SPECIALIZED PETROLEUM ASPHALT COATINGS IN MEMBRANE WATERPROOFING

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INTRODUCTION

Liquid coatings offer a different approach to problems of roof waterproofing, but an approach that is, nonetheless, equally scientific and just as valid as more conventional builtup bituminous membranes or elastomeric sheets.

In rebuttal to the widely prevailing notion that brush coating just cannot be effective in sealing a roof surface, I argue that the problem of excluding moisture from a window or door frame is essentially similar. No one claims that this waterproofing problem requires the gluing or nailing of bits of waterproofing sheets. Brushed-applied paint is accepted as an effective means of obtaining a continuous impermeable barrier. In this paper, I maintain that the same basic concept of a fluid-applied coating can similarly seal a roof surface.

SOME PROPERTIES OF ASPHALT

Asphalt, the base material of our liquid coatings, is a colloidal system, a complicated mixture of those hydrocarbons in crude oil with the greatest molecular weights. (It is almost impossible to ascertain in detail the natures and molecular weights of the individual compounds of which it is composed.) In simple terms, asphalt is a dispersion of a component called asphaltene with molecular weights from about 1000 to 5000 in a lower molecular weight resin/oil moiety called maltene. Affinities between these components give a dispersion that is stable and does not separate under gravitational forces only, a situation described by the scientist as colloidal. There are various methods of performing the componenent analysis of asphalt and the widely used American Bureau of Mines method is shown diagrammatically in Fig. 1. Asphalt of commerce is mainly defined by two properties, fusing point[1] and penetration[2]. Because of the colloidal nature of asphalt fusing point is not a clearly defined borderline between phases above which the asphalt is a mobile liquid and below a solid of fixed shape, asphalt softens gradually all the time as the temperature scale is ascended and the method of determining "fusing point" is in fact a viscosity determination, fusing points, as defined, being the temperatures at which a range of asphalts have the same viscosity. Penetration compares viscosities of asphalts at constant temperature. Fig. 2 lists fusing point and penetration values for a range of asphalts available in the United Kingdom[3]. The figure is arranged to contrast the properties of straight asphalts and blown asphalts and underline the increase in gel type character of the latter. This is characterised by a greater resistance to flow at elevated temperature (higher fusing point) coupled with a relatively high penetration value.

When using asphalt on a roof surface we have the problem of getting it there and keeping it there in sufficient quantity to provide durability. Simple asphalt can, of course, be fused and raised to a temperature at which it is sufficiently fluid to be mopped or poured onto the roof surface. This process is not entirely without hazard. Since asphalt softens with rising temperature and conversely becomes brittle at low temperatures, it is unlikely that this coating of simple asphalt will survive the stresses of roof deck movement, so it is usual to include a reinforcing fabric mostly supplied in the form of pre-saturated "felt". The need to saturate the felt to a pinhole free condition, to seal the overlaps and add enough asphalt to counteract the water-absorptive properties of the fabric generally means that we load the deck with more asphalt than is needed for basic durability, thus adding to weight and fire load. Problems can also be experienced with sagging and flowing on sloping surfaces and vertical details, for example flashings, because the unmodified asphalt can soften under solar radiation, particularly over an insulated surface.

MODIFICATIONS OF ASPHALT AND REPAIR OF COATINGS

Now we turn to consideration of the ways in which the basic asphalt can be modified. These include the addition of mineral fillers, blending with elastomers, plastics and waxes. Figures 4 and 5 give illustrations of the effects of all these types of additions on various asphalts. Figure 5 also indicates the effect of emulsification on the modifying system by including data determined on modified asphalt mixes recovered from emulsions by evaporation of the water.

