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United Nations Industrial Development Organization

Distr.
LIMITED

ID/WG.27/4
29 October 1968

ORIGINAL: ENGLISH

Expert Group Meeting on the Development of the Plastics Industry in Developing Countries

Vienna, Austria, 11 - 15 November 1968

ESTABLISHING AN INTEGRATED COATING AND ADHESIVES INDUSTRY IN DEVELOPING COUNTRIES[1/]

by

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1/ The views and opinions expressed in this paper are those of the author and do not necessarily reflect the views of the secretariat of UNIDO.

id.68-3524

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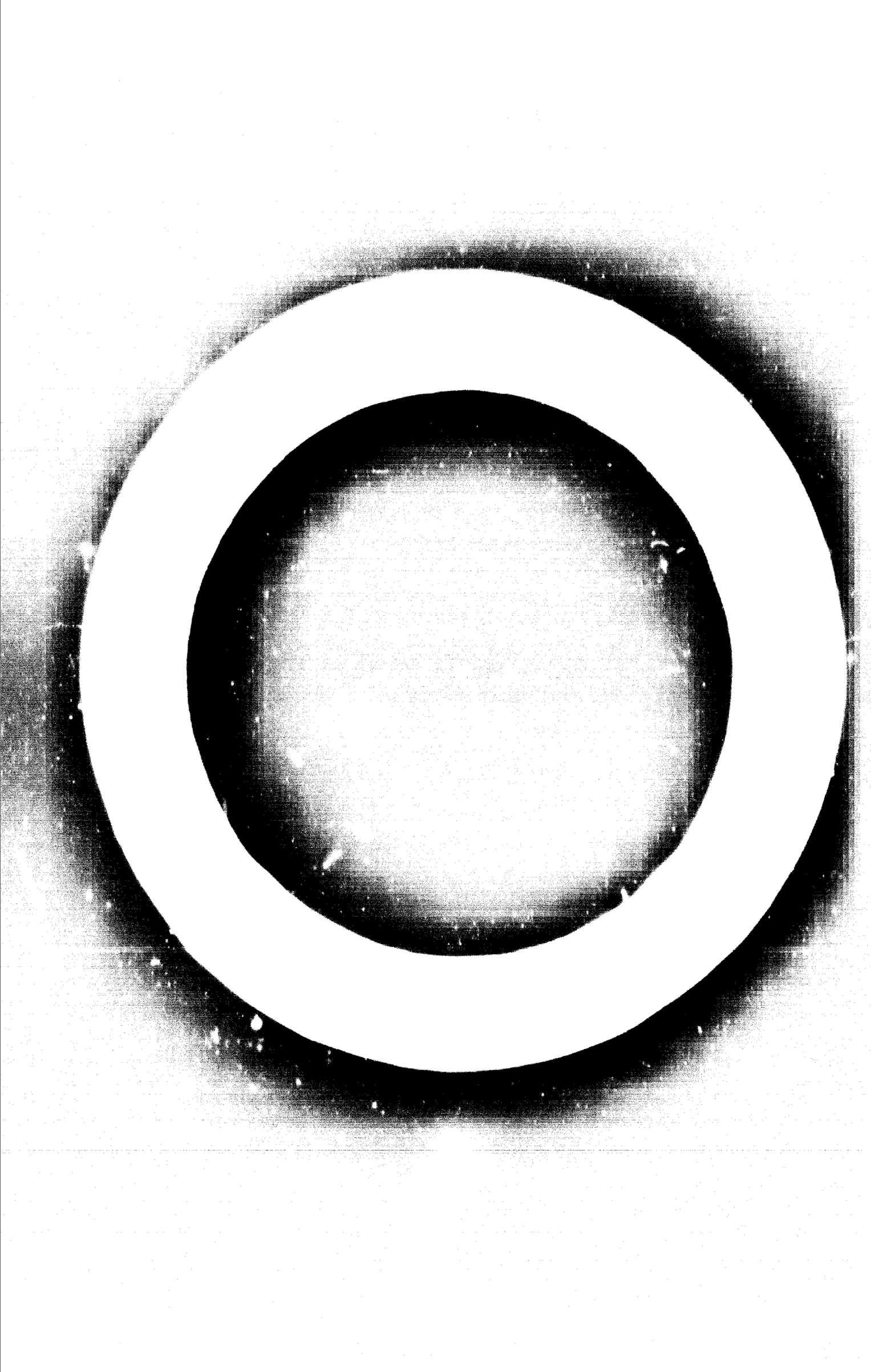


Introduction

1. A viable coatings and adhesives industry can be set up in even the smaller and less developed countries. Indigenous raw materials, especially starches and vegetable oils, can play an important role in production. In addition, petrochemicals derived from petroleum and natural gas can be the basis for the manufacture of a selected few resins which can take care of most of the needs of the industry. The best coatings and adhesives industry for a country is the one that fits into the industrial ecology of the region, utilizing its natural or manufactured raw materials and turning out products needed by the economy.

