Machine Vision Technology Solves Blow-Molding Problems

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The A-B VIM Vision Input Module is used by the Stewart-Walker company to solve their toughest quality problem. The company manufactures blow-molded plastic oil bottles. Returns from the customers have been eliminated since the Vim module was installed. According to Jim Osborn, Director of Purchasing at Pennzoil Products Group (a large user of the bottles), "Plugged bottle necks had been costing us several thousand dollars a month. Now, the problem is gone".

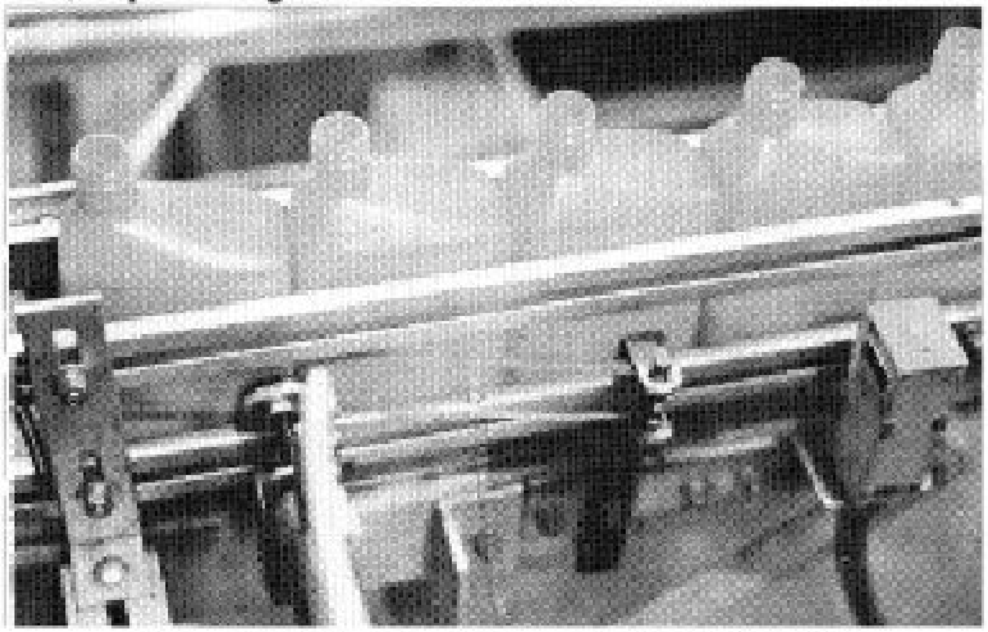


Figure 1- Plastic oil bottles inspected with Machine Vision.

The product inspected at the northern California plant is a yellow plastic motor oil bottle. You have probably seen these bottles in your local auto supply store - many millions are sold each year. The main problem detected by the Vim module is "neck plugs" - excess mold plastic left inside the bottle neck which prevents proper filling. Quart bottles are filled in just a few seconds and the stream of oil is almost as wide as the opening. Any obstruction can shut down the production line for fifteen minutes or more by causing oil to spill out instead of filling the bottle.

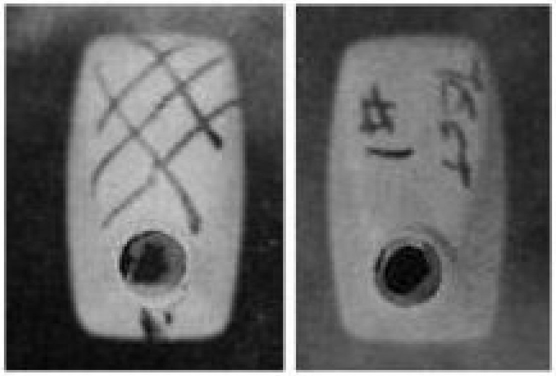


Figure 2 - Typical Obstructions in Bottle Necks

The installation was justified on the basis of catching these blocked necks before they are shipped. "Since we installed the Vim, we haven't had any customer returns", says Delbert Yarborough, Quality Control Manager for Stewart-Walker. "And after it was installed, we discovered that it detects many other problems as well." These include "ovalized" and undersize necks, improperly trimmed or incompletely formed necks, and plastic strings and foreign material in the neck.