Many modifications can be incorporated into solid asphalt but in then attempting to apply this as a hot melt there could be trouble caused by the increased fusing points, polymer degradation or filler settlement. However, these modifications can be incorporated into products that are formulated to be liquids at ordinary temperatures and thus capable or ready and immediate application on site. There are two principal classes of liquids, asphalt emulsions and asphalt solutions (or cutbacks). An asphalt emulsion can be regarded as a dispersion of very small droplets of asphalt in water. Emulsification is achieved by mixing the asphalt (suitably heated to a temperature at which it becomes a free flowing liquid) with an aqueous phase consisting of water plus an emulsifiying agent and/or a clay (e.g. bentonite). The mixing may be achieved in a high speed mill where the liquid asphalt and aqueous phase meet in the narrow gap between a fixed stator and a high speed rotating rotor. Alternatively emulsification can be carried out in a more leisurely way where the liquid asphalt is slowly fed into an aqueous phase which is contained in a vessel fitted with various agitating, beating, kneading devices. Whichever method is used, the asphalt is broken down into very small droplets, usually spherical but sometimes elongated and the majority of these particles will have a particle size of 1-5 microns. Such an emulsion will probably be brown in colour; emulsions having a larger particle size may be black. The asphalt content of the emulsion will be between 50 and 70% by weight. A satisfactory emulsion will be smooth in appearance and should possess sufficient stability for application by spray or brush. Asphalt emulsions are easy to handle, and compatible with water, which enables equipment to be cleaned simply.

The stability of an emulsion can be varied to suit the intended use, e.g. a road emulsion is usually formulated so that it will readily coagulate. Emulsions used for roof maintenance purposes generally contain fillers and are of the stable variety. The storage stability of roofing grade emulsions is good and any slight separation that may occur in the container should be easily rectified by simple stirring before application.

Suitably formulated asphalt emulsions exhibit the useful property of retaining a structure that prevents the dried film from flowing or dripping when heated. Even when the dried asphalt film is set on fire this lack of flow and dripping is evident. It is a most useful property for a roofing material.

Ease of application is one of the obvious advantages of an emulsion product, but there are conditions that limit "year-round" working with asphalt emulsions. Such products are sensitive to water until the applied film of emulsion has dried out. Freshly applied emulsions can be washed off a roof if rain falls with a short time of application. Emulsions can be damaged by frost, both in the container and on the roof, if not already dry. Thus asphalt emulsion should always be stored under frost-free conditions and should not be applied to a roof if frost is imminent. A correctly applied dried asphalt emulsion is, however, completely impervious to liquid water.

Asphalt can also be reduced to liquid state by the incorporation of solvents (usually of petroleum origin) sufficiently volatile to evaporate after application of the coating.

Most asphalt solutions are manufactured by agitating a mixture of the hot fluid asphalt and the chosen solvent or solvents. Sometimes the whole process may be carried out cold, but this generally results in a slower rate of solution of the asphalt in the solvent.

For roofing products, an asphalt solution possesses obvious advantages when compared with an emulsion, e.g.:

1. Drying time of thin films can be varied by choice of appropriate solvent.
2. Solutions are not damaged by frost.
3. Freshly applied solutions are not washed off by moderate rainfall and within a fairly short time of application will resist quite heavy rainfall.
4. For a given film thickness, asphalt solutions give a film with lower water vapour permeability than a corresponding film cast from an asphalt emulsion.

There are, however, many disadvantages to asphalt cutbacks:

- Solvents cost much more than water, making asphalt solutions more expensive than the corresponding emulsion.
- Cutbacks present more hazards than emulsions – notably fire, vapor toxicity, solvent odor.
- Thick films of asphalt solution can be very slow drying. Solutions tend to dry from the top down, and the formation of a surface skin retards evaporation of the solvent trapped underneath. Contrary to expections, a thick film of asphalt solution may take longer to dry on a warm, windy day (usually thought to be ideal drying conditions) because of the quick formation of a surface skin. Certain tricks can be employed at the formulation stage to keep the asphalt solution film open and free from surface skin but this can backfire if drying conditions change and again excessively long drying times can result.
- Asphalt solutions tend to thicken with long storage and become difficult to apply unless first thinned with solvent. Asphalt solutions are not damaged by frost but their viscosity is greatly affected by temperature. At temperatures near or below freezing point, these solutions become extremely difficult to apply.
- Asphalt coatings deposited from an asphalt solution do not show the same lack of flow under fire con-

ditions as do emulsion coatings. Under special circumstances this resistance to flow can be achieved, but inevitably increases cost.

- Application of an asphalt solution product to a wet surface is very much inferior to that of an emulsion. For all practical purposes the substrate should be surface dry before an asphalt solution is applied. It is possible to formulate asphalt solutions with damp surface application properties, but again at increased cost.

Modifiers can be simply incorporated into the basic liquid asphalts, whether emulsion or solution, in a mixing vessel under suitable conditions of agitation which in many cases can be the propeller blade-type stirrer. Polymer additions to emulsions are made by incorporation of the polymer in latex form, but asphalt solutions are rarely modified in this way; addition of mineral fillers is the usual method. Polymers, particularly elastomers, have an adverse effect on the application properties of asphalt solutions, causing stringiness and cobwebbing.

