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Preventing Sheet Metal Wrinkling in Coil Lines

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ABSTRACT

Preventing Sheet Metal Wrinkling in Coil Lines

by

David Revers

The University of Wisconsin-Milwaukee, 2012
Under the Supervision of Professor Ilya V. Avdeev

Coil lines are used in metal packaging facilities to treat the metal before forming the final product. As the sidewalls of cans are becoming thinner and thinner, one can see that the equipment has not been designed properly to feed up lighter plate weight metal. Thinner can walls cause the metal sheet to be fed into the machine crooked and results in a wrinkling of the first few feet of metal, which then needs to be thrown away. Because the current equipment is not working properly, operators have been feeding sheets of metal up a ten-foot ladder into the machine to feed the sheet in straight. This method puts the operator at a safety risk. The feed mechanism that is currently installed does work better with heavier plate weight metal. After talking with the operators and looking at the current equipment, a conceptual design test prototype was built to see if it would fix the problem. When running numerous tests with the prototype it was verified that the conceptual design would fix the problem. After the test prototype proved to be successful, a full design of the roller system was implemented. The design is currently finished and is in the process of being purchased. The expected installation date will be December 3-7th of this year.
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CHAPTER 1: INTRODUCTION

1.1 Coil Lines

1.1.1 Coil Lines

Coil lines have been around for hundreds of years in the metal industry. Although coil lines are primarily used for metal purposes, they can also be used for paper and some plastics [28]. In the metal industry, coil lines are used in many applications predominantly for coating, cutting, and punching. There are a wide variety of metal materials that can be used on coil lines like steel, aluminum, copper, stainless steel, and alloy metals [29].

Coil coating lines are used to coat the metal sheet as it goes through the line. Coating lines vary in size, but are often hundreds of feet long consisting of un-coilers, re-coilers, accumulators, coaters and ovens. As shown in Figure 1-1 above, there are two un-coilers which uncoil the large metal rolls to keep the line running continuously. There are two accumulator sections, one in the front of the line and one in the back. The accumulators are used when the line needs to switch rolls. They accommodate about a

Figure 1-1: Process diagram of a coil coating line
45-second window for the operator to crimp and connect the end of one sheet to the beginning of the other. The accumulators allow for the line to run continuously. Depending on the product you are making, the metal sheet sometimes goes into a pretreatment and rinse section of the line where the metal is cleaned of all dirt and oils to ensure good adhesion of the coating [30]. The coaters come next, where the metal sheet goes through a series of rollers and a set of large applicator rolls apply a controlled thickness coating to both sides. The protective coating is applied to protect the metal from the environment and the product that the metal will be used for. This coating also creates a good-looking finish [30]. After the metal sheet is coated, it travels through a series of different temperature ovens ranging from $400^\circ$ to $1000^\circ$ to bake and cure the coating on the metal [30]. Once out of the oven, the metal sheet is wrapped back up into a large roll to be used on a different line.

Coil cutting lines are used in industry to take large rolls of metal and cut them into smaller metal sheets. Figure 1-2 below shows the floor plan for a typical coil cutting line.

![Figure 1-2: Coil cutting line floor plan](image)

The start of the line is on the right, where a large roll of metal is put on the reel. The metal sheet is fed through a straightener that straightens the metal sheet from being coiled on the roll, this ensures that the metal sheet is flat when the sheet gets cut into smaller
pieces. The metal sheet then advances to the build-up loop, which allows the roll to continuously pay out instead of starting and stopping a 5-10 ton roll [31]. The metal sheet is then aligned by side guide rollers and goes into the shear. The shear cuts the metal sheet into specific sizes and lengths to help minimize the amount of scrap that is left over [31]. From here, the metal sheets are stacked on bundles to be used on a different line.

Coil punching lines are extremely similar to coil cutting lines. The main difference is that instead of having a cutting shear, there are series of punches that punch out the product. If the product is simple, the process can be completed all in one step by forming the shape in a die and cutting it out from the metal sheet [31]. Other processes simply cut the metal shape out of the sheet and form it in another machine later on.
Figure 1-4 above shows an accurate representation of a pattern of a coil punch layout system for can ends. Once the product is punched out, there are scrap choppers which cut the metal waste into small pieces so it can be recycled [31].

1.1.2 **Silgan Containers Coil Lines; Process Description**

Silgan Containers began their company back in 1899 under the name Carnation Company, which specialized in metal packaging [1]. Over the course of 113 years in business, Silgan has become the leading supplier of the metal packaging market in the United States with some big brand companies like Campbell’s Soup, Spam and Del Monte [1]. Using their 28 manufacturing facilities, on average Silgan produces 28-30 billion cans per year [32]. Worldwide Silgan operates 82 manufacturing facilities in North and South America, Europe, and Asia.

Out of Silgan Containers’ 28 manufacturing facilities, they currently run 31 coil lines. Out of the 31 coil lines at Silgan, 13 are coil cutting lines, 17 are coil punch lines, and only one is a coil coating line [32]. Wrinkling is more prominent in coil coating lines because the metal sheet is run through a line that is 100-700 feet long, compared to a three-foot by three-foot cut piece of metal. This is why the majority of Silgan’s coil lines are either coil line cutters or coil punch lines.

One of Silgan’s manufacturing plants in Hammond, IN is having issues with their coil coater. In Hammond, this manufacturing plant coats five-foot in diameter by three-foot wide rolls of bare metal, with an epoxy coating on either side. The large five-foot diameter rolls are first placed on a large mandrel in the beginning of the 500-foot long coil line [33]. Once on the mandrel, the three-foot wide metal sheet is fed up a conveyor
to a set of pinch rolls that are ten feet off the ground. The pinch rolls feed the metal sheet to the shear, where a straight edge is cut and then continues to the crimping machine to connect the sheet to the end of the last roll. The machine is set up to run continuously where there are two mandrels in the beginning of the machine. For mandrel #2 the roll is fed directly horizontally, but for mandrel #1 the roll is fed up and over the first process. When one roll runs out, the crimper crimps the end of one roll to the beginning of the other to keep it a continuous process. After going through the crimpler, the metal goes through a series of two coaters which applies an epoxy coating to either side of the metal. Next, the metal is suspended through a massive oven, where the metal is heat treated at different temperatures to cure the epoxy coating. At the end of the line, there is one mandrel that rolls the metal back up into a five-foot diameter roll so that it can be used in another plant.

1.1.3 Problems

The coating line in Hammond is having problems with the mandrel #1 loading station. The problem exists because mandrel #1 has to go up ten feet in order to go over the mandrel #2 station. A hydraulic conveyor system is the current process that allows
the sheet to be fed up ten feet. Once the roll is on the mandrel, the operator sets the angle for the conveyor. After the angle is set, the dead plate moves out to almost touch the metal roll. The operator then turns on the conveyor belt and pinch rolls at the top of the conveyor. The operator then advances the mandrel to feed the metal sheet up to the pinch rolls.

![Current conveyor system](image)

**Figure 1-6:** Current conveyor system

The key to this entire process is to have the metal sheet fed straight into the pinch rolls. If the metal sheet goes into the pinch rolls crooked, then it wrinkles and destroys the first 10 to 20 feet of metal sheet until it straightens out. Throughout the entire day, the plant runs on average 30 to 36 rolls [33]. When looking at the average day, the approximate cost per foot of a three-foot wide roll is $0.40 and the number of occurrences where the metal

![Metal sheet as it enters the pinch rolls](image)

**Figure 1-7:** Metal sheet as it enters the pinch rolls
sheet wrinkles is about five times per day [33]. Estimating that about ten feet of material is wasted during each occurrence, this calculates to be $20 of wasted material per day. If this is projected though the 235 work days per year, the average estimated material wasted per year adds up to $4,700 per year [33].

![Image of damaged metal sheet](image)

**Figure 1-8**: 20 Feet of damaged metal sheet

This problem does not occur every time a new roll is started; however, it does take extra time to straighten the metal sheet for the operator, and costs the company money every time there is wasted metal. To some people, a few wasted feet of metal is not a significant issue, but from the cost of wasted material mentioned above, one can see that it does add up throughout the year.

Operators have been avoiding this problem by not using the current in-feed conveyor. Instead of using the conveyor and hoping the metal sheet is fed straight into the pinch rolls, operators have been climbing up a ten-foot step ladder to feed the metal sheet perfectly into the pinch rolls. This is a huge safety hazard for any operator and is against Silgan’s safety policy. The first reason for this rule is because the metal sheet is heavy and awkward to carry up a ten-foot tall ladder. Another reason is that the operator’s hand could get sucked into the pinch rolls; the metal sheet is extremely sharp.
and could cut the operator very easily. With these problems occurring on the coating line, Silgan’s equipment engineering group was asked to help fix the problem.

1.1.4 Similar Coil Coating Lines

There are similar coil coaters like the one at the Hammond, IN plant that operate the same way. Since the coil lines have to run continuously, the rolls have to be in-line. The newer coil lines have better designed metal sheet in-feeds, where the metal sheet does not have to go up ten feet and over the first roll. The newer designs have the rolls offset in height and the framing is not as bulky as the older machines.

The coil coating line from Figure 1-9 is at Shanghi Fenghang Industrial Automatic Equipment facility [4]. They specialize in debugging integrated equipment for processing metal sheets [4]. As depicted in Figure 1-9, the conveyor extends out to the

Figure 1-9: Coil line in-feed, Shanghai, China
large roll and the metal sheet is fed up to the pinch rolls via a conveyor. There is no record of any issues with this line, but making an assumption that this facility would be having similar problems that Silgan is facing with their in-feed coil coating line because the in-feed conveyor and roll set-up in Shanghai looks very similar to Silgan’s coil coater in-feed at Hammond.

