SYNTHESIS REPORT FOR

PUBLICATION

Contract Number: BREU - CT92 - 0627

Project Number: 6096

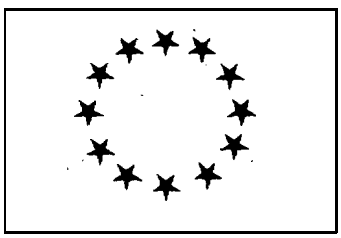
Proi ect Title: Water-born lacquering syst em for coated plastic materials and calendered films

PROJECT **CO-ORDINATOR:** Domenico Randi

Names of Partners: 1)- Vulcaflex S.p.A. - I -
2)- Rowa GmbH. - D -
3)- TIS N.V. - B -
4)- University of Bologna - I -

Reference Period: 1.3.1993- 31.S. 1996

Starting date: 1.3.1993 Duration: 42 Months



PROJECT FUNDED BY THE EUROPEAN COMMUNITY UNDER THE BRITE/EURAM PROGRAMME

TITLE: Water-born lacquers: an innovative system for lacquering coated plastic materials arid calendered films,

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ABSTRACT:

The existing technology for lacquering coated plastic materials and calendered films uses solvent-based lacquers: together with good technological and appearance results, some drawbacks are present, due to the residual solvent retention in the Plastic material, and mainly to the organic solvent emission from the process into the working place and atmosphere.

This research had the objective to develop a new water-based system for lacquering coated plastic materials and calendered films. To reach this goal a complete innovation of the lacquering system was required: in fact it was necessary to modify the lacquer basic polymer together with its additives, the substrates, the production parameters and also the plants for producing and applying the lacquers.

The final objective was reached: water-based lacquers were obtained having technical and appearance characteristics equivalent and in some cases also better than the solvent-based ones. Moreover the percent decreasing of the organic solvent emissions of the new system compared with the old one is approx.98%.

At present the unitary price of a water-base lacquer is not cheaper than the price of the solvent-based products, but it can be foreseen that within the next few years the environmental legislation for the limitation of the organic solvent emissions in the atmosphere will accelerate the conversion from solvent-based to water-based lacquers.

INTRODUCTION:

The total market for plasticized P.V.C. and polyurethane sheeting in Western Europe is estimated to be about 2.200 x106 m^2/year, several industrial areas being involved. It is also estimated that more than 50% of this material is lacquered: a calculation of the lacquer consumption based on a wet film of 25 g/m^2 gives a value of more than 27.000 tons of lacquer per year in Europe.

The existing technology for the lacquering process uses solvent-based lacquers and it presents good characteristics 'as far' as physical and chemical properties of the final product are concerned: high resistante to aggressive environmental factors, good visual appearance and extended life span of lacquered materials. How-ever, the use of organic solvents in the lacquering technology presents some drawbacks: during the lacquering operation the solvent emission causes environmental pollution in the working place and in the atmosphere; moreover, the low explosion limit of the organic solvents (the value of their LEL is approx. 1 %) makes this production system a very dangerous process. Besides, the residual solvent retention in the plastic material (about 4-5%) causes, a reduction of their mechanical resistance' and several other negative secondary effects.

Therefore it becomes more and more difficult to work with solvent- based lacquers and local laws limit more and more their use: in the near future the insertion of an postburning system mto the solvent lacquering systems will be inevitable.

As a consequence, there is a great demand of new technologies which can eliminate the described negatives effects, without diminishing the present high. quality of the final products: water-based lacquers could solve a lot of problems. Realistically it is possible that ca. 75°/0 of the current solvent-based lacquers could be replaced by the water-based products within the next 5-6 years: as the organic solvent content of solvent-has ed lacquers is approximately 85% and the organic co-solvent content of water-based lacquers, on the contrary, is 5°/0, the annual amount of solvents used nowadays in Europe in this field could drop from 23.375 tons to 1.375, assuming an equal solid residue for both types of lacquers. As indicated later, the content of co-solvents can be also lesser(3% or less), and there is as well the possibility to eliminate almost completely this source of atmospheric pollution.

The specific objective of this research was to develop a new water-based lacquering technology for coated plastic materials and calendered films, in order to guarantee the same quality and eliminate the negative effects affecting the existing solvent-based lacquering technology. Obviously, all modifications must produce a final lacquered material with technical and appearance characteristics at lease equivalent to the characteristics of the present material.

The new water-based lacquering technology could be convenient also from the economic point of view, owing to the high cost the organic solvents substituted in the new technology by-water with only a little quantity of an organic 'co-solvent.

