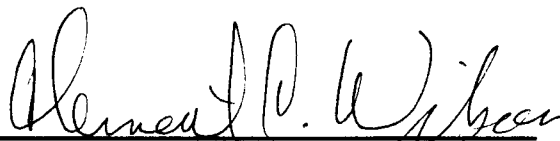


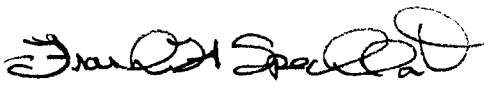
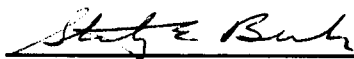
To the Graduate Council:

I am submitting herewith a thesis written by Timothy William Wyrick entitled "The Development of a Parting-Line Removal Technique for the Saturn 1996 Model Fender." I have examined the final copy of the thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Mechanical Engineering.



Dr. Clement C. Wilson, Major Professor

We have read this thesis
and recommend its acceptance:



Accepted for the Council:



Associate Vice Chancellor
and Dean of The Graduate School

THE DEVELOPMENT OF A PARTING-LINE REMOVAL
TECHNIQUE
FOR THE SATURN 1996 MODEL FENDER

A Thesis
Presented for the
Master of Science
Degree
The University of Tennessee, Knoxville

Timothy William Wyrick
May 1995

DEDICATION

This thesis is dedicated to my parents
Mr. Larry H. Wyrick and Mrs. Judith M. Wyrick

and to my grandparents
Mr. W. A. Anderson and Mrs. Velma T. Anderson
and

Mr. Hugh M. Wyrick and Mrs. Ruth Wyrick

who have provided me with the encouragement and
the opportunities to achieve my educational goals.

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ABSTRACT

The investigation involved the development of an approach for removing the parting line from the fenders of Saturn Corporation's SL-2, SL-3, and 1996 models. A parting line is a surface defect caused by the leakage of polymer into the voids between two sections of a mold. The existing method of removal was a completely manual operation and, as a result, was inconsistent and costly. Saturn had examined methods for removing the parting line that could be partially or fully automated in order to improve the consistency of its injection-molded body panels, yet it was unable to find an applicable technology. Consequently, this study explores a new method that incorporates a belt (stroke) sander and a cutting tool.

This investigation was composed of five steps. First, the abrasive-belt concept, an idea not already explored by Saturn, was formulated. Second, a prototype, which would permit a test plan to be carried out, was designed and built. Third, after assessing the effectiveness of the belt sander, improvements were made to the prototype. Fourth, a cutting tool was developed to compensate for the inadequacies of the sander. Finally, the two-phase process of cutting and sanding was evaluated based on the requirements (fender geometry, surface finish, and time to complete) outlined by Saturn.

The two-phase process was found to meet the surface finish and geometry requirements; however, the investigation failed to show how fast the process could be completed due to the sander's lack of sufficient power. The prototype force-loaded cutting tool, developed for use on SL-3 and 1996 model fenders, removes enough material from the fender in three passes to reduce the

amount of abrasive required for the sanding process by approximately 90%.

The belt sander completes the process by removing discontinuities in the slope of the fender and improving the surface finish. Encouraged by the results of this study, Saturn has expressed the desire to further the development of the cutting process with the goal of completing a fender in one pass with an automated procedure.

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CHAPTER 1

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Background

Automotive companies have used steel as the material for body panels for many decades; however, the use of injection-molded thermoplastics for the panels is relatively new. One problem with the injection-molded panels is the presence of a surface defect known as a parting line. Saturn Corp. is currently shipping its fenders and quarter-panels to an off-site company to have the parting line removed by a labor-intensive operation. Then, they are inspected and shipped back to the Saturn plant. Understandably, Saturn is looking for new ways of removing the surface defect that will improve panel consistency and reduce manufacturing costs.

Project Overview

This investigation was a feasibility study of a new process that removes the parting line from Saturn's 1996 model fenders; however, some discussions of the SL-3 and SL-2 models were undertaken. More specifically, the purpose of the study was to determine whether an abrasive belt could be used in conjunction with a cutting tool to remove the parting line. Figure 1.1 shows what must be done to remove the parting line—a radius of 1.5 to 2.0 mm must be formed in place of the sharp corner. Success of the new process was

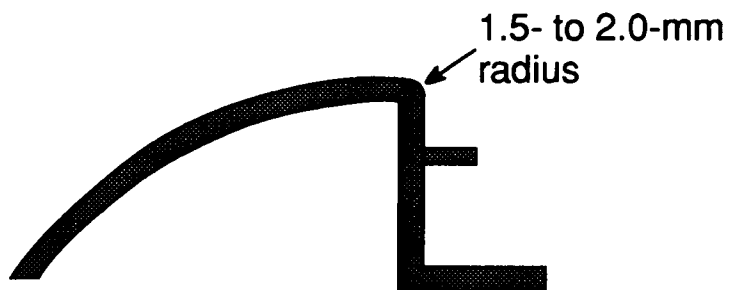
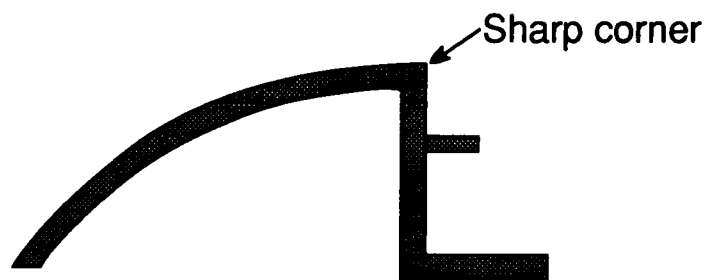
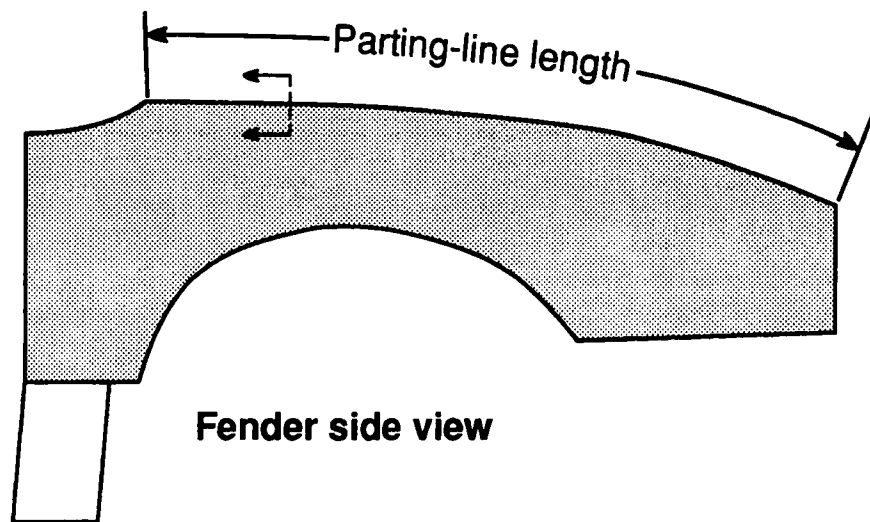


Figure 1.1. Parting-line removal. Cross-section of fender before and after removal.

judged by how it met the fender geometry, surface-finish, and time requirements. With that goal, a prototype belt sander was designed, built, and tested on the fenders. Next, a cutting tool was developed to remove the majority of the material from the sharp-cornered fenders (1996 and SL-3 models) prior to the sanding operation. The two-phase process was evaluated, and recommendations were made.

Design Descriptions

Prototype sander

The prototype belt sander, shown in Figure 1.2, drives a one-inch wide abrasive belt perpendicular to the parting line. The sander is intended to be translated along the fender, parallel to the parting line, by another machine, but, for this phase of the study, the fender was translated manually through the sander. Composed of an uptake and a supply reel, the sander accommodates a 100-meter roll of belt that has a 3 mil thick polyester backing and a 40 micron abrasive. The belt conforms to the profile of the fender and is loaded by the tension of the belt and an elastic pressure pad, located behind the belt. Each reel is driven independently by a DC gearmotor in order to maintain the speed and tension of the belt.

Force-loaded cutting tool

The force-loaded cutting tool, shown in Figure 1.3, is intended to be used on the sharp-cornered fenders before the sanding operation in order to simplify the sander's task in shaping the fender and reduce the amount of abrasive belt

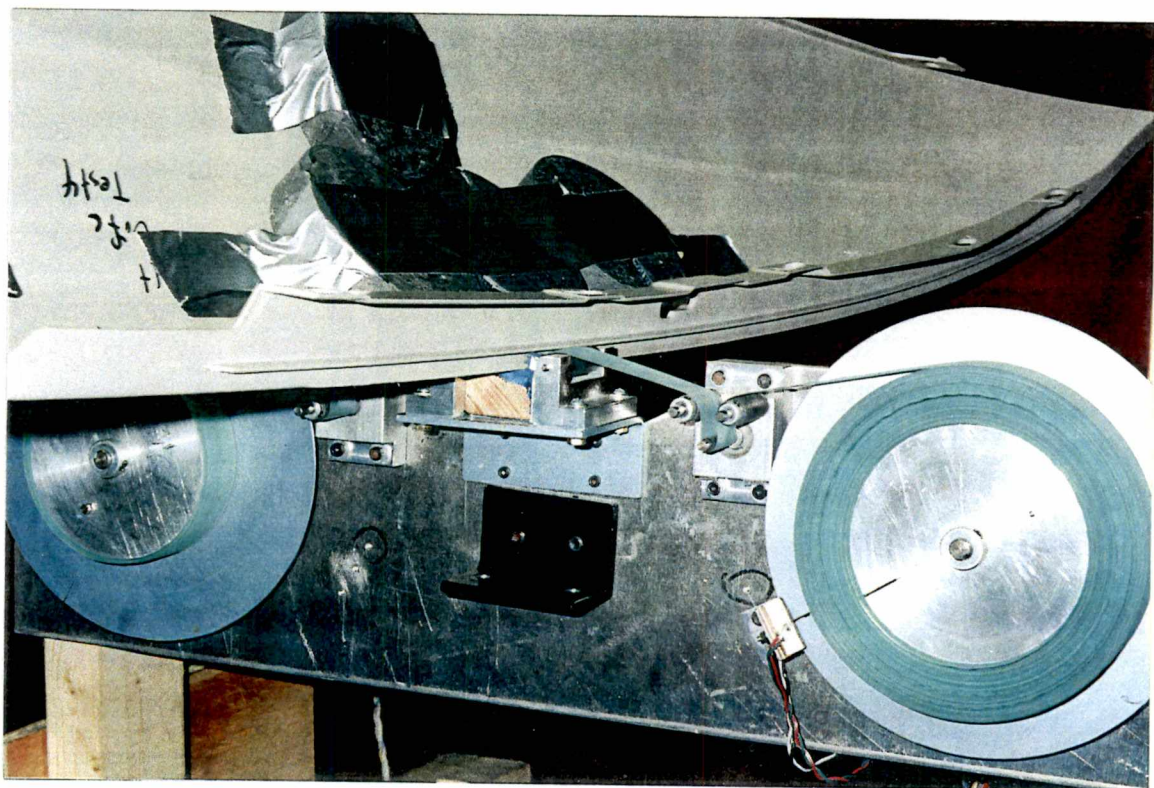
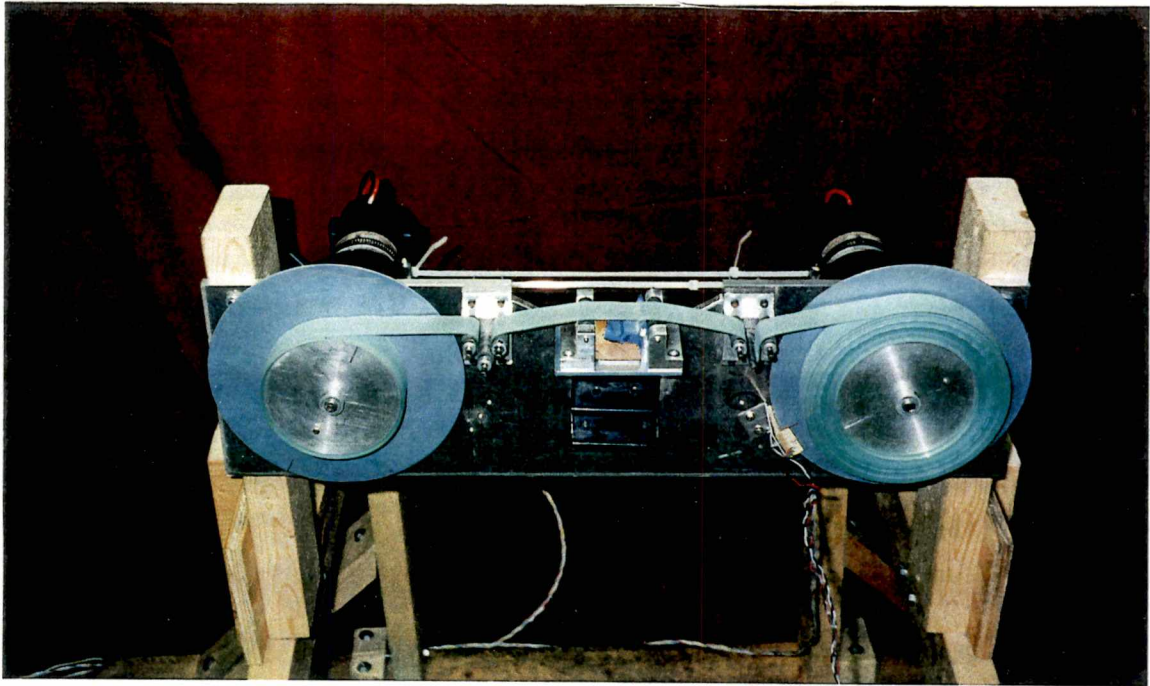


Figure 1.2. Prototype belt sander.

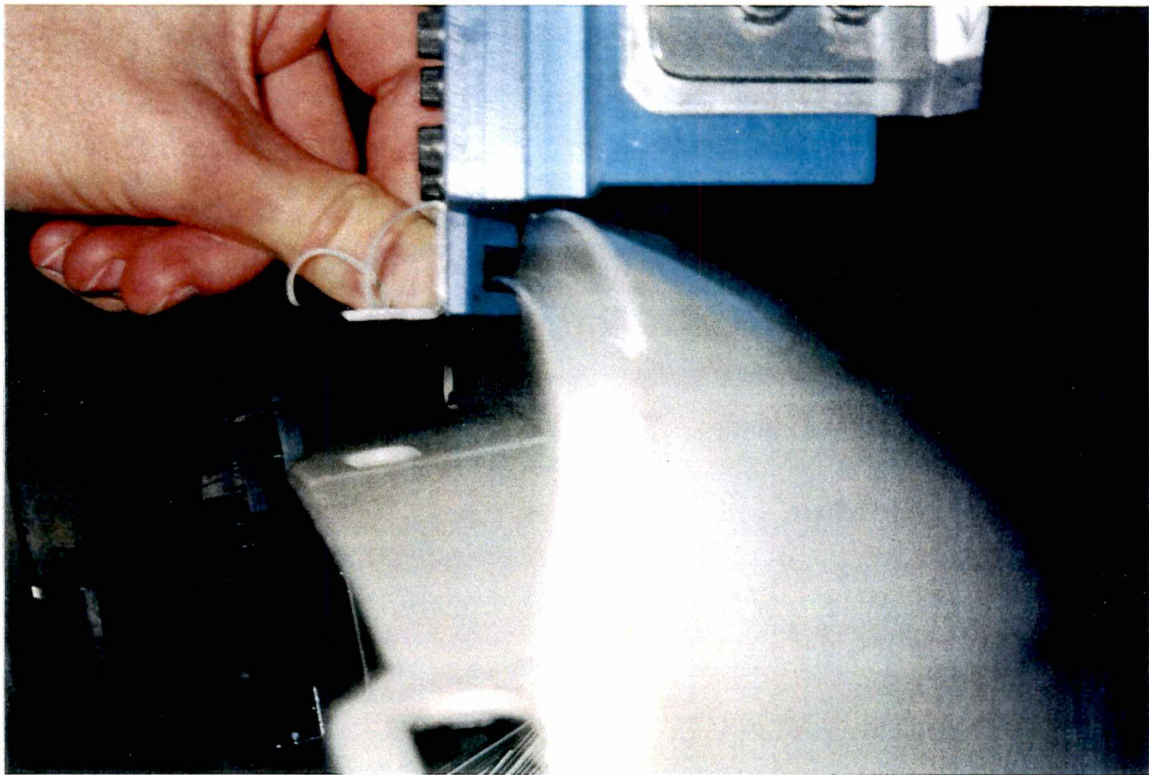
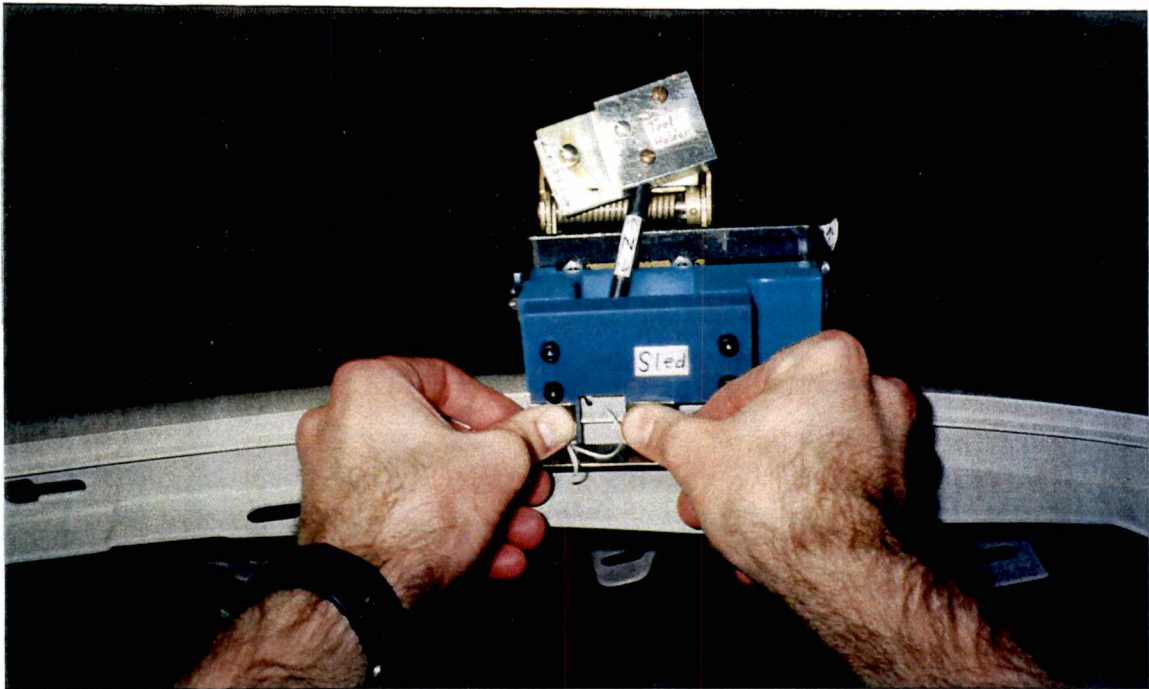


Figure 1.3. Force-loaded cutting tool operation. Photographs show how the tool is applied to the fender.

required to complete a fender. When pressed against the fender, in the manner shown in the figure, and translated along the fenders length, the device removes a continuous chip of constant thickness. Like the sander, the cutting tool is intended to be translated by a separate machine.

Conclusions

The investigation results enable several conclusions to be made about the technical feasibility of the two-phase process for removing the parting line. First, surface-finish requirements were met with the 40-micron, 3-mil polyester belt. Second, the geometry of the fender produced by the process was acceptable. The 1.6-mm radius achieved by the process falls within the 1.5- to 2.0-mm range set by Saturn. However, the prototype equipment failed to prove that the process can be completed in the 30-second time frame outlined by Saturn. Likewise, a conclusion about the total cost required to process a fender cannot be made; however, material cost (disposal of the abrasive media) is expected to be a large percentage of the total cost. Based on extrapolation from belt-life tests and the cost of the abrasive media, the material cost is expected to be well below \$1 per fender.

Recommendations

Further development of the cutting tool

The prototype cutting tool requires three passes to remove the required material from the fender prior to the sanding operation. A new cutting tool that

incorporates three independently loaded blades should be developed so the fender can be cut in one pass. Also, additional material can be removed by the new cutting tool if each blade has a different orientation with respect to the fender. Because the prototype cutting tool slides on the vertical catwalk surface to maintain the orientation of the blade with respect to the fender, an investigation should be undertaken to observe the effects of using the curved surface to maintain blade orientation. A final recommendation would be to grind a custom blade that more closely matches the desired shape of the fender profile.

New sander development

If there is still a need to automate the sanding process after the new cutting operation has been characterized and controlled, a new belt sander should be developed. One possible concept to explore could greatly simplify control of the sander. The idea is to use a continuous belt that recirculates about a single supply reel, much like an 8-track tape recirculates. This type of sander would require one motor and a pinch roll to drive the belt and a continuous slip clutch and a pinch roll to provide the belt tension. Because the belt would always travel in one direction and the load on the motor would remain constant, the required electronics might be reduced to a power supply and a relay.

CHAPTER 2

INTRODUCTION

The goal of this investigation was to develop a method for removing the parting line from the Saturn's fenders and quarter panels in a manner that is conducive to automation. Ideally, the method should be adaptable to other body panels; for directness, however, the SL-2, SL-3, and 1996 models were chosen for this feasibility study. The current method of removing the parting line, a description of the fenders, and the requirements for removal are discussed.

Problem Description

Origin of the parting line

The fenders, as well as all of the vertical body panels, are constructed of injection-molded thermoplastics. Both the fenders and the quarter panels are a polyphenyl ether, nylon 6,6 blend. The molds for the panels comprise multiple sections forced together during the molding process; as a result, there can be both misalignment and gaps between them. Under enormous pressure, the polymer leaks into the cracks separating the various sections. When the part is ejected from the mold, the polymer that leaked into the gap remains intact on the fender and is called a parting line. A segment of the parting line on the fenders and quarter panels runs along an external surface that must later be painted; therefore, the method for removing the defect is critical.

Current method of removal

Due to the location of the parting line, it must be removed before the panel can be painted. The current process involves transporting the body panels (fenders and quarter panels) offsite and completing the parting-line removal manually.

Removing the parting line involves three steps:

- 1) scraping off the defect,
- 2) sanding the fender to the correct shape with a random orbital sander and 320-grit sand paper, and
- 3) sanding the fender by hand with 30-micron-grade paper.

A paint scraper is used in the first step to remove the parting line. Then, the random orbital sander is manipulated around the top edge of the fender until the final shape is achieved. In the final step, the altered surface is prepared for the painting process by using a soft rubber pad with the 30-micron-grade paper. These modifications to the fenders and quarter panels are called body secondaries. In order for Saturn to bring the body secondary operations back on site, the process must be less labor intensive but still meet quality specifications.

Saturn's mission

Saturn's mission is either to develop a means of parting-line removal that is [Del Bosco, 1991]:

- 1) less labor intensive,
- 2) manually completed,
- 3) less time consuming,

- 4) higher quality, and
 - 5) more consistent,
- or

to develop a means to automate the operation and attain:

- 1) high-quality panels,
- 2) consistency,
- 3) improved cycle times,
- 4) less labor intensive operation, and
- 5) flexibility for future programs.

Ideally, the process would be fully automated and require only 30 seconds to complete a fender [Del Bosco, 1993].

Previous Investigations

The location of the parting line and the nature of the part on which it is located make automation difficult. Normally, flashing and parting lines are simply cut from plastic parts with CNC mill/routing processes, but these and many other alternatives were eliminated by a manufacturing team at Saturn. Some of the techniques tested were media blasting, cryogenic blasting, laser, water jet, and thermoforming [Del Bosco, 1991]. In addition, toy and wood-working industries were investigated for applicable methods. The lack of available technology led Saturn to develop its own approach. To this end, a G.M.F 420-S robot, armed with a random orbital sander, was programmed to replicate the human movements involved in the current manual operation.

The following are advantages of a robotic operation [Del Bosco, 1991]:

- 1) flexible tooling,
- 2) accuracy,
- 3) ease of programming,
- 4) quick modifications,
- 5) speed of operation, and
- 6) consistency of panels.

Replicating the human movements with the robot was found to be too slow.

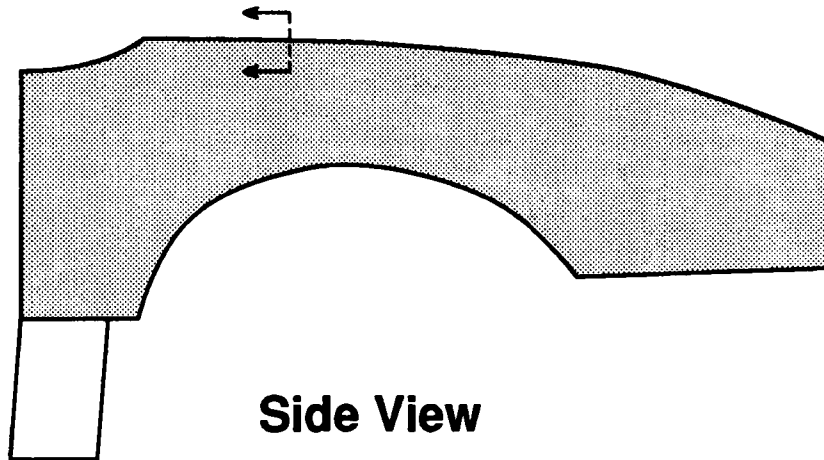
The conclusions of this study were that parting-line removal needs to be eliminated via styling or product design.

Fender characteristics

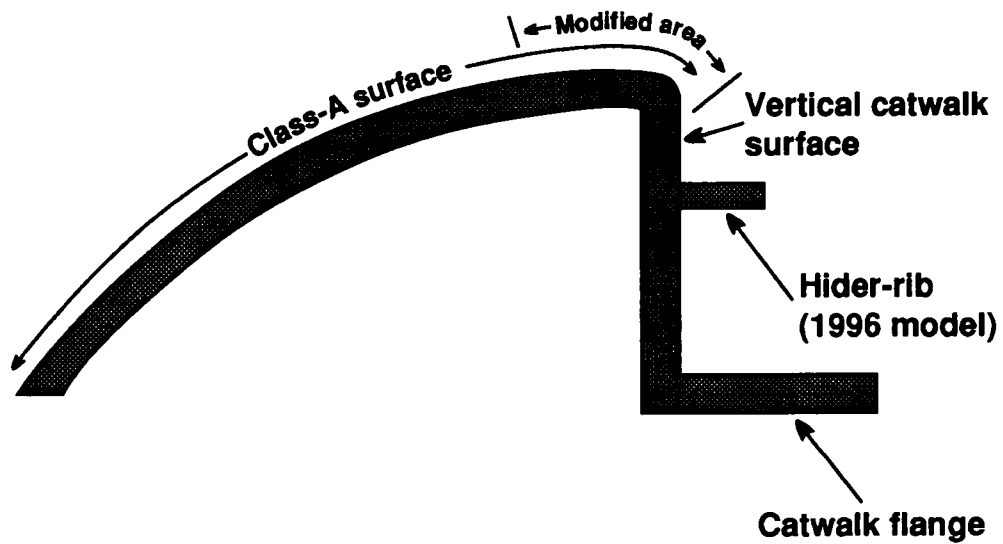
Figure 2.1 shows the side view of the fender (top) and a cross-sectional view (bottom). A class-A surface is one that will be painted and visible to the customer; therefore, the shape and finish of these surfaces is very important. The views in this figure show the extent of the fender's class-A surface and the location of the area to be modified. At the time this study began, in 1992, the fender of the SL-2 sedan was to be the center of investigation. However, late in the study, but before prototype building began, efforts were focused on the SL-3 model and, finally, the 1996 model. There are important differences between the three fenders.

Parting-line location and other features differ between the three models. Pictured in Figure 2.2 is a cross-sectional view of the SL-2 model fender.

■ Class-A surface



Side View



Cross-Sectional View

Figure 2.1. Fender anatomy

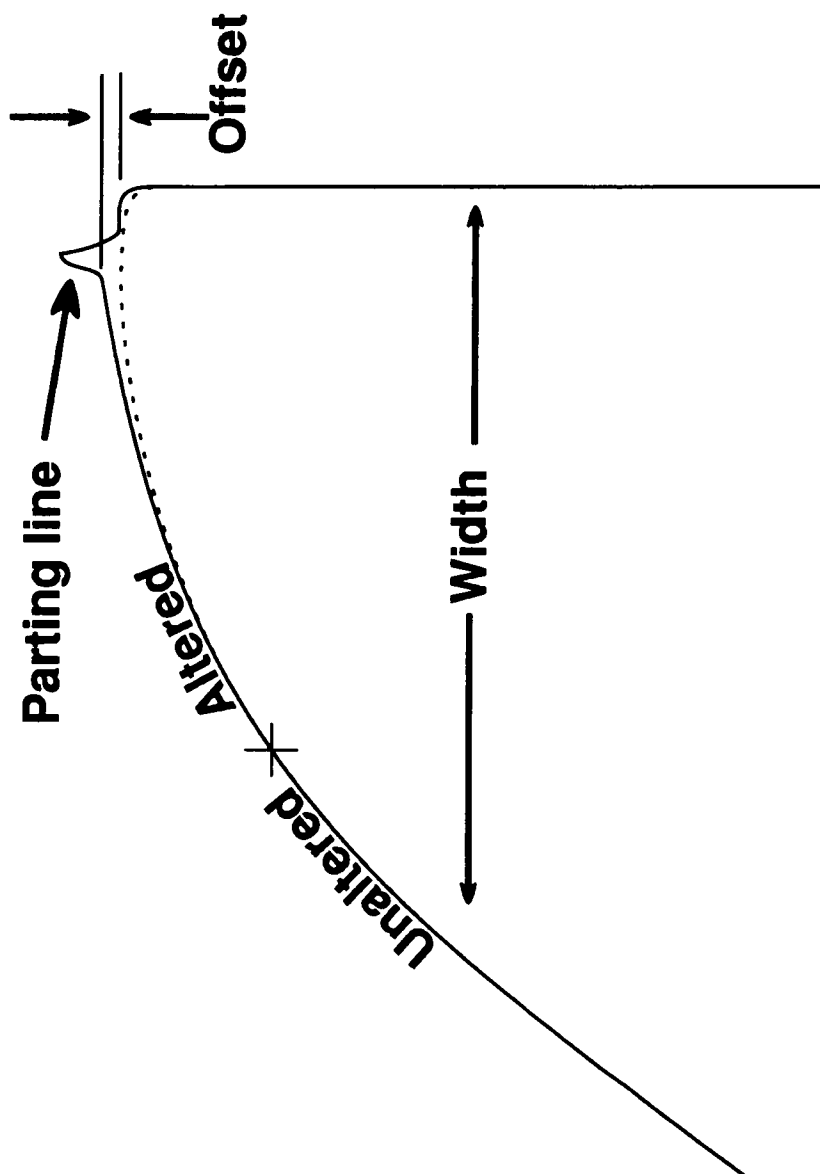


Figure 2.2. SL-2 cross-sectional view. Parting line, offset due to mold misalignment, and area to be modified are shown.