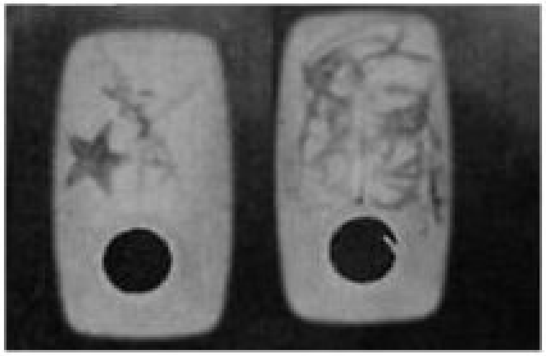


Figure 3 - Subtle Problems with Bottle Necks

Another unexpected benefit of the installation is the real-time process control information it provides. Figure 4 shows how this works. The bottles from all the molding machines are merged and fed into a single stream prior to labeling and packaging. One Vim module inspects this high-speed stream. Rejected bottles are sorted out into a rework bin. Periodically, the rejects are analyzed and uses the information to adjust the plastic molding machines. The number of the mold is marked on the bottom of each bottle. When a problem appears, it is quickly corrected.

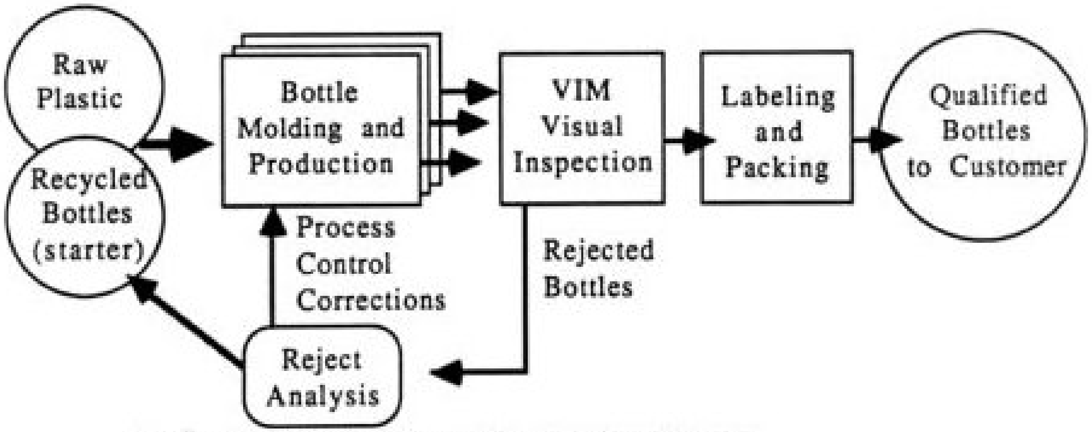


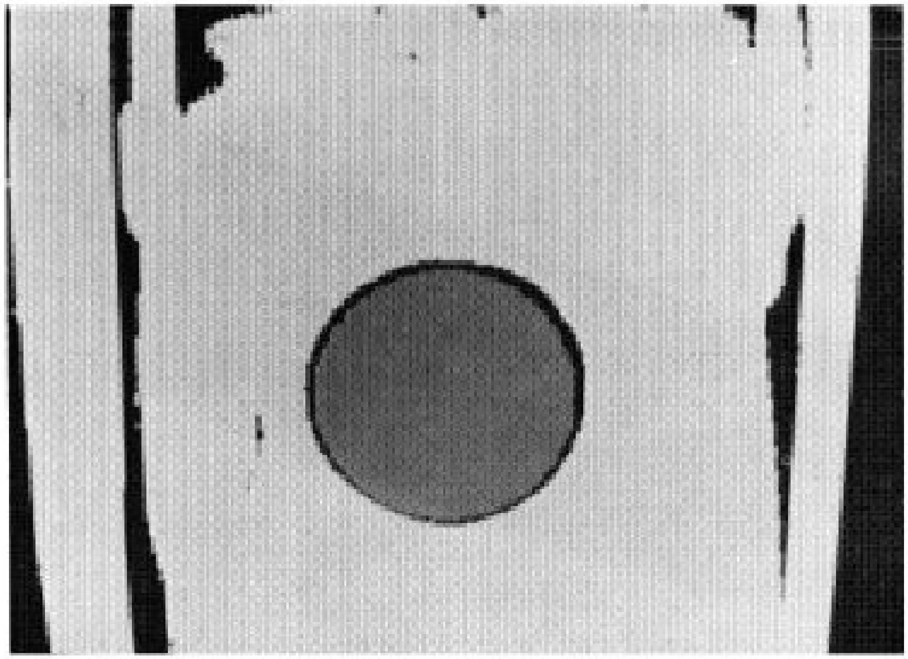
Figure 4 - Statistical Process Control Flow Diagram