However the substitution- of the solvent-based with water-based lacquers requires a complete innovation in the lacquering system, both in the starting materials and in the working technology. Before all it is necessary to modify the lacquer basic polymer by making it water-

soluble or, at least, water-dilutable. Then also the lacquer add tives (e.g. plasticizers, pigments, stabilizers and coalescing, defoaming, wetting, thickening, matting and conserving agents) are to be modified in order to make them compatible with the new aqueous medium. Besides, it, was necessary to solve several other technical problems in the manufacturing process to reach the final goal of the research, for instance:

- water-based lacquers after drying are not chemically removable from the cylinder of the printing plant, while the solvent-based ones can be easily removed;
- the surface tension of the water-based lacquers is higher than the solvent-based ones, causing trouble of wetting on the plastic surfaces.

Modification of the preparation and production plants are also necessary: at fist, considering that the vapor, pressure of the water is lower than the vapor pressure of the usual organic solvents, a modification of the thermochannels will be necessary as a consequence of the water-base lacquers employment. ..Moreover, an adjustment of the laying process (rotogravure process) must be arranged.

Finally, new analytical tests and characterization methods can be necessary, not for the final material (which must have the same characteristics of the material produced with the old solvent-based technology), but in order to characterize the intermediate products as well as the single intermediate working phases.

All these aspects were considered and a workprogramme was prepared in accordance with them. In fact, the research work was divided in five main tasks, as reported later, and for each task the specific research field for each Partner was identified; this field was then divided in a number of sub-tasks, each referring to a specific and limited problem, and for each problem a goal was fixed.

The Partners of the research were four, three industrial manufacturers and one University department:

- Vulcaflex S.p.A. is an Italian industrial company which produces and lacquers PVC coated sheets and calendered films mainly for internal use. Among the European companies potentially interested in employing the new water-based lacquering system, foremost are certainly the ones producing coated PVC. In this sector the most important companies are situated in, Germany, Great Britain, Spain and France: in the other European countries there are numerous smaller companies. Taking into consideration its dimensions and coated PVC output, Vulcaflex is the most important Italian company, the only one comparable with the 5 European leaders in this sector.

- Rowa GmbH is a German industrial company which produces lacquers and whose main task in the research was to set up the formulation of water-based lacquers with all the required properties. Since 1969 Rowa produces surface coating lacquer systems for plastic finished textiles: in Europe there are three other companies that also produce and trade comparable products, but so far none reached the dimensions and importance of Rowa: nowadays Rows is, from a global viewpoint, one of the enterprises with a larger comprehensive technical knowledge in the field of the lacquering for flexible surfaces.

- N.V. TIS is a Belgian industrial company, one of the biggest in its field in Europe, which produces and lacquers PVC-coated synthetic fabrics mainly for external use and for

different applications such as: transports (with different types of covers and/or side-curtains), structures, ventilation tubing, sports and mainly gymnastic mats.

Finally, the Applied Chemistry and Material Science Department of the Bologna University has a long years experience in environmental fields connected to the subject of this research. Its main task in the research was the scientific supervision and co-ordination of the work, the exchange of information among the partners and the critical examination of the intermediate as well as of the final results of the single steps.

Owing the peculiar characteristics of the partners, their competence are complementary and a rational tasks distribution of the research programme was possible.

TECHNICAL DESCRIPTION:

The fundamental idea of this research was to replace with water the organic solvents contained at present in the lacquers used for lacquering coated plastic materials and calendered films. The good characteristics of the present final product hac to be kept and, if possible, also improved.

Some important partial goals of the new lacquering system were as follows:

- trouble-free working only through an adjustment of the existing plants and systems for lacquering;
- very good wetting properties on the surface;
- very good adhesion to the surface, even after bending and deforming;
- chemical resistance (to the light, chemical agents and weather);
- mechanical resistance (crease and scratch "resistance);
- outside: protection against dirt, thus easier cleaning; .
- inside: barrier against plasticizer and additive migration;
- antiblocking effect, good slipping property and pleasant hand;
- weldability with high frequency, heat-sealability;
- either high gloss finish or matt finish by means of smoothing or embossing; '
- suitability for indirect system of coating with the help of release paper;
- suitability to automatic process working;
- clean manufacturing.

The research programme was divided in five principal tasks:

TASK 1 - Study, modification and preparation of the potential substrates and lacquers in laboratory.
TASK 2 - Technological feasibility test samples lacquering.
TASK 3 - Lacquered samples performance control.
TASK 4- Industrial verification and optimization of the process parameters.
TASK 5- Finished product quality control and data collection.

