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[illegible] IN

[illegible] HORTICULTURE)[1]

by

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[illegible]

[illegible]

[illegible]

[illegible] agriculture. [illegible]

[illegible] 7. [illegible] [illegible] [illegible] [illegible] The very positive [illegible]

In defining [illegible] outside the world [illegible] sizes and involvement. [illegible] serves to illustrate [illegible] countries. [illegible] compare to [illegible] rising and growing, [illegible] appears to have [illegible]

In dealing with [illegible] horticulture) it has been found convenient to [illegible] groups,

[illegible]

1. [illegible]
2. [illegible]
3. [illegible]
4. [illegible]
5. [illegible]
6. [illegible]
7. [illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible] in agriculture and horticulture

[illegible]	[illegible]	[illegible]	[illegible]
[illegible]			[illegible] 12 [illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible] (PE [illegible] PVC) [illegible]
[illegible]	[illegible]	[illegible]	[illegible] in forced growing (tunnels, greenhouses), [illegible] and irrigation [illegible] pots [illegible]; and [illegible]

[illegible]

Estimates of comparative consumption of plastics in agriculture and horticulture by five countries

[illegible]	[illegible]	[illegible]	[illegible]
US	[illegible]	[illegible]	[illegible]
JAPAN			[illegible] (1[illegible]) ([illegible] irri[illegible] and [illegible] packaging)
ITALY	100[illegible] (19[illegible]) irrigation [illegible] supplying 2[illegible] (45[illegible])		700 [illegible] ([illegible] cluding [illegible] in [illegible] fertilizer [illegible])
FRANCE	15[illegible] tons (19[illegible]) irrigation and drainage pipe (15[illegible] for sprinkling) ([illegible])	Est. 2000-3000 tons (19[illegible]) used for equipment, tools and machines	Est. [illegible] 1500 (1[illegible]) (excluding packaging) Est. upwards of 2000 (19[illegible]) for fertilizer and produce packaging
UK	3500 tons (19[illegible]) irrigation and drainage pipe (85% PE/ 15% PVC)	3500 tons (1966) film and sheet used for variety of applications (e.g. crop and silage covers, liners, [illegible], 7[illegible] tons (19[illegible]) polypropylene baler twine; 100 tons (19[illegible]) used for buildings 500 tons (1966) used for construction; 500 inc.(1966)	1000 (1966, excluding packaging) 2000 (19[illegible]), for fertilizer and produce packaging

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

Mouldings
[illegible]

[illegible]

Netting [illegible]

[illegible]

Tubing and Pipe
Soil heating and steaming

Mouldings
Growing boxes, pots
Produce containers

Poultry houses
equipment
Poultry [illegible]
[illegible]
Equipment components
[illegible]
Baler twine
[illegible]

Netting
Fill support (greenhouses, shelters, etc.)
Windbreaks
[illegible]

VINYL (PVC)

Film
Greenhouse covering
Tunnels and cloches
Crop and silage covers
Reservoir and irrigation
channel lining
Soil sterilization covers
Machine covers

Tubing and Pipe
Land drainage
Irrigation
Seating
Wire fencing

Sheet
Corrugated roofing and
walling
Dairy and cattle
house lining
Protective clothing

POLYSTYRENE

Mouldings
Seed trays
Growing boxes
Plant pots

Produce containers
Growers' accessories
Formings
Produce containers
and separators

Foam
Building and livestock
house insulation
Produce containers

[illegible]

[illegible]

[illegible]

[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	Greenhouse glazing

[illegible]

Foam
Building and livestock
house insulation

[illegible]

Foam	Building [illegible] [illegible]

[illegible]

Sheet	[illegible] Liquid fertilizer and [illegible] insecticide containers [illegible] effluent pit lining Soil [illegible] sheets

[illegible] (PTFE)

Tape (thread sealing)

[illegible]

Dairy equipment components

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

In commercial usage they have to stand considerable mechanical stress due to wind and can be readily damaged and torn by careless handling, factors which tend to contribute to the shortness of their 'horticultural life' which [illegible] by [illegible] ultra violet radiation, high temperature, and the thickness of the material used.

These differences in contrast between the properties of various transparent materials, [illegible] between plastics as a whole and glass, are considerable [illegible] and cannot be ignored.

The successful utilization of plastic films in crop production depends, however, upon the skilful adaptation of the materials to both climatic conditions and to prevailing methods of culture. The lesson has already been learned that the direct substitution of glass by plastic films can prove costly in respect of both plant performance and the economic outcome of such substitution.

The use of very cheap thin films - such as polythene - in a manner which does not call for much in the way of extra structural support, provides [illegible] which justifies consideration for use on a range of crops during the cold months of the year. The choice of crop will be dictated by [illegible] much, when highly forwarded in advance of their normal season, will produce returns that justify the extra cost of such cover, [illegible] protection will result in useful extension of season and improved quality. The horticultural industry has already, to some extent, learned to use these plastic films in this manner and has developed production techniques which take advantage of the characteristics of the different materials. Nevertheless, there is still room for further study of the effects of plastic coverings on quality and season of harvest, on the extension of such coverage to a wider range of crops, and on the development of complete production techniques capable of easy operation and requiring minimum labour inputs.

Growers' trials, as well as more critical experiments at Research and Ministry of Agriculture Experimental Stations, have shown that there are problems of production requiring further investigation, but equally important, that profitable crops can be produced under cheap coverage, provided the right techniques are applied. Should further work prove successful it could lead to protective cultivation of crops which are at present uneconomical or marginally so when grown in the traditional manner.

Crops such as marrows, lettuce, runner beans, sweet corn and possibly asparagus and gherkins, are to form part of a study in relation to plastics coverage in the spring. Short term protection of a range of brassicae or celery seedlings may also be well worthwhile, and the list could be extended to include some of the cheaper flower crops as well.

The coverage of strawberries with thin polythene plastics film has already been fairly widely adopted by the horticultural industry, the methods used, providing an excellent example of the need to modify techniques previously developed in association with glass coverage.

The use of thin films of suitable gauge in the construction of plastics houses is attractive because the light weight of these permits the use of lighter structures or frames more readily formed from cheaper materials than those required in the construction of glasshouses. The results of combining the comparatively cheaper film with the cheaper supporting structure, produces the main advantage of thin film plastic houses - lower first cost. The better actual light transmission, due to the absence of the number of supports associated with glass structures, and the curved shapes that are possible has yet to be proved in growing trials. This type of cover produces no other major advantage, but does create environmental and other problems of a completely new character. These are associated with high humidity, and the form of condensate droplet which forms on the film and which can reflect light. Furthermore, the high transparency to infra-red radiation of polythene films can, under high radiation conditions, result in lower air and plant temperatures than would be experienced under glass - thus the cost of heating these film clad structures can, on occasion, be somewhat greater, even allowing that the film of condensate reduces long wave radiation - to some extent. The need to annually replace the roof cover is a further factor which cannot be ignored, although development with ultra violet screened polythene suggests a two growing season life and would proportionally reduce costs. Nevertheless, plastic houses become much more feasible with the introduction of fan ventilation, which assists in over-coming the problem of high humidity and permits improved control of air temperature. Although it is possible to list a whole range of minor advantages and disadvantages associated with the use of plastic structures, the main issue remains one of first cost of erection and of annual costs, when compared with those associated with the cheaper forms of modern glasshouses.

At the present time it is difficult to show that the difference between plastics and glass in this respect are sufficiently wide to encourage rapid extension of the use of thin film plastic houses in commercial crop production. The situation may well change in the future if costs of glasshouses continue to increase and as further development work takes place, both in the field of plastics materials and the manufacture of cheap supporting frames at reasonable cost. In the U.K. this position is accentuated since a glasshouse receives a government capital grant, whilst none are paid on plastics houses. At present, the most obvious place for thin film houses is in situations where available capital is very limited, where traditional glass cannot be obtained at reasonable rates and where 'house' or large tunnel forms of coverage of a temporary nature only, are required. In such cases, plastic houses can be built to generate capital for further development, to provide space for plant over-spills from glasshouses, or to meet other short-term needs.

Considerable development work on the design and construction of high forms of plastic coverage has already taken place - designs now ranging from the 'Bubble' house, which is air supported and requires no major structural frame, to a number of designs, some of which are manufactured ready for use, and others which can be erected by the purchaser. The 'Bubble' house is particularly attractive because of its low first cost, through it yet has to be proven that it can be built in large commercial units and will stand up to bad weather conditions commonly experienced in this country. Indications, at present are that thin film clad houses, including light structural supporting frames, are more likely to meet commercial requirements. It is perhaps interesting to examine the two types of house in more detail.

TABLE NO. 3

CHARACTERISTICS OF GR[illegible]

Material:	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Nominal thickness, micrometres	125	125	[illegible]	[illegible]	[illegible]
Transmission of visible light ([illegible] C.[illegible])	[illegible]	89	[illegible]	[illegible]	[illegible]
Transmission of infra-red radiation. ([illegible] 5-25 [illegible])	77	12	[illegible]	24	[illegible]
Estimated life (years)	1	[illegible]	[illegible]	[illegible]	[illegible]
[illegible] (m[illegible])	17.[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

For 1.0 [illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

pressure of about [illegible] or [illegible] water gauge (W.G.) provides adequate rigidity, but to limit movement under storm conditions this can be raised to a value between 12 and [illegible].

The most serious problems arise during storm conditions when both high winds and strong turbulent gusts impose additional stresses in the envelope. So far little work appears to have been carried out on the effect of wind gusts on the stresses in flexible structures, so there is little information available on which to base a scientific design. It is [illegible] problem in which the structure deforms under the influence of the wind pressure with a consequent change in the forces acting upon it.