Another coil line similar to the line Silgan uses is a Red Bud Industries coil line that is installed at Stripco, Inc [5]. The in-feed on the Red Bud coil line is a little different, but some of the same issues are present. The machine in Figure 1-10, does not have a conveyor to allow the coil line to feed up the metal sheet; therefore, an operator has to physically put the sheet into the pinch rolls. This is the same issue that Silgan is having with their coater; operators are putting the sheets into the pinch rolls by hand, which puts the operator at risk of injury. Although the Red Bud line is not as high as the one in Hammond, IN, it is still a safety hazard to allow operators to handle the metal sheet by hand. This system at Stripco, Inc is a similar design to what is at Silgan’s Hammond, IN plant and it could benefit from the findings of this research.
1.1.5  **Coil Cutting Line Straightener**

There are many areas throughout the 28 Silgan manufacturing plants where the same or similar issues are occurring when feeding metal sheet stock. One such area is on a specific Minster servo feed machine that is at numerous Silgan plants. The Minster servo feed machines are on coil cutting lines where a large five-foot in diameter roll is cut into smaller sheets to later be coated and converted to can ends. The Minster machine is placed right before the shear, where it allows slack to build up so the sheet has time to start and stop when the shear cuts the metal sheet [3]. The slack is built up in the build-up loop because it would be too hard to start and stop a 20-ton metal roll of metal every second [3]. The metal roll continuously pays out the metal sheet at a constant speed, and the slack is taken and replenished at a consistent rate to keep up with the shear. As the servo drive pulls the metal sheet from the build-up loop, it is moving so fast that it causes the metal sheet to sway and jerk around. Therefore, on the Minster machine, there is a swing away-bracket that prevents the metal sheet from jumping off the track due to the

![Figure 1-11: Minster servo feed drive machine](image)
swaying and jerking. However, it does not keep the sheet aligned perfectly. The swing-away brackets are simply guide bars that keep the sheet on the track [3]. The tolerance between the metal sheet and the sway bars is so large that it allows the metal sheet the freedom to float back and forth. This issue is similar to the conveyor at the Hammond, IL plant, where the light plate allows the metal sheet to float until about halfway up the conveyor until the conveyor belt finally grabs the metal sheet.

The Minster press could use a differently-designed swing away bracket to help keep the alignment of the metal sheet straight all the time. This alternate design would happen by decreasing the tolerance between the table and the sway brackets. If the sway brackets tolerance were to be decreased to a point at which they almost touched, the bars would have to be replaced with rollers so the sheet could still pass through the machine without scuffing the metal sheet. By decreasing the tolerance, the jerk and sway would lessen because the freedom of the metal sheet would be minimized.
1.1.6 Roller Bar Coil Line

After doing some research and looking at all of Silgan’s 28 plants, a straightener was found that is similar to the machine that was described in section 1.1.5 at Silgan’s Rochelle, IL facility. This machine is a little older, but performs the same job as the Minster servo drive feed machine. Instead of having swing away bars on the machine, custom roller bars were installed instead because of metal sheet control issues. Therefore, rollers were installed on the top and bottom of the out-feed of the straightener to sandwich the metal sheet.

This straightener on the coil cutting line at Rochelle has implemented the suggestions as suggested in section 1.1.5. This machine has decreased the tolerance by actually sandwiching the metal sheet between two rollers, which gives complete control of the metal sheet exiting the machine and decreases the jerk and sway in the build-up loop. After talking to the plant mechanics, when the straightener had the old swing away bars they were having so much trouble with alignment and markings so the roller bar design was installed. The plant mechanics inferred that after the roller bars were installed
on the coil line, there was less damage on the metal sheet with markings from the swaying and jerking and better sheet handling as it would enter the shear. The control gained from adding the rollers was enormous compared to only having the guide bars.

1.2 Sheet Metal Wrinkling

Wrinkling is one of the most common and difficult obstacles in sheet metal forming. Wrinkling is a plastic buckling process in which the wavelength of the mode in one direction is very short [20]. The mode is based on the local curvatures and thicknesses of the metal sheet, as well as the material properties and the stresses on the area. Wrinkling can be related to certain shell buckling modes and can be useful in predicting and understanding wrinkling.

1.2.1 Plastic Bifurcation Theory

One theory that is used for wrinkling theory is the plastic bifurcation theory for thin plates and shells. In order for this theory to be applied, there are a few assumptions
that are assumed; the metal sheet is assumed to be isentropic in the unstressed state and uniform over the region where there is a uniform thickness throughout the sheet [20].

According to the theory and shallow shell approximations, buckling from the uniform membrane gives incremental stretching ($\dot{E}_{\alpha\beta}$) and bending strains ($\dot{K}_{\alpha\beta}$) [21].

$$\dot{E}_{\alpha\beta} = \frac{1}{2} (\dot{U}_{\alpha\beta} \ast \ddot{U}_{\alpha\beta}) + b_{\alpha\beta} \dot{W}$$  \hfill (1-1)

$$\dot{K}_{\alpha\beta} = -\dot{W}_{\alpha\beta}$$  \hfill (1-2)

Where $\dot{U}_{\alpha}$ ($\alpha, \beta = 1,2$) are the incremental displacements in the $X_1$ and $X_2$ directions, $\dot{W}$ is the incremental buckling displacement normal to the middle surface of the metal sheet, and $b_{\alpha\beta}$ is the curvature tensor of the middle surface [21]. From Equations (1-1) and (1-2) above, the stretching and bending strains result in causing stress resultants $\dot{N}_{\alpha\beta}$ and bending moments $\dot{M}_{\alpha\beta}$.

$$\dot{N}_{\alpha\beta} = t\bar{L}^{-\alpha\beta\kappa\gamma} \dot{k}_{\kappa\gamma} \dot{E}_{\kappa\gamma}$$  \hfill (1-3)

$$\dot{M}_{\alpha\beta} = \frac{t^3}{12} \bar{L}^{-\alpha\beta\kappa\gamma} \dot{k}_{\kappa\gamma}$$  \hfill (1-4)

Where $t$ is the metal sheet thickness and $\bar{L}$ is the plane stress incremental moduli [22].

Now that the stress resultants and moments are determined, the critical stress state for buckling equation is calculated using the bifurcation functional theory:

$$F(\dot{U}, \dot{W}) = \int \left[ \frac{t^3}{12} \bar{L}^{\alpha\beta\kappa\gamma} \dot{k}_{\alpha\beta} \dot{k}_{\kappa\gamma} + t\bar{L}^{\alpha\beta\kappa\gamma} \dot{E}_{\alpha\beta} \dot{E}_{\kappa\gamma} + N^{\alpha\beta} \dot{W}_{\alpha} \dot{W}_{\beta} \right] ds$$  \hfill (1-5)

In Equation (1-5), $S$ is the area of the metal sheet middle surface where the wrinkles occur. When $F > 0$ for all $\dot{U}, \dot{W}$ warrants that bifurcation will not occur and when $F=0$ bifurcation is possible [23]. Using Equations (1-1)-(1-5) from the plastic bifurcation theory, it is a reliable method for relating the metal sheet geometry and material properties to determine the formation of wrinkling on a metal sheet surface.
1.2.2 Donnell-Mushtari-Vlasov Theory

The Donnell-Mushtari-Vlasov theory is another wrinkling concept based on the plastic buckling and shallow shell theory [20]. The DMV theory uses the Hutchinson bifurcation functional that involves substituting fields that represent wrinkling into the functional. When assuming incompressibility and pre-wrinkling loading is proportional, then the theory can be used to model the material behavior. Using the power law hardening relationship, the first principal direction reduces to:

$$\sigma_1^{cr} = K \left[ \frac{\sqrt{3(1+2r)}}{\sqrt{n}} \right] \left[ \frac{1+r}{R_2} \right] \left[ \frac{\sqrt{n} \alpha_1}{n} \right]$$

(1-6)

$$\gamma_1^{cr} = \frac{2\sqrt{3n}}{1+r} \frac{\left[ 1 + \frac{2r}{1+r} + \alpha_1^2 \right]}{\alpha_1}$$

(1-7)

Where $R_2$ is the radius of curvature in the second principal direction, $K$ is a constant, $n$ is related to the number of values, and $r$ is the average Lankford strain ratio [25].

$$\alpha_1 = \left[ 1 - \frac{2r}{1+r} + \alpha_1^2 \right]^{\frac{1}{2}}$$

(1-8)

$\alpha_1$ is the proportionality factor of the principal stress in the second direction over the principal stress over the first direction [25].

$$f_\sigma = \frac{\alpha_1}{\sigma_1^{cr}}$$

(1-9)

When the wrinkling risk factor $f_\sigma$ is greater than 1, a wrinkling risk exists on the material surface.
Figure 1-15: Possible wrinkling directions

Figure 1-15 above shows the different combinations in which wrinkling can occur. As stated in the DMV theory, the wrinkling depends on the orientations of the principal stresses on either side of the metal mesh that are analyzed [21]. The Donnell-Mushtari-Vlasov theory is used highly in the finite element analysis software because the theory demonstrates the use of adaptive meshes in the material for wrinkling prediction analysis.

1.2.3 Finite Element Analysis

As the metal sheet thickness becomes thinner and thinner, the more prominent the issue of wrinkling becomes. A study was done by the Netherlands Institute for Metals Research where they analyze wrinkling theory [13]. From their research, they showed that the issue of wrinkling theory is larger than the geometries they have studied. However, with using finite element analysis (FEA) software and finite element method
(FEM) calculations, wrinkling assumptions can be shown. In another journal, engineers analyzed a flat metal sheet being pulled by an advancing roll using FEA software [14].

