USACERL Technical Report N-91/27
July 1991

US Army Corps
of Engineers
Construction Engineering
Research Laboratory

AD-A241 372

Use of Programmable Logic Controllers To Automate Control and Monitoring of U.S. Army Wastewater Treatment Systems

by
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Although Programmable Logic Controllers (PLCs) have been successfully used at municipal and industrial wastewater treatment plants (WWTPs), the Army has not yet automated its WWTPs by using this relatively simple, low-cost, available technology. PLCs are widely used in environmental engineering facilities and in applications with control requirements similar to water/wastewater operations to: (1) reduce manhours dedicated to repetitive operational monitoring tasks, (2) ensure operational and equipment safety, and (3) monitor and reduce facility chemical and energy costs.

PLCs offer many benefits over competing microcomputer technologies:

1. Off-the-shelf availability
2. Low-cost procurement, installation, and repair
3. Small physical size
4. Simplified programming and troubleshooting
5. Standalone or networked operation
6. Multiple sensor monitoring.

This report summarizes the concepts underlying PLC use in WWTPs, outlines successful applications of PLC technology in commercial WWTPs, and details specific operations in military WWTPs that may benefit from PLC implementation. Vendor and product information is also listed.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (Leave Blank)

2. REPORT DATE
July 1991

3. REPORT TYPE AND DATES COVERED
Final

4. TITLE AND SUBTITLE
Use of Programmable Logic Controllers To Automate Control and Monitoring of U.S. Army Wastewater Treatment Systems

5. FUNDING NUMBERS
PE 4A162720
PR A896
TA NN
WU TY0

6. AUTHOR(S)
Byung J. Kim, James E. Alleman, Chai S. Gee, and John T. Bandy

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
U.S. Army Construction Engineering Research Laboratory (USACERL)
PO Box 9005
Champaign, IL 61826-9005

8. PERFORMING ORGANIZATION REPORT NUMBER
TR N-91/27

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
USAEHSC
ATTN: CEHSC FU-S
Fort Belvoir, VA 22060-5586

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES
Copies are available from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

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PLCs offer many benefits over competing microcomputer technologies: (1) off-the-shelf availability, (2) low-cost procurement, installation, and repair, (3) small physical size, (4) simplified programming and troubleshooting, (5) standalone or networked operation, (6) multiple sensor monitoring.

This report summarizes the concepts underlying PLC use in WWTPs, outlines successful applications of PLC technology in commercial WWTPs, and details specific operations in military WWTPs that may benefit from PLC implementation. Vendor and product information is also listed.

14. SUBJECT TERMS
programmable logic controllers
wastewater treatment plant

15. NUMBER OF PAGES
100

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	SAR

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std 239-18
298-102

FOREWORD

This study was funded by U.S. Army Construction Engineering Research Laboratory, Environmental Division (USACERL-EN) Intra Division Independent Research (IDIR). Partial funding was also provided by the U.S. Army Engineering and Housing Support Center (USAEHSC), Fort Belvoir, VA, under Project 4A162720A896, "Base Facility Environmental Quality," Task NN; Work Unit TY0, "Microcontroller Technology for Water and Wastewater Treatment Systems." The technical monitor was Mr. Thomas Wash, CEHSC-FU-S.

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COL Everett R. Thomas is Commander and Director of USACERL, and Dr. L.R. Shaffer is Technical Director.

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1 INTRODUCTION

Background

The *U.S. Army Operator's Assistance Program Summary Report*[1] indicates that Army wastewater treatment plants (WWTPs) range from 0.003 million gallons per day (MGD) to 8 MGD (1 gal = 3.78 L), an average size of approximately 1.0 million gallons per day. The Army currently operates more than 100 small WWTPs, of which 75 percent use trickling filters, 15 percent use an activated sludge process, and 10 percent are other types. Operation and maintenance of Army water and wastewater treatment plants are further complicated by the limited funds available to these activities and by the shortage of skilled operational personnel.

A recent U.S. Army Construction Engineering Research Laboratory (USACERL) report[2] validated the concept of applying sophisticated artificial intelligence (AI) programs at these water and wastewater facilities, but did not recommend that these programs be immediately implemented. Use of these advanced applications was considered premature since Army costs for software and related sensor development of these AI systems would outweigh the apparent benefits.

It was determined that any future effort to automate Army environmental engineering systems (including the control and monitoring of wastewater treatment operations) must meet the following criteria:

1. The system's actual control requirements

2. The system's requisite product quality constraints

3. The system's desired performance (i.e., cost-effectiveness, reliability, etc.)

4. The system's present requirements for the capabilities and qualifications of operators assigned to these systems.

The control systems now used for environmental engineering process automation and monitoring span a considerable range of electronic sophistication, from unintelligent electromechanical timers and relay units to artificial intelligence packages. Both extremes are inappropriate for the control requirements of most U.S. Army wastewater treatment operations (i.e., small-scale facilities at or below 2 to 4 MGD). Electromechanical units are not sophisticated enough, and artificial intelligence/mainframe control systems are simply too complex for these facilities.

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[1] Law Environmental, *U.S. Army Operator's Assistance Program*, Draft Summary Report (U.S. Army Engineering and Housing Support Center [USAEHSC], Fort Belvoir, VA, January 1989).

[2] Byung J. Kim, John J. Bandy, K.K. Gidwani, and S.P. Shelton, *Artificial Intelligence for U.S. Army Wastewater Treatment Plant Operation and Maintenance*, Technical Report (TR) N-88/26/ADA200434 (U.S. Army Construction Engineering Research Laboratory [USACERL], September 1988).

Programmable logic controllers (PLCs) provide control capabilities better matched to the needs of wastewater treatment operations by their middle range of sophistication and low cost. In addition, programmable logic controllers have recently been successfully used at a number of small-scale, innovative municipal and industrial wastewater treatment facilities, both in the continental U.S. (CONUS) and overseas.

Although PLC technology and other automation technologies have been used successfully at municipal and industrial WWTPs, the Army has not yet exploited opportunities to automate its WWTPs by using these relatively simple, economically practical technologies.

To address this need, USACERL is involved in an ongoing project to explore the U.S. Army's opportunities to use PLCs to improve the effectiveness of operation and maintenance of water and wastewater systems, and to reduce manhours, chemicals, and energy costs by the integrating PLCs with personal computer (PC) technologies.

Objective

This report summarizes current information on PLC technologies to provide a conceptual basis for implementation of PLC technology in WWTPs maintained by the U.S. Army.

Scope

Actual installation and testing of automation technologies at Army WWTPs is beyond the scope of this phase of work.

Approach

A literature review and market survey were conducted to assess the current state of PLC technology and its applicability to wastewater treatment plants. The literature review included case studies of 17 wastewater treatment plants that currently use PLC technology (Chapter 7).

Mode of Technology Transfer

It is anticipated that applications derived from this research will be disseminated through workshops and demonstrations developed through the U.S. Army Engineering and Housing Support Center (USAEHSC), Fort Belvoir, VA.

2 BACKGROUND OF WASTEWATER TREATMENT PLANT AUTOMATION AND PROGRAMMABLE LOGIC CONTROLLERS

Automation of WWTP

Historically, the wastewater treatment industry has experienced mixed results from computer use. At the beginning, computers seemed to offer only high-cost, complex solutions to WWTP operational problems. Early journal articles were critical of computer applications for WWTPs.[3]

However, after nearly a decade of persistent development, computer control and management of wastewater treatment systems have become a reality. Reliable computer systems perform well and cost effectively, in conjunction with affiliated on-line instrumentation and analyzers.[4] Many WWTPs have found that computer applications offer a diverse range of technical services, from keeping off-line administrative or maintenance records to real-time monitoring and control.

Many of these highly successful environmental facilities have experienced a problem commonly associated with computer automation; a computer can generate far more data than a human operator can immediately interpret.

One USACERL study reviewed several related operations and maintenance (O&M) software applications for use at U.S. Army wastewater plants.[5] However, none of these software applications actually hardwired computers into associated wastewater plant processes. As such, they lacked both a real-time understanding of actual performance status and an ability to effect true process control changes.

Most water and wastewater conveyance and treatment operators might accordingly claim that they use computers—without actually having any actual process control or automation. In fact, few computer systems presently in use truly interact with their affiliated processes or operations on a real-time basis. Appropriate implementation of computer-based technology still remains an elusive goal. The wastewater treatment industry has expended much effort to incorporate such hardware, with limited success. In addition, the associated learning process has been slow.

The majority of locations within the United States originally provided with real-time control capabilities (e.g., mostly large-scale installations such as those at Atlanta, Washington, DC, Cleveland, Detroit, and Indianapolis) were equipped with large, expensive, dedicated mainframe computer systems. Unfortunately, these latter units have shown an erratic record of performance and reliability.

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[3] "High Tech Junk Litters Wastewater Landscape," Feature Editorial, *Engineering News-Record*, vol. 211, No.5 (1983), pp. 22-24; J.M. Jutila, "Computers in Wastewater Treatment: Opportunities Down the Drain," *Intech*, vol. 26, No. 10, pp. 19-21; W.F. Garber and J.J. Anderson, "From the Standpoint of an Operator - What Is Really Needed in the Automation of a Wastewater Treatment Plant," *Proceedings of the Fourth IAWPRC Instrumentation and Control of Water and Wastewater Treatment and Transport Systems Workshop, Houston, TX* (Pergammon Press, Oxford, UK, 1985), pp. 429-442.

[4] B. Roffel and P.A. Chin, *Computer Control in the Process Industries* (Lewis Publishers, Chelsea, MI, 1987).

[5] C.P. Poon et al., *Evaluation of Microcomputer-Based Operation and Maintenance Management Systems for Army Water/Wastewater Plant Operations*, TR N-86/18/ADA171992 (USACERL, July 1986).

Programmable Logic Controllers

PLCs are designed for logic-based control of high-voltage equipment within a harsh industrial environment. They are agile, powerful equipment controllers, in spite of their simplistic hardware and programming capabilities. Simply stated, PLCs comprise a "blue-collar" technology (i.e., transistor-transistor logic [TTL] based mechanisms, with virtually no moving parts) within the hierarchy of computer control systems.[6]

Although PLCs lack the artificial intelligence capabilities of computers, they are able to logically evaluate a given control and/or monitoring situation and to make rational control decisions based on input information. This capacity matches PLCs appropriately to each of the four control requirements of an environmental engineering system.

PLCs have been extensively used in conjunction with a variety of industrial manufacturing operations for several years and are widely employed in applications with control requirements similar to water/wastewater operations. These applications include: substrate processing for food preparation, pharmaceutical and paint production; and robotic manipulations associated with drilling, sampling, and welding operations.

Lift/pump station,[7] blower,[8] digestor,[9] solids recycling,[10] and ion exchange/filter[11] operations have also recently realized considerable growth in the use of small PLCs for control of their involved hardware. These applications largely stem from the mere economics of replacing standard electrical relay banks with PLC output modules rather than from the programming capabilities of these units. In addition, these PLCs are highly flexible, easier to troubleshoot, and generally more resistant to contamination and corrosion than are electrical relay banks.

One significant area of PLC application has been in sequencing batch reactor (SBR) wastewater treatment facilities. In the late '70s Congress developed its "Innovative and Alternative Technology Program" to promote the development and application of new, cost-effective technologies within the wastewater engineering field through financial incentives within its construction grants program. One such

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6 E. Alleman et al., "Programmable Controller Application to Innovative Wastewater Treatment Design," *Journal of Civil Engineering Design*, Vol. 1 (1979), pp. 287-304; A.F. Gilbert and G. Belanger, "Logic Controls on a Pinball Machine," *Engineering Education - ASEE* (1986), pp. 223-225.

7 W.F. Garber and J.J. Anderson.

8 S. Takarai, S. Fukuya, and M. Ohta, "The Supervisory Control and Data Acquisition System at the Toba Wastewater Treatment Plant, Japan," *Instrumentation and Control of Water and Wastewater Treatment and Transport Systems* (Pergammon Press, 1985), pp. 679-682.

9 J. Cooper et al. "Programmable Control of High Rate Anaerobic Digestion," *Pollution Engineering*, vol. 34, No. 9 (1987), pp. 52-54.

10 T. Norman et al., "Start-Up and Interim Control of Houston's 69th Street Wastewater Complex," *Proceedings of the Fourth IAWPRC Instrumentation and Control of Water and Wastewater Treatment and Transport Systems Workshop, Houston, TX* (Pergammon Press, 1985), pp. 359-365.

11 J.M. Ray et al., "Denver's Potable Water Reuse Demonstration Project: Instrument and Control System," *Proceedings of the Fourth IAWPRC Instrumentation and Control of Water and Wastewater Treatment and Transport Systems Workshop, Houston, TX* (Pergammon Press, 1985), pp. 489-496.

technology that has drawn considerable interest, and has used PLC control hardware, is that of the SBR process.[12]

During the early 1900's, the originally devised "fill-and-draw" strategy for wastewater processing was dropped in favor of continuous-flow wastewater treatment systems, in large part due to the manual effort associated with regulating intermittent systems. Discontinuous operation of the valves, blowers, mixers, etc. in these intermittent systems was simply too difficult and tedious for human operators to successfully manage on a routine basis.

Today's computer technology provides a timely solution for the automation needs associated with these "resurrected" types of wastewater treatment strategies.[13] These control systems require only PLCs instead of the larger, more expensive mainframe machines used in the earlier large-scale installations.

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[12] J.E. Alleman, M.W. Sweeney, and D.M. Kamber, "Automation of Batch Wastewater Treatment Systems Using Programmable Logic Controllers," *Proceedings of the Fourteenth Biennial Internation IAWPRC Conference* (Brighton, UK, 1987), pp. 1271-1283; J.E. Alleman et al. (1979); J.E. Alleman and R.L. Irvine, "Nitrification in the Sequencing Batch Reactor," *Journal of Water Pollution Control Federation*, vol. 52 (1980), pp. 2747-2754; E.E. Halmos, "Treating Sewage in One Tank," *Civil Engineering - ASCE*, vol. 56, No. 4 (1986), pp. 64-67; P.A. Herzbrun, R.L. Irvine, and K.C. Malinowski, "Biological Treatment of Hazardous Waste in Sequencing Batch Reactors," *Journal of the Water Pollution Control Federation*, vol. 57 (1985), pp. 1163-1167; M.G. Mandt, "The Innovative Technology of Sequencing Batch Reactors," *Pollution Engineering*, vol. 7, No. 7 (1985), pp. 26-28; A.S. Weber and M.R. Matsumoto, "Remediation of Contaminated Ground Water by Intermittent Biological Treatment," *Proceedings of the American Society of Civil Engineering, Environmental Engineering Specialty Conference* (1985), pp. 174-179; R.L. Irvine et al. "Municipal Application of Sequencing Batch Treatment," *Journal of the Water Pollution Control Federation*, vol. 55, (1983), pp. 484-488; R.L. Irvine and R.O. Richter, "Comparative Evaluation of Sequencing Batch Reactors," *Journal of the Environmental Engineering Division, American Society of Civil Engineers (ASCE)*, vol. EE3, No. 104 (1978), pp. 503-.

[13] J.E. Alleman, et al., (1979); D.F. Bishop and W. Schuk, "Water and Wastewater: Time To Automate?", *Civil Engineering - ASCE* (1986), pp. 56-58; J. Erickson, "Getting Control of Industrial Wastewater Treatment," *Pollution Engineering*, vol. 18, No. 2 (1986), pp. 42-46; E.E. Halmos.

3 POTENTIAL BENEFITS OF PROGRAMMABLE LOGIC CONTROLLERS

Positive PLC Attributes

Low-Cost Procurement and Installation

PLCs are far less expensive than advanced computer systems. At the low end of this technology, PLCs can easily be purchased for less than $1000 Most PLC hardware will cost about the same as personal computer equipment (i.e., about $2000 to $3000); some high-end equipment may range from $5000 to $9000. Aside from initial capital cost, the inexpensive nature and modular arrangement of these PLCs offers several advantages. Should a PLC become damaged or obsolete, it can be completely replaced far more cheaply than a larger computer. Moreover, a complete set of PLC modules can be inexpensively kept on hand as spare parts.

Cross-Over Technology

Programmable logic controllers presently have many industrial applications, including: vehicle manufacturing lines, batch paint development and spray systems, pharmaceutical production lines, oil refinery distillation towers, etc. The demonstrated success of these PLC applications establishes a precedent for the use of PLCs in environmental engineering facilities.

Off-the-Shelf Hardware Availability

PLC units are commercially available from a wide variety of vendors, in sizes and configurations commensurate with any foreseen need. At present, there is virtually no requirement for research on PLC component hardware. Conversely, there are no present hardware limitations for the use of PLCs in environmental engineering facilities.

Small Physical Size

Unlike mainframe computers whose size and environmental sensitivity warrant a dedicated room and a heating, ventilation, and air conditioning (HVAC) system, PLCs are extremely small and can tolerate harsh environments. Low-end "micro" PLCs can even be carried in a briefcase. Their size makes PLCs convenient and less intimidating to work with than large computers. In addition, PLCs can be inserted in control cabinets, distributed on-site, and possibly networked throughout a facility rather than being located in one central main control room.

Small Memory Size

PLCs have smaller memory capacity than mainframe computers. This means that PLCs are less sophisticated in computational power, but also that their smaller-sized programs are easier to follow and troubleshoot, and easier for operators to comprehend than more complex computer-based software. While mainframes must be monitored and maintained by computer-literate experts, PLCs require only a rudimental understanding of a basic, straightforward programming language (i.e., relay ladder logic). Such small programs are less intimidating, and their visual Boolean logic frequently is easily and quickly learned.

Stand-Alone Operation

Individual PLCs can be used in singular, dedicated fashion to monitor and control specific tasks. Should one PLC system fail, the loss would not disrupt the operation of a second PLC. By comparison, mainframe computer control systems are seriously blinded by the loss of the central computer. This weakness is generally resolved by installing two redundant mainframes, an extremely expensive proposition.

Multiple Sensor Monitoring and Correlation

Unlike dedicated microprocessor controllers, which can usually accept only one form of input signal voltage or amperage, PLCs can easily accept a diverse range of sensory inputs. Instruments can be selected and installed with reasonable confidence that the PLC will be able to handle their data input.

Interface Opportunities

Should the need arise, the newest generation of programmable logic controllers can be electronically linked into a control network that provides supervisory access to all coupled PLC units. This feature allows standalone controllers to operate either independently or networked with a master controller that monitors the discrete operation of the remaining PLCs. Such networks are designed for fault tolerance, with independent control assumed by each PLC in case contact with the supervisory computer unit is lost.

Perceived Application Benefits

Relieve Human Operator Monitoring Commitments

Operations personnel assigned to environmental engineering systems are often responsible for routine and tedious monitoring tasks. Monitoring a facility for proper function demands repetitive (and tedious) operator attention to one or more performance indicators. Unfortunately, this problem can also be seriously aggravated by the placement of inadequately educated or transient operational staff. Such complications do occasionally arise within environmental engineering systems, including those maintained by the military.

By contrast, PLCs do not degrade in their level of interest or diligence. Any number of environmental parameters in a water or wastewater treatment plant, cooling tower, wet well, etc. can be consistently monitored by a PLC at split-second intervals with constant attention to operational abnormalities, upsets, or failure.

Ensure Operational and Equipment Safety

A properly implemented PLC system could complement the operational staff by routinely monitoring a facility's equipment and performance for possible failure. Within a chlorination room, for instance, an ambient atmospheric halogen monitor could trigger a PLC to warn of a leakage problem far in advance of a possible life-threatening emergency. Most electrical equipment could be monitored both for electrical demand (e.g., current draw) and operation (e.g., motor RPMs, etc.) to verify their actual status. Accidental wastewater effluent discharges of harmful materials (e.g., extreme pH, zero dissolved oxygen [D.O.], high solids, etc.) could be detected and reported.

Monitor and Reduce Facility Energy Costs

Presently, energy use does not represent a primary concern at most environmental engineering facilities. At best, a facility superintendent may track a monthly kilowatt-hour use to monitor energy demand, even though electrical demand for most operations may well exceed the labor costs by a substantial margin.

With minimal expense, specific energy-intensive equipment or whole sections of an operation could be retrofitted to provide a PLC with real-time information about the facility's electrical demand. This data could be used to identify and perhaps to implement energy-saving opportunities. For example, the PLC could "trend" and monitor peak electrical demand occurrences, resulting in a PLC-controlled shedding of nonessential equipment to buffer these peaks. At the very least, the PLC might implement and supervise intermittent equipment operation programs for items such as reactor mixers, aeration blowers, and recycle pumps, thereby reducing the facility's routine electrical demand.

Basic PLC Hardware

Contemporary PLC systems include four primary hardware components:

1. Central processor unit (CPU)
2. Input (I) modules
3. Output (O) modules
4. Program loader.

Figure 1 provides a general schematic of a typical PLC system.

The CPU represents the "brains" of the controller, and performs the logical determinations and communications required for the PLCs overall operation. These processors are ranked by memory capacity and ability to handle inputs and outputs. At the low end of the product line, several PLC vendors distribute a "micro" system equipped with approximately 1000 words (1K) of memory, and a capacity to handle a few dozen inputs and outputs. Successively larger PLC sizes (i.e., small, medium, and large) provide correspondingly larger memories, eventually reaching the capacity of personal computers (e.g. ~128 to >256K).

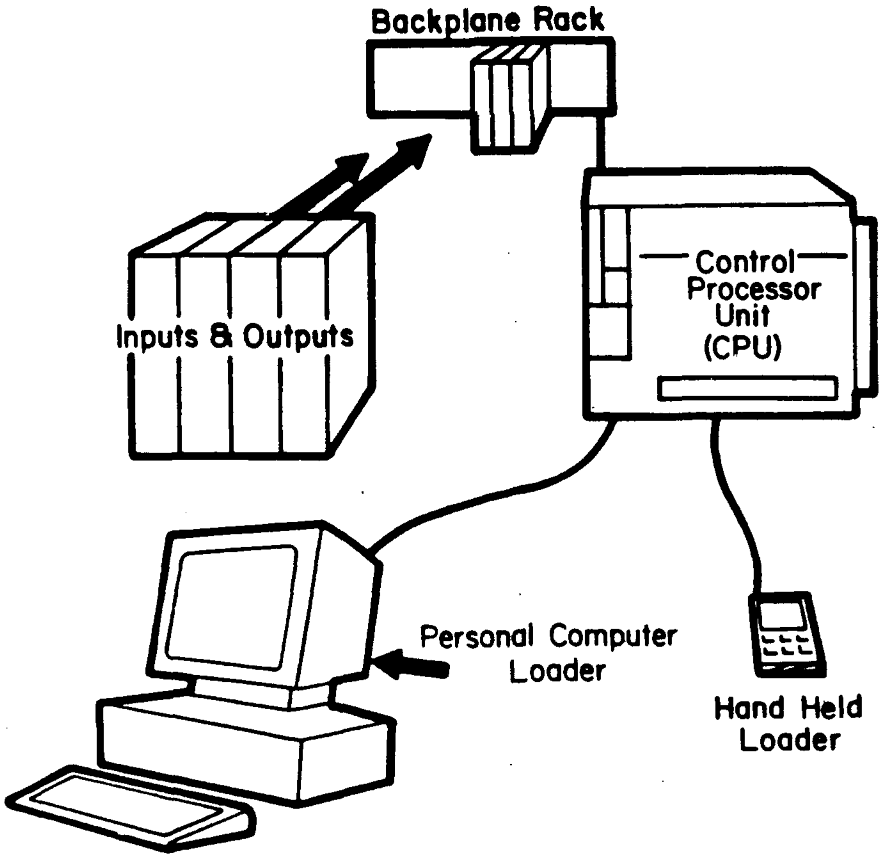

Figure 1. Programmable Logic Controller hardware overview.

The circuitry employed by a programmable logic controller's CPU is inherently dissimilar to that which would be found in higher-level computers. Whereas personal computers employ integrated circuit (IC) chips, PLCs employ TTL devices, which are somewhat less electronically advanced. However, the current generation of PLCs commonly use 16-bit words and are, at least to the layman, roughly analogous to most other computer hardware.

Input and output modules (I/O elements) send and receive signals for the PLC. Input and output modules are typically built with from 4- to 16-point sizes per module. The newer PLCs have module sizes of 8 to 16 points to improve module density.

Input and output modules are designed to handle single voltage (AC or DC) forms and levels. Output modules rated for 115 volts AC (VAC) may be used for direct operation of individual equipment at loads as high as ~ 2 amp. In most PLCs, these outputs are fused to protect against electrical overloads. Relay-type outputs, should they be necessary for applications such as power transfer, etc., can also be obtained for control of contact closures.

All three of these components are then mounted on a backplane or rack, including one CPU and an assortment of I/O modules. Additional racks containing only I/O modules may be successively linked together, as long as the primary rack contains a central processing unit able to handle the combined load.

The last item, known as a program loader, is often sold by PLC vendors as a dedicated, hand-held device similar in appearance to a large calculator. These portable loaders are commonly used for field troubleshooting of PLC operations, or for making small changes in program memory. Most such loaders can be connected with small cassette recorders to both record and download actual PLC programs, thereby avoiding a requirement for manual loading of long programs.

However, over the past few years, most PLC manufacturers have also begun marketing software to interface PLCs with personal computers. This capability creates the need for a dedicated loader. For most users already equipped with PC systems, this option further reduces the overall cost of using programmable logic controllers and allows operators to gain a significant increase in their storage and downloading capacity of optional PLC programs. Furthermore, these programs can be mailed to a PLC user site and installed by the user.

These CPU systems may be equipped with internal battery backups that retain memory during power outages. The NiCad batteries most often used can meet this need for several days of extended power loss, and have an unused life of several years.

Finally, PLC units are normally encased within an industrially-hardened enclosure (i.e., rated as NEMA4, NEMA12, etc.). The PLC requires protection against exposure to water.

Basic PLC Software

At present, most PLCs are programmed with relay ladder logic. Figure 2 depicts a simplified section of code for this language.

The left and right side risers for this code are analogous to the sides of a ladder, and the connecting lines equate to the ladder's rungs. The example shows five such rungs. The CPU starts its program evaluation at the head (top) of this ladder and works its way downward through the ladder until reaching the end. At this point, the CPU then jumps back to the head of the ladder and resumes its descent. Although the length of the total program does affect the speed of passage, each trip is completed in a microseconds interval.

In this example, the first rung establishes whether an input point has been activated. Should this be the case (i.e., if IN001 is activated or 'hot'), the affiliated control relay (i.e., CR001) will be correspondingly engaged within the CPU's memory. The CR001 contact then activates three successive outputs (CR002, CR003, and CR004).

For the fifth rung, activation of the control relay (CR005) by IN001 initiates a latch (using CR005) in parallel with the IN001 contact. Once IN001 has been disengaged, all control relays also disengage, with the exception of CR005. Once its status has been fixed by IN001, this control relay cannot be changed. (It is "latched.")

