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UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

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DP/ID/SER.A/746
11 September 1986
ENGLISH

ASSISTANCE TO THE NATIONAL CENTRE FOR CONTAINERS AND PACKAGING

DP/CUB/81/012

CUBA

Technical report: Development of flexible packaging materials*

Prepared for the Government of Cuba
by the United Nations Industrial Development Organization,
acting as executing agency for the
United Nations Development Programme

Based on the work of Bohdan Czerniawski,
Expert in Evaluation of flexible packaging materials

United Nations Industrial Development Organization
Vienna

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V.86-59816

CONTENTS:

1. INTRODUCTION

1.1 Project background

Centro Nacional de Envases y Embalajes (CNEE) is the Government Executing Agency in Cuba of the Project DP/CUB/81/012. Its activities are aimed at improving the equipment, technical expertise and organization of the Centre. It has a staff of 84, including the administrative employees.

Its four main departments are the following:

- construction of machinery prototypes (including repair services)
- investigations
- technical (covering technical and economic aspects)
- technical services (operating in areas of packaging design, planning and technical information).

The Department of Investigation, to which the expert was assigned, covers the problems associated with standardization, quality control, different aspects of consumer packaging using plastics, paper and board, glass and transit packaging. The main purpose of the expert's assignment, in accordance with the job description, was the assistance to CNEE in training specialists for the development of research work on how to obtain a better quality in the production of plastic films and laminates.

1.2 Objectives of the mission

According to the job description the following activities were carried out during the mission:

a) evaluation of production of flexible materials and determination of development tasks in the field;

b) elaboration of proposals for the expansion of the use of flexible packaging materials for food and pharmaceutical products;

c) recommendations on necessary expansion of laboratory activities in the light of development of research work in the field of flexible packaging materials;

d) organizing conferences on the mentioned subjects;

e) providing information on technical literature concerned with the mentioned subjects.

2. SUMMARY OF FINDINGS AND RECOMMENDATIONS

2.1 Recommendations concerning present productions of flexible materials and plastic sheets

Polyethylene films PS sheets and Al foil and its' laminates (based completely on imported raw materials, excluding paper), with paper produced in a limited amount, constitute the only materials of the analysed group which are now manufactured in Cuba.

The improvement in the economics of the present production methods and applications should be considered as first priority, not questioning the need for a greater diversification of these materials.

Equipping coextrusion lines with the die enabling production of LDPE films 50-60 μm thick and PS extrusion line with additional die for production sheets of about half the thickness of the ones actually used, should have an evident influence on the improvement in this respect, provided that the ONEE specialists will assist in the implementation of thinner materials into the market. It is recommended to check whether the price for the thinnest PE film produced now (35 μm) provides sufficient demand for the production of this film.

It is highly recommended to accelerate the ONEE programme for implementation of LDPE shrink films for collective wrapping as a partial substitute for corrugated boxes, that may assure approximately 30% reduction in the packaging costs. Plastics waste recycling processes initiated and conducted by Plasticos Industriales should be expanded, especially of already used packages and heavy duty bags for fertilizers which represent a good example in this case. More detailed suggestions on the above mentioned subjects are given in section 3.4 also containing recommendations for further development of PE films area. Suggestions were made in respect of LLDPE and HDPE film production, as a way to reduce resin imports. A proper analysis of this task including - a complete picture of the possible applications of these films prepared by the ONEE staff should have a decisive influence on the investments in this case.

2.2 Recommendations concerning the substitution of oriented polypropylene for cellophane

On the basis of a detailed analysis given in Section 3.2 recommendations were made for a gradual substitution of coextruded OPP films for cellophane which is presently being imported. This substitution should provide savings in the range of US $ 900 per ton of substituted cellophane.

Proposals concerning the range of film thicknesses depending on the type of products to be packed and their weight were given in Section 3.2. It is assumed that the experience gathered from the application of the imported OPP films will have an essential influence on the final decisions concerning the eventual local production of the OPP films.

The coextrusion process in the case of OPP film making, shows a definite advantage over the traditional coating processes, as indicated by the operating, investment, wastage and material costs.

2.3. Recommendations concerning production of flexible laminates by coating and laminating ready-made films

There is a need, especially due to the high humidity conditions in Cuba, to expand the application of high barrier materials and to adjust them to different products and packaging technique requirements. A particularly essential role can be fulfilled in this case by the different plastic and non-plastic materials combined in the form of laminates. The shortage of this type of material owing to their high price, is evident in Cuba and due to this all efforts should be concentrated on the proper use of the extrusion line installed in Combinado de Papeles Blancos de Jatibonico, being the only one of its type in Cuba. Unfortunately up to now the line has only been used in the production of PE coated papers as overwrap of writing and offset paper produced by this plant.

Taking into account the huge capacity of this line, detailed proposals are given in Section 3.5 concerning possible additional production. It is obvious that the exisiting capacity is used to a very low extent while it can easily produce PE coated paper and boards, better than al foil laminates, because the line cannot use the width of foil produced in Cuba. This does not mean that some trials in this direction are not recommended and in the expert's opinion they should be carried out in direct co-operation with the manufacturers, ONEE staff and Enalum, a well experienced plant in al foil conversion.

Independently of this, assistance of UNIDO for the future manufacture of materials based on extrusion coating and laminating in the form of Special Industrial Services (S.I.S.) would be highly appreciated and recommended. The technical staff at Jatibonico was trained in processing much simpler materials in comparison to those found in typical packaging usage. The complexity of the packaging materials with respect to the selection of the materials, processes and fulfillment of packaging requirements, demand specific knowledge and experience that could be otained through the SIS assistance mentioned above, thus accelerating to a high degree the availability of these new packaging materials in Cuba. The further development of multilayer flexible materials in Cuba should be closely related with ONEE's investigation programme to be carried out in the new pilot scale coater-laminator recently purchased. In these investigations, apart from the extrusion coating and laminating technique it is highly recommended to concentrate on lamination by dry bonding. This process provides a high flexibility in the selection of different layers for the obtension of a wide range of materials with the required packaging properties.

2.4 Recommendations concerning the expansion of ONEE laboratory activities

During the expert's assignment some recommendations were given regarding the use of the presently available equipment, and the addition thereto by purchase as well as by manufacturing simple devices. In the case of high barrier materials it is recommended to carry out water permeability tests as recommended in Appendix 6. A special type of equipment known as Gelbo Tester and produced by Ameresco World Corp. (Montclair, N.J.), is also recommended for purchase. It is also advisable to use the so called automatic applicator available at the ONEE laboratory, which is useful as a preliminary coating test even in the case when a pilot scale coater-laminator is available.

The measurement of flatness, according to instructions provided by the expert, is a useful test for evaluating the quality of flexible materials and it is recommended to introduce this test for evaluation of film quality for printing, laminating, coating and also for predicting machine running of flexible materials.

The system of stiffness measurement described in Appendix 7 is extremely accurate and should be built based on the drawings presented at the ONEE workshops, provided that a proper compression cell in the range of 5 N will be available for installation at the ONEE laboratory (Alwetron Tensile Testor).

In the case of gas permeability of flexible materials in the first instance it is recommended to purchase an apparatus operated on the principle of measurement of pressure changes, in the version supplied by Davenport. This equipment provides a rather high range of gas permeability measurements, though in the lowest range of values (high barrier materials) its accuracy is not adequate and for this purpose it is much more suitable to use the Oxtran 100 produced by Mocon Instruments (Minneapolis, Minn). This equipment presents the possibility of checking gas permeability below 1 cm^3/m^2 in 24 h at 1 atm with high accuracy.

For control of oxygen permeability of ready-made packages it is recommended to apply a very simple gas balance produced by Taylor Servomex on license of BP Chemicals, operating on the basis of differences of gas density. Explanations on the use of this balance, in conjunction with a specially designed system for measurements in plastic bottles were also given.

3. SUBSTANTIVE SECTION

3.1 General situation of the production and consumption of flexible packaging materials

The interest of the developing countries in packaging can be considered according to their level of industrial growth. For the group of less developed countries the main problem is the availability of adequate transport packaging for the protection of the goods for export to foreign markets. For the group of more developed countries the introduction of retail packaging, modernization of packaging processes, implementation of more economical solutions and improvement of packaging quality, including design, up to international trade requirements, start to be at least the same or even more important problem. Development, in this respect, is not possible without the introduction of more diversified flexible packaging materials. This has been carefully evaluated by the ONEE management and is reflected in their decision of initiating their own investigations in this area and to prepare recommendations based on proper analytical works for further development of flexible packaging materials in Cuba. Flexible packaging materials are nowadays used in Cuba in a rather limited range of applications. There are many reasons for this, but among the most important ones are the need to import all the materials (polymers), combined with the difficulties in making payments in hard currency, as well as the lack of their own research in this area.

Among flexible plastic films, at present only LDPE film is produced in a blown extrusion and coextrusion process. The total amount of these films, mainly converted into bags and sheets, including heavy duty bags (for fertilizers) and shrink films exceeds slightly 6000 tons. The production of polyethylene extrusion coated papers has finally started, but unfortunately at present this production is not delivered for the market and is used only by the manufacturer of writing paper as a protective wrapping. 1200 tons of Al foil produced in the country, partially converted in limited range of coating and laminating materials is used for packaging purposes.

Polystyrene sheets, qualified rather as a semirigid material, are produced in the amount of 1000 tons/year. Manufacturers of the above mentioned materials belong to three different ministries; these are Ministry of Light Industry (MINIL), Ministry of Food Industry (MINAL) and Ministry of Basic Industry (MINBAS).

Evidently in many cases the capacity of installations is higher compared with the production scale and in some cases, for example, coextrusion and PS sheets, production is limited to a higher range of thicknesses only. Besides this production, different grades of cellophane, PVC stretch films and thermoformable sheets and PA/PE laminates are being imported. Among these materials only cellophane is imported in evident quantity, and only a small amount of stretch PVC film (Hungarian made) is used for meat and hard cheese packaging in the supermarkets nowadays. PA/PE laminates transformed in packages in Multivac system are used by the dairy industry for cheese packing and are also supplied to the supermarkets. PVC sheets are consumed by the pharmaceutical industry for "blister" type packaging used for tablets. Some more details concerning the above mentioned subjects are given in appendices 1 + 2.

3.2 Analysis and recommendations concerning the substitution of oriented polypropylene film for cellophane

According to the statistics introduced by the expert's counterpart, the different grades of cellophane imported, their application and forecast for their growth during the next five years are as follows:

TABLE 1

Present situation and forecast for the application of cellophane in Cuba

Grade	1985	1990	Application
	Tons		
MAT 300	2	4	marmalade in blocks
MS 350	225	319	coffee,cigarettes, sweets
MSAT 300	40	60	marmalade in blocks
MSAT 350	260	500	coffee, cigarettes, candies, confectionary
330 M 50	10	10	tobacco products
MXXT/A350	6	86	coffee, pharmaceutical tablets
XS 350	150	300	coffee
XS 500	60	300	wafers
KZ 500	10	15	coffee
KZ 350	10	20	tobacco products
JT 300	10	10	tobacco products
	843	1624	

There is no doubt that the decision for the local production of OPP films in Cuba, at least a partial substitution by these films for the presently imported cellophane, is fully justified and will be advantageous above all allowing considerable savings in the hard currency expenditures.

The implementation of these new materials on the Cuban market should take place gradually. The scale of the substitution can be determined on the basis of the experience gathered from the application in selected cases, provided that observation of a realistic protection of the products and machine performance will be made. The obtained results would allow determination of the directions in which the application in a mass scale is possible for the future progress in packing mechines and converting equipment (printing, laminating, slitting). A more realistic data for determining the scale of an eventual production of this material in Cuba and the most required OPP film grade for this production can also be obtained on this basis.

Detailed information covering the general situation in the production and consumption of OPP films in different countries, the possibility of cellophane substitution and its present position on the market, properties and applications of different OPP film grades are given in Appendix 4, which constitutes the full text of the paper prepared for one of the conferences, arranged with the participation of the industrial organizations.

Differences in prices between different grades are closely connected with the type of protective heat sealable layer and to a degree are influenced by the film's thickness. As was indicated in the Appendix because of a much lower OPP film density compared with cellophane, it is more reasonable to compare the prices per unit of surface than per unit of weight. Taking the US market as an example the range of prices depending on the grade of OPP film is on the level of 170 - 129 $ per 1000 square meters and 125 - 150 $ for cellophane in the same unit.

Vinylidene copolymer coated grades belong to the most expensive OPP films and uncoated - forseen as a layer for lamination or self adhesive tape production are the cheapest ones. Uncoated heat sealable grades are also classified in the cheaper group, but because of an evidently lower heac sealing strength the range of their applications is limited to some types of packaging only (overwrapping of cigarette boxes for example). The newest grades of OPP film - coextruded types are also evidently cheaper in comparison to classical coated grades. In the case of imported goods, the prices being paid are the result of the actual situation on the market and mutual relations between the commercial partners, but on the basis of European experience including the Polish conditions, it is reasonable to assume, that in the case of Cuba appr. 30% less expenditure is possible due to the implementation of the same amount of OPP films (in surface units) instead of the previously used cellophane. Assuming that the average price of the cellophane is on the level of 3000 $ per ton the substitution of each ton of cellophane should provide a saving of about 900 $. Assuming that 50% of the presently used cellophane can be replaced by OPP films which certainly is reasonable, the savings can be estimated at a level of 380,000 $ per year.

Specifications of the different grades of OPP films, including viryl and vinylidene copolymer type coating, and also coextruded ones produced by well known European manufacturers are given in Tables 7 - 11 of Appendix 4.

Polypropylene films similar to other polyolefins present good barrier properties against water vapour and the differences from grade to grade are relatively small. For a more direct comparison data concerning water vapour permeability (very important properties in Cuba's climatic conditions) for OPP coextruded films, which are considered now as the most economical grade, and for vinylidene copolymers coated are presented in tables 2 and 3. Because of different measurement conditions used in different countries these comparisons are made according to testing procedures used in G. Britain and W. Germany. As is evident on the basis of this data due to the natural resistance of polypropylene films to water vapour permeability, vinylidene copolymer type coating does not significantly change this feature of polypropylene films. Practically very close values of water permeability can be observed for coextruded and vinylidene type coated polypropylene. By increasing the thickness, further improvement of water vapour properties can be obtained. When comparing their properties with those of cellophane it should be noticed that water vapour transmission rate is somewhat higher for MSAT grades and similar for MXXT grades. (Table 6, Appendix 4) Polypropylene films do not absorb water and are not influenced by changes in climatic conditions as in the case of cellophane, especially when subjected to conventional converting and handling conditions. In this respect OPP films can be considered the more valuable material than, estimated on the basis of comparible permeability date, MSAT cellophane.

Moreover OPP films are not sensitive to mechanical hazards which might account for the increased permeability. The situation in regard to other gas permeability (oxygen, nitrogen, carbon dioxide) is different as can be observed in the comparable data presented in tables 5 and 6, Appendix 4. The orientation process provides a certain decrease of oxygen permeability, but a significant decrease is possibly due to the application of vinylidene chloride polymer coating. It should be underlined however that

TABLE 2

Water vapour permeability of OPP films (ICI production) Coextruded and vinylidene copolymers coating grades 90% rel. hum. 38°C

Film thickpress (total)	Coextruded film Trade name Propafilm MP	Vinylidenc copolymer coated Trade name Propafilm CG
μm	g/m^2.24 h	g/m^2 24 h
20	7	
21		6
25	6	
26		5
30	5	
32		4
35	4,5	

TABLE 3

Water vapour permeability of OPP films

ICI - Great Britain and Wolf - West Germany coextruded and vinylidene copolymers coating types

85 % rel. hum. 23°C

Film thickness Total	Coextruded films trade name Propafilm MP (ICI)	Walothene CF (Wolf)	Vinylidene copolymer coated Propafilm CG (ICI)
μm	g/m². 24 h		g/ m². 24 h
20	1,4		
21			1,2
25	1,2	1,6	
26			1,0
30	1,0		
32			0,8
35	0,8		
40		1,0	
50		0,8	

in the case of non-laminated films the differences in oxygen permeability do not play so important a role as is commonly considered. It should be taken into account that the amount of oxygen which is introduced into the package together with the product in particular when using a film with very well developed surface is absolutely sufficient for oxydising the product and permeability, in this case, plays a secondary role. The heat sealing strength of OPP films is not adequate for applying vacuum or neutral gas packing techniques, which would significantly change the situation in this case. Applying this type of technique is possible however in the case of laminates, where one of the layers provides sufficiently low gas permeability rate and the other suitable heat sealing strength. This may not be so clearly evident on the basis of the data presented in the tables, as the type of heat sealable layer strongly influences the range of sealing temperatures. It should be underlined, that OPP films are more sensitive to deviations in heat sealing temperatures specified for particular grades, in comparison to cellophane. For processing of OPP films more accurate control of heat sealing bars is required.

This involves necessity to use more accurate thermostatic devices and temperature controller. It is worthwhile to notice however that coextruded grades are less sensitive to these deviations. The present sealability interval is about 30°C with the initial sealing temperature 105°C. It is expected that OPP coextruded films with an initial sealing temperature of 95°C and with 40°C intervals will soon be available.

Preliminary difficulties, which can be encountered with OPP films on some type of machines, e.g. Trans-wrap are used for ground coffee, are easy to solve as far as film cutting is concerned, by simple adjustment of separation of sealing and cutting operations.

