Automation in a Vegetable Oil Extraction Plant

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ABSTRACT

Based on the experience in erecting an automated extraction plant, this paper discusses why automation is used in an extraction plant, process design and the choice of automation level, the choice of a microprocessor, demands on system hardware, the use of a microprocessor for security control, the cost of automation, maintenance costs for an automated system, and personnel factors when planning to use automation.

INTRODUCTION

Process development in the vegetable oil industry has been quite slow. This has been one reason for the low degree of automation in this field.

Microprocessor-based instrumentation systems have today, however, become more and more popular for control of the processes in vegetable oil plants.

Most of the discussions in this paper will be directed toward the aspects which affected the choice of automation of the extraction plant erected at Raision Tehtaat, description of the selected microprocessor system and experiences with it.

PROCESS AUTOMATION SYSTEM

An automated process plant, shown in Figure 1, is divided into three sections: process, automation system and operator.

An automation system is further divided into sections, as shown in Figure 2. The sections are measurement, signal conditioning and calculation, information, operation and controls.

By the time process automation systems have been developed, the technologies applied in them have been changed and modified many times. Hydraulics, pneumatics, electrics and electronics have been used. Each of them has had their own point in time when they have been forced to produce technologies applying more efficient, more reliable and more cost-effective systems. Today we are changing over to memory programmable, digital, microprocessor-based and distributed systems.

However, hydraulics, pneumatics and electrics offer in certain cases clear advantages and will have their limited significance in the future also. In Table I, life periods of different technologies applied in process automation systems are shown.

In Figure 3, the applicability of technologies in different sections of automation and estimated development trends for them are shown.

Process application determines the basic requirements for the automation system and the systems to use can be decided accordingly. Thereafter, the decision is affected by extent, complexity, possibilities to connect separate sections, analog/binary relation, safety requirements, reliability requirements, design/operational experiences, and technical/economic evaluation.

Microprocessor-based automation systems have the following advantages and disadvantages compared with other systems.

The advantages are that they are easy to expand and increase automation level, they can be integrated with computer and PLC systems, they can be programmed just before start-up, it is easy to make modifications, there are small

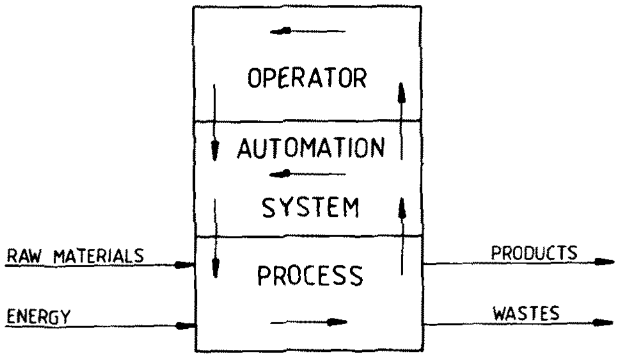


FIG. 1. Automated process.

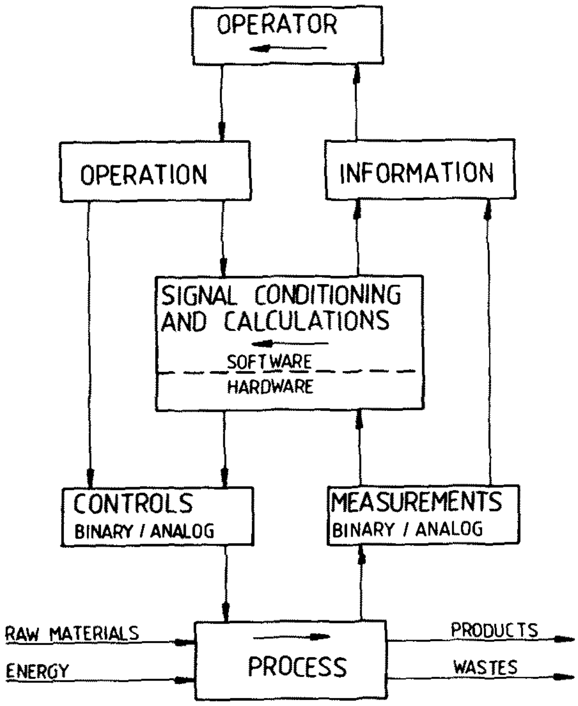


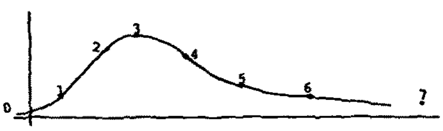
FIG. 2. Process automation system.

