A NEW METAL DECORATOR

by

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ABSTRACT

A new beverage can printing machine is presented in this report. This machine, code named the "STAR decorator", will be capable of printing near-photographic images on a conventional two piece aluminum can. It is intended to revolutionize the commodity two piece can package and give new life to the common soft drink or beer can. The machine utilizes many technologies that have not yet been applied in the mature beverage can industry. Among these technologies are wet lithography, ultra-violet ink curing and a number of mechanical innovations that have not been used in any application to date. This report will present a comprehensive background of the project and then will make a subsystem by subsystem review of the machine. Technical challenges encountered during the design process will be presented as well as the approach to their solutions.

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1. INTRODUCTION

The common beer or soft drink can, known as the two piece beverage can, has been around since the early 1970's. It was developed by Reynold's Aluminum together with the Coors brewing company as a cost effective package for beer. Up until that time, beer was packaged in either glass bottles or three piece welded steel cans. The introduction of the two piece can significantly reduced the cost of the beverage container because the middle portion and the bottom, known together as the can body, could be formed in a single stroke machine with a process known as drawing and ironing. This process is much simpler than the rolling and welding process that is used to form the middle and bottom of the three piece can and, consequently, allows much higher production rates. Also, the geometry of the two piece can is inherently stronger than the three piece can and, therefore, allows opportunities for weight and cost reduction. Figure 1.1 shows a typical un-necked can body, which is the main part of the two piece can. The other part is the lid or end of the can, which is placed on the can after filling.

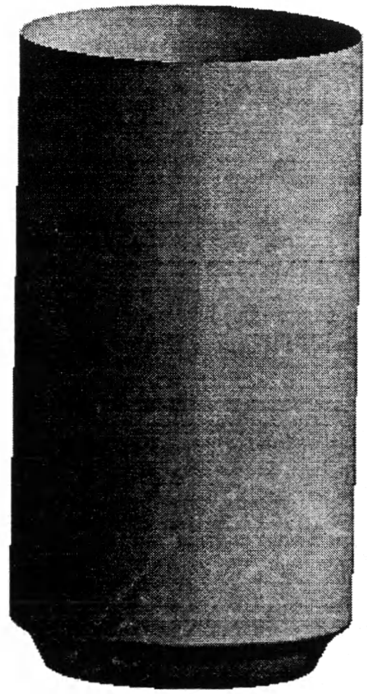

Figure 1.1: Can body.

The two piece can grew in popularity during the 1970's to a point where it constituted the vast majority of can sales for beer and beverages in the United States by the end of the decade. In the ensuing two decades, the U.S. market has grown to 99 billion cans produced annually and the package has become a commodity subject to fierce competition [Coors Container Technical Services 1993]. Large corporations such as Crown Cork and Seal, American National Can and Ball Metal Container have the two piece can as their primary source of revenue. Since the 1970's, the focus of new development in this package has been on cost reduction. Because the raw material (typically aluminum, but two piece cans can also be made of steel) of the can constitutes about 83% of the cost of the can, a great deal of effort has gone into reducing amount of metal in the can [Coors Container Technical Services 1993]. This has resulted over the years in the can side wall becoming thinner and thinner. In 1975, it took 44 pounds of aluminum to make 1000 cans and by 1998 that number had dropped to 31 [Aluminum Association 1998]. In the same time period, typical can line production speeds have increased from about 900 cans produced per minute to over 1600 cans per minute.

Worldwide expansion in the two piece can market was very robust in the 1970's and 1980's with annual growth rates as high as 15%. In the 1990's the growth has drastically flattened out to 1% [Can Manufacturers Institute 1998]. There are a number of reasons for this trend:

- Per capita beer and beverage consumption growth in the U.S. is not as strong as in the past.
- Package aesthetics and resealability has become more important. Plastic bottles used for soft drinks, sports drinks and "new age" drinks have become more popular as can be seen in the refrigerated section of the local convenience store. These containers are much more expensive than the two piece can, but the consumer is willing to pay for it and the beverage filler is willing to forego margin in order to attract new customers.
- Microbreweries from the start have been unwilling to put their product in cans because it has an image that implies "low cost" and therefore glass is more attractive to their target market.

As a result, aluminum manufacturers, can manufacturers and beverage companies and beverage filler companies have searched for ways of enhancing the two piece can to give it renewed popularity in the marketplace. Some of the new technologies that are being developed include: can shaping, can embossing, a resealable aluminum "bottle" and high quality graphics. Millions of dollars are being invested in these technologies in order to recover eroding market share. The topic of this report is a project that falls into the category of high quality graphics. The goal of the project is to design and build a printing machine capable of applying and curing a near-photographic image on a two piece can body at speeds of up to 800 cans per minute. There are many engineering challenges associated with such a task. The following sections will describe the technologies and methodologies used to address those challenges.

2. PRINTING TECHNOLOGY

Printing on a two piece can is performed after the can body, has been formed, but before it is filled or the lid is put on. The printing machine is referred to as a can decorator and utilizes a process called offset letterpress printing [Stevenson 1979]. In this process, the ink is applied to a plate, called a letterset plate that has a raised image surface. The image is then transferred to an intermediate rubber printing blanket and from the blanket the image is transferred to the can. Figure 2.1 shows a typical eight color can decorator.

A conventional two piece can decorator has six or eight color capability and all colors of the image are transferred to the blanket sequentially and then the complete image is transferred to the can at one time. There are inherent advantages and disadvantages to this approach. Some advantages are:

- Registration (positional relationship) between colors is relatively easy to establish and maintain. This results in a machine that is mechanically simple.
- Cans are loaded onto mandrels that are supported on free spinning bearings (no gear drive for mandrel necessary).
- Very high speeds can be achieved with reasonably good registration.

