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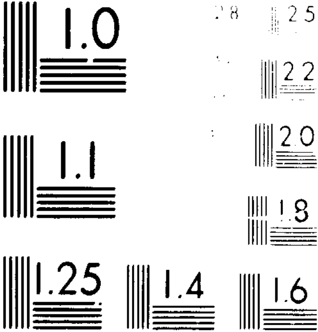
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Egypt.
Plastics Development Centre

DP/EGY/77/004 - 11-02K

Alexandria, Egypt

Technical Report

Assistance in Training for Procedure and Specifications of Testing

Based on the work of Dr.K. Ramamurthy
UNIDO Expert

Abstract

The title of the post for the project No. DP/EGY/77/004/11-02/ K/32.1.H was Plastics Technologist- Procedures and Specifications of testing with a purpose to assist the establishment of a Plastics Development Centre (PDC) in order to provide technical support for both strengthining and expanding the Egyptian Plastics Industry. The development of a testing laboratory forms one of the important facilities within the PDC. The duration of the first repeat mission was one month.

The main objectives were to assist and advise the PDC in certain of its specific requirements including the setting up of a chemical laboratory, drawing up test procedures for available test equipments and train the counterpart on the test specimen selection, operation, evaluation of procedures and quality control techniques, expose the counterpart staff on certain theoritical aspects of plastics testing.

The specific requirements have been completed in most of its aspects. The test procedures have been prepared in addition to training the staff in sample preparation and selection, operation and maintenance of test equipments, recording procedures, calculations and evaluation of test results. The staff were also trained on the preparation of test reports, maintenance of equipment records, test allocation procedures etc. Exposures were given to staff in certain topics on testing, additives, compounding etc. through lectruing, discussions and demonstrations. For the benifit of the PDC staff and plastics industrialists a special lecture on "Testing and Evaluation of Plastic Film and Laminates" was delivered. Based on the assessement of the need, additional facilities has been suggested.

The mission was successfully completed.

1. Introduction

The repeat mission assignment in Plastics Development Centre (PDC) at Alexandria was taken up after briefing at UNDP Cairo. On reaching PDC the Director and Head of Technical Affairs briefed regarding the progress made in the centre during the last one year and expressed the desire for the assistance and advise needed in tackling some of their problems in addition to the nature of work proposed to be carried out as per the job description. The counterpart staff intended for the exposure to the training were then introduced. Names of these personnel are given in Annexure (1). Three new additions were there.

A brief discussion took place regarding the added facilities in PDC and the nature of training and other requirements needed. It was found that stabilised power has been established and a few new additional test equipments have been received.

It was therefore planned to inspect and install the new additional test equipments, put them into operation along with some of the earlier equipments, draw up test procedures, train counterparts in all aspects of the objectives, assist and advise the centre in some of its specific requirements. These were intended to be carried out through practical involvement in the demonstration work, supported with necessary lectures, which were to be specifically prepared for this requirements from books and background matter brought from India followed by discussions. These were to be carried out in consultation with the Head of the Technical Affairs and the progress to be mentioned.

The training, assistance and advise rendered have been very well received by the staff of the PDC. The overall progress of the testing centre with regard to the staff and services have been found to be good.

2. Body of the Report

2.1 The main duties of the assignment were to assist and advise the centre in its following specific requirements in addition to assist in drawing up the test procedures according to relevent standards on plastics and to train the personnel in all the aspects of operation of test equipments and evaluation of test results.

(a) Operation/experiments/discussions on Brabender plasticorder with planetary mixer, E.S.C. apparatus, Instron tester, Gas permeability apparatus and impact tester.
(b) Operation of Xenotest and a design for natural exposure.
(c) Setting up of calibration system.
(d) Setting up of a chemical laboratory
(e) Evaluation of laboratory equipment results
(f) Lectures and discussions on plastics in packaging and applications. additives and compounding.
(g) Adhesive material

During the last mission, the operation, calibration and standardization of the many of the test equipment could not be carried out because of the non availability of test specimen and stabilised power. Further few additional equipments and spare parts have been received subsequently and new additional staff have been recruited. Keeping all these factors in mind, it has become necessary that systematic operations and training of the staff with test equipments, more or less to be done wholesomely in order to achieve the best results.
The results were achieved in the following manner.

2.1.1 The test equipments available in PDC as on date is given in Annexure (2). The list include 9 of the additional equipment received during the last one year. As agreed upon during the last mission, American Standard for Testing Material

were decided to be followed for conducting tests and drawing up procedures. Accordingly test procedures were prepared for additional test equipments received and also for the experiments planned in the chemical laboratory.
The list of test procedures drawn up as per the standard and available test equipments is given in Annexure (3). As done in previous mission, the test procedures were made comprehensive by including details about the scope, definitions, significance, the apparatus, the test specimen, conditioning, operational procedure, observation chart, calculation and test report. And also files were build up for all the new equipment/ experiments containing the test procedures, relevant standard and maintenance record.

Basic concepts regarding the test equipments and methods of testing were then imparted to the staff in the form of lectures, discussions and demonstrations. This also included some of the old equipments for the benefit of new personnel and on the specific requirements of other counterpart staff. As detailed in the earlier report the tecnnical personnel were then trained in all the test equipments for operations, observations, calculations, interpretation, reporting, maintainence and precautionary measures. Equipments like Instron tester for tensile and compression tests with mixer head and plasticiser absorption tests with planetary mixer which were not fully put into operation last time were given special attention and put into various experimentation, and training were completed in all its aspects. Similarly attention were bestowed upon Gas Permeability apparatus, Volume and Surface Resistivity apparatus and Enviromental Stress Cracking apparatus also for the operational difficulty and interpretation of the test results. On the major new equipment Xenon Tester was installed and commissioned successfully, for temperature humidity and rain cycles. The training was also given on this equipment.

Because of the defective Xenon arc. lamp this could not be included in the cycle. However necessary training and instructions were given to the staff so that as soon as this part is received they will be in a position to incorporate it and conduct the tests for evaluation. A design for natural exposure was also recommended as per ASTM D 1435 and Indian Standard IS:2076.

2.1.2 Test specimens with known test values for important tests were brought from India and were tested in PDC, for the equipments reliability and standardization. The ranges of values were checked and their reliability were ascertained. Guide lines were given regarding setting up of calibration system for important test equipments. The Centre has been advised to get in touch with the Institute of calibration and chart out a detailed programme for adoptation.

2.1.3 Settin up for a chemical laboratory with basic facilities were found to be one of the priorities of the PDC. The place for the laboratory was already identified. The tables and service facilities were arranged. The list of apparatus, glasswares, chemicals etc. suggested during last mission was arranged and few additional items found to be needed were then included. The list of these additional items is given in Annexure (4). The staff intended for the chemical laboratory was taken to a reputed scientific company in Cairo and the apparatus, etc. were selected based on the drawn up specifications. These are being arranged for procurement by the PDC. Instructions have been given regarding the positioning of the apparatus in the laboratory. The staff was also briefed enough regarding tests and experiments that may be able to be conducted with the basic facilities. The methods of experimentation were also explained and discussed with the detailed procedures drawn up specifically for this purpose that are given in Annexure (3).

With these there should be no difficulty in initiating the activities of the chemical laboratory. Special attention was devoted to the determination of carbon black and carbon black dispersion in olefin plastics and the methods of UV stabilizer determination which is generally done by instrumental methods.
It was realised that the staff still require further knowledge and practice in identification methods of plastics by simple confimatory methods as this is very important and basic requirement of a plastics testing laboratory. A brief **write** up was made available to them on this topic and the training was given by practical demonstrations with the sample **pockets** brought from India, with explanation to enable them to take up such tests in future.

2.1.4 In depth explanation and discussions were held frequently in connection with the evaluation of the laboratory equipments test results and their usefulness limitations in various practical applications. The laboratory personnel showed great interest by their active participation which is to be well appreciated and recorded.

2.1.5 General lectures on introduction to plastics materials, processing and applications of plastics and Brabender Plasticorder were taken in order to acquaint the personnel with necessary background information for expanding their knowledge in testing and advisory services.

2.1.6 Building up of knowledge and then facilities for compounding of plastics especially for PVC in view of the emergence of a large petrochemical complex in Egypt was found to be one of the area which is occupying the attention of PDC. So, in this connection lectures and discussions on additives and compounding was arranged and also literatures brought from India were provided to the centre for their use and facility build up.

2.1.7 Preparation of a water soluble adhesive for cassette labeling as an import substitute came up to PDC. In this connection M/S. Sono Cairo Co., Alexandria was visited with the PDC staff and the available date and connected details were collected. Outlines for identification of the basic resin and guidelines for preparation of such adhesive were given to the Centre. Further advise will be given through correspondance.

2.1.8 Discussions regarding the formalities and procedures to be adopted in taking up a testing assignment initiating, following up action and test results forwarding etc. was held with the Head of the Technical Affairs and the counterpart and adequate informations were given in this connection.

2.1.9 The PDC is a member of Plastics Standardization Committee of Egypt. During the assignment period formulations of specification of PVC sheet for passport purposes came up for discussions. Guidelines for approaching such type of problems were given and also the ASTM standard D1593 and Indian Standard IS 2076 were specifically discussed for this purpose.

2.1.10 Industrial visits were undertaken to the following industries in order to know their activities and requirements, acquaint them with the available PDC test facilities and advise them for utilising such services for getting best results.

(a) M/S. Al Sherief and Co. Cairo (13/4/83)
(b) M/S. Sono Cairo Alexandria (16/4/83)

2.1.11 During the mission period few assignments from Industry came up to PDC for testing and evaluation purposes.

(a) Compression testing evaluation of encopsulated fuel for Atomic Centre purpose.

(b) Tensile testing and evaluation of PVC sheet for passport application.

(c) Property specifications evaluation of PVC compound for applications.

Guidance were given to complete these assignments.

2.1.12 Also on 26/4/83 had an oppor ity to meet the Committee of Plastics Raw Materials procurement of Egypt Government at PDC and acquainted them with the purpose and background of the expert mission and the potentials of the PDC testing facilities for their utilization. This was done through a slide programme. Later the Committee had appointed PDC as a consultant for the procurement of plastics raw materials for imports. This is really a prestigeous assignment to PDC.

2.1.13 At the request of PDC a special lecture on "Testing and Evaluation of Plastic Films and Laminates" was delivered on 28/4/83 for the benefit of the PDC staff and plastics industrialists from Alexandria and Cairo. The content and details of this lecture is given in Annexure (9). During this meeting had an opportunity to discuss with the industrialists and also with Prof. Dr. S.A.El Garf of Alexandria University who is extending excellent services to develop the theoratical background of PDC staff in polymers.

2.1.14 A final meeting was held at the end of the mission with the Head of Technical Affairs and the counterpart staff. The work carried out was reviewed. Also the type of facilities training and assistance needed in connection with the progress and implementations of the project were also discussed.

3. Findings and Recommendations

3.1 The progress of the testing centre and its staff has been exceedingly good in the last one year.

3.2 The counterparts had responded to the training well.

3.3 Many of the test equipments, spares and accessories recommended/ suggested during the last mission are yet to be procured by PDC. This may be reviewed and necessary steps be taken to procure these items in order that the centre may serve the industry effectively.

3.4 During the training, it was identified that few of the test equipments is to be provided with certain accessories/spares so that these may be put into full use. The recommended list of these items is given in Annexure (5). These items may be made available to PDC.

3.5 Keeping in mind the coming up of a petrochemical complex in Egypt and the appointment of PDC as a consultant by the Government of plsatics raw materials, it is necessary that PDC strengthen its facilities in the areas of testing, compounding and chemical identifications (Evaluation of Stabilizers Antioxidants etc)

It is therefore recommended that equipments given in Annexure (6) for such facilities may be considered for procurement in stages. As the compounding and the identification of additives etc. by sophisticated instruments are specialised areas, it is necessary that the technical personnel are provided training in the firms from where these equipments/instruments are procured so that the instruments are put into immediate best use.

3.6 Formulation of standards and standardisation activities has already been started by the PDC by being the members of the National Committee on Standardization for Plastics and assisting them. This should be further activily taken up by the PDC. If necessary training of one personnel abroad for this specific purpose is suggested. For the benifit of the Centre few useful Indian Standards have been left in their library.

3.7 For the expanding activities of the testing centre, in order to extend the best services to the Egyptian Plastics Industry it is necessary now that the staff are trained in specific/ specialized areas of testing. It is therefore recommended that the PDC personnel may be identified for various specific areas and trained accordingly in various test centres mentioned in the earlier report. Few additional training centres are also given in Annexure (7).

