

Modernization of Control System for Enzymatic Hydrolysis

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Abstract: - This paper describes new computer system for measurement and control for laboratory system for recycling chromium from tannery waste. The system is used for research and verification of unique chromium-recycling technology based on enzymatic hydrolysis developed at our institute. As the original control equipment became outdated, it was necessary to rebuild the technology with modern means of automatic control. This paper introduces the whole system for chromium recycling with focus on the control structure of the most important parts of the technology. The development and implementation of a new computer control system is described, from choosing the devices to final activation.

Key-Words: - Tannery waste, Chromium, Advantech, Control Web, Saia, Hydrolysis

1 Introduction

Chromium still remains the most used agent for hide-tanning in tanning industry even though one of its variants – hexavalent chromium - is highly toxic and is proved to cause cancer. Attempts to find substitute that would give comparable results as to the quality of the product and production costs were not successful so far and thus it seems unlikely, that in the near future chromium in tanning industry would be replaced [10]. Therefore it is important to develop methods for disposing of the waste containing chromium.

The amount of waste in tanning industry is very high. Only about 20 per-cent of raw hide is transformed into the final product; the rest being waste in various forms. The portion of this waste which contains chromium presents great burden for the environment and in the result, due to the cost of disposal, significantly affects the effectiveness of the production. As already mentioned, it seems unlikely that chromium in the tanning process will be replaced and therefore it is useful to look for options of effective disposal of chromium containing waste or, even better, methods for recycling chromium from this waste. The main problem nowadays is not the technological solution to recycling chromium from the tannery waste, but the economical side of the problem. It is required that the process is as effective as possible. At our institute a method was proposed for hydrolyzing chromium waste which produces relatively expensive protein hydrolyzates and also chromes sludge [1, 7]. If any new method is to be

successfully implemented in industry it needs to be optimized in the means of investment and operating costs. For this reason the method is realized in small scale in our laboratory. Recently, when the laboratory was moved into a new building it was it decided to completely upgrade the equipment of this laboratory with new control system.

2 Problem Formulation

Enzymatic hydrolysis appears to be the best method for processing chromium-containing tannery waste both from the economic and ecologic point of view. This technology yields protein hydrolyzates that contain virtually no chromium while the dose of expensive enzyme is less than 1% and the filter cake can be recycled.

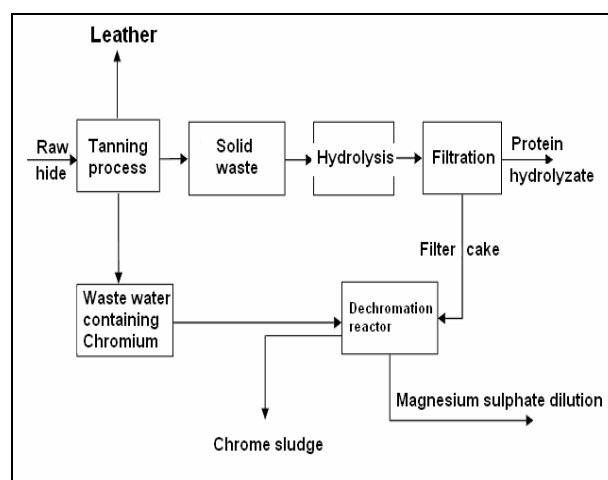


Fig. 1 Principle of the technology

Technology for this process is realized in our laboratory. The complete process for tannery waste recycling can be divided into four workplaces that we named as follows: fermentation, filtration, evaporator and dechromation. The principle of the method can be seen in Fig. 1.

First step of the process is chemical reaction in bioreactor (fermenter) – hydrolysis [2]. Product of this reaction is then filtered and the resulting filtrate (which is valuable protein hydrolyzate) is dried in under-pressure evaporator. Filter cake which contains magnesium hydroxide (material used in enzymatic hydrolysis), reacts in the dechromation reactor with tannery waste water (spent liquor) which contains chromium. As a result the waste water is freed of chromium and moreover the chromium thus obtained can be used in other industrial applications.

In this article we will focus on the new control system for this technology.

Because the equipment in the laboratory has been built over a period of years and many of the original devices became outdated, it was decided to rebuild the laboratory with new means of automatic control. The aim of the modernization was to equip the laboratory with modern computer systems and other means of automatic control. The equipment was to be chosen not only with regard to technology but also so that it can be helpful for demonstrating automatic control equipment to students of our university. The aims for modernization were defined as follows:

- Modern computer technology for the computers that control the technology
- Intelligent sensors whereas useful
- Connect components using industrial buses
- Connect the technology with supervising system
- Use modern programming equipment with visualization

In the following text the solution we implemented will be described.