Some houses now in use at the Electrical Research Station operate with a maximum inflation pressure of 12 mm W.G., which is about 20% of the ultimate strength of the polythene after a year's exposure. These have so far successfully withstood gales with wind gusts of up to 96 km per hour, though they may have been somewhat sheltered from the full force of the wind.

Experience has also shown that external restraints, in the form of entrance doors, end plates, etc., are undesirable. The use of flexible ducts and connections allows flexing to take place without causing local areas of excessive stress.

Snow provides another hazard, but increasing the pressure to 12 mm W.G. should support falls of up to [illegible].

The need for high optical light transmission limits the choice of film to one of the transparent or translucent plastics films which are available in large sizes or which can be economically joined to make a suitable sized sheet. So far only polythene and PVC have been used, except in one experimental house in [illegible] which was made with polyethylen terephthalate. Other requirements include low price, high resistance to tearing and to tear propagation, long life in exposed conditions and a low transmission of far infra-red radiation.

The maximum size of house is dictated by the maximum available size of a single piece of film. This is 10 m X 30 m for 125 micron u.v. inhibited polythene which gives a house about 27 m X 8 m. Larger houses may be made by jointing the material, subject to the restrictions imposed by stress considerations, and both tape-and-staples and heat-sealed joints have been used. One house, 50 m long and 9 m wide, was made from strips of 3 m wide material heat-sealed together.

PVC has been used in California and in the Netherlands. The latter house, of German design, was constructed of relatively thin (50 micron) material held in place by a net. PVC is more expensive than polythene but will last proportionately longer, giving a saving in re-erection costs. It can be heat-sealed more readily and is rather more opaque to heat radiation. Sandwich laminated PVC using nylon mesh reinforcement has also been tried in France, as well as polythene and PVC. Other transparent plastic films which might be worth examination are polyvinyl fluoride (PVF) and polyethylene terephthalate (such as Mellinex).

A suitable method of anchorage is required round the periphery to counteract the upward forces exerted by the air pressure and wind suction. This can be easily achieved by the method of burying the edges of the film in a trench about 500 mm deep which is then backfilled.

Access to the structure is generally by means of an airlock fitted at one end, where the door framework can be used to carry the ventilator.

One or more fans are required (a) to provide support pressure at all times and (b) to provide ventilation at appropriate periods. A single 600 mm diameter simple propeller fan operating at two speeds was used on two houses at Shinfield which fulfilled these requirements.

The fan is run at a reduced speed for normal support purposes by reducing the applied voltage developing about 6 mm W.G. When ventilation is required, it is switched to full speed. This higher pressure causes a counter-weighted ventilator flap at the opposite end of the structure to open and allow the hot air to be blown out. At 5 mm W.G. pressure the fan will pass enough air to provide about 25 air changes per hour. When the fan is once more switched to support speed, the ventilator closes under the influence of the counter-weight and the pressure reverts to 6 mm W.G.

Under these conditions, however, there is an appreciable temperature and humidity gradient along the length of the house, which results in more rapid growth and earlier crop maturity at the ventilator end of the house than at the fan end.

A battery-operated direct current stand-by fan is essential to maintain support pressure in the event of a mains electricity supply failure.

It would appear that no direct comparisons have yet been made between the way plants grow in an air-supported plastics structure and in a cold glasshouse, with which it is more directly comparable. It is known that temperature and humidity conditions can differ in the two types of structure.

A wide range of plants have been grown in air-supported structures for two years at the NVRS at Wellesbourne, and at the Electrical Research Station, Shinfield. Most of these were grown successfully but in some cases the habit was slightly modified and varieties tended to respond differently. Winter lettuce were difficult due to seasonal high humidity but, on the other hand, most spring and summer crops have responded satisfactorily. Successful crops have included beetroot, carrot, cauliflower, cucumber, French bean, lettuce, onions, pea, radish, spinach, sweet corn, tomato, turnip, gherkin, watercress, bulb flowers, self blanching celery, herbaceous perennials for cut flowers, rhubarb and seed crops of red beet, carrot, onion, radish, spinach. Strawberry plants were satisfactory but needed wider spacing than normal to avoid botrytis problems.

It is not possible to assess accurately the economics of a bubble house as the structures are still in the experimental stage. Nevertheless, a figure of 14.3d per square metre has been calculated whilst a comparable figure for a simple form of cold Dutch light single-span (glass) house, erected on concrete base blocks, would be about 11.5d. per square metre. This latter figure does not include automatic ventilation which is a basic part of the air-supported structure.

b) Light-weight structures

For a light-weight structure type of greenhouse there are certain construction requirements that need to be considered.

To be attractive for commercial use, the construction must be simple and functional and low in cost. The design must provide for quick and simple replacement of the film plastic as this will be necessary at frequent intervals. To minimise the risk of tearing the plastic, the supporting structures should be smooth and of design that places an even stress on the film. In order to withstand gales, the structure and plastic must be securely anchored. If tomatoes, cucumbers or climbing beans are to be grown it will be necessary to provide a separate support or to use a structure sufficiently strong enough to support these crops.

A curved profile shape would appear to be the most suitable shape. Ideally, one continuous sheet of film should cover the whole structure as joints are expensive if fabricated by the manufacturer. They may be potential points of weakness as well as time consuming if home-made. The widest polythene sheeting available is 1[illegible] which will give a width of 7 m for a structure with a curved profile. Apart from needing more than one sheet, the disadvantage of wider structures are the height that the operators must work when cladding them with plastic and the heavy weight of the material. A satisfactory method of securing the edge of the plastic at ground level is to sandwich it between two layers of wood which can be horizontal members of the structure. Alternatively, the edge can be placed in a trench 15[illegible] mm deep and covered with soil. Although wood is used for structures, galvanised tubing is preferred in the U.K. as it is strong, durable, smooth, easily formed into a curved profile and reasonable in cost.

The Ministry of Agriculture, Fisheries and Food, National Agricultural Advisory Service (N.A.A.S.) Lea Valley Experimental Horticultural Station has developed several designs for structures, which can be made at low cost by growers. These prototype tunnels 2[illegible], 4.3 and 7 m wide are now being used for cultivation trials. The tunnels 2[illegible] and 4.3 wide are intended to give coverage at minimum cost and to achieve this, the length of the 4.3 wide tunnels has been restricted to 2[illegible] to avoid the need for fan ventilation.

In the case of 7 m wide tunnels, it is anticipated that these would generally be longer and fan ventilation has been included in the cost given below. The tunnels 2 m wide are intended for temporary coverage, but the walk-in structures 4.3 m and [illegible] m wide would generally accommodate a crop for the whole of its life.

A walk-in polythene covered tunnel of [illegible] m ([illegible] square metres) provided with 1.[illegible] m diameter, electric fan giving ventilation of 1.8 cubic metre/square metre per minute has been constructed using 21 galvanised steel tubes, 2.[illegible] [illegible], secured with proprietary anchors or wooden railway sleepers, or on concrete foundations. The cross-pipes were rolled to produce the necessary curvature, and were braced horizontally with three rows of galvanised steel tubing.

The cost of this structure, including labour for erection, have been calculated at £1.7.[illegible]d per square metre covered, with an annual replacement cost of 2s.6d. per square metre covered.

Whilst a nylon net ([illegible] mesh) may be required to secure the polythene in exposed areas at an additional cost of approximately £18, trials using polypropylene twine tensioned over the tunnel are in hand and could be considerably cheaper.

A tunnel 47 m in length necessitates the joining of two polythene sheets, and although this is an additional operation during construction, the cost per square metre covered can be lower than for a shorter tunnel using a single polythene sheet.

The polythene covered tunnel 2 m [illegible] 4.3 ([illegible] square metres) was constructed with 12 galvanised steel hoops, 1.6 m apart, braced horizontally with wires, and a central galvanised tube. The hoops were secured by inserting the ends into 25 mm diameter galvanised steel tube driven into the ground. Manual ventilation is achieved by opening the ends of the tunnel.

The initial cost of this structure, including labour, has been calculated at 9s. 0d. per square metre covered, and an annual replacement charge of 2s. 6d. per square metre covered.

Cultivation trials are being carried out in these structures and will include:

Tomatoes (unheated) - lettuce (heated autumn and winter
celery (unheated) - watercress winter and spring
melons summer - sweet peppers - aubergines - runner beans
Antirrhinums and stocks (unheated) - Chrysanthemums - Dahlias

Although plastic covered structures are currently in very wide [illegible] France and Italy, it is believed [illegible] the [illegible] U.K. use.

[illegible] transparent [illegible] resin bonded glass-fibre [illegible] costly, [illegible] capable [illegible] or in whether [illegible] for long [illegible].

So[illegible] that of [illegible] trans[illegible]. [illegible] advantage [illegible] and the [illegible] which could lead [illegible] presently [illegible].

Rigid PVC [illegible] is already becoming [illegible] used to cover new structures [illegible], heating and cooling are all fully automated, [illegible].

The use of [illegible] with glass, in identical structures, [illegible] in hand in the U.K.

The cladding of standard wide [illegible] transparent plastics, moreover the necessity for glazing bar, [illegible] reduces the amount of opaque material in the structure. Further improvements in respect of the shape of the structure could be made, using the most promising of the [illegible] shape with reduction in opaque material could, [illegible] result in some 15 to [illegible] improvement in the light transmission values currently obtained in [illegible] glasshouse. If this improved transmission could be obtained in practice, and can be converted to plant performance, be it yield or speed of growth or quality, the enhanced crop returns which should result would be considerable and permit some latitude in increased constructional costs.