SOME ASPHALTS SOLD IN U.K. TO B.S. 3690 — FIG. 2

	Straight run			Blown		Straight run hard	
Penetration x 10^{-1} mm	200 ± 30	50 ± 10	25 ± 5	25 ± 5	15 ± 5	9 ± 3	5 ± 2
Fusing point °C	33/42	47/56	55/67	80/90	100/120	80/90	100/120

As indicated by the tables, considerable improvement in the physical properties of bitumen can be achieved, in the sense that an increase in fusing point (resistance to flow) can be achieved without a dramatic fall in penetration (resistance to low temperature embrittlement.) It is possible on the basis of practical experience to select products yielding dry films of considerable stability and durability on exposure to weathering. These dry films can typically contain 90% or more of asphalt, compared with about 55% in a built up felt membrane and 15% in a rock asphalt layer. This accounts for their water tightness and durability in relatively thin layers. To echo what was said earlier, it is just a different approach to the provision of a waterproof membrane.

PRACTICAL USE OF LIQUID ASPHALT COATINGS

How are such products used in practice? Depending on features such as size and complexity of the roof area, each coating is applied by brush or by spray. Multiple coatings should always be used to reduce the chances of pinholes and misses. With products that are not polymer modified a successful membrane can only be produced by using a reinforcing fabric, usually a woven glass, although many roofs have been reinforced with jute fabrics rotproofed with copper compounds. There is one effective process featuring a random fabric of glass fibre produced by blowing chopped rovings into the wet film. When a fabric is embedded at least three layers of coating should be applied and sometimes four. With a well formulated elastomer-modified film, there is need only for two coat application because the elastomer provides sufficient flexibility and tensile strength of film for it to survive roof movements without external fabric reinforcement. Each coat is continuous and seam-free because of the character of the basic product and because each succeeding coat bonds uniformly to the earlier ones. Flashings are automatically brought into seamless unity with the main body of the work.

Fluid-applied coatings thus offer a seamless membrane over roof surfaces of complex shape (see Figs. 3 and 6).

A wide range of properties can thus be developed from simple asphalt, in product forms suitable for roof waterproofing. In the main the chemical properties of asphalt are unchanged; so for maximum durability, it is necessary to supply a shield against solar radiation. Classically on the flat horizontal roof gravel bedded in an asphaltic flood coat is used, adding considerably to the weight, and not usable on sloping or heavily contoured surfaces. By extending the principle of liquid coatings it is very easy to supply a u.v. shield by the application of a pigmented coating. These can be asphalt-based with traditional paint pigments – for example red oxide of iron – forming dull colours because of the asphalt base. Use of a leafing grade of aluminum flake gives a very bright specular coating that lowers surface temperature due to solar gain and can be particularly useful for an insulated deck. Some copolymer films are flexible enough to be compatible with an asphaltic substrate and these are used to provide a range of brighter colours.

Here, in summary, are the major features of liquid coating membranes:

- A continuous, monolithic finished surface.
- Self bonding.
- Easily applied durable colour finish.
- Adaptability to beneficial modifications of the asphalt.

PERFORMANCE OF ROOF MEMBRANES AND CAUSES OF FAILURE

Arguments against fluid-applied membranes focus on the belief that thickness and weight are required for durability.

To examine how well conventional membranes perform, we collected field reports including the following items:

1. Substrate and pitch.
2. Existing waterproofing.
3. Age of existing waterproofing.
4. Apparent cause of leakage – splitting, seam adhesion failure or general deterioration.

Copies of field reports were collected on 200 roofs that failed because of leakage. Over half of these roofs had been waterproofed originally with a felted specification. (The remainder were one-third rock asphalt specifications and two-thirds roof surfaces that initially do not need added waterproofing, for example slates, corrugated steel and asbestos cement.) If, for these felted roofs, we draw a bar graph (Fig. 7) of number of roofs versus age we find that a felted specification giving trouble is likely to be ten years old or less. Obviously the chart shows some roofs that have survived way beyond this to twenty and even thirty years old, but on examing the data reported for these older roofs it is invariably found that the deck is good old fashioned solid in-situ concrete.