Taking into account actual application of cellophane in Cuba and the above mentioned considerations it is recommended to start implementation of OPP films into the market with coextruded grades. This does not exclude simultaneous introduction of vinylidene coated grades in the future as this also proves to be necessary from the gas permeability point of view.

Wide introduction of OPP films into the market doesn't exclude parallel application of some amount of cellophane, for example for strip packing of pharmaceutical tablets. It is recommended to start trials with OPP film thickness range of 20, 25-30 and 40 μm depending on the weight and type of product and required protection.

After gathering more experience with this range of thicknesses better adjustment of the thickness to the specific application will be possible.

It is recommended to start tests with the representatives of the machine and product types to gather at the same time experience regarding machine performance and shelf life of the products.

As it was explained during the discussion with participation by the Head of the Machinery Department and expert's counterpart, there are a considerably big amount of the machines which can be used in the future for conversion of OPP films. Among the vertical form-fill-seal machines there are about 60 Rovema machines, 14 old type transwrap (Stock Smith) and also machines constructed in Cuba (13 already installed and 17 in the construction phase) can be mentioned.

There are a considerably smaller amount of horizontal form-fill-seal machines used in Cuba and among them 5 SIG machines can be taken into account as machines for OPP film conversion. Overwrapping machines presently operated with cellophane should not be omitted.

There is no doubt that not all of these machines are ready to work with cellophane, but proper adjustment is possible in the majority of cases.

As was mentioned during the visit to Pilon (manufacturer of ground coffee) the device for temperature control of heat sealing bars could be exchanged to allow reduction of temperature variation not to exceed 15°C, which is absolutely enough for any OPP film processing.

For preliminary introduction of OPP films it is recommended to use only machines which assure proper temperature control of constantly heated sealing bars.

Some experience of IIIA staff, as far as OPP film performance is concerned, when packing food products should be underlined. Co-operation of both organizations in this area can accelerate wider implementation of OPP films into the Cuban market. This co-operation should prove to be very profitable due to the experience of CNEE in packaging machines and IIIA in shelf life testing. On the basis of analysis of the types of products presently packed in cellophane, taking into account situation with regard to packing machines and the discussions conducted with the expert's counterpart some suggestions for future application of OPP films were made.

3.3 Some considerations concerned with local production of OPP films

As it was mentioned before, the results and experience obtained by wider introduction of foreign made OPP films onto the Cuban market should have an essential influence on the final decision concerning the local production of OPP films.

If the foregoing recommendations are followed the suitability of coextruded OPP film grades will be clarified definitely. The coextrusion process from the investment, operating and wastage point of view has an advantage over the traditional coating process.

According to the actual information of manufacturers of coextruded OPP films line, basic investment costs for the line with efficiency up to 1500 tons per year (calculated for 25 μm thicknesses), which seems reasonable in the Cuban case, are on the level of 2,4 mln $. The line can be adjusted for film thickness in the range 15-60 μm and consists of main extruder, two small ones for extrusion heat sealable layers and equipment for biaxial orientation.

Following proposals can be considered for implementation trials of OPP films:

Coextruded OPP films			Vinylidene chloride copolymer coated OPP film
Film thickness μm			
20	25 - 30	40	
1. Hand wrapping bisquits	1. Candies (100-250g)	1. Instant drinks (considering shelf-life trails)	Comparative tests with 25 μm films for control of shelf life of ground coffee comparing with coextruded grade.
2. Bisquits (bag in folding carton)	2. Instant drinks	2. Pasta	
3. Non-hygroscopic products	3. Coffee (ground) *	3. Wafers (considering shelf life trials)	
4. Candies (in 100g or less)	4. Snacks		
5. Blocks of marmalade	5. Cornflakes		
6. Small and light textiles	6. Wafers		
7. Light toys			
8. Cigarette overwraps that due to machine operation might require special grade of film like: Propafilm MIT 21			

* inserting coffee in the list does not mean that this solution is recommended, but could be acceptable considering present application as accepted by the market.

From the investment point of view, production of acrylic or vinylidene copolymer coated grades would have involved higher cost at least on the level of o.6 mln \$. In both cases the investment costs don't include printing and slitting machines. In addition more space for operational area, more labour and energy is required for coated film production.

Production wastage of coated films cannot be recovered and put back into original extrusion process, which is possible in the case of coextrusion. Costs of raw materials is also evidently lower for coextruded films, where the core is based on traditional grades for film making, and specialized grade of ethylene-propylene copolymer providing heat sealability is used in the form of a thin layer on the level of 1 g/m^2 per side.

It should be mentioned that vinylidene copolymer coating is equal to 6–10 g/m^2 for both sides (Wolf's technology for example) prices of vinylidene chloride copolymers, usually supplied in the form of 50% water dispersion, are on the level of 2000 \$/ton. Dispersion itself requires rather careful handling and storage conditions.

Assuming that the yield of 0.25 mm OPP film is on the level of 45 m^2/kg, the minimum consumption of vinylidene chloride copolymer films coated on both sides is equal to

45m x 6 g/m^2 = 270 g/kg and

0,27 t/ton (solid substance).

For production of 1,27 tons of OPP coated film consumption of dispersion (solid form) is equal to 0,27 t. Participation of copolymer in both sided coating: 1500 t of ready made film is equal to 50% contents of the solid substance which corresponds to 640 t. of the dispersion (1500 x 0,27/1,27 = 320 t. solid form).

The typical thickness of heat sealable layer of coextruded films is equal to 1 g/m^2 per side. In analogical case of 0,025 mm both side heat sealable OPP film's consumption of necessary resin will be equal to:

45 m^2 x 2 g/m^2 = 90 g/kg

and 0,090 t/t.

For production of 1,09 t of OPP coextruded grade consumption of heat sealable resin is equal to 0,09 t.

Use of this resin in 1500 t of both side sealable film is equal to 1500 x 0,09/1,09 = 124 t.

In both analysed cases production wastage was not taken into account it should be underlined however, than in the case of dispersion coated films recovery of production wastage into the process of film making is not possible and that this possibility exists in the case of coextrusion.

It is also worthwhile to mention, that not all OPP films have to be produced as a both side coated material and consumption of heat sealable layer should prove to be lower than indicated above.

Polypropylene resin for OPP film making is generally available on different markets both in capitalist and socialist countries. The prices of OPP resins on West European markets is on the level of 800 $. The grades suitable for heat sealable layers are produced by some companies only, and are available in some West European markets such as West Germany and Great Britain.

It should also be mentioned that OPP films constitute a valuable component of laminates with Al foil and LDPE and are nowadays considered especially in a coextruded form as the most important substrate for metallisation, which was described in detail in the paper handed out during the conference concerning metallised materials.

In consideration of the above the possibility of producing solvent coated OPP films was not taken into account, because there has not been any justification for implementation of this grade from the time, when coextruded grades entered into the market; from the point of view of functional properties coextruded grades indicate advantages over solvent coated grades (higher costs of the production process involved in the last case).

By using the solvent recovery system or, when it is not economical, the system of solvent combustion, are consituted additional factors for which this technology was excluded from presented analysis.

3.4 Evaluation of present situation and development proposals in polyethylene films area

LDPE films are produced in Cuba in a total amount (including heavy duty sacks for fertilizers) equal to appr. 6000 tons.

Two of the film manufacturers Plinex and Plasticos Industriales belong to MINIL and Envalac to MINAL.

The extruding line for thermoshrink LDPE films production was installed recently all other equipment is of an older type (Bielloni blown extrusion lines in the case of Plinex) and also an old (Macchi) coextrusion line installed in Envalac.

Among 17 lines used in Plinex only two are adjusted for manufacturing films suitable for machine running, one based on the extruder ∅ 60 mm and the second one with rotating head and ∅ 45 mm.

The efficiency of a single line is estimated on the level of approx. 34 kg/h. The majority of film production is converted into bags or sheets predicted for hand packing. Thicknesses covered are in the range of 0,040 – 0,150 mm.

Envalac's 3 coextrusion lines with rotated extruders were preliminarily predicted for production of film for liquid milk packing and for this reason are adjusted for making 0,090 mm thick film. This preliminary expectation has changed and 0.090 mm thick film produced by Envalac is used for other purposes, applying vertical form-fill system, in which case it is not necessary to use such a thick material.

According to CNEE production of polyethylene films should increase to 9000 tons in 1990. In other words the consumption should reach the level of approx. 0.9 kg/capita, this amount is relatively low compared with the average consumption of this material in other countries. Taking this into account and also the necessity of resin importation special attention should be paid to the economy of PE film production and application, providing in the first instance the material saving.

As it is easy to observe when glancing in local shops and supermarkets the real need exists to reduce the film thickness. Presently the main supplier of so called "machine quality" film is producing only 90µm thick film and under this condition it is obvious that this film is sometimes justifiably used, but also it is used for packing small amounts of the product which do not always require special protection against water vapour transmission.

There is no doubt that proper adjustment of Envalac lines for production of 50-60 µm LDPE films, should be considered as a first priority task. It is worthwhile to underline that, taking into account present price of PE resin on the market, each ton of 90 µm film which is replaced by 60 µm film thick provides a saving on the level of 260 $.

Of course some amount of Envalac production, specially for milk or yogurt packing, will be produced at present thickness, but assuming that 50% of the production can be supplied as a 60 µm film, the decrease of the resin consumption at present production scale, would provide a saving on the level of 130,000$.

Whilst discussing Envalac's production the need for implementation of pigmented LDPE films should be mentioned. This seems easier to realize than in the case of coextrusion; with the use of master batch containing for example titanium oxide in an amount not higher than o.8% into exterior layer only.

It should provide proper protection for some types of products such as powdered milk, which is now exhibited for direct interaction of the light when stored for a long term on the shop shelf. Pigmented films are usually used for liquid milk packing too.

It should also be mentioned, that proper ratio of the prices allowing for different film thickness could lead to some saving of the resin. The price per 1000 bags produced by Plinex in the dimension of 210 x 660 mm x 0.035 is equal to 13.73 pesos and for 155 x 320 x 0.05 to 6.54 pesos.

It is easy to calculate that the price per unit of the surface of 0.05 thick bags is 25% higher compared to 0.035 mm thick bags. Consumption of polyethylene resin is about 30% less per unit of the surface of thinner bags.

In this case it should be checked whether with the production of shrink films, the differences in price stimulate to a sufficient extent the production of thinner materials. There is no doubt that production of the thinnest films causes evident decrease in capacity and requires more control of the process compared to thicker one.

If the proper ratio between the prices is not provided manufacturers indicate a tendency to avoid production of thinner films, or what very often takes place they supply the film in the upper limit of tolerated thicknesses.

Proper ratio between the material prices for different thicknesses supplied in rolls also stimulates increase of consumption of thinner ones. Taking for example the situation in Poland it should be mentioned that the introduction of plastic films and sheets with a new system of prices per unit of surface, with preferences for thinner materials influenced to a high degree increased production and application of thinner films.

There is no need to justify how important diminishing of the thickness of the materials to a reasonable limit is in the case of Cuba, where all polymers are the subject of importation.

Considering present application of LDPE 0.05mm thermoshrink film used for portion meat packing, which doesn't provide proper protection of this product, it is recommended to compare the prices (based on the price of imported resin) with the price of thermoshrink or stretch ready made PVC films, which are available and used as 0.015mm thick films and are produced among others by Kalle, Borden Chemicals and Hungarian manufacturers.

These are typical films used for protection of these products. Such films are also used for forming heat sealable overwrapping of trays and the system applying thermoshrink PVC film as a lower layer and stretch PVC as upper one can be mentioned as an example.

At present in Cuba, further diminishing the thickness of thermoshrink PE film used for meat packing cannot be seriously considered, because of the limitation of the existing line, which is adjusted for film thicknesses typical for collective wrapping and pallets' hoods and is used mainly in these applications.

Where meat packing is concerned, the influence of construction of the trays for the shelf life of the product should be mentioned. In the case of presently used PS trays proper profile on the bottom of the tray, allows for separation of the product from its leakage, which is gathered in free spaces of the profiled bottom. It was confirmed that direct contact of the meat with the leakage accelerates processes responsible for spoiling the product. Easy absorption of paper pulp trays is considered as an advantage in this case, though the appearance of swelled trays is far from appropriate.

It is highly recommended to accelerate the CNEE programme to implement LDPE thermoshrink films as a partial substitute for corrugated boxes especially for collective wrapping of filled tinplate cans and in other similar applications.

The possibility of introducing thermoshrink films for collective wrapping for filled glass jars in Cuban conditions should also be checked.

It is worthwhile to underline that this implementation can provide approx. 30% saving of packing costs.

In this case one directional thermoshrink film (shrinkability in machine direction 70% and 15% in transverse direction) can be considered as typical, when combined with so called sleeve wrap system.

Details connected with required thickness in relation to the product weight and information in regard to packing systems were given in the material prep[illegible]ed for the conference dealing with thermoshrink films.

There is no doubt that for further saving of raw materials, the recycling processes initiated and conducted by Plasticos Industriales should be expanded.

Besides presently employed technologies there is real need to expand recycling process for some of the already used packages; LDPE heavy duty sacks used for fertilizers are the best example in this case.

Due to the large amount, equal to 2000 tons of polymer, used for the production and rather concentrated supply of the packed product, collection of these packages should not create special problems. These wastages after cleaning, cutting and extruding in the form of pellets, create valuable materials for the production of some other type of packages and bottles for liquid detergents and for general household chemicals.

It is worthwhile to underline, that mainly due to their location in one place, recycling of the materials is possible and provides direct economical profit for the company, which constitutes a very important factor for expansion of recycling processes and assures evident profit for the national economy.

This approach seems to be a rather important factor as generally speaking manufacturers are not very interested to produce recycling pellets for sale, becase technically justified price of reprocessed resin is often higher compared with the new one.

There is no doubt, that because of the age of presently installed LDPE extrusion lines and the predicted 50% increase of the production, investment in new lines is necessary.

Taking into account progress in the machines manufacturing area, a line with higher efficiency should be considered. Blown extrusion lines equipped with an internal cooling system allows production of high quality film fulfilling the requirements of packaging machines with typical thickness in this case (for LDPE film) 0.05-0.06 mm, at capacity higher than 300 Kg/hr.

Due to the economical advantages of linear low density polyethylene (LLDPE) and above all the possibility of producing at least 30% thinner films compared with LDPE films; also due to much higher mechanical strength; investment in lines adjusted for processing this film should be seriously considered. This line should allow production of the film into the range of thicknesses 0.02-0.1 mm.

There is no doubt, however, that thin LLDPE films indicate higher water vapour permeability compared to presently, used thicker LDPE films and possibility of applying thinner films is limited to nonhygroscopic products only.

Before a decision concerning LLDPE line is taken, if possible, a full picture of future applications of this type of film should be completed, taking into account poorer barrier properties of thinner films. In other words the amount of non hygroscopic products forseen for packing, should have influence on the decision concerning this investment and specially on the capacity of selected line.

Economical production of LLDPE constitute the basis for assumption of lower price of this resin compared to LDPE. On the basis of this assumption, introduction of LLDPE film is justified even without diminishing the thicknesses in comparison with LDPE films.

Compared to typical LDPE blown extrusion lines, those adapted for LLDPE processing first of all differ in construction of the screw, which is more similar in design to that used for HDPE film extrusion, and should allow to equalize higher shear forces. There are some differences in construction of the die and air ring which should provide higher air volume at moderate velocity.

Generally speaking further conversion of LLDPE should not present special problems. A few points worthwhile to note are as follows:

- LLDPE is more abrasive, so cutters should be kept particularly sharp and their service life should be increased by proper treatment;
- sealing temperatures are higher than LDPE of the same thickness but since LLDPE is usually sealed by downgauging the same equipment this doesn't involve difficulties;
- if LLDPE is heavily downgauged over conventional LDPE, then some alteration of the winding tension is necessary to avoid film creasing.

Information concerning the properties and applications of LLDPE films were presented and discussed in the material prepared for the conference dealing with polyethylene film and stretch films. It is worthwhile to remember that LLDPE film is one of the most economical stretch films. Production of stretch films however requires special grade of resin containing additives providing so called "cling effect", which is the basis for application of stretch films.

The majority of polyethylene films are consumed in Cuba in the form of ready-made bags and sheets. If this tendency remains in the future, it is worthwhile to invest in a line for HDPE film making. This film presents specially good properties for production of bags for manual or half - manual operation. Prices of a standard HDPE resin are practically on the same level, when comparing with LDPE and due to natural stiffness and strength the material for sheets can be produced at thicknesses starting at 0.01mm and for bags 0.02 mm thick. In the last case high molecular grade of HDPE should be indicated as the adequate material, because of its much higher strength.

Additional justification for this production is constituted by present import of ready-made shopping bags used by Intur shops. If one takes into account that thickness of the thinnest LDPE film produced now is equal to 0.035 mm and majority of these films are produced starting from 0.050 mm. economical advantages connected with the implementation of HDPE films are evident.

It is worthwhile to mention, that in the case of HDPE films decrease of thickness compared to LDPE films is compensated by much lower water vapour permeability in the first case. It is reasonable to assume that at the same thickness water vapour permeability of HDPE film is approx. two and a half times lower compared to LDPE. This feature combined with economical advantages and form of application seems to be a very important factor justifying introduction of HDPE films in Cuban conditions.