![Figure 1-17: Metal sheet being pulled over the tapered roll](image)

FEA uses its adaptive mesh to help determine the location and details of the wrinkles on the metal part it is analyzing [24]. In this study, a metal sheet was analyzed as it passed through a continuous processing line. Within the process the flat metal strip was run over a tapered roll under tension, shown in Figure 1-16 and analyzed using FEA [14].

In Figure 1-17 above, as the metal sheet gets past the taper on the tensioning

![Figure 1-18: Simulation of forming a wrinkle](image)
roll, it causes much stress in the metal sheet. When the tensioning roll pulls the sheet, it creates a compression region 90 degrees from the maximum tension location [14]. This compression region in the metal sheet causes it to form a bubble. When bubbles get large enough, a wrinkle will form. From the findings in Figure 1-17, they simulated the formation of a wrinkle using FEA, Figure 1-18. This figure shows the metal sheet contacting the roll in three different locations, ultimately forming a wrinkle [14]. Figure 1-19 shows a 3-D visual of the formed simulated wrinkle from the trial.

Comparing the findings of the study with the pinch rollers that are installed on the Hammond, IN coil coating line, some of the same issues exist. When the metal sheet is not fed into the pinch rolls straight, the roll acts as if it is a tapered roll such as the one found in the study. If the metal sheet is not fed into the pinch rollers straight, a compression region forms within the sheet, forming the bubble. The further misaligned the metal sheet is, the larger the compression region is and the bigger the bubble will be which then ultimately forms the start of the wrinkle in the sheet. From what was analyzed in this study, connections are being created as to why the wrinkles are being formed. It was found that there must be a consistent tension on the metal sheet where no compression regions will form.
1.2.4 **Arc Roller**

Coil coating lines sometimes have an issue with feeding thin metal sheets over feed rollers throughout the coil coating line process. To reduce the wrinkling while the metal sheets are running over the rollers, a special roller design was invented. The rollers are called the Arcostretcher AV rollers [27]. The specially designed rolls are bowed in the middle of the roll in order to keep the metal sheet stretched over the top. This allows the top of the metal sheet to always be in tension and the bottom side of the sheet to always be in compression [27]. If the metal sheet changes from tension to compression or vice versa, this is when wrinkling occurs. Many coil lines have gone forward in using these bowed rolls because it eliminates any potential for wrinkling to occur where a normal roller still has the potential.

**Figure 1-20:** Arcostretcher AV bowed roller
CHAPTER 2: Understanding the Issues

With any problem, there is a reason why the problem has occurred. For the in-feed conveyor at Hammond, there are numerous predictions and assumptions as to why the metal is not being fed into the pinch rollers straight.

2.1 Analyzing the Problems

One of the first issues that the current conveyor design has is that it was not designed for light gauge metal. Silgan is always looking for ways to make a better lightweight and cheaper cost can for the customer. Since technology and Silgan’s expertise has grown in the can-making field, they are able to make cans out of lighter gauge metal. In the past, Silgan’s lightest gauge metal was 80 gauge and today the lightest gauge is 55 gauge metal [1].

One of the first issues is how the sheet is fed up the conveyor. If the metal sheet is not heavy enough, the conveyor will not be able to pull the metal sheet up until the sheet is halfway up the belt. With heavier gauge metal, the plate weight will cause the metal sheet to hit the conveyor sooner, which will convey the metal sheet up straight to the pinch rollers. When operators are running the lighter gauge metal up the conveyor, it either buckles, causing it to fall back down the conveyor, or it veers off to the right side of the conveyor.

Another issue with the current conveyor are the magnets behind the rubber conveyor belt. As shown in Figure 2-21, there are two magnetic strips 1” x 18.5” long behind the rubber conveyor belt. When testing the magnetism on the magnets by placing a 4” x 4” 105 gauge and 55 gauge metal sample over the magnets, the samples barely
held any attraction at all. Since both samples had the same magnetic attraction toward the magnets, this does not explain why the heavier gauge metal goes up the conveyor fine, but not the lighter gauge metal.

When looking at all the times the metal sheet would feed up crooked to the pinch rollers, 90% of the time it went crooked to the right side [32]. When the back side of the conveyor was inspected, another issue was found. When the conveyor sets the angle up to the five-foot metal roll, there is only one hydraulic cylinder supporting the conveyor angle position on the left (operator) side. When the angle is set and the dead plate is extended, the conveyor has an enormous moment of inertia hanging out. A test was performed when the angle on the conveyor was in position up to the five-foot metal roll and either side of the conveyor was measured from the corner to the ground. The test showed that the conveyor sagged 9/16\textsuperscript{th} of an inch lower on the side that did not have the hydraulic cylinder (motor side) on it. This is why whenever the metal sheet went up crooked, it veered off to the right side of the conveyor and not the left.
2.2 Safety Hazards

Ultimately, if the metal sheet does not feed into the pinch rolls with a ± 1” tolerance, it will create unwanted stresses in the metal sheet and cause wrinkling. Once the wrinkle has started, it causes a crease until the sheet moves within the tolerance. When the metal sheet crinkles 10 to 20 feet, it takes extra time for the operator to prepare the roll for coating. When the sheet crinkles, the operator has two options. One is to use the hydraulic sheer at the top of the line to cut the damaged sheet into one foot sections or two, reverse the pinch rolls, cut off the damaged sheet by hand, and then feed the sheet back up again. Since both of these options take extra time on the operators behalf, operators have been using a ladder to place the metal sheet in the pinch rolls instead of using the conveyor. To do this, operators take the end of the metal sheet, climb up the ten-foot ladder, and place the sheet into the pinch rollers straight. This is a big safety hazard for three reasons: One; the operators are climbing up a ten-foot ladder while handling an awkward three-foot wide heavy metal sheet, which creates a risk of falling off the ladder. Two; the edges of the metal sheet are thin and act like razor blades when objects are run along the edges. Operators are required to wear gloves whenever handling the metal sheets, but if an operator would fall off the ladder, gloves or clothing would still not provide adequate protection from the metal sheet edge. Three; the operators could get his or her hand or shirt caught in the pinch rollers. Before the operator climbs up the ladder with the metal sheet, he or she turns the pinch rollers on so they are always turning. If the operator leans over or loses his or her balance, he or she could easily get their shirt or hand caught in the pinch rollers. Another point is that while the operator is on the top of the ladder, the on and off switch for the pinch rollers are on
the ground. So, if he or she did get caught in the pinch rollers, there would be no way for the operator to turn the rollers off.

Another safety risk involved for operators is when the metal sheet wrinkles in the pinch rollers and the operator has to back the sheet out of the pinch rollers. When operators do this most of the time the sheet buckles and falls back down the conveyor. With ten feet of metal sheet falling back down the conveyor, it could fall in any direction putting the operators at risk. With the sheets as sharp as they are, if the operators are in the wrong place at the wrong time, then an accident could occur.
CHAPTER 3: Conceptual Design

After reviewing the issues that the plant currently faces, a conceptual design was created. Since the metal sheet is not heavy enough for the conveyor to pull it up until it is halfway up the conveyor, the proposed design uses contact rollers. The metal sheet advances straight up at the beginning of the conveyor when it comes off the roll, so if there is no chance for the metal sheet to float or shift over then the alignment issue would be solved. Therefore, with rollers installed at the beginning of the conveyor, the sheet will remain straight and the conveyor will convey it up to the pinch rollers. A 3-D model was created using Inventor for the concept. It uses three roller bars to distribute the force on the metal sheet equally, 2- 80/20 bars, and mounting plates to allow it to be clamped to the sides of the conveyor.

Figure 3-22: Roller 3-D model concept design
3.1 Conceptual Design Calculations

Since three roller bars were used to distribute the load on the metal sheet, the bars needed to be evenly spaced and avoid the conveyor belt holes. If the rollers were mounted over the conveyor holes, the rollers could cause the metal sheet to warp as the sheet goes underneath the rollers, therefore the roller spacing $R_S$ was calculated:

$$R_S = L_c - A \times 2$$  \hspace{1cm} (3-10)

Where $L_c$ is the conveyor length and $A$ is the hole distance. For this conveyor system, $L_c = 33.25\, \text{in}$ and $A = 3.5\, \text{in}$.

$$R_S = 33.25\, \text{in} - 3.5\, \text{in} \times 2 = 26.25\, \text{in}$$

From Equation (3-10) it was determined to place the rollers 1.5 inches inside the conveyor belt on either side, and the third roller bar was directly placed in the center.

In addition to placement, the pressure applied to the metal sheet was also determined to be 20 psi. This allows for the sheet to have enough force to contact the belt, but it is not enough force to damage the sheet.

After collecting information from the operators, supervisors, and equipment at Hammond, the conceptual design was built to be trialed. The trial occurred February 9th, 2012 while the coil line was down for cleaning and maintenance.

3.2 Prototype Test

During the trial, numerous tests were performed to test the current conveyor system and the prototype concept system. The first tests were solely with the current system, where the metal sheet was fed up to the pinch rolls and back down five times. A scrap roll of 55-pound plate with a diameter of 35 inches was used for the test. The first
three times the metal sheet was fed up normally, with the five-foot roll coiled perfectly straight. Out of those three times, two of them went into the pinch rolls crooked, at 1-2” outside of the pinch roll tolerance zone. The next two times, the top two layers on the five-foot roll were offset 0.5” to either side of the roll and then fed up the conveyor. When the roll was offset to the left (operator side), the roll went into the pinch roller straight. The reasoning for this is because the left side is higher, due to the hydraulic cylinder support located on that side. When the roll was offset to the right (motor) side, the sheet was fed into the pinch rollers crooked at ≈ 2” outside the pinch roller tolerance.