TABLE I

Life Period of the Technologies Applied in Process Automation Systems

Applied technology	System development	Main application	Significance decreasing	Limited used
1. Hydraulics	1905-1920	1920-1930	1930-1945	1945-
2. Pneumatics	1920-1930	1930-1960	1960-1975	1975-
3. Electrics	1945-1950	1950-1965	1965-1970	1970-
4. Electronics	1945-1960	1960-		
4.1 Electronic tube	1945-1950	1950-1960	1960-1965	1965-
4.2 Separate semiconductive components	1950-1960	1960-1970	1970-1975	1975-
4.3 Integrated circuits	1965-1970	1970-1980	1980-	
4.4 Microprocessors	1972-1977	1977-		

Automation section \ Applied technology	Hydraulics	Pneumatics	Electronic analogtechnics	Electromechanical - switchsensor	Electromechanical - relaytechnics	Electromechanical - record- and indicator technics	Electronic binary logic	Electronic programmable logic	Digital technics (Process Computers)	Digital technics (μP)	Electrics
ANALOG MEASUREMENT	6	4	3	-	-	-	-	-	-	0	-
BINARY MEASUREMENT	6	5	2	3	-	-	-	-	-	0	6
ANALOG SIGNAL CONDITIONING AND CALCULATION	6	4	3	-	-	-	-	-	2	2	-
INFORMATION	7	6	3	-	-	3	-	-	2	2	-
CONTROL SIGNAL FORMULATION	6	4	3	-	-	-	-	-	K	2	-
CONTROL LOGIC	6	5	-	-	4	-	3	2	K	1	5
SAFETY LOGIC	6	5	-	-	4	-	3	K	E	K	-
ALARM AND INDICATION LOGIC	-	-	-	-	5	-	3	2	K	1	-
OPERATION	Valve, Solenoid valve 6		Pushbuttons, switches Potentio meters, etc. 3						Keyboard Luminouspen etc. 2		-
BINARY CONTROL ACCOMPLISHMENT	6	4	-	-	-	-	-	-	-	-	3
ANALOG CONTROL ACCOMPLISHMENT	6	4	-	-	-	-	-	-	-	-	3



0 Will be used in the future
1 Limited use (increasing)
2 Reasonably widely used (increasing)
3 Generally used
4 Widely used (decreasing)
5 Limited use (decreasing)
6 Used only in special applications
7 Not used
K Used, development trend unknown
E Not used, development trend unknown
\- Not applicaple

FIG. 3. Technologies applied in process automation systems and their development trends.

space requirements, self-diagnostics, complex reports, displays, control and fault control, etc., systems can be developed, redundant systems are possible, distributed hardware structures are available, and the price per loop decreases when the loop number increases.

The disadvantages are that microprocessor-based systems are technically complicated, that specialists are required for design, programming and maintenance, and that small systems are expensive.

The application finally determines how much the following aspects are emphasized in the final choice: reliable function of the system, utilization of the system, capacity of the system, easy maintenance of the system, ease of altering the program, price of the system, and space requirements of the system.

Process

In the following will be presented some reasons which favor a high degree of automation in extraction plants and the principal of our solutions:

- Safety.
- Microbiological security of the meal.
- The number of motors and complexity of interlocking systems.
- Cost of manpower.
- Quality of products.
- Energy conservation and process optimization.

One of the most important applications of the microprocessor-based instrumentation system in extraction plants is to improve plant safety, because fire and explosion hazard of hexane is always present. Because of this and because our extraction plant is located in the center of crowded industry, we did everything we could to improve the standard of safety of the plant.

N-hexane is used as a solvent in the plant. Hexane is explosive when the hexane in the air is between 1.1 and 7.5%. When thinking of safety, the most critical points are start-ups and stoppings of the process. During these operations there are explosive amounts of hexane in the vessels. Because of this an interlocking system has been designed, according to which it is impossible to get the screen belt of the extractor to run unless the inside temperature of the extractor is above 40 C. The extractor is heated by solvent circulation.

The plant is supplied with 17 hexane detectors which are continuously measuring the level of hexane mainly on the ground level of the plant. The security system operates in such a way that if the level of hexane increases above 10% of the lower explosive limit (1100 ppm) the ventilation of the plant will be doubled, i.e., from 10,000 m^3/hr to 20,000 m^3/hr. At the same time, an alarm will be actuated in the control room. In case the hexane content increases further to 25% above the lower explosive limit, a new alarm will be actuated in the control room. If the content of hexane is above 25% for more than 30 minutes, there will be an automatic stoppage of the plant.