Plant containers

The traditional red clay pot [illegible] plants [illegible] is being steadily replaced by plastics [illegible], injection moulded in high-impact polystyrene, [illegible] large [illegible] in the U.K. In addition [illegible], vacuum formed pots [illegible] from [illegible] sheet [illegible] polystyrene [illegible] for seedlings. [illegible] multiple [illegible], [illegible] interconnected, [illegible] formed in one sheet. [illegible] ease of handling [illegible] spacing of the [illegible] in the greenhouse; [illegible], [illegible] readily detached from the sheet.

Containers for seedlings [illegible] are also made from black, gusseted bags, produced from extruded layflat polythene tubing. These bags can be also produced in a wide range of sizes suitable for most horticultural produce.

Recent work [illegible] has received [illegible], [illegible] in the U.K., of multi-stepped containers in greenhouses to make greater use of the space available. [illegible] are undergoing trials.

The first consisted of wooden boxes, about [illegible], filled with soil, and lined with polythene sheet. [illegible] boxes are placed back to back and the [illegible] drawn [illegible] to form a triangle with the top of the boxes on the apex. Holes are made in the plastic, at appropriate spacing for the crop, and the plants then inserted. In one installation the box frames were about [illegible] high and had [illegible] vertical rows of strawberries.

A variation of this idea was a trestle frame fitted with suitable cross supports set-up in a similar manner to the soil boxes. However, the plant containers consisted of a strip of black, 125 micron thick, layflat polythene tubing laid over the supporting trestle. The tubing was made into pockets by heat sealing, and one surface of the film slit across the width some 15 mm below the weld. Holes approximately 5 mm diameter were punched through the film about [illegible] mm above the lower weld, thus forming a suitable drainage point for each pocket in the continuous length of layflat tubing. These pockets were filled with soil and planted with strawberries.

A more novel idea was illustrated in vertically stacked pots. These consisted of injection moulded pots, each unit comprising two pieces. The lower half containing a mesh in the base to support the soil and a ventilation mesh in the side. The upper pot had a lipped cup protruding from one side into which the plant was inserted. [illegible] will have two such cups on opposite sides of the pot.

These units fit neatly into each other and were stacked vertically to a height of 2 m, being [illegible] supported in the ground at the base and by wire supports at the top. Planted with strawberries they appear to be giving some interesting results.

In countries with plenty of light, this multi-stage high plant intensity technique [illegible] of higher yields than can be obtained by ground level growing. In the U.K. where light is a restricting factor, the technique tried many years ago did not give encouraging results.

Black-out screens

Optically black polythene sheeting is used in greenhouses for controlling the light cycle that a plant receives. By this technique it is possible, with certain types of flowers, to produce blooms on an all the year round (AYR) basis. Chrysanthemums have been particularly developed in the U.K. on a large scale commercial basis, and more recently, production has begun [illegible].

Other plastics used in growing

In the heating systems used in greenhouses, much use is made of layflat polythene as the distribution duct for hot air, which is blown along the length of the greenhouse. A more recent development in Italy is the installation of plastic pipes buried approximately 300 mm below ground level, in order to provide sub-soil heating. It is intended that hot water will be circulated through the pipes for this purpose. The effect of this heating system on cultural systems will be examined.

The use of synthetic nets and polypropylene twine in providing not only support for plants as they grow but for a multitude of other general purpose uses in the greenhouse industry should not be overlooked.

The use of plastic sheets for steam sterilizing and soil isolation as well as plastics pipes for irrigation are dealt with elsewhere in this survey.

2) DISEASE AND PEST CONTROL

a) Chemical and steam sterilisation

The intensive cultivation of crops under greenhouse conditions, has shown that unless preventive steps are taken, an undesirable build-up of soil born pests and disease occurs and it can quite easily and rapidly arise. Unless controlled, this can have the ultimate effect of total loss of crop and ultimate financial loss for the grower concerned. There has been an increasing awareness of this problem over the last few years during which period there has been a bigger effort towards more intensive cultivation, and the partial sterilising of the soil, between successive crops, is essential. This has been achieved either by introducing chemical sterilisers into the soil, or by the use of steam to raise the soil temperature to 83°C. (180°F.) and higher.

When chemical sterilisers are used, these are effective in a gazeous state and some form of surface seal is required to ensure that the fertilising gasses do not escape from the soil prematurely. Polythene sheeting has been successfully used for this purpose and in the U.S.A., has been used, in the market garden industry, on open ground where the black polythene sheeting acts as a subsequent mulch for the next crop.

With steam sterilisation, the basic problem is one of ensuring that the steam is spread across the surface of the soil, thus thoroughly sterilising the soil surface as well as through the depth. Specially formulated PVC sheets of both 200 microns (0.008 inch) and 250 microns (0.010 inch) thickness are used for this purpose. Recent developments indicate that if a plastic knotted-net of approximately 150 mm X 150 mm (6 inches X 6 inches) mesh is used over the top of the PVC sheeting, then faster steam penetration of the soil is achieved or, alternatively, deeper depth of the soil is sterilised in a given time. Steaming sheets are normally fabricated to specific sizes, suitable for the particular growing beds to be steamed and allowing a generous overlap of width of 250 mm - 300 mm (10 inches - 12 inches) on either side. Sheeting of 17 m (50 feet) X 34 m (100 feet) lengths is placed over the ground to be steamed and fairly heavy chain, wooden battens, or other locally available material, ... laid along the sides of the sheeting, in order to form a reasonable seal against [illegible]. The [illegible] length of sheeting that can be used is limited by the capacity of the [illegible] quite small [illegible].

When [illegible] chain or wooden [illegible] over the [illegible] PVC sheet [illegible] means of [illegible].

Spe[illegible] today there [illegible] steaming [illegible] have proved [illegible] 12% [illegible] represents [illegible].

b) Isolation of growing bed

In [illegible] greenhouse growing, [illegible] be troubled [illegible] during the winter months, [illegible] problem [illegible] growing beds [illegible] development [illegible] isolation [illegible] It provides [illegible] of limited quantities [illegible] together [illegible].

Additional[illegible] significant [illegible] types of [illegible] greenhouse [illegible] [illegible] essential [illegible] necessary width [illegible] (1 inches) deep and [illegible] (14 inches) [illegible] the centre, [illegible]

[illegible] fill was provided for [illegible] [illegible] proposed [illegible] [illegible] filled with [illegible] mining [illegible] of fill.

C. [illegible]

[illegible] control [illegible] of the [illegible] head wall, [illegible] or [illegible] resistant. [illegible] high quality [illegible]

3) WATER CONSERVATION, SUPPLY AND DRAINAGE

a) Plastic membranes for water conservation

There is an ever increasing need for water and, storage of water becomes an increasing necessity in many countries. Reservoirs in the U.K. can basicall be divided into two kinds, those below 15 million litres (3 million gallons) and those above this amount. This division is based on the fact that for the large volume, civil engineering design and construction is involved.

In constructing reservoirs, there is need to make the unit waterproof and where this cannot be achieved naturally, by the nature of the soil, then, plastics offer a positive means of achieving a waterproof membrane.

Polythene, PVC and butyl rubber are the three materials most commonly used for reservoir construction. The choice of material depends on several factors, including the type of reservoir that is to be built, the expected life and the economics of the system.

Polythene has the advantage that it is available in very large widths of up to 1[illegible] (3[illegible] feet) in a gauge of 125 microns (0.005 inch). However, jointing can become a difficult problem when on-site methods are considered. Heat sealing has been used but was found to be unreliable under on-site conditions. The latest development for jointing involves the use of a double sided adhesive tape which is pressed to the overlapping surface of the sheets to secure a waterproof joint.

For reservoir application, black polythene film is used and this colour is achieved with a special grade of carbon black, in order to provide adequate protection against sun light degradation, which could occur both during installation and subsequently, if left exposed. It is advisable, therefore, when using polythene, to ensure that after it has been laid it is covered with a layer of earth. This should be at least 150 mm - 225 mm deep (6 inches - 9 inches), in order to securely anchor it against damage from wind when large areas are being laid, and to prevent subsequent sun light degradation.

For smaller reservoirs, where land is scarce and it is not possible to use the shallow slopes necessary for a back-filling operation, polythene film can be used without back-filling but its ultimate life in this case will be limited.

For large scale reservoirs, it is economically desirable to use mechanical laying techniques and development work in this area is proceeding.

In the U.K. 350 microns (0.014 inch) PVC has been the basic standard thickness of sheeting used for reservoir lining, particularly those under 15 million litres capacity. In the U.S.A. 200 microns (0.008 inch) and 250 microns (0.010 inch) are commonly used, even for very large scale reservoirs. PVC sheeting is normally manufactured in relatively narrow widths, by comparison to polythene, 1.5 m (54 inches) being normal and 2 m (72 inches) currently becoming available, although widths up to [illegible] m are known to be available in Italy. The present technique is to prepare large-sized sheets under factory conditions by welding the sheets together. This welding is achieved by means of fast operating, radio frequency (R.F.) welders. By this means, sheets of 80 m x 17 m (264 feet x 56 feet) can be prepared and suitably packed by concertina folding and subsequent winding up into roll form for easy despatch to the reservoir. There the roll is unwound and the concertina folded sheet is easily and rapidly opened out into position.

On-site jointing can be achieved by means of portable R.F. welding units but is tedious and time consuming.

Adhesive jointing, by hand, is commonplace and very satisfactory waterproof joints have been made by this means. This type of joing has the advantage of providing very high breaking strength and thereby adding to the security of the membrane.

Jointing, by means of a solvent jointing technique, has been satisfactorily used both in the U.S.A. and in some Middle East countries. Little information has been disclosed on the details of the technique used.