The essential feature of this Statistical Process Control (SPC) loop is that corrections are made *during* the batch run. According to Delbert Yarborough, head of Quality Control at Stewart-Walker, "By the time a bottle gets to the warehouse, it's too late. The Vim module lets us make corrections in real time, as the molds are running. It gives us a tool to help identify and correct the real cause of any problem."

The neck inspector has been so successful that similar installations are now in progress at the company's other plants. Other Vim applications are planned to sense label position and orientation, label agreement (front and rear labels for the same product) and exterior bottle flash.

Technical Discussion - How the Machine Vision Inspection Works.

The solid-state camera sees a digital image shown in Figure 5. The dim circle inside the neck is a "window" which fits into the image like a touch-probe and verifies that the stream of oil will flow unobstructed.



The inspection cycle is performed in six steps:

Step 1. A photoswitch detects a bottle under the camera and triggers the Vim module to perform an inspection.

Step 2. The module flashes the strobe light and simultaneously captures an image from the camera. The bottle never stops moving. Each bottle is at a slightly different position in the field of view, so the next two steps compensate for its uncertain position.

Step 3. The vertical (Y) line gauge finds the black opening of the bottle neck and computes its vertical (up/down) position (see figure 6).

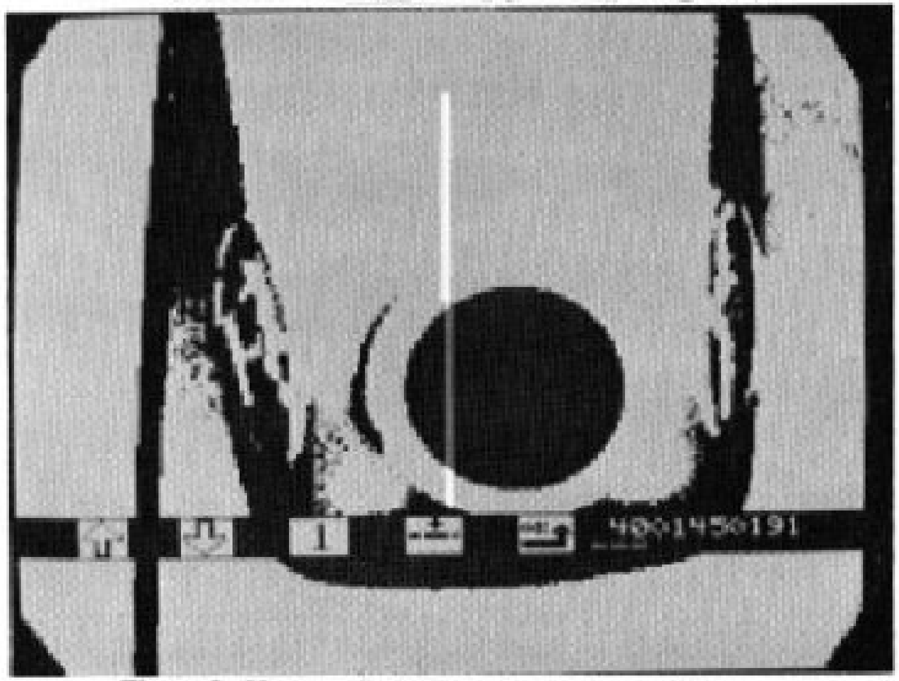


Figure 6 - Y-gauge finds the neck's vertical position.

Step 4. The horizontal (X) line gauge is placed across the neck's vertical center, and computes its horizontal (left/right) position (see figure 7).