It should not be expected however, that introduction of HDPE films solves the form-fill-seal packing problem and HDPE films are not recommended for these applications.

3.5 Development possibilities of flexible coating and laminating materials

There is no doubt that to a great degree the present position of flexible materials is the result of implementation of mutual combination of plastic and traditional materials through coating and lamination.

Independently of the production process it is reasonable to consider as a laminate, any combination of different or the same plastic films or plastic plus non-plastic material (paper, Al foil, cellophane) wherein each major layer is generally thicker than 0.006 mm.

Laminates are formed by extrusion and coextrusion coating and laminating. Overview of all these techniques was given at one of the conferences, now it is only worthwhile to remember that the main aim of laminating is to provide a combination of physical properties, which cannot be achieved by use of single ply and to provide this combination of properties in the most inexpensive way possible.

It should be underlined that through proper composition of laminate layers, there are examples when these types of materials were able to substitute more expensive tinplate and not only in the case of very sophisticated retortable pouches, but also for pasteurized packing of bigger blocks of ham with use of thermoformable PA/ionomer laminates.

In this group of flexible materials some types of laminates are based on Al foil combined with paper by wax or wet bonding lamination process, in the last case they are partially coated with heat sealable lacquer and produced in Cuba. Polyethylene coated paper from the new line installed in Combirado de Papeles Blancos de Jatibonico can also be qualified to the same group of laminates, which up to now unfortunately are used only as a protection overwrap for the paper produced by this company. Also in use are some amount of PA/PE, imported as a ready-made laminate.

From a technical and economical point of view further development of production is out of the question. As it was mentioned previously proper understanding of the meaning of flexible laminates is reflected in the decision of CNEE management to initiate it's own investigation in this area. There is no doubt that the installation of a pilot scale laminator-coater recommended by the previous expert Mr. J. Salisbury will be helpfull for faster implementation of properly selected and of quality controlled materials into the market. It is worthwhile to realize that the whole procedure from purchasing the equipment through to its installation, gathering experience of technical staff in its operation and in manufacturing required quality of materials is a time consuming operation.

In the meantime all efforts should concentrate on providing assistance to the industry and on undertaking the required action for proper exploitation of the already installed extrusion line and for adjusting its production to the markets' needs.

This high efficiency line is able to convert at maxium capacity and maximum material thickness 6800 tons of paper 680 tons of polyethylene and 2000 tons of Al foil. The width of the line is equal to 1800 mm and with proper blockade it is possible to convert the material to widths starting from 900 mm. The lines of this type are designed for continuous running and all stoppages of the machine and putting back into operation again involve severe losses of raw materials and difficulties in stabilization of parameters of the process. This line has been put into operation and during the last two - three months some amount of coated paper was produced.

This line was preliminarily predicted for use as a protection overwrapping for writing and offset type paper, being an export of the Jatibonico plant. This explains the choice of high width of the line and some other decisionssuch as the printing system which is suitable practically for this purpose only (printing under the coating layer), but doesn't justify to any extent capacity of the line if one takes into account production and export scale of the Jatibonico products. Under these conditions and because of the packaging market requirements of supplying more diversified materials, providing better protection of wide variety of goods and fulfilling the requirements of foreign customers, this line should be used as soon as possible for enriching the market of flexible materials in Cuba.

The line is adjusted for production of extrusion coated paper and theoretically for extrusion lamination with Al foil. The possibility of coating Al foil previously combined with paper exists. It should be mentioned however, that converting Al foil usually requires application of so called primer (for improving adhesion) or other preliminary coating (e.g. for improvement slip characteristic).

According to information given by the representative of the Technical Department of MINBAS, the line is not equipped with devices enabling this type of treatment.

As a result of the preliminary assumption the line is not fitted well to the dimensions of the materials produced in Cuba and the width of Al foil is lower than the indicated limit of extrusion line. From the point of view of production of flexible packaging materials the location of the line should also be questioned. None of the material necessary for production is available in Jatibonico and nor do the printing facilities exist. Under these conditions transportation costs will have evident influence on the cost of ready-made material. Despite all these objections; taking into account that the described extrusion coating line constitutes the only one of this kind in Cuba, all the efforts should be concentrated on making best possible exploitation of production of packaging materials under existing conditions. Generally speaking one can expect better chances for production on existing lines for polyethylene coated paper and carton boards than Al foil laminates.

At the present time no programme exists for production and implementation of these for the Cuban market. There is no doubt that this type of programme requires proper study of the market needs including availability of packing machines, analysis of technical and economical consequences and justification of implementation of new solution. Availability of the materials for coating or laminating should be considered.

On the basis of the discussions with CNEE management and staff and the expert's own observations of the market some suggestions for this programme can be made; polyethylene coated materials can be considered for at least three groups which cover:

- sulphite paper (in lowest substance possible) used for sugar packing in small portions (hotels, airlines, restaurants) strip packing of pharmaceutical tablets, less sensitive to moisture, direct ice cream packing (lollypop type), inner layer of composite can;
- kraft paper as an inner layer of multiwall paper sacks used for transportation of some food products (sugar) and some chemicals;
- carton board used for folding boxes predicted for frozen food: e.g. lobsters (substitute of imported carton board) vegetable salads, and ice cream.

Despite this it is also recommended to start trials in respect of combinations with Al foil.

Extrusion coating of Enalum Al foil with paper seems to be a reasonable solution in this case.

In thetrials being conducted it is recommended to pay special attention to the behaviour of Al foil on its contact with paper. Additional treatment of Al foil (protective coating) may be required for providing sufficient adhesion to extrusion coating. An assumption was made that PE layer will be placed on all sides to provide better barrier properties.

Possibilities of combining thicker Al foil e.g. 0.020 mm with PE in lamination unit can also be checked. This type of material is especially useful for strip packing of pharmaceutical tablets highly sensitive to moisture.

In this case close co-operation with Enalum would be helpful as far as application of intermediate layer of Al foil is concerned.

Independently of this, assistance of UNIDO for the future manufacture of packing materials based on extrusion coating and lamination in the form of Special Industrial Service would be highly appreciated.

The technical staff of Combinado de Papeles Blancos were trained in the operation of the process predicted for the production of much simpler material, adhering to typical packaging uses.

The complex character of packaging applications, as well as raw material selection and technology of production to fulfill the requirements of food packaging, requires specific knowledge and therefore the above mentioned assistance seems to be justified.

3.6 Training the personnel of the Centre in the use of already existing equipment and recommendation for expansion of laboratory activities

During the expert's assignment some recommendations were made as far as the use of presently available equipment was concerned. This also included some simple adjustment, possible in local workshops, extending the testing possibilities. The list of 15 subjects discussed in this area also include the tests conducted under the supervision or according to the expert's suggestions are given in Appendix 5.

In the case of instructions for new laboratory personnel these were prepared and submitted in the way presented in Appendix 6. This example constitutes measurements for standard crushing of the flexible materials prior to water vapour permeability measurements. Full cycle of measurements for selected materials was made and suitability of the system for evaluation of the materials was proven.

Appendix 7 presents a proposal given for extension testing possibilities for construction of simple devices. They provide a possibility to evaluate the stiffness of flexible materials in a very accurate way. Installation of this type of device on Alwetron strength measuring machine will involve equipping this machine with extra compression cell (range up to 5N).

Some recommendations concerning extending the testing possibilities by buying and installing new equipment were also made. These cover gas permeability measurement of flexible materials, permeability of ready made plastic packaging and Gelbo flex tester. Recommendations in this respect are given in section 2.4. The importance of chromatographic analysis in respect of wide scale planned investigations in flexible materials area and the range of its possibilities was discussed and technical documentation concerning this subject was submitted to laboratory personnel.

Suggestions concerning the need for implementation of sensoric analysis of flexible materials were also made. There is no doubt that future development of flexible materials in Cuba is closely connected with the integration of the materials into the market.

In this connection, CNEE can play a specially important role. This has been evaluated by the management of the centre and attempts are underway to buy a pilot scale coater laminator which was recommended by the previouly employed ITC Export Packaging Consultant Mr. J. Salisbury.

It was explainedby the expert, however, that even before the installation of a pilot scale laminator, some tests in the use of simple laboratory devices are very useful as an introductary trial. In connection with this the application of so called Mayer bars was discussed and it was indicated how to produce them in workshops.

On the other hand there is a possibility of using a so called automatic applicator (Toyoseiki, Sho Ltd. Japan) which already exists in the laboratory of the Centre.

On the basis of practical experiments the range of applications of this equipment were suggested. The trails were made with available flexible materials. Possibility and manner of using this equipment for coating even flexible materials as thin as OPP films were presented.

The experiments made with paper and acrylic resin used in Cuba for Al foil coating confirmed the possibility to obtain quite uniform thickness of the coating. In the case of paper, which is qualified as the substrate of high absorbtion rate it seems more useful to regulate the thickness by proper change of concentration, than by exchange of so called 'master blades'.

This is not necessarily true in the case of nonabsorbing surfaces such as Al foil or plastic films, where both possibilities for regulation of the thickness are of equal value.

During the visit to the Food Industry Institute (IIIA) I observed a relatively good and possibly even better equipped packaging laboratory than that of CNEE, though not all the equipment is ready for operation. Nevertheless close co-operation of both investigation centres seems to be very profitable for both sides.

3.7 Conferences and talks with customers and manufacturers of flexible packaging materials and representatives of the research centres

The cycle of seven conferences covering production, application and properties of flexible packing materials were arranged with participation of representatives of industrial organizations and research centres. A paper was prepared and printed for each conference and handed out to participants. An example of one of the seven topics is presented in Appendix 4. A list of the topics of the conferences in the form of an invitation sent by CNEE to different organizations is given in Appendix 8.

Also more specialized conferences were arranged on some subjects which took place mainly during the visits to the different organizations; these are mentioned in Appendices 1 and 3.

APPENDIX 1

Visit to Envalac

The company which belongs to the Ministry of Food Industry is a big converter of milk products and at the same time manufacturer of some plastic films, sheets, ready-made packages (crates for bottles) and closures (for glass bottles).

Envalac produces plastic materials for its own application in the plant and for sale. Coextruded LDPE films are produced on older type Macchi (Italian) lines.

The line consists of two extruders in vertical positions rotated together with the head, with capacity appr. 67 kg/h when producing film of total thickness 0.09mm (2 x 0.045 mm).

No other die is available at the moment, though a new one, enabling the production of thinner films (0.06mm) is to be installed. Three lines of this type are installed in the factory with a total capacity of approx. 1200 tons/year though the present production is on the level of 500-600 tons/year.

Coextruded LDPE films are printed (up to two colours) in the same company. These lines were previously forseen to produce the film for liquid milk packed in Envalac. For this purpose prepack type machines were installed in the company and to some extent are used for yoghurt and milk packing, but the majority of LDPE coextruded film is produced for sale and used for packing on form-fill-seal machines for such types of products as instant soft drinks, 'natilla', candies and confectionary, milk powder, wafers, pasta products, cornflakes, cereal products; in all cases in a heavy gauge 0.09mm because thinner film is not available yet.

Using Covema extruders Envalac produces 1000 tons/year of polystyrene sheets (final width after cutting the edges 750 mm) and full capacity is estimated on the level of 2000 tons. PS is partially consumed by Envalac for packing of yoghurt on form-fill-seal machines, the rest is for sale.

The material available is 1mm thick and is now produced with the use of Soviet made shock resistant UPM 0503 PS. The 1mm thick sheets are used for yoghurt packing on form-fill-seal machines where thermoformed cups are closed with heat sealable aluminium foil produced in the country by Enalum. The laboratory of Envalac is relatively well equipped, but MFI which is an especially important value in the case of coextrusion is checked in another place.

Visit to Empresa Plasticos Industriales

The company belongs to Plasticos Cubanos to which Plinex is also incorporated. During this visit a conference was arranged with participation by representatives of the Ministry of Light Industries: Ing. Eduardo Estrada and I.F. Alonso; the factory's management: Lazaro Navarete and technical staff: Efrain Cardenas. At this conference it was possible to explain some of the technical problems experienced by Plinex, the largest producer of LDPE films in Cuba.

This firm among other packaging items produces plastic boxes, polypropylene banding tapes and thermo shrink films and is also reprocessing some waste plastics (including polyethylene films and boxes), which either arise in this company or are supplied from other plastic factories (e.g. Plinex). The reprocessing line contains a crushing machine for plastic boxes; film cutting machine; machine for segregation of polymer particles according to density and extruding line for regranulation. The material gained from the crushing equipment for plastic boxes is immediately recirculated in proportion of up to 50% for production of new boxes.

For thermoshrink LDPE films the Bielloni line is installed with 0.09mm extruder, ratio L/D=30, capacity up to 150 kg/h with possibility to produce 0.04-0.15 mm thick films. The machine is equipped with three different dies: 250, 350 and 400 and is adjusted to produce the tube dimensions up to 2 m wide (width of flat tube).

The production of this film is in the stage of stabilization and full capacity of the machine is not yet obtained. So far this is used mainly for palletizing empty beer bottles; packaging of textiles in rolls and blocks of lobster. The thinnest films (0.04mm) are also used for direct wrapping of portioned meat. Some examples of shrinkability of the films for different applications based on quality control tests were presented.

The shrinkability values measured at 120 C were as follows:

Application	Film's dimension Width x thick. mm	Immersion Time 5	Shrinkability % Long.	Trans.
Direct meat packing	400 x 0.05	5	55	42
Block lobster	360 x 0.05	5	50	40
Film for pallets	1275 x 0,150 (2 x 537,5)	15 30 45	45 53 57	36 35 43

Plinex, a manufacturer of approx. 2800 tons/year of LDPE films is equipped with 17 Bielloni older type 60 mm diameter extrusion lines. The height of the building (only 5 m) is the limitation for the installation of LDPE film making lines with a higher capacity.

The thickness of films produced are in the range of 0.04-0.15 mm. The realistic capacity is on the level of 34 kg/h. Only one 60 mm diameter line is equipped with rotating tower and another 45 mm diameter with rotating head; films from these machines are only adequate for conversion on form-fill-seal machines.

The majority of LDPE films are converted into bags or sheets. These packaging films are used for manual packing of different goods the main applications of which are listed below:

Pharmaceutical industry: cotton woll; bags for medicaments.

Food industry: instant soft drinks, powder for ice cream, rabbit and chicken meat, fish fillets, lobsters, cottage cheese, shrimps in blocks.

Agricultural industry: seeds and rice samples, ground samples, raticides animal's medicines, ground and little plants.

Light industry: toys, dolls, table games, shoes, clothes, socks, spare parts, chemical reagents.

Visit to Enalum

This manufacturer of Al foil and its combination with paper and heat sealing coating, belongs to MINIL and specializes in rolling thick plates (0.5-1.0 mm) down to different thicknesses of which 0.009 mm is the minimum. These plates are imported from different countries, such as Yugoslavia, Spain and Argentina. The total production of pure Al foil is equal to 2200 tons.

Approximately 1200 tons are used for packaging and the rest is mainly consumed in building construction and electrical appliances.

The total amount of Al foil is produced in the soft form. The largest amount approx. 500 tons is used for milk bottle closures. For this purpose lacquered foil with one coloured side of approx. 0.06 mm is applied, the lacque coating in this case diminishes the friction, which is required on the filling and closing line.

Coating approx. 38 µm thick Al foil with the acrylic type lacque has a double advantage, it separates the Al from the type of film used for yoghurt packaging, which is able to react with the aluminium and secondly provides heat sealing capabilities. The substance of the coating in this case is on the level of 11-14 g/m^2. The required strength of heat sealing with polystyrene sheets is on the level of 5 N/15 mm. Approx. 70 tons of this type of Al foil is used for yoghurt packing. About 65 tons of this Al foil is consumed by the production of the 9 m Al/microcrystaline wax/41 g/m^2 paper complex, used for butter and cream cheese packing. The same combination is used for wrapping candies. 30 tons of Al foil is used for the production of the complex paper 60 g/m^2, used for pharmaceutical products (citrogal). Silicate type adhesives made for ENALUM are used in this case for combining Al foil with paper.

20 tons of Al foil combined in the same way with paper is used for closing blister packs made of PVC pharmaceutical tablets.

Paper 50 g/m^2 combines with 9 µm foil is used as an inner layer for cigar boxes and overwrapping cigarettes. For chocolate bars and chocolate sweets approx. 10 µm pure Al foil is used.

An amount of Al foil (approx. 4 tons) combined with paper is applied for beer labels. In this connection the best quality paper (Swedish-made) was found inadequate by the customer because of difficulties in washing off the labels for the repeated use of the bottles. A poorer quality paper is now used in the production of the labels, overcoming this difficulty.

Machines of a rather old type are used for coating; Reynolds Co of Canada for Al foil and Intra Roto Richmond Virginia for wax lamination. Enalum uses Gravure Champlain (6 colours) presses for printing on Al foil and on other meterials not necessarily combined with Al foil such as paper and cellophane used for single cigarette packets.

Conference with the participation of representatives of the Ministry of Basic Industries

Participants: Ing. Maria de las Nieves Menendez (Export Dept.)
Ing. Marta Garcia (Paper Department)
Cand. of Sc. Reynaldo Aleman (Technical Dept.)
Ing. Lourdes Sanchez (Specialist of CNEE)

Subject: Extrusion line for paper coating installed in Jatibonico.