Double-sided adhesive jointing for PVC sheeting, as used in the polythene technique, has been examined and satisfactory waterproof joints achieved.

The last development for jointing of PVC sheeting is by a hotair welding technique. This obviates much of the on-site problems involved in handling a wet plastic film which inevitably occurs in practice. The experimental unit is designed to lay and weld the sheeting together as it travels along the reservoir.

Whilst in the past PVC has been pigmented black for reservoir applications, the latest indications are that a specific blue/green colour achieved by special pigmentation can give better long-term protection to the PVC against deterioration by weathering. Reservoirs have already been installed, for a period of 3 years, with such sheeting, without any back-filling, and it is anticipated that a useful life of 1[illegible] years in the U.K. can be achieved. If back-filling is used, then an extensive long-life is assured.

Butyl rubber sheeting finds a very special area of application for reservoirs due to its very high resistance to weathering under most climatic conditions. Its high degree of chemical resistance makes it an ideal material for liquid fertiliser lagoons, which are discussed under a different heading. For reservoirs, it does not require back-filling in order to ensure a long and useful life. It can be used for steep sloped banks of canals and reservoirs. However, it is an expensive material, approximately four times the price of PVC and its use in any particular application, therefore, has to be economically justified.

To secure the excellent weathering resistance, a specially formulated black butyl rubber sheeting is manufactured and a thickness of approximately 750 microns (0.030 inch) is regarded as the minimum to be pre-fabricated by means of special vulcanising jointing units. On-site jointing of butyl rubber is achieved again by the vulcanising technique, which is slow and tedious. The slowness of the jointing operation, the technical skill involved, all add to the high cost of butyl sheeting as a reservoir liner. Nevertheless, in many locations it can be economically justified and is known to give good and satisfactory service.

b) Reservoirs

Large scale reservoirs above 15 million litre capacity, are normally designed by specialist civil engineers, and are constructed as an engineering project. When plastic liners are used, special joints to concrete surfaces become involved, and in these cases it is necessary to consult with the supplier of the sheeting who normally have the necessary details available. Each project has to be considered as a separate entity and the systems to be used for the installation of the sheeting discussed and agreed with the engineer in charge of the scheme.

Reservoirs below 15 million litres capacity, as used on U.K. farms, are normally bulldozed out of the ground, using the excavated earth to form an integral part of the sloping walls. Where a back-fill technique is to be used, the slope should, preferably, not exceed a 1:2½ ratio, 1:3 in some soil conditions. Where back-fill is not being used, a 1:1 ratio could be used. In all constructions, after the reservoir has been made and filled, safety precaustions such as fencing off the area, or by the placing of safety ropes (polypropylene) across the reservoir, at suitable intervals, is felt to be necessary since in steep-sided banked reservoirs it is not possible to walk out unaided.

Water is extracted from small reservoirs by means of pipes laid on the surface of the reservoir banks, in which case it is necessary to protect the plastic lining from mechanical damage by using cheap and locally available material such as hessian matting. In larger reservoirs, the pipework is floated out from the bank, about 30 m by means of old oil drums or other suitable items, so that the intake end of the pipe is kept well clear of any weeds which form near the banks of the reservoir.

In the horticultural field, there is a demand for smaller reservoir units of up to 85,000 litres capacity. For this purpose, circular reservoirs, above ground level, can be constructed either by using curved, corrugated galvanised steel sheets or by means of galvanised steel mesh. In the latter case, additional mechanical protection is provided to the liner by means of a special sisal-reinforced waterproof paper. In the former case, butyl rubber liners are used, whilst in the latter, PVC liners are used. Pipework is taken through the bottom section and are made water-tight by means of rubber or plastic gaskets and satisfactory units are in use. The demand for smaller sized storage units of 1,000 litres and lower capacity can be met by rotational moulded plastics tanks.

c) Water supplies

Whether the water reservoir is of large or small scale construction, it is necessary to pipe the water from it to the areas of requirement. For agricultural purposes, irrigation forms a large demand, and the use of plastics pipes for this purpose has grown considerably in recent years and has replaced many other conventional materials. The changeover has made handling and installation easier, it has given a longer life to some types of equipment, and it has reduced the cost in most of the others.

Where plastic pipes have not completely replaced other materials they have provided a useful alternative, to be used as and when circumstances allow it; the very adaptable nature of plastic being of considerable help when considering its use for any particular purpose.

From an irrigation point of view, the use of plastic pipes falls roughly into two categories.

Water supplies, where the pipes are used to get the water to the point of distribution. In this application they are used mainly for underground permanent mains, feeding the various hydrants.

Distribution where pipes are used to distribute the water to the crop, and in these circumstances are usually incorporated into a manufactured equipment system.

The use of plastic pipes for underground water mains has many advantages over other types of piping. It is light in weight, it is not attacked by soil acids, does not rust or scale, and is very easy to install. In addition to this, the internal surface of plastic pipe is very smooth, giving good flow properties, with the minimum of friction loss. In many cases this enables a slightly smaller bore of piping to be used compared with pipes made from other materials.

Two types of piping are used for water supply purposes. Rigid PVC and polythene piping. Of these two more rigid PVC is being used than polythene.

Polythene

Polythene piping is extruded in continuous lengths and because it is flexible it can be coiled and if necessary supplied in lengths of several hundred metres.

The most popular method of jointing for the smaller diameters is by the use of compression fittings made of metal. If a large number of joints are to be made, this method can be very expensive because of the high cost of the compression fittings. On the other hand if long runs with very few junctions are involved, the installation is very speedy, and the use of this pipe can prove economical.

Polythene pipe will not burst if water freezes in it due to the slight elasticity of the pipe wall. This property can be very useful if pipes are to be used under circumstances where freezing might occur, such as in rising mains, and overhead permanent mains which may be difficult to drain in winter.

Rigid PVC

Rigid PVC is also extruded in continuous lengths, but is cut into standard lengths of up to 10 m for ease of handling and transportation. More irrigation schemes today use rigid PVC pipes than any other material.

The lengths of pipes are joined together by two main methods:

1 Spigot and socket cemented joints
2 Push fit joints which incorporate a rubber sealing ring.

The spigot and socket method requires the end of each length of tubing to be formed into a socket. This is done by the manufacturers and the piping is supplied with the socket already formed.

To make a joint the inside of the socket and the outside of the spigot are roughened, and then cleaned with a special cleaning fluid supplied by the manufacturers of the pipe. PVC cement is applied to both surfaces and the joint is pushed home. Providing it is correctly made this type of joint is extremely strong and completely reliable.

For the push-fit type of joint, a socket is formed at the end of the pipe which also has a recess to take the rubber sealing ring. The parts are cleaned, the ring libricated, and the joint pushed home.

This method of jointing can be carried out both by unskilled operatives and also in wet weather. (Spigot and socket jointing require dry conditions and trained operatives). The joint is not, however, end load bearing, and so must be anchored, preferably in concrete, at all changes in direction and at all thrust points. Failure to do this can result in joints pushing apart under pressure.

A complete range of fittings is available for both solvent cement and push fit joints, and these are very inexpensive compared with the metal compression fittings for use with polythene.

For flanged joints at pumps and valves etc. PVC stub flanges are available which can be cemented on to the PVC pipe and will match up with the flanges provided on all steel fittings.

The cost of installing underground plastic pipes shows a considerable saving over other types of piping. As it is not necessary to get into the trench to effect jointing, the width of the trench can be considerably reduced, and with suitable trench digging equipment a trench width of just 25 mm or 50 mm wider than the pipe itself can be used.

With spigot and socket joints the piping can be joined together on the surface and then simply laid into the trench. With push fit joints the pipe-end is kept above the trench, and the next length pushed on.

With polythene pipe, and with spigot and socket PVC pipe, it is also possible to lay with a mole plough. The technique of using a mole plough to lay piping has been highly developed in recent years and for big installations provides the quickest and most economical method of pipe laying available.

Small trenches are dug to the depth at which the piping is to be laid to enable the mole plough to pull in the pipe. The piping is connected to the back of the mole and the plough is winched through the soil. 300 - 400 metres of piping can be laid in one length by this method with the only disturbance on the surface of the soil being the slot cut by the mole plough.

This technique of trenchless pipe laying can cut installation costs by as much as [illegible] on a large scheme, and it reduces disturbance of the soil surface to a minimum.

Outdoor irrigation

In the United Kingdom plastic pipes are now being used almost exclusively for the water mains on all the major outdoor irrigation schemes.

The fully permanent schemes at present being installed on fruit farms for both irrigation and frost protection purposes all use rigid PVC pipes for the permanent mains from the pumps. On a lot of schemes PVC is also being used for the sprinkler laterals, where these are being installed under ground. This is an alternative to aluminium pipe laterals fitted above ground. The sprinkler laterals usually of 50 mm or 75 mm PVC are installed below ground along the rows of the level of the trees, the standpipes being connected into the laterals by means of 'T' pieces.

PVC pipes are also being used for a system of semi-permanent sprinkler irrigation. The PVC laterals in this case being laid on the soil surface with the sprinklers fitted on to PVC standpipes and connected into the lateral via T-pieces in a similar manner to permanent irrigation.

Couplings are inserted every 20 m or 27 m or, sometimes, just pipe clips at each side of the T pieces, and this allows the equipment to be dismantled at the end of the season, having usually been left in situ for the entire growing season.

For trickle irrigation uses, for which accurate measurements are essential, these characteristics put flexible PVC at a slight disadvantage when compared with rubber. The long life, on the other hand, far outweighs any slight disadvantages which it may have in other directions and makes the use of flexible PVC a great step forward in this particular field.