3.8 The technical library of PDC need further strengthening. ASTM and other standards, other books and periodicals that were earlier suggested may be arranged for earlier procurement. Keeping in mind the present and future activities of the PDC few more literatures are recommended in the Annexure (8). These may be procured.For the benifit of the PDC, training course materials on "Plastics Materials and Product Testing" and "Refrences Course on Blown Film Extrusion" prepared by the Central Institute of Plastics Engineering and Tools, Madras have been given to them.

Annexure (1)

Plastics Development Centre, Alexandria.
DP/EGY/81/029

Director: Dr. Osman Abuzeid

Head Technical Affairs: Ms. Eng. N. Nosseir

Names of Counterpart and C .her Staff

(1) Eng. Magdy Ghareeb	Electrical Engineer
(2) Eng. Nagwa El Menawy	Chemical Engineer
(3) Chem. Khaled El Sayed	Chemist
(4) Chem. Hisham El Shammaa	Chemist
(5) Chem. Hisham Hussein	Chemist
(6) Chem. Mahmoud Nada	Chemist

Annexure (2)

List of Test Equipment at Plastics Development Centre

1)	Instron Universal Testing Instruments	Instron, U.K.
2)	Pendulum Impact Tester	ZWICK & Co.,FRG
3)	Dart Impact Tester	Daventest ltd., U.K.
4)	Elmendorf Tear Tester	Daventest ltd., U.K
5)	Melt Flow Indexer	" " "
6)	Brabender Plasticorder	Brabender, FRG
7)	Spherical Haze Meter	Daventest ltd., U.K.
8)	Gloss Meter	Daventest ltd., U.K.
9)	Stereo Microscope	Olympus, Japan
10)	Volume and Surface Resistivity Apparatus.	Daventest Ltd., U.K.
11)	Gas Permeability Apparatus	" " "
12)	Enviromental Stress Cracking Apparatus.	" " "
13)	Torsional Modulus Tester	Wallace & Co., U.K.
14)	Radiation Thermometer	Heimann, FRG
15)	Tong Welding Unit	Riche & Herfurth, FRG.
16)	Ultrasonic Welder	Telesonic,Switzer-land.
17)	Laboratory Oven	Daventest ltd.,U.K.
18)	Mixer	Hobart Corp., USA
19)	Xenotest 250	Original Hanau, FRG
20)	Microtome	Reichert Jung, FRG
21)	Buffing Machine	Wallace, U.K.
22)	Polariscope	Kayness,Inc., USA
23)	Balance	Sartorious, FRG Zaklady Mechaniki Precyzy jnej,Poland
24)	Film Thickness Gauage	Wallace & Co., U.K.
25)	Melting Point Apparatus	Electrothermal,UK
26)	PH Meter	Griffin & George Ltd UK.
27)	Oven	Memsnert, FRG

Annexure (3)

List of Test Procedures

1) Identification of plastics by simple methods
2) Testing of the plasticiser absorption of PVC by planetary mixer.
3) Methods of exposure to laboratory light sources (Xenontest) (ISO 4892-1981 & BS 2782:Part5:Method540 B: 1982)
4) Specific gravity and density of plastics by Displacement, (ASTM D - 792)
5) Density of plastics by the density gradient technique, (ASTM D 1505)
6) Determination of logrithimic viscosity number of polyvinyl chloride (PVC) in formulated compounds (ASTM D 3591).
7) Viscosity of ethylene polymers dilute solution (ASTM D 1601)
8) Density, apparent, bulk factor and pourability of plastics materials (ASTM D 1815)
9) Particle size (sieve analysis) of plastics materials (ASTM D 1921)
10) Water absorption of plastics (ASTM D570)
11) Determination of melting point by capillary method.
12) Index of refraction of transparent plastics (ASTM D542).
13) Carbon black in olefin plastics (ASTM D 1603, Indian Standard- IS - 2530).
14) Microscopical examination of pigments dispersion in plastic compounds (Determination of carbon black dispersion in poly-ethylene materials ASTM D 3015, IS - 2530).
15) Acetone extraction of phenolic moulded or laminated products.
16) Resistance of plastics to chemical reagents (ASTM D 543).
17) Resistance of plastic film to extraction by chemicals (ASTM D 1239).
18) Rate of burning and/or extent and time of burning of flexible plastics in a vertical position (ASTM D 568).
19) Rate of burning and/or extent and time of burning of self supporting plastics in a horizontal position (ASTM D 635).
20) Extraction and analysis of plasticiser mixtures from vinyl chloride plastics (ASTM D 3421).

Annexure (4)

List of Additional Chemical Lab. Facilities

1) Reaction kettle.
2) Moisture balance.
3) Softening point apparatus.
4) Flow meter.
5) Digital temperature indicator
6) Humidity indicator/recorder.
7) Sieve analyser (as per ASTM D 1921)
8) Freezing point depression apparatus.
9) Boiling point elevation apparatus
10) Hygrometers
11) Combustion boats
12) Special burners (as per ASTM D 568 and D 635)
13) Microscope Magnification 200 and more
14) Additonal glass wires and chemicals

Annexure (5)

List of Spares and Accessories

Name of Equipment	Spares/accessories
1) Plasticorder PLE330 (Brabender OHG W. Germany)	- Special mixer type MB 30H - Extruder Type 25D (Screws forP.E., PVC & other common thermoplastics). - Capillary viscometer die assembly (with connected dies, pressure transduces etc. for measurement) - Round die assembly (with inter-changable nozzles) - Water bath for cooling the ext-rudate. - Pellatizer
2) Xeno test 250 (Heraues, W. Germany)	- Xenon lamp - 2nos (Type NXe 2700 Xenon burner)
3) Gas Permeability (Daventest Ltd. U.K.)	- Manometer assembly- 2 nos

Annexure (6)

List of Additional Test Equipment

Equipment	Suggested Supplier
1) Apparent density apparatus (as per ASTM D 1895)	Davenport/ U.K. Custom Scientific Inst.,USA Testing Machines Inc.,USA
2) Colour comparative/Colour meter (evaluation of colour fading in plastics) (ISO 4892/ISO872)	Gardner Inst., USA
3) Oxygen Index Flamability Tester (ASTM D 2863)	Testing Machines Inc.,USA MKM & Co. / USA Stanton Red Craft/England
4) Drop tester (ASTM D 2463)	Custom Scientific Inst.,USA
5) **Taber** Abrasion tester for plastics	**Taber** & Co./USA Testing Machine Inc.,USA
6) Arasion tester for elastomers	ZWICK & Co., FRG Beckmann/Switzerland
7) Dielectric break down tester (50 KVA))	
8) Dielectric tester AC loss characteritics and dielectric constant).)	Engelmann & Buckham Ltd., U.K.
9) High speed mixer	Henschel Werke A.G./FRG
10) Banbury Mixer	Farrel Corporation/USA
11) Granulator	" "
Chemical Analyis Instruments	
12) Thin layer chromotograph)	Fisher Scientific Co., Switzerland.
13) Gas chromotograph)	Perkin Elmer, U.K. Dupont and Co./U.K.
14) HPLC/GPLC	Water Associates, U.K. Dupont and Co., U.K. Beckmenn, Switzerland
15) IR spectra photometer (double beam, frquency 1200cm^{-1} to 400cm^{-1}	Perkin Elmer, U.K. Schim**adzu** , Japan

cont.../

Equipment	Suggested Supplier
16) UV spectra photometers	Dupont & Co./U.K.
	Jeol, Japan
17) Thermal analysis apparatus	Dupont, U.K.
	Perkin Elmer, U.K.
	Stanton Red Craft, U.K.
	Heraues GMBH, FRG

Additional Training Centres and Labs.

1) I.C.I. Plastics Division, Welwyn Garden City, Hertfordshire, England

2) Chemistry and Polymer Technology Department, Polytechnic of South Banic London.

3) I P C L, Baroda, India.

4) TNO/Delft- Holland

5) Shell Reserach Laboratory, Amsterdam, Holland.

6) ATO Chemie, Paris, France

List of Books and Periodicals

Annexure (8)

1) A Concise Guide to Plastics. Simonds, R., and Church
Reinhold - New York

2) The Encyclopedia of Basic Materials for Plastics. Simonds, R.
Reinhold - New York

3) The Role of Additives in Plastics, Mascia, L., Edward Arnold
London

4) The Identification of Plastics and Rubbers, K.J. Saunders.,
Chapman & Hall Ltd. - London

5) Impact Tests and Service Performance of Thermoplastics
Vincent, P.I., Plastics and Rubber Institute London

6) Mechanics of Plastics, Turner.S., Newnes Butterworth, U.K.

7) Mechanical Properties of Solid Polymer, Ward, L.M.,
Wiley interscience, New York

8) Extrusion and Compounding - Published by ICI Plastics Division
Walwyn Garden City, Herts, England

9) Plastics Design Data Book - Glenvil

10) RAPRA Abstracts - RAPRA, U.K.

11) Introduction to the Chemical Analysis of Plastics
A.Krause and A.Lange

12) Principles of Polymer Systems, Rodriguz Mc Graw Hill, N.Y.

Annexure (9)

TESTING AND EVALUATION OF PLASTICS FILMS AND LAMINATES

K. RAMAMURTHY

Introduction

Plastic films are used for packaging, construction and industrial applications. Each end use or application requires a film with a particular set of properties to perform the functions of package fabrication, product protection, containment, and appearance or display.

Film properties may be broadly classified as physical, mechanical, chemical, optical and thermal, with other subjective values such as machinability and printability.

The mechanical and thermal properties of plastic films are important factors in the fabrication of packages. Relatively low elongation and high slip are required for bag making.

Films with higher modulus (greater stiffness) and medium slip are used on overwrap machines. The stiffness is required for film feeding, and the medium slip level is necessary to ensure a tight wrap that doesn't wrinkle or distort.

Thermoforming is required for skin and blister packaging, so heat stable sheets that have good hot strength and forming characteristics are required. Skin packaging materials should have high impact strength and puncture resistance. Blister packs are usually rigid and materials with a high tensile modulus are required. Good optical properties are required for both applications.

The package must provide different protective properties for different product types. Baked goods require a low moisture vapour transmission rate (MVTR) and resistance to greases and oils. A low MVTR is required for all types of candy packaging, and grease and oil resistance are also needed for chocolates. Bags for hard candy need good impact strength and resistance to puncturing. Cheese, other dairy products, and processed meats need low MVTR, low oxygen permeability, and good resistance to grease and oils. Fresh meat and fresh produce on the other hand require films that are permeable to gases. Frozen foods and boil-in-bag items need packages with good low temperature impact strength and moisture protection. The boil-in-bag also requires heat resistance to withstand the effects of boiling water during food preparation. Toys, hardware, housewares, and paper goods in general require high clarity, high impact strength films. Many of these items are skin or blister packaged and displayed on racks, so that excellent clarity is essential. Shrink packaging is also used for toys, hardware, paper goods and records. Tobacco needs moisture protection for freshness, but the film should have moderate transmission properties. One of the requirements of packaging films for tobacco and candy is high speed machinability.

For various industrial applications, high strength, temperature resistance, chemical resistance, or electrical properties are required. Examples are films used for electrical insulation, dielectrics in capacitors, liners for tanks and drums, diaphragms for chemical pumps and valves, and gasketing materials.

The factors that influences the properties of a plastic film are;

the chemical composition of the base polymers
the compounding ingradients
the method of manufacture of the film
the thickness and
the post treatments, coatings and laminations

The basic film properties come from the chemical structure of the resin. Some of the commonly used resins for the film applications are;

LDPE	HDPE
PP	EVA
PVC	PVDC
PVA	PS
PA	POLYESTER
PC	CELLOPHENE

Their typical characteristics and applications are given in Table - I.

The addition of plasticizers usually increases elongation, flexibility, and permeability but lowers the maximum temperature. Similarly many other additives have varying influence on many other properties.

Cast films usually have excellent optical properties, little heat distortion and good gauge and flatness.

Extruded films have greater mechanical strength than cast film

Oritented film have significantly greater mechanical strength and slightly reduced permeability rates, but will shrink at elevated temperatures.

Post treatments and coatings are used to improve ink adhesion, slip, barrier properties, heat sealibility and sealing.

LAMINATES take advantage of the properties of two or more materials to improve the over all properties of the structure.

Though laminates are invariably more expensive than the some of their component parts, they are generally preferred for particular jobs to achieve a balance of properties at a lower cost than is possible in any other way.