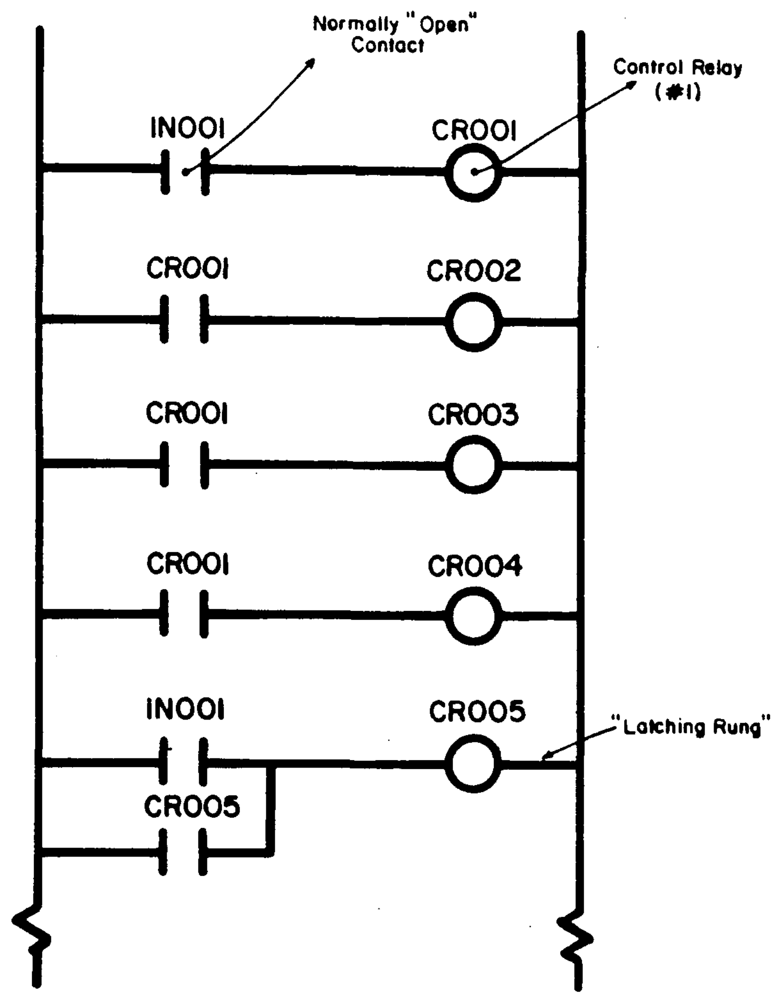

Figure 2. PLC ladder logic schematic.

Beyond this simplified example, most PLCs offer a standard set of operational software functions, normally including timers with intervals of either 0.1 s or 1 s (or perhaps both). PLC counters are normally ascending and descending in form, and PLC memories are designed to handle register addressing and storage, as afforded by the memory capacity of the CPU. These holding registers are commonly used to store current timer or counter values, as well as data inherent to the operation of the user's intended program.

Current PLC Vendors

A complete listing of programmable logic controller options and vendors can be found in Cleaveland, and Ball and Robinson.[14] Cleaveland lists 70 vendors and each vendor's products to show contemporary programmable logic controller hardware options. Ball and Robinson subdivide PLC models by the four PLC size ranges. Appendix A includes examples of both references to show available information. In spite of the diversity of vendors, the market appears to be dominated by a small group of well-known firms.

[14] K.E. Ball and C.V. Robinson, "Programmable Controllers: Alive and Well," *Programmable Controls*, vol. 8, No. 1 (1989), pp. 24-60; P. Cleaveland, "PLCs Take on New Challenge," *I & CS*, vol. 62 (1989), pp. 29-38.

5 ADVANCED PROGRAMMABLE LOGIC CONTROLLER CONCEPTS

Advanced PLC Hardware

Alphanumeric Displays

The use of alphanumeric displays can significantly improve an operator's understanding of the current operating status of a PLC system. Several such displays are commercially available, including both devices sold by PLC manufacturers and by secondary market vendors. These displays may or may not be equipped with internal memories.

Displays lacking on-board memory operate solely as slave message displays whose messages must be constructed and sent from the PLC. These types of alphanumeric displays typically cost about $400 and are designed to receive either of these standardized transmitting formats. For example, Cherry Inc.[15] markets a low-cost (~$350), self-powered (115 VAC) display that handles its own RS-232, RS-422, etc., formats. Rather obviously, the connected PLC must be able to prepare and transmit this sort of signal string to "speak" with the display (NOTE: see following discussion of advanced PLC software options).

The second type of alphanumeric display, which includes on-board memory, can store and display its own messages. These messages must be prepared in advance and their display is triggered simply by some form of contact closure input to the device actuated by the PLC. This approach relieves the PLC from creating and transmitting the message, and may sizably reduce the commitment of PLC memory to this task. However, these types of displays are inherently less flexible in their message generation capabilities than displays that merely create and transmit messages.

A number of prospective vendors for these types of PLC alphanumeric displays are given in Appendices B, C, and D.

Graphics and Alphanumerics Displays

The combined use of graphics and alphanumeric displays enhances the visual information transferred by PLC equipment. While alphanumeric displays are becoming a standard feature for PLC systems, graphics capabilities are still an uncommon PLC feature for several reasons. First, graphics are an expensive addition. Second, the generation and display of graphics requires more computational power than most PLCs can provide. Only the high-end, high-memory PLCs can presently meet this need. Graphics displays will probably not be used with PLCs for several more years. However, several vendors do sell these products (Appendices C and D).

In the meantime, PLC users can mimic graphics displays on RS-232/RS-422 alphanumeric systems through bar diagram patterns. Bar diagrams can be easily generated by a PLC and transmitted in alphanumeric patterns. Westinghouse PLC units are now distributed with user's manuals that explain how to achieve these low-cost "graphics" displays.

[15] Cherry Electrical Products, Waukegan, IL 60087 (708/360-3500).

Data/Register Entry Modules

Perhaps the most common interaction between an operator and a PLC would be to transfer register data. For example, an operator might wish to know the current running time for a given motor, and would query the PLC to obtain the register value for this variable.

This information would normally be obtained either from a program loader or interconnected personal computer (see *"Dumb" Interface Personal Computers*, and *Intelligent Supervisory Personal Computers* in this chapter). These same devices are used for both programming and monitoring purposes. It is possible for an operator to reprogram a PLC while trying to read current register values.

For this reason, and to simplify operator access to PLC register data, most vendors sell a data-entry module that interconnects directly with their PLC. These modules allow the operator to select and read the current value for any given PLC register, and also to change the value of this register if they desire. The authority to change register settings is usually limited by a requirement to change a keyswitch setting of the data entry module. Any operator possessing this key should be properly trained in the importance of this action.

An overview of data entry module/interface/workstation options is provided in Appendix D. These modules are normally mounted on an operator control panel (often the face of the PLC enclosure), and may use either thumbwheel or tactile membrane data inputs. Their cost varies with sophistication, and ranges from ~$200 to $1000s.

Combined Alphanumeric Displays and Data Entry Modules

Modules that combine alphanumeric displays with data entry modules are relatively recent additions to the PLC marketplace, and are designed to interactively combine the relative advantages of each individual component. At present, they are rather expensive, but their price should fall in the immediate future. Appendixes C and D provide a short list of potential vendors.

Analog to Digital (A/D) Converters

Prior to the computer era, electronic signals generated by instrumentation were typically documented on strip chart recorders. These recorders converted an analog electronic signal into the physical movement of a pen across a chart.

By comparison, computers and PLCs are designed to "think" in terms of digital values. Hence, an instruments analog signal must be digitized to be read by the monitoring computer/PLC. Analog to digital (A/D) converter modules marketed by PLC manufacturers handle this conversion, and are individually designed to handle one of the standard analog formats (e.g., 4 -> 20 ma, 0 -> 5 VDC, etc.). These modules inherently represent an alternative input scheme for the PLC, and are mounted on the same backplane as the remaining I/O and CPU.

The sensitivity of these A/D modules depends on their digital "word" size, commonly with bit-values of 8, 12, or 16. Word size and sensitivity are synonymous. Eight-bit A/D units can resolve an input analog signal into 256 (2^8) segments, and are the cheapest A/D converters; 12-bit units offer an intermediate resolution, at 4096 (2^{12}) segments; and 16 bit A/D systems offer a much higher resolution, at 1 in 65,536 (2^{16}) segments, but are much more expensive.

A/D converter modules may range in price from ~$200 to $600, and are purchased directly from each PLC vendor. For PLC systems designed to monitor and evaluate incoming analog instrumentation data, their use is mandatory.

Digital to Analog (D/A) Converters

D/A modules are opposites to the previously discussed A/D converters. D/A modules generate an "analog" output (e.g., 4 -> 20 ma, 0 -> 5 VDC, etc.) in response to a digital parameter set within the PLC. D/A converters are most useful for controlling DC motors and pumps whose speed is determined by the PLC's analog output. Again, D/A modules are purchased directly from each PLC vendor.

"Dumb" Interface Personal Computers

As mentioned earlier, most PLC devices can now be linked with a personal computer with a software connection. This linkage provides an operator with several improvements in PLC programming and monitoring. First, personal computers are faster than most vendor-marketed program loaders. Second, the PC allows an operator to record programs on either a floppy disk or hard drive. This provides a backup program security and accelerates the portability and downloading of old or new programs. Since this PLC - PC link does not fully use the computational power of the personal computer, the term "dumb" interface is used.

Appendix B summarizes PLC manufacturers that sell their own line of software and secondary vendors that offer competing systems.

"Intelligent" Supervisory Personal Computers

The use of "intelligent" supervisory personal computers represents a logical extension to the linkage of personal computers and programmable logic controllers. Each such device has its inherent advantages. PLCs are designed for control of industrial equipment; PCs are designed for computational power. Rather than using the PC as merely a "dumb" program loader and monitor for the PLC, an "intelligent" personal computer would be able to control, monitor, and diagnose an operation by synergistically coupling the relative capabilities of both PC and PLC.

This "intelligent" PLC/PC interaction depends on the use of advanced software packages discussed in the following section.

Advanced PLC Software

Advanced Internal PLC Software Functions

The "relay ladder logic" programming language provided by the PLC manufacturer generally contains two levels of sophistication. At the low end, the programming language offers basic capabilities like those of timers, counters, and register moves.

However, as the memory size of a PLC increases, the programming language becomes correspondingly more advanced. For all but the simplest PLCs, these advancements offer a significant increase in programming power and flexibility.

The first advanced function is generally a math function set. This function normally provides internal PLC addition, subtraction, multiplication, and square root calculations.

Several advanced register functions might also be included, many of which address the register words as both single entities and individual bits. At the single-bit level, these functions include: bit set, bit shift, bit move, bit masking, bit reversal, and bit pick. For full word groups, the advanced functions may provide: word move, table move (for larger word blocks), word sort, and word shuffling.

Some PLCs can generate and transmit ASCII messages. Finally, some PLCs include a drum control feature, which sequences successive memory words through a step- or batch-wise shift. This latter feature has many similarities to the instructional drum used by a player piano, in which the notes called by the piano's drum are like control instructions to the PLC. In general, these advanced internal PLC functions greatly enhance the power and flexibility of the PLC control language.

Advanced External PLC/PC Software

Two forms of advanced external PLC software may be obtained. The first is usually obtained from the PLC manufacturer and is used solely to facilitate the use of an interconnected personal computer as a "dumb" program loader and monitor. This software is usually moderate in price, ranging from gratis contributions by the PLC vendor to a few hundred dollars. (Appendix B)

The second type of advanced external software may also be bought from most of the PLC manufacturers, or from a secondary vendor. This software also links PLCs with PCs, but is designed to exploit the power of the personal computer for data analysis and presentation. Inexpensive varieties of this software will directly import PLC data into PC spreadsheet software, such as Lotus 1-2-3®, or will provide rudimental graphical data displays on the PC screen. More expensive software packages will provide a complex real-time interface complete with plant control documentation, histographs, alarm annunciators, and diagnostic guidance. (Appendix B)

As an intermediate option, PLC manufacturers and secondary vendors now offer a set of interface "drivers" which allow callable routines (i.e., using BASIC language) from the personal computer to directly access the PLCs central processor and memory. This type of software, priced in the range of ~$200 to $400, probably offers the most flexibility and value for the application opportunities being addressed by this report. Rather than being constrained by the programming features inherent to "off-the-shelf" software, these intermediate drivers allow a design engineer to tailor a given PLC/PC system to a given process or operation. Vendor information is given in Appendix B.

Advanced PLC Networking

For large-scale PLC applications, the need may arise to link individual PLCs into a network to share data sets and control algorithms. The latest generation of PLCs (e.g., the Westinghouse PC-1200 series) offers this capability as a basic feature.

The next step beyond linking individual PLCs is to add a supervisory controller to a PLC network. One secondary vendor (i.e., METRA; see Appendix D) employs specialized personal computer hardware and software to provide real-time networking of distributed PLCs. This type of control system has been installed at a recently renovated 50 MGD wastewater treatment facility (see review in Chapter 7, Location 14, p 31).

6 INSTRUMENTATION INPUTS FOR PROGRAMMABLE LOGIC CONTROLLER SYSTEMS

General Overview of Instrumentation Technology

On-line instrumentation will unquestionably play a major role in the successful use of automated process monitoring and control. These instruments are the "eyes and ears" of the system. They provide important real-time sensory inputs to their associated controller.

This chapter presents the state-of-the-art in on-line instrumentation. These instruments play a vital role in providing an automated system such as PLCs with real-time sensory information about the status of the controlled process. The value of this data critically depends on routine maintenance and calibration of the sensors; the machine is highly dependent upon human cooperation for assistance.

During early attempts at computer automation, failures commonly encountered with this innovative technology could as much be blamed on the instruments themselves as on the computers. The two technologies were simultaneously struggling through two distinctly different and yet intertwining learning curves, jointly compounding the difficulty of melding their applications. The success of early on-line instrumentation in the environmental field was compromised. Many of these sensors are technically complex and require much manual attention to maintain over long periods of time. The instrumentation is exposed to a harsh environment, thereby reducing the effective lifetime of the calibrated device.

Over the past decade, on-line instrumentation has become significantly more reliable and robust. Several broad technical reviews of the instrumentation commonly used within environmental engineering systems state that, while progress has yet to be made in several analytical areas, several generic instrumentation groups can now be used with reasonable confidence.[16]

For PLC systems, these sensors are assumed to be connected to a dedicated meter, which subsequently relays an electrical signal to the PLC. For example, a dissolved oxygen probe would first be connected to a dissolved oxygen meter; this meter would then forward an analog or digital output signal to the PLC.

Such an approach provides several benefits. First, field calibration of the sensor can be simplified if the technician has direct access to a dedicated meter and signal readout. Second, the PLC system need only handle the A/D conversion of standardized output signals generated by the sensor's meter. Should these meters not be used, the PLC would have to directly link to the sensor and deal with an assortment

[16] A.S. Bonnick and J.M. Sidwick, "Instrumentation, Control, and Automation - The Choices," *Water Science and Technology*, vol. 13 (1981), pp. 35-40; A.W. Manning and D.M. Dobs, *Design Handbook for Automation of Activated Sludge Wastewater Treatment Plants*, EPA 600/8-80-028 (U.S. Environmental Protection Agency [USEPA], Cincinnati, OH, 1980); R.C. Manross, *Wastewater Treatment Plant Instrumentation Handbook*, EPA 68-03-3120 (USEPA, 1985); A.J. Molvar et al., *Instrumentation and Automation Experiences in Wastewater Treatment Facilities*, EPA 600/2-76-298 (USEPA, 1976); J.P Stephenson, "Instrumentation for Wastewater Treatment," Unpublished paper presented at the *Canadian Society of Civil Engineers Workshop on Computer Control of Wastewater Treatment Plants* (McGill University, Montreal, Quebec, 8 May 1986); J.P. Stephenson and S.G. Nutt, "On-Line Instrumentation and Microprocessor-Based Audit of Activated Sludge System," *Proceedings of the ISA-87 International Conference and Exhibit* (Anaheim, CA, 4-8 October 1987).

of electrical requirements (e.g., amplification, etc.). Finally, the operators themselves would have these meters as a visual reference on-site and would not have to return to a control station to check with the PLC.

Specific Instrumentation Considerations

In general, the current inventory of instrumentation options may be grouped into four levels, by reliability:

1. Can be used with reasonable reliability
2. Reliability will likely require frequent maintenance
3. Presently not reliable, but technology is improving
4. Not presently recommended.

The following discussion categorizes each generic sensor group by the four instrumentation levels, to indicate the perceived confidence which might be placed in their near-term use. It should be understood that several vendors may be available for a single group of instrumentation, and that the performance of one vendor's instrument may differ from another's. Complementary technical, installation, and maintenance information regarding these instruments has also been provided in Appendix D.

Level #1 Instrumentation

Dissolved Oxygen

Reliable measurement of D.O. levels in water and wastewater streams and reactors can be successfully achieved as long as the D.O. probe is properly maintained with suitable cleaning and calibration.

pH

On-line measurement of pH can be reliably performed, as long as routine maintenance and calibration are provided for the probe.

Turbidity

Turbidimetric analysis of fluids using flow-through cells is becoming a commonplace procedure among larger water and wastewater treatment facilities. Biological (biofilm growth), physical (scratching), or chemical (scaling) alteration of the instrument's optical surface(s) will probably represent major long-term problems, and can be corrected with routine cleaning or cell replacement.

Flow

Ultrasonic and magnetic flow meters have been successfully used in many water and wastewater treatment facilities. Although maintenance requirements are minimal, frequent calibration may be difficult. In some ultrasonic flow meter applications, and particularly those involving clean water streams, sensor accuracy may also be questionable due to a lack of reflective bubbles or solids.

Temperature

Temperature measurement is quite advanced and can be reliably employed with little risk. Problems are infrequent, but may be associated with insulative fouling of the sensor, causing reduced response times.

Liquid Level

Several types (i.e., resistive, bubbler, ultrasonic, etc.) of dependable liquid level sensors can be obtained in the current marketplace. Scum and foam formation may pose a problem with certain types of these devices.

Hydrogen Sulfide

Hydrogen Sulfide (H_2S) analysis is quite successful and commonly used today, particularly in solids handling facilities in wastewater treatment operations.

Level #2 Instrumentation

Residual Chlorine

On-line analysis of residual halogen levels in clean (i.e., potable or wastewater effluent) streams has become a fairly reliable procedure. However, these devices require frequent maintenance and replenishment of their chemical solution reservoirs.

Sludge Blanket

Several types (i.e., based on acoustical, optical, electrical, etc., principles) of solids interface sensors have recently been developed and marketed. For the most part, though, these devices exhibited marginal to less-than-satisfactory performance. Field testing of a newly marketed unit by Royce at Indianapolis, IN this past summer did, however, successfully demonstrate long-term utility.

Oxygen Reduction Potential

On-line measurement of a system's oxidation-reduction potential (ORP) may provide valuable information about a system's status. However, the platinum electrodes used to acquire this potential are subject to surface fouling and subsequent degrading of the sensor's accuracy. Future refinements in cleaning and on-line calibration of ORP probes will be necessary.

Conductivity

Conductivity cells are presently available but are not commonly used with water or wastewater treatment systems. Problems encountered with long-term sensor reliability are primarily related fouling of the electrodes; temperature sensitivity is also a concern.

Level #3 Instrumentation

Ammonia

On-line measurement of ammonia has been available for several years. However, the employed ion-selective probe and affiliated chemical dosing and sample filtration hardware are mechanically complex and difficult to maintain over extended periods. The most likely application of this instrumentation group will be to clean wastewater effluents that require minimal pretreatment (solids removal).

Level #4 Instrumentation

Suspended Solids

Optical-based devices for measurement of suspended solids are presently available. However, most instrumentation surveys suggest that these units have questionable reliability.

Organic Carbon

Relatively few vendors presently offer instruments for on-line measurement of total organic carbon. Furthermore, none of these units have received favorable ratings in the previously cited instrumentation reviews.

Supplementary Electrical Instrumentation

In addition to the mentioned groups of environmental sensors, PLC controllers can also be coupled with a diverse array of electrical sensors designed to monitor or control electrical energy demand and motor performance. These devices would include: motor starters, current sensors, horsepower sensors, proximity sensors, and vibration sensors. All of these devices tend to be considerably more reliable than the previously discussed environmental sensors, and should be considerably more dependable over their lifetime.

With the exception of the motor starters, all of these instruments are moderate in cost (typically in the range of ~$100 -> $400) and simple to install.

With nominal effort and expense, therefore, a PLC system could be equipped to monitor the electrical demand of key operations within a facility. For example, clarifier rake assemblies could be routinely checked both for rotation speed (tracking the elapsed time of a recurring proximity sensor signal into the PLC) and current demand by the rake motor.

7 REPRESENTATIVE PROGRAMMABLE LOGIC CONTROLLER APPLICATIONS

Over the past decade, many environmental engineering facilities around the United States have begun using PLCs for partial or full automation purposes. These plants evolved through a progressive advancement of their process control mechanisms and hardware. The earliest plants to experiment with automation technology typically started with electromechanical or microprocessor systems, and eventually switched to the use of PLCs.

Several of these PLC-equipped plants were designed and operated as SBRs. The automated control capabilities required for these full-scale, innovative wastewater treatment systems depart significantly from a conventional facility's reliance on human oversight and control. While most plants are maintained as continuous-flow processes, an SBR operates in discontinuous fashion. In turn, the dynamic nature of the SBR considerably escalates the required control effort. PLCs offer an ideal solution to the control requirements imposed by these sequencing batch reactors.

The following synopses provide an overview of the evolution of these PLC systems and their control and instrumentation hardware:

Location 1: Culver, IN[17]
Date: 1978
Application: 2 MGD Wastewater Treatment Facility Automation

This municipal wastewater treatment system was originally constructed in the late 1950s as a continuous-flow activated sludge process. However, an experimental renovation was undertaken in 1977, when its biological processing strategy was switched to an SBR scheme. This facility's two aeration tanks were fitted with jet aerators, pneumatic inlet valves, and a floating decant apparatus to complete this change.

A prototype microprocessor system was then installed to provide control over the plant's equipment sequencing. This microprocessor generally provided adequate automation of the Culver SBR process; however, it was not rated for industrial exposure (i.e., dust, humidity, etc.) and exhibited random malfunctions. After 2 years, therefore, this system was replaced by a small Texas Instruments (TI) programmable logic controller designed specifically for batch processing control.

This plant is still being run in the SBR mode, and the same TI PLC system handles all phasing of the plant's equipment. In relative terms, the control package now used at Culver is a "first-generation" system. Instrumentation monitored with this PLC is limited to liquid level in the tanks.

Location 2: SECOS International Inc., NY[18]
Date: 1980
Application: 3 MGD Wastewater Treatment Facility Automation

This SBR system probably represents the first system originally designed to incorporate a dedicated TI programmable controller for routine process control of a sequencing batch reactor activated sludge

[17] R.L. Irvine et al. (1983).
[18] A.S. Weber, Personal communication with J.E. Alleman (West Lafayette, IN, August 1989).

facility. This plant is presently used in conjunction with an industrial "treatment, storage, disposal" facility. The employed PLC maintains total control of the plant's two reactor vessels and related equipment, including on-line monitoring and control of system pH and D.O.

Location 3: Rockford, IL[19]
Date: 1981
Application: 0.5 MGD Wastewater Treatment Facility Automation

This SBR system was experimentally installed at the Rockford municipal facility by Aqua-Aerobic Systems Inc. (Location 3)[20] as a retrofit of an existing continuous-flow reactor. This operation is also controlled by a Siemens programmable controller, although here again the employed logic solely covers equipment operation (i.e., on-off cycling) according to a desired phasing sequence.

Location 4: Grundy Center IA[21]
Date: 1982
Application: 1 MGD Wastewater Treatment Facility Automation

The Grundy Center SBR system uses a TI programmable controller for automation of its sequential equipment operation in a fashion comparable to that employed at Culver (Location 1), SECOS International (Location 2), and Rockford (Location 3). Once again, the programmable logic controller provides routine equipment control with only a nominal degree of human oversight.

Location 5: Kansas City, MO[22]
Date: 1983
Application: 5 MGD Wastewater Treatment Facility Automation

The TI programmable controller used in conjunction with the Kansas City SBR facility included one distinct improvement over the previously mentioned systems. A modem option was included with this controller to facilitate remote connections via telephone to the controller, to monitor equipment on-off status. The Kansas City PLC facility extends beyond the sophistication of the earlier plants (e.g., Culver [Location 1], Rockford [Location 2], Grundy Center [Location 4]) to represent a "second-generation" system.

Location 6: Poolesville MD[23]
Date: 1985
Application: 1 MGD Wastewater Treatment Facility Automation

A Westinghouse programmable controller installed at this ~1MGD facility comprised a significant advancement in the state-of-the-art for SBR control and, for that matter, the overall technology of automated wastewater processing. This PLC not only controlled all of the equipment in the plant (i.e., more than 50 equipment items, including pumps, blowers, valves, filters, ultraviolet disinfection vessels, etc.) but also routinely tracked their operational status. In the event of equipment failure, the controller's logic

[19] W.M. Shubert, *SBR: Sequencing Batch Reactor*, Unpublished Corporate Report (Aqua-Aerobics Inc., Rockford, IL, 1986).
[20] Aqua-Aerobics Systems, Inc., 6306-T N. Alpine Road, PO Box 2026, Rockford, IL 61130 (815) 654-2501.
[21] R.L. Irvine et al. "Analysis of Full-Scale SBR Operation at Grundy Center, IA," *Journal of the Water Pollution Control Federation*, vol. 55 (1987), pp. 132-138.
[22] K. Norcross, Personal communication with J.E. Alleman (West Lafayette, IN, 1989).
[23] Alleman et al. (1979).

routine was able to either activate backup equipment or to disable isolated segments of the plant to accommodate this failure. This ability to handle irregular facility operation also extended to power outages, in which case the controller was able to restart the plant in a staggered fashion to ease the peak electrical demand during equipment startups. These types of upsets (i.e., equipment failures or power outages) also triggered a series of audible and alphanumeric visual alarms built into the PLC, including the initiation of telephone calls to remote operations personnel to alert them of the occurrence. The controller's modem connection also facilitated remote phone connections with the system in a fashion comparable to that mentioned for the Kansas City system (Location 5), although in this case the remote hookup could be used not only to monitor the status of the plant and its equipment, but also to make actual changes in the operation of the plant. Finally, this facility's control system was the first to use a personal computer, albeit for the trivial (dumb PC) purpose of uploading the programmable controller's memory and monitoring the PLC's data registers.

Location 7: Horn Point, MD[24]
Date: 1988
Application: 0.3 MGD Wastewater Treatment Facility Automation

The Horn Point SBR facility, installed near Cambridge, Maryland, has PLC-control capabilities comparable to those of the Poolesville system (Location 6). Both such controllers are "third-generation" systems for automated wastewater processing, given their semi-intelligent capabilities for operational diagnostics and corrective process modification. Here again, the plant's on-line instrumentation is limited to level measurement within each of its four activated sludge reactors.

Location 8: Indianapolis, IN[25]
Date: 1985
Application: 200 MGD Wastewater Treatment Facility Automation

Indianapolis' two sister wastewater treatment facilities (each operating at ~100 MGD) employ many PLC systems within their plants. At one plant, a TI PLC was installed to control effluent pumping of their polished discharge into the receiving water body. PLCs are also used extensively for sludge conditioning, dewatering, and incineration. One such PLC controls the dissolved air flotation system, and each of their belt filter presses are individually controlled by General Electric (GE) micro-PLCs. Another set of GE micro-PLCs control the headworks operations (i.e., screw lift pumping and grit chambers) at each plant. Plans are now being formulated to use PLCs for control of their sludge incinerators.

Location 9: Elkhart, IN[26]
Date: 1987
Application: High-Rate Industrial Anaerobic Digestor Control

Four TI PLCs are being used by Miles Laboratories Inc. for real-time control of their industrial pretreatment system. This innovative biological treatment process annually generates enough by-product gas from their high-strength waste stream to heat 60,000 average size homes, resulting in as much as a 10 percent reduction in the natural gas demand for this production facility. Interestingly, Miles

[24] J.E. Alleman, M.W. Sweeney, and D.M. Kamber (1987).