Because of mold misalignment, the surfaces to either side of the parting line are not at the same level. This requires that material in addition to the parting line be removed. For example, the dashed line in Figure 2.2 represents a probable final profile. As can be seen from Figure 2.1 and 2.2, the parting line and the additional material to be removed from the fender are located on a curved surface that must later be painted. Thus the slope of the fender profile must be continuous; otherwise, a line or flat spot would be visible along the length of the fender. Another characteristic of the fender is that the width of the cross-section is not constant, but dependant on its position along the length of the fender.

The parting line on the SL-3 and 1996 fenders is located on the edge of the fender, forming a sharp corner (see Figure 2.3). In this case, there is not a significant parting line to be removed; however, a radius must be formed by the removal process. A radius already exists on the corner of the SL-2; however, it may be altered by the removal process as shown by the dotted line in Figure 2.2. Figure 2.2 shows that the region to be altered on the SL-2 model fender includes a larger area away from the corner of the fender than either the SL-3 or 1996 models. In conclusion, removing the parting line is only a small part of the removal process for all three of the fenders; the shaping of the fender is the formidable task required for successful removal of the defect.

Removal requirements

In order for the removal to be completely successful, three requirements must be met:

- 1) a differentiable fender profile,

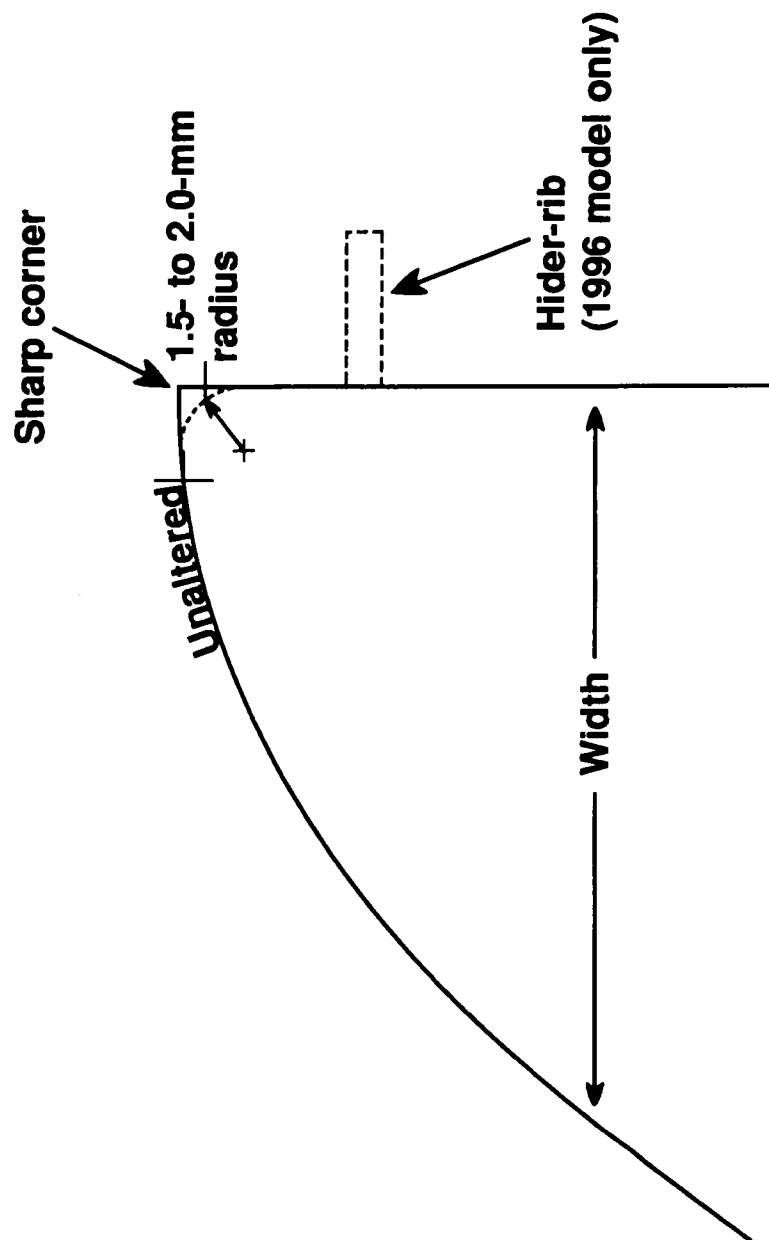


Figure 2.3. SL-3 and 1996 models. Cross-sectional views showing hider-rib and sharp corner.

- 2) a consistent and properly sized radius along the fender edge, and
- 3) a class-A surface finish (prepared for painting).

First, a differentiable fender profile means that flat spots and edges are unacceptable. Second, the correct radius must be obtained for each model. On the SL-2 model, the radius is formed somewhat by the mold; however, the radius on the SL-3 and 1996 models must be formed entirely by the removal process. The radius should be between 1.5 and 2.0 mm on the SL-3 and 1996 models. Third, a class-A finish is necessary for the painting process to be successful; in other words, no scratch marks should be visible through the paint.

CHAPTER 3

PROTOTYPE BELT SANDER

Concept Description

A concept for removing the parting line was formulated based on Saturn's mission as stated in Chapter 2. The investigation began with the SL-2 model fender; afterward, as already mentioned, the SL-3 and, later, the 1996 model were given priority. In any event, the concept chosen for development incorporates an abrasive belt, under tension, as shown in Figure 3.1. The belt is driven with a velocity directed parallel to the length of the belt (which remains perpendicular to the parting line) while it is also translated at a much slower velocity parallel to the parting line. As seen in the figure, the belt is forced to conform to the profile of the fender. Not shown in the figure, is a pressure pad that can be used to push the belt against the fender with a greater force than can be provided by the belt tension alone. The process parameters that have an effect on the shape of the fender were determined before the prototype machine was designed.

Process parameters

The desired shape of the fender's cross-section is obtained by removing material in the right proportions. Further, the quantity of material removed per unit length of the fender is a function of the material removal rate and the time period over which the removal takes place. In turn, the material removal rate is

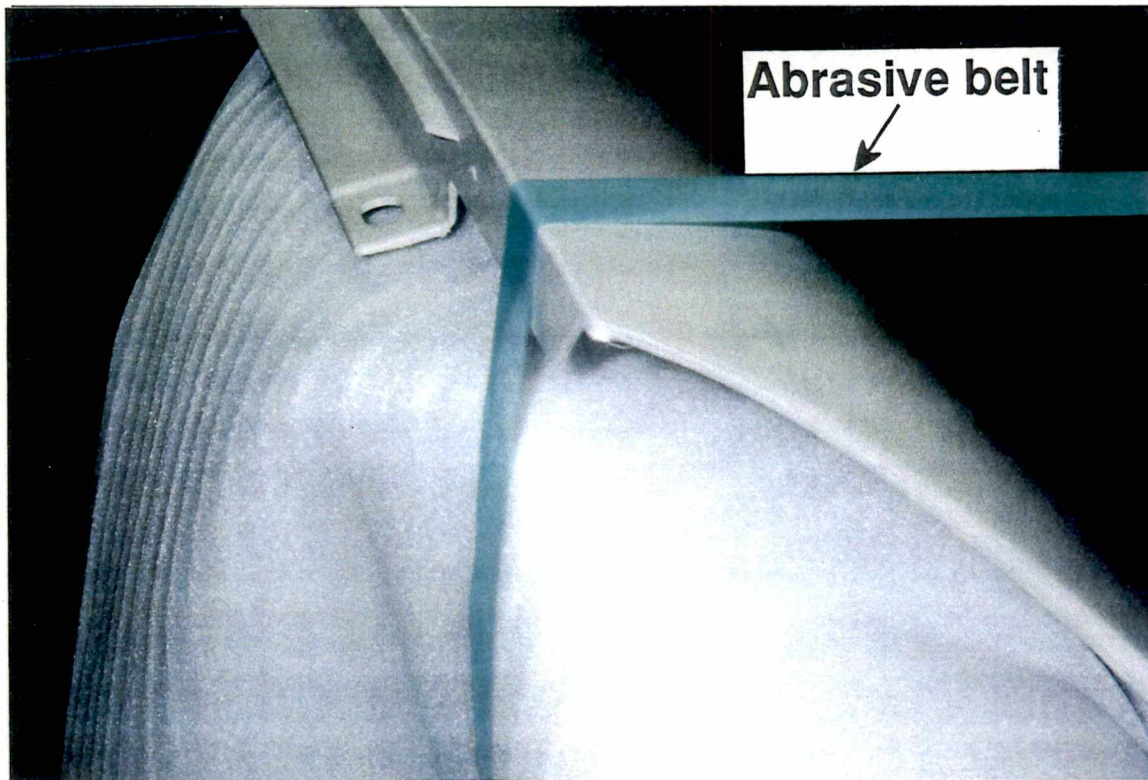


Figure 3.1. Abrasive belt concept. The belt, under tension, conforms to fender profile.

a function of the pressure distribution between the belt and the fender and the velocity of the belt with respect to the fender. The velocity and time factors can be combined into one factor—the length of belt required to complete a given length of fender. The remaining factor is the pressure distribution between the belt and the fender. To this end, the factors that change the pressure distribution were determined. These factors were found to be belt stiffness, direction of belt travel, belt application angles, belt tension, pressure pad configuration and loading, and fender model.

Belt stiffness

The stiffness or flexural rigidity of the belt affects how sharply the pressure increases from the initial points of contact between the belt and the fender. Figure 3.2 shows how stiffness, in general, affects the contact area and pressure distribution between the belt and fender. The figure merely serves the purpose of identifying belt stiffness as a process parameter.

Direction of belt travel

The direction that the belt is traveling with respect to the fender affects the pressure distribution because the tension of the belt is reduced by the force imparted from the fender and the frictional resistance from the pressure pad (if one is used). For example, the tension of the belt at location A in Figure 3.3 would be greater when the belt is traveling right to left than if the belt were traveling left to right. In addition, because the belt has thickness, a moment is created from a force couple, and the

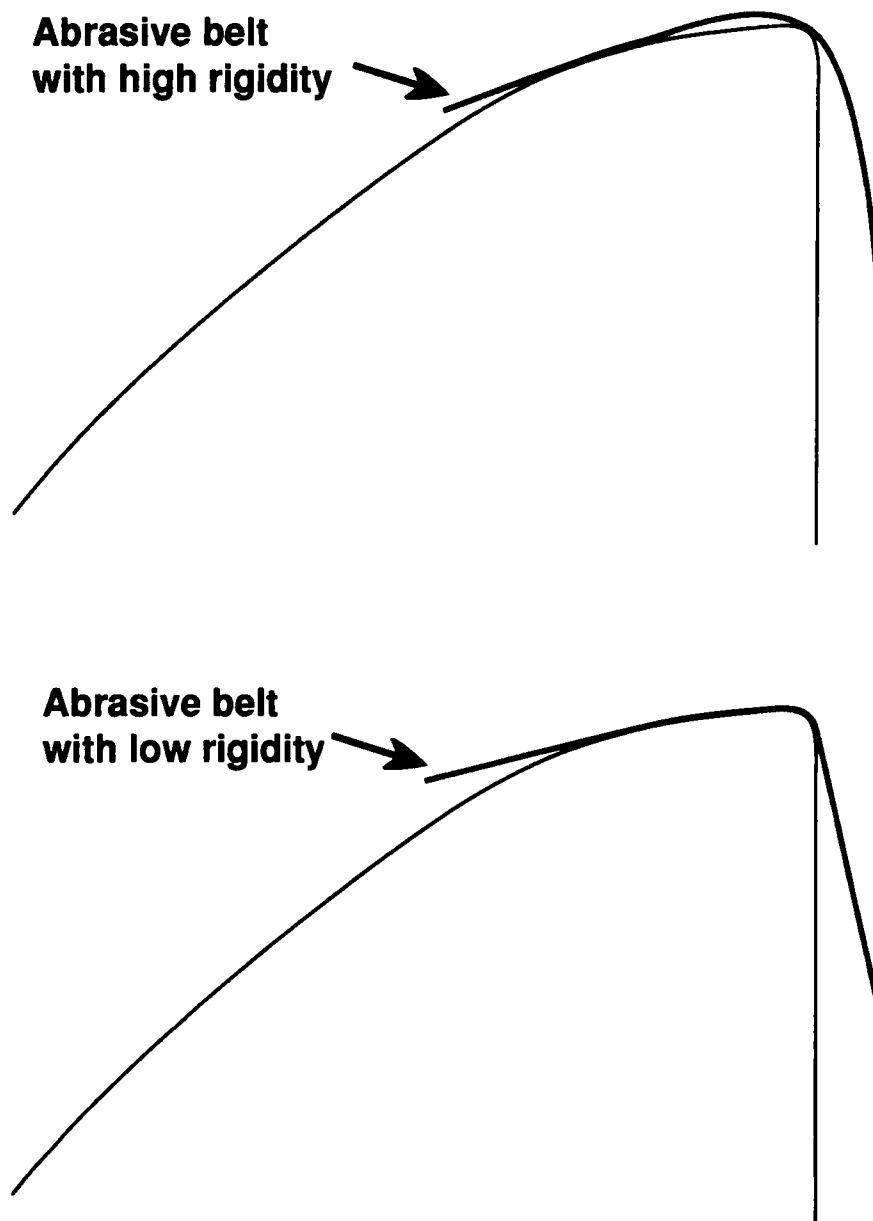


Figure 3.2. Belt stiffness. Rigidity of the belt affects the pressure distribution between the belt and the fender.

T: Tension
 T_s : Tension due to sanding
M: Moment on belt caused due to couple of T and T_s

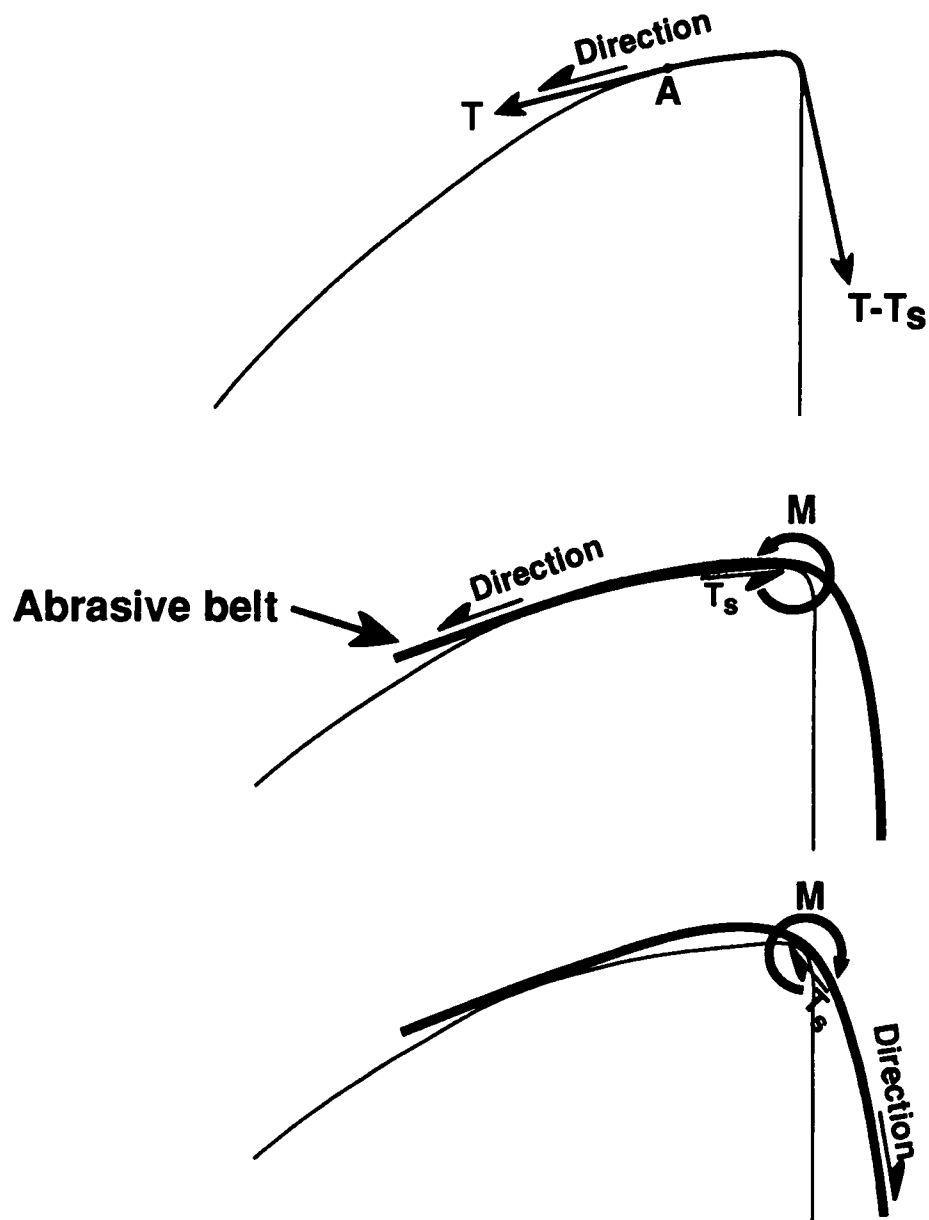


Figure 3.3. Direction of belt travel. Two ways belt direction can affect the pressure distribution between the belt and the fender.

sense (clockwise or counter-clockwise) is determined by the direction in which the belt is traveling. Figure 3.3 illustrates how this moment can affect the pressure distribution between the belt and the fender.

Belt application angles

Figure 3.4 illustrates how different angles can be used to obtain different pressure distributions and, therefore, different fender profiles. The pressure distribution is altered because the contact area between the belt and fender is altered; furthermore, the resultant force applied to the fender from belt tension is altered. If an elastic pressure pad is used, these angles are determined by the geometry of the pad.

Belt tension

Increasing belt tension increases the pressure between the belt and the fender. Also, a higher belt tension could affect how belt stiffness influences the shape of the fender because a greater percentage of the pressure distribution results from the belt tension. Likewise, as the tension of the belt decreases, a greater percentage of the pressure distribution is caused by the rigidity of the belt.

Elastic pressure pad

Another means of modifying the pressure distribution is to apply direct pressure to the back of the belt with an elastic pad, as shown in Figure 3.5. The pad material must be able to conform to the shape of the fender to ensure that a differentiable curve is obtained. The factors affecting the

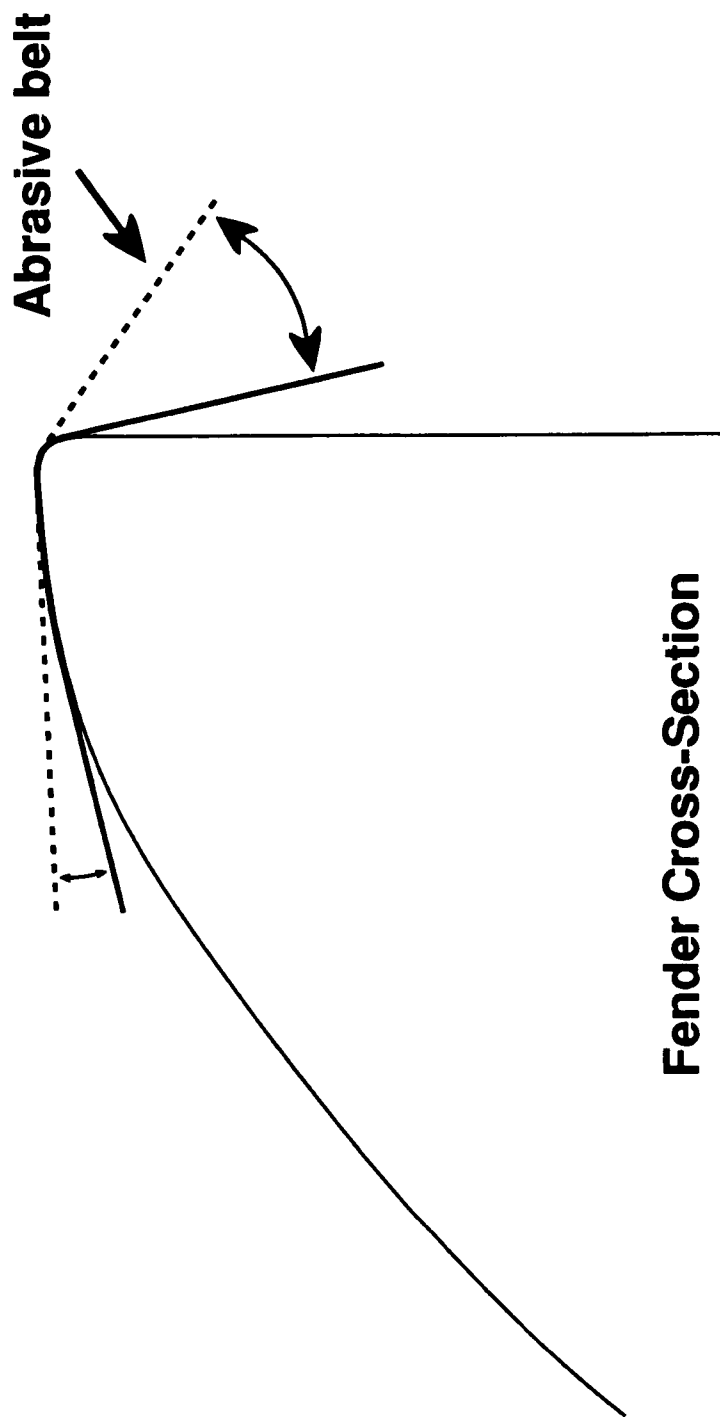


Figure 3.4. Belt application angles. The angle at which the belt approaches and recedes from the fender affects the pressure distribution between the belt and the fender.

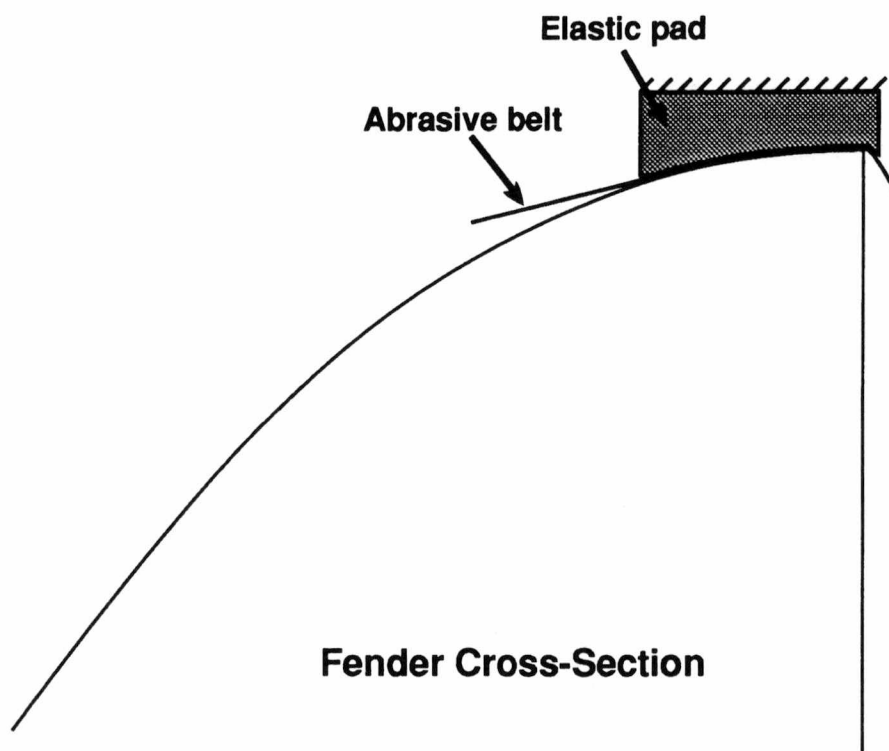


Figure 3.5. Elastic pressure pad. Direct pressure can be applied to the belt with the pressure pad.

pressure distribution are the force with which the pad is applied to the fender, the undeformed shape of the pad, the stiffness of the pad, and friction between the pad and the belt.

Fender model

The relevant distinctions between the SL-2, SL-3, and 1996 model fenders, discussed in Chapter 2, affect the abrasive process. For example, the belt must initially conform around the sharp corner of the SL-3 and 1996 fender; thus, belt stiffness is a greater factor. On the other hand, the cutting tool, to be discussed in Chapter 4, can be used on the sharp-cornered fenders prior to sanding; as a result, the belt would not have to bend around the sharp corner. In addition, there are differences in fender width and in the angle between the two fender surfaces being modified. Hence, the contact area and pressure distribution are a function of the fender model and position of the belt along the fender length.

Prototype Design

Figure 1.2 of the prototype reel-to-reel belt sander shows the orientation of the sander with respect to the fender. Also shown in this figure is how the sander is oriented with respect to the fender. With this setup, the sander is fixed and drives the one-inch-wide belt perpendicular to the parting line while the fender is manually translated parallel to the parting line. To automate the process, the fender can be fixed and another machine (i.e., robot) could translate the sander.

No complex motion is required of the machine that would translate the sander. The prototype belt sander consists of three subsystems: the drive system, belt-alignment system, and belt-loading system. An operating procedure for the sander can be found in Appendix B.

Drive system

The purpose of the drive system is to control the speed, tension, and direction of the belt. It was shown earlier that tension affects the pressure distribution between the belt and the fender. For this reason, it was deemed necessary to maintain a constant tension to produce a consistent radius along the fender. Being able to adjust the tension is also important in testing the sander. Although speed should not affect the pressure distribution between the belt and the fender, it does affect material-removal rate. Consequently, speed should be kept constant so that one location of the fender is not sanded to a greater degree than another. However, the speed changes because the load on the motors changes as the belt winds up on the uptake reel. The drive system requires both electrical and mechanical components. A brief description of the drive system follows; more detailed information about the electronics software can be found in Appendix D.

The sander can be divided into two halves—the supply side and the uptake side. The belt travels from the supply reel to the uptake reel with the abrasive side of the belt facing out from the reel center. Each reel is driven independently by a DC gearmotor coupled directly to the reel shafts. The uptake-side motor controls the speed of the belt, while the supply-side motor

controls the supply-side tension. As was shown in Figure 3.3, the tension of the belt to one side of the fender is not equal to the tension on the other side of the fender; in other words, the supply-side tension is not equal to the uptake-side tension.

The mechanical components of the drive system consist of two 1/20-hp DC gearmotors, a DC tachometer, and the two reel assemblies. The motors were chosen based primarily on approximate torque requirements before the need for a pressure pad was determined. The diameter of the reel hubs was chosen based on the maximum radius of a 50-yard-long shop roll and motor performance. Motor specifications are located in Appendix F.

An MC68HC11 EVB (a microcontroller board), some supporting electronics, and software comprise a pulse width modulated drive system for the two motors. Two H-drive circuits are used to drive the two motors in forward and reverse directions. The feedback for the speed is provided by a tachometer coupled to a shaft that is driven directly by the belt. Unfortunately, the electronics for tension feedback were never able to be debugged; however, open-loop control was still available when short lengths of belt were used to maintain a relatively constant radius.

Belt-alignment system

The function of the belt-alignment system is to keep the belt from wandering or being pulled off center. This is important because while the sander drives the belt perpendicular to the parting line, the sander is translated parallel to the

parting line. The main components are a set of three crowned pulleys which form a triangle in front of one reel. Likewise, the tachometer transmission shaft and two crowned pulleys form a triangle in front of the other reel, as shown in Figure 3.6.

Belt-loading system

The belt-loading system consists of the abrasive media and the elastic pressure pad in combination with the two pulleys that straddle the parting line.

Abrasive media

The sander was designed to use a one-inch-wide belt. Various types of belts were tried to find the best combination of flexibility and coarseness. Consequently, a belt having a 3-mil-thick polyester backing and 40-micron-grade abrasive was found to be the most favorable; these belts are available in rolls of 100 meters. The polyester belts were found to be superior to the cloth variety because they are more flexible and do not fray.

Elastic pressure pad

The elastic pressure pad served to reduce the length of abrasive belt required to complete a fender and improve fender geometry. The pad is a 1/8-inch-thick, 30-durometer polyurethane sheet covered by a nylon fabric that serves as a non-rigid wear surface. The location and geometry of the pad determine the belt-application angles. For the sharp-cornered fender, the situation is as shown in Figure 3.6. Here, the

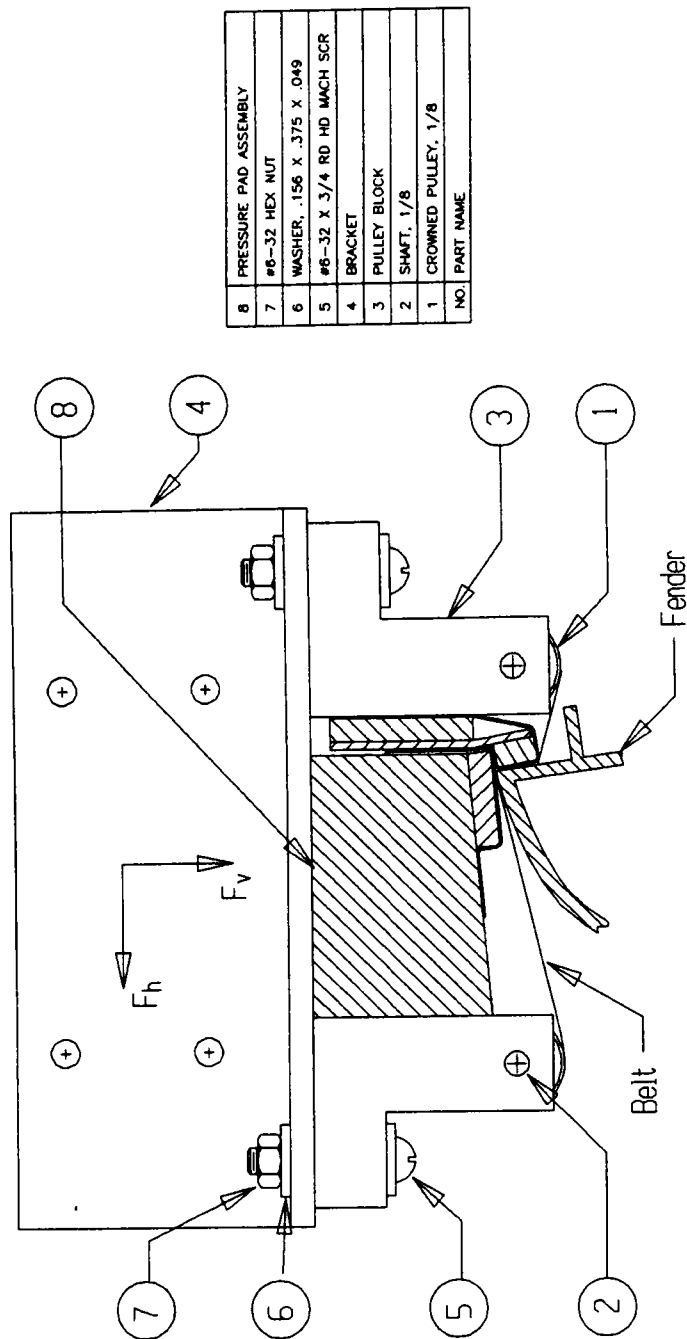


Figure 3.6. Elastic pressure pad configuration. F_h and F_v are forces applied to the fender by the pressure pad.

pad forces the belt against the vertical catwalk surface and the curved surface of the fender with forces F_h and F_v , respectively.

