

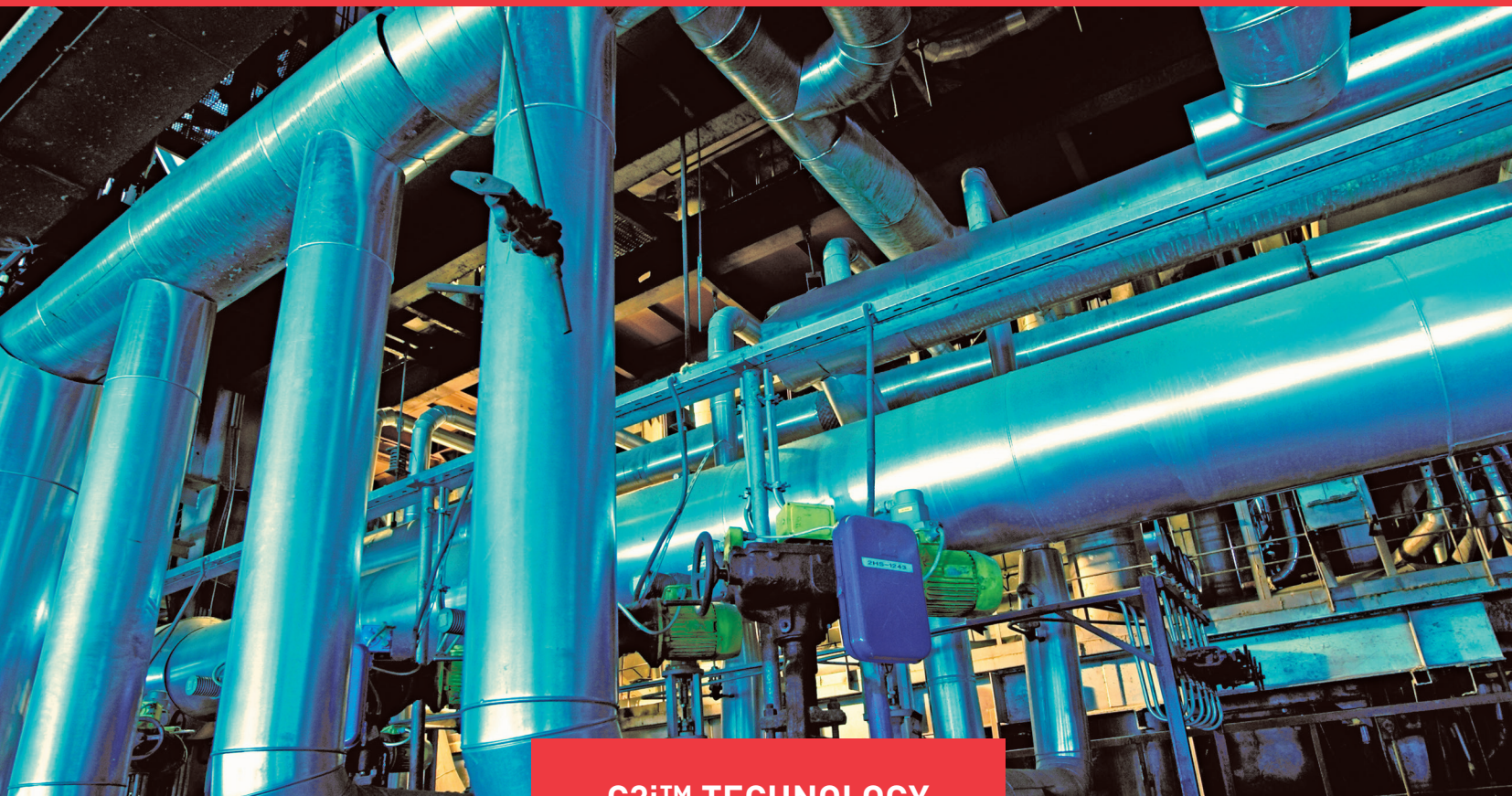


C2i™ TECHNOLOGY

**IMPROVED SYSTEM RELIABILITY, SAFETY AND PROCESS CONTROL
WHILE REDUCING RISKS, OPERATING AND INSTALLATION COSTS**

**An integrated intelligent network of advanced control technologies that
delivers superior system integrity through innovative process heating
and temperature management solutions.**