During the meeting it was confirmed that a line adjusted for paper coating and for lamination by extrusion with Al foil (range of width 900-1800 mm) has been installed and during the last 2-3 months an amount of coated paper was produced. The line is adjusted for processing paper in the range of 40-240 g/m^2, Al foil 0.009-0.012 mm with PE thicknesses from 10-25 g/m^2.

At its maximum capacity the line is able to convert 6800 tons of paper, 680 tons of PE and 2000 tons of aluminium. At present the coating papers produced on this line are used for overwrapping rolls of paper produced by the company as a protection during transportation. A relatively small amount is needed for this purpose in comparison to the capacity of the line which is used only periodically (unacceptable for this equipment). MINBAS doesn't have the information or marketing possibilities for this type of material.

There is also a lack of information on which particular grades of combinations (polyethylene paper and aluminium) and the amount to be produced.

MINBAS representatives suggested that proper input in this respect from CNEE's side with expert's participation would be especially appreciated.

Some technical details concerning the production of Al foil laminates such as necessity to avoid Al foil oxidizing before extrusion coating. The meaning and eventuality of Al priming prior to extrusion was also explained during this meeting.

APPENDIX 2

Visits to the customers for Packaging Materials

Visit to "Pilon" (Coffee Plant)

Two main types of consumer packaging are in use. For larger amounts (1kg) of ground and unground coffee the same type of tinplate cans with Al membrane are in use. Vacuum technique is not applied for coffee predicted for few month storage. 57 and 114 g pouches for ground coffee packed in MX type cellophane predicted for local market are formed on double type vertical form-fill-seal machines (tranwrap-Bl-Stock Smith, USA).
Thirteen machines of this type (40 years old) are operating with capacity 60 bags/ min (2x30).

Consumption of cellophane per year is equal to 85 tons. Cellophane is printed by local converter-celloprint and its price (after printing) is equal to 5040 pesos/ton.

For smaller bags consumption of cellophane is 28 kg/ton of the coffee and 14.5kg for larger bags.

According to company's management the whole cycle of coffee distribution in this type of packaging is not longer than 20 days.

Trials made with MSAT type cellophane indicated poorer properties and faster deflavouring. The company's technical staff realized that using pigmented type of material should provide somewhat better protection of the product, but trials did not work since problems occured adjusting a photocell to transparency.

In the trials being conducted with OPP films no difficulties were encountered as far as heat sealing is concerned, and no higher fluctuation of temperature than 15°C can occur with the use of presently installed temperature controlling devices.

The cutting system in this type of machine is separated from heat sealing and did not provide adequate cutting.

Visit to Supermercado Centro

The system of Supermarkets is not yet widespread in Cuba and was one of the few existing.

Due to the courtesy of the Supermarket's management, general overview of the packing systems, first of all with the use of flexible materials was made. The majority of the products contained in flexible materials are packed in the Supermarket. Among the plastic films stretch PVC films (imported from Hungary), bags made of LDPE films and Netlon type nets (imported from Spain) are in use. Generally the products are packed by hand with use, in some cases only, of simple auxilliary equipment. Pieces of cheese are overwrapped in stretch film. Part of the cheese is prepacked by the manufacturer and supplied in thermoformed PA/PE laminates. In the last case complete decay of vacuum was observed.

Processed meat (ham, sirloin) and portioned fresh meat is placed on open flat folding type carton board boxes and overwrapped in stretch film. In some cases closed folding boxes are also in use. Non impregnated carton board is used in these cases. Sausages and bacon are overwrapped directly with stretch films. Sausages of the "hot dog" type are packed directly into LDPE film bags.

Due to the shortage of these types of products, storing time is relatively short but even so a change in the colour of meat products is evident.

Frozen rabbits and chilled chickens are packed in LDPE film bags. Netlon bags are used for fruits and for dried salted fish. A relatively high amount of products packed in LDPE film bags can be observed on the supermarket shelves. Some of them are packed with the use of form-fill-seal system mainly with the use of thick LDPE coextruded films produced by Envalac (instant soft drink, very popular product in Cuba, pasta products, bean and peas and others). This thick film is often used for as small amount of a product as 200 g.

It is worthwhile to mention that LDPE film independent of the thickness, doesn't present a barrier for the flavour and the depreciation of the flavour is extremely fast in this type of package.

Ready-made polyethylene bags are also used for packing powder products such as corn flour and some ready-for-use products based on flour. These polyethylene bags are closed by sewing through the paper labels. Double layer paper bags used for rice packing (approx. 2,3 kg heavy) are also closed by sewing. There are two existing systems of butter packing one with the use of aluminium foil laminated to paper (sold in much smaller quantities than 1/4 kg); the other system closes four small bars of butter, previously packed in vegetable parchment into folding carton boxes. Two systems of ice cream packing were observed both of them should be considered as inadequate.

In one case ice lollipops are inserted into paper bags, and packed then in LDPE bags. It should be underlined that sulphate type paper without any impregnation or coating is used for direct ice cream packing.

Similarly in the other case impregnated spirally wound paper cans are used for packing portions of ice-cream.

Different bisquits are sold in cellophane bags or overwrappings often manually packed and in some cases additionally packed in folding boxes.

Some types of dairy products are packed in small portions in very thick HDPE cups.

Visit to a small self-service shop

The range of flexible packaging observed here was limited to a few cases only, among them coextruded LDPE films used for powdered milk packing (1kg bag) and yoghurt (1 liter). For the latter thermoformed PS containers closed with heat sealable Al foil were in use.

A few applications of cellophane for powdered products were also observed. Relatively big amounts of imported products were exhibited on the shelves of this shop and among others retortable pouches with ready-made meat products placed in attractively printed folding boxes produced in China.

APPENDIX 3

Visit to the Research Institute of Food Industry

This visit was made on the invitation of Packaging Department Staff.

The Institute is a combined research and pilot scale production organization for a wide range of food industry areas. This institute is funded mainly by FAO with participation by some individual countries.

The programme is not yet completed, but some divisions including for example meat and milk processing pilot plants are already operating.

The Packaging Department is now located in a temporary building and is quite well equipped with different consumer and transit packaging areas. The institute has some equipment which is not yet available at CNEE e.g. completely equipped glass packaging laboratory.

It also seems that in the area of flexible materials the equipment of both organizations supplement each other well. Among investigations made are some trials with different OPP films as a substitute for cellophane. Both the machine performance and product's shelf life were tested. As a result OPP film has been implemented for packing candies on form-fill-seal vertical type machines.

It is highly recommended to conduct further investigations in this area in close co-operation with both organizations. This co-operation should provide possibility to accelerate wider introduction of OPP films into the market and to achieve in this way higher profit in a shorter time.

During the visit, a conference with participation of Head of Department: Ing. Soledad Bolumen Marti and Laboratory staff: Ing. Ada Castillo Coto and Ing. Sergio Valdes was arranged. During which different aspects of flexible material testing were explained. Some particular topics being a subject of presently conducted investigations e.g. unit packing of water for emergency purpose was discussed and suggestions concerning this project were given.

APPENDIX 4

Polypropylene Films

Polypropylene films (PP) are now classified in the group of the most important packaging films.

In some countries the consumption of these films are the second highest after polyethylene films.

During the stereo specific polimerisation of propylene (obtained by cracking oil) in the presence of $TiCl_4$ and organic compound of aluminium, both regular structure so called isotactic polymer and unregular atactic polypropylene are formed.

Polymerization of polypropylene, based on Ziegler catalysts was developed by Natta in 1954. The differences in chemical structure are illustrated in Fig. 1.

The isotactic polypropylene, due to its regular structure, is able to crystallize and distinguishes itself by valuable physical properties. The atactic polymer, which is an associate of the polymerization process is usually considered as a waste, though some possibilities of application exist such as blending with paraffin wax for paper coating (non-food application).

As already mentioned isotactic polymer is able to crystallize and only this type of material is used for film making. Because of tendency to degradation it is necessary to use stabilizers in polymerization of polypropylene. Practically the same grade of polypropylene usually consists of few types of stabilizers providing protection against UV radiation and stabilizing polypropylene at higher temperatures.

Polypropylene started to be used in packaging when ICI in Great Britain and Montecatini in Italy introduced it into the market as oriented sealable polypropylene film. Oriented polypropylene films (OPP) are used in packaging as a substitute for modified cellophane. The rapid growth of interest for these types of materials on the market, where not so long ago cellophane was used on a very large scale, is mainly due to:

- Resistance of polypropylene in variable climatic conditions, which excludes damage

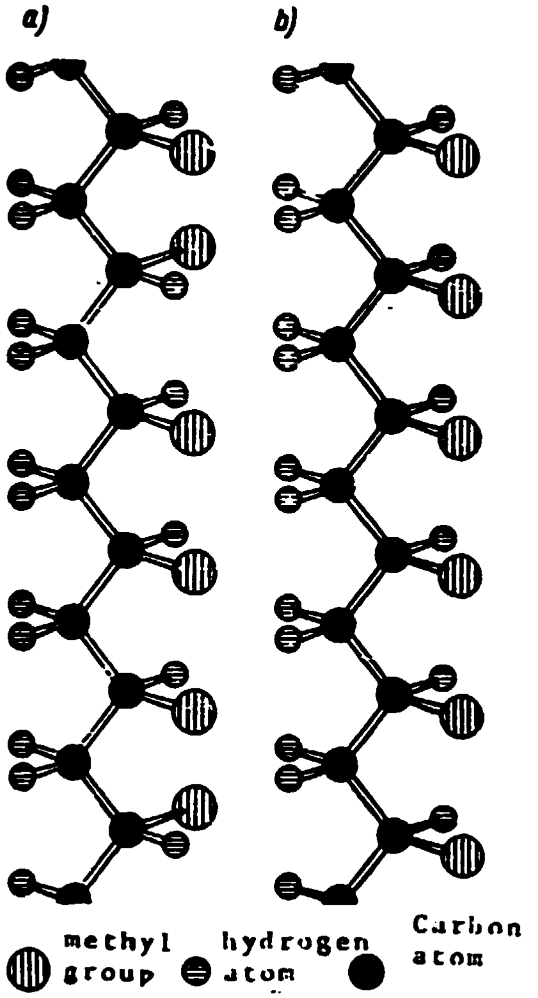

Fig. 1 Structure of polypropylene molecule
a) atactic b) isotactic

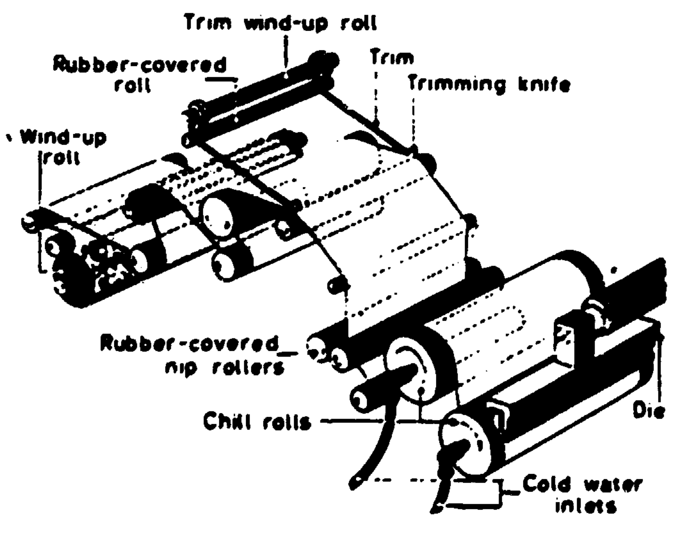

Fig. 2 Principle of so called chill roll casting process of flat films making.

and surface deformation often found in the case of cellophane, which involves wastage of the material and has a negative influence on the appearance of a package.

- Lower consumption of energy for production of OPP films compared to cellophane, which calculated in tons of oil equivalent (TOE) is estimated in the first case on the level of 2,6 and 4,3 in the second, of the same TOE units.

- Cellophane making involves a highly complex chemical process and serious difficulties are encountered in production to attain proper protection of air and water against pollution.

- Technological evaluation in OPP film production, providing possibility to supply different grades of material well adjusted for machine performance and protection of different goods including easily convertible films with a thickness of 15 μm.

- Evidently lower weight of OPP films (0.90 g/cm^3) compared to cellophane (appr. 1,40 g/cm^3) provides higher packaging efficiency when the same weight of the material is considered. In any comparisons multiplying factor equal to at least 1,5 is fully justified.

- Generally lower price of OPP film equal to for example on the american market 70-129$/1000 m2 compared to 125-150 $/1000 m2 of cellophane, depending on the grade of film in both cases.

All these factors have their influence on the situation in cellophane - OPP film market. Production capacity of cellophane in West European Countries is illustrated below: (According to L. Vidino Inmont, Packaging, March 1985.)

		Thousands of Tons		
		1982	1985	1990**
Hoechst - Kalle (W.G)		4,0	0	-
Wolf - Walsrode	"	13,0	10,0	0
UCB	Belg.	14,0	14,0	0
BCL	G.B	37,0	33,0	30,0
BSL	G.B	13,0	10,0	C
TPL	G.B	5,0	0	
SLC	Fr.	20,0	0	
Fortec Sidac	Jt.	4,0	0	
Safta	Jt.	2,7	2,7	0
Cello Español	Sp.	16,0	16,0	14,0
Portugal		0,7	0	
Yugo slavia		9,5	9,5	9,5
		138,9	95,2	53,5

** Forecast

In Poland and in Czechoslovakia production of cellophane has stabilized to a present level of 7000 and 10000 tons respectively.

As can be seen the majority of West European manufacturers of cellophane have stopped or intend to stop production of this material. This forecast is based, to some extent, on the present situation and non-predictable changes cannot be excluded. A different approach for example is presented in some US prognosis; according to which a rapid decrease of cellophane application is still taking place however, in long-term forecasts gradual increase compared to present consumption figures is expected. This was described in more detail in the paper prepared for the "Cellophane Conference".

There is not doubt that the regress in cellophane production is the result of wide use of OPP films on the market.

According to the same source mentioned above West European production capacity of OPP films is as follows:

		Thousands of tons	
		1982	1985
ICI	(G.B)	16,7	18,0
ICI Sidex	"	12,0	14,0
ICI Gand	"	6,0	8,0
Moplefan	Jt.	18,0	24,0
BCL -Shorko	G.B.	8,0	10,0
Wolf Walsrode	W.G.	9,0	15,0
Hoechs-Kalle	W.G.	9,0	15,0
Vifan	Jt.	4,0	10,0
4 P	W.G.	4,0	4,0
Toyobo-Azolene	B.	6,0	12,0
B.I.Hercules	G.B	3,0	6,0
Grace-U.K	Fr.	3,0	3,0
Manuli	Jt.	2,0	6,0
SLC-BCL	Fr.	4,0	4,0
Sitrosir	Jt.	5,0	5,0
Mobil	Jt.	5,0	5,0
Mobil	B.	15,0	30,0
Others		4,0	7,5
		133,7	196,5

Among East European countries OPP film production is well established in Czechoslovakia where 3000 tons of vinylidene chloride copolymers coated grade is produced now and another 7000 tons of coextruded grade is predicted for the near future. Rapid growth in production is taking place in USA and Japan, which is illustrated by production figures on the level of 147 000 tons of OPP films, in the first case and 82 000 tons in second.

Unoriented polypropylene films

Though OPP films are used on a much wider scale, there is still a small market for unoriented PP films consumed in unoriented form. The unoriented PP films are made as a cast and directly cooled by water/films.

The principle of casting unit is shown on Fig. 2.

The homopolymer or copolymer of MFI 4 - 10g/10 min is extruded through a slot die with a gap of between 0,25 - 0,50 mm and after traversion of an air gap they melt, solidify on a highly polished cooled roll (chill roll) and are transferred to a second cooled roll before being passed through a nip roll onto idler and then to a wind-up system. The film thickness is determined by the relative speed of the extruder screw and the nip roll.

Isotactic polypropylene is a crystalline polymer with melting point of about 170^{o}C and if the film made from it is not quenched rapidly large spherulites are formed and the product is opaque and has poor impact resistance.

This is the reason why before introduction of polypropylene tubular extrusion with air cooling it was not widespread in this case. However, because of the rapid quenching achieved by the flat film casting unit the formation of large spherulites in the film is prevented and transparency is maintained. The cast polypropylene film which is most interesting to the packaging industry falls into the thickness range 0,2-0,3mm (films for thermoforming) and appr. 0,025 mm for textile packing.

The thermoformable PP films are stiffer and have higher clarity than low density polyethylene films of similar thickness. As the thickness of cast polypropylene film is increased, rapid cooling, becomes more and more difficult therefore opacity of cast film increases with increase in thickness. Cast film of thickness of 0,5 mm and above is quite opaque.

The biggest advantage of thin cast polypropylene films e.g. 0,025 mm (typical films used for textile packing) is their high transparency and gloss as important factors for achieving acceptable sales appeal of the product.

The unoriented PP film can also be produced as a tubular film which is cooled by the use of water. The film is extruded through the head with ring type die (direction up and down) and is passed through the ring where it remains in direct contact with the water. In these conditions larger spherulites are not formed and a film with high transparency is achieved. The blow ratio in this method does not exceed 2:1 which assures however some improvement in mechanical properties. The possibility of applying a rotated head in this process provides that eventual differences in thickness are not located in the same place on the ready rolls but are dislocated throughout the whole width of the tube.