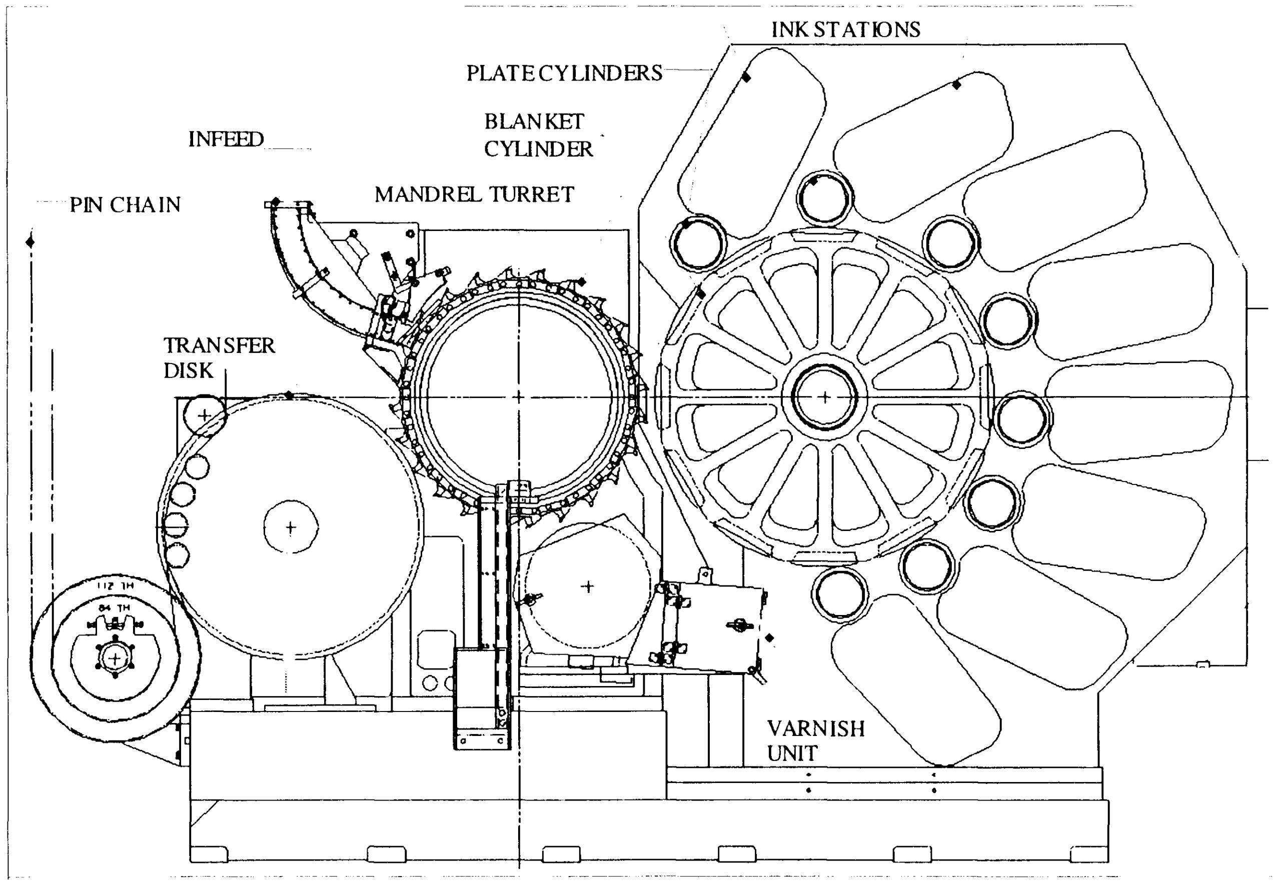

Figure 2.1: Conventional two piece can decorator.

The main disadvantage is related to the fact that inks are sequentially applied to the blanket in their wet state and then transferred to the can. As will be discussed later in this section, this severely limits the quality of the printing that can be achieved on a conventional can decorator.

2.1 Process Printing

Very high quality printing, such as that seen in publications like National Geographic, is usually performed with one color at a time being placed on the print media and then cured before the next color is applied. This approach allows overlapping of colors to form intermediate colors. When the colors of cyan, magenta, yellow and black are used as the basic printing colors, any color in the rainbow can be formed by combining two or more of these colors. This concept is known as four color process printing and is the most commonly used method applied to printing where near-photographic quality is required [International Paper Company 1976]. It is not possible on a conventional can decorator to effectively implement process printing because the inks cannot be cured individually due to the fact that all colors are being applied to a common blanket. If the colors were to be cured on the blanket, the image could not be transferred to the can.

The type of plate that is used in process printing is usually what is known as a lithographic plate. This type of plate does not have a raised surface as with the letterset plate mentioned above, but rather has a flat surface that is chemically presensitized when it is manufactured. The plate is made utilizing a photographic process, which results in an image area, to which ink adheres and a non-image area, to which water will adhere. Thus, the lithographic printing process uses a combination of ink and water on the plate. The water requires a separate “dampening system” and gives the added advantage of controlling the temperature of the printing process, which is essential to maintaining a consistently high quality image during production printing.

At the outset of the project, a study of all of the available printing technologies was conducted. Over thirty print technologies were evaluated against several criteria. These criteria include: achievable print quality, cost per can, cost of equipment, Speed capability as well as several others. The result of the evaluation was that four color process printing using wet lithography would give the best chance of achieving the goals of the project.

3. MACHINE SPECIFICATIONS

The specifications of the STAR decorator can be broken down into two categories: mechanical specifications, which outline what features the machine is to have and performance specifications, which define the characteristics of the printed can.

3.1 Mechanical Specifications

18 mandrel machine with the following features:

- Rated at 800 cans per minute
- 6 inker stations (6 color machine)
- 6 water dampening systems for wet lithography
- 6 printing blanket cylinders
- 6 plate cylinders
- 1 varnish unit
- 6 ultraviolet interstation curing units
- 1 machine control system
- 1 can infeed system

- 1 can outfeed system
- Lubrication, cooling, pneumatic and vacuum subsytems
- Complete safety guarding and interlocks

The reason that a six color machine was specified was that, although all colors in the rainbow can be made with the four process colors: cyan, magenta, yellow and black, some colors such as metallic silver and gold cannot be produced with process colors. The fifth and sixth ink stations could be used for these colors or special dedicated colors such as "Coke Red". Interstation curing, or curing between print stations, is needed to be able to realize full process printing as described earlier. Since, due to speed constraints, it would be impossible to cure the inks thermally in between print stations, it was decided to implement ultraviolet curing technology. Ultraviolet curing is the topic of another section of this report.

3.2 Performance Specifications

- Quality

  150 lines per inch screen (maximum)

  Dot overlap (true process printing)

  Prints on basecoated cans

  Process colors (cyan, magneta, yellow, black) plus two special colors

  Registration: .04 to .05 mm total range

  Dot resolution 3% to 100% based on area

- Speed

  Initial target speed: 800 cans per minute (2 machines per high speed line)

  Machine to be mechanically capable of 1000 cans per minute

- Flexibility

  Label change over time: 30 minutes or less

  Scrap at label change: 3000 cans or less

  Height change over time: 1 day or less

The 150 lines per inch screen specification together with the 3% dot resolution require the smallest possible dot capable of being printed to be about 0.0013" in diameter. At the time these specifications were written (May 1995) a proposed concept drawing for the machine was generated and is shown as Figure 3.1.

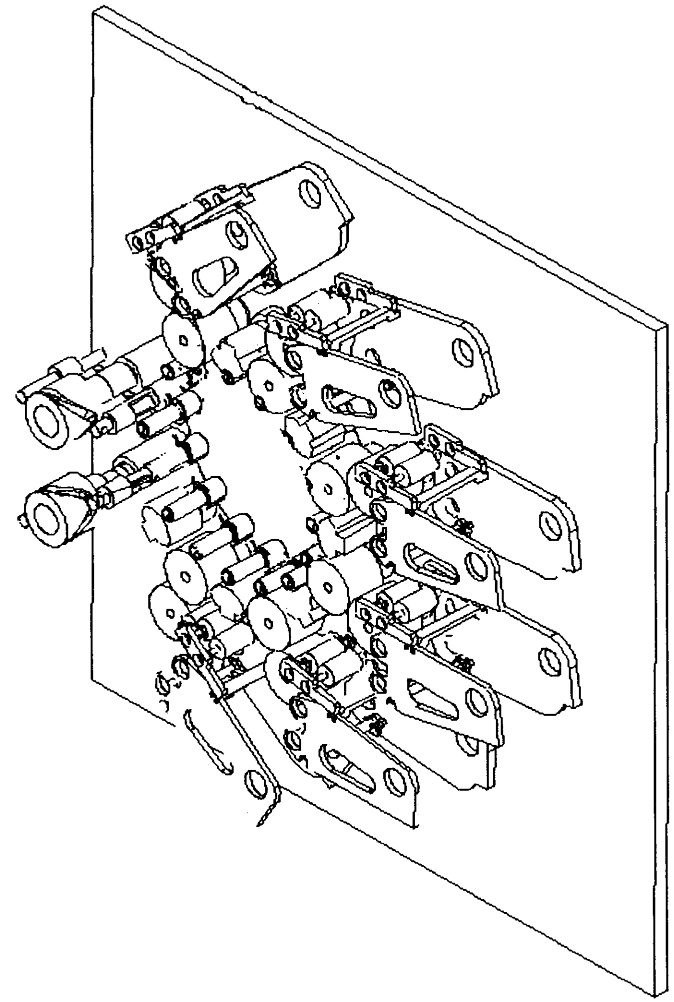

Figure 3.1: STAR decorator concept drawing.

4. ULTRAVIOLET (UV) CURING

In conventional two piece can printing, the cans are printed and coated with an overvarnish material and immediately transferred onto a conveyor that takes the cans through a multiple pass, gas-fired oven for drying the ink and overvarnish. There are a number of issues that make this technology a burden. First, the inks and varnish material have a high VOC (Volatile Organic Compound) content. These VOC's are burned off and emitted into the atmosphere during the drying process and, when combined with the other emissions created such as nitrogen oxides and carbon dioxide, this creates a significant burden to the environment. Second, the size of the oven and initial cost are quite high. A typical oven is about 18 feet wide by 60 feet long by 20 feet tall and costs about $675,000 installed [NICE3 1997].