- Reduces operating costs with advanced continuous condition monitoring
- Lowers risk with proprietary control algorithms and engineered technologies
- Decreases installation costs by minimizing material and labor content
- Enables process optimization with developed control systems



C2i™ TECHNOLOGY

Improved process integrity and greater cost savings with C2i™ Technology

C2i™ Technology is an integrated intelligent network of advanced control technologies, component products and systems from Chromalox that delivers superior system process integrity through innovative temperature sensing, process heating and temperature management solutions. By utilizing exclusive control algorithms and engineered technologies developed by Chromalox, C2i™ Technology reduces both installation and operation costs while mitigating system risk and supporting process optimization.

Unplanned equipment maintenance and catastrophic failures occur when component health is unknown or not properly managed. C2i™ Technology maintains process integrity by providing predictive intelligence and process protection capabilities. This coverage reduces equipment downtime, permits properly scheduled maintenance and keeps your process running as planned.

To ensure comprehensive coverage and protection, mission-critical equipment must be able to remotely communicate to facility central control centers. C2i™ facilitates operation-wide, real-time system health status via a multitude of industrial fieldbus protocols and developed supervisory control technologies.

C2i™ Technology concisely equates to exceptional system process integrity. It is a result of engineered ingenuity and it incorporates proprietary condition monitoring algorithms and process safety features, delivering continuous predictive analysis monitoring and proactive alerts of potentially emerging system issues.

C2i™ offers all-encompassing coverage as it expertly integrates these control technologies across multiple systems and enables system-wide compatibility through industrial communication protocols.

C2i™ Technology is present throughout the Chromalox product offerings. It is embedded in discrete temperature and power control components, control panel systems, and fully integrated power distribution skid systems and it is available for Chromalox heat trace cable and industrial heaters and systems.

Engineering Ingenuity

Chromalox C2i™ Technology is unmatched in its breadth of innovative temperature sensing, process heating and temperature management solutions. For nearly a century, Chromalox has emphasized superior system reliability by integrating advanced control technologies with our

heating systems. These proprietary C2i™ technologies are a result of engineered ingenuity and they provide progressive condition monitoring, process safety, and system-wide integration, which are instrumental components of process integrity.

Condition Monitoring

Condition Monitoring, a major element of predictive maintenance, can provide accurate, real-time health status of process equipment to reduce unexpected equipment downtime and expensive repairs. It serves notice of deteriorating conditions and allows for preventive and corrective actions to be scheduled at the optimal time and before the equipment ultimately fails.

Parameter Diagnostics, an advanced C2i™ control technology, is a powerful condition monitoring feature that should be utilized on all vital process heating equipment. Expected values for common parameters, such as temperature, voltage, current, and power, and their respective rates-of-change, are entered as reference point values during controller programming. These values are continuously monitored

during normal operation to identify and report on unacceptable levels or significant changes. Such variations can be indicative of developing equipment problems.

As an example, elevated load or leakage current readings, measured in Amperes (Amps), can be a clear symptom of imminent electric heater issues. In such a case, SCR power controllers equipped with proprietary C2i™ algorithms will automatically adjust the output power to a safe level and enable an alarm condition.

C2i™ Technology also provides condition monitoring on non-traditional process variables, such as battery health. Exclusive firmware developed by Chromalox seamlessly integrates wireless temperature sensing into its heat trace control systems. An industry first, this firmware distinguishes between wired and wireless circuits to provides three levels of remaining battery life for each wireless temperature transmitter on the system. As a result, process uptime is maximized and facility owners have the peace of mind knowing that service may be properly planned well before the transmitter battery expires.



C2i™ Technology is a comprehensive intelligent network of advanced control technologies that delivers consummate system-wide process integrity through highly engineered innovative temperature sensing, process heating and temperature management solutions.