The major techniques employed in the fabrication of laminates are;

Extrusion coating	Extrusion lamination
Adhesive lamination	Heat lamination
Wax lamination	Co-extrusion
Hot melt coating	

The characteristics of the base material and the properties and uses of the commonly used laminates are given in Tables II and III.

<u>Testing methods</u>

In order to carry out this matching of properties against requirements, it is necessary to know that the various properties actually mean in practice and to have some method of quantifying them. The testing of film properties is also necessary for other reasons. Research laboratories must have some method of testing film properties in order to evaluate new products. The more efficient such an evaluation can be made, the more liklihood there is that the guesswork can be taken out of the decision as to whether the product is worth commercialising and, if so, for which market it is particularly suitable. Another objective of testing is to aid in process development. Test results can help in evaluating the results of changes in raw materials or processing variables, and can enable realistic manufacturing specifications to be set up.

Some basic aspects regarding testing namely variability of test results conditioning, isotropy of test specimens and caliberation of test machines are to be taken into consideration.

Further the properties tested should be capable of intrepretation with relevance to actual practical conditions. Otherwise no useful purpose is served. There is a very wide range of criteria to be applied when considering the selection of a film for a particular purpose. Broadly the tests to be considered fall into four main classifications;

<u>PROPERTIES CONCERNED WITH THE STRENGTH OF THE FILMS</u>

- Tensile strength
- Burst strength
- Impact strength
- Stiffness
- Tear strength
- Flex resistance

<u>PROPERTIES CONCERNED WITH TRANSMISSION</u>

- Gas permeability
- Odour permeability
- Water vapour permeability
- Light transmission -
- See through clarity
- Haze
- Gloss

<u>PROPERTIES CONCERNED WITH SURFACE</u>

- Friction
- Blocking
- Heat sealability
- Mar Resistance
- Electrostatic charge
- Printability &
- Print adhesion

OTHER PROPERTIES

- Density
- Flatness
- Dimensional stability
- Melt flow index
- Light resistance
- Solvent resistance
- Electrical properties
- Thickness
- Water absorption
- Orientation & shrinkage
- Flammability
- Chemical resistance
- Toxicity

Strength Properties

Since a large number of film is used for general packing the strength properties described here are important. They are also of use in assessing film quality.

Tensile Strength (Fig. 1&2)

Although tensile strength is a property which is useful for differentiating between different types of film, test results are not usually reliable for estimating the performance of a given film in practice. Moreover an estimate of the resistance of the film to rupture while under tensile strain can be obtained more quickly by a bursting strength test. However, when films are anisotropic the magnitude of the difference in strength along different directions can be ascertained only by meansuring the (tensile)in each direction. The differences in tensile properties often have to be taken into account during conversion of the film into bags on other packages. The preparation of the test strips is very important and should be done with no mixes or other imperfection in the edges. The tensile strength of film may be measured by stretching a conventional dump-bell specimen or a parallel sides strip in standard test equipment as, fore ample in ASTM method.

Strength at yield is a useful property and should be measured as well as strength at break. Elongation is useful as a measure of the films ability to stretch. Modulus is a measure of the force required to deform the film by a given amount and so it is also a measure of the intrinic stiffness of the film.

The importance of the various tensile properties depends on the specific end-use requirements but some general observations can be made. The tensile strength, for instance, must be great enough so that the film will not break when subjected to the sort of load likely to be encountered in practice. In many cases the yield strength may be more important than the ultimate tensile strength. This is because once the yield point has been reached, a large increase in elongation may result from a small increase in stress. In packaging uses, this can result in a tight wrap becoming loose. The yield strength is also important in handling on printing and laminating equipment. Up to the yield point, any elongation is reversible and the film will revert to its original strength when the stress is removed. After the yield point, some of the elongation is non-elastic and there is always a residual elongation. A sudden anatch which leads to stresses greater than the yeild strength will permanently stretch the film and lead to registration problems.

Films having a high elongation are sometimes used in order to relieve any stresses caused by an applied load and so reduce the risk of rupture. Under similar circumstances, films with low elongations would need to have fairly high tensile strength to withstand any applied loading.

A great deal of information about the film can be obtained from the shape of its stress/strain curve. In addition, to the numerical values for tensile strength, young's modulus, elongation, etc., it is possible to obtain some idea of the toughness of the material by measuring the area under the curve. This area is a measure of the energy needed to break the test specimen and hence is directly related to toughness.

<u>Burst Strength</u> (Fig 3)

The burst strength of a film is the resistance it offers to a steady pressure applied at right angles to its surface under certain defined conditions. The burst strength is taken to be the pressure at the moment of failure of the film and is essentially a measure of the capacity of the film to absorb energy. Brittle films, which can absorb only a small amount of energy before breaking, have low burst strengths.

A part of the film is clamped between two plane annular clamps over a flexible rubber diaphragm which is clamped between the lower clamp and the rest of the apparatus. The rubber diaphragm, is forced against the film under test by hydraulic pressure, using a liquid. The pressure in the fluid is increased until the specimen ruptures, the flexibility of the diaphragm being such that any distortion of the specimen is followed. Pressure is applied by a motor driving a piston into the liquid and the pressure at which the film rupture is read on a gauge attached to the apparatus.

The method is simple in principle and needs little comment. However, it should be remembered that films are usually anisotropic and stress system in the film as it approaches rupture is complicated. Films which have a high extensibility may stretch too far to allow this method to work and in that case the bursting strength may be measured using air under pressure instead of a liquid.

- <u>Impact Strength</u> (Fig 4)

Impact strength of a film is a measure of its ability to withstand shock loading. The property is a measure of the ability of a material to absorb energy in a very short period of time and usually is regarded as that measured property most closely related to the some what vague quality called toughness. Impact resistance is also related to brittleness. Brittleness denotes the lack of ductility, poor flexing properties, or more generally, a lack of toughness. It is highly dependent on the rate at which the stress is applied.

A circular section of film is clamped horizontally at its periphery and a dart is dropped from a specified constant height on to the centre of the film sample. The dart consists of a shaft carrying a hemispherical striking head and the shaft is capable of carrying various weights so that a convenient range of striking energies can be obtained. Two techniques are normally employed. In both a few specimens are used in a trial run to obtain an indication of the impact energy at which about 50% failure will occur. The first specimen is tested at an arbitrary level of dart weight (with a given height of fall) and subsequent specimens are tested at half or double this dart weight until with a given weight some specimens fracture and some withstand the impact.

In the first (staircase) method upto 20 further specimens are then tested with each successive dart weight deviating from the proceeding one by a constant weight which is normally chosen to be about one tenth of the total weight found in the trial run. When a specimen fractures the next one is tested at a lower dart weight and when a specimen does not fracture the next one is tested at a higher dart weight. The impact strength is defined as the level of dart weight, for a given height of fall, at which 50% of the specimens will fail and is the mean weight of all the values used in the test run proper. This method gives a fairly reliable estimate of the average impact strength.

The second or probit method assesses impact strength by determining the percentage failures in a given number of specimens when tested with different dart weights.) With this test one determines that dart weight which will result in the fracture of 50% of the samples tested. The general procedure is as follows. A dart weight is selected which will fracture at least one of a group of ten specimens. The actual number of failures in ten trials is recorded. The dart weight is then changed by uniform increments and ten samples are tested at each of several dart weights with the number of failures at each weight being recorded. The data are plotted on probability graph paper, the dart weights on the linear scale and the percent failures on the probability scale. But reading the graph, the dart weight at which 50% of the specimen will fail the impact failure weight or impact resistance expressed in grams.

Another approach to the matter of impact testing is the use of a pendulum instead of the falling dart. The film is clamped vertically and struck by a pendulum which has swung from a known height. The residual energy of the pendulum after it has ruptured the film, is measured by a pointer on a calibrated scale of by an electric timer activated by a pair of photoelectric cells. The loss in energy is a measure of the impact strength of the film. Produce bags failing in service conditions usually as a result of repeated impact, the fracture eccuring in a region of film already strained beyond the yield point by a previous accident. This is generally measured as impact fatique strength rather than fracture initiation strength. The film's impact fatigue strength is defined as the medium of the number of blows required until fracture accurs at a given load and angle (or height of fall) For a complete assessment of the film's performance both the fracture initiation energy and impact fatigue strength should be measured.

In the bag-drop test, a sealed bag made of the material to be tested and containing a specified weight of sand (or other suitable material) is dropped from test and falls onto a rigid surface. If rupture occurs, the bags is examined to see if the failure was in the seal or in the film. The results are only qualitative and difficult to analyse.

- Tear Strength (Fig 5 & 6)

Tear strength is an important property of packaging films and a knowledge of both resistance to tear initiation and tear propagation, may be necessary. In heavy duty sacks, for instance, possible rough handling may demand that tears do not run from small snags on punctures incurred during transit. On the other hand, applications relying on a tear tape to give easy access to the contents, require ease of tear propagation in one direction.

One of the most common tests for measuring tear strength is the Elemendorf Test -------- which, like so many other film tests, was originally developed for paper testing. The Elemendorf Test measures the energy required to propagate a tear through a specified length of film. The apparatus has two grips set side by side with only a small separation. One grip is stationary and is mounted on an upright on the instrument base. The second grip is moveable and is mounted on a pendulum or a heavy sector of a circle. This pendulum is mounted on an almost frictionless bearing and swings on a shaft fixed perpendicular to the upright pillar. The sample of film is clamped in the two grips and a slit of standard dimensions. is introduced centrally into the film using a razor blade. When the pendulum is released it swings down and tears the sample along a continuation of the slit. The energy required to complete this tear is measured on a scale attached to the pendulum by means of a pointer carried by the pendulum on its return swing. This indicates the residual energy in the pendulum and thus the amount of energy lost in tearing the film sample.

The strength can also be measured at slower rates of tear using a tensile testing machine. In one test the tear propagation is measured as the force necessary to keep the tear moving at a fixed speed. The stress-strain curves obtained are analysed in different ways depending upon their shape and a tear strength is defined.

Tear initiation can also be measured on a tensile testing machine using a film sample cut to the shape as in ASTM D 1938. The geometry of the test piece is such that a stress concentration is produced in the region of the right angle and the tear initiates at this point. The maximum stress during the tearing process is recorded as the tear initiation strengths.

When the sample is pulled between the grips of a tensile testing machine, a tear starts at the root of the 90° notch. For fairly flexible films both the load necessary to initiate the tear and to continue it can be recorded. For brittle films, however, only the maximum tear initiation force is measured.

In all the tear tests described, samples should be cut from both machine and transverse direction as the tear strength can vary widely according to the direction of tear.

<u>Stiffness</u>

Stiffness can be considered as the resistance of the film to distortion and in particular to bending. It is a compound property and depends on the thickness of the film as wide as the inherent stiffness of the material.

The stiffness of film is sometimes important. For example, it may be advantageous to use a stiff film in the operation of certain types of automatic bag making or wrapping machines while for other applications a soft flexible film is more suitable. A simple measurement of stiffiness is obtained from the modulus of elasticity in tension and is calculated from the slope of the stress-strain curve, usually at low elongations. However, there is a difficulty here in that the stress-strain curves of films are often not linear even near the origin and stiffness is conventionally defined by means of a secant modulus (stress/strain) which is calculated from the stress occurring at a specified strain.

There are more direct methods of measuring stiffness, one of which is by means of the Handle-O-Meter stiffness Tester. The test is a simple one and consists in measuring the force required to push a sample of film into a slot of a given width over which the film has been laid.

The results may be affected by slip agents in the film and by electrostatic attraction (increasing the frictional resistance between the film and the base plate). However, the behaviour of the film in practice, on packaging machines, is probably more closely related to results obtained when they are affected by factors such as slip and electrostatic attraction.

For thicker films, stiffness may be measured by treating a film strip as a beam. The test sample is placed on two supports, suitably spaced, and the resultant beam is loaded at the centre. The deflection produced for a given load is then measured. The test can be performed in other ways. Thus, the maximum load which the strip/beam is able to support can be measured or the load necessary to produce a specified deflection can be determined.

One of the simplest tests for measuring stiffness is the cantilever test where one end of the film strip is clamped in a horizontal plane and the amount by which the film droops under its own weight is measured.

Like most other properties already discussed, stiffness is usually different in the machine and transverse direction so that separate measurements must be made on strips cut in each of these directions. The main importance of stiffness in a packaging film is the influence it has on its performance on packaging machines, to the final package.

Thus in the packaging of woolen good a limp film is preferred so that the softness of the contents can be appreciated without opening the package.