CHAPTER I COATINGS

2. The world production of coatings is approximately 3,000 million gallons. More than three fourths of the total is accounted for by the eight major producing countries the United States of America, the Union of Soviet Socialist Republics, the Federal Republic of Germany, Japan, France, the United Kingdom, Canada and Italy.

3. In the United States, the consumption of paints and other coatings has now reached about five gallons per capita, with a value at the manufacturer's level of about US$15. Among other highly industrialized countries, usage varies from one to four gallons per person. Discounting the eight major producing countries, the rest of the world, including the smaller highly industrialized countries, have an average consumption of less than one half gallon per capita. Consequently, for developing countries, the typical usage might be one fourth gallon per person, there are, however, wide variations.

4. Coatings have two main functions protection and decoration. They are applied over steel, wood, paper, concrete, textiles, leather, and many other types of substrates.

5. The essential ingredient of any organic coating is a polymer a resin or rubber that is capable of forming a continuous film, usually hard and tough.

6. In the industrial countries where a large variety of materials is available, twenty different polymers each have at least 1 per cent of the market for binders. Many other polymers are used to a lesser extent. Obviously, it would not be feasible to build a coatings industry in an emerging country with such a complexity of raw materials. Fortunately, however, it is not necessary to do so. It is possible to manufacture paints and other coatings that will satisfy nine tenths of the needs with only four basic materials, two natural and two synthetic: unsaturated vegetable oils, alkyd resins, vinyl acetate polymers, and starch. These materials need not be used in precisely the same manner in which they are employed in the highly industrialized countries.

7. Along with the organic binder, various other ingredients are necessary, e.g. pigments, fillers etc. These may also be selected according to availability. Thus, the finished formulations may be quite different from those in the United States.

8. As the coatings industry and its customers become more sophisticated, the number of binders can be expanded greatly with little or no change in the equipment for making the resins or compounding the finished paints and other coatings. Thus, an alkyd resin kettle lends itself to the manufacture of amino resins, phenolics, epoxy esters, and urethanes. A system capable of producing vinyl acetate polymer emulsions can also be used for acrylic resins and vinyl chloride resins (PVC). Similar equipment capable of withstanding higher pressures may be employed for styrene resins and a variety of synthetic rubbers.

9. If polyethylene resin is being manufactured for film and injection moulded plastics, a suitable grade can be utilized for the extruder coating of paper to make inexpensive waterproof containers for food. A petroleum refinery may have as a by product waxes which are also good paper coatings. Bituminous coatings can be made from petroleum derived asphalt, coal tar or natural mineral deposits, if these are available. In the unlikely event that casein (from milk) is available in excess of food requirements, it is a valuable coating constituent. Thus, local conditions of supply can determine the nature of the formulated coatings.

End uses

10. In the United States, about one half of all paints go into "trade sales" markets, that is to say, they are sold to home owners and painting contractors for the painting of homes and other buildings. Wood is a significant construction material in most parts of the United States, along with brick and concrete. Concrete is usually painted while brick and stone are not. In any case, home interiors are almost always painted, over such substrates as wood, plaster and paper covered gypsum wallboard.

11. In Western Europe, interior decoration practice is similar to that in the United States, but the exteriors are far more often unpainted brick.

12. In the developing countries, there is and will continue to be a variety of building materials. The increased use of paint on wood and concrete can result in a longer life for these structures. Furthermore, the use of white or light coloured paints is not only aesthetically pleasing but it also helps to radiate heat from the sun, keeping buildings cooler.

13. Besides architectural uses coatings go into a wide variety of industrial and maintenance applications. In the United States, iron and steel are the most important surfaces that must be coated in order to protect them from rust and to improve their appearance. Automobiles, machinery, metal furniture, ships, cans for food and beverages and pipe are some of the major outlets. In the developing countries there is little or no metal OEM (original equipment of manufacturers) to be coated but there is a considerable quantity of imported metal products whose useful life can be lengthened by periodic application of maintenance coatings.

