Project no. COOP-CT-2003-508180

EDY – Efficient Dyeing

Development of a Clean and Efficient Automatic Dyeing Control System

Co-operative Research Project

Publishable Final Activity Report

Period covered: 1st November 2004 / 31st October 2006 Date of preparation: 31/10/2006

Start date of project: 01/11/2004 Duration: 24 Months

Project coordinator name: Valerio Dell'Oca
Project coordinator organisation name: IrisDP S.r.l. first revision

Section 1 – Project execution

1.1 Project objectives

The main strategic objective of EDY project (EDY - Efficient DYeing) was focused on providing the European textile-finishing industry with an efficient, cost-effective tool for monitoring and optimally controlling the process of fabric and yarn dyeing.

This goal was achieved through the development of a clean and efficient dyeing automatic control system able to collect real-time process data from a dye-bath machine and allow optimal control of the dyeing process, thus improving current dyeing performances.

EDY system is now able to provide optimal control and early detection of dyeing faults that are the basis to increase the product quality, also by giving the chance to correct wrong processes, and to reduce the waste of time and dyestuff with obvious benefits to the production and environmental costs.

The overall impact on textile dyeing sector will be an increase of the competitiveness of the SME proposers, and more generally of the entire textile filiere as:

- it strengthen the technological basis of SME proposers and of the textile sector;
- it makes the systematic approach developed in the project available and easy exploitable during the dissemination phase in the textile-dyeing sector with the aim to expand the knowledge base of the large number of SMEs of this sector;
- it provides a scientific base for future norms and standards in the textile sector as far as dyeing pigment and dyeing recipes are concerned which prevents imports of goods from low cost labour and less ecological-looking countries.

1.1.1 Contractors involved

The Consortium involved in EDY project includes seven industrial partners and three research companies, Among the first, technical competencies were as follows: 3 dyeing SMEs (Felli Color, ATB, Pecco&Malinverno), 1 textile machine manufacturer (Gesten), 1 textile probe manufacture (Giussani), 1 control software developer (IrisDP), 1 developer of spectroscopic systems (Macros). Besides the, three member nations are included in the overall consortium (Italy, Portugal, and The Netherlands).

As mentioned, the present Consortium was well consolidated thanks to the experience gained in previous projects and was deemed to have the necessary resources to carry out the work. Some of the companies in the Consortium, like IRISDP, MACROS, have contacts with Eastern European countries like Turkey and this will enable the project to have a wider European perspective.

In the following, details of the role covered by each contractor inside the project is given.

IrisDP is an Italian company specialised in the development of innovative software and hardware tools for the textile industry by means of modern technologies and platforms. They were in charge for the coordination of the project and its resources. Their main technical contribution consisted in the supporting of the integration and optimization of the VOPS probe first, and of the EDY sub-systems afterwards. They were also in charge for the evaluation of system performances and optimization of the same. They are interested in exploiting commercial opportunities under an agreement with the other contractors.

Felli Color is an Italian company specialised in the dyeing of yarns. Felli, as end-user, was mainly involved in the definition of the system requirements, in supporting the other partners during the integration of the EDY dyeing monitoring and control system and, finally, in the system performances evaluation phase.

ATB is the Textile Finishing of Barcelos, founded 15 years ago, is since then rendering a high quality service for what concerns knitting finishing and dyeing. They acted as end-user in EDY project. They were consequently involved in the definition of the system requirements and in the evaluation of the system performance. They supported Citeve and the whole Consortium during the evaluation phase of the prototype installed in Portugal, performing a critical analysis of the obtained results.

Giussani is an Italian mechano-textile company specialised in the production of dyeing control equipment. They were in charge of supporting the integration both of the VOPS probe and of the whole EDY monitoring & control system. They developed the whole hydraulic connections in the system, helped with the installation of the electromechanical valves. They provided, thank to their experience in dyeing control equipment, a versatile interface that could guarantee the system installation on the textile machines, involving a limited investment for the system implementation and bringing a fast industrial exploitation of the results. They also gave their support to the Consortium during the evaluation of the system performances and its optimization.