3 Control System

Scheme of the complete technology from the point of view of the control equipment can be seen in figure 2. The whole technology in the laboratory is divided into five workplaces, four of which are directly connected with the technology and one is supervising. The conception is based on distributed structure with a supervising computer on top, connected with the workplaces by industrial Ethernet and alternatively also using Wi-Fi or GSM.

The main components of the system are based on devices manufactured by Advantech [4]. At the top level an industrial personal computer is used. This computer should work as a supervising place from which it is possible to watch all the technology in the lab. However, it should also be able to control any of the workplaces directly [5].

The supervising computer is connected with the workplaces via Ethernet network which is implemented using Industrial switch Advantech ADAM 6520-B.

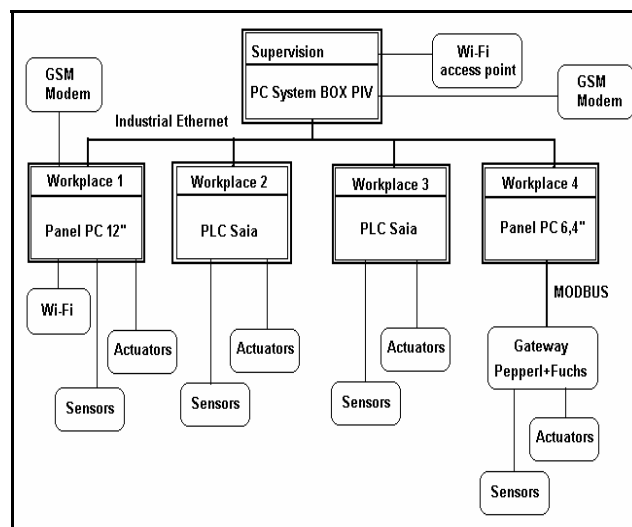


Fig. 2 Scheme of the whole control system

The dechromation workplace is also connected via wireless network – the central computer creates access point and the workplace can connect to this access point. The computer at the dechromation workplace as well as the central computer are further equipped with GSM modem, so that it is possible to demonstrate also this communication option in practical application. In the following sections the equipment of each workplace will be described in details.

3.1 Fermentation workplace control system

For the control of the fermentation workplace we use programmable logic controller (PLC) SAIA PCD2 manufactured by SAIA-Burgess Controls. It is compact controller with central unit and up to 8 input/output modules. For the control of the fermenter the following three modules are used:

- PCD2.A400 – binary output module with 8 outputs with transistors.
- PCD2.W200 – analogue input module with 8 channels, 0-10V, with 10-bit resolution.

- PCD2.W315 – analogue output module with 7 channels, 0(4) - 20 mA, with 12-bit resolution.

Temperature sensor from the old version of the equipment was retained, which is a Pt100 platinum sensor. The pH sensor is new, with 4-20 mA output connected directly to the PLC.

The PLC is connected with the supervising computer via RS232-Ethernet converter ADAM 4571. This converter allows the PLC to communicate using RS232 serial line as if it was connected directly to the serial port of the PC even though it is in fact connected via Ethernet. The principle of this can be seen in figure 3.

