHER NOTES		RADI UNLESS NOTED	DESIGNER	BDC
		EDGE/CORNER BREAKS	CHECKED	
			APPROVED	
IBMCAD FILE	AIRBRCK.MCH			

QUANTITY: 2

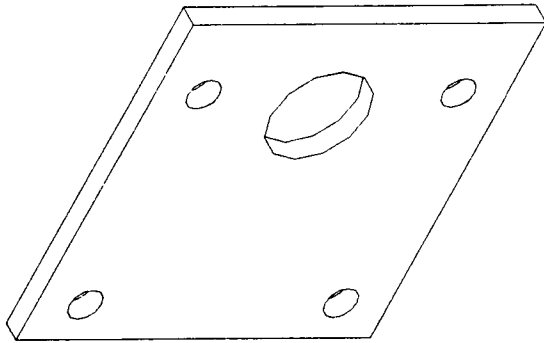
 ISOMETRIC VIEW						QUANTITY: 2	
SCALE	1:1	DIMENSIONS IN INCHES		PART #	UT		
MATERIAL	2" X 2" X .125"	TOLERANCES UNLESS NOTED		215			
LOW CARBON STEEL SQUARE		LINEAR +/-	.010	TITLE FRAME SPACER			
TUBING		ANGLES +/-	N/A				
OTHER NOTES		RADII UNLESS NOTED	N/A	DESIGNER	BOC	06/26/91	
		EDGE/CORNER BREAKS	N/A	CHECKED			
IBMCAD FILE	FRMSPCR.MCH	OUTSIDE MAX	N/A	APPROVED			
		INSIDE MAX	N/A				





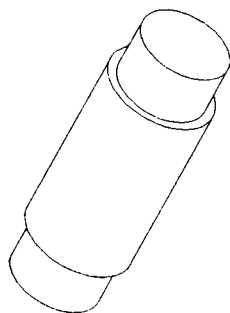
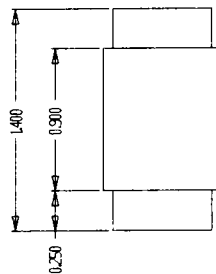


ISOMETRIC VIEW

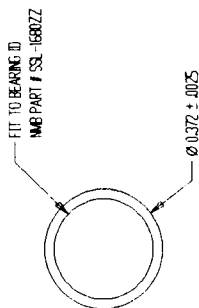


SCALE	2:1	DIMENSIONS IN INCHES	PART #	UT
MATERIAL	FREE MACHINING	TOLERANCES UNLESS NOTED	219	
ALUMINUM		LINEAR +/-		
		ANGLES +/-		
		RADI UNLESS NOTED		
OTHER NOTES		EDGE/CORNER BREAKS		
IBMCAD FILE	BRORETNMCH	OUTSIDE MAX	DESIGNER	BDC 05/13/91
		INSIDE MAX	CHECKED	
			APPROVED	

QUANTITY: 2

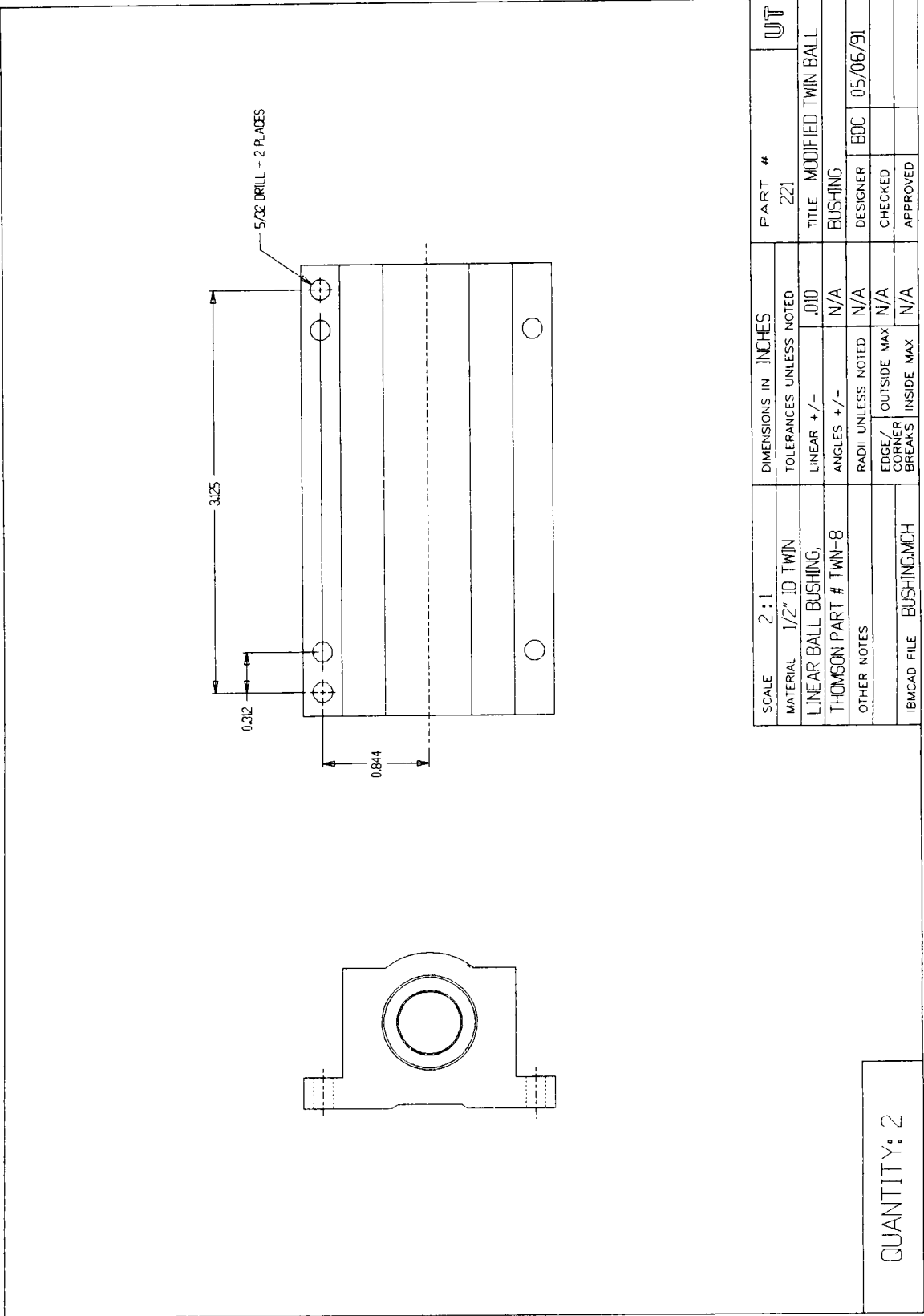


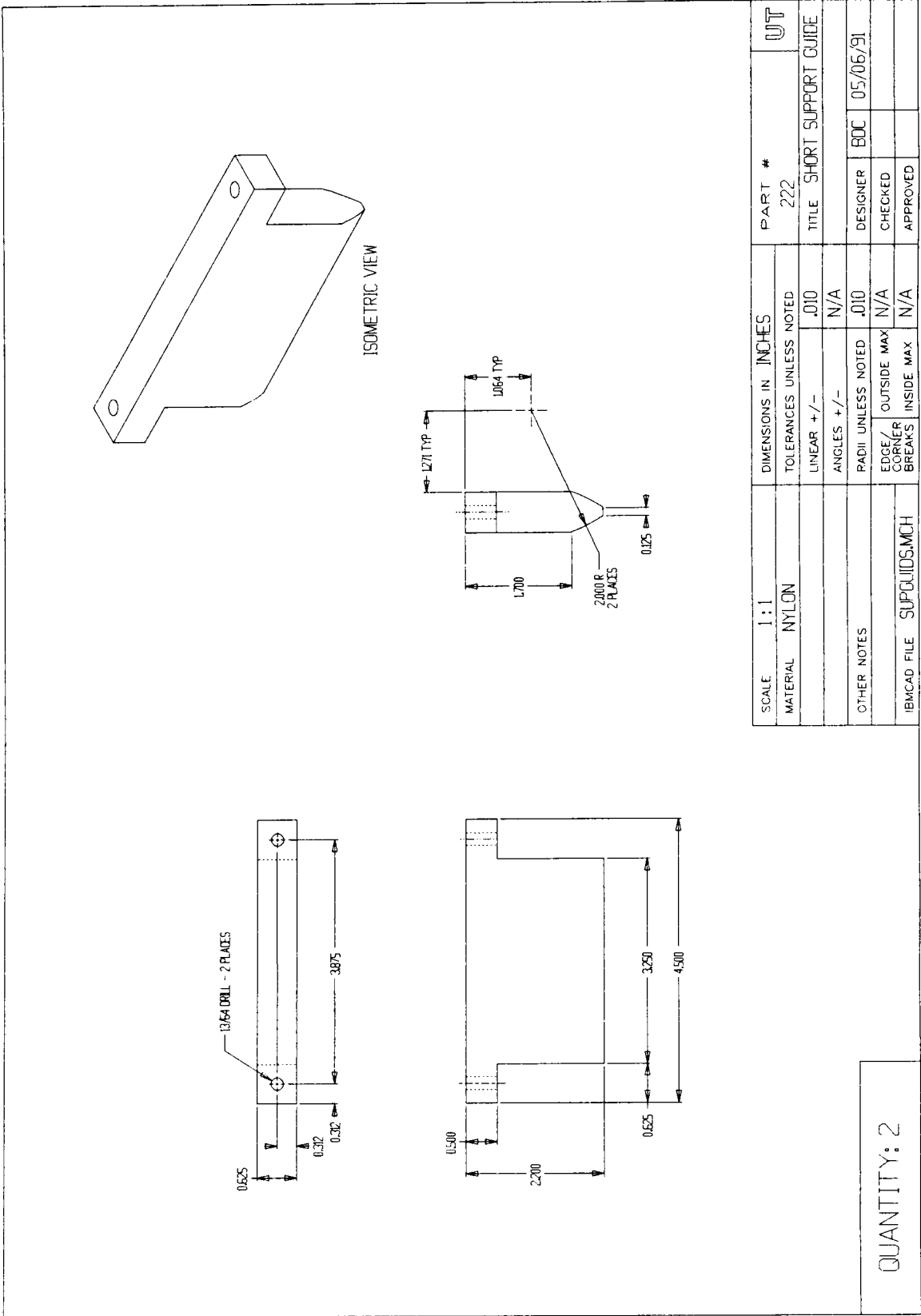
ISOMETRIC VIEW
NOT TO SCALE

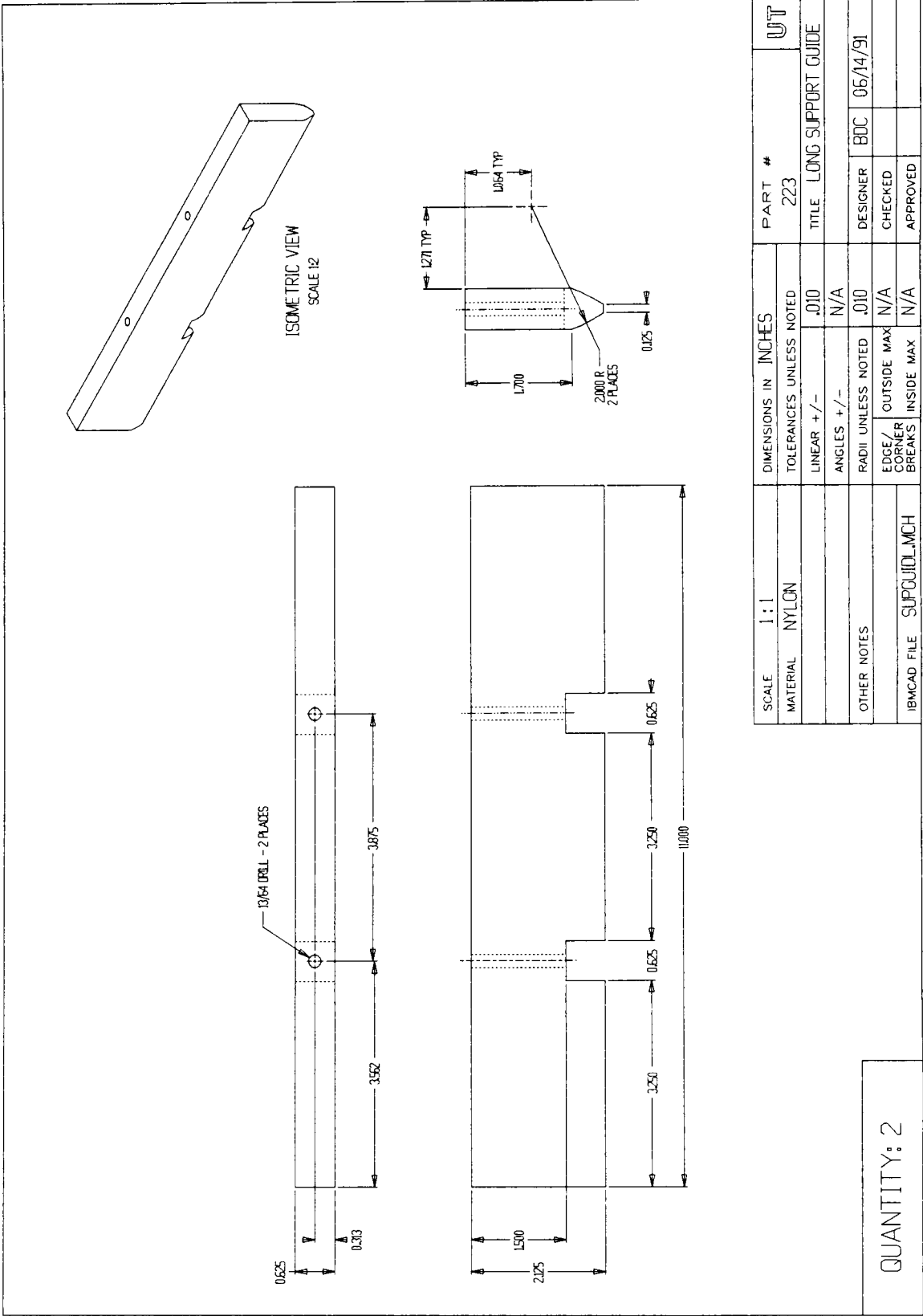


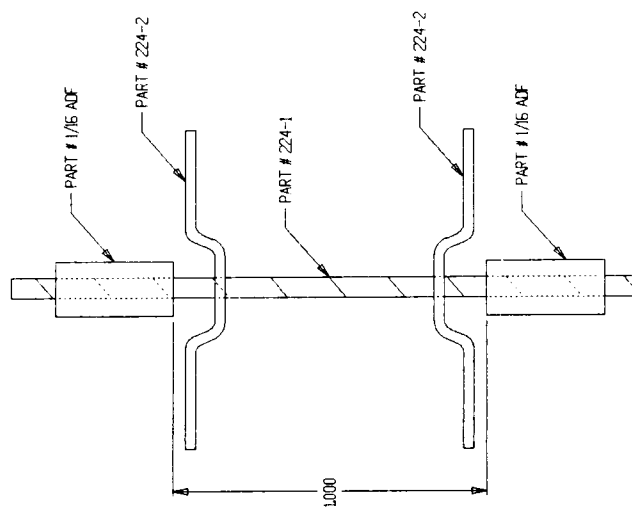
QUANTITY: 1

SCALE	1:1	DIMENSIONS IN INCHES	TOLERANCES UNLESS NOTED	PART #	UT
MATERIAL	LOW CARBON STEEL	LINEAR +/—	.010	220	
		ANGLES +/—	N/A	TITLE	PULLEY SHAFT
		RADI UNLESS NOTED	N/A	DESIGNER	BDC 05/13/91
OTHER NOTES		EDGE/CORNER	OUTSIDE MAX	CHECKED	
IBMCAD FILE	PULSHT.MCH	BREAKS	INSIDE MAX	APPROVED	









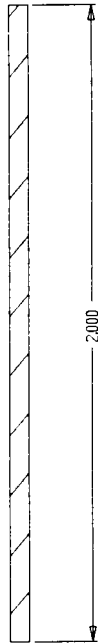
ISOMETRIC VIEW

ASSEMBLY NOTES

1. SLIDE PART # 224-2 ONTO
PART # 224-1 AS SHOWN
2. SLIDE PART # 1/16 ADF ONTO
PART # 224-1 AS SHOWN
3. CRIMP PART # 1/16 ADF
ONTO PART # 224-1

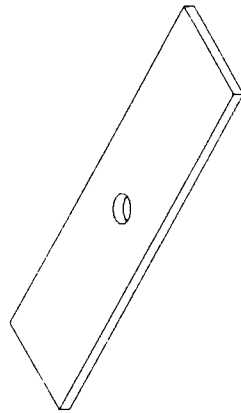
QUANTITY: 4

SCALE	4 : 1	DIMENSIONS IN INCHES		PART # 224	UT
MATERIAL	N/A	TOLERANCES UNLESS NOTED			
		LINEAR +/-	.010	TITLE SUPPORT PLATE	
		ANGLES +/-	N/A	HANGER	
OTHER NOTES		RADI UNLESS NOTED	N/A	DESIGNER	BDC 05/26/91
		EDGE / CORNER BREAKS	OUTSIDE MAX	CHECKED	
RECORD FILE	HANGER ASM		INSIDE MAX	APPROVED	

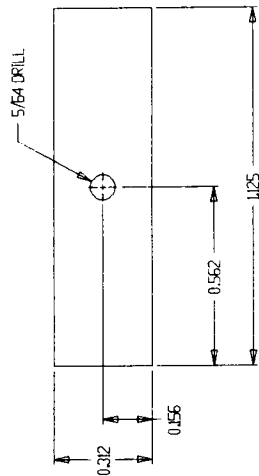


QUANTITY: 4

SCALE	4:1	DIMENSIONS IN INCHES	PART #	UT
MATERIAL	1/16" DIA STEEL	TOLERANCES UNLESS NOTED	224-1	
CABLE, VOLUNTEER WIRE ROPE		LINEAR +/-	TITLE	SUPPORT PLATE
PART # 1/16 GAC		ANGLES +/-	HANGER CABLE	
OTHER NOTES		RADI UNLESS NOTED	DESIGNER	BDC
		EDGE / CORNER BREAKS	CHECKED	06/28/91
			APPROVED	

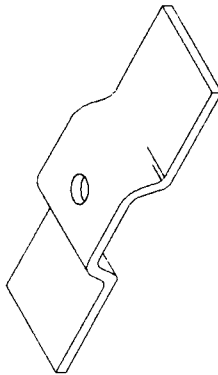
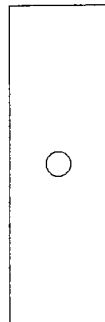


ISOMETRIC VIEW

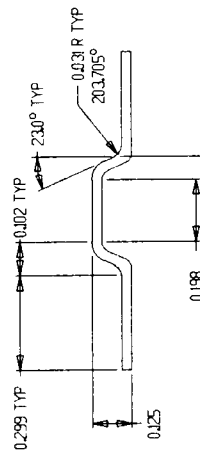


SCALE	4 : 1	DIMENSIONS IN INCHES			PART #	UT
MATERIAL	1/32" THICK LOW CARBON STEEL	TOLERANCES UNLESS NOTED			224-2	
		LINEAR +/-	.010	TITLE	SUPPORT PLATE	
		ANGLES +/-	N/A		HANGER STOP, MCH DWG	
OTHER NOTES		RADI UNLESS NOTED	N/A	DESIGNER	BDC	06/26/91
		EDGE/ CORNER BREAKS	OUTSIDE MAX	N/A	CHECKED	
IBMCAD FILE	HANGER.MCH		INSIDE MAX	N/A	APPROVED	

QUANTITY: 8

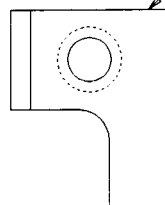
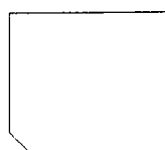
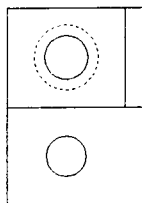
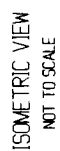


ISOMETRIC VIEW



SCALE	4:1	DIMENSIONS IN INCHES	PART #	UT
MATERIAL	1/32" THICK LOW	TOLERANCES UNLESS NOTED	224-2	
CARBON STEEL		LINEAR +/-	TITLE	SUPPORT PLATE
		ANGLES +/-	HANGER STOP, BND DWG	
OTHER NOTES		RADI UNLESS NOTED	DESIGNER	BDC 06/26/91
		EDGE/CORNER BREAKS	CHECKED	
IBMCAD FILE	HANGER.BND		APPROVED	

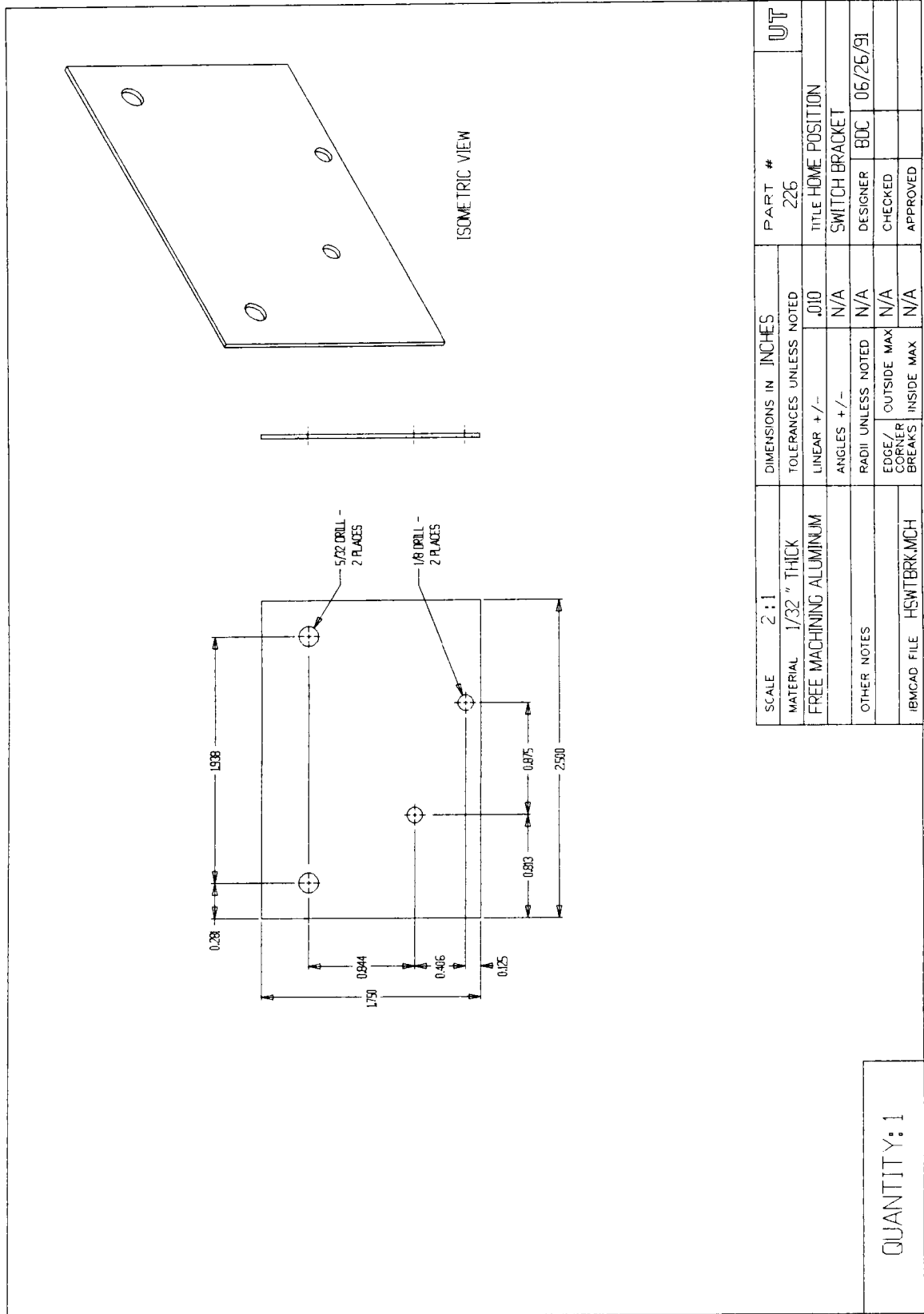
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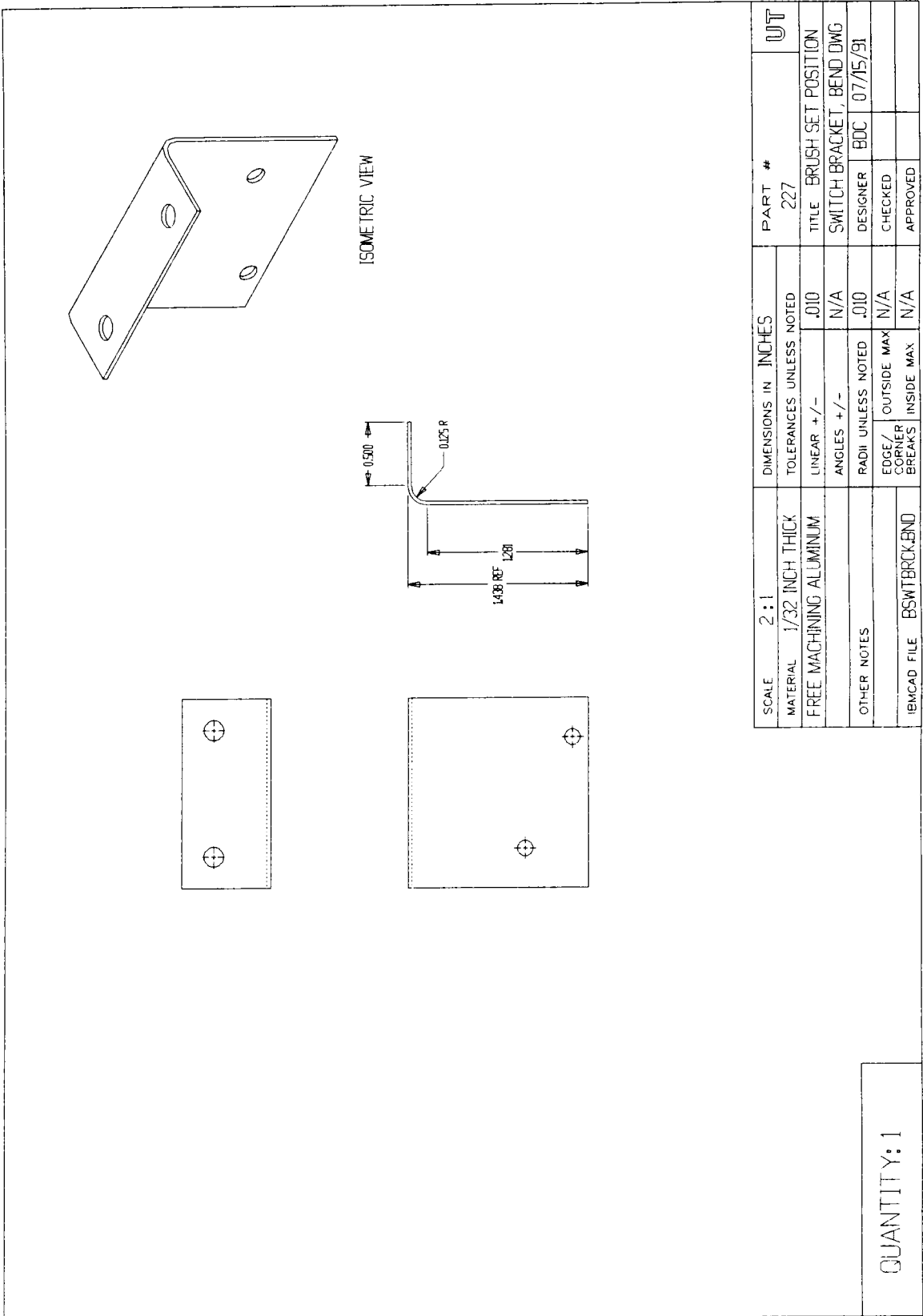


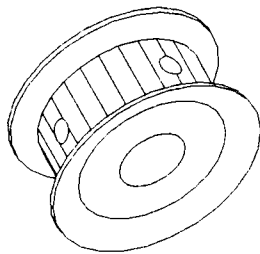
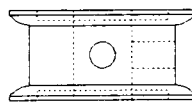
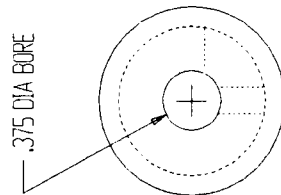
— WALL OFF MOUNTING FLANGE
FLUSH WITH FITTING EXTENSION

SCALE	2:1	DIMENSIONS IN INCHES		PART #	UT
MATERIAL	90° ELBOW, 1/8"	TOLERANCES UNLESS NOTED		225	
NPT, AIR PAC PART #		LINEAR +/-	.010	TITLE MODIFIED VACUUM	
2200PDE-2AP		ANGLES +/-	N/A	FITTING	
OTHER NOTES		RADII UNLESS NOTED	N/A	DESIGNER	BDC 06/26/91
		EDGE/CORNER	N/A	CHECKED	
RENCAD FILE BRASEIT MTD		BREKAS INSIDE MAX	N/A	APPROVED	

QUANTITY: 1

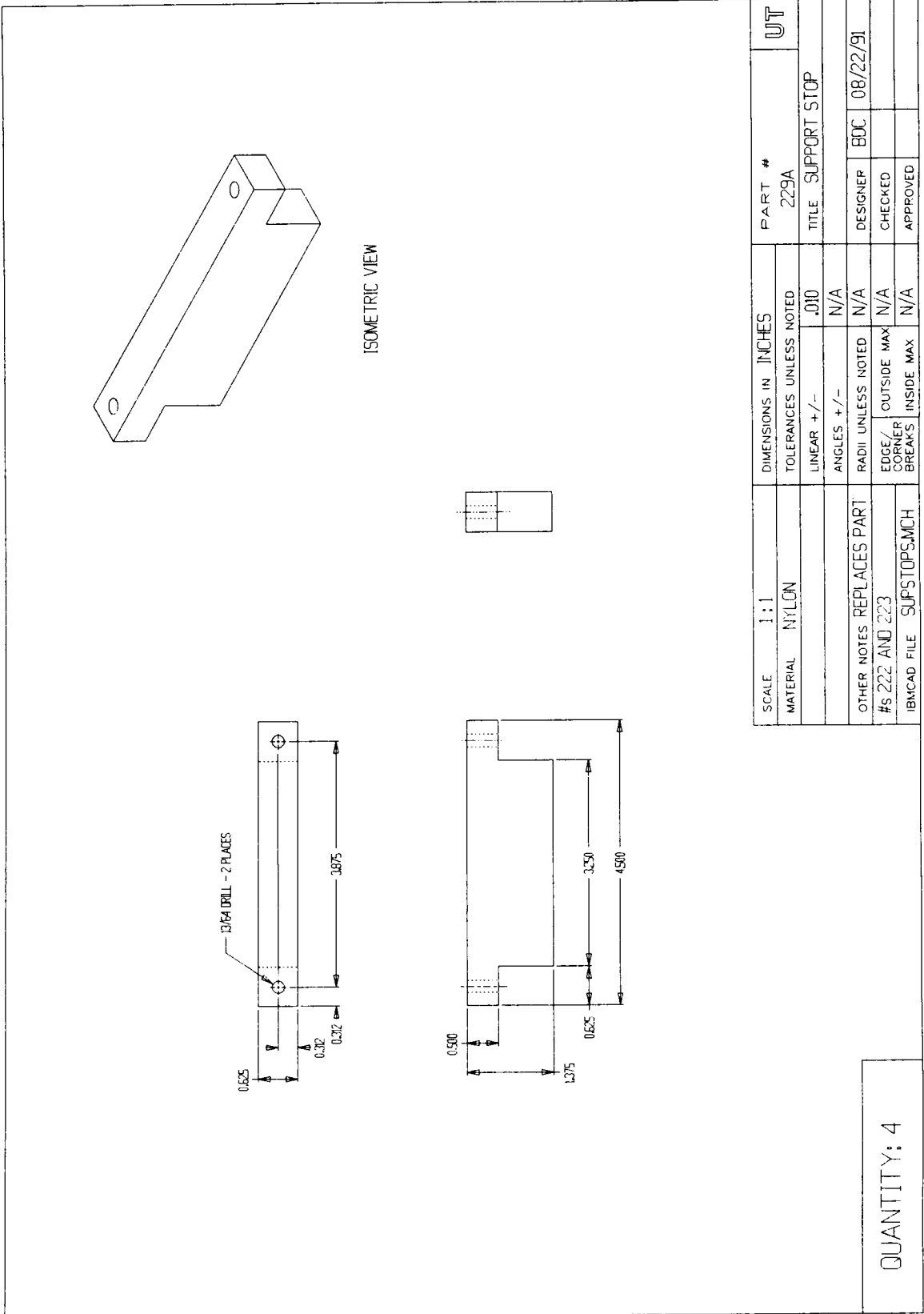






QUANTITY: 2

SCALE	2:1	DIMENSIONS IN INCHES	PART #	UT
MATERIAL	16 GROOVE ALUMIN.	TOLERANCES UNLESS NOTED	228	
TIMING PULLEY - STOCK		LINEAR +/-	TITLE	TIMING PULLEY -
DRIVE PART # 6A3-16H3710		ANGLES +/-	MCH DWG	
OTHER NOTES		RADI UNLESS NOTED	DESIGNER	BDC
		EDGE / CORNER BREAKS	CHECKED	07/24/91
		OUTSIDE MAX	APPROVED	
		INSIDE MAX		
IBMCAD FILE	PULLYALM.MCH			