CHAPTER 4

FORCE-LOADED CUTTING TOOL

Methods for reducing the amount of belt required to complete a fender were explored as indicated by test runs with the belt sander. The theory of operation of the Shaviv deburring tool was investigated and followed by the design, construction, and testing of a device based on this tool. The device removes enough material to define the required radius prior to the sanding operation; however, the sander is still required to blend discontinuities and improve surface finish.

Theory of Operation

The Shaviv deburring tool consists of two functional parts: the blade and the blade holder. These items are shown in Figure 4.1. A variety of blades can be used; however, a B30-sized blade was found to be the best geometry. The blade is connected to the blade holder by a detented-swivel joint. Due to the geometry of the blade and its ability to rotate in the swivel joint, a chip of constant thickness can be cut under certain loading conditions. As the following analysis shows, the ratio between the cutting force and the downward (into workpiece) thrust force is the critical factor.

The Shaviv deburring tool is force loaded; in other words, the blade is not held in a fixed position to provide a given depth of cut. Evidently, the relief angle, as

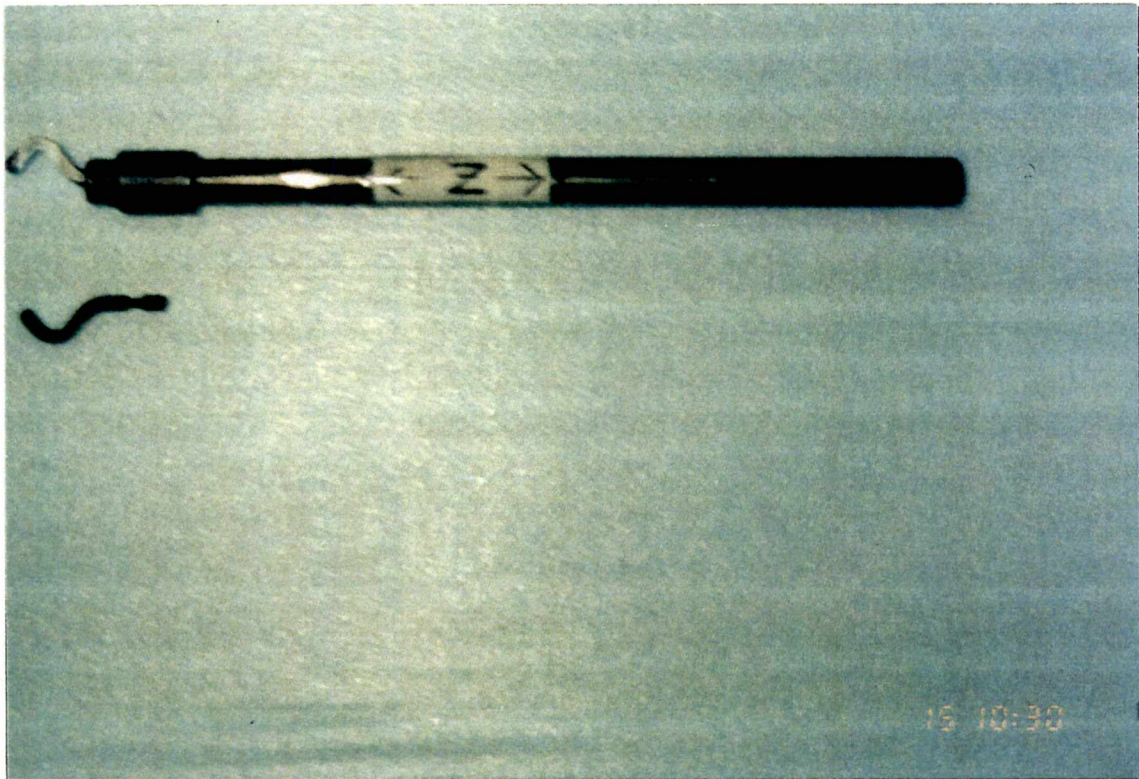
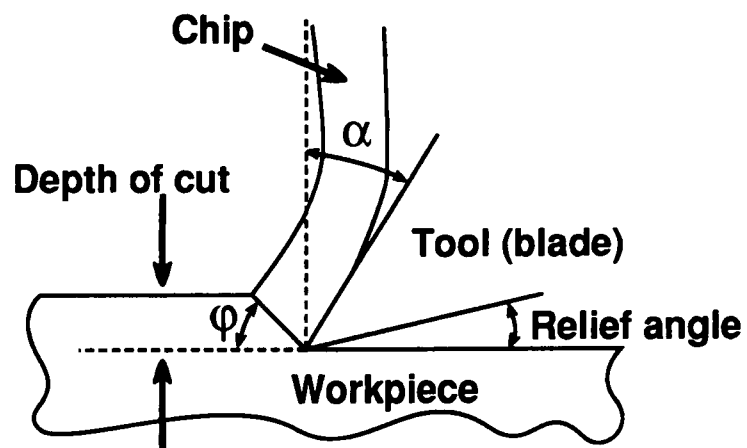


Figure 4.1. Shaviv deburring tool.

defined by Figure 4.2, must be maintained at zero degrees in order to maintain a constant depth of cut. Simply stated, the bottom of the blade face (relief face) rides on the workpiece. This condition can be visually verified when the Shaviv product is used on the fender.

The cutting process is three-dimensional oblique cutting; however, a two-dimensional model sheds some insight into how the tool works. Figure 4.3 is the particular model used for the deburring tool. The swivel axis is offset a distance, l , from the point on the blade where the chip is forming. The forces acting on the blade result from chip formation at the rake face (F_c and F_t) and contact between relief face and workpiece (F_{tr}). Also, the blade is loaded by the blade holder at the swivel axis. Here, the applied force can be divided into two orthogonal forces: F_c and F_d . For the tool to be stable (0° relief angle), the sum of the moments must be zero. By summing moments, it can be shown that the ratio F_d/F_c should fall within a certain range to obtain stability. Appendix C shows the full analysis used to arrive at this conclusion. Again, the analysis was not intended to provide a value for the required loading condition, but to determine the nature of the load. Hence, a device could be constructed that loads the tool in the correct manner and, then, allows the value of the load to be determined experimentally.

Another important factor for successful operation of the tool is the orientation of the blade with respect to the fender. Figure 4.4 shows the coordinate systems x_n , y_n , and z_n . x_1 is parallel to the vertical catwalk surface and perpendicular to the parting-line. x_2 is parallel to the parting-line and F_c . The y_n system,



α : Rake angle
 ϕ : Shear angle

Figure 4.2. Two-dimensional cutting.

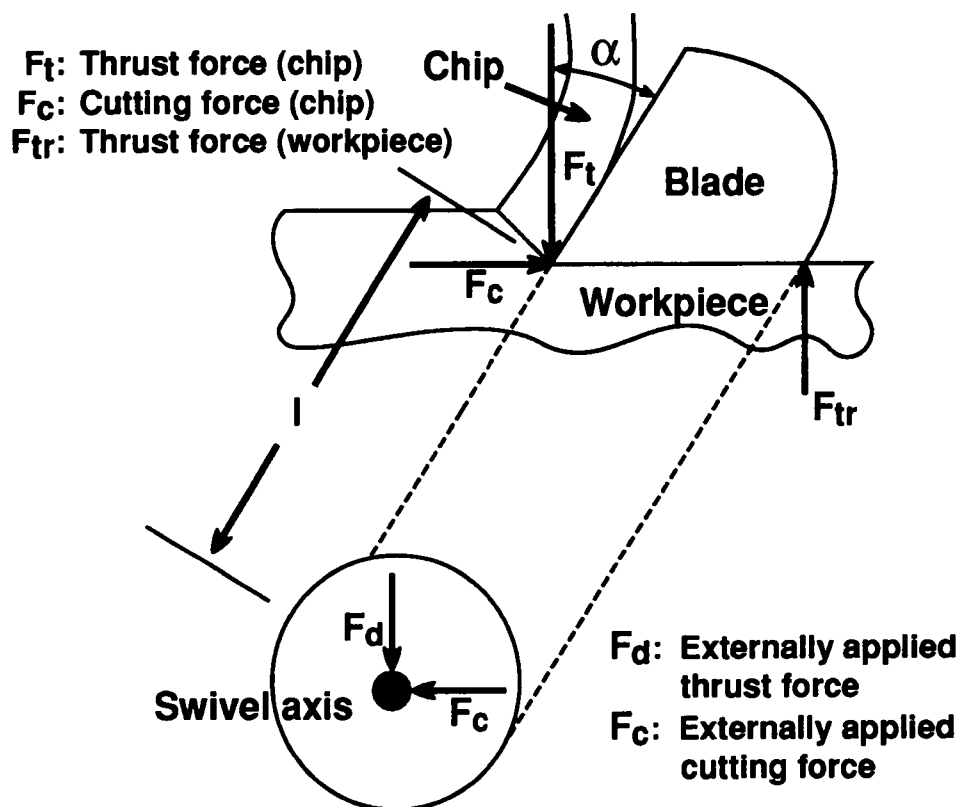


Figure 4.3. Two-dimensional model

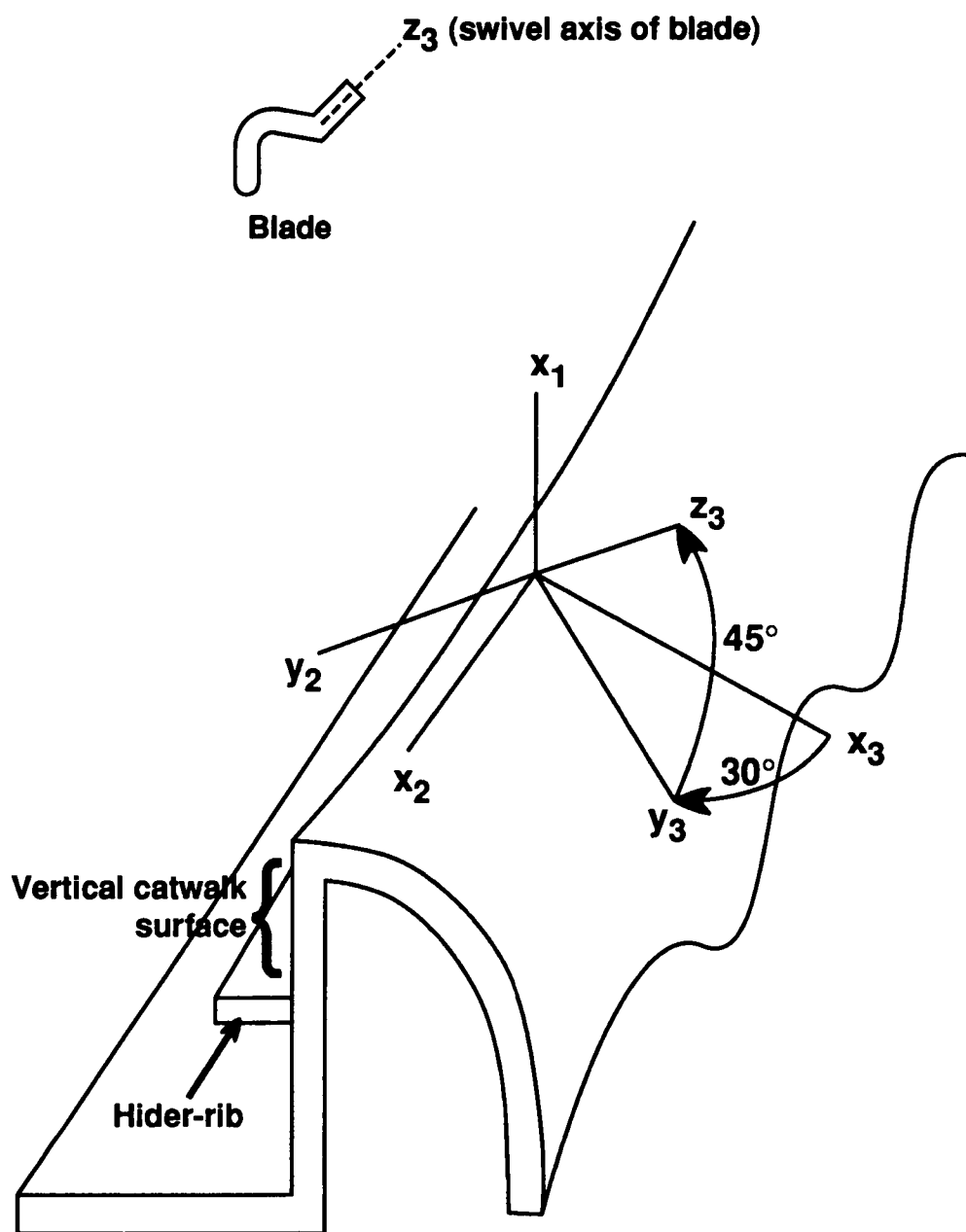


Figure 4.4. Blade orientation. Angles shown represent approximate orientation of the blade's swivel axis with respect to the fender.

originally coincident to the x_n system, is obtained by a 30° rotation about x_1 . Likewise, the z_n system, originally coincident to the y_n system, is obtained by a 45° rotation about y_2 . z_3 is the approximate direction of the blades swivel-axis.

Prototype Device

The information from the preceding analysis served as the guidelines for the construction of the prototype. It is composed of five parts (see Figures 4.5 and 4.6): the Shaviv deburring tool (blade and blade holder), tool holder, spring hinge, bracket, and sled. The device works by sliding the plastic sled along the length of the fender, as shown in Figure 1.3. In order to maintain its relative position with the fender, the sled has two legs that follow the vertical catwalk surface and top edge of the fender. The spring hinge provides the constant thrust force, F_d , on the tool. With the correct orientation, a continuous chip of constant thickness is removed from the fender. An operating procedure for the device is included in Appendix A.

The device allows for five adjustments—four change the blade orientation, and one changes the spring tension. The blade holder can be translated relative to the tool holder (Z) and locked down with two screws. Secondly, the tool holder can be rotated relative to the hinge (Θ) and locked into position. Because the angle Θ is not easily measured, it is represented by a linear dimension, W , as shown in Figure 4.6. Third, the hinge can be translated relative to the

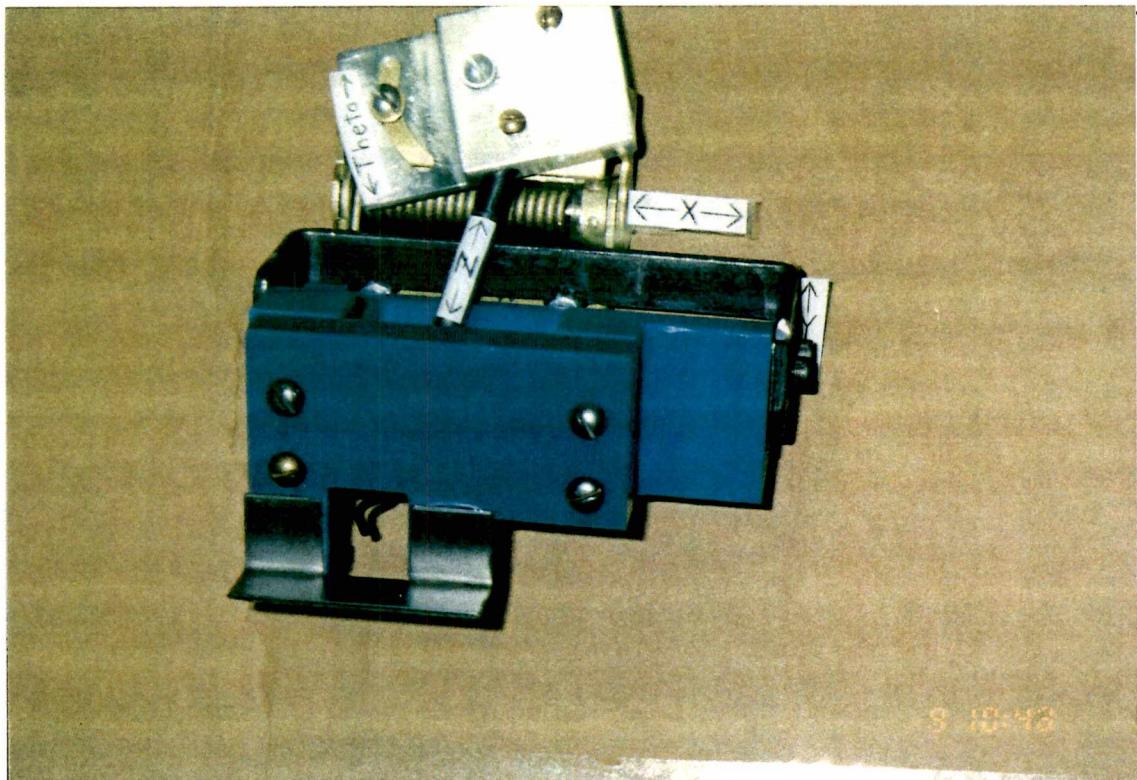


Figure 4.5. Force-loaded cutting tool. Adjustments X, Y, Z, and Theta are labeled.

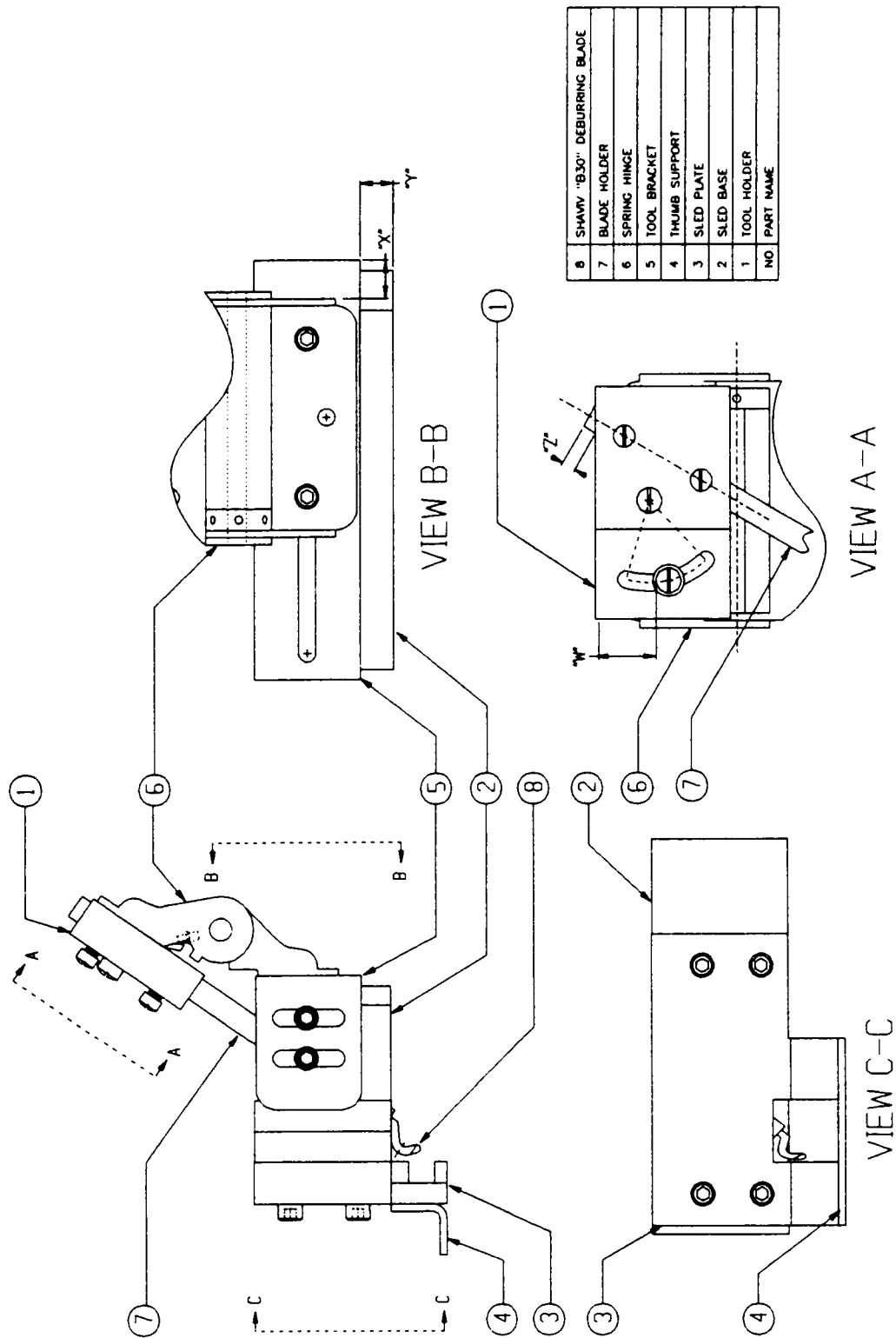


Figure 4.6. Cutting tool assembly. Controlling variables X, Y, Z, and W are shown.

bracket (X). And fourth, the bracket's position can be translated relative to the sled (Y). Finally, the spring tension can also be adjusted.

Maintaining a continuous chip of constant thickness

As determined, the prototype must maintain the correct ratio of F_c and F_d to obtain a constant depth of cut over the entire length of the fender. The spring hinge maintains a constant F_d . F_c is kept constant if the following variables that affect chip formation are kept constant: tool material and condition, tool shape, cutting angles (rake and inclination), workpiece material and condition, cutting speed, depth of cut, and tool stiffness and damping [Kobayashi, 1967]. As for the prototype device, the tool (blade) material, condition, and shape do not change over the length of the fender; however, the blade will gradually dull and need to be replaced after an unknown number of fenders have been cut. Rake and inclination angles do not change while cutting a fender because the blade orientation (determined by X, Y, Z, and W) is set. The workpiece material does not change; however, the shape of the fender profile does not remain constant over the length of the fender. Furthermore, cutting speed may not be constant due to the cutting tool being translated manually along the fender. The depth of cut could change if the tool is not set properly. Because the tool is spring loaded and attached with a swivel joint, there is little stiffness in the direction parallel to the thrust force, F_d , or about the swivel axis, z_3 , of the blade.

Testing

Controlling variables

The controlling variables are X, Y, Z, W, and spring tension. The reference point for the dimensions X, Y, Z, and W were shown in Figure 4.6. Spring tension, or preload, is changed by altering initial spring deflection.

Fender measurements

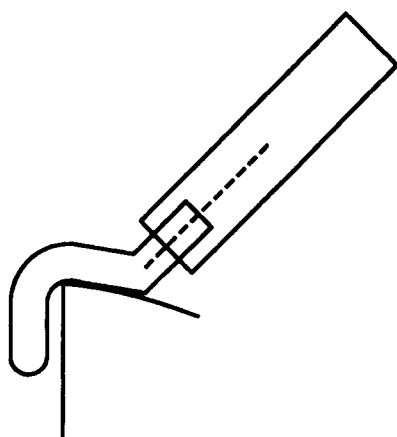
The objective of the testing is to determine the configuration of the cutting tool that best meets the following criteria:

- 1) continuous chip formation of constant thickness,
- 2) tangency with vertical and horizontal catwalk surfaces, and
- 3) number of passes required by the cutting tool.

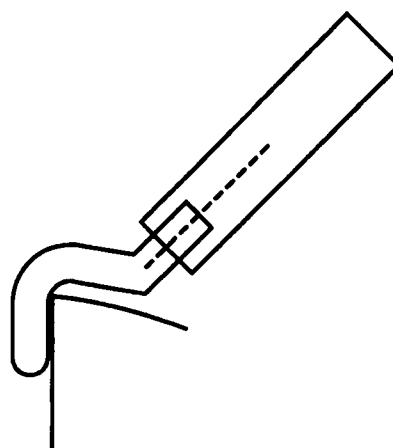
Continuous chips are necessary to obtain a consistent radius and a good surface finish along the entire length of the fender. The discontinuities left by the cutting process must be removed by the sanding process; therefore, tangency is important to reduce the amount of abrasive used. Minimizing the number of passes required to complete the cutting process is the final condition.

Methods

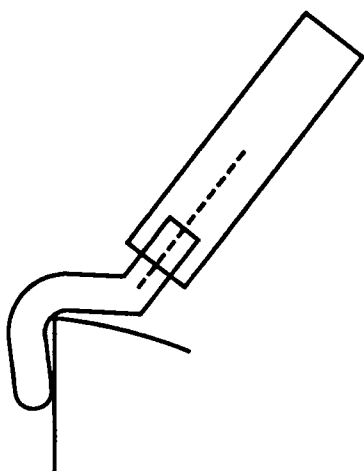
Initial values of X, Y, Z, and W were found that produce a continuous chip of uniform thickness. Because the blade must be located next to the trailing leg of the sled (see View C-C in Figure 4.6), X and W are dependent. With X and Theta values fixed, Y and Z were varied according to the four conditions shown in Figure 4.7. A determination of which condition exists was made by observing



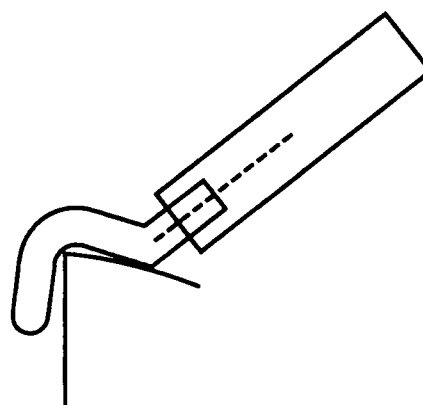
Reduce Z



Increase Z



Reduce Y



Increase Y

Figure 4.7. Determination of blade orientation. Y and Z are adjusted as shown for each set value of X and Theta.

what portions of the fender profile have been cut. The process was continued as long as the first criterion, continuous chip formation, was met, and the second criterion, tangency, was not met. Next, new values of X and W were set and the process for changing Y and Z was repeated. Spring tension was increased to minimize the number of passes required of the cutting tool. The best samples for each X value were compared under magnification to determine which configuration resulted in the best fender measurements.

Results

For the 1996 model fenders, the nominal values of X, Y, Z, and W were found to be 0.455, 0.550, 0.162, and 0.465 inches, respectively. Again, the reference points for these measurements were shown in Figure 4.6. Next, the load placed on the blade by the spring hinge was measured to be 3.75 lb, directed perpendicular to the blade's swivel axis. For this applied load, three passes were made with the cutting tool. In addition, the tool was translated at a speed of 4 to 5 inches per second. A continuous chip was formed; however, chatter marks were sometimes present. Finally, there is a circular protrusion on the vertical catwalk surface that prevents the legs of the cutting tool from passing freely.

Conclusions

The device leaves two discontinuities, as shown in Figure 4.8. As the angle between the two surfaces of the fender profile decrease, the size of the discontinuities increase. The difference that size of the discontinuities makes is

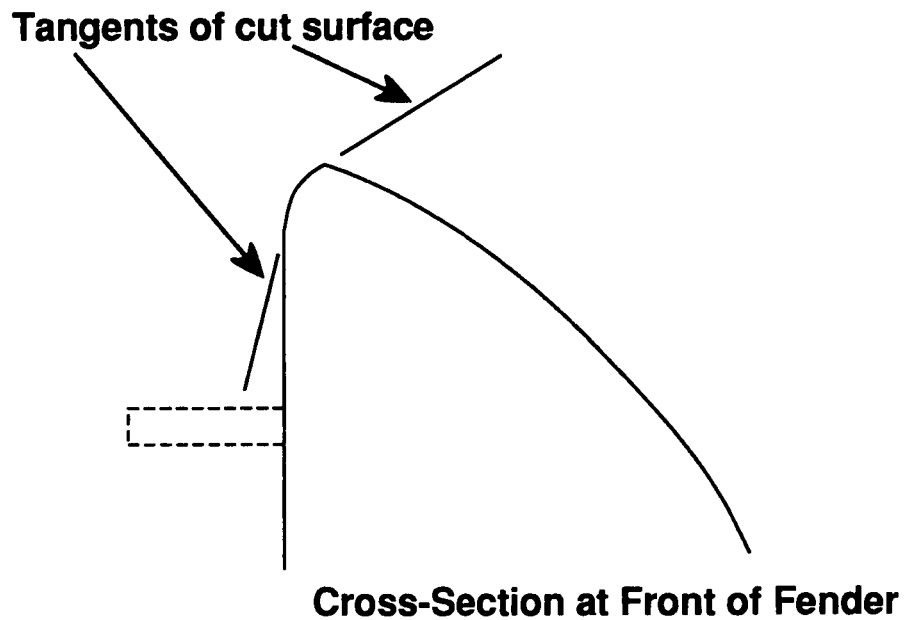
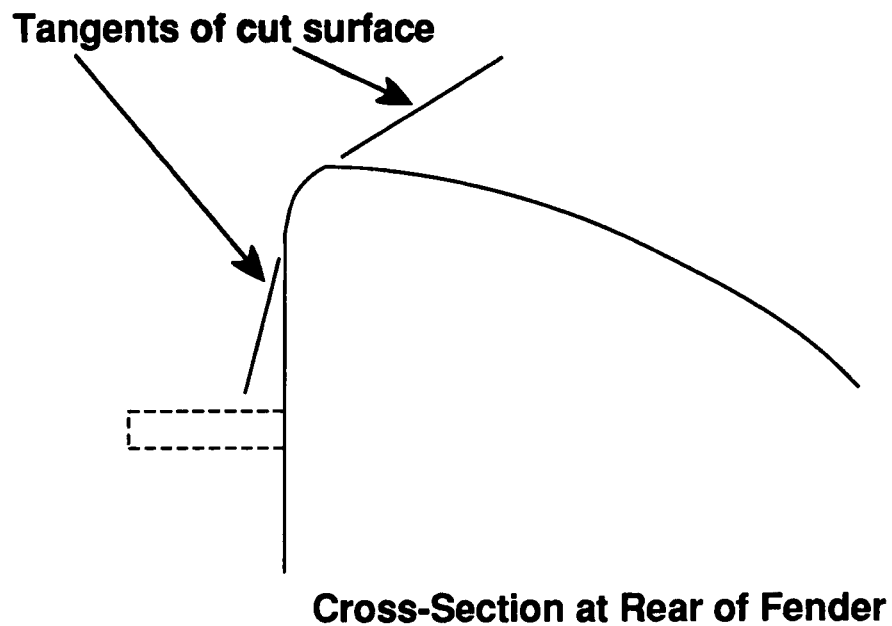


Figure 4.8. Fender profile after cutting phase. The discontinuity in the slope caused by the intersection of the cut surface and the uncut curved surface is greater for cross-sections toward the front of the 1996 fender than toward the rear.

quantified (in Chapter 5) by the increased amount of abrasive required to complete the front 8 inches of the fender. Also, near the front of the fender, where the hider-rib starts, was a defect. Since the blade follows this surface and maintains a constant depth of cut, the deformity was not corrected by the cutting tool. Another concern was the presence of a circular protrusion, a pressure transducer, on the vertical catwalk surface that interfered with the legs of the sled. However, Saturn has disclosed that this defect will be flush with the vertical catwalk surface of future panels [Del Bosco, 1995].