Can any reasons be found for these early failures on more modern structures? When the data on the roofs ten years old or less was separated out, it was found that there was no particular trend with regard to roof structure – they were pretty well evenly divided between metal, pre-cast concrete and timber product decks – however, over 90% of the roofs were flat and almost 30% were flat and insulated.

Insulation leads to a higher temperature due to solar gain at the upper surface and this means that there will be more movement in a thermoplastic substance like asphalt and membranes based on it will be softer and weaker at the higher temperatures. Conversely during clear sky radiation conditions at night the surface membrane will fall to a lower temperature because it is isolated from the building as a heat source by the presence of the insulation. At these low temperatures the asphalt is brittle.

On flat roofs where water is ponded, higher temperatures increase the severity of attack by water. Water immersion will eventually weaken any adhesive bond and warm water is even more aggressive.

To accommodate the effects of a wider range of service temperatures asphaltic products modified with polymers are being used more and more widely. Effective specifications for insulated decks (Fig. 8) can be built up from modified liquid coatings. There is the plus feature of being able to furnish very easily an effective solar reflective finish (Fig. 9) without recourse to reflective chipping which can cause a lot of trouble when the need for maintenance arises. Moreover, chippings cannot be used on a pitched surface, where again a reflective coating comes into its own. It is not surprising that after a time a roof surface begins to show signs of wear and tear. It is, in fact, truly a working surface. Not only does it have to shield the building from rain and snow-fall but it also has to collect the resulting water and discharge it from the building via the drainage system.

MAINTENANCE OF WEATHERED ROOFS

Apart from some old buildings, most large roof surfaces are finished with organic substances which are degraded by ultra violet radiation. The flow of rainfall erodes the products of degradation and thus gradually the original surface. This can, for example, expose fabrics used in the construction of the roof waterproofing materials and encourage more rapid penetration and spread of water, particularly on a flat roof where water may be ponded and the initial rate of attack is accelerated. Silting up of gutters and rain water outlets may cause flooding of roof areas if there is no inspection.

Inorganic coverings such as slate, tiles and asbestos cement are not free from attack; they all absorb water to a greater or lesser extent and this can eventually degrade the surface so that it forms a home for plant life – such as moss, etc. – which then accelerates degradation of the surface. Corrosive elements can also attack the original fixing methods used so that leakage occurs due to partial displacement of the roof surface.

Thus eventually the whole spectrum of roof structures becomes due for maintenance, and the owner is faced with the choice – apply an effective maintenance system or strip and refix the original specification. In a few cases the latter is the only sensible course of action, but again the versatility of liquid coatings, even over complex contours, offers a course of action that avoids total stripping of the existing membrane and waterproofs without adding a high additional loading of flammable material to the deck.

We can conclude with some details of the specification that may be used for the build up of a successful cold applied membrane. At present there is little available in the way of official guidance on the subject in the form of Codes of Practice. However, the author's company has been in and survived in the business of roof waterproofing with liquid coatings for over thirty years, so it could be argued that the process used is viable. Details of coverages and film weights are given in Fig. 10. In general the basic membrane specification is built up from four applications of the liquid asphalt coating and incorporates a fabric reinforcement.

Reinforcing fabrics are available in a wide variety of types.

Woven hessian, treated with rot proofing agent or impregnated with asphalt is still widely used as a membrane reinforcement for asphaltic roof waterproofing systems. It conforms well to awkward coutours, but may wick moisture into the system, and although rotproofed, may not be rot proof. Glass fibre, either as a woven or random bonded fabric is a popular reinforcement for roofing systems. It is completely rot proof and can be very strong but is virtually non-extensible and does not always conform well to irregular shapes. This type of product will not wick moisture into a system and is of course resistant to fire conditions.

Synthetic fibre membranes based on nylon, terylene etc., have all been used in liquid-applied roofing systems. Such membranes are strong, rot resistant and drape well around awkward contours, but tend to be expensive.

