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for the Radioactive Waste Evaporator*

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COMPUTER-BASED SUPERVISORY CONTROL AND DATA ACQUISITION SYSTEM FOR THE RADIOACTIVE WASTE EVAPORATOR

by

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ABSTRACT

The evaporator process at TA-55 reduces the amount of transuranic liquid radioactive waste by separating radioactive salts from relatively low-level radioactive nitric acid solution. A computer-based supervisory control and data acquisition (SCADA) system has been installed on the process that allows the operators to easily interface with process equipment. Individual single-loop controllers in the SCADA system allow more precise process operation with less human intervention. With this system, process data can be archived in computer files for later analysis. Data are distributed throughout the TA-55 site through a local area network so that real-time process conditions can be monitored at multiple locations. The entire system has been built using commercially available hardware and software components.

INTRODUCTION

The evaporator process system, located in Room 401 of Building PF-4 at the TA-55 Plutonium Facility, is used to concentrate and separate radioactive waste materials from less radioactive nitric acids solutions (Fig. 1A and Fig. 1B). After the separation process is complete, the nitric acid is sent to the TA-50 waste-processing facility, and the more radioactive waste materials, primarily chemical salts used in processes upstream, are immobilized in cement and packaged for shipment to the Waste Isolation Pilot Plant (WIPP). The evaporator system was placed into service in 1989, replacing an older system, and was the first aqueous process at TA-55 to incorporate a computerized supervisory control and data acquisition (SCADA) system. The system has been upgraded since its original start-up, and this report discusses its current hardware and software configuration and methods.

The evaporator process consists of two separate steam-heated, natural circulation, thermosyphon evaporators, which may be used interchangeably. The primary feed solutions for the evaporators are nitric acid effluents from the ion exchange and filtrates from the oxalate precipitation processes. Generally, a typical run consists of the following steps: 1) Nitric acid solution is transferred into feed tanks from nearby storage tanks; 2) One of the two evaporators is filled with solution to a specified level; 3) Steam is supplied to a heat exchanger reboiler in the evaporator so that the nitric acid solution is heated; 4) As the solution begins to boil in the heat exchanger leg of the evaporator, the solution expands, rises, and spills over into the cold leg of the evaporator; 5) Solution from the cold leg replaces the hot solution and also begins to heat, causing the solution inside the evaporator to naturally circulate and provide uniform heating; 6) Nitric acid vapors from the boiling solution rise up into a condenser and cool to form relatively clean

Fig. 1B. Evaporator installed in evaporator room enclosure before initial start-up.

compatible computers. Multitasking allows easy configuration of the process control system because different computer operations can be tested simultaneously. Recently, the computer operating system was upgraded to OS/2, a multitasking operating system from IBM Corporation, to accommodate additional features such as networking.

METHODS

The evaporator SCADA system consists of an IBM-compatible computer (Fig. 2) running a commercial man-machine interface (MMI) software program that interacts with two separate data acquisition and control systems through software drivers. Separate commercial loop controllers control two loops on each evaporator. The MMI also operates digital valves on the process and displays several data parameters such as temperatures, levels, and valve position sensors. Feed and distillate flow rates as well

Fig. 2. Evaporator instrumentation rack with computer interface and PID controllers.

as solution density inside the evaporator can also be measured; however, they are not yet fully supported by the current configuration because of difficulties implementing suitable instrumentation. As better equipment becomes available, additional hardware and software additions may be incorporated when the measurement of flow rates and solution density becomes necessary.

There are two control loops on each of the evaporators, one for the solution level and the other to control steam flow rate. The solution level inside each evaporator is controlled by a proportional-integral-derivative (PID) controller, which can operate in either a manual or automatic mode (Fig. 3). A magnetic level indicator mounted on the side of the evaporator cold leg measures the solution level. The level measurement is transmitted by a 4–20-mA signal to one of four available controller inputs. As the level in the evaporator changes, the level measurement signal varies similarly. After the controller reads this input signal, it sends an output signal to open and close an electric control valve that varies the airflow to an air-driven pump on the feed line. As the level in the evaporator falls, the control valve opens, allowing more air to flow to the pump. This action causes the pump to feed more solution into the evaporator as needed to maintain the liquid level.