Starting the tool proved to be an area of concern. Because the blade is force loaded, it seeks a steady-state depth of cut after initial contact with the fender. This transient length amounts to less than 1/4 inch. In addition, since the B30 blade is right handed, the cutting tool must be started at the front of the right fender. At the front of the fender, approximately 1/2 inch was left uncut because the sled could not be supported by the fender. On the left fender, the tool is started at the rear of the catwalk and translated toward the front of the fender. When the tool gets to the front, the sled's leading leg falls off the edge of the fender; as a result, the blade orientation and load are altered. This situation is more advantageous than starting the tool in the front because the only material left uncut is a 1/4-inch section at the rear of the catwalk. These cutting schemes are illustrated in Figure 4.9.

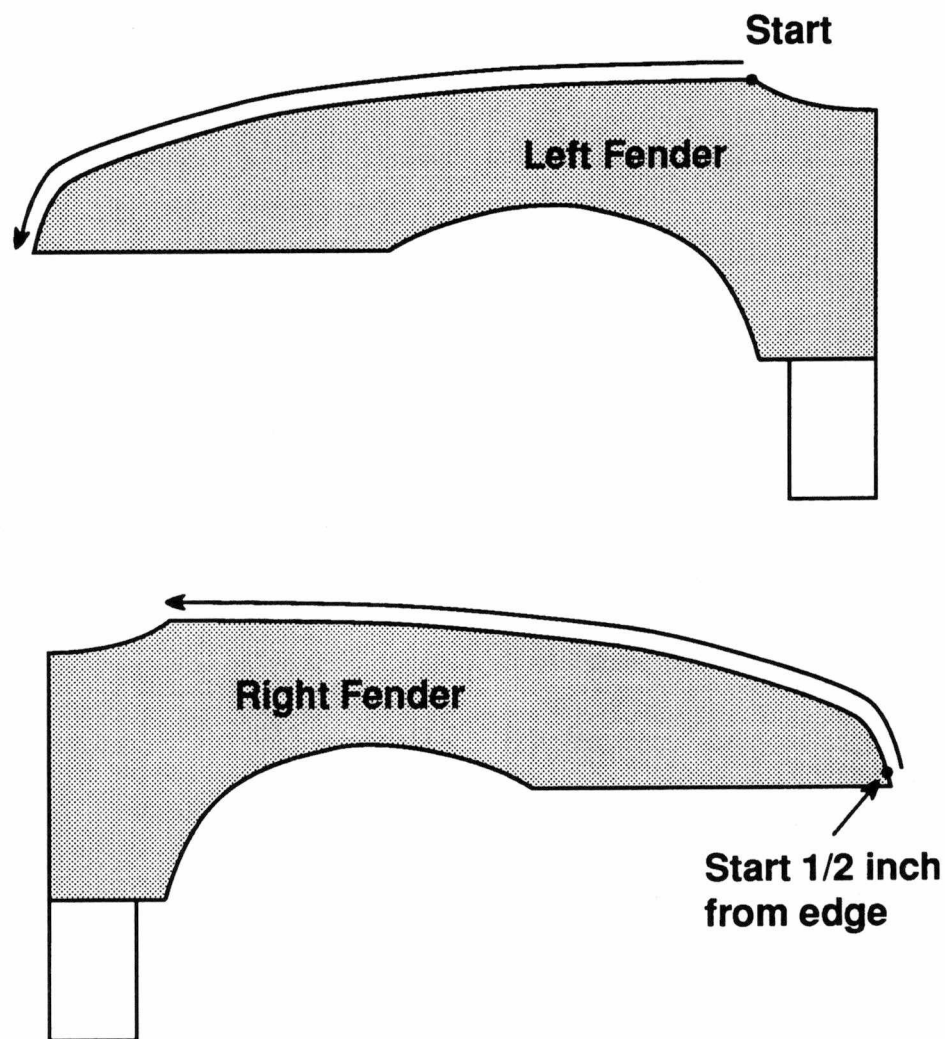


Figure 4.9. Cutting schemes. The cutting schemes used with the prototype cutting tool on the left and right fender are shown. Direction of cut differs because the prototype uses a right-handed deburring blade.

Recommendations

The cutting process can benefit from run-offs placed at the beginning and end of the fender so that the legs on the sled will be supported beyond the end of the fender. This addition should result in the ability to start the tool closer to the front and rear edges of the fender and, consequently, leave a smaller amount of the fender uncut. If a left-handed B30 blade can be obtained, the cutting tool can be started at the rear of the right fender as is done with the left fender.

A new cutting tool with three independently loaded blades should be developed in order to complete the fender with one pass instead of three. Thus each blade can have a different orientation and thrust-force vector. Also, the tool can be constrained from rotating by the curved surface of the fender instead of the vertical catwalk surface. In addition, adding damping to the system might reduce the possibility of chatter. Finally, an automated system that provides a constant cutting speed should be developed. As discussed earlier, cutting speed, a variable that affects chip formation, is difficult to maintain when translating the tool manually.

CHAPTER 5

PROTOTYPE SANDER TESTING

The prototype sander, discussed in detail in Chapter 3, was tested to determine the feasibility of the sanding process. First, the controlling variables were reduced or eliminated by determining which were critical variables. These critical variables were investigated while observing the fender measurements to determine if an operating space exists. Finally, Saturn verified that the fender measurements were acceptable.

Controlling Variables

The controlling variables involved with the sanding process that affect fender geometry are, as shown in Chapter 3, belt stiffness, belt-application angles, direction of belt travel, belt tension, geometry of the pressure pad, the forces applied to the fender by the pressure pad or vice versa, and the length of belt required to complete a unit length of the fender. Also, although not a variable of the sanding process itself, the use of the cutting tool greatly affects the sanding process because the tool alters the shape of the fender before the sanding process begins.

There are two factors that affect the surface finish of the fender: abrasive coarseness and pressure pad components. Obviously, the coarseness of the abrasive has a direct effect on the finish. However, the pressure pad material

and the fabric covering the pad can also have consequences on the surface finish.

Fender Measurements

The fender measurements are the same as the removal requirements discussed in Chapter 2. They are surface finish, differentiability of the fender profile, and radius of the fender. The surface finish and differential profile were graded by Saturn after the fender had been painted by the company's process. If no scratch marks were visible through the paint, the finish was acceptable. Likewise, the profile was judged to be differential if no edge was present through the paint. The radius of the fenders was measured with a radius gage.

Methods

The testing apparatus and setup for the sanding operation are shown in Figure 5.1. The prototype sander was mounted so the pressure pad faced up. Then, the vertical load placed on the pressure pad could be applied by adding weights to the inside of the fender. Because of this loading scheme, only about 6 inches of the fender could be sanded at a given time. Then the weights needed to be moved to the location directly above the next area to be sanded.

The fender was constrained by hand and the pressure pad. For instance, the rotation of the fender about the X and Y axis (shown in Figure 5.1) was constrained manually; as a result, some rotation of the fender about these axes

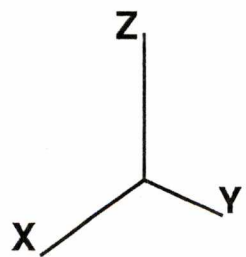
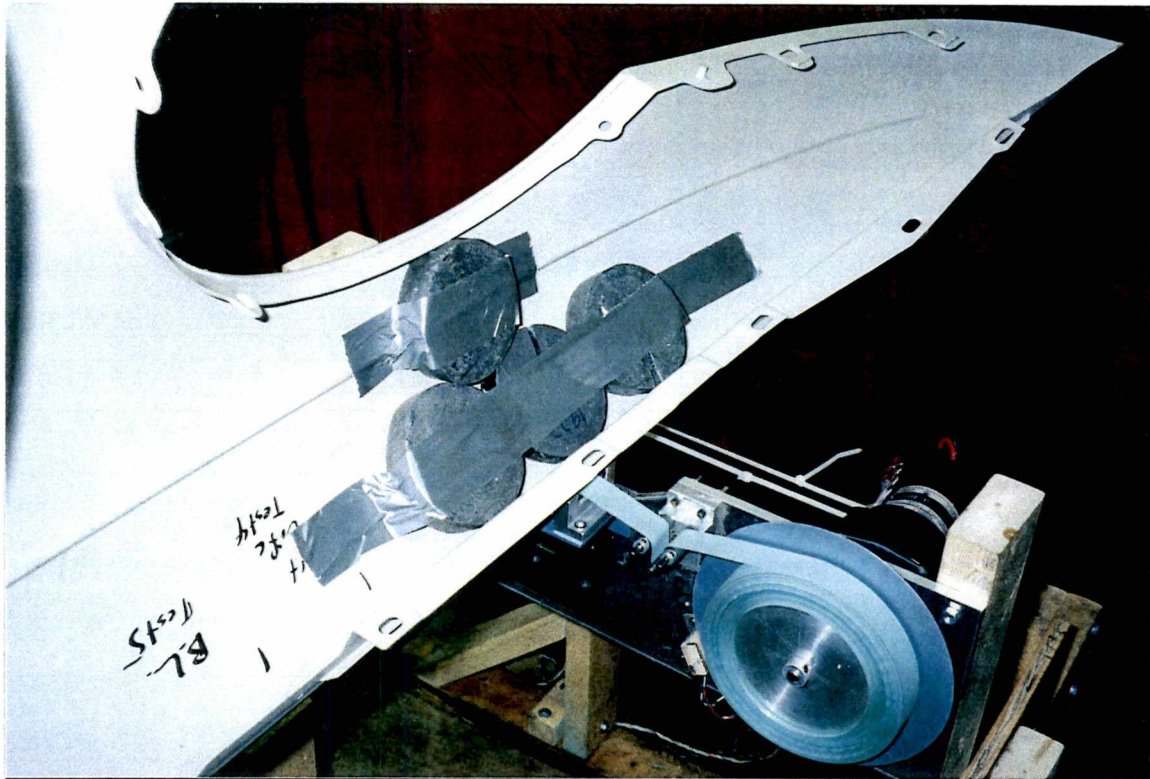


Figure 5.1. Prototype belt sander operation. Weights are fixed to the inside of the fender while the fender rests on the pressure pad.

occurred. Furthermore, the fender was translated by hand in the Z direction, parallel to the parting line. The pressure pad constrained the fender in the remaining degrees of freedom.

In order to determine the amount of belt required per unit length of the fender, the belt was marked where each test run began. When the test run was completed, the length of the belt was measured while rewinding to the starting mark. The same length of belt was used for 23 test runs so that a conclusion about the life of the belt could be made.

Pressure pad geometry was determined by blackening the area of the fender to be modified with a marker. After sanding the area, an observation was made as to what portion of the blackened area had been removed. The angle of the support block was changed until it was observed that the first area to be modified by the sander was located at the discontinuity left by the cutting tool.

Test Results

Operating space

The investigation determined which of the controlling variables were critical variables. Also, some interactions between the variables were found. Finally, an operating space for these variables was sought.

Abrasive belt rigidity and coarseness

The most favorable belt found during the investigation has a 3-mil-thick polyester backing and a 40-micron-grade abrasive; the flexibility and durability of this belt were found to be superior to all other belts that were investigated. For example, forcing the cloth belts to conform to the fender profile caused rapid deterioration of the belt as evidenced by fraying of the cloth and cracking and removal of the abrasive from the belt.

Polyester or "Mylar" belts with a thickness greater than 3 mil were too rigid. The 40-micron abrasive provided an acceptable surface finish.

Since the coarsest abrasive readily available on the 3-mil polyester backing is 40 microns, coarser abrasives were not investigated.

Because the 40-micron abrasive provided an acceptable surface finish, a finer abrasive should not be used.

Belt application angles

These angles are determined by pressure-pad geometry. This was a departure from the original concept that did not use a pressure pad. In conclusion, these variables were replaced by the geometry of the pressure pad.

Belt tension

Belt tension by itself was unable to provide an adequate pressure between the belt and the fender, especially on the vertical catwalk surface. With the pressure pad, the uptake-side tension was measured to be 13 to 15 pounds; the motor stalls when the tension reaches 18 to 19

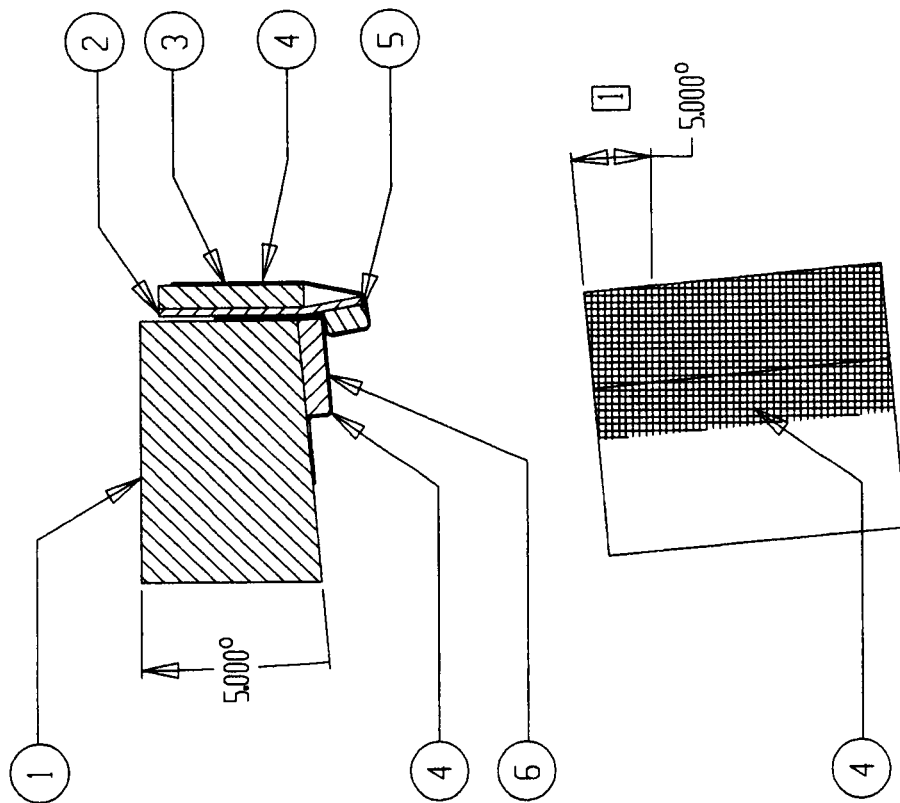
pounds. Also, in conjunction with the pressure pad, the supply-side tension should be maintained at a minimum of 2.5 to 3 pounds to ensure proper tracking of the belt on the crowned pulleys. The procedure for the setting the belt tension is located in Appendix B.

Pressure pad geometry and material

A diagram of the pressure pad is shown in Figure 5.2; its configuration with the sander is shown in Figure 3.6. The pressure pad material is 30-durometer, 1/8-inch-thick polyurethane, and it is covered by nylon bunting material that serves as a low-friction, non-rigid wear surface. Because the texture of the fabric caused a noticeable pattern in the surface finish when oriented improperly, the material is applied at a 5° to 10° angle as shown. The major fibers were no longer parallel to the direction in which the sander is translated along the fender. The support block is slanted at a 5° angle, as shown, in order to apply the load at the proper location on the fender. A 15° angle was found to sand the incorrect area of the fender.

Pressure pad loading vs. direction of belt travel

The loading of the pressure pad was found to be dependent on the direction in which the belt is traveling. If the belt is travelling such that the vertical catwalk surface is closer to the supply reel, a horizontal load (F_h in Figure 3.6) of 5 to 10 pounds is required to keep the fender's vertical catwalk surface against the vertical pressure pad. If the belt is travelling in the other direction, the loading against the vertical pressure pad is



NOTES:

- 1 NYLON BUNTING IS APPLIED SO THAT THREADS ARE AT 5° ANGLE WITH SUPPORT BLOCK SIDES
 - 2 POLYURETHANE PRESSURE PAD MATERIAL IS GLUED TO THE SUPPORT BLOCK AND VERTICAL SUPPORT PLATE.
- NYLON BUNTING IS ALSO GLUED TO THE SUPPORT BLOCK AND VERTICAL SUPPORT PLATE, BUT NOT TO THE POLYURETHANE

6	HORIZONTAL PRESSURE PAD
5	VERTICAL PRESSURE PAD
4	NYLON BUNTING
3	VERTICAL SPACER
2	VERTICAL SUPPORT PLATE
1	SUPPORT BLOCK, PRESSURE PAD
NO.	PART NAME

Figure 5.2. Elastic pressure pad assembly.

induced by the sanding force. In other words, no horizontal load is required to keep the fender against the vertical pressure pad. The necessary vertical load (F_v in Figure 3.6) was found to be between 20 and 25 pounds for both belt directions. At least 20 pounds must be applied to properly deform the pressure pad, but the force must be kept below 25 pounds to prevent overloading of the uptake-side motor.

Length of belt required per unit length of fender vs. use of cutting tool

The same length of belt was used for successive tests to make an estimate on how the belt's efficiency degrades over time. For example, the first five times the belt is used, the length of belt required to complete one inch of the fender was an average of 6 feet. The average for the 19th through 23rd cycles was 9 feet. At the front 8 inches of the fender, the average is 11 feet because the cutting tool does not remove as much material from this location. These values are based on three passes with the cutting tool before the sander is applied. When the cutting tool was not used, the quantity of belt required for the 24th cycle was 175 feet per inch.

Measured results

The 3-mil polyester belt easily conforms to the fender profile after the cutting tool has been used. The belt speed was measured to be 12 to 16 inches per second. For the first 23 times the belt was used, the quantity of belt required per inch of fender length was an average of 7.5 feet when the cutting tool was used first. The pressure pad material, geometry, and configuration are shown in

Figures 5.2 and 3.6. Although the belt can be run in either direction, the pressure-pad loading is simpler when the belt direction is such that the vertical catwalk surface is closer to the uptake reel; no horizontal load (F_h in Figure 3.6) is required. The minimum vertical load (F in Figure 3.6) required from the pressure pad was 20 pounds, and the maximum was 24 pounds.

A fender that was completed with the two-phase process (cut and sand) was judged by Saturn to be satisfactory. The surface finish provided with the 40-micron-grade abrasive belt did not leave any visible scratch marks through the belt. Furthermore, the radius produced by the process was measured to be 1.6 mm, and differentiability was satisfactory. Referring to Figures 2.1 and 2.3, the modified region for this process extends 0.25 to 0.30 inches from the vertical catwalk surface.

Conclusions

The prototype sander requires too much time to complete a fender; however, geometry and surface-finish requirements were met. From extrapolation of the measured results, an average of 340 feet of belt would be required to complete the 45-inch-long 1996 model fender. Consequently, based on belt speed, 290 seconds, or 4.8 minutes, would be required to complete a fender with the prototype sander.

The material cost of the process is based on the length of belt required to complete a fender, the number of times a belt is reused, and the cost of the belt.

Again, based on extrapolation, if the belt is reused 23 times, approximately 22 fenders could be completed with one 100-meter roll at a cost of \$16.50. The material cost per fender would then come to \$0.75 per fender.

Recommendations

There are two ways to reduce the time required to complete a fender. First, the cutting operation could be further developed so that more material is removed before the sanding operation begins. Second, belt speed could be increased by using more powerful motors. Development of the cutting operation should be undertaken first because it would reduce the required amount of abrasive belt to complete a fender; as a result, both time and material cost are reduced. If a sander is still required after the cutting process, one might be developed that uses an "8-track" type of supply reel, enabling a continuous belt to be used. The belt could be driven in just one direction by one motor and a pinch roll; furthermore, the supply-side tension could be provided by a continuous slip clutch and a pinch roll. This sander would require very little electronics to operate because the load on the motor would be relatively constant. Eliminating one motor and a reel would also reduce the size of the machine.

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APPENDIXES

APPENDIX A
OPERATING PROCEDURE
FOR THE
FORCE-LOADED CUTTING TOOL

OPERATING PROCEDURE FOR THE FORCE-LOADED CUTTING TOOL

Tool Setup

The four tool adjustments (X, Y, Z, W, and spring tension) must be set properly. If the tool gets out of adjustment or is taken apart, the following procedure should be used to reset it. The cutting tool assembly drawing (CT-ASY1000) in Appendix E should be consulted to see where the X, Y, Z, and W dimensions are measured. Also, the item numbers are referred to in this drawing. A set of dial calipers with a depth indicator should be used for measurements.

1. Begin by setting X to 0.455 in. Make sure the bottom of the hinge remains parallel to bottom of the bracket before tightening the two screws (item 11).
2. Set Y to 0.55 in. Make sure bracket is square with sled before tightening the four screws (item 17). More precise adjustments can be made to Y by adjusting one side of the bracket at a time.
3. Set Z to 0.16. Start by inserting blade holder (item 7) into the tool holder so that Z is approximately 0.25 in. The flattened side of the shaft with the notches should face down, away from the two screws (item 10). Do not tighten the screws yet. Let the spring hinge force the blade holder against the sled to keep the blade holder from sliding in the tool holder. Then, by tapping the back of the blade holder, its position can be changed precisely. Continue until $Z = 0.16$ in. Tighten the two screws (item 10).
4. Set W to 0.47. Slightly tighten the two screws (items 12 and 9) that hold the tool holder to the spring hinge so that there will be some frictional resistance between the two parts. Then, use the blade holder as a lever for rotating the tool holder until $W = 0.47$. Fully tighten the two screws.
5. Set the spring tension. The tension pin is in the correct hole when 3.75 pounds are required to deflect the blade to its cutting position.
6. Place cutting tool on the fender. Push the sled plate against the vertical catwalk surface of the fender as is shown in Figure 1.3. The cutting direction is from left to right. Observe the back of the blade as cutting force is gradually increased. The blade should not touch the sled but should come within $1/16$ in. of making contact. Adjust W accordingly.

7. Refer to Figure 4.7 for fine tuning of Y and Z.

Manual Operation of the Tool

Figure 1.3 shows how to hold the tool; furthermore, the figure illustrates how the sled plate (item 3 in CT-ASY1000 in Appendix E) is held against the vertical catwalk surface of the fender.

1. Before placing the tool on the fender, pull back the spring hinge to prevent the blade from making contact with the fender before the sled and sled plate.
2. Position the tool on the fender and let down the blade about 1/4 in. from the end of the catwalk. Figure 4.9 shows the starting location of the tool.
3. Translate the tool to the front of the fender while trying to maintain a constant cutting speed.
4. Because the front of the sled plate will run off the front of the fender while the blade is still cutting, the orientation of the sled with respect to the fender must be kept from changing drastically (this takes practice).

APPENDIX B
OPERATING PROCEDURE
FOR THE
PROTOTYPE BELT SANDER

OPERATING PROCEDURE FOR THE PROTOTYPE BELT SANDER

Hardware Connections

Make sure all electrical connections are made before operating the sander. Appendix D gives a schematic of the connections to be made. These include connecting the motors to the driver board, the foot switch to the DAC board, the tach to the tach board, the power supplies to their respective boards, and the 68HC11 EVB to the COM1 port of the host computer.

Loading and Running Software

1. Start Kermit program.
 2. Press return to get BUFFALO prompt from 68HC11.
 3. Then type "load t."
 4. Press "cntrl -]-p" to get back to DOS.
 5. Type "type test5e.s19 > com1"
 6. Then type "exit" to get back to BUFFALO.
- If prompt does not show, type "cntrl-]-c" to get back to Kermit. Type "conn" and press the reset button on the 68HC11 EVB.

At the BUFFALO prompt, type the following commands:

1. MM 1007 <ret>
2. FE <ret> (sets up port c)

Set the supply-side tension by typing:

1. MM C0EA <ret>
2. 04 <space> A0 <ret>

Set the belt direction by typing:

1. MM C0EF <ret>
2. 00 <ret> (for one direction) or 01 <ret> (for the other direction)

Belt Installation

The 3-mil thick polyester belt is one inch wide and comes in rolls of 100 meters on a plastic core. This belt can be purchased from Mipox (1-800-886-6476) in California. Also, 3M might be a possible supplier.

1. Bend the first 1/2 inch of the belt over in order to double the thickness. Then insert doubled end into the slot on a reel of the prototype belt sander.
2. Wrap belt around the reel at least three times. Feed belt through the two sets of crowned pulleys. Make sure the abrasive side of the belt is facing out from the reel center and pressure pad.
3. Turn variac down so supply voltage is low (approximately 50 VDC) and hold belt so it is lined up with pulleys and pressure pad.
4. Depress foot switch and the belt will begin to wind up. If the reel turns in the wrong direction, change the direction bit in the program.
5. When belt runs out, double over end and insert into slot of empty reel. Manually wind up on reel at least 3 revolutions.

Sanding

These directions assume that the belt direction is such that the vertical pressure pad is closest to the uptake reel. First, tape weights to inside of the fender as was shown in Figures 1.2 and 5.1. The weights should be centered over the location to be sanded. 24 pounds is the upper limit. Make sure the motor supply voltage is set at 110 VDC. Place the fender on the pressure pad as was shown in Figures 1.2, 3.6, and 5.1. Depress the foot switch while slowing pulling or pushing the fender parallel to the parting line while maintaining its orientation about the X, Y, and Z axis (see Figure 5.1). Watch belt to make sure it is staying in the middle of the crowned pulleys. If the belt is being pushed off to one side, the fender is tilting too much about the Y axis.

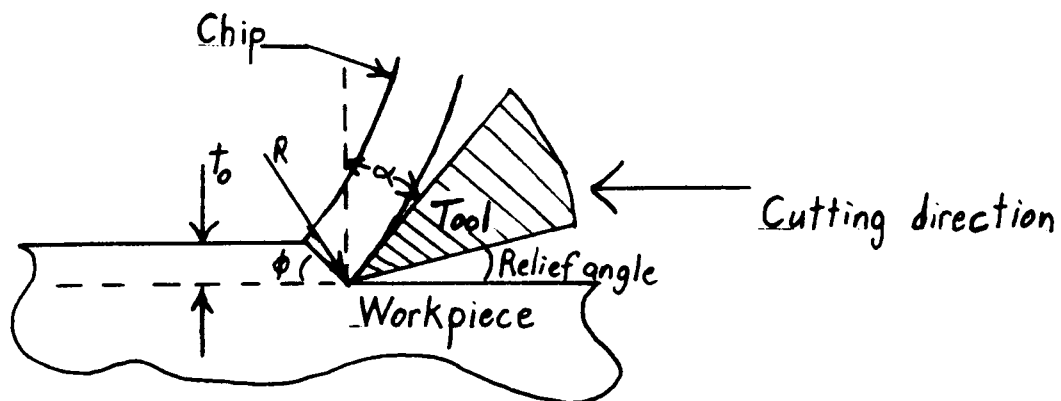
Maintenance

There are two items that may need periodic maintenance. First of all, the crowned pulleys on the 3/16 inch shafts need graphite lubrication. Next, the nylon fabric covering the pressure pad should be checked for buildup (abrasive and plastic dust) and wear.

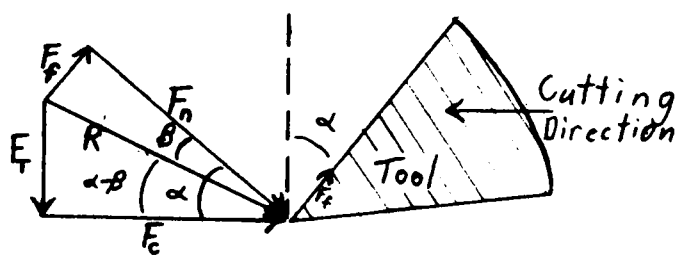
Additional Information

The front reel side can be left off of the sander as shown in Figure 1.2. Also, there appears to be no benefit in using the tachometer for the manual operation.

APPENDIX C
STABILITY ANALYSIS
FOR THE
FORCE-LOADED CUTTING TOOL



2D orthogonal cutting. α = rake angle; ϕ = shear angle;
 R = resultant force of chip acting on tool's rake face
 t_o = depth of cut.