There are very strict demands for the microbiological purity of the meal in Finland. Because of this we have to overtoast the product and thus be ready to decrease the protein value of the meal.

In order to ensure that the retention time in the desolventizer/toaster is long enough, a control system has been developed according to which it is not possible to discharge meal from the toaster unless the temperature of the product has been heat-treated for a minimum of 20 min above 100 C.

The automation of the plant has been planned so that all motors can be started and stopped from the operator's panel in the control room. In addition to this, the biggest and most critical motors have local switches.

Figure 4 shows the comparison between a conventional instrumentation system and microprocessor-based instrumentation in the case of our automation level.

It was found that as the number of loops increases, microprocessor-based automation became cheaper than the conventional system when the number of loops was above 50.

In the operation, the cost of manpower has increased rapidly. When automating the process the need for new workers decreases. Because of safety, however, there cannot be less than two persons per shift in the extraction plant.

The vegetable oil extraction process is by nature very slow so that a change of one parameter influences the end-products after several hours. A rapid change of one parameter can, however, damage hundreds of tons of product. When having an automated control system a small disturbance in the process can give an alarm to the operator and thus minimize the economic loss.

The price of energy is so high that when designing a process, energy conservation is very important at every point. Conservation of energy is an optimization between operational costs, quality of products and safety. This optimization can easily be done with a microprocessor-based instrumentation system. It is quite clear that when we get correct and accurate knowledge about the process, this knowledge is used in the computer to minimize the operational costs of the products, to increase the quality of the products, and to increase the microbiological purity, without decreasing the safety of the plant.

Process Design and Choice of Automation Level

When, as in our case, the automation process was designed by the buyer of the plant, good contact with the supplier is needed because automation is an essential part of getting the guaranteed values of the plant. In our project a separate group was formed to determine the goals of automation. The group consisted of: a process engineer from the supplier, a process engineer from the buyer, a system engineer from the engineering division of the buyer, and a plant supervisor. One cannot overemphasize the presence of the plant supervisor in the group because the biggest difficulty is how to transfer knowledge from the system engineer to the user of the equipment.

In Figure 5 is shown a total plant automation system. The highest level is the plant computer for production control and supervision. On the next level are the central control systems for one product line and the lowest level has the controls systems for separate processes.

In our extraction plant, a local control system was selected (one local control panel and three process control units).

In the future, the preparation plant will have its own local system and the two will be connected by a data highway to a central control panel. The higher system will allow process optimization, more sophisticated reports, etc.

A provision is also made to have a plant computer for still more sophisticated production control, supervision and management level reporting.

Description of the Selected Instrumentation System

The selected instrumentation system is a modern microprocessor-based distributed control instrumentation system. The system consists of three digital control and instrumentation units, with analog and multicontrol units and process scanning unit (see Fig. 6). Each unit has a fixed amount of different program modules for the various measuring and control operations.

Program modules in the analog and multicontrol units operate in the same way as corresponding analog instruments. Except for normal instrumentation function, they are provided with a large selection of signal conditioning and calculation functions. The multicontrol unit is also provided with sequence control functions to control discrete

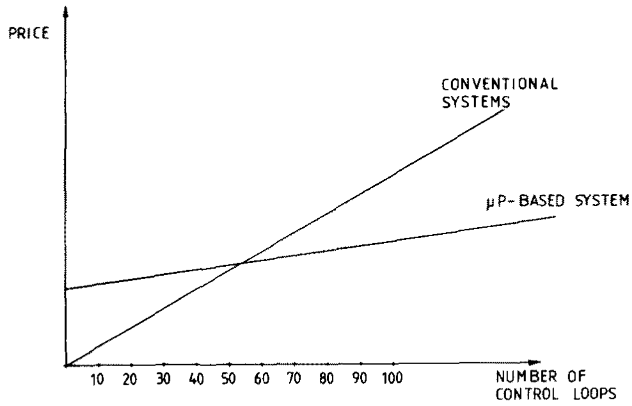


FIG. 4. Price comparison between conventional and microprocessor-based systems.