Macrosystem is a Dutch company which deals with the development of machinery/software and applications for quality control in textile sector. They were in charge of the development of the automation and control system. In particular they helped DV in the development of the VOPS spectrometer. They gave their support during optimization of the probe phase, and also during the integration of the whole EDY system in a real industrial environment.

GESTEN is a company of the Portuguese textile filiere specialised in the development and adaptation of dyeing and finishing machines. They were in charge for the activities of integration of the VOPS probe on the dyeing machine and the control of the dyeing parameters. They gave to the Consortium their support in integrating the EDY system in a real industrial plant, especially for what concerns the Portuguese prototype. They also gave their support during the evaluation of the system performances.

Pecco & Malinverno is an Italian company specialised in the dyeing of fabrics and the finishing of the textiles. They, as end-user, were involved in the definition of the system requirements and in the evaluation of the system performance. They tested the system at their premises under the control of

the R&D partners. They performed a critical analysis of the control systems currently used in plants or of which they have experience providing inputs to the system optimization.

D'Appolonia is an Italian engineering company specialised in design and integration of complex systems and specific software applications. They were in charge of the definition of EDY control system. D'Appolonia main role was the identification of the control rules based on VOPS measurements and in the development and integration of the control system. D'Appolonia gave also support to the Consortium for the definition of the VOPS specification activity and in the on-line system testing of the whole system, for the optimization of both the VOPS probe and the whole EDY system. They gave also technical assistance during trials.

Citeve is the Technological Centre for the Textile and Garment Industries of Portugal. Citeve is involved in R&D activities in textile sector. They were the major expert in the consortium of problems related to fabrics dyeing and more in general quality control for the textile industry. They were responsible for the definition of system requirement, for the definition of the control parameters. Moreover Citeve helped in the definition of dyeing models, through the intensive experimental campaign. They had also a key role in the exploitation of results of the project and the dissemination of relevant information to the European industry.

DV s.r.l. is an Italian technology laboratory whose mission is the development of studies, design and manufacturing of advanced devices and solutions in spectroscopy techniques. They were in charge of the whole development of the technological base of the project: the Variable Optical Path Spectrometer. They developed it, optimised it and then integrate in the EDY system. They gave also technical assistance during EDY system trials.

1.2 Work performed and obtained results

Work performed during the two year of activities, carried to the following main results:

- development of the dyeing monitoring system able to evaluate the status of the dyeing bath, through parameters such as spectral content, pH, conductivity and temperature;
- development of control algorithms consisting in a suggestions given to the operator in order to eventually correct the bath if needed;
- optimization of the VOPS probe and of the whole EDY system, following trials in real dyeing environment (both in Italy and Portugal).

Thanks to this development a new and innovative on-line monitoring/control system for the dyeing textile market was initially introduced in the reference market.

A further stage of industrialization may be useful for creating a final product ready to be sold and immediately used by each end-user on the market. The developed prototypes showed that the technology introduced with the present CRAFT project is the winning one and that it is possible to

have on-line monitoring of the dyeing bath and not only a sampling laboratory evaluation of it.

EDY system was integrated in an industrial environment (Pecco&Malinverno, Italy; Citeve, Portugal). It was optimized, in order to give the best performances for that application. A number of tests were done for improving its capabilities. Besides this, an intensive campaign of parallel laboratory tests was also carried out, in order to define the best controlling algorithms.

Summarizing the previous paragraphs it can be assumed that the application of EDY system shall provide the following technical advantages to the whole dyeing industry:

- less dyeing defects on dyed product due to easier on-line correction of the dyeing recipe;
- lower environmental impact of the dyeing process by avoiding wrong processes and consequently dyeing bath disposal;
- lower dyeing time due to a more controlled process.