Cutting forces for 2D orthogonal cutting

R = resultant cutting force of chip acting on tool's rake face; F_c = force component parallel to cutting direction; F_T = force component perpendicular to cutting direction; F_f = friction force on rake surface; F_n = normal force on rake surface; β = friction angle; μ = coefficient of friction between chip and tool.

$$\mu = \frac{F_f}{F_n} = \tan \beta \rightarrow \beta = \tan^{-1} \mu$$

$$F_T = F_c \tan(\alpha - \beta)$$

$\dot{\theta}_c < 0$ when clockwise moments are greater than counter-clockwise moments. Moments taken about point A. So $\dot{\theta}_c < 0$ when

$$F_c l \sin \theta_c > F_T w + F_d l \cos \theta_c$$

$$F_c l \sin \theta_c > F_c \tan(\alpha - \beta) w + F_d l \cos \theta_c$$

$$\frac{F_d}{F_c} < \frac{l \sin \theta_c + w \tan(\beta - \alpha)}{l \cos \theta_c}$$

$\dot{\theta}_c > 0$ when counter-clockwise moments are greater than clockwise moments. Also, $F_{TR} \rightarrow 0$. Taking moments about point S, $\dot{\theta}_c > 0$ when

$$F_d (l - w \cos \theta_c) \cos \theta_c > F_c (l - w \cos \theta_c) \sin \theta_c$$

$$\frac{F_d}{F_c} > \tan \theta_c$$

Conclusion: $\dot{\theta}_c = 0$ when

$$\frac{l \sin \theta_c + w \tan(\beta - \alpha)}{l \cos \theta_c} < \frac{F_d}{F_c} < \tan \theta_c$$

Example: For $l = 0.25 \text{ in.}$, $w = 0.10 \text{ in.}$, $\theta_c = 35^\circ$, $\alpha = 55^\circ$,

$$\mu = 0.30$$

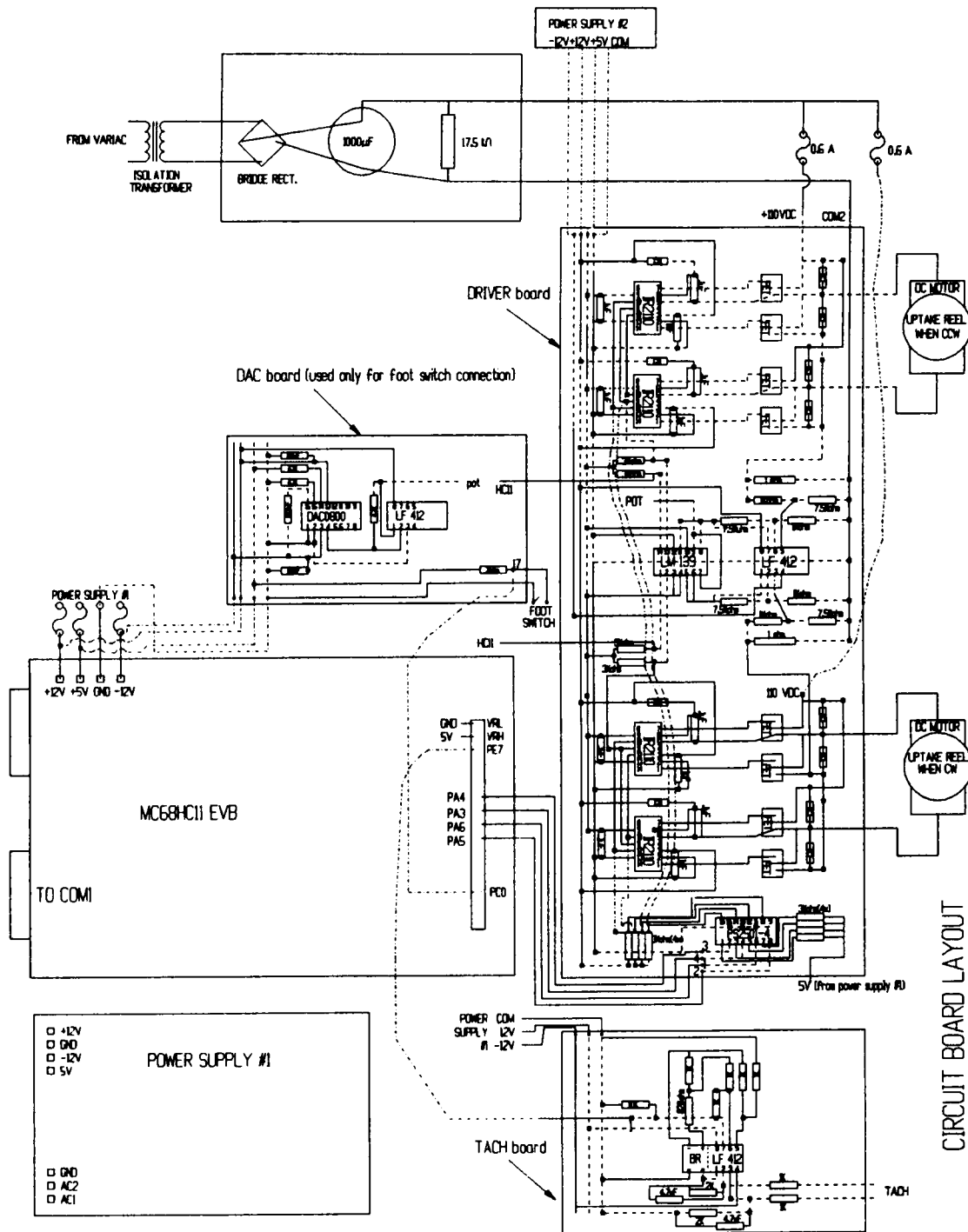
$$0.31 < \frac{F_d}{F_c} < 0.7$$

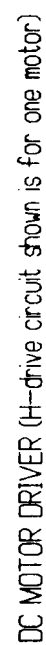
APPENDIX D
BELT SANDER ELECTRONICS
AND SOFTWARE

Electronics and Software

An MC68HC11 EVB is used to pulse a high voltage MOS gate driver (IR2110). The IR2110 keeps the gates of HEXFET's (transistors) saturated so they act as switches. The 110 volt supply voltage for the motors can be turn on and off at high frequencies with a pulsed 5 volt signal from the MC68HC11 EVB. It requires two IR2110's and four HEXFETS to make an H-drive that controls the motor in forward and reverse directions; therefore, there are two H-drive circuits for the sander.

The speed and tension of the belt are controlled by pulse width and frequency, which are determined by three constants in the program—TIMEOFF, TON1, and TON2. TON1 is the number of clock cycles that the uptake-side motor is turned on; likewise, TON2 is the number of clock cycles that the supply-side motor is turned on. TIMEOFF is the length of time that the uptake-side motor is turned off. Currently, the pulse frequency is 300 Hz.





```

*   DATE:          9/02/94
*   PROGRAMMER:    TIM WYRICK
*   CONTAINS:      TEST5E VERSION OF SANDER CONTROL PROGRAM
*                   PULSE ACCUMULATOR OVERRIDE WITH FOOT
*                   SWITCH
*   HARDWARE CONNECTIONS FROM MC68HC11 EVB TO DRIVE BOARD:
*       MC68HC11          DRIVER
*       PIN PA3(31)        PIN 4
*       PIN PA4(30)        PIN 3
*       PIN PA5(29)        PIN 2
*       PIN PA6(28)        PIN 1
*
*   HARDWARE CONNECTIONS FROM MC68HC11 EVB TO DAC BOARD:
*       MC68HC11          DAC BOARD
*       PIN PA7(27)        PIN 17
*
*   HARDWARE CONNECTIONS FROM DAC BOARD TO SANDER:
*       PIN 5              IED (WAS NOT USED)
*       PIN 6              IED (WAS NOT USED)
*       PIN 7              PHOTO DETECTOR(WAS NOT USED)
*       PIN 8              PHOTO DETECTOR(WAS NOT USED)
*
*   HARDWARE CONNECTIONS FROM MC68HC11 EVB TO TACH BOARD
*       MC68HC11          TACH BOARD
*       PIN PE7(50)        PIN 1
*
**EQUATES - REGISTERS WILL BE ADDRESSED WITH IND,X MODE
*
REGBAS    EQU          $1000    STARTING ADDRESS FOR REGISTER
                                   BLOCK
PORTC     EQU          $03      I/O PORT C
PORTA     EQU          $00      DATA REGISTER PORT A
CFORC     EQU          $0B      FORCE COMPARE REGISTER
TCNT      EQU          $0E      TIMER REGISTER
TCTL1     EQU          $20      TIMER CONTROL REGISTER 1
TOC2      EQU          $18      OUTPUT COMPARE REGISTER 2
TOC3      EQU          $1A      OUTPUT COMPARE REGISTER 3
TOC4      EQU          $1C      OUTPUT COMPARE REGISTER 4
TOC5      EQU          $1E      OUTPUT COMPARE REGISTER 5
TFLG1     EQU          $23      INPUT/OUTPUT TIMER FLAG REGISTER
                                   1
TFLG2     EQU          $25      INPUT/OUTPUT TIMER FLAG REGISTER
                                   2
PACTL     EQU          $26      PULSE ACCUMULATOR CONTROL
                                   REGISTER
PACNT     EQU          $27      PULSE ACCUMULATOR COUNT REGISTER
ADCTL     EQU          $30      ANALOG/DIGITAL CONTOL REGISTER
ADR4      EQU          $34      ANALOG/DIGITAL RESULT REGISTER
                                   1
OPTION    EQU          $39      OPTION REGISTER
*
                                   ORG          $C000    PROG. STARTS IN EVB RAM AT $C000

