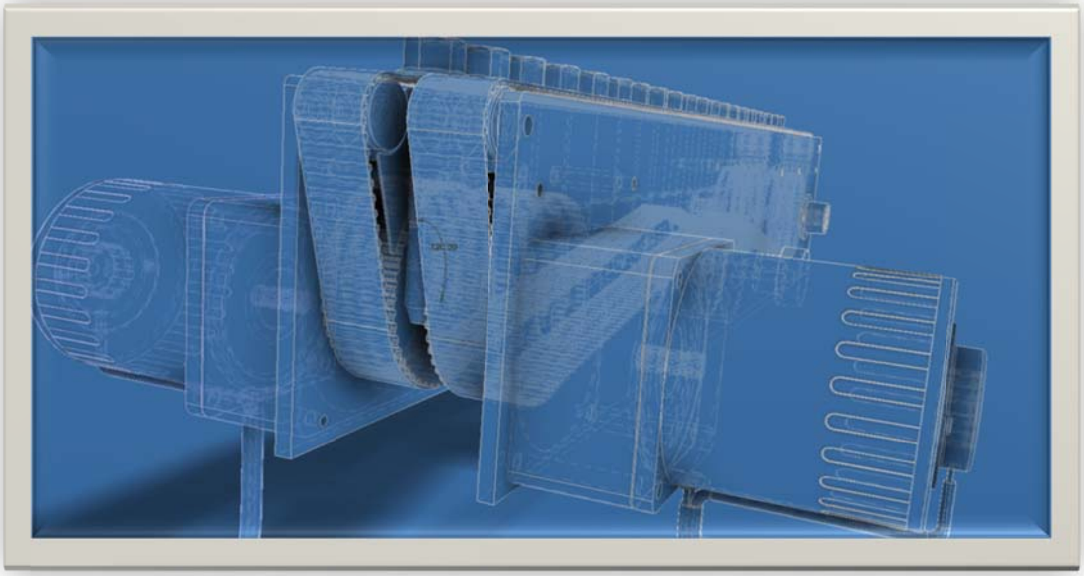

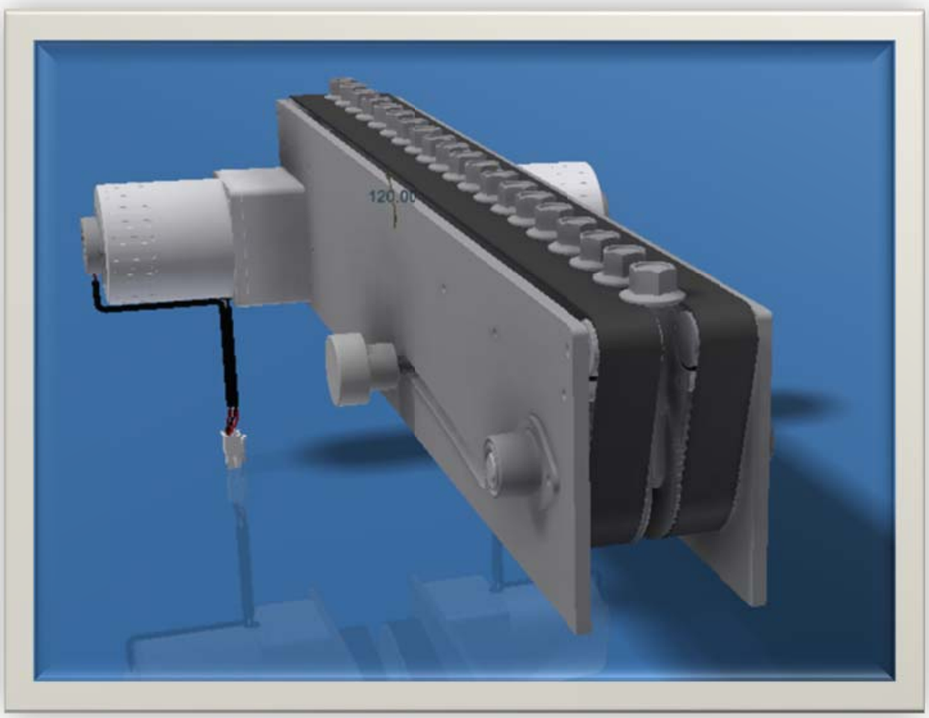

**4-23-17**

# Final Report

## Positive Feed Accelerated Rail

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**Department:** Mechanical Engineering Technology and Computer Science
**Sponsored by:** Cold Heading Company

## Contents

## Positive Feed Accelerated Rail

**Executive Summary:**

The project described in the following report is to resolve feed issues to a thread rolling machine for the Cold Heading Company. Cold heading Company is a fastener supplier to all major automotive companies, and some agricultural sectors. The issue is parts being fed to the machine would get stuck on the existing rails causing the injection point to be empty while the machine still made a reciprocating stroke. This causes efficiency issues and unnecessary machine wear without producing the sought after end result of the process.

**Introduction:**

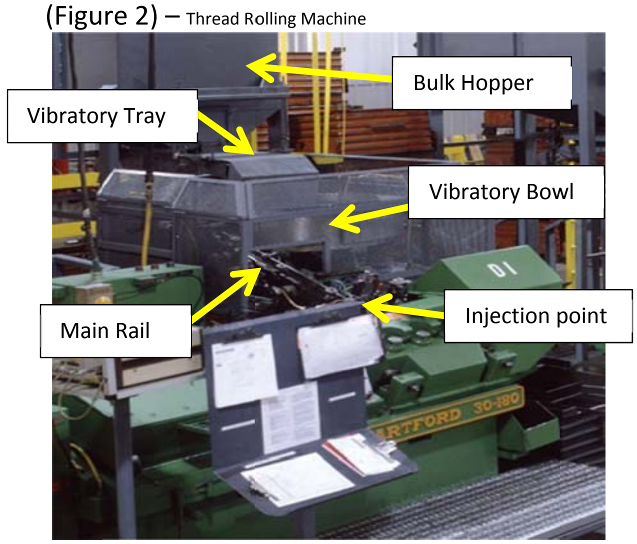
The concept to potentially resolve this issue was a rail that would accelerate the parts to the injection point by using a synchronized belt system using alternating current electric motors. This rail would replace a current section of the rail. The second possible future benefit if the rail proved out would be that all machines could eventually be fed on a horizontal plain instead of an incline. This would allow hoppers and vibratory bowl bases to be lowered using less material to produce.

**Background:**

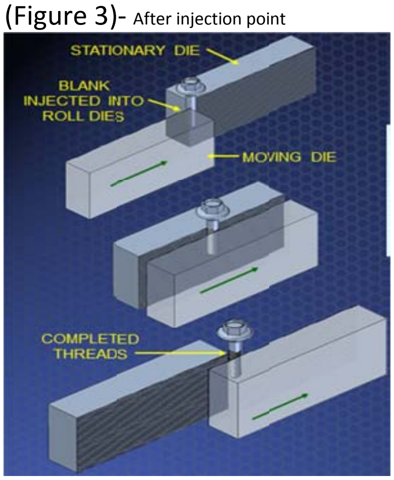
In fastener production coiled steel is first ran through a cold forming machine that produces a blank or a non-threaded bolt seen in figure 1. After this process the blank is introduced to a thread rolling machine in which the project is the focus of as seen in in figure 2. The thread rolling machine puts threads on the blank by using to dies in which one is stationary and the other the moving die. A tub of blanks will be dumped in a bulk hopper, and under the bulk hopper is a vibratory tray. The vibratory tray shakes parts into the vibratory bowl as needed, and then orientates the parts to fall onto the inclined main rail. Once the parts are on the rail they slide down it until they reach the die pocket entry, then a finger pushes the part into the die pocket.

(Figure 1)- Blank Bolt

(Figure 2) – Thread Rolling Machine

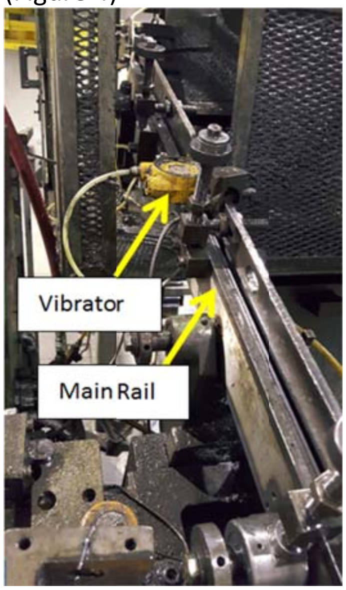



(Figure 3)- After injection point



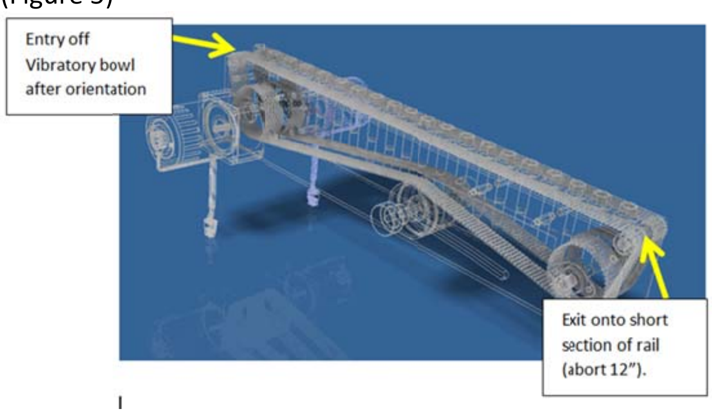
**Problem Statement:**
Due to oil or mud the product will either stop or slow while sliding down the rail, causing empty die pocket strokes. In past history many techniques have been used to relieve the issues. One being forced air bursts at certain points of the rail, and two a device mounted to the side of the rail that vibrates that uses air to run seen in figure 4. Problems with these methods are compressed air is not cheap and the company would like not to use compressed air when possible.

(Figure 4)

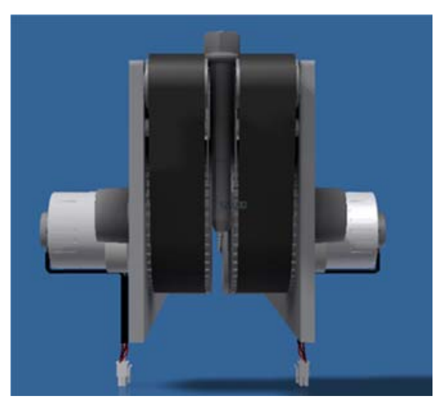



**Solution:**
Our team came up with a solution by taking a majority of the rail out and replacing it with a synchronized belt system driven by two alternating current motors seen in figures 5&6. The rail is split into two halves so one side can be fixed and the other half can adjust in and out for different product diameters. Product would still continue to ride down by its flange. The theory is the product is forced down the rail accelerating at whatever speed needed to keep up with machine demand. There will still have to be a very short section of rail after the new rail. Currently there is already a photo eye that turns off the vibratory tray and bowl when parts are detected backed up to a certain point. In the short section of rail the photo eye will be re-located to shut off the belts when enough parts are present.