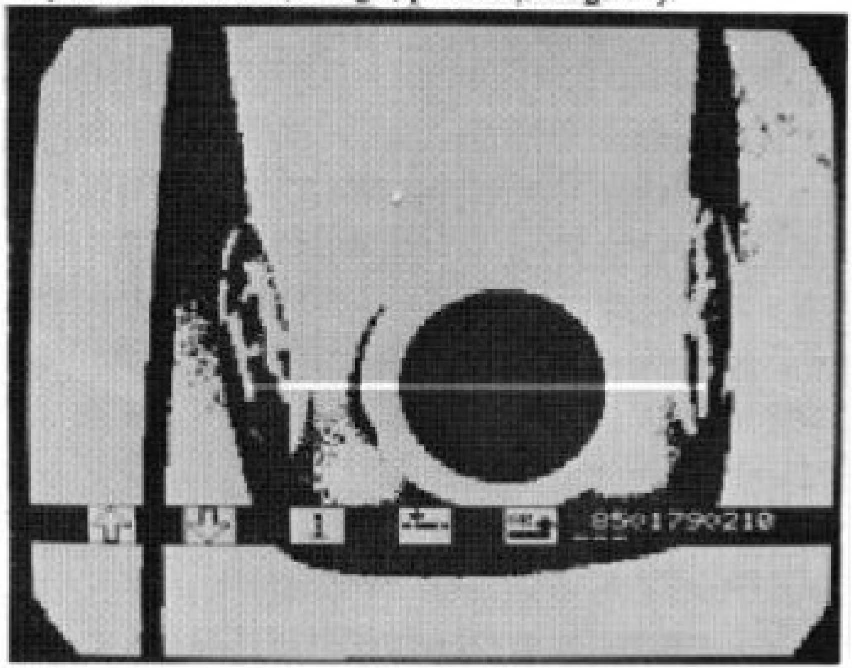


Figure 7 - X-gauge finds the neck's horizontal position.

Step 5. Window #1 has been set up as a circle and calibrated to the minimum neck width spec. This window is placed precisely over the center of the neck using the XY-float feature described in steps 3 and 4. The area of bright plastic inside the window is measured and compared against preset Hi/Lo limits. If the area is within the Hi/Lo acceptance range then the bottle is accepted. Otherwise it is rejected. Figure 8 shows an image of a typical rejected bottle neck.

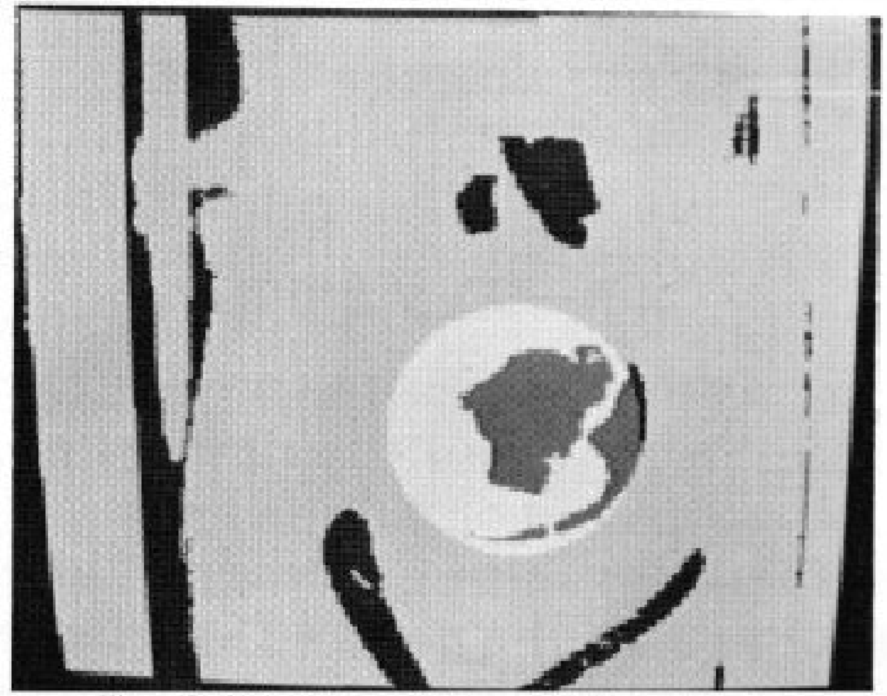


Figure 8 - Video image of a plugged bottle neck.