```

```

***
* PROGRAM BEGINS HERE
***
*   INITIALIZATION
*
START      LDX      #REGBAS      POINTER TO REGISTER BLOCK
           LDS      #$004A      LOAD STACK POINTER FOR USER
                                   STACK ON EVB

***
* SET UP ANALOG/DIGITAL CONVERTER
           BSET      OPTION,X    #$80  TURN ON ANALOG/DIGITAL
                                   CONVERTER
           LDAA      #$27        CONTINUOUSLY SCAN PIN PE7
           STAA      ADCTL,X     STORE IN ANALOG/DIGITAL
                                   CONTROL REGISTER

***
AGAIN      JSR      DELAY        DELAY 197ms BEFROE
                                   REVERSING DIRECTION

***
* SET UP TIMER CONTROL
           CLR      ONOFF        MAKE SURE ONOFF IS CLEARED
           LDD      TCNT,X
           STD      TOC2,X
           STD      TOC3,X
           STD      TOC4,X
           STD      TOC5,X
           LDAA      #$AA        SET TCTL1 TO CLEAR PINS ON
                                   A COMPARE
           STAA      TCTL1,X     STORE TO TCTL1 REGISTER
           LDAA      #$FF        FORCE A COMPARE TO ALL OCX
                                   PINS
           STAA      CFORC,X     STORE TO FORCE COMPARE
                                   REGISTER

*
           TST      PORTC,X      CHECK FOOT SWITCH
           BEQ      AGAIN
           TST      DIR
           BNE      REVERSE

*****
FORWARD    LDAA      #$66        SET UP PA6,PA4 TO TOGGLE
                                   WHEN COMPARE OCCURS
*
                                   DISCONNECT PA3,PA5 FROM
                                   COMPARE REGISTERS
           STAA      TCTL1,X     WRITE TO TIMER CONTROL
           LDAA      #$78        CLEAR COMPARE FLAGS
           STAA      TFLG1,X     WRITE TO FLAG REGISTER
PULSE1     BRCLR    TFLG1,X     #$40 PULSE1 WAIT UNTIL OC2F
                                   SETS
                                   AND TOGGLES PIN
                                   IF PIN WAS ON TURN IT OFF
           TST      ONOF
           BNE      OFF

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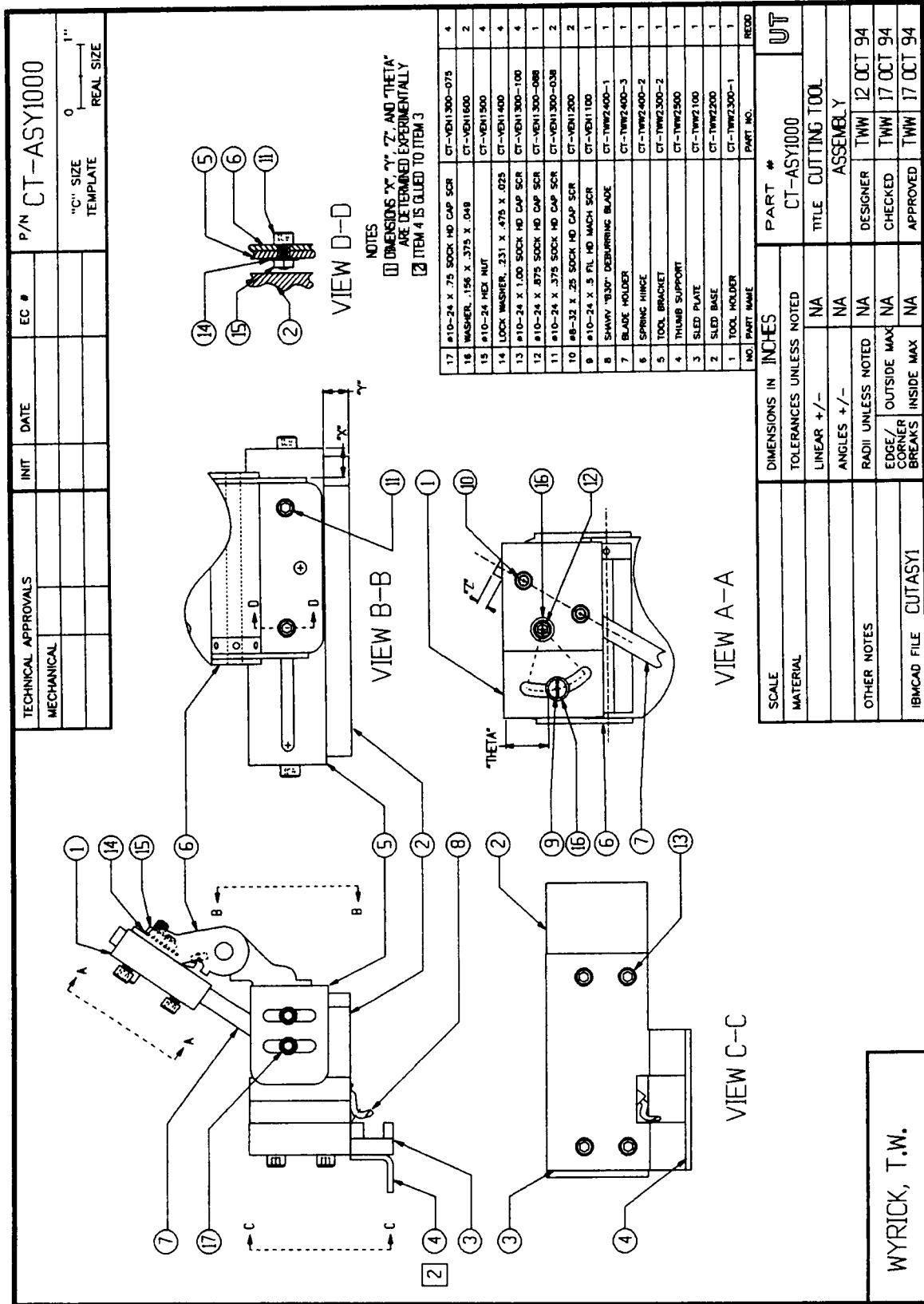
*				
ON	LDAA	ADR4,X		GET RESULT IN A/D RESULT REGISTER 4
	CMPA	SPEED		COMPARE RESULT WITH DESIRED SPEED
	BLO	SLOW		IF TOO SLOW BRANCH TO SLOW
	LDD	TON1		
	LSRD			
	ADDD	TOC2,X		
	STD	TOC2,X		STORE IN OC2 REGISTER
	LDD	TON2		
	LSRD			
	ADDD	TOC4,X		
	STD	TOC4,X		
BACK1	LDAA	#\$01		STORE TO MEM THAT OC2 IS ON
	STAA	ONOFF		STORE IN ONOFF LOCATION
* CHECK FOOT SWITCH				
	TST	PORTC,X		CHECK IF PACNT OVERFLOWED
	BEQ	AGAIN		
*				
	BRA	CLEAR1		BRANCH TO LOOP1 TO CLEAR COMPARE FLAG
*				
SLOW	LDD	TON1		GET COUNT IN OC4 REGISTER
	ADDD	TOC2,X		ADD AMOUNT OF TIME TO STAY ON
	STD	TOC2,X		
	LDD	TON2		
	ADDD	TOC4,X		
	STD	TOC4,X		
	BRA	BACK1		BRANCH TO BACK1
*				
OFF	LDD	TOC2,X		GET COUNT IN OC2 REGISTER
	ADDD	TIMEOFF		ADD AMOUNT OF TIME TO STAY OFF
	STD	TOC2,X		STORE IN OC2 REGISTER
	STD	TOC4,X		STORE IN OC4 REGISTER
	CLR	ONOFF		STORE TO MEM THAT OC2 IS OFF
	BRA	CLEAR1		BRANCH TO LOOP1 TO CLEAR COMPARE FLAG

REVERSE	LDAA	#\$99		SET UP PA5,PA3 TO TOGGLE WHEN COMPARE OCCURS
	STAA	TCTL1,X		WRITE TO TIMER CONTROL
CLEAR2	LDAA	#\$78		CLEAR COMPARE FLAGS
	STAA	TFLG1,X		WRITE TO FLAG REGISTER
PULSE2	BRCLR	TFLG1,X	#\$08	PULSE2 WAIT UNTIL OC5F SETS AND TOGGLES PIN
	BRCLR	TFLG1,X	#\$20	PULSE2 THEN CHECK IF OC3F IS SET
	TST	ONOF		IF PIN WAS ON TURN IT OFF

	BNE	OFF2	
* ON2	LDAA CMPA	ADR4,X SPEED	COMPARE RESULT WITH DESIRED SPEED
	BLO LDD LSRD ADDD	SLOW2 TON1 TOC5,X	IF TOO SLOW BRANCH TO SLOW ON ADD AMOUNT OF TIME TO STAY
	STD LDD LSRD ADDD	TOC5,X TON2 TOC3,X	ON STORE IN OC5 REGISTER ADD AMOUNT OF TIME TO STAY
BACK2	STD LDAA STAA	TOC3,X #\$01 ONOFF	ON STORE IN OC3 REGISTER STORE TO MEM THAT OC5 IS ON STORE IN ONOFF LOCATION
* CHECK FOOT SWITCH	TST BEQ	PORTC,X OFLOW2	CHECK IF PACNT OVERFLOWED BRANCH TO OFLOW2 IF OVERFLOWED
	BRA	CLEAR2	BRANCH TO CLEAR2 TO CLEAR COMPARE FLAG
* SLOW2	LDD ADDD	TON1 TOC5,X	GET COUNT IN OC4 REGISTER ADD AMOUNT OF TIME TO STAY ON
	STD LDD ADDD STD BRA	TOC5,X TON2 TOC3,X TOC3,X BACK2	
* OFLOW2	JMP	AGAIN	BRANCH TO START
* OFF2	LDD ADDD	TOC5,X TIMEOFF	GET COUNT IN OC5 REGISTER ADD AMOUNT OF TIME TO STAY OFF
	STD STD CLR	TOC5,X TOC3,X ONOFF	STORE IN OC5 REGISTER STORE IN OC3 REGISTER STORE TO MEM THAT OC5 IS OFF
	BRA	CLEAR2	BRANCH TO CLEAR2 TO CLEAR COMPARE FLAG
*** * DELAY - SUBROUTINE TO DELAY 197 mS (FOR E=2MHZ) ***	PSHX LDX DEX BNE	 #\$FFFF DLOOP	SAVE X VALUE 65535*6*0.5uS=197mS DECREMENT THE X REGISTER CONTINUE FOR 65535 TIMES

DLOOP2	LDX	#\$FFFF	65535*6*0.5uS=197mS
	DEX		DECREMENT THE X REGISTER
	BNE	DLOOP2	CONTINUE FOR 65535 TIMES
	PULX		RECOVER X VALUE
	RTS		END OF SUBROUTINE
**			
*	CONSTANTS		
**			
TIMEOFF	FDB	#2000	TIME PIN STAYS OFF
TON1	FDB	#5400	TIME PIN STAYS ON
TON2	FDB	#900	TIME PIN STAYS ON (SUPPLY REEL)
TON3	FDB	#900	TIME PIN STAYS ON IF TOO FAST
SPEED	FCB	#\$40	REFERENCE SPEED
DIR	FCB	#\$01	DIRECTION MOTORS WILL RUN
ONOFF	FCB	#\$00	MEM LOCATION FOR ON/OFF STATUS OF PIN
REV	FCB	#\$06	NUMBER OF REV REEL WILL TURN BEFORE REV DIR

APPENDIX E
ASSEMBLY AND DETAIL DRAWINGS
FOR THE
FORCE-LOADED CUTTING TOOL

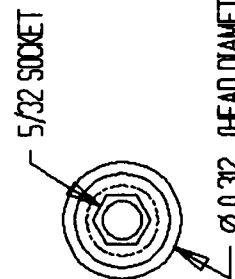
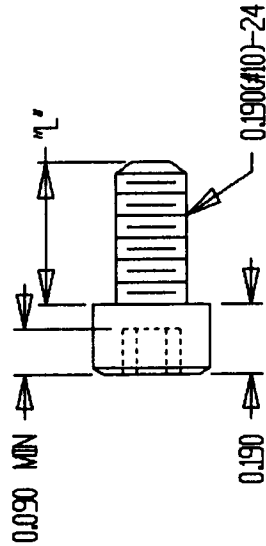


PART NO.	REL FOR ASM	QTY	TECHNICAL APPROVALS	INT	DATE	EC #	P/N
CT-VEN300-038	CT-ASY000	2	MECHANICAL				CT-VEN300-LLL
CT-VEN300-075	CT-ASY000	4					
CT-VEN300-088	CT-ASY000	1					
CT-VEN300-100	CT-ASY000	4					

NOTES:

1. SCREW LENGTH IS DETERMINED BY THE P/N SUFFIX CHART.

2. SUGGESTED VENDOR:
McMASTER-CARR SUPPLY COMPANY
CHICAGO, IL



P/N SUFFIX CHART:

P/N SUFFIX	"L"
-038	0.375
-075	0.750
-088	0.875
-100	1.000

SOCKET END VIEW
SCALE: 2x

SIDE VIEW
SCALE: 2x
-038 C/B LONG SHOWN

SCALE	1:1	DIMENSIONS IN INCHES	PART #	UT
MATERIAL	STEEL	TOLERANCES UNLESS NOTED	CT-VEN300-LLL	
		LINEAR +/-	N/A	
		ANGLES +/-	N/A	
OTHER NOTES		RADI UNLESS NOTED	N/A	
		EDGE/CORNER ROUNDS	N/A	
REWORK FILE	CT9C300			

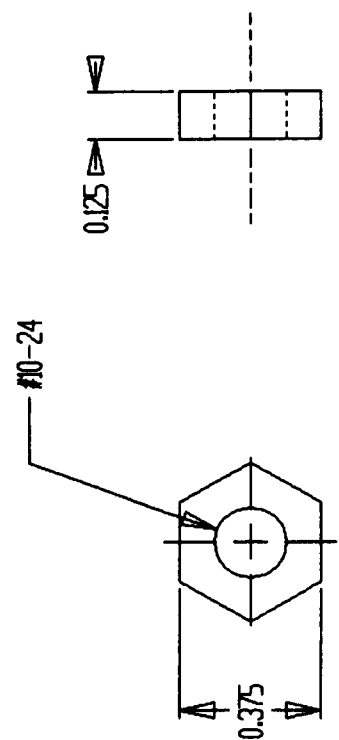
WYRICK, T.W.

REL FOR ASM	QTY	TECHNICAL APPROVALS	INT	DATE	ED #	P/N
CT-AST0000	4	MECHANICAL				CT-VEN500

1/8" SIZE
TEMPLATE
0 .001 .25"
REAL SIZE

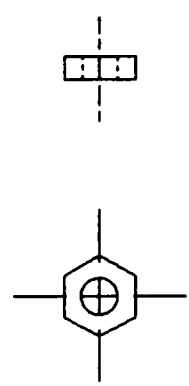
NOTES:

- SUGGESTED VENDOR
McMASTER-CARR SUPPLY COMPANY
CHICAGO, IL



"FRONT" VIEW
SCALE: 2X

SIDE VIEW
SCALE: 2X

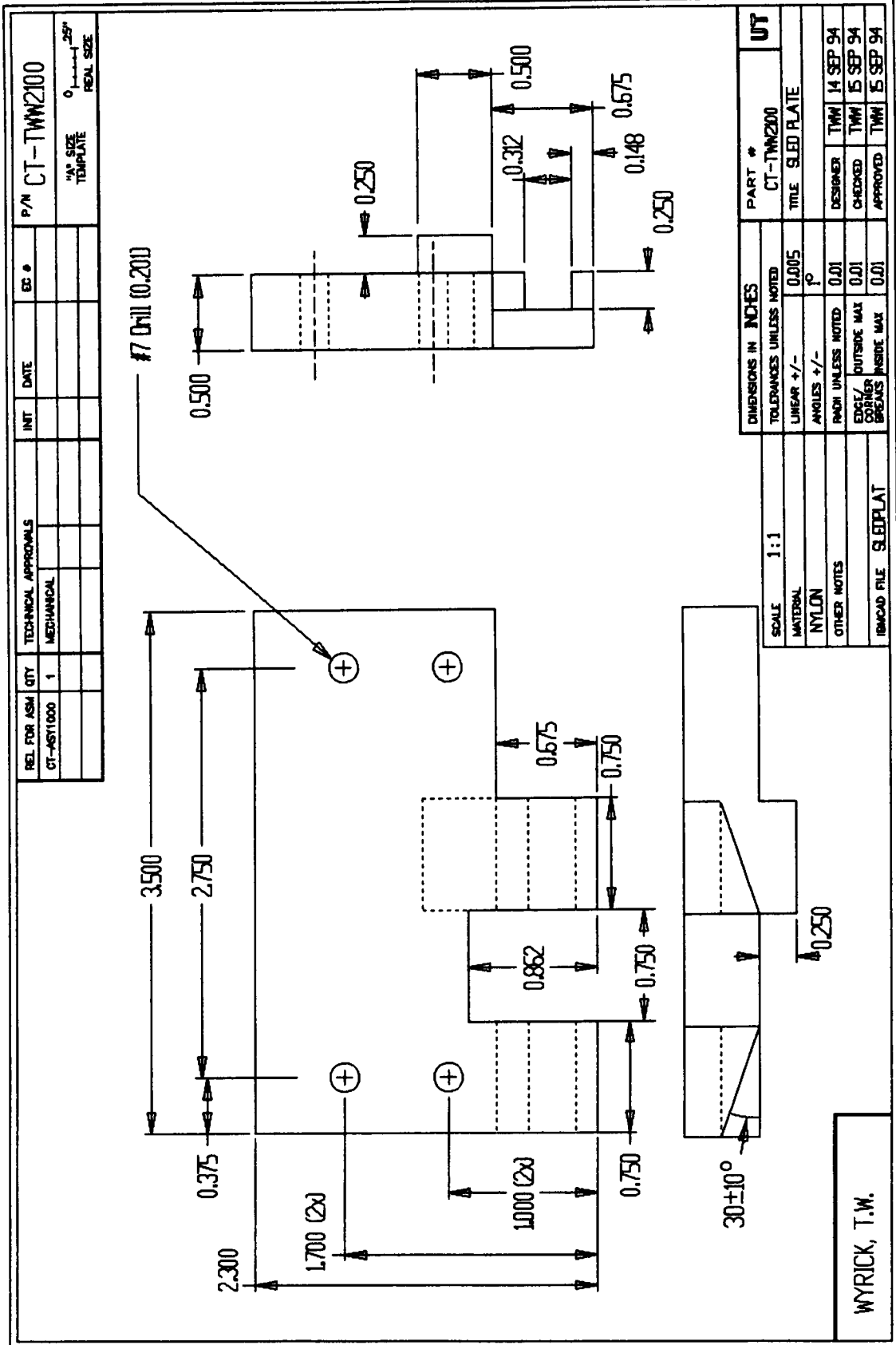


"FRONT" VIEW
SCALE: 1X

SIDE VIEW
SCALE: 1X

WYRICK, T.W.

SCALE	DIMENSIONS IN INCHES	PART #	UT
MATERIAL	STEEL	CT-VEN500	
	TOLERANCES UNLESS NOTED	TITLE	HEX NUT
	LINEAR +/-		
	ANGLES +/-		
OTHER NOTES	RADI UNLESS NOTED	DESIGNER	TWM 10 OCT 94
	EDGE / OUTSIDE MAX	CHECKED	TWM 10 OCT 94
	CORNER	APPROVED	TWM 10 OCT 94
	BREKES		
REMOVAL FILE	HEXOUT10		



APPENDIX F
ASSEMBLY AND DETAIL DRAWINGS
FOR THE
PROTOTYPE BELT SANDER

REL FOR ASM QTY		TECHNICAL APPROVALS		INIT	DATE	EC #	P/N	ASY100	
								'A' SIZE	REAL SIZE
								0	25"

34	SQUARE KEY, .125	VEN270	2	RECD	PART NO.	NO. PART NAME	RECD
33	SHIM	VEN220	3				
32	#4-40 X .375 SLOT HD MACH SCR	VEN170	4				
31	#8-32 X .75 SOCK HD CAP SCR	VEN120-075	4				
30	#8-32 X 1.75 SOCK HD CAP SCR	VEN130-175	2				

SCALE		DIMENSIONS IN		PART #		UT	
MATERIAL		TOLERANCES UNLESS NOTED		ASY100		TITLE MAIN ASSEMBLY	
		LINEAR +/-					
		ANGLES +/-					
OTHER NOTES		RADII UNLESS NOTED					
		EDGE/OUTSIDE MAX					
		SURFACES INSIDE MAX					
IB/CAD FILE MANASV1				DESIGNER		TWN 16 DEC 93	
				CHECKED		TWN 08 DEC 94	
				APPROVED		TWN 08 DEC 94	

29	#8-32 HEX NUT	VEN122-164	8				
28	WASHER, .189 X .438 X .048	VEN131-189	16				
27	#8-32 X 1.25 SOCK HD CAP SCR	VEN130-125	6				
26	#10-32 X .375 SOCK HD CAP SCR	VEN123-038	8				
25	#10-32 X .5 SOCK HD CAP SCR	VEN123-050	8				
24	#10-32 HEX NUT	VEN122-190	16				
23	WASHER, .218 X .438 .085	VEN121-218	16				
22	#10-32 X 1 SOCK HD CAP SCR	VEN123-100	8				
21	#8-32 HEX NUT	VEN122-138	8				
20	WASHER, .156 X .375 X .048	VEN121-156	20				
19	#8-32 X 1.25 SOCK HD CAP SCR	VEN120-125	8				
18	SHOULDER SCREW, SOCK HD, .313	VEN810	1				
17	DC TACHOMETER	VEN820	1				
16	COLLAR, SHAFT, .375 BORE	VEN750	2				
15	COUPLING BODY	VNE840-375	2				
14	COUPLING SPIDER	VEN835	2				
13	COUPLING BODY	VEN840-500	2				
12	DC GEARMOTOR	VEN820	2				
11	TACHOMETER COUPLING	TWN810	1				
10	TACHOMETER MOUNTING BLOCK	TWN800	1				
9	REEL SPOOL	TWN720	2				
8	REEL SIDE	TWN710	4				
7	MOTOR BRACKETS	TWN800-2	2				
6	MOTOR BRACKETS	TWN800-1	2				
5	BELT LOADING ASSEMBLY	ASY900	1				
4	PULLEY SHAFT ASSEMBLY	ASY400	1				
3	TACHOMETER TRANS ASSEMBLY	ASY300	1				
2	REEL SHAFT ASSEMBLY	ASY200	2				
1	BACK PLATE	TWN100	1				

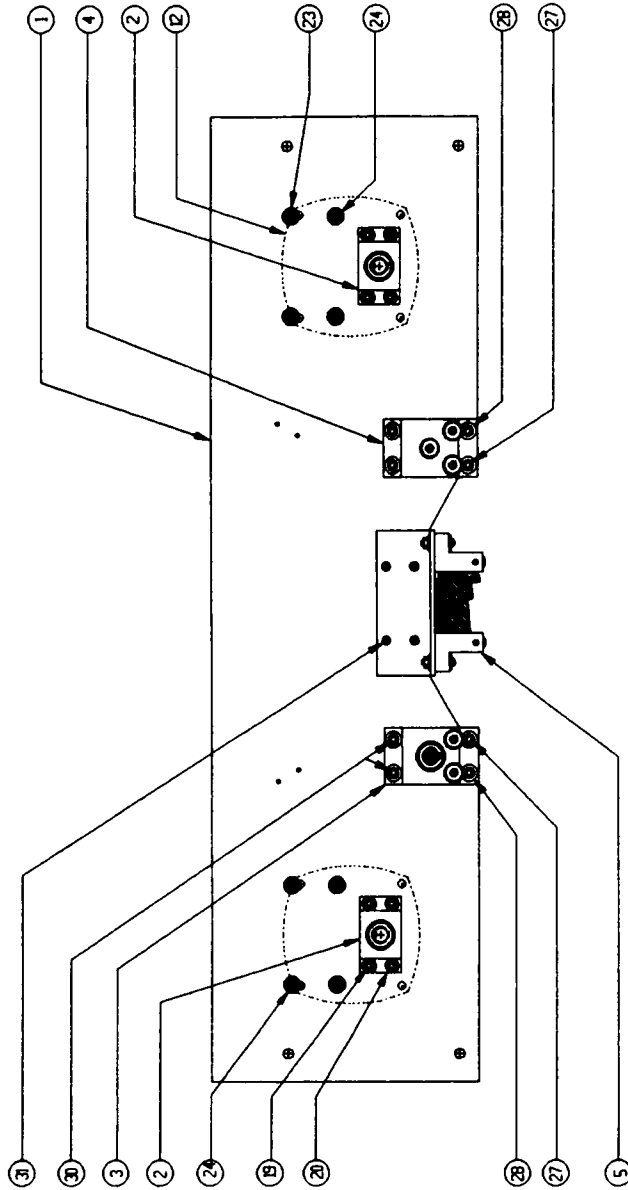
SHEET 1 OF 4

WYRICK, T.W.

REL FOR ASM	QTY	TECHNICAL APPROVALS	INIT	DATE	EC #	P/N
ASY100	1	MECHANICAL				ASY100

"C" SIZE
TEMPLATE

0 1"
REAL SIZE



FRONT SANDER ASSEMBLY
(REELS NOT ATTACHED)

SCALE	1/2	DIMENSIONS IN INCHES	PART #	UT
MATL		TOLERANCES UNLESS NOTED	ASY100	
		LINEAR +/-	TITLE FRONT SANDER	
		ANGLES +/-	ASSEMBLY	
		RADI UNLESS NOTED	DESIGNER TWW	16 DEC 93
		EDGE / OUTSIDE MAX	CHECKED TWW	08 JAN 94
		CORNER BREAKS INSIDE MAX	APPROVED TWW	08 JAN 94
IBMCAD FILE	MAINASY2			

SHEET 2 OF 4

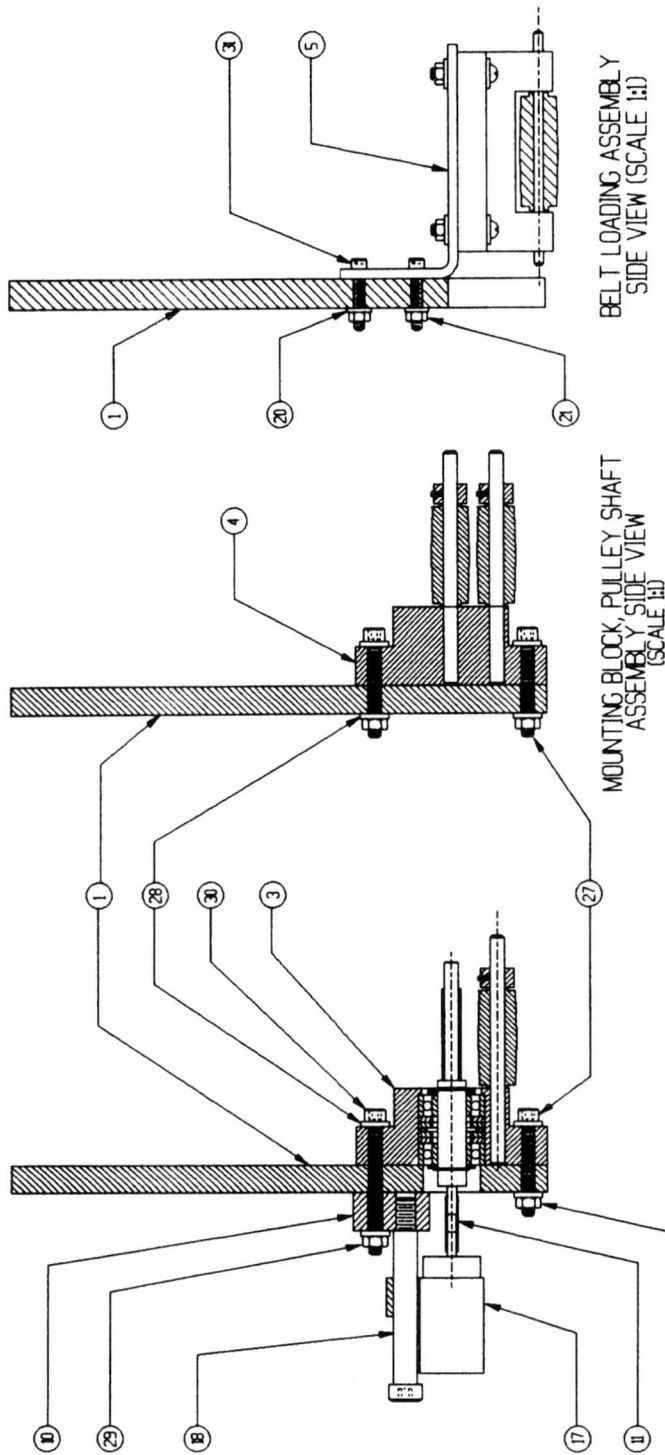
WYRICK, T.W.

REL FOR ASM QTY		TECHNICAL APPROVALS		INIT	DATE	EC #	P/N	ASY100
		MECHANICAL						

SCALE	1:1	DIMENSIONS IN INCHES		PART #	UT
MATL		TOLERANCES UNLESS NOTED		ASY100	
		LINEAR +/-		TITLE MAIN ASSEMBLY	
		ANGLES +/-			
		RADI UNLESS NOTED			
		EDGE/CORNER BREAKS		DESIGNER	TWW 16 DEC 93
				CHECKED	TWW 08 JAN 94
				APPROVED	TWW 08 JAN 94

DC GEARMOTOR-REEL ASSEMBLY DRIVE TRAIN SIDE VIEW (SCALE 1:1)	WYRICK, T.W.	SHEET 3 OF 4
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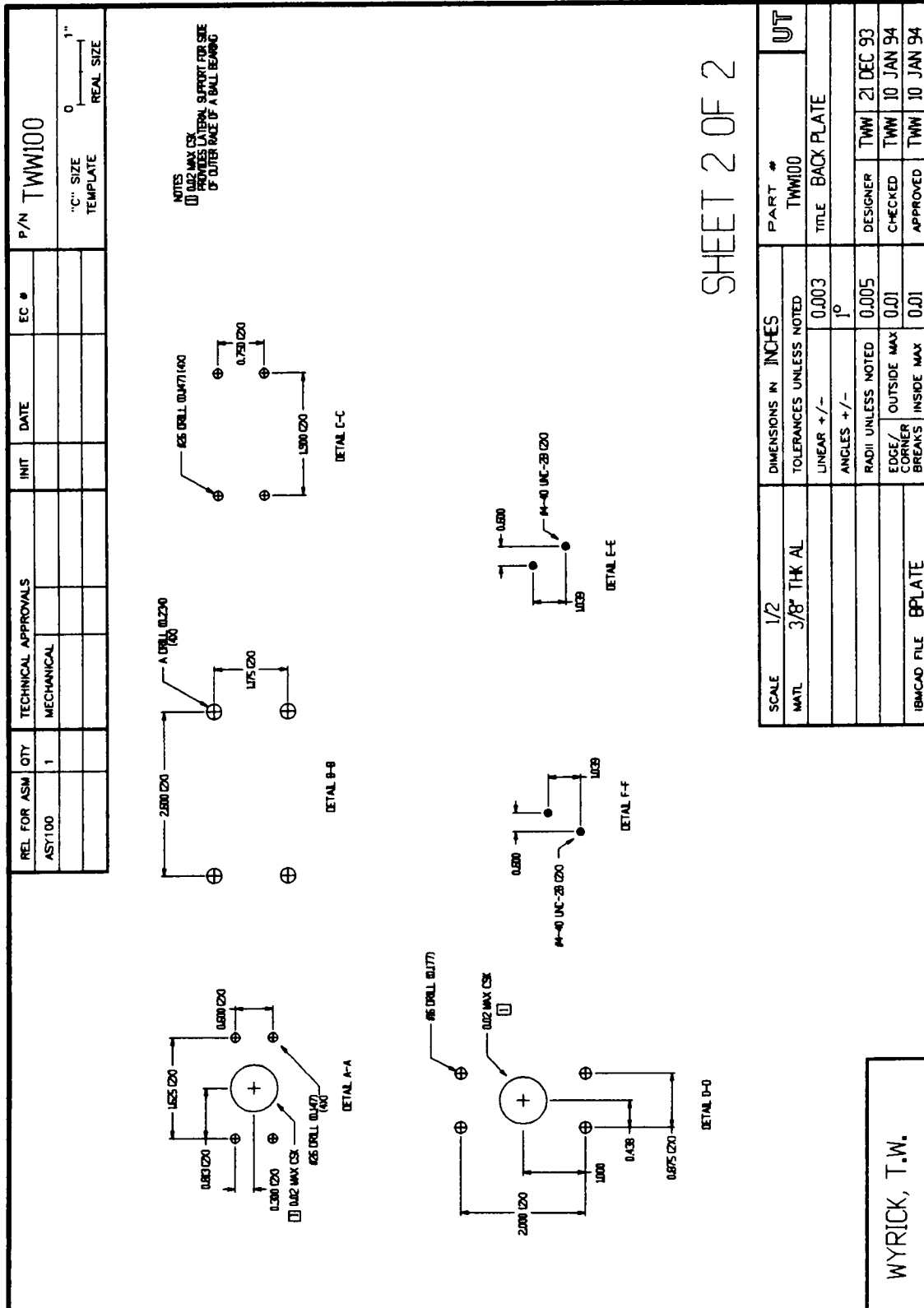
REL FOR ASM QTY	TECHNICAL APPROVALS	INIT	DATE	EC #	P/N
	MECHANICAL				ASY100



SCALE 1:1	DIMENSIONS IN INCHES	PART #	UT
MATERIAL MATL	TOLERANCES UNLESS NOTED	ASY100	
	LINEAR +/-	TITLE MAIN ASSEMBLY	
	ANGLES +/-		
OTHER NOTES	RADI UNLESS NOTED	DESIGNER	TWW 16 DEC 93
	EDGE / CORNER BREAKS	CHECKED	TWW 08 JAN 94
IBMCAD FILE MAINASY3		APPROVED	TWW 08 JAN 94

SHEET 4 OF 4

WYRICK, T.W.

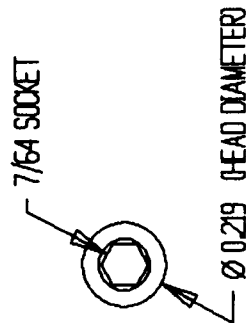
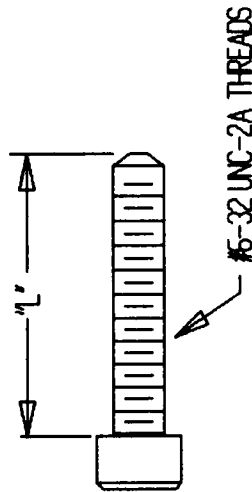


PART NO.	REL FOR ASM	QTY	TECHNICAL APPROVALS	INT	DATE	ED #	P/N
VEN120-075	ASY100	4	MECHANICAL				VEN120-LLL
VEN120-125	ASY100	8					
VEN120-075	ASY500	4					

"A" SIZE
TEMPLATE
0.0001-0.0002
REAL SIZE

NOTES:

1. SCREW LENGTH IS DETERMINED BY THE P/N SUFFIX CHART.
2. SUGGESTED VENDOR:
McMASTER-CARR SUPPLY COMPANY
CHICAGO, IL



P/N SUFFIX CHART :

P/N SUFFIX	"L"
-075	0.750
-125	1.250

SIDE VIEW
SCALE: 2:1
-075 (3/4 LONG) DOWN

SOCKET END VIEW
SCALE: 2:1

SCALE	2:1	DIMENSIONS IN	NOTES	PART #	UT
MATERIAL	STEEL	TOLERANCES UNLESS NOTED		VEN120-LLL	