Fig. 3. Typical PID loop controller.

The steam flow rate can also be controlled using a PID controller. The original intent of the system was to control the steam flow rate into the evaporator heat exchanger based on the temperature difference between the liquid vapor and the solution. A signal from the controller is sent to a current-to-pneumatic (I-to-P) transducer, which in turn sends a pneumatic signal to a steam control valve. However, operational testing revealed that the steam flow can be set as high as possible to maximize boil-off rate and minimize processing time with no detectable problems. The result is that after the system is initially started on each batch, it can be run with full steam until the batch is complete. Although the steam PID control system is not normally used, it has remained in place for future applications in which a more sensitive operation is required.

PID parameters are set by the operator and are generally determined using a variety of industrial tuning methods. Segmented graphic displays on the controllers indicate the set point, process measurement, and controller output. Each segment represents an incremental reading of 2% of span. The set point and process measurement (level) are displayed in percent of full scale of evaporator capacity. The controller output is displayed in percent of full scale of the feed control valve. Readings to

within $\pm 0.1\%$ of the upper-range value are displayed alphanumerically (including engineering units) above the graphic display. The desired numeric reading (set point, process measurement, or controller output) can be selected by pushing a selector key on the controller face plate. The function being displayed is identified by an illuminated dot located above the corresponding bar graph. All configuration parameters (such as input channel number and PID values) can be entered by using buttons on the controller face plate following the manufacturer's instructions. Alternately, the operating set points, control signal output, and other controller parameters can be set using the computer keyboard or trackball on the computer graphics interface.

Computerized Man-Machine Interface (MMI)

Computer Software. A SCADA MMI is used as an interface between the process operator and the evaporator system hardware. A commercial MMI software package is used on an IBM-compatible computer running an Intel 80486 processor and the OS/2 operating system. From the keyboard, the process operator can enter controller data, including set points and control valve settings, and can open and close valves. Real-time process parameters are displayed, including levels, temperatures, and set points. Data are archived to computer disk and tape for historical preservation.

Network. Data collected on the process computer are routinely transferred throughout the site by ethernet link. A program translates information stored in the MMI internal database and allows any other machine running the same software to receive the data and display it on a separate machine. In this way, live process data are viewed using the same MMI process display format on machines routinely used by supervisors, maintenance personnel, and other management.

HARDWARE AND SOFTWARE DESIGN

Data are acquired through either a network of four Foxboro single-loop controllers or a separate Digitronics Sixnet input/output hardware network. The Digitronics Sixnet system is a general data acquisition tool that has been configured to accept several signal protocols, including 0–5 Vdc, 4–20 mA, and 120 Vac. Up to 64 separate analog signals can be measured. Also, forty-eight 120-Vac digital inputs and 48 digital outputs are possible. The type and range of the inputs and outputs are user selected by switch setting or by software and require the installation of an appropriately configured relay module. The digital inputs and outputs are used typically to control open/closed valves, to indicate the state of each valve, and to measure point liquid-level sensors. The Sixnet remote units communicate with a coprocessor board in the computer through a simple two-wire network link.

The Foxboro single-station microcontrollers are self-contained, microprocessor-based controllers having the standard PID functions. The units communicate to the computer through a serial communications line. A special adapter is used to convert the RS-232 serial signal from the communications port of the computer to an RS-485 serial protocol, which is more suitable for industrial applications. Each unit has four separate analog inputs, some of which are used to collect data from other sensors (i. e., temperature transmitters) not directly used to control the specific loop (these additional inputs were used simply for convenience because the unit also supplied required power-supply signals to run certain sensors).