Other variations of the standard trickle irrigation equipment, for watering beds of carnations and chrysanthemums; and multipoint equipment for watering pot- plants use a combination of flexible and rigid PVC in the make-up of the equipment. The flexible PVC tubing used in the multipoint equipment to take the water to the individual pots is only 3 mm in diameter, being fed via the plastic multipoint nozzles, from a rigid PVC mains piping of 25 to 40 mm in diameter. The total amount of flexible PVC tubing used for trickle irrigation requirements in the U.K. is in excess of 1 million metres per annum.

Drip irrigation

Another type of greenhouse irrigation, similar in many ways to the trickle irrigation system, but introduced much more recently in the drip irrigation system. This uses a polythene mains pipe of approximately 25 mm in diameter into which is fitted extremely narrow bore flexible PVC tubes which take the water to the plants. The restriction created by the extremely narrow bore of the tube is sufficient to make water drip out of the ends of the tube, even though the mains pipe is under some pressure.

Spray irrigation

Finally, another type of irrigation, used mainly for watering plants grown in beds, uses a very light gauge polythene pipe into which is screwed the spray nozzles which give a flat fan like spray. The polythene tubing is laid around the outside of the growing beds and the water sprayed onto the plants.

Land drainage

Plastics land drainage pipe has created interest in virtually all countries where artificial sub-surface drainage is practiced on any scale. It is perfectly natural that this should be so since its use offers one of the most promising ways of reducing the capital cost of drainage. Similarly any drainage system must have a long life in order to spread this capital cost over as many years as possible. If these two basic requirements are to be met the plastic tubes used must be adequately but not over-designed. To fix suitable values for the different properties many countries have carried out experimental work and quite a number now have national specifications.

In studying this subject, the U.K. Ministry of Agriculture, Fisheries and Food Field Drainage Experimental Unit, has indicated that the general effect of the main design options on test performance would seem to be as follows: -

1) Material

Polythene has the advantage of being virtually impact proof whereas PVC is stronger but tends to be brittle. In general, about twice as much material is needed to make a tube in polythene, having the same long term crushing strength, this advantage is frequently masked by more PVC being used than strength would dictate, in order to obtain suitable impact resistance.

2) Tube conformation

Using equal weights per metre of finished tube in smooth and corrugated conformations gives the corrugated tube an advantage by a factor of about three in crushing strength tests. The corrugations, however, create turbulence and in general, such tubes have only 70% of the water transport capacity of smooth tubes having the same diameter.

3) Slotting

Since corrugated tube is relatively strong, no practical effect on tube strength has been observed although it is believed impact results can be effected. Transverse slotting of smooth tubes has no significant effect on the strength but even the better patterns of longitudinal slotting can reduce strength by 30%. If the slots are roughly cut this can reduce the water transport of the pipe by up to 8%.

4) Tube diameter

Recent work indicates that the current 44 mm to 50 mm tubes are capable of meeting a considerable share of the U.K. market.

5) Manufacturing tolerances

Tolerances on wall thickness and diameter both affect tube strength markedly. A ±5% tolerance on both can produce more than ± 25% variation in crushing strength.

From the above it will be seen that there are two distinct forms of plastics drainage tube, the smooth bore tube which is available in 7 metre lengths, and the coilable, flexible tube made in continuous length. The first tube to be introduced was the straight length and this was laid by conventional means in the open trench. The coilable, flexible tube was introduced with the development of the trench-less ploughing method of laying which was initially developed by the U.K. Ministry of Agriculture research unit. This system relies on a hardened steel blade being drawn through the earth at a predetermined depth and gradient by a large track-laying tractor, the gradient being accurately controlled by the surveyor through a [illegible]-link laying the tube in a preformed bed.

In one machine the [illegible] undulations that the pipe goes over [illegible], such as ridge and furrow; whilst in the mole drain plough, drawn by a [illegible] winch, and gradients are controlled by the traditional mole plough method. In this [illegible] the predetermined gradient is maintained by the operator directly controlling the gradient through hydraulic hand controls. The acceptance of plastic pipe is in many ways directly linked to these machines, for they can offer considerable economies in laying.

Traditionally, drainage has been undertaken, and most successfully, for well over 100 years with clay tiles laid in open trenches. The farmer can satisfy himself that the tiles are laid, correctly, and the trench to a gradient that he can see and can be proven either by a [illegible] or with rods. The straight length plastic pipes give savings in cost of handling, but these savings are not sufficient to influence the general acceptance of plastic tube. The trenchless method of laying does, however, offer tangible savings. These are found not only in the ease of handling of plastic pipe but in the speed of the operation and the saving of a third in the cost of the permeable fill.

Experience has shown that the larger of these laying units can be deployed economically only on large contracts - areas exceeding 15 to 20 hectares, and invariably undertaken by drainage contractors. This is due to the size of the machine which has to be transported to the site on a low-loader, and its running costs, and the ancillary equipment that is needed. However, when such an area is available, the contract can be undertaken quickly and with minimum disturbance, often through standing crops.

The availability of continuous length plastic tube, with the provision of a positive jointing system has resulted in a new development in land drainage. This now permits the drainage of both marsh and fenland to be undertaken where previously tiles were unsuitable, as under these conditions there is no solid bed for individual 300 mm lengths of clay pipe to be laid. Using continuous lengths the ground may shrink and alter without materially affecting the

This system enables considerable areas of, about 3 hectares rather than 5 hectares to be created by filling in open drainage dykes and reclaiming useful areas of land that, in the main, are extremely productive. Most schemes that are being undertaken, other than in polders, are mainly in general farming.

In horticultural work, the size of unit is invariably smaller than typical for areas that have been mentioned above; therefore, the practical characteristics of plastic pipe when laid by non-skilled labour are perhaps of interest. 200 metres of flexible pipe weighs approximately 30 kg, and this can be carried by one man. In comparison, an equivalent length of clay tiles would weigh over one metric ton. In greenhouse work it is immediately apparent that these handling characteristics would be of the greatest use. Longer straight lengths of flexible tube under these conditions can not only be laid with ease, but will remain straight in their line under heavy top irrigation and can be recovered and used again should the soil have to be changed.

Work is now being done on the development of small self-powered open trenchers that can effectively lay plastic drainage tube between current crops in greenhouses with the minimum of disturbance. The disruption that large drainage schemes can cause in a confined space are well known. Also, whilst it is known that certain areas must be drained for the usual reasons of earlier cultivation, warmer ground and a longer growing season, this problem of disruption can postpone a drainage scheme indefinitely to the detriment of profitability. Plastics, with their property of lightness and continuous length, and by the machines that have been developed, are altering this picture. Currently, plastics drainage tube is available in 50, 75 and 100 mm diameters, together with a range of fittings that make up a complete scheme.

The tubes are perforated with slits which are designed to exclude soil and build up a natural filtering action, and pass the maximum amount of water. In the average scheme where 440 metres of tube are used to drain 1 hectare of ground, the holes in the tube would be capable of absorbing

50 mm of rainfall per hour. This same length of tube laid with a fall of 1 in 500 will pass 750 litres per hour due to the rate of flow in the tube. In PVC corrugated tube there are three rows of small slits. These slits have 4.8 times its capacity of the flow capacity of the tube.

Extensive research work continues to be undertaken in land drainage, both by the U.K. Ministry of Agriculture and by manufacturers, and thought is being given by the manufacturers to the problems of drainage in horticulture.

Greenhouse spraylines

Over the last few years considerable amounts of PVC tubing have been used in the manufacture of greenhouse spraylines. First used in Holland in about 1959 and in the U.K. about one year later, the tubing is either drilled and tapped to allow the sprayline nozzles to be screwed in, or the nozzle is clamped into position around the outside of the tubing.

Plastic spraylines were introduced as an inexpensive means of installing permanent sprayline irrigation in greenhouses and as such have proved extremely successful. In the U.K. alone more than 700,000 metres of rigid PVC tubing is in use today for this particular purpose.

One great advantage in the use of this type of piping, which became evident after the introduction of plastic spraylines, is that liquid fertilizers can be applied without fear of corrosion. Since the application of fertilizers and other materials of a corrosive nature through the irrigation system is becoming more and more widespread the non-corrosive properties of plastic are of positive advantage.

One slight disadvantage of the material for this purpose is that, unless supported at very frequent intervals, the spraylines will sag very badly, and loose their straight and neat appearance. It is necessary therefore to provide support at intervals of at least 1 metre. This is usually facilitated by fitting galvanised straining-wire about 100 - 200 mm above the spraylines and hanging the spraylines on to this wire with small hooks, at suitable spacings. In common with other plastics PVC has a high coefficient of thermal expansion, the value being some 7 times that of steel. For this, allowance must be made during installation, particularly in greenhouses, for this expansion to take place. Pipes must not be fixed rigidly to the superstructure in any way, except that they are connected to the header mains. Hanging them on wire hooks as mentioned above is an ideal method of fixing as it allows for this expansion of the material to take place without strain or distortion.

In addition to overhead irrigation, plastic spraylines are also used for low-level irrigation of greenhouse crops. For this purpose the spraylines are usually supported on wire stakes, one or two hundred millimetres above ground level. These stakes are pushed into the soil at spacings close enough to keep the pipe rigid.

Tomatoes and roses are the main crops on which this type of irrigation is used.

Trickle irrigation

More than 50% of the greenhouses in the U.K. are irrigated by the trickle irrigation system. Introduced almost 20 years ago, the standard equipment comprises small bore flexible piping of from 6 mm to 12 mm in diameter into which is fitted, at intervals to suit crop spacing, special nozzles which allow the water to drip out on to the soil.

Flexible PVC has been in use in this application for four years in the Channel Islands and after this period of time there is no sign of deterioration in the tubing.