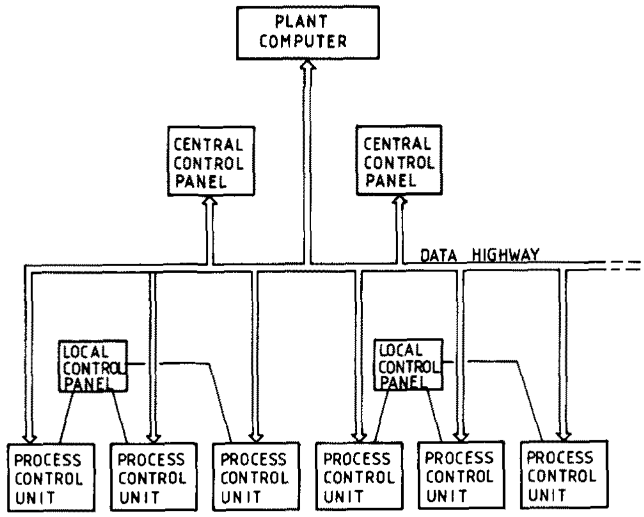


FIG. 5. System hierarchy.

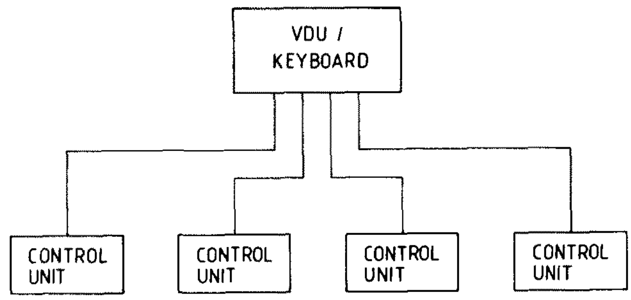


FIG. 6. System build-up.

outputs and to monitor discrete inputs. Binary controls such as motor startings and stoppings, interlocking and other logic sequences can be very smoothly achieved in the system. This way the control and monitoring systems of the process can be integrated. For instance, continuous monitoring of status of all motors is written into the software.

The distributed control unit has internal on-line diagnostics. It checks the operation of interface analog/digital (A/D)-converter-, memory- and control process unit (CPU)- cards and operation of transmitters and sensors (thermoelements).

System Application

Except for all analog measurement and control operations and direct binary controls, the complete interlocking and restarting system of meal processing and conveying is accomplished in instrumentation system software.

The control system of the extraction plant is also connected with the automation of the product silos, where a programmable logic controller (PLC) automatically controls silo selection and all product handling in the silos.

There are 100 analog instrumentation loops in the system, of which 36 are analog control loops. There are three ratio stations, two analog manual control stations and four analog counters. There are 16 automatic on/off-valves, 34 pressure-, level-, temperature- and overload switches and 32 limit switches. Altogether there are 79 process motors, all of which are controlled from the instrumentation system.

Connection with the PLC in the product silos is accomplished by using parallel inputs and outputs. There are three outputs and 18 inputs from the instrumentation system to the PLC.

The whole interface with the process in the extraction plant is accomplished by using intrinsic safety methods so that in no situation is there enough energy supplied in an instrumentation loop to make a spark.

Instrumentation system hardware consists of two videos and keyboards, two multicontrol units, one analog control unit, four 3-line recorders and a printer. There is also one programming unit, the engineering console, in use (see Fig. 7).

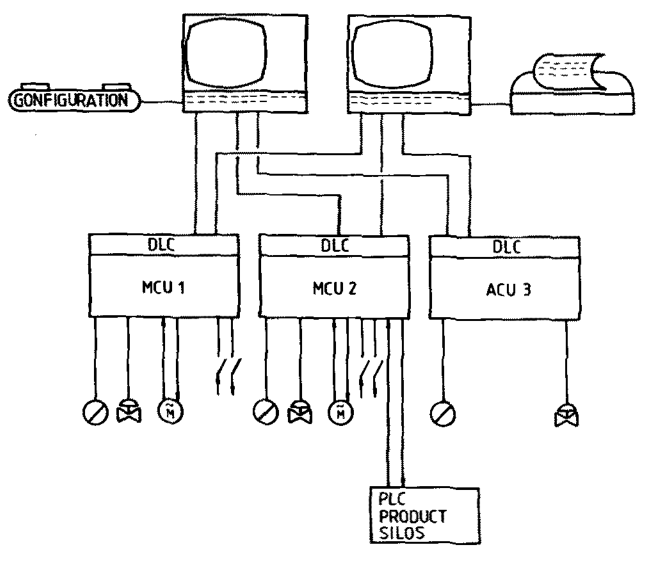


FIG. 7. Instrumentation system hardware.