After the five trials were run on the current conveyor system, the prototype roller design was put on the conveyor. Describing the roller prototype from Figure 3-23, there are three rollers mounted on an 80/20 frame that is meant to sandwich the metal sheet between the rubber conveyor and the rollers. The prediction for the rollers are to allow for the conveyor to grip the metal sheet sooner and to help keep the metal sheet aligned straight. Otherwise if the sheet is misaligned the rollers are predicted to help re-align the sheet as it gets fed up to the pinch rollers.

![Figure 3-23: Roller design](image-url)
The 80/20 frame for the design was clamped to the conveyor sides for the test. The dead plate extension for the conveyor had to remain extended due to the clamps that were mounted on the sides for the test. The rollers were mounted so they were in direct contact with the rubber conveyor belt. Figure 3-24 above shows the roller design mounted on the conveyor.

The 55-gauge metal sheet was run up the conveyor to test the roller design five times. During the first run, the metal sheet was solely fed up the conveyor to see how it would work, and there were no issues at all. The sheet was fed up and was sandwiched in between the conveyor belt and the rollers, which brought the metal sheet up straight to the pinch rollers. The second run was performed the same way, but this time the mandrel speed was increased which fed up the metal sheet faster. As a result, the metal sheet hit the end of the roller bracket instead of sliding underneath the roller. During the last three runs, the metal sheet was purposely offset to the right side to see if the rollers would help re-align the sheet. During the third run which was offset 0.5”, the sheet fed up and re-aligned itself. During fourth run, when fed up the sheet re-aligned itself to be just within

Figure 3-24: Prototype roller design mounted for testing
the pinch roll tolerance, but did not re-align perfectly. During last run, the top three layers of metal sheet on the coil were offset 0.75” to the motor side. When feeding up the metal sheet, the sheet began re-aligning itself; however because it wasn’t perfect, the coil was stopped and backed down the conveyor and then fed back up again and the metal sheet was then re-aligned straight into the pinch rollers. The rollers supplied pressure between the conveyor and the metal sheet, which allowed the sheet to reverse and go back down in order to re-align straight.

| Prototype Testing |
|-------------------|------------|
|                   | Trial | Description | Straight | Misaligned |
| Current System    |       |             |          |            |
| 1                 | Fed Straight | X         |          |
| 2                 | Fed Straight | X         |          |
| 3                 | Fed Straight | X         |          |
| 4                 | 0.5” Left Offset | X |          |
| 5                 | 0.5” Right Offset | X |          |
| Prototype         |       |             |          |            |
| 1                 | Fed Straight | X         |          |
| 2                 | Fed Straight | X         |          |
| 3                 | 0.5” Right Offset | X |          |
| 4                 | 0.5” Right Offset | X |          |
| 5                 | 0.75” Right Offset | X Reversed |          |

Table 3-1: Prototype testing results

When analyzing Table 3-1 for the prototype test, the results show that the roller system will help and provide pressure to keep the metal sheet feeding straight and to help in correcting misalignment issues. The rollers allowed the metal sheet to make contact with the belt sooner, which allowed the sheet to be fed up the conveyor more quickly. The

Figure 3-25: Roll hold down unit
pressure that was applied to the metal sheet prevented the sheet from feeding up crookedly. Because the rollers provide down pressure against the conveyor, the hold down unit shown in Figure 3-25, which holds the 5 foot rolls on the mandrel, was able to be lifted off the roll without the metal sheet sliding down the conveyor. This allows more flexibility if the operator needs to reverse the coil to re-align the metal sheet.

3.3 Trial Recommendations

After the prototype design was tested, some recommendations for the final design proposed solution were established:

- Implement the roller design onto the conveyor belt to help adjust for mis-alignment.
- Mount gradual bars on the rollers to ensure that the metal sheet is fed under the rollers and not over them.
- Mount the roller design on the framework above the conveyor system. The sides

Figure 3-26: Frame work where roller design will be mounted
of the conveyor are too cluttered and have limited mounting space available.

- Use pneumatic cylinders to raise and lower the rollers from the top framework to the conveyor belt surface. This will allow for the conveyor to be placed at different angles.

- Install a second hydraulic cylinder on the left (motor) side to eliminate conveyor offset. Currently there is only one hydraulic cylinder on one side of the conveyor. When a measurement was taken on each side, the conveyor was sloping down by 9/16” on the side with no hydraulic cylinder. This could be a cause to the metal sheet shifting off to one side when fed up the conveyor.

![Figure 3-27: Back side of the conveyor](image)

- All of the recommendations listed will be implemented on the final design. The prototype test and trial was proved to be successful and helpful in the process of moving forward to the final design.
CHAPTER 4: Proposed Solution

4.1 Design

The proposed design will be based off of the knowledge gained from the operators, supervisors, and the prototype test, please refer to Figure 4-28 above. As recommended from the prototype test, the sides of the conveyor are too cluttered and there is not enough room for the roller system. Also, once the metal sheet is fed into the pinch rollers, the roller system needs to be able to retract so it is not touching the metal sheet. Therefore, the proposed solution is going to be fixed to the existing upper metal framework above the conveyor. The roller system will use the same three roller bars
used for the prototype. The framework that will hold the roller bars will be constructed with 80/20 because of its ease of assembly, strength, and lightweight material. The system will be pivoting from the front and middle back, where pillow block bearings will be used for a smooth fluid motion. There are two pneumatic cylinders mounted on the back of the roller system to lift and lower the roller design to and from the conveyor. The rollers will be free-floating because the system is on a pivot. This is to allow the rollers to adjust to any angle the conveyor will be set at. The rollers will be set off balance so the weight of the rollers will cause the roller frame to hit rubber stops and always be in the right orientation. The system will be controlled by a dual pressure regulator and Mac valve that will allow 70 psi to raise the system and 20 psi to lower the system. There will be a proximity sensor and a pressure sensor incorporated into the system to ensure that the roller design remains in the home position, and to make sure that the right pressure is applied to the conveyor at all times. The operator will only have two extra buttons then they currently have to raise and lower the rollers. Figure 4-29 shows the final roller design.

Figure 4-29: Roller design
The second part of the proposed design will be to add a second hydraulic cylinder to the right side of the existing conveyor (refer to Figure 4-30 below). To fix the offset of the conveyor, an identical hydraulic cylinder will be purchased and mounted to the right (motor) side of the conveyor. A custom bracket was designed to fit onto the right side of the conveyor without hitting the existing hydraulic motor. The bracket does restrict the dead plate from coming up as far as it does by 2.75 inches. As a result of this, the home proximity sensor for the dead plate needs to be lowered by 2.75 inches as well. Two additional custom cylinder mounting brackets were designed to ensure that the hydraulic cylinders are at the same location and because of existing space restrictions on the right side. The additional hydraulic cylinder will tee off of the existing hydraulic cylinder, causing no extra buttons for the operator.

Figure 4-30: Adding the rear bracket, hydraulic cylinder and front bracket to the conveyor
4.2 Calculations

Throughout the design process, a few calculations had to be performed to ensure that the right parts were purchased for the roller design. The first set of calculations were performed to determine the proper pneumatic cylinder diameter. The roller design is cantilevered from the framework. Therefore, the moments were calculated to determine and make sure that the pneumatic cylinders would be able to raise and lower the design with the 100 psi plant air supply. The maximum bending moment $M_A$ exerted by the rollers:

\[
\sum M_A = F \times D
\]

Where $F$ is the force in pounds and $D$ is the distance in inches from the center of gravity to the cantilever point. Using the 3D modeling software inventor that the design was drawn up on, an estimated weight for the roller system was determined to be 51.85lbs which was used as the force $F$. Also using Inventor, the center of gravity where the force acts from on the design was found to be 32.08 inches from the pivot point which was used as distance $D$. When the roller design is in the up position, this will be where the design has the largest bending moment and greatest force that the pneumatic cylinders will have to overcome.

\[
\sum M_A = (51.853 \text{ lbs}) \times (32.08 \text{ in}) = 1663.44 \text{ in} - \text{lbs}
\]
For determining what diameter of cylinder required for operation, both a 1-1/2” and 2” cylinder was used.

<table>
<thead>
<tr>
<th>Bimba Pneumatic Cylinder Specs</th>
</tr>
</thead>
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<tr>
<td></td>
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<tr>
<td>1-1/2”</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>2”</td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

*Table 4-2: 1-1/2” and 2” Bimba pneumatic cylinder specifications*

Now knowing the maximum force that the pneumatic cylinders have to overcome, the equation is worked backwards using the cylinder mount distance from the end of roller system as \( D = 24.284 \) inches instead of using the center of gravity distance to find the force \( F_y \) in the vertical direction. Equation (4-12) is also multiplied by 2 because there are two cylinders that will raise the rollers assembly.

\[
\sum M_A = F_y \cdot D \cdot 2
\]

\[
\sum M_A = 1663.44 \text{ in} - \text{lbs} = (F_y) \cdot (24.284 \text{ in}) \cdot 2
\]

\[F_y = 34.24 \text{ in} - \text{lbs}\]

The roller design will not be raised as high where the 80/20 frame is horizontal with the floor. Using Inventor, the angle \( \theta \) was measured from horizontal to the 80/20 frame which was 17.26° to determine the cylinder lifting force \( F \).

\[F_y = F \cdot \sin(\theta) \]

\[34.24 \text{ in} - \text{lbs} = F \cdot \sin(17.26^\circ)\]

\[F = 115.43 \text{ lbf} \rightarrow 0.51346 \text{ KN}\]

Using the required force \( F \) needed and the Bimba pneumatic cylinder diameters \( D_1 \) and \( D_2 \) (from Table 4-2), the air pressure \( P \) required to lift the roller design can be solved for:
1-1/2” Cylinder:

\[ F = P \cdot A \]  \hspace{1cm} (4-14)

\[ F = P \cdot \frac{\pi}{4} (D_1^2 - D_2^2) \]  \hspace{1cm} (4-15)

\[ 0.51346 \text{ KN} = P \cdot \frac{\pi}{4} \left[ (0.03830 \text{ m})^2 - (0.01110 \text{ m})^2 \right] \]

\[ P = 486.53 \text{ kpa} \to 71 \text{ psi} \]

2” Cylinder:

Using Equations (4-14) and (4-15) for the 2” cylinder results:

\[ 0.51346 \text{ KN} = P \cdot \frac{\pi}{4} \left[ (0.05105 \text{ m})^2 - (0.01588 \text{ m})^2 \right] \]

\[ P = 277.66 \text{ kpa} \to 41 \text{ psi} \]

The calculations show that both the 1-1/2” and 2” diameter cylinders will work for the roller design. The 1-1/2” diameter pneumatic cylinders were chosen for the design because they are smaller, cheaper, and will be able to operate with no issues using the supplied 100 psi plant air. The pressure required to lower the roller design does not have an impact on the cylinder selection because it does not require as much force as raising the roller design requires.