[25] A.J. Callier, *A Primer for Computerized Wastewater Application*, MOP #SM-5 (Water Pollution Control Federation, Alexandria, VA, 1986).

[26] Cooper (1987).

Laboratories Inc. has over 100 similar TI model 550 PLCs in use throughout their Elkhart, IN plant for pharmaceutical manufacturing.

Location 10: Deer Park, TX[27]
Date: 1988
Application: Incinerator Monitoring and Emergency Shutdown

This conceptual proposal for PLC use was developed in anticipation of its application with hazardous waste incinerator operations. The PLC would conceivably be used to control and monitor all of the incinerator valves, blowers, feed lines, and sensors, and maintain optimal operation of the incinerator on the basis of real-time monitoring of the off-gas quality (i.e., O_2, CO, etc.).

Location 11: Siesta Key, FL[28]
Date: 1989
Application: Water Supply and Treatment Monitoring

Modicon Micro 84 PLCs have been installed to monitor the flow (using ultrasonic flow analyzers) and pressure (strain-gauge type) at various points along a potable water supply route in Sarasota County, Florida. These PLCs do not have a direct control responsibility, but are used as intermediate data feeds into a larger supervisory computer, which in turn controls the actual operation of the upstream water treatment facility.

Location 12: Moorehead, MN[29]
Date: 1983
Application: 6 MGD Wastewater Treatment Facility Automation

This high-purity activated sludge treatment was equipped with four programmable logic controllers. These PLCs provide automated control and monitoring of the following plant components: remote pumping station, flow equalization, primary treatment, activated sludge aeration, ozonation, and sludge thickening and digestion. The plant is staffed only during the week (0830 AM until 1630 PM). During weekends and holidays, the PLCs operate the plant solely. Should upset events occur, the PLC initiates telephone alarms to designated personnel to correct the problem. Among the advanced instrumentation placed in this plant, problems were noted in the sludge blanket and ozone monitors.

Location 13: Colorado Springs, CO[30]
Date: 1988
Application: 70 MGD Water Supply and Treatment Automation

The Colorado Springs water system encompasses a vast and complex matrix of reservoirs, pumps, transfer conduits, booster stations, hydroelectric generators, and well fields. Recently, five existing and two new water treatment plants were equipped with an extensive array of automation equipment and sensors, including numerous PLCs. These PLCs serve as redundant distributed controllers, which in turn are networked into a variety of personal and minicomputers.

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[27] D.G. Wene, "Using PLC To Test Incinerator Emergency Shutdown," *Pollution Engineering*, vol. 36, No. 8 (1988), pp. 116-118.

[28] R. Taylor, "Micros Plus Telemetry Track Water System," *Programmable Controls*, vol. 8, No. 5 (1989), pp. 109.

[29] Garber and Anderson (1985).

[30] E.W. Von Sacken, and T.M. Brueck, *Integration of Control and Information Systems Provides Effective Water Management Tools for Colorado Springs*, Unpublished Corporate Report (EMA Services, Inc., 1988).

Location 14: Fort Wayne, IN[31]
Date: 1989
Application: 50 MGD Activated Sludge Process Automation

The facility at Fort Wayne, IN has recently undergone extensive renovation, and has been provided with networked SQUARE-D PLCs for real-time process automation. By most standards, this PLC application is rather large, with approximately 2000 total inputs and outputs. Considerable effort has been made to make the overall control package as robust as possible, including the use of fiber optic data transfer and radio telemetry to avoid electrical interference. These PLCs are networked into a proprietary METRA "data concentrator" using a SYMAX interface board. The METRA system uses a DOS-based industrially hardened machine that provides extensive control and data manipulation services (i.e., graphical depiction, records maintenance, report generation, etc.).

Location 15: Moline, IL[32]
Date: 1984
Application: 9 MGD Grit Chamber and Pump Control

In conjunction with an expansion of this plant from 5 to 9 MGD, PLCs were installed for control of both the grit chamber operations and raw wastewater pumping. Alternate combinations of four constant speed raw wastewater pumps were controlled to accommodate variable influent flows. PLC operation of the grit chamber includes real-time control of the collector mechanism, grit washer, water seal pump, grit conveyor, and grit pumps.

Location 16: Portland, OR[33]
Date: 1984
Application: 200 MGD Solids Handling, Digestor, and Aeration Control

At the Portland plant, one set of PLCs are used for routine operation of the belt filter presses and anaerobic digestors. The PLC used for aeration control was installed to achieve energy savings through intermittent use of the centrifugal blowers. These PLCs are connected to touch-sensitive CRT displays which provide the operations personnel with a direct interface into their current control status and algorithms.

Location 17: Houston, TX[34]
Date: 1983
Application: 100 MGD Pure-Oxygen Activated Sludge Process Control

This system may well represent the most advanced programmable logic controller application used to date in the field of wastewater treatment. The employed PLC system controls the flow of cryogenically generated pure oxygen gas into their activated sludge systems. Extensive instrumentation has been added to the control loop, including: oxygen line pressure, oxygen line temperature, differential oxygen flow, head space pressure, and head space oxygen purity. Based on its diagnosis of this real-time data, the PLC then regulates the head-space vent valve and the oxygen inlet valve to achieve a desired dissolution of oxygen into the mixed liquor.

[31] J. Springer, *Information Systems Tied to Real-Time Plant Control Systems Provide Added Benefits*, Unpublished Corporate Report (EMA Services, Inc., St. Paul, MN, 1989).
[32] Callier (1986).
[33] Callier (1986).
[34] Norman (1985).

8 PROSPECTIVE MILITARY PROGRAMMABLE LOGIC CONTROLLER APPLICATIONS

Overview

There appear to be several opportunities for PLC use within military environmental engineering facilities using off-the-shelf technologies. Tables 1 and 2 contain a representative assortment of topic areas to which PLC systems could be applied in dedicated fashion, divided respectively between "water" and "wastewater" systems:

Table 1

Water Treatment and Conditioning Systems

Reservoir monitoring and control	Filter backwash
Prechlorination	Effluent fluoridation
Chemical feed	Effluent chlorination
Reverse osmosis	Effluent ozonation
Ion exchange	Product distribution
Filter operation	Cooling water blowdown

Table 2

Wastewater Treatment Systems

Interceptor storage	Effluent ozonation
Plant lift stations	Gravity sludge thickening
Flow equalization	Sludge dissolved air flotation thickening
Hydraulic flow control	Anaerobic sludge digestion
Bar screening	Sludge vacuum filtration
Grit removal	Sludge centrifugation
Primary clarification	Belt filter press sludge dewatering
Dissolved oxygen control	Plate and frame sludge dewatering
Cryogenic oxygen generation	Sludge cake incineration
Return activated sludge control	Return liquor feedback
Waste activated sludge control	Chemical feed
Post-chlorination	

Basic PLC System Development

This section gives several possible examples of PLC use. Each example is designed to demonstrate a simple control or monitoring application that would benefit operations personnel.

A basic PLC system that would accommodate these example applications would need sufficient memory size and I/O capability to interchangeably handle most envisioned control needs.

Basic PLC Hardware:

CPU: Westinghouse Numa-Logic PLC-1200-1020 (2K total memory; Special function set included)

Inputs: Two input modules (8 points per module); One eight-bit A/D module (with external DC power supply)

Outputs: Two output modules, at 8 points per module

Software: Westinghouse NLSW IBM-compatible programming software

Total cost: ~ $3500

Accessory Hardware:

Display: Cherry Alphanumeric Display, Single Line, RS-232-C Compatible; D.C. Power supply included; Total cost - ~ $350.

Computer: IBM Compatible Personal Computer; 20 mb hard drive; 684K internal RAM memory; Serial and parallel ports; Parallel dot-matrix printer; Total cost - ~ $2500.

Enclosure: Hoffman Inc. or Rittal Inc. - NEMA12 unit; Total cost - ~ $300.

Alarm: Audible alarm horn; Total cost - ~ $30.

Selected Potential Applications

This section presents a representative set of six potential PLC applications. Each system is designed to demonstrate the potential utility and benefit associated with PLC use.

Application 1: Effluent Wastewater Turbidity

Hardware: Basic PLC system; Turbidimeter with flow-through cell (e.g., HACH Ratio Turbidimeter Model 18900); Flow meter (e.g., ultrasonic device placed at parshall flume).

Overview: This simple PLC application (Figure 3) will provide a wastewater treatment facility with continuous monitoring of its effluent turbidity and effluent flow. Admittedly, clarity only provides indirect evidence of satisfactory effluent quality. However, this parameter often serves as a vital symptom of problems occurring elsewhere in the facility, and is commonly the first sign of trouble identified by the operator. This information will be visually scrolled across the alphanumeric display on a continuous basis for routine operator evaluation. An alarm function would also be built into the PLC logic to trigger operator response in the event of abnormal facility behavior. Although not included, pH and dissolved oxygen sensors could be added to this application package to boost the overall data base. In turn, the PLC would have even more information on which to develop a real-time assessment of the current plant performance. Ideally, this latter instrumentation would be added after first experimenting with the simplified set of turbidity and flow measurements.

Control Strategy: The real-time signal taken from the turbidity instrument would constantly be analyzed in terms of apparent effluent solids overflow. This information would also be compared against the incoming flow data to assess the occurrence of a hydraulic overload or general plant upset. Should the effluent turbidity show evidence of a significant deviation from the plant's historical trend (i.e., developed by the PLC using continuous data evaluation), the PLC will signal an operator using an audible alarm. The alphanumeric display will also generate a visual message to the operator, advising of the nature of the problem (i.e., relative to the current flow and turbidity conditions).

Critical Factors: By virtue of its simplicity, this application should be easy to implement and maintain. An ultrasonic level (flow) detector would require virtually no maintenance, and the effluent turbidity analyzer should require relatively little care.

Expected Benefits: This application should complement the routine oversight of a wastewater treatment plant presently provided by the operators. (The PLC essentially serves as a monitoring program that continuously advises the operations personnel of the final effluent's clarity.)

Application 2: Effluent Wastewater Chlorine Disinfection

Hardware: Basic PLC system; Residual chlorine analyzer (e.g., HACH, Capital Controls, etc.); Flow meter (e.g., ultrasonic device placed at Parshall flume).

Overview: Placement of a residual chlorine instrument on the effluent end of a disinfection tank would provide continuous monitoring of the system's residual halogen level. This information would continuously reassure the operators that proper chlorination of the effluent stream was being maintained.

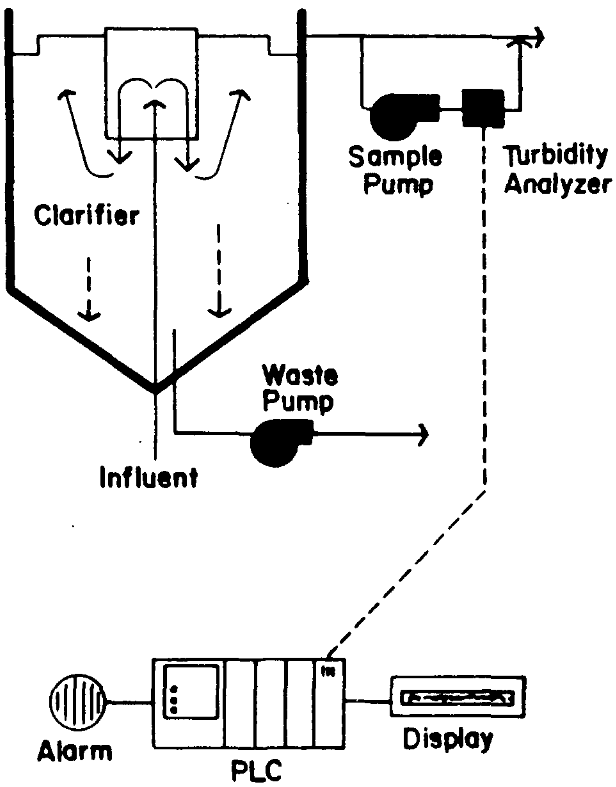

Figure 3. Effluent wastewater turbidity PLC system.

Control Strategy: As with the previous application, this package is designed to provide real-time monitoring rather than actual control of the disinfection system. Should automated control be desired as well, however, the PLC could be used to trim this chlorine input by adjustment of disinfectant feed (i.e., hypochlorite or CNd2Nu gas supply). Figure 4 provides a schematic overview of the control hardware used for this PLC application. This control would be based on feedback adjustment to achieve a predetermined chlorine residual.

Critical Factors: Residual chlorine monitors are Level #2 instrumentation devices and may require more operator care and attention than would parameters such as D.O. or pH. Proper calibration of this device would play an important role in the overall success of the application.

Expected Benefits: Human operators are presently limited to infrequent information (e.g., grab sample data) regarding the residual chlorine level for their disinfection reactor. This PLC application would greatly improve routine awareness of these chlorine levels, and promote the ability to interactively optimize the plant's disinfection effectiveness. Full automated control using the PLC would be a logical step after a demonstration of the success of this preliminary monitoring procedure.

Application 3: Blower or Turbine Aeration Control

Hardware: Basic programmable logic controller system; Power transfer relays (as needed for individual blower control); Dissolved oxygen analyzer and electrode; Flow meter (e.g., ultrasonic device placed at Parshall flume); Temperature probe (RTD or thermocouple) and transmitter.

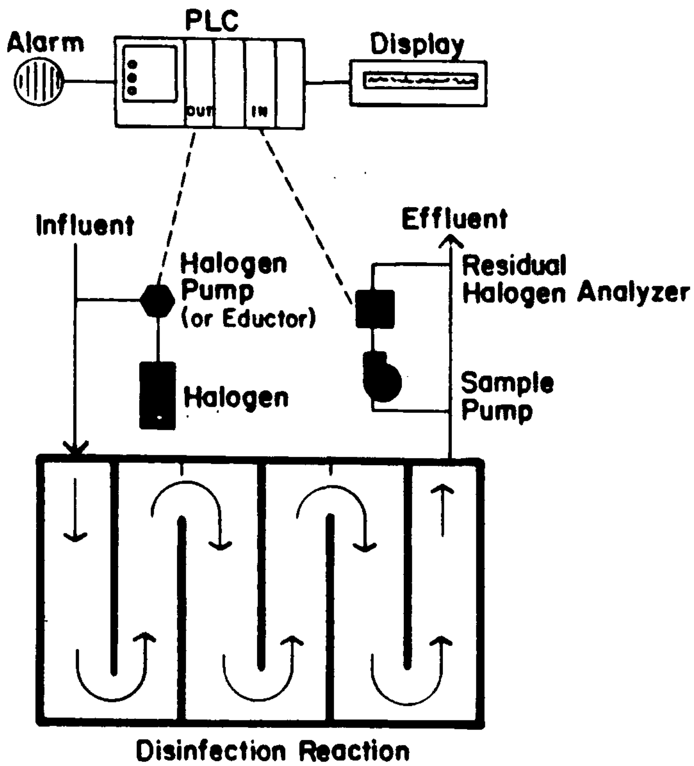

Figure 4. Effluent wastewater chlorination PLC system.

Overview: Small-sized wastewater treatment plants (~1 MGD) are commonly equipped with multiple positive displacement blowers or multiple surface turbines, and are manually controlled in terms of operating D.O. The proposed PLC application would regulate the operation of these aerators according to one of two alternative strategies. First, these aerators could be regulated according to flow relative to the PLCs perception of a normal diurnal wastewater flow pattern. As the flow drops in the evening, the PLC would inactivate a preset series of aerators. Use of these aerators rotate to spread the operating times evenly. Second, the PLC could regulate these aerators according to its measurement of the *in-situ* dissolved oxygen levels. Here again, the PLC would implement a discontinuous aeration pattern to trim the dissolved oxygen level into a preset range.

Control Strategy: Cyclic aerator control is usually not used due to complications with solids settling during unaerated periods, and lag times between controlled aerator input and system response. As a result, aerator control strategies often follow complex closed-loop algorithms that involve sophisticated manipulation of such factors as blower speed, inlet guide valves, or suction throttling valve positioning. However, for this example, the PLC would nonetheless be installed for simple on-off aerator manipulation. Figure 5 provides a schematic overview of the control hardware used for this PLC application. The real-time reactor D.O. and temperature data would be evaluated by the PLC to determine whether one or more of the aerators might be inactivated. After detecting a high D.O. level, the PLC would chronologically begin inactivating a preset series of aerators until reaching either a predetermined minimum number of aerators, or the preset minimum D.O. This preset limit for aeration intensity would be necessary to assure some degree of solids mixing within the reactor even during down-scaled aeration. At the other extreme, the PLC would also be instructed to re-engage the aerators in succession should the D.O. fall below this preset limit.

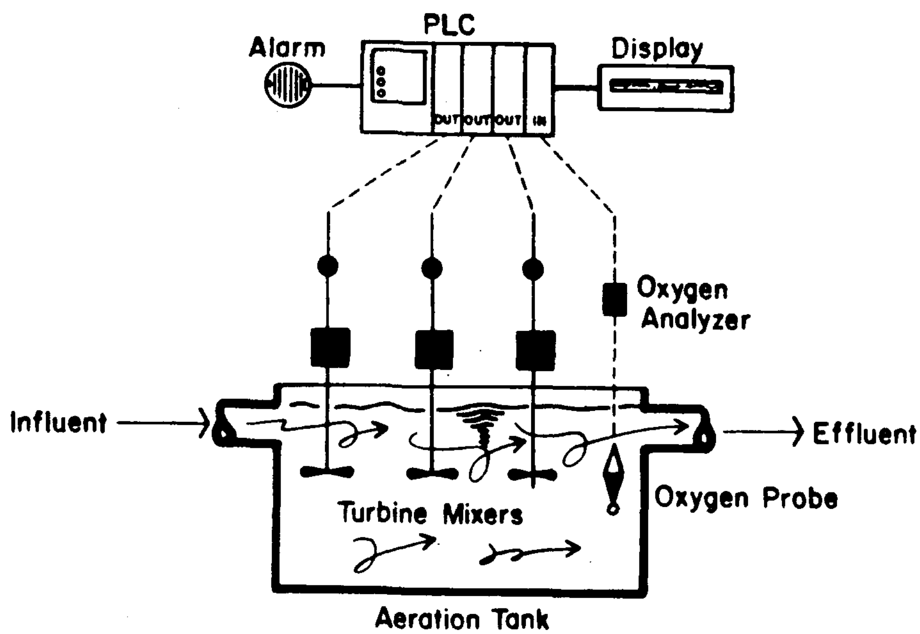

Figure 5. Turbine aeration PLC system.

Critical Factors: The dynamic character of activated sludge processes greatly complicates routine control of reactor parameters such as dissolved oxygen. Aside from the lag problems associated with these types of dynamic reactors, water clogging of diffusers may occur during periods of reduced or zero air pressure within their air lines. For this reason, the control scheme for blower-based aeration systems would have to ensure that at least one blower were active at all times, to prevent the whole air delivery system from having to be purged of entrained water. Cycling of electrical motors may also be detrimental to their performance. For this reason, the PLC would have to be programmed not to stop and start these motors too frequently.

Expected Benefits: Automatic control of dissolved oxygen may provide better energy savings than infrequent use of a manual blower or turbine operation. The desired dissolved oxygen levels will also be maintained on a routine basis, thereby promoting optimal biological activity in the reactor. This technique may also extend the serviceable lifetime of this equipment by reducing annual run times.

Application 4: Primary and Secondary Clarifier Underflow

Hardware: Basic programmable logic controller system; High range turbidimeter (e.g., HACH Surface Scatter Turbidimeter); Flow meter (e.g., ultrasonic device placed at Parshall flume).

Overview: This application, as simplistically depicted by Figure 6, would be implemented for routine control of the underflow from primary and activated sludge clarifiers. Solids withdrawn through these underflow streams would be analyzed for their apparent solids content using a surface scattering device such as the HACH unit suggested above.

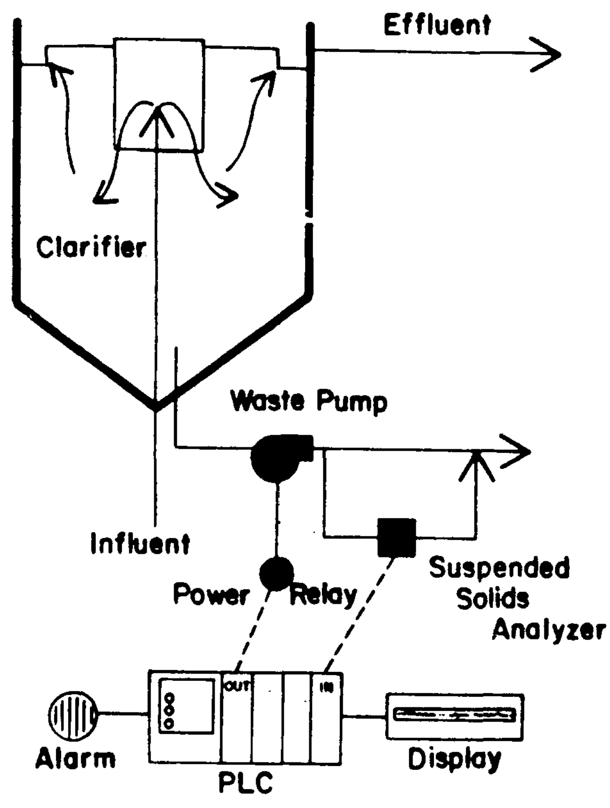

Figure 6. Clarifier underflow PLC system.

Control Strategy: This HACH device was recently developed to determine the presence of high suspended solids levels in wastewater streams. As applied to a clarifier underflow, this data would be used to discontinue underflow pumping for a preset period, after which the underflow would be resumed. Intermittent pumping of this underflow could stabilize the performance of many clarifiers by ensuring that solids do not unnecessarily collect within the clarifier.

Critical Factors: If the solids analyzer failed by sending a consistently low signal, the PLC would mistakenly believe that the underflow was devoid of solids and need not be continued. Hence, the PLC would have to be programmed to anticipate this type of failure (or a failure from too many solids) and to implement a backup operating mode should problems with the sensor be detected.

Expected Benefits: This PLC application might yield a considerable improvement in clarifier effectiveness. Ideally, this PLC application would be configured jointly with an effluent turbidity analyzer. In turn, the PLC could positively respond to the onset of high effluent turbidity (i.e., solids) by attempting to increase the underflow wastage.

Application 5: Wet-Well Control

Hardware: Basic PLC system; Level sensor - bubbler type (with pressure sensor); Power transfer relays (as needed for individual pump control).

Overview: The pump control requirements for sewerage wet wells usually depend simply on power control relays triggered by high water levels in the well. Mercury-contact "tear-drop" level sensors are commonly installed in these applications, and are sensitive only to fixed level indications. Conversely, the proposed PLC application shown in Figure 7 would monitor a bubbler-type level sensor. This device would give the PLC continuous information about the actual liquid level, and could also be used to operate the wet-well pumps.

Control Strategy: The PLC would be instructed to activate the wet-well pumps according to preset liquid levels in the well. In doing so, the PLC would merely replace the control relays previously used for this purpose. However, the PLC could also be instructed to track and evaluate the wastewater flow (by virtue of its knowledge of dynamic liquid depth and outgoing pumped flow), so it could diagnose the real-time pattern of the wet well's operation. In storm-related high flow events, this "intelligent" wet-well PLC system would sense that the flow had increased and would shift its desired "high" well level to a lower setting, providing a buffer against short-term well overflow.

Critical Factors: For this application, the power of the suggested basic programmable logic controller is clearly too advanced for the control needs of the situation. Indeed, this PLC could be downscaled to a much less expensive micro-PLC costing only a few hundred dollars. The involved technology and sensors should be robust enough to serve over an extended period with minimal routine care and maintenance.

Expected Benefits: This PLC application could improve the operation of wet wells and lift stations by using the intelligence of the PLC as an operational asset not possible with mere control relays activated by level floats. The ability of this system to perceive storm events could be enhanced by use of tipping-bucket precipitation sensors placed in protected fashion on the roof of the wet-well facility. This additional information would allow the PLC to validate its flow-based perception of a storm event against an actual measurement of precipitation. These sensors could, in fact, be placed at all wet-well locations on a sewer network. All of the wet-well PLCs would be given modem access to a supervisory PLC or PC unit that, in turn, would provide executive oversight and control of the entire sewer network.

Application 6: Cooling Tower Water Conditioning

Hardware: Basic PLC system; pH probe and transmitter; Conductivity probe and transmitter; Temperature probe (remote data transmitter [RTD], or thermocouple) and transmitter; Chemical feed pump (e.g., for concentrated sulfuric acid).

Overview: The necessity for blowdown in cooling towers stems from the progressive build-up of solids within this water. Commercial water monitoring and blowdown control systems make use of on-line pH and conductivity data to trigger the influx of acid, fresh makeup water, and simultaneous discharge of high-solids blowdown water. This application will provide a similar system, but based on PLC control rather than a proprietary controller. Figure 8 provides a simplistic overview of the proposed system.

Control Strategy: On-line pH and conductivity probes would be continuously monitored for elevated levels. If the pH exceeds a preset level, the PLC would be used to initiate the addition of (usually sulphuric) acid. The conductivity data would be used to control actual blowdown. Upon recognizing an elevated solids level, the makeup system discharge valves would be opened to initiate a tower blowdown. In turn, the drop in water level on the floor of the cooling tower would result in an opening of the mechanically-operated makeup water inlet valve. Once the conductivity dropped below a preset minimum, the blowdown cycle would be discontinued.

Critical Factors: The PLC must be programmed to monitor for sensor errors and operational irregularities. For example, after sensing the pH rise and starting acid feed, the PLC would have to ensure that the pH actually responded by beginning a downward movement within a finite time period. Should this trend not occur, the PLC would have to assume that either the acid feed is not functioning or that the pH probe is not working properly.

Expected Benefits: This PLC application essentially replaces a similar package that could be purchased from an industrial water conditioning vendor. In this case, however, the proposed PLC system would offer considerably more flexibility in the logic that could be incorporated into the unit.

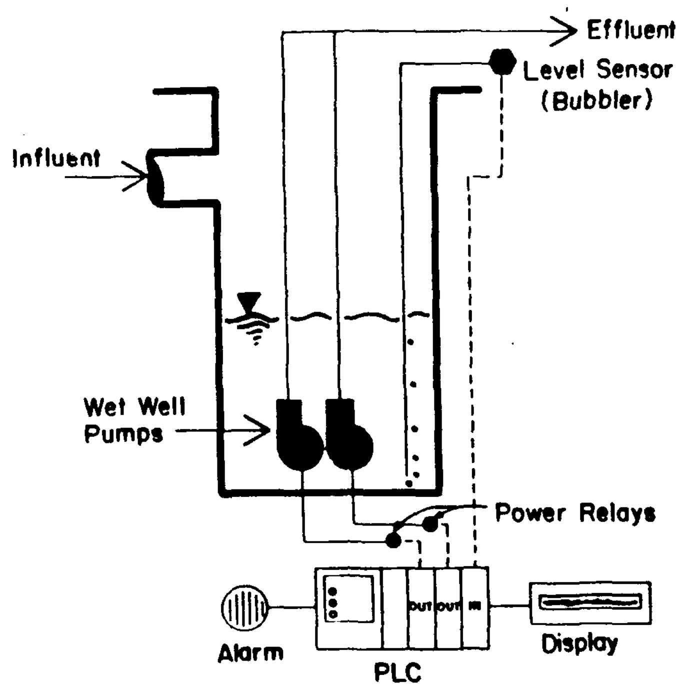

Figure 7. Wet-well PLC system.