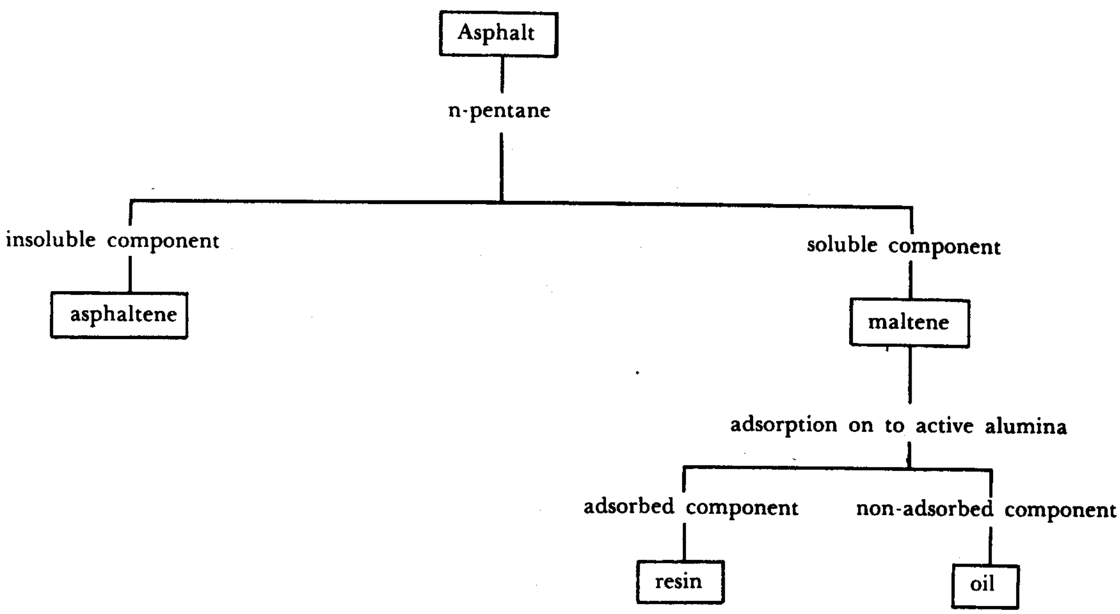
Woven membranes based on polyethylene and, to a great extent, polypropylene have recently entered the market. Such membranes are strong, rot resistant and extensible, but their draping properties are only moderate, and they melt under fire conditions.

In general, reflective and colour finishes are regarded as additional to the basic specification.

As remarked earlier there is little official guidance on specification in this field. Lacking a British Standard Specification, our Company has submitted its process for Agrément Board assessment. Here, with respect to the liquid asphalt membrane designated THE EVODE SYSTEM®, the Agrément Board through tests on the products and by examination of completed work of various ages assessed its service life at 15 years[4]. This estimate of durability refers to coating weights as shown in Fig. 10. Outside the U.K. some guidance can be found in specification[5,6] terms, but perhaps nothing so detailed as we ourselves have undertaken.

REFERENCES

1. ASTM D36; British Standard 4692; Institute of Petroleum Method IP 58/65.
2. ASTM D5; also IP 49/72.
3. British Standard 3690.
4. Agrément Certificate No. 76/362.
5. ASTM D1227, ASTM D1167.
6. Canadian Government Specifications Board 37GP14, 37GP8, 37GP2, 56GP13, etc.



