USING STATE-OF-THE-ART ELECTRONIC CONTROLS FOR CONTROLLING BOILER/ FURNACES IN REFUSE-TO-ENERGY PLANTS

GEORGE R. KOTYNEK AND CALVIN L. HARTMAN
Vølund USA Ltd.
Oak Brook, Illinois

ABSTRACT

Using state-of-the-art electronic controls for controlling boiler/furnaces in refuse-to-energy plants places special design and start-up requirements on these control systems, especially for smaller plants. Successful installation and operation require careful planning and flexibility as well as careful selection of equipment. Vølund's approach to the design and commissioning activities are reviewed.

INTRODUCTION

Refuse-to-energy plants built before the mid-1980s have typically employed separate systems for modulating control, sequential logic control, and process monitoring. The modulating control loops in these plants utilize dedicated pneumatic or hard-wired electronic analog controllers located in the control room or an adjacent electrical equipment room. Sequential logic controls, consisting of on/off control and interlocks necessary for the proper start-up and shutdown of plant equipment, utilize discrete mechanical or solid-state relays or programmable logic controllers (PLCs). Process monitoring is accomplished with control board mounted process indicators, recorders, indicating lights, alarm annunciators, etc. which receive electrical signals directly via hard-wires from process transmitters, thermocouples, switches, relays, etc. The transfer of information between the three systems is usually limited because of the additional engineering, wiring, interfacing devices, etc. and associated costs.

Since the mid-1980s, a majority of the large refuse-to-energy plants have been built utilizing microprocessor-based distributed control systems. The basic microprocessor-based distributed control system consists of intelligent, digital controllers; power supplies; process input and output signal conditioning, converting, and processing equipment; operator control consoles with CRT monitors, keyboards, and printers; a data highway; and process instrumentation as shown in Fig. 1. Additional hardware may include an engineering work station, manual/automatic control stations, control switches, process recorders and indicators, alarm annunciators, etc. Because transferring data digitally is simpler than using analog and discrete electronic hardware, a microprocessor-based distributed control system can transfer all required information between the various components rapidly, accurately, and economically via the data highway. The data highway consists of a shielded twisted pair of wires, coaxial cable, or a fiber-optics cable connected to various interface devices which contain the proprietary communication protocol for transmitting messages between each other.