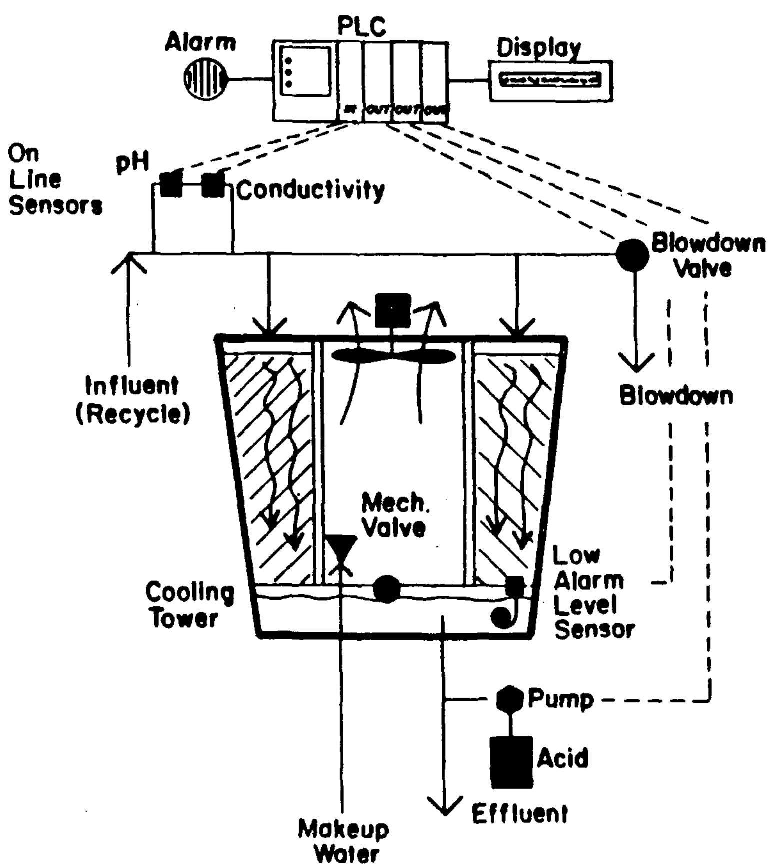

Figure 8. Cooling tower water conditioning PLC system.

9 CONCLUSIONS

This report has explored the opportunities for coordinated implementation of PLC technology in U.S. Army WWTPs and concludes that the decision to use PLCs in military environmental engineering systems should be based on the following requirements and considerations:

1. PLC applications should be designed to complement rather than to replace the existing workforce.

2. All PLC applications should be accompanied by an intensive training effort to familiarize the associated workforce in handling and using PLC hardware and software.

3. The control hardware, instrumentation, etc. of PLC systems should be designed for simplicity.

4. The design engineer should incorporate an uninterrupted power supply for any controlled system whose long-term failure or (down-state) will constitute a critical or unsafe condition.

5. The design engineer should consider initial installation of a parallel manual backup for the controlled system.

6. Any employed PLC system should always be provided with a full set of replacement parts/modules. (NOTE: PLC parts and modules are inexpensive and should be available for prompt replacement of failed hardware.)

7. PLC applications will likely evolve on a trial-and-error basis over an extended period of time. (PLCs will not become an overnight panacea.)

8. Effective PLC implementation will require an ongoing quality control effort to clarify situations commonly associated with PLC performance failures or shortcomings, and to promote facility confidence in successful applications (i.e., past errors, as well as success stories, should be addressed during the inherent "learning" curve).

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APPENDIX A: PLC Vendors and Options

I&CS Guide to programmable controllers

Manufacturer & Model	Memory		I/O Capability								Languages				Programming Devices					Networking					Other					Reader Service No.
	Type	Size	No.	Types																										
			Total I/O	Analog	AC	DC	H.S. Counter	Positioning	PID	ASCII	Ladder	Boolean	Grafcet	Other	Manual	CRT	Tape	Computer	Other	Remote I/O	Host Comp.	PLC-to-PLC	Data Highway	MAP	Math	Diagnostics	Documentation	Color Graphics	Multiple CPUs	
Westinghouse																														289
PC-100	RAM, EPROM	3K	40		•	•						•					•	•												
PC-110	RAM, EPROM	1K	112		•	•						•					•	•												
PC-1100	RAM	3.5K	144	•	•	•				•	•					•	•	•					•		•			•		
PC-900	RAM	2.5K	256	•	•	•	•	•		•	•					•	•	•		•			•		•		•	•		
PC-700	RAM	8K	576	•	•	•	•	•	•	•	•					•	•	•		•			•		•		•	•		
HPPC-1500	CMOS RAM	224K	8192	•	•	•	•	•	•	•	•							•		•	•	•	•		•		•	•	•	
HPPC-1700	CMOS RAM	224K	8192	•	•	•	•	•	•	•	•							•		•	•	•	•		•		•	•	•	
MAC-4500	CMOS RAM	288K	8192	•	•	•	•		•	•	•			•				•		•	•	•	•		•		•	•		
PC-1250	RAM	16K	576	•	•	•			•	•	•							•				•	•		•		•	•		
PC-1200	RAM	16K	256	•	•	•			•	•	•							•				•	•		•		•	•		

Editor's note: Information in this chart came directly from questionnaires returned by the companies listed. Two questionnaire mailings were made to all known manufacturers of programmable controllers. To obtain further information about any of the products listed, circle the appropriate number on the reader service card.

(Source: P. Cleaveland, "PLCs Take on New Challenge," *I & CS*, vol. 62 (1989), pp 29-38.)

I&CS Guide to programmable controllers

Manufacturer & Model	Memory		I/O Capability								Languages				Programming Devices					Networking					Other					Reader Service No.
	Type	Size	No. Total I/O	Analog	AC	DC	H.S. Counter	Positioning	PID	ASCII	Ladder	Boolean	Grafcet	Other	Manual	CRT	Tape	Computer	Other	Remote I/O	Host Comp.	PLC-to-PLC	Data Highway	MAP	Math	Diagnostics	Documentation	Color Graphics	Multiple CPUs	
ABB Industrial Systems																														210
MasterPiece 51	E^{2}PROM, PROM, CMOS		64		•	•					•	•			•	•		•	•		•		•			•	•			
MasterPiece 100	CMOS, PROM	64K	128	•	•	•	•	•	•	•			•	•		•	•	•	•		•	•	•		•	•	•	•		
MasterPiece 280	CMOS, PROM	2MB	2K	•	•	•	•	•	•	•			•	•		•	•	•	•		•	•	•		•	•	•	•	•	
MasterPiece 200/1	CMOS, PROM	4MB	4000	•	•	•	•	•	•	•			•	•		•	•	•	•	•	•	•	•	•	•	•	•	•	•	
Adatek																														211
System 10 Series E	RAM, EPROM	32K	1272	•	•	•		•	•	•				•	•	•		•	•		•				•	•	•		•	
Allen-Bradley																														212
SLC-100	RAM, E^{2}PROM	885 words	112	•	•	•	•				•				•			•								•	•			
SLC 150	RAM, E^{2}PROM	1200 words	112	•	•	•	•				•				•			•								•	•			
SLC 500	RAM, E^{2}PROM UVPROM	1K Instructions	72		•	•	•				•				•			•			•				•	•	•			
SLC 5/01	RAM, E^{2}PROM UVPROM	1K or 4K Instructions	256		•	•					•				•			•			•				•	•	•			
PLC-2/30	BBRAM	16K	1792	•	•	•	•	•	•	•	•			•		•	•	•		•	•	•	•	•	•	•	•	•		
PLC-5/25	BBRAM opt. E^{2}PROM	21K	1920	•	•	•	•	•	•	•	•			•				•		•	•	•	•	•	•	•	•	•		
PLC-3/10	BB EDC RAM	128K	4096	•	•	•	•	•	•	•	•			•		•	•	•		•	•	•	•	•	•	•	•	•	•	
PLC-3	BB EDC RAM	2K	8192	•	•	•	•	•	•	•	•			•		•	•	•		•	•	•	•	•	•	•	•	•	•	
PLC-5/250	BBRAM	384K	4096	•	•	•	•	•	•	•	•			•			•	•		•	•	•	•	•	•	•	•	•	•	
PLC-5/15	BB CMOS, RAM E^{2}PROM	14K	1024	•	•	•	•	•	•	•	•			•				•		•	•	•	•	•	•	•	•	•		
PLC-2/16	BBRAM E^{2}PROM	3K	256	•	•	•	•	•	•	•	•			•		•	•	•		•	•	•	•	•	•	•	•	•		
PLC-2/17	BBRAM	6K	512	•	•	•	•	•	•	•	•			•		•	•	•		•	•	•	•	•	•	•	•	•		
PLC-5/12	BBRAM E^{2}PROM	6K	512	•	•	•	•	•	•	•	•			•				•		•	•	•	•	•	•	•	•	•		
PLC-5/VME	BBRAM, E^{2}PROM	14K	1024	•	•	•	•	•	•	•	•			•				•		•	•	•	•	•	•	•	•	•		
PLC-2/02	BB CMOS, RAM E^{2}PROM	1K	128	•	•	•	•	•	•	•	•			•		•	•	•		•	•	•	•	•	•	•	•	•		
Analog Device, Inc.																														213
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	Type	Size	No.	Types																										
			Total I/O	Analog	AC	DC	H.S. Counter	Positioning	PID	ASCII	Ladder	Boolean	Grafcet	Other	Manual	CRT	Tape	Computer	Other	Remote I/O	Host Comp.	PLC-to-PLC	Data Highway	MAP	Math	Diagnostics	Documentation	Color Graphics	Multiple CPUs	Reader Service No.
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Manufacturer & Model	Memory		I/O Capability								Languages				Programming Devices					Networking					Other					Reader Service No.
	Type	Size	No.	Types																										
			Total I/O	Analog	AC	DC	H.S. Counter	Positioning	PID	ASCII	Ladder	Boolean	Grafcet	Other	Manual	CRT	Tape	Computer	Other	Remote I/O	Host Comp.	PLC-to-PLC	Data Highway	MAP	Math	Diagnostics	Documentation	Color Graphics	Multiple CPUs	
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324 Prog Seq.Cont.	CMOS RAM	16K-byte	512		•	•	•				•			•				•			•	•	•	•	•	•	•	•	•	
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C28K	RAM EPROM	1,194 ins	84	•	•	•	•				•	•			•	•	•	•		•	•	•			•	•	•			
C20	RAM EPROM	1,194 ins	140		•	•					•	•			•	•	•	•		•	•	•			•	•	•			
C120	RAM EPROM	2.6K wrds	256	•	•	•	•		•		•	•			•	•	•	•		•	•	•			•	•	•			
C200H	RAM EPROM	4K, , 8K words	384	•	•	•	•	•	•	•	•	•			•	•	•	•		•	•	•	•		•	•	•			
C500	RAM EPROM	5.3K, 8K words	512	•	•	•	•	•	•	•	•	•			•	•	•	•		•	•	•	•		•	•	•			
C1000H	RAM EPROM	12-36K words	1024	•	•	•	•	•	•	•	•	•			•	•	•	•		•	•	•	•		•	•	•			
C2000H	RAM EPROM	12-38K words	2048	•	•	•	•	•	•	•	•	•			•	•	•	•		•	•	•	•		•	•	•		•	
Opto 22																														277
LC2/OPTOMUX	RAM EPROM	32K 32K	4096	•	•	•		•	•	•				•		•		•		•	•	•	•		•	•	•			
LCX/OPTOMUX, PAMUX	RAM EPROM	64K 32K	4096	•	•	•		•	•	•				•						•	•	•	•		•	•	•	•	•	
Phoenix Digital																														278
Modbus Port Expander II	EPROM RAM	32K 32K												•		•		•			•	•	•							
Modbus Port Expdr III	EPROM RAM	32K 32K												•		•		•			•	•	•							
Pro-Log Corporation																														279
System 2 Model 30/PLC	Static	96K bytes	1800	•	•	•	•		•	•	•					•		•		•	•				•		•	•	•	
RBB Systems																														280
Micro-1	RAM ROM PROM	64K	256	•	•	•	•		•	•	•			•				•			•				•	•	•			
Reliance Electric																														281
AutoMax	BBRAM	256K	12K +	•	•	•	•	•	•	•	•			•				•		•	•	•	•		•	•	•	•	•	
DCS 5000	BBRAM	80K	12K +	•	•	•	•	•	•	•	•			•				•		•	•	•	•		•	•	•	•	•	
AutoMate 15	E^{2}PROM RAM NVRAM	1K	64		•	•					•				•	•		•				•	•			•	•	•		
AutoMate 20	E^{2}PROM RAM NVRAM	2K	256		•	•					•				•	•		•		•		•	•		•	•	•	•		
AutoMate 30	E^{2}PROM RAM NVRAM	8K	512	•	•	•	•		•	•	•				•	•		•		•	•	•	•		•	•	•	•	•	
AutoMate 40	E^{2}PROM RAM NVRAM	104K	8192	•	•	•	•		•	•	•					•		•		•	•	•	•		•	•	•	•	•	
Shark X	EPROM or E^{2}PROM	1K or 2K	60	•	•	•	•				•	•			•		•	•							•	•	•			
Shark XL	EPROM or E^{2}PROM	1K or 2K	60	•	•	•	•				•	•			•		•	•							•	•	•			

Manufacturer & Model	Memory		I/O Capability								Languages				Programming Devices					Networking					Other					Reader Service No.
	Type	Size	No. Total I/O	Types: Analog	AC	DC	H.S. Counter	Positioning	PID	ASCII	Ladder	Boolean	Grafcet	Other	Manual	CRT	Tape	Computer	Other	Remote I/O	Host Comp.	PLC-to-PLC	Data Highway	MAP	Math	Diagnostics	Documentation	Color Graphics	Multiple CPUs	
Siemens Energy & Automation																														282
S5-100U (CPU 100)	RAM, EPROM, E²PROM	[illegible] bytes	128	•	•	•					•	•		•	•	•		•		•	•	•	•		•	•	•			
S5-100U (CPU 102)	RAM, EPROM, E²PROM	4K bytes	256	•	•	•	•		•		•	•		•	•	•		•		•	•	•	•		•	•	•			
S5-100U (CPU 103)	RAM, EPROM, E²PROM	20K bytes	256	•	•	•	•		•		•	•		•	•	•		•		•	•	•	•		•	•	•			
S5-115U (CPU 941)	RAM, EPROM E²PROM	10K words	512	•	•	•	•	•	•	•	•	•	•	•	•	•		•		•	•	•	•	•	•	•	•	•		
S5-115U (CPU 942)	RAM, EPROM, E²PROM	10K bytes	2048	•	•	•	•	•	•	•	•	•	•	•	•	•		•		•	•	•	•	•	•	•	•	•		
S5-115U (CPU 943)	RAM, EPROM, E²PROM	16K bytes	2048	•	•	•	•	•	•	•	•	•	•	•	•	•		•		•	•	•	•	•	•	•	•	•		
S5-135U/R	RAM, EPROM	128K words	8192	•	•	•	•	•	•	•	•	•	•	•	•	•		•		•	•	•	•	•	•	•	•	•	•	
S5-135U/S	RAM, EPROM	128K words	8192	•	•	•	•	•	•	•	•	•	•	•	•	•		•		•	•	•	•	•	•	•	•	•	•	
S5-115U (CPU 944)	RAM, EPROM E²PROM	96K bytes	2048	•	•	•	•	•	•	•	•	•	•	•	•	•		•		•	•	•	•	•	•	•	•	•		
S5-135U/928	RAM, EPROM	92K bytes	6144	•	•	•	•	•	•	•	•	•	•	•	•	•		•		•	•	•	•	•	•	•	•	•	•	
S5-135U/920	RAM, EPROM	128K words	2048											•		•		•							•		•		•	
Square D																														283
SY/MAX Model 50	RAM EPROM E²PROM	4K 4K 4K	256	•	•	•					•	•			•	•	•	•			•		•	•	•	•	•	•	•	
SY/MAX Model 300	RAM, UVPROM	½K-2K or	256	•	•	•	•	•	•	•	•				•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	
SY/MAX Model 400	RAM, UVPROM	4K-16K	4000	•	•	•	•	•	•	•	•				•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	
SY/MAX Model 500	RAM, UVPROM	2K-8K	2000	•	•	•	•	•	•	•	•				•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	
SY/MAX Model 600	RAM, UVPROM	16K-32K	8000	•	•	•	•	•	•	•	•				•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	
SY/MAX Model 700	RAM, Bubble	8K-64K	14K	•	•	•	•	•	•	•	•				•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	
Telemecanique																														284
TSX 17-10	RAM E²PROM UVEPROM	24K byte	120		•	•						•			•	•	•	•								•	•			
TSX 17-20	RAM E²PROM UVEPROM	24K byte	160	•	•	•	•	•		•	•	•	•		•	•	•	•			•	•	•		•	•	•	•		
TSX 47 JR	RAM, UVEPROM	32K byte	80	•	•	•	•	•		•	•	•	•		•	•	•	•			•	•	•		•	•	•	•		
TSX 47-10	RAM UVEPROM	32K byte	256	•	•	•	•	•		•	•	•	•		•	•	•	•			•	•	•		•	•	•	•		
TSX 47-20	RAM, UVEPROM	32K byte	256	•	•	•	•	•		•	•	•	•		•	•	•	•			•	•	•		•	•	•	•		
TSX 47-30	RAM, UVEPROM	56K words	512	•	•	•	•	•	•	•	•		•	•		•	•	•		•	•	•			•	•	•	•	•	
TSX 67-20	RAM, UVEPROM	56K words	1024	•	•	•	•	•	•	•	•		•	•		•	•	•		•	•	•	•		•	•	•	•	•	
TSX 87-10	RAM, UVEPROM	128K words	1024	•	•	•	•	•	•	•	•		•	•		•		•		•	•	•	•		•	•	•	•	•	
TSX 87-30	RAM, UVEPROM	128K words	2048	•	•	•	•	•	•	•	•		•	•		•	•	•		•	•	•	•		•	•	•	•	•	
TeleMonitor																														285
Master*Link	ROM, RAM	64K 8		•	•	•	•	•	•	•				•	•	•		•	•	•	•		•		•	•	•			
Texas Instruments																														286
TI565	RAM	384K byte	8192	•	•	•	•	•	•	•	•		•	•		•		•	•	•	•	•	•		•	•	•	•	•	
TI560	RAM	384K byte	8192	•	•	•	•	•	•	•	•					•		•	•	•	•	•	•		•	•	•	•	•	
TI535	CMOS RAM or E²PROM or EPROM	8K words	1023	•	•	•	•	•	•	•	•	•			•	•		•	•	•	•	•	•		•	•	•	•		
TI530T	CMOS RAM or E²PROM or EPROM	20K words	1023	•	•	•	•	•	•	•	•	•			•	•		•	•	•	•	•	•		•	•	•	•		
TI525	CMOS RAM or E²PROM or EPROM	8K words	1023	•	•	•	•	•	•	•	•	•			•	•		•	•	•	•	•	•		•	•	•	•		
TI520C	RAM or EPROM	3.5K word	512	•	•	•	•	•	•	•	•	•			•	•		•	•		•	•	•		•	•	•	•		
PM550C	RAM or EPROM	7K	512	•	•	•					•				•	•					•		•		•	•	•			
TI510	RAM or EPROM	256 words	40		•	•					•				•	•											•			
5TI	RAM or EPROM	4K words	512		•	•					•				•	•					•		•			•	•			
TI100	RAM	1K words	128		•	•					•				•												•			
Toshiba/Houston																														287
EX14B	CMOS RAM	1K	34	•	•	•	•				•										•						•	•		
EX20 Plus	CMOS RAM	1K	40	•	•	•	•				•										•						•	•		
EX40 Plus	CMOS RAM	1K	80	•	•	•	•				•										•						•	•		
EX40H	CMOS RAM	1K	120	•	•	•					•										•						•	•		
EX100	CMOS RAM	4K	240	•	•	•	•								•			•		•	•		•		•	•		•		
EX250	CMOS RAM	4K	256	•	•	•	•		•	•	•				•			•		•	•		•		•	•		•		
EX260B	CMOS RAM	4K	224	•	•	•			•	•	•				•			•		•	•		•		•	•		•		
EX500	CMOS RAM	8K	512	•	•	•	•		•	•	•				•			•		•	•		•		•	•		•		
Triconex																														288
Tricon	RAM	350K byte	2528	•	•	•	•		•	•	•	•		•		•		•		•	•	•	•		•	•	•	•	•	

AUTOMATIC TIMING AND CONTROLS	AUTOMATION SYSTEMS	COMPUTER DYNAMICS SALES	DAIGNEAULT	DIVELBISS	EAGLE SIGNAL CONTROLS	EATON
ATCOM 64	5100	CD1-LAD-SBC	a. C50/6024 b. C50/6048 c. C50/6080	PIC-BB-22	EPTAK 100	a. D100CRA14 b. D100CR20A
32	64	24	8	10	16	14 (a), 20 (b)
64			24 (a), 48 (b), 80 (c)	58		34 (a), 40 (b)
4	32	16	4			2
4	32		2			
Yes	Yes	Yes	Yes	No	No	No
		1,0	1,0	1		
					0	
3 Counters, 12 kHz	100 kHz		3 kHz	10 kHz		2 kHz (a), 4 kHz (b)
High current transistor, low current relay outputs	Resolver converter		Positioning, message printout, Basic coproc.	Timer/counter access, PIC-AB-01, Presto, PIC-PI-02		
21-77 85 85	1000 250 250	6000 120 100	256 128 32	235 10 10	64 12 8	128 64 64
2-3 ms	1 ms	2 ms	8 ms	5 ms	25 ms	5 ms
8k	24-892k	1 M	16k	4k max	250 steps	3k
6.6k	8-64k	32k	12k			1k
Math	Math, trig	Math, compare	Math, compare			
Display and/or transmit messages, presets, timers & counters	Arrays, logic	Shift reg., stepper drums, jumps,	Clock, calendar, jump, shift reg., blk. transfer			Bi-dir. shift reg. (a), immed. update I/O (a), 10-ms timers (b), command to inhibit all outputs (b)
Watchdog	CPU, memory, program, I/O		Cycle time, hardware, memory, program	Watchdog		Internal fault contacts
Yes	No	Yes	Yes	Yes	No	Yes
SNAP	C, PL/M		Ladder, Grafcet, Literal, French/Eng.			
RS232	1-12	2 RS232 or RS485	3 (a), 6 (b), 8 (c) RS232C/422/485			1 RS232
Yes	Yes		Yes	No	No	No
HH, PC	PC, Apple II	PC	HH, PC, CRT, French/Eng.	HH, PC	HH	HH, PC
FD	FD	FD	TL, FD	FD	TL	FD
PL	LD	LD	PL, LD, I/O, Grafcet list		PL, LD	PL, LD, I/O, comments, text
UL		UL	UL, CSA			UL, CSA
206	207	208	209	210	211	212

MICRO Programmable Controllers — 64 or Fewer I/O

Company	ABB INDUSTRIAL SYSTEMS	ABB INDUSTRIAL SYSTEMS	ALLEN-BRADLEY	ALLEN-BRADLEY	ALLEN-BRADLEY
(1) Model(s)	Master Piece 51	Master Piece 100	a. SLC 100 b. SLC 150	SLC 500	SLC 5/01
I. I/O Capabilities (2) No. discrete I/Os in basic unit	32	64	16 (a), 32 (b)	20/30/40	
(3) Expandable to	64	128	112	56/62/72	256
(4) No. analog inputs poss.		64	24		
(5) No. analog outputs poss.		16			
(6) PID control		Yes	No	No	No
(7) TTL: true on (1); true off (0); selectable (1,0)					
(8) Max. no. of remote I/O racks					
(9) Max. distance for remotes					
(10) Remote communication rate	2 Mbaud	153.6 kBaud			
(11) High speed counter module, max. rate		100 kHz	5 kHz (b)	8 kHz	
(12) Special-purpose modules:	Seq. advanced				
II. CPU & Memory Features (13) Available no. of relays Available no. of timers Available no. of counters	999 16 16		 32 32	User config.	User config.
(14) Approx. scan time per 1k memory	<3 ms	User specified	15 (a), 4 (b) ms	<10 ms	<10 ms
(15) Total memory		64k	885 (a), 1200 (b) wds.	1k inst.	1k/4k inst.
(16) Application memory		32k	885 (a), 1200 (b) wds.	1k inst.	1k/4k inst.
(17) Math capabilities		Math, trig		Math, compare	Math, compare
(18) Enhanced instruction features	Pulse, jump, seq.	PID, int, func. gen., lead/lag, lim, pulse-PID, ramp		Seq., shift reg., file/logic, BCD/bin, subroutine	Seq., shift reg., file/logic, BCD/bin, subroutine
(19) Internal diagnostic features	Self-test, watchdog	Total memory, hardware	Yes	Yes	Yes
III. Programming & Interfacing (20) Force I/O?	Yes	Yes	Yes	Yes	Yes
(21) Higher level language(s)		Function Block			
(22) Nos. & types of serial ports		RS232	1 RS422	1 RS485	1 RS485
(23) Configurable I/O mapping		Yes	No	Yes	Yes
(24) Programming by: handheld (HH); IBM PC or comp. (PC); special CRT unit (CRT); others (listed)	HH, other	HH, PC, other	HH, PC	HH, PC	HH, PC
(25) Program loading by: tape loader (TL); floppy disk (FD); others (listed)	FD	FD	FD	FD	FD
(26) Hard copy documentation: program listing (PL); ladder diagram (LD); I/O wiring (I/O); others (listed)	PL	Complete graphic block	LD	LD	LD
IV. Ratings			UL, CSA	Pending	Pending
CIRCLE NUMBER	201	202	203	204	205

Company	EATON	ENTERTRON INDUSTRIES	FURNAS ELECTRIC	GE FANUC	GE FANUC
(1) Model(s)	D100CRA28	a. SK1600 b. SK1600R	a. 96HM12 b. 96HM20 c. 96KM20	Series One Junior	a. Series One/E b. Series One/Plus
I. I/O Capabilities (2) No. discrete I/Os in basic unit	28	28 (a), 32 (b)	12 (a), 20 (b,c)	24	32
(3) Expandable to	28	56 (a), 64 (b)	32 (a), 40 (b,c)	96	112 (a), 168 (b)
(4) No. analog inputs poss.			4 (c)		24
(5) No. analog outputs poss.			2 (c)		12
(6) PID control	No	No	No	No	No
(7) TTL: true on (1); true off (0); selectable (1,0)		1,0			
(8) Max. no. of remote I/O racks				1	3
(9) Max. distance for remotes				100 ft	3000 ft
(10) Remote communication rate			19.2 kBaud	19.2 kBaud	19.2 kBaud
(11) High speed counter module, max. rate			2 kHz (c)	2 kHz	10 kHz
(12) Special-purpose modules:			Peer-to-peer (c), timer access, computer i/f	Fast response I/O, thumbwheel interface	Fast response I/O, thumbwheel interface, ASCII/Basic
II. CPU & Memory Features (13) Available no. of relays Available no. of timers Available no. of counters	128 16 16	149 24 24	64 (a,b), 192 (c) 8 (a,b), 32 (c) 8 (a,b), 32 (c)	160 20 20	144 64 64
(14) Approx. scan time per 1k memory	7 ms	15 ms	45 (a,b), 7 (c) ms	5 ms/100 wds	12 ms/1k wds
(15) Total memory	3k	2k or 4k	320 (a,b), 1000 (c) steps	700 wds	700, 1700, or 3.7k wds
(16) Application memory	1k	1k or 3k	320 (a,b), 1000 (c) steps	700 wds	1700 wds
(17) Math capabilities		Math, compare	Math (c)		Math (b)
(18) Enhanced instruction features	Jump function to skip parts of ladder	Drum timer, shift reg., master cont. relay	Shift reg. (a,b), jumps (c), subroutine (c), BCD in/out (c), moves (c), comp. (c)	Seq.	Seq. (a); data moves, BCD-BIN-BCD, shift left/right (b)
(19) Internal diagnostic features	Fault contact independent of I/O	Software		WDT, low battery, parity	WDT, low battery, parity
III. Programming & Interfacing (20) Force I/O?	Yes	No	Yes	Yes	Yes
(21) Higher level language(s)		Assembler	Step Ladder (c)		Basic using ASCII/Basic
(22) Nos. & types of serial ports	1 RS232			1 RS422	1 RS422
(23) Configurable I/O mapping	No	No	No	No	No
(24) Programming by: handheld (HH); IBM PC or comp. (PC); special CRT unit (CRT); others (listed)	HH, PC	PC	HH,PC, other	HH, PC, other	HH, PC, LCD portable
(25) Program loading by: tape loader (TL); floppy disk (FD); others (listed)	FD	FD	TL	TL, FD	TL, FD
(26) Hard copy documentation: program listing (PL); ladder diagram (LD); I/O wiring (I/O); others (listed)	PL, LD, I/O, comments, text	PL, LD	PL, LD, I/O	PL, LD, nicknames, comments	PL, LD, nicknames, comments
IV. Ratings	CSA	Pending	UL (b), CSA (b)	UL	UL, CSA
CIRCLE NUMBER	213	214	215	216	217