For each task the specific research field for each partner of the research was identified (see later). This field was then divided in a number of sub-t asks, each referring to a specific problem and for each problem a goal was fixed. The project flow diagram and the critical parameters to evaluate the success of the research are reported (Tables 1-2-3).

Tabella n°1: project flow diagram

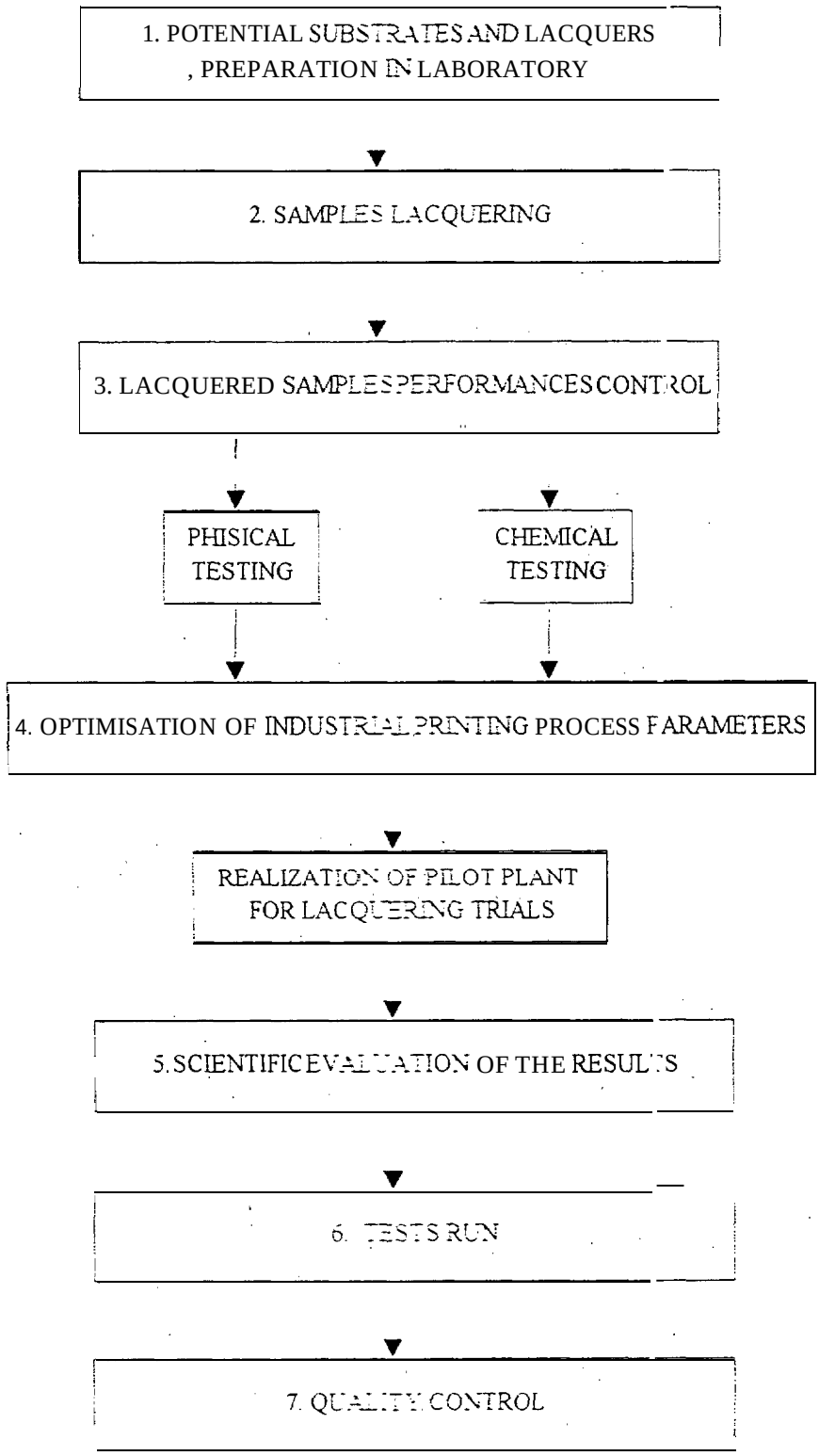

Tabella n°2: value of characterization

TEST ITEMS	UNITS	PASS WHEN...	TEST METHOD	MACHINE
Breaking load	WMD daN AMD daN	> 10.0 > 10.0	EU-BN 150-4	CRT tensile testing machine
100% modulus	WMD daN AMD daN	6.5- 7.5 6.5 -7.5	EU-BN 150.4	CRT tensile testing machine
Elongation at break	WMD % AMD %	> 280 > 300	EU-BN 150-4	CRT tensile testing machine
Tear Strenght	WMD daN AMD daN	> 3.0 > 2.8		CRT tensile testing machine
Colourfastness to light	Rating	5	SAE J1885	Xenotest
Vacuum forming test	note	no defects in finishing	GM 9191 P	Vacuum forming machine
Bally B flexing -20°C	WMD AMD	resistant resistant	DIN 53351 30000 Cycles	Bally flexometer
HF Welding	WMD daN AMD daN	> 55 > 55	EU-BN51- 1	HF welding machine"
Fogging	?40	> 65	BO 116-3	fogging tester
Cold crack resistance	-30°C	no cracks	GME 60306 G500-H150	impact tester
Blocking	N/25 cm	< 5	SAE J 912 a	air circulation oven

Tabella n°3: value of characterization

TEST	MACHINE	REGULATION	U N I T S
Adhesion test	Bally Flexometer	DIN 53351	number of cycles,
Gloss measurement	Dr. Lange Gloss meter	DIN 67530	Gloss > 65 Matt <2
De-foaming" test	-	Rowa House Test	Foam < 5% Volume
Viscosity control	Din 4 mm Cup	DIN 53211	Seconds
Viscosity control	Brookfield Viscometer	DIN 51550..	mPa.s
Artificial weathering	***QW*** machine	DIN 1910 part 3	Exposure> 2000hrs
HF weldability	HF machine	-	Watt/cm^2
Weld strenght	Tensile tester	DIN 53354	N/cm
Dirt resistance	Frank Hauser	DIN 53528	Scale 0-10<2.
Surface friction	Betex	DIN 53375	Friction <0.5
Block tendency	Tensile Tester	DIN 53357	N/cm*

DIN
The main roles of the partners were as follows:

For Vulcaflex:
- Task 1: calendered and coated sheets formulation planning;
- Task 2: choice of the most suitable lacquering systems and parameters;"
- Task 3: chemical and physical testing;
- Task 4: tests run;
- Task 5: quality tests.

For Rowa:
- Task 1: study and change of lacquers production parameters in laboratory;
- Task 2: samples lacquering in laboratory scale;
- Task 3: physical testing;
- Task 4: lacquering trials in pilot plant;
- Task 5: evaluation of achievements and test data. "