The microprocessor-based distributed control sys-

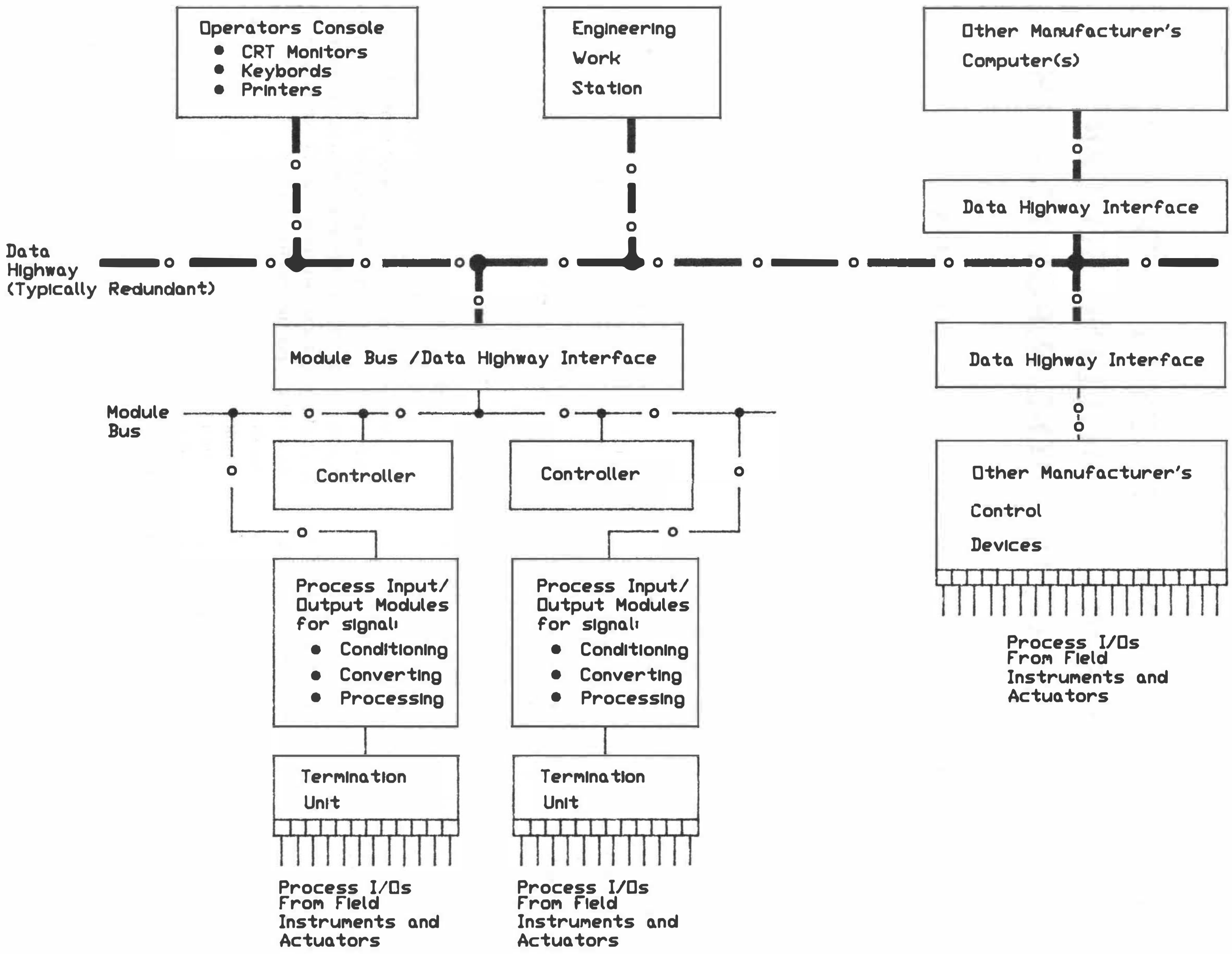

FIG. 1 LAYOUT OF A TYPICAL DISTRIBUTED CONTROL SYSTEM

tems offered on the market today have many advantages over the traditional, hard-wired, electronic control systems used in the past. Some of these advantages are:

(a) Compact design of control room operator/plant interface equipment, such as CRT monitors.

(b) Complex control strategies easily implemented.

(c) Control strategies easily changed at any time.

(d) Modulating control loops easily tuned.

(e) Drift-free operation.

(f) Very accurate and precise control.

(g) Control equipment continually monitored by extensive fault diagnostics.

(h) Savings in original installation of process sensor/actuator input and output wiring when controllers are located near process sensors/actuators.

Because of these many advantages, most medium or large control systems being installed today in new or modernized plants are of the microprocessor-based distributed control type. This paper will present the methodology of applying these control systems to mass burn refuse-to-energy plants.

CONTROL SYSTEMS IN REFUSE-TO-ENERGY PLANTS

To produce steam and electricity, refuse-to-energy plants require a considerable amount of equipment for charging and burning refuse, producing steam for direct use as well as generating electricity, ash handling, and flue gas cleaning. For all this equipment to operate as designed, many instruments and control systems are required. A refuse-to-energy plant employing mass burning technology utilizes the following major mechanical equipment and associated controls:

(a) One or two cranes for mixing refuse stored in the pit and charging the furnaces are generally provided. Crane operation is usually controlled by a programmable logic controller (PLC). The amount of refuse charged into each furnace is weighed using crane trolley-mounted load cells and a microprocessor-based data processing unit.

(b) One or more boilers and furnaces are installed for burning refuse and generating steam. An electronic-analog or microprocessor-based combustion control system is provided for controlling grate speed, combustion air flow and preheating, furnace draft, boiler drum level/feedwater flow, and main steam temperature. Natural gas- or oil-fired auxiliary burners, supplied with a microprocessor-based flame monitor and control system, are provided for start-up/shutdown and maintenance of a minimum furnace temperature when required. The boiler tube cleaning system is usually controlled by a programmable logic controller, although relays are occasionally utilized.

(c) The ash handling system is controlled by a microprocessor-based controller either as a stand-alone programmable logic controller or as part of a larger distributed control system.

(d) The flue gas cleaning system generally consists of a scrubber for removing acid gases followed by either an electrostatic precipitator or a baghouse. Each piece of equipment is supplied with a microprocessor-based control system containing proprietary software programs. The continuous emissions monitoring system consists of an assortment of instruments and analyzers all controlled by microprocessor-based controllers and a small computer.

(e) The steam turbine-generator governor for controlling the operation of the main steam stop and control valves utilizes a microprocessor-based controller. The generator excitation system is of solid-state design. Pneumatic and electronic-analog controls are provided for the lubricating oil, steam seal, turning gear, generator cooling systems, etc.