14. In addition to the binder, the pigment can play a vital role in protecting metal parts from corrosion. The historic anti-corrosive pigment was red lead, but now metallic zinc is taking its place. These two materials will be discussed below in the section on pigments.

15. The largest volume coatings for paper are those which make the paper more readily printable. A pigment usually clay, is blended with a small proportion of binder in order to provide an opaque coating that can be printed on two sides and through which the ink will not penetrate. While not all grades of clay are equally good many types are adequate, along with other pigments widely distributed throughout the world.

Oils

16. Oils and fatty acids are widely distributed in the world. They are obtained from seeds, nuts, beans, fish, and as by products from the kraft wood-pulping process. These vegetable and animal oils are esters of glycerine with three fatty acid groups. For centuries they were the sole binders in most paints. They are still used by themselves, but are now employed to an even greater extent in conjunction with other resins, mostly alkyds, but also to make epoxy esters and oil-modified urethanes.

17. The unsaturated oils and fatty acids are liquids which harden by air oxidation. The oxygen causes the unsaturated molecules to link up with each other, a process called "polymerization". Sometimes the oils are used as obtained. At other times they may be boiled with metallic driers, "blown" by passing air through them or "bodied" in some other manner to make them more viscous and enable them to harden faster.

18. The ease with which the various oils are capable of hardening depends upon the extent and kind of unsaturated groups they contain. Those having the most unsaturated groups are usually the fastest to react. In the accompanying table, the oils are listed in the order of their reactivity. In addition, their usage in the United States is compared with that of linseed oil. Also listed are late 1967 quotations for the various materials. The prices fluctuate widely according to supply and demand.

Table

Oils used in coatings

Oil	Average unsaturations per fatty acid	Usage index (linseed = 100)	Price (cents/lb)
Tung	2.7	10	12.3
Oiticica	2.4	5	17.0
Linseed	2.1	100	13.2
Marine (menhaden)	2.0	10	9.5
Safflower	1.7	10	12.5
Soy	1.5	30	9.0
Tall oil fatty acids	1.4	30	7.5
Castor	1.0[a/]	10	22.0

a/ Can be increased to about 2.0 by dehydration.

19. Linseed oil, from flax seed, is obtained principally from Argentina and Uruguay. Other important sources are the USSR, India and the United States. Regions with similar climates could presumably also produce flax.

20. Tung oil, obtained from the nut of a tree, is also known as China wood oil. It is produced in China, the United States, Indonesia, the USSR, Burma, India, various South American countries (including Argentina, Brazil, Paraguay), and elsewhere in the world. The most favoured conditions include a warm climate with a cold season, but no frost. In the United States, tung oil production is subsidized by the Government, which pays the producer a "pool support price" of US$.24 per pound no matter what the market price may be. In many developing countries, however it could be a profitable crop and aid to an integrated coatings industry because it offers quick drying characteristics and provides a very hard coating.

21. Oiticica oil, also a nut extract, is obtained from Brazil. It competes with tung oil, usually at prices closer together than those indicated in the table for late 1967.

22. Marine oils are obtained from various fish, particularly menhaden, but also from sardine, mako, and pilchard. In view of their low cost, they are a useful partial replacement for linseed oil in many applications. Most of the menhaden oil used in the United States is obtained off the mid-Atlantic coast. There are no doubt many other regions in the oceans of the world where oily fish can be caught.

23. Safflower oil, extracted from the safflower seed, is a viable crop in several western states of the United States, and therefore, should be all the more attractive in developing countries with moderate climates. It grows wild in northern India.

24. Soy oil is available in China and several other countries of Asia. Soy beans are now grown in the United States, particularly in the North Central states. It is utilized as a food as well as a raw material for paints. With less unsaturation than linseed oil, it is also less reactive and is classified as a semi drying oil.

25. Tall oil fatty acids are by-products of the kraft or sulphate process for manufacturing paper and paperboard. Rosin, another by-product, is also useful in paints. The kraft process is utilized principally with pine, available in northern Europe, northwestern United States and Canada.

26. Castor oil, from the castor bean, has many uses besides coatings, such as soaps, medicines, and lubricants. The castor plant grows well in Brazil, southern United States, India, and other semi tropical areas.