For TIS:
- Task 1: study on preparations according to different water-based lacquers ;
- Task 2: study of laying suitability using the photoengraved cylinder;
- Task 3: physical testing ;
- Task 4: industrial tests run;
- Task 5: evaluation of quality tests.

For the Applied Chemistry And Material Science Department of the Bologna University:
- Task 1: study of the materials characteristics;
- Task 2: evaluation of the new products performances in comparison with the traditional ones;
- Task 3: tests integration;
- Task 4: evaluation of the results of printing machines notifications;
- Task 5: data processing and scientific evaluation of the results.

RESULTS:

The results of the research are referred on a 'task-by-task basis.

TASK 1- Study, modification and preparation of the potential substrates and lacquers in laboratory.

This task was the most important one for ROWA which had the goal to prepare the new water-based lacquers. The results can be summarized as follow::

For the time being no dispersion is available on the market which can work as lacquer without modifications, but formulation of waterborne products for lacquering" tarpaulins and artificial leather is possible.

The modifications were made either by a suitable combination of several dispersion systems (different in the chemical nature and/or in the characteristic within a specific chemical class), or by developing new types of copolymers in dispersion (terpolymers, blockpolymers, blockcopolymers, graft polymers etc.). Economic reasons and the experience obtained in this research indicated the opportunity to study a specific polymerization program.

Further modifications were necessary for all the studied dispersions regarding film-forming, defoaming, wetting, viscosity modifying chemicals. Variation of the basic polymer(s) doesn't, influence these properties decisively; on the centraly the adhesion properties are influenced only by the polymer base and the additives have a negative effect.

The scale-up of a water-borne lacquer is different and more difficult than the scale-up of solvent-based lacquers. The general rules which were worked out differ from chose for solvent system lacquers, and each waterborne lacquer needs a process engineering of its own.

A far as the other two industrial Partners are concerned, the study of the influence of the potential substrates related to the new water-based lacquers can be summarized in three main points:

nettability;
adhesion;
chemical interaction.