Parameter Diagnostics may also be enabled on processes which operate intermittently. The Chromalox-developed Autocycle feature employs a Cyclical Condition Monitoring function that is useful during prolonged scheduled down time periods. When enabled, this proprietary C2i™ firmware technology exercises all heating circuits with a pulsed voltage which facilitates a system-wide functional test. The frequency of the test is user selectable from 1 to 999 hours in one hour increments and is established during controller setup. System faults, such as high or low temperatures and currents, current leakage, sensor and communication failures, and low wireless transmitter battery levels will present themselves accordingly. This allows for maintenance personnel to correct the faults during non-essential operating periods.

Process Safety

Equipment breakdown is not always predictable. **Undesirable parameter values, harmful external events,** and unknown **mechanical failures** can render process equipment completely helpless. C2i™ Technology has the ability to remedy unacceptable conditions and tolerate certain mechanical failures to keep your process running safely and securely until the specified fault can be properly addressed.

Undesirable Parameter Values

Traditional linear-resistant electric heating elements employ Magnesium Oxide (MgO) to provide the necessary dielectric strength or electrical isolation from the heater coil to the outer sheath. The MgO however, is inherently hygroscopic, which means it naturally absorbs moisture.

When excessive moisture contaminates the MgO the dielectric strength becomes compromised. During lengthy inactive periods, the moisture content may exceed a safe limit, allowing internal arcing to take place when the element is energized. Unless the moisture is removed, catastrophic heater failure can occur which can destroy equipment, shut down entire processes, and cause significant production losses.

The solution to this problem is to utilize controllers with sophisticated C2i™ parameter monitoring technology that sense when heating elements contain moisture and understand how to remedy the condition.

The dielectric strength of a heater can be monitored by the amount of leakage current within each circuit. As the dielectric strength deteriorates, the leakage current, which is measured in milliamps (mA), increases. High leakage current levels typically occur at system startup since the heater has been de-energized long enough for it to absorb moisture. In this instance, controllers with C2i™ Technology detect the elevated leakage current and enable one of several proprietary soft start algorithms, such as a current limiting output. This control method reduces the output power to a safe level so that no damage to the electric heater occurs until the moisture is driven out of the element. Both the output power and the duration of the soft start profile are programmable by the user.

In the event that the current leakage level exceeds the maximum allowable limit during normal operation, our industry exclusive C2i™ Technology controllers automatically reduce output power to 15% and switch the control firing mode from Zero Cross to Phase Angle. The

When C2i™ Technology is employed, electrical process heater life is extended, thermal systems function more efficiently, overall process awareness and safety are increased, and both installation and operating costs are reduced.

controller will remain in this control mode until the leakage current parameter value returns to a safe level.

By utilizing controllers with C2i™ Technology in applications where moisture can be detrimental, heater life is greatly extended, system safety and process integrity is significantly improved and operational costs are reduced.

Harmful External Events

Events external to the process, such as sudden significant current or voltage surges, can damage electronic and mechanical components and be detrimental to process equipment resulting in an unplanned system shut down.

In applications susceptible to intermittent short-circuits and voltage overloads, Chromalox power controllers with C2i™ Technology are able to manage these events and can be programmed to restore power automatically or manually when the fault has cleared, preventing complete process shutdown and maintaining production. These

controllers continuously monitor the load current and instantaneously isolate the power switching device if the load exceeds a pre-set threshold. The controller automatically enters into a soft-start control mode after current is restored. During this ramp-up time, the firmware tests for any permanent short circuits and once again cuts the power should any exist. This prevents further system damage in the event that the fault is not effectively cleared.

This patented C2i™ fault-protection feature eliminates the need for extra-rapid fuses, reduces machine downtime and the costs associated with replacing fuses. By reacting immediately and tolerating the harmful event, this C2i™ Technology also prevents increased operating costs associated with process equipment damage and product loss.

Mechanical Failures

Without warning, critical system components such as temperature sensors, can fail or be inadvertently damaged. Excessive corrosion or vibration, exposure to extreme temperatures and even human error





can contribute to unexpected sensor failures. In most control systems, the process controller does not know how to properly behave when the expected sensor input signal is not received. As a result, controllers resort to default output settings as a safety precaution. In many cases, alarms are enabled and the heater output is set to zero percent, which brings the process to a halt.

This unplanned downtime, production stoppage and potential loss of valuable material can be avoided with C2i™ Technology. Chromalox utilizes exclusive controller features and developed control technologies to efficiently manage sensor faults and failures.