27. Many other oils are used to only a minor extent in paints for various reasons. they may be too saturated, hence unreactive, more valuable as food, or not readily available. Important examples are the oils from coconut and cotton seed. Others include tobacco seed, walnut, sunflower, rape seed, perilla, isano, and mustard. It is feasible for developing countries to utilize various indigenous nuts and seeds as sources of unsaturated oils provided that proper modifications are made in the preparation of the coating materials in accordance with the chemical composition of the oils.

28. About one half of the oils used in finishes are the sole binder. In this case, it is necessary to employ linseed oil or other highly unsaturated oils, so that air oxidation will cause enough cross-linking of the molecules to convert the liquid into a solid film.

29. Linseed oil and similar unsaturated oils are usually bodied if they are to be used as the sole binders. This thickening process is accomplished by heating the oils in agitated kettles, often over an open flame. The cost of the equipment is moderate if the quality requirements are not too demanding. In the manufacture of blown oils, a stream of air is passed through the liquid at a moderately elevated temperature. On the other hand, stand oils are made by heating the liquid to much higher temperatures without an air stream.

30. The oil-based coatings have excellent adhesion to wood, but upon exposure to sunlight, with its ultra violet component, they tend to become brittle and yellow. The most unsaturated materials are the worst offenders. When pigmented (usually with titanium dioxide in the United States if the colour is white), the air oxidized oils are degraded at a much slower rate.

31. Alkyd resins, made partly from oils, have much less a tendency to yellow since there is less unsaturation. However, they are more expensive.

Alkyd resins

32. The alkyds, developed forty years ago, are the synthetic resins most widely used in the coatings industry, especially for metal coating. A typical alkyd resin contains three main constituents.

(a) A polyacid or anhydride, such as phthalic anhydride and maleic anhydride.

(b) A polyol (polyalcohol), such as glycerine or pentaerythritol;

(c) Fatty acids, usually unsaturated, such as tall fatty acids or those derived from oils: linseed, soy, castor, marine, tung, safflower, coconut, etc.

33. The most common alkyd resins comprise phthalic anhydride, glycerine and linseed oil, soya oil, or tall fatty acids.

34. To prepare an alkyd, the ingredients are heated with agitation, and the water formed by esterification is removed. A direct fired kettle (i.e. an open flame) can be used, but better results are obtained with a jacketed kettle containing the heat transfer medium in the jacket. In either case, there must be provision for mixing.

35. In modern equipment, a condenser is provided to cool the steam formed by esterification but some open kettles are also still in use. These, of course, are much cheaper.

36. For best control, the viscosity of the alkyd batch is kept low by incorporating a solvent, such as xylene. The solvent also facilitates the removal of the water of esterification.

37. The use of hydrocarbon solvents carries with it the danger of fire or explosion. Therefore, in a developing country where personnel may be inexperienced, it would be advisable to maintain the safer "fusion" solvent-free process, even though this requires higher temperatures and does not give as uniform a product.

38. The reaction is continued until the acidity of the contents in the kettle has dropped to some predetermined value. In the most modern plants, elaborate instrumentation is provided for optimum quality control. However, acceptable products can be made without these expensive accessories, using only the simplest devices and techniques for determining temperature, viscosity and acid number.

39. It is possible to complete two or three batches per 24 hour day. If we assume only one batch a day, a 1000-gallon kettle operated at 70 per cent of capacity for 250 days per year can make 170,000 gallons per year. (The 70 per cent filling allows room for subsequent thinning with solvent. Manufacturers in the United States often handle two or even three batches per day per kettle.) Initially this might be enough alkyd resin to serve the needs of several million people in a developing country.

40. Phthalic anhydride, the main polyacidic constituent of alkyd resins, is made either from naphthalene (from coal tar) or from orthoxylene (from petroleum). Glycerine can be a by product from the rendering of fats to make soap. In the United States, however, glycerine is a petrochemical, as is pentaerythritol.

41. Alkyds are classified according to the amount of oil they contain as follows:

(a) Long-oil alkyds:	more than 60 per cent oil,
(b) Medium-oil alkyds:	40 per cent to 60 per cent,
(c) Short oil alkyds:	less than 40 per cent.