GEC AUTOMATION PROJECTS	GIDDINGS & LEWIS ELECTRONICS	IDEC	INDUSTRIAL LOGIC SYSTEMS	KLOCKNER-MOELLER	McGILL MFG	MINARIK ELECTRIC
MicroGEM	PIC 4.9 a. Model 10 b. Model 20	MACH 1	IRIS R1024Q	a. PS3-AC b. PS3-DC c. PS3-8	a. 1701-2000 b. 1701-7000	LS1000A
20	16	24	24	24 (a), 32 (b), 16 (c)	24 (a), 64 (b)	25
160	40	24	2048	96 (a), 128 (b), 64 (c)	48 (a), 512 (b)	120
	1 (a), 2 (b)			4 (a,b)	16 (b)	
	2 (a), 3 (b)			1 (a,b)	1 (b)	
	Yes	No	Yes	No	No	Yes
	1,0	1,0	1,0		0	
7			254	3		
30 ft			5000 ft	2000 ft		
			19.2 kBaud	187.5 kBaud		
		2 kHz		10 kHz (a,b)	100 kHz	1.4 kHz
Commun.	Encoder inputs, 1 (a), 2 (b); intel. commun. port (76.8 kBaud)			Man/machine i/f, ext. timer adjust, remote bus i/f	Servo cont. (b)	
80 32 32	3800 512 900	 16 16	Unlimited Unlimited Unlimited	36 32 32	512 56 56	64 800 800
1.25 ms	.8 ms	20 ms	<4 ms	<1.5 ms	2 ms	5-10 ms
2k	68k	700 wds		3.6k		22k
2k	68k	700 wds	32k	3.6k	4k (a), 8k (b)	3k
	Full math, 3-byte-wide		Math	Math		Math
Seq.	200 call routine; 2-axis circ. & 3-axis linear interpolation			RTC timers (32), shift reg., comparators	Master cont. relay jump	SPC blocks
Full/continuous system monitoring	Start-up, real-time debug, voltage & scan monitors	CPU, program, syntax, battery, run/stop	Power-up, run, commun., watchdog	Output short (b), circuit detect (b)	Programmable	Circ. error, mem check, monitoring
No	Yes	Yes	Yes	No		Yes
Ladder Logic	Assembly, PIC Position, PIC Motion		Ladder, C, Pascal, Assembly	Sucosoft		
1	2 RS232		2 RS232C/422/485	1 RS485	1 RS232	
Yes	Yes	No	Yes	No	No	No
HH, PC, system programmer	HH, PC	HH	PC	HH, PC, CRT	PC	HH, PC
TL, FD	TL, FD	TL	FD	TL, FD	FD	TL, FD
PL, LD	PL, LD, I/O		PL, LD	PL, LD, I/O	PL, LD, I/O	PL
		UL		CSA, IEC		UL
218	219	220	221	222	223	224

MICRO Programmable Controllers — 64 or Fewer I/O (Continued)

Company	MINARIK ELECTRIC	MITSUBISHI ELECTRIC	MODICON	MODICON	NAVCOM
(1) Model(s)	WP6200A	a. F2-20M b. F2-40M c. F2-60M	MICRO-84	PC-0085	FOEM
I. I/O Capabilities (2) No. discrete I/Os in basic unit	12	20 (a), 40 (b), 60 (c)	0	24	0
(3) Expandable to	20	40 (a), 80 (b), 120 (c)	112	120	40
(4) No. analog inputs poss.		4 (a), 8 (b), 12 (c)	12	16	32
(5) No. analog outputs poss.		2 (a), 4 (b), 6 (c)	12		16
(6) PID control	No	No	No	No	No
(7) TTL: true on (1); true off (0); selectable (1,0)			1		0
(8) Max. no. of remote I/O racks			0		
(9) Max. distance for remotes					
(10) Remote communication rate					
(11) High speed counter module, max. rate		2 kHz		5 kHz	
(12) Special-purpose modules:		Peer-to-peer, I/O mult., pulse gen. positioning unit, TCAM		4-20 mA, 0-5 Vdc, 0-15 Vdc setpoints	PWM (3), LCD/keypad operator, TTL/BCD
II. CPU & Memory Features (13) Available no. of relays Available no. of timers Available no. of counters	 79 79	 216 32 32	 64 64 64	 344 48 48	 1000 100 10
(14) Approx. scan time per 1k memory		7 ms	20 ms	6 ms	10 ms
(15) Total memory	2k	1000 (a), 2000 (b,c)	504 elements	928 wds	640k
(16) Application memory	0.5k	1000 (a), 2000 (b,c)	504 elements	928 wds	600k
(17) Math capabilities		Math, logic	+, −		+, −
(18) Enhanced instruction features	Sequential inst. set	64 data reg., read, write, move, immediate I/O, jump, shift reg., others	Seq.	Shift reg., BCD convert; MCR	Compares, moves, addressing, IF
(19) Internal diagnostic features		Hardware, software, battery	Power supply, memory	Power supply, memory	
III. Programming & Interfacing (20) Force I/O?	No	Yes	Yes	Yes	Yes
(21) Higher level language(s)		Ladder including Step Ladder			Forth
(22) Nos. & types of serial ports			1 RS232	1 RS422	2 RS232
(23) Configurable I/O mapping	No	No	No	No	Yes
(24) Programming by: handheld (HH); IBM PC or comp. (PC); special CRT unit (CRT); others (listed)	Built-in	HH, PC, CRT, other	HH, CRT	HH, PC	PC
(25) Program loading by: tape loader (TL); floppy disk (FD); others (listed)		TL, FD	TL	TL, FD	FD
(26) Hard copy documentation: program listing (PL); ladder diagram (LD); I/O wiring (I/O); others (listed)			LD	PL, LD, annotation	PL
IV. Ratings		UL (b,c)	UL, CSA		
CIRCLE NUMBER	225	226	227	228	229

NAVCOM	NEDERLANDSE PHILIPS	NEDERLANDSE PHILIPS	OMRON ELECTRONICS	RELIANCE ELECTRIC	RELIANCE ELECTRIC	SAAB AUTOMATION-EVERETT/CHARLES
a. F10 b. F20 c. F40	a. MC40 b. MC41	MC30	a. C28K b. C20	Shark X	AutoMate 15	PCC 930
10 (a), 20 (b), 40 (c)	20	40	20/28/40 (a), 28 dc/26 ac (b)	20, 28, 40	64	32
30 (a), 40 (b)		120	140 (a), 140 dc/ 130 ac (b)	60	64	128
0			16 (a)	2		16
0			4 (a)	2		16
No	No	No	No	No		No
0					1	1,0
	10 kHz		2 kHz (a)	10 kHz	N/A	
LCD/keypad, TTL/BCD, RS485 multidrop		Computer/network i/f, bidir. parallel i/f, 16 × 8 bit	Commun., (a,b), analog set timer (a), ext set timers (a)	Serial commun.	Voltage comparator, electronic input	
150-1500 mix	20 max	20	296 48 48	384 24 40		256 16 32
80 ms	10 ms	2 ms	10 ms	5 ms		7.5 ms
48k wds		2k	1194 ins	1k or 2k		
46k wds	2k	2k	1194 ins	1k or 2k		4000 inst/ 10k text
+, −	Math	Math	Math (a); +, − (b)	Math, compare		Math
Reg., compares, moves, addressing	Prog. I/O, jump, shift bit left/right	Prog. I/O, jump, shift bit left/right	Compare, move, shift reg. (a,b); jump (a), subroutine (a), I/O refresh (a)		Shift	Commun., bar code reader
Memory, CPU	Watchdog, low battery		CPU/memory/I/O bus/bat. failures; program error	Checksum, watchdog, instruction check	Checksum, watchdog,	Yes
Yes	Yes	Yes	Yes	Yes	Yes	Yes
	IL, SFC (b), FBD (b), LD (b)	SFC, IL, FBD, LD				
RS 485, RS232, RS422	RS232 (b) RS485 (b)	1 RS485 1 RS232		1 RS232	1 RS232	2 RS232C
	No	Yes	No	No	No	Yes
PC,CPM	HH, General VDU (b)	HH, PC	HH, PC, CRT	HH, PC	HH, PC, CRT	HH, PC, CRT
	FD (b)	FD	TL, FD	TL, FD	FD	
PL	PL (b), LD (b), SFC-listing (b)	PL, LD, SFC-listing (b)	PL, LD, I/O	PL, LD, I/O	PL, LD, I/O	PL
			UL, CSA		UL	
230	231	232	233	234	235	236

MICRO Programmable Controllers — 64 or Fewer I/O (Continued)

Company	SELECTRON/J F GASKILL	SELECTRON/J F GASKILL	SIEMENS ENERGY & AUTOMATION	SQUARE D	TELEMECANIQUE
(1) Model(s)	PMC 10	PMC 20	S5-100U/CPU100	SY/MAX Model 50	TSX 17.10
I. I/O Capabilities (2) No. discrete I/Os in basic unit	32	24		16	20
(3) Expandable to	96	144	128	256	120
(4) No. analog inputs poss.	4	8	2, 4	1	
(5) No. analog outputs poss.		1	2	1	
(6) PID control			No	No	No
(7) TTL: true on (1); true off (0); selectable (1,0)					
(8) Max. no. of remote I/O racks			3		
(9) Max. distance for remotes			100 ft		
(10) Remote communication rate			9600 Baud		
(11) High speed counter module, max. rate		50 kHz	500 kHz		
(12) Special-purpose modules:					
II. CPU & Memory Features (13) Available no. of relays Available no. of timers Available no. of counters	 512 512	12 512 512	1024 16 16	256 80 47	256 32 15
(14) Approx. scan time per 1k memory	5 ms	5 ms	70 ms	8 ms	5 ms
(15) Total memory	32k	32k	2k	4k	8k
(16) Application memory	16k	16k	2k	4k	1k inst.
(17) Math capabilities	Math	Math	+, −	Math	
(18) Enhanced instruction features	Indirect addressing, data transmission, copy D-block, jump, shift	Indirect addressing, data transmission, copy D-block, jump, shift		Jump, transitional outputs	
(19) Internal diagnostic features	Direct data access	Integrated LCD, direct data access			CPU, program, I/O, memory, battery
III. Programming & Interfacing (20) Force I/O?	Yes	Yes	No	No	Yes
(21) Higher level language(s)			Statement List		Boolean, Grafcet, Ladder
(22) Nos. & types of serial ports	RS232C	RS232C RS485		1 RS422	RS485
(23) Configurable I/O mapping			No	No	Yes
(24) Programming by: handheld (HH); IBM PC or comp. (PC); special CRT unit (CRT); others (listed)	HH, PC, ASCII term.	HH, PC, ASCII term.	HH, PC, CRT	HH, PC	HH, PC
(25) Program loading by: tape loader (TL); floppy disk (FD); others (listed)	FD	FD	No	TL, FD	TL, FD
(26) Hard copy documentation: program listing (PL); ladder diagram (LD); I/O wiring (I/O); others (listed)	PL	PL		LD	PL
IV. Ratings			UL, CSA	UL, CSA, FM Class I, Div 2	UL, CSA, IEC 65a
CIRCLE NUMBER	237	238	239	240	241

TELEMECANIQUE	TENOR	TEXAS INSTRUMENTS	TOSHIBA	WESTINGHOUSE	WESTINGHOUSE	WESTINGHOUSE
TSX 17.20	Series 100ICC	TI 510	a. EX14B b. EX20 Plus c. EX40 Plus	a. PC-100 b. PC-110	PC-900	a. PC-1100 b. PC-1200
20, 40	4	20	14 (a), 20 (b), 40 (c)	20 (a), 30 (b)		
160	252	40	34 (a), 40 (b), 80 (c)	30 (a), 12 (b)	256	128 (a), 256 (b)
12	60				16	8 (a), 64 (b)
6	60				16	8 (a), 64 (b)
No	Yes	No		No	No	No (a), Yes (b)
	1,0	1			1,0	1,0
	1	1			8	
	1000 ft	50 ft			2 mi	
	9600 Baud				9600 Baud	
2 kHz	10 kHz		2 (a), 4 (b,c) kHz		50 kHz	50 kHz
Commun., network	Relay, triac, t/c, temp., op i/f, I/O sim., others	2 (a), 4 (b,c) kHz	2-chan. analog input (a,b,c), RS422 i/f (b,c)		ASCII/Basic, RTD & t/c, servo	ASCII/Basic, RTD & t/c
256 40 32	252 63 63	 16 16	256 64 64	240 60 60	256 256 256	192 (a), 1024 (b) 192 (a), 512 (b) 192 (a), 512 (b)
5 ms	10 ms	16.7 ms	60 ms	8 ms	20 ms	8 (a) or .7 (b) ms
26k	48k	256 wds	1k	320 (a), 1k (b) wds	1k-2.5k	1.5k/3.5k (a), 2k-16k (b)
3k inst.	32k	256 wds	1k			
Math	Math, logic				Math	Math
Fast task, ASCII text, compute & transfer blocks	Multitasking, multi-dim arrays, string variables	Drum timer	Shift reg., flip-flop, step-seq., analog & HS counter setpoints		ASCII TX, matrix, table functions	ASCII TX, matrix, table functions
CPU, program, I/O, memory, battery	Watchdog, hardware/software, editor syntax	PC, battery, power	Program, low battery		16-bit fault table	16-bit fault table
Yes	Yes	No	Yes	Yes	Yes	Yes
Graphic Grafcet, Ladder	Boolean/Basic		Ladder Logic			
RS485	1 RS232 1 RS232/422		1 TTL (a,b,c) 1 RS422 (a)		1 RS232	2 RS232
Yes	No	No	No	No	Yes	No
HH, PC, CRT	HH, PC, ASCII term.	HH, CRT, TI	HH, PC	HH, PC	PC, CRT	HH (a), PC, CRT
TL, FD	FD, HHP/PROM loader	FD	FD,EEPROM		TL, FD	TL,FD
PL, Ladder, Grafcet, I/O wiring, I/O xref	PL	PL, LD	LD, comment., reg. values, inst. & reg. usage		PL, LD	PL, LD
UL, CSA, IEC 65a		UL, CSA, FM	UL, CSA		UL	UL
242	243	244	245	246	247	248

SMALL Programmable Controllers — 65 to 255 I/O

Company	ADATEK	ALLEN-BRADLEY	ASC SYSTEMS	AUTOMATION SYSTEMS	BAILEY CONTROLS
(1) Model(s)	a. D10 b. DA10	PLC-2/02	PC/80	5110	a. CSC01 b. CBC01
I. I/O Capabilities (2) No. discrete I/Os in basic unit	24	128	16	128	28 (a), 6 (b)
(3) Expandable to	1176		128		112 (a), 90 (b)
(4) No. analog inputs poss.	0 (a), 8 (b)	128	64	64	9 (b)
(5) No. analog outputs poss.	0 (a), 8 (b)	64	32	64	2 (b)
(6) PID control	Yes	Yes	Optional	Yes	No (a), Yes (b)
(7) TTL: true on (1); true off (0); selectable (1,0)	1	1,0	1,0		
(8) Max. no. of remote I/O racks	48		8		32
(9) Max. distance for remotes	200 ft		2000+ ft		2000 ft
(10) Remote communication rate	19.2 kBaud		to 128 kBaud		83 kBaud
(11) High speed counter module, max. rate	4 kHz	50 kHz	1 MHz	100 kHz	50 kHz
(12) Special-purpose modules:	Parallel port, network	PID, Basic, motion cont., I/O logic cont., t/c & RTD input, contact output	ac/dc power, motor cont., LAN commun., color/graphics display	Resolver converter	
II. CPU & Memory Features (13) Available no. of relays Available no. of timers Available no. of counters	 Unlim. 96	 1k 296 296	 128 16 64	 1000 250 250	 2048 total
(14) Approx. scan time per 1k memory	10 ms	12.5 ms min	10 ms	1 ms	2 ms
(15) Total memory	18k	1k	256k	24-892k	272k
(16) Application memory	16k	1k	512k	8-64k	16k
(17) Math capabilities	Math, trig, fl point	Math, trig	Full math, optional fl point	Math, trig	Math (b), trig (b), reg. (b), matrix (b)
(18) Enhanced instruction features	PID loop	File, seq., bit shift, fifo load/unload	IBM/PC compat. other options	Arrays, logic	Easy-Step config., data handling, matrix (b)
(19) Internal diagnostic features	Full self-test	Power-up, run-time	Self-test, options	CPU, memory, program, I/O	Memory, CPU I/O, commun.
III. Programming & Interfacing (20) Force I/O?	Yes	Yes	Yes	No	Yes
(21) Higher level language(s)	PSM, State Logic	Basic	Ladder-Logic, Flow-Charts, Macro or Basic C	C, PL/M	Easy-Step (a), Easy-Step Plus (b)
(22) Nos. & types of serial ports	1 RS232	1 RS232/423 1 RS232/422/423	Up to 8 RS232/422	1-12	1 RS232
(23) Configurable I/O mapping	No	Yes	Yes	Yes	Yes
(24) Programming by: handheld (HH); IBM PC or comp. (PC); special CRT unit (CRT); others (listed)	HH, PC (b)	PC, CRT	HH, PC, cartridge	PC, Apple II	HH, PC
(25) Program loading by: tape loader (TL); floppy disk (FD); others (listed)		TL, FD, EEPROM	EIA commun. or IBM/PC	FD	FD, handheld
(26) Hard copy documentation: program listing (PL); ladder diagram (LD); I/O wiring (I/O); others (listed)	PL, I/O	PL, LD	PL, LD, or Flow-List	LD	PL, LD, I/O, comments
IV. Ratings			Optional, including −40 to 80 C range		UL, CSA, FM
CIRCLE NUMBER	249	250	251	252	253

See also item 3 under Micro PLCs for models that can be expanded into this range.

B&R INDUSTRIAL AUTOMATION	CINCINNATI MILACRON	CONTROL TECHNOLOGY	DAIGNEAULT	EAGLE SIGNAL CONTROLS	EAGLE SIGNAL CONTROLS	EAGLE SIGNAL CONTROLS
a. Minicontrol b. Midicontrol	a. APC-500 Relay b. APC-500MCL	2200	C-100	EPTAK 120	a. Eptak 225 b. Eptak 245	a. Eagle 1 b. Eagle 2
16	128	32	16	22	32	64
96 (a), 176 (b)	512 (a), 2048 (b)	160	256	66	128	224
8 (a), 40 (b)	64	80	8		16 (b)	32 (b)
8 (a), 40 (b)	64	80	4		16 (b)	32 (b)
Yes	No	Yes	Yes	No	No (a), Yes (b)	No (a), Yes (b)
	1		1,0		1,0	1,0
	3 (a), 15 (b)	2		0		8
	5000 ft	100 ft				10,000 ft
	9600 Baud	9600 Baud				187 kBaud
50 kHz	150 kHz	1500 kHz	3 kHz			15 kHz
Op panel (a), merge (a), clock (b), t/c & RTD (b)	Motion cont., ASCII, RTD & t/c, switch counter, reg. ser. I/O, bulk data stor.	Stepper control (5 axes), thumbwheel & display	Positioning, message printout, Basic coproc.		Simulator, BCD/binary, circuit test, DPDT & SPDT relays	
800 150 150	Memory opt. dep. 256 256	40 256 628	256 128 32	90 16 16	256 128 32	1500 125 100
4 ms	5 ms	3 ms	8 ms	10 ms	16 ms (a), 23 ms (b)	0.75 ms
32k	128k (a), 64k (b)	65k	48k	520 steps	8k, 16k	16, 32, 48k
16k	92k (a), 48k (b)	4-8k	32k		8k, 16k	8, 24, 40k
Math, 8-32 bit	Dbl. prec. math	Math, logic	Math, compare		Math, compare	16-bit fixed pt (a), 32-bit fl pt with transfer func. (b)
PID, positioning, data tables, drums	Shift left/right, indexed addressing, get/put, convert bin.-dec., dec.-bin.	DSP, English structured	Clock, calendar, jump, shift reg., blk. transfer			PID config/tuning on-line (b), report gen (b)
Watchdog (b), runtimer (a), checksum	Hardware, processor	Status, I/O, memory	Cycle time, hardware, memory, appl. program			32 CPU errors indicated
No	Yes	Yes	Yes	Yes	Yes	Yes
Ladders, Logic Blks, Function Blks, Statements	MCL (a)	Direct sequential programming	Grafcet, Ladder, Literal French/Eng.			Basic, C
1-3 RS232, RS485	RS232/422/485	1 RS232	8 RS232C/422/485			2
Yes	No (a), Yes (b)	Yes	Yes	No	No	No
PC, CRT	PC	HH, PC	HH, PC, CRT, French/Eng.	HH	HH, PC	PC
TL, FD	FD	FD via PL	TL, FD		FD	FD
PL, LD, symbolic programming	LD (a), PL (b), I/O	Self-doc. PL, I/O	PL, LD, I/O, Grafcet list		PL, LD, xref	PL, LD, I/O
VDE	UL		UL, CSA			
254	255	256	257	258	259	260

SMALL Programmable Controllers — 65 to 255 I/O (Continued)

Company	EAGLE SIGNAL CONTROLS	EATON	EATON	EATON	EATON
(1) Model(s)	a. Eptak 7000 b. Eagle 3	D100CRA40A	D100CA40H	MPC1	a. D200PRO4 b. D200PRO4C
I. I/O Capabilities (2) No. discrete I/Os in basic unit	64	40	40	65	112
(3) Expandable to	224	80	120	128	224
(4) No. analog inputs poss.	104 (a), 100 (b)	2		8	56
(5) No. analog outputs poss.	56			8	28
(6) PID control	Yes	No	No	No	No
(7) TTL: true on (1); true off (0); selectable (1,0)	1,0				
(8) Max. no. of remote I/O racks	8			3	1
(9) Max. distance for remotes	10,000 ft			4000 ft	1 km
(10) Remote communication rate	187 kBaud			128 kBaud	187.5 kBaud
(11) High speed counter module, max. rate	15 kHz	4 kHz			100 kHz
(12) Special-purpose modules:				Intell. analog I/O	Network comm., fiber optic i/f
II. CPU & Memory Features (13) Available no. of relays Available no. of timers Available no. of counters	1500 125 (b) 100 (b)	128 64 64	128 64 64	128 128 128	 128 96
(14) Approx. scan time per 1k memory		7 ms	3 ms	10 ms	1 ms
(15) Total memory		3k	3k	4k	8k
(16) Application memory		1k	1k	2k	4k
(17) Math capabilities				Math	12-function math
(18) Enhanced instruction features	32-bit fl point data reg, PID tuning on-line, report gen	10-ms timers, immed. update I/O			a: on-line program change, 60 advanced instr.; b: real-time clock, trig, tab move
(19) Internal diagnostic features	32 CPU errors indicated	Internal fault contacts	External fault contacts	Fault contacts	30 fault contacts
III. Programming & Interfacing (20) Force I/O?	Yes	Yes	Yes	Yes	Yes
(21) Higher level language(s)	Basic, C				
(22) Nos. & types of serial ports	16 (a), 8 (b)	1 RS232	1 RS232	1 RS232	1 RS232 1 RS485 (b)
(23) Configurable I/O mapping	Yes (a), No (b)	No	No	Yes	Yes
(24) Programming by: handheld (HH); IBM PC or comp. (PC); special CRT unit (CRT); others (listed)	PC	HH, PC	HH, PC	HH	HH, PC
(25) Program loading by: tape loader (TL); floppy disk (FD); others (listed)	FD	FD	FD		TL, FD
(26) Hard copy documentation: program listing (PL); ladder diagram (LD); I/O wiring (I/O); others (listed)	PL, LD, I/O	PL, LD, I/O, comments, text	PL, LD, I/O, comments, text	LD, I/O	LD, I/O, comments, text
IV. Ratings		UL, CSA	UL, CSA	UL, CSA	UL, CSA
CIRCLE NUMBER	261	262	263	264	265

See also item 3 under Micro PLCs for models that can be expanded into this range.

EATON	ENCODER PRODUCTS
a. D500CPU25A b. D500CPU50A	a. 7152 b. 7252
128 (a), 256 (b)	24
256 (a), 512 (b)	408
60	14
30	8
Yes	No (a), Yes (b)
	1
1 (a), 3 (b)	
1 km	
187.5 kBaud	50-19.2 kBaud
50 kHz	250 kHz
ASCII, PID, RTD, t/c, stepper	Dual serial commun., thumbwheel, universal display
1024 128 96	2
2 ms (a), 1 ms (b)	
8k (a), 16k (b)	52k
4k (a), 8k (b)	52k
12-function math	Math, trig
10 ms timers, 60 advanced functions	Motion cont. (b)
30 fault contacts	
Yes	
	Basic
1 RS232 1 RS422	17 RS232/422
Yes	
HH, PC	HH, PC, CRT
TL, FD	Quick release sockets
LD, I/O, text	PL
UL, CSA	
266	267

..MALL Programmable Controllers — 65 to 255 I/O (Continued)

Company	ENTERTRON INDUSTRIES	GEC AUTOMATION PROJECTS	KLOCKNER-MOELLER	MESSUNG SYSTEMS	MITSUBISHI ELECTRIC
(1) Model(s)	SK1800	MiniGEM	PS 32	MEPROLOG XMP8	A2CPU
I. I/O Capabilities (2) No. discrete I/Os in basic unit	44	64	224	128	
(3) Expandable to	88		2048	256	512
(4) No. analog inputs poss.		16	56	16	128
(5) No. analog outputs poss.		16	56	16	32
(6) PID control		Yes	Yes	No	Yes
(7) TTL: true on (1); true off (0); selectable (1,0)	1,0		1		1
(8) Max. no. of remote I/O racks			9		64
(9) Max. distance for remotes			5 ft		10 km
(10) Remote communication rate					1.25 MBaud
(11) High speed counter module, max. rate	10 kHz	20 kHz	20 kHz	10 kHz	50 kHz/chan., 2 chan.
(12) Special-purpose modules:	Quadrature decoder	Commun., RTD	Serial bus I/f for Suconet	Intell. servo pos., remote console, remote intell. display	Motion cont., Basic, ASCII, interrupt, parallel I/F
II. CPU & Memory Features (13) Available no. of relays Available no. of timers Available no. of counters	512 256 256	1600 100 100	4096 64 64	512 32 32	3k 256 256
(14) Approx. scan time per 1k memory	1.8 ms	1.25 ms	2 ms	5 ms	2.25 ms
(15) Total memory	8k	2k	32k wds	32k	14k steps
(16) Application memory	6k	2k	32k wds	16k	Yes
(17) Math capabilities	Math	Math, logic, BCD	Math, shift, rotate	Math, compare, conversion, shifts	4/8 BCD, 16/32 bit BIN
(18) Enhanced instruction features	Drum counter, shift reg., master cont., pack/unpack, latch/unlatch, compare	Signal processing, data movement	RTC, comparators, fifo, lifo,TGEN, para./serial conv.	Pulse timers, program blks., fault message sent on serial port, others	Compares, fifo, seq., shifts, ASCII conv., logic (16 bit)
(19) Internal diagnostic features	Software	Full system monitoring with fault shutdown	Prog. diag. word	Scan time, I/O data exchange mon., logic, hardware	256 diag. relays, 256 diag. reg.
III. Programming & Interfacing (20) Force I/O?	No	Yes	Yes	Yes	Yes
(21) Higher level language(s)	Assembler	Enhanced relay logic	Sucosoft	Ladder, Statement List	Assembler, Basic
(22) Nos. & types of serial ports		8	32 RS485/RS232 8 RS485		5 RS422 4 RS232
(23) Configurable I/O mapping	No	No	No	Yes	Yes
(24) Programming by: handheld (HH); IBM PC or comp. (PC); special CRT unit (CRT); others (listed)	PC	PC, system programmer	PC	HH, PC	HH, PC, CRT, other
(25) Program loading by: tape loader (TL); floppy disk (FD); others (listed)	FD	TL, FD	FD		TL, FD
(26) Hard copy documentation: program listing (PL); ladder diagram (LD); I/O wiring (I/O); others (listed)	PL, LD	PL, LD, text	PL, LD, I/O	PL, LD, I/O	PL, LD, xref, coils used, comments
IV. Ratings	Pending		CSA, IEC		
CIRCLE	268	269	270	271	272

See also item 3 under Micro [illegible] models that can be expanded into [illegible] range.