Flex Resistance (Folding endurance)

The resistance to repeated flexure of creasing is important in use. Some films are highly resistant where as others will fail by pin holing or total fracture after bending only a few times. In essence the resistance to flexing is measured by repeatedly folding the film, backwards and forwards, at a given rate. The number of cycles to failure is recorded as the flex resistance. One method of measuring is known as the folding endurance test.

With some of the more tough and flexible polymer films, even a large number of flexings may not lead to fracture. In such cases it may be worth running the test on various thicknesses since a thicker film may show failure at a relatively low number of flexings. Another point is that even if failure does not occur, certain properties of the film may be seriously impaired. Permeability may be increased, for example, or tensile properties may be reduced. The optical properties may also be seriously affected. One other way of testing crease or flex resistance, therefore, is to subject the film to a given number of cycles in the test equipment and then compare the relevant properties with those of the uncreased film.

TRANSMISSION PROPERTIES

In essence there are two mechanisms by which a gas or vapour can pass from one side of a plastic film to another. If the film is porous then the gas or vapour can flow through the holes. This effect is not usually present except in the case of very thin films. When porosity is not present then gases and vapours can still pass through the film by a process of solution (or abscrption) and diffusion and this compound process is known as permeation.

Suffice it to say that where permanent gases are concerned, and under conditions, of constant temperature and a constant partial pressure differential, a steady state will be achieved after a certain time has elapsed. The quantity of gas, Q, passing through the film is directly proportional to the difference in gas pressure on either side of the film, and inversely proportional to the thickness of the film. In addition, it is directly proportional to the time during which the permeation has been occuring, and to the exposed area. Thus one may write:

$$Q \propto \frac{At(P_1 - P_2)}{x}$$

where Q - quantity of gas which passes through the film:

A - the surface area in contact with the gas;

t - time;

(P_1-P_2) - partial pressure differential;

x - thickness of plastic

This expression can also be put in the form of an equation, thus:

$$Q = \frac{P\,At(P_1-P_2)}{x}$$

where P is a constant for a specific combination of gas and plastic at a given temperature. The factor P is variously known as the permeability factor (or 'P - factor'), permeability cpefficient or permeability constant. It should be emphasised that the above equation applies only to steady state conditions.

The position with regard to vapours, including water vapour, is less clear. For one thing, the steady state condition is reached more slowly, while there may also be chemical interactions between the permeant and the plastics film.

The practical importance of permeability hardly needs emphasising. One of the prime functions of a packaging film, very often, is to act as a barrier to gases and vapours. Biscuits, for example, need to be kept dry, while conversely, cigarettees and tobacco need to be protected from moisture loss. The position with regard to the permanent gases is similar. Fresh produce needs to be able to lose carbon dioxide and pick up oxygen while fatty food may go rancid if oxygen is not kept out. Many foods are packed in a vacuum and a good barrier is essential if this condition is to be maintained. The measurement of permeability is, therefore, important and standard methods are available for both water vapour and the permanent gases.

Gas permeability (Fig 7)

The Gas Transmission Rate (GTR) is defined as the volume of gas that passes through a sample of unit area under unit pressure differential, the rate being determined after the slope of the transmitted volume-time curve has become constant. The temperature and specimen thickness must also be given as an integral part of the GTR.

The permeability Coefficient represents a more fundamental property and is independent of the geometry of the test sample since it has defined in terms of unit thickness. It is the product of the solubility of the gas in the film and the diffusion rate of the gas through the film. GTR's are usually expressed in cc (at °C and 76 cm Hg) per sq.m 24 hr. atm.

The flow of gas through a film may be measured using three different methods. In the first, the increase in oxygen concentration in an isolated compartment on one side of the film under test is measured. The isolated compartment contains nitrogen at at pressure of 1 atm and the comprtment on the other side of the film contains oxygen at a pressure of 1 atm. Thus there is no overall pressure difference across the film but the oxygen partial pressure difference is equal to aprroximately 1 atm.

In the second method the permeability is measured by determining the increase in volume of an isolated compartment on one side of the film. The partial pressure difference of the gas under examination is equal to the total pressure difference, the low pressure side being at atmospheric pressure and the other at a pressure of 2 atm.

In the third method the increase in pressure in an isolated compartment on one side of the film is measured. The partial pressure difference is equal to the total pressure difference, the low pressure side being at a pressure of about 2 mmHg and the high pressure side at a pressure of about 1 atm.

The method adopted by ASTM D 1434 for measuring gas transmission rate is essentially at pressure increase method. Measurement of gas permeability is carried out under controlled conditions of pressure, as well as of temperature and relative humidity. In essence the usual tests consist in making the film a partion between a test cell and an evacuated manometer. The pressure across the film is usually one atmosphere. As the gas passes through the film sample the mercury in the capillary leg of the manometer is depressed. After a constant transmission rate is achieved, a plot of mercury height against time gives a straight line. The slope of this line can be used to calculate the gas transmission. Gas permeability measurements are described in ASTM D 1434.

Wate· Vapour Permeability

Films used for packing foodstuffs usually have a low water vapour permeability. The permeability is measured by method in which the test film is fastened over the mouth of a cup containing either a desiccant or water. This sealed cup is then placed in a controlled atmosphere of specified temperature and humidity. From the weight gain or loss of this unit a rateof water vapour transmission through the film can be calculated. The water vapour transmission rate, WVTR or MVTR, is the flow rateof water vapour through a unit area of film after the steady state has been reached. It is often expressed in units of gm/24 hr sq.m.

The water vapour permeability may also be measured by enclosing the desicent in a sachet made from the film itself instead of using a dish. The water vapour permeability of films falls as the temperature is lowered. With polythene film the transmission rate varies exponentially with the reciprocal of the absolute temperature and a plot of log permeability against reciprocal of absolute temperature is a straight line of negative slope. This is commercially important since a film which may have too high a water vapour permeability at room temperature may be suitable for storing frozen food at low temperatures.

- Odour Permeability

There are no standard tests for the measurement of odour permeability although it is an important characteristic in many cases. One method which can be used to compare the efficiency of several films as odour barriers is to make up pouches with each film. The pouches can be filled with some odiferous material and then placed in separate clean glass bottles, sealed by crimping with aluminium foil. The minimum time for an odour to be apparent in the bottle can be measured and will give a rough ranking list of the test films. This ranking list may vary somewhat according to the type of odiferous material used so that the substance to be packed should be used as the test material if possible.

- Light Transmission

Light transmission is measured by means of a photoelectric cell. The intensity of a light source is measured by the cell, both with and without the interposition of the film sample. The light transmission is the ratio of the light intensity measured with the film to that obtained without it, and is expressed as a percentage. The figure for light transmission takes no account of the quality of the light transmitted by the film and it is possible that a blurred image might be obtained even when looking through a film with a high light transmission value. Such a film might be suitable for a light overwrap but would be undesirable when the film is acting essentially as a window.

Other important optical properties of films are haze, gloss and clarity. Haze is caused by random scatter of incident light upon the film and is detrimental to appearance in most packaging applications. Gloss is caused by sharp specular reflections and is an advantage in some applications because of its value in attracting attention. However, for other applications in, for example, the packaging of knitwear, it is important for the film to lack gloss. Clarity is a property of a film which determines the resolution of detail on an object when viewed through the film. The need for high film clarity depends on the application. When objects are in close proximity to film it is not so essential to have high clarity as when they are further from the film.

See-Through Clarity or Transparency (Fig 8)

This referes to the capability of seeing objects through a film without loss of detail caused by blurring or distortion. It has been found that narrow angle scatter correlates with see-through clarity. Hence the test measures the light transmitted by a film within a cone of semi-angle of three minutes about the normal to the specimen. The ratio of the intensity of this light to the intensity of the incident beam is a measure of see-through clarity

In actual practice the visual test can be of observing the maximum distance behind a film at which standard size letters can be distinguished when viewed through the film being tested.

Haze (Fig 9)

Haze is the property often referred to as cloudniness. This is of more importance than see-through clarity in the case of packaging films since the film is closer to the contents of the pack. Haze is defined as the percentage of light which in passing through a specimen, deviates by more than 2.5° on average from an incident parallel beam. This is measured using a haze meter
A beam of light is passed through the film sample and on to the highly reflecting internal surface of an integrating sphere in such a manner that all transmitted light is collected into a photo electric cell referred to as T_1, in the figure. Next the sphere is moved through a small angle so that the path of the light beam now falls on an extension of the sphere comprising a matt black surface that absorbs all the light transmitted straight forward along the path of the beam. Any light that is appreciably scattered in a forward direction is still gathered by the highly reflective internal surface of the sphere and into the photo cell; referred to as T_2 in the figure. The ratio of the second reading of the photo cell to the first is a measure of haze. i.e.

$$\% \text{ haze} = \frac{T_2}{T_1} \times 100$$

- Gloss

Gloss referes to the shining appearance of a plastic film and is defined in terms of the ability of a surface to reflect light regularly. Specular surface gloss of the film is measured as the portion of light reflected from the film at an angle of 45°. This is compared with a perfect mirror which is given a value of 1000 for the purpose of comparison and is expressed as a percentage. The maximum value of gloss for low density polyethylene is about 9.9%.

Surface Properties

Important properties which depends on the nature of film surfaces comprise of the following:

Friction

The coefficient of friction is a measurement of the ease with which the surface of one material will slide over another. Thus films which are slippery and move easily over various surfaces have a low coefficient of friction.

One of the simplest methods of measuring the coefficient of friction is by means of an inclined plane. The surface of the plane is covered by a sample of film,as is the weight on the plane. The angle of the plane is slowly increased until the weight just starts to move when the various forces can be taken to be in equilibrium. The angle at this point is known as the angle of repose. The coefficient of friction measured in this way is known as the static coefficient of friction. If the plane is set at an angle such that the weight moves easily, and the slope is then reduced until the weight just comes to rest, then the value measured is known as the dynamic coefficient of friction. This is usually lower than the static coefficient although the two can also be equal. The value of the coefficient of dynamic friction is affected by the speed of movement of one surface over the other and the coefficient of friction may also be affected by humidity, temperature and the presence of static electricity.

A more satisfactory method of measuring coefficient of friction is by the procedure of ASTM 1894 -75.

Two methods are given in ASTM standard for the measurement of coefficients of friction of plastic films. Procedure,A, designated the " Stationary sled, Moving plane procedure ", and procedure B, the " Moving sled Stationary Plane procedure " In both methods, one covers the surface of the plane with the film to be tested and also wraps the sled (a metal block covered with sponge rubber) with the same film. The sled is placed on the plane and, in Procedure A, the sled is attached to a spring which measures the frictional force when the plane is moved at a constant by taking the scale reading after sliding is initiated. The recommended space and block weight should be used, since the coefficient depends on these quantities. In procedure B the plane remains stationary and the sled is pulled at a uniform speed for the kinetic coefficient of friction.

The frictional properties of a film are important, both during its passage through printing or warpping machines and after being made up into a bag, sack of overwrap. During the passage of a film, through packaging equipment of all sorts, it is subjected to a variety of forces including some which press the film tightly against flat metal surfaces. If the slip characteristics are low the passage of the film through the equipment can be arrested completely. The consequent strain in the film (particularly in a thin film) can lead to elongation or other distortion of the film which will affect register in the printing or bag making stages. High slip is also generally required once the package has been overwrapped since the finished packs have to slide over various surfaces as they are rejected from the machine.

Frictional properties are also important in the manufacture of the film. Especially when being wound up. Good roll formations, for instance, is dependent on the correct level of friction. Too much slip may cause telescoping of the roll during handling or transit whereas too little can cause buckling on the roll. There are of course, occasions when a low slip value is a definite requirement. Heavy duty sacks, for instance are often required to be stacked to heights of several metres and any tendency towards slip can be a possible danger.

· Blocking (Fig 10)

A property somewhat akin to friction is blocking, which is the tendency of two adjacement layers of film to stick together, particularly when left under pressure for some time, as when films are stacked in cut sheets. It can also make bags made from lay flat film difficult to open. Blocking is particularly marked in the case of films with very smooth surfaces which can come into very close contact with consequent exclusion of air. Other factors which affect blocking are static charges, surface treatment (such as printing pre-treatment) and storage conditions. Anti-blocking additives are often added to the film to reduce the tendency to blocking. These act by diffusing to the surface and forming non-adherent layers. The degree of blocking is determined by the force required to separate the two layers of blocked film, when the force is applied perpendicularly to the surface of the film. The principle of testing this property according to ASTM standard is shown in Fig .