42. The long oil and medium oil types are air drying, whereas the article being coated with a short-oil alkyd must be baked after application in order to complete the reaction. The long oil alkyds are tougher and withstand impact better, the short oil alkyds are harder and more scratch resistant. The drying oils constitute about half the weight of alkyd resins in highly industrialized countries, and could attain an even greater proportion in the developing countries. When one adds to this the glycerine which can also be derived from natural fats and oils, it is apparent that alkyd resin manufacture can be started with a minimum of imports even before a petrochemical industry has been established.

43. It is necessary, however, to dissolve the alkyd resin in hydrocarbon solvents in order to reduce its viscosity to a sufficient extent to enable it to be brushed or sprayed. The solvent is usually a mixture of aliphatic and aromatic hydrocarbons. The former are cheaper, and can be used exclusively for long-oil alkyds, short oil alkyds, however, require some proportion of aromatic solvents, such as toluene and xylene. The aliphatic solvents are available from petroleum refining processes; the aromatics can also come from this source or are by products in the manufacture of coke from coal.

Polyvinyl acetate

44. Vinyl acetate resins for paints are made by polymerization in emulsion. This process is used also for the manufacture of other paint resins, notably styrene butadiene and acrylic resins. Styrene butadiene resins are more hazardous to make however and their use in paints is declining because of inferior light resistance. The acrylics are significantly more expensive than the vinyl acetate resins. Therefore, it would be advisable for a developing country to concentrate on the vinyl acetate materials.

45. Vinyl acetate is a liquid monomer with a vinegary odour. It is made by reacting either acetylene (derived from coal or oil) or ethylene (from oil or natural gas) with acetic acid (now a petrochemical). It is one of the cheaper and more abundant of the monomers, the liquid building blocks that are combined to make solid polymers.

46. Two classes of vinyl acetate resins are in common use in paints: the homopolymers, in which vinyl acetate is the only building block, and the copolymers, in which vinyl acetate is combined with acrylates, maleates or fumarates. The homopolymer is easier to make and is cheaper, but its films can be brittle. An inexpensive way to overcome the brittleness is by adding a small amount of a liquid plasticizer, such as dibutyl phthalate. The copolymers of vinyl acetate with acrylate esters etc. provide a more sophisticated answer to the brittleness problem. The technology of copolymerization can be undertaken once the manufacture of homopolymers has been mastered.

47. In the United States, the size of the kettles for making polyvinyl acetate in emulsion is at least 2,000 gallons. However, it might be prudent for a developing country to begin with 1,000-gallon kettles. Since vinyl acetate is a combustible and volatile monomer, the kettles must be enclosed and jacketed for indirect heating. The emulsion is commonly made in approximately 55 per cent solids content, with water as a carrier. A small percentage of hydroxyethylcellulose or polyvinyl alcohol is employed as a protective colloid. A 1,000-gallon kettle could produce approximately 130,000 gallons per year if operated solely on a single shift using the redox process. Batch times in the United States vary from six to ten hours, making it feasible to double or even triple the output from one kettle by working around the clock. Thus, a single 1,000-gallon kettle might initially satisfy the interior house paint needs and some of the exterior needs of several million people.

48. In exterior paints, the vinyl acetate resins are particularly good for concrete and stucco.

Starch

49. Starch, as already noted, is the most widely used binder for the clay coating of paper. In the United States, starch is derived from corn. Also used are tapioca starch from Indonesia and potato starch from the Netherlands.

50. Starch is available, of course, from many other vegetables, including rice. The various starches differ in their properties, for example, the relative amounts of the crystalline amylose fraction and the amorphous amylopectin fraction. But it is possible to modify processing techniques so that most starches can be utilized.

51. The starches are treated with heat and/or acid catalysts to convert them into dextrins of various kinds: white, canary, and British gum. The white dextrins and the lighter types of British gums are the materials most widely used for colour coating, i.e. the clay coating of paper. In addition to clay, calcium carbonate, titanium dioxide (for whiteness) and/or satin white may be incorporated into the coating.

52. Among the materials competing with starch in paper coating are polyvinyl acetate, casein and soy protein. The starch is adequate for most printing paper, the other materials may be preferred for the coating of paper for cartons which are required to have some degree of water resistance.

Other polymers

53. As the technology of a developing country becomes more sophisticated, a larger number of binder materials should be examined. At first, it will be preferable to import these from the highly industrialized countries. Later on, at least some of them can be made domestically.

Phenolic resins

54. Phenolic resins (phenol-formaldehyde resins) are made by the reaction of phenol and substituted phenols with formaldehyde. Formaldehyde and phenol are made synthetically from petroleum, phenol is also a product of the distillation of coal tar. Various cresols and other substituted phenols are also employed in the manufacture of coatings, especially when solubility in cheap hydrocarbon solvents is desired.