(f) A demineralizer plant consisting of anion and cation exchangers provides boiler feedwater make-up. A programmable logic controller is used to control all the valves in the proper sequence for regeneration, rinsing, etc.

(g) Balance-of-plant systems, such as circulating water, condensate/feedwater, boiler blowdown, station air, closed cooling water, etc., may be controlled by a mix of microprocessor-based, electronic-analog, and pneumatic controllers, or by the distributed control system.

(h) Interlocks and permissives for the electric motor, solenoid, heater, etc., stop/start and on/off electrical control circuits are implemented by utilizing microprocessor-based controllers, programmable logic controllers, or relays.

As can be seen by reviewing the above list of major mechanical equipment and associated controls, there are many independent control systems furnished by an assortment of manufacturers in the typical mass-burn refuse-to-energy plant. Modulating control loops for controlling process flow, pressure, temperature, etc. generally utilize electronic-analog or microprocessor-based controllers. Small, self-contained control loops, such as those for controlling tank and heater levels, may use pneumatic controllers. Sequential logic control used in electric motor-driven equipment start/stop and interlock control circuits utilize microprocessor-based controllers, programmable logic controllers, or relays.

Controllers for modulating control loop output signals to either electric or pneumatic final drive units such as valves and dampers to control the process. Controllers used in sequential logic control circuits output signals to electric motor starters or valve electric motor operator reversing starters. Many controllers now on the market can perform both modulating control and sequential logic control functions within the same unit.

PROJECT SCOPE

Determining the scope of the distributed control system for a project is the first major activity. It would be advantageous to have all of the above listed mechanical equipment controlled by one manufacturer's distributed control system because of a reduction in:

(a) Spare parts inventory.

(b) Time spent training operating and maintenance personnel.

(c) Time spent maintaining the plant controls.

This approach is usually not practical from an initial cost and delivery viewpoint. Except for the boiler/furnace and balance-of-plant equipment, most suppliers of the major mechanical systems listed above already utilize a specific manufacturer's microprocessor-based controller, which usually is a PLC. The programming and input/output interfacing is usually already developed and is unique for each manufacturer. Requiring these suppliers to use a particular manufacturer's distributed control system necessitates developing new programs and input/output interfaces by the supplier of each mechanical system or the distributed control system. Proprietary programs further complicate the situation. As a result, equipment costs, engineering costs, and delivery times are increased.

Because the typical microprocessor-based distributed control system possesses considerable computational power, high speed data gathering and processing ability, and well developed operator interfaces, it is ideally suited for controlling the:

(a) Boiler/furnace combustion process.

(b) Furnace draft.

(c) Boiler drum level.

(d) Final steam temperature.

(e) Deaerating heater level.

(f) Condenser level.

All these process systems are highly interactive, and it is very desirable that a common control system be utilized. Since a distributed control system is capable of handling both modulating and sequential logic control loops, additional systems, such as ash handling, circulating water, steam distribution, etc., can easily be added to its scope. However, PLCs and single loop electronic or pneumatic controllers can be used very cost effectively for controlling these secondary systems.

The distributed control system's high speed data gathering, processing, and display capabilities permit the use of a large number of process inputs in addition to those used for control purposes. The number of process inputs required depends on the extent of the display, logging, and alarm annunciation functions assigned to the distributed control system. Additional data can be obtained via data links from PLC-controlled systems, such as water treatment, ash handling, etc.

A careful investigation regarding the scope of the distributed control system is required before the specification is written and bids are solicited. Budgetary prices should be obtained from various distributed control system manufacturers regarding costs of process inputs and outputs, data links with other manufacturers' PLCs or computers, etc. This information is useful to determine the configuration to be used, and if separate PLCs should be utilized for some secondary systems.

CONTROL SYSTEM STRUCTURE

While defining the scope of the distributed control system, the system structure should be considered. Figure 1 shows a layout of a typical microprocessor-based distributed control system consisting of the operators control console, redundant data highway, controllers, process input/output modules and termination units, engineering work station, field-mounted instruments and actuators, and interfaces with other manufacturers' computers and control devices such as PLCs. To obtain a reliable and user-friendly distributed control system, the amount, type, and location of the various components must be carefully considered. The system should be fault-tolerant so as not to be brought down by a single-component failure.