		LINEAR +/-	N/A	TITLE	SCREW, SOCKET HEAD
		ANGLES +/-	N/A	CAP	0.138(0.6)-32 UNC
OTHER NOTES		ROOM UNLESS NOTED	N/A	DESIGNER	TWM 10 NOV 93
		EDGE/CORNER BREAKS	OUTSIDE MAX	CHECKED	TWM 15 NOV 93
			INSIDE MAX	APPROVED	TWM 15 NOV 93
				REWORK FILE	940308

WYRICK, T.W.

PART NO.		REL FOR ASM	QTY	TECHNICAL APPROVALS		INT	DATE	ES. #	P/N	VEN121-ISO
VEN121-55		ASY100	20	MECHANICAL						
VEN121-88		ASY100	15							
VEN121-28		ASY100	15							
VEN121-55		ASY500	8							

WASHER FRONT VIEW
SCALE: 2x
-55 Ø.55 ID X 0.375 OD SHOWN

SIDE VIEW
SCALE: 2x
-55 Ø.049 THO SHOWN

NOTES:

☐ WASHER DIMENSIONS ARE DETERMINED BY P/N SUFFIX CHART.

☒ SUGGESTED VENDOR
McMASTER-CARR SUPPLY COMPANY
CHICAGO, IL

P/N SUFFIX	"ID"	"OD"	"THK"
-156	0.156	0.375	0.049
-189	0.189	0.438	0.049
-218	0.218	0.438	0.065

SCALE	2:1	DIMENSIONS IN INCHES	PART #	UT
MATERIAL	STEEL	TOLERANCES UNLESS NOTED	VEN121-ISO	
		LINEAR +/-	TITLE	WASHER, FLAT
		ANGLES +/-		
OTHER NOTES		RADI UNLESS NOTED	DESIGNER	TMM 10 OCT 94
		EDGE/CORNER BREAKS	CHECKED	TMM 10 OCT 94
			APPROVED	TMM 10 OCT 94

WYRICK, T.W.

PART NO.		REL FOR ASM	QTY	TECHNICAL APPROVALS		INT	DATE	EE #	P/N	VENI22-THD
VENI22-138		ASTY100	8	MECHANICAL						
VENI22-164		ASTY100	8							
VENI22-190		ASTY100	16							
VENI22-138		ASTY500	8							

"A" SIZE TEMPLATE	REAL SIZE
0	0
1	1
2	2
3	3
4	4
5	5
6	6
7	7
8	8
9	9
10	10
11	11
12	12
13	13
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97	97
98	98
99	99
100	100

NOTES:

1 SUGGESTED VENDOR:
MCMASTER-CARR SUPPLY COMPANY
CHICAGO, IL

HEX NUT SIZE DETERMINED BY
P/N SUFFIX CHART

P/N SUFFIX CHART:

P/N SUFFIX	"THD"	"HT"	"FLATS"
-138	#6-32	7/64	5/16
-164	#8-32	1/8	11/32
-190	#10-32	1/8	3/8

ISOMETRIC VIEW
SCALE: 1/4"
VERTICAL ORIENTATION

ISOMETRIC VIEW
SCALE: 1/4"
HORIZONTAL ORIENTATION

SCALE 2:1

MATERIAL STEEL

OTHER NOTES

IBMCAD FILE HEXNUTS

SCALE: 1/4"
SIDE VIEW
SCALE: 1/4"
-138 (06-32) SHWN

SCALE: 1/4"
SIDE VIEW
SCALE: 1/4"
-138 (06-32) SHWN

SCALE: 1/4"
FRONT VIEW
SCALE: 1/4"
-138 (06-32) SHWN

SCALE: 1/4"
FRONT VIEW
SCALE: 1/4"
-138 (06-32) SHWN

WYRICK, T.W.

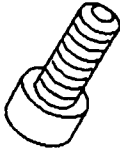
PART NO.		REL FOR ASM		TECHNICAL APPROVALS		INT	DATE	ES #	P/N
VEN23-038		AS1000		MECHANICAL					VEN23-LLL
VEN23-050		AS1000							
VEN23-100		AS1000							

P/N SUFFIX CHART	
P/N SUFFIX	"L"
-038	0.375
-050	0.500
-100	1.000

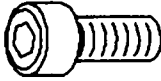
NOTES:

☐ SCREW LENGTH IS DETERMINED BY THE P/N SUFFIX CHART.

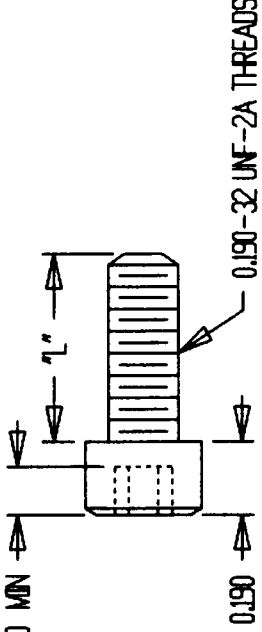
☒ SUGGESTED VENDOR:
McMASTER-CARR SUPPLY COMPANY
CHICAGO, IL



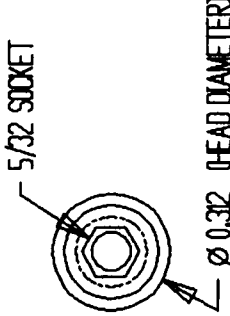
ISOMETRIC VIEW
SCALE: 1/2
-050 0/2 LONG SHOWN
HORIZONTAL - THREAD END VIEW



ISOMETRIC VIEW
SCALE: 1/2
-050 0/2 LONG SHOWN
VERTICAL ORIENTATION



0.090 MIN 1/2 0.190 0.190-32 UNF-2A THREADS



5/32 SOCKET Ø 0.312 HEAD DIAMETER

SOCKET END VIEW
SCALE: 2/3

SIDE VIEW
SCALE: 2/3
-050 0/2 LONG SHOWN

SCALE 1:1		DIMENSIONS IN INCHES		PART #	
MATERIAL	STEEL	TOLERANCES UNLESS NOTED	N/A	VEN23-LLL	UT
OTHER NOTES		LINEAR +/-	N/A	TITLE	SCREW, SOCKET HEAD
		ANGLES +/-	N/A	CAP, 0.350(0.00)-32 UNF	
		RADI UNLESS NOTED	N/A	DESIGNER	NEX 29 SEP 90
		EDGE ROUNDED	N/A	CHECKED	TMM 14 SEP 93
		INSIDE MAX	N/A	APPROVED	TMM 14 SEP 93
ENCLOSURE FILE 94CS90					

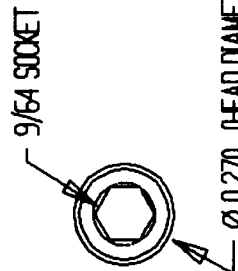
WYRICK, T.W.

PART NO.	REL FOR ASM	QTY	TECHNICAL APPROVALS	INT	DATE	ED #	P/N
VEN30-125	ASY100	6	MECHANICAL				VEN30-LLL
VEN30-175	ASY100	2					
							"N" SIZE TEMPLATE
							0-----25" REAL SIZE

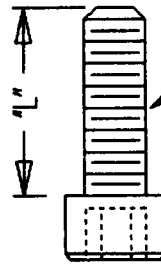
NOTES:

1 SREW LENGTH IS DETERMINED BY THE P/N SUFFIX CHART.

2 SUGGESTED VENDOR:
McMASTER-CARR SUPPLY COMPANY
CHICAGO, IL



SOCKET END VIEW
SCALE: 2x



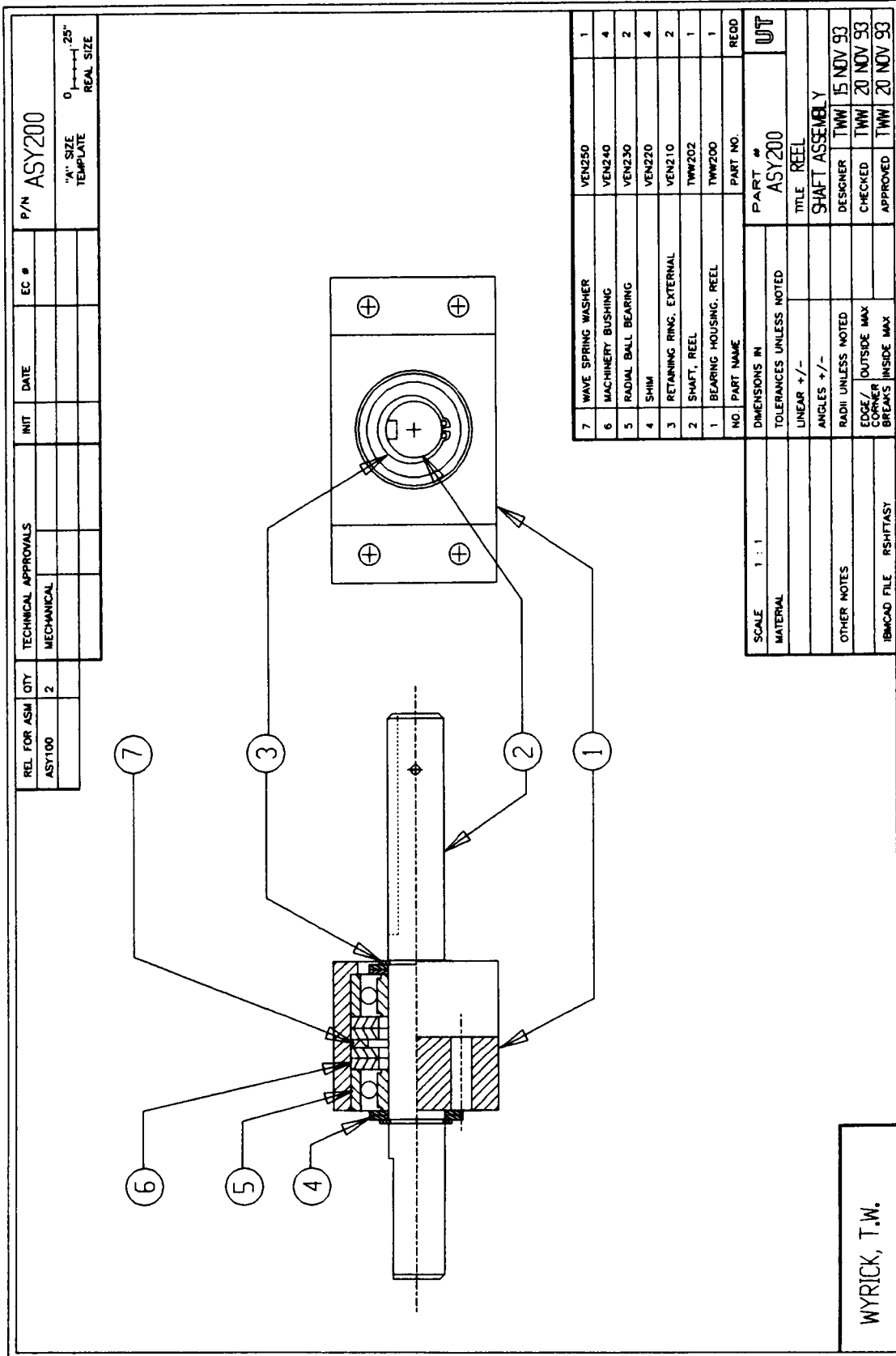
SIDE VIEW
SCALE: 2x
-050 0/2 LONG SHOWN

P/N SUFFIX CHART:

P/N SUFFIX	"L"
-125	1.250
-175	1.750

SCALE	2:1	DIMENSIONS IN	NOTES	PART #	UT
MATERIAL	STEEL	TOLERANCES UNLESS NOTED		VEN30-LLL	
		LINEAR +/-	N/A	TITLE	SREW, SOCKET HEAD
		ANGLES +/-	N/A	CAP, 0.354000-32 UNC	
OTHER NOTES		RACH UNLESS NOTED	N/A	DESIGNER	TMM 14 DEC 93
		EDGE/ CORNER BREAKS	OUTSIDE MAX	CHECKED	TMM 17 DEC 93
			INSIDE MAX	APPROVED	TMM 17 DEC 93
IMC/AD FILE 940364					

WYRICK, T.W.



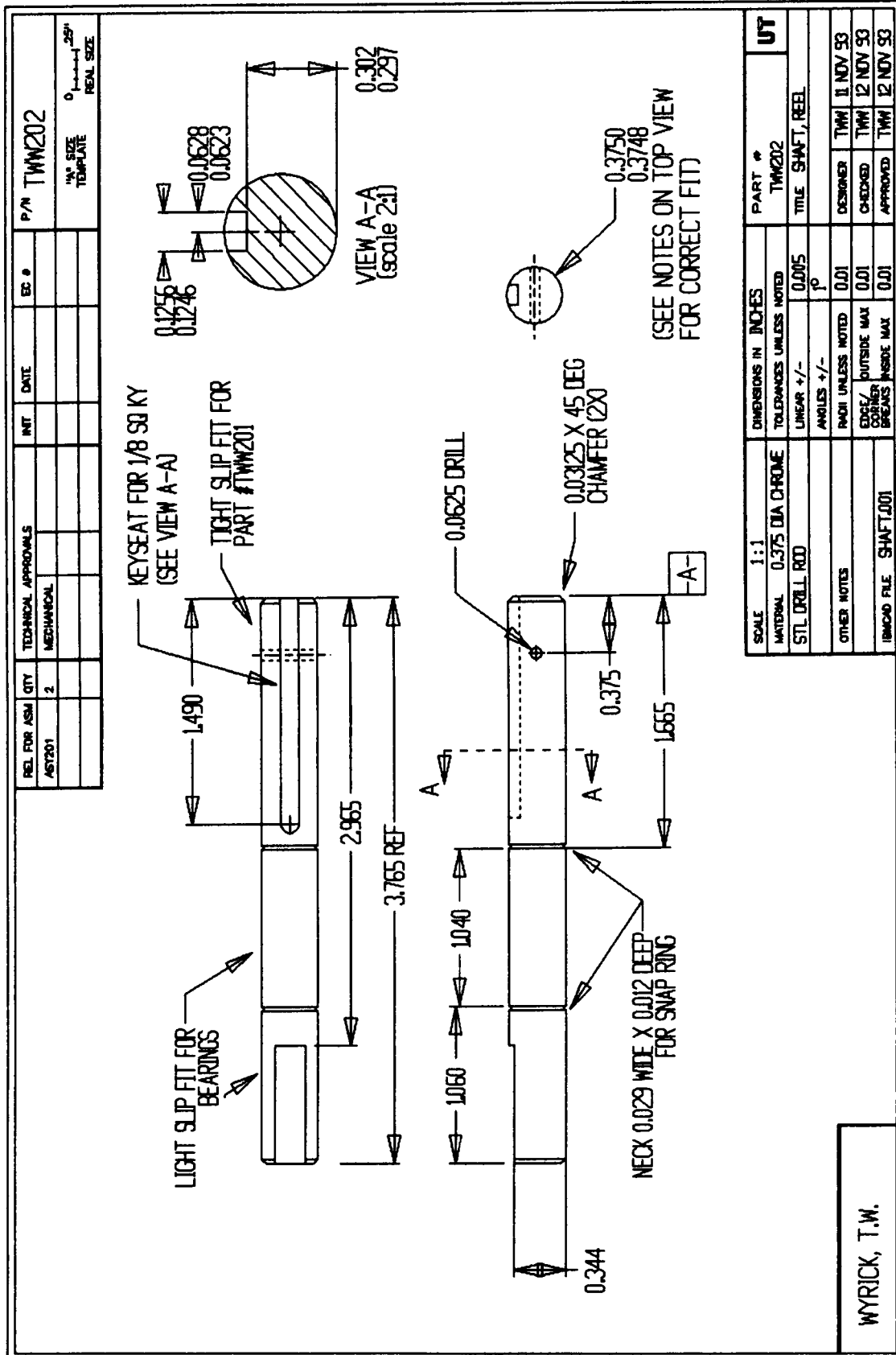
REL FOR ASM		QTY	TECHNICAL APPROVALS		INIT	DATE	EC #	P/N	ASY200
ASY100		2	MECHANICAL						

"A" SIZE TEMPLATE	0	1.25"	REAL SIZE
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7	WAVE SPRING WASHER	VEN250	1
6	MACHINERY BUSHING	VEN240	4
5	RADIAL BALL BEARING	VEN230	2
4	SHIM	VEN220	4
3	RETAINING RING, EXTERNAL	VEN210	2
2	SHAFT, REEL	TWW202	1
1	BEARING HOUSING, REEL	TWW200	1
NO. PART NAME		PART NO.	RECD

SCALE 1 : 1		DIMENSIONS IN		PART #	UT
MATERIAL		TOLERANCES UNLESS NOTED		ASY200	
		LINEAR +/-		TITLE REEL	
		ANGLES +/-		SHAFT ASSEMBLY	
OTHER NOTES		RADI UNLESS NOTED		DESIGNER	TWW 15 NOV 93
		EDGE / OUTSIDE MAX		CHECKED	TWW 20 NOV 93
IBMCAD FILE RSHTAST		BREAKS INSIDE MAX		APPROVED	TWW 20 NOV 93

WYRICK, T.W.

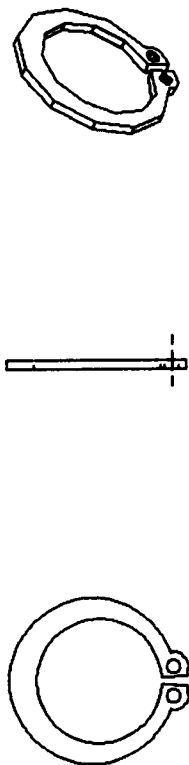


REL FOR ASM	QTY	TECHNICAL APPROVALS	INT	DATE	ED. #	P/N
ASY200	2	MECHANICAL				VEN210
ASY300	2					

0" 25"
REAL SIZE

NOTES:

- GENERIC PART NAME
EXTERNAL RETAINING RING



TECHNICAL DATA

SHAFT DIA : 3/8
GROOVE DIA : 0.352
GROOVE WIDTH : 0.029

SCALE	2:1	DIMENSIONS IN INCHES	PART #	UT
MATERIAL	STL	TOLERANCES UNLESS NOTED	VEN210	
		LINEAR +/-		
		ANGLES +/-		
OTHER NOTES		RACH UNLESS NOTED		
		EDGE/ CORNER		
		BROOKS		
ISN/CAD FILE	RETENR			

WYRICK, T.W.

REL FOR ASM		QTY	TECHNICAL APPROVALS		INIT	DATE	ED #	P/N	VEN220
ASY200		3	MECHANICAL						
ASY200		3							

NOTES:

☐ SUGGESTED VENDOR:
McMASTER-CARR SUPPLY COMPANY
CHICAGO, IL

SCALE	2:1	DIMENSIONS IN		NOTES	PART #	UT
MATERIAL		TOLERANCES UNLESS NOTED			VEN220	
		LINEAR +/-		N/A	TITLE	SHM 0.375 ID.
		ANGLES +/-		N/A	0.625 OD, 0.031 THICK	
OTHER NOTES		FACE UNLESS NOTED		N/A	DESIGNER	TWM 10 DEC 93
		EDGE / OUTSIDE MAX		N/A	CHECKED	TWM 12 DEC 93
		CORNER BREAKS		N/A	APPROVED	TWM 12 DEC 93
REWORK FILE	SHM/G75					

WYRICK, T.W.

REL FOR ASM	QTY	TECHNICAL APPROVALS	INT	DATE	ED #	P/N
AS7200	2	MECHANICAL				VEN230
AS7300	2					

"A" SIZE
TEMPLATE
0 1 2 3 4 5 6 7 8 9 10
REAL SIZE

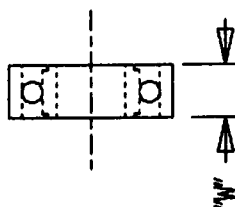
NOTES:

- 1 GENERIC PART NAME/REQUIREMENTS:
 - BALL BEARING, RADIAL
 - SHIELDED BOTH SIDES
 - GREASE LUBE
 - SINGLE ROW

TECHNICAL DATA AND DIMENSIONS
ARE FOR REFERENCE ONLY.

TECHNICAL DATA:

ABEC CLASS : 1
BORE DIA : 0.375
OUTER DIA : 0.875
WIDTH (TOTAL) : 0.281



SCALE	1:1	DIMENSIONS IN INCHES	PART #	UT
MATERIAL		TOLERANCES UNLESS NOTED	VEN230	
		LINEAR +/-	N/A	
		ANGLES +/-	N/A	
OTHER NOTES		FACE UNLESS NOTED	N/A	
		EDGE / OUTSIDE MAX	N/A	
		CORNER	N/A	
		BREAKS	N/A	
ISN/CAD FILE	BBR0375			

WYRICK, T.W.

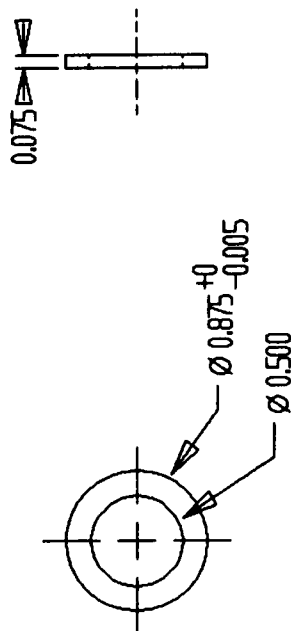
REL FOR ASM	QTY	TECHNICAL APPROVALS	INT	DATE	ED #	P/N
ASY200	4	MECHANICAL				VEN240
ASY200	4					

"A" SIZE
TEMPLATE
0.0001-0.0002
REAL SIZE

NOTES:

☐ GENERIC PART NAME
MACHINERY BUSHING

☒ SUGGESTED VENDOR
McMASTER-CARR SUPPLY COMPANY
CHICAGO, IL



SCALE	1:1	DIMENSIONS IN	NOTES	PART #	UT
MATERIAL	STL	TOLERANCES UNLESS NOTED	N/A	VEN240	
		LINEAR +/-	N/A	TITLE	BUSHING, MACHINERY
		ANGLES +/-	N/A	0.875 OD, 0.50 ID, 0.075 THK	
OTHER NOTES		PAGE UNLESS NOTED	N/A	DESIGNER	TMM 09 DEC 93
		EDGE/ CORNER BREAKS	OUTSIDE MAX	CHECKED	TMM 12 DEC 93
REWORK FILE	BSHNG/75		INSIDE MAX	APPROVED	TMM 12 DEC 93

WYRICK, T.W.

REL FOR ASM	QTY	TECHNICAL APPROVALS	INT	DATE	EE #	P/N
AST200	1	MECHANICAL				VEN250
AST300	1					

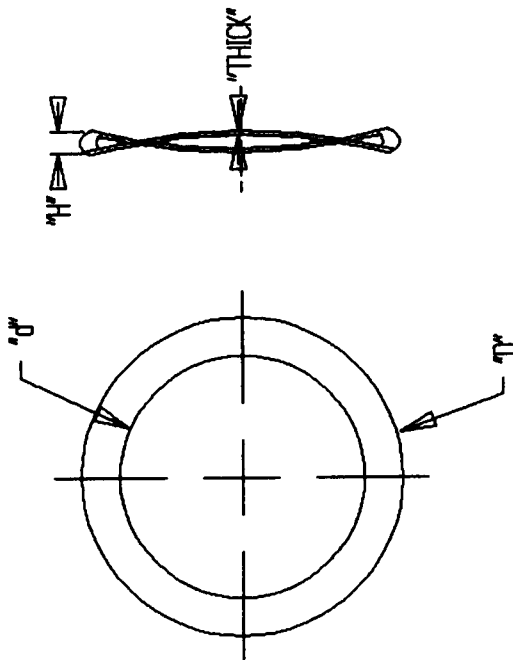
0.0001 25"
REAL SIZE

NOTES:

- ☐ GENERIC PART NAME
- WAVE SPRING WASHER
- ☒ SUGGESTED VENDOR:
- McMASTER CARR SUPPLY COMPANY
- Cat No. 9714K55

TECHNICAL DATA:

"d" : 0.650
"D" : 0.855
"THICK" : 0.0100
"H" (Undeformed Width) : 0.050



SCALE	2:1	DIMENSIONS IN	NOTES	PART #	UT
MATERIAL	STL	TOLERANCES UNLESS NOTED		VEN250	
		LINEAR +/-	N/A	TITLE	WAVE SPRING WASHER
		ANGLES +/-	N/A		0.855 OD, 0.650 ID
OTHER NOTES		RADI UNLESS NOTED	N/A	DESIGNER	TMM 18 NOV 93
		EDGE/ CORNER BREAKS	OUTSIDE MAX	CHECKED	TMM 12 DEC 93
REWORK FILE	WAVESPRG		INSIDE MAX	APPROVED	TMM 12 DEC 93

WYRICK, T.W.

REL FOR ASM	QTY	TECHNICAL APPROVALS	INT	DATE	ED #	P/N	VEN260
ASY300	2	MECHANICAL					
ASY400	3						

NOTES:

GENERIC PART NAME:

- SHAFT COLLAR WITH SET SCREW

SCALE	2:1	DIMENSIONS IN	NOTES	PART #	UT
MATERIAL		TOLERANCES UNLESS NOTED		VEN260	
		LINEAR +/-	N/A	TITLE	SHAFT COLLAR
		ANGLES +/-	N/A		0.1875 BORE
OTHER NOTES		FINISH UNLESS NOTED	N/A	DESIGNER	TMM 15 NOV 93
		EDGE/ CORNER BREAKS	N/A	CHECKED	TMM 12 DEC 93
ENCAD FILE	SCOLLAR		N/A	APPROVED	TMM 12 DEC 93

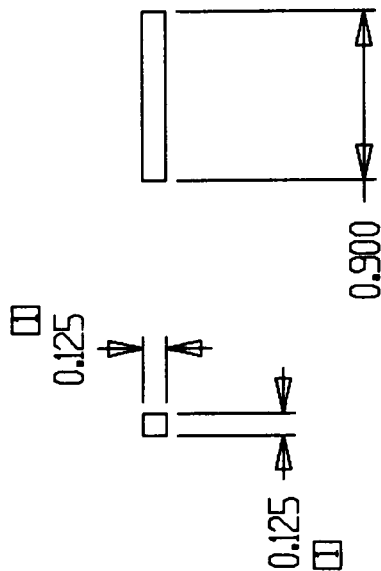
WYRICK, T.W.

REL FOR ASM	QTY	TECHNICAL APPROVALS	INT	DATE	ED #	P/N
AST100	2	MECHANICAL				VEN270

0.125
25°
REAL SIZE
REAL SIZE

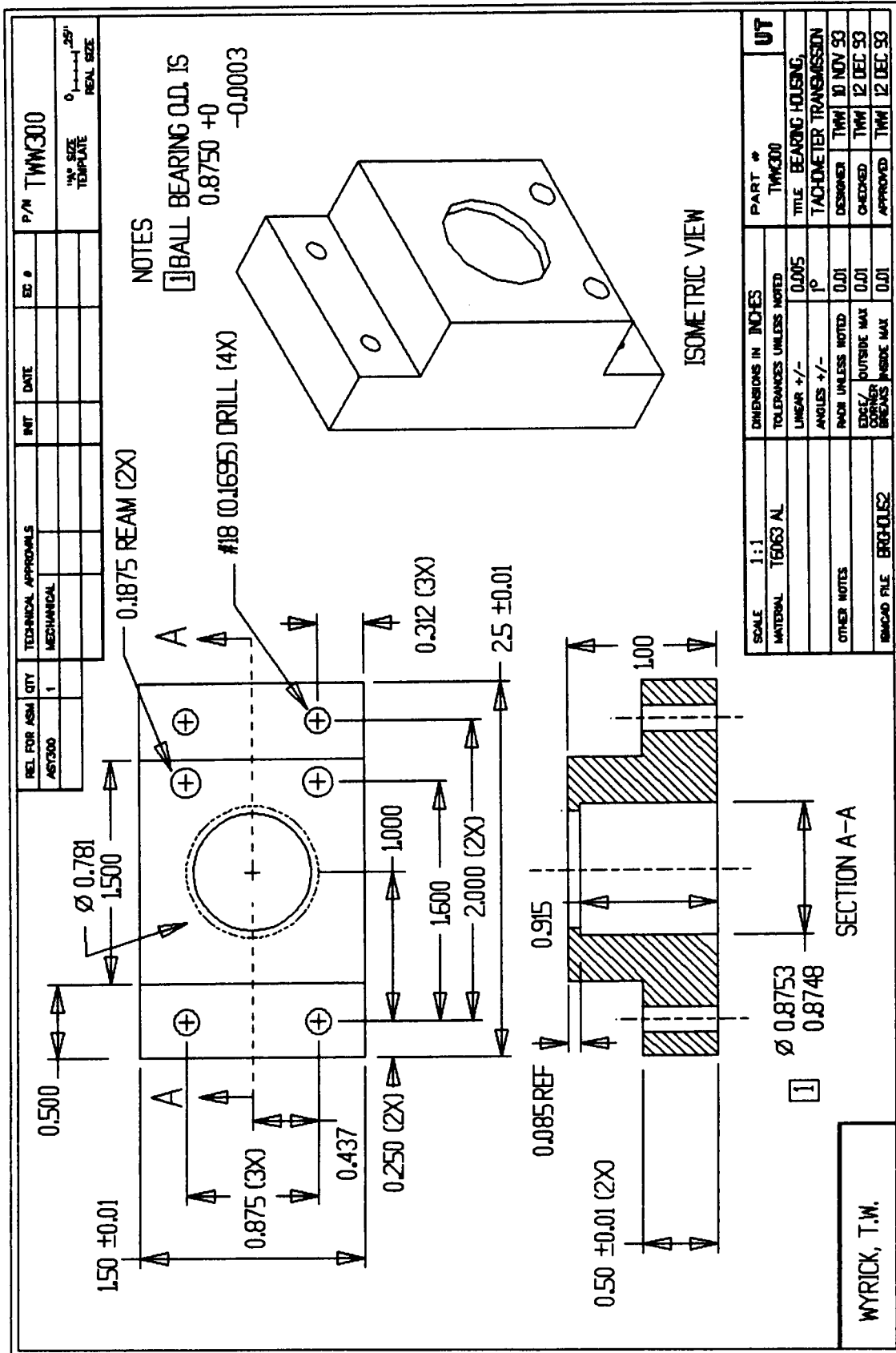
NOTES

- 1 MAKE TO FIT KEYSEAT IN
PART # TWK202



SCALE	1:1	DIMENSIONS IN	NOTES	PART #	UT
MATERIAL	125 SQ KY STK	TOLERANCES UNLESS NOTED		VEN270	
		LINEAR +/-	0.005	TITLE	SQUARE KEY, 125
		ANGLES +/-			
OTHER NOTES		FINISH UNLESS NOTED		DESIGNER	TWM 23 NOV 93
		EDGE/ CORNER BREAKS	OUTSIDE MAX	CHECKED	TWM 23 NOV 93
RECORD FILE	SKKEY1	INSIDE MAX		APPROVED	TWM 23 NOV 93

WYRICK, T.W.



REL FOR ASM		QTY	TECHNICAL APPROVALS		INT	DATE	ED #	P/N	TWNC320
AST300	2								
AST400	3								

IN" SIZE TEMPLATE		REAL SIZE
0	1	25"

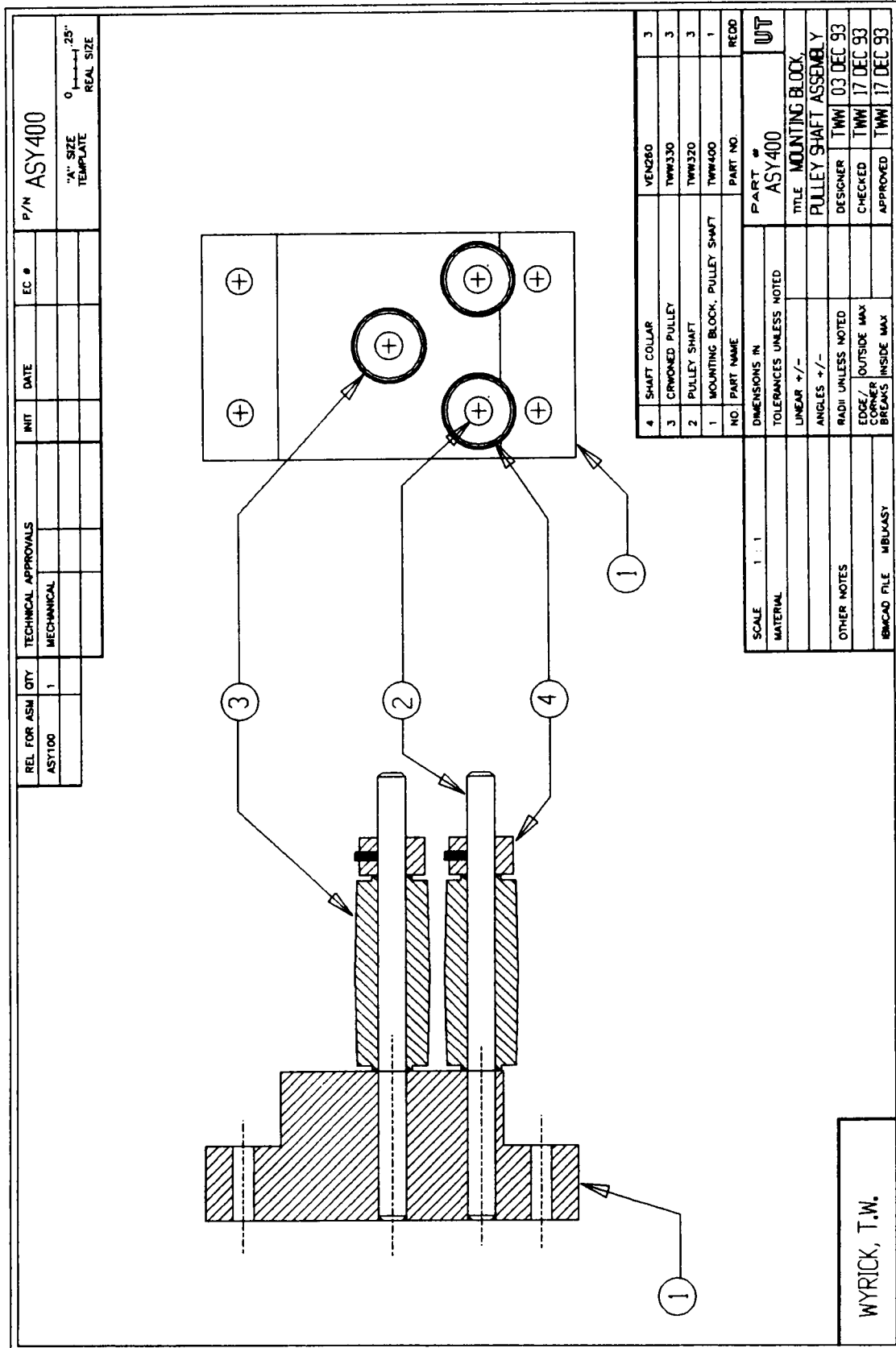
3.000

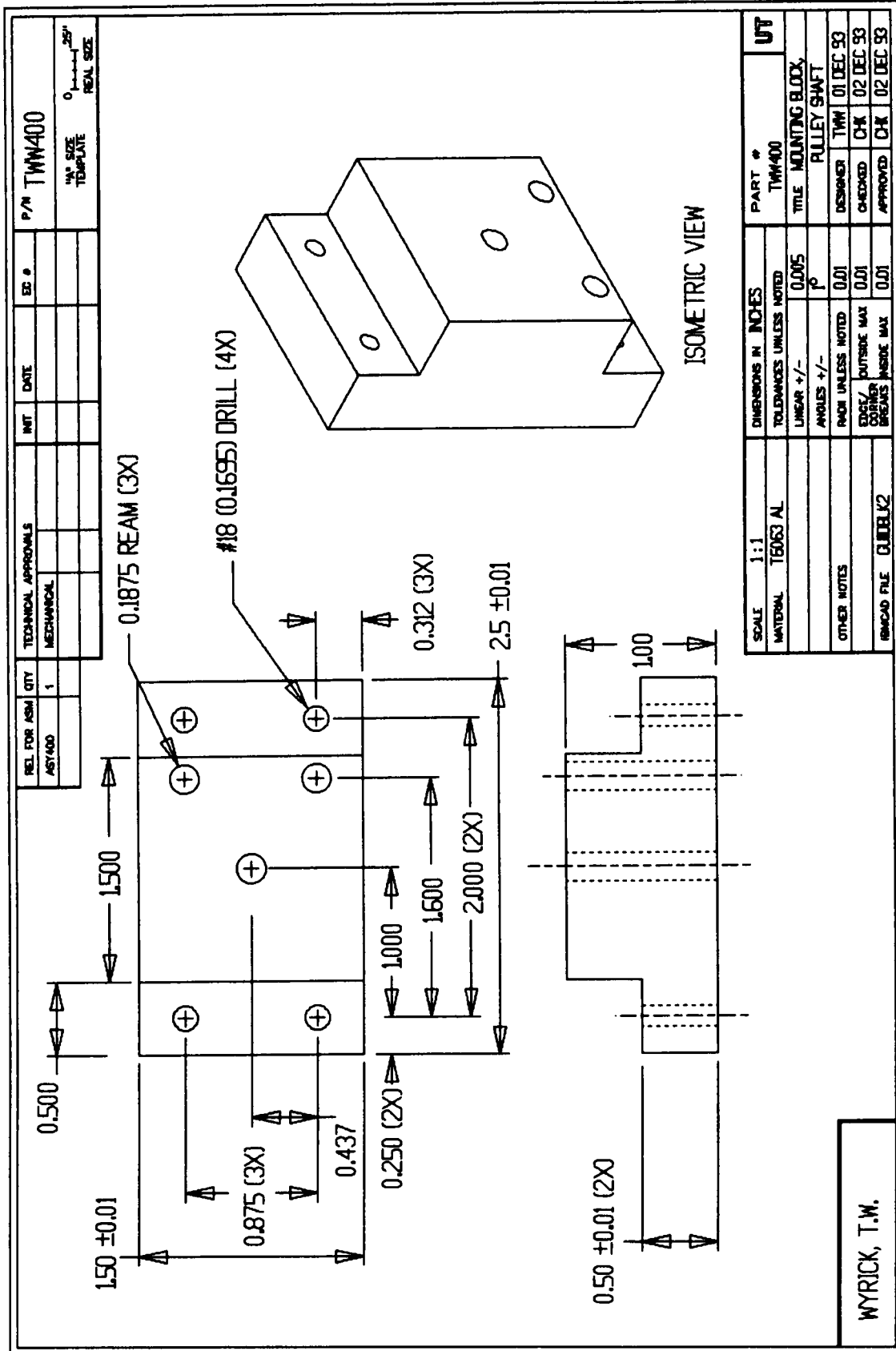
Ø 0.188 STK

0.031 X 45° CHAMFER (2X)

SCALE	1:1	DIMENSIONS IN	NOTES	PART #	UT
MATERIAL	3/16 INCH CHROME	TOLERANCES UNLESS NOTED		TWNC320	
STL DRILL ROD		LINEAR +/-	0.005	TITLE	PULLEY SHAFT
OTHER NOTES		ANGLES +/-	1°	DESIGNER	TWNC 07 JUL 93
		ROUN UNLESS NOTED	0.01	CHECKED	TWNC 01 DEC 93
		EDGE/CORNER BREAKS	0.01	APPROVED	TWNC 01 DEC 93
BASIC FILE		SHAFT2			

WYRICK, T.W.





REL FOR ASM		QTY		TECHNICAL APPROVALS		INT		DATE		EP #		P/N		ASY500	
ASY100		1		MECHANICAL										"A" SIZE TEMPLATE 0 1/2" 25" REAL SIZE	

FRONT VIEW

SCALE		1 : 1	
MATERIAL			
OTHER NOTES			
BROAD FILE		BLINDFAST	

DIMENSIONS IN		PART #	
TOLERANCES UNLESS NOTED		ASY500	
LINEAR +/-		TITLE	
ANGLES +/-		BELT LOADING	
RADIUS UNLESS NOTED		ASSEMBLY	
EDGE / OUTSIDE MAX		DESIGNED TMM 15 NOV 93	
CORNER		CHECKED TMM 20 NOV 93	
BREAKS		APPROVED TMM 20 NOV 93	

NO.		PART NAME		PART NO.		REDO	
6		PRESSURE PAD ASSEMBLY		ASY500		1	
7		64-32 HEX NUT		VEN122-138		4	
8		WASHER .156 X .375 X .040		VEN121-156		6	
5		64-32 X 3/4 SOCK HD MACH SCR		VEN120-075		4	
4		BRACKET		TWN505		1	
3		PULLEY BLOCK		TWN504		2	
2		SHAFT, 1/8		TWN502		2	
1		CROWNED PULLEY, 1/8		TWN501		2	

WYRICK, T.W.	
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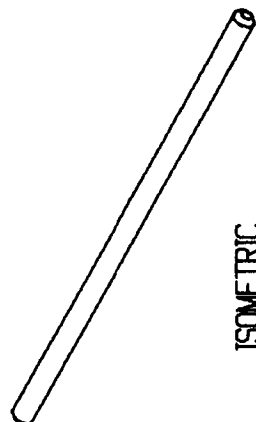