The basic properties of unoriented (cast) PP films are specified in the table describing OPP films, Table 3. It should be mentioned that some improvement of mechanical properties can be expected in the case of blown extrusion PP films.

This is especially true in the case of tear resistance. It is noticed that mechanical properties of unoriented PP films are somewhat better compared to PE films, however resistance of PP films to low temperature is much worse. Due to low density 0,90 g/cm^3 PP films indicate the highest yield (corresponding higher amount of square meters from the same mass of the material). The essential properties of PP films not mentioned in the table are optical properties and resistance for chemical compound. Similar to PE films, PP films indicate excellent resistance against acids and alkalies and the same excellent resistance against oils and fats (PE indicate swelling on longer contact).

The resistance to organic solvent is also good and this resistance remains when the temperature rises a little. Excellent optical properties are probably the most important factor for application of unoriented PP films in packaging technique.

Comparison of these properties with those of PE films are given below:

Optical properties of unoriented PP and LDPE films (25μm)

Property	Testing method	Unoriented PP film	LDPE film
Gloss %	ASTM D 2457 /45°/	75 - 87	60 - 75
Haze %	ASTM D 1033	1 - 3	4 - 15
Transparency	ASTM D 1746	90 -95	80 - 90

The application of unoriented PP films

The range of application for PP films is a direct consequence of their properties. Compared to LDPE films apart from the essential difference in optical properties the difference in resistance to temperature should be mentioned. Resistance of PP films to low terperature is poor and this film is for example never used for frozen food packing. However the resistance of PP films against high temperature is high and PP films and their laminates are taken into consideration when products need heat sterilization. This type of application is not possible in the case of LDPE films.

Becuase of the higher price in comparison with LDPE films PP films can be taken into consideration as a substitute for LDPE films only in cases when better properties justify their higher price.

The main applications for unoriented PP films in packaging technique are as follows:

- textile packing, mainly mens shirts, socks, stockings, garments, nightwear. Due to excellent transparency and the gloss of the film proper presentation of this type of product without change of their natural colour is possible. This is the main application for the described type of material. The bags made of unoriented PP films used for mens shirts were prices based on European packaging competition in Holland;

- food products are packed in unoriented PP film in cases where protection against transmission of water vapour and resistance to fats is required and at the same time rather high permeability of these films for gases and odours is acceptable Bags for vegetables such as lectuce, fresh spinach, cauliflower and mushrooms belong to typical applications of cast PP films. Twist wrapping of hard candy is a typical application of these films. Other flexible materials have a spring back characteristic which causes them to open after the twisting phase of packing and no other materials exist other than special grade of PP and cellophane, which can be used in this case;

- products subject to heat sterilization in the package such as the medical instruments used by surgeons, PP film is resistant to long term action of 120°C temperature;

- packing of toys, paper products, decorations, where similar effect as in the case of textile products is needed.

Unoriented PP films are also used as a component of packaging laminates. Laminates used for retortable pouches and for the package called Aluseal (substitute for some types of cans) and also spirally wound composite cans often consist of unoriented PP layer, which may be directly extruded or laminated.

Theory of orientation

As was mentioned before the use of polypropylene in packaging started after introduction into the market of oriented heat sealable polypropylene films. Before further discussion concerning these films and to give a wider meaning to orientation process in production of other packaging films some explanation concerning the orientation and its influence on properties of the films should be made. When conditions lack exterior forces polymer chains remain in the state of completely random entanglement. In stress induced orientation due to hot stretching or drawing the chains of macromolecules are displaced into a more orderly arrangement parallel to the direction of stress. When chain straightening has occurred, the closer packing of macromolecules takes place, this involves the increase of mutual attraction between the polymer chains as a result of exerting greater secondary valence forces. These are particularly large if the chains are symmetrical and/or strongly polar. This and unfolding of polymer chains result in increased tensile strength and elastic modulus. The polymer chains are rigid below their glass transition temperatures (Tg.). However, at the glass transition temperature (Tg.) they gain a degree of freedom and become able to unfold as stress is applied. The stretching of the polymer above a temperature of its Tg causes the polymer chains to disentangle, straightening and also sliding past one another. Three phenomena are taking place during stretching the polymer which can be considered as three components or orientation process:

E_1 - the instantenous elastic deformation caused by valency angle deformation or stretching the valency bonds, this component is completely recoverable when the stress is removed.

E_2 the molecular aligmment deformation caused by uncoiling, which results in a more linear molecular arrangement parallel to the surface and which is frozen into the structure when the material is cooled.

E_3 the nonrecoverable viscous flow caused by molecules sliding past one another.

E_4 is the orienting component, the one desired to be the major component of the stretching process.

On the basis of the orientation theory the following general statements can be made:

- the lowest stretching temperature above Tg will give the greatest orientation at a given percent and rate of stretch /E_3 flow component is held to a minimum by keeping the temperature as low as possible;

- the highest stretch rate will give the greatest orientation at a given temperature and percent of stretch. Since E_3 is slower than E_2 - at rapid stretching the time is too short for the viscous ow to occur. In these conditions E_2 component will predominate;

- the highest percent stretch will give the greatest orientation at a given temperature and rate of stretch;

- the greatest quench will preserve the most orientation under any stretching condition.

Types of orientation

Uniaxial orientation takes place when the polymer chains are aligned in one direction only. This produces maximum strength in one direction, that of orientation. The tensile strength of nylon for example can increase by orientation as much as 8 times. This type of orientation is desirable in the case of fiber. Uniaxially oriented film tends to crack and split along lines parallel to the direction of stretching.

Biaxial or planar orientation occurs, when a film is drawn in more than one direction commonly along two axis at right angles to one another. Polymer chains are those oriented in a web parallel to the surface rather than to one another as in the case of uniaxial orientation. The level of tensile properties although significantly higher than in the case of unoriented film is not as great as uniaxial oriented filaments.

As a result of different degree of stretching in different directions balanced and unbalanced oriented films can be produced and are used. In the case of balanced oriented films the tensile ratio (the value of lower tensile strength to higher) achieves at least the value of 80%. For most oriented film applications, it is desirable to have a film as closely balanced as practicable, since these films will react in the same way or nearly so.

There are however some applications (for example some types of thermoshrink films) in which unbalanced oriented film is preferred. There is a significant difference in behaviour between heated crystallizable and noncrystallizable polymers in oriented form. There is no known way to stabilize noncrystallizable (amorphous) oriented polymers against shrinkage above its glass transition temperature. When a sample of oriented polystyrene (typical amorphous polymer) is heated and restrained from shrinking, it slowly loses the orientation, though not so rapidly as it would if it shrinks freely.

The crystallizable type of polymer can exert different content of crystalline and amorphous phase depending on the condition of its processing. If for example, polyethylene terephthalete (crystallizable polymer) is melted at 290°C, then rapidly quenched to below its Tg (69°C) an essentially amorphous material is obtained. This material stretched at 90°C and quenched after reheating will show the same behaviour as oriented PS. It means that after heating above Tg it will start to shrink. The mechanism of shrink behaviour or oriented amorphous polymer is quite simple. The shrinkage as an effect of reheating above glass transition temperature of this type of polymer can be explained as the start of relaxing out the orientation being frozen-in.

A simple experiment with a stretched rubber band immersed in a dry ice - alcohol mixture will retain its stretched dimensions when the stress is removed. After taking it out of the cold bath the rubber band spontaneously reverts to its original dimensions. When an extra processing step is applied a film made of the same polymer can indicate only negligible shrinkage at 100°C. This extra step involves restraining the film at its stretched dimension, heating it briefly to 150-225°C and quenching after that as previously. Under these conditions crystallization in oriented polyester film can occur.

When crystallization occurs from an oriented planar melt, it is believed that the crystallites and spherulites also become two dimensionally oriented during their formation. As these crystallites and spherulites grow they encompass and lock in place many molecular chains which are already aligned. Thus these chains are not free to retract even if they are above the Tg for the bulk material.

Production of oriented polypropylene films (OPP)

Two main systems are used for OPP film making as a substrate for further processing. In the first one used among others by Kalle, Wolf Walsrode (West Germany) Mitsui (Japan), Montedison (Italy), Mobil Chemicals, Diamond (USA) the so called tenter process is applied. The principle of two stage drawing process is illustrated on Fig. 3.

The introductory thickness of the film is equal to approx. 0,5 mm. The film being cast is almost completely hazy, though at this thickness cooling is not fast enough. The cast film is heated again to the temperature 150-160°C and is drawn in the machine direction without significant loss of width at the draw ratio in the range 4 : 1 to 10 : 1 provided by differential velocity nip rolls. After leaving these rolls the film is fed into stenter where its edges are gripped by clips closed afterwards and follows a divergent path. The film is now drawn transversely, at a draw ratio in the same range as indicated previously. Maintaining the film under tension for some time at a temperature near to 140°C provides the orientation stability. After leaving the stenter the film is cooled and fed to a wind-up station.

There is a possibility to reverse the drawing sequence and the cast film is firstly drawn transversely in a stenter and then in the machine by means of a differential roll system. A simultaneous, one stage orientation process, which is also possible is illustrated on Fig. 4.

In this case a stenter in which clips are moved by means of an increasing pitch screw is used. The forward draw - ratio is controlled by the rate of increase of pitch and the sideway draw by the angle of divergence of the clips.

In another system of OPP film making introduced by ICI (Great Britain) and widely used in the USA (e.g. by Du Point, Hercules) simultaneous forward and transverse draw is achieved by tubular extrusion system. The molten polymer is extruded from a circular die and is quenched to a form of cast tube. The thickness of the tube is controlled partly by die dimensions, partly by the relative speeds of tube hand-off and the extruder. After passing through the haul-off device such as pinch-roll, the tube is reheated to a uniform temperature. By increasing the air pressure inside the tube and by running the pinch rolls at a higher speed than the extruder haul-off, simultaneous orientation in both directions is provided. The draw ratio can be varied by adjusting the volume of the air enclosed by the bubble and the relative nip roll speeds. In this process the thickness of the final film is a result of reducing the thickness of the extruded tube in the range from 1/25 to 1/50 of its introductory value. The principle of orientation by tubular process is shown on Fig. 5.

As was mentioned before it is possible to produce biaxially balanced and unbalanced oriented films and also uniaxially oriented. It should be noted however that uniaxially oriented films are of little interest for packaging because of their marked tendency to fibrillate, when subjected to stress from certain angles.

The degree to which orientation is balanced depends mainly on the production process. Films of balanced biaxial orientation, where ratio of lower value of tensile strength to higher exceeds 80% are most frequently achieved in blowing process.

Unbalanced biaxial orientation on the other hand can be considered, as a characteristic feature of the flat film stretchingprocess - tenter process. The ratio of the tensile strength in transverse direction to machine direction in this case usually exceeds 1,5.

Though polypropylene is a typical example of thermoplastic material in the majority of applications OPP films require heat sealed coating. Heating the OPP film up to the melting temperature involves waste of orientation and shrinkage in the sealing area. As a result the film tears easily near the sealing area. For this reason OPP films have to be modified. This allows the film to be sealed well below the temperature where reduction of orientation can take place. OPP films being used can be divided in the following way:

- oriented introductory treated films e.g. corona treated, which involves combined effects:
  chemical (surface changes) mainly due to oxidizing and non durable peroxide groups forming, and
  mechanical due to minutely pitting the surface.

This provides decreasing of surface tension and increases adhesion to other layers, which can be used with OPP films. These types of films are often used for lamination after printing.

- OPP uncoated films.
  Heat sealability is achieved due to use of a modified polymer which broadly increases the range of heat sealing temperatures, in comparison to typical OPP films. This type of film is available on the american market. It is used for processing on conventional overwrapping machines, but is not acceptable for packing products with the use of form-fill-seal machines.
- OPP films with vinyl polymer and copolymer coatings.
  These are suitable for conversion with the use of wide range of packaging machines and their water vapour and gas permeability are typical for polypropylene films.
- OPP films with vinylidne chloride copolymer coatings.
  (Known commercially e.g. as Diofan or Saran coatings.) Excellent barrier properties in relation to oxygen, nitrogen and carbon dioxide essentially differentiate this kind of film from those previously mentioned. Machineability of this film does not create a problem.
- Coextruded OPP films.
  In this case heat sealability is provided by a very thin layer usually in the range of one micrometer per side of special grade ethylene-propylene copolymer. This compound melts at evidently lower temperature than polypropylene itself and is coextruded and oriented together with a main polypropylene film. This kind of film is typical for polypropylene low water vapour transmission rate and also has rather high oxygen and other gas permeability.
  Coextruded OPP films are rapidly improving their performance characteristic and above all they present higher range of heat sealing temperatures than other grades, one of the most critical values, when converting of OPP film is considered.

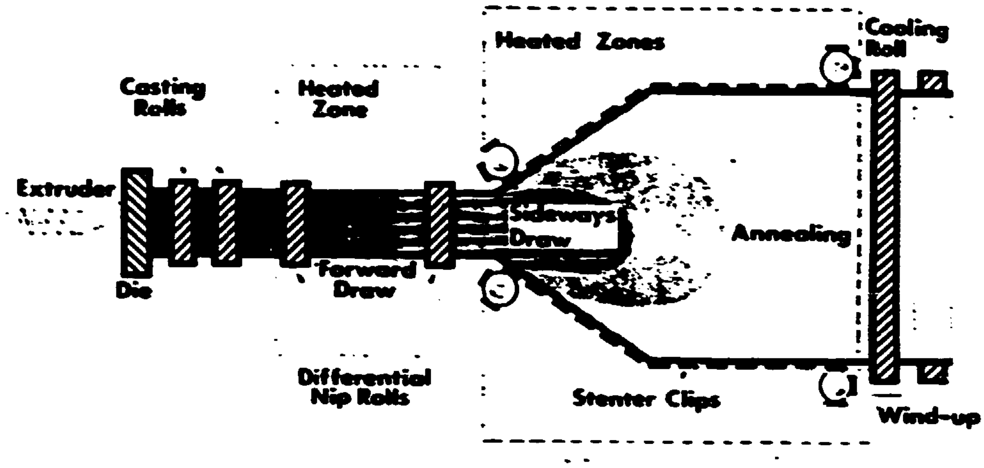

Fig.3 Sequential orientation process of flat film making

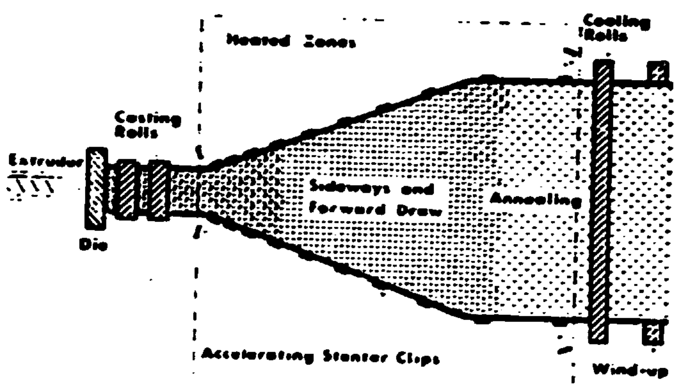

Fig.4 One stage orientation process of flat film making

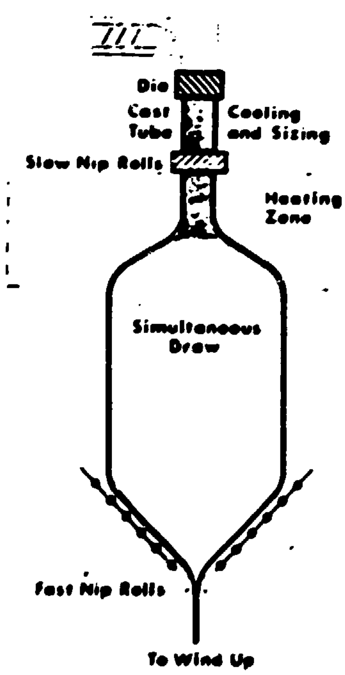

Fig.5 Orientation of the film by tubular process

OPP coextruded grades available on the market can be sealed at heat sealing intervals of 30°C and it is expected that this range will be increased soon. This factor combined with economical advantages as far as the investment cost, production cost and recovery of production wastage are concerned, justify expansion of coextruded OPP films and gradual substitution of some other types e.g. vinyl copolymer coated grades.
Possibility to achieve the same degree of product protection with better machine performance and at lower production cost constitute the main motivation in this case.

Clearly OPP coextruded film will be more widely used in future. This does not exclude simultaneous application of vinylidene copolymer coated grades, but rather limits their use to cases where protection against oxygen transmission remains a critical factor even in the case of single film application.

Properties of oriented polypropylene films

Generally speaking the properties specific of OPP films are as follows:

- low density 0,905 g/cm^3 as an average;
- the possibility to produce very thin films starting from 0,012 mm;
- specially high tensile strength (for example approx. 4 times higher than that of cast PP film);
- excellent clarity;
- sufficient stiffness for easy machine running;
- resistance to high temperature, facilitating sterilization process;
- resistance to water and majority of chemical substances (fats and oils included);
- low permeability for gases and vapours (with vinylidene chloride copolymer coatings);
- physiological neutrality in the case of properly stabilized polymers;
- easiness for printing;
- easiness for laminating.