Outside the actual instrumentation system there is a separate alarm center and hexane detecting system. The operation of all motors is shown in the mimic diagram.

In system engineering, every single analog loop will be designed in software and displayed in the visual display units (VDU). For every analog measurement there is reserved and tagged one analog input module. A wiring loop diagram for this kind of loop is shown in Figure 8. Operation of every module is selected according to input signal and engineering unit. Loop display location in the VDU is also selected here.

For an analog control loop there is reserved one analog input, one analog control and one analog output module. Loop display location is selected in the control module.

According to selected control parameters, a control module works as PID controller, step-controller, batch controller, or as any other kind of controller. An analog output model is used to forward a control signal (4-20 mA) to the actuater or converter. A loop diagram for an analog control loop is shown in Figure 9.

For every binary input there is reserved and tagged one control input module. The system checks potential free contacts every second with a 24 VDC pulse. The contact state can be displayed.

Motor controls are throughout in the system. Motors are started and stopped using system keyboard and small software sequences. Step modules in the sequence modules control the contact output module. There is also one contact input module for every motor. Safety modules are checking contact inputs and outputs all the time and if there is any difference, the system will display an alarm and start an interlocking sequence. A motor control loop diagram is shown in Figure 10.

On/off-valves are controlled in the same way as motors. Both open and closed limits are checked.

Interlocking sequences are accomplished on two levels. Interlocking conditions are checked with continuously running sequences, where stop modules are doing the actual testing and starting the interlocking sequences as shown in Figure 11.

The principal of the interlocking system is: sequence A monitoring interlocking conditions is running continuously. When an interlocking condition is noticed in a step – e.g., motor fault, overload situation, etc. – the step starts separate interlocking sequence B. The interlocking sequence runs once through according to predetermined interlocking system, that is sequence B from a to c. When the interlocking sequence has gone to the end it stays passive and waits for a new start from monitoring sequence A.

In case sequence A has been started because of some normal process conditions such as change of product silo where product is conveyed, sequence B goes only to a predetermined step. Sequence B then waits for accomplishment of restarting conditions, i.e., empty product silo has been started, and starts the motor, which has been stopped before, according to restarting order. This is in sequence B from a to b.

Monitoring sequence A is also used for controlling automatic sampling units, updating totalizers, etc. The sequence is also controlling some analog control loops. If, for instance, a pump running extract to a heat exchanger breaks, temperature control will be changed to manual and the steam valve will be closed automatically.

INSTRUMENTATION HARDWARE

Classification of process, control and marshalling rooms was done together with company management and authorities (electrical safety rules and standards) before purchasing any instruments. Process area was classified as explosion hazard

