Purdue University Calumet
School of Technology

Feasibility Study of Flowmeter & Operator Interface for a Liquid Filler Manufacturer

In partial fulfillment of the requirements for the
Degree of Master of Science in Technology

A Directed Project Proposal

By
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Abstract

A liquid filler manufacturer in Northwest Indiana sought to expand the capabilities of its machine lineup in order to address a common customer problem (overfilling) by taking advantage of a price drop in higher-accuracy filling equipment (Coriolis flowmeters). Additionally, there are several other filler manufacturers in the immediate area, and this one needs to stand out against the crowd in order to retain and attract business. The operator interface offered with many of its machines has been identified as an item for improvement.

Overfilling and subpar operator interfaces have one thing in common: Lost revenue. Overfilling containers gives away product, and poorly designed interfaces can result in mistakes or accidents, customer dissatisfaction, and damage to company image.

The purpose of this study was to determine the accuracy and precision of a Coriolis flowmeter versus other filling methods, as well as design a fresh, new operator interface based on proven design concepts and modern expectations. Feasibility of both items was evaluated based on the needs of the manufacturer and its customers.

Introduction

There have been clear signs in recent years that the food and beverage manufacturing industry is facing some major challenges. Prices of commodities (such as milk, wheat, soy, corn, coffee, rice, and meat) have risen dramatically, and some have achieved the highest prices in decades. To make matters worse, there are indications that the industry will be facing price hikes for years to come; the next 15 years or longer, in fact (Sutcliffe, 2008).

Given the situation described above, food processors are seeking ways to reduce costs. The largest cost in most food and beverage production facilities is material cost (MainStream, 2012). However, it is common practice for food processors to overfill containers. This is to avoid falling out of spec, avoid fines, and ensure high customer satisfaction. Because of escalating prices, however, this is not sustainable (Sutcliffe, 2008).

Material handling, processing, and packaging have a major impact on profitability. Low or underperforming yield can be the biggest loss for a facility, and yield recovery is the single highest return on investment (MainStream, 2012). Therefore, fill accuracy has become a top priority to minimize product giveaway and retain revenue.

Coriolis flowmeters, the most accurate flowmeters made, are now being offered at considerably lower cost. This has contributed to their extremely rapid growth in recent years (Yoder, 2010). Previously, these meters were considered affordable only in certain industries (such as pharmaceutical), but they have recently become economically feasible for many other industries.

In addition to rising material costs, the industrial workforce in the United States is changing. According to the International Society of Automation (ISA), the U.S. currently employs approximately 200,000 automation professionals. The demand for new workers grows roughly 3% each year, but workers are retiring at a rate above 5% each year. Because of this, many automation professionals are expected to wear more than one hat. Additional responsibilities can include additional duties (such as maintenance), or oversight of plants in another city or state (Miller, 2011). These people need to be able to do their jobs efficiently, effectively, and with minimal mistakes, but there is at least one thing standing in their way: Poorly designed operator interfaces.

The operator interface has evolved over the past 50 years. It originated as a collection of physical lights, switches, and annunciator panels with analog gauges and trend displays. Then it transitioned to electronic simulations and finally, to the computer interfaces of today. The human-machine interface (HMI) that many are using today evolved from a hard panel to group faceplate displays to piping and instrumentation diagram (P&ID) graphics with live faceplate values. Each type has been better than its predecessor and the progression from one to the other has been logical, but this does not mean that P&ID graphics are the best approach. In fact, these interfaces were created with little knowledge or science added into the design. Consequently, they are the cause of many issues, including major accidents (Nimmo 2012).

The purpose of this research is to aid a liquid filler manufacturer in Northwest Indiana in expanding the capabilities of its machine lineup. Overfilling containers has been identified as an industry problem, and a price drop of Coriolis flowmeters has spurred this study. Additionally, the HMI offered with many of its machines could benefit from a redesign.

Statement of the Problem

At a food processing facility, overfilling containers is a common practice (Sutcliffe, 2008). However, material costs are rising rapidly and overfilling significantly impacts profitability (MainStream, 2012). In addition, HMIs have evolved over the past 50 years without implementing formal design concepts, which can cost a company in a number of ways (Nimmo, 2012). Poor designs impede rather than assist operators and can contribute to abnormal situations, billions of dollars of lost production, accidents, and fatalities (Gruhn, 2011).