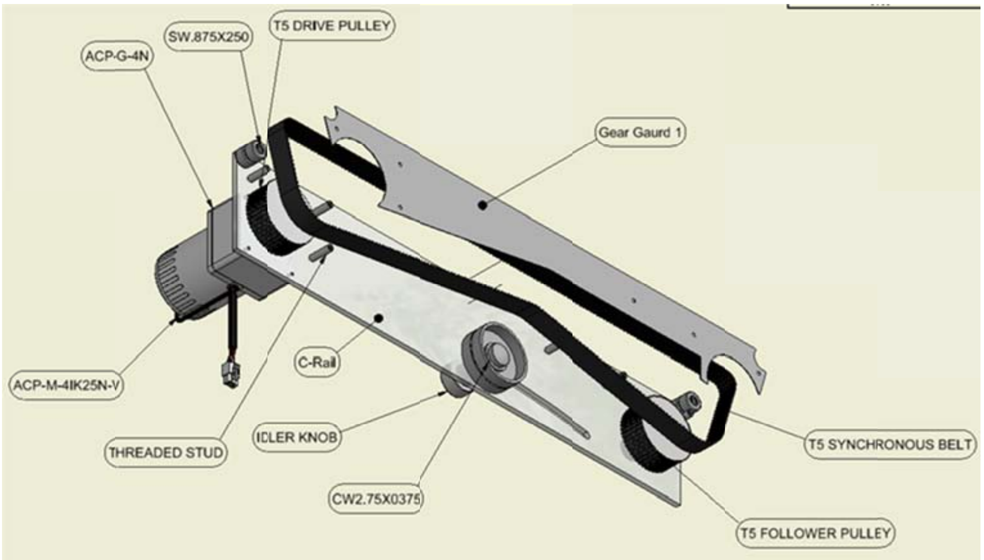
(Figure 5)




(Figure 6)



(Figure 7)- One side of the rail




**Rail System Cost:**

| PART | DESCRIPTION | COST | QUANTITY | TOTAL |
|---|---|---|---|---|
| 1434K150 | ROLLER MOUNT | $10.72 | 2 | $21.44 |
| ACP-G-4N120-K | GEAR HEAD | $79.00 | 2 | $158.00 |
| ACP-M-4IK25N-AUV | AC MOTOR | $129.00 | 2 | $258.00 |
| ACP-US-4125A | VARIABLE SPEED CONTROL | $134.00 | 2 | $268.00 |
| C-RAIL | MAIN MOUNTING RAIL | $122.00 | 2 | $244.00 |
| CW2.75X0375 | IDLER WHEEL | $30.10 | 2 | $60.20 |
| GEAR GUARD 1 | GEAR GUARD / DEFLECTOR | $70.00 | 2 | $140.00 |
| IDLER KNOB | IDLER KNOB | $50.00 | 2 | $100.00 |
| SW.875X250 | SKATE WHEEL | $7.71 | 8 | $61.68 |
| 93265A491 | THREAD SPACER STUD | $1.42 | 12 | $17.04 |
| T5 PULLEY | T5 DRIVE / FOLLOWER PULLEY | $31.24 | 4 | $124.96 |
| T5 BELT | BELT | $40.00 | 2 | $80.00 |
| | | | | |
| | | | TOTAL | $1,533.32 |

**Design Calculations:**

***Calculations Used from AutoDesk Inventor Design Accelerator and below is from the design handbook. All calculations passed during checks.***

Calculation basics

First pulley is considered to be a driver pulley. The rest of the pulleys are driven pulleys or idlers. Input power can be split among several driven pulleys by using power ratio factor of each pulley. The forces and torques are calculated accordingly. Flat pulleys are considered as idlers.

### Service factor $c_P$

Total service factor takes into account the safety factors required to compensate for belt life-reducing factors encountered during service, such as load, acceleration and fatigue. Load factor depends on the type of the driver and driven machine. The acceleration add-on factor $c_{pa}$ can be considered if speed up ratio is> 1.24, please see table below. Fatigue add-on factor takes into account operational hours per day and unusual service conditions.

| Speed up ratio 1/i | $c_{PA}$ |
|---|---|
| 1.00 - 1.24 | 0.0 |
| 1.25 - 1.74 | 0.1 |
| 1.75 - 2.49 | 0.2 |
| 2.50 - 3.49 | 0.3 |
| 3.5 and more | 0.4 |

### Teeth in mesh factor $k_z$

Teeth in mesh factor take into account the number of teeth in contact zc of the synchronous pulley. If the teeth in contact of the given synchronous pulley is less than 6 it can have significant impact on belt power capacity. Application finds a minimum value of teeth in contact among all synchronous pulleys within belt drive and then use following rule to obtain $k_z$ factor.

| | |
|---|---|
| $z_c \leq 6$ | $k_z = 1$ |
| $z_c < 6$ | $k_z = 1 - \frac{1}{5}(6 - z_c)$ |

Number of teeth in contact is determined based on arc of contact angle of each individual pulley as follows

$$z_c = abs\left(z \cdot \frac{\beta}{360}\right)$$

### Tension factor $k_1$

Tension factor gives an option to adjust belt initial tension. When belt drive operates under load tight and slack side develops. The initial tension prevents the slack side from sagging and ensures proper tooth meshing. In most cases, synchronous belts perform best when magnitude of the slack side tension is 10% to 30% of the magnitude of effective pull {$k_1$ = 1.1 ~ 1.3}.

### Efficiency $\eta$

When properly designed and applied, belt drive efficiency is usually high as 96%-98% {$\eta$ 0.96 ~ 0.98}. This high efficiency is primarily due to the positive, no slip characteristic of synchronous belts. Since the belt has a thin profile, it flexes easily, thus resulting in low hysteresis losses as evidenced by low heat buildup in the belt.

### Belt length correction factor $c_L$

Belt length correction factor takes into account modification of belt power rating of extreme belt length. By default the value is 1.0 what does not affect the results.

### Resultant service factor $c_{PR}$

The resultant service factor is determined from equation below. The belt power rating for given transmission layout is compared with power to transmit. The resultant service factor gives fast answer of how much the belt drive is over designed.

$$c_{PR} = \frac{P_R}{P}$$

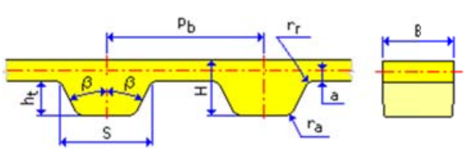
| | |
|---|---|
| $c_{PR} < c_P$ | Strength check fails |
| $c_{PR} \geq c_P$ | Strength check succeeds |
| $c_{PR} > c_P$ | Consider to change transmission layout, use different belt or decrease belt width |

Meaning of used variables:

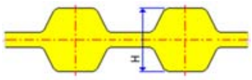
| | |
|---|---|
| $z_c$ | Number of teeth in contact of given pulley [-] |
| $z$ | Number of teeth of given pulley/ Number of belt teeth [-] |
| $\beta$ | Arc of contact [deg] |
| $P$ | power to transmit [W] |
| $P_R$ | Belt power rating for given transmission layout [W] |
| $c_p$ | Service factor [-] |

Geometry design properties

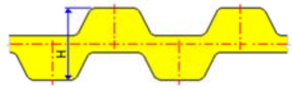
### Belt with trapezoidal teeth



Symmetrical double-sided teeth



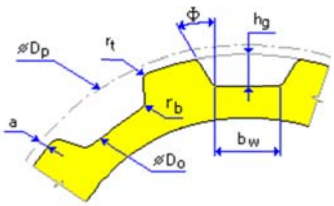

Staggered double-sided teeth




Pitch belt length can be determined as

$L = z\ p_b$

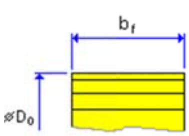
**Straight-sided Teeth Pulley**



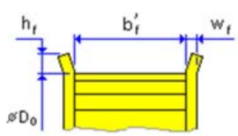

Outside pulley diameter can be determined as

$$D_0 = \frac{z \cdot p_b}{\pi} - 2 \cdot a$$

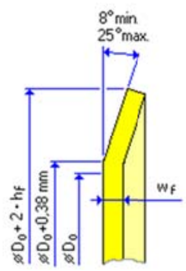
Unflanged pulley



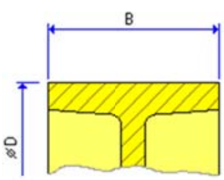

Flanged pulley




Flange detail




**Flat pulley**

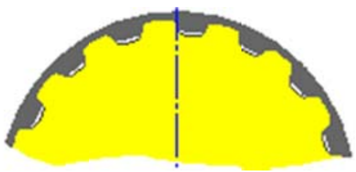



Meaning of used variables:

| | |
|---|---|
| z | Number of teeth of given pulley/ Number of belt teeth [-] |
| $p_b$ | Circular pitch [m] |
| a | Pitch line offset [m] |

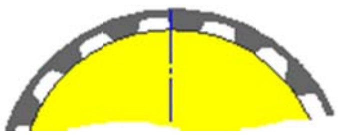
Belt pitch length is given by number of belt teeth and circular pitch. The belt trajectory is based on individual pulley position. The pitch diameter of each pulley is determined based on the following equations. The sliding pulley position is adjusted to accomplish standard belt length criteria. The calculation uses an iteration solution to find the appropriate sliding pulley position that is closest to the desired sliding pulley position.

### Determine exact pitch diameter



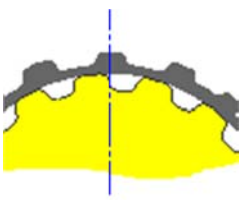
Synchronous pulley clockwise or double-sided belt

$$D_p = \frac{z \cdot p_b}{\pi}$$



Flat pulley clockwise or double-sided belt

$D_p = D + 2(a + h_t)$



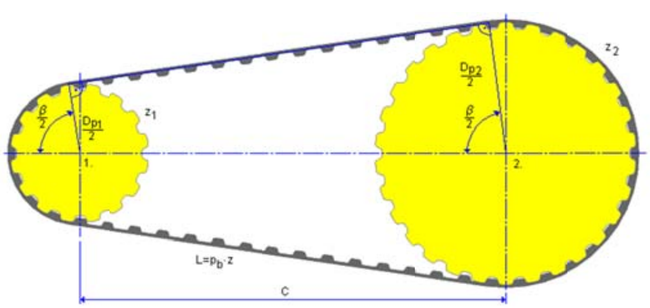
Synchronous pulley counterclockwise and single-sided belt

$D_p = D_0 + 2(H - a - h_t)$

Flat pulley counterclockwise and single-sided belt

$D_p = D + 2(H - a - h_t)$

### Example of power transmission with 2 pulleys



Arc of contact

$$\beta = 2 \cdot \arccos\left[\frac{p_b \cdot (z_2 - z_1)}{2 \cdot \pi \cdot C}\right]$$

Pitch belt length

$$L = 2 \cdot C \cdot \sin\frac{\beta}{2} + \frac{p_b}{2}\left[z_1 + z_2 + \left(1 - \frac{\beta}{180}\right) \cdot (z_2 - z_1)\right]$$

Center distance

$$C \approx \frac{1}{4} \cdot \left[L - \frac{p_b}{2} \cdot (z_2 + z_1) + \sqrt{\left[L - \frac{p_b}{2} \cdot (z_2 + z_1)\right]^2 - 2 \cdot \left[\frac{p_b}{\pi} \cdot (z_2 - z_1)\right]^2}\right]$$

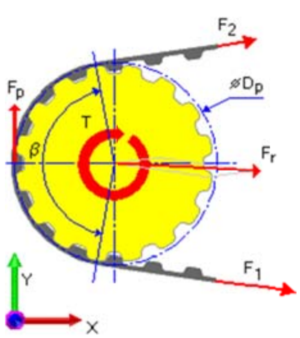
Following formula is recommended when determining the center distance of a new drive

$0.2\ p_b(z_1 + z_2) \le C \le 0.7\ p_b(z_1 = z_2)$

Meaning of used variables:

| | |
|---|---|
| $z$ | Number of teeth of given pulley/ Number of belt teeth [-] |
| $p_b$ | Circular pitch [m] |
| $D$ | Nominal flat pulley diameter [m] |
| $a$ | Pitch line offset [m] |
| $h_t$ | Belt tooth height [m] |
| $D_0$ | Outside synchronous pulley diameter [m] |
| $H$ | Belt height [m] |
| $C$ | Center distance of given pulley and driver pulley [m] |
| $\beta$ | Arc of contact [deg] |

Calculation of strength proportions




For each pulley

$F_2 - F_1 + F_p = 0$

$$\vec{F}_r = \vec{F}_1 - \vec{F}_2$$

$$F_r = \sqrt{F_1^2 + F_2^2 - 2 \cdot F_1 \cdot F_2 \cdot \cos\beta}$$

$$F_Y = (F_1 + F_2) \cdot \sin\frac{\beta}{2}$$

**For the driver pulley**

$$P = \frac{T \cdot \pi \cdot n}{30}$$

$$v = \frac{D_p \cdot \pi \cdot n}{60}$$ $v \leq v_{max}$

$$f_b = \frac{v \cdot k}{L}$$ $f_b \leq f_{max}$

$$F_p = \frac{P}{v}$$

$F_c = mv^2$

$F_{Tmax} = k_1 F_p + F_c$

$F_1 = F_{tmax}$

$F_2 = F_1 - F_p$

**For individual driven pulleys and idlers**

i-index of the pulley

$F_{Pi} = P_{xi} F_p$

$$T_i = \frac{D_{pi}}{2} \cdot F_{Pi} \cdot \eta$$

$$n_i = \frac{n}{i_i}$$

$$P_i = \frac{T_i \cdot \pi \cdot n_i}{30}$$

$F_{1i} = F_{2i-1}$

$F_{2i} = F_{1i} + F_p i$

where:

$i_i = \frac{z_i}{z_1}$ for synchronous pulley

$$i_i = \frac{D_{Pi}}{D_{P1}}$$ for flat pulley

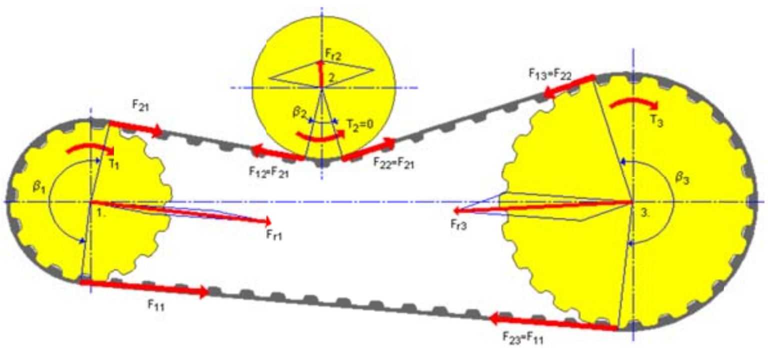
**For entire belt drive**

$$P_{x1} = \sum_{2}^{k} P_{xi} = 1$$

**Required belt installation tension** is determined from forces at driver pulley as follows

$$F_t = \frac{F_1 + F_2}{2}$$

**Example of power transmission with idler**




| Driver pulley | Flat idler | Driven pulley |
|---|---|---|
| $P_{x1} = 1$ | $P_{x2} = 0$ | $P_{x3} = 1$ |
| $P = \frac{T_1 \cdot \pi \cdot n_1}{30}$ | $F_{P2} = 0 \cdot F_p \Rightarrow T_2 = P_2 = 0$ | $F_{P3} = P_{x3} F_p$ |
| $D_{P1} = \frac{z_1 \cdot p_b}{\pi}$ | $i_{12} = \frac{D + 2 \cdot (H - a - h_t)}{D_{p1}}$ | $D_{P3} = \frac{z_3 \cdot p_b}{\pi}$ |
| $v = \frac{D_{p1} \cdot \pi \cdot n_1}{60}$ | $n_2 = \frac{n_1}{i_{12}}$ | $T_3 = \frac{D_{p3}}{2} \cdot F_{P3} \cdot \eta$ |
| $f_b = \frac{v \cdot 2}{L}$ | $F_{12} = F_{21}$ | $i_{13} = \frac{z_3}{z_1}$ |
| | $F_{22} = F_{12} + F_{p2} = F_{12}$ | |

| | | |
|---|---|---|
| $F_p = \frac{P}{v} = F_{p1}$ | | $n_3 = \frac{n}{i_{13}}$ |
| $F_c = m\ v^2$ | $F_{r2} = \sqrt{F_{12}^2 + F_{22}^2 - 2 \cdot F_{12} \cdot F_{22} \cdot c}$ | $P_3 = \frac{T_3 \cdot \pi \cdot n_3}{30}$ |
| $F_{Tmax} = k_1\ F_p + F_C$ | - | $F_{13} = F_{22}$ |
| $F_{11} = F_{Tmax}$ | - | $F_{23} = F_{13} + F_{p3} = F_{11}$ |
| $F_{21} = F_{11} - F_p$ | - | $F_{r3} = \sqrt{F_{13}^2 + F_{23}^2 - 2 \cdot F_{13} \cdot F_{23} \cdot c}$ |
| $F_{r1} = \sqrt{F_{11}^2 + F_{21}^2 - 2 \cdot F_{11} \cdot F_{21} \cdot c}$ | - | - |

Meaning of used variables:

| | |
|---|---|
| $F_p$ | Effective pull [N] |
| $F_1$ | Belt tension on input side of the given pulley [N] |
| $F_2$ | Belt tension on output side of the given pulley [N] |
| z | Number of teeth of given pulley/ Number of belt teeth [-] |
| $\beta$ | Arc of contact / tooth angle of side inclination [deg] |
| P | power to transmit [W] |
| $P_R$ | Belt power rating for given transmission layout [W] |
| $c_L$ | Service factor [-] |
| $\beta$ | Arc of contact [deg] |
| T | Torque acting on given pulley [Nm] |
| n | Speed of given pulley [rpm] |
| $D_p$ | Pitch pulley diameter [m] |
| v | Belt speed [m/s] |
| k | Number of pulleys within belt transmission [-] |
| L | Belt pitch length [m] |
| P | power to transmit [W] |
| m | Specific belt weight for given width [Kg/m] |
| $k_1$ | Belt tension factor [-] |
| $F_p$ | Effective pull [N] |

$F_c$ Centrifugal force [N]

$F_t$ Minimum belt installation tension [N]

$P_{xi}$ Power ratio of given pulley [-]

$D_{pi}$ Pitch pulley diameter [m]

$i$ Transmission ratio (speed ratio) of given pulley [-]

$T_i$ Torque acting on given pulley [Nm]

$\eta$ Efficiency [-]

$p_b$ Circular pitch [m]

D Nominal flat pulley diameter [m]

H Belt height [m]

$h_T$ Belt tooth height [m]

a Pitch line offset [m]

- **Strength check**
- Maximum allowable belt working tension can be set up or it is calculated as follows

$$T_a = T_{a0} \cdot \left(\frac{B}{B_0}\right)^{1.14}$$

- 
- Specific belt weight is calculated as follows

$$m = m_0 \cdot \left(\frac{B}{B_0}\right)$$

- 
- $T_{a0}$, $m_0$, $B_0$, $f_{max}$, $v_{max}$ are defined within belt XML data table as well as belt dimensions and available lengths and widths.
- Belt power rating
- $P_r = (k_z\ T_a - v\ m^2)\ v\ c_L$
- Resultant service factor

$$c_{PR} = \frac{P_R}{P}$$

- 
- Strength check fails if resultant service factor $c_{Pr} < c_P$.
- **Over-tensioning inspection**
- If $F_{t\ max} > F_a$ or $F_t > F_a$ the strength check fails as the maximum tension in belt span or static belt tension exceeded its maximum.
- Recommended step if one of the criteria fails is increase belt width or driver pulley diameter. Also, the installation tension can be decreased if possible by decreasing belt tension factor $k_1$. If number of teeth in mesh factor $k_z$ is less than 1.0 then consider to modify belt transmission layout.
- **Valid belt speed and flexing frequency inspection**
- If belt flex frequency $f_b > f_{max}$ the reduced efficiency and premature belt damage might appear. The error warning is displayed.
- If belt speed $v > v_{max}$ the error warning is displayed as the belt is not designed for such speed.

- **Meaning of used variables:**

| | |
|---|---|
| $T_{a0}$ | Maximum allowable belt working tension for base width [N] |
| B | Belt width [m] |
| $B_0$ | Belt base width [m] |
| $m_0$ | Specific belt width for base width [kg/m] |
| $k_Z$ | Teeth in mesh factor [-] |
| $T_a$ | Maximum allowable belt working tension for given width [N] |
| m | Specific belt weight for given width [kg/m] |
| v | Belt speed [m/s] |
| $c_L$ | Belt length correction factor [-] |
| $P_R$ | Belt power rating for given transmission layout [W] |
| P | power to transmit [W] |

Standards

| | |
|---|---|
| ISO 5294:1989 | Synchronous belt drives - Pulleys |
| ISO 5295:1987 | Synchronous belts - calculation of power rating |
| ISO 5296:1989 | Synchronous belt drives - Belts |
| DIN 7721 | Synchronous belt drives, metric pitch |
| ANSI/RMA IP-24 | Synchronous Belts |
| JIS B 1856 | Synchronous Belts Drives - Pulleys |
| JIS K 6372 | Synchronous Belts for General Power Transmissions |

## Results to Our Belt System:

### Belt Properties

| | | |
|---|---|---|
| Display name | | Synchronous Belt |
| Size | | 25T5 x 1500 |
| Circular pitch | $p_b$ | 0.19685 in |
| Number of teeth | z | 300.00000 ul |
| Pitch length | L | 59.05512 in |
| Width | B | 0.98425 in |
| Height | H | 0.08661 in |
| Tooth width | S | 0.10433 in |
| Tooth angle | β | 20.00 deg |
| Tooth height | $h_t$ | 0.04724 in |
| Root fillet radius | $r_r$ | 0.01575 in |
| Tooth head fillet radius | $r_a$ | 0.01575 in |
| Minimum pulley pitch diameter | $D_{min}$ | 0.59055 in |
| Allowable maximum working tension | $T_a$ | 196.70781 lbforce |
| Maximum flex frequency | $f_{max}$ | 60.00000 Hz |
| Maximum belt speed | $v_{max}$ | 262.46719 fps |
| Specific mass | m | 0.04032 lbmass/ft |

### ⊟ Strength check

| | | |
|---|---|---|
| Power | P | 0.00670 hp |
| Torque | T | 1.76000 lbforce ft |
| Speed | n | 20.00000 rpm |
| Efficiency | η | 0.97000 ul |
| Service factor | $c_p$ | 3.00000 ul |
| Resultant service factor | $c_{PR}$ | 14.00636 ul |
| Belt Speed | v | 0.26247 fps |
| Effective pull | $F_p$ | 14.04418 lbforce |
| Centrifugal force | $F_c$ | 0.00009 lbforce |
| Belt installation tension | $F_t$ | 11.23543 lbforce |
| Maximum tension in belt span | $F_{tmax}$ | 18.25751 lbforce |
| Teeth in mesh factor | $k_z$ | 1.00000 ul |
| Tension factor | $k_1$ | 1.30000 ul |

**5:39:37 PM Calculation: Calculation indicates design compliance!**

## Further Calculation/Analyisis:

The maximum speed the machine runs is 180 pieces minute. The maximum diameter part that will be in the machine is 1 inch. So we will lose about 3 inches per second during feed. So the maximum we needed the belt to feed is about .25 fps.

**Performance Specifications:**
Current machine rates for pieces per minute and pieces per hour are shown below in table 1. Note that this data also includes set-ups and die changes for actual rates, evaluated over a year. A separate analysis will be performed before and after the new system is installed. The proposed analysis will include the number of miss-feeds per minute and/or miss-feeds per pieces produced.
Current machine Rates:

<u>Table 1</u>

| Current Machine Rate (Includes machine set-ups/Die Changes for Actual) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ID | Thread Rolling Machine | (Actual) PPH MCH AVG | (Actual) PPM MCH AVG | (Actual) PPH Best week out of 52 | (Actual) PPM Best week out of 52 | PPM Machine Capability | PPH Machine Capability | Actual vs. Capability Percentage | | | |
| 27D-4 | 30 HARTFORD | 3,263 | 54 | 5,894 | 98 | 180 | 10,800 | 30.21% | | | Minutes |
| 27D-1 | 30 HARTFORD | 3,306 | 55 | 5,551 | 93 | 180 | 10,800 | 30.61% | | Machine Set-up | 45-60 |
| 27D-3 | 30 HARTFORD | 3,724 | 62 | 6,400 | 107 | 180 | 10,800 | 34.48% | | Die Change | 20 |
| 27D-5 | 30 HARTFORD | 4,275 | 71 | 6,592 | 110 | 180 | 10,800 | 39.59% | | | |
| 27D-6 | 30 HARTFORD | 4,366 | 73 | 9,378 | 156 | 180 | 10,800 | 40.43% | | | |
| 27D-2 | 30 HARTFORD | 4,475 | 75 | 7,527 | 125 | 180 | 10,800 | 41.44% | | | |

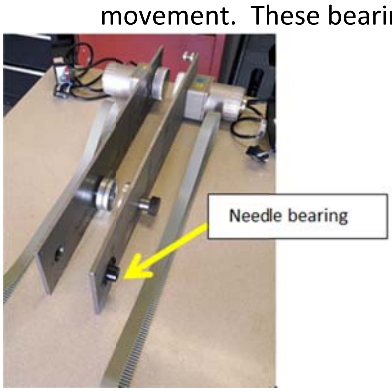
Note: Data in table 1 also includes set-ups and die changes for actual rates, evaluated over a years' time. Machine 27D-4 is the concentration of the project, also shown is other machines that are identical, and their rates.

**Goal Specifications for new system**: 99.00% successful feed with 180 ppm or greater delivery with a secondary goal of improving the year rate evaluation with machine set-ups and die changes included from 30.21% to 45.00% or greater.