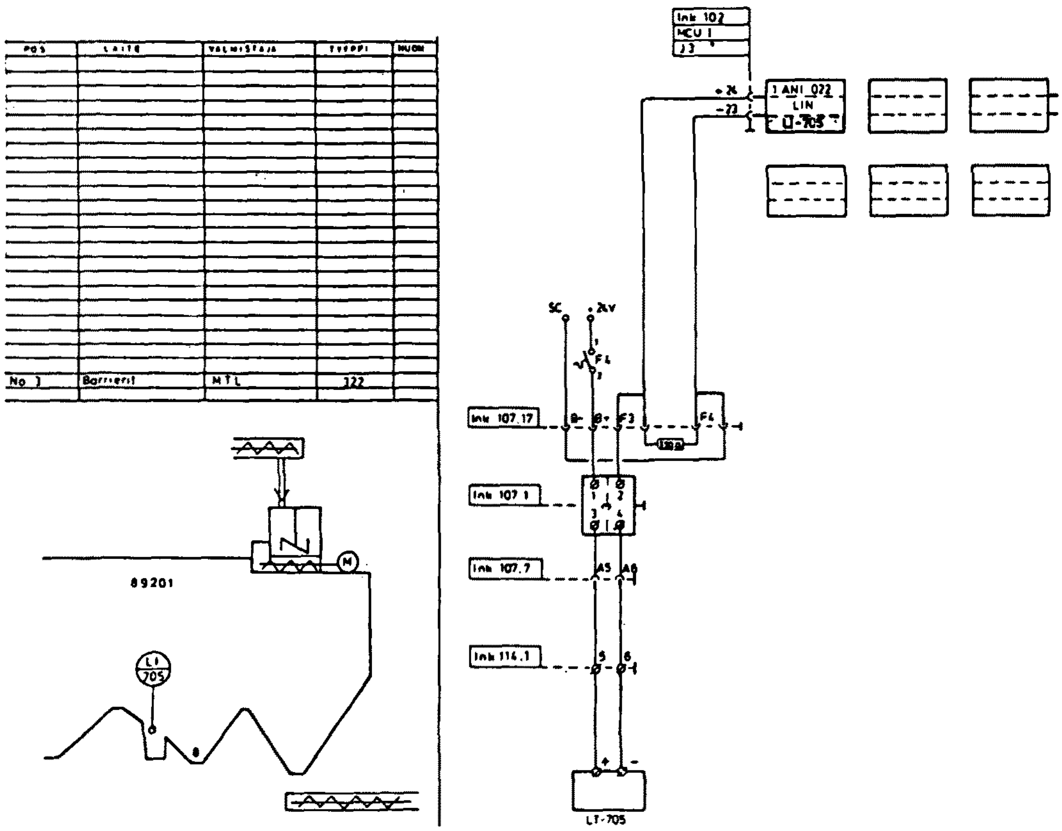


FIG. 8. Wiring diagram of an analog input loop.

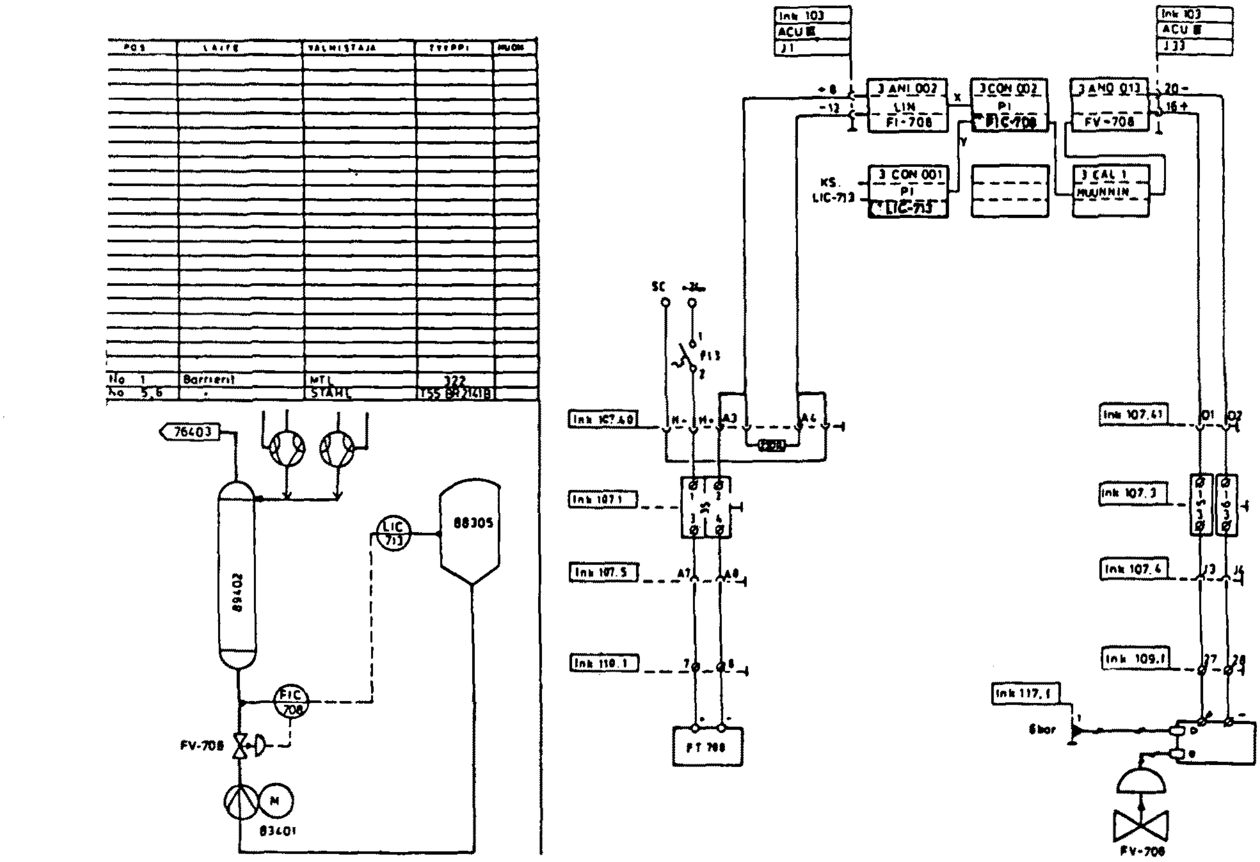


FIG. 9. Wiring diagram of an analog control loop.