(a) American Bureau of Mines method

FIGURE 1

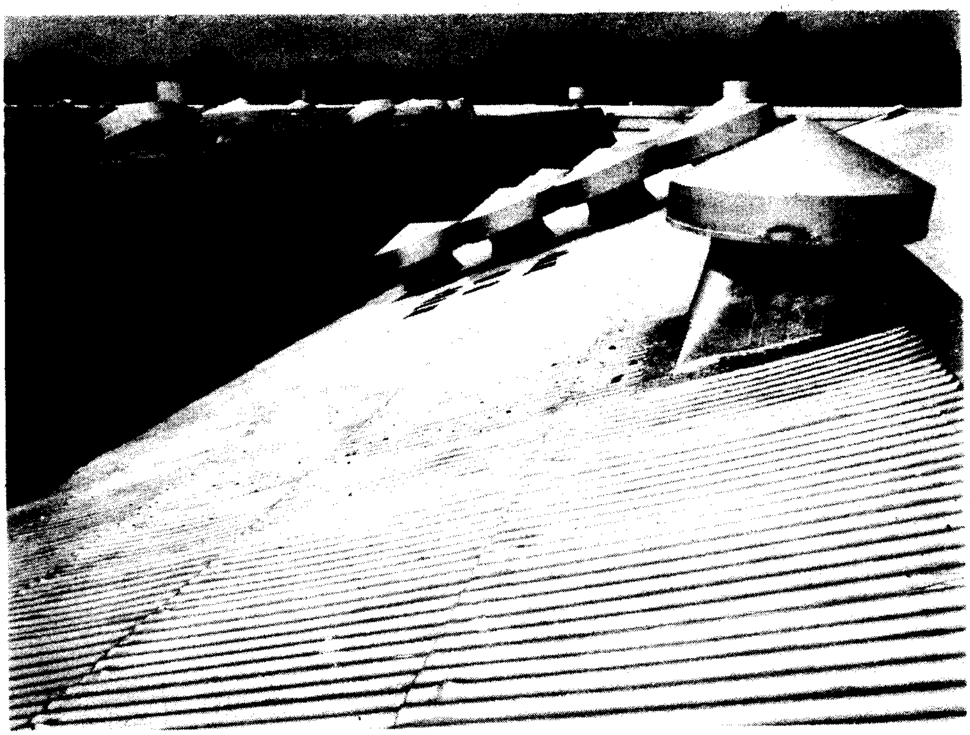


FIGURE 3 - A PART OF THE CORRUGATED ROOFING AT THE STANDISH, NEAR WIGAN, FACTORY OF H. J. HEINZ CO. LTD. WHICH HAS BEEN TREATED WITH THE EVODE SYSTEM AND FINISHED IN EVODE SILVERFILM.

Additive (A)		Natural Rubber	Liquid Polyiso-butylene	Hypalon 30	Butadiene/ Styrene (25% styrene)	Polyethylene wax (2000 mol. wt.)	Acrawax	Elvax 150	Butyl 035	Paraffin wax
Original Pen. of asphalt mm x10^{-1}	U	166	178	178	178	178	178	178	178	178
	B	21	19	19	19	19	19	19	19	19
Original Fusing Point oC	U	37	37	37	37	39	39	39	37	39
	B	82	84	82	84	82	82	82	82	82
Pen. with 3% A	U	119	163	51	120	128	114	137	80	102
	B	20	18	16	18	14	18	15	36	22
Fusing Point with 3% A	U	51.5	38	52	44	47	49	40	47	43
	B	96	86	85	-	90	98	100	80	77
Pen. with 5% A	U	100	172	58	109	117	102	104	71	95
	B	16	17	16	-	14	16	14	-	22
Fusing Point with 5% A	U	60	38	52	68	51	115	44	52	45
	B	110	90	89	-	107	113	110	78	76

U = Unblown

B = Blown

FIGURE 4

	Original Asphalt	With 2.0% Bentonite		With 55% Speswhite Clay		With 100% Slate Dust		With 35% Silica Sand	
		Straight Mix	Recovered from Emulsion	Straight Mix	Recovered	Straight Mix	Recovered	Straight Mix	Recovered
Fusing Point (°C)	51	56	65	60	77	60	67	50	57
Penetration mm x 10^{-1}	47	40	26	30	30	23	38	33	35

FIGURE 5 - EFFECT OF MINERAL FILLERS ON ASPHALT (FILLER PER HUNDRED PARTS ASPHALT)

FIGURE 6 – THE UNIQUE SPORTS DOME AT NACTON HEATH SECONDARY MODERN SCHOOL, IPSWICH, WHICH HAS BEEN TREATED WITH THE EVODE SYSTEM TO GIVE A SEAMLESS WATERPROOF ROOF FINISH.