55. The main outlet for these materials is in metal finishes, for both OEM (original equipment of manufacturers) and maintenance. They are used on ships, trucks, buses, cars, motors and other electrical equipment, e.g. wire enamels, and for miscellaneous metal decorating. They may either be primers or topcoats. They are being used to some extent in the water-borne primers being applied to metal articles by the new electrocoating techniques. Some phenolics, especially the modified oil soluble types, go into trade sales coatings to be applied to floors and other surfaces which are exposed to heavy traffic.

56. The phenolics produce hard, durable, chemical resistant surfaces. They may be slightly yellow to dark brown in colour, but this is usually not an objection

Amino resins

57. Amino resins are made by the condensation of urea with formaldehyde or melamine with formaldehyde, often followed by reaction with butanol or isobutanol, to give alkylated resins. The resins based on urea are less expensive, but those based on melamine have greater heat resistance. Both types have excellent colour.

58. Although they may be used alone, they are more often blended or reacted with alkyds, epoxies or acrylics, in order to produce hybrids that combine the best features of the various constituents.

59. Metal finishing is again the main use for these thermosetting coatings. They are applied to cans, machinery, appliances, autos and trucks, railroad cars, and metal furniture, and may also be used on wood furniture and other wooden articles. Shrink proof textiles are made by treatment with melamine resins.

60. These resins are easy to manufacture. Furthermore, urea resins are among the staples in the manufacture of particleboard and other adhesive-bonded wood products, which will be discussed below. An amino resin manufacturing operation could readily serve both the coatings and adhesives fields.

Acrylic resins

61. Acrylic resins may be prepared either in emulsion or in solution, and may be either thermoplastic or thermosetting. Thermoplastic acrylic emulsions, made by polymerization of acrylic esters such as ethyl acrylate, methyl methacrylate and 2 ethylhexyl acrylate, are utilized for trade sales paints which must have very good resistance to ultra-violet light. Since many of the developing countries are in the tropics, thermoplastic acrylic emulsion paints may have special merit as topcoats for outdoor structures, over wood and other substrates. However, they are somewhat more expensive than vinyl acetate paints, and will be at a further comparative disadvantage in the emerging countries since vinyl acetate polymers are dual purpose materials used extensively in adhesives as well as in paints.

62. The solution based acrylics, mostly thermosetting, are now being used extensively as topcoats in automobiles and appliances. Again, their excellent colour and colour retention when exposed to light are important justifications for their use. The thermoplastic types are comprised principally of acrylate and methacrylate esters. The thermosetting types may consist partly or primarily of styrene, along with acrylate esters and acrylic acid or acrylamide. Cross-linking is brought about by reaction with the acid or amide groups or their derivatives, using amino resins, epoxies, and other resins.

Styrene butadiene resins

63. Styrene butadiene copolymers are popular in the United States as trade sales coatings for interior use. In Europe they are considered to be too light sensitive. In countries with hot climates and intense ultra-violet exposure, this key disadvantage of styrene butadiene resins would be magnified. Furthermore, butadiene has such a high vapour pressure under polymerization conditions that it requires a high pressure reactor and is dangerous to handle. For these reasons, styrene butadiene resins are not recommended for the developing countries. In both the United States and Europe, they are used as binders for the clay coating of paper, but they can be replaced by vinyl acetate polymers which can be made with less danger and in less expensive equipment.

Vinyl chloride resins

64. Vinyl chloride resins, homopolymers and copolymers, are widely used for the top-coating of textiles and for the internal coating of food cans. The latter operation calls for copolymers that require rather sophisticated know-how. On the other hand, the PVC resins for fabric coating would be more within the competence of technologists in developing countries.

65. The resins are applied to textiles in the form of plastisols and organosols. A plastisol is essentially a dispersion of resin in a high proportion of plasticizer, usually phthalate and adipate esters. An organosol is similar, except that some of the plasticizer is replaced by volatile solvents. Vinyl-coated fabrics go into upholstery, clothing, automobiles, washable wall paper, and many other end uses.

66. Vinyl chloride is among the cheapest of monomers, with the exception of the olefins, ethylene and propylene. The polymerization of vinyl chloride is well understood and "package plants", completely designed and instrumented, are available from many sources.