[illegible]NCE ELECTRIC	RELIANCE ELECTRIC	RELIANCE ELECTRIC	SAAB AUTO-MATION-EVERETT/ CHARLES
Shark XL	AutoMate 20	AutoMate 30	a. PCC960 b. PCC963
80			224 (a), 160 (b)
160	256	512	1024
8	16	128	256
8	16	128	32 (a), 64 (b)
No	Yes	Yes	No (a), Yes (b)
1	1	1,0	1,0
	4	12	
	1000 ft	6000 ft	
	256 kBaud	8000 kBaud	
10 kHz		100 kHz	
		Multibus, t/c, counter	Pulse encoder I/f, servo cont.
545 96 96	Yes	Yes	1536 256 256
5 ms	10 ms	1.6 ms	0.9-1.3 ms
1k, 2k	2k	4k, 8k	1 M
1k, 2k	2k	8k	64k
	Math, compare	Math, compare	Math
Shifts, jumps, latch	Moves, drums, GOTO, logic	Moves, drums, tables, bit manip.	Extensive
	Yes	Extensive	Yes
Yes	Yes	Yes	Yes
	No	No	
1 RS232	1 RS232	3 RS232 per module	4 (a) or 5 (b) RS232C
No	Yes	Yes	Yes
HH, PC	HH, PC, CRT	HH, PC, CRT	HH, PC, CRT (b)
TL, FD	FD	FD	
PL, LD, I/O	PL, LD, I/O	PL, ID, I/O	PL, LD, I/O
	UL	UL	
273	274	275	276

SMALL Programmable Controllers — 65 to 255 I/O (Continued)

Company	SELECTRON/J F GASKILL	SIEMENS ENERGY & AUTOMATION	SIEMENS ENERGY & AUTOMATION	TELEMECANIQUE	TEXAS INSTRUMENTS
(1) Model(s)	PMC 30	a. S5-100U/CPU102 b. S5-100U/CPU103	S5-115U/CPU941	a. TSX47.10 JR b. TSX47.20 JR	TI 100
I. I/O Capabilities					
(2) No. discrete I/Os in basic unit	64			160	64
(3) Expandable to	256	256	512	160	128
(4) No. analog inputs poss.		4, 2	8, 16	16 (b)	
(5) No. analog outputs poss.	128	2	4, 8	16 (b)	
(6) PID control		No (a), Yes (b)	No	No	No
(7) TTL: true on (1); true off (0); selectable (1,0)					0
(8) Max. no. of remote I/O racks	8	3	19		1
(9) Max. distance for remotes	600 m	100 ft	3280 ft		3 ft
(10) Remote communication rate	187.5 kBaud	9600 Baud	9600 Baud		
(11) High speed counter module, max. rate	2x 100 kHz	500 kHz	500 kHz	2 kHz	
(12) Special-purpose modules:	A/D, D/A, commun. controller			Serial commun. (b), network (a,b), high speed I/O (b), Modbus i/f (b)	
II. CPU & Memory Features					
(13) Available no. of relays	8	1024 (a), 2048 (b)	2048	256	
Available no. of timers	512	32 (a), 128 (b)	128	24	20
Available no. of counters	512	32 (a), 128 (b)	128	16	8
(14) Approx. scan time per 1k memory	5 ms	5 (a), 2 (b) ms	30 ms	10 ms	5 ms
(15) Total memory	32k	4k (a), 20k (b)	10k wds	32k	1k
(16) Application memory	32k	2k (a), 8k (b)	10k wds	14k instr.	1k
(17) Math capabilities	Math	+, − (a), math (b)	Math	Math	
(18) Enhanced instruction features	Indirect addressing, data transmission, copy D-block, jump, shift			ASCII char. handling, compute & transfer blks.	
(19) Internal diagnostic features	Integrated LCD, direct data access			CPU, memory, I/O	
III. Programming & Interfacing					
(20) Force I/O?	Yes	No	Yes	Yes	Yes
(21) Higher level language(s)		Statement List	Statement List	Graphic Grafcet, Ladder	
(22) Nos. & types of serial ports	RS232C RS485			RS232/485 (b)	Proprietary
(23) Configurable I/O mapping	No			Yes	No
(24) Programming by: handheld (HH); IBM PC or comp. (PC); special CRT unit (CRT); others (listed)	HH, PC, ASCII term.	HH, PC, CRT	HH, PC, CRT	HH, PC, CRT	HH
(25) Program loading by: tape loader (TL); floppy disk (FD); others (listed)	FD		No	TL, FD	TL
(26) Hard copy documentation: program listing (PL); ladder diagram (LD); I/O wiring (I/O); others (listed)	PL			Ladder, Grafcet, I/O wiring, I/O xref	LD
IV. Ratings		UL, CSA	UL, CSA	UL, CSA, IEC 65a	
CIRCLE NUMBER	277	278	279	280	281

also item 3 [illegible] Micro PLCs for that can be expanded into this range

TEXAS INSTRUMENTS	TEXAS INSTRUMENTS	TRICONEX	WESTINGHOUSE
5TI	TI520C	TRICON	a. PC-1250 b. PC-700
255	255	128	
512		2368	512
Threshold	255	2272	128 (a), 32 (b)
	255	284	128 (a) 32 (b)
No	No	Yes	Yes
	0		1,0
24		13	8 (b)
50 ft		6 km	2 mi (b)
		375 kBaud	9600 Baud (b)
	50 kHz	20 kHz	50 kHz
		All modules triple-voting; full range t/c	ASCII/Basic, RTD & t/c, servo (b)
 200 200	511 256 256	1 byte/element 4 byte/element 4 byte/element	1024 (a), 512 (b) 512 (a), 256 (b) 512 (a), 256 (b)
8.3 ms	4 ms	2 ms	.7 (a), 8 (b) ms
4k wds	3.5k wds	768k	2k-15k (a), 2/4/8k (b)
4k wds	3.5k wds	350k	
	Math	Math, trig	Math
	Matrix, drum seq., data handling	Shift, pack/unpack, process cont., others	ASCII TX matrix table
		Complete online system, power, I/O	16-bit fault table
Yes	Yes	Yes	Yes
		Tag name & func. blk. prog., programming with std math strings	
	1 RS232	8	2 RS232
No	Yes	Yes	No (a), Yes (b)
HH, CRT	HH, PC, CRT, DEC, TI	PC	HH (b), PC, CRT
TL, FD	FD	FD	TL, FD
Yes	Yes	PL, LD, I/O, xref, tag name programming	PL, LD
UL, CSA, NEMA	UL, FM, CSA	UL, CSA	UL (a)
282	283	284	285

MEDIUM Programmable Controllers — 256 to 1023 I/O

Company	ABB INDUSTRIAL SYSTEMS	ADATEK	ALLEN-BRADLEY	ALLEN-BRADLEY	ASC SYSTEMS
(1) Model(s)	Master Piece 200	a. System 10 b. System 10, Series E	PLC-5/VME	a. PLC-2/16 b. PLC-2/17 c. PLC-5/12	PC/88
I. I/O Capabilities (2) No. discrete I/Os in basic unit	~ 1000	24	768	256 (a), 512 (b,c)	64 +
(3) Expandable to	~ 1200	1176			512
(4) No. analog inputs poss.	~ 1000	1-96		256	128
(5) No. analog outputs poss.	~ 400	1-96	256	64	64
(6) PID control	Yes	Yes	196	Yes	Optional
(7) TTL: true on (1); true off (0); selectable (1,0)		1	1,0	1,0	1,0
(8) Max. no. of remote I/O racks		48	6		32
(9) Max. distance for remotes		200 ft	10,000 ft		2500+ ft
(10) Remote communication rate	153.6 kBaud	19.2 kBaud	57.6 kBaud		to 1 MBaud
(11) High speed counter module, max. rate	100 kHz	4 kHz	50 kHz	50 kHz	1 MHz
(12) Special-purpose modules:		Parallel port, network	PID, Basic, motion cont., I/O logic cont., RTD & t/c input, contact output	PID, Basic, motion cont., I/O logic cont., RTD & t/c input, contact output	ac/dc power, motion cont., LAN/MAP commun., RF or IR telecommun., color/graphics display, s.s. disc storage
II. CPU & Memory Features (13) Available no. of relays Available no. of timers Available no. of counters		 Unlim. 96	 14k 4600 4600	 3k (a), 6k (b,c) 296 (a,b), 2000 (c) 296 (a,b), 2000 (c)	 512 32 128
(14) Approx. scan time per 1k memory	User defined	10 ms (a), 5 ms (b)	2 ms	12.5min(a,b),2(c)ms	5 ms
(15) Total memory	2 M	18k (a), 40k (b)	14k	3k (a), 6k (b,c)	1 M
(16) Application memory	1 M	16k (a), 32k (b)	14k	3k (a), 6k (b,c)	1 M
(17) Math capabilities	Math, trig	Math, trig, fl point	Math	Math (a,b,c), trig (a,b)	Full math, fl point and/or array opt.
(18) Enhanced instruction features	PID, ratio, integrator, ramp, filter, func. gen.	PID loop	File, seq., bit shift, fifo load/unload, PID, others	File, seq., bit shift, fifo load/unload, PID (b,c), others	IBM/PC/AT compatibility. Other options
(19) Internal diagnostic features	Memory, hardware, program checks	Full self-test	Power-up, run-time	Power-up, run-time	Self-test. Options: I/O, commun., others
III. Programming & Interfacing (20) Force I/O?	Yes	Yes	Yes	Yes	Yes
(21) Higher level language(s)	Function Block	PSM, State Logic	Basic, Seq. Function Chart	Basic (a,b,c), Seq. Function Chart (c)	Ladder-Logic Boolean, Flow-Charts, Basic, C, Macros
(22) Nos. & types of serial ports	4 RS232	1 RS232 (a), 2 RS232 or RS422 (b)	1 RS232/423 1 RS232/422/423	1 RS232/423 1 RS232/422/423	Up to 32 RS232/422
(23) Configurable I/O mapping	Yes	No	Yes	Yes	Yes
(24) Programming by: handheld (HH); IBM PC or comp. (PC); special CRT unit (CRT); others (listed)	HH, VAX	HH, PC	PC	PC (a,b,c), CRT (a,b)	HH, PC, cartridge
(25) Program loading by: tape loader (TL); floppy disk (FD); others (listed)	FD		FD	TL (a,b), FD, EEPROM	EIA commun. or IBM/PC
(26) Hard copy documentation: program listing (PL); ladder diagram (LD); I/O wiring (I/O); others (listed)	Complete graphic block	PL, I/O	PL, LD	PL, LD	PL, LD, Flow-Chart or Print-Out
IV. Ratings					Optional
CIRCLE NUMBER	286	287	288	289	290

:ee also item 3 under Micro an... ..l: PLCs
;or models that can be expanded i..to this range.

AUTOMATION SYSTEMS	BAILEY CONTROLS	B&R INDUSTRIAL AUTOMATION	CINCINNATI MILACRON
5200	a. NLMM02 b. NMPC01	Multicontrol a. CP40 b. CP80	a. APC-500 Relay b. APC-500 MCL
384	16 (a), 0 (b)	256	32
	1024	1024 (a), 1536 (b)	512
192		128	64
192		128	64
Yes	No	Yes	No
			1
2	32	3	1 (b)
	1000 ft		5000 ft
	83 kBaud		9600 Baud
100 kHz	50 kHz (b)	50 kHz	150 kHz
Resolver converter		Positioning, memory, arithmetic, parallel I/O, Basic	Motion cont., ASCII, RTD & t/c, switch counter, bulk data storage, reg. ser. I/O
4000 100 100	1024 (a), 2048 (b) total	800 150 150	Memory opt. dep. 256 256
1 ms	20 (a), 2 (b) ms	4 ms (a), 2.5 ms (b)	5 ms
60-892k	56k (a), 176k (b)	32k (a), 128k (b)	128k (a), 64k (b)
32-64k	16k (a), 32k (b)	16k (a), 74k (b)	92k (a), 48k (b)
Math, trig	Math (b), trig (b)	Math, trig, fl point	Dbl. prec. math
	Data handling, commun. (a), matrix (b)	PID, positioning, data tables, drums	Shift right/left, indexed address, get/put, convert bin/dec., dec/bin
CPU, memory, program, I/O	Memory, CPU, I/O, commun.	Watchdog, runtimer, checksum	Hardware, processor
No	Yes	No	Yes
C, PL/M		Ladders, Logic Blocks, Function Blks., Statements, Basic	MCL (a)
1-12	2 RS232 (b)	1-10 RS232, RS485	RS232/422/485
Yes	Yes	Yes	No (a), Yes (b)
PC, Apple II	HH, PC	PC, CRT	PC
FD	FD, handheld	FD, TL	FD
LD	PL, LD, I/O, comments (b)	PL, LD, symbolic programming	LD (a), PL (b), I/O
	CSA, UL	VDE	UL
291	292	293	294

.DIUM Pr::grammable ∪ontrollers — 256 to 1023 I/O (∪ontinued)

Company	COMPUTER DYNAMICS SALES	CONTROL TECHNOLOGY	CONTROL TECHNOLOGY	DIVELBISS	EATON
(1) Model(s)	a. CDI-LAD-LOG b. CDI-LAD-REM	a. 2400 IE b. 2800 IE	2800IEA	PIC-BB-15	D500CPU20
I. I/O Capabilities					
(2) No. discrete I/Os in basic unit	24			16	56
(3) Expandable to	576 (a), 680 (b)	128 (a), 256 (b)	2048	249	224
(4) No. analog inputs poss.	16-64 (a), 2-180 (b)	32 (a), 64 (b)	64	20	56
(5) No. analog outputs poss.	0-16 (a), 2-158 (b)	32 (a), 64 (b)	64		28
(6) PID control	Yes	Yes	Yes	No	Yes
(7) TTL: true on (1); true off (0); selectable (1,0)	1,0			1	
(8) Max. no. of remote I/O racks	256 (b)	7	7		3
(9) Max. distance for remotes	5000 ft (b)	1000 ft	1000 ft		1 km
(10) Remote communication rate	9600 Baud (b)	230.4 kBaud	230.4 kBaud		187.5 kBaud
(11) High speed counter module, max. rate		1000 kHz	1000 kHz	10 kHz	50 kHz
(12) Special-purpose modules:	RTD & t/c	Up to 8 (a) or 16 (b) axes stepper, 4 (a) or 16 (b) axes servo	16 axes stepper, 16 axes servo	Timer/counter, access, PIC-AB-01, Presto, PIC-PI-02	ASCII, PID, RTD, t/c
II. CPU & Memory Features					
(13) Available no. of relays Available no. of timers Available no. of counters	6000 120 100	0 256 1000	0 1024 1000	491 32 32	1024 128 96
(14) Approx. scan time per 1k memory	2 ms	1.5 ms	1.5 ms	2 ms	2 ms
(15) Total memory	1 M	256k	256k	16k max	8k
(16) Application memory	32k	4k	12k		4k
(17) Math capabilities	Math, compare	Math, logic	Math, logic		12-function math
(18) Enhanced instruction features	Shift reg., stepper drums, jumps	English structured	English structured		10 ms timers, 60 advanced functions
(19) Internal diagnostic features		Status, I/O, memory	Status, I/O, memory	Watchdog	30 fault contacts
III. Programming & Interfacing					
(20) Force I/O?	Yes	Yes	Yes	Yes	Yes
(21) Higher level language(s)		Direct seq. programming	Direct sequential programming		
(22) Nos. & types of serial ports	2 RS232 or RS485	2 RS232	2 RS232		1 RS232
(23) Configurable I/O mapping	Yes	Yes	Yes	No	Yes
(24) Programming by: handheld (HH); IBM PC or comp. (PC); special CRT unit (CRT); others (listed)	PC	HH, PC	HH, PC	HH, PC	HH, PC
(25) Program loading by: tape loader (TL); floppy disk (FD); others (listed)	FD	FD via PL	FD via PL	FD	TL, FD
(26) Hard copy documentation: program listing (PL); ladder diagram (LD); I/O wiring (I/O); others (listed)	LD	Self-doc. PL	Self-doc. PL		LD, I/O, text
IV. Ratings	UL				UL, CSA
CIRCLE ' 'ER	295	296	297	298	299

item 3 under Micro and Small PLCs for models that can be expanded into this range.

ENCODER PRODUCTS	FURNAS ELECTRIC	FURNAS ELECTRIC	GE FANUC	GEC AUTOMATION PROJECTS	GIDDINGS & LEWIS ELECTRONICS	GIDDINGS & LEWIS ELECTRONICS
Synergy	a. 96JM40 b. 96KM40 c. 96KM60	a. PC/96 b. PC/96 Plus	Series Three	a. GEM 80/131 b. GEM 80/100	a. Pic 49 b. Pic 49 Turbo	a. PIC 409 b. PIC 409 Turbo
48	40 (a,b), 60 (c)	256 (a), 480 (b)	64	512	232	256
12,000	80 (a,b), 120 (c)		400			2032
8	8 (b), 12 (c)	56	24	32	64	120
2	4 (b), 6 (c)	56	12	32	64	120
Yes	No	Yes	No	Yes	Yes	Yes
0		1	1,0	1	1,0	1,0
250		7 (a), 14 (b)	7	32	1	7
4000 ft			3000 ft	10,000 ft (a)		4000 ft
2.4 MBaud	19.2 kBaud	19.2 kBaud	19.2 kBaud	180 kBaud		76.8 kBaud
250 kHz	2 kHz		10 kHz	20 kHz	12 MHz	12 MHz
Servo cont., serial commun. with I/O counter	Peer-to-peer, timer access computer i/f	System integration, timer/counter access, message, computer i/f	I/O simulator, built-in programmer	LCD outputs, thumbwheel, keypad, alpha-num display, t/c & RTD, Coronet (a), GEMstart (a)	FPA, motion cont., intell. commun.	FPA motion cont., intell. commun.
	168 32 32	256 (a), 768 (b) 128 (a), 256 (b) 128 (a), 256 (b)	368 128 128	38.4k 2400 2400	3800 512 900	3800 512 900
	7 ms	5 ms	12 ms	0.25 (a), 1.25 (b) ms	.57 ms	.57 ms
32k	1000 (a), 2000 (b,c) steps	2k (a), 5k (b) wds	4k wds	22.5k (a), 12k (b)	40k	288k
15k	1000 (a), 2000 (b,c) steps	2k (a), 5k (b) wds	4k wds	22.5k (a), 12k (b)	40k	288k
Math, trig	Math (b,c)	+, − (a) math (b)	Math, compare	Math, logic	Full math, 3-byte wide, 1400 statements	Full math, 3-byte wide, 1400 statements
	Immed. update, BCD in/out, moves, comparison	Func. blk. prog., PID, clock, Boolean	Data moves, BCD-BIN-BCD, shift left/right	Process cont., data move, comparisons	200 call routines; 2-axis circ. & 3-axis linear interp.	200 call routines; 2-axis circ. & 3-axis linear interpolation
Memory, CPU, serial i/f			WDT, low battery, parity	Full system monitoring with fault shutdown	Startup, real time debug, volt. & scan monitors	Start-up, real-time debug, voltage & scan monitors
	Yes	Yes	Yes	Yes	Yes	Yes
Forth	Step Ladder			Enhanced Relay Logic	Assembly, PIC Motion	Assembly, Pic Motion
500 RS232/422/485			1 RS422	3 (a), 2 (b)	≥2 RS232	≥2 RS232
No	No	No	Yes	Yes	Yes	Yes
HH, PC, CRT	HH, PC, other	PC	Built-in HH; PC, LCD portable	PC, System programmer	HH, PC, Lear Siegler	PC, Lear Siegler
FD	TL	FD	TL	TL, FD	TL, FD	TL, FD
PL	PL, LD, I/O	PL, LD, I/O	PL, LD	PL, LD, text	PL, LD, I/O	PL, LD, I/O
	UL, CSA	UL, CSA				
300	301	302	303	304	305	306

M[illegible]UM Programmable Controllers — 256 to 1023 I/O (Continued)

Company	HONEYWELL IPC	HONEYWELL IPC	HONEYWELL IPC	IDEC	INDUSTRIAL CONTROL LINKS
(1) Model(s)	a. 620-10 b. 620-15	620-20	a. 620-25 b. 620-35	a. FA-2 b. FA-2J	a. 1100 b. 1100/OEM
I. I/O Capabilities					
(2) No. discrete I/Os in basic unit	256 or 512	256 or 512	512, 1024, 2048	512 (a), 256 (b)	32 (a), 64 (b)
(3) Expandable to	256 or 512	512	512, 1024, 2048	512 (a), 256 (b)	256 (a), 4000 (b)
(4) No. analog inputs poss.	8 (b)	8	8	32 (a), 16 (b)	128
(5) No. analog outputs poss.	4 (b)	4	4	16	64 (a), 128 (b)
(6) PID control	Yes (b)	Yes	Yes	Yes	Yes
(7) TTL: true on (1); true off (0); *selectable (1,0)*	1,0	1,0	1,0	1,0	1,0
(8) Max. no. of remote I/O racks	2	11	32	30	126
(9) Max. distance for remotes	50 ft	10,000 ft	10,000 ft	3000 ft	5000 ft
(10) Remote communication rate	Parallel	100 kBaud	100 kBaud	9600 Baud	38.4 kBaud
(11) High speed counter module, max. rate	1000 kHz (b)	100 kHz	100 kHz	1 kHz, 10 kHz	8 kHz
(12) Special-purpose modules:	Commun. i/f, sys. diag., motion cont., ASCII (b), t/c (b), BCD conv. (b), pulse input (b)	Commun. i/f, sys. diag., motion cont., ASCII, t/c, BCD conv., pulse input	Commun. i/f, motion cont., sys. diag., ASCII, t/c, BCD conv., pulse input	Computer link, ext power unit, fiber optic link, cable link, logger/events mon.	Serial ASCII, RTD (b), alpha-num display (b), high-density analog I/O (a,b)
II. CPU & Memory Features					
(13) Available no. of relays	512	512	2048	480 (a), 608 (b)	256
Available no. of timers	256	1024	2048	168 (a), 160 (b)	256
Available no. of counters	256	1024	2048	80	256
(14) Approx. scan time per 1k memory	10 ms	3.3 ms	2.5 ms	3 ms	1 ms
(15) Total memory	.5, 1, 2, 4k	2, 4, 8k	2-32k	4000 wds	32k or 48k
(16) Application memory	4092 wds	4092 wds	to 32,764 wds	3940 wds	
(17) Math capabilities	– (a), math (b)	Math	Math	b: math, logic, conversion	Math, 32-bit
(18) Enhanced instruction features	Push/pull (b)	Push/pull	Matrix, push/pull	Networking (a,b), peer-to-peer comm. (a), step adv. (b), indirect inst. (b), ext dis./pt (b) pg br (b)	Serial ASCII in & out, network commun.
(19) Internal diagnostic features	Extensive	Extensive	Extensive	b: CPU, program, syntax, battery, run/stop	ROM, RAM, CPU, checksums, watchdog
III. Programming & Interfacing					
(20) Force I/O?	Yes	Yes	Yes	Yes	Yes
(21) Higher level language(s)	With MiniCOP (b)	With MiniCOP	With MiniCOP	Ladder Logic, Boolean, Lotus 123, Pascal (Turbo) (a)	Ladder Logic, Forth
(22) Nos. & types of serial ports	2 RS232/422/485	4 RS232/422/485	4 (a), 8 (b) RS232/422/485	RS232C/R422	9 RS232/422
(23) Configurable I/O mapping	No	No	No	No	Yes
(24) Programming by: handheld (HH); IBM PC or comp. (PC); special CRT unit (CRT); others (listed)	PC, CRT, laptop	PC, CRT, laptop	PC, CRT, laptop	HH, PC	PC
(25) Program loading by: tape loader (TL); floppy disk (FD); others (listed)	TL,FD	TL,FD	TL, FD	TL,FD	
(26) Hard copy documentation: program listing (PL); ladder diagram (LD); I/O wiring (I/O); others (listed)	PL, LD	PL, LD	PL, LD	PL, LD, I/O	PL, LD, xref
IV. Ratings	UL, CSA, FM	UL, CSA, FM	UL, CSA, FM	UL (b)	
CIRCLE NUMBER	307	308	309	310	311

...e also item 3 ...er Micro and Sma... PLCs for models th... ...t be expanded into this range.