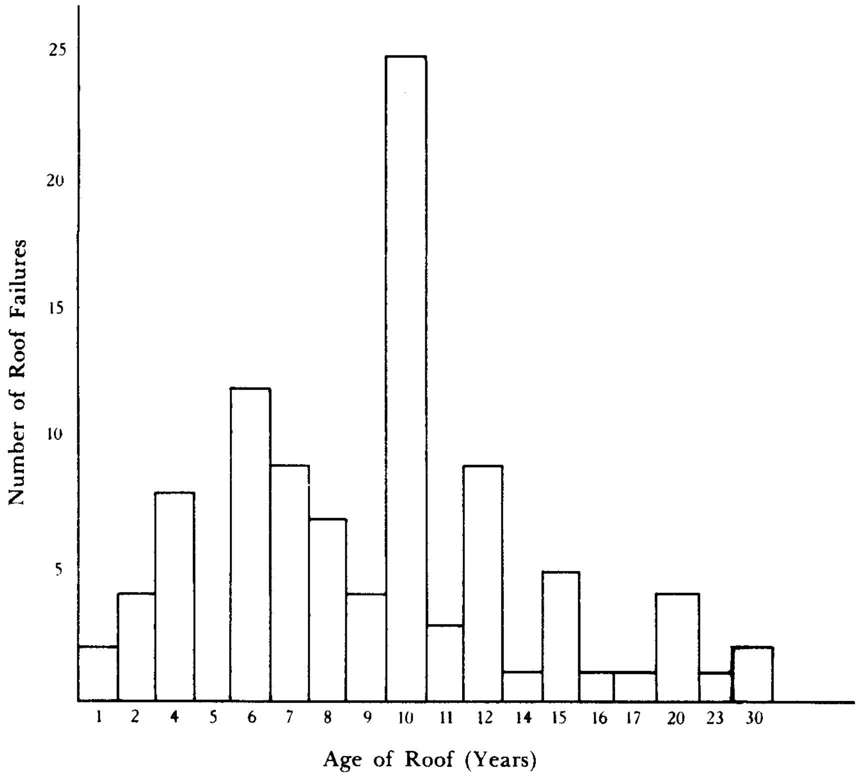


FIGURE 7

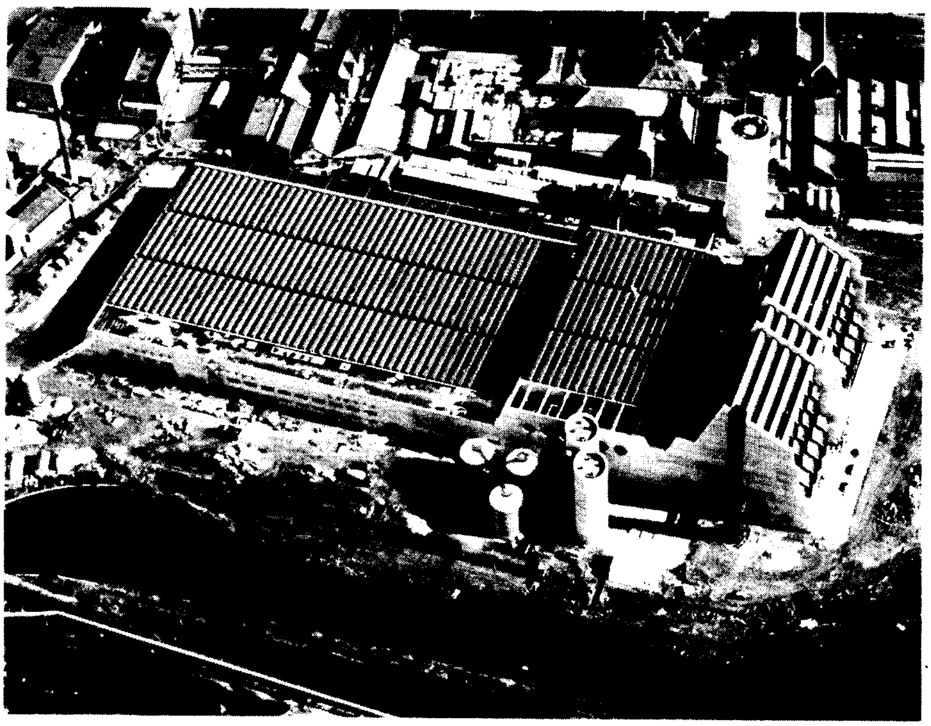


FIGURE 8 – AERIAL VIEW OF THE NEW AND IMPRESSIVE CARLSBERG BREWERY AT NORTHAMPTON SHOWING THE 30,000 SQ. METRES OF ROOFING WHICH HAS BEEN FULLY INSULATED AND COVERED USING THE EVODE ROOF WATERPROOFING SYSTEM.