Chromalox offers controllers that can be programmed with a default heater output from 0% to 100% when presented with a sensor fault condition. This permits an enhanced level of process reliability and allows the owner to maintain production at a compromised level of control until the sensor problem can be properly addressed.

Particularly vital systems demand uninterrupted heater output and full process control. In these cases, a predetermined heater output level is an unacceptable solution to a failed sensor condition. Chromalox's unique and powerful sensor mapping feature solves this problem by providing multiple layers of sensor redundancy. This developed control

Chromalox's C2i™ supervisory control technology efficiently provides remote monitoring and value management of each parameter on every heater circuit across all control systems.

technology permits up to 252 sensor inputs per circuit and the output behavior can be based on the minimum, maximum, or average sensed temperature of all sensors mapped to that particular circuit. Additionally, a sensor alarm will be enabled should any sensor fail within that circuit. This C2i™ Technology lowers operating costs and provides the user with unmatched flexibility and security, thus ensuring 100% system reliability through continuous system uptime and complete process control.

System Integration Expertise

In today's sophisticated industrial systems it is impractical to have process heating equipment which may only be monitored locally. To ensure complete system awareness and safety, all process equipment must efficiently communicate with centralized control centers and provide real-time system wide health status. To satisfy these needs, C2i™ Technology provides expert system-wide integration using a multitude of widely accepted industrial protocols and developed supervisory control technologies.

Industrial companies utilize a distributed control system (DCS) to remotely communicate with all significant process systems throughout their facilities. Chromalox offers several Fieldbus protocols, such as Profibus, ProfiNet, DeviceNet, Modbus, EtherCAT, and several others,

which provide the necessary language and connectivity for proper remote equipment monitoring and parameter management. In addition, Chromalox has developed an industry exclusive wireless temperature sensing C2i™ Technology which permits Chromalox heat trace controllers to seamlessly integrate with existing *WirelessHART* protocol networks. This capability solves remote application challenges where wired temperature sensing becomes cost prohibitive.

Understanding equipment health status of multiple control systems requires an effective and comprehensive integrated central monitoring solution. Chromalox's C2i™ supervisory control technology is just that. It efficiently provides remote monitoring and value management of each parameter on every heater circuit across all control systems.

However, monitoring a large volume of circuits can be difficult to manage. Such complexity can lead to missed alarm events as well as an overwhelming amount of nuisance alarm notifications. The Chromalox proprietary engineered software technology continuously provides instant alarm event visibility from five different resolution levels as well as selective alarm announcement control. As a result, this well-organized C2i™ supervisory control technology lowers operating costs and improves system reliability by efficiently providing total system health awareness and eliminating missed alarm events.





Chromalox's exclusive C2i™ in-situ condition monitoring technology provides unmatched process integrity through true parameter predictability. As a result, operational costs are significantly reduced and system safety is greatly improved.

The Unique Benefits of C2i™ Technology

Reduced Operating Costs

The costs associated with unexpected downtime can be substantial and far-reaching. As previously described, unacceptable leakage current levels in resistive heating elements can stop a thermal process dead in its tracks. As a result, unplanned maintenance and additional service are needed that will increase operating costs significantly. The following scenario is a real-world illustration of that impact:

After sitting idle for several months due to onsite construction delays, startup services began on a 400 kW immersion heater system that did not employ C2i™ Technology. As a result of improper storage by the end user, the elements began operating with extremely high current leakage levels due to excessive moisture in the elements. Attempts to dry out the heater through conventional means were proven unsuccessful. The only solution was to remove the heater and return it to the manufacturer for re-work. The extra unplanned service fees, shipping and rework charges as well as the revenue losses due to the unexpected downtime, cost the

customer \$53,200. By incorporating C2i™ Technology upfront to either prevent or correct the situation, the customer would have saved over \$50,000 and production would have remained on schedule.

However, this particular case could have turned out much worse. When catastrophic electric heater element failure occurs due to internal arcing, temperature sensors and control systems can also be compromised. Ancillary process components such as pumps, valves and motors are typically integrated with heating systems and when the heater fails, collateral damage to these components frequently occurs. With C2i™ Technology, proprietary algorithms and engineered technologies provide continuous in-situ condition monitoring which alerts the operators of deteriorating conditions and can properly mitigate the root cause. C2i™ Technology protects industrial heating systems, permits nonstop process uptime, allows for timely maintenance service scheduling and eliminates additional operational costs.