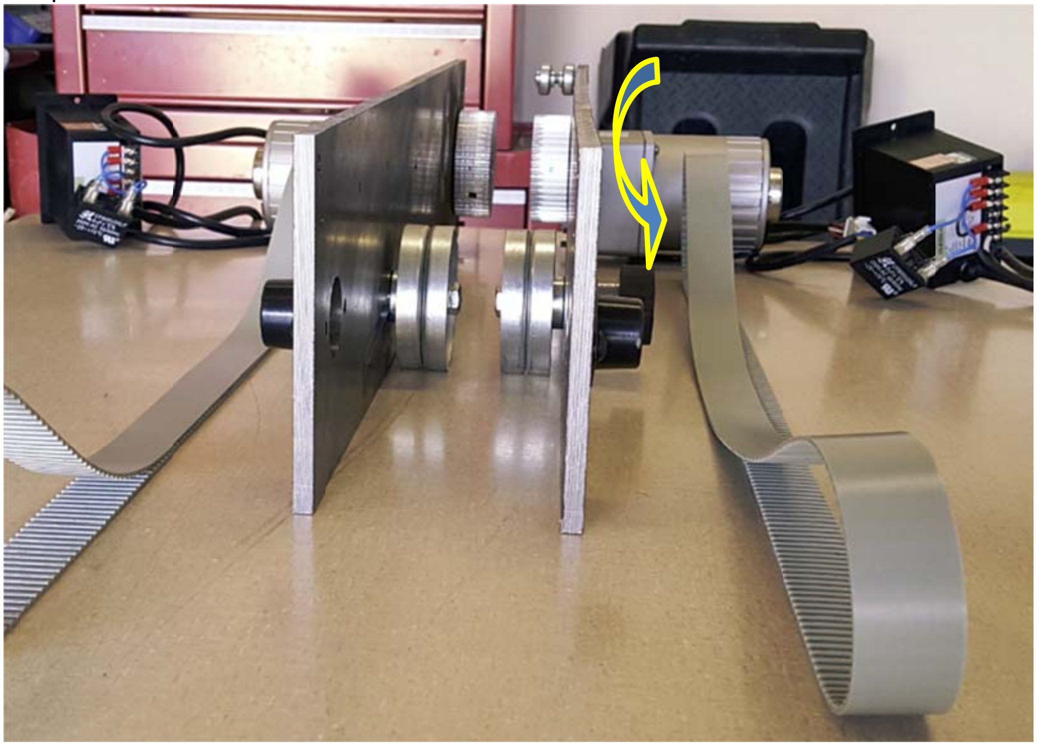
**Testing the new System:**
Testing of the new system unfortenatly has not occurred yet due to some assembly issues which will be described further in the report. Once the issues have been corrected testing and annalysis will follow by first running several lots of product through the existing rails counting miss-feeds. The miss-feeds will be counted by using the force monitor on the machine. The force monitor detects force when product is present in the die pocket, and can detect an empty stroke. After new rail is installed the same will be analyzed over several lots. Furthermore, over a longer period we will evaluate if the machines effeciancies have increased to our goal and beyond the current state.

**Issues Encountered:**
Issues were encountered while assembling each side of the rails as followed postponing installation and will be corrected for a later install.

- Bearings for each side of the second toothed pulley allowed for the gear to wobble because the shaft was able to move about five degrees. Synchronize belt system is sensative to alignment and would cause belt to come off. Using the flange mounted needle bearings caused the issue. To correct this a bearing should be pressed directly into the plate or the gear allowing no movement. These bearings are designed more for a shaft to run though two bearings.



- Second issue encounter was during assembly one side of the rail was observed to be bent or worped as seen.



**Bibliography:**

**"**AutoCad Inventor 2013" Software (Design Calculation Handbook)

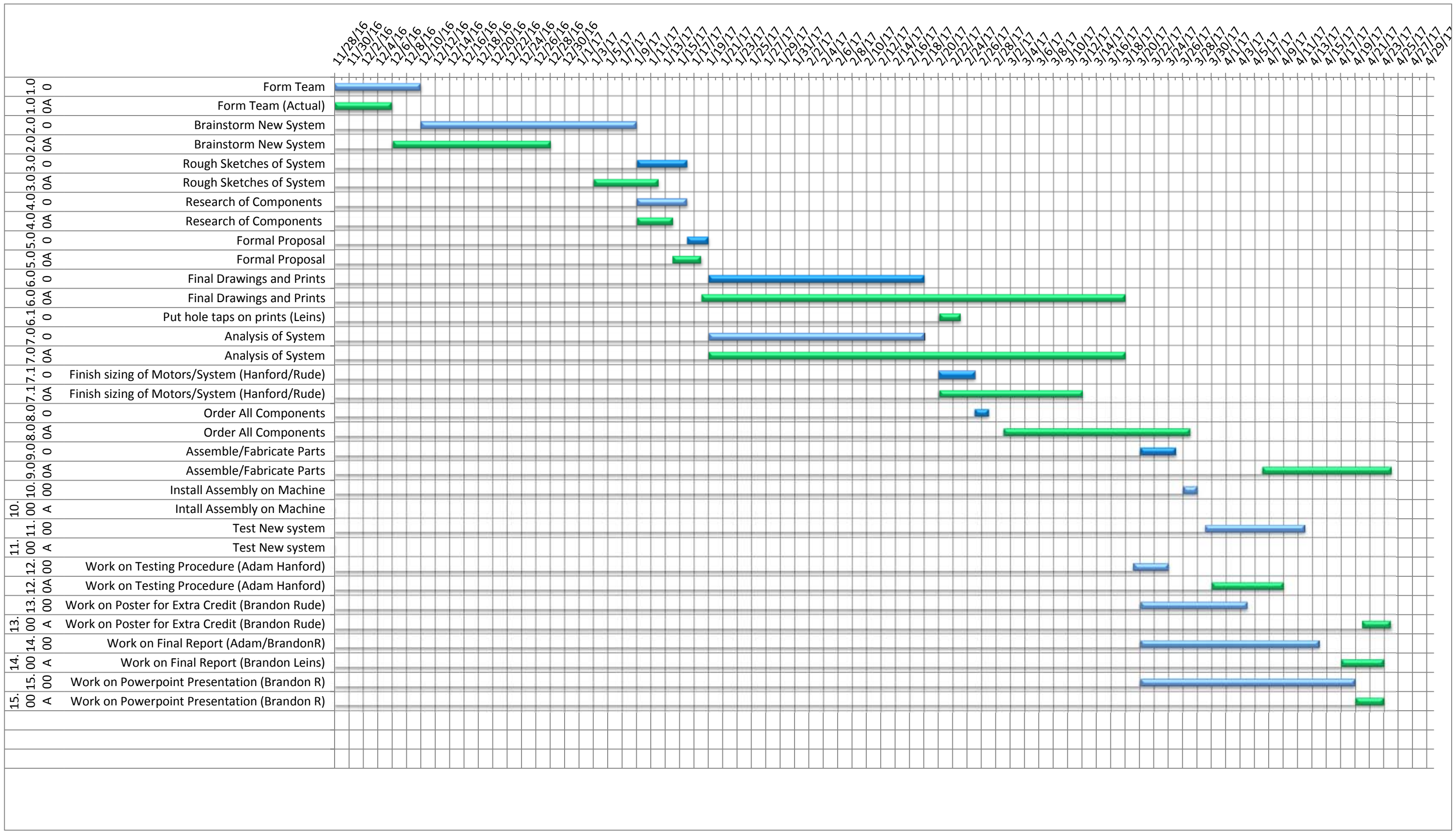
- All formulas and explanation of formulas came from handbook

**Conclusion:**

In conclusion the synchronized belt system has not proven to be a success to date but after some corrections of straightening the plate and using a different method of securing the second pulley then installation can take place.

# Senior Design Gantt Chart

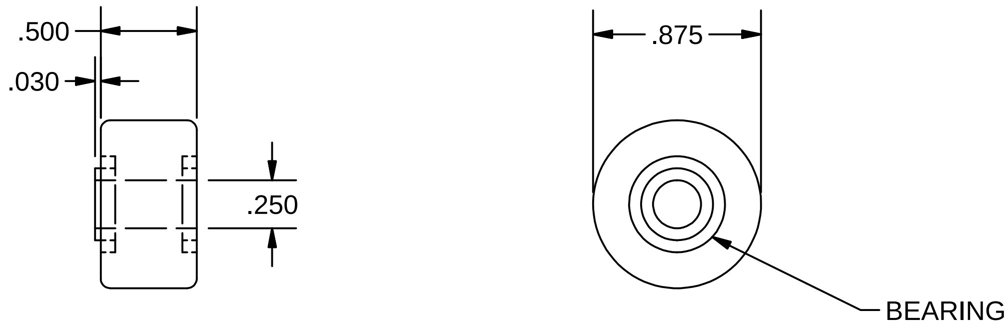
**Start** **End** **Days** **0**




**Senior Design Gantt Chart**

| # | Task | Start | End | Days |
|---|---|---|---|---|
| 1.00 | *Form Team* | 11/28/2016 | 12/10/2016 | 12 |
| 1.00A | Form Team (Actual) | 11/28/2016 | 12/6/2016 | 8 |
| 2.00 | Brainstorm New System | 12/10/2016 | 1/9/2017 | 30 |
| 2.00A | Brainstorm New System | 12/6/2016 | 12/28/2016 | 22 |
| 3.00 | Rough Sketches of System | 1/9/2017 | 1/16/2017 | 7 |
| 3.00A | Rough Sketches of System | 1/3/2017 | 1/12/2017 | 9 |
| 4.00 | Research of Components | 1/9/2017 | 1/16/2017 | 7 |
| 4.00A | Research of Components | 1/9/2017 | 1/14/2017 | 5 |
| 5.00 | Formal Proposal | 1/16/2017 | 1/19/2017 | 3 |
| 5.00A | Formal Proposal | 1/14/2017 | 1/18/2017 | 4 |
| 6.00 | Final Drawings and Prints | 1/19/2017 | 2/18/2017 | 30 |
| 6.00A | Final Drawings and Prints | 1/18/2017 | 3/18/2017 | 59 |
| 6.10 | Put hole taps on prints (Leins) | 2/20/2017 | 2/23/2017 | 3 |
| 7.00 | Analysis of System | 1/19/2017 | 2/18/2017 | 30 |
| 7.00A | Analysis of System | 1/19/2017 | 3/18/2017 | 58 |
| 7.10 | Finish sizing of Motors/System (Hanford/Rude) | 2/20/2017 | 2/25/2017 | 5 |
| 7.10A | Finish sizing of Motors/System (Hanford/Rude) | 2/20/2017 | 3/12/2017 | 20 |
| 8.00 | Order All Components | 2/25/2017 | 2/27/2017 | 2 |
| 8.00A | Order All Components | 3/1/2017 | 3/27/2017 | 26 |
| 9.00 | Assemble/Fabricate Parts | 3/20/2017 | 3/25/2017 | 5 |
| 9.00A | Assemble/Fabricate Parts | 4/6/2017 | 4/24/2017 | 18 |
| 10.00 | Install Assembly on Machine | 3/26/2017 | 3/28/2017 | 2 |
| 10.00A | Intall Assembly on Machine | n/a | #VALUE! | n/a |
| 11.00 | Test New system | 3/29/2017 | 4/12/2017 | 14 |
| 11.00A | Test New system | n/a | #VALUE! | n/a |
| 12.00 | Work on Testing Procedure (Adam Hanford) | 3/19/2017 | 3/24/2017 | 5 |
| 12.0A | Work on Testing Procedure (Adam Hanford) | 3/30/2017 | 4/9/2017 | 10 |
| 13.00 | Work on Poster for Extra Credit (Brandon Rude) | 3/20/2017 | 4/4/2017 | 15 |
| 13.00A | Work on Poster for Extra Credit (Brandon Rude) | 4/20/2017 | 4/24/2017 | 4 |
| 14.00 | Work on Final Report (Adam/BrandonR) | 3/20/2017 | 4/14/2017 | 25 |
| 14.00A | Work on Final Report (Brandon Leins) | 4/17/2017 | 4/23/2017 | 6 |
| 15.00 | Work on Powerpoint Presentation (Brandon R) | 3/20/2017 | 4/19/2017 | 30 |
| 15.00A | Work on Powerpoint Presentation (Brandon R) | 4/19/2017 | 4/23/2017 | 4 |

TOOL NO. SW.875X250




VENDOR: MSC SW.875X250

| SYM | REVISIONS | BY | DATE |
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RED INDICATES ORIGINAL DRAWING
CAD CHANGES ONLY

TOLERANCES UNLESS OTHERWISE SPECIFIED

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|---|---|---|
| DECIMAL | .XX ± .01 | .XXXXX ± N/A |
| | .XXX ± .002 | ANGULAR ± 1.0° |
| | .XXXX ± .0005 | CONCENTRICITY ± .0002 |

32 FINISH ALL SURFACES UNLESS OTHERWISE INDICATED

MATERIAL: Generic
HEAT TREAT: -
REF. .