Significance of the Problem

As mentioned previously, overfilling significantly impacts profitability. In order to illustrate the gravity of this, consider the following example (Bui, Grimm, Kagan, & Orellana, 2007):

> Charcoal lighter fluid costs $2.29 per gallon from the supplier. 80,000 32-ounce bottles are produced per month, with 0.51 ounces wasted per bottle (319 gallons wasted per month). This results in $731 lost per month, and $8,772 per year.

Amount of overfill, value of the product, and volume produced directly impact the amount of lost revenue. Producing a large number per day of an expensive product with a large percentage of overfill, especially with multiple production lines, can result in a substantial amount of lost revenue per year. Better filler accuracy results in less product giveaway (Hi-Speed, 1997).

Overfill is not the only way to lose revenue. Poorly designed HMIs can also contribute. Research shows that HMIs that neglect ergonomics are more likely to increase occupational diseases, operating errors, and accidents. They can also contribute to costs associated with wasted working time, user frustration, and poor corporate image. Poor design can lead to customer dissatisfaction, which results in lost sales and damage to a company's image (European Agency for Safety and Health at Work, 2009).

Statement of the Purpose

The purpose of this study was to determine the accuracy and precision of a Coriolis flowmeter versus other filling methods, as well as design a fresh, new operator interface based on proven design concepts and modern expectations. Feasibility of both items was evaluated based on the needs of the manufacturer and its customers.

Definitions

Accuracy—degree of conformity of a measure to a standard or a true value ("Accuracy," n.d.)

Efficiency—the percentage of elapsed time during which the line was running (Hi-Speed, 1997)

Giveaway—the amount by which item weights exceed the label weight (Hi-Speed, 1997)

Human Machine Interface (HMI)—The user interface in a manufacturing or process control system; it provides a graphics-based visualization of an industrial control and monitoring system (PC Mag, 2012)

Normal Distribution—a frequency probability distribution centered around the mean of a population of data and following a bell shaped curve; the width is determined by the standard deviation of the data (Hi-Speed, 1997)

Overfill—the amount of product that exceeds the target (Wischhusen, Meier, & Brown, 2012); see *giveaway*

Particulate—of or relating to separate particles ("Particulate," n.d.)

Programmable Logic Controller (PLC)—a central control system from which one can operate and program functions of several independent or dependent systems. A PLC consists of a user interface, central processor, links to subsidiary controls, and an electrical control interface (Hi-Speed, 1997)

Piping & Instrumentation Diagram (P&ID)—A diagram which shows the interconnection of process equipment and the instrumentation used to control the process. In the process industry, a standard set of symbols is used to prepare drawings of processes (Automation Engineering, n.d.)

Repeatability—the standard deviation, or variation of the value of an item property, measured several times (Hi-Speed, 1997)

Standard Deviation—the spread of data around a central point; the data must follow a normal distribution (Hi-Speed, 1997)

Viscosity—the property or resistance to flow in a fluid or semifluid ("Viscosity," n.d.)

Assumptions

It was assumed that there is reliability of data and consistency of results between methods, since there was one individual (the author) conducting all tests. There was reasonable assumption that a semi-automatic, one-head setup could be scaled to an automatic, multi-head setup with a similar outcome. It was also assumed that the data provided for customer profiles was accurate, since the manufacturer provided them.

Delimitations

The scope of this study focused on one manufacturer, but results could be relevant for similar liquid filler manufacturers of the same scale in the same industry. Conducting detailed customer case studies was considered to be outside the scope. Also, Statistical Process Control with regard to overfilling is deemed to be outside the scope. The results of this study strictly pertain to customers who have made the choice to invest capital in machine upgrades or replacement; not for those who wish to improve existing systems. Additionally, the PLC Ladder Logic program and overall functionality of the manufacturer’s HMI remain unchanged. Improvements are suggested at the end of the report.

Limitations

The study was limited to four liquids, four container sizes, one Coriolis flowmeter, and two other filling methods. This was due to limited materials and equipment allowed by the company for testing, as well as time constraints. However, it provided an accurate picture despite the limits set.