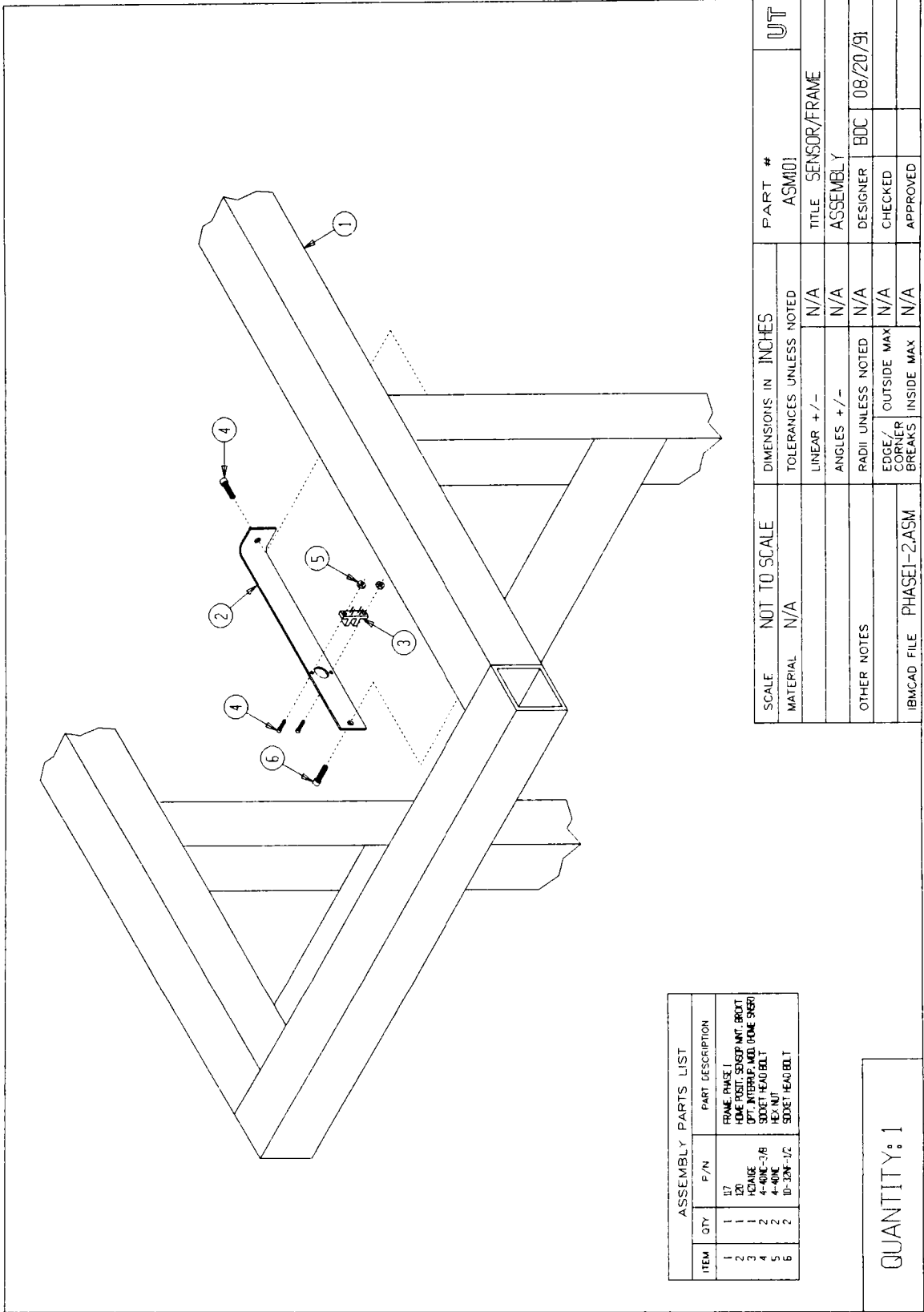


APPENDIX F

Assembly Procedures

ASSEMBLY PROCEDURES

The assembly of the Separator is documented in the form of assembly drawings, supplemented by assembly notes when necessary. Drawings beginning with part number ASM101 and ASM201 illustrate the assembly of the Punch device and Pick/Place device respectively. The sequence of the assembly should follow the drawings in the order presented. The assembly notes are presented after the assembly drawings.

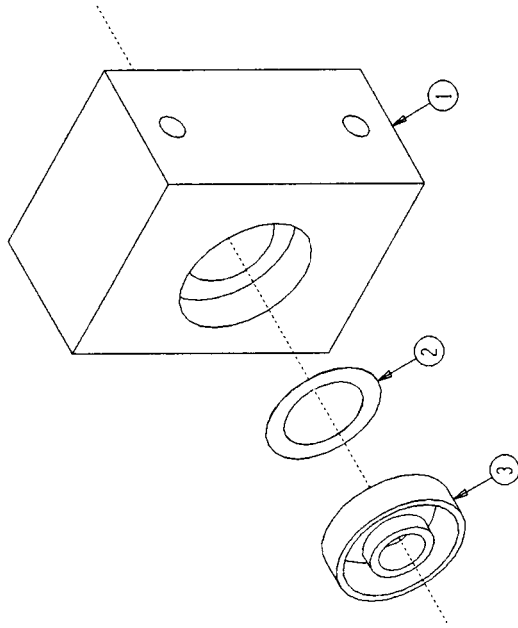


ASSEMBLY PARTS LIST		
ITEM	QTY	P/N
1	1	117
2	1	120
3	1	PC-100
4	2	4-40NC-3/8
5	2	4-40NC
6	2	10-32NC-1/2

SCALE		NOT TO SCALE		DIMENSIONS IN INCHES		PART #		UT		
MATERIAL		N/A		TOLERANCES UNLESS NOTED		ASMD1				
				LINEAR + / -		N/A				
				ANGLES + / -		N/A				
OTHER NOTES				RADI UNLESS NOTED		N/A		DESIGNER	BDC	08/20/91
				EDGE/ CORNER BREAKS		OUTSIDE MAX		N/A		CHECKED
						INSIDE MAX		N/A		APPROVED
IBMCAD FILE		PHASE1-2ASM								

QUANTITY: 1

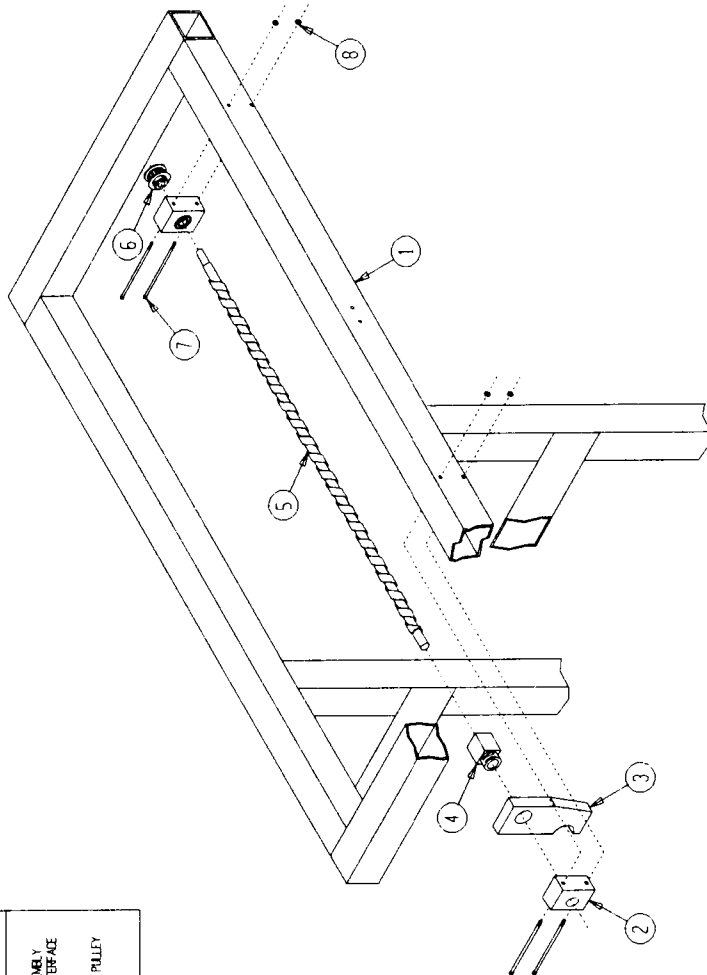
ASSEMBLY PARTS LIST			
ITEM	QTY	P/N	PART DESCRIPTION
1	1	108	DRIVE SCREW BRG. SUPP. BLOCK
2	AS REQD	388A-230	SHAFT BRG.
3	1	ED	AXIAL CONTACT BEARING



QUANTITY: 2

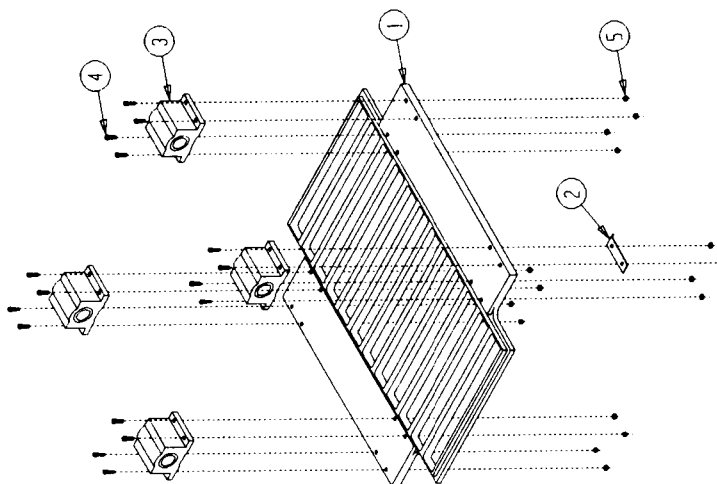
SCALE	NOT TO SCALE	DIMENSIONS IN INCHES		PART #	UT
		TOLERANCES UNLESS NOTED			
MATERIAL	N/A	LINEAR $\pm$ -	N/A	ASMI02	
		ANGLES $\pm$ -	N/A	TITLE BEARING BLOCK	
OTHER NOTES		RADI UNLESS NOTED	N/A	ASSEMBLY	
		EDGE/CORNER BREAKS	OUTSIDE MAX	DESIGNER BDC	08/20/91
			INSIDE MAX	CHECKED	
IBMCAD FILE	BRBLOCK.ASM			APPROVED	

ASSEMBLY PARTS LIST		
ITEM	QTY	PART DESCRIPTION
1	1	FRAME PHASE 1
2	2	BEARING BLOCK ASSEMBLY
3	1	BEARING/SHIM INTERFACE
4	1	BALL-BOLT
5	1	DRIVE SCREW
6	1	DRIVE SCREW TIMING PULLEY
7	4	1/4-28NF-33/4
8	4	1/4-28NF
		HEX NUT



SCALE	NOT TO SCALE	DIMENSIONS IN INCHES		PART #	UT
MATERIAL	N/A	TOLERANCES UNLESS NOTED	N/A	ASM03	
		LINEAR +/-	N/A	TITLE TRAY DRIVE/FRAME	
		ANGLES +/-	N/A	ASSEMBLY	
OTHER NOTES		RADII UNLESS NOTED	N/A	DESIGNER BDC	08/20/91
		EDGE/CORNER BREAKS	OUTSIDE MAX	CHECKED	
			INSIDE MAX	APPROVED	
IBMCAD FILE	PHASE1-3.ASM				

QUANTITY: 1

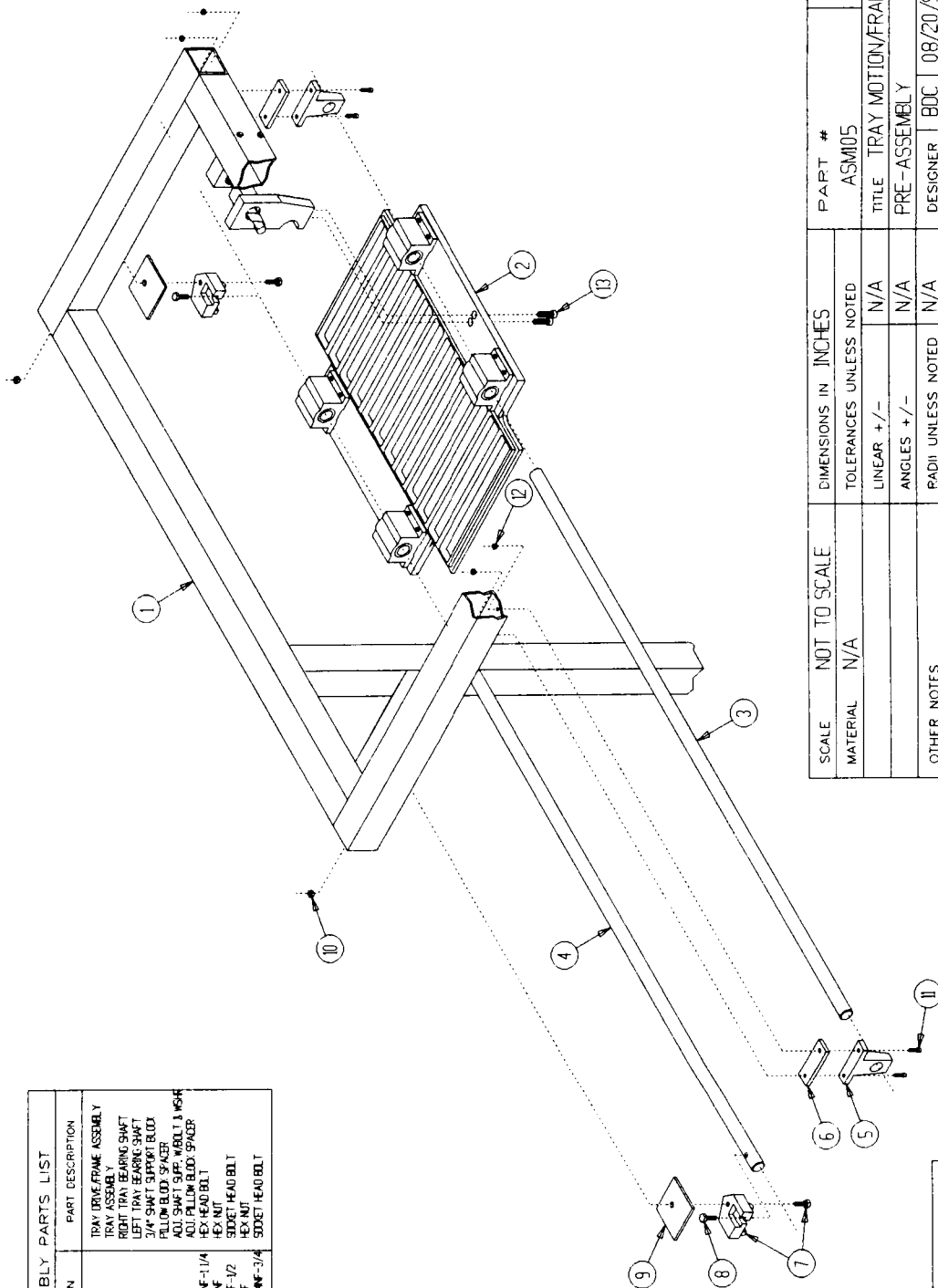


ASSEMBLY PARTS LIST			
ITEM	QTY	P/N	PART DESCRIPTION
1	1	102	800T-STE-UP TRAY
2	1	102	TRAY-HOLE POSITION INDICATOR
3	4	5982	3/4" LINEAR BALL BEARING
4	16	8-32NC-1	STEEL HEX NUT
5	16	8-32NC	HEX NUT

QUANTITY: 1

SCALE	NOT TO SCALE	DIMENSIONS IN INCHES		PART #	UT
		TOLERANCES UNLESS NOTED	NOTED		
MATERIAL	N/A	LINEAR +/-	N/A	ASMD04	
		ANGLES +/-	N/A	TITLE TRAY ASSEMBLY	
OTHER NOTES		RADII UNLESS NOTED	N/A	DESIGNER	BDC 08/20/91
		EDGE/CORNER BREAKS	OUTSIDE MAX	CHECKED	
			INSIDE MAX	APPROVED	
IBMCAD FILE	TRAY.ASM				

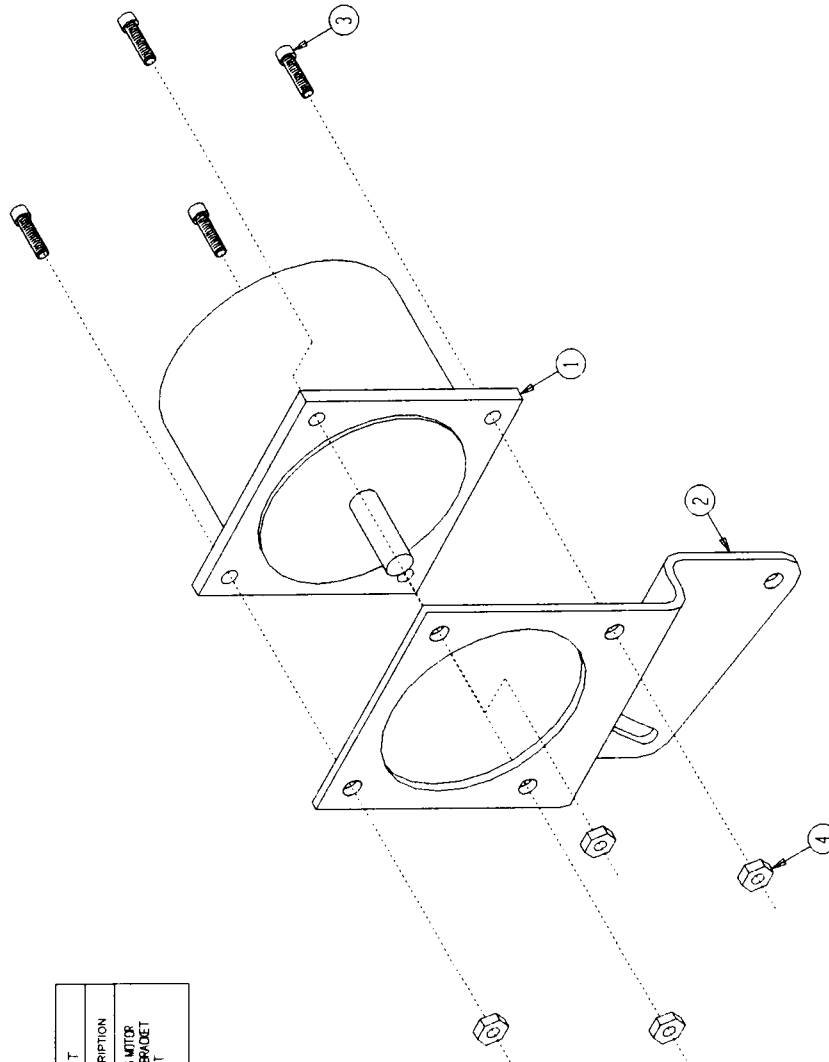
ASSEMBLY PARTS LIST			
ITEM	QTY	F/N	PART DESCRIPTION
1	1	ASM03	TRAY DRIVE FRAME ASSEMBLY
2	1	ASM04	TRAY ASSEMBLY
3	1	104	RIGHT TRAY BEARING SHAFT
4	1	105	LEFT TRAY BEARING SHAFT
5	2	106	2X SHFT SPACER BLOC
6	2	107	2X SHFT SPACER BLOC
7	2	108	2X SHFT SPACER BLOC
8	2	109	2X SHFT SPACER BLOC
9	2	110	2X SHFT SPACER BLOC
10	2	111	2X SHFT SPACER BLOC
11	4	112	10-20NF-1/2
12	4	113	10-20NF-1/2
13	2	114	5/16-20NF-3/4



SCALE	NOT TO SCALE	DIMENSIONS IN INCHES		PART #	UT
MATERIAL	N/A	TOLERANCES UNLESS NOTED		ASM05	
OTHER NOTES		LINEAR +/-	N/A	TITLE	TRAY MOTION/FRA
		ANGLES +/-	N/A	PRE-ASSEMBLY	
		RADI UNLESS NOTED	N/A	DESIGNER	BDC 08/20/91
		EDGE/CORNER BREAKS	N/A	CHECKED	
IBMCAD FILE	PHASE1-1.ASM	OUTSIDE MAX	N/A	APPROVED	
		INSIDE MAX	N/A		

QUANTITY: 1

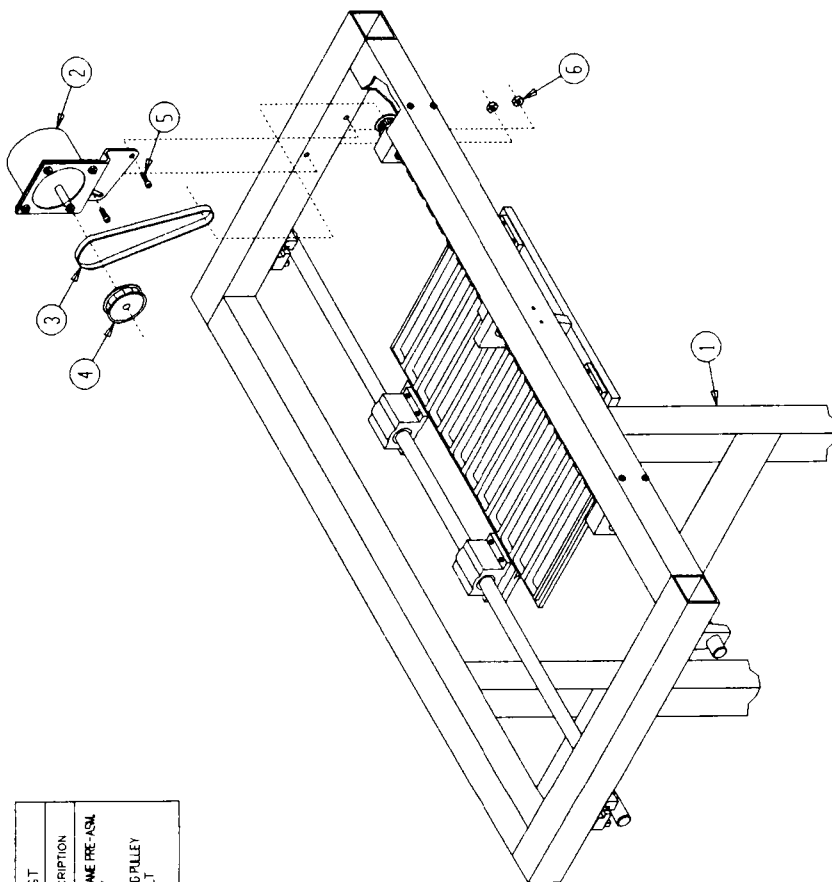
ASSEMBLY PARTS LIST			
ITEM	QTY	P./N	PART DESCRIPTION
1	1	340065	SIZE 34 STEPPING MOTOR
2	1	122	STEPPING MOTOR BRACKET
3	4	80-CON-1/2	SIDE HEAD BOLT
4	4	80-CON	HEX NUT



SCALE	NOT TO SCALE	DIMENSIONS IN INCHES		PART. #	UT
MATERIAL	N/A	TOLERANCES UNLESS NOTED		ASW06	
		LINEAR + / -	N/A	TITLE	MOTOR ASSEMBLY
		ANGLES + / -	N/A		
OTHER NOTES		RADI UNLESS NOTED	N/A	DESIGNER	BDC 08/20/91
		EDGE/ CORNER BREAKS	OUTSIDE MAX	CHECKED	
IBMCAD FILE	MTR,ASM		INSIDE MAX	APPROVED	

QUANTITY: 1

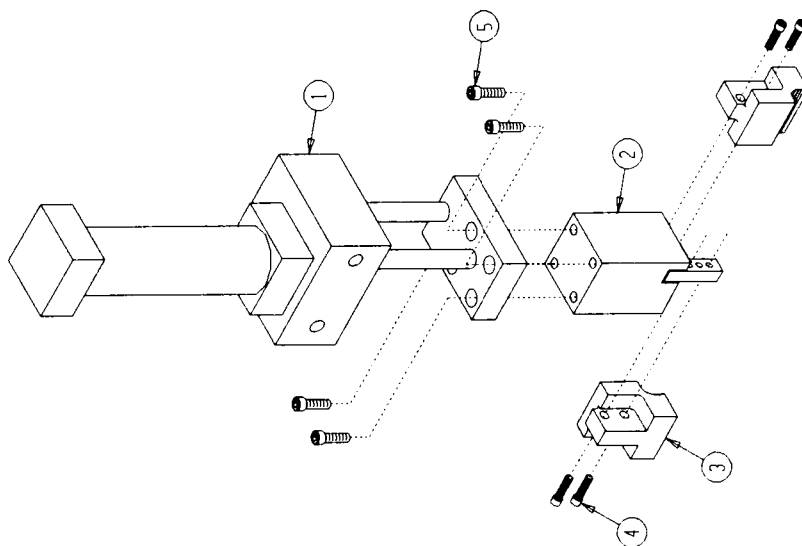
ASSEMBLY PARTS LIST		
ITEM	QTY	PART DESCRIPTION
1	1	TRAY MOTION/FRAME PRE-ASM
2	1	MOTOR ASSEMBLY
3	1	TRIM BELT
4	1	62-200F1032
5	2	1/4-20X 1/2
6	2	HEX NUT



SCALE	NOT TO SCALE	DIMENSIONS IN INCHES		PART #	UT
MATERIAL	N/A	TOLERANCES UNLESS NOTED		ASMI07	
OTHER NOTES		LINEAR +/-	N/A	TITLE	TRAY MOTION/FRAME
		ANGLES +/-	N/A	ASSEMBLY	
		RADI UNLESS NOTED	N/A	DESIGNER	BDC 08/20/91
		EDGE/CORNER BREAKS	N/A	CHECKED	
IBMCAD FILE PHASE1-4.ASM		INSIDE MAX	N/A	APPROVED	

QUANTITY: 1

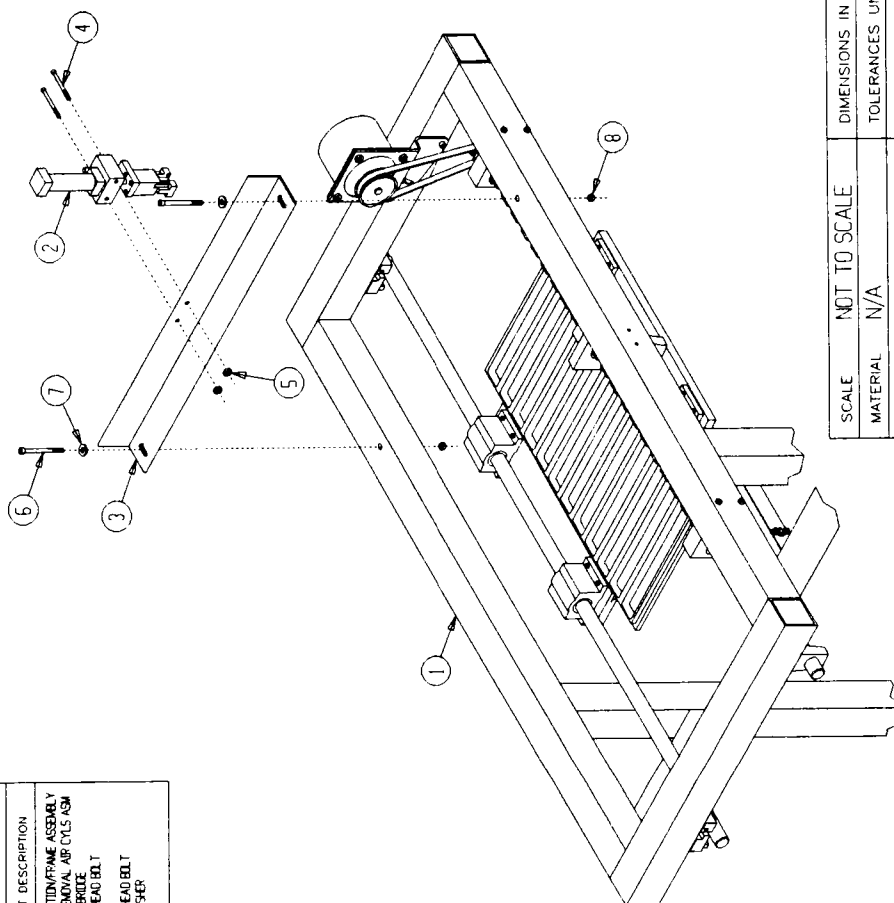
ASSEMBLY PARTS LIST		
ITEM	QTY	P/N PART DESCRIPTION
1	1	POWER SLEEVE NON-ROT AIR (V.L.)
2	1	640-01-001
3	2	EXHAUST FIBERS
4	4	4-40NC-1/2
5	4	6-30NC-3/8



SCALE		NOT TO SCALE		DIMENSIONS IN INCHES		PART #		UT			
MATERIAL		N/A		TOLERANCES UNLESS NOTED		ASM08					
				LINEAR +/-		N/A					
				ANGLES +/-		N/A		TITLE	SCRAP REMOVAL AIR CYLINDERS ASSEMBLY		
OTHER NOTES				RADIO UNLESS NOTED		N/A				DESIGNER	BDC
				EDGE / CORNER BREAKS		OUTSIDE MAX		N/A		CHECKED	
IBMCAD FILE		PICKER.ASM				INSIDE MAX		N/A		APPROVED	

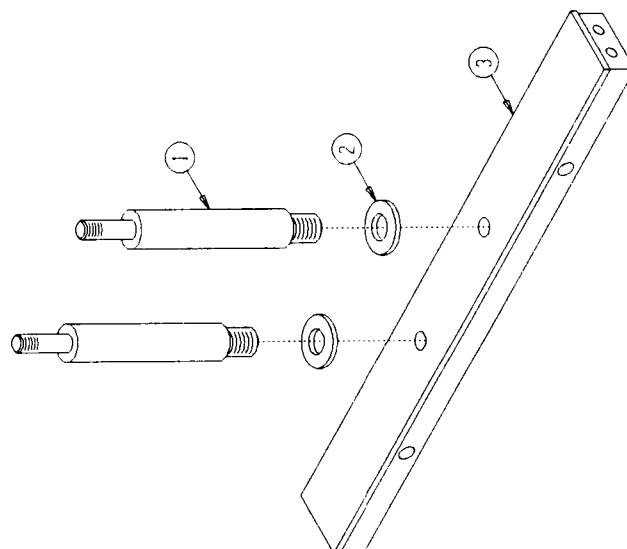
QUANTITY: 1

ASSEMBLY PARTS LIST			
ITEM	QTY	P/N	PART DESCRIPTION
1	1	ASMI07	TRAY MOTION/FRAME ASSEMBLY
2	1	ASMI08	SCRAP REMOVAL AIR CYLS ASM
3	1	18	COPPER BRIDGE
4	2	10-12NF-1 3/4	SIDET HEAD BOLT
5	2	10-12NF	HEX NUT
6	2	1/4-28F-2 1/2	SIDET HEAD BOLT
7	2	1/4	FLAT WASHER
8	2	1/4-28F	HEX NUT