Unlike rubber, which was previously used, flexible PVC is affected by changes in temperature. In warm conditions it is soft and pliable and in cold conditions it becomes much harder and less pliable. It is also affected by thermal expansion, the same as rigid PVC.

4. FERTILISER TRANSPORT, STORAGE AND APPLICATION

The packaging of fertilisers in the last few years has seen a major change in moving away from the conventional paper sacks to the plastic sack. Although the initial sacks were based on PVC formulations, subsequent work and development shows this market to be now dominated by polythene, although in fairly large volume usage of polypropylene film for fertiliser sacks is developing. Polythene sacks have the advantage of remaining sufficiently rigid at the fertiliser filling temperatures which are relatively hot, 60°C. - [illegible], such that they can be fed into the top sealing unit without becoming limp and the top edge dropping down. Whilst it is possible to formulate a more rigid PVC sack to meet this requirement, it is unfortunate that such a sack cannot be economically reproduced to meet the low temperature performance requirements that ensure the sacks are satisfactory in subsequent transit and use in the U.K.

The problem of slippage of polythene sacks in stacking has been overcome by surface treatment. Polythene sacks are designed in many types suitable for high speed filling machines to meet most customers' requirements. By packing the fertilisers into a waterproof polythene sack, this has eliminated the demand for storing fertilisers in weatherproof buildings. It has consequently eased the fertiliser manufacturers' problem of the cost of stocking fertilisers during the out-of-season period. Fertiliser, in plastic sacks, can now be delivered direct to the fields where it is to be used and left safely in the open until ready for use.

In the U.K. most fertiliser sacks are pigmented white and suitably printed with descriptive details in relation to contents. The bags are produced from layflat tubing, with a wall thickness of 200 microns (0.008 inch) and this represents a volume market for polythene material of some 2[illegible],000 tons being used in the U.K.

A more recent development in the U.K. has been the use of liquid fertilisers. Prepared liquid fertiliser concentrate can be effectively sprayed, using the same equipment that would normally be used for pesticide spraying.

One of the major advantages of liquid fertiliser over its granular equivalent, is the ease and ability of handling in bulk, and this can be more economic.

Bulk storage on the farm can be carried out by the use of butyl rubber sheeting lined lagoons when quantities of not more than 1[illegible] tons of liquid fertilisers are involved. For smaller quantities, light rigid containers based on steel or wooden structures lined with butyl are suitable for quantities in the 20 - 2[illegible] tons range. Free standing butyl bags with an outer net support are suitable for storage of 2 - [illegible] ton capacity. Free standing, rigid, plastic tanks, whether fabricated from GRP, polythene or PVC, whilst very attractive in theory, tend to be too expensive.

Polythene and PVC piping can be used for the pipework necessary for conveying the liquid fertiliser, whilst PVC, acetal and polypropylene can be used for components for valves and pumps.

5. PRODUCE COLLECTING AND TRANSPORTING

This is an area of interesting potential development in which the economic factors are critical and difficult to ascertain. In the U.K. it is a market which is only just beginning and the following comments indicate how it is progressing. Produce collecting and transporting can be undertaken with re-usable boxes and crates, and it is in this specific field of re-usable units that plastics have a future market.

Plastic boxes and crates in Agriculture and Horticulture

Re-usable boxes and crates can be divided into two groups of application:

a) Boxes for delivery and return
b) "In plant" handling and storage boxes.

At present, of course wood is mainly used and it is strong, cheap and familiar. Plastic, therefore, is only considered if it justifies itself for cleaning or sterilising (typically with mushrooms, seed potatoes); or whether it competes in cost in use. Although the trend of raw material prices favours plastic, the gap, for example between low density polythene and wood, is far from closed. Hence the familiar problem that although a change to a more expensive article can provide a reduction of cost in use because of its longer life, yet it demands a higher initial investment and often an act of faith on the part of the potential user. This is a difficult step to take even in the more highly organised branches of industry with its specialised work study, production engineering and cost accountancy staff.

Delivery boxes made to serve for many journeys are acceptable only when they satisfy the condition that the cost per journey is less than that of disposable boxes after allowance for capital, return cost and losses.

The cost of return depends on the means of delivery and the design of the box. Thus if a grower or processor uses his own lorry, boxes will cost almost nothing to bring back empty. On the other hand, tapered or collapsible boxes result in space economy for empty return loads. Plastic moulding techniques enable such designs to be easily achieved.

The cost of loss is often the biggest disadvantage which limits reusable boxes to co-operate groups or companies moving produce between their own branches. In practice, the savings that are often possible, from the use of correctly engineered boxes, can carry quite a high loss rate; but it is naturally difficult to persuade potential users to take the risk.

"In plant" (process) handling and storage boxes take many forms according to the needs of various branches of agriculture and horticulture. Only a limited number of successful applications have been developed. Plastic boxes must justify themselves as against traditional containers or none at all because of hygiene; cost in use, and any labour saving.

An interesting example of a successful labour saving use of a moulded plastic tray is a planting-out tray recently put into quantity use by a grower of azaleas. These trays are used for cuttings grown under glass. Previously such cuttings were planted in beds in the greenhouses; later pricked out by hand for hardening; later lifted by hand together with a root ball and transported in wooden boxes for packing and despatch for sale.

Using the new trays, in which the cuttings are raised, the tray is taken and laid upon the ground for hardening off; later the tray is moved to the packing station where the plants, together with root balls are lifted out without difficulty for packing.

With this method the labour was reduced to approximately 20% of that previously needed. Stock control was made much easier since the cuttings were in multiples of 20 per tray. Additionally, it was possible to introduce semi-mechanical handling between the greenhouses and the hardening off beds; and the beds and the packing station.

A box for potato chitting (the process of starting growth with seed potatoes) has been developed at the prototype stage and appears to offer significant advantages. The present wooden boxes, although cheap are not only easily broken but also rot and warp. This can cause stacks of boxes, full of potatoes. to collapse and also to contaminate the potatoes.

During the chitting process, exposure of the potatoes to the atmosphere and to light is regarded as very desirable in order to encourage the chitting (the formation of young shoots); and an openwork box of this type is expected to be of value.

Apart from the above, many boxes, trays and other plastic containers designed initially for use in the food and other industries have proved successful in horticultural and agricultural applications.

Where growers have their own direct links with volume outlets such as canners, freezers and supermarket chain stores, the advantages of continental plastic containers have proved to be considerable. They also increase the payload [illegible], [illegible] handling in the factory areas, and can be washed (in combined washer [illegible] if available) to prevent cross infection and staining. Among the known users of different types of plastic containers are: -

Soft fruit growers
Apple and pear growers
Mushroom growers
Root vegetable growers
Pea growers
Dairy farmers.

The market penetration in the U.K. is still small. It is calculated that for every re-usable plastic box or tray there is still conservatively estimated to be 100,000 wooden boxes or trays in use. It is anticipated, however, that market penetration should be rapid in the months and years to come.

Large containers

Whilst not directly connected with produce collecting and transporting box and crate containers, there is another area of general interest in larger containers which can be most conveniently dealt with at this stage. These containers are of varying sizes ranging from 20 litres up to 45,000 litres.

Until recently, the large container market in agriculture has tended to be dominated by containers manufactured from metal or galvanised steel, and for dairy work stainless steel or glass lined tanks and receptacles. With the steady development of larger units in agriculture, coupled with the modern tendency toward bulk handling of all suitable products for economic reasons, this situation may now be expected to change.

Plastics have already made a considerable impact in farming generally. Similarly, in allied fields, plastics crates for instance have taken over from metal for the retail distribution of milk where their merits of light weight, quietness and suitability for high speed handling have been quickly recognised.

A look at industry generally, shows that plastics are now taking over at other levels. For example, in domestic water storage, plastics cisterns are fast replacing conventional materials. In the larger sizes plastics are being specified with increasing promotion for the storage and handling of corrosive [illegible], where traditionally, stainless steel or lined tanks have been the only ones [illegible] capable of resisting these substances.

Initially, in the pioneering stage, standards had to be established and prejudice had to be overcome. This, in turn, led to recognition that by using plastics, one could [illegible] replacement of a container already known in traditional materials, but a designed engineering module superior in performance to the traditional.

The controlling factors in the use of large containers are the processes available, and the development of suitable materials.

The general advantages of plastics materials such as their strength, lightness, durability and freedom from corrosion are all well known. Those most commonly used for large containers are the low and high density polythenes and polypropylene, all of which are well tried materials.

The processes available for large containers are fabrication from sheet, injection moulding, blow moulding, rotational moulding, and the spiral winding process.

Of these, fabrication has a place for short run applications, injection moulding is most suitable for mass production in sizes up to around 20[illegible] litres, the rotational moulding process can produce tanks (containers) of any shape and in any capacity up to [illegible] litres or greater. The [illegible] process is more flexible, and produces more rugged tanks in a range up to [illegible] litres. Blow moulding is another mass production method only for closed containers such as barrels, etc.

These processes are of course also suitable for smaller containers, boxes, tubs, etc., many of which are suitable for agriculture and horticulture and packaging applications.

The cost of these large plastics containers tends to be greater than that of conventional materials such as mild steel, but this cost gap is gradually narrowing. However, compared with the more expensive materials such as stainless steel, glass lined containers, etc., considerable savings can be shown.

Whilst this is only a direct comparison of first cost, what also has to be considered is the low operational cost of plastics containers. They are light weight, and out of the ordinary shapes can be produced relatively cheaply.

Progress in the use of large plastics containers in U.K. agriculture and horticulture has so far been slow, both for the understandable reasons of unfamiliarity, and [illegible] the initial cost barrier.