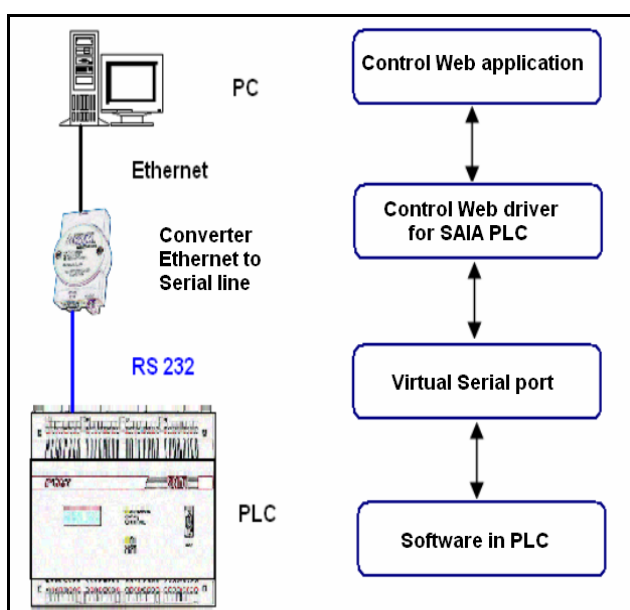


Fig. 3 Principle of connection between PLC and PC

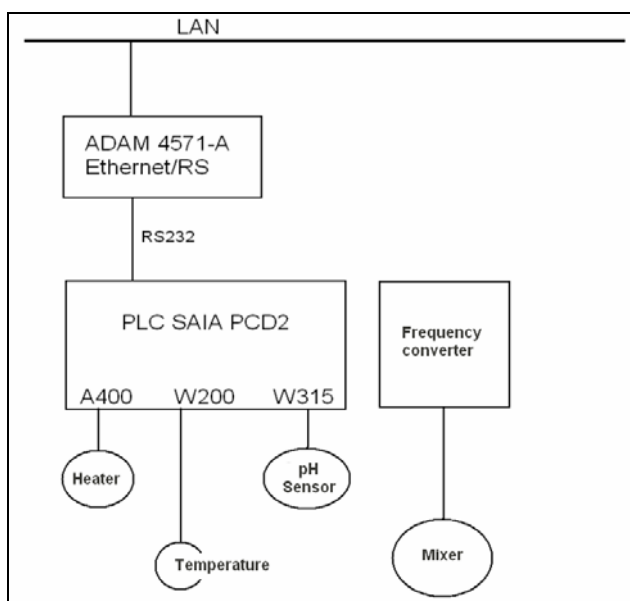


Fig. 4 Scheme of the fermentation control system

Simplified scheme of the control system can be seen in figure 4. Figures 5 and 6 then depict the control board with PLC and converter and the whole workplace respectively.

For the temperature sensor and output (heater control) there is a converter box which performs necessary conversions of voltage and power levels and also allows basic manual control of the process. The PLC can work as a stand-alone control unit or it is possible to control the workplace from the supervisor computer where the PLC acts only as an input-output unit.



Fig. 5. Board for fermentation workplace



Fig. 6. The fermentation workplace

3.2 Filtration workplace control system

The control system for filtration workplace is very similar to the system used for fermentation. It also uses SAIA PCD2 PLC which is connected to the Ethernet via Serial-To-Ethernet converter ADAM 4571. Scheme of the control system can be seen in fig 7.

At this workplace the original temperature sensors which are built-in into the filtration funnel were retained but a new converter was created which converts the signal levels from sensors to unified 0-10V signal required by the PLC input modules and also provides power output for heater in the funnel. The stirrer is currently controlled manually but the converter box includes simple D/A converter which will be used to control the speed of the stirrer in 8 steps using three binary outputs from the PLC.

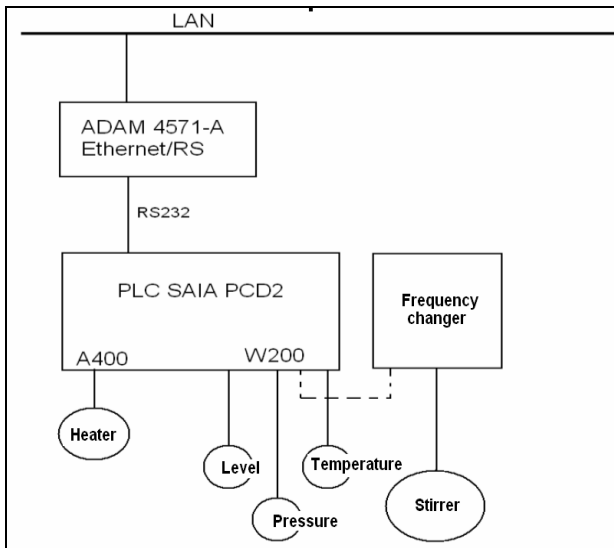


Fig. 7 Scheme of the filtration control system

3.3 Evaporator workplace control system

Workplace 4, evaporator, is controlled by Advantech TPC650T-CE panel PC with 5.7-inch touch screen and Windows CE operating system. Main features of the panel PC include Intel Pentium 266 MMX CPU with 32 MB DRAM, touch screen and support for Compact flash memory cards. For communication the computer is equipped with one PC/104 slot, Ethernet port, PS/2 port for mouse and keyboard and 2 serial ports, one of which can be configured to run in RS422 or RS485 mode.

The sensors and actuators are connected with the computer via modular system made by Pepperl+Fuchs which includes gateway KSD2-GW2, relay modules KSD2-GW2 and analog input modules KSD2-CI-2. The analog modules can be used to connect sensors with current output 4-20 mA or smart sensors which support HART protocol. The gateway communicates with the computer via RS 485 line using MODBUS protocol and with the input/output modules using CAN protocol.