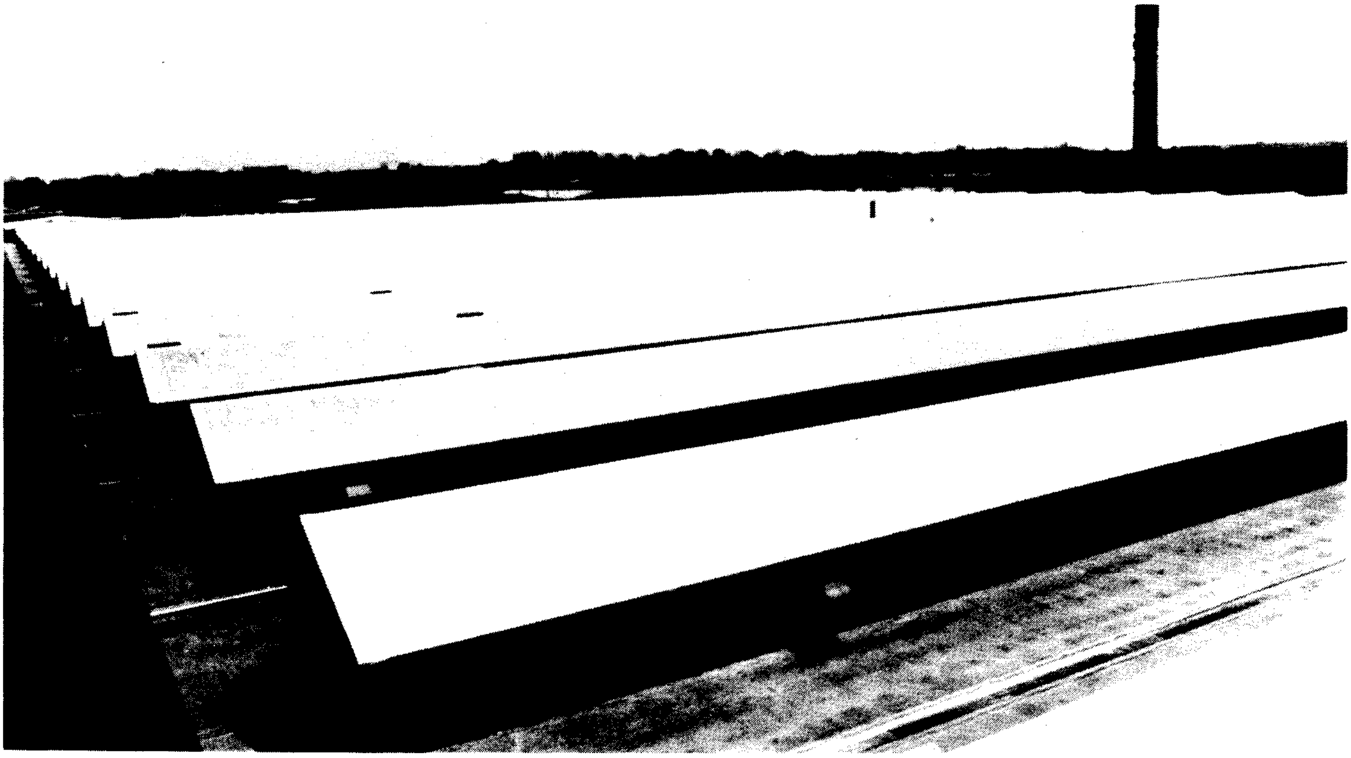


FIGURE 9 -- A TOTAL OF 19,900 SQ. METRES OF ROOFING COVERING THE PRODUCTION UNIT AT STANDARD TELEPHONES AND CABLES TRANSMISSION DIVISION, BASILDON, ESSEX, HAS BEEN TREATED WITH THE EVODE SYSTEM OF ROOF WATERPROOFING AND COLOUR FINISHED IN EVODE SILVERFILM.

Material	Average S.G.	Average Mass Solids	Average Volume Solids	Coverage Rates		Wet Film Weight		Dry Film Weight		Average Wet film Thickness		Average Dry Film Thickness	
		%	%	Yd^2/gal	m^2/litre	g/Yd^2	g/m^2	g/Yd^2	g/m^2	Thou	Millimetres	Thou	Millimetres
Filled asphalt emulsion	1.02	57	56	8	1.5	580	693	330	395	26.8	0.7	14.9	0.4
Filled asphalt solution	1.05	55	39	10	1.8	477	571	262	313	21.4	0.5	8.2	0.2
Asphalt emulsion primer	1.0	50	50	20	3.7	227	272	113	135	10.7	0.3	5.3	0.1
Asphalt solution primer	0.93	41	37	35	6.4	121	145	49	59	6.1	0.2	2.2	0.1
Reflective aluminium coating asphalt based	1.02	52	39	30	5.5	155	185	80	96	7.1	0.2	2.8	0.1
Pigmented asphalt emulsion, grey, green, red.	1.20	52	42	40	7.3	126	163	71	85	5.4	0.1	2.3	0.1

FIGURE 10