Another calculation performed was to determine the force for the hydraulic cylinder brackets. The same hydraulic cylinder that is currently being used will be the same make and model for the cylinder that will be added to the motor side of the conveyor. Since one cylinder operates the conveyor with no issues, calculations do not have to be made for adding the second. However, calculations were performed to determine the strength of the rear bracket for the hydraulic cylinder. For the calculation,
the maximum hydraulic pressure that the Parker cylinder can accept is found to be 3,000 psi [8]. From this, a simple calculation was used to determine the area of the cylinder to define the maximum force $F_{Max}$ that the cylinder can exert on the rear hydraulic bracket:

$$A = \frac{\pi}{4} (D_1^2)$$  \hspace{1cm} (4-16)

$$A = \frac{\pi}{4} (2.0^2 \text{ in}) = 3.14 \text{ in}^2$$

$$F_{Max} = 3.14 \text{ in}^2 \times \frac{3,000 \text{ lbs}}{\text{in}^2} = 9,424 \text{ lbs}$$

Since the maximum force will occur when the cylinder is pushing, the cylinder rod does not have to be accounted for when calculating the area. After calculating the maximum force that the hydraulic cylinder can produce, the rear hydraulic bracket was analyzed using FEA analysis using the maximum force found. For the analysis, 9,500 lbs was used for the maximum force.

Figure 4-32: Free body diagram of the rear hydraulic cylinder bracket
After running the program through the Abaquis package, Figure 4-33 shows the results.

The analysis shows that the maximum stress point is at the corner of the bracket yielding a maximum stress of 35 ksi. The rear hydraulic bracket is being made with ASTM A572 steel, which has a maximum yield stress of 50 ksi. The FEA analysis shows that the rear bracket is well below the material yield stress; therefore, no permanent deformation will occur when using the hydraulic cylinder.

4.3 Timing Sequence

The timing sequence below shows the sequence in which the operator will need to operate the system. The system will be programmed this way for safety reasons and to ensure that the metal sheet will not get damaged when starting or retracting the conveyor and roller system.
Starting a New Roll:

1. Place roll on the mandrel
2. Set the angle of the feed conveyor
   - There is a proximity switch that controls when the conveyor is in the home (vertical down position)
3. Extend the dead plate of the feed conveyor to the roll outer diameter
   - Another proximity switch makes sure the dead plate is in the home (all the way up position)
   - The angle of the conveyor, sequence #2, cannot be adjusted unless the dead plate is in the home position
4. Lower the rollers to the conveyor surface
   - A proximity sensor controls the home position (up) for the rollers
   - A pressure sensor monitors the down pressure on the conveyor surface to be in a range from 20 to 40 psi
5. Start the conveyor belt
6. Start the pinch rollers
7. Feed the roll up using the mandrel

Once the System is Running:

1. Raise the rollers until the system hits the shut-off home proximity switch
2. Retract the dead plate to the home proximity switch
3. Lower the conveyor table in the vertical home position
4.4 Parts List

All of the parts for the roller design and the addition of the second hydraulic cylinder are listed in Appendix A.

The coil line assembly parts list from Table A-3 are the parts for the upper assembly. The upper assembly parts are mainly for adding the second hydraulic cylinder to the existing conveyor. This includes the new hydraulic cylinder brackets, the hydraulic cylinder, and all the necessary hardware.

The coil line feeder assembly parts list from Table A-4 are the parts for the roller assembly. All of the parts listed are for the complete package for the installation of the mechanical components for the roller design.

The coil line electrical components found in Table A-5 are the electrical components for the roller assembly. There are no electrical components for the upper assembly. The electrical components are everything that will control the roller system and will allow it to function.

4.5 Final Design

After finishing the design work for the proposed solution, the project was presented to the supervisors, operators, and plant managers at the Hammond, IN plant. The design was presented and an explanation was provided as to how this would solve the issues at the plant. After asking a few questions and further understanding a few more things for the design in more detail, the plant personnel approved the roller design. After the roller design was approved, the proposed solution could go into the final design stage. During the final design stage, the parts are detailed on drawings in order to be
made, manufactured, and assembled. Once the parts were detailed, the entire design was reviewed by another equipment engineer. The finished drawings were then sent to the plant services department, where the entire project was sent out to be quoted for the parts, labor, and assembly of the roller design. When the quotes were received, a project engineer wrote up the project and the capital money was requested from the company. The final design has now gone through the approval stage, during which the upper managers, plant managers, and accounting department review and sign off on the project. The design package was ordered the week of October 22, 2012 through NEFF Engineering. All parts will be ordered and the entire assembly will be assembled at NEFF Engineering. Once NEFF starts on the order, there is a six-week lead time for acquiring the parts and finishing the build.
5.1 Installation

As aforementioned in section 4.5, this project has a six-week lead time to be completed once the order is sent into NEFF Engineering. The roller design will come fully assembled, but not for the addition of the second hydraulic cylinder. Before the rollers and the second hydraulic cylinder can be installed, some work needs to be done.

For the roller design, there are a few things that have to be moved or modified on the existing framework in order for the system to be installed. The first thing is a guarding bracket that is mounted to where the roller pillow block must be mounted. The guarding bracket needs to be cut off on the bottom side, and the rest of the bracket will remain welded to the framework. This will allow enough room for the pillow block to be installed.

![Figure 5-34: The bracing on the motor side needs to be lowered; cylinder mounting bracket needs to be ground off and welded to match the motor side](image-url)
In order to add the second hydraulic cylinder, three modifications must occur. First, the existing cross-bracing on the back side of the conveyor needs to be lowered on the motor side where the new cylinder will be going. The bracing needs to be lowered to the same height as the bracing on the existing cylinder side. Second, the dead plate sensor needs to be moved down on the front side of the conveyor. With the custom hydraulic cylinder bracket being installed around the conveyor motor, the dead plate will not be able to retract as far as it currently does. Therefore, the sensor must be moved 2.75 inches down from its current location, (See Figure 5-35). The third modification required for the installation of the second hydraulic cylinder is to modify the existing hydraulic mounting bracket. The cylinder mounting bracket will be ground off, and a new bracket will be welded in place to match the exact location of the new mounting bracket for the new hydraulic cylinder.

After these modifications are performed, the two components can be installed. The roller system requires ten bolts to be fastened to the existing framework, the plant air to be hooked up to the valve, and the electrical switch to be hooked up. After the roller
system is installed, there will need to be adjustments to the regulator and roller position. The home position sensor also needs to be fastened to the existing framework with two bolts, and then be wired into the system logic and adjusted for exact positioning. To install the second hydraulic cylinder, some more work has to be performed. For the cylinder bracket, four 1” holes need to be drilled through the conveyor side to mount the bracket. Then, the new rear bracket needs to be aligned and welded into place. The existing side rear cylinder bracket needs to be modified as aforementioned. The existing cylinder hydraulic lines need to be teed off, and then hooked up to the new cylinder.

5.2 Summary of Design

The roller system was designed as a simple system that will fix the problems that the plant is having. The design utilizes 80/20 parts which are lightweight, easy to use, and easy to adjust. In using the 80/20 components, almost the entire system is adjustable, which is great for dialing in the process so the problem can be resolved. The design uses a dual regulator with a three-position valve. The dual regulators allow two different pressures to be used for the raising pressure and lowering pressure. This helps the system work well by allowing the capability for it to adjust if more pressure or less pressure is needed for the down force. The three-position valve is a great built-in safety system because every time the air pressure is off, the valve goes into the center safe position. This allows no air to leave or enter the valve, which keeps the rollers stationary even if the plant air were to shut off. This prevents the roller system from crashing down if the cylinders lose air pressure or break an airline. The design also had bearings and slip bushings for ease of motion and to prevent wear from occurring. The last key to the
The design that was incorporated was the place it was mounted. Since it is being mounted on the upper existing framework, the rollers when in the home position are completely out of the way. Mounting the rollers on top allows for the rollers to be out of the way of the coating process when the line is running.

The design for adding the second hydraulic cylinder was copied from what existed. The current cylinder has been working for years; therefore, the same design was copied as closely as possible for the other side. Because of the conveyor motor, the bracket was lowered, causing a custom front and rear bracket to be made. Other than the custom brackets, the design for the second cylinder includes the same Parker cylinder that exists on the current design and getting the front and rear bracket locations to line up with either side of the conveyor.