The results of this study may be limited by operator error, filler setup (electronic or manual), reusing containers and materials during testing, low product supply, error caused by fillhead malfunction, or equipment out of calibration. Care was taken to prevent issues that might contaminate results; some data were discarded and tests were re-conducted when an issue surfaced.

When demonstrating the overfill analysis (see Table 3), costs for product supply were not readily available. Wholesale prices were found and reduced to account for profit margins. The information in the table was merely provided to demonstrate how overfill can affect the bottom line, and accuracy was not crucial for the point.

Literature Review

The review of the literature for this research is separated into four primary areas: liquid filling methods, operating principles and benefits of Coriolis flowmeters, flowmeter case studies, and HMI design principles. The sum of these areas serves to illustrate the current climate surrounding fill practices and HMI design, and provide justification for this study.

Liquid Filling Methods

When choosing a liquid filler, there are many factors to consider. These include product characteristics (such as viscosity, temperature, chemical compatibility, particulate size, foam characteristics), accuracy and speed required, giveaway toleration, changeovers, and so on. Fillers typically take the shape of rotary or inline, and can range from simple methods (simple time gravity) to more complex and accurate (piston, flowmeter, and netweigh). The following list describes the small sample of liquid fillers addressed in this study (ASYSCO, n.d.; Inline Filling Systems, 2006):

Piston filler—This is one of the oldest and most reliable filling methods in the packaging industry. It operates by drawing a piston into its cylinder, thereby drawing a precise amount of product into the cylinder by suction. There are two types: rotary valve and check valve. A rotary valve changes position and the product is pushed out of the nozzle. This type is easy to use, cost-effective, accurate, and fast for fairly thick products. It costs more than overflow and gravity fillers, but less than a servo pump filler. However, there are several disadvantages to this filler. It is not suitable for thin products because its mechanical characteristics allow for leaks (check valve piston fillers are suited for those applications). Cleanup and setup involved in changing products or container sizes can be tedious and time-consuming. Also, small and large volumes cannot be filled accurately using the same piston (gallon-size might be accurate, but 8-ounce won't be if the piston is large). Rotary valve piston fillers are best suited for viscous products that are paste, semi-paste, or chunky with large particulates. They commonly fill heavy sauces, salsas, salad dressings, cosmetic creams, heavy shampoo, gels, conditioners, and can also be used for paste cleaners and waxes, adhesives, epoxies, heavy lubricant oils, and greases. Check valve piston fillers are suitable for products like mineral spirits, water, and hand soaps.

Pump filler—This type of filler is very versatile and capable of filling nearly any type of product that can be pumped. Each nozzle has a dedicated motor-controlled pump. Disadvantages include a high capital cost, and expertise required for troubleshooting and maintenance. It is able to handle thin, medium, and thick liquids, as well as liquids with large particulates. Examples include soaps, pharmaceutical products, oils and greases, cosmetics, salsa, and sauces.

Coriolis flowmeter filler—This type of filler measures mass directly. It can handle a wide range of viscosities, from thin to thick with particulates, with high accuracy. It can also measure density and temperature. Changeover procedures are quick and easy. This filler can be used with many container types, from fractional to 55-gallon drums.

Operating Principles and Benefits of Coriolis Flowmeters

Coriolis flowmeters (named after the Coriolis effect) operate on the principle that "inertia created by fluid flowing through an oscillating tube causes the tube to twist in proportion to mass flowrate." Some meters have two tubes, which vibrate in opposition to each other and contain a magnetic coil. Sensors, made up of magnet and coil assemblies, are mounted at the inlet and outlet of the tubes. The coils move through the magnetic field created by the magnet, which creates voltage in the form of a sine wave. The sensors detect the amount of twist in the tubes when flow is present. This produces a sine wave, and the phase shift is measured. Flowrate is derived from the difference in phase shift formed by the sensors. When flow is not present, the sine waves are in phase with each other (Yoder, 2011).

Many products are sold by weight rather than volume, which make Coriolis flowmeters desirable. They measure mass flow of liquids and gases, and the measurement is not affected by viscosity, density, temperature, vibration, or pressure (Packaging Digest, 2006). In addition, they are the most accurate flowmeters made. Many Coriolis flowmeters achieve accuracies of 0.1 percent (Yoder, 2011). They offer superior overall measurement accuracy, repeatability, and multivariable capability. The bent-tube variety offers highly accurate, reliable and rangeable mass flow/density measurement. The flow tubes are constructed with all-welded metal surfaces that are free of synthetic materials, which prohibit absorption of process chemicals (Salupo & Parson, 2006). Despite their higher cost, many companies choose these meters because of their high accuracy and reliability (Yoder, 2010). Reduced piping requirements help decrease size and cost of these systems (Packaging Digest, 2006).