Ultraviolet curing is the "drying" of printing ink using ultraviolet light. The inks need to be specially formulated for UV curing, which adds to the cost. But this technology can contribute substantially to addressing the problems associated with thermally cured inks and overvarnish material. In their report, the NICE3 states that "The UV process in comparison to...the thermal process...showed significantly lower total evironmental emissions." The report also goes on to indicate that the installation and operation costs of a UV process are significantly lower than that of the traditional thermal process. Although the decision to implement UV curing in the STAR project was largely dictated by the necessity to do interstation curing very quickly and in a very small physical space, the savings to the environment and cost were very attractive elements to the technology.

UV inks contain a very large percentage of solids and therefore have very low VOC's. They are composed of oligomers and monomers together with pigment, for color, and a photoinitiator [Stowe 1998]. The photoinitiator is dispersed evenly throughout the mixture and it is the photoinitiator that drives the chemical reaction transforming the ink from a liquid to a solid state when it is exposed to UV light. This photo-chemical reaction is almost instantaneous. The UV lamp consists of a quartz bulb filled with an elemental gas, typically mercury, and a reflector. When a voltage is applied to the ends of the bulb, a plasma arc is created and the arc emits light at the characteristic wavelengths of mercury. The spectral distribution of a mercury-based "H" bulb is shown in Figure 4.1 [Stowe 1998].

The main consideration for the STAR machine is to achieve adequate cure after the print station to obtain good adhesion of the ink onto the substrate (can, basecoat material or other ink) as well as a tack-free surface to prepare it for receiving the next color. A tack-free surface is necessary so that the ink will not be pulled back off of the can when it comes into contact with the next blanket. Ink pull-back would result in color contamination (mixing of colors in the supply train) and would quickly cause image quality to degrade to an unacceptable level. Because the ink has a finite thickness and the

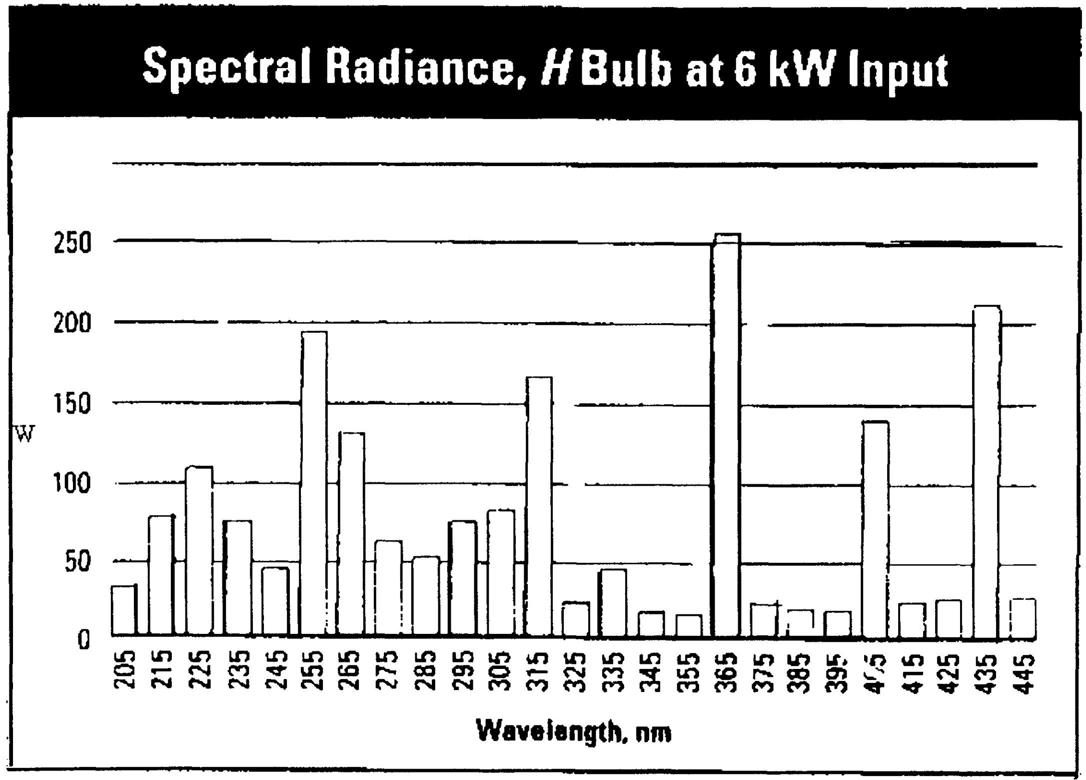

Figure 4.1: H bulb spectral distribution

pigment tends to block UV light, adequate incident energy at the proper wavelength must reach the surface of the ink in order to fulfill the curing requirements. In the case of the inks being used on the STAR decorator this energy requirement has been experimentally determined to be 12.6 mJ/cm^2 of UVA light (320-390nm). For this purpose, two H bulbs with 400 W/in rating were selected for each curing station.

5. MACHINE DESIGN

This chapter will give a subsystem by subsystem review of the STAR machine design as well as reveal some of the thinking that went into design synthesis process. Any machine design starts with the key functional criteria. What functions is the machine to perform and at what speed and accuracy? Most of this information has already been described in the mechanical and performance specifications. But it will be helpful to elaborate on some points to give a clearer picture of the design task. First, the can has to be loaded onto a mandrel, which has to be moved through a series of print and cure stations, an overvarnish station, and then transferred off of the machine to a conveyor. Because the can and the printing blanket are both cylindrical, the only way to print a complete image on the can is to have the can rotating on a non-translating mandrel during printing (indexing machine) or to have the mandrel translating and rotating during printing (continuous machine). Because the machine was specified to operate at a speed of 800 cans per minute, inertial considerations eliminated the option of an indexing machine. It would be impossible to start and stop the machine fast enough to realize the required production speed as this would result in unacceptably high drive torques and machine element loads. The continuous machine approach dictates that the can orbit around the blanket while it is rotating on its own axis so that the can surface is synchronized with the blanket surface. In order to minimize print pressure variations during the printing process, the can must orbit the blanket at a radius that varies by not more than 0.005" from the radius of the blanket.

5.1 Basic Mechanism Design

In order to accomplish the above requirements, it was necessary to design a special mechanism. This mechanism is based on a kinematic construct known as hypotrochoidal motion. In essence, the motion is obtained by rotating a disk of some diameter along the inside of a ring with a much larger diameter. A point lying on the disk between the center and the diameter will describe hypotrochoidal motion as the disk is "rolled" along the inside of the ring. The path formed by the motion is a series of inward pointing arcs, with cusps located where the arcs meet each other. A schematic drawing showing the motion and blanket cylinders can be seen in Figure 5.1. The can printing and curing process will occur as the mandrel is following the arcs in alternating orbits around blanket cylinders and through curing stations. In the case of the STAR decorator, the disk is a planet gear, which is attached to an eccentric housing containing the mandrel for the can. There are a total of 18 mandrel assemblies, each containing a planet gear and eccentric housing. The mandrel assemblies are mounted in a wheel that is externally driven around a stationary ring gear. This arrangement gives the can its translational motion through the machine. For the generation of the rotational motion, each mandrel is mounted on a shaft and