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| | | |
|---|---|---|
| DRAWN BY: B.LEINS | DATE: 3/15/2017 | SCALE: 1:1 |
| CHECKED BY: | APPROVED BY: | CAD MODEL: YES |

DESCRIPTION: SKATE ROLLER

TOOL NO.: SW.875X250
REV.: .

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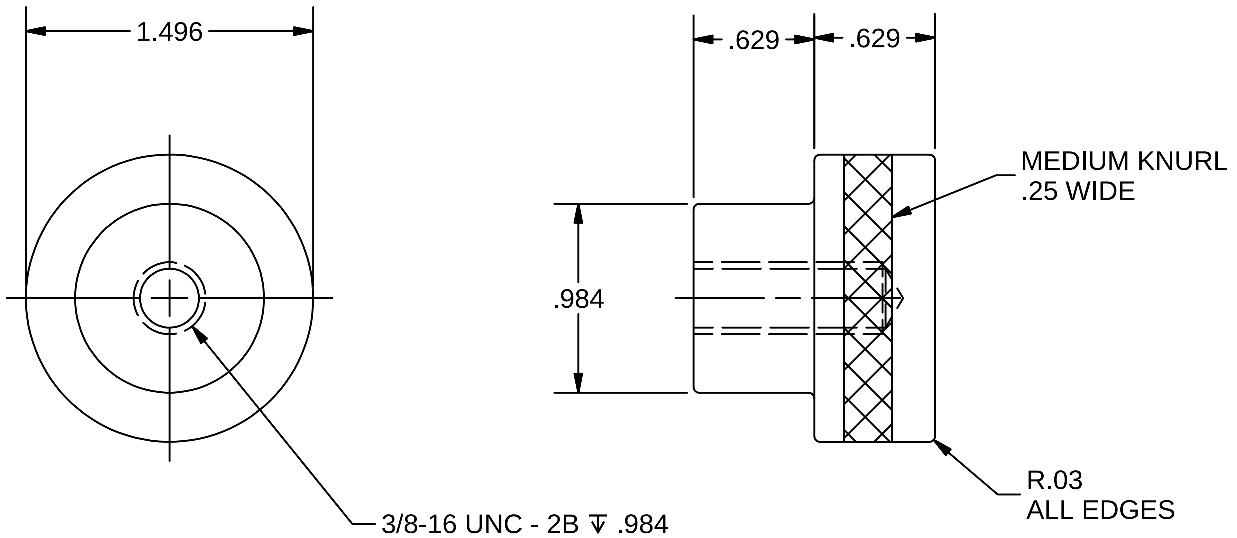
TOOL NO.
IDLER KNOB




ENGLISH UNITS
EXCEPT THREAD

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RED INDICATES ORIGINAL DRAWING
CAD CHANGES ONLY

TOLERANCES UNLESS OTHERWISE SPECIFIED

| | | |
|---|---|---|
| DECIMAL | .XX ± .01 | .XXXXX ± N/A |
| | .XXX ± .006 | ANGULAR ± 1.0° |
| | .XXXX ± .0005 | CONCENTRICITY ± .0002 |

32√ FINISH ALL SURFACES UNLESS OTHERWISE INDICATED

| MATERIAL | HEAT TREAT |
|---|---|
| 4140 | PRE-HEAT |

REF. .

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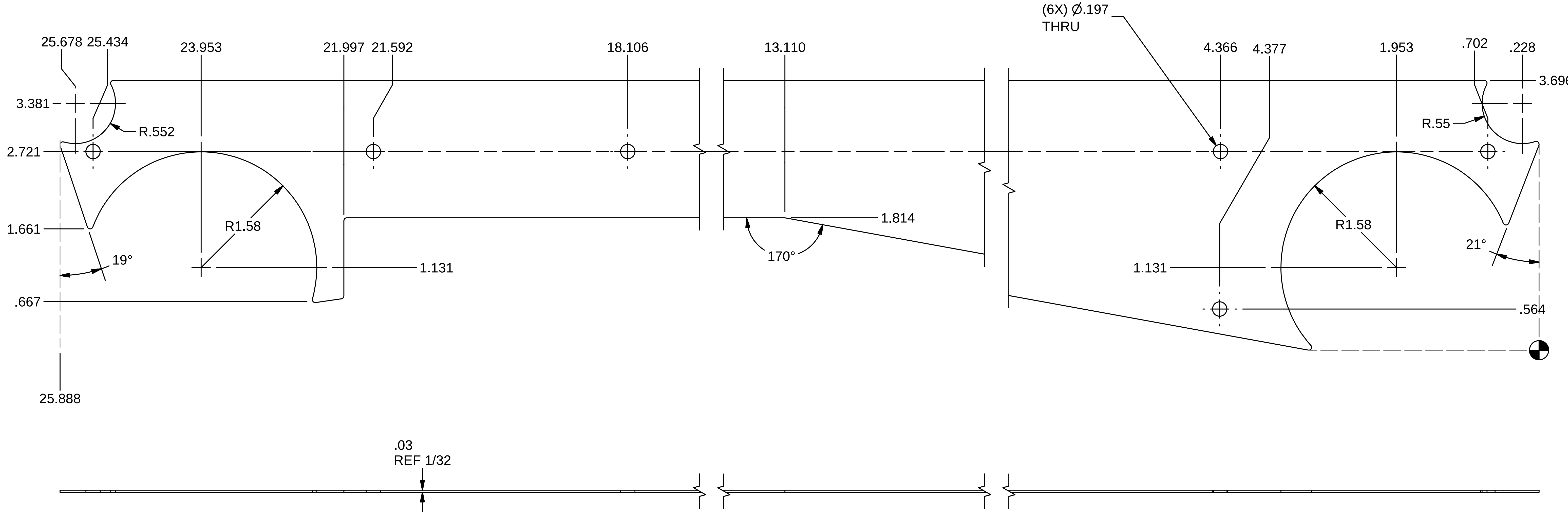
| DRAWN BY | DATE | SCALE |
|---|---|---|
| B.LEINS | 3/12/2017 | 1:1 |
| CHECKED BY | APPROVED BY | CAD MODEL |
| | | YES |

DESCRIPTION
THREADED IDLER KNOB

| TOOL NO. | REV. |
|---|---|
| IDLER KNOB | . |

\\cad\ENG\Temp\BRANDON\30 Hart Rail\Model\Prints\IDLER KNOB.dwg

TOOL NO. Gear Gaurd 1




VENDOR: WOLVERINE CARBIDE AND TOOL

ENGLISH UNITS: INCH

| SYM | REVISIONS | BY | DATE |
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RED INDICATES ORIGINAL DRAWING
CAD CHANGES ONLY

TOLERANCES UNLESS OTHERWISE SPECIFIED
DECIMAL .XX ± .01 .XXXXX ± N/A
.XXX ± .006 ANGULAR ± 1.0
.XXXX ± .0005 CONCENTRICITY ± .0002
32 FINISH ALL SURFACES UNLESS OTHERWISE INDICATED

| MATERIAL | HEAT TREAT |
|---|---|
| PLATE STEEL | PRE-HEAT |

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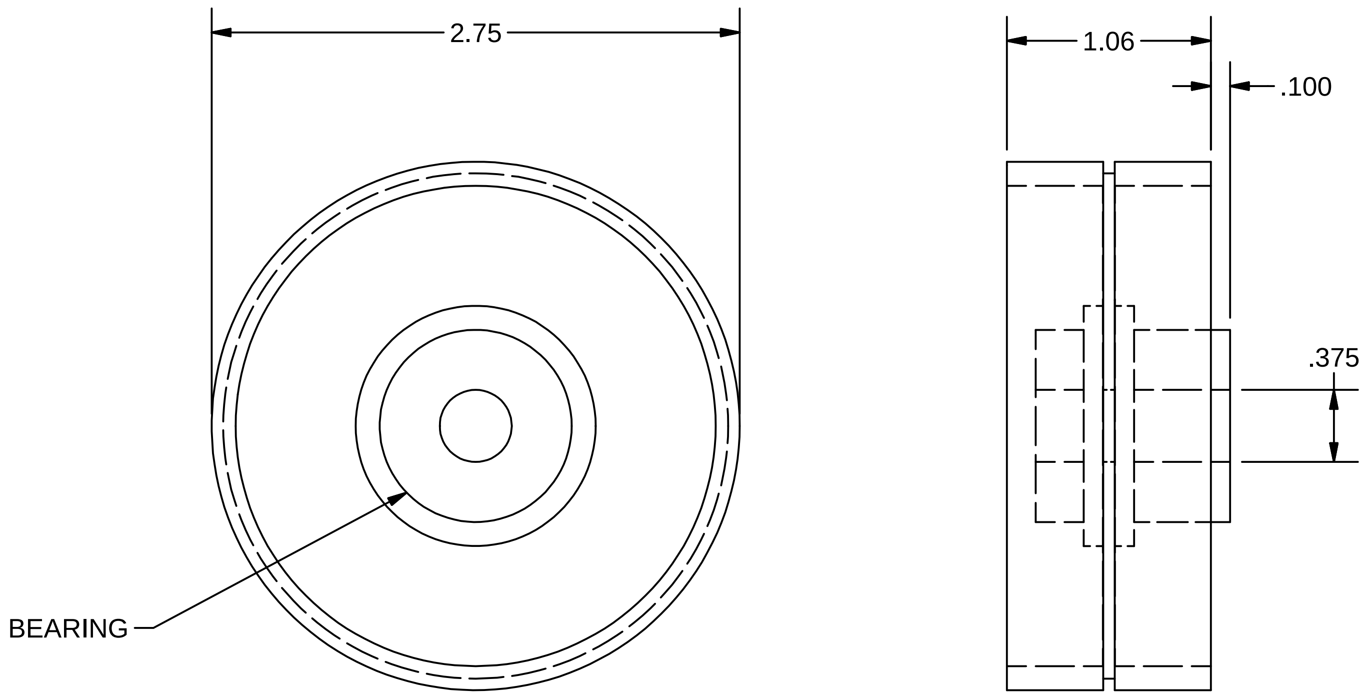
| DRAWN BY | DATE | SCALE |
|---|---|---|
| B.LEINS | 3/10/2017 | 1:1 |
| CHECKED BY | APPROVED BY | CAD MODEL |
| | | YES |

DESCRIPTION
GEAR GAURD AND DEFLECTOR

TOOL NO. Gear Gaurd 1
REV.

\\cad\ENG\Temp\BRANDON\30 Hart Rail\Model\Prints\Gear Gaurd 1.dwg

TOOL NO.
CW2.75X0375




VENDOR: MSC CW2.75X0375

ENGLISH UNITS

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RED INDICATES ORIGINAL DRAWING
CAD CHANGES ONLY

TOLERANCES UNLESS OTHERWISE SPECIFIED
DECIMAL .XX ± .01 .XXXXX ± N/A
.XXX ± .002 ANGULAR ± 1.0°
.XXXX ± .0005 CONCENTRICITY ± .0002
32 FINISH ALL SURFACES UNLESS OTHERWISE INDICATED

MATERIAL: Generic
HEAT TREAT: -
REF.: .

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| DRAWN BY | DATE | SCALE |
| --- | --- | --- |
| B.LEINS | 3/16/2017 | 1:1 |
| CHECKED BY | APPROVED BY | CAD MODEL |
| | | YES |

DESCRIPTION: IDLER PULLEY

TOOL NO.: CW2.75X0375 REV.: .