Flowmeter Case Studies

In 2004 a cosmetics industry customer chose to replace all piston filling machines with flowmeter-based machines in order to increase productivity and ensure more consistent quality of their shampoo and conditioner. Shampoo and conditioner are susceptible to entrainment of air bubbles, which results in overfill; this can shut down the production line if it goes unrecognized. The aim was to increase filling speed and accuracy (0.5 percent or better), as well as decrease production downtimes. According to the customer, the line that was converted is "the line with the highest productivity, the highest accuracy, and the lowest downtime." The setup includes sixteen Coriolis flowmeters (Endress+Hauser Dosimass series, the "highest accuracy Coriolis flowmeter") and diaphragm valves, and an Omron PLC (Technolead, 2012).

In 2006 a nationally known paint manufacturer switched to Pneumatic Scale Corp. machines equipped with Micro Motion Coriolis flowmeters from a piston filler/loadcell weight measurement system made by the same company. The problem was that piston fillers sometime have issues with high-texture paints or frequent product and/or color changes. Also, the loadcells accumulated spilled paint (which becomes nearly impossible to clean) and as a result, the measurement becomes inaccurate or the loadcell ceases to function after awhile. Seven machines were installed with Coriolis flowmeters. Of the five rotary-style machines, four have twelve heads and one has six; the remaining two in-line machines have three heads. The customer says the new systems have met expectations and host several benefits: there are no concerns about paint spillage, frequent cleaning, maintenance, or calibration. The new fillers are also simple and reliable to operate (Packaging Digest, 2006).

This year, after significant research and rigorous comparison to competitive products, U.S. Bottlers chose flowmeters from Endress+Hauser to meet its needs. The company had this to say:

"Liquid bottling machines are available in several styles including pressure gravity, vacuum, piston, electronic weigh scale, flow, and mass measurement. All have advantages and disadvantages in various applications but—in general—flowmeter-based filling machines have emerged as the first choice for most of our customers."

Liquid bottling machines can have up to 120 filling heads that need to operate at speeds up to 1,000 bottles per minute. Machine design is based on balancing speed, filling accuracy, and cleanliness; accurate and repeatable flow measurements are critical. The accuracy of the flowmeters in use at U.S. Bottlers is "better than any previous sensor technology for liquid filling." They note, however, that overall accuracy can be less than the flowmeter rating due to the effect of valves, solenoids, pneumatics, vibration, and pressure swings present in the system. They stated these advantages:

"Because flowmeter-based filling machines are so accurate, they don't need an overflow to establish a liquid fill level, as with mechanical fillers. Thus, a flowmeter system requires about half the total amount of piping, hoses, nipples, manifolds, etc. It also doesn't require as much pressure, cleaning solutions, and time to clean as a mechanical filling system . . . Coriolis and magnetic flowmeters have no moving parts or obstructions, which makes them easy to clean and flush . . . With a flowmeter system, changing product doesn't require calibration as we simply store recipes based on empirical data from previous runs to allow quicker switching between bottle sizes and ingredient change."

They also stated that each filler equipped with Endress+Hauser flowmeters meets quoted accuracy guarantees and is as good as any filler they've produced in the history of the company. Also, and perhaps more importantly, many customers that have purchased these fillers have come back for repeat orders (Risser 2012).

HMI Design

Complex HMIs can lead to longer training times, and they are not easily understood by operators with less experience or formal skills, especially by those who do not understand the English language very well (Hoske, 2012). Operators can also struggle with tracking information or get overloaded with information, and develop situation awareness issues. In essence, a poorly designed HMI is an environment that supports human error (Nimmo, 2012). This can lead to mistakes or accidents, which can cost a company money. These typically occur in one of the following ways (European Agency for Safety and Health at Work, 2009):

"The most common cause is an operational error arising out of, for example, failure to understand or to act upon the information provided by the machine, or inability to control the machine correctly, for example because of an input error. Many accidents, however, can also be attributed to the HMI not being adapted to non-routine operation, such as maintenance or repair. Finally, a badly designed HMI can also encourage bypassing safety devices, which often lead to accidents."