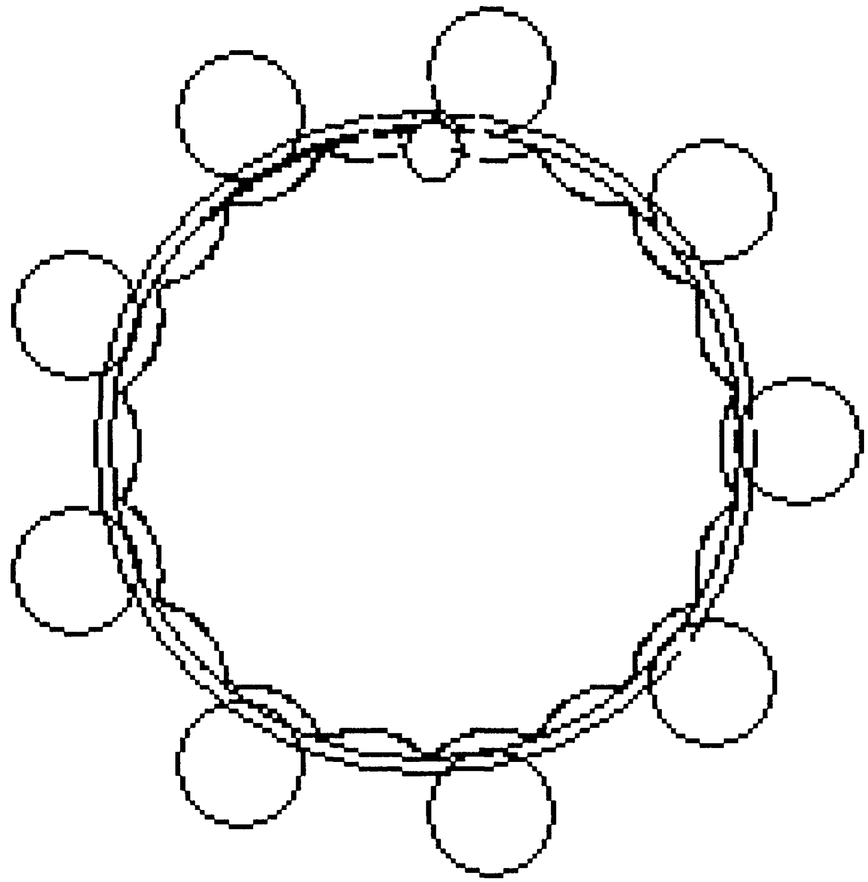

Figure 5.1: Schematic of hypotrochoidal motion.

bearings and the shaft has a gear mounted to it. Figure 5.2 shows a cross sectional view of the mandrel assembly.

Each blanket cylinder has a gear fixed to its shaft. The mandrel gear and the blanket gear are sized such that when the blanket gear drives the mandrel gear, there is no relative motion at the point of contact between the can and blanket and therefore printing can occur. The relationship between the mandrel gear, blanket gear, intermediate gear and plate gear are shown in Figure 5.3 Because the mandrel gears are engaging and disengaging with blanket gears and intermediate gears during the operation of the machine, a special gear tooth design was needed. This gear tooth has a very tall and slim profile to ensure an adequate contact ratio at all times, yet avoid having gears lock up during the transition from one gear to the next at the cusp of the hypotrochoidal motion. Figure 5.4 shows the unique shape of the mandrel gear tooth.

5.2 Blanket Cylinder Assembly

The blanket cylinder assembly consists of the blanket cylinder and the blanket cylinder shaft assembly. Its purpose is to accurately transfer the image from the plate cylinder to the can.

5.2.1 Blanket cylinder

The blanket cylinder is a precision ground cylinder that holds three adhesive backed blankets made out of EPDM rubber. The blanket cylinder needs to be removable from the machine to facilitate machine maintenance, but also needs to be very accurately mounted to achieve consistently high print quality. For this reason, the cylinder is

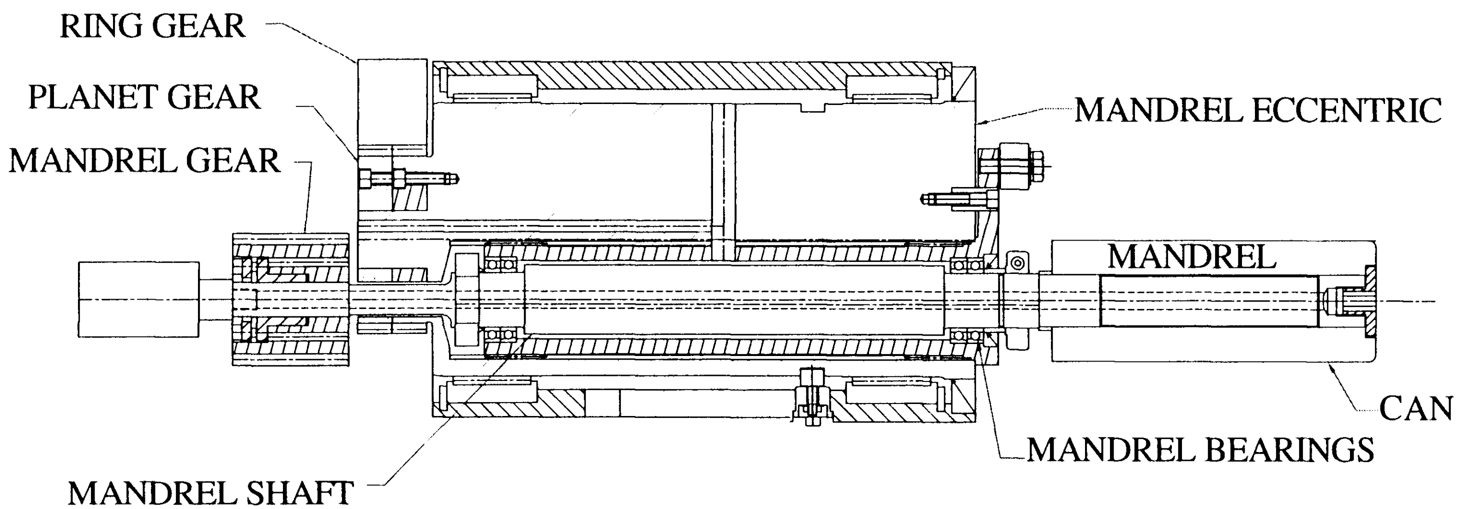

Figure 5.2: Mandrel assembly.

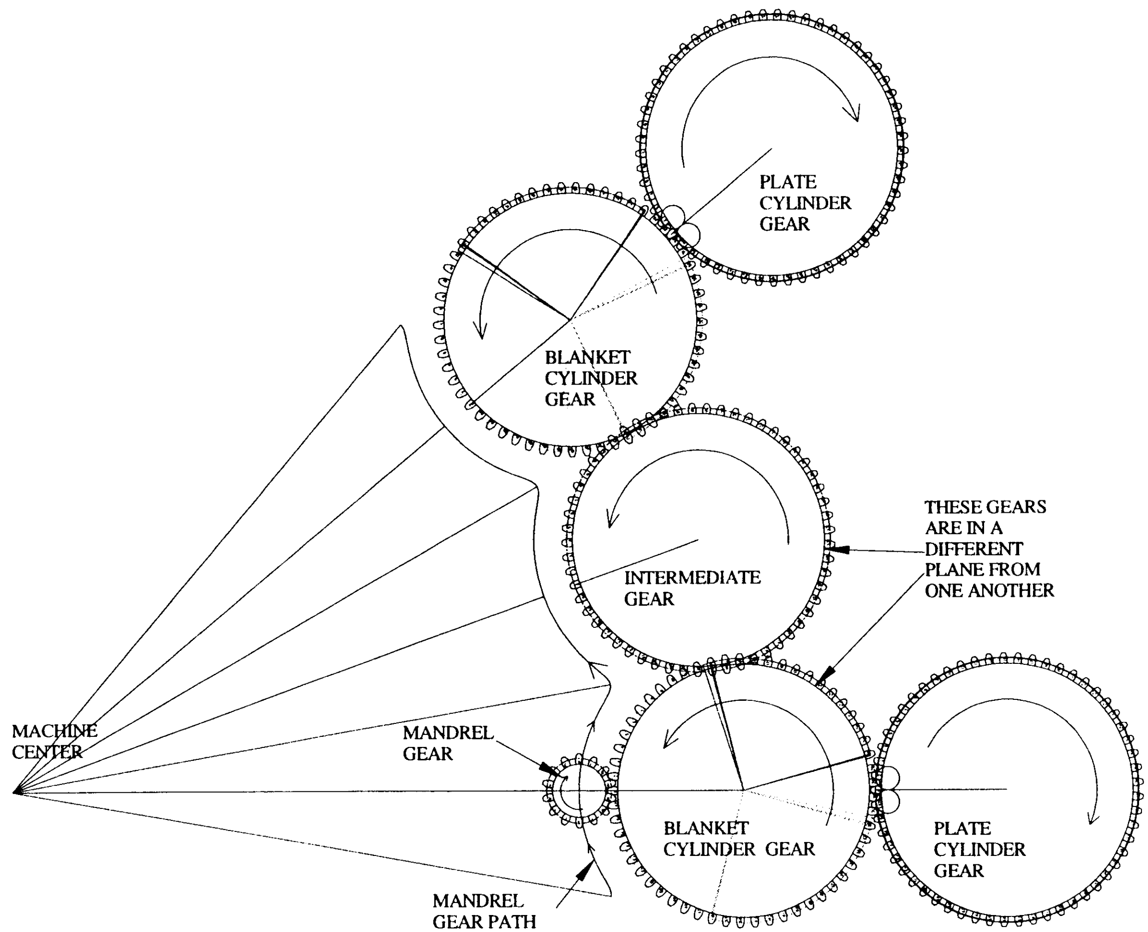

Figure 5.3: Relationship between mandrel, blanket, intermediate and plate gears.