The metal frame is clamped in the movable jaw of a constant rate of grip separation tensile tester. The specimen (two blocked layers) to be tested is clamped in the fixed jaw as shown. The test consists of moving the lower jaw downward at a rate of five inch per minute. As the jaw moves it draws the frame and rod downward. The motion of the rod causes the layers of film to separate, and the force required to perform the separation is recorded on a chart. This process continues until the layers are completely separated. The blocking force is taken as the average force measured during the test.

Heat Sealability

The heat sealability of a packaging film is one of the most important properties when considering its use on wrapping or bag making equipment and, of course, the integrity of the seal is also of tremendous importance to the ultimate package. The heat sealability of a film has to be considered in relation to many other factors, including the available pressure, the dwell time, temperature and the rate of heat transfer of the sealing bars.

Two tests are in common use, the dynamic and the static. In both tests a 25 mm strip is cut through the heat seal. The dynamic test uses a sensitive tensile testing machine and the two free ends of the film strip are placed in the machine clamps. The force necessary to peel apart the two pieces of film is then measured. In the static test the strips are hung from a frame with one free end clamped and the other attached to a weight. The seals are examined at intervals for signs of failure. When recording the results of this test, the weight and the length of time the load was in operation are both noted.

Both of the above tests can, of course, be used for investigating the effect of changes in dwell time, temperature and pressure on heat sealing equipment if standard film samples are used.

Mar Resistance

Following ASTM standard D 1044 - 76 the surface of a specimen is subjected to an abrasive action and then the light scattering properties of the abraded area are determined and compared to those of the original unmarred sample.

In ASTM standard D 673 - 76 the film surface is abraded by dropping abrasive particles onto the film from a fixed height. The gloss of the marred area is measured and compared to the unabraded film to determine the mar resistance.

A third ASTM standard D 1242 - 75 describes a procedure wherein the surface is abraded in a standard way and the volume of material lost by the specimen due to this abrasive action is determined. The loss in volume is taken as a measure of the abrasion resistance.

Electrostatic Charge (Fig 11)

Some simple qualitative methods for measuring the static accumulation on plastic materials have been described in the literature. In one common test the sample to be tested is lowered over a pile of cigarette ashes. The distance between specimen and ashes at which ashes are attracted to the specimen is taken as a measure of the charge on the plastic. In a second test the film is supported vertically and carbon black dust is blown on to it. The dusted film is tapped to remove excess dust and it is then visually examined. If any charges are present, they show up as areas which retain dust.

Surface resistivity is also used as a measure of antistatic properties but the tests are difficult to make and to relate to acceptable antistatic performance. For all practical purposes the cigarette ash test is sufficient to distinguish between antistatic grades and non antistatic grades.

Printability and Print Adhesion

It is important to try to assess the ease which any type of film may be printed (printability) and also the degree of permanence of the print (print adhesion). These properties are, of course, related but it is useful to designate two properties, the printability being primrily a function of the film and its treatment and the print adhesion depending on both ink and film.

A method for measuring the printability or degree of treatment of film measures the force required to peel a strip of pressure sensitive tape from a section of film. The tape is applied to the film and the assembly is clamped together for a standard time under a standard pressure. Any suitable machine may be used to measure the " peeling force " although an autographic recording device is to be preferred.

PRINT ADHESION

The permanence of the printing on a film my be measured by subjecting the printed film to an abrasion test. This can be done in various ways and in one method, a sample of the printed film under rest is mounted on the glass plate and is rubbed forwards and backwards against the metal peg which is covered with a strip of standard fabric. The number of cycles required to produce visible damage to the print is recorded.

Other Properties: This include

Density

Density is a very important property of films because it is closely linked with the film's strength. The weight of a specimen of convenient size of film is too small to give an accurate result by the hydrostatic weighing method. The usual practice is to place specimens in a column containing a fluid, the density of which increases smoothly from the top to the bottom of the column, or to observe the behaviour of specimens placed in a series of solutions of gradually increasing density. In the former method the quilibrium position of the specimen, which is normally attained within a few hours of its insertion in the column, is used to read off its density from a calibration graph prepared by observing the positions of glass beads of known density over the length of the column.

In the second method the most dense liquid in which a specimen sinks and the least dense in which it floats are observed. The density of each of these liquids is then determined by conventional methods. The density of the film lies between the values of the two liquids. The accuracy of this determination increases as the densities of the liquids in the series are made closer together.

The density gradient column takes longer to prepare than the series of solutions but provides a more accurate method and, once assembled, should be satisfactory in use for about three months. An accuracy of about $\pm$ 0.0002 g/ml is fairly readily obtained.

Melt Flow Index (Fig 12)

The MFI is useful in grading films for different applications and controlling the quality of incoming raw materials. The MFI is an indirect measure of the molecular weight of the particular polymer and is important to the converter because of the differences in processability between polymers of the same chemical type but with different molecular weights. The liability to environmental stress cracking is dependent on molecular weight.

The melt flow index is a measure of the melt viscosity of the polymer which in turn is related to the molecular weight. It is measured using the apparatus which is basically an extrusion plastometer with a standard orifice. The weight, in grams, of the material extruded in 10 min under a constant dead weight and at a constant temperature is called the melt flow index. A low melt flow index corresponds to a high melt viscosity and since melt viscosity is directly related to the molecular weight of the polymer a low MFI corresponds to a high molecular and vice versa. A strict relationship obviously only applied to polymers of the same chemical constitution, but it also is restricted to polymers of the same density since density also affects melt viscosity. In the case of the polyethylenes and EVA the standard temperature is 190° C but for polypropylene the temperature 230°C in order to allow for its higher melting point.

The relationship between melt viscosity and MFI is a logarithmic one. Thus, for a MFI of 0.2 the melt viscosity of a low density polyethylene (density 0.92 g/cm^3) is 3000000 P, while for a MFI of 2, it would be 30 000 P. Similarly a MFI of 20 corresponds to a melt viscosity of 3000 P. Extrusion processes, such as film making, require high melt viscosities and so low MFI grades are used.

Flammability

Plastics films are no more hazardous than most other wrapping materials but it may still be important to assess the way in which a film will behave when exposed to a flame. Tests depend on the material to be examined but one typical method consists in igniting a strip of film bent to the shape of an inverted 'U'. The distance over which the strip burns is an assessment of its flammability The oxygen index is also used in order to grade the polymer film for various nonflammable applications.

Dimensional Stability

Dimensional stability is a desirable property in any film conversion process and particularly so in printing. Even small changes in film dimensions while passing through the printing process may lead to serious problems in print registration. In the finished package, too, dimensional stability is important. Dimensional stability is normally tested by cutting film strips in both the machine and transverse directions, and then subjecting them to varying conditions and noting the percentage change in dimensions. Where possible, the test conditions should be closely related to the conditions likely to be encountered in conversion or end-use.

An allied property, that of maximum shrinkage, is of interest in the case of heat shrinkage films. This can be determined by immersing marked film samples for 5 a in water (for temperature upto 100°C) or in silicone 550 oil (for temperatures above 100°C). The temperature of testing,is, of course related to the shrink tunnel temperature in actual use.

Chemical Resistance

The effect of chemicals on a packaging film is obviously an important factor when assessing its suitability for containing a particular product. It might also, under certain circumstances, be important from an environmental point of view.

The normal test for chemical resistance involves subjecting a film sample to the chemical under test, usually by total immersion under specified conditions. Any change in appearance is noted at intervals as is the change in a particular property such as tensile strength.

One important phenomenon associated mainly with the polyolefins (although not polypropylene) is environmental stress cracking. This is caused by the action of stress in combination with particular chemical environments such as certain polar organic compounds. The chemicals are normally without action on the plastic in the absence of stress but the combination of stress and chemical environment can cause cracking in a very short time. The use of high molecular weight grades has been found to reduce the effect to a great extent.

Light Resistance

Prolonged exposure to light may bring about many undesirable effects in certain films. In particular, light may catalyse certain other reactions such as oxidation. Brittleness, loss of clarity, colour changes and surface imperfections are some of the undesirable effects. If a film is intended for applications involving continued use in sunlight it should contain stabilisers such as ultra - violet absorbers.

Tests are usually carried out by exposing samples of the film to light of a specified wavelength, or combination of wavelengths, for a given time and noting the effect on various properties such as tensile strength of the various optical properties. The intended end-use is of importance when assessing the suitability of the film as the type of radiation may be very different. In addition to the effect of sunlight it is important in many applications to know the effect of shop or display cabinet lighting. The screening effect of glass is also important when packs are to be on display in shop windows. In the case of coloured films, exposure to daylight or artificial light may cause undesirable colour changes.

Other properties are also useful in assessing films, but however, only important test methods are disscussed here.

In conclusion, testing methods have been developed to measure the most pertinent film properties to almost any desired degree of precision. These measurements correlate sufficiently well, in many instances, with actual film performance, that little more is needed by way of analysis. In other instances, where the end use may inv-lve complex laminates or complicated applications, measures of single properties still do not correlate well with performance. In these cases the protective packaging material still has to be evaluated in the actual end use.

Table I:

FILM PROPERTIES AND CHARACTERISTICS	APPLICATIONS
LDPE	
HIGHLY TRANSPARENT, FLEXIBLE, STRETCHABLE, CREASE RESISTANT, WATER RESISTANT, WATER VAPOUR IMPERMEABLE, GAS PERMEABLE, LOW TEMPERATURE RESISTANCE, RESISTANT TO NEARLY ALL ORGANIC AND INORGANIC CHEMICALS, PHYSIOLOGICALLY HARMLESS	PACKAGING: LINERS, SACKS & BAGS PRODUCE PACKS, SHRINK OVER WRAPS, CONSUMER & INDUSTRIAL PRODUCT WRAPS FOR FRUITS, VEGETABLES, FOOD STUFFS, CLOTHING, LEATHER GOODS, TOYS METAL GOODS, CHEMICALS & SO ON CONSTRUCTION: DAMP PROOF MEMBRANES, CONCRETE LINING, PROTECTIVE COVERS, TEMPORARY STRUCTURES, WATER STORAGE AGRICULTURE: STORAGE, SILAGE AND STACK COVERS, CROP PROTECTION, GLASS HOUSE LINING
HDPE	
MILKY TRANSPARENT, RESISTANT TO LOW TEMPERATURE, STERILISABLE, WATER RESISTANT, VERY LOW WV PERMEABILITY, RESISTANT TO NEARLY ALL ORGANIC AND INORGANIC CHEMICALS OIL AND GREASE PROOF, PHYSIOLOGICALLY HARMLESS	PACKAGING: BOIL IN BAG FOOD PACKS, OVERWRAPPING, STRETCHED FILM RIBBONS, ELECTRICAL INSULATION
PP	
COLOURLESS TRANSPARENT, GLOSSY WITH HARD SURFACE, STRONG, STERILISABLE, HIGHLY RESISTANT TO TEMPERATURE CHANGES, WATER RESISTANT, EXTERNALLY WATER VAPOUR IMPERMEABLE, RESISTANT TO MANY CHEMICALS OIL AND GREASE PROOF, PHISIOLOGICALLY HARMLESS	PACKAGING: OVERWRAPPING, BAGS SHRINK WRAPPINGS, SLIT FILM FOR ROPES, WOVEN SACKS, ELECTRIC AND CABLE INSULATION
EVA	
LOW HEAT SEAL TEMPERATURE, HIGH IMPACT STRENGTH, GREATER ELASTICITY HIGHER PERMEABILITY TO GASES AND WATER VAPOUR AND LOW TEMPERATURE PROPERTIES ARE BETTER	STRETCH PACKING OF FROZEN POULTRY, LINING OF BAG IN BOX CONTAINERS

RIGID PVC

COLOURLESS TRANSPARENT, GOOD TEAR RESISTANCE, STABLE, WATER RESISTANT, AROMA RETAINING, HIGHLY GAS AND WATER VAPOUR IMPERMEABLE, NOT EASILY INFLAMMABLE, OIL AND GREASE PROOF, GOOD CHEMICAL RESISTANCE, NO ODOUR OR TASTE, PHYSIOLOGICALLY HARMLESS

PACKAGING: FORMED PACKS, CHOCOLATE BOX, TYPE TRAYS

INDUSTRIAL ADHESIVE TAPES, RECORDING TAPES, ELECTRICAL GASKETS

CONSUMER LAMPSHADES, STATIONERY, DISPLAY, MEDICAL DRESSINGS

PLASTICISED PVC

MORE SOFTER, LOW TEMPERATURE PROPERTIES, BETTER, GOOD GLOSS AND TRANSPARENCY, HAVE ODOUR AND LIABLE FOR SOLVENT ATTACK

PACKAGING: SACHETS, SHRINK WRAPPING LINER, CONSTRUCTION, PROTECTIVE COVERS, PROTECTIVE CLOTHING, WATER STORAGE, TRANSLUCENT CEILINGS