The operators control console, located in the main control room, typically consists of CRT monitors, keyboards, printers, manual/automatic control stations, control switches, recorders, process indicators, etc. The number of CRT monitors, keyboards, and printers should allow simultaneous performance of various control and surveillance functions. In addition, failure of one device (e.g., a CRT monitor) should not prevent continued and safe operation of the plant. For critical control loops, back-up manual/automatic control stations, which internally generate the control signal when in manual, should be considered for reliable operation. Strip chart recorders and process indicators should be included to display critical process variables and environmental data such as opacity, CO level, etc.

The microprocessor-based controllers perform both modulating and sequential logic control functions. This allows them to control process flows, pressures, temperatures, etc., as well as properly starting and stopping electric motors. Because many control loops usually reside in one controller, it is common practice to have a standby controller for each active controller to increase reliability.

The process input/output modules provide the interface between process sensors and actuators and the controllers. The various electrical signals received from process sensors such as transmitters, thermocouples, relays, etc. are conditioned, converted, and processed into digital signals and transmitted to the controllers. Digital signals output from the controllers are processed and converted into the required electrical signals for use by the process actuators. Distributed control system manufacturers typically offer different process input/output modules for control and data acquisition functions. An input/output module for control functions usually processes inputs and outputs for one or two loops to minimize process upsets caused by module hardware failure. An input/output module for data acquisition usually processes eight to sixteen inputs or outputs.

Termination units of various types are often available to accommodate different sizes and styles of terminal blocks. Some distributed control system manufacturers' termination units can be physically separated from the input/output modules. A plug-connected cable connects the termination units with the input/output modules. This system allows the termination units to be mounted in separate cabinets and shipped to the jobsite early. Field wiring can then be terminated at these termination units. When the remainder of the distributed control system is installed, the plug-connected cables between the termination units and the input/output modules are quickly installed. Where separation between the termination units and input/output modules is not feasible, then separate field wiring termination cabinets can be installed at additional cost.

Because most distributed control systems have not yet been industrially hardened, it is important to locate the control units and field input/output modules in air-conditioned rooms for reliable operation and reasonable service life. Cabinets for the control units and the field input/output modules can be provided with self-contained air conditioners if it is necessary to locate them adjacent to the controlled equipment. The advantages of locating these devices near the controlled equipment are less field wiring, shorter installation time, and reduced main control room building space. The disadvantages are higher equipment cost and possibly higher maintenance.

To properly control a plant, solid state control systems need a well-regulated and continuous source of electrical power. Voltage spikes caused by opening and closing large circuit breakers, lightning, etc. are very detrimental to the operation of a distributed control system. In addition, the occasional total loss of plant auxiliary power will shut down the distributed control system, causing uncontrolled process upsets which compromise the safety of the personnel and equipment. Therefore, a reliable, uninterruptible power supply system (UPS) with battery back-up is a necessity.

CONTROL SYSTEM PROCUREMENT

Before the specification is written, decisions regarding control philosophy, system fault tolerance, operator interface, types of power supplies, electrical wiring practices, control equipment locations, other manufacturers' control device interfaces, etc. will have to be made. All interested parties should participate in this decision-making process so that costly changes do not have to be made at a later date. Once the scope and structure of the distributed control system for a particular project have been determined, a specification can be written. This specifying and design process is best illustrated by describing the procurement by Vølund of a microprocessor-based distributed control system for the newly commissioned University City Resource Recovery Facility in Charlotte, North Carolina.

Plant Description

The University City Resource Recovery Facility is a 235 ton/day (213 t/day) refuse-to-energy plant utilizing mass burn technology to produce both steam and electricity. It is located in the northeast section of the City of Charlotte, North Carolina.

The plant is provided with two boiler/furnaces manufactured by Vølund A/S for burning as received municipal solid waste on reciprocating type grates. Each boiler can generate 25,000 lb/hr (11.3 t/hr) of superheated steam at a pressure of 600 psig (4137 kPa) and temperature of 750°F (399°C) at the design refuse higher heating value of 4500 Btu/lb ($10,467 \times 10^3$

J/kg). The furnaces are equipped with natural gas-fired auxiliary burners for preheating during start-up. Refractory is used extensively in the lower furnaces to prevent corrosion due to the alternating oxidizing/reducing atmosphere which occurs when burning a nonhomogeneous fuel such as refuse.

Electricity is generated by a 5 MW, direct condensing, extraction type, skid-mounted turbine-generator. Steam extracted from the turbine is used for boiler feedwater heating and supplying the heating steam needs of the University of North Carolina.