5.3 Future Work

After the complete cylinder and roller package is installed at the Hammond, IN coil coating line, the problems that the plant was having will hopefully be solved. Though this is the only continuous roll coil coating line in the Silgan Containers Company, Silgan utilizes thousands of conveyors, tracks, coil cutting and coil punching lines throughout all of their plants. From the research found, there are similar coil line set-ups that will be able to benefit from the roller design and research gathered. Therefore, looking toward the future, the roller design could be used to help metal sheet to be conveyed, eliminating damage and safety issues with the final product.
REFERENCES


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### Appendix A: Parts List

#### Coil Line Upper Assembly Parts List

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<th>Item #</th>
<th>Description</th>
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<td>5/16&quot;-18 Hex Nut</td>
<td>80/20</td>
<td></td>
<td>15</td>
</tr>
<tr>
<td>2</td>
<td>1&quot;-8 X 1-3/4&quot; Hex Screw</td>
<td>80/20</td>
<td></td>
<td>16</td>
</tr>
<tr>
<td>2</td>
<td>1&quot;-8 X 2-3/4&quot; Hex Screw</td>
<td>80/20</td>
<td></td>
<td>17</td>
</tr>
<tr>
<td>2</td>
<td>1&quot;-8 Hex Nut</td>
<td>80/20</td>
<td></td>
<td>18</td>
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</table>

Table A-3: Coil line upper assembly parts list

#### Coil Line Feeder Assembly Parts List

<table>
<thead>
<tr>
<th>Item #</th>
<th>Description</th>
<th>Vendor</th>
<th>Part #</th>
<th>Qty</th>
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<tr>
<td>3</td>
<td>Roller Bar 4 Meter</td>
<td>Quixx Smart</td>
<td>A4MS</td>
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<td>3</td>
<td>Feed Bar, In-Feed</td>
<td>Custom</td>
<td>6CL58190</td>
<td>2</td>
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<td>2</td>
<td>Mounting Bracket, Cylinder</td>
<td>Custom</td>
<td>6CL58191</td>
<td>3</td>
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<tr>
<td>2</td>
<td>Mounting Plate, Air Cylinder</td>
<td>Custom</td>
<td>6CL58192</td>
<td>4</td>
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<tr>
<td>1</td>
<td>Base Plate, Valve</td>
<td>Custom</td>
<td>6CL58106</td>
<td>5</td>
</tr>
<tr>
<td>2</td>
<td>8 Hole Inside Corner Bracket</td>
<td>80/20</td>
<td>4513</td>
<td>6</td>
</tr>
<tr>
<td>1</td>
<td>T-Slotted Profile, 1530 Lite X 65&quot;</td>
<td>80/20</td>
<td>1530 LITE X 65</td>
<td>7</td>
</tr>
<tr>
<td>2</td>
<td>T-Slotted Profile, 1515 Lite X 44.25&quot;</td>
<td>80/20</td>
<td>1515 LITE X 44.25</td>
<td>8</td>
</tr>
<tr>
<td>2</td>
<td>T-Slotted Profile, 1515 Lite X 42.00&quot;</td>
<td>80/20</td>
<td>1515 LITE X 42.00</td>
<td>9</td>
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<tr>
<td>2</td>
<td>T-Slotted Profile, 1515 Lite X 33.25&quot;</td>
<td>80/20</td>
<td>1515 LITE X 33.25</td>
<td>10</td>
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<td>1</td>
<td>T-Slotted Profile, 1515 Lite X 33.00&quot;</td>
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<td>1515 LITE X 33.00</td>
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<td>1</td>
<td>Ground Polished Steel Tube, 1515 Tube X 72&quot;</td>
<td>80/20</td>
<td>5015 TUBE X 72</td>
<td>12</td>
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<tr>
<td>1</td>
<td>Ground Polished Steel Tube, 1515</td>
<td>80/20</td>
<td>5015 TUBE X 48</td>
<td>13</td>
</tr>
<tr>
<td>Item</td>
<td>Description</td>
<td>Brand</td>
<td>Model/Part Number</td>
<td>Page</td>
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<td>-------------------</td>
<td>------</td>
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<tr>
<td>1</td>
<td>TUBE X 48&quot;</td>
<td>McMaster</td>
<td>3730T28</td>
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<tr>
<td>2</td>
<td>1-1/2&quot; Food Grade Sealed Ball Bearing</td>
<td>McMaster</td>
<td>6391K172</td>
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<td>2</td>
<td>Lubricated Sleeve Bearing, 1/2&quot;OD, 3/8&quot;ID, 3/8&quot;Length</td>
<td>McMaster</td>
<td>C-1716-DPW-D-229-F-D-231-1-2-14A-15</td>
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<tr>
<td>2</td>
<td>Air Cylinder, 1-1/2&quot; Bore X 16&quot; Stroke</td>
<td>Bimba</td>
<td>92B-JAF-BAA-DM-DDAP-1DM-9</td>
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<tr>
<td>1</td>
<td>MAC Valve With PR92C-KECA-9 Regulator</td>
<td>Neff Eng</td>
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<tr>
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<td>3/8&quot; OD Speed Control 1/4&quot; NPT</td>
<td>SMC</td>
<td>ASN2-N02-S</td>
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<td>&quot;T&quot; Tube Fitting 3/8&quot; OD</td>
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<td>KQ2T11-00</td>
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<td>4</td>
<td>Single Horizontal Base, 1-1/2&quot;</td>
<td>80/20</td>
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<td>Rubber Bumper, 1-1/2&quot;</td>
<td>80/20</td>
<td>2849</td>
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<td>6</td>
<td>5 Hole 90° Joining Plate</td>
<td>80/20</td>
<td>4351</td>
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<tr>
<td>20</td>
<td>Standard T-Nut</td>
<td>80/20</td>
<td>3203</td>
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<td>19</td>
<td>Double Economy T- Nuts</td>
<td>80/20</td>
<td>3279</td>
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<td>8</td>
<td>Triple Economy T- Nuts</td>
<td>80/20</td>
<td>3285</td>
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<td>8</td>
<td>1/4&quot;-20 X 5/8&quot; Bolt, SHCS</td>
<td>80/20</td>
<td>3067</td>
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<tr>
<td>12</td>
<td>5/16&quot;-18 X 1/2&quot; Bolt, SHCS</td>
<td>80/20</td>
<td>3106</td>
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<tr>
<td>44</td>
<td>5/16&quot;-18 UNC X 11/16&quot; Lg. Flngd, BHCS</td>
<td>80/20</td>
<td>3330</td>
<td></td>
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<tr>
<td>14</td>
<td>5/16&quot;-18 X 7/8, BHSCS</td>
<td>80/20</td>
<td>3119</td>
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<tr>
<td>12</td>
<td>5/16&quot;-18 X 1- 1/4&quot; Bolt</td>
<td>80/20</td>
<td>3123</td>
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<tr>
<td>2</td>
<td>#6-32 x 1-1/2&quot; Cap Screw</td>
<td>80/20</td>
<td>33</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>#6-32 Hex Nut</td>
<td>80/20</td>
<td>34</td>
<td></td>
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<tr>
<td>2</td>
<td>#6-32 Lock Washer</td>
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<td>35</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>1/4&quot;-20 x 1&quot; Hex Bolt - UNC</td>
<td>80/20</td>
<td>36</td>
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<tr>
<td>6</td>
<td>1/4&quot; Narrow-Flat Washer</td>
<td>80/20</td>
<td>37</td>
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<td>1/4&quot; Flat Washer</td>
<td>80/20</td>
<td>38</td>
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<td>14</td>
<td>1/4&quot; Lock Washer</td>
<td>80/20</td>
<td>39</td>
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<td>1/4&quot;-20 Hex Nut</td>
<td>80/20</td>
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<td>26</td>
<td>5/16&quot; Flat Washer</td>
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<td>4</td>
<td>1/2&quot;-13 x 1-3/4&quot; Hex Bolt - UNC</td>
<td>80/20</td>
<td>42</td>
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<td>1/2&quot; Flat Washer</td>
<td>80/20</td>
<td>43</td>
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</tr>
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</tr>
<tr>
<td>4</td>
<td>1/2&quot;-13 Hex Nut</td>
<td>80/20</td>
<td>45</td>
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<tr>
<td>1</td>
<td>3/8&quot; Air Lines, ~20'</td>
<td>80/20</td>
<td>46</td>
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<tr>
<td>1</td>
<td>3/8&quot; to 1/4&quot; Quick Fitting</td>
<td>SMC</td>
<td>KQ2H07-11A</td>
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<tr>
<td>1</td>
<td>1/4&quot; Quick Fitting to 1/8&quot; NPT Female Thread</td>
<td>SMC</td>
<td>KQ2F07-34A</td>
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<td>1</td>
<td>Pressure Switch Sensor</td>
<td>Honeywell</td>
<td>480-2041-ND</td>
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Table A-4: Coil line feeder assembly parts list