SCALE	NOT TO SCALE	DIMENSIONS IN INCHES		PART #	UT
		TOLERANCES UNLESS NOTED			
MATERIAL	N/A	LINEAR +/-	N/A	ASMD09	SCRAP REMOVAL/TRAY
		ANGLES +/-	N/A		MOTION/FRAME ASSEMBLY
OTHER NOTES		RADII UNLESS NOTED	N/A	DESIGNER	BDC 08/20/91
		EDGE / CORNER BREAKS	OUTSIDE MAX	CHECKED	
IBMCAD FILE	PHASE1-5.ASM	INSIDE MAX	N/A	APPROVED	

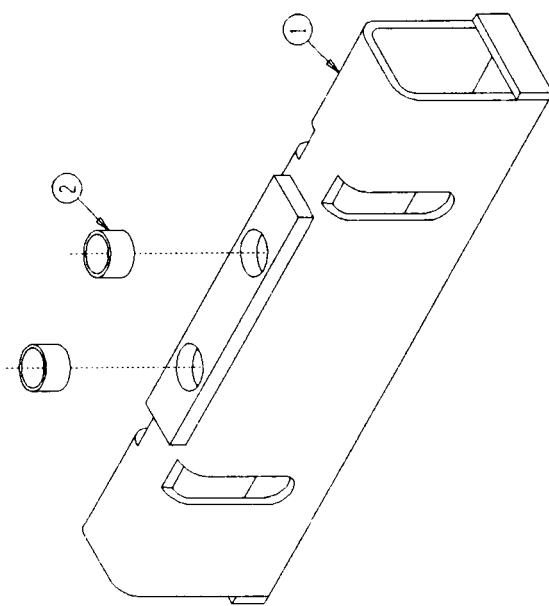
QUANTITY: 1



ASSEMBLY PARTS LIST			
ITEM	QTY	P/N	PART DESCRIPTION
1	2	107	ASSEMBLY PLATE EXT.
2	2	516	FLAT WASHER
3	1	102	PUNCH BASE

QUANTITY: 1

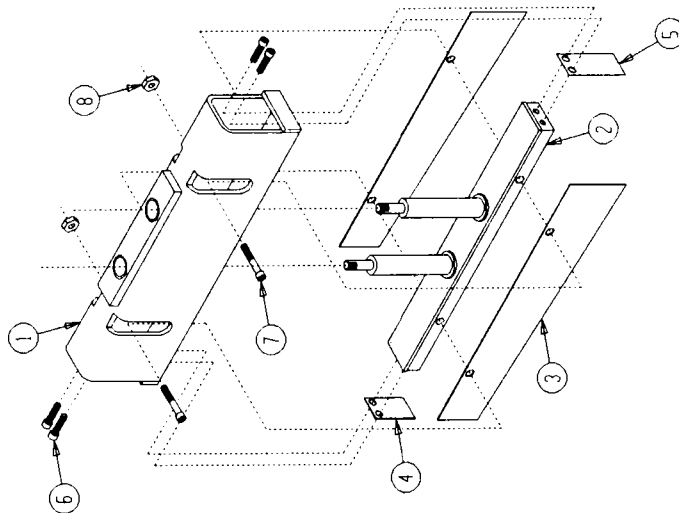
SCALE	NOT TO SCALE	DIMENSIONS IN INCHES		PART #	UT
MATERIAL	N/A	TOLERANCES UNLESS NOTED	NOTED	ASM10	
		LINEAR + / -	N/A	TITLE	PUNCH BASE ASSEMBLY
		ANGLES + / -	N/A		
OTHER NOTES		RADI UNLESS NOTED	N/A	DESIGNER	BOC 08/20/91
		EDGE/CORNER BREAKS	N/A	CHECKED	
IBMCAD FILE	PUNCHES.ASM	INSIDE MAX	N/A	APPROVED	



ASSEMBLY PARTS LIST			
ITEM	QTY	P/N	PART DESCRIPTION
1	1	101	CLAMP
2	2	081.06	BUSHES

QUANTITY: 1

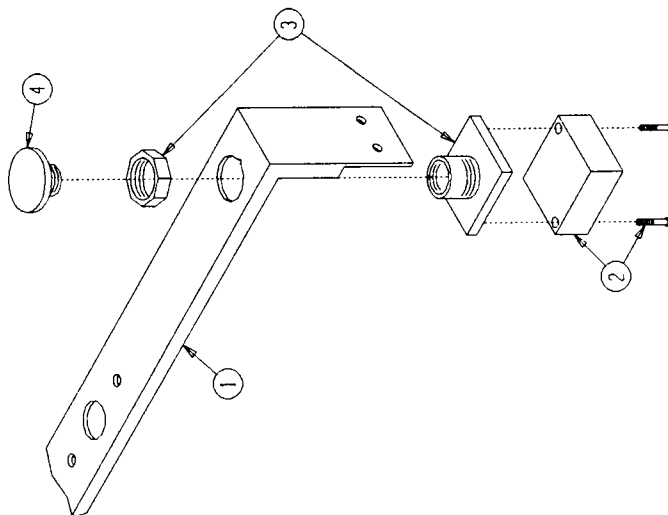
SCALE	NOT TO SCALE	DIMENSIONS IN INCHES		PART #	UT
MATERIAL	N/A	TOLERANCES UNLESS NOTED		ASMIII	
		LINEAR +/-	N/A	TITLE	CLAMP ASSEMBLY
		ANGLES +/-	N/A		
OTHER NOTES		RADIO UNLESS NOTED	N/A	DESIGNER	BDC 08/20/91
		EDGE/CORNER BREAKS	N/A	CHECKED	
IBMCAD FILE	CLMFBASHM	INSIDE MAX	N/A	APPROVED	



ASSEMBLY PARTS LIST		
ITEM	QTY	PART DESCRIPTION
1	1	CLAMP ASSEMBLY
2	1	PUNCH BASE ASSEMBLY
3	2	PUNCH SIZE GEAR
4	1	SHORT PUNCH END GEAR
5	1	LOCK PIN END GEAR
6	4	LOCK PIN END GEAR
7	2	LOCK PIN END GEAR
8	2	LOCK PIN END GEAR

QUANTITY: 1

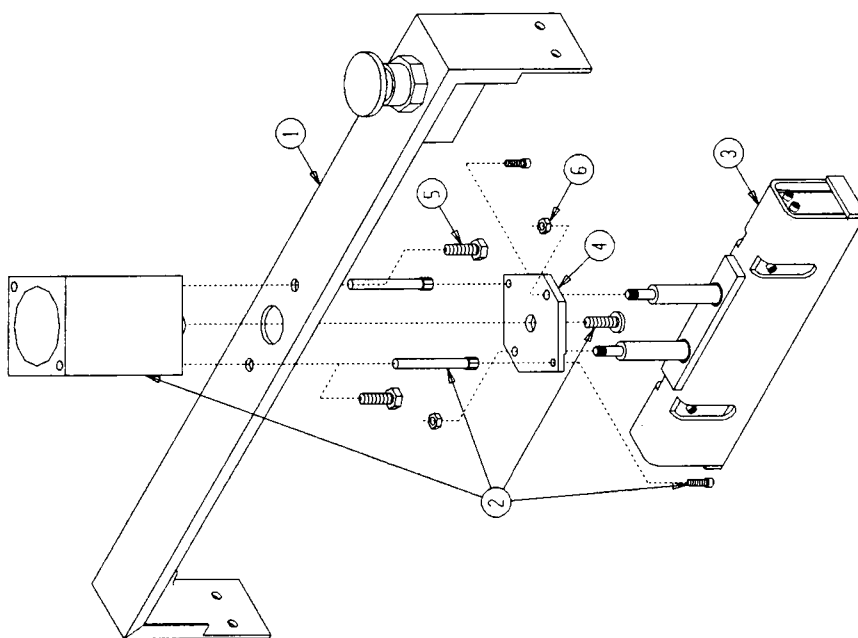
SCALE	NOT TO SCALE	DIMENSIONS IN INCHES		PART #	UT
MATERIAL	N/A	TOLERANCES UNLESS NOTED		ASMI12	
		LINEAR	+/-	TITLE	CLAMP/PUNCH
		ANGLES	+/-	ASSEMBLY	
OTHER NOTES		RADII UNLESS NOTED	N/A	DESIGNER	BOC 08/21/91
		EDGE/ CORNER BREAKS	OUTSIDE MAX	CHECKED	
			INSIDE MAX	APPROVED	
IBM CAD FILE	CLAMPINCH.ASM				



ASSEMBLY PARTS LIST		
ITEM	QTY	PART DESCRIPTION
1	1	PUNCH BRIDGE
2	1	SWITCH CONTACT BLOCK
3	1	PUSH-PULL SWITCH OPERATOR
4	1	EMERGENCY SWITCH LENS

QUANTITY: 1

SCALE	NOT TO SCALE	DIMENSIONS IN INCHES	PART #	UT
MATERIAL	N/A	TOLERANCES UNLESS NOTED	ASM113	
		LINEAR +/-	TITLE PUNCH BRIDGE	
		ANGLES +/-	PRE-ASSEMBLY	
		RADII UNLESS NOTED	DESIGNER	BDC 08/21/91
		EDGE/CORNER BREAKS	CHECKED	
		OUTSIDE MAX	APPROVED	
		INSIDE MAX		
BMCAD FILE BRIDGE3.ASM				

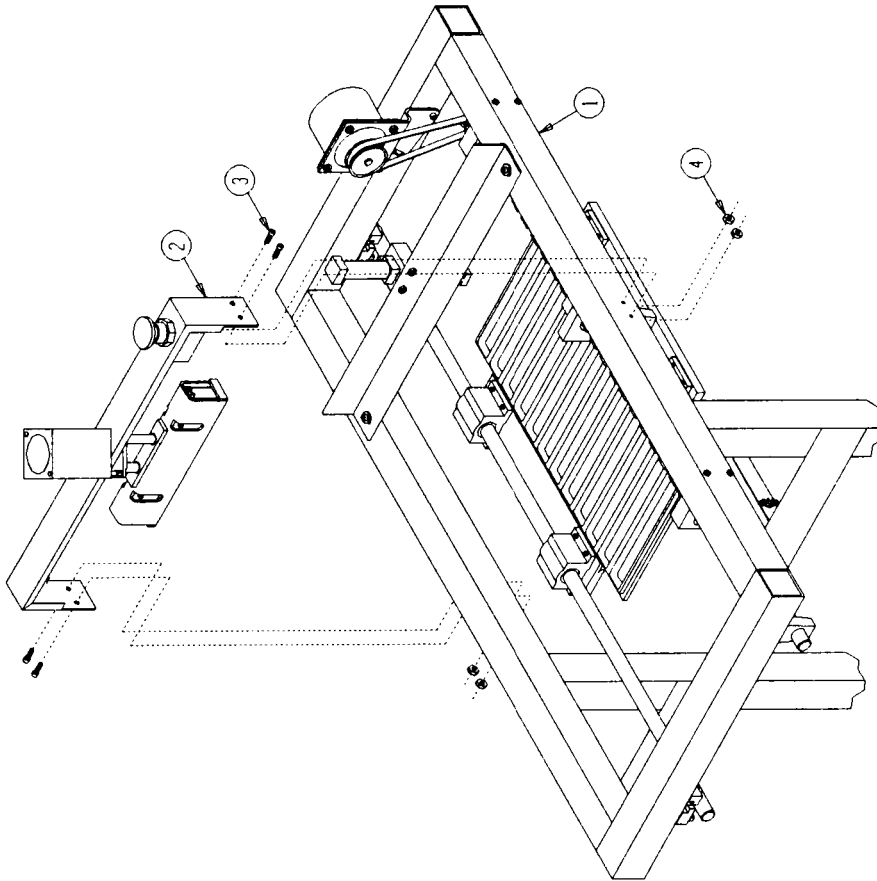


ASSEMBLY PARTS LIST			
ITEM	QTY	P/N	PART DESCRIPTION
1	1	ASM13	PUNCH BRIDGE PRE-ASSEMBLY
2	1	022X8TP	NON-ROTATING AIR CYLINDER
3	1	ASM12	CLAMP/PUNCH ASSEMBLY
4	1	06	AIR CYLINDER TOOLING PLATE
5	2	5/16-18X1-1	HEX HEAD BOLT
6	2	1/4-28NF	HEX NUT

QUANTITY: 1

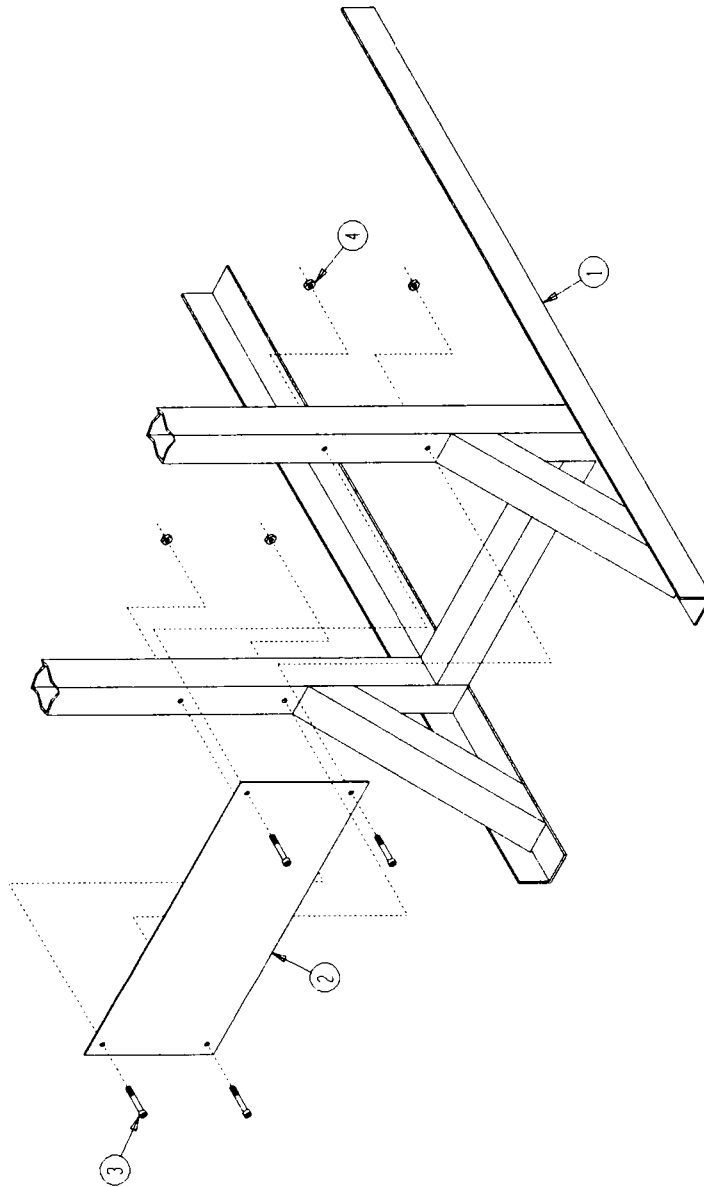
SCALE	NOT TO SCALE	DIMENSIONS IN INCHES		PART #	UT
		TOLERANCES UNLESS NOTED	N/A		
MATERIAL	N/A	LINEAR +/-	N/A	ASM114	
		ANGLES +/-	N/A	TITLE PUNCH BRIDGE	
OTHER NOTES		RADIUS UNLESS NOTED	N/A	ASSEMBLY	
		EDGE/CORNER BREAKS	N/A	DESIGNER	08/21/91
IBMCAD FILE	BRIDGE2.ASM	OUTSIDE MAX	N/A	CHECKED	
		INSIDE MAX	N/A	APPROVED	

ASSEMBLY PARTS LIST			
ITEM	QTY	P/N	PART DESCRIPTION
1	1	ASMI09	STP BELT/TRAN MITT FRAME AS
2	1	ASMI15	PUNCH BRIDGE ASSEMBLY
3	4	1/4-28F-1/2	SOCKET HEAD BLT
4	4	1/4-28F	HEX NUT



SCALE		DIMENSIONS IN INCHES		PART #	UT
MATERIAL	NOT TO SCALE	TOLERANCES UNLESS NOTED			
N/A		LINEAR +/-	N/A	ASMI15	
		ANGLES +/-	N/A	TITLE	PUNCH BRIDGE/SCRAP
OTHER NOTES		RADI UNLESS NOTED	N/A	REMOVAL/FRAME ASSEMBLY	
		EDGE/CORNER BREAKS	N/A	DESIGNER	BDC 08/21/91
		OUTSIDE MAX	N/A	CHECKED	
		INSIDE MAX	N/A	APPROVED	
IBMCAD FILE	PHASE1-E.ASM				

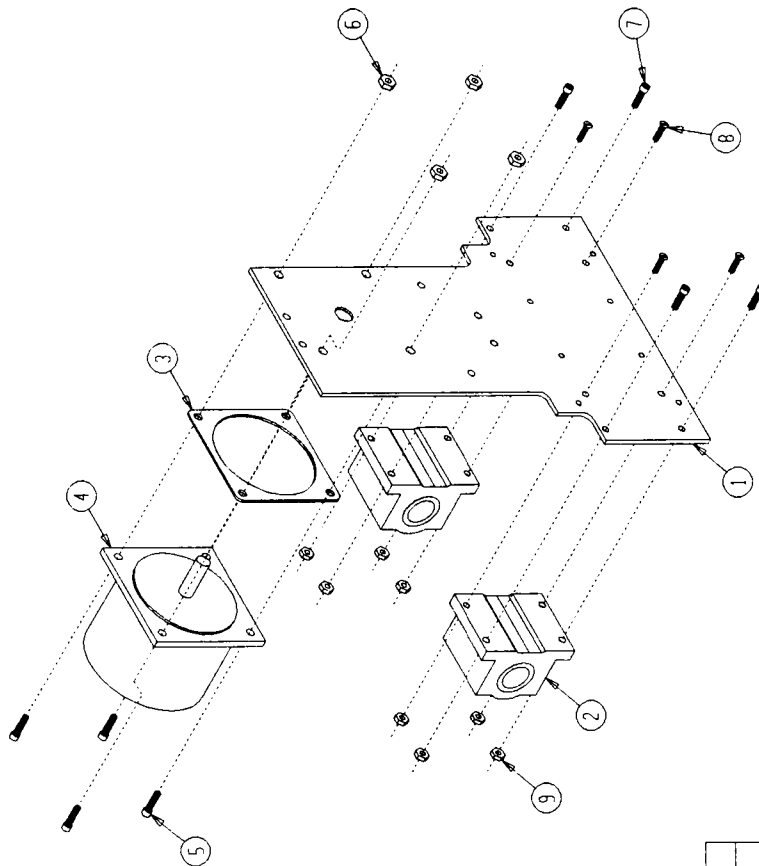
QUANTITY: 1



ASSEMBLY PARTS LIST		
ITEM	QTY	P/N
1	1	UT
2	1	FRAME PANEL
3	4	UT-38F-2 1/2
4	4	UT-38F 1/4-38F HEX NUT

SCALE	NOT TO SCALE	DIMENSIONS IN INCHES		PART #	UT
MATERIAL	N/A	TOLERANCES UNLESS NOTED		ASM116	
OTHER NOTES		LINEAR +/-	N/A	TITLE	PHASE I ASSEMBLY
		ANGLES +/-	N/A		
		RADI UNLESS NOTED	N/A	DESIGNER	BDC 08/21/91
IBMCAD FILE	PHASEI-8.ASM	EDGE/CORNER BREAKS	OUTSIDE MAX	CHECKED	
			INSIDE MAX	APPROVED	

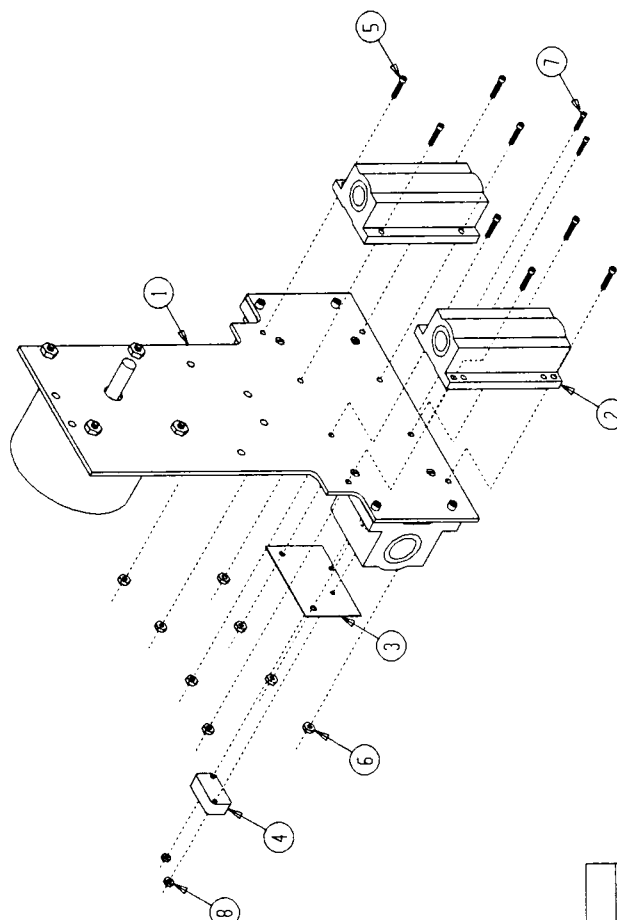
QUANTITY: 1



ASSEMBLY PARTS LIST		
ITEM	QTY	P/N PART DESCRIPTION
1	1	201 VERTICAL SUPPORT PLATE
2	2	5982 3/4" LINEAR BALL BEARING
3	1	202 STEPPING MOTOR ADAPTER
4	1	203 3/4" STEPPING MOTOR
5	4	10-1208-3/4" 10-1208-3/4" HEX NUT
6	4	10-1208-3/4" 10-1208-3/4" HEX NUT
7	4	8-1208-3/4" 8-1208-3/4" FLAT HEAD BOLT
8	4	8-1208-3/4" 8-1208-3/4" FLAT HEAD BOLT
9	8	8-1208-3/4" 8-1208-3/4" HEX NUT

SCALE	NOT TO SCALE	DIMENSIONS IN INCHES	PART #	UT
MATERIAL	N/A	TOLERANCES UNLESS NOTED	ASM201	
		LINEAR +/-		
		ANGLES +/-		
OTHER NOTES		RADIUS UNLESS NOTED	TITLE VERTICAL SUPPORT	
		EDGE/CORNER BREAKS	PLATE PRE-ASSEMBLY	
		OUTSIDE MAX	DESIGNER BDC	08/21/91
		INSIDE MAX	CHECKED	
IBMCAD FILE	PLATE.FASM		APPROVED	

QUANTITY: 1

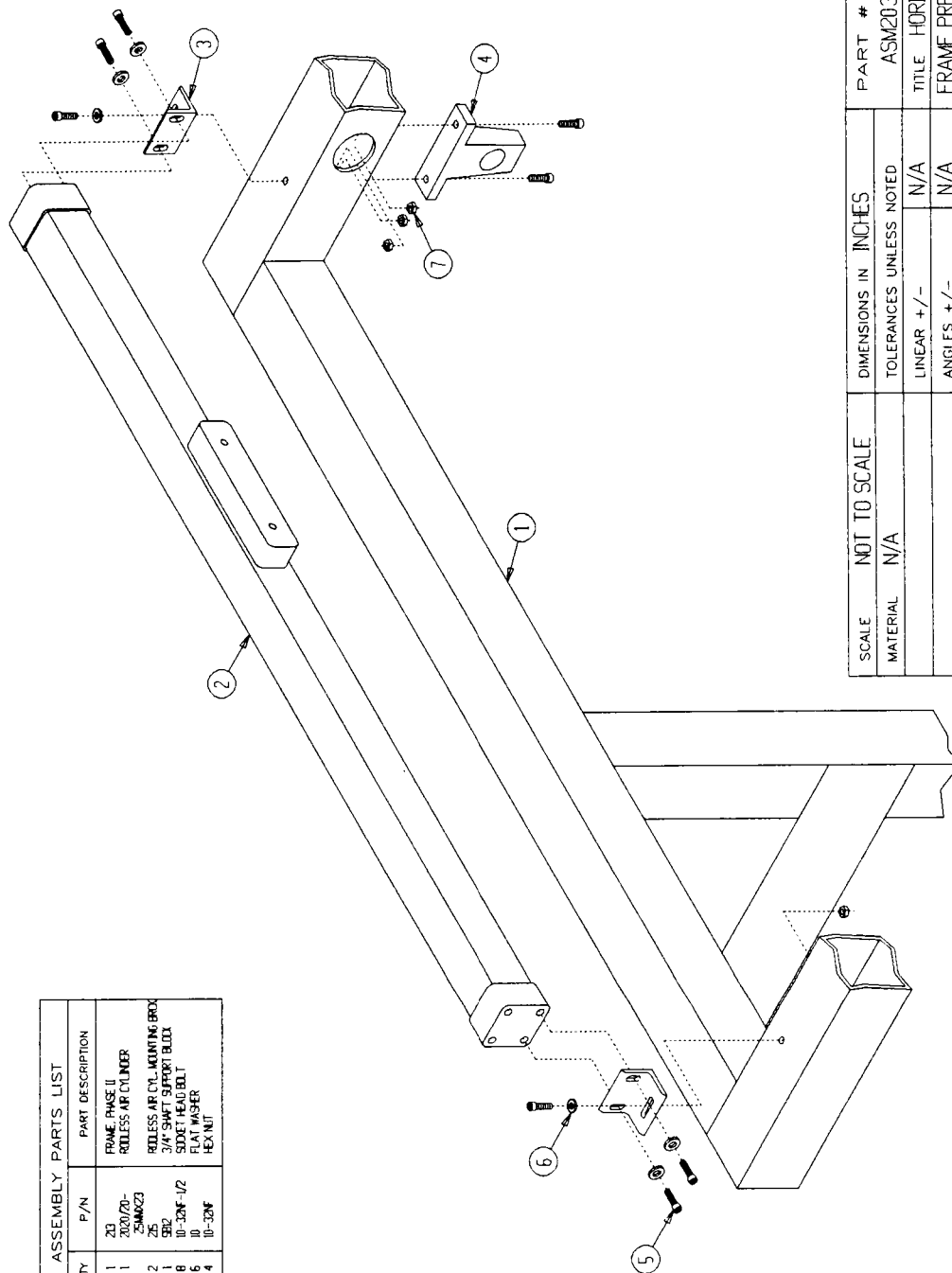


ASSEMBLY PARTS LIST		
ITEM	QTY	PART DESCRIPTION
1	1	VERT. SUPPORT PLATE PRE-ASL
2	2	VERT. SUPPORT PLATE PRE-ASL
3	1	HORIZONTAL SUPPORT PLATE
4	1	INTERMEDIATE SUPPORT PLATE
5	8	6-32NC-1/2
6	8	STREET HEAD BOLT
7	2	HEX NUT
8	2	HEX NUT

SCALE	NOT TO SCALE	DIMENSIONS IN INCHES		PART #	UT
		TOLERANCES UNLESS NOTED			
MATERIAL	N/A	LINEAR +/-	N/A	TITLE	SUPPORT PLATE
OTHER NOTES		ANGLES +/-	N/A	ASSEMBLY	
		RADII UNLESS NOTED	N/A	DESIGNER	BDC
		EDGE/CORNER BREAKS	OUTSIDE MAX	CHECKED	
			INSIDE MAX	APPROVED	
IBMCAD FILE		PLATE2RF.ASM			

QUANTITY: 1

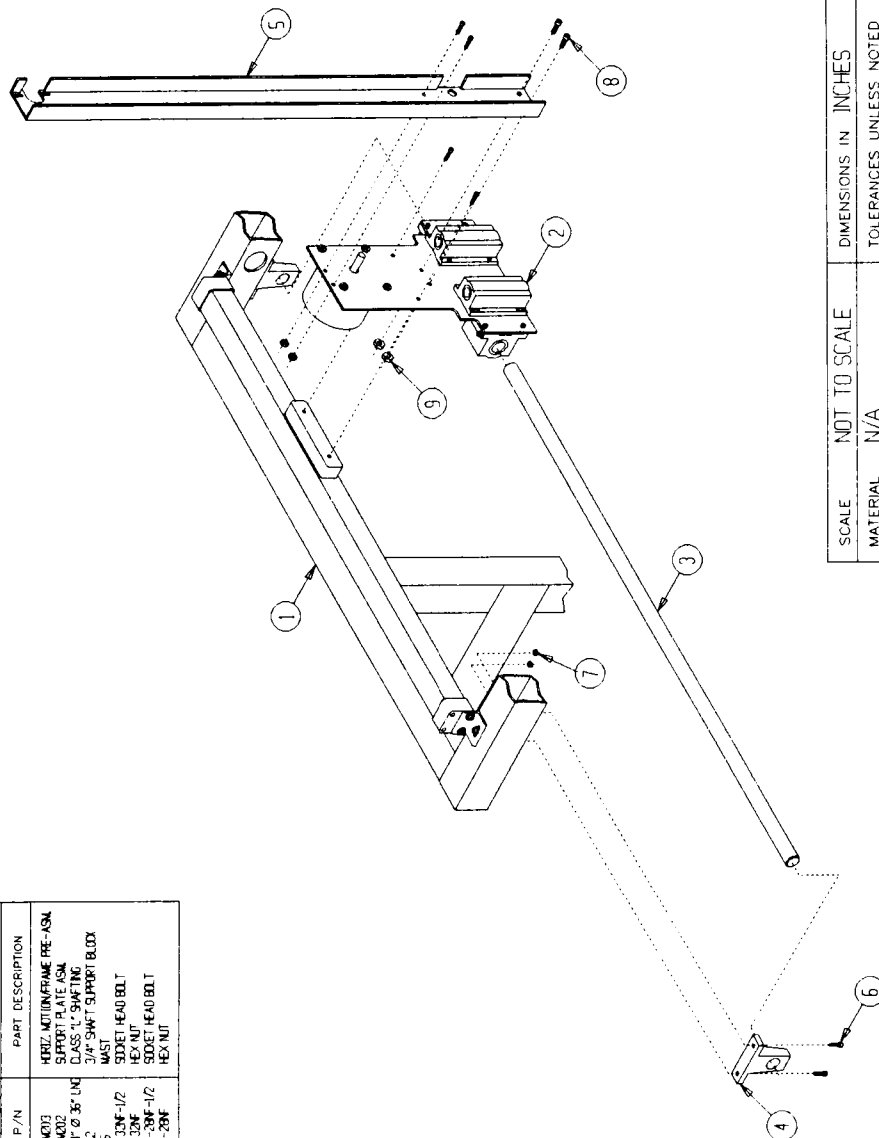
ASSEMBLY PARTS LIST			
ITEM	QTY	P/N	PART DESCRIPTION
1	1	Z3	FRAME, PHASE II
2	1	200070-254023	RODLESS AIR CYLINDER
3	2	Z5	RODLESS AIR CYLINDER BOX
4	1	382	3/4" SWFT SUPPORT BLOCK
5	6	10-10NF-1/2	SIDE HEADBOLT
6	6	10-10NF	WASHER
7	4	10-10NF	HEX NUT



SCALE	NOT TO SCALE	DIMENSIONS IN INCHES		PART # ASM203	UT
MATERIAL	N/A	TOLERANCES UNLESS NOTED			
		LINEAR +/-	N/A	TITLE	HORIZONTAL MOTION/
		ANGLES +/-	N/A	FRAME PRE-ASSEMBLY	
OTHER NOTES		RADII UNLESS NOTED	N/A	DESIGNER	BDC 08/21/91
		EDGE / CORNER BREAKS	OUTSIDE MAX	CHECKED	
			INSIDE MAX	APPROVED	
RM/CAN FILE	PICKER/ASM				