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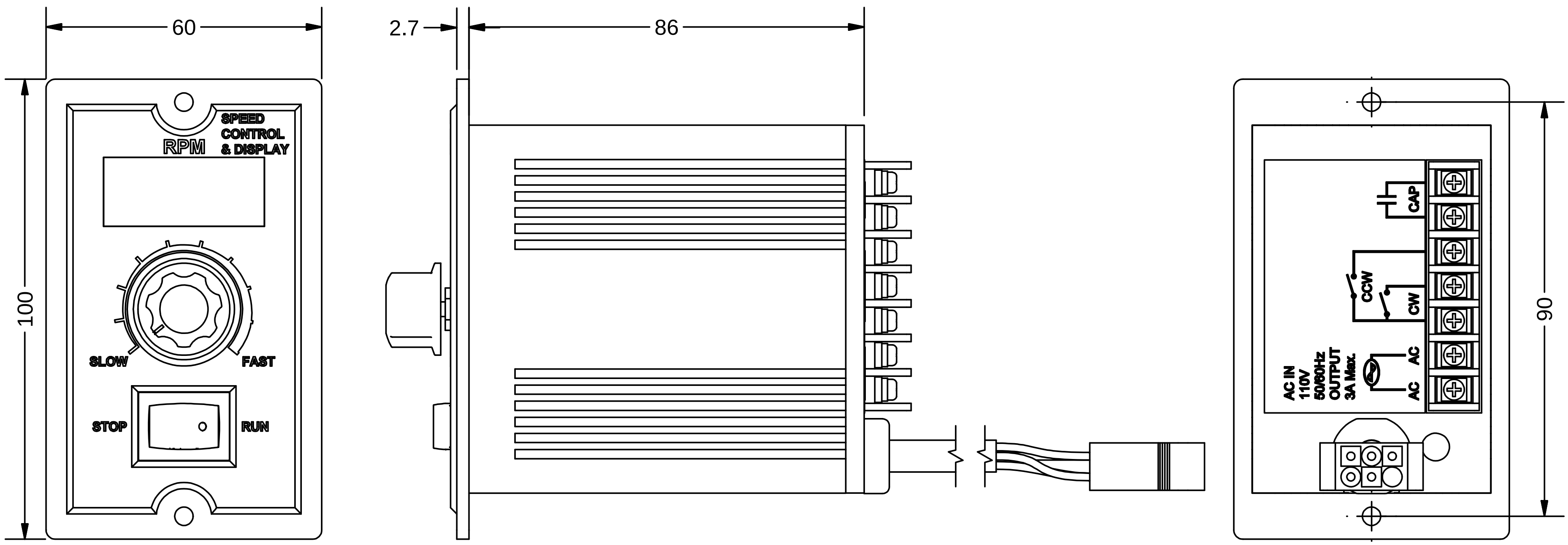
TOOL NO.
ACP-US-4125A-AL




* CLOSE LOOPED SPEED CONTROL
* FORWARD AND REVERSE
* START STOP SWITCH
* DIGITAL DISPLAY READ OUT

INPUT VOLTAGE: 110 VAC, 1ohm
RATED POWER: 25 WATTS
PEAK CURRENT: .23 AMPS

VENDOR: ANAHEIM AUTOMATION

METRIC UNITS (MM)

| SYM | REVISIONS | BY | DATE |
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RED INDICATES ORIGINAL DRAWING
CAD CHANGES ONLY

TOLERANCES UNLESS OTHERWISE SPECIFIED
DECIMAL .XX ± N/A .XXXXX ± N/A
.XXX ± N/A ANGULAR ± N/A
.XXXX ± N/A CONCENTRICITY ± N/A
32√ FINISH ALL SURFACES UNLESS OTHERWISE INDICATED

MATERIAL: Generic
HEAT TREAT:
REF.:

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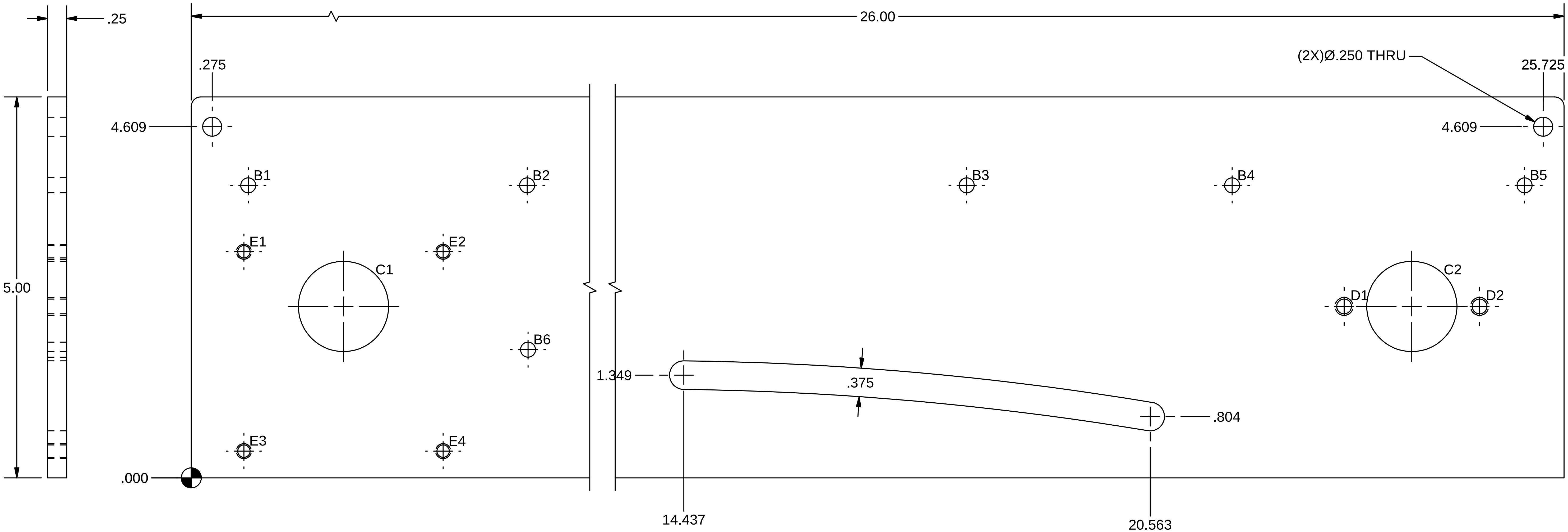
| DRAWN BY | DATE | SCALE |
|---|---|---|
| B.LEINS | 3/15/2017 | .75:1 |
| CHECKED BY | APPROVED BY | CAD MODEL |
| | | YES |

DESCRIPTION: SPEED CONTROL

TOOL NO.: ACP-US-4125A-AL
REV.:

\\cad\ENG\Temp\BRANDON\30 Hart Rail\Model\Prints\ACP-US-4125A-AL.dwg

TOOL NO. C-Rail




| Hole Table | | | |
|---|---|---|---|
| HOLE | XDIM | YDIM | DESCRIPTION |
| B1 | .748 | 3.839 | Ø.197 THRU |
| B2 | 4.412 | 3.839 | Ø.197 THRU |
| B3 | 18.153 | 3.839 | Ø.197 THRU |
| B4 | 21.639 | 3.839 | Ø.197 THRU |
| B5 | 25.481 | 3.839 | Ø.197 THRU |
| B6 | 4.424 | 1.683 | Ø.197 THRU |
| C1 | 2.000 | 2.250 | Ø1.185 THRU |
| C2 | 24.000 | 2.250 | Ø1.185 THRU |
| D1 | 23.110 | 2.250 | M6x1 - 6H ↧ THRU |
| D2 | 24.890 | 2.250 | M6x1 - 6H ↧ THRU |
| E1 | .692 | 2.968 | M5x0.8 - 6H ↧ THRU |
| E2 | 3.308 | 2.968 | M5x0.8 - 6H ↧ THRU |
| E3 | .692 | .351 | M5x0.8 - 6H ↧ THRU |
| E4 | 3.308 | .351 | M5x0.8 - 6H ↧ THRU |

VENDOR: WOLVERINE CARBIDE AND TOOL

ENGLISH UNITS: INCH

| SYM | REVISIONS | BY | DATE |
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RED INDICATES ORIGINAL DRAWING
CAD CHANGES ONLY

TOLERANCES UNLESS OTHERWISE SPECIFIED
DECIMAL .XX ± .01 .XXXXX ± N/A
.XXX ± .004 ANGULAR ± 1.0
.XXXX ± .0005 CONCENTRICITY ± .0002
32√ FINISH ALL SURFACES UNLESS OTHERWISE INDICATED

| MATERIAL | HEAT TREAT |
|---|---|
| 4140 | PRE-HEAT |

REF. .


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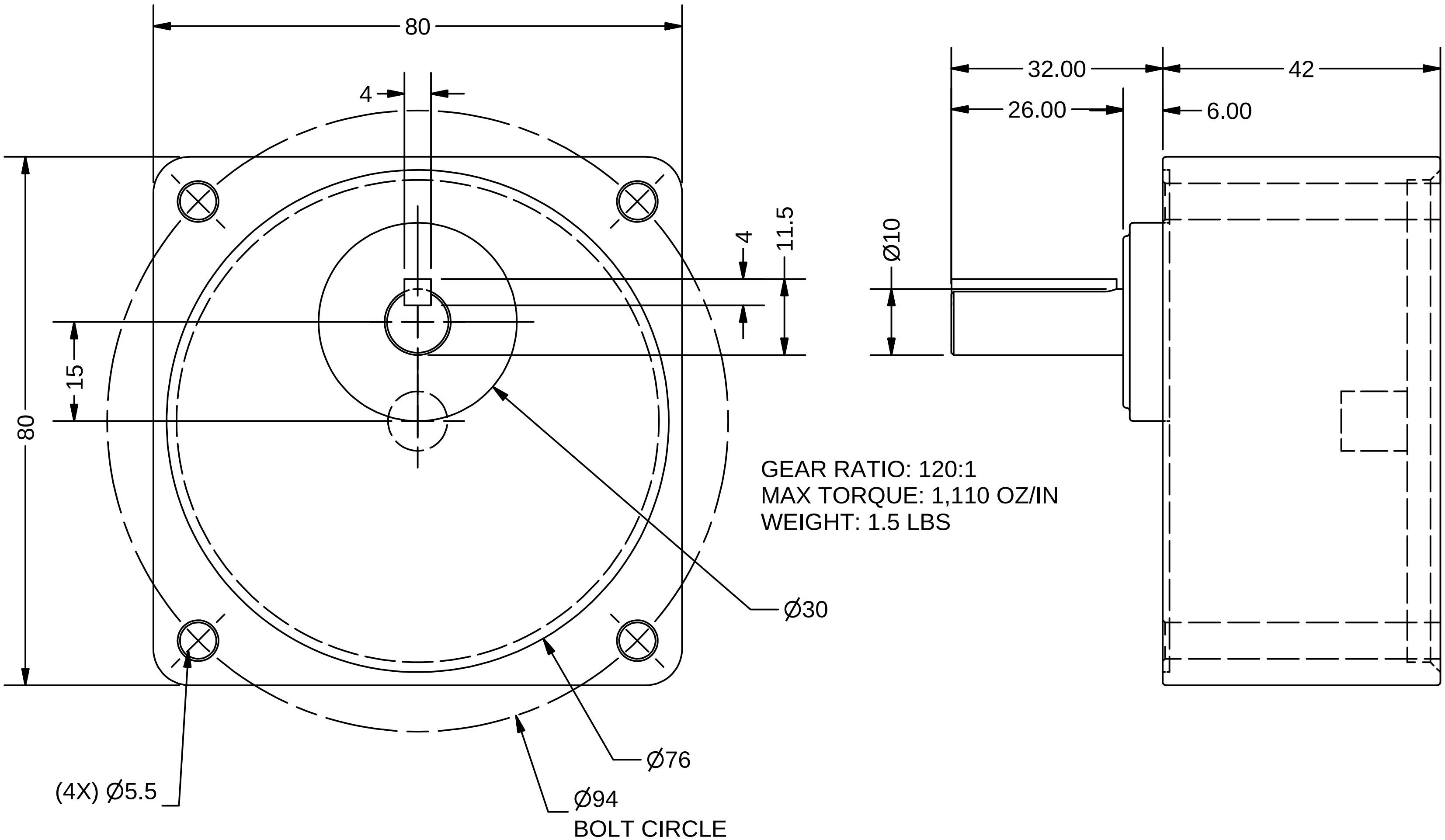
| DRAWN BY | DATE | SCALE |
|---|---|---|
| B. LEINS | 1/13/2017 | .75:1 |
| CHECKED BY | APPROVED BY | CAD MODEL |
| | | YES |

DESCRIPTION: MAIN MOUNTING PLATE

| TOOL NO. | REV. |
|---|---|
| C-Rail | . |

\\cad\ENG\Temp\BRANDON\30 Hart Rail\Model\Prints\C-Rail.dwg

TOOL NO.
ACP-G-4N120-K




GEAR RATIO: 120:1
MAX TORQUE: 1,110 OZ/IN
WEIGHT: 1.5 LBS

VENDOR: ANAHEIM AUTOMATION

METRIC UNITS

| SYM | REVISIONS | BY | DATE |
|---|---|---|---|
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RED INDICATES ORIGINAL DRAWING
CAD CHANGES ONLY

TOLERANCES UNLESS OTHERWISE SPECIFIED

| | | | |
|---|---|---|---|
| DECIMAL | .XX ± N/A | .XXXXX ± | N/A |
| | .XXX ± N/A | ANGULAR ± | N/A |
| | .XXXX ± N/A | CONCENTRICITY ± | N/A |

32 FINISH ALL SURFACES UNLESS OTHERWISE INDICATED

| MATERIAL | HEAT TREAT |
|---|---|
| Generic | |

REF.