Figure 8 shows the schematics of the control system of the evaporator workplace. As can be seen in the figure, the technology requires measurement of pressure and temperature and control of a heater and

a small engine for rotating the ballon. These requirements dictated the number and types of the modules connected to the gateway. Of course other modules can be easily added. At the lowest level we use sensors with 4-20mA output.

Figure 9 shows the real control system and figure 10 then a test program running on the panel PC.

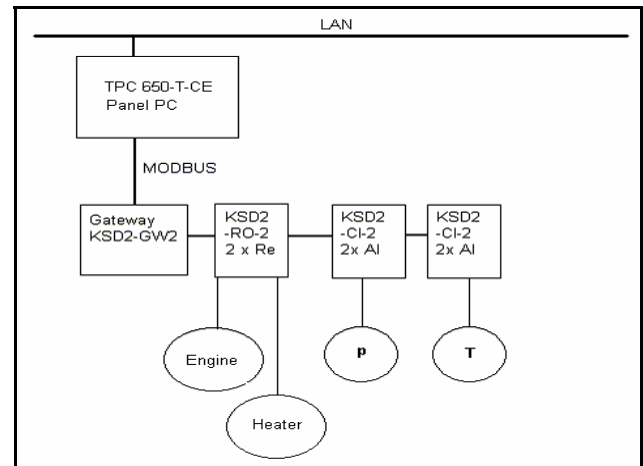


Fig. 8 Scheme of the evaporator control system

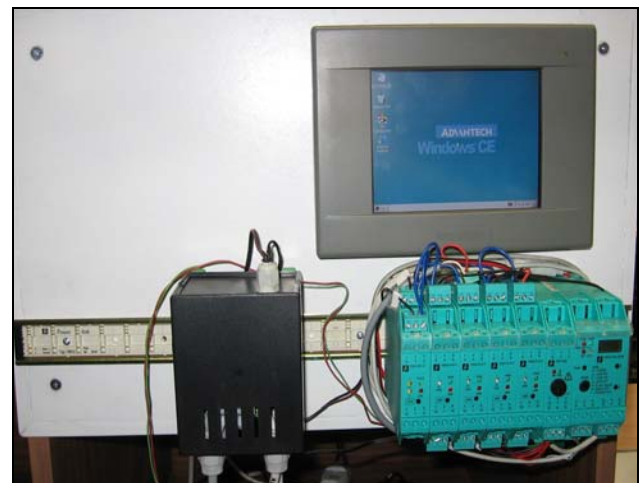


Fig. 9 The evaporator control system



Fig. 10 Main window of a test program running on the TPC-650 panel PC.

3.4 Dechromation workplace control system

In Fig. 11 the technological schema of the dechromation workplace can be seen. The process works as follows. Suspended filter cake obtained at filtration workplace is transported from tank S3 to filter press FP. After filling it, the tank M is filled with waste water. The water is then circulated through the filter press until concentration of the chromium in the waste water drops below level where it is cheaper to precipitate the residual chromium using alkali. The necessary amount of alkali is then measured from tank S2.

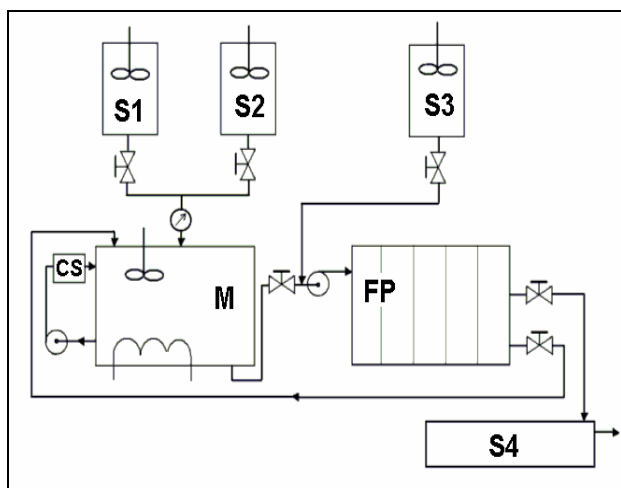


Fig. 11 Technological scheme of the dechromation

Fig. 12 shows the schematics of the control system of the dechromation workplace. At the heart industrial panel PC Advantech PPC-L126T-R70 is used. This computer with 12" touch screen and Windows XP operating system allows comfortable control and visualization of the technology directly at the workplace. The computer is equipped with Via processor at 667 MHz with low power consumption and passive cooling which promises maintenance free operation for long time. To connect the computer with the technology, we use Advantech ADAM modules. These modules form a RS 485 bus that is connected to the RS323 port of the panel PC through RS 232/485 converter ADAM 4520.