This pattern follows that of industry where slow initial acceptance has often been followed by dominance of the market. Perhaps a similar trend will be seen to emerge in the present context.

The areas in which a switch to plastics can first be expected, make an interesting study. Water storage, as already mentioned elsewhere, an obvious choice where the traditional galvanised steel tank has served so long.

Steel, especially in hard water areas, is subject to rapid corrosion and, in the domestic field, a range of plastics tanks around 250 litres, injection moulded or rotationally cast, from low density polythene may be regarded as the standard product.

One interesting development is the use of these tanks, simply coupled to polythene pipe, as readily movable cattle drinking troughs. Many other applications, particularly in horticulture are foreseen for these standard products.

In the larger sizes of containers, tanks made by the Helix and rotational casting methods are in production in a range of standard sizes and are eminently suitable for water storage, particularly when there are corrosion or installation problems.

Standard, or specially constructed plastics containers, are specially suitable for the bulk storage and transport of corrosive solids or liquids such as fertilisers or insecticides since plastics are inert to and unaffected by these products.

Mention should also be made of the development, by the rotational moulding process, of intricately moulded specialised containers for crop spraying and similar machinery. This process is specially suitable for the development of special mouldings of this type.

The development of special containers for handling in bulk of agricultural and horticultural produce can be foreseen. Again the light weight, freedom from noise and the chemical resistance of plastics materials make them eminently suitable.

6. TOOLS, MACHINERY AND EQUIPMENT

Under this heading a number of miscellaneous items can be considered, many of which are a re-application of a component developed for another product such as tool handles moulded in polypropylene, control knobs moulded in high density polythene, or polypropylene.

In crop spraying and fertiliser spreading equipment, particularly of the man-carried and light powered types it is factors of weight, corrosion-resistance and high volume production which influence any change over from conventional materials to plastics. Mouldings in polyester/fibreglass (GRP), polypropylene or high density polythene are most used in this area of application.

The plastic coating of metal surfaces by the development of the fluidised-bed technique has enabled many items of equipment, produced in steel, to be protected from corrosion by this means - plastic coated wire mesh being just one example of this technique.

Plastic netting is also widely used in agriculture and can be produced from synthetic fibres of nylon, polyester, or fibrillated polypropylene by the normal knotting technique of net production. Another form of plastic netting, varying from thick section for fences, to thin section for packaging has been produced by a special extrusion technique. In this process the net is made by a hot fusion of the plastic, mostly polythene, to itself at the intersecs of the net, and no actual knotting operation is involved. The use of this type of net is perhaps most commonly known in the packaging of citrus fruit.

In agricultural machinery GRP plastic is beginning to make some impact. It is already used for the production of tractor cabins, and for machine and equipment covers. However, it is the old problem of plastics having to have to penetrate an industry that has a traditional technology and experience based on metal which is controlling the rate of growth in the machinery area. Plastics require different fabrication and manufacturing processes and work people have to learn a new technology. Thus, unless there are distinct and positive advantages in using plastics, and in continuing production runs, it will be a process of slow change. However, the fact that nylon mouldings are being produced for agricultural equipment components such as seed drills, sprays, etc., indicates that the superior performance characteristics of selected plastics, are being utilised to advantage by engineers. The excellent abrasion resistance of nylon makes it an ideal material for seed drills, and it is in the exploitation of this type of application that ensure plastics have a future in agriculture machinery and equipment.

7. BUILDINGS AND CONSTRUCTION

The term 'buildings and constructions' requires definition and in the present context is taken to mean structures used in farming practice, for example livestock houses and crop storage buildings. It does not include domestic buildings. It is convenient to consider farm buildings in two categories, a) livestock housing and b) crop storage buildings, and to discuss the applications of plastics under these headings.

The plastics which are currently of most interest in relation to agricultural buildings are polythene, polyvinyl chloride, glass reinforced polyesters (GRP), polystyrene and polyurethane, the last two being of interest mainly in cellular form as insulating materials. Whilst most of these materials already have an accepted place in traditional farm buildings, there is a great deal of scope for plastics in this field, where techniques and construction methods are changing.

a) Livestock Housing

Most of the existing livestock buildings in the United Kingdom are for climatic shelter to guard livestock, specially young livestock, from extremes of damp and cold. An increasing amount of new building, however, is being erected to provide a controlled environment which will improve livestock yield in terms, for example, of eggs produced or rate of animal growth. Plastics materials can make a major contribution in the satisfactory performance of a controlled environment house.

One of the major factors in any environment is temperature, and for many animals the range of temperatures at which they are most comfortable and give optimum performance is quite small.

For example it has been indicated that the optimum temperature for various animals is as follows: -

OPTIMUM TEMPERATURES FOR LIVESTOCK

Livestock	Optimum Temperature °C
Piglets	21 - 27
Fattening pigs	16 - 24
Farrowing sows	10 - 16
Brooder chicks	32 - 35

(continued)

(chart continued)

Livestock	Optimum Temperature °C
Broiler poultry	16 - 21
Laying poultry	10 - 16
Baby calves	16 - 18
Older calves	10 - 13

These figures give some general indication of the range of temperatures at which the conversion factor (the proportion of food used directly to produce meat or eggs) is at its highest. The efficient utilisation of good food has a considerable bearing on profit; it has been calculated for example that food accounts for 80% of the cost of rearing a pig to market weight. In many cases of animal husbandry there is, therefore, a marked cost incentive to provide the correct environment, which as indicated above usually involves a temperature, in the U.K., higher than ambient for most of the year. This means that the building must incorporate some form of thermal insulation if the optimum temperature within the building is to be maintained economically from animal body heat and artificial heating. In addition, good insulation helps to prevent fluctuation of temperature within a building arising from the wide and rapid swings of external temperature which can occur, particularly in winter. Consequently, insulation plays an important part in the economic effectiveness of any controlled environment scheme.

The standard of insulation required depends on factors such as the desired temperature in the building, unit costs of heating, etc., but where the working temperature inside the house is relatively high, farmers have been recommended to aim at a target of heat transfer coefficient of 0.5678 X 10^{-4} for roofs and 1.1356 X 10^{-4} for walls.

Underfloor insulation too is often desirable and in certain cases, where floors are electrically heated, it is an economic necessity. In pig rearing for example an economic case can be made out for providing floor heating in the creep area. This reduces the mortality rate and encourages growth in young pigs. The insulation, conveniently polyurethane or polystyrene board, is generally placed on a damp-proof membrane, for example polythene film, immediately below the concrete screed bearing the heating elements.

Insulating performance under laboratory conditions is not the whole story. Installed cost, resistance to attack by vermin, fungi and a corrosive atmosphere as well as the maintenance of performance in damp conditions are all relevant factors. It could well be that in certain types of low cost building, cheap materials such as straw will always be the most suitable material to use for insulation. For permanent buildings, however, with a life expectancy of more than 20 years, it is likely that cellular plastics, particularly polyurethane foam, will ultimately become the materials of choice for total insulation of roof, walls and floor since they can offer characteristics such as ease of application, low water vapour permeability, low water pick-up and a long service life.

Ease of application is particularly important when existing buildings are being insulated. In these circumstances, the insulation in the form of board stock, which can be readily installed as wall and ceiling linings by the farmer himself is most suitable. Pre-finished boards with a water-impermeable and sterilisable surface are also now available. Other ways in which insulation can be provided in an existing farm building include spraying polyurethane foam on to the internal surfaces of the building, or where the building has a cavity wall, injecting urea-formaldehyde foam into the building. Both operations are skilled and need to be executed by contractors.

Other factors, in addition to temperature, have a bearing on the 'comfort index' of any environment. These factors are freedom from persistent moisture, availability of adequate fresh air and light. Plastics materials may be used to help fulfil these requirements. For example, rising damp can be prevented by the use of a polythene damp-proof membrane under a concrete floor, and liquid effluent from the animal house can be removed in a PVC drain. Electrical wiring for ventilation fans and lighting is almost invariably sheathed in PVC or polypropylene. Natural lighting may be provided, where required, by inserting transparent or translucent panels in standard corrugated sheet roofing. GRP, acrylic and PVC corrugated sheet have all been used to form roof-lights.

Many of these applications are well established in building generally, and not confined to farm buildings. One special problem of controlled environment housing, however, is the risk of spread of disease, and here plastics can provide a more effective answer than more traditional materials. In building terms - there are two requirements - an easily washed surface for day-to-day cleanliness and a surface which is impervious to ingress by micro-organisms and easily sterilisable for more positive disease control measures. There is a need for cheap building panel, faced with a plastics material with a jointing system free from surface gaps.

The surface of such a panel need not necessarily be able to withstand the temperatures of steam sterilisation, since chemical washes can be used instead of steam. Floors also can provide suitable conditions for bacteria and fungi to flourish. Again the requirement of cleaning and sterilising have to be met, with the further need for wear and corrosion resistance. In Germany experimental animal houses have been provided with epoxy resin floors, which fulfill these requirements admirably but which are expensive. It remains to be seen whether a cheaper form of impervious flooring will be developed for farm buildings.

Climatic Shelter

In the United Kingdom it is often uneconomic to go to considerable lengths to create an artificial environment because, as for example in the case of dairy cows, the animal performance shows little change at the atmospheric temperatures experienced through most of the year. The traditional livestock building therefore is essentially a shelter from the climate, from wind, rain and extremes of cold. No special provision is made for ventilation apart from openings in the building structure, and no provision is made for heating. Natural lighting is usually preferred to artificial lighting and as already mentioned daylight may be introduced by means of the many roof panels in transparent or translucent plastics materials now available. A complete shelter of the 'Nissen' type is now marketed in GRP translucent sheet.