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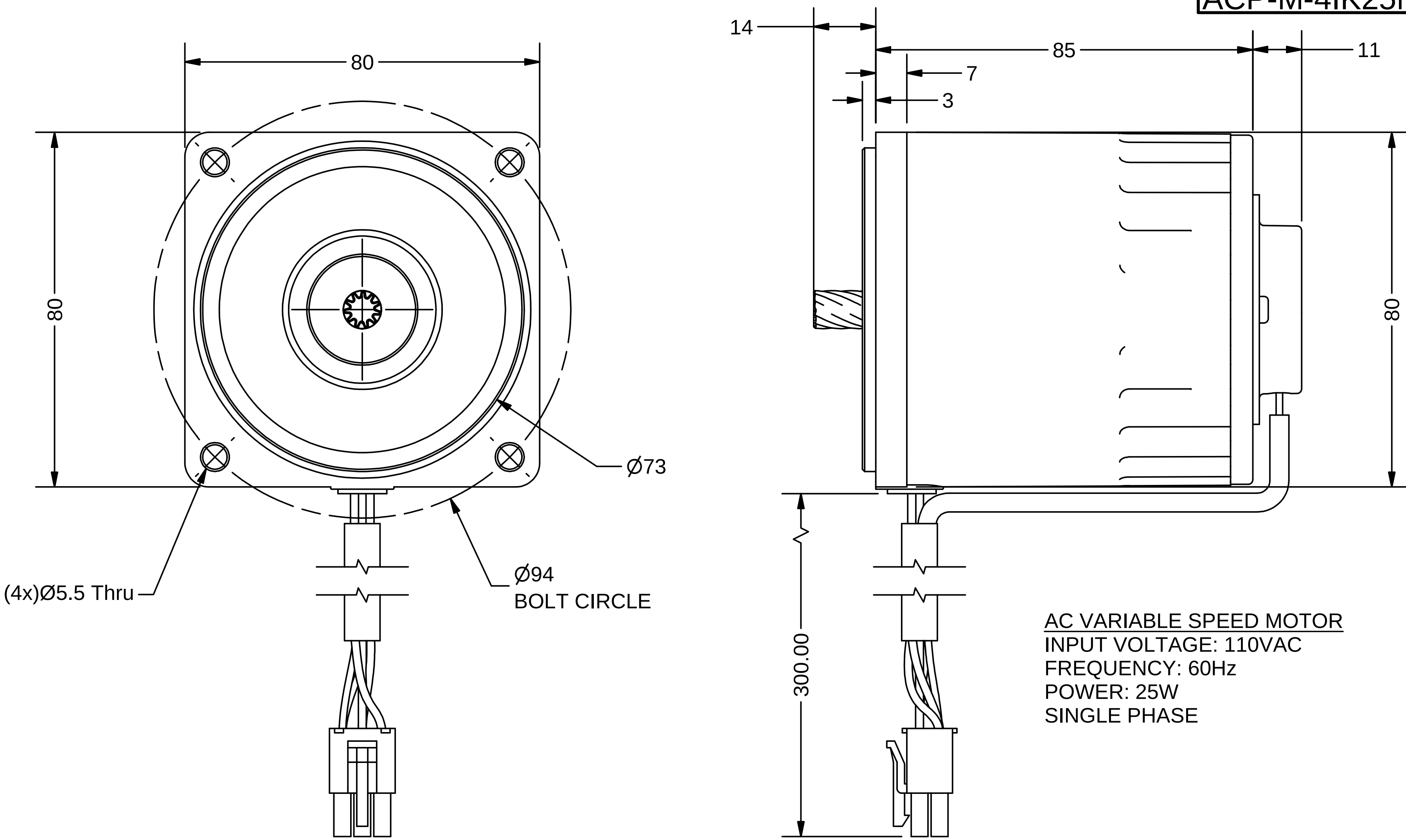
| DRAWN BY | DATE | SCALE |
|---|---|---|
| B.LEINS | 3/15/2017 | 1:1 |
| CHECKED BY | APPROVED BY | CAD MODEL |
| | | YES |

DESCRIPTION
GEAR HEAD

| TOOL NO. | REV. |
|---|---|
| ACP-G-4N120-K | |

F:\Temp\BRANDON\30 Hart Rail\Model\Prints\ACP-G-4N120-K GH.dwg

TOOL NO.
ACP-M-4IK25N-AUV




AC VARIABLE SPEED MOTOR
INPUT VOLTAGE: 110VAC
FREQUENCY: 60Hz
POWER: 25W
SINGLE PHASE

VENDOR: ANAHEIM AUTOMATION

METRIC UNITS (MM)

| SYM | REVISIONS | BY | DATE |
|---|---|---|---|
| | | | |
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RED INDICATES ORIGINAL DRAWING
CAD CHANGES ONLY

TOLERANCES UNLESS OTHERWISE SPECIFIED

| DECIMAL | | |
|---|---|---|
| .XX ± N/A | .XXXXX ± N/A | |
| .XXX ± N/A | ANGULAR ± N/A | |
| .XXXX ± N/A | CONCENTRICITY ± N/A | |

N/A FINISH ALL SURFACES UNLESS OTHERWISE INDICATED

MATERIAL: Generic
HEAT TREAT:
REF.:

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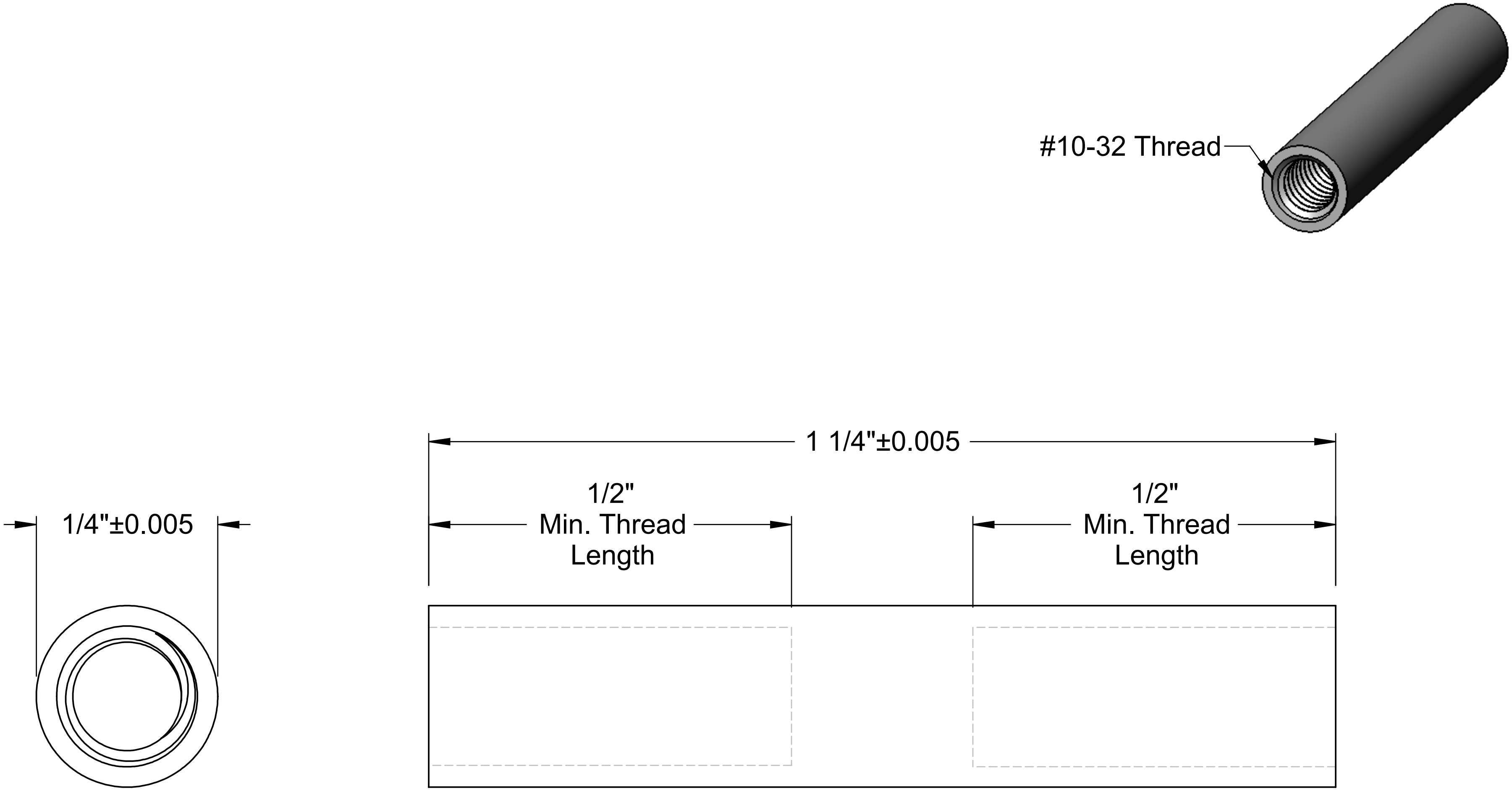
21777 HOOVER WARREN, MICHIGAN 48089 586-497-7000

| DRAWN BY | DATE | SCALE |
|---|---|---|
| B.LEINS | 3/15/2017 | .75:1 |
| CHECKED BY | APPROVED BY | CAD MODEL |
| | | YES |