QUANTITY: 1

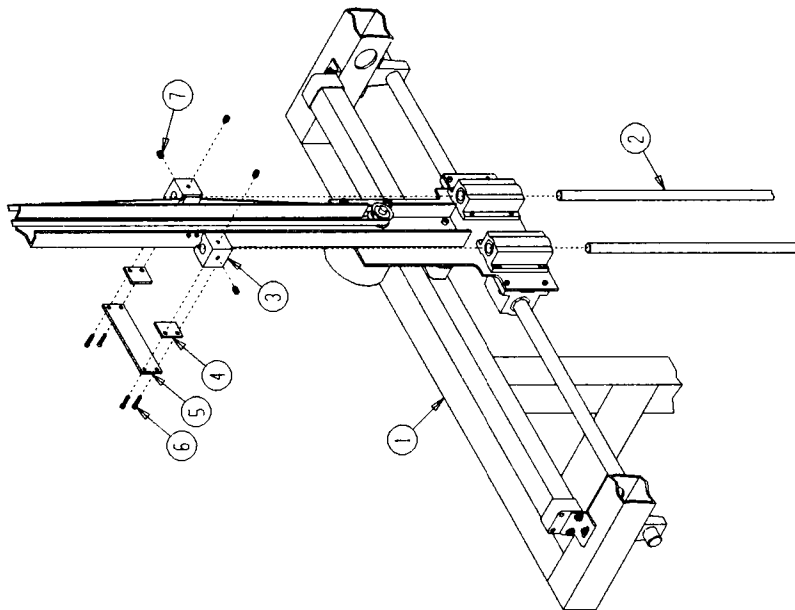
ASSEMBLY PARTS LIST			
ITEM	QTY	P/N	PART DESCRIPTION
1	1	ASM003	HORIZ MOTION FRAME PRE-ASM
2	1	ASM002	SUPPORT PLATE ASM
3	1	1/4" x 36" LUG	CLASSIC SPACING
4	1	3/8"	3/8" SHW SUPPORT BLOCK
5	1	3/8"	3/8" SHW SUPPORT BLOCK
6	5	10-32NF-1/2	10-32NF-1/2
7	4	1/4-20NF-1/2	1/4-20NF-1/2
8	2	1/4-20NF	1/4-20NF
9	2	1/4-20NF	1/4-20NF



SCALE	NOT TO SCALE	DIMENSIONS IN INCHES	PART #	UT
MATERIAL	N/A	TOLERANCES UNLESS NOTED	ASM204	
		LINEAR +/-	N/A	TITLE HORIZONTAL MOTION/
		ANGLES +/-	N/A	FRAME ASSEMBLY
OTHER NOTES		RADII UNLESS NOTED	N/A	DESIGNER BUC 08/21/91
		EDGE/CORNER BREAKS	N/A	CHECKED
			N/A	APPROVED
IBMCAD FILE	PICKFRM2.ASM			

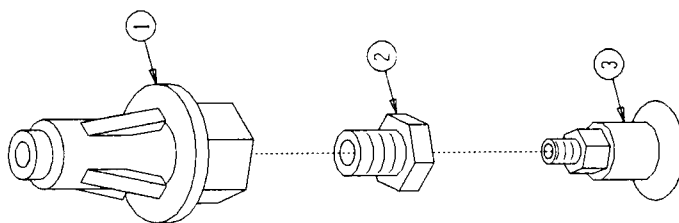
QUANTITY: 1

ASSEMBLY PARTS LIST			
ITEM	QTY	P/N	PART DESCRIPTION
1	1	ASM205	VERT-HORIZ MOT FRAME PRE-ASM
2	2	288	VERTICAL SHWT
3	1	208	BELT CONNECTOR
4	2	200	BELT CONNECTOR TIE SPACER
5	1	205	BELT CONNECTOR TIE
6	4	107-24NF-1/2	SOCKET HEAD BOLT
7	4	1/4-28NF-3/8	HALF DUTY PIN SOCKET SET SCREW



SCALE	NOT TO SCALE	DIMENSIONS IN INCHES		PART #	UT
MATERIAL	N/A	TOLERANCES UNLESS NOTED			
		LINEAR + / -	N/A	ASM205	
		ANGLES + / -	N/A	TITLE	VERTICAL - HORIZONTAL
OTHER NOTES		RADII UNLESS NOTED	N/A	MOTION/FRAME ASSEMBLY	
		EDGE/ CORNER BREAKS	OUTSIDE MAX	DESIGNER	BDC 08/21/91
IBMCAD FILE	PICKER.M5.ASM		INSIDE MAX	CHECKED	
				APPROVED	

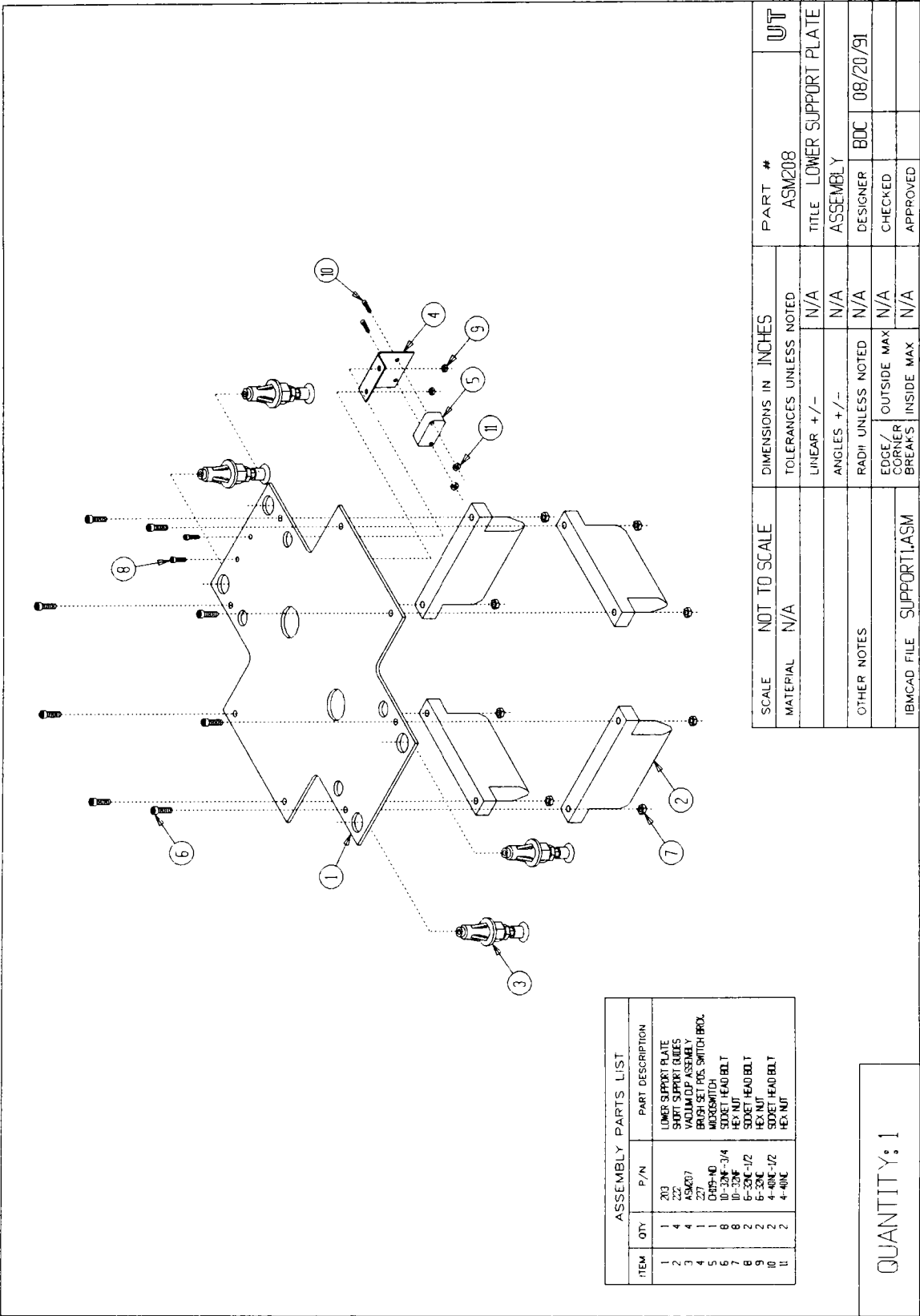
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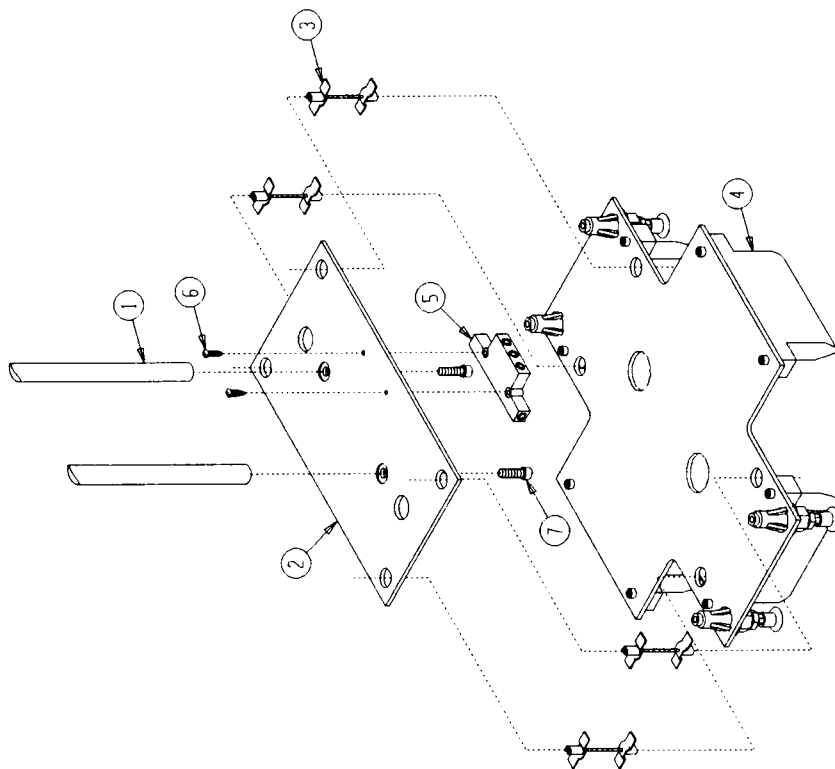
ASSEMBLY PARTS LIST		
ITEM	QTY	P/N PART DESCRIPTION
1	1	306-54-11
2	1	306-54-12
3	1	306-54-13

QUANTITY: 1

SCALE		NOT TO SCALE		DIMENSIONS IN INCHES		PART #		UT
MATERIAL		N/A		TOLERANCES UNLESS NOTED		ASM207		
OTHER NOTES				LINEAR +/-		N/A		TITLE VACUUM CUP ASSEMBLY
				ANGLES +/-		N/A		
				RADIO UNLESS NOTED		N/A		
IBM/CAD FILE VACFIT.ASM				EDGE/CORNER BREAKS		N/A		DESIGNER BDC
				OUTSIDE MAX		N/A		
				INSIDE MAX		N/A		
						CHECKED		APPROVED



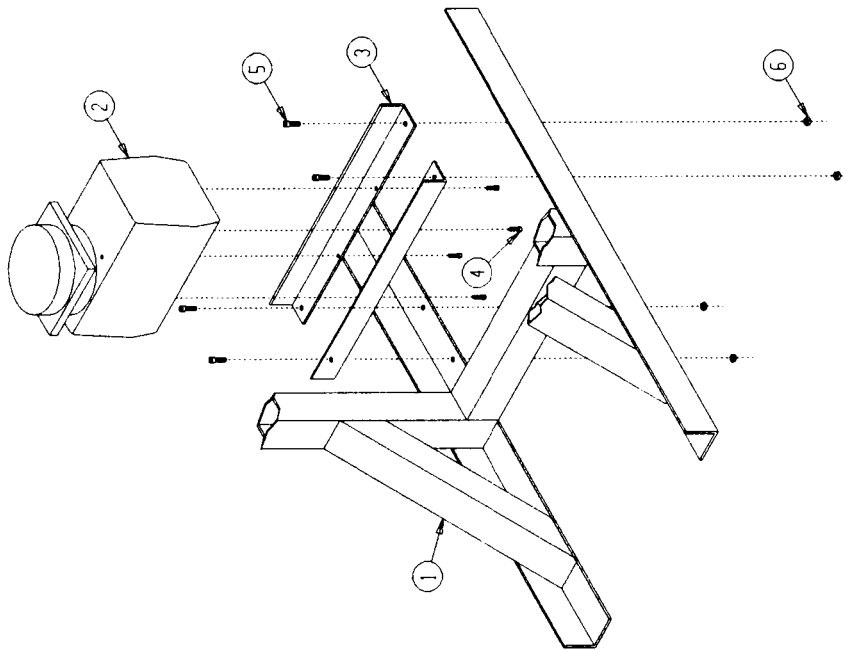
ASSEMBLY PARTS LIST			
ITEM	QTY	P/N	PART DESCRIPTION
1	1	AS006	VERT-HORIZ MOUNTING ASM
2	1	204	UPPER SUPPORT PLATE
3	4	224	SUPPORT PLATE W/KEY
4	1	AS008	LOWER SUPPORT PLATE ASSEMB
5	1	1304-56-54	MULTIPLE TEE TUBE W/ANFIELD
6	2	8-1/2	ROUND HEAD WOOD SCREW
7	2	1/4-28NF-1/2	SOCKET HEAD BLT



SCALE		NOT TO SCALE		DIMENSIONS IN INCHES		PART #		UT	
MATERIAL		N/A		TOLERANCES UNLESS NOTED		ASM209			
				LINEAR +/-		N/A		TITLE	END EFFECTOR
				ANGLES +/-		N/A			
				RADI UNLESS NOTED		N/A		ASSEMBLY	
OTHER NOTES				EDGE/ CORNER BREAKS		OUTSIDE MAX		DESIGNER	
						INSIDE MAX		CHECKED	
IBMCAD FILE		PICKER7.ASM						APPROVED	
								08/20/91	

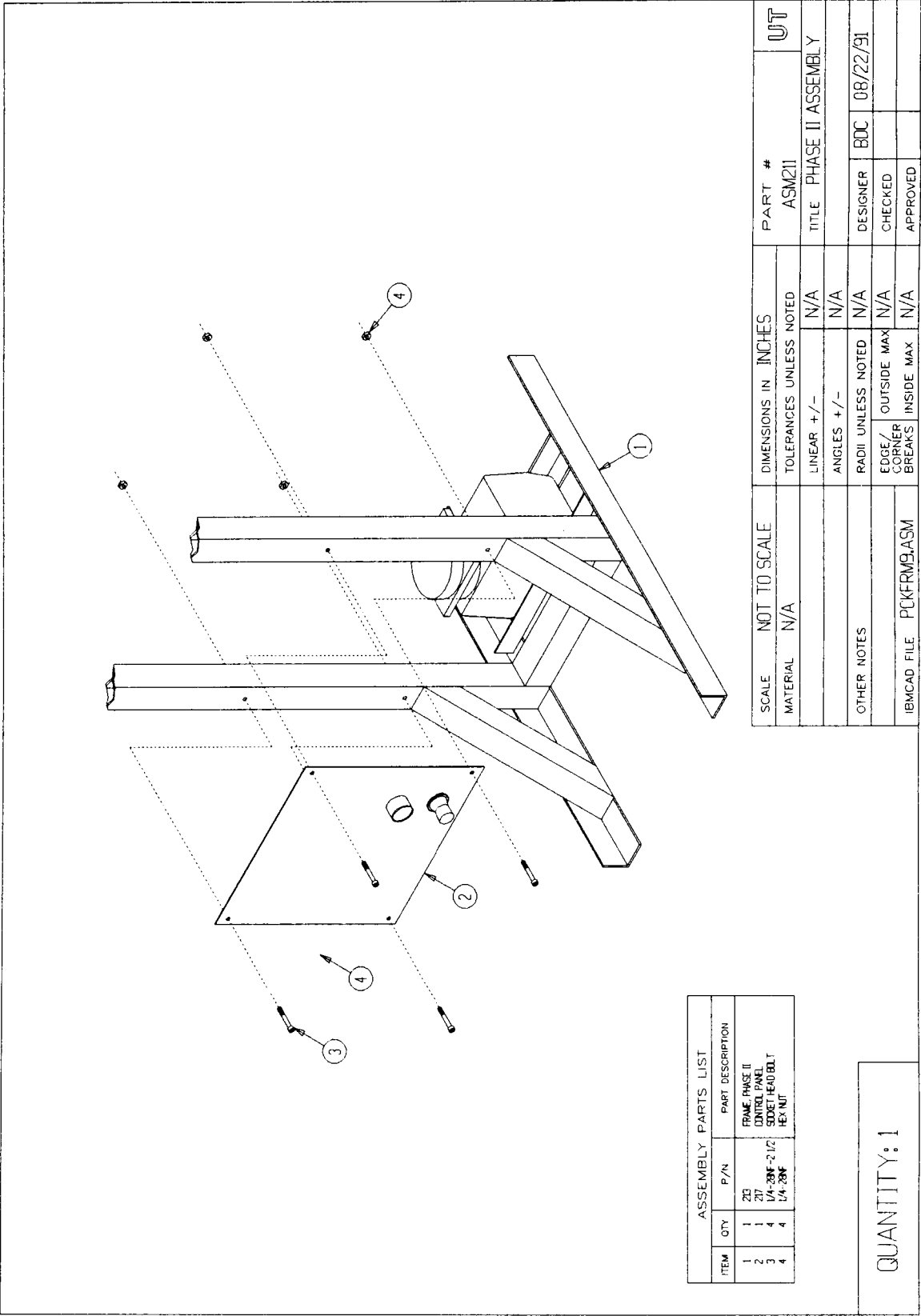
QUANTITY: 1

ASSEMBLY PARTS LIST			
ITEM	QTY	P/N	PART DESCRIPTION
1	1	23	FRAME PVICE II
2	1	23555	VACUUM PUMP
3	2	24	VACUUM PUMP SHELF
4	4	10-20F-1/2	STEEL HEAD BOLT
5	4	1/4-20F-1/2	STEEL HEAD BOLT
6	4	1/4-20F	HEX NUT



SCALE	NOT TO SCALE	DIMENSIONS IN INCHES		PART #	UT
		TOLERANCES UNLESS NOTED			
MATERIAL	N/A	LINEAR $\pm$ / -	N/A	ASM210	
		ANGLES $\pm$ / -	N/A	TITLE VACUUM PUMP FRAME	
OTHER NOTES		RADII UNLESS NOTED	N/A	ASSEMBLY	
		EDGE/CORNER BREAKS	N/A	DESIGNER BOC	08/22/91
			OUTSIDE MAX	CHECKED	
			INSIDE MAX	APPROVED	
IB/CAD FILE	PICKFRMB.ASM				

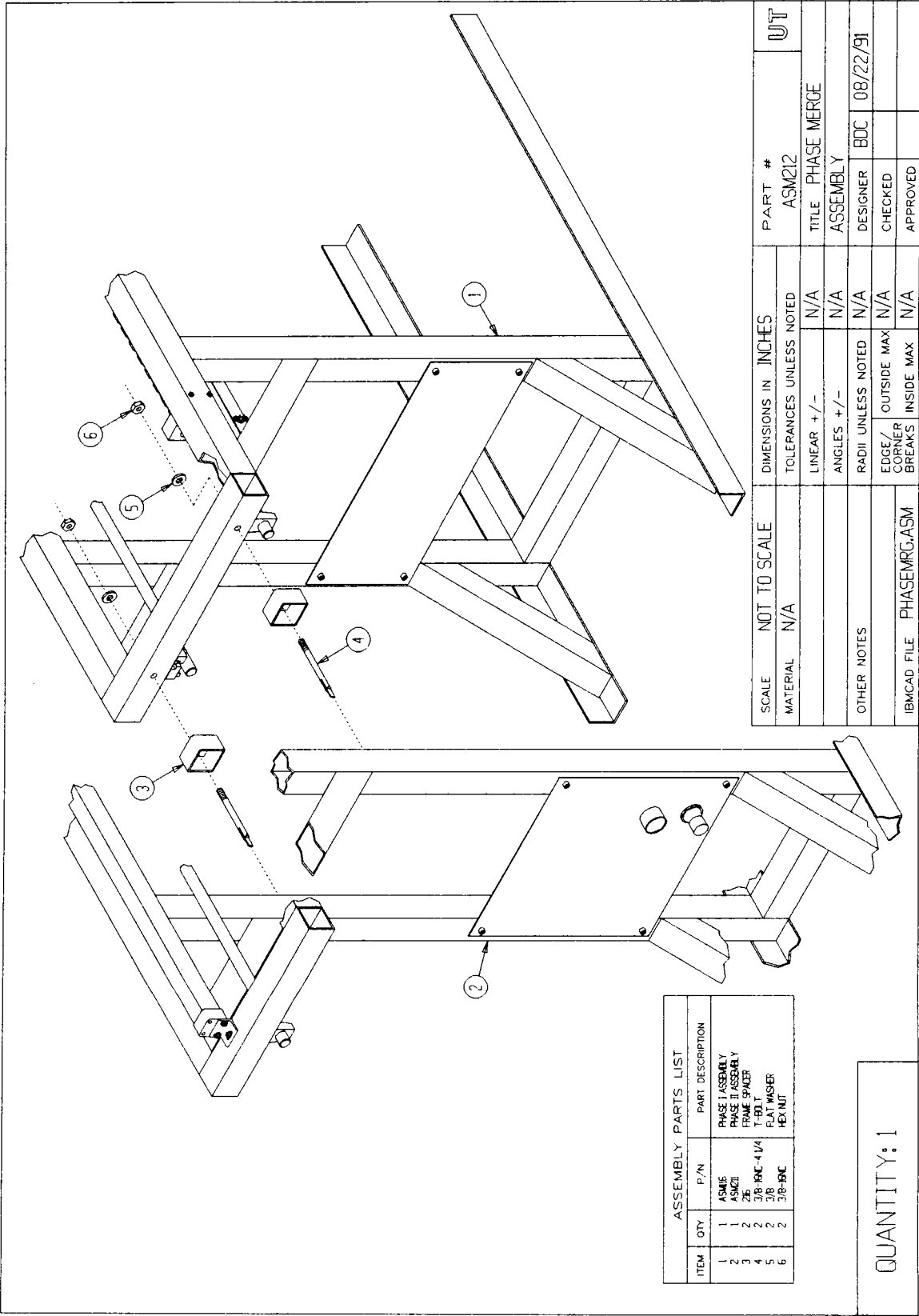
QUANTITY: 1



ASSEMBLY PARTS LIST		
ITEM	QTY	P/N
1	1	20
2	1	20
3	4	1/4-20F-2 1/2
4	4	1/4-20F HEX NUT

SCALE	NOT TO SCALE	DIMENSIONS IN INCHES		PART #	UT
MATERIAL	N/A	TOLERANCES UNLESS NOTED		ASM211	
OTHER NOTES		LINEAR +/-	N/A	TITLE	PHASE II ASSEMBLY
		ANGLES +/-	N/A		
		RADI UNLESS NOTED	N/A	DESIGNER	BDC 08/22/91
		EDGE / CORNER BREAKS	OUTSIDE MAX N/A INSIDE MAX N/A	CHECKED	
IBMCAD FILE	PCKFRM9.ASM			APPROVED	

QUANTITY: 1



ASSEMBLY PARTS LIST		
ITEM	QTY	P/N PART DESCRIPTION
1	1	ASM212 PHASE I ASSEMBLY
2	1	ASM212 PHASE II ASSEMBLY
3	2	26 FRAME SPACER
4	2	3/8-FNC-4 1/4 T-BOLT
5	2	3/8 FLAT WASHER
6	2	3/8 HEX NUT

SCALE	NOT TO SCALE	DIMENSIONS IN INCHES		PART #	UT
		TOLERANCES UNLESS NOTED			
MATERIAL	N/A	LINEAR +/-	N/A	ASM212	
		ANGLES +/-	N/A	TITLE PHASE MERGE	
OTHER NOTES		RADI UNLESS NOTED	N/A	ASSEMBLY	
		EDGE/ CORNER BREAKS	OUTSIDE MAX	DESIGNER BDC	08/22/91
			INSIDE MAX	CHECKED	
IBMCAD FILE	PHASEMRC.ASM			APPROVED	

QUANTITY: 1

ASSEMBLY NOTES

The following notes are provided to assist in the assembly of additional Separator devices. The specific notes should be used in conjunction with the assembly drawings which show the order and location of all major components. The general notes should be applied where applicable.

Specific Notes

- ASM101 The tray home position sensor (the optical interrupter module) should be wired before it is assembled onto the frame.
- ASM103 After assembling the drive screw onto the frame, the horizontal play between the drive screw and the drive screw bearing blocks should be measured. To eliminate this play bearing shims (part # 3088A233) should be placed between the angular contact bearing and the bearing block, as illustrated in the bearing block assembly drawing (part # ASM102). The maximum play should be no more the .002 inches.
- ASM104 When the tray home position indicator is mounted onto the tray, the indicator position should be adjusted such that the leg of the indicator is extended approximately 80 percent into the slot of the mounted home position sensor. The mounting holes of the home position indicator are large enough to allow some adjustment.
- ASM105 The drive screw and the shafts of the tray must be parallel. After mounting the tray drive to the frame, mount the "right tray bearing shaft" onto the frame. Now, adjust the drive screw and "right tray bearing shaft" as required. The "left tray bearing shaft" may now be easily adjusted to the mounted shafts via the adjustable pillow blocks.
- ASM107 The timing belt should be adjusted tight enough to prevent the belt from slipping. Do not stretch the belt.
- ASM108 Before assembling the scrap removal air cylinders, install the air cylinder return spring (part # 5168-008) in the gripper air cylinder (part # NAV3/4X2-P). This spring prevents the possibility of a collision between the gripper and the indexing tray in the event of no air pressure.
- ASM114 Before mounting the clamp punch assembly (part # ASM112) onto the punch bridge, place the compression springs (part # 9656K29) over the air cylinder tooling plate extensions.

ASM115 After mounting the punch bridge assembly to the frame, the lateral movement of the air cylinder/punch assembly must be adjusted such that the short punch end shear pushes directly on the blister-pack sealing seam when extended. This will prevent the blister-pack from hinging during the punching operation. The punch and clamp assembly should also be parallel to the slots in the tray.

Place a 1 by 2 inch rectangular piece of polyurethane foam 1/2 inch thick into the punch between the punch shears. This foam will prevent a toothbrush from traveling up into the punch and becoming stuck.

- The assembly drawings show a Punch device designed to punch out brush sets which are placed face-up on the serving tray. To punch out face-down brush sets the following additions should be implemented:

- Place the indexing tray side guide (part # 126A) in the groove down each side of the indexing tray. The side guide should be positioned such that the guide taper is facing the center of the tray.

- Slide the indexing tray end guide (part # 127A) onto the beginning and ending edges of the indexing tray. The end guide should be positioned such that the guide taper is facing the center of the tray.

- Bolt the end guides to the side guides with four 4-40NC-1/2" socket head bolts.

ASM204 For proper operation, the rodless air cylinder and the horizontal shaft must be adjusted parallel to each other when the mounting plate is vertical. Sliding the vertical support plate assembly to each end during this adjustment will ensure that the air cylinder and the shaft will be parallel.

ASM205 The timing belt should be adjusted tight enough to prevent the belt from slipping.

After assembling the vertical-horizontal motion/frame pre-assembly, rotate the belt such that the belt connector is 12 inches from the top of the mast. At this time, mount the counterweight on the belt directly across from the belt connector. The left counterweight should be placed on the outside of the belt loop and the right counterweight should be placed on the inside of the belt loop.

Plastic slides should be mounted to the sides and back of the counterweight to reduce friction and prevent rattling between the counterweight and the mast.

- ASM207 A thread sealant should be used to seal the threads of the vacuum cup assembly.
- ASM208 The short support guides of the lower support plate assembly should be replaced by the long support guides. The use of the long support guides should be implemented in order to guarantee the alignment of the brush set within the required tolerances.
- ASM209 To allow the lower support plate sufficient freedom to move relative to the upper support plate, coiled tubes should be used to connect the vacuum manifold to the vacuum cup fittings. Since short coiled tubes are not readily available, they may be constructed by coiling a 5/32 inch OD tube around a large bolt with the desired coil ID. After securing the tube to the bolt the assembly should be placed in an oven at approximately 250° F for 8-10 minutes. Remove the assembly from the oven and wait a minimum of two hours before removing the tube from the screw to permit sufficient cooling. Bends in the tubing may also be achieved in the described manner. The shape of the tubes on the prototype should be duplicated for each additional pick/place device.

A spring should be placed between the upper and lower support plates to transfer the required force from the stepping motor to the vacuum cups thus providing the proper seal for the vacuum.

A recoil tube and a recoil wire should be used to provide vacuum and electrical connections to the end effector. Using recoil tube and wire will prevent interference with the end effector operation.

- To accurately pick-up and place face-down brush sets, replace the support guides (part # 222 and 223) with the support stops (part #229A)

General Assembly Notes

- Lockwashers should be used on all fasteners to prevent fasteners from vibrating loose. Lockwashers were not shown on assembly drawings to simplify drawings.
- A light lubricant should be applied to the vertical and horizontal shafts as required.
- The stepping motor drivers must be directly mounted to the control panel. This will allow the control panel to act as a heat sink for the stepping motor driver.

- Circuit board covers (part # 270-672) must be ventilated with holes drilled on both the side and bottom surfaces, as defined by the mounting orientation of the cover.
- Use plug in connectors for electrical parts that are not mounted directly to the circuit board. This will aid in assembly maintenance, and reliability. Different types of plug in connectors or labeled connectors should be used to avoid errors during assembly.
- The 110 V power supply connection should be insulated to avoid the risk of an electrical shock.
- 1 1/8" diameter access holes should be drilled in the frame to aid in the assembly process.
- To provide a connection between the parallel port cable and the circuit, simply cut off the female connector (the end that contains the small holes) of the cable, strip back the insulation, and solder the individual leads as required. Please note that all parallel port pin leads are not color coded the same, therefore, it is important that a pin-color chart be made for each cable.

APPENDIX G

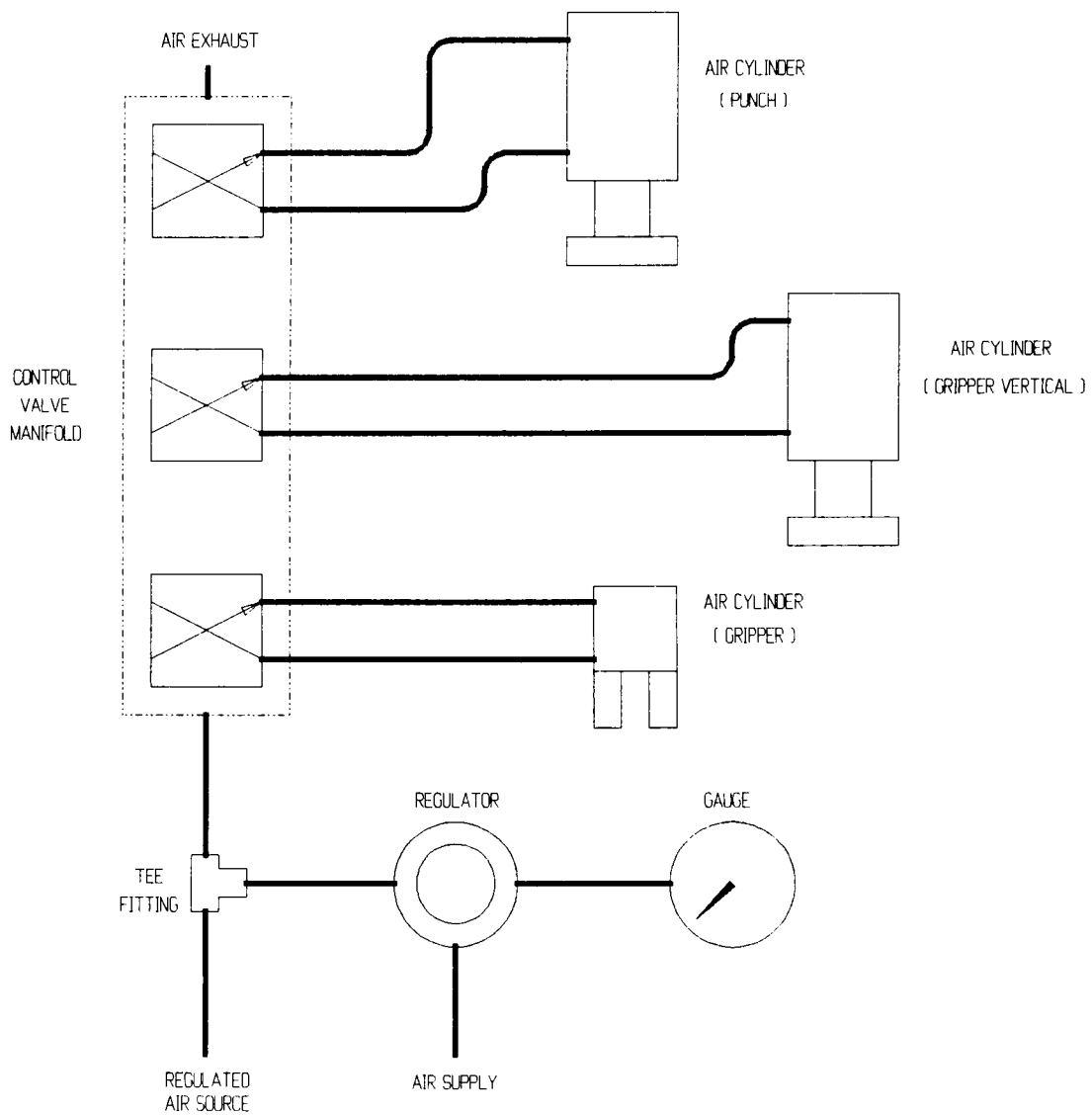
Pneumatic Circuits

PNEUMATIC CIRCUITS

The following schematics represent the pneumatic circuits of the Pick/Place and the Punch devices individually. Note that the available regulated air supply of Phase I may be used as the required regulated air supply of Phase II.