KLOCKNER-MOELLER	MITSUBISHI ELECTRIC	MODICON	MODICON	OMNICON	OMRON ELECTRONICS	OMRON ELECTRONICS
PS316	A1CPU	a. 984-380 b. 984-381	a. 984-480 b. 984-680 c. 984X	S3000	C120	C200H
256		0		256	32	384
2032	256	256	1024 (a), 2048 (b,c)		256	1432
64	64	32	224 (a,c), 1900 (b)	4	16	40
64	16	32	224 (a,c), 1900 (b)	4	16	20
Yes	Optional	Yes	Yes	No	Yes	Yes
	1	1	1		1,0	1,0
6	64	1	6 (a,c), 31 (b)	32	6	64
5 ft	10 km	20 ft	5000(a,b), 15,000(c) ft	1000 ft	Unlimited	Unlimited
	1.25 MBaud	750 kHz	1.5 MBaud	62.5 bps	187.5 kBaud	187.5 kBaud
20 kHz	50 kHz/chan., 2 chan.	50 kHz	50 kHz	50 kHz	30-50 kHz	75 kHz
Serial bus i/f for Suconet, remote bus i/f	Motion cont., interrupt, Basic, ASCII, parallel i/f	CAM emulator, PID, ASCII/Basic	CAM emulator, PID, ASCII/Basic	Motion control	Commun.	Commun., high-density I/O, direct temp. inputs, ASCII/Basic, position cont.
2048 64 64	3k 256 256	2048 1920 1920	2048 1920 1920	Variable	1739 128 128	6680 512 512
.5 ms	2.25 ms	5 ms	5 (a), 3 (b), .75 (c) ms	1 ms	10 ms	0.75 ms
32k wds	6k steps	8k	10k (a,c), 18k (b)	32k	2.6k wds	8k
32k wds		5k	7k (a,c), 15k (b)	30k	2.6k wds	7k
Math, shift, rotate	4/8 BCD 16/32 bit BIN	Dbl. int math, trig, fl point	Dbl. int math, trig, fl point	Math	Math, fl point +	Math, fl point + 4/8 digit
RTC, comparators, fifo, lifo, TGEN, para/serial conv.	Seq., fifo, jump, logic (16 bit), shift, compares, ASCII conv.	Seq. PID, table & block functions, stat block, subroutines	Subroutines (a,b), seq., PID, table/block/status functions		Compare, move, shift reg., jump	Extensive
Prog. diag. word	256 diag. relays, 256 diag. reg.	Memory & reg. checksums, power supply	Memory & reg. checksums, power supply		CPU/mem./I/O bus/bat. failure; program error	Extensive
Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sucosoft	Assembler, Basic	C	C (a,b)			
4 RS485	4 RS232 5 RS422	1 (a) or 2 (b) RS232	12 (a,c) or 32 (b) RS232			
No	Yes	Yes	Yes	Yes	Yes	Yes
PC	HH, PC, CRT, other	PC, CRT	PC, CRT		HH, PC, CRT	HH, PC, CRT
FD	FD, TL	TL, FD	TL, FD		TL, FD	TL, FD
PL, LD, I/O	PL, LD, xref coils used, comments	LD	LD	LD	PL, LD	PL, LD
CSA, IEC		Pending	Pending (a,b), UL/CSA (c)	UL	UL, CSA	UL, CSA
312	313	314	315	316	317	318

M[illegible]DIUM Programmable Controllers — 25[illegible] to 1023 I/O (Continued)

Company	OMRON ELECTRONICS	SIEMENS ENERGY & AUTOMATION	SIEMENS ENERGY & AUTOMATION	SQUARE D	SQUARE D
(1) Model(s)	C500	a. S5-115U/CPU942 b. S5-115U/CPU943 c. S5-115U/CPU944	S5-135U/920	SY/MAX Model 300	a. SY/MAX 400 b. SY/MAX 500
I. I/O Capabilities (2) No. discrete I/Os in basic unit	512				
(3) Expandable to	512	2048	2048	256	40,000 (a), 2000 (b)
(4) No. analog inputs poss.	32	8, 16	8, 16	16	16
(5) No. analog outputs poss.	32	4, 8	4, 8	4	4
(6) PID control	Yes	Yes	No	Yes	Yes
(7) TTL: true on (1); true off (0); selectable (1,0)	1,0			1,0	1,0
(8) Max. no. of remote I/O racks	64	63		16	112
(9) Max. distance for remotes	Unlimited	10,000 ft		15,000 ft	15,000 ft
(10) Remote communication rate	187.5 kBaud	187 kBaud		31.25 kBaud	31.25 kBaud
(11) High speed counter module, max. rate	50 kHz			100 kHz	100 kHz
(12) Special-purpose modules:	Commun., PID, position cont., ASCII/ Basic, interrupt	20 M hard drive, high-speed analog, closed-loop cont., valve cont., positioning, others		Stepper, BCD I/O, data logger	Stepper, BCD I/O, data logger
II. CPU & Memory Features (13) Available no. of relays Available no. of timers Available no. of counters	1483 128 128	2048 128 128		256 112 112	14,000 (a), 2000 (b) 4000 (a), 2000 (b) 4000 (a), 2000 (b)
(14) Approx. scan time per 1k memory	10 ms	18(a), 10(b), 3(c)ms		30 ms/2k	2.9 ms (a), 2.6 ms (b)
(15) Total memory	5.3, 8k wds	10k (a), 76k (b), 16k (c)		0.5k, 1k, 2k	4/8/16k (a), 2/4/8k (b)
(16) Application memory	5.3, 8k wds	42k (a), 46k (b), 96k (c)		0.5k, 1k, 2k	4/8/16k (a), 2/4/8k (b)
(17) Math capabilities	Math, fl point +, 4/8 digit, BCD/Bin conv.	Math	Fl point	Math	Math, fl point
(18) Enhanced instruction features	Extensive			Read, write, alarm, print	PID (a), sequencer (a), ASCII input (a) subroutines (b), matrix (b)
(19) Internal diagnostic features	Extensive			5 diagnostic LEDs	7 (a), 5 (b) diagnostic LEDs
III. Programming & Interfacing (20) Force I/O?	Yes	Yes		Yes	Yes
(21) Higher level language(s)		Statement List	Assembler, Basic, C compiler	Basic in datalogger	Basic in datalogger
(22) Nos. & types of serial ports				2 RS422	2 RS422
(23) Configurable I/O mapping	Yes	Yes		Yes	Yes
(24) Programming by: handheld (HH); IBM PC or comp. (PC); special CRT unit (CRT); others (listed)	HH, PC, CRT	HH, PC, CRT	PC, CRT	HH, PC, CRT, other	HH, PC, CRT, other
(25) Program loading by: tape loader (TL); floppy disk (FD); others (listed)	TL, FD			TL, FD	TL, FD
(26) Hard copy documentation: program listing (PL); ladder diagram (LD); I/O wiring (I/O); others (listed)	PL, LD			LD, annotation	LD, annotation
IV. Ratings	UL, CSA	UL, CSA		UL, CSA, FM Class I, Div. 2	UL, CSA, FM Class I, Div. 2
CIRCLE NUMBER	319	320	321	322	323

S... n 3 under Micro and Small PLCs ... models that can be expande... ... this range.

TELEMECANIQUE	TELEMECANIQUE	TEXAS INSTRUMENTS	TEXAS INSTRUMENTS	TOSHIBA	TOSHIBA	UTICOR TECHNOLOGY
a. TSX 47.10 a. TSX 47.20 c. TSX 47.30	a. TSX 67.20 b, TSX 87.30	PM550C	a. TI 530T b. TI 525 c. TI 535	EX100	a. EX250 b. EX500	4001
256	256 (a), 512 (b)	255	384 (a), 512 (b,c)	240	256 (a), 512 (b)	384
512	1024 (a), 2048 (b)		1023	752	768 (a), 1024 (b)	384
16 (b), 32 (c)	168 (a), 256 (b)		1023	64	32 (a), 64 (b)	256
4 (b), 8 (c)	42 (a), 64 (b)		1023	64	32 (a), 64 (b)	64
No (a,b), Yes (c)	Yes	Yes	Yes	Yes	Yes	Yes
		0	1,0 (a,b) 1 (a)	0		1
	1 (a), 4 (b)		14	15	15	12
	3250 (a), 6500 (b) ft		1300 (a,b) 1000 (c) ft	1000 m	1000 m	4000 ft
	2.5 MHz		1 MBaud	187.5 kBaud	187.5 kBaud	
2 (a,b), 40 (c) kHz	40 kHz		50 (a), 10 (b,c) kHz	100 kHz	50 kHz	150 kHz
Modbus i/f (b,c), high-speed I/O (b,c), network (b,c) serial commun. (b,c)	Modbus i/f, high-speed I/O, axis cont., network, serial commun.		Network i/f (a,b,c); RTD & t/c (a), servo (a), high-speed pulse (a), ASCII (a), Basic (a), others (a)	High-speed dc input	PID, ASCII/Basic, RTD & t/c, stepper cont.	Multiplex, latching
256 (a,b), 512 (c) 24 (a,b), 160 (c) 16 (a,b), 256 (c)	512 160 256	800	511 256 256	1024 128 96	1024 128 96	440 64 64
2 (a,b), 0.5 (c) ms	0.2 ms	8 ms	.93 (a,c), 3.8 (b) ms	0.9 ms	0.9 (a), 0.75 (b) ms	10 ms
32k (a,b), 112k (c)	112k (a), 256k (b)	7k wds	20k (a,c), 8k (b) wds	4k	4k (a), 8k (b)	6k
4k (a,b), 16k (c) inst.	16k (a), 32k (b)	7k wds	20k (a,c), 8k (b) wds	4k	4k (a), 8k (b)	6k
Math	Math	Fl point, compare	Math	Math, trig, 32-bit +, −	Math, trig, 32-bit +, −	Math
Fast task (a,b), 4 task (c), index I/O (c), compute & transfer blks.	5 tasks, index I/O, table transfer		Matrix, drum seq., data handling	Immed. I/O update, func. gen., table move, and/or/xor	Immed. I/O update, func. gen., table move, and/or/xor, blk. transfer	Table, seq.
CPU, memory, I/O	CPU, memory, I/O		Yes	CPU, I/O, program, battery	CPU, I/O, prog., low battery	Self-check
Yes	Yes	Yes	Yes	Yes	Yes	Yes
Graphic Grafcet, Ladder, Literal (c)	Graphic Grafcet, Ladder, Literal			Ladder Logic, Function Block	Ladder Logic, Function Block	Relay
RS232/485 (b,c)	RS232/485	1 RS232 1 RS422	1 RS232 (a,b,c) 1 RS422 (a,c)	1 RS485	1 RS422	1 RS232
Yes	Yes	No	Yes	Yes	Yes	Yes
HH (a,b), PC, CRT	PC, CRT	HH, CRT	HH, PC, CRT, DEC, TI	HH, PC, special LCD type	HH, PC, special LCD type	PC, CRT
TL, FD	TL, FD	FD	FD	FD, TL, EEPROM	FD, TL, EEPROM	TL, FD
Ladder, Grafcet, I/O wiring, I/O xref	Ladder Grafcet, I/O xref, I/O wiring	Yes	Yes	LD, comment., reg., values, inst. & reg. usage	LD, comment., reg., values, inst. & reg. usage	PL, LD, I/O
UL, CSA, IEC 65a	UL, CSA, IEC 65a	CSA	UL, CSA, FM (a), IEC (b,c)		UL, CSA	UL, CSA
324	325	326	327	328	329	330

..RGE Programmable Controllers — 1024 or More I/O

Company	ABB INDUSTRIAL SYSTEMS	ALLEN-BRADLEY	ALLEN-BRADLEY	ALLEN-BRADLEY	AUTOMATION SYSTEMS INC.
(1) Model(s)	Master Piece 200/1	a. PLC-5/15 b. PLC-5/25	PLC-2/30	a. PLC-3/10 b. PLC-3	5300
I. I/O Capabilities (2) No. discrete I/Os in basic unit	1500	1024 (a), 1920 (b)	1792	4096 (a), 8192 (b)	1024
(3) Expandable to	3000			8192 (a)	
(4) No. analog inputs poss.	1500	512 (a), 1024 (b)	896	2048 (a), 4096 (b)	512
(5) No. analog outputs poss.	1000	256 (a), 512 (b)	448	1024 (a), 2048 (b)	512
(6) PID control	Yes	Yes	Yes	Yes	Yes
(7) TTL: true on (1); true off (0); selectable (1,0)		1,0	1,0	1,0	
(8) Max. no. of remote I/O racks	64	6 (a), 14 (b)	14	128	7
(9) Max. distance for remotes	6000 ft	10,000 ft	10,000 ft	10,000 ft	
(10) Remote communication rate	2 MBaud	57.6 kBaud	115.2 kBaud	115.2 kBaud	
(11) High speed counter module, max. rate	100 kHz	50 kHz	50 kHz	50 kHz	100 kHz
(12) Special-purpose modules:	Positioning, Basic, IEEE 802.3 Ethernet	PID, Basic, motion cont., I/O logic cont., RTD & t/c input, contact output	PID, Basic, motion cont., I/O logic cont., RTD & t/c input, contact output	PID, Basic, motion cont., I/O logic cont., RTD & t/c input, contact output	Resolver converter
II. CPU & Memory Features (13) Available no. of relays Available no. of timers Available no. of counters		14k (a), 21k (b) 4600 (a), 7000 (b) 4600 (a), 7000 (b)	16k 488 488	128k (a), 2000k (b) 10,000 10,000	8000 1000 1000
(14) Approx. scan time per 1k memory	User defined	2 ms	5 ms	2.5 ms	1 ms
(15) Total memory	4 M	14k (a), 21k (b)	16k	128k (a), 2000k (b)	108-792k
(16) Application memory	3 M	14k (a), 21k (b)	16k	128k (a), 2000k (b)	64k
(17) Math capabilities	Math, trig	Math	Math	Math	Math, trig
(18) Enhanced instruction features	PID, ratio, pulse, pos, ramp, report, filter, func. gen.	File, seq., bit shift, fifo load/unload, PID, file diag., Boolean logic	File, seq., bit shift, fifo load/unload, PID, file diag., Boolean logic	File, fifo load/unload, bit shift, file diag., Boolean logic	Arrays, logic
(19) Internal diagnostic features	Memory, hardware, program checks	Power-up, run-time	Power-up, run-time	Power-up, run-time	CPU, memory, program, battery
III. Programming & Interfacing (20) Force I/O?	Yes	Yes	Yes	Yes	No
(21) Higher level language(s)	Function Block	Basic, Seq. Function Chart	Basic	Basic	C, PL/M
(22) Nos. & types of serial ports	8 RS232	1 RS232/423 1 RS232/422/423	1 RS232/423 1 RS232/422/423	68 RS232	1-12
(23) Configurable I/O mapping	Yes	Yes	Yes	Yes	Yes
(24) Programming by: handheld (HH); IBM PC or comp. (PC); special CRT unit (CRT); others (listed)	HH, VAX	PC	PC, CRT	PC, CRT	PC, Apple II
(25) Program loading by: tape loader (TL); floppy disk (FD); others (listed)	FD	FD, EEPROM	TL, FD	TL, FD	FD
(26) Hard copy documentation: program listing (PL); ladder diagram (LD); I/O wiring (I/O); others (listed)	Complete graphic block	PL, LD	PL, LD	PL, LD	LD
IV. Ratings					
CIRCLE NUMBER	331	332	333	334	335

L[illegible]E Programmable Controllers — 1024 or More I/O (Continued)

Company	BAILEY CONTROLS	COMPUTER DYNAMICS SALES	GE FANUC	GE FANUC	GEC AUTOMATION PROJECTS
(1) Model(s)	a. NMFC03 b. NMFP02	CD1-LAD-FUL	Series Five	a. Series Six Plus b. Series Six Plus/II	GEM80/140
I. I/O Capabilities					
(2) No. discrete I/Os in basic unit		24	64	80	2048
(3) Expandable to	10,000	1152	1023/2048	4000 (a), 8000 (b)	
(4) No. analog inputs poss	10,000	16-260	512	992	128
(5) No. analog outputs poss.	10,000	4-174	128	992	128
(6) PID control	Yes	Yes	Yes	Yes	Yes
(7) TTL: true on (1); true off (0); selectable (1,0)		1,0	1,0	1,0	1
(8) Max. no. of remote I/O racks	1024	256	7	128	32
(9) Max. distance for remotes	10,000 ft	5000 ft	7500 ft	10,000 ft	10,000 ft
(10) Remote communication rate	1 MBaud	9600 Baud	153 kBaud	57.6 kBaud	180 kBaud
(11) High speed counter module, max. rate	50 kHz		50 kHz	50 kHz	20 kHz
(12) Special-purpose modules	Smart field device i/f, turbine cont.	RTD & t/c	Genius I/O, ASCII/Basic, snap-on op i/f.	Genius I/O, ASCII/Basic, motion, interrupt	LCD outputs, thumbwheel, keypad, alpha-num display, t/c & RTD
II. CPU & Memory Features					
(13) Available no. of relays Available no. of timers Available no. of counters	10,000 total	6000 120 100	Config. to 4k/16k	Config. to 16k	384k 24k 24k
(14) Approx. scan time per 1k memory	1.5 (a), 1 (b) ms	2 ms	1 ms	1 ms (a), 0.8 ms (b)	1.25 ms
(15) Total memory	848k (a), 1384k (b)	1 M	8k/32k	48k (a), 80k (b)	112k
(16) Application memory	80k (a), 128k (b)	32k	4k/16k	4-32k (a), 4-64k (b)	112k
(17) Math capabilities	Math, trig, reg., matrix	Math, compare	Dbl. prec. math	Fl point, expanded time ref	Math, logic
(18) Enhanced instruction features	Self-tuning, Basic, C data handling, Fortran (b), AI rules (b)	Shift reg.[illegible], stepper drums, jumps	Yes	Yes	Closed loop cont., signal proc., data move
(19) Internal diagnostic features	Memory, CPU, I/O, commun.		WDT, low battery, parity	WDT, low battery, dynamic checksum	Full system monitoring with fault shutdown
III. Programming & Interfacing					
(20) Force I/O?	Yes	Yes	Yes	Yes	Yes
(21) Higher level language(s)	Basic, C, Fortran (b)		Basic using ASCII/Basic	Basic	Enhanced Relay Logic
(22) Nos. & types of serial ports	2 (a), 1 (b) RS232 1 (b) RS232/485	2 RS232 or RS485	8/64 RS232/422	256 RS232/422	2
(23) Configurable I/O mapping	Yes	Yes	Yes	Yes	Yes
(24) Programming by: handheld (HH); IBM PC or comp. (PC); special CRT unit (CRT); others (listed)	HH, PC	PC	PC, Workmaster	PC, Workmaster	PC, System programmer
(25) Program loading by: tape loader (TL); floppy disk (FD); others (listed)	FD, handheld	FD	TL, FD	TL, FD	TL, FD
(26) Hard copy documentation: program listing (PL); ladder diagram (LD); I/O wiring (I/O); others (listed)	PL, LD, I/O, comments	LD	LD, nicknames, comments	LD, nicknames, comments	PL, LD, text
IV. Ratings	CSA, UL	UL	UL, CSA pending	UL, CSA	
CIRCLE NUMBER	336	337	338	339	340

See also ite[illegible] under Micro, Small, and [illegible]um PLCs for models that can be expanded into this range.

GEC AUTOMATION PROJECTS	MITSUBISHI ELECTRIC	MODICON	NEDERLANDSE PHILIPS
GEM a. 80/300 b. 80/700 c. 80/163	a. A3CPU b. A3HCPU	a. 984A b. 984B	PC20
4096 (a,b), 8192 (c)			24
8192 (a,b)	2048	2048 (a), 16,384 (b)	2000
512	512	1900 (a), 2048 (b)	128
512	128	1900 (a), 2048 (b)	128
Yes	Yes	Yes	Yes
1	1	1	
64	64	32	6
10,000 ft	10 km	15,000 ft	2000 m
180 kBaud	1.25 MBaud	1.5 MBaud	400 kBaud
25 kHz	50 kHz/chan., 2 chan.	50 kHz	40 kHz
Video graphics, MAP, STARNET, verif. I/O, pulse train counter, fiber optic i/f t/c & RTD, others	Motion cont., Basic, ASCII, interrupt, parallel I/F	CAD emulator, PID, ASCII/ Basic	Coproc.'s, loop cont., graph. user i/f, expand. data mem.
512k 32k 32k	3k 256 256	2048 1920 (a), 9999 (b) 1920 (a), 9999 (b)	SW
1.25 ms	2.25 (a), 0.2 (b) ms	.75 ms	1 ms
512k	2 × 30k steps	34k (a), 138k (b)	16k
512k	Yes	37k (a), 63k (b)	16k
Math, logic	4/8 BCD, 16/32 bit BIN	Dbl. int math	Math
Signal proc., closed loop cont., data move, printer i/f	Compares, fifo, seq., shifts, ASCII conv., logic (16 bit)	Seq., PID, block/table/status functions	Prog. I/O, jump, shift bit left/right
Full system monitoring with fault shutdown	256 diag. relays, 256 diag. reg.	Parity, memory, reg. checksum, power supply	Watchdog
Yes	Yes	Yes	Yes
Enhanced Relay Logic	Assembler, Basic		SFC, IL, FBD, LD
4	8 RS422 4 RS232	32 RS232	RS232 RS485/422
Yes	Yes	Yes	Yes
PC, System programmer	HH, PC, CRT, other	PC, CRT	HH, PC General VDU
TL, FD	TL, FD	TL, FD	FD
PL, LD, text	PL, LD, xref, coils used, comments	LD	PL, LD, SFC listing
		UL, CSA	
341	342	343	344

LARGE Programmable Controllers — 1024 or More I/O (Continued)

Company	OMRON ELECTRONICS	OMRON ELECTRONICS	RELIANCE ELECTRIC	RELIANCE ELECTRIC	SAAB AUTO-MATION-EVERETT/CHARLES
(1) Model(s)	C1000H	C2000H	AutoMate 40	a. AutoMax b. DCS 5000	a. PCC9600 b. PCC9630
I. I/O Capabilities (2) No. discrete I/Os in basic unit	1024	2048			192 (a), 128 (b)
(3) Expandable to	2048	2048	8092	12k +	2048
(4) No. analog inputs poss.	128	128	2048	4k +	256
(5) No. analog outputs poss.	128	128	2048	4k +	64
(6) PID control	Yes	Yes	Yes	Yes	No (a), Yes (b)
(7) TTL: true on (1); true off (0); selectable (1,0)	1,0	1,0	1,0	0	1,0
(8) Max. no. of remote I/O racks	64	64	32	346	250
(9) Max. distance for remotes	Unlimited	Unlimited	6000 ft	6000 ft	2950 ft
(10) Remote communication rate	187.5 kBaud	187.5 kBaud	800 kBaud	1.75 MBaud	375 kBaud
(11) High speed counter module, max. rate	50 kHz	50 kHz	100 kHz	100 kHz	
(12) Special-purpose modules:	Commun., PID, position cont., ASCII/Basic, interrupt	Commun., PID, position cont., ASCII/Basic, interrupt	5-channel counter, RTD & t/c	2-axis servo, pulsetach, resolver, RTD & t/c	Pulse encoder i/f, servo cont.
II. CPU & Memory Features (13) Available no. of relays Available no. of timers Available no. of counters	6135 512 512	5111 512 512	Yes	Yes	3000 6000 Unlimited
(14) Approx. scan time per 1k memory	0.4 ms	0.4 ms	0.8 ms	User defined	0.5-1.0 ms
(15) Total memory	12-36k wds	12 to 38k wds	104k	256k	1 M
(16) Application memory	8-32k wds	8 to 32k wds	104k	160k	200k
(17) Math capabilities	Math, fl point +, 4/8 digit, BCD/Bin conv.	Math, fl point +, 4/8 digit, BCD/Bin conv.	Math, compare	Advanced trig	Math
(18) Enhanced instruction features	Extensive	Extensive	Moves, drums, GOTO, logic interrupts, string manip.	Real-time o.s., multitasking, symbolic programming	Extensive
(19) Internal diagnostic features	Extensive	Extensive	Extensive	Extensive	Yes
III. Programming & Interfacing (20) Force I/O?	Yes	Yes	Yes	Yes	Yes
(21) Higher level language(s)				Ladder, Control Blocks, Enhanced Basic	Yes
(22) Nos. & types of serial ports			3 RS232 per module	2 (a) or 1 (b) RS232C per module	4 (a) or 5 (b) RS232C
(23) Configurable I/O mapping	Yes	Yes	Yes	Yes	Yes
(24) Programming by: handheld (HH); IBM PC or comp. (PC); special CRT unit (CRT); others (listed)	HH, PC, CRT	HH, PC, CRT	PC	PC	HH, PC, CRT (b)
(25) Program loading by: tape loader (TL); floppy disk (FD); others (listed)	TL, FD	TL, FD	FD	FD	
(26) Hard copy documentation: program listing (PL); ladder diagram (LD); I/O wiring (I/O); others (listed)	PL, LD	PL, LD	PL, LD, I/O	PL, LD, I/O	PL, I/O
IV. Ratings	UL, CSA	UL, CSA			
CIRCLE NUMBER	345	346	347	348	349

See also item 3 under Micro, Small, and Medium PLCs for models that can be expanded into this range.

SIEMENS ENERGY & AUTOMATION	SIEMENS ENERGY & AUTOMATION	SQUARE D	TEXAS INSTRUMENTS	WESTINGHOUSE	WESTINGHOUSE	WIZDOM SYSTEMS
S5-135U/928	a. S5-135U/R b. S5-135U/S c. S5-150U	a. SY/MAX 600 b. SY/MAX 700	a. TI560 b. TI565	a. HPPC-1500 b. HPPC-1700	MAC-4500	a. 86L-PC b. 86L-LC c. 86L-CO
			8192	8192	1024	2048
6144	8192	8000 (a), 14,000 (b)			8192	
8, 16	8, 16	16	8192	512	512	128
4, 8	4, 8	4	8192	512	512	128
Yes	Yes	Yes	No (a), Yes (b)	Yes	Yes	No
		1,0	1	1,0	1,0	1,0
63	63	112	128	32		255
10,000 ft	10,000 ft	15,000 ft	15,000 ft	10,000 ft	10,000 ft	5000 ft
187 kBaud	187 kBaud	31.25 kBaud	1 MBaud	825 kBaud	825 kBaud	307 kBaud
2000 kHz	2000 kHz	100 kHz	50 kHz	50 kHz		SBX card
High-speed analog, closed-loop cont., 20M hard disk, valve cont., positioning, others	20 M hard disk, high-speed analog, closed loop cont., valve cont., positioning, others	Stepper, BCD I/O, data logger	ASCII, Basic, high-speed pulse, servo, RTD & t/c, rapid response, others	Func. proc.-ASCII/Modbus/ 1100 LAN; ASCII/Basic, RTD & t/c	ASCII/Basic, RTD & t/c	Bar code, scanner, motion cont.
4096 512 512	8192 512 (a,b), 256 (c) 512 (a,b), 256 (c)	14,000 4000 (a), 8000 (b) 4000 (a), 8000 (b)	21,000 21,000	8192 Memory dep. Memory dep.		8k 4k 4k
1.1 ms	20(a), 1.3(b), 2.3(c)ms	2.4 (a), 1.3 (b) ms	2.2 ms/RLL	1 ms	1.2 ms	3-5 ms
92k	256k (a,b), 96k (c)	16/32k (a), 8/16/32/64k (b)	512k	16-224k	288k	32k
92k	256k (a,b), 352k (c)	16/32k (a), 8/16/32/64k (b)	384k			
Fl point	Fl point	Math, fl pt	Math, trig, fl point	Dbl. prec. math	Fl point	3 dig.; 4 dig. for get/put
Loop counting, flag data block saving, dbl wds add with subtract		PID, seq. (a), ASCII input (a)	Indexed & scanned RLL, subroutines, matrix compares, others	Matrix, table, UDSF	Complete process cont. algorithms	Online doc., 12-digit math, transient on/off
		8 diagnostic LEDs	Op system, RAM/ROM, watchdog, others	48-bit fault table	Extensive-CPU, I/O	Checksum, initial diag., doc. (online)
Yes	Yes	Yes	Yes	Yes	Yes	Yes
Statement List	Statement List	Basic in data logger	Special Function Programming (a), APT (a), SFC (a), CFC (a)			C, Basic
		2 (a) or 4 (b) RS422	1 RS232 (a,b), 1 RS422 (a), 1 ASCII-out only (b)	To 33 RS232	To 33 RS232	
Yes	Yes	Yes	Yes	Yes	Yes	Yes
HH, PC, CRT	HH, PC, CRT	HH, PC, CRT other	PC, CRT, DEC, TI	PC	PC, WDPF console	PC, dumb term.
		TL, FD	FD	FD	FD	FD, hard disk
		LD, annotation (a)	Full featured	PL, LD	PL, LD	PL, LD, I/O, xref
	UL, CSA	UL, CSA, FM Class I, Div. 2	UL, CSA, FM		UL	
350	351	352	353	354	355	356

Circle No.	Company	Product	Programming: Off-Line Entry	Programming: On Line Changes	Programming: Enter elements With: Keyboard (K), Function Keys (F), Mnemonics (M)	Programming: Cut & Paste	Programming: Global Search & Replace	Programming: Off Line Emulation	Documentation: Cross-Referencing	Documentation: Comments (# lines)
208	Action Instruments	AICS-PLC 11 (Modicon)			KF	•	•			
209		AICS-PLC 10 (AB)			KF	•	•		•	
210	Adatek, Inc.	CMAX	•	•	K	•	•	•		
211		System-10	•	•	K	•	•	•		
212	Datablend Corp.	LadderDoctor	•		KM		•		•	3
213		LadderDoctor Professional	•	•	KFM		•		•	3
214	Digital Machine Control	DMC-7	•		KFM	•	•		•	5
215		DMC-8		•	KFM		•			5
216	Entertron Industries, Inc.	SK1600	•		K			•	•	64
217		SK1800	•		K			•	•	64
218	Gray-Soft, Inc.	Comms	•	•	F				•	20
219	Honeywell IPC	PLC Loader	•	•	KF	•			•	20
220	ICOM, Inc.	PLC Ladder Logistics	•		KF	•	•		•	
221		SLC Ladder Logistics	•		KF	•	•		•	
222	Industrial Software, Inc.	LD-8086							•	3
223	Process & Inst. Design, Inc.	ProDoc for AB	•		KM	•	•		•	5
224		ProDoc for Gould	•		KM	•	•		•	5
225	Process Control Consultants	PC/EXEC	•	•	FM	•	•		•	
226	RDY Automation, Inc.	PC Doc								
227	Square D Company	SYM-322	•		KF	•			•	•
228	Straightforward	HP41E	•	•	KFM	•	•	•		16K
229	Taylor Industrial Software	Taylor Documentation							•	4
230		Taylor Programming	•	•	KFM	•	•			
231	Tele-Denken Resources	TOPDOC (AB PLC-2)	•		M	•	•	•	•	64K
232		TOPDOC (PLC-3)	•		M	•	•	•	•	64K
233		TOPDOC (PLC-5)	•		M	•	•	•	•	64K
234	Texas Instruments	TISOFT II (520/530C)	•	•	F	•			•	16
235		TISOFT II (560/565)	•	•	F	•			•	16
236	Westinghouse Electric	NLSW	•	•	KF	•	•		•	8
237	Xcel Controls, Inc.	UP/DOC	•		KM	•	•		•	50

(Source: C. Robinson, "Programmable Area Displays: Getting the Message Out," *Programmable Controls*, vol. 8, No. 7 (1989), pp. 19-22.)