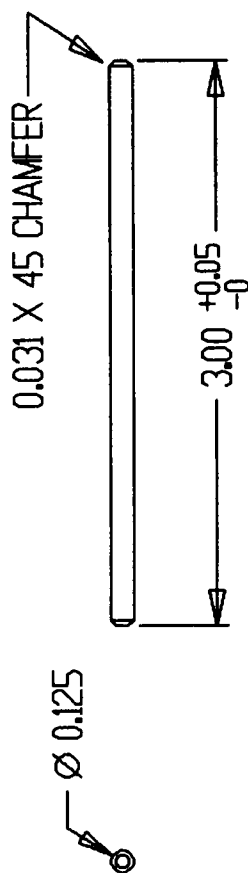
SHEET 1 OF 2

REL FOR ASM	QTY	TECHNICAL APPROVALS	INT	DATE	ES. #	P/N
AST500	2	MECHANICAL TWM 25 AUG 93				TWWS02

1/8" SIZE
TEMPLATE
0 1/8" 1/4" 3/8"
REAL SIZE

NOTES:

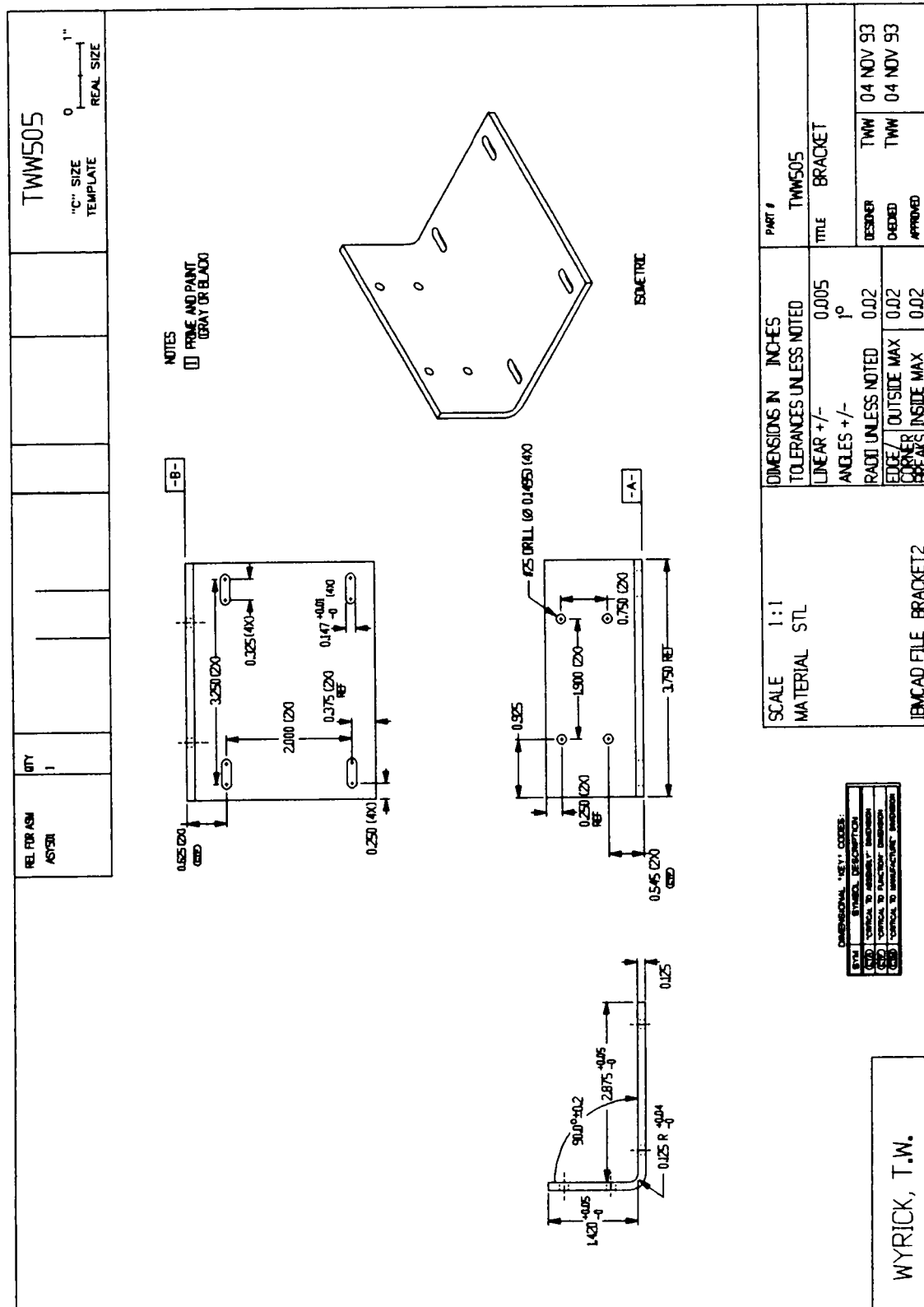
- 1 MATERIAL IS CHROME TOOL STEEL,
0.125 DIA DRILL ROD



ISOMETRIC

SCALE	1:1	DIMENSIONS IN INCHES	PART #	UT
MATERIAL	CHROME TOOL STL	TOLERANCES UNLESS NOTED	TWWS02	
		LINEAR +/-	TITLE SHAFT, 1/8	
		ANGLES +/-		
OTHER NOTES		RNDI UNLESS NOTED		
		EDGE/ CORNER	DESIGNER TWM 24 AUG 93	
		BREMS INSIDE MAX	CHECKED TWM 25 AUG 93	
			APPROVED TWM 25 AUG 93	

WYRICK, T.W.



REL FOR ASM		QTY		TECHNICAL APPROVALS		INIT	DATE	EC #	P/N
ASY500		1							ASY520

$\frac{0}{1} \pm .25$ "A" SIZE TEMPLATE	$\frac{0}{1} \pm .25$ REAL SIZE
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NOTES:

- 1 NYLON BUNTING IS APPLIED SO THAT THREADS ARE AT 5° ANGLE WITH SUPPORT BLOCK SIDES
- 2 POLYURETHANE PRESSURE PAD MATERIAL IS GLUED TO THE SUPPORT BLOCK AND VERTICAL SUPPORT PLATE.

NYLON BUNTING IS ALSO GLUED TO THE SUPPORT BLOCK AND VERTICAL SUPPORT PLATE, BUT NOT TO THE POLYURETHANE

NO.	PART NAME	PART NO.	RECD
6	HORIZONTAL PRESSURE PAD	TWWS50-2	1
5	VERTICAL PRESSURE PAD	TWWS50-1	1
4	NYLON BUNTING	TWWS40	2
3	VERTICAL SPACER	TWWS30-2	1
2	VERTICAL SUPPORT PLATE	TWWS30-1	1
1	SUPPORT BLOCK, PRESSURE PAD	TWWS20	1

SCALE 1 : 1	DIMENSIONS IN	PART #	UT
MATERIAL	TOLERANCES UNLESS NOTED	ASY520	
	LINEAR +/-	TITLE BELT LOADING	
	ANGLES +/-	ASSEMBLY	
OTHER NOTES	RADI UNLESS NOTED	DESIGNER	TWWS 10 SEP 94
	EDGE / CORNER BREAKS	CHECKED	TWWS 10 SEP 94
IBMCAD FILE PPADASY	INSIDE MAX	APPROVED	TWWS 10 SEP 94

WYRICK, T.W.

REL FOR ASM		QTY		TECHNICAL APPROVALS		INIT	DATE	EC #	P/N
ASY500		1							ASY520

"A" SIZE TEMPLATE		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	REAL SIZE
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NOTES:

1 NYLON BUNTING IS APPLIED SO THAT THREADS ARE AT 5° ANGLE WITH SUPPORT BLOCK SIDES

2 POLYURETHANE PRESSURE PAD MATERIAL IS GLUED TO THE SUPPORT BLOCK AND VERTICAL SUPPORT PLATE.

NYLON BUNTING IS ALSO GLUED TO THE SUPPORT BLOCK AND VERTICAL SUPPORT PLATE, BUT NOT TO THE POLYURETHANE

6	HORIZONTAL PRESSURE PAD	TWWS50-2	1
5	VERTICAL PRESSURE PAD	TWWS50-1	1
4	NYLON BUNTING	TWWS40	2
3	VERTICAL SPACER	TWWS30-2	1
2	VERTICAL SUPPORT PLATE	TWWS30-1	1
1	SUPPORT BLOCK, PRESSURE PAD	TWWS20	1

NO. PART NAME		PART NO.		RECD
DIMENSIONS IN		PART #		UT
TOLERANCES UNLESS NOTED		ASY520		
LINEAR +/-		TITLE		BELT LOADING
ANGLES +/-		ASSEMBLY		
RADI UNLESS NOTED		DESIGNER		TWWS 10 SEP 94
EDGE/ CORNER BREAKS		CHECKED		TWWS 10 SEP 94
IBMCAD FILE PPADASY		APPROVED		TWWS 10 SEP 94

WYRICK, T.W.

REL FOR ASM		QTY		TECHNICAL APPROVALS		INIT	DATE	EC #	P/N
ASY500		1							ASY520

$\frac{0}{1} \pm .25"$ "A" SIZE TEMPLATE	$\frac{0}{1} \pm .25"$ REAL SIZE
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NOTES:

1 NYLON BUNTING IS APPLIED SO THAT THREADS ARE AT 5° ANGLE WITH SUPPORT BLOCK SIDES

2 POLYURETHANE PRESSURE PAD MATERIAL IS GLUED TO THE SUPPORT BLOCK AND VERTICAL SUPPORT PLATE.

NYLON BUNTING IS ALSO GLUED TO THE SUPPORT BLOCK AND VERTICAL SUPPORT PLATE, BUT NOT TO THE POLYURETHANE

NO.	PART NAME	PART NO.	RECD
6	HORIZONTAL PRESSURE PAD	TWWS50-2	1
5	VERTICAL PRESSURE PAD	TWWS50-1	1
4	NYLON BUNTING	TWWS40	2
3	VERTICAL SPACER	TWWS30-2	1
2	VERTICAL SUPPORT PLATE	TWWS30-1	1
1	SUPPORT BLOCK, PRESSURE PAD	TWWS20	1

SCALE 1 : 1	DIMENSIONS IN	PART #	UT
MATERIAL	TOLERANCES UNLESS NOTED	ASY520	
	LINEAR +/-	TITLE BELT LOADING	
	ANGLES +/-	ASSEMBLY	
OTHER NOTES	RADI UNLESS NOTED	DESIGNER	TWWS 10 SEP 94
	EDGE / CORNER BREAKS	CHECKED	TWWS 10 SEP 94
IBMCAD FILE PPADASY	INSIDE MAX	APPROVED	TWWS 10 SEP 94

WYRICK, T.W.

REL FOR ASM		QTY		TECHNICAL APPROVALS		INIT	DATE	EC #	P/N
ASY500		1							ASY520

"A" SIZE TEMPLATE		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	REAL SIZE
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NOTES:

1 NYLON BUNTING IS APPLIED SO THAT THREADS ARE AT 5° ANGLE WITH SUPPORT BLOCK SIDES

2 POLYURETHANE PRESSURE PAD MATERIAL IS GLUED TO THE SUPPORT BLOCK AND VERTICAL SUPPORT PLATE.

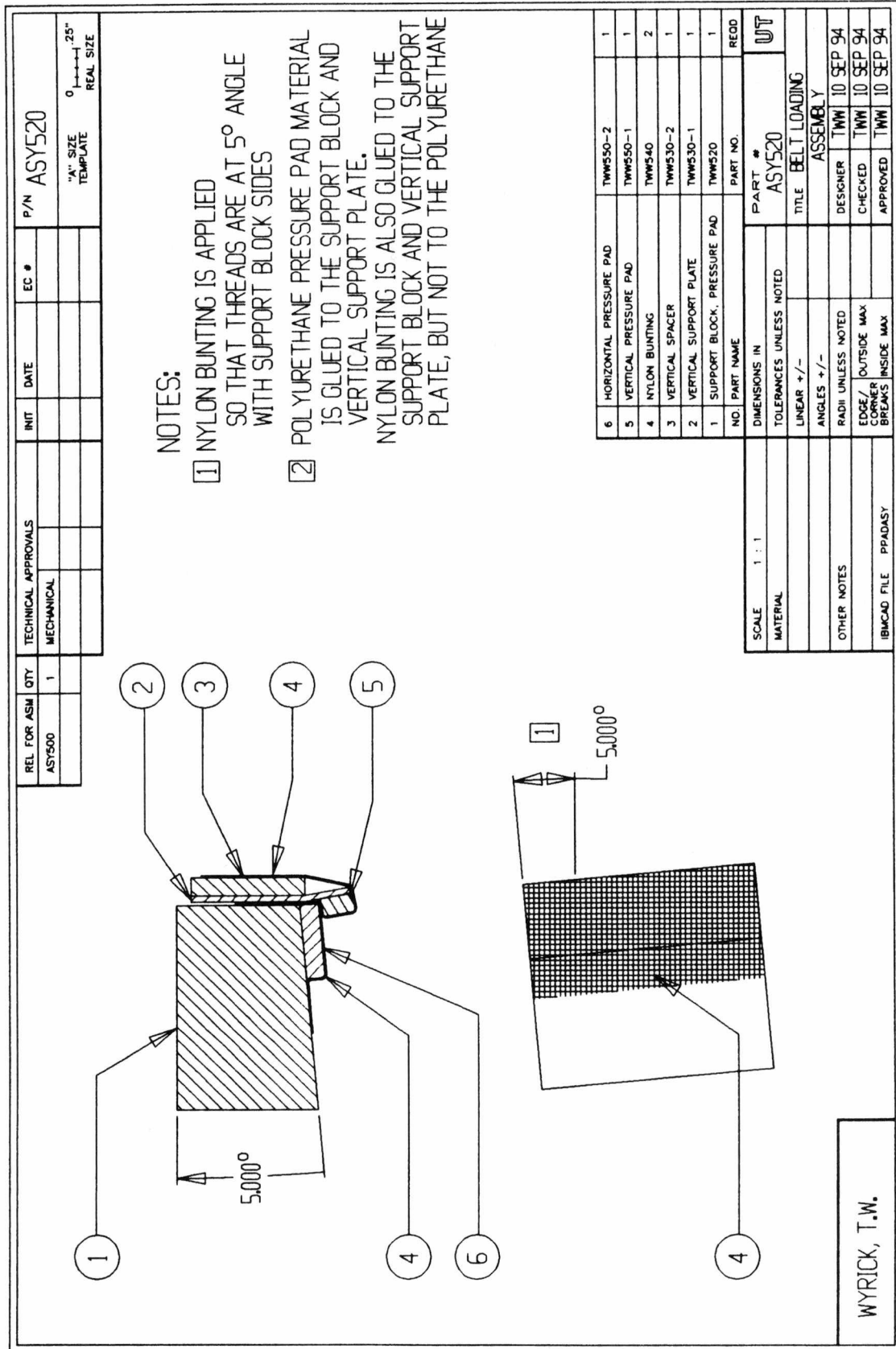
NYLON BUNTING IS ALSO GLUED TO THE SUPPORT BLOCK AND VERTICAL SUPPORT PLATE, BUT NOT TO THE POLYURETHANE

6	HORIZONTAL PRESSURE PAD	TWWS50-2	1
5	VERTICAL PRESSURE PAD	TWWS50-1	1
4	NYLON BUNTING	TWWS40	2
3	VERTICAL SPACER	TWWS30-2	1
2	VERTICAL SUPPORT PLATE	TWWS30-1	1
1	SUPPORT BLOCK, PRESSURE PAD	TWWS20	1

NO.	PART NAME	PART NO.	RECD
DIMENSIONS IN			
TOLERANCES UNLESS NOTED			
LINEAR +/-			
ANGLES +/-			
RADI UNLESS NOTED			
EDGE/ CORNER BREAKS			
IBMCAD FILE PPADASY			

SCALE	1 : 1	PART #	ASY520	UT
TITLE BELT LOADING ASSEMBLY				
DESIGNER TWM 10 SEP 94				
CHECKED TWM 10 SEP 94				
APPROVED TWM 10 SEP 94				

WYRICK, T.W.



PART NO.	REL FOR ASM	QTY	TECHNICAL APPROVALS	INT	DATE	EC #	P/N
TWWS30-1	ASYS20	1	MECHANICAL				TWWS30-1
TWWS30-2	ASYS20	1					

1/4" SIZE TEMPLATE		REAL SIZE	
0	1/4"	0	1/4"

1

2

2		1	
VERTICAL SPACER	TWWS30-2	VERTICAL SUPPORT PLATE	TWWS30-1
NO.	PART NAME	NO.	PART NAME

SCALE 1:1		DIMENSIONS IN		PART #	
MATERIAL	AL	TOLERANCES UNLESS NOTED		TITLE	VERTICAL SPACER & VERTICAL SUPPORT PLATE
		LINEAR +/-	.03	DESIGNER	TWM 12 JAN 95
		ANGLES +/-	3	CHECKED	TWM 12 JAN 95
OTHER NOTES		RADI UNLESS NOTED	.03	APPROVED	TWM 12 JAN 95
		EDGE/CORNER BREAKS	OUTSIDE MAX		
			INSIDE MAX		
INCAD FILE	PPACPLAT				

WYRICK, T.W.

PART NO.		REL FOR ASM		QTY	TECHNICAL APPROVALS		INT	DATE	EC #	P/N	TWWS50-1
TWWS50-1		ASTS50		1	MECHANICAL						
TWWS50-2		ASTS50		1							

0.125 REF

1

0.125 REF

2

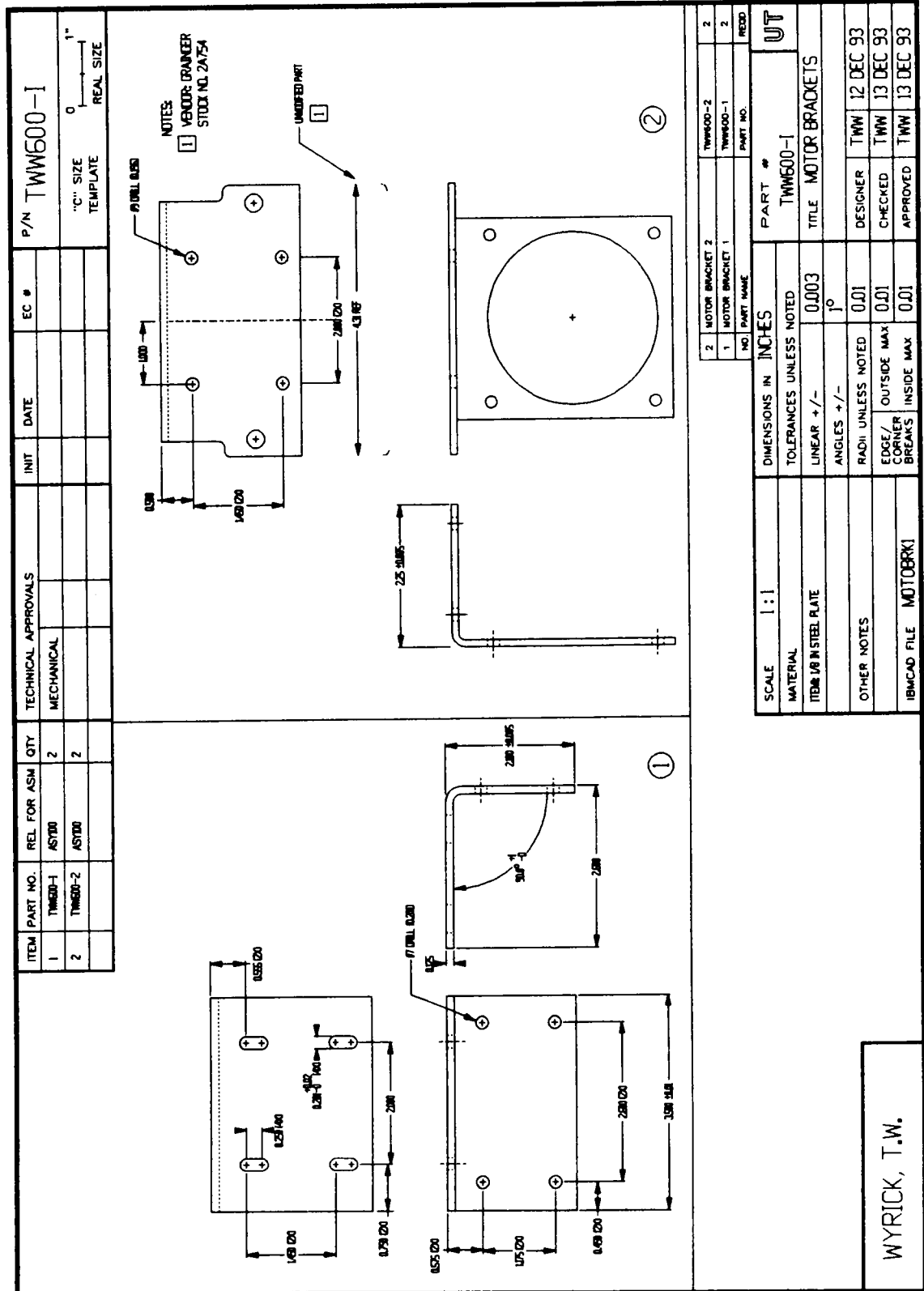
NOTES:

1 MATERIAL IS 1/8" THICK,
30 DUROMETER,
POLYURETHANE

2 SUGGESTED VENDOR:
KASTALON, INC.
ALSIP, IL

WYRICK, T.W.

2		HORIZONTAL PRESSURE PAD		TWWS50-2	1
1		VERTICAL PRESSURE PAD		TWWS50-1	1
NO.		PART NAME		PART NO.	
SCALE		1 : 1		PART #	
MATERIAL		1/8" THK.		TWWS50-1	
30 DUROMETER, POLYURETHANE		TOLERANCES UNLESS NOTED		TITLE	
		LINEAR +/-		PRESSURE PAD	
		ANGLES +/-		VERTICAL AND HORIZONTAL	
OTHER NOTES		RACH UNLESS NOTED		DESIGNED	
		EDGE/ CORNER BREAKS		TWM 12 JAN 95	
RMCAD FILE		PRESSPAD		APPROVED	
				TWM 12 JAN 95	



REL FOR ASM	QTY	TECHNICAL APPROVALS	INIT	DATE	EC #	P/N
ASY100	2					VEN620

"A" SIZE TEMPLATE

0"-----25"

REAL SIZE

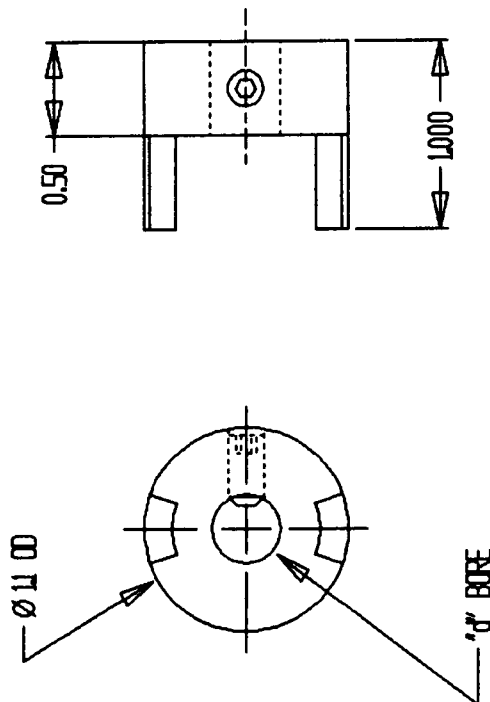
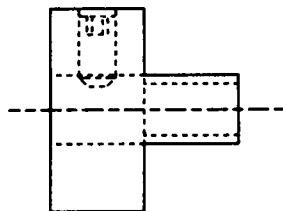
-
- 3.60 SQ.
- 2.65 (REF)
- 1.12 DIA.
- 0.57
- 0.750
- 2.65
- #10-32 X 0.40 DEEP
- 7.0
- 1.420
- 0.420
- 5.000 DIA.
- .4554
- .4554
- GEAR RATIO (INPUT): 25.2:1

SCALE	1:2	DIMENSIONS IN INCHES		PART #	UT
MATERIAL		TOLERANCES UNLESS NOTED		VEN620	
		LINEAR +/-		TITLE DC GEARMOTOR	
		ANGLES +/-			
OTHER NOTES		RADI UNLESS NOTED		DESIGNER	TWN 06 SEP 93
		EDGE / OUTSIDE MAX		CHECKED	TWN 14 SEP 93
		CORNER		APPROVED	TWN 14 SEP 93
		BREAKS INSIDE MAX			
ENCAD FILE	DDMOTOR				

WYRICK, T.W.

PART NO.	REL FOR ASM	QTY	TECHNICAL APPROVALS	INT	DATE	EC #	P/N
VEN630-375	ASTY000	2	MECHANICAL				VEN630-LLL
VEN630-500	ASTY000	2					

1/16" SIZE
TEMPLATE
0.0001-0.0002
REAL SIZE



NOTES:

- 1 LOVEJOY COUPLING BODY
- 2 INSIDE DIAMETER IS DETERMINED BY THE P/N SUFFIX CHART.
- 3 SUGGESTED VENDOR:
GRAINGER INDUSTRIAL AND COMMERCIAL
EQUIPMENT AND SUPPLIES
STOCK NOS. 4X175, 4X176

P/N SUFFIX CHART:

P/N SUFFIX	"d"
-375	0.375
-500	0.500

SCALE	1:1	DIMENSIONS IN INCHES	PART #	UT
MATERIAL		TOLERANCES UNLESS NOTED	VEN630-LLL	
		LINEAR +/-	TITLE	COUPLING BODY
		ANGLES +/-		
OTHER NOTES		RADI UNLESS NOTED	DESIGNER	TMM 15 OCT 93
		EDGE/ CORNER BREAKS	CHECKED	TMM 30 OCT 93
REWORK FILE	COUPLING		APPROVED	TMM 30 OCT 93

WYRICK, T.W.

REL FOR ASM	QTY	TECHNICAL APPROVALS	INT	DATE	EC #	P/N
AST000	2	MECHANICAL				VEN635

0 1/2" 25"
W/ SIZE
TEMPLATE
REAL SIZE

NOTES:

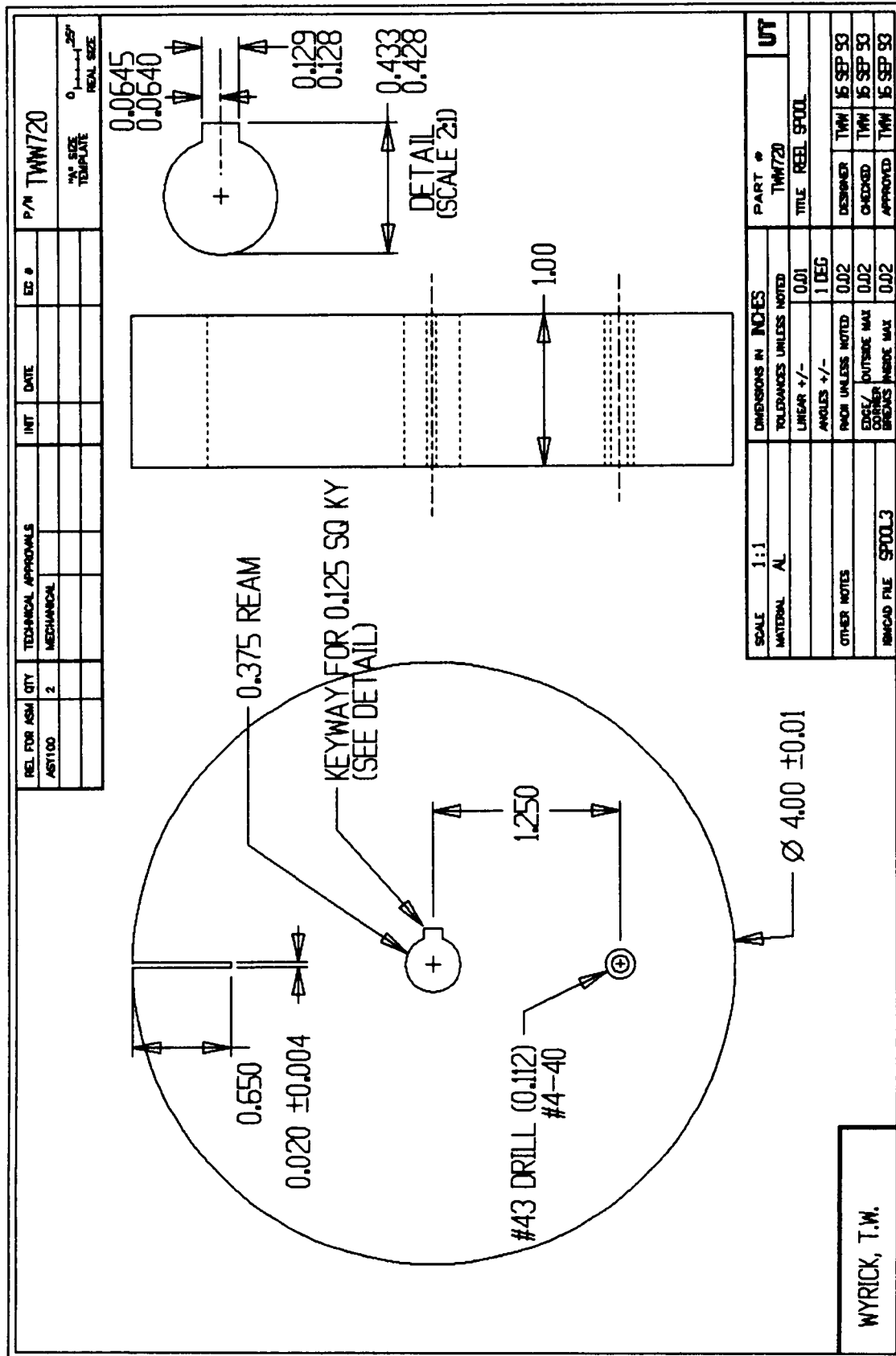
- 1 LOVEJOY COUPLING SPIDER FOR
L050 STYLE COUPLING BODY
- 2 SUGGESTED VENDOR:
GRAINGER INDUSTRIAL AND COMMERCIAL
EQUIPMENT AND SUPPLIES
STOCK NO. 1A923
- 3 DIMENSION FOR REFERENCE ONLY



11.00 3

SCALE	1:1	DIMENSIONS IN INCHES	PART #	UT
MATERIAL		TOLERANCES UNLESS NOTED	VEN635	
		LINEAR +/-	N/A	
		ANGLES +/-	N/A	
OTHER NOTES		RADI UNLESS NOTED	N/A	
		EDGE / OUTSIDE MAX	N/A	
		CORNER	N/A	
		BREKES	N/A	
INMAD FILE	SPIDER			
			DESIGNED	TMM 15 OCT 93
			CHECKED	TMM 30 OCT 93
			APPROVED	TMM 30 OCT 93

WYRICK, T.W.



REL FOR ASM	QTY	TECHNICAL APPROVALS	INT	DATE	EF #	P/N
AST000	2	MECHANICAL				VEN750
						"A" SIZE TEMPLATE
						0.25" REAL SIZE

Ø 0.750 OD

Ø 0.375 BORE

"FRONT" VIEW
SCALE: 2:1

0.375

Ø 0.125 HEX SOCKET

Ø 0.250 -20 UNC THREADS

"SIDE" VIEW
SCALE: 2:1

NOTES:

1 SUGGESTED VENDOR
McMASTER-CARR SUPPLY COMPANY
CHICAGO, IL

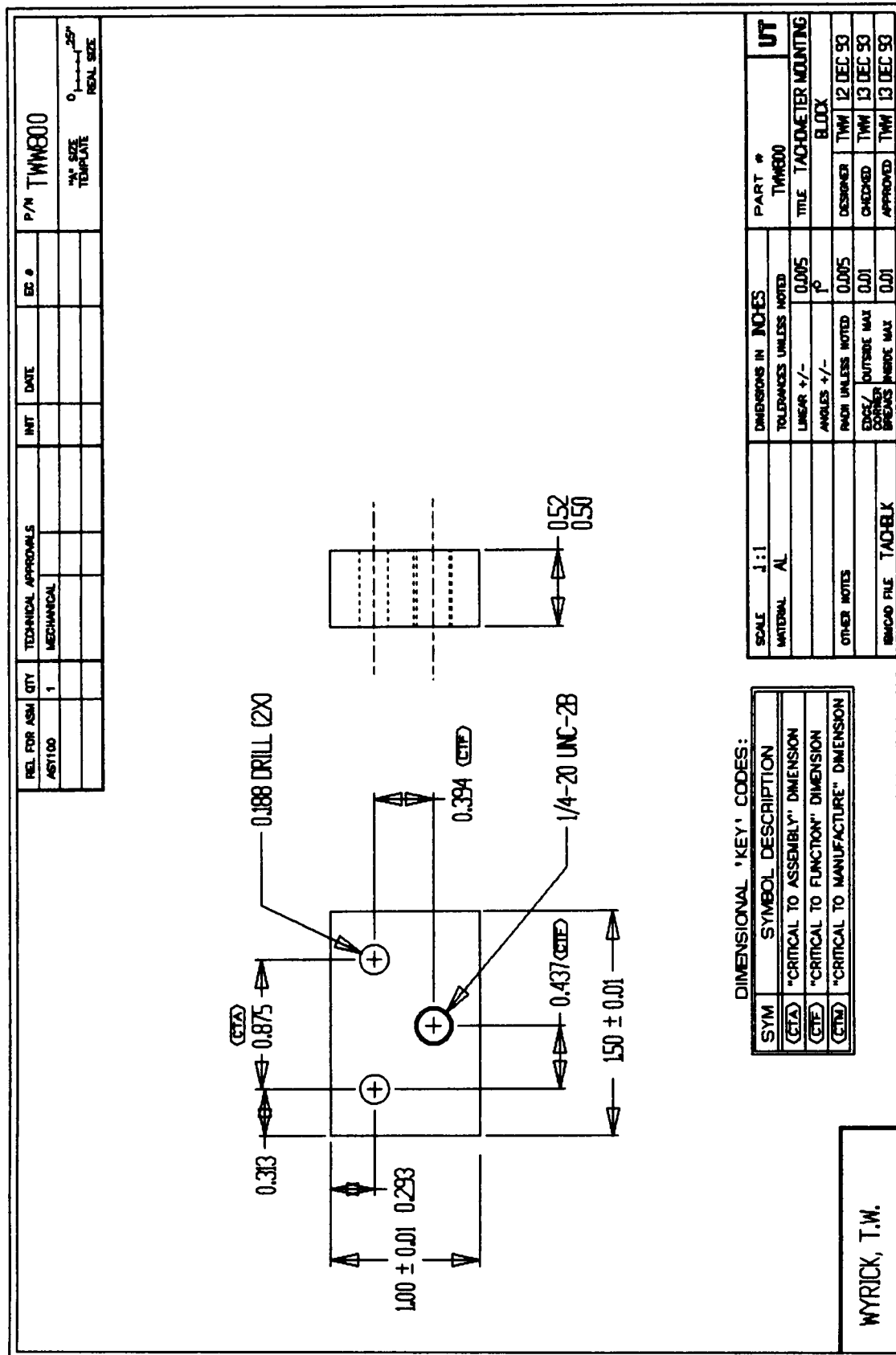
VENDOR P/N 6166K23

ISOMETRIC VIEW
SCALE: 1:1
"SET SCREW ON SIDE"

ISOMETRIC VIEW
SCALE: 1:1
"SET SCREW ON TOP"

SCALE 2:1		DIMENSIONS IN INCHES		PART #	UT
MATERIAL	SINTERED STEEL	TOLERANCES UNLESS NOTED		VEN750	
		LINEAR +/-	N/A	TITLE	COLLAR, SHAFT,
		ANGLES +/-	N/A		0.375 BORE
OTHER NOTES		RADI UNLESS NOTED	N/A	DESIGNER	MEK 13 MAR 91
		EDGE/ CORNER BREAKS	N/A	CHECKED	TWM 20 SEP 93
			N/A	APPROVED	TWM 20 SEP 93
BOMCAD FILE		SCOLLAR2			

WYRICK, T.W.

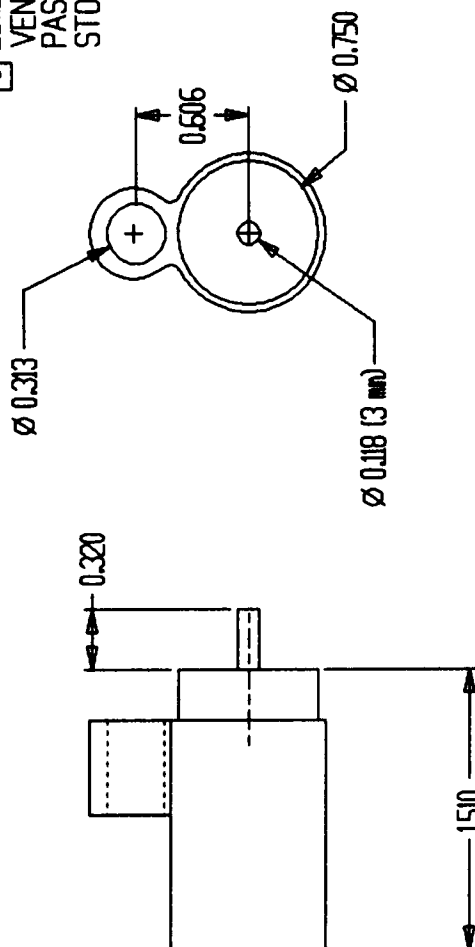


REL FOR ASM	QTY	TECHNICAL APPROVALS	INT	DATE	ED #	P/N
AST100	1	MECHANICAL				TWMB20

1/4" SIZE
TEMPLATE
0.001" 25"
REAL SIZE

NOTES

- DIMENSIONS ARE FOR REFERENCE ONLY
VENDOR: C & H SALES CO.
PASADENA, CA
STOCK NO: DCT68500



SCALE	1:1	DIMENSIONS IN	NOTES	PART #	UT
MATERIAL		TOLERANCES UNLESS NOTED		TWMB20	
		LINEAR +/-	0.005	TITLE	DC TACHOMETER
		ANGLES +/-	0		
OTHER NOTES		RADI UNLESS NOTED	0.005	DESIGNER	TMM 10 NOV 93
		EDGE / OUTSIDE MAX	0.01	CHECKED	TMM 12 DEC 93
		CORNER		APPROVED	TMM 12 DEC 93
		BREASTS	0.01		
ISOCAD FILE	DCTACH				

WYRICK, T.W.

Vita

Timothy William Wyrick was born on January 17, 1970 in Oak Ridge, Tennessee. He graduated from Oak Ridge High School in June, 1988. Then, he attended the University of Tennessee at Knoxville, where he obtained his Bachelor of Science degree in Mechanical Engineering in May, 1992. Without delay, he began his graduate work at the University of Tennessee. He completed a Master of Science degree in April, 1995.

He began the co-op program at the university in January, 1990 with Martin Marietta Energy Systems, Inc. In this program, he worked at Martin Marietta every other semester. In all, he worked for three semesters at three different departments at the X-10 (Oak Ridge National Laboratory) and Y-12 Plants. His last co-op work period ended in August, 1991.

His other interests include antique furniture restoration, radio-controlled model airplanes, and watermelon cultivation.