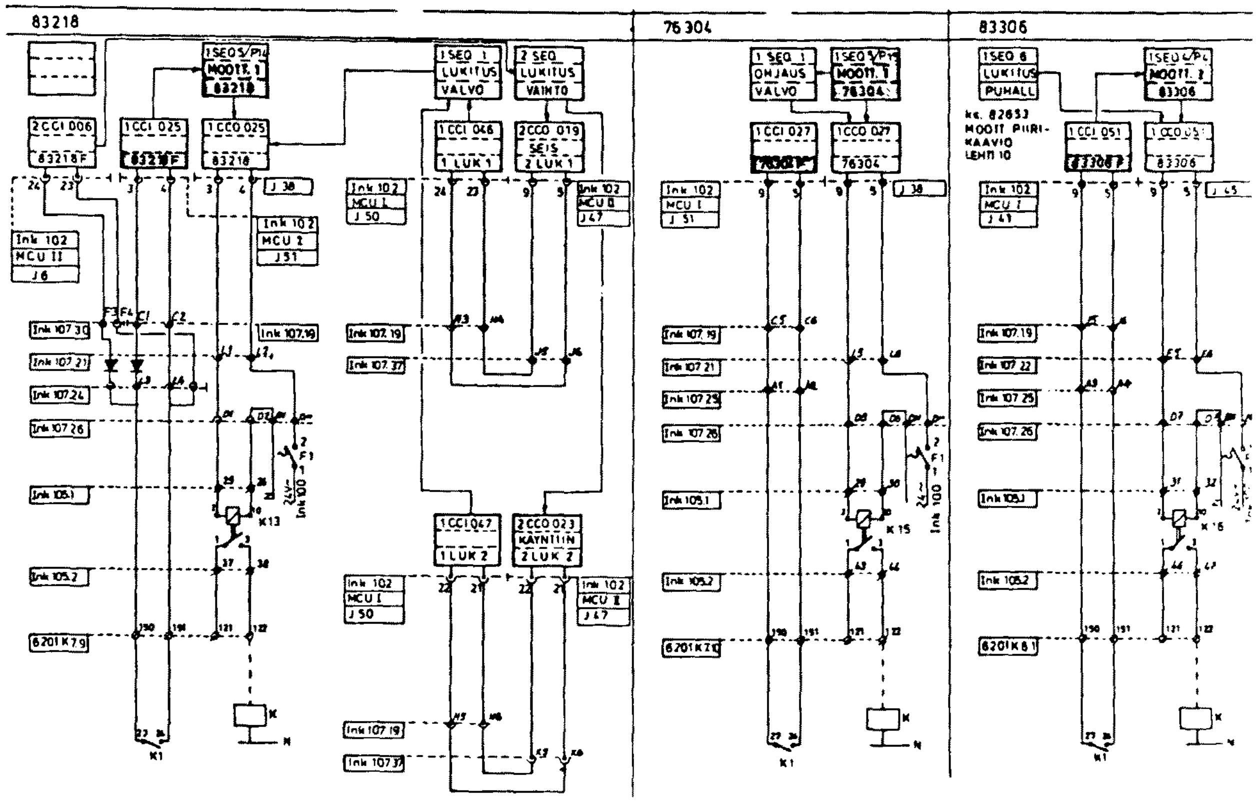


FIG. 10. Wiring diagram of a motor control loop.