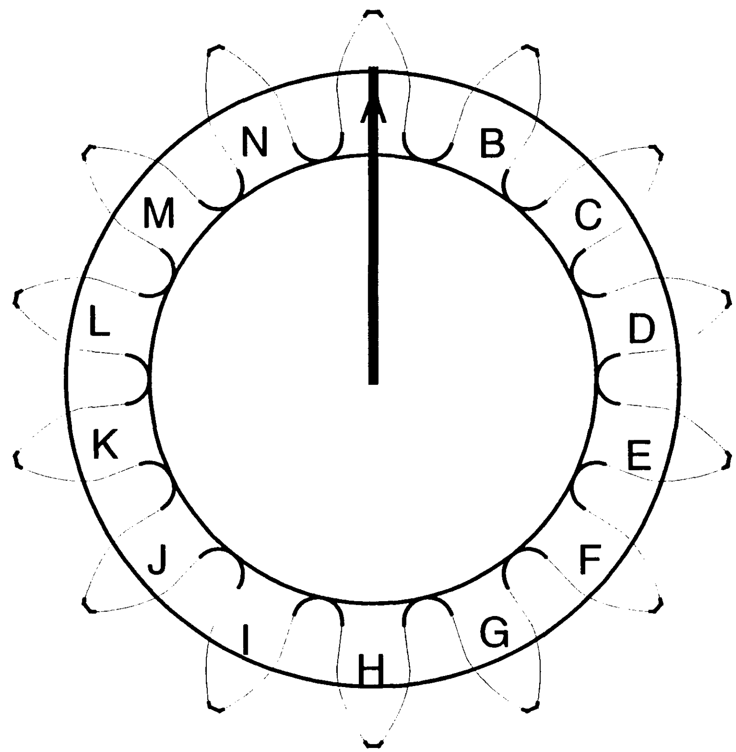

Figure 5.4: Mandrel gear.

designed with a tapered bore and is fastened to the blanket cylinder shaft via a clamping mechanism that applies an axial load to the cylinder.

5.2.2 Blanket cylinder shaft assembly

In order to provide the highest quality printing, the blanket cylinder shaft, which has a tapered nose to mate with the blanket, utilizes precision bearings. The bearings are axially preloaded to eliminate clearances and therefore minimize radial movement of the shaft during machine operation. The blanket shaft and bearings are mounted in an eccentric housing, the position of which can be adjusted via a screw. The eccentric adjustment allows the operator to set the print pressure between the blanket and the can. A cross sectional view of the blanket cylinder, plate cylinder and mandrel assemblies can be seen in Figure 5.5.

5.3 Plate Cylinder Assembly

The plate cylinder assembly consists of the plate, plate cylinder, plate cylinder shaft assembly and the registration assemblies. The purpose of this subsystem is to hold the printing plate and facilitate an accurate and consistent transfer of the image from the plate to the blanket as well as to allow adjustment of the position of the image on the blanket. The image position adjustment is referred to as registration.

5.3.1 Plate and plate cylinder

The blank printing plate is a piece of aluminum with a photosensitive coating. A photo imaging process utilizing a negative is used to transfer the image to be printed on the can to the plate. The plate is then placed on a bending machine to put special bends in

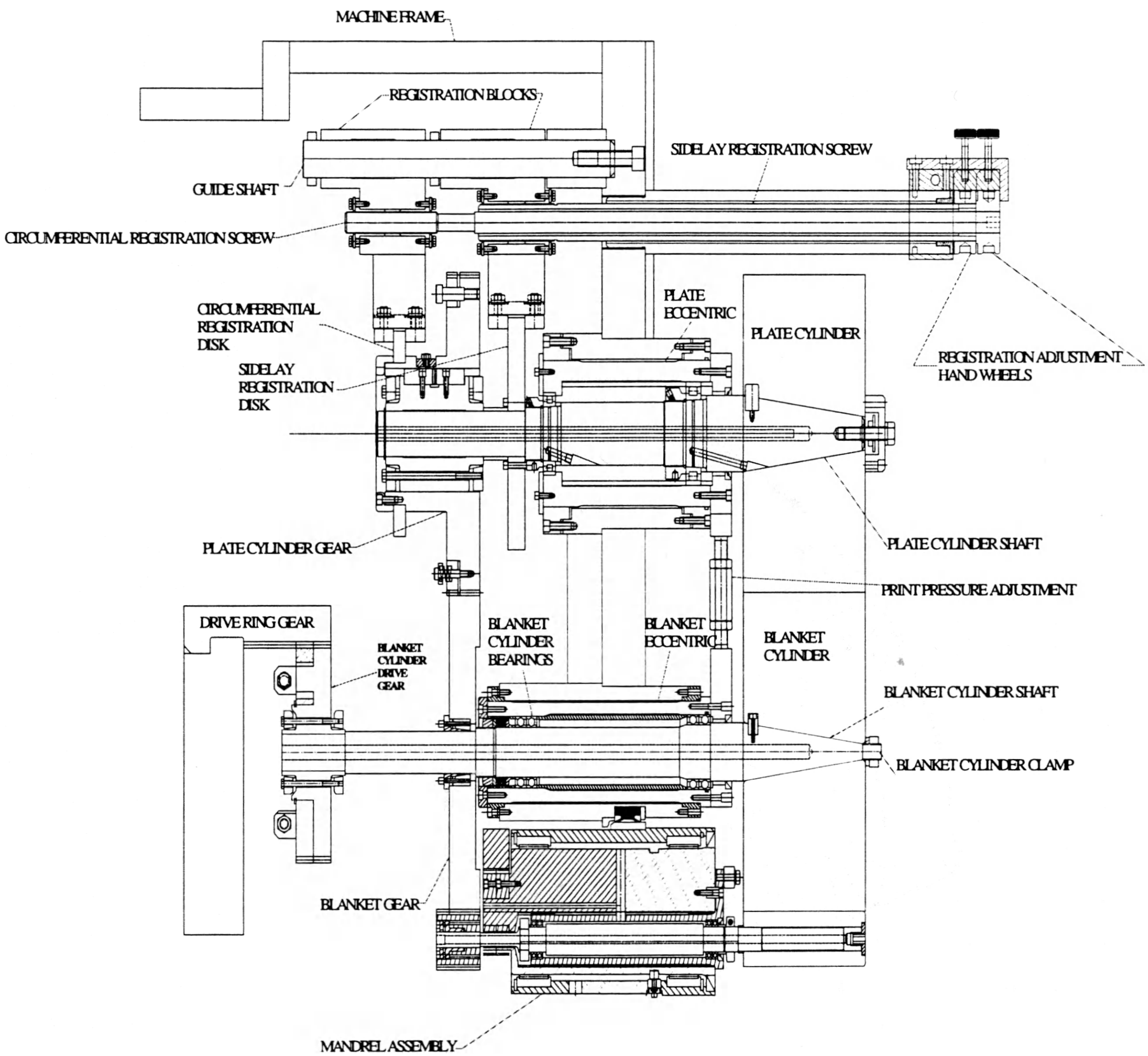

Figure 5.5: Blanket and plate cylinder assemblies.

the leading and trailing edge of the plate. The plate is mounted on the cylinder by placing the leading edge in a slot in the plate cylinder, wrapping it around the cylinder and placing the trailing edge in a rotary tensioning mechanism. The tensioning mechanism keeps the plate from slipping on the cylinder during machine operation.