Step 6. The PLC reads the accept/reject decision and takes action. Rejected bottles are pneumatically sorted off line.

All six steps are completed in less than 70 milliseconds. The Vim module's capacity for this inspection is about 15 bottles per second.

In addition to finding obstructions inside the neck, the circular window also measures deviation from perfect roundness. Since the stream of oil is round, it is important that the neck be round as well. Roundness sensing is often expensive, complex, or difficult to implement with alternative technologies but with machine vision in this case it was simple and relatively cheap.

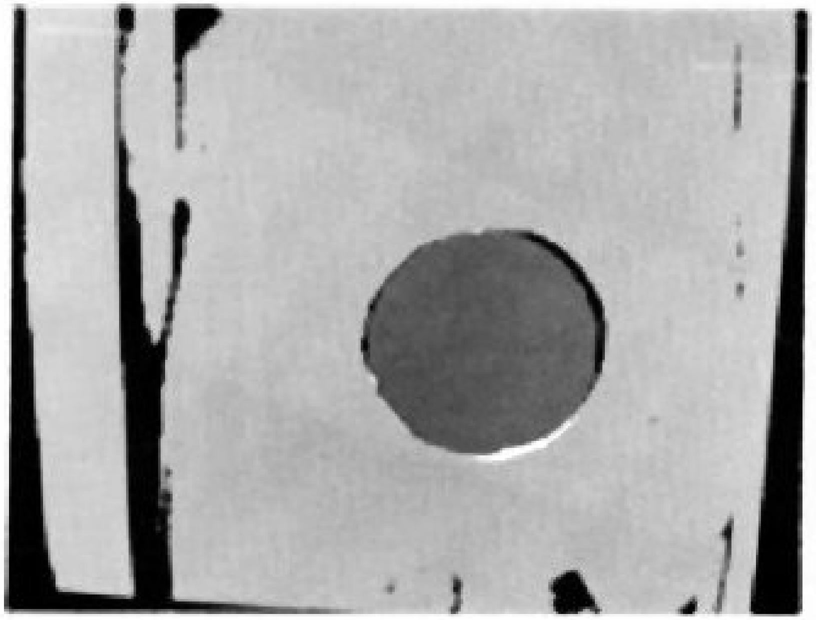


Figure 9 - Video image of an ovalized bottle neck.

The rejection rate is typically about one-half of one percent. About twenty percent of the rejected bottles are minor false alarms and would actually be acceptable to the customer. They are caused, for example, by plastic strings in the neck (see figure 10).

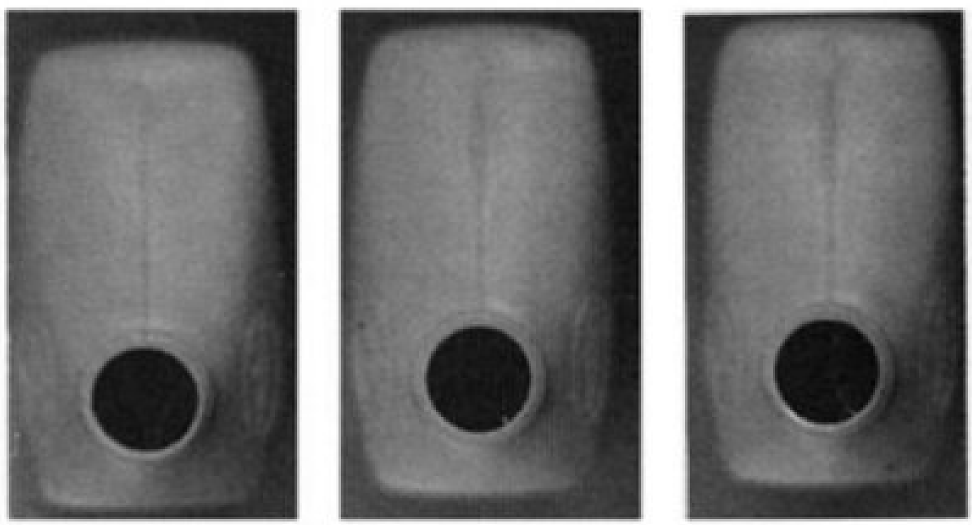


Figure 10 - Rejects caused by plastic strings in the neck

False alarms (borderline rejects) are actually useful for several reasons. First, they indicate process variations before they become problems and are therefore a leading indicator that helps stabilize production. Second, rejected bottles are required to be mixed with virgin plastic to help accelerate the melting process. The sensitivity of the Vim system is kept high deliberately to make sure there are always a few false rejects. And third, occasional rejects give a positive indication that the system is working. When the process is tuned up properly, rejects are rare. Since the Vim system was installed, no defective bottle neck has been reported by a customer.