The nettability is a measure of the chemical and physical weak bonds between the molecules of the substrates and the molecules of the lacquers; a homogeneous film of lacquer can be obtained when the surface tension of the lacquer is lower than the surface tension of the substrate. The surface tension of the PVC is 39-40 dyne/cm and it decreases when additives migrate toward the surface. On the same way the adhesion (due mainly to polar-polar interactions) is influenced by the presence of migrating substances.

The resins made by emulsion technology and used to coat, the plastisol have a low percentage of emulsifier agents that migrate toward the surface this migration is influenced by the amount and the type of the emulsifier agent. Many tests showed that some resins can be better lacquered than others: anyway plasticizers, stabilizers and other additives are more important to determine the nettability than the type of resin used. Above all the nettability is influenced by the type of plasticizers used. Tests were made also to analyze the different plasticizers and their influence on the final results: the best plasticizers are the less migrating, but unfortunately they are also the most' expensive. Comparing different types of phthalates the plasticizers with the longest linear chain proved be the best.

As far as the stabilizers are concerned, the market does not offer a sufficient number of types for a wide study. However their influence on the final results seems less important than for the plasticizers.

The chemical interaction between the lacquer and the substrate is not well known; usually this interaction changes the nature of the molecules and can be evaluated by a quick-aging. In fact this point is important when it influences the color of the surface and the characteristics of the lacquers themselves.

The nettability of the coated materials is also influenced by the nature of the released paper. The release spent have not a great influence on the nettability, the roughness of the paper being more important: the mar paper increases the wettability as a consequence of the increasing of the roughness of the PVC surface.

At last the influence of the lubricants on nettability has been studied: usually the amount of these additives is very low and it does not influence the surface tension in a significant amount.

To lacquer the tarpaulins with water-based lacquers, the present paste formula can be used, i.e. a polyester base cloth,. coated with PVC paste: the best ingredients were emulsion PVC, DIDP as plasticizer and CaZn as a stabilizer.

Studies of the composition of these new products indicated that no toxicological danger exists for their industrial use: this part of the work was completed the following step of the research.

Also for the environmental impact no danger exists by using the new products; on the contrary, a very relevant decreasing in the organic solvent t missions can be obtained with water-based instead of solvent-based lacquers, with a great decreasing of pollution.

TASK 2- Technological feasibility test: samples lacquering.

Both in the production and in the application stages the waterborne lacquers are more sensitive with respect to shear stability than solvent-based ones: for. example exposition to heavy metal ions as Fe-III, Cu-II, Cr-III, Sri-II must be avoided. In fact many heat stabilisers added to the PVC are Sri-based, and now this is no longer possible. Production and processing of waterborne lacquers should be made in vessels, pipes anc machines made from stainless steel, type V2A.

Samples of water-base lacquers were tested at laboratory scale before the use in the production plant: no differences were observed checking the features of the final substrates lacquered with the water-based product. More significant is t ne better nettability obtained in the production plant than in laboratory.

The application tests were mainly performed in order to identify the extent of nettability and adhesion between the surface and the substrate. In task 1 it was demonstrated that the . nettability is strongly connected to the surface tension. Now it can be said that to obtain a good wettability also the viscosity of theacquer is important: the test results showed that

when the viscosity is high enough it is possible to coat the surface with a continuous film. This means that the nettability must be checked and if it is poor it must be increased for coating the surface. On the other hand if the lacquer has a too high viscosity it cannot be used in production.

The performances of the lacquer samples have been evaluated under many point of view, and in some cases results" were obtained in good compliance with the present standards. These lacquers were then studied in detail for industrial applications in the successive tasks.

The photoengraved screen surface does not influence the results but cylinders made by ceramic material are better compared to the stainless steel ones. The operative conditions used to dry the samples were not too far from those for the solvent-based lacquers: in general the amount of energy necessary to evaporate the water seemed not higher compared to the process with the solvent.

Also the tests to determine the amount of foam anc. the sedimentation were very important. A great amount of foam has many disadvantages in the industrial use and it must be avoided; also the sedimentation decreases the characteristics of the lacquers and it must be eliminated by stirring the samples before the use: sometimes the stirring is not sufficient and in this case the lacquers are not usable. Finally, important indication were found in this stage of the research to modify the printing plants (see later).

The data obtained during this task confirmed that no toxicological danger exists for these new products, neither for the industrial use, nor as far as emissions are concerned: at this stage of the research all the fixed partial goals were reached.

TASK 3- Lacquered samples performance control.

