

Feature

Automation & Control

Roasting Plant's Javabot Combines Engineering and Coffee

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If Willy Wonka designed a coffee store, he would likely end up with something like the [Roasting Plant Coffee Company](#) in New York. Built around a complex machine that takes automated coffee production to a new level, Roasting Plant functions as much like a small factory as a retail coffee shop. Coffee beans travel overhead in pneumatic tubes, whooshing between storage bins, a roasting station, a grinder and a brewing machine.

Willy might not entirely appreciate the degree of automation. A modern distributed control system runs the entire operation, so Oompa Loompas and human baristas need not apply. In fact, other than loading the machine with raw beans and handing over the finished coffee drink, the system requires no manual labor at all.

Roasting Plant is the brainchild of Mike Caswell, a former engineer for [Starbucks](#), where he worked on supply chain and operational efficiency projects. He describes his time there fondly. "Starbucks really helped me develop my love of coffee," he says. He had also worked as a manufacturing engineer earlier in his career, including a stint at [Digital Equipment Corporation](#). So he knew about factory automation too, especially its potential to improve product quality.

His concept for an automated coffee store, which has been awarded a patent in Europe and has a U.S. patent pending, doesn't feature automation for its own sake. It doesn't even use automation just to keep labor costs low. Instead, the automation serves Caswell's desire to make better coffee. "I set out to make the freshest, most flavorful cup of coffee available. Automation makes that possible," he says.

It does so, in large part, by addressing a lack of freshness, which Caswell views as one of the biggest barriers to a truly good cup of coffee. "Arguably freshness is not readily available," he says, explaining that most retail coffee shops don't roast their own beans on site. "Some don't even know when their beans were ground, much less roasted," he says. Automation allows Roasting Plant to combine the roasting, grinding and brewing at the point of consumption — both physically and temporally.

And it gives consumers more choice than they might otherwise get. Even Roasting Plant's beta-site store, which is about half the size of a larger shop under construction in another part of New York, offers a choice of seven different beans and the usual lineup of espresso-based and brewed coffee drinks. The automated system also allows customers to blend those beans on the fly. "I don't know if that makes for a better cup of coffee, but it doesn't really matter what I think. The customer is completely in control here," Caswell says.

Automation also brings some much needed consistency to the roasting, brewing and grinding processes in ways that human beings can't muster day in and day out. "The industry view is that good coffee is an art that requires master roasters and baristas to flip the switch and twirl the knobs, but in reality it's easy for humans to fat-finger their way to bad coffee," says Matt Youney of [Youney Automation](#), one of two custom machine builders who worked on Roasting Plant's coffee system. "Automation brings control and repeatability to what had been a black art," he says.

That view may rankle some coffee aficionados, but it will resonate with engineers trying to improve product quality by automating the best practices of human experts. In Roasting Plant's case, some of that human expertise came from Caswell himself as well as from NY-based [Kobricks Coffee](#), which consulted on bean selection, roasting profiles and drink recipes.

Automatic Coffeemaker

Roasting Plant's automated coffee system is called the Javabot. And though its looks have been dressed up to make it fit into a retail environment, this machine has an industrial heart. "We approached it as we would any industrial project," says Youney.

Caswell came up with the specs for what Javabot should do, but he left much of the nitty-gritty design work to Youney and Dave Phillips of [Advanced Design Solutions Inc.](#) The two worked closely from the beginning of the project with Youney tackling the controls and Phillips handling the mechanical design.

The machine they came up with looks mechanically straightforward at first glance. Its storage section consists of clear tube-like bins; six hold the green coffee beans prior to roasting and seven hold the roasted beans. Pneumatic tubes connect these storage bins to each other as well as to the micro-roaster and automated grinding-brewing machines.

Most of what the Javabot does takes place on demand. When a customer orders the coffee, the beans shoot from the storage bins over to the grinding unit and drop down into the brewing machine. It takes only about 30 sec to convey, grind and brew the coffee beans.

The roasting process, meanwhile, usually takes place daily but not per individual beverage. "The beans need time to cool and out-gas after roasting. Most people wouldn't want to wait around that long," says Michael Hodor, Roasting Plant's head of technology. So after roasting in small batches, the beans are conveyed into the storage bins, whose tubular shape and bottom-mounted metering system ensure the beans exit on a first-in, first-out basis.

Though it seems straightforward, the system had its share of design challenges. Phillips recalls the pneumatic tubes and the weight-based metering subsystem all needed lots of optimizing to keep the beans intact as they made their way through the system. "Coffee beans are fragile, so we spent a lot of time making sure the system treated them gently," he says. Part of that effort involved the creation of rotary diverters that accurately guide just the right amount of beans into the pneumatic conveyor for their trip to one of two brewing machines, both the same off-the-shelf model from [Egro Swiss Coffee Systems](#).

It needed a few mechanical modifications to integrate with the Javabot. Since these machines are normally loaded manually, most of those changes related to making them accept beans from the pneumatic tubes.