1.2.1 Methodologies and approaches

The technological base of the project was the application of the VOPS methodology (Variable Optical Path Spectrometer). This innovative approach was able to guarantee a reliable spectral information of the dyeing bath, as the probe was always able to modify its path length as a consequence of the darkness of the bath itself. This measure, together with the values of temperature, pH and conductivity is what is needed for having a clear and complete monitoring of the status of the bath during the dyeing process.

The controlling mathematical equations, obtained both from laboratory tests and from first trials on the system, have been added to the software so that the machine can calculate the optimum concentration of salt and alkali once the dyestuff concentration and the desired K/S have been input by the operator. These equations allow a complete automation of the system: the operator needs only to input the dyestuff concentration and the desired K/S and the machine calculates the dyeing recipe.

An intense campaign of laboratory tests was also carried out by the Consortium in order to verify the influence on dyeing bath of certain parameters (fixation time, ionic conductivity and pH). This activity revealed to be of major importance for the definition of the controlling algorithms, as it demonstrated how to change the dyeing bath in order to obtain the correct and desired result.

The old algorithm considered the exhaustion as the maximum colorant insertion point. From there, the maximum exhaustion value decreased. After the initialization process (white and dark references) the algorithm evaluated step by step the exhaustion following formulas previously shown.

A new algorithm for the definition of colour contents was then defined. The goal this time was to highlight, with an acceptable approximation, the colour components, and then monitoring the single exhaustion curves.

The algorithm assigns a percentage of the maximum peak value and evaluate the value of the first component basing on the first peak. Then the same procedure is replicated more times in case of more peaks. This new algorithm simulates the existence of a number of single ad hoc band-pass filters centered on the most representative wavelengths of the components colour.

A configuration including a client PC and a number of server PCs was foreseen. In this case the client PC works as controller for a number of server PC installed on each remote dyeing machine. The communication among them is performed through Ethernet network.

The production probe was mounted on the production machine for on-line analysis. The activity of personnel dedicated to monitor and control is limited to the signalling of starting and stopping of dyeing process and to the signalling of possible existing anomalies.

1.2.2 Achievements to the state of the art

Considering the state of the art of dyeing textile sector, we can notice that very few things are changed during the last years. As a consequence, the level of innovation introduced with the EDY project concerns the following aspects:

- development of an automatic system able to identify and correct dyeing bath characteristics in real-time during the dyeing process;
- introduction of the VOPS technology in the automation of dyeing, allowing the fulfillment of ISO quality standards with respect to the state of the art technologies;
- development of new methodologies for spectral and colorimetric analysis of dyeing bathes with VOPS technology;
- development of new methodologies for the identification of the process state by taking advantages from the application of VOPS technology;
- development of new control roles for the control of the dyeing process variable (temperature, salt concentration, and pH).

1.2.3 Impact of the project on its industry

EDY system, once introduced and accepted by the dyeing textile market, will have the following impact on the same sector:

- Decrease in manufacturing costs: the dyeing process involves a high consumption of chemicals and energy both for fixing dyeing agents and recycling solvents. It has been estimated that these costs will be reduced by 20% due to early identification of faults and real-time correction. This was and is still confirmed by a investigations on finishing costs performed by ASSTEX;
- Increase of quality improvement: the possibility to monitor the dyeing process automatically shall allow for prompt identification of problems thus avoiding the production of hundreds of meters of low quality fabrics. On average, currently 10% of the production has to be discarded or sold at about 30-40% of its price

- Increase of production rates: production performance shall take benefit from the ability to early interrupt or to in-time correct wrong processes and from the reduction of reprocess needs.

- Minor implementation costs: the versatility of the EDY system shall allow the installation by retrofit with minor impact on the dyeing process and on the plant layout.

1.2.4 Photos and diagrams

In the following, photos and diagrams describing this two years activity are given. In particular, details of the two prototypes installed in Italy and Portugal are shown. Finally, examples of the old and of the new graphical interface are given too.