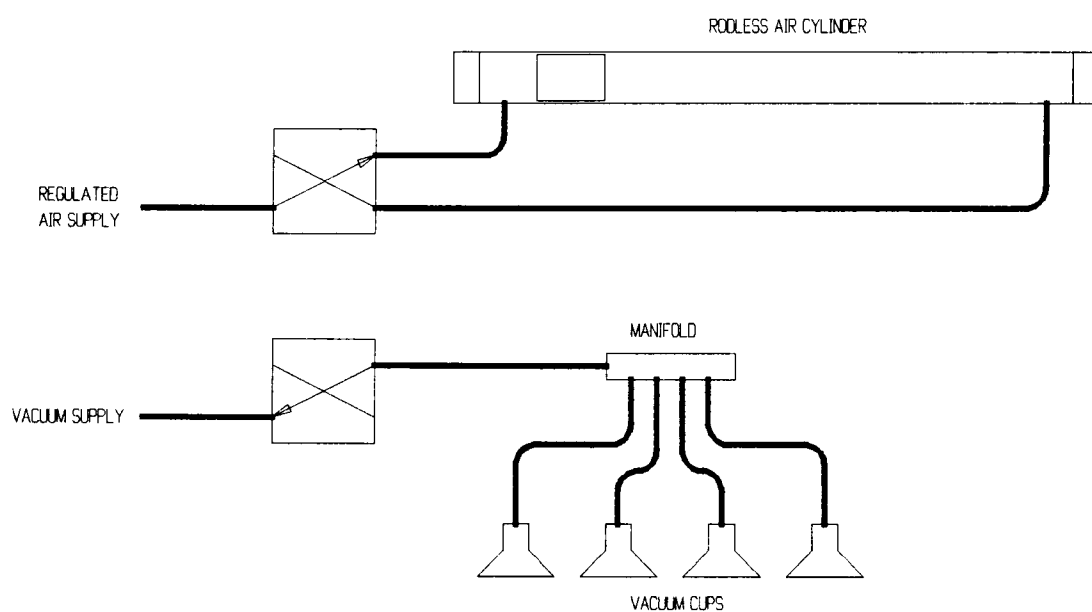
PNEUMATIC CIRCUIT

PUNCH DEVICE



PNEUMATIC CIRCUIT

PICK/PLACE DEVICE



APPENDIX H

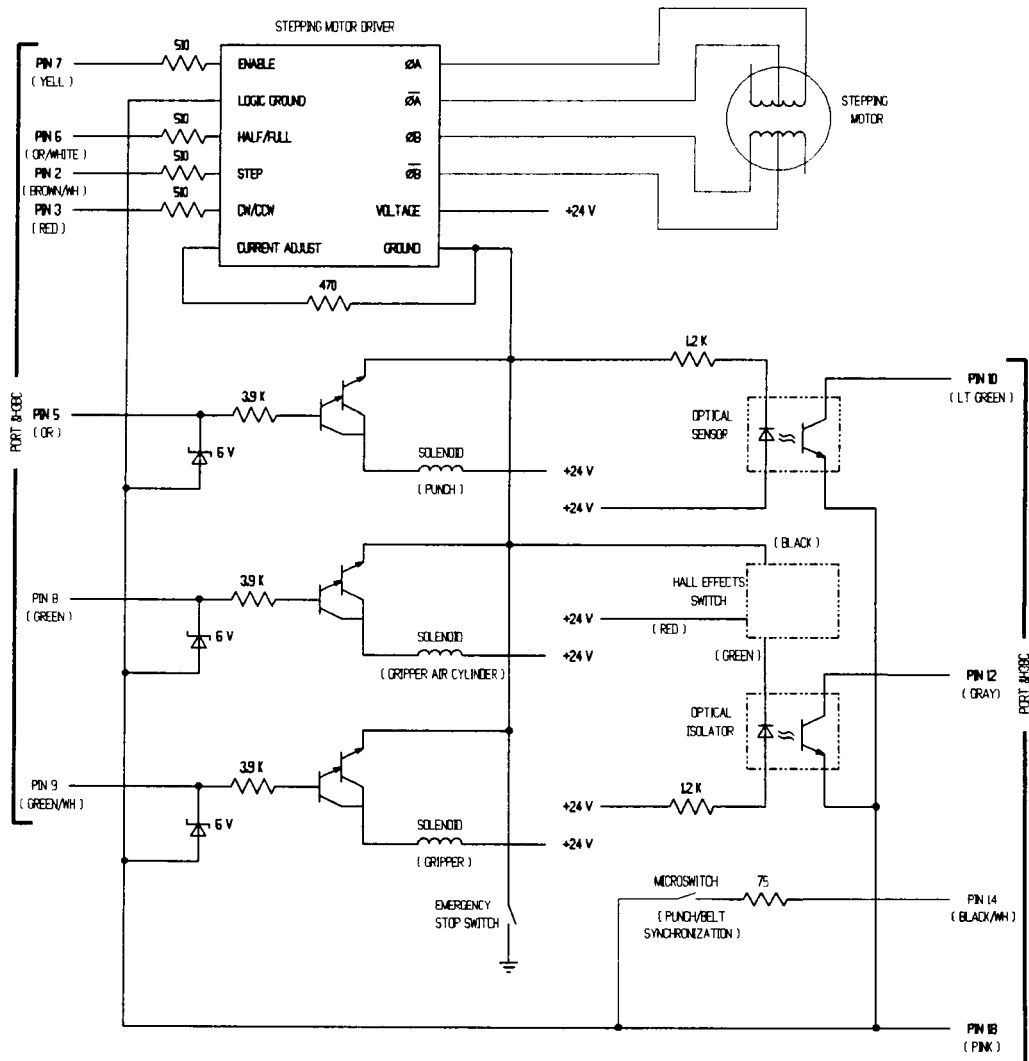
Electrical Circuits and Parallel Port Assignments

ELECTRICAL CIRCUITS AND PARALLEL PORT ASSIGNMENTS

The following schematics represent the electronic circuits of the Pick/Place and the Punch devices individually. Each schematic is supplemented by a parallel port assignment chart, which provides essential information of the connection between the electronic circuit and the parallel port of the computer.

ELECTRICAL CIRCUIT

PUNCH DEVICE



Parallel port assignments Punch Device

Parallel port pins

Output port 3BC

CONNECTION	GRIPPER	GRIPPER AIR CYLINDER	STEPPING MOTOR ENABLE	STEPPING MOTOR HALF/FUL	PUNCH AIR CYLINDER		STEPPING MOTOR DIRECTION	STEPPING MOTOR STEP
PIN	9	8	7	6	5	4	3	2
BIT	7	6	5	4	3	2	1	0
BIT VALUE	128	64	32	16	8	4	2	1

Input port 3BD

CONNECTION		TRAY HOME SENSOR	PUNCH HOME SENSOR					
PIN	11	10	12	13	15	-	-	-
BIT	7	6	5	4	3	2	1	0
BIT VALUE	128	64	32	16	8	4	2	1

Output port 3BE

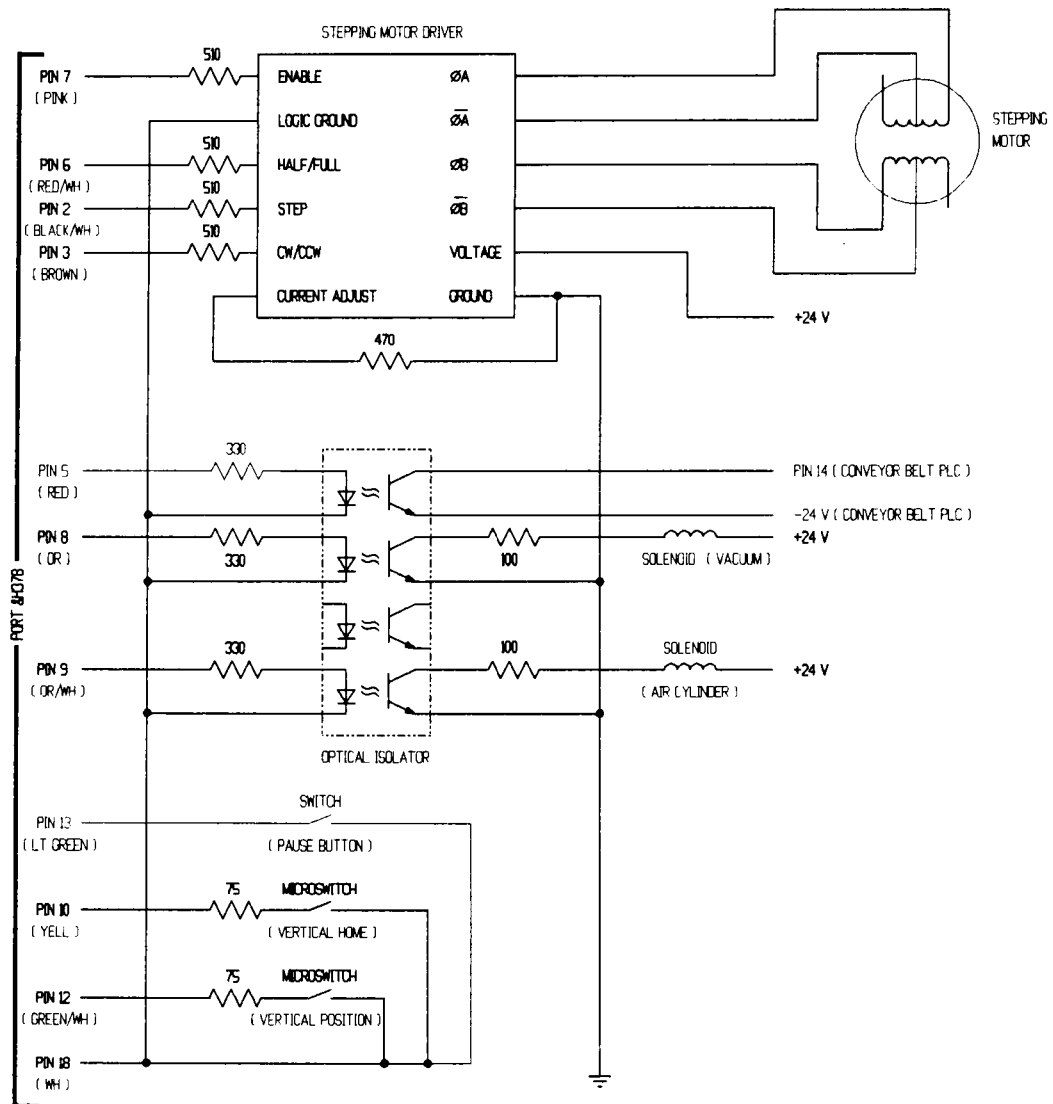
CONNECTION							PUNCH/BLT SYNC SWITCH	
PIN	-	-	-	-	17	16	14	1
BIT	-	-	-	4	3	2	1	0
BIT VALUE	-	-	-	16	8	4	2	1

Parallel port connector

PIN NO.	1	2	3	4	5	6	7	8	9
WIRE COLOR	BROWN	BROWN/W	RED	RED/W	ORANGE	ORANGE/W	YELLOW	GREEN	GREEN/W

PIN NO.	10	11	12	13	14	15	16	17	18-25
WIRE COLOR	LT GREEN	WHITE	GRAY	BLACK	BLACK/W	BLUE	BLUE/W	VIOLET	PINK

ELECTRICAL CIRCUIT PICK/PLACE DEVICE



Parallel port assignments
Pick/Place Device

Parallel port pins

Output port 378

CONNECTION	AIR CYLINDER	VACUUM SOURCE	STEPPING MOTOR ENABLE	STEPPING MOTOR HALF/FUL	CONVEYOR BELT CTRL LINE		STEPPING MOTOR DIRECTION	STEPPING MOTOR STEP
PIN	9	8	7	6	5	4	3	2
BIT	7	6	5	4	3	2	1	0
BIT VALUE	128	64	32	16	8	4	2	1

Input port 379

CONNECTION		END EFFECTOR HOME SWITCH	BRUSH SET SWITCH	PAUSE SWITCH				
PIN	11	10	12	13	15	-	-	-
BIT	7	6	5	4	3	2	1	0
BIT VALUE	128	64	32	16	8	4	2	1

Output port 37A

CONNECTION								
PIN	-	-	-	-	17	16	14	1
BIT	-	-	-	4	3	2	1	0
BIT VALUE	-	-	-	16	8	4	2	1

Parallel port connector

PIN NO.	1	2	3	4	5	6	7	8	9
WIRE COLOR	BLACK	BLACK/W	BROWN	BROWN/W	RED	RED/W	PINK	ORANGE	ORANGE/W

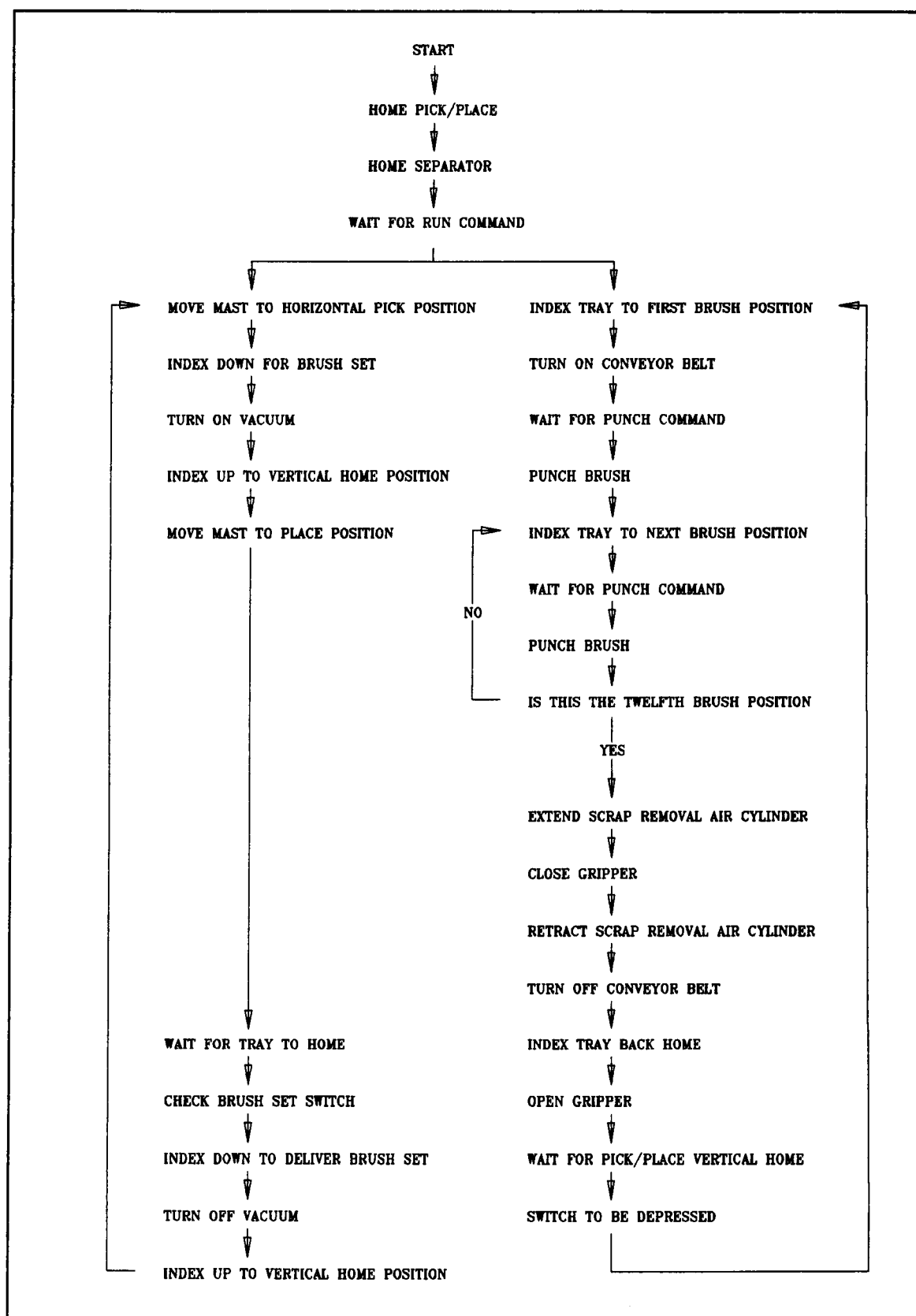
PIN NO.	10	11	12	13	14	15	16	17	18-25
WIRE COLOR	YELLOW	GREEN	GREEN/W	LT GREEN	BLUE	BLUE/W	VIOLET	GRAY	WHITE

APPENDIX I

Computer Program and Flowchart

COMPUTER PROGRAM AND FLOWCHART

A listing of the computer program follows the program flow-chart. The program is written in the programming language "C". The flow-chart was developed on a time line, therefore, a branch in the flow of the chart indicates operations that are performed simultaneously by the program. Providing these required simultaneous operations in the program involved incorporating a time sharing scheme between two individual programs.



Filename: PUNCH.C

```
#include <stdio.h>
#include <conio.h>
#include <math.h>
#include <dos.h>
#include "punch.h"

int home_tray(int *);
void move_home(int);
void init_run_pp(void);
void init_run_mp(void);
int error_handler(int);
void get_brushes(void);
void calc_ramp(void);
MODE_TYPE run_mp(MODE_TYPE);
MODE_TYPE run_pp(MODE_TYPE);
int place_brushes(int, int *);
void lift_arm(int *);
void menu_options(void);
int pause_control(void);

int max_speed = 1800;           /* max speed of tray */
int max_home_speed = 28000;     /* max speed of homing tray */
int first_steps = 1290;         /* no. steps home to first brush */
int mid_steps = 750;           /* no. steps between each brush */
int home_for_steps = 50;        /* no. steps forward b4 homing */
int place_steps = 390;          /* no. steps arm goes down to reach tray */
int mp_down_delay = 3500;        /* time to allow punch to go down */
int grip_close_delay = 4000;     /* time to allow gripper to go down */
int grip_up_delay = 4000;        /* time to allow gripper to close */
int grip_home_delay = 13000;     /* time to allow gripper to raise */
unsigned int mode_delay = 25;    /* speed delay */
unsigned int pp_step_delay = 40; /* speed of pick & place arm */
unsigned int pp_vac_wait = 5000; /* time delay to seal to brushes */
unsigned int slide_mast_time = 50000; /* time to move mast to opp. end */

int dly[RAMPSTEPS+1];           /* array of delays for ramping motor */
int error_cond;

#define MOVE_MAST_TIME 3000      /* time in ms for mast to move */

void punch_check() {
```

```

    /* wait till user presses a key and check again */
    while ((inportb(READPORT) & PUNCH_MASK) == PUNCH_DOWN) {
        printf("\nThe punch is in a down position. Please check for proper\n");
        printf("air pressure and press any key to try again.\n");
        getch();
    }
}

void my_delay(int time) {

    int i;

    for (i=0; i < time; i++);
}

void get_brushes() {

    MODE_TYPE ppmode = PP_DOWN;          /* start with picker in place */

    init_run_pp();
    while (ppmode != DONE) {
        ppmode = run_pp(ppmode);          /* pick up brushes */
        my_delay(2*mode_delay);           /* speed control */
    }
    if (error_cond == OK)                  /* check if got brushes */
        delay(MOVE_MAST_TIME);            /* then wait for mast to move */
}

/* function calc_ramp computes the acceleration ramp used to
 * move the stepping motors */
void calc_ramp() {

    float sqo,sqn,alpha,accel;
    int i;

    accel = 200;
    alpha = max_speed*sqrt(2.0/accel);
    sqo = 0.0;
    for (i = 0; i < RAMPSTEPS; i++) {
        sqn = sqrt(i+1);
        dly[i] = alpha/(sqo+sqn);          /* calculate ramp */
        sqo = sqn;
    }
}

```

```

/* function run operates the toothbrush extractor */
int run() {

    unsigned int return_steps;          /* total steps to return tray */
    MODE_TYPE mpmode;                  /* move & punch mode */
    MODE_TYPE ppmode;                  /* pick & place mode */

    return_steps = first_steps + (mid_steps*11);    /* total steps to return */

    if (home_tray(dly) != OK)           /* return tray to home position */
        return(RESET);
    lift_arm(dly);                       /* return arm to top */

    init_run_pp();                       /* init vars for pick & place */
    init_run_mp();                       /* init vars for move & punch */
    mpmode = FIRST_MOVE;                 /* set move & punch to first pos. */
    ppmode = HOME_MAST;                 /* move pick & place to pile */
    outportb(PICK_OUTPORT, LIFTER_DN_HI); /* move mast home, vacuum off */
    while (mpmode != DONE) {
        mpmode = run_mp(mpmode);        /* run move & punch machine */
        if (mpmode == PAUSE) {
            if (error_handler(USER_BREAK) == RESET) {
                return(RESET);
            } else {
                mpmode = MP_MOVE;        /* stay in last mode */
            }
        }
        my_delay(mode_delay);           /* delay between two modes */
        ppmode = run_pp(ppmode);        /* run pick & place machine */
    }

    /* go back to home */
    move_home(return_steps);            /* return tray home */

    outportb(WRITEPORT, GRIP_UP&GRIP_OPEN); /* drop scrap */

    while (error_cond != OK) {          /* try till we get it right */
        if (error_handler(error_cond) == RESET) /* print error message */
            return(RESET);
        get_brushes();                  /* pick up brushes */
    }

    if (place_brushes(place_steps,dly) == RESET) /* put brushes on tray */
        return(RESET);
}

```

```

    outportb(PICK_OUTPORT, LIFTER_UP_HIIMAST_MASK); /* turn off vacuum */
    lift_arm(dly);                                /* raise arm */

    return(RUN_AGAIN);
}

void main() {

    outportb(WRITEPORT, DISABLE); /* initialize port to raise air cyls */
    outportb(PICK_OUTPORT, LIFTER_UP_HI); outportb(PICK_OUTPORT);
                                /* Enable motor on pick & place */
    calc_ramp();                /* compute accel. ramp */
    lift_arm(dly);              /* move arm up */
    home_tray(dly);             /* move tray to home position */

    menu_options();             /* gives user control of program */

    printf("\nExiting program and disabling motor\n");
    outportb(WRITEPORT, DISABLE); /* disable punch motor */

}

```

Filename: PP.C

```
#include <dos.h>
#include "punch.h"

#define PP_EVEN_DLY    4    /* delay for run_pp() to execute in constant time
*/
#define DONE_DLY 6      /* same as PP_EVEN_DLY for when finished */
#define SQUASH_STEPS  20    /* no. steps to lower arm once sense brushes */
#define MAX_PP_DOWN  930    /* max no. steps to move arm down */
#define ARM_SPEED      25    /* speed of moving arm in placing brushes */

void my_delay(int);        /* prototype */

extern unsigned int pp_step_delay;
extern unsigned int slide_mast_time;
extern unsigned int pp_vac_wait;
extern int error_cond;

int miss_count;
unsigned int ppsteps;
unsigned int ppcount;

void init_run_pp() {
    ppcount = 0;
    error_cond = OK;
    ppsteps = 0;
    miss_count = 0;
}

/* raise pick & place arm to top */
void lift_arm(int *dly) {

    /* ensure that the motor is going in the right direction */
    outportb(PICK_OUTPORT, LIFTER_UP_HI|(inportb(PICK_OUTPORT)&0xDC));
    while ((inportb(PICK_INPORT) & PP_HOME_MASK) == PP_HOME_MASK) {
        outportb(PICK_OUTPORT, LIFTER_UP_HI);
        outportb(PICK_OUTPORT, LIFTER_UP_LO);
/*      outportb(PICK_OUTPORT, LIFTER_UP_HI|inportb(PICK_OUTPORT));
        outportb(PICK_OUTPORT, LIFTER_UP_HI^inportb(PICK_OUTPORT)); */
        my_delay(dly[2]*ARM_SPEED);
    }
}
```

```

/* place_brushes puts the brushes onto the tray */
int place_brushes(int place_steps,int *dly) {

    if ((inportb(PICK_INPORT) & TOUCH_MASK) == TOUCH_MASK) {
        /* here if not touching brushes */
        return(error_handler(DROP_BRUSH));
    }
    for (ppsteps = 0; ppsteps < place_steps; ppsteps++) {
        outportb(PICK_OUTPORT, MAST_MASK | VAC_MASK | LIFTER_DN_HI);
/* step down */
        outportb(PICK_OUTPORT, MAST_MASK | VAC_MASK | LIFTER_DN_LO);
/* vacuum on */
        my_delay(dly[2]*ARM_SPEED);
    }
    return(OK);
}

MODE_TYPE run_pp(MODE_TYPE mode) {

    switch(mode) {
        case HOME_MAST:
            if (ppcount > slide_mast_time) { /* then change modes */
                error_cond = OK; /* reset error flag */
                ppcount = 0; /* reset counter */
                miss_count = 0; /* reset miss counter */
                /* ensure that the motor is going down */
                outportb(PICK_OUTPORT,
LIFTER_DN_HI|(inportb(PICK_OUTPORT)&0xFC));
                ppsteps = 0; /* reset step counter */
                return(PP_DOWN); /* next mode */
            } else {
                ppcount++; /* incr. counter */
                my_delay(PP_EVEN_DLY-1); /* even out speed */
                return(HOME_MAST); /* stay in this mode */
            }
        case PP_DOWN:
            if (ppcount > pp_step_delay) {
                if ((inportb(PICK_INPORT) & TOUCH_MASK) == TOUCH_MASK) {
                    /* here if not touching brushes */
                    /* step motor */
                    outportb(PICK_OUTPORT, LIFTER_DN_HI|inportb(PICK_OUTPORT));
                    outportb(PICK_OUTPORT,
LIFTER_DN_LO|(inportb(PICK_OUTPORT)&0xFC));
                    if (ppsteps++ > MAX_PP_DOWN) { /* no brushes */

```



```

        error_cond = NO_BRUSH;                /* set error flag */
        return(PP_UP);                        /* lift arm to top */
    }
    ppcount = 0;
} else {
    ppcount = 0;
    ppsteps = 0;
    return(PP_SQUASH);                        /* change to next mode */
}
} else {
    my_delay(PP_EVEN_DLY);                    /* even out speed */
    ppcount++;                                /* incr. counter */
}
return(PP_DOWN);                            /* stay in this mode */
case PP_SQUASH:
    if (ppcount > pp_step_delay) {
        if (ppsteps < SQUASH_STEPS) {
            /* step down, vacuum on */
            outportb(PICK_OUTPORT, VAC_MASK |
LIFTER_DN_HI(inportb(PICK_OUTPORT)));
            outportb(PICK_OUTPORT,
LIFTER_DN_LO((inportb(PICK_OUTPORT)&0xFC)));
            ppcount = 0;
            ppsteps++;
        } else {
            ppcount = 0;
            ppsteps = 0;
            return(PP_WAIT);                  /* change to next mode */
        }
    } else {
        my_delay(PP_EVEN_DLY);                /* even out speed */
        ppcount++;                            /* incr. counter */
    }
    return(PP_SQUASH);                        /* stay in this mode */
case PP_WAIT:
    /* allow vacuum time to
    seal on brushes */
    if (ppcount > pp_vac_wait) {              /* then change modes */
        ppcount = 0;                          /* reset counter */
        ppsteps = 0;
        /* ensure that the motor is going up */
        outportb(PICK_OUTPORT,
LIFTER_UP_HI((inportb(PICK_OUTPORT)&0xFC)));
        return(PP_PART_UP);                  /* next mode */
    } else {

```

```

        ppcount++;
        my_delay(PP_EVEN_DLY-1);
        return(PP_WAIT);
    }
    case PP_PART_UP:
        if (ppcount > pp_step_delay) {
            if (ppsteps < (SQUASH_STEPS+SQUASH_STEPS)) {
                /* step up, vacuum on */
                outputb(PICK_OUTPORT, VAC_MASK |
LIFTER_UP_HIinportb(PICK_OUTPORT));
                outputb(PICK_OUTPORT,
LIFTER_UP_LO(inportb(PICK_OUTPORT)&0xFC));
                ppcount = 0;
                ppsteps++;
            } else {
                ppcount = 0;
                ppsteps = 0;
                miss_count++;
                /* if not holding brushes & have tried less than 3 times */
                if (((inportb(PICK_INPORT) & TOUCH_MASK) == TOUCH_MASK)
&&
                    (miss_count < 3)) {
                    /* ensure that the motor is going down */
                    outputb(PICK_OUTPORT,
LIFTER_DN_HI(inportb(PICK_OUTPORT)&0xFC));
                    return(PP_DOWN);
                }
                else
                    return(PP_UP);
            }
        } else {
            my_delay(PP_EVEN_DLY);
            ppcount++;
        }
        return(PP_PART_UP);
    case PP_UP:
        if (ppcount > pp_step_delay) {
            if ((inportb(PICK_INPORT) & PP_HOME_MASK) == PP_HOME_MASK)
{
                /* step up, vacuum on */
                outputb(PICK_OUTPORT, VAC_MASK |
LIFTER_UP_HIinportb(PICK_OUTPORT));
                outputb(PICK_OUTPORT,
LIFTER_UP_LO(inportb(PICK_OUTPORT)&0xFC));

```

```

        ppcount = 0;
    } else {
        ppcount = 0;
        if (miss_count >= 3) {
            error_cond = MISS_BRUSH;    /* couldn't get brush */
        }
        if (error_cond == OK) {
            outportb(PICK_OUTPORT, VAC_MASK | MAST_MASK |
inportb(PICK_OUTPORT)); /* move mast */
        }
        return(DONE);                /* finished */
    }
} else {
    my_delay(PP_EVEN_DLY);            /* even out speed */
    ppcount++;                        /* incr. counter */
}
return(PP_UP);                       /* stay in this mode */
case MOVE_MAST:
    if (ppcount > slide_mast_time) { /* then change modes */
        ppcount = 0;                /* reset counter */
        return(DONE);                /* next mode */
    } else {
        ppcount++;                  /* incr. counter */
        my_delay(PP_EVEN_DLY-1);    /* even out speed */
        return(MOVE_MAST);          /* stay in this mode */
    }
default:
    my_delay(DONE_DLY);              /* even out speeds */
    return(DONE);                    /* wait for move & punch */
}
}