Far more engineering work went into the air conveyor. Phillips says he optimized the pneumatic system “in the usual way” by tweaking air velocities and tube layout as well as minimizing any restrictions in tubes. That same work also helped keep the system relatively quiet.

The noise from the pneumatic conveyor is still noticeable, but not oppressive. And Caswell says some noise is beneficial. “We want customers to know what we’re doing isn’t just theater. Part of our brand is that the customers are actually walking into the machine that’s making their coffee,” he says.

Other mechanical design challenges involved the system’s micro-roaster, which usually handles batches of about a pound or so. To save time and money when building the prototype machine, Caswell selected an off-the-shelf, manual micro-roaster and asked Phillips to integrate it into the rest of the Javabot. “It would have been a lot easier to make a new roaster from scratch,” Phillips says.

And he ended up making extensive mechanical modifications to what started out as a manually operated roaster, including the addition of a pneumatically actuated butterfly valve to transfer the beans from a staging area into the roasting chamber below. He also added a cooling section below the chamber, which required him to raise the entire roaster on a pedestal. The completed roaster can stage, roast and cool beans simultaneously, which helps the small unit keep up with the demand for roasted beans.

Aside from the mechanical changes, the off-the-shelf roaster also needed a controls upgrade. “It came with low-level controls, just rheostats and switches,” Youney says, noting temperature deviations as small as 0.1 degrees F can create noticeable differences in the roasted beans. “Even temperature deviations this small were not acceptable,” Youney says. So he revamped the roaster controls, adding air temperature sensors and PID controls with ramp-soak capabilities.

Coffee Controls

The roaster wasn’t the only part of the Javabot to get a high-end controls package. Like many factories today, the Javabot has what Youney describes as “a real-time distributed control system.”

A supervisory PC sits at the top of that system, managing Roasting Plant’s drink- and roasting-related databases. The PC also gives the system a nice graphical user interface. “The PC basically does the things that PCs are good at,” Youney says. Below the PC are two compact [WAGO](#) 750 Series PLCs, one that oversees the roasting operations and another that supervises the storage and conveying operations — for example, controlling the air velocity of the pneumatic conveyor. Communications take place via Modbus TCP/IP.

The system’s lowest level of controls can be found on the bins themselves and on the Egro machines. Each bin features its own microprocessor, which talk to one another and the supervisory controls via serial communications. Working together, individual microcontrollers direct the metering operations related to individual storage bins while bigger bean movements such as those related to roasting or transfers between bins are handled by the PLCs.

Youney says the bin-mounted microprocessors and the system’s software together make the Javabot a very flexible machine. One good example of this flexibility involves changes to the contents of individual bins. If a new variety is added to a given bin or if an existing

variety is moved to another bin, the change cascades all the way back to the recipe management system.

Another good example involves on-the-fly blending. The system's control and software architecture makes it possible for customers to create their own blends by combining different percentages of coffee from two or more bins.

As for the Egro coffee machines, they required some integration work to become part of the Javabot. "The coffee machines run on 8051 microcontrollers, which was just fine with me. I cut my teeth on them," says Youney. The problem was the machines usually manage the entire grinding and brewing process themselves. Youney had to make them accept grinding and brewing parameters from the Javabot's supervisory control system. To do that, he created a new communications protocol that passes on all those parameters — more than 25 of them once you start combining all the brewing temperatures, infusion times and pressures with the various grinds.

So how good do all these control systems have to be? "Even small variations anywhere in the system can influence the taste of the coffee," Caswell says. Consider weight, for example. "People don't usually have tight control over weight. The target for a shot of espresso might be 14 grams but an individual barista could actually put in 10 or 16 grams or whatever. Our control is much tighter than that," he says.

In fact, the Javabot's metering system, which also takes bean volume and density into account, has "granularity down to the individual bean," Youney says, adding that tests of the metering system's accuracy have shown a standard deviation of just 0.25 grams.

Scaleable Design

Roasting Plant's first store in New York serves coffee to the locals in its Lower East Side neighborhood every day, but in many ways the first Javabot is really just a prototype. Caswell is currently building a second store in another New York neighborhood, and its Javabot will be about twice as big in terms of brewing machines and storage bins. The new system will also feature a custom-designed roaster instead of the modified off-the-shelf roaster of the prototype. And Hodor reports the supervisory controls will be migrated over to an Apple Macintosh, which is also the platform Roasting Plant uses for its point-of-sale system.

Scaling up the Javabot won't likely prove to be too big a deal. "It's been designed for scalability from the beginning," Youney says. His software, for instance, has all the hooks needed to add more coffee machines and bins. "The software even has a whole bunch of features we didn't use in the prototype," he says. These include Web-based ordering, customer profiles tied to bar codes and a slick roasting scheduler that uses fuzzy logic to predict demand patterns. And the modular design of the bins, with their self-contained metering systems and on-board microprocessors, allows the system to grow with a few extra tube runs.

Caswell says he plans to take full advantage of that scalability as he opens new Roasting Plant shops. "Another nice thing about automation is that it allows us to replicate our concept over and over again," he says.

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