CASE STUDY: OPERATIONAL COST SAVINGS

Chromalox C2i™ Technology Can Significantly Lower Operating Costs And Reduce Risk.

Example: Flanged Immersion Heater With Poor Dielectric Strength

PROBLEM

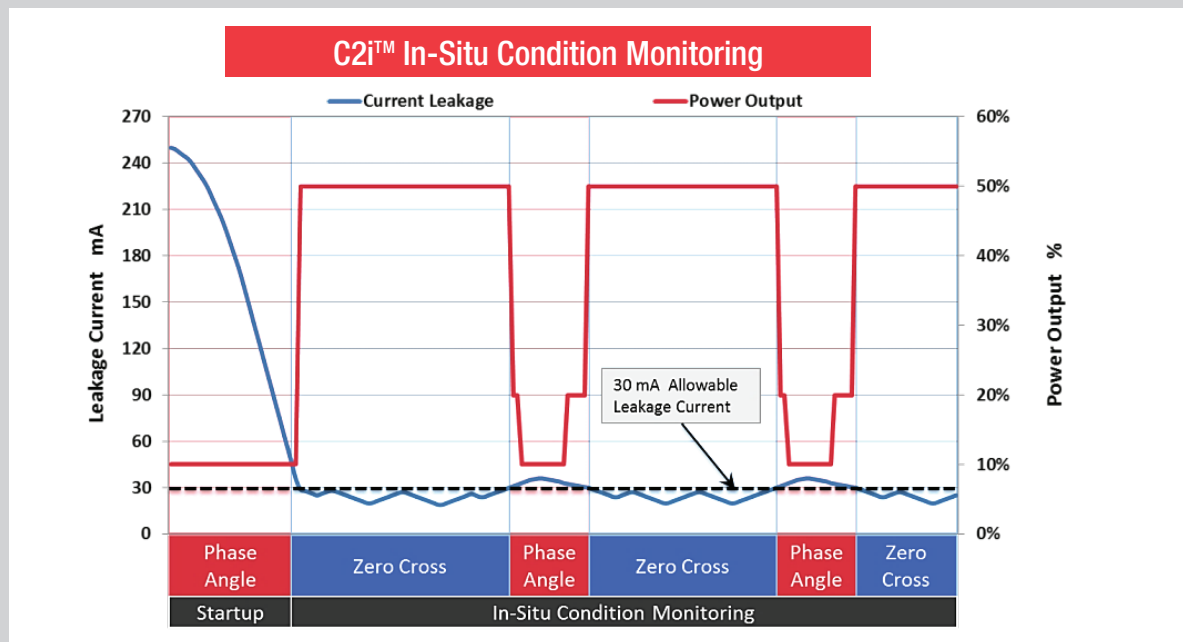
Elevated current leakage levels indicate high element moisture content and if unresolved, eventual electric heater failure will occur. High current leakage can cause additional process equipment damage and be a safety hazard.

SOLUTION

Controllers with C2i™ Technology continuously monitor leakage current during start up and throughout operation. When needed, C2i™ automatically regulates output power and safely dries out the electric heater elements.

Project Costs	TECHNOLOGY	
	Standard	C2i
System Value	\$ 100,000	\$ 102,500
Installation (Electrical & Mechanical)	\$ 7,500	\$ 7,500
Start Up Service	\$ 3,700	\$ 3,700
Project Sub-total	\$ 111,200	\$ 113,700
Rework Costs	Standard	
	Standard	C2i
Heater Dry Out Attempt	\$ 2,000	\$ -
Remove Heater & Re-install	\$ 15,000	\$ -
Ship Heater to Mfr. & Return	\$ 2,500	\$ -
Mfr. Rework Costs	\$ 5,000	\$ -
Start Up Service	\$ 3,700	\$ -
3 Week Downtime Revenue Loss	\$ 25,000	\$ -
Rework Sub-total	\$ 53,200	\$ -
Total Project Costs	\$ 164,400	\$ 113,700