Like the blanket cylinder, the plate cylinder needs to be removed from the machine during machine maintenance as well as for plate changes. For this reason, the plate cylinder also has a tapered bore and a clamping mechanism to fix it to the plate cylinder shaft.

5.3.2 Plate cylinder shaft assembly

The plate cylinder shaft assembly is similar to the blanket cylinder assembly in that it is designed to have minimum radial movement during operation through the use of precision bearings and components. In order to allow print pressure adjustment between the plate and blanket, the plate cylinder shaft and bearings are contained in an eccentric housing and the housing is adjustable through a turnbuckle that attaches the plate cylinder eccentric to the blanket cylinder eccentric. In order to facilitate axial registration adjustment, the plate cylinder shaft bearings are designed to allow 0.125" of movement of the shaft in the bearings.

5.3.3 Registration assemblies

There are two types of registration adjustment: circumferential and sidelay. Circumferential registration allows the plate cylinder timing to be rotationally advanced or retarded with respect to the blanket cylinder. This has the effect of moving the image around the can in a circumferential direction. Circumferential registration is mechanically accomplished by moving the plate cylinder gear axially with respect to the blanket gear. Because the plate and blanket gears are of a helical design, and because the plate cylinder gear is allowed to move axially on the plate cylinder shaft, the axial movement of the plate cylinder gear has the effect of advancing or retarding the plate cylinder with timing with respect to the blanket cylinder. Sidelay registration is the movement of the plate cylinder shaft in its bearings. The actuation of circumferential and sidelay registration adjustments are accomplished through similar mechanisms. These mechanisms consist of handwheels attached to lead screws. The lead screws drive registration blocks back and forth on a guide shaft. Each registration block has a pair of cam followers attached to it and the cam followers straddle a registration disk. The circumferential registration disk is attached to the plate cylinder gear housing and the sidelay registration disk is attached directly to the plate cylinder shaft. These mechanisms are shown in Figure 5.5.

5.4 Infeed Assembly

The infeed assembly takes cans from the infeed conveyor and continuously loads them onto the mandrels. The main component of the infeed assembly is the infeed starwheel. The infeed starwheel is a nylon wheel with four can shaped pockets machined out of it. There are also vacuum passageways machined into the starwheel to allow the cans to be held in the pockets prior to being loaded onto the mandrels also using vacuum. The infeed starwheel is attached to a shaft mounted on bearings and is driven through a low backlash, right angle, 10:1 reduction gearbox via a permanent magnet servo motor. The infeed assembly is shown from two views in Figure 5.6.

5.5 Outfeed Assembly

The outfeed assembly receives the cans as they are ejected from the mandrels after printing and transfers them to an outfeed vacuum conveyor, which transports the cans to the next process in the production line. The outfeed has many similarities to the infeed. It has a four pocket wheel, a shaft, bearings, is driven by a servo motor/gearbox combination and utilizes vacuum for holding the cans. The main difference between the outfeed and the infeed is that the outfeed wheel has pockets with an axial orientation to hold the ejected cans from the bottom. The outfeed assembly can be seen in Figure 5.7.

5.6 Varnish Unit

A coating of varnish material is placed on the can prior to the can being unloaded from the machine. The purpose of the varnish is to provide the can with abrasion resistance during the rest of the can making process as well as the filling process and transportation to the point of usage. Varnish material is applied to the can in a wet state with a rubber applicator roller. A ceramic gravure roller with small engraved cells is used to meter the varnish from a manifold fountain to the applicator roller. The gravure and applicator rollers have individual shaft and bearing assemblies and are driven with a common chain drive. A vector motor and right angle gearbox drive the varnish unit chain. Figure 5.8 shows the STAR varnish unit.

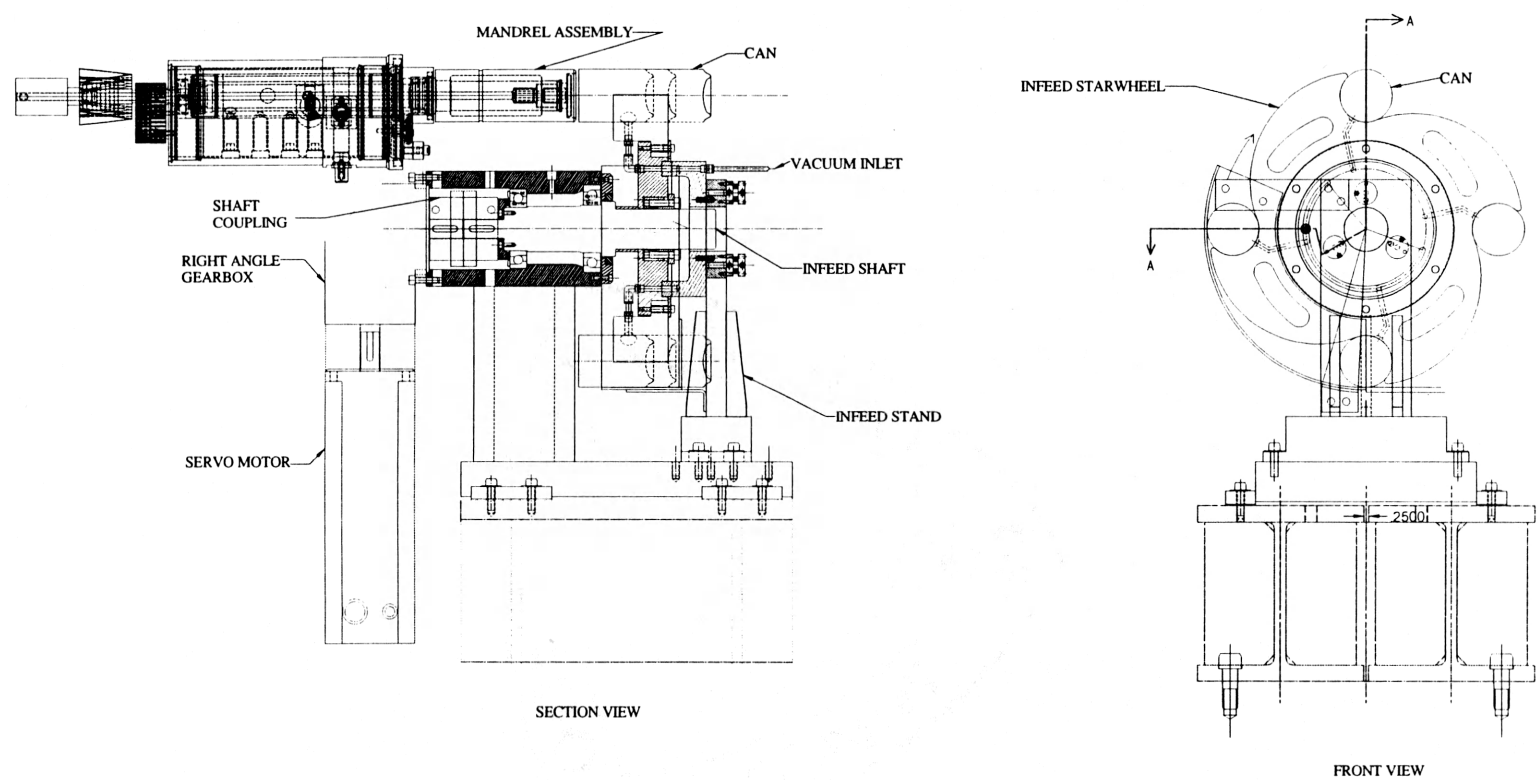

Figure 5.6: Infeed assembly.