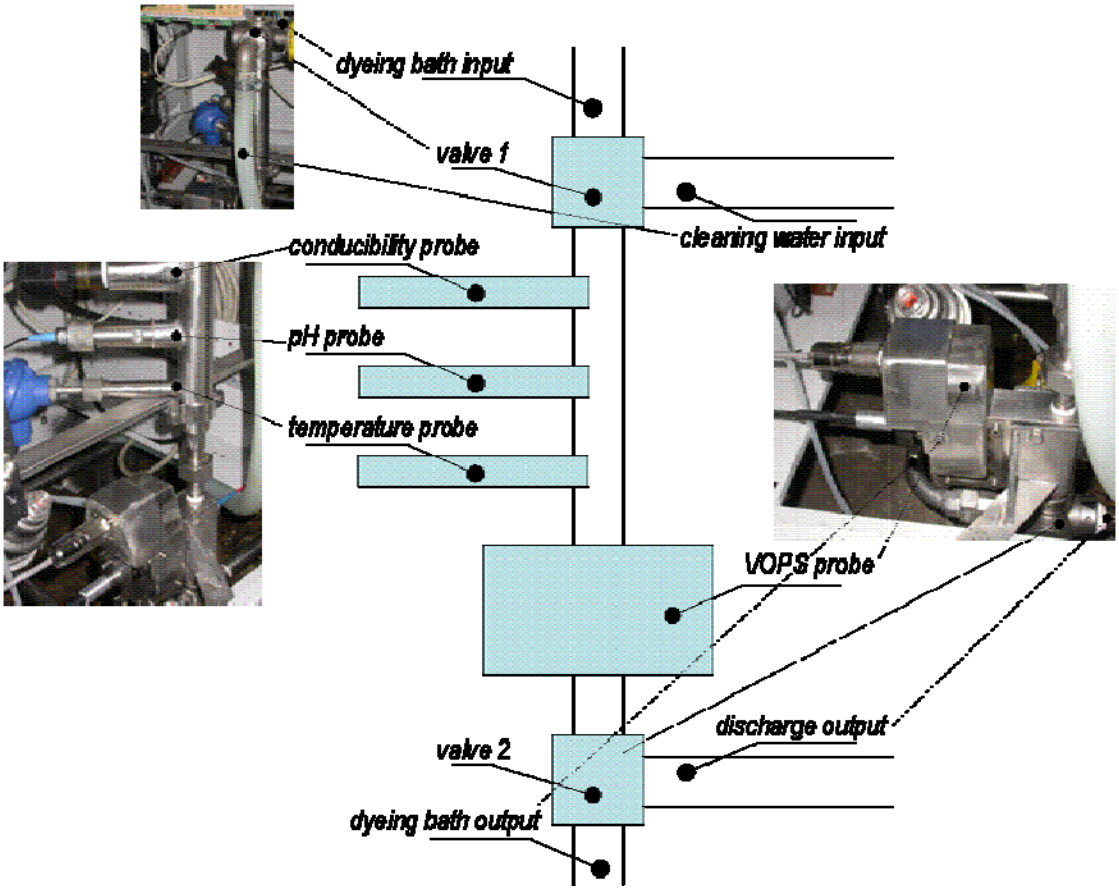

Figure 1 – Layout of EDY monitoring/control system

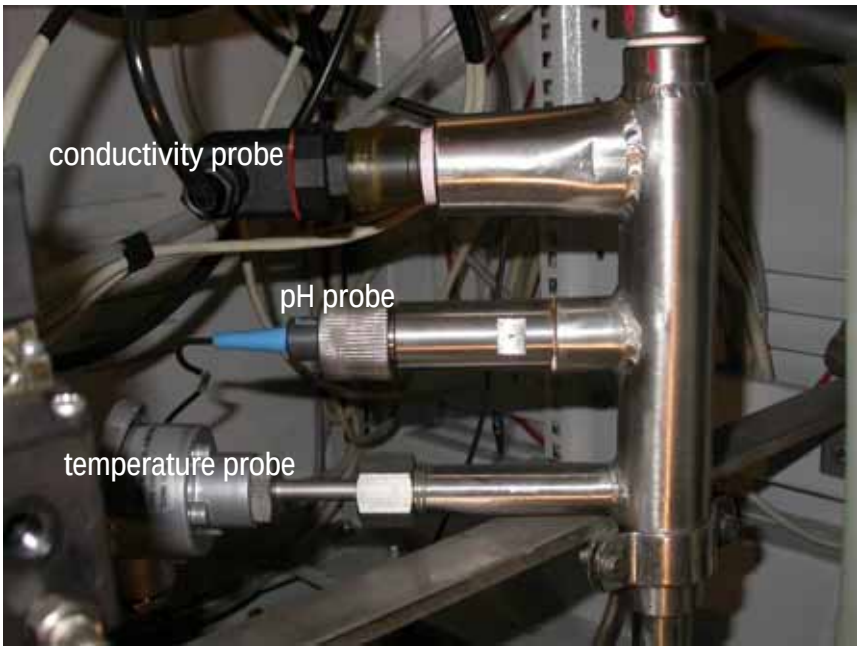

Figure 2 – Details of the EDY system: temperature, pH and conductivity probes /1

Figure 3 – Details of the EDY system: temperature, pH and conductivity probes /2

Figure 4 – Details of the EDY system: VOPS probes /1

Figure 5 – Details of the EDY system: VOPS probes /2

Figure 6 – Details of the EDY system: control electronics /1

Figure 7 – Details of the EDY system: VOPS probes and control electronics /2

Figure 8 – Details of the EDY system: rack with control PC and probes: prototype installed in Italy

Figure 9 – Details of the EDY system: rack with control PC and probes: prototype installed in Portugal