Based on requirements of the technology the following ADAM modules are used on the RS 485 bus:

- Digital output module ADAM 4056S – to control the actuators such as solenoid valves and pump. The module provides 12 outputs with open collector only, so the actuators are actually connected to a relay box controlled by the module.

- Analog-input module ADAM 4017B – used for sensors with current or voltage output.
- Input counter module ADAM 4080-D to connect flow meter.
- Converter module ADAM 4521-A (RS 232/485) used to connect intelligent color sensor to the RS 485 bus.

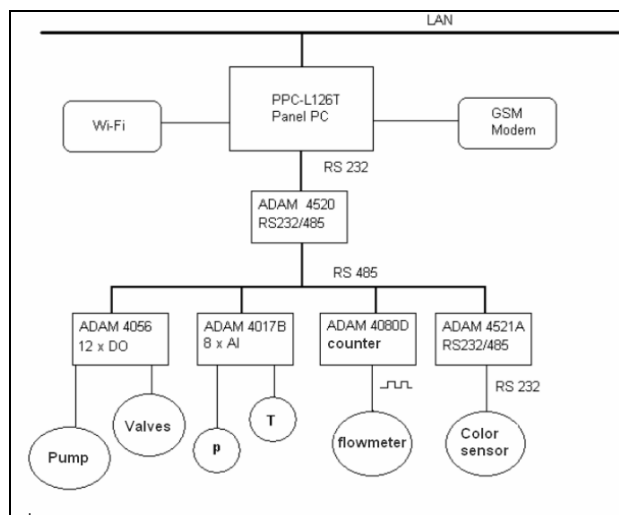


Fig. 12 Scheme of control system for dechromation



Fig. 13 Filter press workplace – side view



Fig. 14 Filter press workplace – front view

For measuring temperature in the tank and pressure in the filter press sensors with 4 to 20 mA current outputs are used. Special attention deserves sensor of color. Color of the spent liquor circulating through the filter press is used as a measure of the chromium concentration. We use intelligent sensor HSDC16 which communicates with the computer via serial line and sends the color values directly in RGB [3]. This sensor is described in detail in the next paragraph.

Figures 13 and 14 depict the dechromation workplace in the laboratory. The filter press itself can be seen in front.

3.4.1 Color sensor for the dechromation system

An important component of the dechromation system is a sensor which determines the concentration of chromium in the waste water which circulates through the filter press. In this place a colorimetric sensor seems to be good option. Colorimetry is a way of measuring a concentration of certain element in a solution based on the change of color which different concentrations of this element cause. Various options for sensing the color change can be used, for example it is popular to use a web camera and obtain the result by processing the image from this camera in special software. We decided to use a dedicated color detector HSCD16 made by m.u.t. GmbH Company based in Germany [9]. HSCD16 is a high speed detector system for precise color detection in fast sorting processes. Up to 16 colors can be pre-set with a build in "Teach mode". The HSCD16 is based on RGB-color detection. The detection process can be easily started with a trigger signal or via the build in RS232 interface from any external device. The detection process and the "good/bad" evaluation is extraordinary fast and precise.



Fig. 15 HSCD16 color detector

The manufacturer suggest wide range of possible applications for the HSCD16 sensor in many industries e.g. sorting of blood sample tubes in clinical laboratories, any sorting or separation processes based on color detection such as manufacturing, quality assurance etc. Main features of the detector are summarized in the following table.

Wavelength range	400 nm – 750 nm
Focus (distance from housing)	17,2 mm
Intensity	1,4 mW (at 400 nm)
Speed	
Maximum color measurements:	880 per second
Maximum color comparisons:	
With 1 taught color	660 per second
With 2 taught colors	520 per second
With 8 taught colors	240 per second
With 16 taught colors	135 per second
Interfaces	RS232
Dimensions	2 modules: sensor module / CPS module (power supply)
	Sensor: 100 x 107 x 63 mm, approx. 430 g CPS: 104 x 104 x 30 mm, approx. 260 g
Power supply	8 - 30V (typ. 24V)
Consumption	4 W