A poorly designed HMI has the following characteristics (European Agency for Safety and Health at Work, 2009; Gruhn, 2011; Nimmo, 2012):

- P&ID representation
- Presentation of raw data as numbers

- No trends
- Animated graphics
- Bright/high contrast colors, 3D shadows
- Color coding of piping and vessel contents
- Measurement units in large, bright text
- Lots of crossing lines
- Alarm related colors for non-alarm related elements
- Inconsistent colors/design
- Lack of hierarchy and functionality
- Too many screens

Effective HMIs should have the following characteristics (Gruhn, 2011; Nimmo, 2012):

- Depiction of process status and values as information, not numbers
- Layout consistent with operators model of the process (not P&ID)
- Key Performance Indicators as trends
- No gratuitous information
- Gray backgrounds, low contrast
- Very limited use of color (for alarms)
- Consistency in visual elements and color coding
- Gray process lines
- Measurement units in low contrast lettering

- New graphics should be designed to the new life cycle model (ISA-101 draft standard) and follow Human Factor/Ergonomic rules (ISO 11064-5 standard)
- Application of Gestalt principles of perceptual grouping in user interaction design

In addition, new hires are expecting the same level of usability and functionality that they have with their personal technology (such as smart phones). They are demanding the same level of easy access and simple interaction with plant-floor and business data on their HMIs (Miller, 2011). Miller also notes that “a lot of operators in North America will be retiring in the next decade or less. Their replacements will be people who have grown up with sophisticated hardware and software, with Twitter and iPhones. They will have a different perspective on information than did previous generations. That factor is driving current research and development, and will drive HMI systems of the future. As the need grows for richer graphics and greater integration capabilities to support modern mobile platforms, we will have operators who know how to and want to use them” (Katzel, 2011).

Methodology

With regard to Coriolis flowmeters, it was difficult to establish accuracy and value for a specific application based on the reviewed literature. As stated, accuracy can be affected by other components in the system. Also, no raw data was given (actual accuracy percentages, precision, detailed Return on Investment, etc.), so testing was conducted for the manufacturer’s specific needs and applications. However, it seemed that the Endress+Hauser flowmeter had a proven track record for other manufacturers and seemed to be an excellent candidate for performing tests. In addition, the manufacturer and its customers could reap many benefits if the flowmeter returned similar results to the case studies, which made testing worthwhile.

With respect to HMIs, it was clear that there were many principles for designing one that is effective, and justification seemed sound. However, younger operators entering the workforce are expecting a certain level of user-friendliness and functionality and are accustomed to having information presented in certain ways. These two ideas can contradict one another in practice. The key here was to design an interface that has a good balance of intuitiveness and effectiveness and abides by the most important HMI design principles documented.

Hypotheses

The primary hypothesis was that the Endress+Hauser Coriolis flowmeter would be more accurate than the other two methods with at least one type of liquid. Second, the newly-designed HMI would be deemed an improvement over the previous HMI and accepted if cost and benefits can be justified.

Instrumentation

As mentioned previously, Endress+Hauser Coriolis flowmeters were the most accurate. Testing utilized an Endress+Hauser Dosimass 8BE, along with the following equipment (paired with the flowmeter or for comparison):

- Allen-Bradley MicroLogix 1400
- Maple Systems HMI, 7”
- Pressure vessel
- Gear pump

- Piston filler system (check valve, rotary-valve)
- Centrifugal pump

For HMI design, a 10.4” B&R PowerPanel 520 was generously provided by B&R and IFP Automation for the duration of the project. The MicroLogix Ladder Logic was created fresh in B&R’s Automation Studio, and this is where HMI design took place as well.

Data Collection

Testing for accuracy and precision consisted of filling 100 containers of each size (2-ounce, 4-ounce, 8-ounce) with four liquids of varying viscosities (water, cooking oil, alcohol gel, and a crushed tomato/water mixture with particulate) using three types of fillers (Coriolis flowmeter, positive displacement gear pump, and piston). Each container was weighed, and the weight was entered into a spreadsheet. Upon completion of testing, the accuracy and standard deviation of each container type (per liquid, per filler) was calculated, and an average was taken that combined all container sizes (per liquid, per filler) to account for certain factors, such as low supply/refill during testing.