The plant is provided with additional major equipment as follows:

(a) One 6 ton refuse handling overhead bridge crane with an electrohydraulic motor orange peel type grapple.

(b) An ash handling system utilizing hydraulically-operated ash pushers for furnace bottom ash removal, a vibrating pan conveyor, skiphoist, and screw conveyors.

(c) One two-field, rigid frame type of electrostatic precipitator for each boiler/furnace.

(d) One dual flue, steel stack and an induced draft fan for each boiler/furnace.

(e) One closed, low pressure feedwater heater and a deaerating heater.

(f) One motor-driven and one turbine-driven boiler feed pump.

(g) A two-pass surface condenser with steam jet air ejectors.

(h) A one-cell cooling tower.

(i) A full capacity demineralizer for make-up water.

(j) A combustion air system including an air preheater for each boiler/furnace.

(k) A hydraulic system for furnace grate and ash pusher actuation.

Located in the main control room are the boiler/furnace, turbine, and balance-of-plant control panels; the distributed control system cabinets; precipitator T/R control cabinets; electrical system control panel; and the refuse crane operator's chair and controls.

The University City Resource Recovery Facility is owned by the County of Mecklenburg, North Carolina. The MK-Ferguson Company, the prime contractor, performed the overall procurement, installation, erection, and performance testing. Vølund USA Ltd. designed and manufactured or procured the equipment and controls (crane through stack) associated with the boiler/furnaces. Initial firing of refuse occurred on April 12, 1989 and performance tests were successfully completed on schedule on June 9, 1989. MK-Environmental is operating and maintaining the facility.

Specification Development

The plant's owner specified a microprocessor-based distributed control system for all combustion controls, boiler drum level controls, deaerator storage tank level control, and other balance-of-plant loops as required. Pneumatic, local, analog controls were specified for the minor control loops. Additional requirements included two CRT monitors and keyboards for the distributed control system operator interface and a back-up control panel containing manual/automatic control stations for critical control loops, process indicators and recorders, and control switches to operate rotating equipment.

Before the procurement specification was written, meetings were held with all distributed control system suppliers interested in bidding on the project. Because of different system design approaches used by the various manufacturers, a functional specification was necessary to avoid being biased towards one or two manufacturers. The procurement specification was written for a turnkey control system supply to limit the degree of risk, specialized engineering, and interfacing with the distributed control system supplier.

The distributed control system suppliers were asked to bid on a system for controlling two boiler/furnaces, an ash handling system, and selected balance-of-plant systems. The following control loops were included:

(a) Boiler/furnace combustion control including control of grate speeds, combustion air flow, and combustion air preheating.

(b) Furnace draft.

(c) Boiler drum level/feedwater flow.

(d) Main steam temperature.

(e) Boiler start-up valve.

(f) Starting and stopping with interlocks of combustion air fans, induced draft fans, hydraulic system pumps, and furnace grates.

(g) Ash handling system start-stop and interlock functions for all conveyors, skiphoist, and bottom ash pushers.

(h) Deaerator storage tank level.

(i) Condenser hotwell level.

(j) Condensate pumps recirculation.

(k) Main and extraction steam flow to steam distribution system.

(l) Starting and stopping of condensate, boiler feedwater, circulating water pumps, and cooling tower fan.

(m) Opening and closing of various valves.

The turbine-generator, auxiliary gas burners, water treatment, precipitator, boiler cleaning, and crane control systems were purchased as separate systems with

TABLE 1 IMPUTS AND OUTPUTS FOR THE DISTRIBUTED CONTROL SYSTEM
AT THE UNIVERSITY CITY RESOURCE RECOVERY FACILITY

	Analog Inputs		Digital Inputs		Analog Outputs		Digital Outputs	
	Cntrl.	Indic.	Cntrl.	Indic.	Cntrl.	Indic.	Cntrl.	Indic.
Boiler/Furnace Combustion Control								
Furn.Line 1	11	13	26	21	10		28	
Furn.Line 2	11	13	26	21	10		28	
Furnace Draft								
Furn.Line 1	5	11	2	10	1	1	2	
Furn.Line 2	5	11	2	10	1	1	2	
Main Steam Temperature								
Furn.Line 1	3	2			2		1	
Furn.Line 2	3	2			2		1	
Boiler Drum Level/Feed-water Flow								
Furn.Line 1	4	2	1	6	1		2	
Furn.Line 2	4	2	1	6	1		2	
Ash Handling System								
Common			44				12	
Furn.Line 1			102				36	
Furn.Line 2			109				38	
Balance-of-Plant	9	33	12	105	9		32	
TOTAL	55	89	325	179	37	2	184	0

the equipment supply. Some status indication and process variable displays from these systems were included as inputs to the distributed control system. Additional inputs from other balance-of-plant equipment were required for process monitoring, alarming, and logging.