Epoxy resins

67. Epoxy resins are among the most useful of the newer base materials for both coatings and adhesives. They have excellent adhesion to metal and outstanding corrosion resistance, and consequently are used for auto primers, can coating, marine coating, appliances, maintenance finishes etc. Two types are available. In the epoxy esters the epoxy resin is reacted with unsaturated fatty acids to give a one component, solution based coating that dries by air oxidation. In two-component epoxies, the epoxy resin is mixed with a reactive amine hardener shortly before application to the surface. These are more expensive and more troublesome to use, but offer far better mechanical properties and corrosion resistance.

68. The technology of making epoxy resins is quite difficult and requires an extensive capital investment. Therefore, it does not appear feasible for a developing country to go into the manufacture of these materials. On the other hand, imported epoxy resins can be easily utilized for the formulation of coatings and adhesives.

Pigments

69. A paint may contain as many as a dozen different ingredients, the two most essential being the binder and the pigment. In the United States, the most important pigment for paints is titanium dioxide of the rutile type. About two thirds of paint pigments are titanium dioxide or other whites.

70. Modern technology for producing titanium dioxide from ilmenite is beyond the scope of most developing countries at the present time. Although the United States is the leading source of titanium containing ores, these ores are also found in other parts of the world, notably Africa. Rutile ore itself is available in Sierra Leone.

71. Before the development of modern techniques for making titanium dioxide, the white lead pigments were much more prominent. These are still used to a minor extent in the technologically advanced countries, and have the advantage of providing a very thorough "dry", i.e. hardening, with unsaturated oils. The largest deposits of lead are found in North America and Australia, but lead is also available in various Asian, South American and North African countries, as well as in Europe. The lead compounds of greatest interest for coatings are white lead itself, basic sulphate white lead, and basic silicate white lead.

72. For corrosion resistance, the leading pigments are red lead, basic lead silico-chromate, zinc yellow, and metallic zinc. Red lead is simply lead oxide made by roasting litharge. Zinc yellow, also known as zinc chrome, is a chromate pigment. Zinc deposits are often found in the same locations as lead ores.

73. The International Lead and Zinc Study Group of the United Nations has published a report on lead and zinc consumption. Among the Asian countries outside of Japan, India is the leading consumer of lead, with consumption for each of the past five years in excess of 40 000 metric tons. Mexico, Argentina and Brazil are the leading Latin American consumers.

74. Zinc is being utilized in sheet galvanizing plants in Argentina, Ethiopia, Kenya, Malaysia, Mexico, Brazil, the Democratic Republic of the Congo, Peru, the Philippines, Nigeria, the Republic of Korea, the Republic of China, Thailand and Venezuela. In addition, there are continuous strip galvanizing plants in Argentina, India and Mexico. Roofing, siding, conduits, fuel drums and water storage tanks are principal uses for the galvanized sheet.

75. Developing areas can receive advice on utilization of zinc and lead from the Zinc Development Association and the Lead Development Association in London, as well as the Indian Lead Zinc Information Centre in Calcutta.

Examples of development

76. According to a 1961 review by the Agricultural Information Division on paint in the Philippines (AID 0409), there were eighteen paint plants, fourteen of which employed 829 workers in 1960. Five of these fourteen plants were Philippine owned, while three others were Philippine controlled. The others were controlled or owned by American, Swiss, Chinese or British interests. Local raw materials employed included red oxide from iron scrap, inert pigment extenders from mineral mine deposits, alkyd resins, and local drying oils: Lumbang oil, dehydrated castor oil, and even kapok oil.

77. In Somali, a 1961 study (AID 0247) indicated a need for a working capital of US$34,300 to produce 25,000 gallons of paint in 250 working days of one shift each with a staff of twelve employees. White lead was to be the principal pigment. The projected sales price was US$4.43 per gallon. The equipment required, at a delivered cost of US$12,800, included two pebble mills, two portable paint mixers, twenty drums, three hand trucks, one platform scale, laboratory control equipment, miscellaneous scoops, ladles, measuring tins, maintenance tools, and spare parts.

78. A plant of similar capacity has been proposed for Honduras (AID 1/05/02473). A smaller capital investment, US$6,240, is envisioned, but with less equipment: one pebble mill, one portable paint mixer, ten drums, and two hand trucks.