Data sent to the computer are converted into a format that the MMI software can use by a separate program called the device I/O driver. The algorithm to convert the data into a specific calibration range is stored in a separate text file for both the Foxboro and Sixnet systems. In addition, other information such as the configuration of the hardware and the timing of the data acquisition is also stored in these text files. The device I/O driver converts raw data from either the communications port (for the Foxboro controller) or the Sixnet data acquisition board into standard engineering units and places the information into the MMI internal database.

INSTRUMENTATION AND EQUIPMENT

Hardware

Computer. Model 486-66V with 16-Mbyte RAM, VGA Graphics, 1.2-Mbyte 5.25-in. floppy disk drive, 1.44-Mbyte 3.5-in. floppy disk drive, 424-Mbyte, fixed disk drive, 124-key keyboard, 15-in. Crystal Scan monitor. Gateway 2000, N. Sioux City, South Dakota.

RS-232 to RS-485 Serial Converter.

Model 72-CNV-2. Grayhill Inc., La Grange, Illinois.

Converter Power Supply. Model MAP 55-1024 Series converter. Power-One Inc., Camarillo, California.

Data Acquisition Hardware. System consists of several individual components including the model IOMUX input/output multiplexing unit, the model 6-IO32 discrete input/output unit, model 60-AMI analog multiplexor interface, 60-MPLEX analog input multiplexor, model 6-IBM/N network co-processor data acquisition board, model 6MT cable, model OAC-01 20-140 Vac output module, model IAC-01 24-140 Vac input module. Digitronics Sixnet, Clifton Park, New York.

PID Loop Controller. Model 761-CNA-AT-2 Single Station Micro Plus Controller with panel mounting style. The Foxboro Company, Foxboro, Massachusetts.

Valve Position Indicating Switch. Model 12AD0 Mark I magnetic-coupling rotary position indicator switch with mounting kit, yoke, and visual open/closed indicator for use with Kinetrol actuator. Proximity Switches, Forgas Falls, Minnesota.

Solution Level Sensor (Continuous).

Model LG6-C-2-150#-1.3-300degF-20psig-68"-X level gauge with 3/4-in. top-flanged process connection, model LT-68"-4/20 transmitter. Mag-Tech Company, Houston, Texas.

Solution Level Sensor (Point). Model MSL-2 point level sensor. Mag-Tech Company, Houston, Texas.

Differential Pressure Density Gauges.

Model 1151DP3E22TO545L calibrated at 0-6-in. water, model 1199PFW11A11 3-in. pancake-type seal, model 1199CAP 11AO5C11 capillary connection, model 1199-0032-0004 Syltherm seal fluid. Rosemount, Inc., Eden Prairie, Minnesota.

I-to-P Transducer. Model 645 I-to-P transducer with 4-20 mA input and 3-15 psi output. Fisher Controls, Marshalltown, Iowa.

Thermocouples. Model 68N11N00A020T34 temperature sensor and thermowell with model 444RLZWBZE5 transmitter calibrated at 20-150°C, model 78F11N00A020T34 temperature sensor and thermowell with model 444RL2U1B225 transmitter. Rosemount, Inc., Eden Prairie, Minnesota.

Steam Control Valves. Model 35-35612

Camflex II pressure control valve, 1-1/2 in., flow to close, air to open, full trim, for use with 150 psig steam; model 35-35512 Camflex II pressure control valve, 1-1/1 in., flow to close, air to open, full trim, for use with 150 psig saturated steam; model 4600 positioner. Mason-Eilan Company, Avon, Massachusetts.

Software

Operating System. OS/2 version 2.1.

International Business Machines, Boca Raton, Florida.

Control System Software. ONSPEC 4000

Control Software 2.10, ONSPEC Foxboro I/O Driver, ONSPEC Digitronics Sixnet I/O Driver, OnView with Supertrends electronic trend pen recorder, Large Systems ONNET (LSO) version 2.56. Heuristics, Inc., Sacramento, California.