```

Filename: MP.C

```
#include <dos.h>
#include <math.h>
#include <conio.h>
#include "punch.h"

#define MP_EVEN_DLY 5 /* delay for run_mp() to execute in constant time */
#define FIRST_DN_DELAY 75 /* extra time for punching first brush */

extern int max_home_speed;
extern int mid_steps;
extern int first_steps;
extern int mid_steps;
extern int home_for_steps;
extern int mp_down_delay;
extern int grip_up_delay;
extern int grip_close_delay;
extern int grip_home_delay;
extern int dly[RAMPSTEPS+1];

unsigned int punch_num,ramp,mpcount,mpsteps;

void punch_check(void);
void my_delay(int);

/* function init_run_mp() initializes the variables needed to run the
 * move & punch part of the machine.
 */
void init_run_mp() {

    punch_num = 0;
    ramp = 0;
    mpcount = 0;
    mpsteps = 0;
}

void mv_tray_slow(int steps, int direction, int *dly) {

    int step_count;
    unsigned char datahi,datalo;

    if (direction == CW) {
        datahi = MOT_HI;
```

```

    datalo = MOT_LO;
} else {
    datahi = REV_MOT_HI;
    datalo = REV_MOT_LO;
}

punch_check();    /* check if punch is in the down position */

for (step_count = 0; step_count < steps; step_count++) {
    outportb(WRITEPORT, datahi(inportb(WRITEPORT)&GRIP_MASK));
    outportb(WRITEPORT, datalo(inportb(WRITEPORT)&GRIP_MASK));
    my_delay(dly[2]*30);          /* use low constant velocity */
}
}

/* function move_home moves the tray in the home direction "steps" number
* of steps */
void move_home(int steps) {

    int ramp_count = 0;
    int step_count,i;
    float accel, alpha, sqo, sqn;      /* variables used to calc ramp */
    int delay[RAMPSTEPS+1];

    accel = 200;
    alpha = max_home_speed*sqrt(2.0/accel);
    sqo = 0.0;
    for (i = 0; i < RAMPSTEPS; i++) {
        sqn = sqrt(i+1);
        delay[i] = alpha/(sqo+sqn);      /* calculate ramp */
        sqo = sqn;
    }

    /* this is the acceleration, const v, and deceleration loop */
    for (step_count = 0; step_count < steps; step_count++) {
        outportb(WRITEPORT, REV_MOT_HI|GRIP_CLOSE);    /* step motor CCW
*/
        outportb(WRITEPORT, REV_MOT_LO|GRIP_CLOSE);
        if (pause_press() != 0) {                /* if user hit a key */
            return;                                /* and quit */
        }
        my_delay(delay[ramp_count]);              /* use ramp */
        my_delay(delay[ramp_count]);              /* use ramp */
        my_delay(delay[ramp_count]);              /* use ramp */
    }
}

```

```

    ramp_count++;
    if (step_count > steps - RAMPSTEPS)           /* if near end */
        ramp_count = steps - step_count;         /* decelerate */
    else if (ramp_count > RAMPSTEPS-1)             /* if in middle */
        ramp_count = RAMPSTEPS-1;                 /* constant speed */
}
}

int home_tray(int *dly) {

    int step_count = 0;

    outportb(WRITEPORT, 0);                       /* enable motor */
    outportb(PICK_OUTPORT,(CONVEYOR_OFF & inportb(PICK_OUTPORT)));
    punch_check();    /* check if punch is in the down position */

    /* move forward to make sure pointer not behind detector */
    while (((inportb(READPORT) & HOME_MASK) == 0) && (step_count <
home_for_steps)) {
        if (pause_press() != 0) {                 /* if user hit a key */
            return(USER_BREAK);                   /* and quit */
        }
        mv_tray_slow(10,CW,dly);
        step_count++;
    }

    mv_tray_slow(20,CW,dly);    /* move away from sensor */
    my_delay(100);

    /* move backward till home position found */
    while (((inportb(READPORT) & HOME_MASK) == 0x00) {
        mv_tray_slow(2,CCW,dly);
        if (pause_press() != 0) {                 /* if user hit a key */
            return(USER_BREAK);                   /* and quit */
        }
    }
    mv_tray_slow(1,CCW,dly);    /* move an extra step into the sensor */
    return(OK);
}

```

```

MODE_TYPE run_mp(MODE_TYPE mode) {

```

```

    switch (mode) {

```

```

case FIRST_MOVE:
    if (mpsteps < first_steps) {
        if (mpcount >= dly[ramp]) {
            ramp++;
            if (mpsteps > first_steps - RAMPSTEPS) /* if near end */
                ramp = first_steps - mpsteps; /* decelerate */
            else if (ramp > RAMPSTEPS - 1) /* if in middle */
                ramp = RAMPSTEPS-1; /* constant speed */
            outportb(WRITEPORT, MOT_HI); /* step motor CW */
            outportb(WRITEPORT, MOT_LO);
            mpcount = 0; /* reset counter */
            mpsteps++; /* incr. no steps */
        } else {
            my_delay(MP_EVEN_DLY); /* even out speed */
            mpcount++; /* incr. delay counter */
        }
        return(FIRST_MOVE); /* stay in this mode */
    } else { /* done moving tray */
        if (mpcount > FIRST_DN_DELAY) { /* additional time */
            mpsteps = 0;
            mpcount = 0;
            ramp = 0;
            return(MP_DOWN); /* next mode */
        }
        else {
            if (pause_press() != 0) { /* if user hit a key */
                return(PAUSE);
            }
            /* turn on conveyor belt */
            outportb(PICK_OUTPORT, (inportb(PICK_OUTPORT) |
CONVEYOR_MASK));
            while ((inportb(WRITEPORT2) & SYNCHRO_MASK) !=
SYNCHRO_MASK)
                ; /* wait till belt is ready */
            outportb(WRITEPORT, PUNCH_DN); /* move punch down */
            mpcount++;
            return(FIRST_MOVE);
        }
    }
}

case MP_DOWN:
    if (mpcount > mp_down_delay) { /* switch mode */
        if (punch_num == 11) { /* if last punch */
            if (mpcount > grip_close_delay) {

```

```

        outputb(WRITEPORT,GRIP_DN|GRIP_CLOSE);      /* close
gripper and raise punch */
        mpcount = 0;                                /* reset delay count */
        return(MP_GRIP);                            /* change modes */
    }
    else {
        mpcount++;
        return(MP_DOWN);                            /* stay in this mode */
    }
}
else {
    outputb(WRITEPORT, PUNCH_UP);                    /* move punch up */
    mpcount = 0;                                    /* reset delay count */
    return(MP_UP);                                  /* next mode */
}
} else {
    mpcount++;                                       /* incr. delay counter */
    my_delay(MP_EVEN_DLY);                          /* even out speed */
    return(MP_DOWN);                              /* stay in this mode */
}
case MP_UP:
    /* wait till punch is in the up position */
    if ((inportb(READPORT) & PUNCH_MASK) != PUNCH_DOWN) {
        punch_num++;                               /* next punch */
        return(MP_MOVE);                           /* next mode */
    } else {
        return(MP_UP);                             /* stay in this mode */
    }
}
case MP_MOVE:
    if (mpsteps < mid_steps) {
        if (mpcount >= dly[ramp]) {
            ramp++;
            if (mpsteps > mid_steps - RAMPSTEPS)    /* if near end */
                ramp = mid_steps - mpsteps;        /* decelerate */
            else if (ramp > RAMPSTEPS - 1)          /* if in middle */
                ramp = RAMPSTEPS-1;                /* constant speed */
            outputb(WRITEPORT, MOT_HI);             /* step motor CW */
            outputb(WRITEPORT, MOT_LO);
            mpcount = 0;                            /* reset counter */
            mpsteps++;                              /* incr. no steps */
        } else {
            my_delay(MP_EVEN_DLY);                  /* even out speed */
            mpcount++;                              /* incr. delay counter */
        }
    }
}

```



```

        return(MP_MOVE);                                /* stay in this mode */
    } else {                                             /* change modes */
        if (pause_press() != 0) {                       /* if user hit a key */
            return(PAUSE);
        }
        mpsteps = 0;                                    /* reset counters */
        mpcount = 0;
        ramp = 0;
        while ((inportb(WRITEPORT2) & SYNCHRO_MASK) !=
SYNCHRO_MASK)
            ; /* wait till belt is ready */
        if (punch_num == 11)
            outportb(WRITEPORT, GRIP_DN|PUNCH_DN);      /* lower gripper and
punch */
        else
            outportb(WRITEPORT, PUNCH_DN);              /* move punch down
*/
        return(MP_DOWN);                                /* next mode */
    }
case MP_GRIP:
    if (mpcount > grip_up_delay) { /* if time to lift gripper */
        outportb(WRITEPORT, GRIP_UP|GRIP_CLOSE);      /* move punch up */
        mpcount++;
        if ((inportb(READPORT) & PUNCH_MASK) != PUNCH_DOWN) {
            mpcount = 0;
            /* turn off conveyor belt */
            outportb(PICK_OUTPORT, (inportb(PICK_OUTPORT) &
CONVEYOR_OFF));
            return(DONE);                                /* finished */
        } else
            return(MP_GRIP);                            /* stay in this mode */
    } else {
        mpcount++;
        my_delay(MP_EVEN_DLY);                          /* even out speed */
        return(MP_GRIP);                                /* stay in this mode */
    }
}
return(DONE);
}

```

Filename: USER.C

```
#include <ctype.h> /* type conversion, etc. */
#include <conio.h> /* console control */
#include <stdio.h>
#include <stdlib.h>
#include "punch.h"

extern max_speed;
extern max_home_speed;
extern first_steps;
extern mid_steps;
extern home_for_steps;
extern mp_down_delay;
extern grip_close_delay;
extern grip_up_delay;
extern grip_home_delay;
extern unsigned int mode_delay;
extern unsigned int pp_step_delay;
extern unsigned int slide_mast_time;

/* function pause_press returns a zero value if the pause switch is
 * not depressed, else returns a "1" */
int pause_press() {

    if ((inportb(PICK_INPORT) & PAUSE_MASK) == PAUSE_MASK)
        return(0);
    else
        return(1);

}

void run_it() {

    clrscr();
    printf("Press remote pause button to stop\n\n");
    printf("Running...");

    while (run() != RESET) {
        clrscr();
        printf("Press remote pause button to stop\n\n");
        printf("Running...");
    }
}
```

```

    }
}

int error_handler(int error_cond) {

    unsigned int port_state;
    int user_feedback;

    port_state = inportb(PICK_OUTPORT); /* read present state of port */
    outportb(PICK_OUTPORT,port_state & CONVEYOR_OFF); /* turns off conveyor
*/

    clrscr();
    printf("\n\n*****\n\n");

    switch (error_cond) {
        case MISS_BRUSH:
            printf("\nCould not pick up brush set. \n\nPlease check to ensure ");
            printf("the vacuum pump is on \nand/or the brushes are oriented ");
            printf("correctly.");
            break;
        case NO_BRUSH:
            printf("\nNo brushes on serving tray. \n\nPlease restock brushes.");
            break;
        case DROP_BRUSH:
            printf("\nCheck for dropped brush set.");
            printf("\n\nPlace dropped set on tray.");
            break;
        case USER_BREAK:
            printf("\nUser has stopped program. ");
    }
    user_feedback = pause_control();
    outportb(PICK_OUTPORT,port_state); /* restore state of port */
    return(user_feedback);
}

int pause_control() {

    char c;

    if (pause_press() == 1) {
        printf("\n\nRelease the pause button and then press 'C' to continue");
        printf("\n or 'R' to reset.");
    }
}

```

```

    } else
        printf("\n\nPress 'C' to continue or 'R' to reset.");
    while (pause_press() != 0)
        ; /* make sure the pause button is released */
    while (kbhit() == 0)
        ; /* wait till a key is pressed */
    c = getch(); /* retrieve the character */
    switch (c) {
        case 'c':
        case 'C':
            printf("\n\nOperation continued...");
            return(OK);
        case 'r':
        case 'R':
            printf("\nResetting...");
            return(RESET);
        default:
            return(pause_control());
    }
}

/* function print_options clears the screen and prints the options for
 * the main menu.
 */
void print_options() {
    clrscr();
    printf("      Toothbrush Extractor Controller\n\n");
    printf("Press: \n");
    printf("  %c to change paramaters \n", CHANGE_OPT);
    printf("  %c to list parameters \n", LIST_OPT);
    printf("  %c to run extractor \n", RUN_OPT);
    printf("  %c to quit \n", EXIT_OPT);
    printf("\nSelection: ");
}

/* Function update interprets the user input for changing a variable and
 * returns the appropriate value. If the user enters a new value, then
 * update returns that value. If the user does not enter a value by
 * just pressing the enter key, then update returns the old value which
 * is variable "old_var"
 */
int update(int old_var) {

```

```

char buffer[6];
int new_var;
char c;
int i;

for (c = getchar(), i = 0; c != '\n' && i < 6; c = getchar(), i++) {
    buffer[i] = c;
}
buffer[i++] = '\0';
if (buffer[0] == '\0') {          /* if nothing was entered */
    new_var = old_var;           /* return same */
}
else                             /* else something was entered */
    new_var = atoi(buffer);
return(new_var);
}

/* function change_params prints a brief description of each variable
 * and its current value. change_params calls update to allow the user
 * to optionally change the value of the variable.
 */
void change_params(){
    printf("\n\n");
    printf("\nChanging parameters...(defaults in square brackets)\n\n");
    printf("Maximum speed for tray [%d]: ", max_speed);
    max_speed = update(max_speed);
    printf("Maximum speed for homing tray [%d]: ", max_home_speed);
    max_home_speed = update(max_home_speed);
    printf("Overall speed parameter [%u]: ",mode_delay);
    mode_delay = update(mode_delay);
    printf("Number of steps to go forward before homing [%d]: ",home_for_steps);
    home_for_steps = update(home_for_steps);
    printf("Number of steps between home & first brush [%d]: ",first_steps);
    first_steps = update(first_steps);
    printf("Number of steps between each brush [%d]: ",mid_steps);
    mid_steps = update(mid_steps);
    printf("Time to stop tray for punch down [%d]: ",mp_down_delay);
    mp_down_delay = update(mp_down_delay);
    printf("Speed of arm moving up & down on pick & place [%u]: ",pp_step_delay);
    pp_step_delay = update(pp_step_delay);
    printf("Time of mast to move left & right [%u]: ",slide_mast_time);
    slide_mast_time = update(slide_mast_time);
    printf("Time after lowering gripper before closing [%d]: ",grip_close_delay);

```

```

grip_close_delay = update(grip_close_delay);
printf("Time after closing gripper before raising [%d]: ",grip_up_delay);
grip_up_delay = update(grip_up_delay);
printf("Time after raising gripper before homing tray [%d]: ",grip_home_delay);
grip_home_delay = update(grip_home_delay);

}

/* function list_params prints a brief description of each variable
 * and its current value. It holds the screen until a key is pressed
 */
void list_params(){
    printf("\n\n");
    printf("The presently selected variables are:\n\n");
    printf("Maximum speed for tray is %d\n", max_speed);
    printf("Maximum speed for homing tray is %d\n", max_home_speed);
    printf("Overall speed parameter is %d\n",mode_delay);
    printf("Number of steps to go forward before homing is %d\n",home_for_steps);
    printf("Number of steps between home & first brush is %d\n",first_steps);
    printf("Number of steps between each brush %d\n",mid_steps);
    printf("Time to stop tray before punch down is %d\n",mp_down_delay);
    printf("Speed of arm moving up & down on pick & place is %d\n",pp_step_delay);
    printf("Time of mast to move left & right is %d\n",slide_mast_time);
    printf("Time after closing gripper before raising is %d\n",grip_up_delay);
    printf("Time after raising gripper before homing tray is %d\n",grip_home_delay);
    printf("\npress any key to continue...");
    getch();
}

/* function menu_options calls print_options to print the main menu.
 * menu_options then reads in the user input and calls the appropriate
 * function. menu_options is exited upon hitting EXIT_OPT key. If an
 * inappropriate key is hit, nothing happens and the function waits
 * for a new key to be hit.
 */
void menu_options() {
    int c;
    int done = FALSE;

    print_options();
    while (done == FALSE) {
        for (c = getch(); isdigit(c) == FALSE; c = getch());
        switch (c)

```

```

{
case CHANGE_OPT : /* allow user to change parameters */
    clrscr();
    change_params();
    print_options();
    break;
case LIST_OPT :      /* list the parameters to screen */
    clrscr();
    list_params();
    print_options();
    break;
case RUN_OPT :        /* start the machine */
    run_it();
    print_options();
    break;
case EXIT_OPT :       /* this breaks the while loop */
    done = TRUE;
default :             /* nothing happens */
    break;
}
}
}

```

Filename: PUNCH.H

```
#define READPORT      0x3bd      /* 3bd port to read in from detectors */
#define WRITEPORT     0x3bc /* 3bc port to control stepper motors */
#define WRITEPORT2    0x3be /* third output port for move & punch */
#define PICK_INPORT   0x379 /* input port for pick/place device */
#define PICK_OUTPORT  0x378 /* ouput port for pick/place device */
#define LIFTER_DN_HI   0x13 /* step to move lifter down */
#define LIFTER_DN_LO   0x12 /* step to move lifter down */
#define LIFTER_UP_HI   0x11 /* hi bit for raising arm */
#define LIFTER_UP_LO   0x10 /* lo bit for raising arm */
#define MOT_HI         0x11 /* hi bit for CW direction */
#define MOT_LO         0x10 /* lo bit for CW direction */
#define REV_MOT_HI     0x13 /* hi bit for CCW direction */
#define REV_MOT_LO     0x12 /* lo bit for CCW direction */
#define GRIP_MASK      0xC0 /* mask out gripper bits */
#define PUNCH_DOWN     0x20 /* the punch is in the down position */
#define PUNCH_MASK     0x20 /* bit 5 is the punch detector */
#define PUNCH_DN       0x18 /* byte to lower punch */
#define PUNCH_UP       0x10 /* byte to raise punch */
#define PAUSE_MASK     0x10 /* bit 4 is the external pause switch */
#define CONVEYOR_MASK  0x08 /* bit 3 is the conveyor belt control line */
#define CONVEYOR_OFF   0xF7 /* bit 3 is the conveyor belt control line */
#define SYNCHRO_MASK   0x02 /* bit 1 tells when to punch brush */
#define TOUCH_MASK     0x20 /* bit 5 is the switch that touches */
#define PP_HOME_MASK   0x40 /* bit 4 is the homing switch for PP */
#define MAST_MASK      0x80 /* bit 7 moves the mast */
#define VAC_MASK       0x40 /* bit 6 turns on the vacuum */
#define GRIP_DN        0x40 /* bit 6 one to lower gripper */
#define GRIP_UP        0x00 /* bit 6 zero to raise gripper */
#define GRIP_CLOSE     0x80 /* bit 7 zero to close gripper */
#define GRIP_OPEN      0x00 /* bit 7 zero to lower gripper */

#define HOME_MASK      0x40 /* Masks out all bits except 6 */
#define DISABLE        0x20 /* Disables motors to reduce heat */
#define RAMPSTEPS      100 /* Number of ramp steps for motor */

#define CW             1 /* Clockwise */
#define CCW            0 /* Counter-Clockwise */

#define ON             1
#define OFF            0
```



```
#define TRUE      1
#define FALSE    0
```

```
#define CHANGE_OPT  '1'
#define LIST_OPT    '2'
#define RUN_OPT     '3'
#define EXIT_OPT    '0'
```

```
typedef int MODE_TYPE;
```

```
#define FIRST_MOVE  0
#define MP_DOWN     1
#define MP_UP       2
#define MP_MOVE     3
#define MP_HOME     4
#define DONE        5
#define MP_GRIP     6
#define RESET       7
#define PAUSE       8
#define MOVE_MAST   10
#define HOME_MAST   11
#define PP_DOWN     12
#define PP_UP       13
#define PP_SQUASH   14
#define PP_WAIT     15
#define PP_PART_UP  16
```

```
#define OK          0
#define MISS_BRUSH  1
#define NO_BRUSH    2
#define DROP_BRUSH  3
#define USER_BREAK  4
```

```
#define RUN_AGAIN   1
```

APPENDIX J

Start-up and Shut-Down Procedures

START-UP AND SHUT-DOWN PROCEDURES

Follow the applicable procedure for the initial start-up or the shut-down of the Separator. Following the procedures will ensure that the stepping motor drivers are correctly initialized and may prevent hardware damage.

Start-up Procedure

1. With the power to the Separator off and the air pressure relieved, turn on the computer.
2. After the computer is activated, turn on the power to the Separator.
3. Once the Separator is initialized, adjust the air pressure as required.

Shut-down Procedure

1. Relieve the pressure to the Separator.
2. Turn off the power to the Separator.
3. Turn off the computer.

APPENDIX K

Cost Records

COST RECORDS

The cost records itemize the cost of the purchased and the manufactured parts for both the Punch and the Pick/place devices. The cost summary shows the total cost of the Separator, including the assembly cost and the cost of the computer controller.

COST RECORD, PURCHASED PARTS
PUNCH DEVICE

<u>PART NO.</u>	<u>MANUFACTURER</u>	<u>NAME/DESCRIPTION</u>	<u>QTY</u> <u>REQ'D</u>	<u>UNIT</u> <u>COST</u>	<u>EXTENSION</u>
04606-0006	SCHRADER BLLWS	3/8" PIPE PNEUMATIC EXH. MUFFLER	1	\$1.50	\$1.50
08DU06	GARLOCK BEARINGS	BUSHINGS	2	\$1.82	\$3.64
10250T5	CUTLER-HAMMER	SWITCH CONTACT BLOCK	1	\$19.09	\$19.09
10250T51	CUTLER-HAMMER	PUSH/PULL SWITCH OPERATOR	1	\$5.72	\$5.72
10250TC53	CUTLER-HAMMER	EMERGENCY SWITCH LENS	1	\$2.67	\$2.67
130X037	GATES	TIMING BELT	1	\$4.16	\$4.16
20806-3	ALKON	3 STATION CONTROL VALVE MANIFOLD	1	\$38.60	\$38.60
270-627	RADIO SHACK	ELECTRICAL CIRCUIT BOX	1	\$2.69	\$2.69
276-168	RADIO SHACK	CIRCUIT BOARD	1	\$2.00	\$2.00
2-40R2-24/DC	ALKON	4 WAY CONTROL VALVES	3	\$50.90	\$152.70
3088A233	McMASTER-CARR	SHAFT SHIM	10	\$0.24	\$2.40
34D106S	ANAHEIM AUTOMAT	SIZE 34 STEPPING MOTOR	1	\$130.00	\$130.00
3/4" DIA X 42"	THOMSON	CLASS "L" SHAFTING	2	\$42.26	\$84.52
5168-008	PHD	AIR CYLINDER RETURN SPRING	1	\$5.00	\$5.00
5966K16	NOOK INDUSTRIES	BALL NUT FOR 5/8" DIA SCREW	1	\$18.71	\$18.71
5966K999	NOOK INDUSTRIES	5/8" DIA DRIVE SCREW X 28" LONG	1	\$27.44	\$27.44
6F3-14DF037	STOCK DRIVE PROD	1/5" PTCH X 14 GRVE PULL	1	\$4.21	\$4.21
6Z3-28DF03712	STOCK DRIVE PROD	1/5" PTCH X 28 GRVE PULL	1	\$3.28	\$3.28
7765-56-11	LEGRIS	PNEUMATIC FLOW CONTROL VALVE	2	\$13.58	\$27.16
8410-01-001	PHD	GRIPPER	1	\$137.65	\$137.65
9656K29	McMASTER-CARR	CLAMP SPRING	2	\$0.50	\$1.00
AWHE	COMPACT AIR PROD	AIR CYLINDER PISTON POSITION SNSR	1	\$27.00	\$27.00
E10	CONSOLIDATED	ANGULAR CONTACT BEARING	2	\$12.24	\$24.48
GC22X2BTP	COMPACT AIR PROD	NON-ROTATING AIR CYLINDER	1	\$174.50	\$174.50
H21A1GE	HARRIS	OPTICAL INTERRUPT. MOD. (HOME SNSR)	1	\$2.68	\$2.68

**COST RECORD, PURCHASED PARTS
PUNCH DEVICE**

<u>PART NO.</u>	<u>MANUFACTURER</u>	<u>NAME/DESCRIPTION</u>	<u>QTY REQ'D</u>	<u>UNIT COST</u>	<u>EXTENSION</u>
IB463	IMS	STEPPING MOTOR DRIVER	1	\$135.50	\$135.50
NAV3/4X2-P	PHD	POWER SLIDE (NON-ROTATING AIR CYL)	1	\$124.25	\$124.25
PS2502-4NEC	NEC	ELECTRONIC OPTICAL ISOLATOR	1	\$2.34	\$2.34
RS232 M/F	EASYCOM	PARALLEL PORT CABLE, ALL LINES EXT.	1	\$10.95	\$10.95
SB12	THOMSON	3/4" SHAFT SUPPORT BLOCK	2	\$16.73	\$33.46
SPB12	THOMSON	3/4" LINEAR BALL BUSHING	4	\$45.85	\$183.40
TS6	IMS	MOTOR DRIVER TERMINAL STRIP	1	\$9.50	\$9.50
U24Y350	ACOPIAN	24 VOLT POWER SUPPLY	1	\$90.00	\$90.00
WM16	THOMSON	ADJUSTABLE SHAFT SUPPORT	2	\$43.12	\$86.24
-		MISC. PARTS (FASTENERS, WIRE, ETC.)	1	\$30.00	\$30.00
TOTAL					\$1,608.44

NOTE: ALL CLASS "L" SHAFTING COSTS INCLUDE A \$20.00 SET-UP CHARGE

**COST RECORD, PURCHASED PARTS
PICK/PLACE DEVICE**

<u>PART NO.</u>	<u>MANUFACTURER</u>	<u>NAME/DESCRIPTION</u>	<u>QTY</u> <u>REQ'D</u>	<u>UNIT</u> <u>COST</u>	<u>EXTENSION</u>
04604-0004	SCHRADER BLLWS	1/4" PIPE PNEUMATIC EXH. MUFFLER	1	\$1.50	\$1.50
05430-0160	SCHRADER BLLWS	PRESSURE GUAGE	1	\$7.95	\$7.95
05852-3042	SCHRADER BLLWS	PRESSURE REGULATOR	1	\$16.45	\$16.45
1105	ADI	THREAD ADAPTER	4	\$0.33	\$1.32
1/16 ADF	-	CABLE STOP FOR 1/16" DIA CABLE	8	\$0.05	\$0.40
1/16 GAC	-	1/16" DIA CABLE	3	\$0.11	\$0.33
1/2" DIA X 35"	THOMSON	CLASS "L" SHAFTING	2	\$43.80	\$87.60
2020/20-25MMX23	ORIGA	RODLESS AIR CYLINDER	1	\$265.42	\$265.42
2200PDE-2AP	AIR PAC	1/8" PIPE BRASS ELBOW W/MOUNT	1	\$3.65	\$3.65
241S	ALKON	CONTROL VALVE BASE W/1/8" PIPE NPT	1	\$6.05	\$6.05
242S	ALKON	CONTROL VALVE BASE W/1/4" NPT	1	\$6.05	\$6.05
270-627	RADIO SHACK	ELECTRICAL CIRCUIT BOX	1	\$2.69	\$2.69
276-168	RADIO SHACK	CIRCUIT BOARD	1	\$2.00	\$2.00
278-356	RADIO SHACK	RECOIL 4 CONDUCTOR CABLE	1	\$5.00	\$5.00
2Z866	DAYTON	VACUUM PUMP	1	\$166.06	\$166.06
2-40R2-24/DC	ALKON	4 WAY CONTROL VALVES	2	\$50.90	\$101.80
3136-54-11	LEGRIS	SNAP-IN BULKHEAD FITTING	4	\$4.03	\$16.12
3304-56-54	LEGRIS	MULTIPLE TEE TUBE MANIFOLD	1	\$8.76	\$8.76
34D106S	ANAHEIM AUTOMAT	SIZE 34 STEPPING MOTOR	1	\$130.00	\$130.00
3/4" DIA X 36"	THOMSON	CLASS "L" SHAFTING	1	\$39.08	\$39.08
6A3-16H3710	STOCK DRIVE PROD	1/5" PTCH X 16 GRVE HUBLESS PULL	2	\$6.05	\$12.10
6R3-277037	STOCK DRIVE PROD	1/5" PITCH X 3/8" WIDE TIM. BELT	1	\$11.10	\$11.10
7765-56-11	LEGRIS	PNEUMATIC FLOW CONTROL VALVE	2	\$13.58	\$27.16
CH119-ND	CHERRY	MICROSWITCH	2	\$3.56	\$7.12
F15	PIAB	VACUUM CUP	4	\$2.76	\$11.04

**COST RECORD, PURCHASED PARTS
PICK/PLACE DEVICE**

<u>PART NO.</u>	<u>MANUFACTURER</u>	<u>NAME/DESCRIPTION</u>	<u>QTY REQ'D</u>	<u>UNIT COST</u>	<u>EXTENSION</u>
IB463	IMS	STEPPING MOTOR DRIVER	1	\$135.50	\$135.50
PS2502-4NEC	NEC	ELECTRONIC OPTICAL ISOLATOR	1	\$2.34	\$2.34
R140-04-07-9	LEGRIS	5/32" MINI RECOIL TUBING	1	\$4.22	\$4.22
RS232 M/F	EASYCOM	PARALLEL PORT CABLE, ALL LINES EXT.	1	\$10.95	\$10.95
SB12	THOMSON	3/4" SHAFT SUPPORT BLOCK	2	\$16.73	\$33.46
SPB12	THOMSON	3/4" LINEAR BALL BUSHING	2	\$45.85	\$91.70
SSL-1680ZZ	NMB	FLANGED BALL BEARING	2	\$12.75	\$25.50
TS6	IMS	MOTOR DRIVER TERMINAL STRIP	1	\$9.50	\$9.50
TWN8	THOMSON	1/2" TWIN LINEAR BALL BUSHING	2	\$69.30	\$138.60
U24Y350	ACOPIAN	24 VOLT POWER SUPPLY	1	\$90.00	\$90.00
-		MISC. PARTS (FASTENERS, WIRE, ETC.)	1	\$30.00	\$30.00
TOTAL					\$1,508.52

NOTE: ALL CLASS "L" SHAFTING COSTS INCLUDE A \$20.00 SET-UP CHARGE

COST RECORD, MANUFACTURED PARTS
PUNCH DEVICE

PART NO.	NAME/DESCRIPTION	QTY REQ'D	MAT'L COST	PROCESSING	
				COST *	EXTENSION
101	CLAMP	1	\$5.00	\$30.00	\$35.00
102	PUNCH BASE	1	\$12.00	\$60.00	\$72.00
103	PUNCH SIDE SHEAR	2	\$1.00	\$7.50	\$17.00
104	SHORT PUNCH END SHEAR	1	\$1.00	\$7.50	\$8.50
105	LONG PUNCH END SHEAR	1	\$1.00	\$7.50	\$8.50
106	MODIFIED AIR CYLINDER TOOLING PLATE	1	**	\$7.50	\$7.50
107	AIR CYLINDER TOOLING PLATE EXTENSION	1	\$1.50	\$7.50	\$9.00
108	SCREW BEARING SUPPORT BLOCK	2	\$3.00	\$11.25	\$28.50
109	DRIVE SCREW	1	**	\$7.50	\$7.50
111	BALL-NUT/TRAY INTERFACE	1	\$2.00	\$22.50	\$24.50
112	RIGHT-SIDE-UP TRAY	1	\$35.00	\$210.00	\$245.00
113	TRAY HOME POSITION INDICATOR	1	\$1.00	\$7.50	\$8.50
114	LEFT TRAY BEARING SHAFT	1	**	\$7.50	\$7.50
115	RIGHT TRAY BEARING SHAFT	1	**	**	\$0.00
116	PILLOW BLOCK SPACER	2	\$1.00	\$7.50	\$17.00
117	FRAME, PHASE I	1	\$30.00	\$240.00	\$270.00
118	GRIPPER BRIDGE	1	\$5.00	\$15.00	\$20.00
119	PUNCH BRIDGE	1	\$8.00	\$30.00	\$38.00
120	HOME POSITION SENSOR MOUNTING BRACKET	1	\$3.00	\$15.00	\$18.00
121	CONTROL PANEL, PHASE I	1	\$10.00	\$15.00	\$25.00
122	STEPPING MOTOR BRACKET	1	\$4.00	\$30.00	\$34.00
123	GRIPPER FINGER	2	\$6.00	\$15.00	\$42.00
124	DRIVE SCREW TIMING PULLEY	1	**	\$7.50	\$7.50
125	ADJUSTABLE PILLOW BLOCK SPACER	2	\$2.00	\$7.50	\$19.00

**COST RECORD, MANUFACTURED PARTS
PUNCH DEVICE**

PART NO.	<u>NAME/DESCRIPTION</u>	QTY <u>REQ'D</u>	PROCESSING		<u>EXTENSION</u>
			<u>MAT'L COST</u>	<u>COST *</u>	
126A	INDEXING TRAY END GUIDE	2	\$8.00	\$75.00	\$166.00
127A	INDEXING TRAY SIDE GUIDE	2	\$8.00	\$45.00	<u>\$106.00</u>
			TOTAL		\$1,241.50

* PROCESSING COST BASED ON \$30.00 PER HOUR LABOR RATE

** COST INCLUDED ON PURCHASED PART'S COST RECORD

NOTE: PROCESSING AND MATERIAL COST ESTIMATED BY DANIEL GRAHAM, MACHINIST AT
THE DEPARTMENT OF MECHANICAL ENGINEERING, UNIVERSITY OF TN, KNOXVILLE.