<table>
<thead>
<tr>
<th>Item #</th>
<th>Description</th>
<th>Vendor</th>
<th>Part #</th>
<th>Qty</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Push-Button, 30mm, blk, 1NO</td>
<td>Allen-Bradley</td>
<td>800T-A2D1</td>
<td>4</td>
</tr>
<tr>
<td>2</td>
<td>Selector Switch, blk, 1NO/1NC</td>
<td>Allen-Bradley</td>
<td>800T-H2A</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>Legend Plate, 30mm, UP</td>
<td>Allen-Bradley</td>
<td>800T-X556</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>Legend Plate, 30mm, DOWN</td>
<td>Allen-Bradley</td>
<td>800T-X503</td>
<td>1</td>
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<tr>
<td>5</td>
<td>Control Box, 12x14</td>
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<td></td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>Terminal Block, 2-pt Pass-Thru</td>
<td>Allen-Bradley</td>
<td>1492-xx</td>
<td>26</td>
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<tr>
<td>7</td>
<td>Cover for 1492 TB</td>
<td>Allen-Bradley</td>
<td>1492-N36</td>
<td>1</td>
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<tr>
<td>8</td>
<td>Clamp for 1492 TB</td>
<td>Allen-Bradley</td>
<td>1492-xx</td>
<td>2</td>
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<td>9</td>
<td>Din Rail, 15mm, 10&quot; Long</td>
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<td>1</td>
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<td>10</td>
<td>Relay, 3-pole, 120VAC Coil</td>
<td>Allen-Bradley</td>
<td>700-HA33A1</td>
<td>2</td>
</tr>
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<td>11</td>
<td>Relay Base, 3-pole</td>
<td>Allen-Bradley</td>
<td>700-HN101</td>
<td>2</td>
</tr>
<tr>
<td>12</td>
<td>PLC-5 Input Module, 16-pt, 120V</td>
<td>Allen-Bradley</td>
<td>1771-IAD</td>
<td>1</td>
</tr>
<tr>
<td>13</td>
<td>PLC-5 Output Module, 16-pt, 120V</td>
<td>Allen-Bradley</td>
<td>1771-OAD</td>
<td>1</td>
</tr>
<tr>
<td>14</td>
<td>Misc Parts - Wires, Cables, etc</td>
<td></td>
<td></td>
<td>1</td>
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<tr>
<td>15</td>
<td>Legend Plate, 30mm, RAISE</td>
<td>Allen-Bradley</td>
<td>800T-X535</td>
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</tr>
<tr>
<td>16</td>
<td>Legend Plate, 30mm, LOWER</td>
<td>Allen-Bradley</td>
<td>800T-X526</td>
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</tr>
<tr>
<td>17</td>
<td>Legend Plate, 30mm, OUT</td>
<td>Allen-Bradley</td>
<td>800T-X534</td>
<td>2</td>
</tr>
<tr>
<td>18</td>
<td>Legend Plate, 30mm, IN</td>
<td>Allen-Bradley</td>
<td>800T-X515</td>
<td>2</td>
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<tr>
<td>19</td>
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<td>Allen-Bradley</td>
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<td>800T-X504Y</td>
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Table A-5: Coil line feeder assembly electrical parts list

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<th>Description</th>
<th>Vendor</th>
<th>Part #</th>
<th>Qty</th>
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<tr>
<td>1</td>
<td>M12 Female Connector Straight Cable 5M</td>
<td>Murr</td>
<td>PVC-0B</td>
<td>51</td>
</tr>
<tr>
<td>2</td>
<td>1/8&quot; NPT to 3/8&quot; Tube Elbow</td>
<td>SMC</td>
<td>KQ2L11-34AS</td>
<td>52</td>
</tr>
<tr>
<td>3</td>
<td>1/8&quot; Male to 1/4&quot; Female Reducer</td>
<td>McMaster</td>
<td>50785K260</td>
<td>53</td>
</tr>
<tr>
<td>4</td>
<td>1/4&quot; NPT to 3/8&quot; Tube Dual Speed Control</td>
<td>SMC</td>
<td>ASD430F-N02-11S</td>
<td>54</td>
</tr>
</tbody>
</table>
Appendix B: Detailed Drawings of Final Roller Design
4X Ø0.332 DRILL V THRU

2X Ø0.1695 DRILL THRU

NOTE:
PAINT PER SILGAN SPEC. DS69-101-1
BREAK ALL SHARP EDGES WITH 02 X 45° CHAMPS. & INSIDE CORNERS. 0.2X MAX. UNLESS OTHERWISE NOTED

SILGAN CONTAINERS MFG. CORP.
EQUIPMENT ENGINEERING, OCONOMOWOC, WI

1016 C.R. STEEL

BASE PLATE, VALVE ROLL FEED ASSY
COIL LINE FEED TABLE ASSY

DRAWN 1/27/2012  CHECKED  DRAFTED

SCALE: FULL

6CL58106
NOTE: FOUR 1" THROUGH HOLES NEED TO BE DRILLED IN THE LEFT SIDE OF THE CONVEYOR FOR MOUNTING OF THIS BRACKET.

BREAK ALL SHARP EDGES WITH .02 X 45° CHAMFER & INSIDE CORNERS .02 MAX. UNLESS OTHERWISE NOTED.

NOTE: PAINT PER SILGAN SPEC. D069-101-1.

1.00 STOCK

16.25 x 1.00

23.125 x 1.5

3.25

2.00

2.00

8.25

10.25 x 1.00

4.00 x 1.00

2X ø1.031 x THRU

2X ø6.75 x THRU

2X ø8.075 x THRU 1-8 x THRU

R1.00

R1.00

R1.00 x .03

R1.00 x .02

12.5

MACHINED FINISH UNLESS OTHERWISE NOTED

SILGAN CONTAINERS MFG. CORP.
EQUIPMENT ENGINEERING, DOROTHY WY.

FEED ROLL, ANGLE BRACKET - LEFT
LEFT SIDE HYDRAULIC BRACKET
COIL LINE FEED TABLE ASSY

SHEET 1 OF 1

2.0012-01 6CL6S193

41129196

2012-0102

SAME TO

M6CL6S193

41129196

M6CL6S193

6CL6S193

17:1

5

64
DRILL AND USE A 1/4-20 X 3/4" SHEET METAL SCREW TO RETAIN ROLLERS AFTER CUTTING INTO 48" SECTIONS ON EITHER END OF THE ROLLER BAR.

NOTE: CUT THE 4 METER QUICK SMART ROLLER BAR (PART # ASMR) INTO 3, 48" SECTIONS.
BREAT ALL SHARP EDGES WITH .02 X .40" CHISELS & INSIDE CORNERS .02 MAX. UNLESS OTHERWISE NOTED.
Appendix C: Part Specification Sheets

**Mac Valve:** 92B-JAF-BAA-DM-DDAP-1DM
Parker Cylinder: 2.00CBB2HCT14AC31.00

Industrial Cylinder Division

Features:
- Construction: Steel, Tie rod design, Repairable
- Standards: NFPA Heavy Duty Hydraulic, ANSI/NFPA T3.6.7R2-1996
- Bore Size: 1 1/2" through 5"
- Strokes: Available in any practical length
- Piston Rod Diameter: 5/8" to 4"
- Operating Medium: Hydraulic oil
- Mounting Styles: 18 Standard
- Nominal Pressure: 3000 psi (See catalog for details)
- Standard Operating Temperature: -10°F to +185°F
- Optional High Temperature Option: -10°F to 250°F
- Rod Ends: Three standard choices, specials to order
- Cushions: Optional at either or both ends
- Ports: SAE "O" ring are standard, others are available

Theoretical Push Forces for Hydraulic Cylinders — Push Force

<table>
<thead>
<tr>
<th>Cylinder Bore Ø</th>
<th>Piston Area (Sq. In.)</th>
<th>Cylinder Push Stroke Force in Pounds at Various Pressures</th>
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<tbody>
<tr>
<td>1.50</td>
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<td>2.00</td>
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<td>177  443  885  1770  2651  3540  5310</td>
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<td>2.50</td>
<td>4.91</td>
<td>491  1226 2455  4910  7363  9820  14730</td>
</tr>
<tr>
<td>3.25</td>
<td>8.30</td>
<td>830  2075 4150  8300  12444 16600 24900</td>
</tr>
<tr>
<td>4.00</td>
<td>12.57</td>
<td>1257 3143 6285 12570 18680 25140 37710</td>
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<td>1964 4910 9820 19640 29453 39280 58920</td>
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<td>28.27</td>
<td>2827 7056 14135 28270 42412 56540 84810</td>
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Mac Valve: 92B-JAF-BAA-DM-DDAP-IDM

Dimensions shown are metric (mm)

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<th>DIM</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
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Consult “Specifications” page 327 before use, installation or service of MAC Valves.
Mac Valve Regulator: PR92C-KECA-9
**Bimba Pneumatic Air Cylinder:** C-1716-DPW-D-229-F-D-231-1-2-14A

---

**1-1/2" Bore Air Cylinders**

- Force Exerted Approximately 1.7 of Air Line Pressure
- Enclosed Spring Force: 7 lbs. Relaxed — 14 lbs. Compressed
- Rod Wipers Available on D, DP, DX, DXDE, and DXDEH Models

**OPTIONS:**

- **NO CHANGE:**
  - NO THREAD (INT)
  - SIDE PORTED REAR HEAD (C)
  - *Front port rotated 90° on EF models.*
- **SIDE PLATED REAR HEAD (D)**
  - Add .16" to nose mount overall length and DNR; BF and BF" add .36".
  - PILOT BUTTON (V)
  - .375" ID (use D-229-1 pivot bracket)
- SINGLE AND REVERSE ACTING BUMPERS (G)
  - $2.50 additional
  - Add .135" to overall length
- DOUBLE ACTING BUMPERS (G)
  - $5.15 additional
  - Add .135" to overall length
- EXTRA EXTENSION (E5)
  - Single, reverse and double acting, add $1.50 per inch of extension
  - DXDE, add $2.20 per inch of extension; extension added to each end
  - DXDE hollow rod, add $3.35 per inch of extension; extension added to each end
  - DOUBLE ACTING FAILSAFE
    - JS = Spring Return, JR = Spring Extend
      - Add $12.41 to base price $1.78 to stroke adder
      - See page 1.65 and 1.66 for overall length adders
- HEAVY SPRINGS (H) are standard on all single acting block front and block rear mount, and all reverse acting and stroke adjust models. For all other single acting, add $2.45
  - Spring Force: 6.5 lbs. relaxed — 11 lbs. compressed