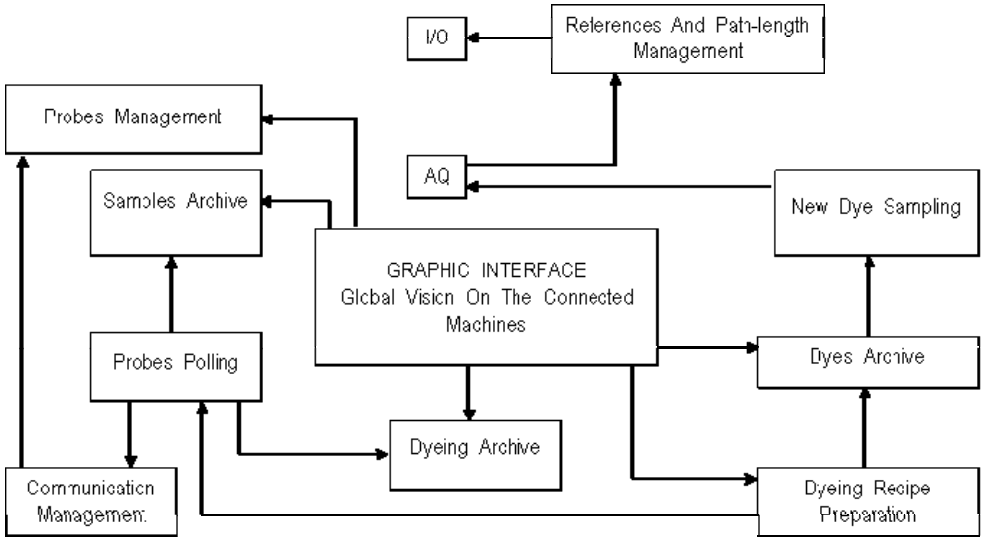

Figure 10 – Scheme of the algorithm implemented on EDY system

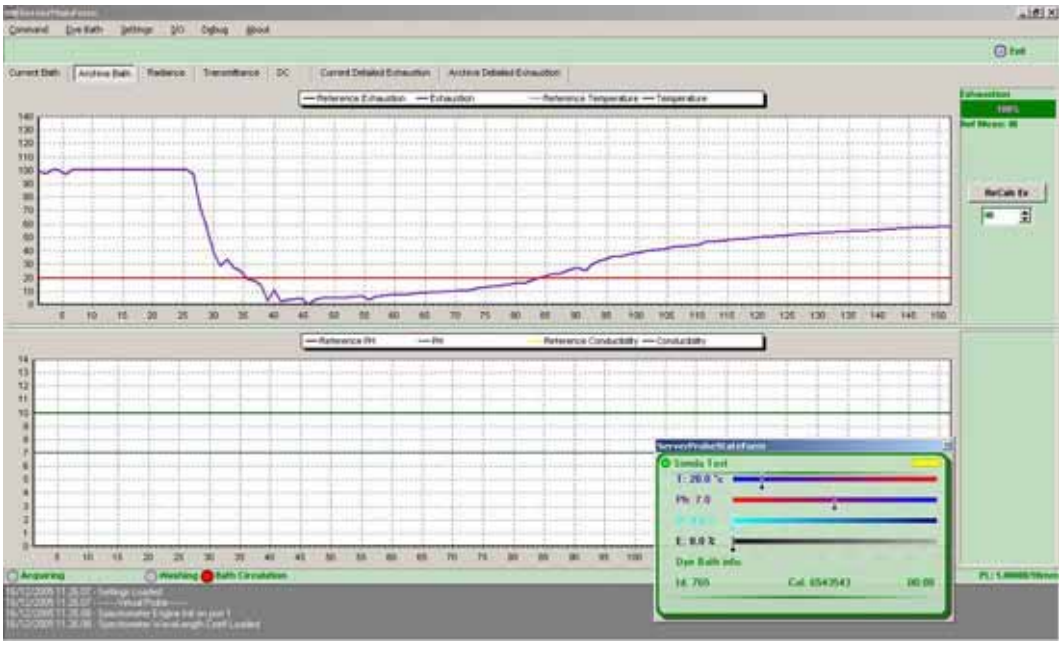

Figure 11 – Details of the EDY system: initial user interface /1

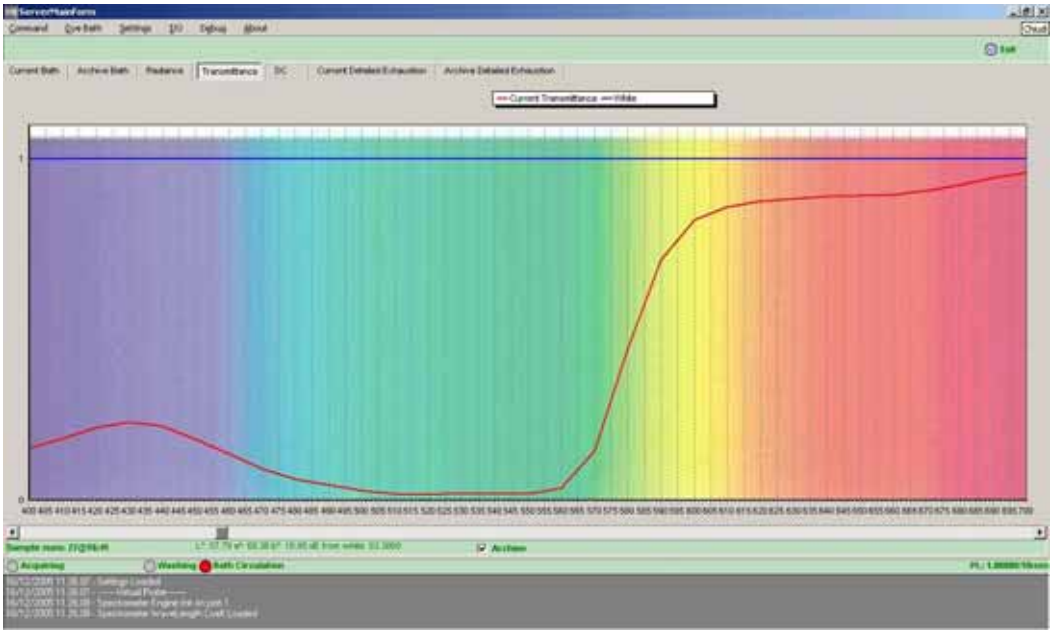

Figure 12 – Details of the EDY system: initial user interface /2

Figure 13 – Details of the EDY system: initial user interface /3

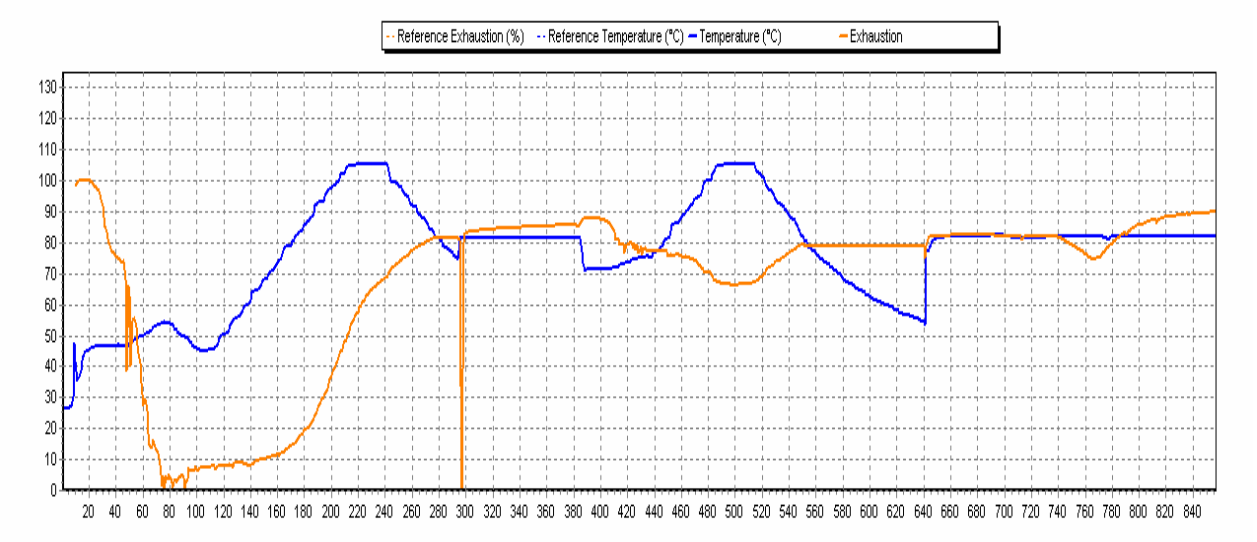

Figure 14 – Screen shot of final EDY user interface: exhaustion and temperature

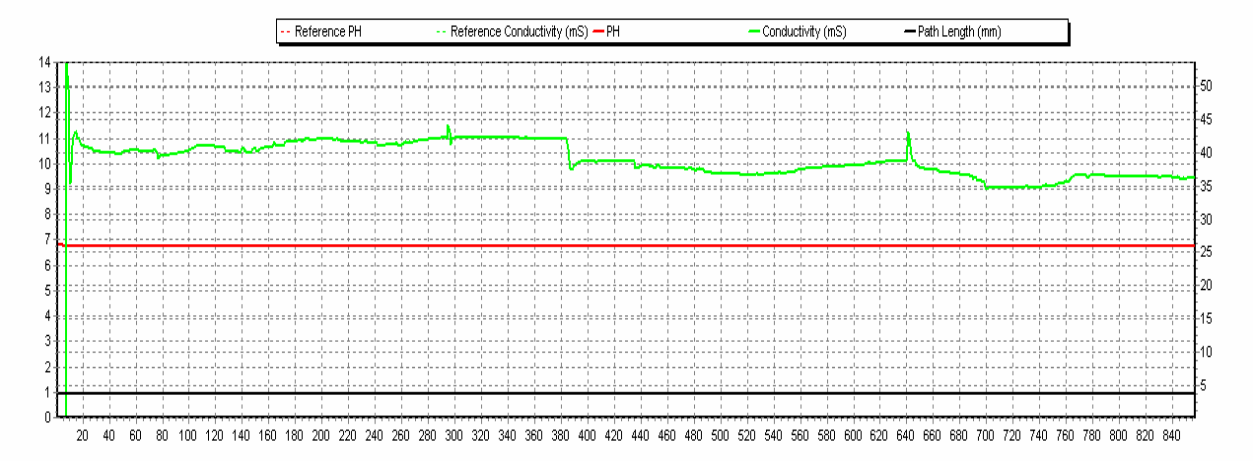

Figure 15 - Screen shot of final EDY user interface: pH and conductivity

1.3 Reference to web-site.

Dissemination activities started with the design and development of the project web-site (www.dappolonia-research.com/edy/home.php); the project website is currently on-line, and has been used by the partners to share information about the progress of the project, to collect the final version of the meeting minutes and reports in the private area, and to give visibility in the web to the project objectives.