AGRICULTURE: SILAGE COVERS, GLASSHOUSE LINING, STERLISATION, FUMIGATION

INDUSTRIAL: MINING, AUTOMOBILE INFLATABLES, PROTECTIVE CLOTHING LINERS, HOSE, TAPES

CONSUMER: RAINWEAR, BABY PANTS, CURTAINS, TABLE COVERS, SELF ADHESIVE WALL COVERS

PVDC

GOOD BURST STRENGTH, LOW HEAT SEALABLE TEMPERATURE, HIGH RESISTANCE TO TEAR PROPAGATION, LOW WATER AND GAS PERMEABILITY

SHRINKABLE FILMS, STRETCH WRAPPINGS

PVA

COLOURLESS, TRANSPARENT, SOFT AND NEARLY AS ELASTIC AS RUBBER, TEMP. RESISTANT, WATER SENSITIVE, HIGHLY GAS IMPERMEABLE, PARTICULARLY RESISTANT TO SOLVENTS OILS AND FATS

SEPARATING LAYER IN THE PROCESSING OF GRP, EATER SOLUBLE PACKAGING FOR DETERGENTS, BATH ESSENCES, DISINFECTANTS, PESTICIDES ETC, WRAPPING FOR TREE AND PLANT ROOTS

P S

EXCELLENT CLARITY AND SPARKLE ORIENTED PS IS RIGID AND HAS A HIGH TENSILE STRENGTH, GOOD RESISTANCE TO LOW TEMP, OUTSTANDING ELECTRICAL PROPERTIES

PACKAGING: WINDOWS, BLISTER PACKS, OVER WRAPPING, SHRINK WRAPPING, FORMED PACKS, BREAKABLE PACKS

INDUSTRIAL: ELECTRICAL

PS EXPANDED

GOOD CUSHIONING AND THERMAL INSULATION PROPERTIES	PACKAGING: CUSHIONING OR INSULATING WRAPS

REGENERATED CELLULOSE

TRANSPARENT, HIGH TENSILE AND BURSTING, GOOD BARRIER TO OILS, GREASES AND ODOUR, FREE FROM STATIC ELECTRICITY	MOISTURE PROOF FILMS, PRESSURE sensitive TAPES, OVERWRAPS

CA

GLASS CLEAR, HIGH GLOSS, STRONG DIMENSIONALLY STABLE, GOOD ELECTRICAL INSULATORS, WATER REPELLENT, GOOD WATER VAPOUR PERMEABILITY, HIGHLY AROMA RETAINING, IMPERMEABLE TO OILS AND FATS, LOW INFLAMMABILITY WITHOUT ODOUR AND TASTE	PACKAGING: DECORATIVE PACKS, PRINTED LAMINATES, FORMED CONTAINERS INDUSTRIAL: PRINTING, PHOTOGRAPHIC FILM BASE CONSUMER: LAMP SHADES, STATIONERY DISPLAY

PA

LOW GAS PERMEABILITY, LOW ODOUR PERMEABILITY	PACKAGING: VACUUM PACKING, BOIL IN THE BAG, PACKING OF SURGICAL INSTRUMENTS, TAPES, CABLE INSULATION

POLYESTER

VERY TOUGH AND STRONG, GOOD TRANSPARENCY, HIGH TEARING RESISTANCE AND FOLD ENDURANCE, POOR BARRIER PROPERTIES, GOOD ELECTRICAL INSULATION PROPERTIES	PACKAGING: COOKED FOOD PACKS, BOIL IN THE BAGS, SHRINK PACKS, ENGINEERING PRODUCTS INDUSTRIAL: PRINTING AND DRAWING OFFICE, MAGNETIC TAPES, FILM BASE, TYPEWRITER RIBBON ELECTRICAL

PC

HIGH TEMPERATURE RESISTANT, HIGH IMPACT STRENGTH, BURST STRENGTH AND CLARITY, GOOD LOW TEMPERATURE PROPERTIES	PACKAGING: BOIL-IN-THE BAG PACKS, COATING WITH PE, SKIN PACKING

Table II

CHARACTERISTICS OF FLEXIBLE MATERIALS

MATERIAL	CHARACTERISTICS
POUCH PAPER	LOW COST, RIGIDITY, STRENGTH
GLASSINE PAPER	GREASE PROOFNESS, FLAVOUR PROTECTION
FOIL	MOISTURE AND GAS PROTECTION, GOOD APPEARANCE
CELLOPHANE	STIFFNESS, MACHINABILITY, TRANSPARENCY
POLYETHYLENE	LOW COST, HEAT SEALABILITY
POLYPROPYLENE	MOISTURE BARRIER, STIFFNESS
POLYVINYL CHLORIDE	CREASE RESISTANCE, HEAT SEALABILITY
SARAN	MOISTURE AND GAS PROTECTION
RUBBER HYDRO CHLORIDE	CREASE RESISTANCE, SEALABILITY
POLYESTER	STRENGTH, HIGH OR LOW TEMPERATURE
NYLON	FORMABILITY FOR DEEP DRAWS, TOUGHNESS

SOME COMMON USES FOR LAMINATIONS

ORIENTED PP/CELLO	SNACK FOODS
CELLO/CELLO	SNACK FOODS
POLYESTER/SARAN/PE	MEAT, CHEESE (THERMOFORMABLE)
NYLON/SARAN/PE	MEAT, CHEESE (THERMOFORMABLE)
ORIENTED PP/PE/CELLO/PE	CHEESE
CELLO/PE	CANDY
POLYESTER/PE	CORROSIVE CHEMICALS
FLUOROHALOCARBON/PE	MOISTURE SENSITIVE PRODUCTS
PP/CELLO	CANDY

Table III

PROPERTIES AND USES OF TYPICAL PLASTICS LAMINATIONS

LAMINATIONS	CHARACTERISTICS	USES
CELLOPHANE/WAX/ CELLOPHANE	EXCELLENT WVTR, SANDWICH PRINTING, GOOD MACHINABILITY	BAGS, POUCHES FOR HYGROSCOPIC ITEMS FROZEN FOODS
CELLOPHANE/ADHESIVE/ PLIO FILM	GREASE PROOF, TOUGHNESS EXCELLENT GAS BARRIER TRANSPARENT PACK	Nut PACKING WITH INERT GAS
CELLOPHANE/ PE COATED	TOUGH, HEAT SEALABLE EXCELLENT GAS BARRIER	SARAN COATED FOR VACUUM AND GAS PACKING
CELLO/PE COATED/ ADHESIVE/SARAN	EXCELLENT FLEXIBLE TRANSPARENT BARRIERS	PHARMACEUTICALS
POLYCARBONATE/ COATED PE	TOUGH TRANSPARENT PUNCTURE RESISTANT	SKIN PACKAGING FOR ROUGH USE
ACETATE/ADHESIVE/ FOIL/VINYL COATED	GOOD RIGIDITY, EXCELLENT GAS AND WV BARRIERS	PHARMACEUTICALS DEHYDRATED CO COFFEE
FOIL/ADHESIVE/PAPERS PE COATED	GOOD MOISTURE BARRIER HEAT SEALABLE	SOUP DRINK POUCHES, DRY MILK SOLIDS
PAPER/ADHESIVE/ ACETATE	GLOSSY, SCRATCH RESIS- TANT	RECORD COVERS PAPERS BACK BOOKS
CELLO/COATED PE/ FOIL COATED/ADHESIVE PE	EXCELLENT GAS, MOISTURE BARRIER, TRAPPED PRINTING	SINGLE USE POUCHES SOUP MIXES, JAM FREEZE DRIED FOODS
NYLON/PE COATED	TOUGH BOILABLE, GOOD BARRIER PROPERTIES	MEAT PACKING CHEESE, BOIL IN BAG POUCHES
POLYESTER/PE COATED	TOUGH, BOILABLE, GOOD BARRIER PROPERTIES HEATSEALABLE	COFFEE, VACUUM AND INERT GAS PACKAGING, UNIT PACKS OF SHAMPOO, FRUIT JUICES ETC. PACKS OF COOCKED MEAT AND FISH

LAMINATION	CHARACTERISTICS	USES
POLYESTERS/FOIL/ COATING OF PE, PP, PVC OR RUBBER HYDROCHLORIDE	STRONG, IMPERMEABLE AND PUNCTURE RESISTANT, CAN BE REVERSE PRINTED BEFORE LAMINATION	VACUUM PACKAGES FOR FREEZE DRIED FOODS FLEXIBLE PROCESSABLE CANS
ORIENTED PP/PE	GOOD CLARITY, GOOD MOISTURE VAPOUR BARRIER, HEAT SEALABLE	ECONOMIC ALTERNATIVE TO CELLO/PE SUITABLE FOR PACKING OF DRIED FOODS
POLYESTER/CAST PP	CAN BE USED AT TEMP. UPTO 130DEG. C, GOOD BARRIER PROPERTIES, HEAT SEALABLE	HEAT SEALABLE TRANSPARENT LIDS FOR THERMO CONTAINERS
PAPERS/FOIL/PE OR RUBBER HYDROCHLORIDE	IMPERVIOUS AND HEAT SEALABLE	SOAP, DRIED FOODS AND SHAMPOO SACHETS
POLYESTER/ PP OR CA/PAPER/ COATED PE OR RUBBER HYDROCHLORIDE	STRONG, GOOD BARRIER PROPERTIES, HEAT SEALABLE	LINERS FOR CARBONS SPIRALLY WOUND CONTAINERS
PAPER/PE COATED/ FOIL/VINYL EXTRUSION COATED	READILY HEAT SEALABLE GOOD BARRIER	INSTANT COFFEE POWDER

APPENDIX

STANDARDS FOR FILM TESTS

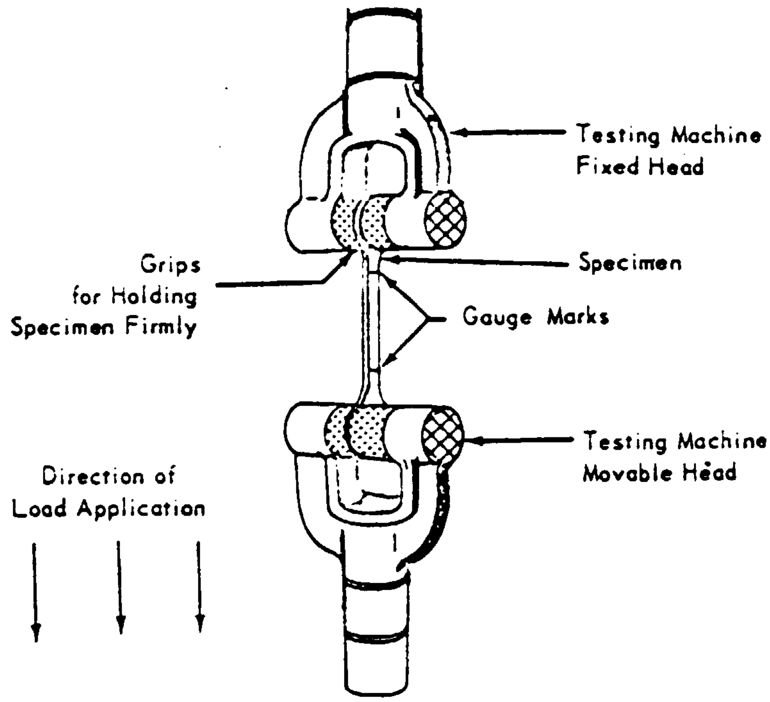
FILM PROPERTY		Test Standards ASTM	Others
1.	Tensile	D 882 - 76	ISO/R 1184 - 70
2.	Bursting Strength	D 774 - 67	-
3.	Dynamic Ball burst impact	D3420 - 75	-
4.	Impact strength	D1709 - 76	BS 2782 method 306 F
5.	Ball Impact resistance	D3099 - 72	
6.	Brittle Temp. by impact	D1790 - 76	
7.	Tear Strength	D1004 - 70, D1922 - 76, D2582 - 72, D1938 - 72	BS 2782 Method 308 B
8.	Stiffness	D 882 - 75	BS 2782 method 332 A
9.	Folding endurance	D2176 - 74	-
10.	Rigidity	D2923 -70	-
11.	Gas permeability	D1434 -75	BS Part V method 514A
12.	Water vapour permeability	E 96 - 72	ISO/R - 1195
13.	Clarity	D1746 - 70	-
14.	Haze	D1003 - 70	BS 2782 Part V method 515 A
15.	Friction	D1894 - 75	BS 2782 method 311 A
16.	Gloss	D 523 - 67, D2457 - 70	
17.	Blocking	D3354 - 74, D1893 - 72	-
18.	Adhesion ratio	D2141 - 74	
19.	Mar resistance	D 673 - 76, D1044 - 76, D1242 - 75	
20.	Density	D1505 - 75	ISO 60/77, B.S. 2782 Part V method 509 B
21.	Melt flow index	D1238 - 73	ISO/R - 1133 - 68
22.	Flammability	D 568 - 76, D1443 - 76, D2863 - 77	ISO/R 1326