In this example, C2i™ Technology provides \$50,700 in Operating Savings



HEATER

400 kW, 480Vac, 3-Phase
13,500 lb. (6,100 kg)

CONTROL PANEL

Chromalox Power Controller with
Advanced C2i™ Technology



Improved Safety

In many industrial heating applications, element failure, due to unacceptable current leakage levels, cannot only cause irreparable heater damage but create unsafe working conditions. When the electrical heating element is damaged by internal arcing, short circuit events within the heater system can occur. Although equipment protection measures are required, these failure types can cause extremely dangerous electrical and physical safety hazards for workers and service personnel.

C2i™ Technology continuously monitors process and electrical variables such that the electric heater health is always known. Chromalox controllers with this technology will automatically initiate a controlled soft-start at system startup or regulate output power during normal operation should the leakage current level violate programmed thresholds. This safely and efficiently dries out the heaters and avoids unsafe conditions due to element failures.

Lower Installation Costs

Wireless is rapidly becoming the preferred sensing technology in commercial and industrial systems due to continued technological advancements, feature enhancements, and the stabilization of standards within the Industrial Wireless industry. Wireless Temperature Sensing can greatly reduce installation costs and it can help solve structural and geographical challenges that often accompany complex installations such as those with multiple walls, excessive heights and distances, and extreme environments. By using wireless sensing technology, much of the engineering design content is removed and the material and labor installation costs directly attributed to sensor wire and conduit are all but eliminated.

Consider a standard 80 feet (25 meter) long run of heating cable, which includes the RTD sensor wire, hardware, fittings and conduit. The total savings for this one circuit is \$1,225. In a moderately sized tank farm of 100 circuits, the owner will save over \$120,000 in installation costs.

In addition to the installations cost savings that wireless technology provides, proprietary Chromalox C2i™ firmware seamlessly integrates wireless temperature sensing into its heat trace control systems.

This maintains system integrity, eliminates the need for third party monitoring and further lowers installation costs.

Process Optimization

Quite often, thermal profiles in system piping do not meet design expectations. Hot and cold spots occur due to heat sources and heat sinks, vertical chases, environmental influences and insulation failures. Extreme temperatures can be detrimental to certain process fluids. This can reduce revenues due to equipment damage, unplanned downtime service costs, and production losses. Through developed C2i™ wireless temperature sensing technology, thermal troubleshooting can be efficiently executed. The portability of wireless sensors permits infinite temperature data collection throughout piping networks, ensuring accurate thermal profiling. In addition, powerful C2i™ sensor mapping technology permits heater circuit output power to be based on the minimum, maximum, or average sensed temperature of multiple wired or wireless sensors. This provides additional system reliability and process integrity. These engineered C2i™ Technologies provide you with the necessary tools to ensure that your process is performing safely, accurately and within the intended design specifications.

CASE STUDY: INSTALLATION COST SAVINGS

Chromalox C2i™ Wireless Temperature Sensing Technology Can Significantly Reduce Installation Costs

Example: 100 Circuit Heat Trace Project with an Average Circuit Length of 80 Feet

PROBLEM

Hard-wired temperature sensing of Heat Trace is extremely labor-intensive and quite often the associated installation costs are the largest cost component of heat trace projects.

SOLUTION

Chromalox C2i™ Seamless Temperature Sensing Technology reduces most of the associated installation costs, maintains system integrity, and eliminates additional components, which further reduces installation costs.

RESULT

The reduced material and installation labor costs of the 100 loop wireless system saved the owner \$122,500.

PER LOOP INSTALLATION COSTS

Installation Consideration	Wired	Wireless
Engineering Design	\$ 200	\$ 50
Instrumentation Documentation	\$ 100	\$ 100
RTD, Wiring & Conduit Materials	\$ 900	\$ 175
Wireless Transmitter & Sensor	\$ —	\$ 2,150
Installation Labor	\$ 2,750	\$ 250
Per Loop Installation Costs	\$ 3,950	\$ 2,725
Savings Per Loop		\$ 1,225
100 Loop System Savings		\$ 122,500
1000 Loop System Savings		\$1,225,000

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