Polypropylene is the lightest of all thermoplastics used for packaging (0.89 -0,91 g/cm^3 depending on crystallization degree) which as a result provides the highest yield, illustrated in Table 4.

Packaging efficiency of polyproylene films depending on their thickness, including OPP and unoriented films, is given in Table 5.

Basic properties of OPP films, non coated, with heat sealable coating and with vinylidene chloride copolymer-barrier coating in comparison to some other packaging films are presented in Table 6.

As can be seen there is a significant difference between tensile strength and elongation in machine and transverse direction of Moplefan OFF, similar in the case of cellophane. For both types of Propafilm these values are very close to one another.

Moplefan should be classified as unbalanced and Propafilm as balanced film. This is a result of stretching and thermal conditions providing stability of orientation - Propafilm (ICI production) is made by tubular process, in which case balanced orientation is usually achieved.

Unbalanced orientation is typical for tenter process (orientation of flat cast film) used in the production of Italian made Moplefan OFF.

As was proven at my institute among others, these differences do not influence the behaviour of films in practice (for example their machineability).

All films produced by biaxial stretching have very low resistance to tear propagation as in the case of cellophane. A distinguised increase of elasticity modulus and to a certain extent a measure of film stiffness is achieved by orientation and this value is much higher than that for polyethylene. In the majority of packaging applications coated OPP films are in use. This is not only for the purpose of solving heat sealing problems of oriented films (without loss of orientation and decrease of mechanical strength in sealing area). Coating formulations also provide good slip, non-blocking and antistatic characteristics.

This is not clearly evident upon the basis of the data given in the table, but

Table 4

Yield of Different Packaging Films
(0,025 mm thickness)

Type of the film	Density g/cm^3	Yield m^2/kg
unoriented polypropylene	0,89	45,0
low density polyethylene	0,92	43,5
high density polyethylene	0,94	42,4
polystyrene	I,05	38,0
pliofilm	I,I5	36,0
polyvinyl chloride	I,23-I,40	32,5-28,5
cellulose acetate	I,25-I,35	32,0-29,6
polyterephtalate of ethylene glycol	I,38	29,0
cellophane	I,4-I,5	28,5-26,7
vinylidene chloride copolymer	I,68	23,8

Table 5
Yield of Polypropylene Films

Thickness			PP films			
			unoriented density 0,89 g/cm^3		oriented density 0,90 g/cm^3	
mm	inch·10^{-3} mil	appr. gauges	substance g/m^2	yield m^2/kg	substance g/m^2	yield m^2/kg
0,oI25	0,492	50	-	-	II,2	92,6
0,0I5	0,59I	60	I3,4	74,5	I3,5	74,0
0,020	0,788	80	I7,8	56,2	I8,0	55,6
0,025	0,958	I00	22,2	45,0	22,5	44,5
0,030	I,I8	I20	26,7	37,5	27,7	37,0
0,040	I,58	I60	35,6	28,I	36,0	27,8
0,050	I,97	200	44,5	22,5	45,0	22,3
0,I00	3,94	400	89,0	II,2	-	-

TABLE 6

Basic properties of oriented polypropylene films in comparison with other materials

Property	Unit	Oriented polypropylene: non heat sealable "Propafilm" "O" 15/730	Oriented polypropylene: heat sealable: vinyl coating Moplefan OFF	Oriented polypropylene: heat sealable: vinylidene coating Propafilm C 23/40	Cast Polypropylene 0,025 nm	LDPE 0,025 nm	Cellulose films 300 MSAT	Cellulose films 300 MXXT
1	2	3	4	5	6	7	8	9
Density	g/cm^2	0,91	0,90	-	0,90	0,92	-	-
Efficiency	m^2/kg	73,4	44,5	42,9	44,0	42,5	28,4	27,4
Tensile strength	M.D Kg/cm^2	1750-2100	800-1100	1600-2000	450	200	900-1350	900-1350
	T.D Kg/cm^2	1750-2100	1800-2400	1400-1750	390	150	420-560	420 660
Elongation at break	M.D %	50-85	100-170	80-110	750	300	20	20
	T.D %	50-85	20-30	80-110	1000	650	60	60
Tear propagation	M.D.) G	ca.5	ca.10	ca.5	50	200	ca.5	ca.5
	T.D.) G	ca.5	ca.10	ca.5	80	150	8-12	8-12
Elasticity modulus	M.D. Kg/cm^2 x10-4	2,2-2,7	1 - 2	1,4-1,7	0,75-1,0	0,2-0,25		
	T.D. Kg/cm^2 x10-4	2,2-2,7	2,5-3,5	1,4-1,7	0,75-1,0	0,2-0,25		
Melting point	°C	168-171	-	-	168-171	107-112		
Heat sealing range	°C	-	100-130	100-145	165-200	120-175	95-150	205-175
Flexibility at low temp.	°C	-70	-70	-70	-10	-70	special grades required	
Water vapour permeability	g/m^2x24h 90%r.h. 38°C	8-10	5-10	3-6	8-10	17	5-12	1-8
Oxygen permeability	cm^3/m^2x 24h 1atm Preasure difference	3000-3400	ca.1000	10-20	4500	ca.9500	5-25	5-15

there is a strong influence of the type of coating on heat sealing range and the strength of the seals being made. The range of heat sealing temperatures may vary from film to film. Relatively narrow heat sealing range (excluding coextruded film with sealable polyolefine layer) is however a typical feature of oriented polypropylene films.

With the exception of coextruded grades higher deviations of temperature than 15°C from the optimum heat sealing for a given grade of OPP film are usually not acceptable, when proper processing of these films on typical packaging machines is taken into account. For processing of OPP films more accurate control of the temperature of heat sealing bars is required. This involves the use of proper thermostatic temperature controllers, which are rather simple devices. They ensure more reliable performance of the machines and can be installed on existing machines previously used for cellophane.

As mentioned above it was indicated that, difference in slip characteristic (coefficient of friction in the range of 0,23 - 0,40) of commercially available films, did not influence the machineability of the film on vertical and horizontal form-fill-seal machines to a great extent. The situation was similar in the case of the differences in orientation degree as was described earlier. Besides the heat sealing range and the strength of the seals the flatness of the web and the quality of ready-made roll of material are the most important factors influencing the quality of machine running. Orientation of the film provides increased resistance at low temperature compared to unoriented films, which are not at all resistant in this case. Polypropylene films similar to other polyolefines present good barrier properties in relation to water vapour and the differences from grade to grade are relatively low. This is quite different in the case of other gas permeability.

The orientation process provides certain decrease of oxygen permeability, but significant decrease is possibly due to choice of the coating for example and the film with vinylidene chloride copolymer coating provides the lowest oxygen permeability. It should be underlined however that in the case of unlaminated films the differences in oxygen permeability does not play so essential a role as some people think. It should be taken into consideration that the amount of oxygen which is introduced into the pack during packaging operations influences the oxidizing processes to a higher degree than the permeability of the material.

The situation is changing significantly in the case of laminates, where due not only to high barrier properties, but also to high heat seal strength one of the laminate layers and with application of approriate packaging techniques (vacuum or neutral gas packing) a low level of oxygen remains inside the pack during the storage. Low permeability of odours is a specific feature of PP films. On the basis of the data collected by Hoffman (Kalle - West Germany) PP films can be classified in the group of the most resistant films for aromatic substance permeability (with the exception of eucalyptus).

Polypropylene films are more resistant than polyethylene to chemical substances. OPP films are completely resistant to oils and fats at normal temperature. Without proper stabilization of polypropylene these films are very sensitive to oxidizing factors and this process is accelerated by ultraviolet radiation and high temperature. According to ICI classification depending on the type of antioxidants used three grades of polypropylene are in use:

- PP resistant for long term action of high temperature,
- PP of general application resistant for short term heating,
- PP acceptable in direct contact with food.

Polypropylene films are resistant to high temperatures. High melting point of polypropylene is a reason why simple OPP films are rather difficult to seal without the use of proper heat sealable coating. The risk of loss of orientation in sealed areas and due to its significant decrease of mechanical strength the possibility of using uncoated or unmodified OPP films for heat sealing operations is excluded.

For the same reason and because of insufficient resistance of the coating to temperature, bags made of OPP cannot be used in sterilization processes.

Tables 7-9 show properties of different grades of coextruded OPP films of well known European manufacturers. Properties of vinylidene chloride copolymers coated grade are specified in Table 10 and based on vinyl chloride copolymers are given in Table 11.

All these tables are taken from the catalogues of corresponding manufacturers.

TABLE 7

Properties of Propafilm MG.
OPP coextruded film ICI production, Great Britain

Property	Test information		Units	MG20	MG25	MG30	MG35	MG40
Thickness			micron	20	25	30	35	40
Density	ASTM D 1505		g/cm^3	0.91	0.91	0.91	0.91	0.91
Water uptake-max	ASTM D 570		%	0.03	0.03	0.03	0.03	0.03
Permeability to:								
Water vapour	23°C 85% RH (DIN 53122)		g/m^2/24h	1.4	1.2	1.0	0.8	0.6
	25°C 75% RH (BS 3177)		g/m^2/24h	1.5	1.3	1.1	0.9	0.7
	38°C 90% RH (ASTM E96)		g/m^2/24h	7.0	6.0	5.0	4.5	4.0
Oxygen	23°C 85% RH (DIN 53380)		cm^3/m^2/24h	2200	1800	1500	1300	1100
	25°C 0% RH (ASTM D 1434)		cm^3/m^2/24h	2300	1900	1600	1400	1200
Nitrogen	25°C 0% RH (ASTM D 1434)		cm^3/m^2/24h	650	500	400	340	270
Carbon dioxide	25°C 0% RH (ASTM D 1434)		cm^3/m^2/24h	7000	5600	4800	3700	2900
Optical								
Gloss	ASTM D 2457 Gardner (45°)		%	75 – 85	→	→	→	→
Haze (wide angle)	ASTM D 1003		%	1 – 2	→	→	→	→
Haze (clarity)	ICI test Gardner (2½°)		%	3 – 6	→	→	→	→
Blocking	ICI test 30°C		g/75 mm	0	→	→	→	→
	50°C		g/75 mm	5	→	→	→	→
	70°C		g/75 mm	30	→	→	→	→
Coefficient of friction	ASTM D 1894 Static			0.30 – 0.40	→	→	→	→
	Dynamic			0.30 – 0.40	→	→	→	→
Tensile strength	ASTMD882	MD	kgf/cm^2	2000	→	→	→	→
	Strain rate 25%/min	TD	kgf/cm^2	1600	→	→	→	→
	DIN 53455	MD	kgf/cm^2	2050	→	→	→	→
	Strain rate 500%/min (speed 8)	TD	kgf/cm^2	1700	→	→	→	→
Elongation at Break	ASTMD882	MD	%	75	→	→	→	→
	Strain rate 25% min	TD	%	90	→	→	→	→
	DIN 53455	MD	%	65	→	→	→	→
	Strain rate 500%/min (speed 8)	TD	%	80	→	→	→	→
Elasticity Modulus (1% secant)	ASTMD882	MD	kgf/cm^2	22,000 – 25,000	→	→	→	→
	Strain rate 25% min	TD	kgf/cm^2	19,000 – 22,000	→	→	→	→
	DIN 53455	MD	kgf/cm^2	21,000 – 26,000	→	→	→	→
	Strain rate 10%/min (speed 3)	TD	kgf/cm	20,000 – 23,000	→	→	→	→
Puncture resistance	ICI test 3mm probe Speed 50mm/min 23°C 50%RH		Newton	35	40	45	50	50
Sealing range	Laboratory heat sealer		°C	130 – 145	→	→	→	→
Seal strength*	ICI test at 130°C (1 kgf/cm^2 for 2 sec)		g/25 mm	> 350	> 350	> 350	> 350	> 350
Shrinkage	ICI test 60 sec/120°C	MD	%	3.0	→	→	→	→
		TD	%	0.0	→	→	→	→
	60 sec/130°C	MD	%	6.0	→	→	→	→
		TD	%	3.0	→	→	→	→
	60 sec/140°C	MD	%	11.6	→	→	→	→
		TD	%	7.0	→	→	→	→
Temperature range for use			°C	-70 to + 75	→	→	→	→
Severe shrinkage point			°C	above 145	→	→	→	→
Melting point			°C	+ 170	→	→	→	→

Properties of Coextruded Film

Walothen CF (Wolf Walsrode - Western Germany)

Table 8

			Method	CF 25	CF 40	CF 50
Thickness		mm	DIN 53370	0,025	0,040	0,050
Density		g/cm^3	DIN 53479		0,7	
Substance		g/m^2	DIN 53352	18,0	28,5	35,5
Yield		m^2/kg	-	55,6	35,1	28,2
Water Vapour Perm.	23°C 85% R.H.	$g/m^2 \cdot d$	DIN 53122	1,6	1,0	0,8
					-	
Perm. N_2	23°C	$\frac{cm^3}{m^2 \cdot d \cdot bar}$	DIN 53380	350	210	180
Perm. O_2	23°C			2500	1500	1300
Perm. CO_2	23°C			6000	3500	3000
Tensile	MD	N/15 mm	DIN 53455	20	35	45
	TD			45	70	90
Tensile strength	MD	N/mm^2	DIN 53455		60	
	TD				120	
Elongation	MD	%	DIN 53455		140	
	TD				35	
Elasticity Modulus	MD	N/mm^2	DIN 53121		2000	
	TD				3500	
Coefficient of friction	Film/Film		DIN 53375		0,35	
	Film/Metal				0,20	
	MD	N/mm	DIN 53363		15	
	TD				8	
Sealing range		°C	Wolff-N 1007		125 - 145	
Sealing bar temp.		°C	-		155	
Temperature after sealing		N/15 mm	Wolff-N1002		2,0	
			Wolff-N1007		2,5	
Temperature resistance air/water					- 50 bis + 120	
Opacity		%	DIN 53146	30	50	55
Gloss		GE	ASTM D2457		70	

Table 9

Principal properties and typical average values of Moplefan OHCT at 25°C.

Base film de 40 µm (coextruded oriented polypropylene film (Montedison Spa-Italy).

Properties	Unit	Typical values (1)	Test method
Thickness	µm	40	
Unit weight	g/m2	25	
Yield	m2/Kg	40	
Tensile strength:	Kg/mm2		ASTM D 882
- Machine direction		7	
- transverse direction		15	
Elongation at break	%		AST' D 882
- machine direction		150	
- transverse direction		50	
Bursting strength	Kg/cm2	4	ASTM D 774
Static coefficient of friction: film/film		0.5	ASTM D 1894
Heatseal range	°C	125÷145	
MVTR at 38°C and 90% R.H.	g/m2.24h	5÷6	ASTM E 96B
Oxigen permeability at 25°C	cm3/m2.24h.atm	1100	ASTM D 1434
Light transmission:	%		Spettrofotometer
- visible range (λ = 750 mm	5		
- UV range (λ = 350 mm	3		

(1) Tolerance ± 10%

PROPERTIES OF "PROPAFILM" CG (TYPICAL VALUES)

TABLE 10

Vinylidene Chloride Copolymer Coating

ICI Production (Great Britain)

Property	Test information		Units	CG 21	CG 26	CG 32
Thickness			micron	21	26	32
Water uptake – max	ASTM D 570		%	0.03	0.03	0.03
Permeability to: Water vapour	23°C 85% RH (DIN 53122)		g/m²/24h	1.2	1.0	0.8
	25°C 75% RH (BS 3177)		g/m²/24h	1.3	1.1	0.9
	38°C 90% RH (ASTM E 96)		g/m²/24h	6.0	5.0	4.0
Oxygen	23°C 85% RH (DIN 53380)		cm³/m²/24h	36	36	36
	25°C 0% RH (ASTM D 1434)		cm³/m²/24h	40	40	40
Optical Gloss	ASTM D 2457 (Gardner 45°)			95-105	95-105	95-105
Haze (wide angle)	ASTM D 1003		%	4	4	4
Haze (clarity)	ICI test (Gardner 2½°)		%	10-15	10-15	10-15
Coefficient of friction	ASTM D 1894 Static			0.20-0.40	0.20-0.40	0.20-0.40
	Dynamic			[illegible].30	0.20-0.30	0.20-0.30
Tensile strength	ASTM D 882	MD	kgf/cm²	[illegible]0	1800	1800
	Strain rate 25%/mm	TD	kgf/cm²	600	1800	1800
	DIN 53455	MD	kgf/cm²	1900	1900	1900
	Strain rate 500%/min (Speed 8)	TD	kgf/cm²	1650	1650	1650
Elongation at break	ASTM D 882	MD	%	85	85	85
	Strain rate 25%/mm	TD	%	95	95	95
	DIN 53455	MD	%	80	80	80
	Strain rate 500%/min (Speed 8)	TD	%	100	100	100
Elasticity modulus (1% secant)	ASTM D 882	MD	kgf/cm²	19,000-24,000 →		
	Strain rate 5%/min	TD	kgf/cm²	17,000-21,000 →		
	DIN 53455	MD	kgf/cm²	21,000-25,000 →		
	Strain rate 10%/min (Speed 3)	TD	kgf/cm²	18,000-22,000 →		
Puncture resistance	ICI test 3mm probe Speed 50mm/min 23°C 50% RH		Newton	30	35	40
Sealing range	Laboratory heat sealer		°C	115-140	115-140	115-140
Shrinkage	ICI test 60 sec/120°C	MD	%	2.0	2.0	2.0
		TD	%	0.0	0.0	0.0
	60 sec/130°C	MD	%	6.0	6.0	6.0
		TD	%	2.0	2.0	2.0
	60 sec/140°C	MD	%	11.0	11.0	11.0
		TD	%	8.0	8.0	8.0
Low temperature flexibility			°C	down to -70 →		
Severe shrinkage point			°C	above 145 →		
Melting point			°C	+170 →		

Note: The typical values quoted in this table are the results of tests made using production samples of films in the quality control laboratories. They are given only for guidance, and do not constitute a specification.