COST RECORD, MANUFACTURED PARTS
PICK/PLACE DEVICE

PART NO.	NAME/DESCRIPTION	QTY REQ'D	MAT'L COST	PROCESSING	
				COST *	EXTENSION
201	VERTICAL SUPPORT PLATE	1	\$8.00	\$60.00	\$68.00
202	STEPPING MOTOR ADAPTER	1	\$3.00	\$15.00	\$18.00
203	LOWER SUPPORT PLATE	1	\$8.00	\$30.00	\$38.00
204	UPPER SUPPORT PLATE	1	\$7.00	\$15.00	\$22.00
206	MAST	1	\$36.00	\$52.50	\$88.50
207	BELT CLIP	1	\$3.00	\$15.00	\$18.00
208	BELT CONNECTOR	1	\$5.00	\$22.50	\$27.50
209	BELT CONNECTOR TIE	1	\$2.00	\$7.50	\$9.50
210	BELT CONNECTOR TIE SPACER	2	\$1.00	\$7.50	\$17.00
211	LEFT COUNTERWEIGHT FOR END EFFECTOR	1	\$4.00	\$7.50	\$11.50
212	RIGHT COUNTERWEIGHT FOR END EFFECTOR	1	\$4.00	\$7.50	\$11.50
213	FRAME, PHASE II	1	\$30.00	\$240.00	\$270.00
214	VACUUM PUMP SHELF	2	\$5.00	\$7.50	\$25.00
215	RODLESS AIR CYLINDER MOUNTING BRACKET	2	\$1.00	\$7.50	\$17.00
216	FRAME SPACER	2	\$2.00	\$7.50	\$19.00
217	CONTROL PANEL, PHASE II	1	\$10.00	\$30.00	\$40.00
218	VERTICAL SHAFT	2	**	\$15.00	\$30.00
219	PULLEY SHAFT BEARING RETAINER	2	\$2.00	\$7.50	\$19.00
220	PULLEY SHAFT	1	\$2.00	\$7.50	\$9.50
221	MODIFIED TWIN BALL BUSHING	2	**	\$7.50	\$15.00
222	SHORT SUPPORT GUIDE	2	\$8.00	\$10.00	\$36.00
223	LONG SUPPORT GUIDE	2	\$8.00	\$15.00	\$46.00
224	SUPPORT PLATE HANGER	4	\$1.00	\$2.50	\$14.00
225	MODIFIED VACUUM FITTING	1	**	\$5.00	\$5.00

COST RECORD, MANUFACTURED PARTS
PICK/PLACE DEVICE

<u>PART</u> <u>NO.</u>	<u>NAME/DESCRIPTION</u>	<u>QTY</u> <u>REQ'D</u>	<u>MAT'L</u> <u>COST</u>	<u>PROCESSING</u> <u>COST *</u>	<u>EXTENSION</u>
226	HOME POSITION SWITCH BRACKET	1	\$2.00	\$7.50	\$9.50
227	BRUSH SET POSITION SWITCH	1	\$2.00	\$7.50	\$9.50
228	TIMING PULLEY	2	**	\$7.50	\$15.00
229A	LOWER SUPPORT PLATE STOP	4	\$6.00	\$5.00	<u>\$44.00</u>
			TOTAL		\$953.00

* PROCESSING COST BASED ON \$30.00 PER HOUR LABOR RATE

** COST INCLUDED ON PURCHASED PART'S COST RECORD

NOTE: PROCESSING AND MATERIAL COST ESTIMATED BY DANIEL GRAHAM, MACHINIST AT
 THE DEPARTMENT OF MECHANICAL ENGINEERING, UNIVERSITY OF TN, KNOXVILLE.

COST SUMMARY

PURCHASED PARTS

PUNCH DEVICE	\$1,608.44
PICK/PLACE DEVICE	\$1,508.52

MANUFACTURED PARTS

PUNCH DEVICE	\$1,241.50
PICK/PLACE DEVICE	\$953.00

ASSEMBLY (\$10.00/HR LABOR RATE)

PUNCH DEVICE	\$400.00
PICK/PLACE DEVICE	<u>\$400.00</u>

SUB TOTAL	\$6,111.46
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COMPUTER	<u><u>\$905.00</u></u>
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TOTAL	\$7,016.46
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APPENDIX L

Reliability Study

Reliability Study

The Pick/Place reliability study involved documenting the implemented reliability improvements, looking for possible failure modes, and qualitatively evaluating the reliability of each component. The study employed the Failure Mode and Effects Analysis (FMEA) Program². To organize the results of the program, the components of the Pick/Place device were divided into subsystems. The reliability improvements that were implemented are listed under the "Safeguards and Comments" heading. The reliability improvements that will further increase the reliability of the device are listed under the "Recommended Actions" heading. In addition, the "Recommended Actions" column contains maintenance requirements, as well as, quality control guidelines.

² FMEA Program is a product of the Superior Engineering Design Program of the Mechanical and Aerospace Engineering Dept. of the University of Tennessee based on work by David A. Walker.

VERTICAL LIFT SYSTEM

FAILURE MODE EVENT IDENTIFICATION		FAILURE MODE CAUSE & EFFECT ANALYSIS		SAFETY CAT.	FAILURE MODE EVALUATION	
ITEM	COMPONENT DESCRIPTION	FAILURE MODE	FAILURE MODE CAUSES		FAILURE MODE SAFEGUARDS AND COMMENTS	FAILURE MODE ACTIONS FOR FAILURE MODE
1.1	BALL BUSHINGS	FAILS TO ALLOW FREE LINEAR MOTION	LUBRICATION FAILURE DUE TO INCORRECT OR INSUFFICIENT LUBRICATION, CORROSION OR CONTAMINATION; HIGH TEMPERATURE EFFECTS, OR MIGRATION INSUFFICIENT INTERNAL CLEARANCE DUE TO INCORRECT FITS CAUSING BINDING OR DEFLECTIONS, OR THERMAL EXPANSION DAMAGE TO RACES FROM MISALIGNMENT OR OVERLOAD, IMPACT LOADING, WEAR FROM EXCESSIVE FRICTION, OR DEFECTIVE HOUSINGS USAGE IN EXCESS OF DESIGNED AND EXPECTED LIFE	3	BEARING ORIENTATION MUST BE MAINTAINED SUCH THAT LOAD IS APPLIED HALF WAY BETWEEN ADJACENT BALL TRACKS BEARING USE IS A SCIENCE WITHIN ITSELF -- CONSULT MANUFACTURER SPECIFICATIONS FOR DETAILS OR SOURCES SUCH AS SKF SERVICE GUIDE BOOKLET	INSURE PROPER LUBRICANT CHOSEN FOR OPERATING CONDITIONS SUCH AS CHEMICAL, HUMIDITY, AND CONTAMINANT RESISTANCE, AND TEMPERATURE RANGES. CONSIDER USING SEALS OR SHIELDS DESIGN FOR NO RELUBRICATION WITH SEALED BEARINGS OR DESIGN FOR EASY RELUBRICATION WITH AMPLE LUB. POINTS AND SET PROCEDURES VERIFY PROPER TOLERANCE FOR FITS - PURCHASE MATCHED BEARINGS AND SHAFTS FROM A SINGLE VENDOR INSURE PROPER INSTALLATION AND MAINTENANCE PROCEDURES FOR MOUNTING AND REPAIRING BEARINGS ARE DEVELOPED AND FOLLOWED

SAFETY CAT: 1 DOES NOT INTERRUPT OPER; 2 INTERRUPTS OPER, RESET/ADJ'MENT REQ'D; 3 INTERRUPTS OPER, REPAIR REQ'D; 4 INTERRUPTS OPER, MAY DAMAGE HARDWARE

VERTICAL LIFT SYSTEM

FAILURE MODE EVENT IDENTIFICATION			FAILURE MODE CAUSE & EFFECT ANALYSIS			SAFETY CAT.		FAILURE MODE EVALUATION	
ITEM	DESCRIPTION	FAILURE MODE	FAILURE MODE CAUSES	FAILURE MODE SYSTEM EFFECTS				FAILURE MODE AND COMMENTS	RECOMMENDED ACTIONS FOR FAILURE MODE
2.1	TIMING BELT	FAILS TO TRANSMIT POWER OR MOTION -- BROKEN BELT	EXCESSIVE TENSION IN BELT DUE TO OVERTENSIONED ADJUSTMENT, RELATIVE MOTION BETWEEN PULLEY CENTERS, OR EXTERNAL IMPACTS	LOSS OF BELT POWER OR MOTION TO SYSTEM POTENTIAL DAMAGE TO OTHER COMPONENTS NEAR THE BELT FROM CONTACT WITH BROKEN BELT LOSS OF BELT SUPPORT MAY CAUSE UNDESIRE FREE MOTION OF DRIVEN COMPONENTS	3			THIS EVENT REQUIRES REPLACEMENT OF BELT DAMAGE TO OTHER EQUIPMENT SHOULD BE CONSIDERED IF BELT IMPACT FORCES COULD CAUSE SOME DAMAGE/INACCURACY; SENSING AND CONTROL DEVICES ARE COMMON EXAMPLES	INSURE PROPER INSTALL/MAINTENANCE PROCEDURES FOR ALIGNING AND TENSIONING BELT ARE DEVELOPED AND FOLLOWED. TRY TO OBTAIN MANUFACT'S INSTRUCTIONS AND LIMITATIONS, ELSE USE GENERAL BELT PROCEDURES.
			BELT FATIGUE DUE TO ALTERNATING STRESSES IN BELT PASSING AROUND PULLEYS					MOVABLE PULLEY IS EMPLOYED TO PROVIDE BELT ADJUSTMENT BELT LOADS ARE LESS THAN THE RECOMMENDED BELT DESIGN STRENGTH	INSURE INCOMING QUALITY OF BELT AND PULLEY BEFORE AND AFTER INSTALLATION ISOLATE BELT AND PULLEYS FROM OPERAT. ENVIRONMENT WITH BELT GUARDS TO PROTECT BELTS AND PULLEYS FROM ENVIRONMENT AND TO PROTECT OTHER COMPONENTS FROM BROKEN BELTS LIMIT BELT CONTACT WITH EXTERNAL HEAT
			FRICTIONAL WEAR OF BELT DUE TO DEFECTIVE PULLEY TEETH, LOW TENSION, EXTERNAL SOURCES OF CONTACT, OR BELT-PULLEY FLANGE FRICTION DUE TO MISALIGNMENT						
			CORROSIVES IN CONTACT WITH BELT FROM PROCESS CHEMICALS, MAINTENANCE CHEMICALS OR SOLVENTS, LUBRICANTS, OR HIGH HUMIDITY						
			CONTAMINANT PARTICLES, CHIPS, OR SHAVINGS LODGING IN BELT CAUSING						

SAFETY CAT: 1 DOES NOT INTERRUPT OPER; 2. INTERRUPTS OPER, RESET/ADJMENT REQ'D; 3. INTERRUPTS OPER, REPAIR REQ'D; 4. INTERRUPTS OPER, MAY DAMAGE HARDWARE

FAILURE MODE EVENT IDENTIFICATION		FAILURE MODE CAUSE & EFFECT ANALYSIS			SAFETY CAT.		FAILURE MODE EVALUATION	
ITEM								
	COMPONENT			FAILURE MODE CAUSES	FAILURE MODE SYSTEM EFFECTS	SEE FOOTER	FAILURE MODE SAFEGUARDS AND COMMENTS	RECOMMENDED ACTIONS FOR FAILURE MODE

OVERHEATING OF BELT DUE
TO HIGH AMBIENT
TEMPERATURES,
FRICTIONAL HEATING, OR
EXTERNAL HEAT SOURCES

BELT USED WHICH IS DEFECTIVE DUE TO INCORRECT THICKNESS, INCORRECT MATERIAL PROPERTIES, OR SURFACE DAMAGE

FAILS TO TRANSMIT
POWER OR MOTION --
LOSS OF MESHING
WITH PULLEY AND
BELT HELD
ACCOUNTABLE

UNDERTENSION IN BELT
DUE TO STRETCHING,
MISADJUSTMENT, MOVEMENT
BETWEEN PULLEY CENTERS,
OR BELT
FASTER/TENSIONING
DEVICE LOOSENING

MAY ONLY REQUIRE
ADJUSTMENT AND
REMOUNTING, BUT COULD
REQUIRE NEW BELT,
PULLEY, LOCAL
COMPONENTS ALONG WITH
REMOUNTING

INSURE PROPER
INSTALLATION/MAINTENANCE
PROCEDURES FOR
ALIGNING AND
TENSIONING BELT ARE
DEVELOPED AND FOLLOW

**DAMAGED OR DEFECTIVE
BELT TEETH FROM
INSTALLATION/MAINTENANCE,
FREE MOTION OF DRIVEN
COMPONENTS
LOSS OF BELT SUPPORT
MAY CAUSE UNDESIRABLE
MOTION OF DRIVEN
COMPONENTS**

DAMAGE TO OTHER
EQUIPMENT SHOULD BE
CONSIDERED IF BELT
IMPACT FORCES COULD

DEFECTIVE OR DAMAGED
PULLEY TEETH, EXCESSIVE
FRICTION, OR
CORROSIVES/CONTAMINANTS

ISOLATE BELT AND
PULLEYS FROM
ENVIRONMENT WITH BELT
GUARDS TO PROTECT
BELTS AND PULLEYS

SAFETY CAT: 1 DOES NOT INTERRUPT OPER; 2 INTERRUPTS OPER, RESET/ADJ"MENT REQ'D; 3 INTERRUPTS OPER, REPAIR REQ'D; 4 INTERRUPTS OPER, MAY DAMAGE HARDWARE

VERTICAL LIFT SYSTEM

FAILURE MODE EVENT IDENTIFICATION		FAILURE MODE CAUSE & EFFECT ANALYSIS		SAFETY CAT.		FAILURE MODE EVALUATION	
ITEM	DESCRIPTION	FAILURE MODE	FAILURE MODE CAUSES	FAILURE MODE SYSTEM EFFECTS	SEE FOOTER	FAILURE MODE SAFEGUARDS AND COMMENTS	RECOMMENDED ACTIONS FOR FAILURE MODE
2.3	TIMING BELT	LOSS OF POSITION ACCURACY	OVERSTRESSES FROM OVERTENSION OR IMPACT LOADING RESULTING IN LOCAL YIELDING AND ELONGATION FRICTIONAL WEAR OF BELT DUE TO DEFECTIVE PULLEY TEETH, LOW TENSION, EXTERNAL SOURCES OF CONTACT, OR BELT-PULLEY FLANGE FRICTION FROM MISALIGNMENT	LOSS OF ACCURACY OF BELT DRIVE TO SYSTEM	1	BELT ACCURACY WILL NOT INFLUENCE VERTICAL LIFT PERFORMANCE - DUE TO POSITION INPUT SWITCHES	MOVABLE PULLEY IS EMPLOYED TO PROVIDE BELT ADJUSTMENT FROM ENVIRONMENT AND TO PROTECT OTHER COMPONENTS FROM JUMPING BELTS LIMIT BELT CONTACT WITH EXTERNAL HEAT SOURCES AND LIMIT OR CONTROL AMBIENT TEMPERATURES INSURE ADEQUATE DESIGN STRENGTH OF BELT FOR FATIGUE AND IMPACT LOADING UNDER THE NECESSARY TEMPERATURES FOR THE EXPECTED LIFE

SAFETY CAT: 1 DOES NOT INTERRUPT OPER; 2 INTERRUPTS OPER, RESET/ADJ'MENT REQ'D; 3 INTERRUPTS OPER, REPAIR REQ'D; 4 INTERRUPTS OPER, MAY DAMAGE HARDWARE

[illegible]

INCOMPATIBLE THERMAL
EXPANSION BETWEEN
PULLEY TEETH AND BELT
TEETH YIELDING BACKLASH
IN MOVEMENT IN HIGH
ACCURACY REQUIREMENT
CONDITIONS

**DEFECTIVE OR MISMATCHED
TEETH ON OR BETWEEN
BELT AND PULLEY**

2.4	TIMING BELT		2.3	
	FAILS TO TRANSMIT POWER -- BELT FASTENER FAILS	FATIGUE FAILURE DUE TO ALTERNATING TENSILE STRESSES IN BELT	LOSS OF BELT POWER OR MOTION TO SYSTEM	USE A THREAD ADHESIVE ON THE BELT CLIP FASTENERS
		OVERSTRESS IN FASTENER DUE TO OVERTENSIONING BELT OR IMPACT LOADING	POTENTIAL DAMAGE TO OTHER COMPONENTS NEAR THE BELT FROM CONTACT WITH LOOSE BELT	LOADS ARE LESS THAN THE RECOMMENDED BELT DESIGN LOADS
				INSURE ADEQUATE FATIGUE STRENGTH OF FASTENER FOR EXPECTED LOADING WITH STRESS CONCENTRATION FACTOR
				INSURE ADEQUATE LOAD

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FAILURE MODE EVENT IDENTIFICATION		FAILURE MODE CAUSE & EFFECT ANALYSIS		SAFETY CAT.	FAILURE MODE EVALUATION	
ITEM						
	COMPONENT DESCRIPTION					
		FAILURE MODE	FAILURE MODE CAUSES	FAILURE MODE SYSTEM EFFECTS	SEE FOOTER	FAILURE MODE ACTIONS FOR FAILURE MODE
AT OPERATING TEMPERATURES AND ENVIRONMENTS LOSS OF BELT SUPPORT MAY CAUSE UNDESIRE FREE MOTION OF DRIVEN COMPONENTS CORROSIVES IN CONTACT WITH FASTNER FROM PROCESS CHEMICALS, MAINTENANCE CHEMICALS OR SOLVENTS, AND HUMIDITY INSURE FASTNER MATERIAL RESISTANT TO CORROSIVES AND HUMIDITY CONDITIONS WHICH WILL BE EXPERIENCED DEFECTIVE BELT CLIP INSURE THE QUALITY OF THE FASTNER BEFORE INSTALLATION LOOSE BELT CLIP ISOLATE BELT AND PULLEYS FROM ENVIRONMENT WITH BELT GUARDS TO PROTECT BELTS AND PULLEYS FROM ENVIRONMENT						
3.1	TIMING PULLEY	FAILS TO TRANSMIT POWER OR MOTION -- PULLEY FAILURE	IMPACTS ON PULLEY OR PULLEY TEETH FROM FOREIGN OBJECTS	LOSS OF DRIVE POWER OR MOTION TO SYSTEM	THE CAUSES FOR THIS EVENT MAY ALSO CAUSE PULLEY SHAFT OR BEARING FAILURES OR DAMAGE	INSURE PROPER INSTALLATION AND MAINTENANCE PROCEDURES FOR ALIGNING AND TENSIONING BELT ARE DEVELOPED AND FOLLOW
			CORROSIVES IN CONTACT WITH PULLEY FROM PROCESS CHEMICALS, MAINTENANCE CHEMICALS OR SOLVENTS, OR HIGH	POTENTIAL DAMAGE TO OTHER COMPONENTS NEAR THE PULLEY FROM CONTACT WITH BROKEN PULLEY OR LOOSE BELT		ISOLATE BELT AND

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	FAILURE MODE EVENT IDENTIFICATION	FAILURE MODE CAUSE & EFFECT ANALYSIS	SAFETY CAT.	FAILURE MODE EVALUATION
	ITEM COMPONENT DESCRIPTION	FAILURE MODE CAUSES	FAILURE MODE SYSTEM EFFECTS	FAILURE MODE SAFE GUARDS AND COMMENTS
		HUMIDITY	LOSS OF BELT SUPPORT MAY CAUSE UNDESIRABLE FREE MOTION OF DRIVEN COMPONENTS	PULLEYS FROM ENVIRONMENT WITH BELT GUARDS TO PROTECT BELTS AND PULLEYS FROM ENVIRONMENT AND TO PROTECT OTHER COMPONENTS FROM BROKEN PULLEY AND LOOSE BELTS
		FATIGUE FAILURE DUE TO ALTERNATING STRESSES RESULTING FROM PULLEY MISALIGNMENT BENDING LOADS		INSURE PULLEY MATERIAL IS APPROPRIATE FOR CHEMICAL AND HUMIDITY EXPOSURE
				INSURE SUFFICIENT PULLEY FATIGUE AND LOAD STRENGTH FOR EXPECTED LOADS AND PERMISSIBLE MISALIGNMENTS. WATCH FOR STRESS CONCENTRATIONS
3.2	TIMING PULLEY	FAILS TO TRANSMIT POWER OR MOTION -- LOSS OF SHAFT TO PULLEY COUPLING	EARLY STAGES -- RESULTS IN ACCURACY PROBLEMS, DEGRADED POWER TRANSMISSION, AND VIBRATION	INSURE PROPER INSTALLATION AND MAINTENANCE PROCEDURES FOR ALIGNING AND TENSIONING BELT ARE DEVELOPED AND FOLLOWED
		FAILURE OF COUPLING DEVICE MECHANISM DUE TO FATIGUE, EXCESSIVE LOADS, WEAR, OR CORROSION		USE A THREAD ADHESIVE ON THE PULLEY SET SCREWS
		LOOSENING OF COUPLING	LOSS OF DRIVE POWER OR	

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VERTICAL LIFT SYSTEM

FAILURE MODE EVENT IDENTIFICATION		FAILURE MODE CAUSE & EFFECT ANALYSIS		SAFETY CAT.	FAILURE MODE EVALUATION	
ITEM						
3.3	TIMING PULLEY	FAILS TO TRANSMIT POWER OR MOTION -- LOSS OF PULLEY TO BELT MESHING WITH PULLEY HELD ACCOUNTABLE	DEVICE DUE TO REVERSING LOADS, WEAR OF COUPLING DEVICE, OR THERMAL EXPANSION OF INTERFERENCE FITS	MOTION TO SYSTEM LOSS OF SUPPORT ALLOWING FREE MOTION OF DRIVEN COMPONENTS	SEE FOOTER	RECOMMENDED ACTIONS FOR FAILURE MODE
			PULLEY TEETH BLOCKED OR CLOGGED WITH CONTAMINANT PARTICLES, CHIPS, OR SHAVINGS PULLEY TEETH DAMAGED FROM IMPACTS WITH FOREIGN OBJECTS OR WEAR MISALIGNMENT CAUSING BELT TO TEND TO RIDE ON PULLEY FLANGES OR JUMP FROM PULLEY	LOSS OF DRIVE POWER OR MOTION TO SYSTEM POTENTIAL DAMAGE TO OTHER COMPONENTS NEAR THE PULLEY FROM CONTACT WITH LOOSE BELT LOSS OF BELT SUPPORT ALLOWING FREE MOTION OF DRIVEN COMPONENTS		INSURE PROPER INSTALLATION AND MAINTENANCE PROCEDURES FOR ALIGNING AND TENSIONING BELT ARE DEVELOPED AND FOLLOW
			USE APPROPRIATE COUPLING MECHANISM FOR SPEED, LOADS, LOADING DIRECTIONS, AND THERMAL EXPANSION. ALSO VERIFY COUPLING DESIGN FOR FATIGUE, WEAR, AND CORROSION			
						INSURE ADEQUATE LOCKING OF COUPLING DEVICE TO PREVENT LOOSENING
						INSURE PROPER INSTALLATION AND MAINTENANCE PROCEDURES FOR ALIGNING AND TENSIONING BELT ARE DEVELOPED AND FOLLOW
						ISOLATE BELT AND PULLEYS FROM ENVIRONMENT WITH BELT GUARDS TO PROTECT BELTS AND PULLEYS FROM ENVIRONMENT AND PROTECT OTHER COMPONENTS FROM LOOSE

SAFETY CAT. 1 DOES NOT INTERRUPT OPER, 2 INTERRUPTS OPER, RESET/ADJ'MENT REQ'D; 3 INTERRUPTS OPER, REPAIR REQ'D; 4 INTERRUPTS OPER, MAY DAMAGE HARDWARE

VERTICAL LIFT SYSTEM

FAILURE MODE EVENT IDENTIFICATION			FAILURE MODE CAUSE & EFFECT ANALYSIS			SAFETY CAT.		FAILURE MODE EVALUATION	
ITEM	DESCRIPTION	FAILURE MODE	FAILURE MODE CAUSES	FAILURE MODE SYSTEM EFFECTS				FAILURE MODE	RECOMMENDED ACTIONS FOR FAILURE MODE
4.1	STEPPING MOTOR	FAILS TO PROVIDE COMMANDED TORQUE OR DUE TO EXCESSIVE LOADS, MOTION -- PRIMARY MOTOR FAILURE	MOTOR BEARING FAILURE OR CONTAMINATION, OR WEAR	LOSS OF DRIVE POWER OR MOTION TO SYSTEM				USE MOTORS WITH SEALED BEARINGS, AS SPECIFIED	INSURE PROPER INSTALLATION AND MAINTENANCE FOR ALIGNING STEPPER MOTOR LOADS ARE DEVELOPED AND FOLLOWED. KEEP BENDING MOMENT ARMS IN SHAFTS SMALL
			INTERNAL WINDING FAILURE FROM OVERHEATING, EXCESSIVE CURRENT OR SURGES, MECH. SHOCKS OR VIBRATIONS, OR WINDING CORROSION	WINDING FAILURE RESULTS IN LOSS OF HOLDING TORQUE WHICH ALLOWS FREE MOTION OF DRIVEN COMPONENTS				STEPPING MOTOR DRIVER AND THE POWER SUPPLY FUSE PROVIDE CURRENT OVERLOAD PROTECTION	
			DEFECTIVE STEPPER MOTOR FROM MANUFACTURER						ISOLATE STEPPER MOTOR FROM OPERATING ENVIRONMENT TO PROTECT FROM CORROSIVES AND CONTAMINANTS
4.2	STEPPING MOTOR	FAILS TO PROVIDE COMMANDED TORQUE OR MOTION -- SECONDARY MOTOR FAILURE	REQUIRED TORQUE BEYOND PULL-IN TORQUE FOR STARTING OR PULL-OUT TORQUE FOR CURRENT SPEED	LOSS OF DRIVE POWER OR MOTION OR HOLDING TORQUE TO SYSTEM				INSURE PROPER INSTALLATION AND MAINTENANCE	ISOLATE STEPPER MOTOR FROM OPERATING ENVIRONMENT TO PROTECT FROM CORROSIVES AND CONTAMINANTS
			REQUIRED TORQUE TO MAINTAIN ZERO MOTION BEYOND MAXIMUM HOLDING TORQUE	LOSS OF POWER EVENT ALLOWS UNDESIRABLE FREE MOTION OF DRIVEN COMPONENTS				PROCEDURES FOR WIRING MOTOR ARE DEVELOPED AND FOLLOWED	
			LOSS OF COMMAND POWER FROM MOTOR DRIVER DUE	WIRING ERRORS MAY CAUSE NO MOTION BUT ALSO MAY CAUSE REVERSED MOTION				ISOLATE STEPPER MOTOR WIRING AND CONNECTOR FROM OPERATING ENVIRONMENT TO PROTECT FROM	

BELT

SAFETY CAT. 1 DOES NOT INTERRUPT OPER; 2. INTERRUPTS OPER, RESET/ADJ. REQ'D; 3. INTERRUPTS OPER, REPAIR REQ'D; 4. INTERRUPTS OPER, MAY DAMAGE HARDWARE

VERTICAL LIFT SYSTEM

FAILURE MODE EVENT IDENTIFICATION		FAILURE MODE CAUSE & EFFECT ANALYSIS		SAFETY CAT.		FAILURE MODE EVALUATION	
ITEM	DESCRIPTION	FAILURE MODE	FAILURE MODE CAUSES	FAILURE MODE SYSTEM EFFECTS	SEE FOOTER	FAILURE MODE SAFEGUARDS AND COMMENTS	RECOMMENDED ACTIONS FOR FAILURE MODE
4.3	STEPPING MOTOR	INACCURATE POSITIONING	EXCESSIVE ACCELERATION AND/OR DECELERATION RESONANCE VIBRATION OF STEPPER MOTOR ROTOR OR STATOR DAMAGE OR DEFECT	LOSS OF ACCURATE POSITIONING OF DRIVEN SYSTEM		INACCURATE POSITIONING DOES NOT EFFECT VERTICAL LIFT SYSTEM PERFORMANCE - DUE TO THE POSITION VERIFICATION SWITCHES	
			TO IMPACTS AND CORROSION OF CONNECTORS RESTRICTED DRIVE TRAIN DUE TO FOREIGN OBJECT INTERFERENCE OR DRIVE TRAIN FAILURES INSTALLATION AND MAINTENANCE ERRORS IN WIRING MOTOR				CORROSION AND PLACE SHIELDED FROM IMPACTS DENY/LIMIT ACCESS OF FOREIGN OBJECTS INTO LOCATIONS WHICH MAY RESTRICT DRIVE TRAIN MOTION. USE GUARDS AND OPERATING PROCEDURES CONSIDER BACK-UP POWER SUPPLY SOURCE IN CASE OF POWER FAILURES INSURE REQUIRED TORQUES AND DUTY CYCLE ARE COMPATIBLE WITH MOTOR SPECIFICATIONS. DE-RATE FOR FACTOR OF SAFETY

SAFETY CAT: 1 DOES NOT INTERRUPT OPER; 2 INTERRUPTS OPER, RESET/ADJ MENT REQ'D; 3 INTERRUPTS OPER, REPAIR REQ'D; 4 INTERRUPTS OPER, MAY DAMAGE HARDWARE

VERTICAL LIFT SYSTEM

FAILURE MODE EVENT IDENTIFICATION		FAILURE MODE CAUSE & EFFECT ANALYSIS		SAFETY CAT.		FAILURE MODE EVALUATION	
ITEM	DESCRIPTION	FAILURE MODE	FAILURE MODE CAUSES	FAILURE MODE	SYSTEM EFFECTS	FAILURE MODE	SAFEGUARDS AND COMMENTS
5.1	SHAFTS	FAILS TO PROVIDE SUPPORT BECAUSE OF FRACTURE	COMBINED LOADING OF BENDING, TORSIONAL, SHEAR, AND AXIAL STRESS CAUSING YIELDING AND EVENTUALLY FRACTURE SOURCES OF LOADS ARE OPERATING LOADS, MISALIGNMENTS, THERMAL EXPANSIONS, VIBRATIONS, AND EXTERNAL LOADS	LOSS OF DRIVE GUIDANCE AND SUPPORT OF DRIVEN COMPONENTS	POTENTIAL DAMAGE TO OTHER COMPONENTS FROM CONTACT WITH BROKEN GUIDE SHAFT OR UNSUPPORTED DRIVEN COMPONENTS	ENSURE TOLERANCES BETWEEN BEARING AND SHAFT - PURCHASE MATCHED BEARINGS AND SHAFTS FROM A SINGLE VENDOR	RECS. FOR INSTALL/MAINT. AND DESIGN
			FATIGUE FAILURE OF SHAFT DUE TO ALTERNATING TENSILE LOADING				REC. FOR RESTRICTING SOURCES OF EXTERNAL IMPACTS
			WEAR FACTORS CONTRIBUTING TO STRESS CONCENTRATION FACTORS OR DECREASED STRENGTHS OF THE MATERIAL				REC. FOR USING PROTECTIVE COVER ON GUIDE SURFACE TO PROTECT SURFACE
			CORROSION OF MATERIAL LEADING TO FRACTURES				
			EXTERNAL IMPACT LOADS				