Documentation			Features							Configuration Requirements						Date First Released	Price	Additional Key Features
Page Titles	Text Annotation	Mnemonic Descriptors	Point Descriptors	Simultaneous Prog & Docu	View Prog&Docu Same Screen	Up & Down-Load Programs	I/O Wiring Generator (opt)	Compressed Rung Display	On-Line Rung Status	KB RAM	KB Floppy	MB Hard Disk	Color Display	Operating System	8087/80287 Co-processor			
•	•		•							256	720		•	DOS 2.0+		1984	$2200	•
•	•		•							256	720			DOS 2.0+		1984	$2200	•
			•	•	•	•				128	360			MS-DOS		1987	$945	•
			•	•	•	•				128	360			MS-DOS		1985	$1100	•
•	•		•			•				192	720	10		DOS 2.0+		1981	$695	•
•	•	•		•	•	•			•	512	720	10		DOS 2.0+		1987	$995	
•	•	•	•	•	•	•	•	•		256	360			DOS		7/86	$4000	•
	•	•	•	•	•					256	360			DOS		9/86	$1500	•
•				•	•								•	MS-DOS	•	1979	$450	•
•				•	•								•	MS-DOS	•	1986	$595	
•	•	•	•	•	•	•			•	512				DOS 2.1+		1986		•
•	•		•		•	•			•	256	360			DOS		1986	$2500	•
•	•		•	•		•	•		•	640	360			DOS		1985	$1600	•
•	•		•	•		•	•		•	512	360			DOS		1986	$500	
•	•		•							256	360			DOS		1986	$2000	•
•	•	•	•	•	•	•	•	•		512	360	20		DOS 2.1+				•
•	•	•	•	•	•	•	•	•		512	360	20		DOS 2.1+				•
•	•	•	•	•	•	•			•	640	360	10		MS-DOS		1985	$5000	
							•			256	360			DOS		1985	$700	•
•			•	•		•			•	165	360			DOS		1986	$1500	•
		•	•		•	•	•			128	360			DOS	•	1985	$115	
•	•		•	•	•	•	•			256	360			DOS		1983	$1250	•
				•	•	•	•			512	360			DOS		1983	$2500	•
•	•		•	•	•	•			•	640		10		DOS		1985	$2000	
•	•		•	•	•	•			•	640		10		DOS		1986	$5000	
•	•		•	•	•	•			•	640		10		DOS		1987		
•			•	•	•	•			•	512	360	10		MS-DOS		1986	$2347	•
•			•	•	•	•			•	512	360	10		MS-DOS		1986	$3289	
•	•		•	•	•	•			•	512	360			DOS		1986	$2448	•
•	•		•			•	•	•	•	384	360			DOS		1/82	$2890	•

APPENDIX B: PLC/PC Software Vendors

Prospective Products

1. UP/DOC[R] Software
   XCEL Controls Inc.
   Mishawaka, IN 46544 (219/259-7804)

2. P-CIM Software
   AFCON Control and Automation Inc.
   Schaumburg, IL 60173 (312/490-9900)

3. Contact individual PLC vendors for machine-specific software options

Further Information

See: K.E. Ball, "Software Update," *Programmable Controls*, vol. 6, No. 9 (1989), pp. 53-56.

APPENDIX C: PLC Accessory Hardware Vendors

1. Cherry Alphanumeric Displays
   Cherry Electrical Products
   Waukegan, IL 60087 (312/360-3500)

2. IEE Alphanumeric Displays
   Industrial Electronic Engineers, Inc.
   Van Nuys, CA 91409-9234 (818/787-0311)

3. DeeCO Displays
   Digital Electronics Corp.
   Hayward, CA 94540-9921 (415/471-4700)

4. Panelogic Inc.
   Huntsville, AL 35801 (205/880-0432)

APPENDIX D: PLC Operator Interface Hardware

Prospective Vendors

1. Nematron Workstations
   Interface Systems Company
   Ann Arbor, MI 48106 (313/99-0501)

2. Metra Workstations
   Metra Instruments, Inc.
   San Jose, CA 95131 (408/432-1110)

3. Ziatech Workstations
   Ziatech Corp.
   San Luis Obispo, CA 93401 (805/541-0488)

4. OmniVU Workstations
   XYCOM Inc.
   Saline, MI 48176 (313/429-4971)

5. IPT-100 Interfaces
   Automation Systems, Inc.
   Eldridge, IO 52748 (319/285-9000)

6. Panelogic Inc.
   Huntsville, AL 35801 (205/880-0432)

Further Information

See: C. Robinson, "Programmable Area Displays: Getting the Message Out," *Programmable Controls*, vol. 8, No. 7 (1989), pp. 19-22.

APPENDIX E: On-Line Instrumentation Specifics

On-line instrumentation are of the following fifteen types:

1. Flow - Magnetic Type
2. Flow - Bubbler Type
3. Flow - Capacitance Type
4. Flow - Ultrasonic Type
5. Temperature - Thermocouple
6. Pressure
7. Lower Explosive Limit
8. Dissolved Oxygen
9. pH
10. Conductivity
11. Ion Selective Ammonia Analyzer
12. Suspended Solids/Turbidity
13. Total Organic Carbon
14. Hydrogen Sulfide
15. Oxidation-Reduction Potential.

Each sensor type is more fully described below.

Sensor 1: Flow - Magnetic Type

Operation: Device based on Faraday's Law of Induction, whereby a conductive fluid passing through an magnetic field generates an electromotive force.

Performance:

Accuracy	-	Approximately 1
Response	-	Within 1 to 2 s
Range	-	Device dependent; magnetic element sizes for 1- to 96-in. diameter pipe sizes (1 in. = 0.0254 m) .

Installation: Orientation is not critical; calibration should be facilitated.

Maintenance: Minimal attention beyond periodic (i.e., seasonal) internal cleaning, with calibration on similar timeframe.

Reliability: Will likely function without major problems for extended periods.

Vendors:

ABB Kent Inc.
Edison, NJ 08837
(201/225-1717)

Brooks Instrument Division
Emerson Electric Company
Statesboro, GA 30458
(912/764-5471)

Fisher & Porter
Warminster, PA 18974
(800/421-3411)

Foxboro Company
Foxboro, MA 02035
(617/543-8750)

Omega Engineering Inc.
Stamford, CN 06907
(203/359-1660)

Schlumberger Industries
Neptune Measurement Division
Telford, PA 18969
(800/445-2943)

Signet (George Fischer) Electronics
Tustin, CA 92680-7285
(800/854-4090)

TURBO Instrumentation Inc.
Orinda, CA
(415/253-1170)

Sensor 2: **Level - Bubbler Type**

Operation: Hydrostatic pressure of gas flow through bubbler tube dependent on liquid depth and density.

Performance:

Accuracy	-	~1 percent of actual hydrostatic head
Response	-	1- to 2-s response time
Range	-	Limited by pressure gauge and supply air; usually held within range of zero to 40 ft.

Installation: Rigid bubbler tube should be securely mounted against the wall of the tank in vertical fashion, with approximately a 3-in. (minimum) gap between tube and bottom of tank. This tube should be fitted with an automatic or manual compressed air purge system to expel debris inside the tube. The air supply to the bubbler should be filtered and passed through a rotameter before entering the differential pressure transmitter and bubbler tube.

Maintenance: Air purge bubbler tube as needed to avoid clogging. Calibration should also be provided as needed, at about monthly intervals.

Reliability: Dependent on the differential pressure transmitter; usually reliable over extended periods (i.e., several months).

Vendors:

Bindicator Inc.
Port Huron, MI 48061
(313/987-2700)

Dwyer Instruments Inc.
Michigan City, IN 46360
(219/872-9141)

Endress and Hauser Instruments
Greenwood, IN 46143
(317/535-7138)

Fluid Products Company, Inc.
Eden Prairie, MN 55344
(612/937-2467)

Kinematics and Controls Corp.
Deer Park, NY 117289
(516/595-1803)

Omega Engineering Inc.
Stamford, CN 06907
(203/359-1660)

MicroSwitch Division
Honeywell
Dayton, OH 45424
(513/237-4075)

Sensor 3: **Level - Capacitance Type**

Operation: Capacitance of electrical capacitance sensor rod or cable varies in relation to depth of submergence in liquid.

Performance:
Accuracy - ~1 percent of span.
Response - 1 to 2 s
Range - zero to 60 ft., depending on probe length.

Installation: Liquid must be electrically conductive. Probe composition must be compatible with liquid. Vertical mounting of the capacitor rod/cable against the reactor wall; electronic probe head is powered by interconnected power transmitter.

Maintenance: Inspect, clean, and calibrate the rod/cable monthly or as needed.

Reliability: Long-term reliability is usually good. Floating foam may cause inaccurate readings.

Vendors:

Bindicator Inc.
Port Huron, MI 48601
(313/987-2700)

Dwyer Instruments Inc.
Michigan City, IN 46360
(219/872-9141)

Endress & Hauser Instruments
Greenwood, IN 46143
(317/535-7138)

Fluid Products Company, Inc.
Eden Prairie, MN 55344
(612/937-2467)

Kinematics and Controls Corp.
Deer Park, NY 11729
(516/595-1803)

MicroSwitch Division
Honeywell
Dayton, Ohio 45424
(513/237-4075)

Omega Engineering Inc.
Stamford, CN 06907
(203/359-1660)

Sensor 4: **Level - Ultrasonic Type**

Operation: Sonic transmitter generates electrical impulse that reflects back from the liquid-air interface. Level measurement depends on proportional time-of-travel measurement at fixed-wave velocity.

Performance:

Accuracy	-	~1 percent of span (depending on temperature correction).
Response	-	1 to 2 s
Range	-	From zero to 160 ft.

Installation: Direct physical contact with liquid not required. Manufacturer's guidelines should be followed for minimum separations between transducer and adjacent wall and transducer and measured liquid.

Maintenance: Inspect, clean, and calibrate the rod/cable monthly or as needed.

Reliability: Long-term reliability is usually good. (Floating foam may cause inaccurate readings.)

Vendors:

Bindicator Inc.
Port Huron, MI 48061
(313/987-2700)

Dwyer Instruments Inc.
Michigan City, IN 46360
(219/872-9141)

Dynasonic Inc.
Naperville, IL 60540
(312/355-3055)

Endress & Hauser Instruments
Greenwood, IN 46143
(317/535-7138)

Fluid Products Company, Inc.
Eden Prairie, MN 55344
(612/937-2467)

Kay-Ray Inc.
Mt. Prospect, IL 60056
(312/803-5100)

Kinematics and Controls Corp.
Deer Park, NY 11729
(516/595-1803)

MicroSwitch Division
Honeywell
Dayton, Ohio 45424
(513/237-4075)

Omega Engineering Inc.
Stamford, CN 06907
(203/359-1660)

Ultrasonics Arrays, Inc.
Woodinville, WA 98072
(206/481-6611)

Sensor 5: **Temperature - Thermocouple Device**

Operation: Dissimilar welded metal junction acting in accordance with Seebeck's principle of thermoelectricity.

Performance:

Accuracy	-	~1 percent of full range
Response	-	1 s to several minutes, depending on thermocouple design and construction
Range	-	Type J: Iron-Constantan -> -20 to 650 °C)
	-	Type K: Chromel-Alumel -> -20 to 1250 °C)
	-	Type T: Copper-Constantan -> -160 to 100 °C).

Installation: Recommended thermocouple placement inside a metal thermowell. Thermocouple may be insulated with ceramic or magnesium coating. Immersion length typically 10 times thermocouple diameter.

Maintenance: Inspect, clean, and calibrate the thermocouple monthly or as needed.

Reliability: Long-term reliability is usually good. Coating of the thermocouple with foreign material (e.g., grease, scum, etc.) may degrade sensor responsiveness.

Vendors:

Foxboro Company
Foxboro, MA 02035
(617/543-8750)

Signet (George Fischer) Electronics
Tustin, CA 92680-7285
(800/854-4090)

Pyromation Inc.
Fort Wayne, IN 46895
(219/484-2580)

Thermo/Cense Inc.
Mundelein, IL 60060
(312/949-8070)

Sensor 6: **Pressure**

Operation: Pressure-induced deflection of flexible diaphragm causes electrical change in adjacent capacitor, strain gauge, or inductor.

Performance:

Accuracy	-	Typically +/- 0.5 percent of span
Response	-	1 to 2 s
Range	-	Depending on selected sensor; low range usually zero to 0.5 psi (1 psi = 6.89 kPa).

Installation: Pressure transmitters should be located as close as possible to the measures gas stream.

Maintenance: Inspect, clean, and calibrate the diaphragm monthly or as needed.

Reliability: Long-term reliability is usually good. Clogging or embrittlement of the diaphragm may degrade sensor responsiveness.

Vendors:

Dwyer Instruments Inc.
Michigan City, IN 46360
(219/872-9141)

Foxboro Company
Foxboro, MA 02035
(617/543-8750)

Omega Engineering Inc.
Stamford, CN 06907
(203/359-1660)

Signet (Geo/ge Fischer) Electronics
Tustin, CA 92680-7285
(800/854-4090)

TTI Transducer Technologies Inc.
Pasadena, CA 91107
(818/793-4164)

Sensor 7: **Lower Explosive Limit (LEL)**

Operation: Combustible gas streams are thermally oxidized on a sensing element whose electrical resistance changes in accordance with increased temperature.

Performance:

Accuracy	-	~2 percent of the lower explosive limit
Response	-	1 to 2 s
Range	-	zero to 100 percent of the lower explosive limit.

Installation: Sensor should be situated near zones of concentration for the combustible gas. Heat tracing of gas transfer lines may be necessary should freezing be possible.

Maintenance: Check gas sampling system weekly. Inspect, clean, and calibrate the sensor (using a cylinder of a known gas makeup) monthly or as needed.

Reliability: Long-term reliability is usually good. Moisture in the gas stream may degrade sensor accuracy and long-term reliability.

Vendors:

MSA Research Corp.
P.O. Box 427
Pittsburgh, PA 15230
412/776-8716

Sensor 8: **Dissolved Oxygen**

Operation: Oxygen passage through a gas-selective membrane causes an electrochemical reaction on D.O. electrode.

Performance:

Accuracy	-	~0.05 mg/L
Response	-	5 to 10 s
Range	-	zero to 20 mg/L.

Installation: Oxygen electrode usually mounted vertically at reactor surface with (a 1- to 2-ft submergence on removable, rigid mounting pole.

Maintenance: Inspect, clean, and calibrate the electrode monthly or as needed.

Reliability: Reported short-term reliability extremely variable. Extreme length of utility without maintenance appears limited to ~30 days for best models. Coating of the electrodes' membrane with foreign material (e.g., grease, scum, etc.) may degrade sensor responsiveness.

Vendors:

Foxboro Company
Foxboro, MA 02035
(617/543-8750)

Great Lakes Instruments, Inc.
Milwaukee, WI 53223
(414/355-3601)

Signet (George Fischer) Electronics
Tustin, CA 92680-7285
(800/854-4090)

Yellow Springs Instrument Company
Yellow Springs, OH 45387
(800/343-4357)

Sensor 9: pH

Operation: Hydrogen ion passage though permeable glass surface results in electrochemically induced potential at electrode.

Performance:

Accuracy	-	+/- 0.1 units
Response	-	1 to 5 s
Range	-	zero to 14.

Installation: pH electrode usually mounted vertically at reactor surface with ~1- to 2-ft submergence on removable, rigid mounting pole. Flow-through sensors may also be used on appropriate liquid sampling lines. Sensor should be isolated from vibration and electrical interference.

Maintenance: Inspect and clean pH electrode on a weekly or as-needed basis. Calibrate the pH electrode monthly or as needed using known pH reference solution. Replace electrode biennially or as needed.

Reliability: Short-term reliability is usually good. Coating of the electrode with foreign material (e.g., grease, scum, etc.) may degrade pH sensor responsiveness.

Vendors:

Foxboro Company
Foxboro, MA 02035
(617/543-8750)

Great Lakes Instruments, Inc.
Milwaukee, WI 53223
(414/355-3601)

Omega Engineering Inc.
Stamford, CN 06907
(203/359-1660)

Signet (George Fischer) Electronics
Tustin, CA 92680-7285
(800/854-4090)

Sensor 10: **Conductivity**

Operation: Electrical conductance between two fixed poles is measured using a Wheatstone bridge arrangement.

Performance:

Accuracy	-	+/- 5 units (mhos)
Response	-	1 to 5 s
Range	-	0 to 2000 (higher ranges available).

Installation: Conductivity electrodes are usually mounted vertically at reactor surface with ~1- to 2-ft submergence on removable, rigid mounting pole. Flow-through sensors may also be used on appropriate liquid sampling lines. Sensor should be isolated from vibration and electrical interference.

Maintenance: Inspect and clean conductivity electrodes weekly or as needed. Calibrate the conductivity electrode monthly or as needed using known salt reference solution. Replace electrode biennially or as needed.

Reliability: Short-term reliability is usually good. Coating of the electrode with foreign material (e.g., grease, scum, etc.) may degrade sensor responsiveness.

Vendors:

Foxboro Company
Foxboro, MA 02035
(617/543-8750)

Omega Engineering Inc.
Stamford, CN 06907
(203/359-1660)

Great Lakes Instruments, Inc.
Milwaukee, WI 53223
(414/355-3601)

Signet (George Fischer) Electronics
Tustin, CA 92680-7285
(800/854-4090)

Sensor 11: **Ion Selective Ammonia Analyzer**

Operation: Electrochemical response to free ammonia passing through gas permeable membrane induces electrical signal at electrode.

Performance:

Accuracy	-	~10 percent of the actual NH_3 concentration.
Response	-	Several minutes lag for NH_3 concentration change.
Range	-	(1) zero to 3 mg N/L, (2) 1 to 50 mg N/L

Installation: Free ammonia sensor placed on prefiltered sample sidestream which has been dosed with NaOH to raise sample pH above 12. Utility generally limited to clean samples.

Maintenance: Inspect and clean the sensor daily or as needed. Check instrument reagents daily and refill as necessary. Check the sample filtration system weekly or as needed and correct performance. Calibrate the sensor weekly or as needed.

Reliability: Short-term reliability, beyond 1 week without extreme operator care is not advised.

Vendors:

Orion Research Company
Boston, MA 02129
(617/242-3900)

Sensor 12: **Suspended Solids/Turbidity**

Operation: Scattering of light beam by suspended solids, as quantified by in-line photodetector.

Performance:

Accuracy	-	+/-2 percent of full-scale
Response	-	2 to 5 s
Range	-	zero to 30,000 mg/L.

Installation: Submerged sensors should be mounted more than 1 ft below liquid surface, and at a 15-degree slope from vertical to obviate collection of air/gas bubbles on the sensor face.

Maintenance: Inspect and clean sensor weekly. Correlate sensor reading against laboratory data weekly. Calibrate the sensor monthly or as needed.

Reliability: Short-term reliability is questionable. Coating of the sensor with foreign material (e.g., grease, scum, etc.) may degrade sensor responsiveness. NOTE: Some vendors offer self-cleaning sensors that employ physical wipers, ultrasonic cleaners, etc.

Vendors:

BTG Inc.
Naperville, IL 60540-1689
(312/355-6699)

Bonnier Technology Group
Decatur, GA 35035
(404)981-3998)

Royce Instrument Corp.
(3lanket solids detector)
New Orleans, LA 70129
(800/347-3505)

Sensor 13: **Total Organic Carbon**

Operation: Oxidized (i.e., using catalyzed thermal reaction, etc.) sample stream releases carbon dioxide which then is quantified using infra-red or flame ionization detector.

Performance:
Accuracy - +/-5 percent of full-scale
Response - 5 to 60 min
Range - zero to 5,000 mg TOC/L.

Installation: Unit purchased as complete system from vendor. Provisions must be made for electrical power and sample input/output.

Maintenance: Daily calibration generally required. Weekly cleanup of clean (i.e., filtered) sample input system.

Reliability: Short-term reliability is extremely questionable. Beneficial instrument utility may be limited to periods of days.

Vendors:

Astro International Corporation
League City, TX 77573
(713/332-2484)

Ionic Inc.
Watertown, MA 02172
(617/926-2500)

Sensor 14: **Hydrogen Sulfide**

Operation: Electrochemical reaction on sensor surface that creates electrical output proportionate to H_2S contaminant level.

Performance:
Accuracy - +/- 1 ppm
Response - 1 to 5 s
Range - ppm to percent levels.

Installation: Atmospheric sensor provided with continuous flow-through ambient gas stream and should be isolated from vibration and electrical interference.

Maintenance: Inspect and clean sensor weekly or as needed. Calibrate the sensor weekly or as needed using known H_2S reference gas. Replace sensor as necessary.

Reliability: Short-term reliability is usually good. Corrosion or fouling of sensor surface may impede performance.

Vendors:

GasTech Inc.
Newark, CA 94560

Mine Safety Appliance Company
Pittsburgh, PA 15208

MTS Systems Corp.
Sensors Division
Research Triangle Park, NC 27709
(919/677-0100)

TAC
Houston, TX 77120
(713/240-4160)

Sensor 15: Oxidation - Reduction Potential

Operation: Electrochemical redox on platinum electrode surface measured in comparison with standard calomel electrode potential.

Performance:

Accuracy - +/- 0.1 mv
Fesponse - 1 to 5 s
Range - ~-700 to +700 mv.

Installation: Redox electrode usually mounted vertically at reactor surface with ~1- to 2-ft submergence on removable, rigid mounting pole. Flow-through sensors may also be used on appropriate liquid sampling lines. Sensor should be isolated from vibration and electrical interference.

Maintenance: Inspect and clean redox electrode weekly or as needed. Calibrate the redox electrode monthly or as needed using known redox (i.e., Zobell's) reference solution. Replace electrode biennially or as needed.

Reliability: Short-term reliability is usually good. Coating of the electrode with foreign material (e.g., grease, scum, etc.) may degrade redox sensor responsiveness.

Vendors:

Foxboro Company
Foxboro, MA 02035
(616-543-8750)

Omega Engineering Inc.
Stamford, CN 06907
(203/359-1660)

Great Lakes Instruments, Inc.
Milwaukee, WI 53223
(414/355-3601)

Signet (George Fischer) Electronics
Tustin, CA 92680-7285
(800/854-4090)

LIST OF ABBREVIATIONS

AC	Alternating Current
A/D	Analog to Digital
AI	Artificial Intelligence
ASCE	American Society of Civil Engineers
ASCII	American Standard Code for Information Interchange
USACERL	U.S. Army Construction Engineering Research Laboratory
CONUS	Continental United States
CPU	Central Processing Unit
CRT	Cathode-Ray Terminal
DC	Direct Current
DOS	Disk Operating System
HVAC	Heating, Ventilation, and Air Conditioning
MGD	Millions of Gallons per Day
O&M	Operations and Maintenance
ORP	Oxygen Reduction Potential
PC	Personal Computer
PLC	Programmable Logic Controller
RDT	Remote Data Transmitter
RPM	Revolutions per Minute
SBR	Sequencing Batch Reactor
TTL	Transistor-Transistor Logic
VAC	Volts AC
VDC	Volts DC
WWTP	Wastewater Treatment Plant

USACE: '. DISTRIBUTION

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USA Berlin
ATTN: DEH (9)
Allied Command Europe (ACE)
ATTN: ACSGEB 09011
ATTN: SHIHB/Engineer 09055
USASETAF
ATTN: AESE-EN-D 09019
ATTN: ACSEN 09168
ATTN: AESE-VE 09168

8th USA, Korea
ATTN: DEH (19)
Camp Page 96208-5000
ATTN: EAFE-PA
Taegu 96218-5000
Western Corridor 96251-5000
ATTN: EAFE-WC
Pusan 96259-5000
ATTN: EAFE-PU
Camp Humphreys 96271-5000
ATTN: EAFE-HU
Cmd, Director 96301-5000
ATTN: ENJ
Fac Engr Activity 96301-5000
ATTN: EAFE-C
FEAK 96301-5000
ATTN: EAFE-E
Plans & Programs 96301-5000
ATTN: EAFE-P
Dir OMA 96301-5000
ATTN: EAFE-O
2nd Infantry Div 96301-5000
ATTN: EAFE-ID
Yongsan Area 96301-5000
ATTN: EAFE-YO
Combined Field Army 96353-5000
ATTN: EAFE-CF
Camp Carroll 96460-5000
ATTN: EAFE-TA-CC

USA Japan (USARJ)
ATTN: DEH-Okinawa 96331
ATTN: DCSEN 96343
ATTN: HONSHU 96343

416th Engineer Command 60623
ATTN: Facilities Engineer

US Military Academy 10996
ATTN: Facilities Engineer

AMC - Dir., Inst., & Svcs.
ARRADCOM 07801-5000
ATTN: DRDAR-PSE
Aberdeen Proving Ground 21005-5001
ATTN: STEAP-DEH
Army Matls Technology Lab 02172-5000
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