To give the distributed control system bidders a quick reference regarding the quantity of inputs and outputs, a table similar to Table 1 was included in the specification, together with the control and instrumentation diagrams. Examining Table 1 reveals the fact that approximately 41% of all the inputs were used exclusively for process monitoring, alarming, and logging and were not required for control funtions. The percentage of inputs for indication only was highly influenced by the inclusion of the ash handling controls. The percentage of inputs used for indication are even greater when consideration is given that inputs used for control are also available for process monitoring, alarming, and logging because, once a process variable is input into the distributed control system, it can be utilized for whatever purpose the software programs require. Microprocessors have the ability to process large amounts of data very rapidly. Because a microprocessor-based distributed control system has access to inputs used for control functions in addition to those inputs needed only for process monitoring, alarming, and logging, it is apparent that these systems can display large amounts of information to the operator.

Table 1 is very useful when a distributed control system manufacturer sizes a system because the type and amount of input and output hardware can now be determined. To aid the bidders in evaluating the effort required to configure the system software, a detailed functional description of each control loop was included in the specification. This approach allowed each bidder to utilize its expertise to develop and present in the proposal the control strategies for each control loop. This is helpful when evaluating the various proposals. Knowing the amount of inputs and outputs and the required control strategies allows the bidder to select properly-sized controllers.

The reliability of the control system is always an important consideration. Typically, redundant controllers are specified because many control loops are processed in one controller. For this project three primary and three back-up controllers were selected. There is a primary controller for each furnace line and one for the balance-of-plant control loops. The associated back-up controller automatically takes over the functions of the primary controller when an error is detected. Because the computational configurations for each controller are stored in nonvolatile memory, reprogramming is not necessary after a power failure. This is an important feature and should be included in the specification.

Preferably, single-loop, or at least two-loop, integrity should be specified for all critical control loops. This means that a hardware failure in any input/output module associated with a critical control loop will cause loss of control in one or, at the most, two control loops. In addition, manual/automatic control stations, which can internally generate the control signal when in the manual mode, were specified by the owner for all critical control loops.

The distributed control system specification should clearly define the required operator interface. This includes both hardware and software. The number of CRT monitors, screen size, resolution, capability of displaying alphanumeric and character graphic symbols, etc. should be stated. The number of keyboards and type of keys ("Hall effect" keys or a membrane with tactile feedback work well) should be stated. CRT control consoles using touch-sensitive screens should be considered. Those employing infrared sensing technology are very reliable. Keyboard-operated CRT control consoles were supplied for this project. Redundant CRT controllers should be required so that loss of one controller does not cause the loss of all CRT displays.

The specification should describe the type and quantity of operator control console CRT displays. Distributed control system manufacturers have standard area and group process variable display packages, which they can offer in addition to customized process graphic displays. Since the software has already been developed for the standard packages, they are much more economical to purchase. A good approach regarding operator displays is to have the manufacturers demonstrate their displays during pre-bid meetings so that reasonable requirements regarding types and quantities can be stated in the specification. The number of operator keystrokes necessary to obtain the various displays should be carefully reviewed during the pre-bid meetings. Some manufacturers' display systems are more "user-friendly" than others. Where possible, plant operating personnel should be present at these meetings.

This project included nine area displays (each area display shows forty-eight process variables), approximately one hundred group displays (each group display is capable of displaying control stations, trends, and process variables), and eighteen custom graphic displays. Control of the process variables is available through the group displays or the graphics.

A minimum of two medium-speed or high-speed printers should be specified. One printer is usually dedicated to printing alarm annunciator messages and the other to printing various logs automatically and on demand. In addition, the printers should print configuration data base information on request and have the ability to copy any CRT screen.

The electrical requirements that the distributed control system supplier must adhere to should be carefully specified. Items that should be covered include:

(a) Codes.

(b) Area classification.

(c) Transient protection and radio frequency interference.

(d) Power supply requirements for controllers, input/output modules, and operator interface devices.

(e) Distributed control system supplier's signal and power grounding and wire segregation requirements, intercabinet wiring, etc.

(f) Field wiring connections.