23.	Chemical resistance	D 543 - 72	ISO/R - 175
24.	Water absorption	ASTM D - 570	ISO/R-62
25.	Solvent resistance	B1239 - 71	-
26.	Wettability	D 2578 - 72	—
27.	Thickness	E 252 - 67	BS 2782: 1970 Method 512 A
28.	Flatness	D 1604 - 75	
29.	Funge	◊ - G 21 (1975) ◊ D 1924	ISO/R 846-68
30.	Orientation and shrinkage	◊ D 1504 - 70 ◊ D 2838 - 75 ◊ D 1204 - 54	
31.	Electrical property		
	i) Volume resistivity	D 257 - 76	ISO - 1325 - 73
	ii) Surface resistivity	D 257 - 76	
	iii) Dielectric constant and Dissipation	ASTM - 150 - 74	
	iv) Arc resistance	D 495 - 73	
	v) Dielectric strength	D 149 - 75	

IS for Film and laminates

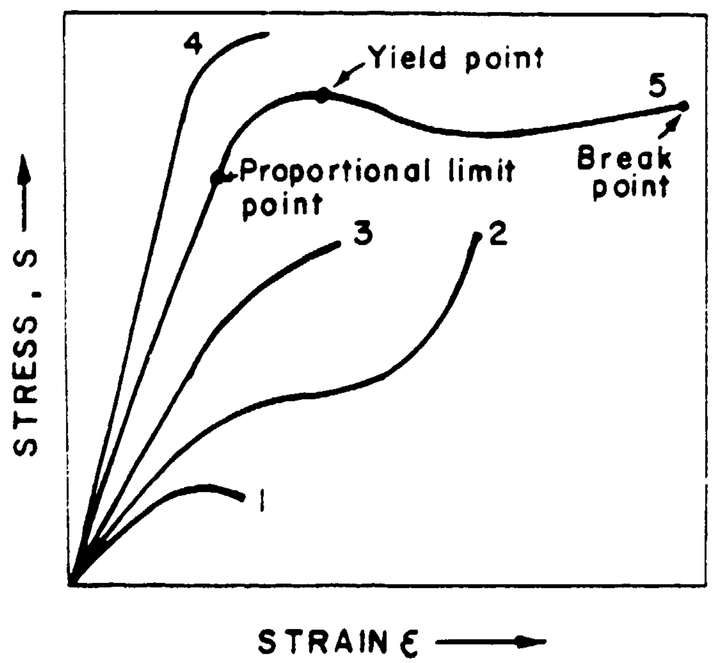
Method of test for thermosetting synthetic resin bonded laminated sheet	- IS 1998 - 1962
Paper base thermosetting synthetic resin bonded laminated sheet	- IS 2036 - 1974
Decorative thermosetting synthetic resin bonded laminated sheet	- IS 2046 - 1969
Unsupported flexible vinyl film and sheeting	- IS 2076 - 1962 (D)
Low density polyethylene film	- IS 2508 - 1977 'revised'
Cellulose film	- IS 5012 - 1968
Recommendation for use of polyethylene film for water proofing of roofs.	- IS 7290 - 1973

Fig 1



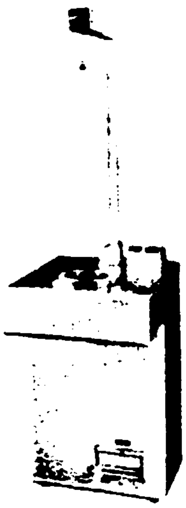
SCHEMATIC ILLUSTRATION OF THE TENSILE TEST FOR PLASTICS.

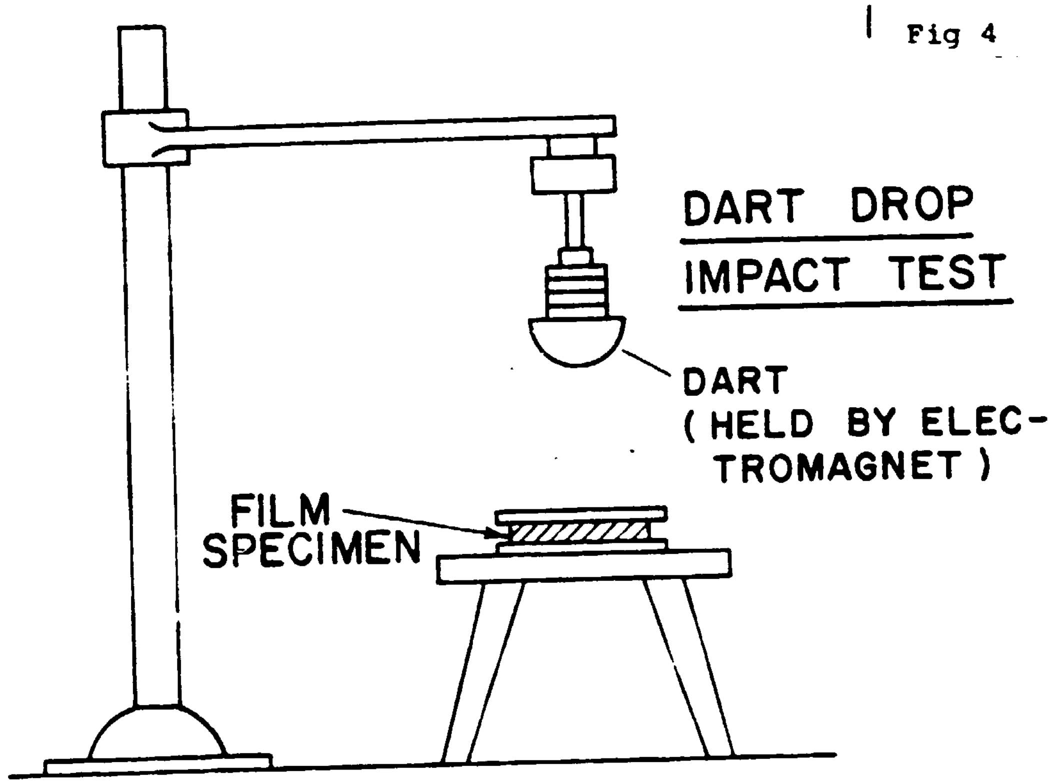
Fig 2



TYPES OF TENSILE STRESS-STRAIN DIAGRAMS FOR DIFFERENT POLYMERS. 1. SOFT WEAK, 2. SOFT TOUGH, 3. HARD BRITTLE, 4. HARD STRONG, 5. HARD TOUGH.