The first developed waterborne lacquers showed bad performances with regard to weathering tests. creasing, dirt resistant{: and surface smoothness. Also data on slip, blocking behaviour. adhesion, gloss, mattness, burnishing, "nail-marking", settling-out, embossing properties. solvent resistance, weld-strength, welding properties, wetting and foaming behaviour were unsatisfactory: a great quantity of work was necessary for producing better lacquers. For each of these points the recipes had to be reformulated and the tasks 1 and 2 had to be done again: information exchange between the partners became more and more important. Finally characteristics of the final products as good as the present ones (lacquered with solvent-based lacquers), were obtained (See Tables 2 and 3).

As far as the application of water-born lacquers is concerned, in this task the tests to characterise the new lacquers were" completed. The gloss degree control is a good technique to compare the gloss of the lacquers coated on the same substrate, but unfortunately many different substrates are used, flat and embossed too. The final results are not always comparable and' a better classification of the gloss can be made by watching the sheets: only when this technique is applied to the same substrate a characterisation of the lacquers was possible.

The , solvent resistance control showed that the alcohol and acetone resistance are crucial: the crosslinking seems the only road to succeed. Also the resistance to abrasion had been improved during the research and the final lacquers are satisfactory in this aspect.

The weather resistance, H.F. welding control and cold flexibility have been good since the first tests.

At last the blocking control gave in general good results with almost all the sample. but in the tarpaulin production immediately after the lacquering process water-based lacquers showed a more sticky effect than solvent based ones. However the sticky effect was greatly reduced by the exposure the tarpaulin surface a few hours to the air. As a consequence, new methods were developed to test the blocking tendency. At present, the blocking effect is no longer an obstacle to use water-based lacquers in production. "

The new products never gave problems for screen printings, but in some cases they showed a lower dirt resistance.

All the tested water-based lacquers showed, in comparison to the solvent-based ones, a poorer gloss result due to "plate-out '". As a consequence on the calender of the lacquering machine, which is one of the means to guarantee the gloss result, a hazy shine becomes visible which gives a dull and lustreless effect on the tarpaulin surface. The hazy shine has to be washed away with water, but the washing effect remains still on the tarpaulin surface, so it is of a lower quality.

During the research, the problem was partially eliminated, but plate- out is still a not fully resolved problem. Solvent-based lacquers also cause plate-out but in this case the extent is lower and it is possible to work without frequent cleaning operations.

At first, some water-based lacquers showed some bubbles or stripes on the tarpaulin "surface, but these effects have been completely overcome.

Good results were obtained for the gloss of the water-based lacquered samples when a lower speed was used (± 10-11 m/min) in comparison to solvent-based lacquers (* 12 m/min).

At the beginning of the project. some samples showed a poor nettability, which resulted in a stripy effect; finally also this problem w-as overcome.

It is also to remark that sometimes water-based lacquers give a small difference in colour to the tarpaulin surface.

The results of the research in this task indicated that the new products can satisfy the present production standards; it was also definitively confirmed that no toxicological danger exists for the new products, neither for the industrial use, nor as far' as emissions are concerned.

TASK 4- Industrial verification and optimization of the process parameters.

In this stage of the research the information exchange between the partners was essential: the reformulations of the lacquers were done by Rows with regard to. the single specific. requirements of Vulcaflex and TIS referred to the different substrates, process parameters and performances of the final products. Task 1, 2 and 3 had to be repeated in any case and many problems could be se;=.eci- e.g. plate-out on the surface of the embossing cylinder for TIS, or constancy and stability of mattness for Vulcaflex.

In this task the suitability of' the new products in the production plants was verified: sheets were produced and tested with the new lacquers, then the tests were promoted applying plant modifications. Most of the results obtained in laboratory scale were reproduced and often better results than in laboratory were obtained: for instance the nettability improved by using the modified production machines.

A quite unexpected result of the production tests was that the amount of energy necessary to dry the water-based lacquers was sometimes lower than the amount necessary for "solvent-based ones: this point is important because at the beginning of the research it was been foreseen that the amount of energy necessary to dry the water-based lacquers would be higher. The reason can arise from the little amount of the organic solvent trapped into the PVC organic matrix: this solvent is very difficult to eliminate and i: causes porous and bad odour. Since the customers are always asking for no-odour materials, the water-based lacquers can give a big impulse toward this direction

During the production tests the number of problems to solve was very high. Among these the most relevant concerned the cleaning of the plant and the embossing process.