Tab. 1 Technical data of the color detector HSCD16

The sensor can be seen in the scheme of the technology as "CS", see fig. 11. Sensor is connected to a pipe on a side of the tank M and the liquid is circulated through the sensor with a small pump, as can be seen in the picture, measuring the color of the liquid continuously. But because the sensor is manufactured for different kind of operation an adapter was needed to make the liquid flow in the focus of the sensor. This adapter also closes the measuring environment from ambient light so that the results do not depend on the light conditions of the room. The sensor has its own light source. The adapter we have constructed can be seen in figure 16. The core of the adapter is a glass pipe 3, which makes the liquid flow in the focus of the sensor. The

frame of the adapter consists of plastic tube 1 and two lids 2. There is a slit in the tube which allows it to be attached and fixed to the body of the detector 5 and a special part 6 which defines the position of the adapter on the sensor body, so that the focus is properly adjusted. Also there is a small mirror 4 from aluminum plate which proved to be necessary for the sensor to work properly.

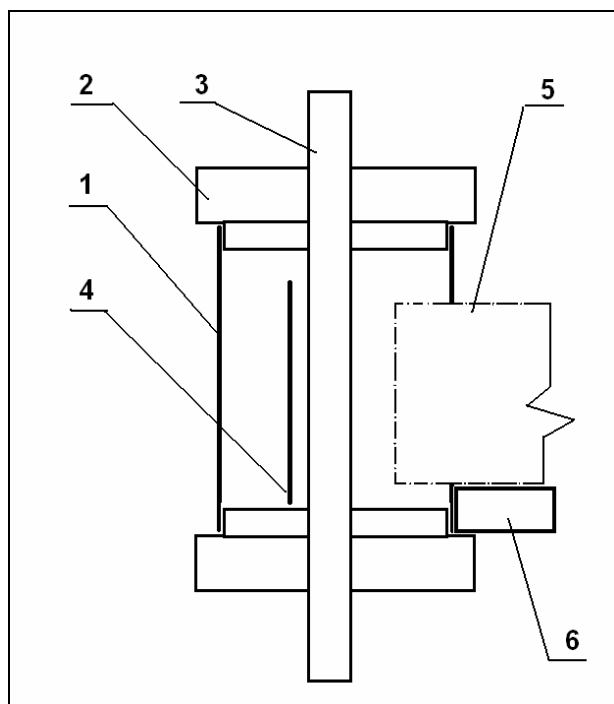


Fig. 16 Scheme of the adapter for colour sensor

Picture of the colour sensor with the adapter attached can be seen in figure 17.



Fig. 17 Color sensor with the adapter attached

As mentioned earlier the color sensor is equipped with RS232 serial interface. It can be connected to the RS485 bus with other sensor modules via RS232 to RS485 converter but for easier debugging it is currently connected directly to the control computer of the workplace (panel PC). It communicates using simple text commands, so it is quite easy to develop custom programs which make use of the sensor by sending and receiving text over the COM port. In case of the software system Control Web, which we use, there is a driver for this kind of communication which is used in the control application. For the purpose of testing the sensor we used utility program supplied by the manufacturer of the sensor. This program called HSCD16 Control makes it possible to set all the features of the sensors such as teaching colors and automatic measurement and also allows saving of the measured values.

To obtain some idea about the sensitivity of the sensor we performed simple measurements with water and ink solutions of different colors. Water colored with small amount of ink was filled into the pipe of the sensor and measured value was read. Obviously this way we could not get any absolute results, but we obtained basic idea about sensitivity of the sensor and reproducibility of the measurements. Some of the results can be seen in table 2. Please note that the RGB values above are in the range 0 to 999 as returned by the sensor, which is in contrast with the most widely used range of 0 to 255.

The solutions were prepared by mixing ink with water.

For each color 200 ml of water was mixed with ink as follows: Brown 0.2 ml sepia brown ink; Blue 1: 0.2 ml ultramarine blue ink. Blue 2: blue 1 + 0.2 ml ink; Blue 3: blue 2 + 1 ml of ink; Yellow 1: 0.6 ml yellow ink; Yellow 2: yellow 1 + 0,4 ml of ink; Yellow 3: yellow 2 + 3 ml of ink. Several measurements with each solution were taken to evaluate the reproducibility of the results. As can be seen from the table, the values returned by the sensor for the same colors are very similar, so the sensor seems to provide very good results with enough sensitivity for our purpose.

Even though by these simple experiments we could not obtain any absolute results, the sensitivity and reproducibility of measurements with the sensor was asserted. However, the final conclusion can be made only after the color detector is used in the technology, which is in progress now.