MD = machine direction TD = transverse direction

PHYSICAL

'Propafilm' CG has a very low moisture uptake. The film thickness profile, mechanical and barrier properties are not affected by absorption of atmospheric moisture into the film. Practical tests confirm that the water vapour barrier of 'Propafilm' CG is superior to that of barrier coated cellulose films.

The PVdC copolymer coating is an excellent barrier to the penetration of flavours and aromas and thus 'Propafilm' CG minimises flavour loss and prevents the ingress of contaminating odours.

The low frictional resistance of 'Propafilm' CG minimises static build-up in packaging machines and permits the use of drag sealing units.

MECHANICAL

The balanced tensile properties of 'Propafilm' CG provide high strength in both machine and transverse directions. Tear tapes can be applied in either machine or transverse directions.

'Propafilm' CG has greater durability than cellulose films. For example, the puncture resistance value of a typical cellulose film is 15-20 Newtons (450 MXXT/S, 30 micron).

THERMAL

The wide sealing range of 'Propafilm' CG enables the film to be used on most packaging machines designed for use with heat-sealable packaging films.

The balanced shrinkage properties of 'Propafilm' CG permit the shrink tightening of packs. 'Propafilm' CG should not be used for shrink tightening in applications where a retraction of more than 5% in either machine or transverse direction will be required.

'Propafilm' CG is suitable for wrapping products to be stored under deep freeze conditions.

Because 'Propafilm' is a thermoplastic material the mechanical properties are dependent on temperature. The temperature of the drying air used in converting operations should be regulated to maintain the film temperature below 70°C.

CHEMICAL

'Propafilm' CG resists attack by acids, bases, salts, oils and solvents. This makes 'Propafilm' CG particularly suitable for packaging products which contain oils and fats, such as biscuits and snack foods.

Table 11
Principal properties and typical average values of Moplefan coated films at 25° C - Base film 25 μm (vinyl copolymer coated biaxially oriented polypropylene films - Montedison Spa ITALY).

Properties	Unit	Typical values		Test method
		OLX	OLX/A	
Tensile strength:	Kg/mm2			ASTM D 882
-machine direction		12		
-transverse direction		26		
Elongation at break	%			ASTM D 882
-machine direction		200		
-transverse direction		50		
Tear strength (ELMENDORF)	g	10		ASTM D 1922
Impact strength	Kg.cm	100		ASTM D 1709 (1)
Stress impact strength	Kg.cm/cm3			ASTM D 1822
-machine direction		600		
Bursting strength	Kg/cm2	5		ASTM D 774
Static coefficient of friction film/film	-	≤0.5		ASTM D 1894
Haze	%	≤2.5		ASTM D 1003
Gloss at 45°	%°	≥85		ASTM D 2547
Heatseal range	°C	90 ÷ 140		-
Seal strength	g/15 mm			MOPLEFAN A29 (2)
-smooth bar at 130°C-40 psi 1 sec		450		
Shrinkage at 140°C - 1 min	%			MOPLEFAN A23
-machine direction		5		
-transverse direction		2		
MVTR at 38°C and 90% R.H.	g/m2.24h	5.5		ASTM E 96B
Oxigen permeability at 25°C	cm3/m2.24h.atm	800		ASTM D 1434
Nitrogen permeability at 25° C	cm3/m2.24.atm	160		ASTM D 1434
Carbon dioxide permeability at 25°C	cm3/m2.24.atm	3000		ASTM D 1434
Surface resistivity	Ohm	1.10^{12}	1.10^{9}	MOPLEFAN A34

(1) 1 cm diameter steel ball - height of drop 66 cm - 15 cm diameter specimen
(2) 40 psi = 2.8 Kg/cm2

Applications of OPP films

The main applications of OPP films can by analysed upon the basis of the figures given below, which illustrate consumption of these films in the packaging area. More than 70% of OPP films used in 1980 in the USA was for food packaging: products listed below:

	1000 tons
Baked goods	16,4
Snacks	14,5
Candy and nuts	7,7
Cheese	4,5
Coffee and tea	1,8
Pet foods	1,4
Dry groceries	0,9
Produce	0,9
Total	48,1

With a thin polypropylene film, which is more limp at elevated temperature, flatter folds can be obtained and more intimate contact between thin films under the more often used low sealing pressures. This ensures more uniform pressure distribution and heat transfer, so that a greater degree of perfection may be attained in finished wraps than is possible using the thicker cellulose films under similar working conditions.

If superior seals are achieved because of these factors then the self-life of the product wrapped in coated oriented polypropylene film may be longer than when wrapped in cellulose film even though laboratory tests might show that uncreased samples of film have very similar permeability characteristic.

Typical applications of OPP films are the following:

- confectionary industry: biscuits, crackers, sweets, candies, boiled sweets, ground nuts;

- bakery industry, bread, rolls;
- snacks, potatoe chips, sandwiches, processed meat, corn products, pies and so on cereal industry, spaghetti, noodles;
- cigarettes in single boxes and in cartons;
- multipacks for different small dimension products as tea bags previously packed in folding boxes.

The most popular form-fill-seal (F.F.S.) horizontal and vertical packaging systems require the use of coated OPP films. The principal of vertical F.F.S. machines system is illustrated in Fig. 6.

OPP coated films are also used in Europe on overwrapping machines. An example of cigarette wrapping machines is illustrated in Fig. 7.

According to the technical literature, specially adjusted uncoated OPP films can be used on overwrapping machines, but this application is not at all popular in Europe. The biggest amount of OPP films used in one year in Great Britain for example (1700 tons) was for potatoe chips packing.

For small portions (28 g) single layer 28 μm films were used, for larger ones (250 g) the laminates made of double layers of OPP films or OPP film laminated to cellophane were in use.

In the confectionary industry vinylidene chloride copolymers coated films are preferable. During the period under consideration about 1000 tons of OPP films were used for 20% of all biscuits produced in the country.

OPP is also widely used in lamination and coextrusion. Nowadays more than 100 different types of combining materials with use of OPP are available on the US market. Homopolymer OPP may be laminated with cast or blown PP, PVDC, cellophane, glassine, LDPE for use in such diversified markets as snacks, candy cookies, coffee, cheese and meat.

Coextruded PP between two layers of MDPE maybe laminated with glassine or cellophane.

There are known combinations of acrylic coated homopolymer OPP with PVDC coated grade or glassine, uncoated and PVDC coated cellophane for use as snack packages. Other constructions consist of PVDC coated OPP homopolymer combined with the same materials as acrylic coated grade. One of the very interesting coextruded combinations consists of two layers of PP copolymers with single ply of PP copolymer in between. In snack and bakery packaging for instance, two 0,018 mm webs are laminated to each other to provide a strong versatile structure with reverse printing capability.

Many OPP film laminates are adjusted for form-fill-seal equipment. Some of them are suitable for deep-freezing, for "boil in bag" and for vacuum packing applications. Beside the types described above, among the materials based on polypropylene shrink films and self adhesive tapes, also semirigid thicker sheets should be mentioned. This type of material will be discussed separately.

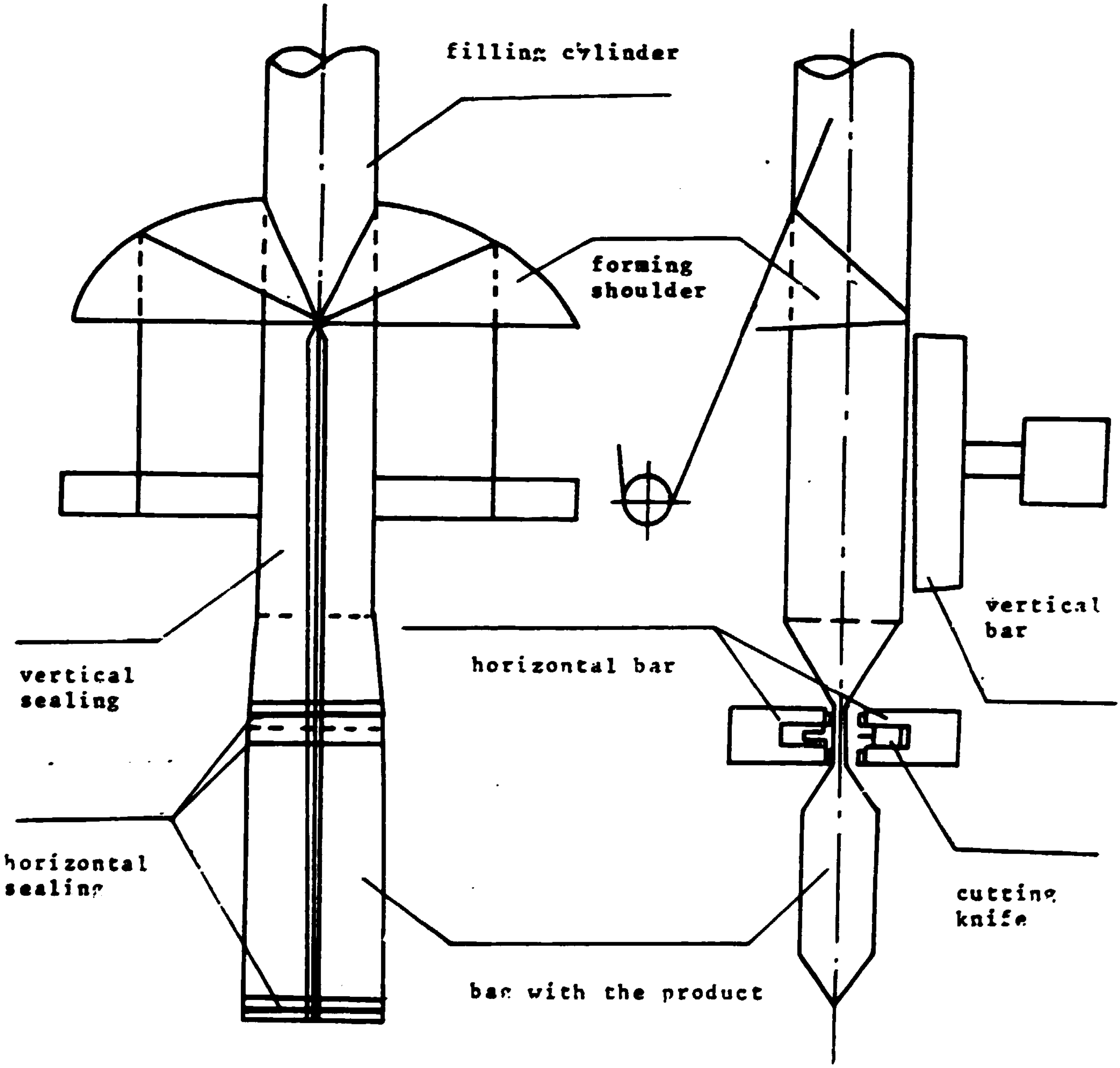

Fig 6 Principle of vertical form - fill seal machine.

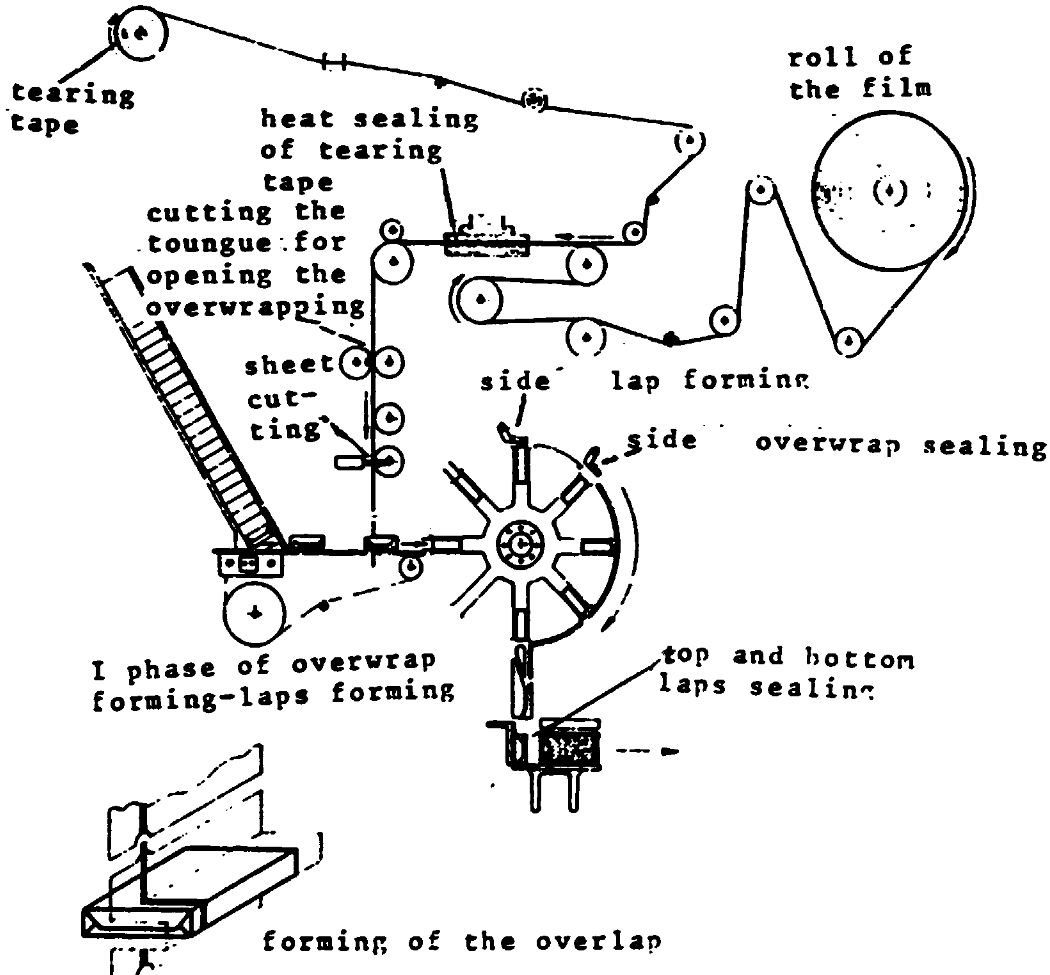

Fig 7 Packing of single cigarette boxes with use of heat sealable films.

APPENDIX 5

The list of quality control tests discussed, presented or conducted according to expert's suggestions.

1. The system of standard crushing of high barrier flexible materials prior to water vapour permeability measurement.

2. Bond strength measurements of flexible laminates.

3. Apparent and Young modulus measurement of plastic films.

4. Stiffness measurement.

5. Tearing strength of films and laminates.

6. Impact strength of polyethylene films.

7. Profile measurement for evaluation of quality of ready-made rolls of flexible materials.

8. Shrinkability measurements of thermoshrink films.

9. Paper and plastic film coating with use of "automatic applicator".

10. Quality control tests for laboratory coated materials.

11. Interpretation of strength measurements conducted with flexible materials.

12. Methods and equipment for checking gas permeability of flexible materials and ready-made packages.

13. Range of applications of gas chromatography for analysis of packaging materials.

14. Sensoric analysis of flexible packaging materials which remain in direct contact with foodstuff.

15. Extraction tests used for evaluating the suitability of flexible materials for food packing.

APPENDIX 6

The Method Used to Control Water Vapour Permeability of Crushed Flexible Materials

Six samples of the dimensions 120 x 120 mm should be cut out from the tested materials. A mark should be made at equal distances from the edges (100 x 100 mm) to determine the edges for further heat sealing.

Each of the samples should be tightly wound up on auxiliary rod (10 mm diameter). The rod is then taken off and the edges of the sample are fixed with the use of self adhesive tape. Rods, made for example of copper, are introduced to both sides of the rolled sample at the depth of 45 mm (on each side). The rods are fixed in this position by means of self adhesive tape. The sample prepared in this way is placed on hard and flat surface of the table. Crushing is realised five times by drawing the rods nearer to one another which takes place at a distance of 30 mm. The sample is then unwound and from two samples of this kind a flat bag is formed by heat sealing.

The internal sizes of the bag should be equal to 100 x 120 mm. The bag is filled with 30-40 g of dried calcium chloride and is instantly sealed according to previously drawn line. The internal dimensions of the bag (between the sealing) should be equal to 100 x 100 mm. The excess of the material on the exterior side of the heat sealing should be cut off. The width of heat sealing should not be less than 3mm.

At least 3 types of bags of this type are prepared for each type of analysed material. The bags are put in the chamber of a constant temperature (38°C and relative humidity (90%)). The bags are weighed on an analytical scale to determine constant increases.

These increases are calculated in traditional system for checking water vapour permeability in $g/m^2 \cdot$ 24 hours.

As a result the average value of all measurements for each analysed material is given.

APPENDIX 7

Stiffness measurements with application of modified H - O - M method and use of the compression cell of strength measuring machines.