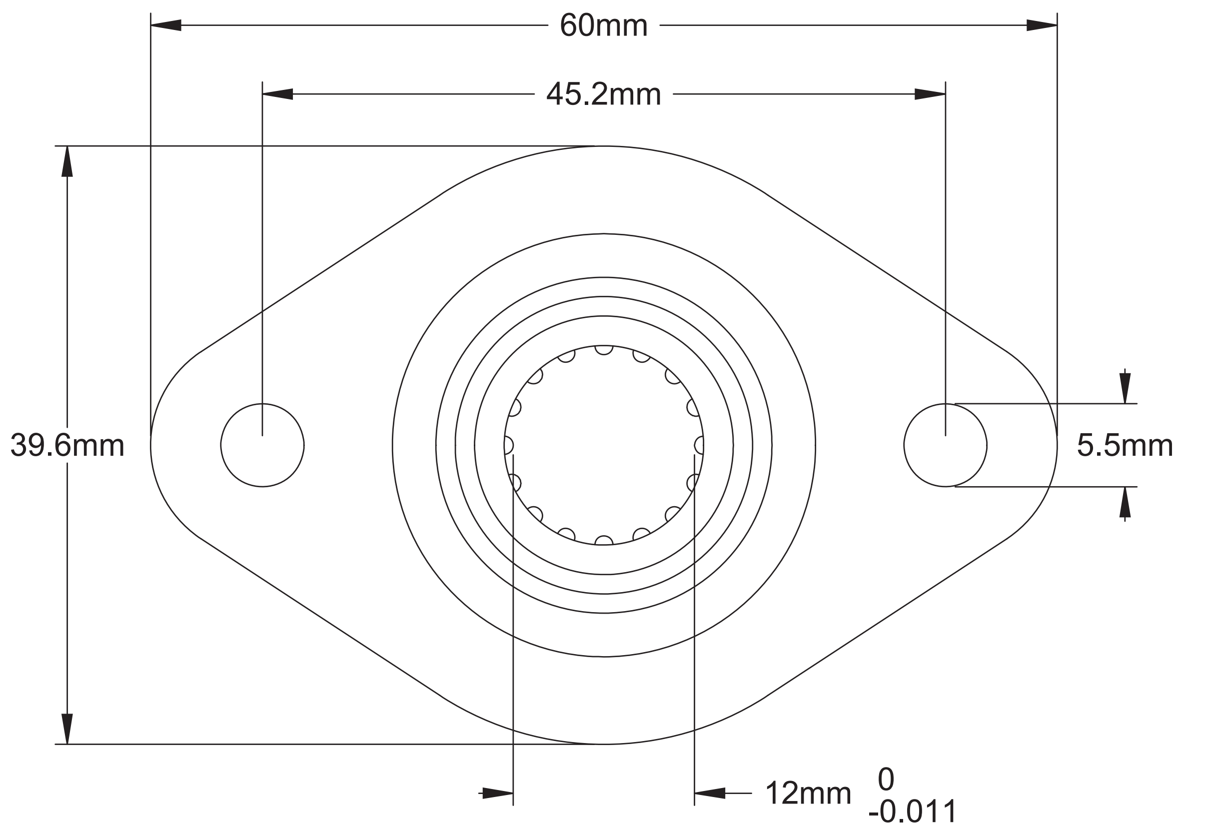
DESCRIPTION: AC VARIABLE SPEED MOTOR

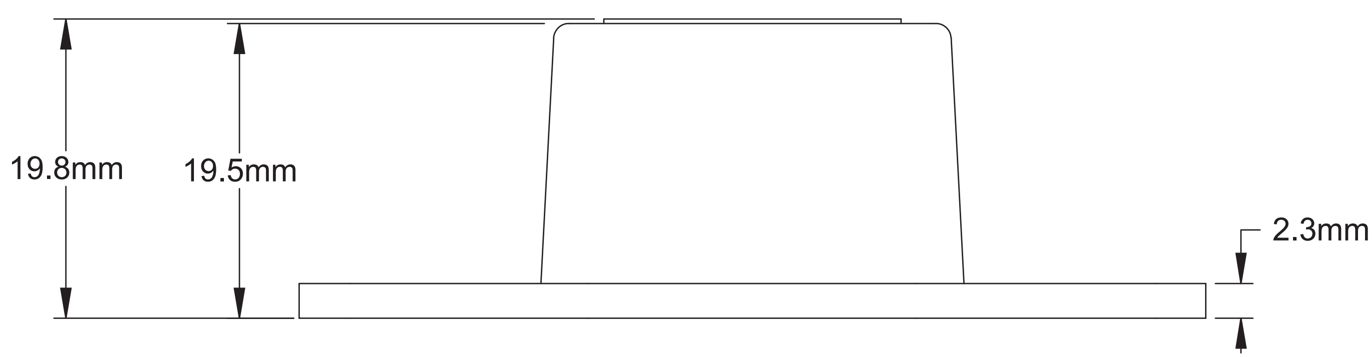
TOOL NO.: ACP-M-4IK25N-AUV
REV.:

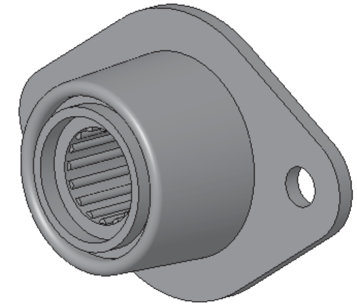
\\cad\ENG\Temp\BRANDON\30 Hart Rail\Model\Prints\ACP-M-4IK25N-AUV.dwg




| McMASTER-CARR | PART NUMBER | 93265A491 |
|---|---|---|
| http://www.mcmaster.com<br>© 2015 McMaster-Carr Supply Company<br>Information in this drawing is provided for reference only. | Female Threaded Round Standoff | |



McMASTER-CARR® CAD

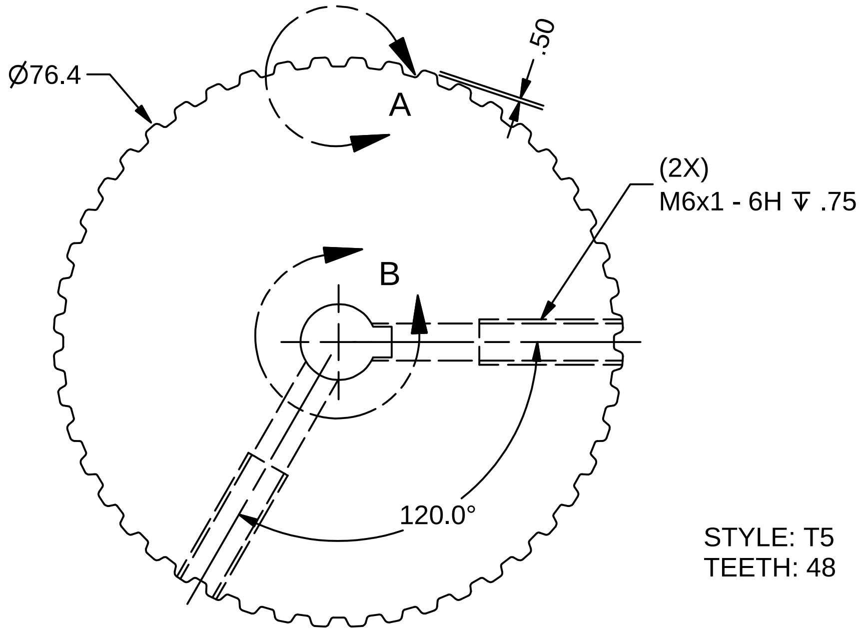
PART NUMBER **1434K15**

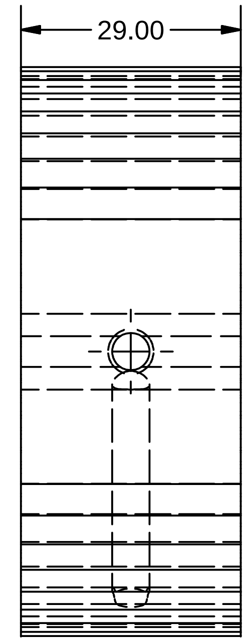
http://www.mcmaster.com



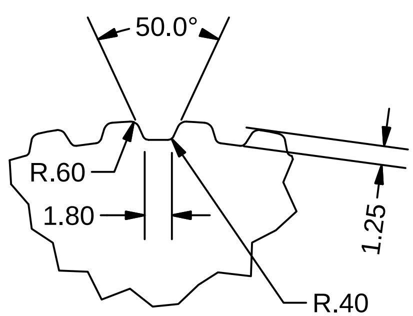
Black-Oxide-Coated Steel
Mounted Needle-Roller Bearing

TOOL NO.
# T5 PULLEY

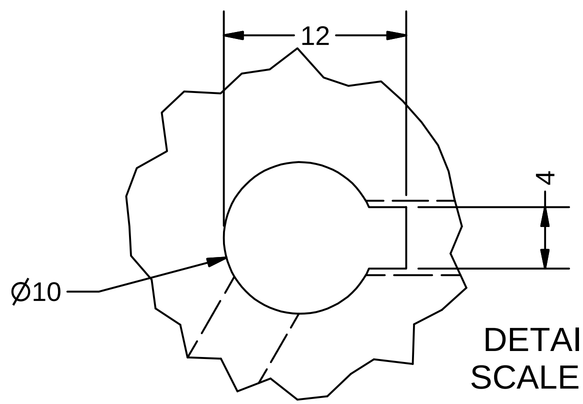



STYLE: T5
TEETH: 48




DETAIL A
SCALE 2 : 1




DETAIL B
SCALE 2 : 1

NOTE: MODIFICATION FROM VENDOR PART
* GRIND STEP OFF FACE
* MAKE KEY
* TAP M6 HOLES

VENDOR: MCMASTER-CARR 1428N77

METRIC UNITS

| SYM | REVISIONS | BY | DATE |
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RED INDICATES ORIGINAL DRAWING
CAD CHANGES ONLY

TOLERANCES UNLESS OTHERWISE SPECIFIED
DECIMAL .XX ± .01 .XXXXX ± N/A
.XXX ± .002 ANGULAR ± 1.0°
.XXXX ± .0005 CONCENTRICITY ± .0002
32√ FINISH ALL SURFACES UNLESS OTHERWISE INDICATED

MATERIAL: ALUMINUM
HEAT TREAT:
REF.


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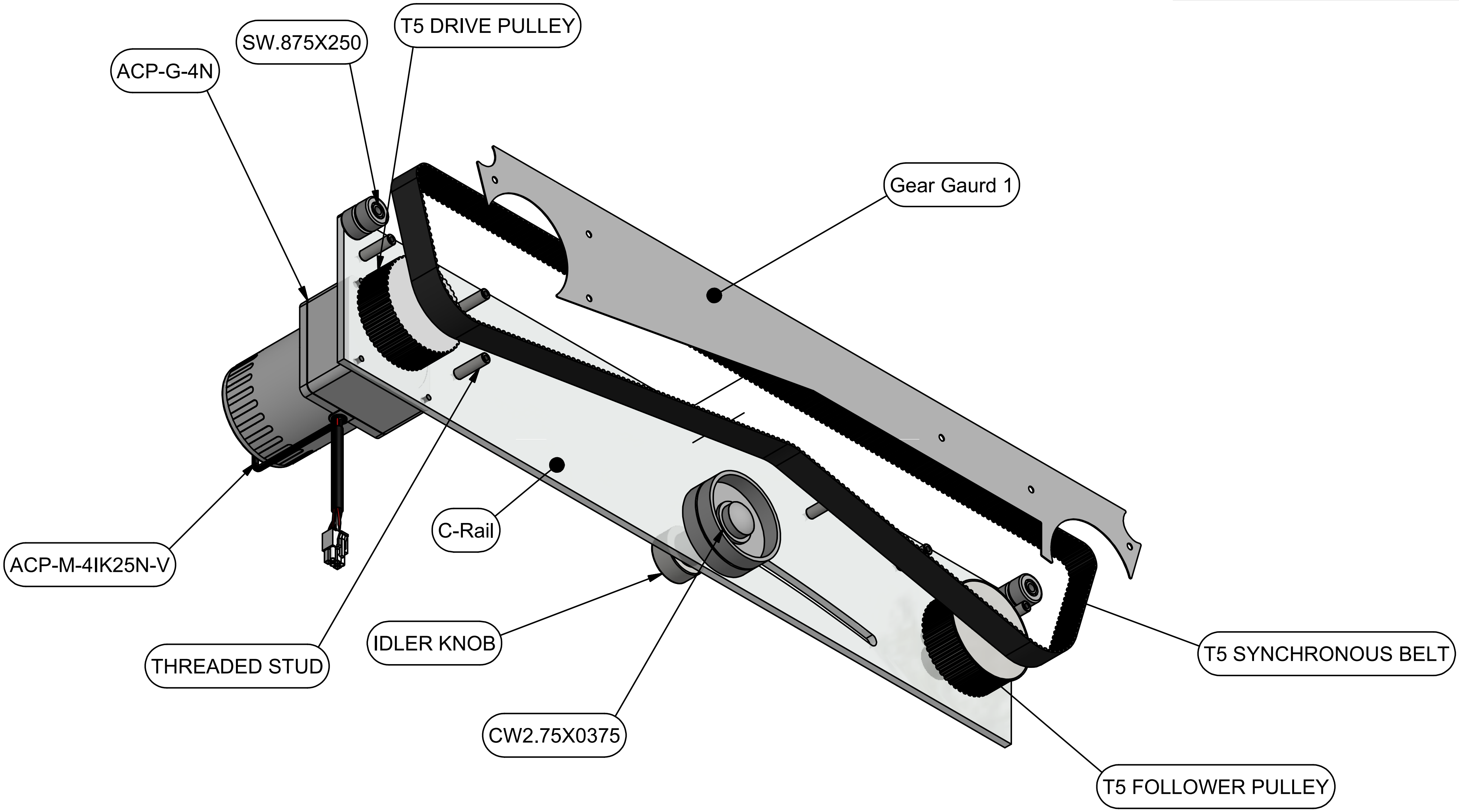
| DRAWN BY | DATE | SCALE |
|---|---|---|
| bleins | 1/30/2017 | 1:1 |
| CHECKED BY | APPROVED BY | CAD MODEL |
| | | YES |

DESCRIPTION: T5 SYNCHRONIZED PULLEY

TOOL NO.: T5 PULLEY
REV.:

\\cad\ENG\Temp\BRANDON\30 Hart Rail\Model\Prints\T5 PULLEY.dwg




TOOL NO. MP

| SYM | REVISIONS | BY | DATE |
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RED INDICATES ORIGINAL DRAWING
CAD CHANGES ONLY

TOLERANCES UNLESS OTHERWISE SPECIFIED
DECIMAL .XX ± .01 .XXX ± .002 .XXXX ± .0005
.XXXXX ± N/A ANGULAR ± 1.0° CONCENTRICITY ± .0002
32√ FINISH ALL SURFACES UNLESS OTHERWISE INDICATED

MATERIAL | HEAT TREAT
REF.

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| DRAWN BY | DATE | SCALE |
|---|---|---|
| B. LEINS | 1/17/2017 | 1:1 |
| CHECKED BY | APPROVED BY | CAD MODEL YES |

DESCRIPTION

TOOL NO. MP | REV.

\\cad\ENG\Inventor Stds\Templates\Tools\MP.dwg