During the past few years, however, there have been experiments with new types of climatic shelter for use where shelter is desirable but the cost of erecting it is difficult to justify. This is often the case with sheep, particularly in winter, where it is advantageous for the shepherd to have the sheep together and under cover for lambing. However, the advantages would not justify the cost of building a traditional shed. For cases like this, there have been developments in the use of plastics, notably polythene film, in low cost structures for shelter.

A sheep-wintering shelter has been developed by constructing a framework of semi-circular cross-section made from second-hand 50 mm metal water pipe and covered with 125 micron thick polythene film, sandwiched between layers of nylon net. The end walls of the building were made from bales of straw and hay.

This type of shelter has also been used successfully for the cubicle housing of cows.

Variations may also be made in the type of materials used in construction. A small plastic-sheeted building for sheep has been made employing PVC film and a larger structure, 2[illegible] m x 6 m is now commercially available. This sheep shelter consists of PVC film reinforced with nylon mesh and supported on a frame of tubular steel.

A calf house, in the form of a simple shed of 3 m X 5 m floor area consists of a light wooden framework clad with polythene film on both sides of the frame. The space between the two skins of film was filled with straw to improve insulation.

Whilst the plastic-covered structures described above have an initial cost advantage compared with more traditional shelters, on the other hand it has yet to be established that they are less expensive than what is often the current alternative - no shelter at all. The plastic skin needs to be kept in good repair and the clear polythene film replaced every two years or so. Grades of clear plastics film under development, however, are likely to extend the useful life of the skin beyond two years and experience already gained in using the structures indicates that cost benefits will accrue from providing livestock shelter in this fashion, particularly in the conditions of a hard winter. It seems likely, therefore, that structures sheeted with plastics film will become established as a distinct type of farm building.

* Heat transfer co-efficient:

A measure of the insulating value of a structure may be defined as the quantity of heat in watts which will flow through 1 cm^2 of structure in one hour when there is $1^\circ C$ difference in temperature between the air on each side.

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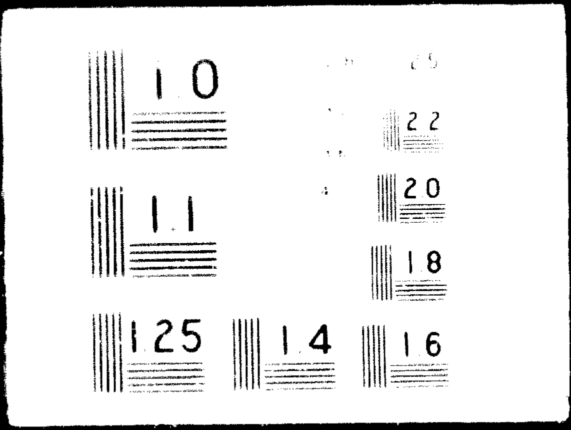

Ancillaries

It is worth noting that plastics materials find important uses in the ancillary services associated with buildings, as well as in the buildings themselves.

For example many miles of polythene pipe are used for general water supply to livestock houses, and PVC pipes are used to remove corrosive effluent. Where gutters and drainpipes are used on the larger farm building, components in PVC are challenging the traditional asbestos cement.

Within livestock houses, fixed equipment such as mangers, drinking troughs, have been fabricated from PVC. Air distribution, in forced ventilation systems, is now efficiently and cheaply achieved by using polythene layflat tubes. Where milk is conveyed from a parlour to bulk storage in a dairy, translucent tubing may be used. With the advantage that the effectiveness of pipe cleaning can readily be checked visually. In Italy large scale use of opaque plastic pipe is made for the transport of milk from the mountain farms to the collection centre in the valleys.

In the U.K. a polypropylene chicken cage is manufactured which is assembled from a kit of components and is designed to house 3 birds. A battery can be built two cages deep, four cages high and up to about 70 m in length. The chickens drink from a PVC trough which runs through the centre of the battery.

It will be seen that trends in farming practice appear to be towards controlled environment working wherever the improved animal or crop yield justifies the additional expense of the building, and towards low cost climatic shelter for vulnerable animals and crops where more elaborate precautions cannot be justified. A further requirement of intensive husbandry is the need to prevent the spread of disease amongst animals living in a small area and this puts a premium on washable surfaces. It is in these areas that plastics materials have a part to play

b) Crop Conservation

Plastics are used in conventional crop storage buildings and in similar applications to those already described for livestock housing. For example many stores are now fully insulated, such as for potato stores. It is important to prevent potatoes from being exposed to temperatures below 0°C., otherwise the potatoes tend to blacken on boiling. This generally means that the air temperature of the store must be above [illegible]°C. since heat generated by the stored crop can set up convection currents bringing cold air in contact with the potatoes. Insulation minimises the chances of 'air freezing'. A further refinement in the storage of potatoes for frying is the control of storage temperatures above 5°C. since potatoes kept below this temperature for any length of time do not produce the desired golden-brown colour on frying.

Here clearly an insulated store is needed. Temperature considerations implying the need for building insulation apply also to the storage of other produce, e.g. fruit, eggs, flower bulbs, and the commercial grower is becoming just as concerned as the farmer with the potential benefit which can accrue from exerting some measure of temperature control on the environment within buildings.

Stores for produce appear to show further progress in the use of plastics than do livestock houses, and the structural applications where the plastics material may have a load-bearing function are developing. The most obvious example is in the construction of tower silos. Tower silos in GRP have been used for some time, particularly in Germany and the U.S.A., and they demonstrate the technical advantages of GRP (corrosion resistance and reduced weight) over the traditional materials concrete and galvanised iron. A large Italian commercial silo (about [illegible] m high and 5 m in diameter) utilises two plastics in combination, GRP and polypropylene. The polypropylene is used as a liner, giving complete resistance to corrosion and a very smooth surface to promote the flow of the silage material. GRP is used for the outer shell to provide structural strength. Because of its lightness the silo can be erected in 4 [illegible] 3 men, instead of about 40 [illegible] necessary for a comparable concrete silo. The initial cost is about the same as that for a comparable solid concrete silo, and less than that for a galvanised steel silo.

Apart from the building aspect of crop storage, there are several applications which fall outside this area.

Silage

This animal feedstuff is prepared by suitably storing, under sealed compression, cut and chopped grass, or other suitable green foliage. Under these sealed conditions the lactic acid, formed by bacterial action, preserves the grass by a pickling action.

In the U.K. a most efficient way of making silage has been the large scale development of vacuum silage. In this process, the grass is stacked on a polythene sheet and then totally enclosed by covering with a second sheet. Air-tight joints between the two sheets are achieved by means of a specially extruded polythene split tube, between which the sheets are mechanically clamped. Air is then extracted by means of a vacuum pump, often attached to and driven by a tractor, until the whole mass is compressed. The air line is then sealed, and the silage left until required for animal feeding. Excellent quality silage is produced by this method with little or no losses.

By this means it is possible to locate silage stock at the points where it will be ultimately required for use. The polythene sheets that are used are only 125 micron thick and are of use for one application only. Silage of up to 500 tons stocks can be made by this technique.

Both polythene and PVC sheets are used for sealing silage made in conventional trenches or clamps, and they reduce physical losses by preventing air getting into the silage after mechanical compression has taken place.

In Italy a further development of vacuum silage has taken place. A mobile circular frame, made up of four sections bolted together and lined with GRP plastic sheeting is used as the outer support for a silage stack. A preformed and welded PVC circular liner is placed within the frame and then filled with chopped grass etc. After filling, the top of the liner is closed with a mechanical clamp and the PVC bag evacuated by means of a vacuum pump. The compressed silage is then sufficiently firm and capable of being free-standing. The mobile frame is removed and used for making additional silage stacks. The PVC sheeting is of 500 micron thickness, and claimed to have a useful life of at least three years.

Moist grain storage

There are specific reasons for needing to store moist grain for animal feeding. Under normal conditions this would deteriorate rapidly due to mould growth and bacterial activity. A portable storage unit based on circular frame of galvanised wire mesh of 75 mm X 75 mm is lined with sisal reinforced paper, and then a preformed PVC circular liner. Appropriate apertures are fabricated in the liner to permit the entry of mechanical screw augers so that the grain can be emptied. The moist grain is filled into the open top liner until within 150 mm from the top of the mesh. The liner is then folded in concertina manner and sealed with a mechanical clamp. Under such air-tight conditions moist barley, up to 28% moisture content, has been satisfactorily stored.

Variations of this type of storage are in development, including moist field beans, but flushing the storage unit through with carbon dioxide so as to exclude residual oxygen. Units for storing up to 25 tons of grain are in current use.

Polythene sacks have been used successfully for storing small quantities of moist grain, while butyl rubber has been used for very large conical containers of up to 500 tons.

Hay and straw

The use of plastic sheets, polythene especially, as hay and straw stack covers, should be briefly mentioned. Used on a one season only basis, they have been steadily replacing traditional tarpaulins, made from textiles, for economic reasons.

Finale

In this general survey it has not been possible to include all and every application of plastics in agriculture. It has, however, been attempted to indicate some of the problems in which plastics might offer a solution. Economic considerations, obviously, play a large part in this matter, and will vary from country to country. Thus, the solution of a problem in one country may not be feasible in another. Moreover, some countries will have their own individual agricultural problems. It is hoped here that this survey will assist in signposting the way in which plastics might be used to resolve such problems.

N.B. It should be noted, wherever indicated, that 'polyethylene' is synonymous to 'polythene'.

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A.E. Canham	Air supported plastics greenhouses
J.D. Langrill	Reservoirs - PVC
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H.R. Neville	Land drainage and plastics pipe - commercial appreciation
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