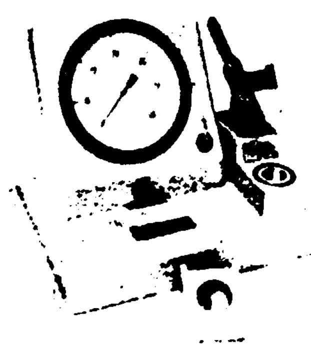
Fig 4





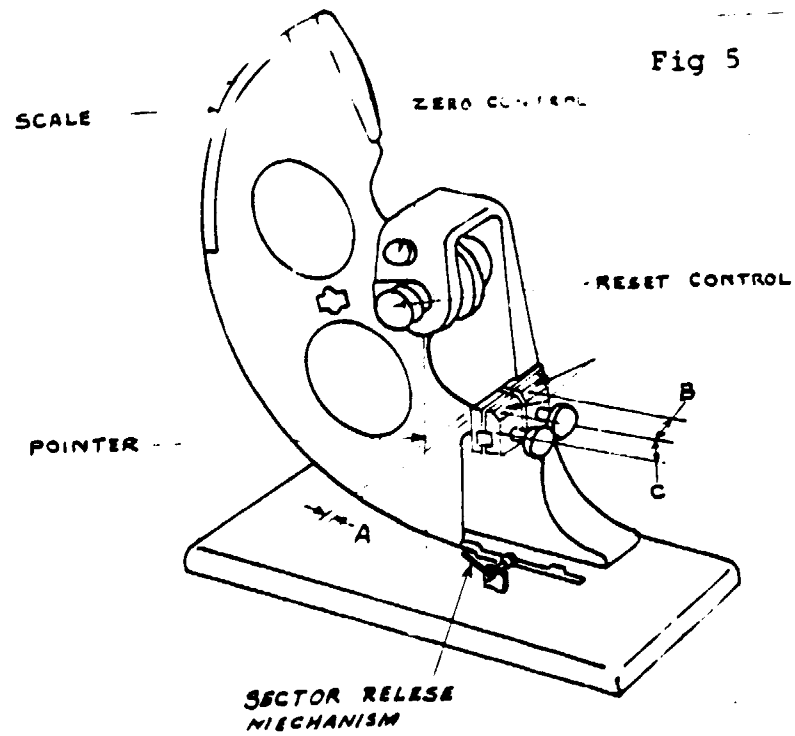
DART DROP IMPACT TEST

Fig 3



Burst strength apparatus

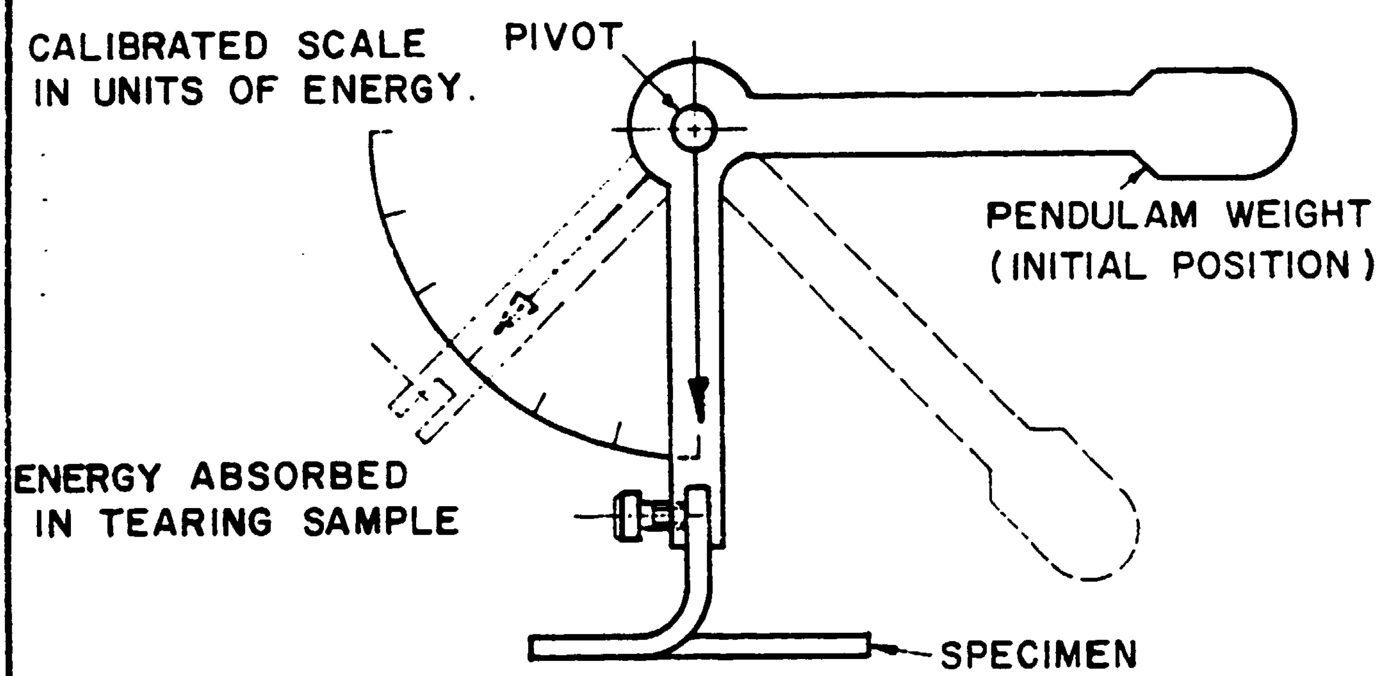
Fig 5



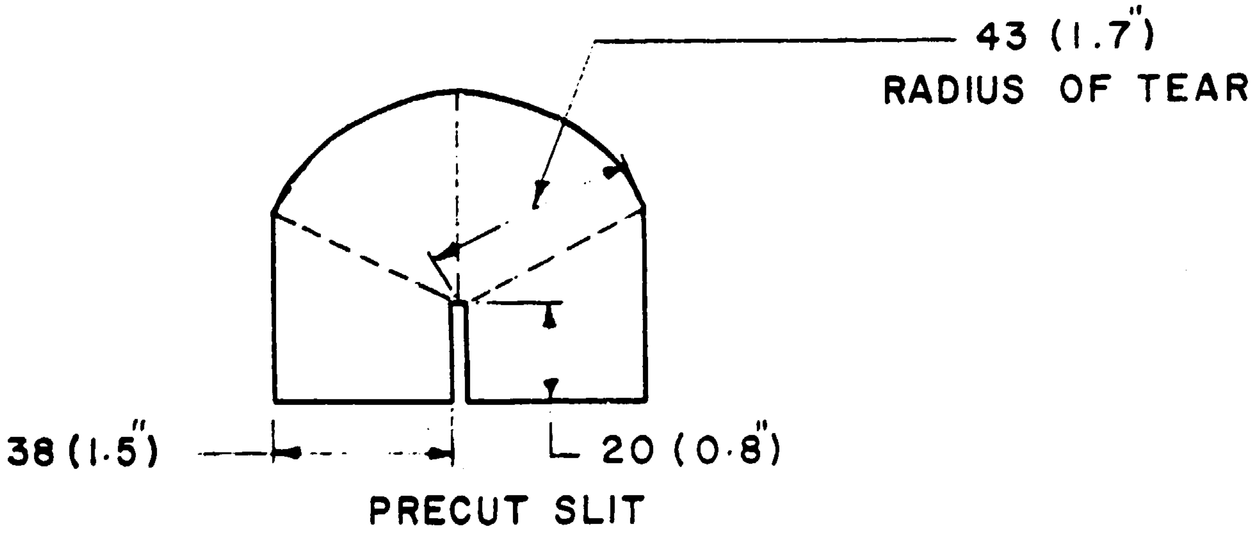
ELMENDORF TEAR TESTING MACHINE

TEST FOR TEAR RESISTANCE

Fig 6



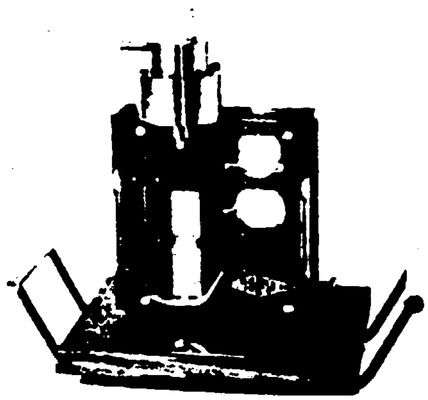
TEST APPARATUS



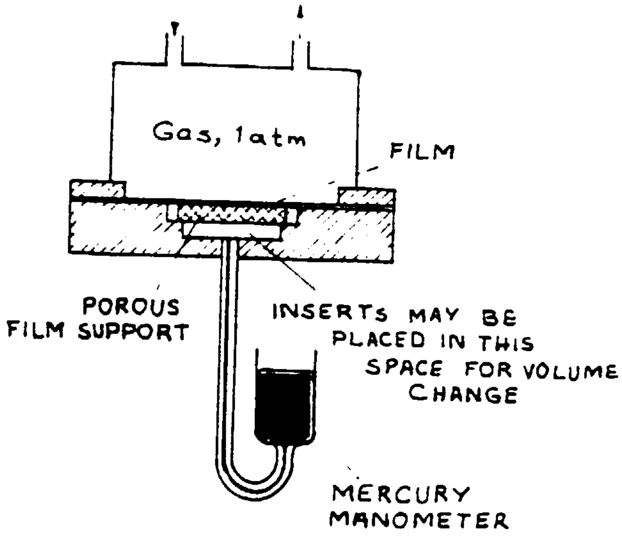
CONSTANT RADIUS TEST SPECIMEN FOR TEAR RESISTANCE TEST.

PRODUCT TESTING CENTRE		

Fig 7

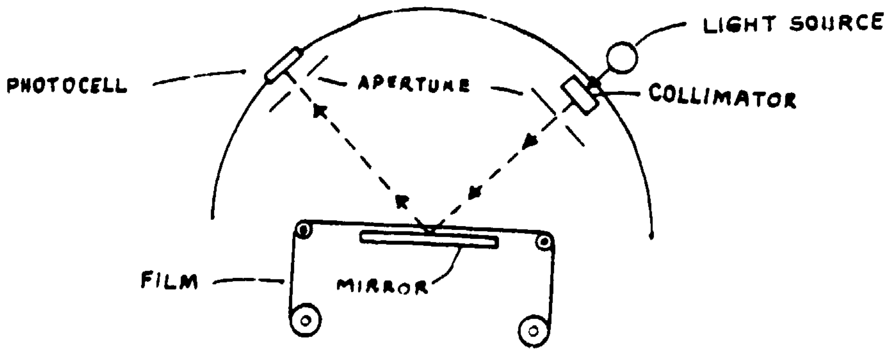


Permeability apparatus



SCHEMATIC GAS TRANSMISSION APPARATUS

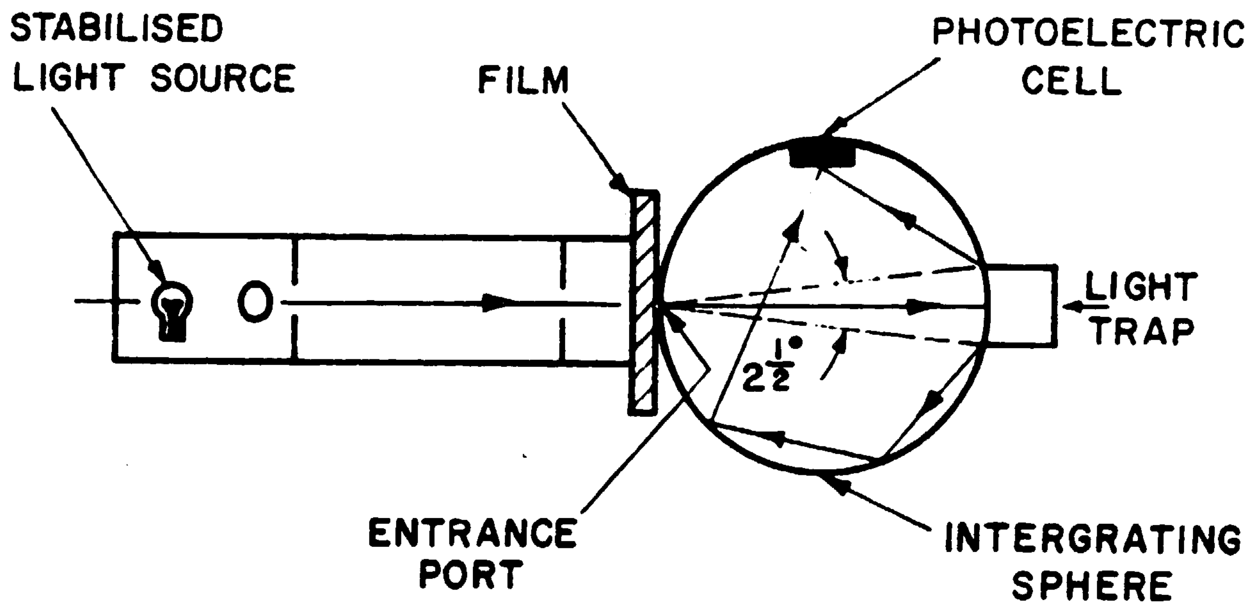
Fig 8



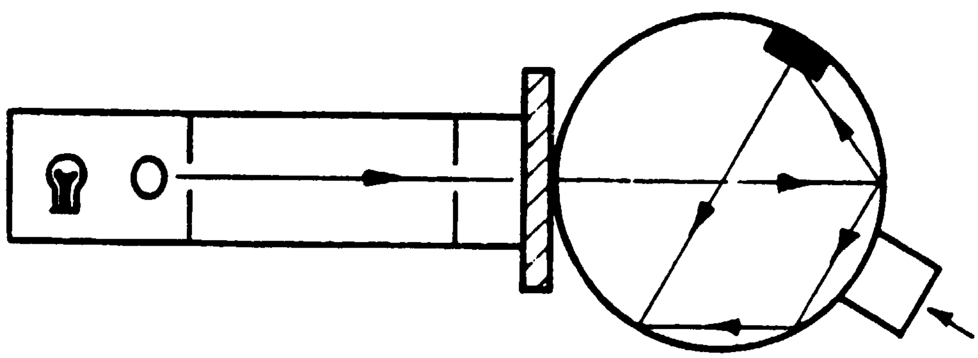
SCHEMATIC DIAGRAM OF CLARITY METER.

SPHERE HAZEMETER

Fig 9



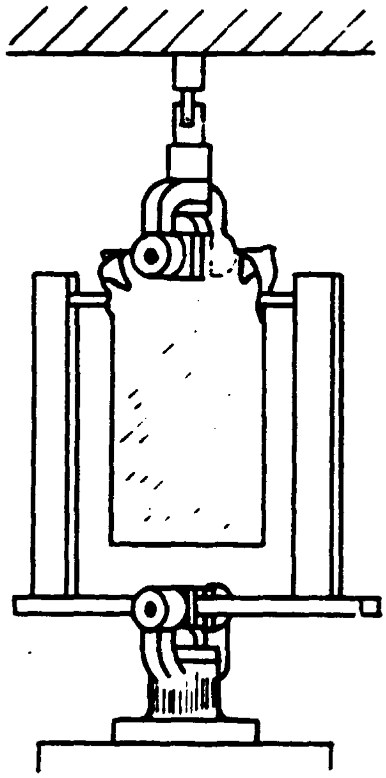
T2 — LIGHT SCATTERED OVER $2\frac{1}{2}°$



T1 - TOTAL TRANSMITTED LIGHT

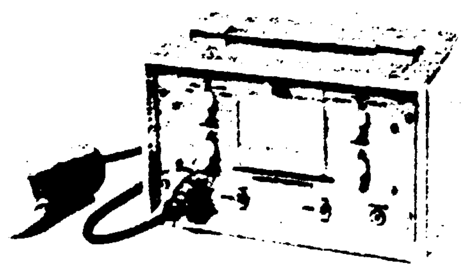
$$\% \text{ HAZE} = \frac{T_2}{T_1} \times 100$$

Fig 10



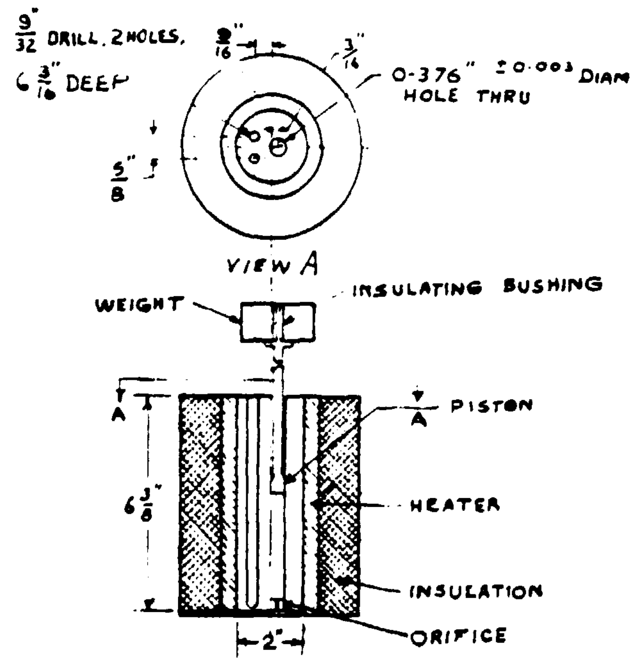
BLOCKING TEST

Fig 11



Electrostatic field meter

Fig 12



GENERAL ARRANGMENT OF EXTRUSION PLASTOMETER.

FLOW RATE (MELT INDEX) BY EXTRUSION PLASTOMETER