The HMI design process sourced information from the literature review regarding effective design practices, while incorporating elements from modern consumer device interfaces (such as smart phones and tablets) and machine interfaces that were visually appealing.

Findings

This section presents the results of both the filler comparison tests and the HMI redesign. Findings include the ideal filler setup for each type of product, example costs of overfill for manufacturer customers, and comparison of the old and new operator interfaces.

Coriolis Flowmeter Comparison & Overfill

After collecting weight data for thousands of containers, the standard deviation was found for each method-liquid-container size combination; the normal distributions are located in the Appendix. The average standard deviation across container sizes was determined and reported in Table 4.1 to show precision for each method and liquid. Accuracy was found for each as well, using a +/- 0.3% error (see Table 4.2). This was chosen because it was a specification for the Coriolis flowmeter.

Naturally, a lower standard deviation pertains to higher precision. The results indicated that the Coriolis flowmeter (in one setup or another) consistently outperformed the other fillers. The following liquid and Coriolis flowmeter pairings achieved the best results:

- Water with Coriolis flowmeter and gear pump
- Cooking oil with Coriolis flowmeter and centrifugal pump
- Alcohol gel with Coriolis flowmeter and pressure vessel
- Crushed tomato and water with Coriolis flowmeter and pressure vessel

The Coriolis flowmeter also achieved the highest accuracy in all categories, with a couple exceptions: It achieved the same accuracy as the rotary valve piston filler with crushed tomato and water, as well as the check valve piston filler with cooking oil. Nevertheless, the following liquid and Coriolis flowmeter pairings achieved the best results:

- Water with Coriolis flowmeter and gear pump; Coriolis flowmeter and centrifugal pump; Coriolis flowmeter and pressure vessel with APACKS fillhead
- Cooking oil with Coriolis flowmeter and gear pump; Coriolis flowmeter and centrifugal pump
- Alcohol gel with Coriolis flowmeter and pressure vessel
- Crushed tomato and water with Coriolis flowmeter and pressure vessel

It was also interesting to note that implementing the APACKS fillhead could improve precision and accuracy further.

Table 4.1: Filler Standard Deviation

	Coriolis Flowmeter & Pressure Vessel	Coriolis Flowmeter & Gear Pump	Coriolis Flowmeter & Centrifugal Pump	Coriolis Flowmeter & Pressure Vessel with APACKS Fillhead	Positive Displacement Gear Pump	Check Valve Piston Filler	Rotary Valve Piston Filler
Water	0.0470	*0.0079*	0.0183	0.0198	0.1894	0.0157	-
Cooking Oil	0.0254	0.0340	*0.0115*	-	0.0285	0.0183	-
Alcohol Gel	*0.0166*	0.0419	-	-	-	-	0.0353
Crushed Tomato & Water	*0.0324*	-	-	-	0.0974	-	0.0354

Table 4.2: Filler Accuracy

	Coriolis Flowmeter & Pressure Vessel	Coriolis Flowmeter & Gear Pump	Coriolis Flowmeter & Centrifugal Pump	Coriolis Flowmeter & Pressure Vessel with APACKS Fillhead	Positive Displacement Gear Pump	Check Valve Piston Filler	Rotary Valve Piston Filler
Water	98.75%	100%	100%	100%	29%	99.67%	-
Cooking Oil	99.75%	99.67%	100%	-	100%	100%	-
Alcohol Gel	100%	85.33%	-	-	-	-	87.67%
Crushed Tomato & Water	99.33%	-	-	-	39.33%	-	99.33%

Table 4.3 provides approximate figures for the cost per gallon of various products. At a rate of 4,000 gallons per day and overfill of just one percent, the table demonstrates how quickly lost revenue adds up each year. Because of the Coriolis flowmeter's versatility, it could handle every product on the list with ease (based on the varied viscosities of the test liquids).