Section 2 – Dissemination and use

A description of key exploitable results is provided below.

Methodology for on-line analysis of the dyeing bath absorbance for evaluation of dyeing process

This result is relevant for a new concept of on-line analysis of the dyeing bath. The perspectives of applications are mainly in dyeing textile sector. The knowledge of Citeve was and will also be of great importance for the understanding of the crucial parameters which have to be monitored for this evaluation. IrisDP and the end-users partners, Felli, ATB and Pecco will be directly involved in the benefits arising by these new methodology.

Design of the variable optical probe

This result is relevant as an innovative probe was used for monitoring absorbance of dyeing bath. A new technology has been introduced with the support of DV. IrisDP and Macros have been and will be directly involved in this development and in the benefits arising from this.

Design of the control system

This result is relevant as the whole control system has been developed for on-line analysis of the dyeing bath. Giussani and Gesten gave their support thanks to their knowledge in mechanical design for their respective areas of knowledge.

EDY system for on-line analysis of the dyeing bath

This result summarises all the previous ones. IrisDP and Giussani will be world-wide distributor of the EDY system, being able, in agreement with the other producer partners, to define new marketing relationship and licensing; Gesten will constitute the main vehicle for the dissemination and marketing in the Iberian Peninsula; Macros supported by IrisDP, will be distributor for Turkey and will be vehicle for the dissemination and marketing in Northern Europe.

The role of the pilot end-users Felli, ATB and Pecco has been important to demonstrate the applicability and efficiency of the system. Some of them installed EDY at their plants with the support of IrisDP, Giussani and Gesten. The other simply participate to the demonstration and performances evaluation phase. Once the project is ended they will be able to provide also training sessions to facilitate the absorption of the technology, and thus demonstrating project results outside the Consortium. Their participation allowed to attract interest within the textile filiere, thus gaining market acceptance for the EDY system.

Publishable results have been included in the following project deliverables:

- Deliverable D15, “Technical Paper on State of the Art of Dyeing Control”;
- Deliverable D17, “Technical Paper on Spectrography in Textile

Sector";

- Deliverable D18, "Dissemination Paper on VOPS Technology";
- Deliverable D20, "Dissemination Paper on EDY Objectives and Advantages";
- Deliverable D21, "Technical Paper on advances Introduced by EDY Technology on Dyeing Control Systems".