Every hour, the quality control department verifies that the inspection system is operating within spec. Several rejected bottles are kept for use as standard references. To test the system, these reference rejects are placed right into the production stream. If they are rejected, then the vision station passes the test. Among the test bottles are several different types of failures including ovalized and blocked necks, and excess flash.

A strobe light was used to freeze the image of the bottles in front of the camera and eliminate motion blur. This was necessary because the bottles move through the vision workstation at relatively high speed. Also, the camera's field of view is fairly small (about 2 inches across), which magnifies the bottles' apparent speed.

The Vim module's light compensation feature was not required, since the strobe light provided sufficiently consistent illumination. The workstage shroud allows the strobe to be operated at about half intensity, which makes the flash very consistent and also lengthens the life of the bulb.

Vision System Hardware

A PLC-2/16 Programmable Logic Controller is used to control the inspection station. Several bottles can fit between the inspection station and the reject station, so the controller keeps track of the reject queue. The controller also archives the Vim setup configuration as a redundant backup.

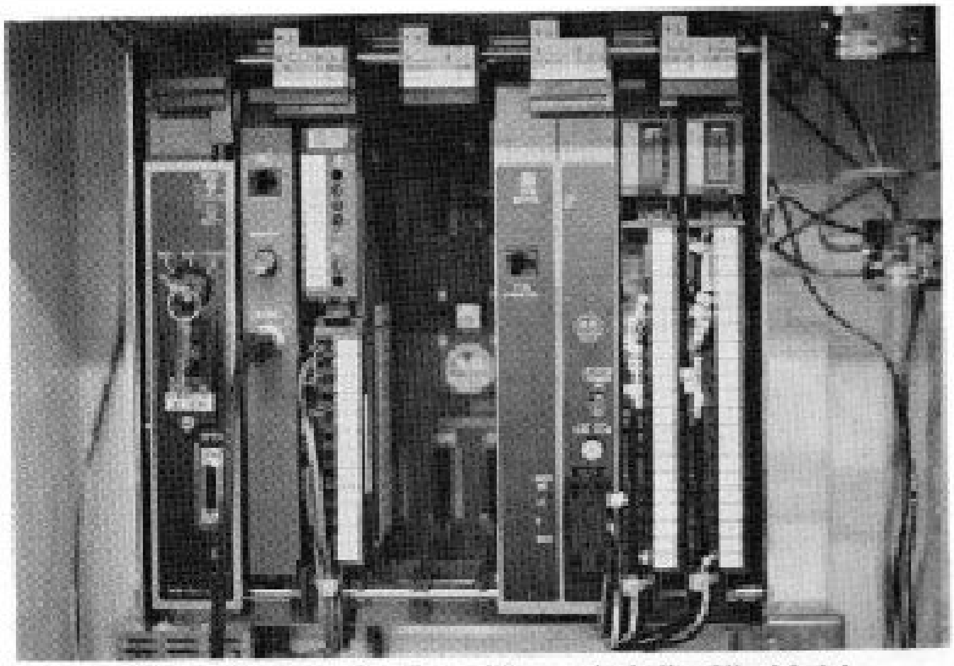


Figure 11 - Inspection Control System including Vim Module

The PLC controller, VIM module, power supply (1771-P4) and I/O modules (1771-OAD and -IAD) are mounted in the 8-slot rack (1771-A2B) shown in figure 11. The AC input and AC output modules are used to interface with sensors and actuators on the line.