Network Software. LAN Manager, International Business Machines, Boca Raton, Florida.

COMPUTER SCREENS

The operator uses computer screens to interact with the process. Each screen displays process information while allowing the operator to make changes to the process configuration. On several screens, space has been left for future installation of

process equipment. The screens are numbered in accordance with the overall NMT-2 process control system configuration; i. e., other unit operations such as the cascade dissolvers and the waste-line monitoring system use other numbered screens. The screens for the evaporator process are described as follows:

Display 41: Evaporator Screen Menu. Provides a menu of MMI screens for the evaporator.

Display 42: Feed Valve Configuration. Displays the configuration of feed valves from two banks of feed tanks. Allows operator to route feed valves and displays confirmation signals for valve configuration.

Display 43: Process System

Parameters. Displays the total system configuration for both evaporator units. Designed to provide complete information on the state of operations inside the evaporator room. The following information is displayed for each evaporator: steam control loop—temperature, control valve set point (in % open), control valve position (in % open), automatic/manual switch position for PID controller, and workstation/panel switch for PID controller; feed control loop—tank valve position and confirmation indicator, flow rate, control valve position, automatic/manual switch position for PID controller, workstation/panel switch for PID controller; evaporator solution level (in % full), level set point (in % full), solution temperature, and solution density (not currently implemented); distillate line information—high-level switch, distillate flow rate, total solution volume (not currently implemented).

Display 44: Evaporator A Process

Information. Displays all information for Evaporator A, including steam loop—temperature, control valve set point (in % open), control valve position (in % open), automatic/manual switch position for PID controller, and workstation/panel switch for PID controller; feed control loop—flow rate, control valve position, automatic/manual switch position for PID controller, and workstation/panel switch for PID controller; evaporator solution level (in % full), level set point (in % full), solution temperature, and solution density (not currently implemented); distillate line information—distillate flow rate, high-alpha-level alarm, and automatic valve switching (not currently implemented).

Display 45: Evaporator B Process Information. Displays all information for Evaporator B, including steam loop—temperature, control valve set point (in % open), control valve position (in % open), automatic/manual switch position for PID controller, and workstation/panel switch for PID controller; feed control loop—flow rate, control valve position, automatic/manual switch position for PID controller, and workstation/panel switch for PID controller; evaporator solution level (in % full), level set point (in % full), solution temperature, and solution density (not currently implemented); distillate line information—distillate flow rate, high alpha level alarm, and automatic valve switching (not currently implemented).

Display 46: Not in use.

Display 47: Not in use.

Display 48: Distillate Valve Configuration. Displays configuration of valves on the distillate line to tanks. Allows operator to route solution as required.

```

Local HMT-2 ONSPEC
Switch Commands Run Link
?_
49
FEED FLOW 0.0L/M
FEED FLOW 0.0L/M
MORE
OFF OFF OFF OFF OFF OFF OFF OFF
OFF OFF OFF OFF OFF OFF OFF OFF
OFF OFF OFF OFF OFF OFF OFF OFF
OFF OFF OFF OFF OFF OFF OFF OFF
CLOS CLOS S1 CLOS S1 CLOS S1 CLOS S1
U19: H U18: H U6: H U7: H
OFF OFF OFF OFF
08:00:00 01-21-94 SHIFT HOUR AND DATE
OS/L window OS/L window

```

Input/Output Modules															
MUX															
3 DI	1 DI	2 DI	3 DI	4 DI	5 DI	6 DI	7 DI	8 DO	9 DO	10 DO	11 DO	12 DO	13 DO	14 DO	15 DO
DII 780	DII 781	DII 782	DII 783	DII 784	DII 785	DII 786	DII 787	D00 788	D00 781	D00 782	D00 783	D00 784	D00 785	D00 786	D00 787

Display 51: Output Maintenance Display. Digital output maintenance screen showing current digital states on Rack 1 of the Digitronics Sixnet hardware.