Expected system services should be carefully stated in the specification. The following items should be addressed:

(a) Documentation format.

(b) Hardware documentation.

(c) User's manuals.

(d) Maintenance manuals.

(e) Recommended spare parts listing.

(f) Maintenance, service, and support.

(g) System checkout.

(h) Warranty.

(i) Training.

During pre-bid meetings these items should be addressed so that an understanding concerning each supplier's capabilities can be assessed early in the project. Unit prices should be requested for adding or deleting various types of system hardware components, associated software, and engineering charges.

Once the distributed control system specification is issued for bids, adequate time must be allowed for the bidders to respond properly. The evaluation and award process is greatly simplified if a thorough and complete functional specification was issued.

CONTROL SYSTEM DESIGN AND MANUFACTURE

Project Kick-off Meeting

After the award has been made, the project kick-off meeting should be held at the manufacturer's facility. An agenda should be developed and reviewed by all parties before the meeting. Schedules and the mechanics of exchanging information are normally discussed, but the distributed control system manufacturer's personnel should be prepared to make a presentation to familiarize the customer with the distributed control system manufacturer's drawings, configuration format, operator control console CRT displays, custom graphic displays, special requirements for process input/output wiring, etc. This is very important to do during the kick-off meeting because, typically, refuse-to-energy projects are fast track and on tight budgets.

Instruction manuals applicable to the equipment purchased should be distributed during this meeting as well as all the required data sheets for the operator control console CRT displays. If data links with other manufacturers' control devices have been purchased, then the specific hardware and software interface requirements should be discussed in detail so this information can be put into the specifications for purchasing other manufacturers' control devices such as programmable logic controllers.

A tour of the distributed control system manufacturer's plant should be included to review the hardware utilized for the project. If possible, the operator control console CRT displays and custom graphics should be observed for future reference when formatting these displays.

Control System Design

Early in the design phase of the project, a layout of the control room and electrical equipment room will have to be developed so this information can be given to the distributed control system manufacturer for ordering plug-connected, multi-conductor, intercabinet cable. This cable is usually a long delivery item. In addition, the front elevation of the back-up control board should be developed early in the project so this custom-built control board can be placed on order. The compatibility of input/output interfaces should be carefully reviewed. During the design phase of the University City project several interposing relays and upgraded relays were added because of higher than anticipated electrical power levels. Any special interposing relays required for operating large closing coils in motor starters should be identified early in the project and ordered. Manufacturers of this electrical equipment no longer have large inventories of these standard items. They are generally manufactured when ordered. For example, the typical lead time on control board mounted rotary control switches is ten weeks.

Input and output lists must be kept current and revised copies sent to the distributed control system manufacturer in a timely manner. As the control logic drawings are developed, reviews by all interested parties should be performed to avoid misunderstandings and delays in schedule due to errors. When the initial issue of the distributed control system drawings is submitted for review, approximately two man-weeks should be spent reviewing them for a project of the size of the University City Resource Recovery Facility. A considerable amount of time must be allocated to developing the operator console CRT displays using the manufacturer's standard format. Each display page should be formatted so that pertinent control stations, trend displays, single point displays, etc. are grouped logically and functionally. Proper formatting of these pages will make for efficient operator control of the plant. Improper formatting will cause confusion among operators and a much slowed response to critical operating situations. For a project the size of the University City Resource Recovery Facility, a total of six man-weeks should be allotted to this task.

Developing the custom graphic displays is very time consuming because of the amount of detail that can be accommodated on each display. Process variables can be displayed as well as equipment status. The process can easily be controlled from the graphic page if all pertinent variables are displayed, some of which, however, may be part of other systems. When developing a graphic page, the operators' needs for all the required variables to meaningfully and efficiently control the process must be continually kept in mind. Proper symbols and color codes must be used consistently for each page. Finally, the proposed layout of all the graphic pages should be reviewed by the client's operating personnel before submitting them to the distributed control system manufacturer for coding.

The facility operating personnel should develop the periodic logs and other special logs so that the format fits in with all the rest of the plant's reports. These logs will appear in monthly performance reports and also be archived.

Control System Factory Checkout

A factory checkout of the distributed control system generally signifies that the manufacturing of the system has been completed. Every hour spent in a thorough factory check will save many hours in field start-up time because all the necessary personnel and materials are available at the manufacturer's facility. The control system specification should state the level of checkout required. A dynamic simulation where a computer models the process and outputs signals to the distributed control system in real time is expensive and usually not necessary because control strategies are so easily changed. A more common form of checkout is to have variable potentiometers and toggle switches simulate the actual process inputs. This gives the observers a feel of how the control algorithms respond to changes in the process and allows checking of the operator control console CRT displays for proper output information. It is very important to have operating staff representation at the checkout so that all CRT display formats can be reviewed and approved before shipment.