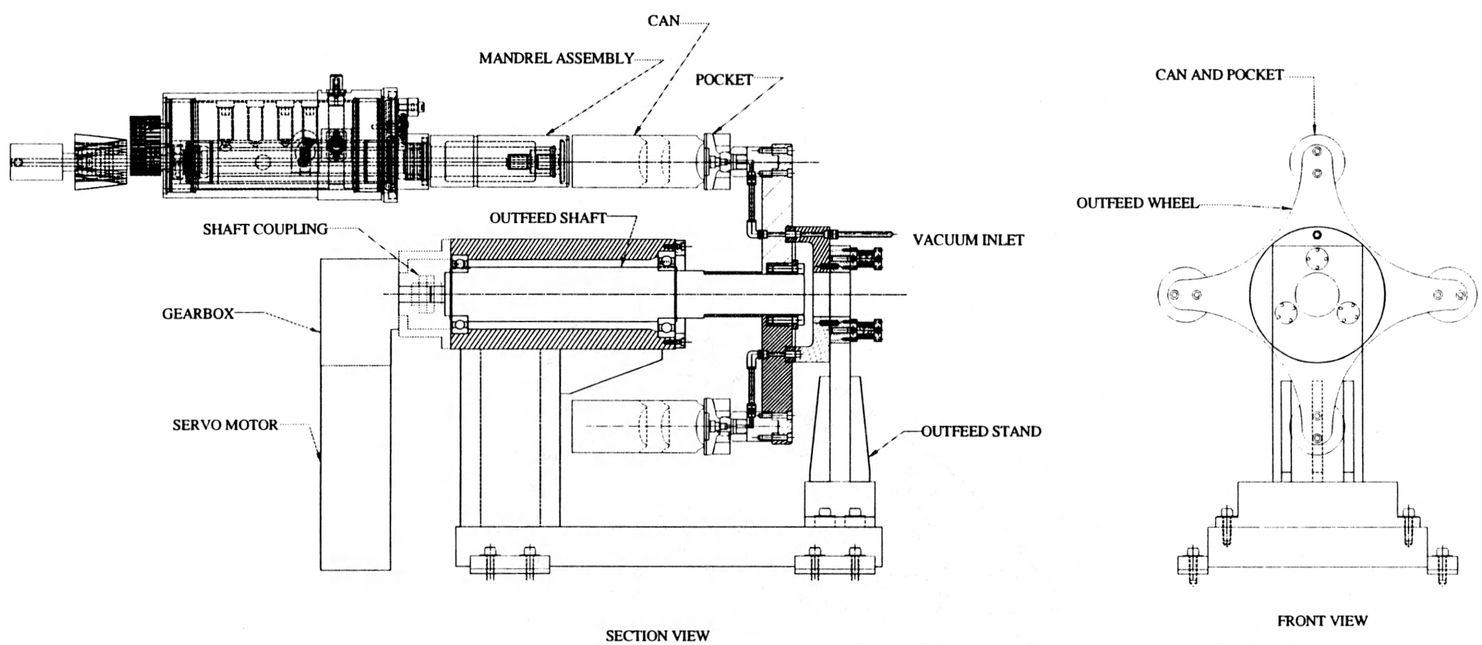

Figure 5.7: Outfeed assembly.

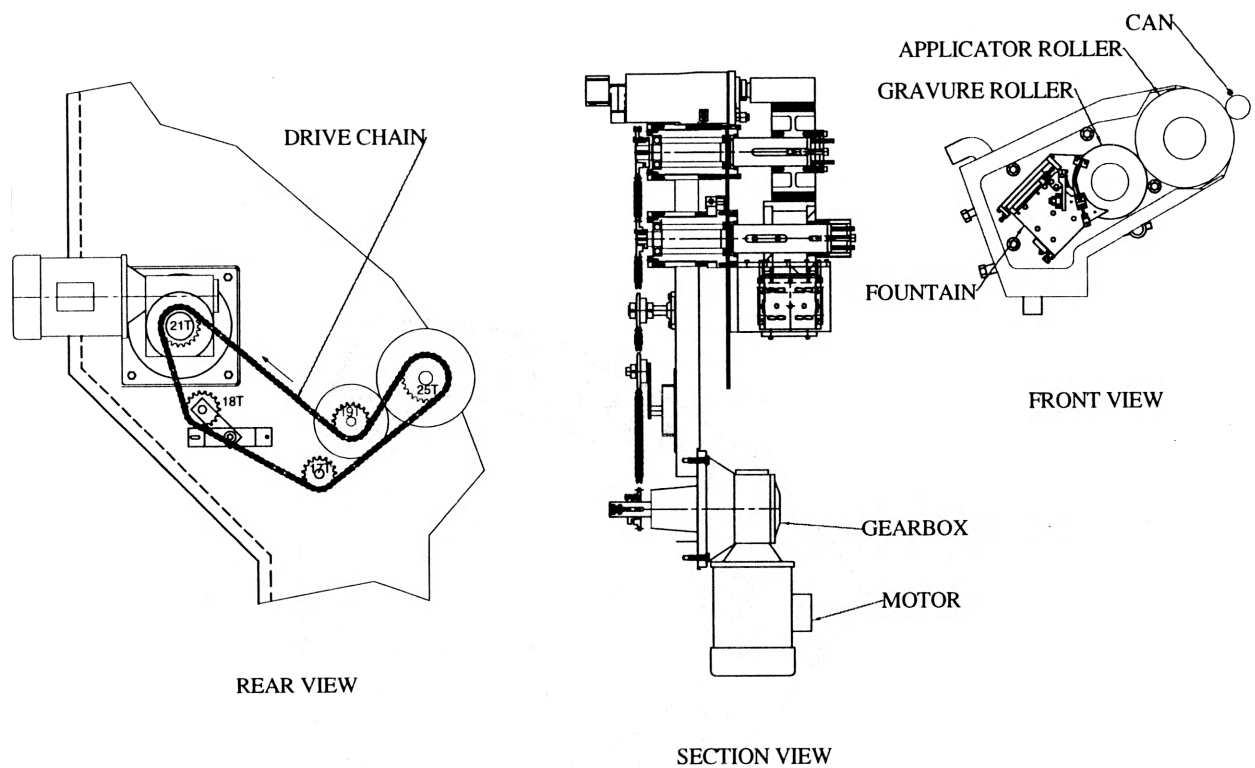

Figure 5.8: Varnish unit.

5.7 Ink Station Assembly

The ink station is a subsystem that holds ink, works it to an acceptable film thickness, and applies it to the plate. There are six ink stations on the STAR decorator and typically there is one ink station for each ink color. In some instances, one ink color is put into two different ink stations, but there is never more than one ink color placed in a single ink station. The ink station consists of an ink fountain and a series of rollers. The roller adjacent to the fountain, called the fountain roller, has an outer coating of a hard material, in this case blue nylon, the second roller is a soft material, EPDM rubber and the remaining rollers in the ink station are alternately hard and soft materials. The hard rollers are gear driven and the soft rollers are non-driven idlers. There are a total of five hard rollers in an ink station and the last three hard rollers are cam driven to oscillate back and forth in an axial direction. The purpose of the oscillation is to work the ink to the proper film thickness and viscosity. All hard ink rollers are water cooled to discharge heat generated as the ink is worked. The last rollers in the sequence are known as the form rollers. There are four form rollers, which transfer ink from the last two hard rollers to the plate. A partial ink station is shown in Figure 5.9.