Local NMT-2 ONSPEC															
Switch Commands Run Link															
Input/Output Modules															
Unit 31															
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
D00	D00	D00	D00	D00	D00	D00	D00	D00	D00	D00	D00	D00	D00	D00	D00
788	789	718	711	712	713	714	715	716	717	718	719	728	721	722	723
OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
D00	D00	D00	D00	D00	D00	D00	D00	D00	D00	D00	D00	D00	D00	D00	D00
724	725	726	727	728	729	738	731	732	733	734	735	736	737	738	739
OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
88:88:88 01-21-94 SHIFT HOUR AND DATE															
OS/2 Window								OS/2 Window							

Display 52: Input Maintenance Display. Digital input maintenance screen showing current digital states on Rack 2 of the Digitronics Sixnet hardware.

Local NMT-2 ONSPEC															
Switch Commands Run Link															
Input/Output Modules															
Unit 2															
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
D11	D11	D11	D11	D11	D11	D11	D11	D11	D11	D11	D11	D11	D11	D11	D11
788	789	718	711	712	713	714	715	716	717	718	719	728	721	722	723
OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
D11	D11	D11	D11	D11	D11	D11	D11	D11	D11	D11	D11	D11	D11	D11	D11
724	725	726	727	728	729	738	731	732	733	734	735	736	737	738	739
OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
88:88:88 01-21-94 SHIFT HOUR AND DATE															
OS/2 Window								OS/2 Window							

Display 53: Input/Output Maintenance Display. Digital input/output maintenance screen showing current digital states on Rack 3 of the Digitronics Sixnet hardware.

Local NMT-2 ONSPEC															
Switch Commands Run Link															
Input/Output Modules															
Unit 3															
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
D00	D00	D00	D00	D00	D00	D00	D00	D00	D00	D00	D00	D00	D00	D00	D00
748	741	742	743	744	745	746	747	748	749	758	751	752	753	754	755
OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
D11	D11	D11	D11	D11	D11	D11	D11	D11	D11	D11	D11	D11	D11	D11	D11
748	741	742	743	744	745	746	747	748	749	758	751	752	753	754	755
OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
88:88:88 01-21-94 SHIFT HOUR AND DATE															
OS/2 Window								OS/2 Window							

Display

Data may be displayed over a user-selected time period using the OnView program. Fourteen process variables can be viewed per OnView program, and multiple programs may be run simultaneously. Data may be displayed at user-defined time periods and may be scanned backwards through time and enlarged for additional detail. Data may also be extracted and displayed using spreadsheet or graphics programs.

CONCLUSIONS

A computer-based SCADA system has been installed on the evaporator process to aid in its operation and to retain process information for later analysis. The system uses commercial hardware and software including PID controllers, an IBM-compatible personal computer, and a man-machine interface software.

The process control system described here is part of a new evaporator system that replaced an older, outdated system in PF-4. The throughput of the old system was approximately 1.5 L/min while the new system's throughput is approximately 5 L/min. It took approximately five operators to run the old system compared with one or two to operate the current system. The new system experiences less process upsets and therefore less recycling of contaminated distillates. Upsets that do occur are generally easily diagnosed by reviewing the process data archived on

computer disk. In addition to the new process control system contributing to this increased throughput, operating information can now be transferred in essentially real time throughout the TA-55 site by a local area network. This allows the process to be viewed in multiple locations simultaneously by management, line supervisors, and maintenance personnel. Also, tuning of the evaporator PID control parameters is now greatly simplified by using on-line computer methods to analyze the system performance.

The evaporator process control system provided a necessary learning step in the development of modern process control methods at TA-55. Since its completion, other systems based in part on the evaporator's design have been installed in other locations. These systems include the Advanced Testing Line for Actinide Separations (ATLAS), the multipurpose cascade dissolvers (MPD), an ion exchange operation prototype, and waste-monitoring operations.