It is advisable to check each modulating and sequential control loop so that inadequacies can be quickly corrected before shipment. This is usually a time consuming job, but the savings in start-up time are well worth it. For the University City Resource Recovery Facility distributed control system checkout, the facilities manager representing MK-Ferguson and the control system project engineer representing Vølund performed the checkout together with the Bailey Controls Company project engineer. The entire distributed control system, including the two operator control consoles, two printers, two digital process indicators, six system cabinets, and the twenty manual/automatic control stations for all critical control loops, was tested as a unit. Variable potentiometers and toggle switches were used to simulate process inputs. Meters and indicating lights displayed the process output signals. The major control loops were verified against the configuration diagrams for proper responses to changes in the process inputs. Approximately fifteen percent of the operator CRT displays were changed as well as some of the control logic. The changes were quickly accomplished because all available resources were present. The system checkout lasted one week, and in the end all parties were satisfied that the control system was ready to ship.

ON-SITE INSTALLATION, TRAINING, AND START-UP

Installation

A distributed control system must be installed with great care just like any other electronic equipment. The control room and electrical equipment room must be finished before the system cabinets and operator control consoles are installed. Floor tiles must be installed to prevent concrete dusting; the air conditioning system must be functioning; and the room(s) clean. If the rooms are not ready, then the control system must be stored per manufacturer's recommendations, which include a clean and reasonably warm room. The atmosphere must be noncondensing.

Field input and output terminations must be carefully supervised for proper installation. Powered inputs must not be mistakenly connected to unpowered input terminal blocks to prevent damage to input signal conditioning modules. A safe but more costly approach is to provide separate field wiring termination cabinets equipped with States sliding link blocks. During installation of field wiring, the links are open and only after a circuit is tested are they closed. The other advantage with this approach is that instrumentation field wiring can start before the distributed control system cabinets are shipped.

Because of budgetary restraints, separate field wiring termination cabinets were not provided for the University City Resource Recovery Facility's distributed control system. As a result of field wiring errors, approximately five input signal conditioning printed circuit boards were damaged. In addition, if field wiring termination cabinets had been provided, the cabinets could have been installed in the partially finished control room and wiring terminations could have proceeded. Start-up would have been easier because more control loops would have been checked before initial start.

Training

In preparation for on-site training of the University City Resource Recovery Facility operating staff, key personnel attended the distributed control system manufacturer's introductory two-week course covering both system hardware and software. Formal training classes were conducted three months before start-up. A detailed written description of the distributed control system and how the operators should use it was included. Many informal training sessions were conducted in the control room during the initial operation of the plant. A complete and thorough training program is essential for a successful plant start-up.

Start-Up

The start-up of the University City Resource Recovery Facility was not without its problems. During the first few weeks of initial plant operation, the uninterruptible power supply was out of service periodically and the distributed control system operated on back-up station auxiliary power. Occasional short-term station power losses or large voltage dips due to severe storms caused shutdowns of the distributed control system. Restarting of the control system was time consuming and prolonged the recovery time of the plant. Once the uninterruptible power supply problems were resolved, the distributed control system was on-line for the entire duration of the start-up.

Because some of the field wiring was being checked during the start-up, many of the control loops were on manual control. Once the field wiring associated with a control loop was checked, the loop was placed in automatic control and tuned. Tuning via the operators control console was very easy to perform because of the well formatted CRT tuning display, which also included a trend display. Minor configuration changes were accomplished on-line with relative ease and with no disruption of operations.

At the time of this writing, the plant has been operating for over six months with only minor problems. One keyboard had to be replaced because of one defective key and the hard disk drive used for data storage failed. Neither problem interfered with the plant operation. Because of the flexibility of the system, a couple of control loops were easily reconfigured on-line, which helped to improve control.

CONCLUSION

A microprocessor-based distributed control system was successfully applied at the University City Resource Recovery Facility. Because of its excellent data acquisition abilities, ease of tuning, the ability to easily make configuration changes, and its excellent operator interface, a distributed control system significantly enhances the operation of a refuse-to-energy facility.

Key Words: Control(s); Design; Electronic; Furnace; Mass Burn; Procurement; State of the Art