**OPTIONS continued...**

- **MAGNET (prefix M) — Add $15.50**
  - Single and reverse acting add .125" to overall length
  - Stainless steel rod becomes standard with this option
  - Must specify threads for use with miniature position sensing (79, 79.3, 79.4) — add $5.20 per track. See page 1.9 for track location details. See Switch Products, page 9.3 for switch selection information.
- **LOW TEMPERATURE (N)**
  - Temperature Range: -40° to 200°F
    - Single acting add $1.40
    - Reverse acting add $1.69
    - Double acting add $2.70
    - DXDE add $3.35
- **HIGH TEMPERATURE (W)**
  - Temperature Range: 20°F to 40°F (16° to 206°C)
    - Single acting add $8.25
    - Double acting add $15.50
    - DXDE add $16.63
    - Reverse acting add $10.70
    - ROD WIPER (W)
      (not available in standard single acting)
      (now available in block mount)
      - Double acting add $2.20
      - DXDE add $6.40
      - STAINLESS STEEL ROD (prefix SR)
        - Add $3.20
        - Standard on DX, DXDE, DXDEH, DNR, DXNR. All block mounts, and M option
  - **LOW PRESSURE HYDRAULIC (HL)**
    - 250 psi maximum
    - Double acting only
    - Option specified as a prefix
    - Add $19.90

---

**17 DP**

- **Double Acting — Pivot Type — Air Return — Rear Pivot Mounting**
- **Maximum Stroke — 32"**
- **Optional Stainless Steel Rod**
- **Optional Rod Wiper**
- **Optional Accessories:**
  - D-231-4 Piston Rod Clevis
  - D-229 Pivot Brackets
  - **Base Weight:** .73
  - **Add $2.85 per inch of stroke**

---

**Options continued...**

- **MAGNET (prefix M) — Add $15.50**
  - Single and reverse acting add .125" to overall length
  - Stainless steel rod becomes standard with this option
  - Must specify threads for use with miniature position sensing (79, 79.3, 79.4) — add $5.20 per track. See page 1.9 for track location details. See Switch Products, page 9.3 for switch selection information.
- **LOW TEMPERATURE (N)**
  - Temperature Range: -40° to 200°F
    - Single acting add $1.40
    - Reverse acting add $1.69
    - Double acting add $2.70
    - DXDE add $3.35
- **HIGH TEMPERATURE (W)**
  - Temperature Range: 20°F to 40°F (16° to 206°C)
    - Single acting add $8.25
    - Double acting add $15.50
    - DXDE add $16.63
    - Reverse acting add $10.70
    - ROD WIPER (W)
      (not available in standard single acting)
      (now available in block mount)
      - Double acting add $2.20
      - DXDE add $6.40
      - STAINLESS STEEL ROD (prefix SR)
        - Add $3.20
        - Standard on DX, DXDE, DXDEH, DNR, DXNR. All block mounts, and M option
  - **LOW PRESSURE HYDRAULIC (HL)**
    - 250 psi maximum
    - Double acting only
    - Option specified as a prefix
    - Add $19.90

---

**Double Acting — Pivot Type — Air Return — Rear Pivot Mounting**

- **Maximum Stroke — 32"**
- **Optional Stainless Steel Rod**
- **Optional Rod Wiper**
- **Optional Accessories:**
  - D-231-4 Piston Rod Clevis
  - D-229 Pivot Brackets
  - **Base Weight:** .73
  - **Add $2.85 per inch of stroke**
McMaster-CARR Bronze Bushing: 6391K172

Lubricated Bronze Sleeve Bearings

SAE 841—Also called ColdSet, this porous material is impregnated with 10% SAE 30 oil. The oil reduces wear as well as required maintenance.

Graphite SAE 841—This porous material is impregnated with a graphite-based material, which provides low-friction dry lubrication in a wide range of temperatures.

SAE 863—Also called Super ColdSet, this material is similar to SAE 841 but contains more graphite for greater strength. Note: Color to picker because of the iron.

View tolerance information for these bearings.

<table>
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<tr>
<th>Bearing Material</th>
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<th>P max</th>
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Lubricated Bronze Sleeve Bearing for 3/8" Shaft Diameter, 1/2" OD, 3/32" Length

Bearing Tolerance Information

In Stock
SMC Dual Speed Control Silencer: ASN2-N02-S

ASN2, Metering Valve with Silencer
Metering valve with silencer series ASN2 has superior sound reducing performance. Over 20dB at maximum flow rate. Cylinder speed is easily set by the shape of the needle being the same as that of the speed controller. Retainer prevents accidental loss of needle.

Configuration Options

Selected Product Options
- Thread: N (NPT)
- Port Size: 2 (1/4)
- Option: S (Sealant)

Options:
- Gray are not compatible with other selected option value.
- Red conflict with another selected option value.
- Amber are not recommended.

Related Products
**SMC Dual Speed Controller:** ASD430F-N02-11S

**ASD-D, Dual Speed Controller, Flat Head Screwdriver Adjustable**

Series ASD-D contains a meter-in and meter-out dual speed controller in a single body. The series is available with PT or NPT ports and one-touch fittings are standard. Temper proof and flat head screwdriver adjustable versions are also available for extra protection against inadvertent operation:

- Adjust flow rates with a flat head screwdriver
- Prevents inadvertent manual operation
- Meter-in and meter-out types easily determined by the flow direction symbol on the body
- Inch or metric sizes available for all models
- One-touch fittings

**Configuration Options**

**Part Number is Complete**

ASD 4 3 0 F - N 02 - 11 S D

**Select Product Options**

Select values from the drop down lists or make appropriate selections to configure the part number.

- **Body Size:** 4 (1/4 Basis) [✓]
- **Thread:** N (NPT) [✓]
- **Port Size:** 02 (1/4) [✓]
- **Applicable Tube OD:** 11 (3/8”) [✓]
- **Sealant:** S (Sealant) [✓]

Options in:
- Gray are not compatible with other selected option value.
- Red conflict with another selected option value.
- Amber are not recommended.

**CAD Downloads**

**Related Files**

**Related Products**
Allen Bradley Limit Switch: 802T-A

802T Lever Type • Maintained Contact and Neutral Position
Plug-in Style Oiltight Switches

Range of Operation

Approximate Dimensions [mm (in.)]

Product Selection—Maintained Contact Models

<table>
<thead>
<tr>
<th>No. of Circuits</th>
<th>Lever Movement vs. Contact Operation</th>
<th>Torque to Operate (Max.)</th>
<th>Travel to Operate Contacts (Max.)</th>
<th>Max Travel</th>
<th>Travel to Reset Contacts (Max.)</th>
<th>Cat. No.</th>
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<td>Clockwise or Counterclockwise</td>
<td>0.31 N*m (2.75 lb-ft)</td>
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<td>0°</td>
<td>32°</td>
<td>802T-ANM</td>
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<td>(Max.)</td>
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*From one maintained position to another.*
Allen Bradley Limit Switch: 802T-A

### Specifications

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<th>Max Voltage</th>
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<th>A Break</th>
<th>Continuous Carrying Current</th>
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<td>3.00</td>
<td>10</td>
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<td>720</td>
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### AC Contact Rating (Maximum per Pole, 50 or 60 Hz, 2 Circuits Same Polarity)

### DC Contact Rating (Maximum per Pole)

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<th>Current Rating</th>
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### Description

Bulletin 802T limit switches are ideal for applications in which heavy duty pilot ratings, small size, a high degree of versatility and a rugged NEMA Type 4, 13 and 6P construction are desirable. An important factor in the automation of industry, these limit switches are being applied extensively on conveyor systems, transfer machines, automatic turret lathes, milling and boring machines, radial drills, and many other types of modern, high speed production equipment.

A wide variety of operating heads and operating levers are available. Operating heads can be mounted in four positions, 90° apart.

### Features

- Front mount for simplified mounting
- Plug-in style for ease of wiring
- Side rotary, wobble stick, cat whisker,
**McMaster-CARR Food Grade Bearing: 3730T28**

**With USDA H1 Solid Polymer-Polyethylene Grease—**Made to ABEC-3 dimensional tolerance standards with sealed bearing inserts to block out dirt. USDA H1 lubricant is solid and long-wearing so it won’t leak out of the bearing. Temperature range is 5° to 212° F.

**With USDA H1 Food Grade Oil—**Made to ABEC-1 dimensional tolerance standards with shielded bearing inserts to block out dirt. USDA H1 oil is permanently sealed into the bearing. The housing has a corrosion-resistant coating. Temperature range is -30° to +250° F.

For technical drawings and 3-D models, click on a part number.

### With USDA H1 Solid Polymer-Polyethylene Grease

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### With USDA H-1 Food Grade Oil

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### CAD | Catalog Page | Bookmark

- Lubricated Cast Iron Mounted STL Ball Brng for 1-1/2" Shaft Diameter
- ABEC Bearing Tolerance Information

In stock: 3730T28 130 73
Honeywell Sensing Pressure Sensor: 480-2041-ND

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All prices are in US dollars.

When the requested quantity exceeds the displayed pricing table quantities, a lesser unit price may appear on your order.
You may submit a request for quotation or purchase orders which are greater than those displayed in the pricing table.
Murr M12 Female Connector: PVC-0B

M12 female connector straight with cable PVC-0B 4x0.34 yellow 5m

Female straight
4 pole
Art.-No. 7005 - M12 Ute - (plastic hexagonal screw) on request