5.8 Water Dampening System

The wet lithographic printing process requires that a thin film of water be placed on the plate prior to inking. This is accomplished with an assembly that is similar to an ink station, except that the dampening assembly contains fewer rollers and transfers water instead of ink. The water dampening system is mounted on the machine frame just above

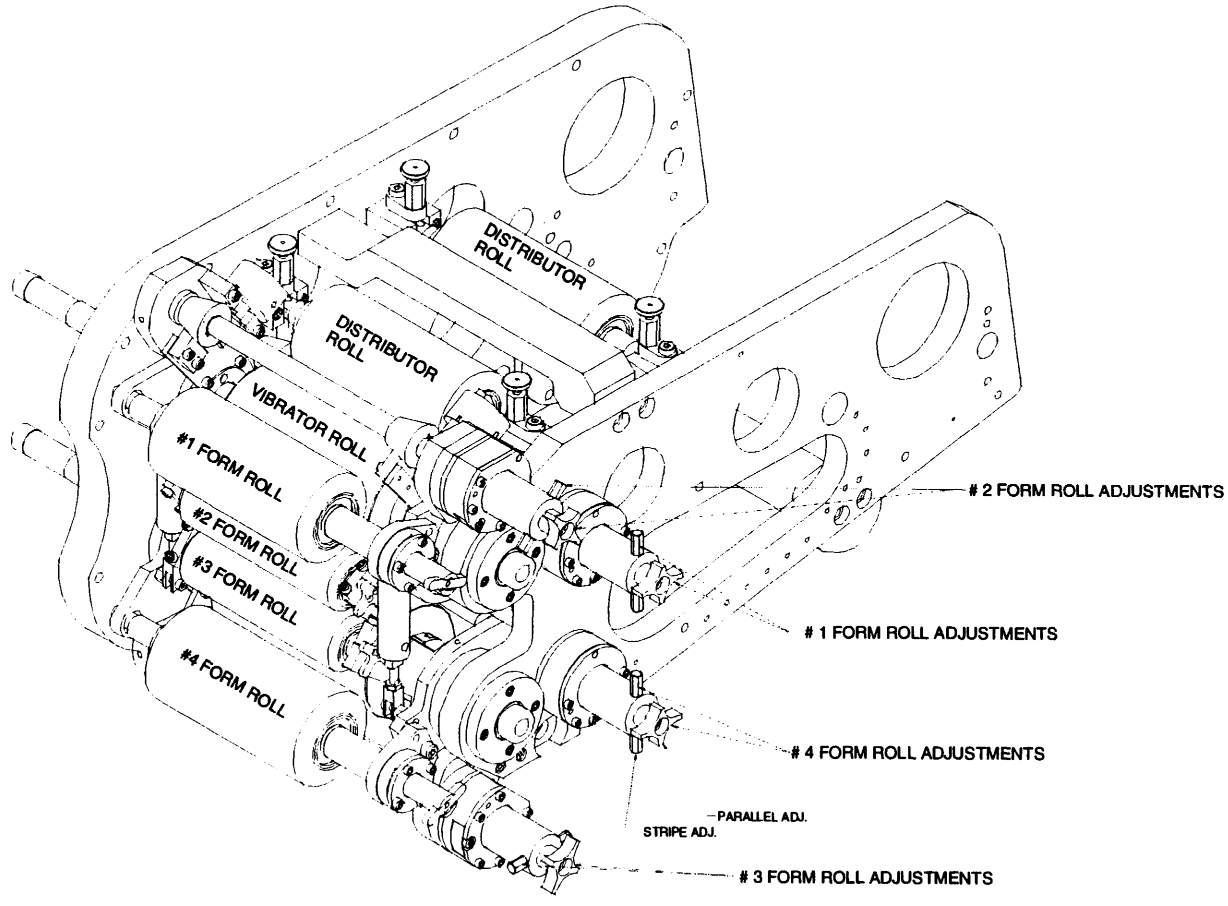

Figure 5.9: Ink station without fountain and fountain roller.

the ink station and has a water form roller that contacts the plate above the first ink form roller.

6. CONCLUSION

The STAR decorator project has been in process for over three years and it is nearing a critical milestone. The design is complete and the prototype machine is in the early stages of assembly. Figure 6.1 shows a drawing of the entire machine viewed from the operator side. It is anticipated that alpha testing will begin in December, 1998. Following successful alpha testing, the prototype will be shipped to a production can line for beta testing. During beta testing, the machine will be monitored for reliability as well as cost per can, and sample cans will be introduced into the marketplace to gauge consumer reaction. The results of cost comparison and test market studies will determine if the STAR machine is a viable innovation for the two piece can industry.

New product development in the field of packaging machinery is an expensive and time consuming endeavor. But these efforts are necessary in any industry in order to remain competitive and are even more important in industries that appear to be in a state of stagnation as is the case with the two piece can industry.

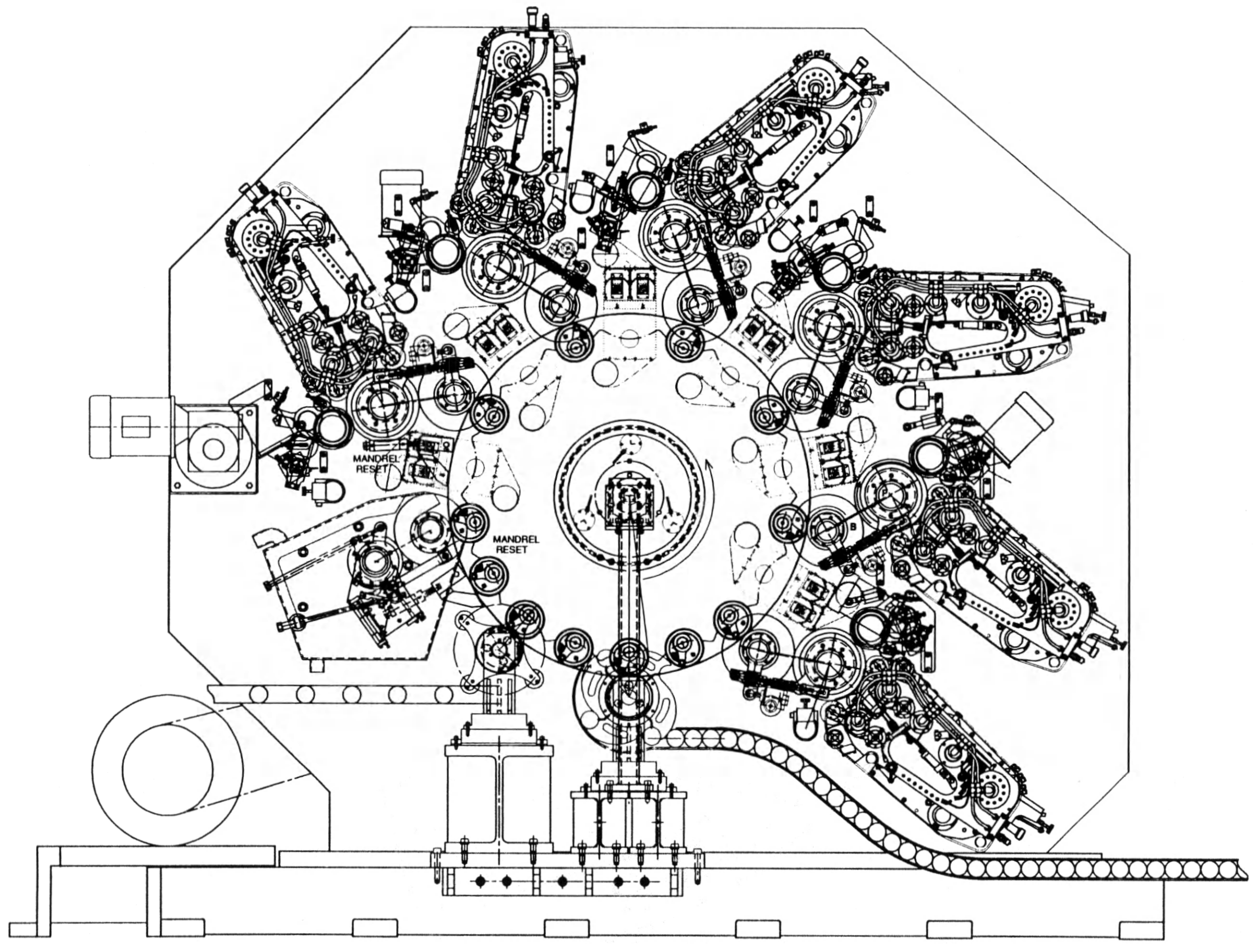

Figure 6.1: The STAR decorator.

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