Solution	Measured value		
	R	G	B
Empty sensor	517	504	454
Clear water	972	980	978
Brown1	859	508	252
Brown 1	847	502	248
Blue1	533	458	678
Blue1	533	458	674
Blue 2	499	423	660
Blue 2	498	422	658
Blue 3	407	325	587
Blue 3	407	325	588
Clear water	969	977	976
Yellow 1	969	977	839
Yellow 2	970	978	707
Yellow 3	970	979	370

Tab. 2 Results of tests with the sensor

3.5 Supervising computer workplace

The last of the workplaces is the supervising computer workplace. The computer is located near the technology and communicates with the lower-level computers that are connected directly to the technological process at each workplace.

As a supervising computer industrial PC made by Advantech is used, type BOX PIV. Configuration of this computer is sufficient for the intended purpose: Intel Pentium 4 processor at 3 GHz, 512 MB RAM, 160 GB hard drive and operating system Windows XP Professional. Its 19-inch display provides enough space for visualization and there is also a printer available at the workplace. The computer is equipped with two network cards, one for connection with the other workplaces and one for connection to the Internet. There is also wireless access connected via USB port so that the computer can communicate with the other workplaces via Wi-Fi network as well.



Fig. 18 The supervising workstation

Currently, only the panel PC at dechromation workplace is connected this way. As mentioned earlier, it is also planned that the computer will be equipped with GSM modem to allow this way of control of the process as well.

Picture of the supervising computer can be seen in figure 18.

3.6 Program equipment

This section describes the software used for the control system. Even the best hardware cannot perform satisfactorily without proper software, so the choice of software is not less important than the choice of computers and sensors.

Due to variety of devices and need of flexibility in the programs, we chose Control Web development system as the main platform in which to create the software for the technology. Control Web [8] is a RAD (Rapid Application Development) system which allows easy development of control systems running in real time with visualization. Main advantage of such a RAD system is that the application is developed by putting together existing components and parameterizing them instead of writing all the required code from a scratch in lower level programming language. This makes the development easy and quick. Another advantage is that the programs are platform-independent – they run in Control Web runtime and thus can be utilized on any computer platform which Control Web supports. Although currently only Windows operating systems are supported, it already brings the benefit of virtually the same method of developing applications for Windows XP and Windows CE systems, which are both used in the laboratory, and in the future if Control Web adds support for other systems, e.g. Linux, the applications will be able to run on Linux-based devices as well.

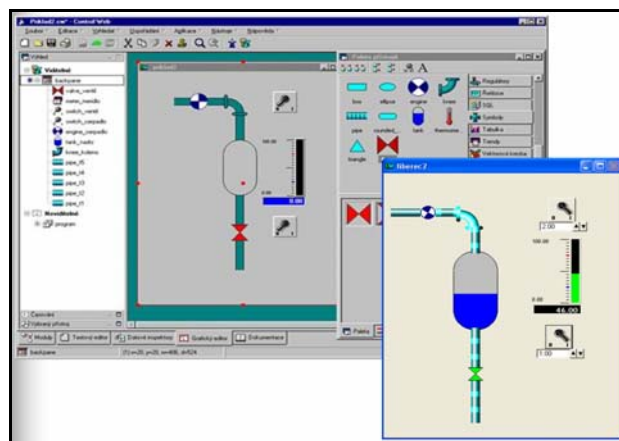


Fig. 19 Control Web development environment

Figure 19 shows the development interface of Control Web system together with a simple demo application which was created in the system. In the right-hand side of the main window a component library can be seen. This library contains the building blocks of any Control Web application, such as displays, switches, etc., which are ready to use.

Control Web supports many devices (PLC, I/O cards, etc.) by means of special drivers. The driver is a library of routines provided either by the manufacturer of the device or by Control Web manufacturer and it allows the applications in Control Web access any device in a universal manner – via driver object which provide input and output channels. This way an application can, for example, set high digital output pin by writing 1 to the appropriate channel of a driver in the same way no matter if the pin is on a I/O cards of different manufacturers or even for a PLC.

Let us now describe the software for each workplace in our laboratory. For the evaporator workplace, where small panel PC with Windows CE operating system is used, we utilized Control Web 2000 with Windows CE runtime builder and Modbus driver for Windows CE.

Figure 10 earlier in this article shows the main window of a simple test program for manual control of the evaporator workplace running on the TPC-650 computer with Windows CE operating system. The program allows viewing of four input values and controlling two outputs through relay modules. The final program will include visualization of the measured values and also support for communication with the supervising computer via Ethernet.