Table 4.3: Simple Overfill Analysis

Product	% of APACKS Business	Viscosity	Approx. Cost per Gallon	Gallons per Day	% Overfill	Lost Revenue Per Year
Water	2	1	$0.30	4,000	1	$4,380.00
40W Motor Oil	2	250-900	$2.93	4,000	1	$42,778.00
Olive Oil	7	65-150	$5.00	4,000	1	$73,000.00
Honey	7	1,500-6,000	$12.94	4,000	1	$188,924.00
Hot Sauce	5	50	$4.17	4,000	1	$60,882.00
Ketchup	5	50000	$3.61	4,000	1	$52,706.00
Salsa	5	10000	$5.47	4,000	1	$79,862.00
Mustard	5	70000	$1.39	4,000	1	$20,294.00
Liquid Fertilizer	8	300	$600.00	4,000	1	$8,760,000.00
Shampoo	5	1000	$35.83	4,000	1	$523,118.00
Conditioner	5	2000	$63.00	4,000	1	$919,800.00
Lip Balm	8	15	$7.69	4,000	1	$112,274.00
Household Spray Cleaner	8	1.0-15	$4.58	4,000	1	$66,868.00
Dish Soap	8	1500	$7.08	4,000	1	$103,368.00
Mouthwash	5	1.0-15	$9.58	4,000	1	$139,868.00
TOTAL:	85					

Operator Interface Redesign

Redesigning an operator interface is something that most companies are not willing to tackle. Ergonomics, ease-of-use, and aesthetics may not be top priorities. Not to mention it involves time and money to complete. However, machine manufacturers like this one are in a unique position: With standardized product lines, they can design one interface and ship identical (or slightly modified) copies with each of their machines. Spending some time and money initially can produce a tremendous return on investment if customers find the design and functionality attractive, especially if there is no added cost. That being said, the following figures are before and after images of the machine interface:

One will take notice the following design elements and improvements:

- Vibrant, attention-grabbing loading screen based on the manufacturer's brochure
- Subtle blues and grays in the background to minimize eye strain and promote contrast with text
- Fixed text is dark gray, and live values are dark blue
- The main layer is full of icons, which aid non-native English speakers and reduce amount of text that requires translation; icon legend is in the help menu
- Icons and buttons change color to reflect selection
- Alarm colors (red, yellow, etc.) are exclusively reserved for alarms

- Distracting animations are absent because they are not necessary to this process
- Total pages number of pages reduced
- One can reach any page from any other page with minimal effort
- VNC is available to connect to a smart phone or tablet; useful for management to check on production, or operators to check machine status while away

Conclusion & Discussion

HMI Design Implementation

Due to limited availability of all involved parties (APACKS, IFP Automation, and B&R), the new HMI unveiling took place after completion of this report. Extremely positive feedback was received from a member of IFP, so it is anticipated that all others will receive it in a similar manner. If adopted, the manufacturer will set itself apart from other competitors in the area by including a fresh, modern face with each of its machines. If B&R equipment replaces machine electrical components (PLC, HMI, etc.), the manufacturer will most likely benefit from reduced cost as well.

Coriolis Flowmeter Implementation

Products listed in Table 3 account for over 85 percent of the manufacturer's business, which is a huge opportunity for sales (more products could be added, such as paints and solvents, but costs were difficult to determine). While a Coriolis flowmeter could improve precision and accuracy of nearly any customer's line, it would have the biggest impact on applications that involve high speed, high volume, and (especially) products with high costs. Detailed customer information was not provided, so it is uncertain how many fit this bill (or how many are struggling with fill accuracy and precision). However, the results indicate that machines fitted with Coriolis flowmeters would quickly become an asset by capturing new business opportunities and helping customers recoup losses.

In addition, customers would benefit from the ability to use the same machine to run containers of nearly any size, easy changeovers, less maintenance, and lower susceptibility to inaccuracy caused by vibration in the line. If the manufacturer's experience is anything like the case studies, it will profit from customer satisfaction in the form of repeat business.

Future Work

Automation is moving in exciting new directions besides improved fill accuracy and HMI design. Companies are taking the plunge and implementing things like LTE, multi-touch interfaces, mobile devices and apps, software that allows them to view Key Performance Indicators on any screen (including televisions). Machines can even call or text engineers when there is a problem. Best of all, companies are seeing immediate improvements (and maintained security) by using new technology. Further work in this area could include performing feasibility studies on these technologies (and more) for specific manufacturers in order to help move everyone forward into an efficient, profitable future.

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