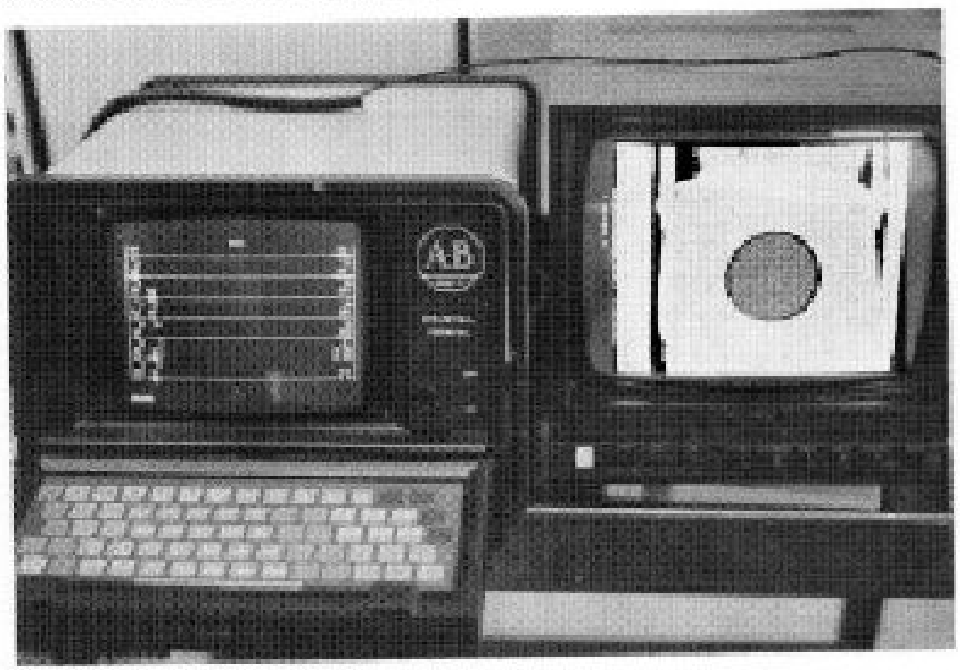


Figure 12 - Programming Terminal and Vim Video Monitor.

Staging and Illumination

The camera is mounted directly above the production line, facing straight down. This gives it a clear view into the bottle necks. A 12.5 mm lens made the field of view about two inches across.

Bottles are sensed with a photoswitch that triggers the system through the Vim's swingarm. The strobe light is flashed and the camera takes its picture as the bottle passes under the lens. The light is carried from the strobe to the bottles through a bifurcated fiber optic guide. This makes the neck and shoulders of the bottle appear bright, while leaving the interior of the bottle dark.

A metal enclosure (shroud) was installed around the camera's working stage for three reasons: 1) the shroud keeps the lens and fiber optics clean, 2) it prevents accidental misadjustment, and 3) it allows the strobe light to be operated at about half intensity. This has greatly increased the life of the strobe bulb which now runs for several months between replacements.

The Stewart-Walker company first heard about the Vim module at a "high-tech product update" given by the Valley Electric company, their local distributor of automation products. It appeared that machine vision might be able to identify bottles with plugged necks. Their production line already uses several PLC-2/15 and SLC-100 controllers for line control. Because of their positive experiences with A-B equipment in the past, they decided to go ahead and give this new technology a try. The Belcan company, a system integrator, was contracted to install the Vim system and integrate it with the production line equipment.

Figure 13 - A warehouse full of bottles - all 100 percent inspected.

Carl Coon of Valley Electric said, "This was the first vision system that we were involved with. It's also the first vision system that Stewart-Walker has installed, and we're all very pleased with its performance."

Summary

Machine vision technology has been shown to be effective and valuable for inspection of molded plastic containers. It guarantees that the outgoing product is within specified limits, and it also senses variations for real-time statistical process control.

According to Bill Gunville, Production Manager at Stewart-Walker, "Since this was our first vision system, we were waiting to see how it worked before we went ahead with anything else. Based on the results we have seen, we are installing vision input modules at all our plants. And we have targeted other applications too, like label inspection and outside flash detection. We are using the Vim to make ongoing improvements in our manufacturing processes. And this gives us a competitive advantage."

About the author:

Donald Christian works at the Allen-Bradley Company in Milwaukee as Product Manager for Vision Products. He conceived and co-invented the company's highly successful VIM Vision Input Module.