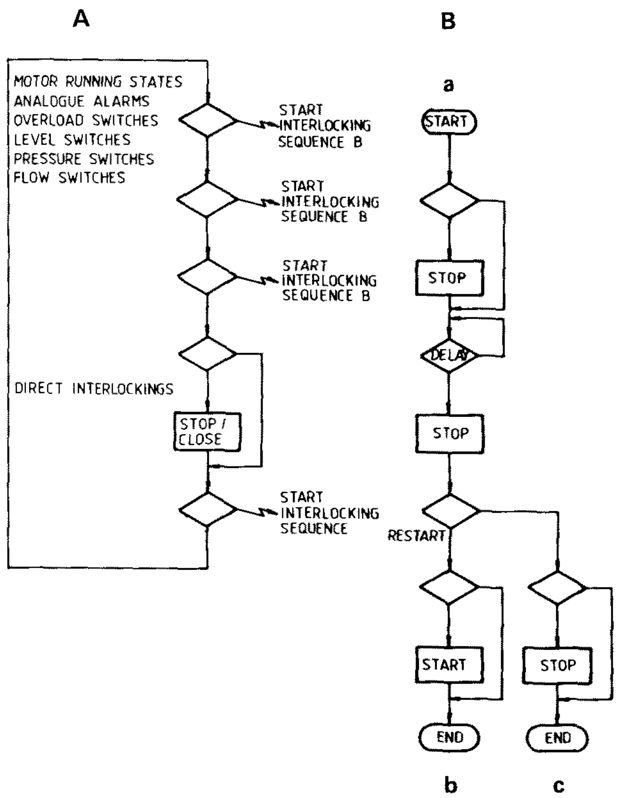


FIG. 11. Interlocking system.

area. Control and marshalling rooms were classified as areas for protective ventilation.

The decision that the process will be controlled and supervised from the control room by a microprocessor-based instrumentation system was also made before purchasing. All auxiliary instruments were specified to be located in the marshalling room, where also Exi-protection of field instruments was to be done by safety barriers.

The following criteria were used in the choice of the hardware:

- To have unified instrumentation hardware.
- To have instrumentation hardware to suit the company's old instrumentation hardware to minimize maintenance, training and spare-part costs.
- Electrical hardware to accomplish accurate measurement and control.
- The whole instrumentation should be purchased together to increase overall responsibility of the supplier.
- Only well known suppliers should be considered.
- Selected instrumentation should be most economic when considering purchasing, maintenance, training and spare-parts.
- Field instruments must be classified as intrinsically safe (Exi). If Exi not available then Exd. The supplier must be able to certify that the instruments are classified and approved.
- The instruments had to be supplied with following documents: installation instructions, operation instructions, maintenance instructions, and spare-parts lists, both in the original language and in Finnish.
- The instruments had to comply with Finnish laws, rules and standards.
- Supply voltage to the field instruments was 24 VDC, if not possible then 220 VAC.

- The instruments had to have the standard signal, 4-20 mA.
- The process connections according to the DIN-standard.

Example: Choice of an Instrument

Pressure- and pressure-difference transmitters:
span adjustable -10% to +80%
zero adjustable -90% to +10%
static and overpressure limits -0.1 to 10 MPa
static pressure effect (maximum range) ≤ 0.2%/maximum static pressure
output signal 4 to 20 mA, linear to input signal
two-wire system
accuracy ≤ 0.25% of calibrated span
load limitations 0 to 450 Ω and 24 VDC
hysteresis 0.05% of calibrated span
repeatability 0.05% of calibrated span
damping time constant must be adjustable
temperature limits
sensing element - 40 to +120 C
amplifier -30 to +100 C
temperature effect ≤ 0.25%/50 C
intrinsically safe Exi PTB approval
materials of construction flanges and adaptors drain/vent valves isolating diaphrams AISI 316 stainless steel

COST OF AUTOMATION

The project was completed as a large addition to existing facilities 1979-80. The percentages of the components were as follows:

purchased equipment (installed)	43.9%
piping (installed)	15.9%
building (including services)	14.4%
instrumentation and automation (installed)	10.6%
electrical (installed)	6.6%
engineering	6.5%
sprinkler system	1.6%
yard improvements	0.5%

The project was started in fall of 1979 and completed in fall of 1980. In the decision-making period, the rate of planning of automation was very low. Microprocessor-based automation gives, however, a lot of flexibility in the time-schedule. In our case, almost all the hardware was ordered long before completion of the design. In a lower degree of automation the design must be ready before ordering hardware.

The maintenance costs of automation in the first year were 2.4% of the total operational costs in the extraction plant. In the second year, the percentage is supposed to be 1.0. A percentage of 2.4 is quite high, but one main reason is that the amount includes training of maintenance personnel. The program also had to be changed a little after having some experience with processing.

We began the training of the operators parallel with the erection of the plant, i.e., one year before the start-up. During the commissioning period it was found that it was easier for younger people to adapt the new technology.

Because of human factors, the startings and stoppings of the plant took quite a long time, longer than the old plant, but today nobody in the plant would be willing to decrease the level of automation.

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