1. Application

The method is applied for determination of the resistance of flexible materials for bending, considered as their stiffness. Described method can be applied to plastic films, paper aluminium foils and flexible packaging laminates.

2. Determination

Resistance of the film for bending (stiffness) is the highest force involved, when material is pressed into the measuring gap and is expressed per unit of length N · m-1 (G · cm -1).

3. Equipment

Strength measuring machine which is equipped with a compression cell allows forces in the range from few grams up to 500 grams to be checked (sensitivity 0,05% of the measured value), with application the speed of the bending mechanism 50 ± 5 mm/min. Construction and dimensions of the device used for measurements are presented at Figure 1.

This device is installed on Instron machine in the way illustrated in Fig. 2.

As can be seen, plate for location and sample is fixed to the compression cell, and penetrator is fixed to the moving bar of Instron machine.

4. Samples

Ten samples of 50-200 mm length and 15 mm width cut in the machine direction and 10 in transverse direction, should be used in one testing. Samples are conditioned at 23°C and 50% relative humidity.

5. Testing procedures

The samples are located on the plate in the manner presented in Fig. 1. Before starting the tests distance between the penetrator and the sample should not exceed 5 mm.

The speed of the moving bar should be fixed at 50 mm/min.

The range, or movement of the moving bar should be adjusted in such a way, that after achieving the lowest position of penetrator allowing to register the maximum force, this penetrator should return automatically to the upper position (5mm distance from the sample).

During the downward movement of the bar penetrator bends the sample against the gap. At the same time maximum force during this bending is registered.

Because of possible differences between both sides of the sample it is recommended to check 5 samples locating their face side to penetrator, another 5 from the opposite side.

Bending resistance considered as stiffness, is calculated by dividing the maximum force registered during bending by the length of the sample and expressed in G . cm-1 or N. m-1.

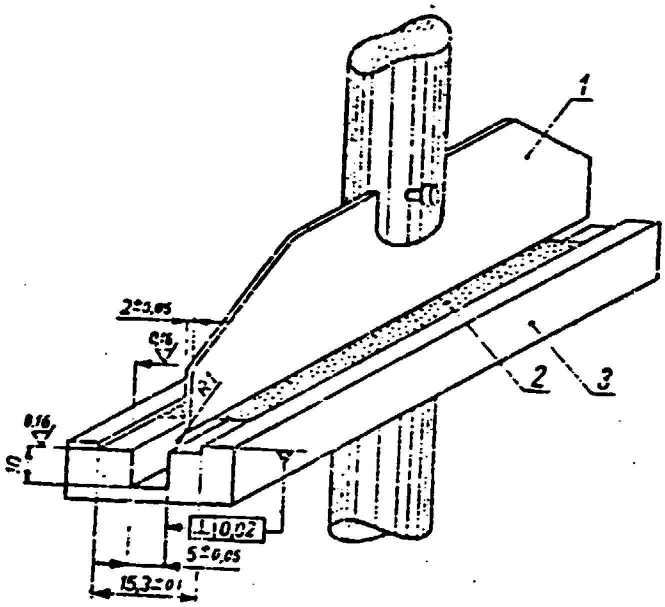

FIGURE 1

DEVICE USED FOR DETERMINATION THE RESISTANCE OF THE FILM FOR BENDING (STIFFNESS.)

1. Penetrator (fixed to moving bar of strength measuring machine).
2. Sample
3. Plate enable to bend the sample against the gap which can be seen at the Figure 2 .

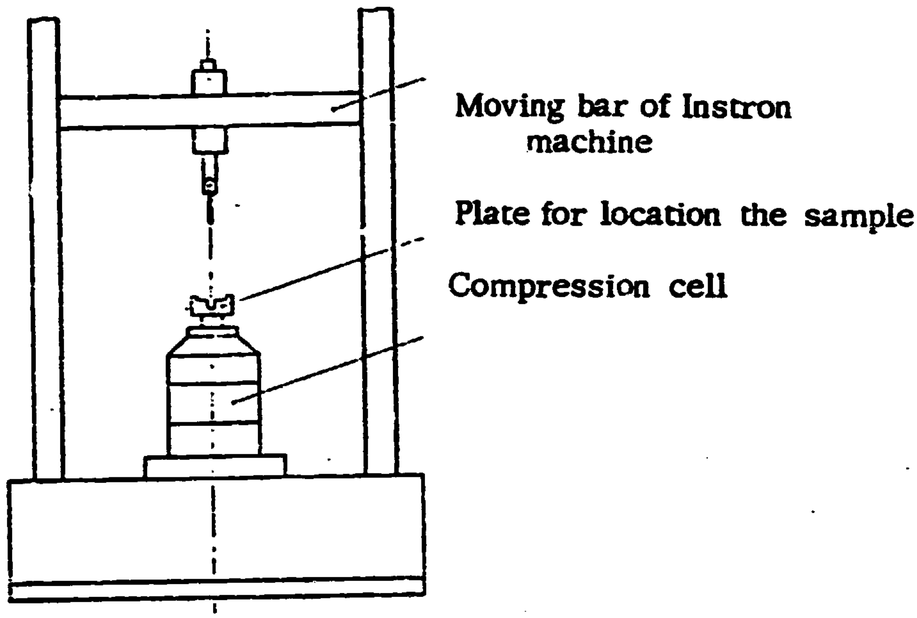

FIGURE 2

DEVICE FOR STIFFNESS TESTING, FIXED AT INSTRONSTRENGTH MEASURING MACHINE.

CENTRO NACIONAL
DE ENVASES
Y EMBALAJES

APPENDIX 8

Ciudad La Habana, diciembre 25/'85
"Año del III Congreso del Partido"

Estimado Compañero (a);

Por este medio le informamos acerca del Ciclo de Siete Conferencias que sobre Envases Flexibles dictará en nuestro Centro el SR. BOHDAN CZERNIAWSKI, experto de Naciones Unidas.

CICLO	FECHAS	HORA
1.- Cellophane y PP.	3/1/'86	2:00 P.M.
2.- PE y otras Poliolefinas	6/1/'86	2:00 P.M.
3.- PET y PA	10/1/'86	2:00 P.M.
4.- Laminados para envases flexibles (Flexible Packaging Laminates)	17/1/'86	2:00 P.M.
5.- Co-extrusión y Tecnologías Termo-Conformadoras (Thermoforming Technologies and Co-extrusion)	24/1/86	2:00 P.M.
6.- Materiales Metalizados de Envases Flexibles Combinados con Laminados de Foil de Aluminio (Flexible Packaging Materials combined with Aluminium Foil Laminates)	31/1/86	2:00 P.M.
7.- Películas Retráctiles y Estirables (Shrink and Stretch Films)	7/2/'86	2:00 P.M.

Informamos además que las Conferencias serán impresas en inglés. En la primera Conferencia se entregará el texto en inglés de la segunda, a fin de que nuestros técnicos las estudien de manera familiar y puedan hacer observaciones y aportes críticos.

Con Saludos Revolucionarios

Carlos Rodríguez Galbán

Director.

República de Cuba · DIRECCION · CENTRO NACIONAL DE ENVASES Y EMBALAJES

List of Books published recently (from 1970 onwards)

Author	Title	No. of pages	Year	Publishing House
Zawadzki J.M.	Konserwacja i pakowanie wyrobow Metałowych (Polish)	390	1985	WNT, Warszawa, PRL
	Oesterreichischer Verpackungs-katalog - 8. Auflage (German)	324	1985	Bastei-Verlag, Wien, Austria
Paine F.A., Paine H.Y.	Handbook of Food Packaging	407	1983	Leonard Hill, Blackie and Son Ltd. Glasgow, England
Haine D.J. Sayers M.C.	Handbook of flexible packaging test methods and their accuracy (internal edition)	30	1983	Pira, Leatharhead, England
Curda D.	Baleni potravin (Czech)	432	1982	SNTL Praha, CSSR
Calvin J. Benning	Plastic film for packaging	181	1983	Techomic Publishing Co. Inc. Pensylvania, USA
Johnsen M.A.	Aerosol Handbook (Second Ed.)	647	1982	Wayne Dorland Co., Mandham, NY, USA

Author	Title	No. of pages	Year	Publishing House
	Verpacken mit kunststoff-Folien (German)	185	1982	VDI Verlag, Kunstofftechnik Dusseldorf, FRG
Smuronov, I.K. Gancovsky, J.N.	Derevjannaja jascicnaja tara (Russian)	184	1982	Derevjannoije proizvodstvo Moskwa USSR
Deppert, W., Stoll, K.	Pneumatic in der Verpackungstechnik (German)	211	1982	Vogel, Buchverlag, Wurzburg, FRG
	Technical packaging dictionary in English, French, German, Swedish Danish, Norwegian.	320	1982	Nord Emballage, Valtngby, Sweden
Crosby N.T.	Food Packaging Materials Aspects of analysis and migration of Contaminants	190	1981	Applied Science Publishers Ltd., London, England
Blagodarskij V.A. and others	I spolnitelnyje mechanismy masinavtomator dlja upakovki izdelij (Russian)	302	1980	Masnostrojenije, Moskwa, USSR
Heiss R.	Verpackung von Lebensmittln - Anwendung der wissenschaftlichen Grundlagen in der Praxis (German)	306	1980	Springer Verlag, Heidelberg, FRG
	Polimernaja tara i upakovka (Russian)	272	1980	Chimija, Moskawa, USSR
Kuzia A. Nassalski A.	Systemy pakowania w folie kurczliwe (Polish)	178	1978	WNT, Warszawa, PRL
Paine F.A.	The Packaging Media	564	1977	Blacke a. Son. Ltd., Glasgow, England
Jakowski S.	Ochrona tadunkow w przewozach (Polish)	176	1977	WKL, Warszawa, PRL.

Author	Title	No. of pages	Year	Publishing House
	Extrudierte Feinfolien und Verbundfolien (German)	184	1976	VDI Verlag, Kunstofftechnik Dusseldorf FRG
Kolakowski E.	Opakowania z tworzyw sztucznych w przemysle rybnym (Polish)	285	1976	Wydawnictwo Morskie, Gdanskm PRL.
Ross C.F.	Packaging of Pharmaceuticals	165	1975	Newnes-Butterworths, London, England
Oswin, C.R.	Plastic Films and Packaging	214	1975	Applied Science Publishers Ltd. London, England
	Dictionary of Packaging-English, German, French, Italian, Spanish, Russian	843	1975	Verlag fur Fachliterature, Heidelberg, FRG
Bruins P.F.	Packaging with plastics	211	1974	Gordon and Breach Science Publishers, New York, USA
Sciarra J.J.	The science and technology of aerosol packaging	710	1974	John Wiley Sons, New York, USA
Kuhne G.	Verpacken mit kunstoffen (German)	304	1974	Carl Hanser Verlag, Munchen, FRG
Briston J.H. Katan	Plastics in Contact with food	466	1974	Food Trade Press Ltd., London, England
Paine F.A.	Packaging Evaluation, The testing of filled transport packages	113	1974	Newnes-Butterworths, London, England
Cairns J.A. and others	Packaging for Climatic Protection	111	1974	Newnes-Butterworths, London, England
Mac Chesney J.C.	Packaging of Cosmetics and Toiletries	135	1974	Newnes-Butterworths, London, England
Park W.R.	Plastics Film Technology (2nd Edition)	210	1973	Robert E. Krieger Publishing Co., New York, USA
Swinbank C.	Packaging of Chemicals and other industrial liquids and solids	203	1973	Newnes-Butterworths, London, England

Author	Title	No. of pages	Year	Publishing House
	Higieniczna ocena tworzyw sztuchznych w zakresie srodkow spozywczych, lekow i przedmiotow uzytku (Polish)	293	1972	PZWL, Warszawa, PRL
Farnhan E.	A Guide to Thermoformed Plastic Packaging	258	1972	Cahners Books, Boston, USA
Jeitteles Kotte	Handbuch für Pappe (German)	272	1971	P. Keppler Verlag KG., Heusenstamm, FRG
Fisher E.G.	Blow Moulding of Plastics	193	1971	The Plastics Institute, London, England
Hanlan J.F.	Handbook of Package Engineering	544	1971	Mc Graw-Hill Book Co. New York, USA
Czerniawski B. Nassalski A.	Folie opakowaniowe (Polish)	313	1970	WNT, Warszawa, PRL

LIST OF SELECTED JOUNALS RECOMMENDED FOR CNEE LIBRARY

1. Journals published in Socialist Countries		Country	Publishing House
1.1.	Packaging only		
1.1.1	Manipulace, skladowani, baleni	CSSR	Imados, Konevova 131, 13083 Praha 3 Distribution: PNS, Press Distribution Centre, Press Export Dept., Jindrinska 14, 12505 Praha 1
1.1.2	Die Verpackung	DDR	VEB Fachbuchverlag, DDR-7031 Leipzig, Karl-Heine-Strasse 16
1.1.3	Opakowanie x/	POL	SIGMA, ul. Biala 4, 00-950 Warsaw
1.1.4	Tara i upakowka Kontiejniery	USSR	
1.2	Various Paper and Plastics		
1.2.1	Papier a celuloza	CSSR	ARTIA, Ve Smeckach 30, 11127 Praha 1
1.2.2	Przeglad papiernicxy	POL	SIGMA, ul. Biala 4, 00-950 Warsaw
1.2.3	Plaste und Kautschuk	DDR	Grundstoffverlag Leipzig, DDR-7031 Leipzig, Karl-Heine-Strasse 27
1.2.4	Plasticzeskije massy	USSR	
1.3	Dealing with corrosion		
1.3.1	Korrosion x/	DDR	Zentralstelle für Korrosionsschutz,DDR-8080 Dresden, Karl-Marx-Str. 228
1.3.2	Korrozija i zaszczita mietallow	USSR	

x/ Two monthly journal

1.4. Review of world literature and patents

1.4.1	Izobrietienija stran mira. Wypusk 46. Upakowka, tara, sbor otchow. MKI B 65. B,C,D,F xx/	USSR	
1.4.2	Targowla za rubiezom	USSR	
1.4.3	Przeglad dokumentacyjny	PRL	COBRO, 02-942 Warszawa, ul. Konstancinska 11

2. Selected journals published in capitalist countries

2.1. Basic journals - packaging only

2.1.1	Emballages magazine	France	Emballages Magazine, 26, rue du Faubourg Poissonniere 75010 Paris
2.1.2	Emballage Digest	France	SEPE, 142, rue d'Aguesseau, 92100 Boulogne
2.1.3	Verpackungs Rundschau	W. Germany	P. Keppler Verlag GmbH + Co Kg, Industriestrasse 2 D 6056 Heusenstamm
2.1.4	Neue Verpackung	W. Germany	Hüting Publikation, Im Weiher 10, D-6900 Heidelberg 1
2.1.5	Packaging	England	Turret-Wheatland Ltd., Rickmansworth, England WD3
2.1.6	Packaging Review	England	Business Press International Ltd., 35 Perrymount Road Harwards Heath W. Sussex
2.1.7	Packaging (previously modern packaging) and package engineering	USA	Packaging, 270 St Paul Street, Denver, Colorado 80206
2.1.8	Paper, Film and Foil Converter	USA	Maclean Hunter Publishing Co., 300 W. Adam St., Chicago Il. 60606
2.1.9	Packaging Science and Technology Abstracts (PSTA) - Referatedienst Verpackung (Review of literature published by PIRA-England and ILV - West Germany)	W. Germany	International Food Information Service, Lyoner St. 44

xx/ Bi-weekly

Papers, Plastics

2.1.10	TAPPI	USA	TAPPI, Washington, USA
2.1.11	Kunststoffe	W. Germany	Carl Hanser Verlag, Kolbergerstrasse 22, D-8000 München 80
2.1.12	Modern Plastics International	USA	Mc Graw - Hill Publication, 14. avenue D'Ouchy 1006 Lausanne, Switzerland

2.2 Other Journals

2.2.1	Conditionnement des liquides-Embouteillage	France	SEPAIC, 42, rue du Louvre, 75001 Paris
2.2.2	Papier + Kunststoff Verarbeiter	W. Germany	Deutscher Fachverlag GmbH, 6000 Frankfurt am Main 1 Postfach 100606
2.2.3	Verpackungs Berater	W. Germany	P. Keppler Verlag, 6056 Heusenstamm, Postfach 1353
2.2.4	Packaging Today	England	Packaging Today, 345 Goswell Road, LONDON EC1B 1BP
2.2.5	Imballaggio	Italy	ETAS KOMPASS Periodici Technici S.p.A, 20154 Milan Via Mantegna 6
2.2.6	Tara	Switzerland	Tara-Verlag, Beustweg 12,8032 Zürich

APPENDIX 11

List of used abbreviations.

Al	Aluminum foil
BOPP	Biaxially Oriented Polypropylene
CNEE	National Packaging Centre.
EVA	Ethylenevinyl acetate.
HDPE	High density polyethylene.
IIIA	Research Institute of Food Industry
LDPE	Low density polyethylene
LLDPE	Linear low density polyethylene.
MSAT	Nitrocellulose coated cellophane.
MXXT	Vinylidene copolymers coated cellophane.
MINIL	Ministry of Light Industry.
MINAL	Ministry of Food Industry.
MINBAS	Ministry of Basic Industry.
OPP	Oriented polypropylene.
PE	Polyethylene
PA	Polyamide
PP	Polypropylene
PVC	Polyvinylchloride
PVDC	Polyvinylidenchloride.