For the most complex workplace - dechromation we use Control Web 5 runtime with Advantech Adam drivers. In the following figure main window of the application for control of the dechromation workplace can be seen. In the next figure the program can be seen running on the control computer at the workplace. The program provides several tabs (windows) for different levels of control of the technology.

The most complex window of the application is shown in the figure 20. It is the user interface for manual control of the system, which allows switching on/off individual components of the technology, such as solenoid valves or pumps and also viewing of the measured variables such as temperature in the tank, pressure in the filter press and the color of the liquid read from color sensor.

It is also possible to control the technology at the level of technological phases, such as filling the

filter press with filter cake, circulating the waste water through the filter press etc. In another window it is also possible to review the history of the measured values such as color of the waste water, temperature in the tank and pressure in the system. The measured values are also archived in database. The fermentation and filtration workplaces are both equipped with PLC automats in place of the computer directly connected to the process. It is not possible to develop applications for the PCD2 automats in Control Web, so the necessary software was created in the development tools provided by the PLC manufacturer using function plan programming language.

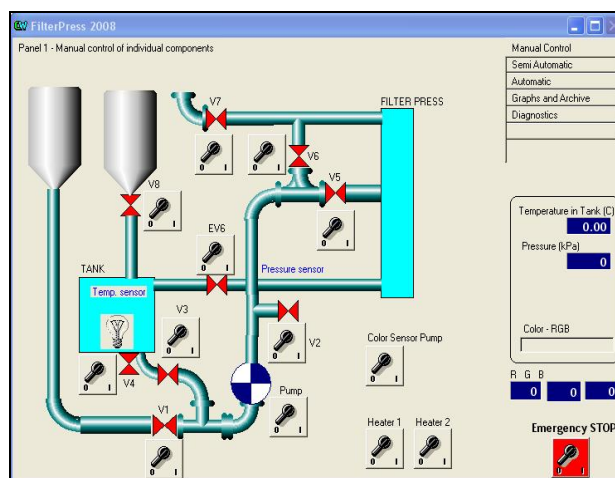


Fig. 20 Main window of Dechromation control software



Fig. 21 Control board with panel PC and the control application running

However, as described earlier, the PLCs are connected to the supervising computer and on this computer Control Web application can run which can directly control the outputs or read the inputs from the PLC. Control Web contains driver for the PLC which allows this communication.

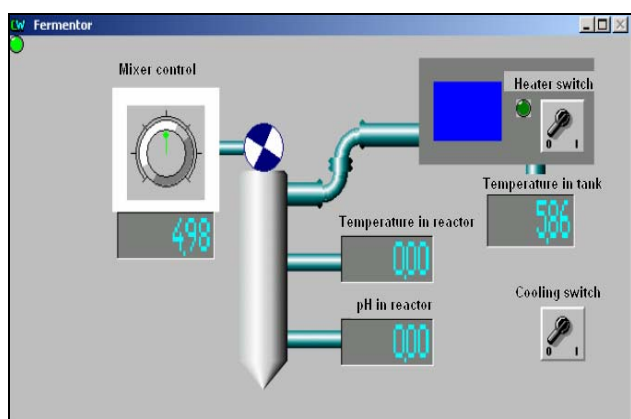


Fig. 22 Test application for Fermentor workplace

A simple test application created for remote control of the fermenter workplace is depicted in figure 22.

4 Conclusion

This article describes control system for recycling chromium from tannery waste which is implemented in laboratory at our institute. The laboratory equipment has been recently updated with modern equipment. Aim of the modernization was to replace relatively outdated devices with modern means of automatic control. The equipment was chosen also with regard to intended use of the laboratory for students as an example of modern automatic control system in real application.

The complete technology is divided into five workplaces, four of which are directly attached to the technology and one is supervising. Workplaces are connected together using industrial Ethernet and optionally also via Wi-Fi and/or GSM modems. The supervising workplace is equipped with industrial computer. The other workplaces are equipped with variety of devices which include PLC automat SAIA PCD2, small panel PC with Windows CE operating system and bigger panel PC with Windows XP. As the main programming system for the whole laboratory we use Control Web, which is modern RAD tool for developing applications running in real time with advanced visualization. In this development environment several programs have been created including the most complex application which runs on the panel PC at dechromation workplace. This application makes it possible to control the equipment either on elementary level or on level of technological phases of the process, such as filling the filter press. For the other workplaces simple test applications were created so far, to verify the communication and input/output system. The equipment is presently tested in real situation and then a fully automatic

control of the dechromation be implemented as well as the other programs necessary for the complete laboratory to be computer-controlled.

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