The cleaning of some part of the plant, above all the printing cylinder, is very difficult: in general for solvent-based lacquers the same organic solvent can be used. On the contrary, with water-based lacquers cleaning of the cylinder and the other parts with water or detergent causes a lot of difficulties. For this and other reasons the Zimmer device and the ceramic cylinder were employed.

For the embossing process the most difficult point has been to' find a lacquer resistant to emboss with hot-cylinder. At last also this problem was solved by using appropriate lacquers.

However the most innovative point from the economic point of view as well the scientific interest has been the introduction of a new object of research: the coating of the paper. Until now the plastisol of PVC was coated on the paper and, when required, finished with printing and/or embossing. One possibility to avoid 'a processing step would be coating the lacquer on the paper, drying it and then coating the plastisol. This possibility cannot be checked with the solvent-based lacquers for safety reasons but water-based lacquers can be used and preliminary results go in the right direction.

The lacquering machine used by TIS for solvent-based lacquers could be used without modifications for all tested water-based lacquers. The best rest lts were obtained when also the same drying temperatures were used.

The present cooling system (calender cooling, and cooling tubes which are placed after the oven) was also sufficient for water-based lacquers in order to guarantee the dimensional stability of the lacquered tarpaulin. To have an optimal gloss re sub, the speed of the lacquering machine had to be increased a little" bit.

The data supplied from the industrial Partners were examined by the University Partner and discussed all together; the results indicated that the single specific objectives of the research were reached.

As far as the environmental effects are concerned, by using the water-base lacquers instead of the solvent-based ones the extent of the reduction of the organic solvent emissions can reach *approx.* 98%. In fact at present the mean composition n of the solvent-base lacquers is approx. 1.50/0 of solid residue and 85% of organic solvents, whilst fo, the new water-based lacquers the mean composition is approx. 24% of solid residue and 3% of organic co-solvent, the remaining being water. As a consequence for 1 Kg of solid film applied on the lacquered surface the quantity of the organic se;;-en~ used and emitted in :he atmosphere is:

- for the solvent-based lacquers

15 : 85 = 1 : x ----> x = 85.1/15 = 5.667 Kg

- for the water-based lacquers: ,

24 : 3 = 1 : y ----> y = 3.1/24 = 0.125 Kg

The reduction of the emission can be calculated as follows:

$$\frac{5.667-0.125}{5,667} = \frac{5.542}{5,667} = 0,978 \text{ i.e. } approx \text{ } 98\%.$$

TASK 5 - Finished product quality control and data collection.

The new water-based lacquers have to present a number of specific characteristics in order to find application in the production steps. At present they seem to be usable for a large scale production and probably' they can already find application also in fields like' shoes, synthetic leather. and, after addition of a hardener. agent, also in the automotive interior field. This last modification is very important in order to pass the alcohol resistance test.

The waterborne lacquers are usable in the production pl rots: adjustment and fine tuning take more care than the solvent-based systems. The velocity of processing is in the range of solvent-based lacquers provided that the drying capacity of the channel is sufficient. As far. as the production plants are concerned. some important and innovative technological modification were necessary, which were not foreseen at the beginning of the research project; as a consequence now it is possible to use many type of water-based lacquers. How-ever because the large number of materials produced by Vulcaflex and TIS it is necessary to find the right type of lacquer for every single case: for instance the type of polymer most suitable for Vulcaflex is not the best choice for TIS, due to the cliff erent end uses of the materials involved in the two industrial processes.

The quality control and the data collection from the University Partner was carried out with the aim to confirm the good results obtained by the Partners. The final result of this work was very satisfactory.

At present the high price of a waterborne lacquer handicaps its fast introduction into the market. The small share in the market for lacquering flexible t ethnical textiles and calendered sheets implies high prices of raw material which vice versa holds up consumption. An appropriate environmental legislation on the organic solvent emissions in the atmosphere could accelerate the conversion from solvent-based to waterborne lacquers.

CONCLUSIONS:

The results of the research were reported in detail in the previous section on a task-by-task basis; from them some general final conclusions can be drawn as follows:

- At the beginning of the research waterborne lacquers showed worse performances than the solvent-base ones with regard to near all character sties (gloss, solvent resistance, weathering tests, creasing, dirt resistance and surface smoothness, slip, blocking behaviour, adhesion, gloss, mattness, burnishing "nail-marking", settling-out, embossing properties, weld-strength, welding properties, wetting and foaming behaviour). At the end all these parameters could be achieved to a satisfactory level, close to those of the solvent-based lacquers. The specifications stated at the beginning of the research were reached in all cases, and it was possible to obtain production samples whose technical and appearance characteristics fulfilled the usual production standards.