IMPACTS OF HIGH LOADS IN OPERATING REGIONS WHICH CAUSE LOSS OF STEPS

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VERTICAL LIFT SYSTEM

FAILURE MODE EVENT IDENTIFICATION		FAILURE MODE CAUSE & EFFECT ANALYSIS		SAFETY CAT.		FAILURE MODE EVALUATION	
ITEM	DESCRIPTION	FAILURE MODE	FAILURE MODE CAUSES	FAILURE MODE SYSTEM EFFECTS	SEE FOOTER	FAILURE MODE SAFEGUARDS AND COMMENTS	RECOMMENDED ACTIONS FOR FAILURE MODE
INTO GUIDE SHAFT MATERIAL DEFECTS FROM MANUFACTURING PROCESS OF VOIDS IN MATERIAL, SURFACE SCRATCHES OR DAMAGE DURING MACHINING, IMPROPER HEAT TREAT, OR UNEXPECTED INTERNAL STRESSES CREATED							
5.2	SHAFTS	ALLOWS EXCESSIVE VIBRATION	OPERATION AT OR NEAR NATURAL FREQUENCY OR HARMONIC OF NATURAL FREQUENCY FOR THE GUIDE TUBE	CAUSES PATH AND PLACEMENT INACCURACIES OF GUIDED DEVICE		THE GUIDE TUBE NATURAL FREQUENCY FROM DESIGN AND INSTALL./MAINT. IN COMPARISON TO DRIVING AND EXTERNAL INPUT FREQUENCIES IS THE KEY OPERATING PARAMETER. THIS SHOULD BE ADDRESSED IN INSTALL./MAINT. AND DESIGN	RECS. FOR INSTALL./MAINT. AND DESIGN
5.3	SHAFTS	FAILS TO PROVIDE ACCURATE DESIRED GUIDE PATH	INSTALL./MAINT. ERRORS SUCH AS MOUNTING IN A STRESSED DEFORMATION OR SHAPE DAMAGE TO GUIDE TUBE	CAUSES INACCURATE PLACEMENT. POTENTIAL DAMAGE TO GUIDED OBJECTS AS A RESULT OF INACCURACY		HIGH QUALITY PARTS AND VERIFIED INSTALL./MAINT. IN ADDITION TO EXTERNAL IMPACTS ARE THE KEY OPERATING PARAMETERS	RECS. FOR INSTALL./MAINT. AND DESIGN REC. FOR RESTRICTING SOURCES OF EXTERNAL

SAFETY CAT: 1 DOES NOT INTERRUPT OPER, 2 INTERRUPTS OPER, RESET/ADJ./MENT REQ'D; 3 INTERRUPTS OPER, REPAIR REQ'D; 4 INTERRUPTS OPER, MAY DAMAGE HARDWARE

VERTICAL LIFT SYSTEM

FAILURE MODE EVENT IDENTIFICATION			FAILURE MODE CAUSE & EFFECT ANALYSIS		SAFETY CAT.	FAILURE MODE EVALUATION	
ITEM	COMPONENT DESCRIPTION	FAILURE MODE	FAILURE MODE CAUSES	FAILURE MODE SYSTEM EFFECTS	SEE FOOTER	FAILURE MODE	RECOMMENDED ACTIONS FOR FAILURE MODE
5.4	SHAFTS	FAILS TO PROVIDE SMOOTH, UNIFORM GUIDE SURFACE	MANUFACTURING DEFECTS SUCH AS TAPERS OR DRIFTS IN CUTTING TUBE	MAY CAUSE BINDING IF GUIDE TUBE IS USED IN PARALLEL WITH ANOTHER GUIDE TUBE			IMPACTS
			DEFORMATIONS DUE TO EXTERNAL IMPACTS				
			SURFACE DAMAGE DUE TO INSTALL/MAINT. CHIPPING OR KNICKS	LOST OR DEGRADED POWER TRANSMISSION CAPABILITIES CAUSING PLACEMENT INACCURACY		ANY IMPACTS, SCRATCHING, CHIPPING, OR WEAR OF GUIDE TUBE ARE KEY OPERATING PARAMETERS. THESE SHOULD BE ADDRESSED IN INSTALL/MAINT.	RECS. FOR INSTALL/MAINT.
			SURFACE DAMAGE DUE TO EXTERNAL IMPACTS OR FRICTIONAL WEAR			SURFACE DAMAGE TO GUIDE TUBE MAY ALSO ALLOW DAMAGE TO GUIDED OBJECT	REC. FOR RESTRICTING SOURCES OF EXTERNAL IMPACTS
			SURFACE DAMAGE DUE TO CORROSIVES OR ABRASIVES CONTACTING THE GUIDE TUBE FROM PROCESS OR MAINTENANCE CHEMICALS AND ABRASIVES OR HUMIDITY				REC. FOR USING PROTECTIVE COVER FOR GUIDE SHAFT TO PROTECT SURFACE
6.1	VERTICAL POSITION SENSOR	SWITCH STUCK ON OR OFF	INCORRECT SURFACE HARDNESS OR PLATING FOR CONDITIONS				
			INTERNAL SHORT INCOMPLETE CIRCUIT	END EFFECTOR IN INCORRECT POSITION		PROPER OPERATION IS CHECKED DURING START-UP	VISUALLY CHECK THE CORRECT POSITION OF THE END EFFECTOR DURING START-UP

SAFETY CAT: 1 DOES NOT INTERRUPT OPER; 2 INTERRUPTS OPER, RESET/ADJUSTMENT REQ'D; 3 INTERRUPTS OPER, REPAIR REQ'D; 4. INTERRUPTS OPER, MAY DAMAGE HARDWARE

VERTICAL LIFT SYSTEM

FAILURE MODE EVENT IDENTIFICATION		FAILURE MODE CAUSE & EFFECT ANALYSIS		SAFETY CAT.		FAILURE MODE EVALUATION	
ITEM	COMPONENT DESCRIPTION	FAILURE MODE	FAILURE MODE CAUSES	FAILURE MODE SYSTEM EFFECTS	SEE FOOTER	FAILURE MODE SAFEGUARDS AND COMMENTS	RECOMMENDED ACTIONS FOR FAILURE MODE
7.1	BALL BEARINGS	FAILS TO ALLOW FREE MOTION	USAGE IN EXCESS OF DESIGNED AND EXPECTED LIFE EXCESS TIGHTNESS OF BELT	LOSS OF MOTION MAY CAUSE OVERLOAD DAMAGE TO DRIVE MECHANISM OR DRIVE TRAIN		BEARING APPLICATION IS WITHIN DESIGN LIMITS	DO NOT OVER TENSION BELT - ADJUST BELT TIGHT ENOUGH TO PREVENT BELT FROM SLIPPING

SAFETY CAT: 1 DOES NOT INTERRUPT OPER; 2 INTERRUPTS OPER, RESET/ADJ'MENT REQ'D; 3 INTERRUPTS OPER, REPAIR REQ'D; 4 INTERRUPTS OPER, MAY DAMAGE HARDWARE

END EFFECTOR

FAILURE MODE EVENT IDENTIFICATION			FAILURE MODE CAUSE & EFFECT ANALYSIS			SAFETY CAT.	FAILURE MODE EVALUATION		
ITEM	DESCRIPTION	FAILURE MODE	FAILURE MODE CAUSES	FAILURE MODE SYSTEM EFFECTS	FOOTER		FAILURE MODE COMMENTS	FAILURE MODE ACTIONS FOR	FAILURE MODE
1.1	VACUUM CUP FITTING	FAILS TO SEAL AGAINST BRUSH	CONTAMINATED SEAL CRACKED SEAL	BRUSH SET IS NOT PICKED-UP	3			PERIODICALLY CLEAN VACUUM CUPS WITH A MILD SOLVENT	
								PERIODICALLY INSPECT CUPS	
								THE VACUUM CUP HAS A LIMITED LIFE, STOCK PARTS/COMPONENTS WITH A LIMITED LIFE	
2.1	SNAP-IN FITTINGS	FAILS TO HOLD VACUUM CUP IN THE DESIRED ORIENTATION	BROKEN TAB ON FITTING FITTING LOOSE IN PLATE	FAILS TO PICK-UP BRUSH SET	3			PERIODICALLY INSPECT FITTING TABS	
								INSPECT PROPER MANUFACTURER OF LOWER SUPPORT PLATE	
3.1	BRUSH MICROSWITCH	SWITCH STUCK ON OR OFF	INTERNAL SHORT INCOMPLETE CIRCUIT	BRUSH SET IS NOT PICKED-UP	3			IN THE CASE OF AN OPEN CIRCUIT - A MAXIMUM REACH LIMIT WILL PREVENT THE STEPPING MOTOR AND THE COMPUTER FROM BEING CAUGHT IN AN ENDLESS LOOP	
4.1	RE-CIOL ELECTRIC CABLE	FAILS TO RETRACT	CABLE BECOMES FATIGUED	CABLE MAY BECOME TANGLED IN THE END EFFECTOR, PREVENTING	3			MOUNT CABLE AS MOUNTED ON PROTOTYPE	INSPECT PERIODICALLY DO NOT OVER EXTEND

SAFETY CAT: 1. DOES NOT INTERRUPT OPER; 2. INTERRUPTS OPER, RESET/ADJUSTMENT REQ'D; 3. INTERRUPTS OPER, REPAIR REQ'D; 4. INTERRUPTS OPER, MAY DAMAGE HARDWARE

END EFFECTOR

FAILURE MODE EVENT IDENTIFICATION			FAILURE MODE CAUSE & EFFECT ANALYSIS		SAFETY CAT.	FAILURE MODE EVALUATION	
ITEM	DESCRIPTION	FAILURE MODE	FAILURE MODE CAUSES	FAILURE MODE SYSTEM EFFECTS		FAILURE MODE SAFEGUARDS AND COMMENTS	RECOMMENDED ACTIONS FOR FAILURE MODE
4.2	RE-COIL ELECTRIC CABLE	DOES NOT TRANSMIT ELECTRIC POWER	BROKEN WIRE WITHIN CABLE	FAILURE TO ACTIVATE STEPPING MOTOR MAKES BRUSH MICROSWITCH INOPERABLE STOCK PARTS/COMPONENTS THAT HAVE A LIMITED LIFE	3	MOUNT CABLE AS MOUNTED ON PROTOTYPE	DO NOT OVER EXTEND DURING INSTALL./OPERATION
5.1	RE-COIL VACUUM TUBE	TUBE GETS TANGLED IN THE END EFFECTOR	FATIGUED TUBE	FAILS TO PICK-UP BRUSH SET END EFFECTOR BREAKS RE-COLORED TUBE	3	MOUNT AS MOUNTED ON PROTOTYPE	DO NOT OVER EXTEND DURING INSTALL./OPERATION INSPECT PERIODICALLY
5.2	RE-COIL VACUUM TUBE	FAILURE TO SUPPLY VACUUM	BROKEN OR CRACKED TUBE	FAILS TO PICK-UP BRUSH SETS	3	MOUNT AS MOUNTED ON PROTOTYPE	DO NOT OVER EXTEND DURING INSTALL./OPERATION INSPECT PERIODICALLY

SAFETY CAT: 1. DOES NOT INTERRUPT OPER; 2 INTERRUPTS OPER, RESET/ADJ'MENT REQ'D; 3. INTERRUPTS OPER, REPAIR REQ'D; 4. INTERRUPTS OPER, MAY DAMAGE HARDWARE

END EFFECTOR

FAILURE MODE EVENT IDENTIFICATION			FAILURE MODE CAUSE & EFFECT ANALYSIS			SAFETY CAT.		FAILURE MODE EVALUATION	
ITEM	DESCRIPTION	FAILURE MODE	FAILURE MODE CAUSES	FAILURE MODE SYSTEM EFFECTS	SEE FOOTER	FAILURE MODE COMMENTS	RECOMMENDED ACTIONS FOR FAILURE MODE		
6.1	VACUUM PUMP	DOES NOT SUPPLY VACUUM	LOSS OF POWER VARIOUS INTERNAL MALFUNCTIONS	FAILS TO PICK-UP BRUSH SET	3	MOUNT TO ALLOW ADEQUATE VENTILATION FOR MOTOR AND FAN	DO NOT OIL PUMP, AS SPECIFIED BY THE MANUFACTURE THE VACUUM PUMP DIAPHRAGM AND FILTER ARE LIMITED LIFE PARTS, STOCK PARTS/ COMPONENTS THAT HAVE A LIMITED LIFE		
7.1	BRUSH SET POSITION SWITCH	SWITCH STUCK ON OR OFF	INTERNAL SHORT INCOMPLETE CIRCUIT	FAILURE TO PICK UP BRUSH SET	3		VISUALLY CHECK THE CORRECT OPERATION OF THE SWITCH DURING THE START-UP		

SAFETY CAT: 1. DOES NOT INTERRUPT OPER; 2. INTERRUPTS OPER, RESET/ADJ'MENT REQ'D; 3. INTERRUPTS OPER, REPAIR REQ'D; 4. INTERRUPTS OPER, MAY DAMAGE HARDWARE

HORIZONTAL MOVEMENT

FAILURE MODE EVENT IDENTIFICATION			FAILURE MODE CAUSE & EFFECT ANALYSIS			SAFETY CAT.	FAILURE MODE EVALUATION		
ITEM	DESCRIPTION	FAILURE MODE	FAILURE MODE CAUSES	FAILURE MODE SYSTEM EFFECTS	FAILURE MODE SAFEGUARDS AND COMMENTS		RECOMMENDED ACTIONS FOR FAILURE MODE		
1.1	RODLESS AIR CYLINDER	FAILS TO PROVIDE LINEAR MOVEMENT	INADEQUATE AIR SUPPLY/PRESSURE	FAILURE TO PICK OR PLACE BRUSH SET ACCURATELY	3	AIR SUPPLY/PRESSURE IS CHECKED VIA THE HOME POSITION SENSOR OF THE PUNCH AIR CYLINDER PISTON	CHECK AIR PRESSURE DAILY DURING INITIAL START-UP		
			MOVEMENT INHIBITED BY END EFFECTOR			END EFFECTOR POSITION IS CHECKED BEFORE CYLINDER PISTON IS MOVED	CHECK FREE MOTION OF HORIZONTAL SYSTEM PERIODICALLY		
			MOVEMENT INHIBITED BY CORROSION OR CONTAMINATION			ENSURE A CLEAN DRY AIR SUPPLY			
2.1	THOMSON BALL BUSHINGS	FAILS TO ALLOW FREE LINEAR MOTION	LUBRICATION FAILURE DUE TO INCORRECT OR INSUFFICIENT LUBRICATION; CORROSION OR CONTAMINATION; HIGH TEMPERATURE EFFECTS, OR MIGRATION	LOSS OF DRIVE POWER OR MOTION TO SYSTEM POTENTIAL GUIDE SHAFT DAMAGE MAY CAUSE OVERLOAD DAMAGE TO DRIVE TRAIN	3	BEARING ORIENTATION MUST BE MAINTAINED SUCH THAT LOAD IS APPLIED HALF WAY BETWEEN ADJACENT BALL TRACKS	INSURE PROPER LUBRICANT CHOSEN FOR OPERATING CONDITIONS SUCH AS CHEMICAL, HUMIDITY, AND CONTAMINANT RESISTANCE; AND TEMPERATURE RANGES. CONSIDER USING SEALS OR SHIELDS		
			INSUFFICIENT INTERNAL CLEARANCE DUE TO INCORRECT FITS CAUSING BINDING OR DEFLECTIONS; OR THERMAL EXPANSION DAMAGE TO RACES FROM MISALIGNMENT OR OVERLOAD; IMPACT LOADING; WEAR FROM EXCESSIVE FRICTION; OR DEFECTIVE HOUSINGS USAGE IN EXCESS OF			BEARING USE IS A SCIENCE WITHIN ITSELF -- CONSULT MANUFACTURER SPECIFICATIONS FOR DETAILS OR SOURCES SUCH AS SKF SERVICE GUIDE BOOKLET VERIFY PROPER TOLERANCE FOR FITS FOR NEEDED PRESSURES OVER THE EXPECTED TEMPERATURE RANGE	DESIGN FOR NO RELUBRICATION WITH SEALED BEARINGS OR DESIGN FOR EASY RELUBRICATION WITH AMPLE LUB. POINTS AND SET PROCEDURES CHECK FREE MOTION OF HORIZONTAL SYSTEM PERIODICALLY		

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HORIZONTAL MOVEMENT

FAILURE MODE EVENT IDENTIFICATION		FAILURE MODE CAUSE & EFFECT ANALYSIS		SAFETY CAT.		FAILURE MODE EVALUATION	
ITEM	FAILURE MODE	FAILURE MODE CAUSES	FAILURE MODE SYSTEM EFFECTS	SEE	FOOTER	FAILURE MODE	RECOMMENDED ACTIONS FOR FAILURE MODE
3.1	HORIZONTAL SHAFT	FAILS TO PROVIDE SUPPORT BECAUSE OF FRACTURE	LOSS OF DRIVE GUIDANCE AND SUPPORT OF DRIVEN COMPONENTS	3		A FULL SPECIFICATION OF SHAFT MATERIAL, MATERIAL PROCESSING, MACHINING AND FINISHING, IN ADDITION TO PROPER TOLERANCES AND STRENGTHS IS REQUIRED	RECS. FOR INSTALL. MAINT. AND DESIGN
		COMBINED LOADING OF BENDING, TORSIONAL, SHEAR, AND AXIAL STRESS CAUSING YIELDING AND EVENTUALLY FRACTURE. SOURCES OF LOADS ARE OPERATING LOADS, MISALIGNMENTS, THERMAL EXPANSIONS, VIBRATIONS, AND EXTERNAL LOADS	POTENTIAL DAMAGE TO OTHER COMPONENTS FROM CONTACT WITH BROKEN GUIDE SHAFT OR UNSUPPORTED DRIVEN COMPONENTS			LIMIT STRESS CONCENTRATION FACTORS TO MAINTAIN FATIGUE STRENGTH	REC. FOR USING PROTECTIVE COVER ON GUIDE SURFACE TO PROTECT SURFACE
		FATIGUE FAILURE OF SHAFT DUE TO ALTERNATING TENSILE LOADING				THE EFFECTS OF COMBINED LOADING, FATIGUE STRESS CONCENTRATIONS, SURFACE WEAR AND DAMAGE, CORROSION, AND ALIGNMENT ALONG DESIRED PATH ARE THE KEY OPERATING	CHECK FREE MOTION OF HORIZONTAL SYSTEM PERIODICALLY
		WEAR FACTORS CONTRIBUTING TO STRESS CONCENTRATION FACTORS OR DECREASED STRENGTHS OF THE MATERIAL					
		CORROSION OF MATERIAL					
		DESIGNED AND EXPECTED LIFE					INSURE PROPER INSTALLATION AND MAINTENANCE PROCEDURES FOR MOUNTING AND REPAIRING BEARINGS ARE DEVELOPED AND FOLLOWED
		EXCESSIVE TIGHTNESS OF ADJUSTABLE RACE USED FOR TORQUE CONTROL					

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HORIZONTAL MOVEMENT

FAILURE MODE EVENT IDENTIFICATION		FAILURE MODE CAUSE & EFFECT ANALYSIS			SAFETY CAT.		FAILURE MODE EVALUATION		
ITEM	DESCRIPTION	FAILURE MODE	FAILURE MODE CAUSES	FAILURE MODE SYSTEM EFFECTS	SEE FOOTER		FAILURE MODE SAFEGUARDS AND COMMENTS	RECOMMENDED ACTIONS FOR FAILURE MODE	
LEADING TO FRACTURES EXTERNAL IMPACT LOADS INTO GUIDE SHAFT MATERIAL DEFECTS FROM MANUFACTURING PROCESS OF VOIDS IN MATERIAL, SURFACE SCRATCHES OR DAMAGE DURING MACHINING, IMPROPER HEAT TREAT, OR UNEXPECTED INTERNAL STRESSES CREATED									
3.2	HORIZONTAL SHAFT	ALLOWS EXCESSIVE VIBRATION	OPERATION AT OR NEAR NATURAL FREQUENCY OR HARMONIC OF NATURAL FREQUENCY FOR THE GUIDE TUBE	CAUSES PATH AND PLACEMENT INACCURACIES OF GUIDED DEVICE	1		THE GUIDE TUBE NATURAL FREQUENCY FROM DESIGN AND INSTALL /MAINT. IN COMPARISON TO DRIVING AND EXTERNAL INPUT FREQUENCIES IS THE KEY OPERATING PARAMETER. THIS SHOULD BE ADDRESSED IN INSTALL /MAINT. AND DESIGN	RECS. FOR INSTALL /MAINT. AND DESIGN	CHECK FREE MOTION OF HORIZONTAL SYSTEM PERIODICALLY
3.3	HORIZONTAL SHAFT	FAILS TO PROVIDE ACCURATE DESIRED GUIDE PATH	INSTALL /MAINT. ERRORS SUCH AS MOUNTING IN A STRESSED DEFORMATION OR SHAPE DAMAGE TO GUIDE	CAUSES INACCURATE PLACEMENT. POTENTIAL DAMAGE TO GUIDED OBJECTS AS A RESULT OF	1,2		HIGH QUALITY PARTS AND VERIFIED INSTALL /MAINT. IN ADDITION TO EXTERNAL	RECS. FOR INSTALL /MAINT. AND DESIGN	

SAFETY CAT. 1. DOES NOT INTERRUPT OPER; 2. INTERRUPTS OPER, RESET/ADJ. MENT REQ'D; 3. INTERRUPTS OPER, REPAIR REQ'D; 4. INTERRUPTS OPER, MAY DAMAGE HARDWARE

FAILURE MODE EVENT IDENTIFICATION			FAILURE MODE CAUSE & EFFECT ANALYSIS			SAFETY CAT.		FAILURE MODE EVALUATION		
ITEM	COMPONENT DESCRIPTION	FAILURE MODE	FAILURE MODE CAUSES	FAILURE MODE	SYSTEM EFFECTS	SEE	FOOTER	FAILURE MODE	RECOMMENDED ACTIONS FOR FAILURE MODE	
3.4	HORIZONTAL SHAFT	FAILS TO PROVIDE SMOOTH, UNIFORM GUIDE SURFACE	MANUFACTURING DEFECTS SUCH AS TAPERS OR DRIFTS IN CUTTING TUBE	INACCURACY	MAY CAUSE BINDING IF GUIDE TUBE IS USED IN PARALLEL WITH ANOTHER GUIDE TUBE			IMPAIRS THE KEY OPERATING PARAMETERS	REC. FOR RESTRICTING SOURCES OF EXTERNAL IMPACTS	
			DEFORMATIONS DUE TO EXTERNAL IMPACTS							CHECK FREE MOTION OF HORIZONTAL SYSTEM PERIODICALLY
			SURFACE DAMAGE DUE TO INSTALL/MAINT. CHIPPING OR KNUCKS	LOST OR DEGRADED POWER TRANSMISSION CAPABILITIES CAUSING PLACEMENT INACCURACY	1,2,3	ANY IMPACTS, SCRATCHING, CHIPPING, OR WEAR OF GUIDE TUBE ARE KEY OPERATING PARAMETERS. THESE SHOULD BE ADDRESSED IN INSTALL/MAINT.	RECS. FOR INSTALL/MAINT.			
			SURFACE DAMAGE DUE TO EXTERNAL IMPACTS OR FRICTIONAL WEAR			SURFACE DAMAGE TO GUIDE TUBE MAY ALSO ALLOW DAMAGE TO GUIDED OBJECT	REC. FOR USING PROTECTIVE COVER FOR GUIDE SHAFT TO PROTECT SURFACE			
4.1	AIR PRESSURE REGULATOR	FAILS TO CONTROL AIR PRESSURE	NOT ADJUSTED CORRECTLY INTERNAL MALFUNCTION	INADEQUATE AIR PRESSURE FOR LINEAR MOVEMENT OF THE RODLESS AIR	1,2,3,4			INSTALLED A PRESSUR LIMITING AIR PRESSURE REGULATOR TO PREVENT		

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HORIZONTAL MOVEMENT

FAILURE MODE EVENT IDENTIFICATION		FAILURE MODE CAUSE & EFFECT ANALYSIS		SAFETY CAT.		FAILURE MODE EVALUATION		
ITEM	DESCRIPTION	FAILURE MODE	FAILURE MODE CAUSES	FAILURE MODE	SYSTEM EFFECTS	SEE FOOTER	FAILURE MODE AND COMMENTS	RECOMMENDED ACTIONS FOR FAILURE MODE
5.1	AIR PRESSURE GAGE	DOES NOT DISPLAY CORRECT PRESSURE	INTERNAL MALFUNCTION LOOSE OR BROKEN CONNECTOR TUBE	UNDER OR OVER PRESSURIZATION OF SYSTEM	1,2			INSPECT PERIODICALLY
								ACCIDENTALLY OVER PRESSURIZING
								SET REGULATOR DAILY DURING INITIAL START-UP

SAFETY CAT. 1. DOES NOT INTERRUPT OPER; 2. INTERRUPTS OPER, RESET/ADJ'MENT REQ'D; 3. INTERRUPTS OPER, REPAIR REQ'D; 4. INTERRUPTS OPER, MAY DAMAGE HARDWARE

CONTROL CIRCUIT

FAILURE MODE EVENT IDENTIFICATION			FAILURE MODE CAUSE & EFFECT ANALYSIS			SAFETY CAT.	FAILURE MODE EVALUATION	
ITEM	DESCRIPTION	FAILURE MODE	FAILURE MODE CAUSES	FAILURE MODE SYSTEM EFFECTS			FAILURE MODE AND COMMENTS	RECOMMENDED ACTIONS FOR FAILURE MODE
1.1	4-WAY CONTROL SOLENOIDS	FAILS TO SWITCH	STICKING VALVE DUE TO CORROSION OR CONTAMINATION LOSS OF POWER - DUE TO LOOSE CONNECTION OR POWER FAILURE	INCORRECT HORIZONTAL MOVEMENT VACUUM SUPPLY ON/OFF AT INCORRECT TIME	3			VISUALLY INSPECT DURING THE FIRST CYCLE ENSURE A CLEAN DRY AIR SUPPLY
2.1	STEPPING MOTOR DRIVER	DOES NOT CONTROL STEPPING MOTOR PROPERLY	STARTED IN THE INCORRECT DRIVING MODE INTERNAL MALFUNCTION	NO VERTICAL MOVEMENT UNCONTROLLED VERTICAL MOVEMENT	2,3		START-UP PROCEDURE WAS WRITTEN TO ENSURE PROPER DRIVER MODE	FOLLOW START-UP PROCEDURE IF NECESSARY, RE-SET STEPPING MTR DRIVER BY TURNING OFF, AND THEN ON, THE POWER TO THE DRIVER
3.1	CIRCUIT	DOES NOT WORK	BLOWN OUT COMPONENT LOSS CONNECTION SHORT ACROSS OR WITHIN COMPONENT COMPONENT INTERNAL MALFUNCTION	COMPONENT/DEVICE DOES NOT OPERATE	3		USE GOOD QUALITY PLUG-IN CONNECTORS MAKE GOOD SOLDER JOINTS	STOCK PARTS/COMPONENTS THAT MAY BE EASILY DAMAGED

SAFETY CAT.: 1. DOES NOT INTERRUPT OPER, 2. INTERRUPTS OPER, RESET/ADJ'MENT REQ'D, 3. INTERRUPTS OPER, REPAIR REQ'D, 4. INTERRUPTS OPER, MAY DAMAGE HARDWARE

CONTROL CIRCUIT

FAILURE MODE EVENT IDENTIFICATION		FAILURE MODE CAUSE & EFFECT ANALYSIS			SAFETY CAT.	FAILURE MODE EVALUATION	
ITEM	DESCRIPTION	FAILURE MODE	FAILURE MODE CAUSES	FAILURE MODE SYSTEM EFFECTS	SEE FOOTER	FAILURE MODE AND SAFEGUARDS AND COMMENTS	RECOMMENDED ACTIONS FOR FAILURE MODE
4.1	24 VOLT POWER SUPPLY FAILS TO PROVIDE POWER		110 VOLT POWER LOSS TO THE SUPPLY BLOWN FUSE INTERNAL MALFUNCTION	DEVICE DOES NOT OPERATE END EFFECTOR MAY HIT FRAME	3	PROPER AIR PRESSURE WILL NOT DAMAGE END EFFECTOR IN THE EVENT THE END EFFECTOR HITS THE FRAME	STOCK SPARE FUSES CHECK AIR PRESSURE DAILY

SAFETY CAT.: 1. DOES NOT INTERRUPT OPER; 2. INTERRUPTS OPER, RESET/ADJ'MENT REQ'D; 3. INTERRUPTS OPER, REPAIR REQ'D; 4. INTERRUPTS OPER, MAY DAMAGE HARDWARE

CONTROL UNIT

FAILURE MODE EVENT IDENTIFICATION		FAILURE MODE CAUSE & EFFECT ANALYSIS		SAFETY CAT.	FAILURE MODE EVALUATION	
ITEM	DESCRIPTION	FAILURE MODE	FAILURE MODE CAUSES		FAILURE MODE	FAILURE MODE EVALUATION
1.1	COMPUTER	FAILS TO OPERATE	PROGRAMMING ERROR POWER LOSS INTERNAL MALFUNCTION	3	PROGRAM WAS USED EXTENSIVELY BEFORE PRODUCT WAS SHIPPED A POWER LOSS WILL NOT DAMAGE THE COMPUTER/PROGRAM. THE PROGRAM WILL RE-START UPON BEING RE-ENERGIZED	RECOMMENDED ACTIONS FOR FAILURE MODE
2.1	PRINTER CABLE	FAILURE TO TRANSMIT POWER	INTERNAL BREAK/SHORT LOOSE CABLE AT COMPUTER	3	DO NOT KINK CABLE DO NOT ALLOW TRAFFIC OVER CABLE	
3.1	AC POWER	NO POWER	PLANT POWER FAILURE LOCAL POWER FAILURE	3	DEVICE WILL RE-SET UPON BEING RE-POWERED	

SAFETY CAT: 1. DOES NOT INTERRUPT OPER; 2. INTERRUPTS OPER; RESET/ADJ'MENT REQ'D; 3. INTERRUPTS OPER, REPAIR REQ'D; 4. INTERRUPTS OPER, MAY DAMAGE HARDWARE

STRUCTURAL COMPONENTS

FAILURE MODE EVENT IDENTIFICATION		FAILURE MODE CAUSE & EFFECT ANALYSIS		SAFETY CAT.		FAILURE MODE EVALUATION	
ITEM	DESCRIPTION	FAILURE MODE	FAILURE MODE CAUSES	FAILURE MODE	SYSTEM EFFECTS	SEE FOOTER	FAILURE MODE ACTIONS FOR FAILURE MODE
1.1	STRUCTURAL COMPONENTS	FAILURE TO HOLD PART(S)/COMPONENT(S) IN CORRECT POSITION	NOT MANUFACTURED CORRECTLY STRUCTURAL FAILURE	VARIOUS MALFUNCTIONS	3,4	APPLICATION REQUIREMENTS ARE BELOW DESIGN STRENGTH OR FATIGUE LIFE	CHECK THAT THE PARTS ARE MANUFACTURED PER SPECIFICATION

SAFETY CAT: 1. DOES NOT INTERRUPT OPER; 2. INTERRUPTS OPER, RESET/ADJ MENT REQ'D; 3. INTERRUPTS OPER, INTERRUPTS OPER, REPAIR REQ'D; 4. INTERRUPTS OPER, MAY DAMAGE HARDW/

VITA

Brian Dale Cook was born on February 17, 1962 in Nashville, Tn. Brian graduated from Whites Creek Comprehensive High School in May, 1980. He received an Associates Degree in Mechanical Engineering Technology from Nashville State Technical Institute in May 1983. After working as an engineering technician for several years, Brian entered the mechanical engineering program at the University of Tennessee. He received a Bachelor of Science degree in Mechanical Engineering in December, 1989, followed by a Master of Science degree in Mechanical Engineering in December, 1991.