- The first step of the research had the target to study and prepare at a laboratory scale new water-based lacquers and new substrates suitable for the water-based lacquering system. The study of the influence can be summarised in three main points:

- nettability;
- adhesion;
- chemical interaction.

The difficulty of the problems to solve were very different for the different users, due to the substrates they uses, but in all cases the research gave good results. The goal was reached modifying in a substantial manner the old recipes: the modification was made by a suitable combination of several dispersion systems or by developing new types of polymers in dispersion: Further modifications of the studied dispersions were necessary in the case, of the film-forming, defoaming, wetting and viscosity modifying chemicals.

The. scale-up of a waterborne lacquer proved different and more difficult than the scale-up of solvent-based lacquers: each waterborne lacquers needed a process engineering of its own.

The new products did not give any toxicological *or* environmental problem, but on the contrary they reduced the existing problems.

- The reformulations of the lacquers were done with regard to the single specific requirements of the Partners as adaptation to different substrates, process parameters, and of course performances of the final properties: many problems could be solved, even if some others are still not fully overcome. After extensive modifications of the recipes, of the processes, and also of the production plants, the industrial verification and optimisation of the process parameters was accomplished with satisfactory results: in some cases, e.g. for the nettability, the results were better in production than in laboratory.

In addition. Vulcaflex obtained an important and quite unexpected result on the energy requirements of the process: in some cases the amount of energy necessary for the drying step of the water-based lacquers in the application stage was lower than the amount necessary for solvent-based lacquers. The reason can be the amount of the residual organic solvent trapped in the PVC organic matrix which is very difficult to eliminate and which is far lower' in the water-based lacquers.

An other innovative point was the introduction of a new subject of research: the coating of the paper, with the possibility to avoid a processing step by simply coating the lacquer on the paper, drying it and then coating the plastisol. This process can't be used with solvent-based lacquers, but it seems possible with water-based product;.

- Relating to the technological feasibility tests, at the beginning waterborne lacquers showed great problems on the grade of wettabilit y and adhesion between the surface and the substrate; an other important point was the amount of foam p roduced from the new lacquers, and their tendency to the sedimentation. Moreover, the water-based lacquers proved more sensitive with respect to shear stability than solvent-based ones, both in producing and in applying them: exposition to heavy metal ions as Fe-III, Cu-II, Cr-III, Sri-II has to be avoided. Production of waterborne lacquers should be made in vessels, pipes and machines made from stainless steel, type V2A. During the research important indica tions were found to modify the printing plants, which were fitted to the new process.

However, after the initial problems it was possible to find out the right modifications of the production cycles and plants which permitted to reach good results in lacquering tarpaulin and calendered sheets. The presence of the water in the lacq uering products had only scanty effects on the materials of the production plants. Moreover, i n some cases the quality of the lacquered materials was better in plant tests than in laboratory tests.

.- Finally, it was possible to develop waterborne systems for lacquering substrates as tarpaulins, artificial leather, calandered sheets, textile construction etc.: the quality of the final products was as good as the quality of the materials treated with solvent-based lacquers. Further researches are in progress to eliminate some residual p roblems; for example the water-based lacquers show still an inferior dirt resistance and their c resumption is greater compared to the solvent-based lacquers; however the results obtained at the end of the project are quite satisfactory.

Adjustment and fine tuning of water-based lacquers take more care than of solvent-based ones. The speed of processing is in the range of the old lac quers provided that the drying capacity of the channel is sufficient. In some case no higher energy consumption was revealed, and in any case it is compensated by saving costs of an incinera :or.

- As indicated before, perhaps the most important goal of the research, was the decreasing of the organic solvents emission which can be obtained using the water-based lacquers instead of the solvent-based ones; this objective wa; reached, and it is possible to evaluate that the decreasing of the emissions is very high, approx. 98°/0,

- At present the unitary price of the waterborne lacquers is not 'cheaper than the price of the solvent-based products, what could handicap their fast introduction into the market: an appropriate environmental legislation for the limitation of the organic solvent emissions in the atmosphere could accelerate the conversion from solvent-based to waterborne lacquers.

ACKNOWLEDGEMENTS:

The authors wish to thank the European Community for the financial support to the research project who allowed the reported results. The data of the funded project are:

Programme name: Water-born lacquering system for coated plastic materials and calendered films.

Contract number: BREU-CT92-0627

project Number: 6096

In particular, the authors wish to thank Dr. E. Campogrande for the help done to solve the administrative and management problems encountered during the research.