79. From a 1966 pre feasibility study of an expanded paint products industry in West Africa (AID 3/00/02623), one calculates an average consumption of paint per person per year varying from one pound or less for Nigeria and Sierra Leone to two pounds or more for Ghana, the Ivory Coast, and Senegal. Usage includes automobile lacquers and baked enamels for vehicle assembly plants in Senegal, Guinea, the Ivory Coast, Ghana and Nigeria, furniture and office fixtures, and marine finishes.

80. For emulsion paints, polyvinyl acetate is imported in dry form from Europe, then redispersed with the aid of a Cowles Disperser. Oil-based paints are made from drying oils, such as linseed oil, tung oil or castor oil, or from resin modified drying oils or semi drying oils, or rosin modified oil. Both air drying and baking types are in use.

81. The formulations are mostly of European derivation and are not designed to take advantage of indigenous materials. There is a dearth of competent paint technologists able to make effective changes in formulation.

CHAPTER II ADHESIVES

82. As with coatings, the United States probably leads the world in adhesives usage per capita: approximately US $ 4 per year at the adhesives compounder's level. Although the evidence of coatings usage is all around us, adhesives are generally not visible in the finished product. They are nevertheless all-important constituents for a score of products, e.g.:

Plywood
Particleboard
Packaging
Water-moistened tapes, labels and envelopes
Pressure-sensitive tapes and labels
Tires
Brake linings
Other automobile components
Shoes
Books
Foundry sand moulds
Coated and bonded abrasives
Building components
Consumer and other small package adhesives
Mobile homes
Aircrafts
Non-[illegible] fabrics
Flocked fabrics

83. A developing country would be unlikely to have such applications as aircrafts and automobiles. On the other hand, there should be good opportunities in many countries to develop at least the various wood industries that make use of adhesives.

84. Since many applications utilize more than one type of adhesive, the adhesives industry will be considered on the basis of end products rather than materials.

Wood products

85. In the United States, plywood is made mostly from softwood, particularly the Douglas Fir that grows in the northwestern United States and southwestern Canada. More recently, the southeastern states have become sites for plywood manufacture, utilizing fast-growing Southern Pine. The favoured resin for American plywood manufacture is phenol formaldehyde, which permits the manufacture of a grade of plywood that can stand heat and humidity, alone or in combination.

86. Grades of plywood suitable for indoor use, where they will not be exposed to excessive humidity, are made in the United States from plywood veneers with urea formaldehyde resin as adhesive. Some imports of cheaper grades of plywood have even used starch as the binder.

87. Many woods can be utilized for plywood, including the hardwoods, such as Philippine mahogany. Thus, it is possible for almost any country with forests to enter into the manufacture of plywood.

88. Various other materials have been or can be used: casein, soy flour mixed with animal blood, polyvinyl acetate. However, phenol formaldehyde gives by far the best quality of product, and is especially desirable if the plywood is to be used outdoors or below grade. In tropical countries, the necessity for good durability of phenolic resins becomes all the more imperative.

89. Both phenol and formaldehyde are derived petrochemically in the United States. Phenol is also available as a product of the coal tar industry.

90. Softwood plywood is used primarily in buildings, e.g. wall panels, flooring, roofing and so on. Hardwood plywood is utilized in furniture manufacture where the beauty of the top veneer is a major consideration.

91. Particleboard makes use of urea formaldehyde resins to bond wood particles, usually flat chips. Many types of wood have been utilized and, in some factories, even blended. The particleboard, three quarters of an inch thick, is a useful underlay over which plastic tile can be applied. With suitable veneers it can be fashioned into furniture which is dimensionally stable as well as attractive.

92. Other wood products which make use of adhesive resins include hardboard, laminated doors, edge-glued and end-glued lumber. The related paper industry makes use of adhesive resins for wet strength and to provide honeycombs for laminated doors and partitions.

93. For gluing furniture joints, animal glue was the standard adhesive until a few years ago. The hide glues are strongest, the bone glues cheapest. Fluctuating supply and price have caused many animal glue users to shift to other materials. However, in a thinly populated country, where the ratio of animals to humans is high, the animal glue industry should be a profitable by-product of the meat industry.

94. In the United States vinyl acetate resins are rapidly replacing animal glue for furniture, bookbinding and various other uses.

Packaging

95. In the United States, packaging is almost as important as the wood industry as an outlet for adhesives. Food and other articles are placed in paper bags, bottles or cans with adhesive-bonded labels, set-up boxes, envelopes and paper tubes. Smaller containers go into corrugated cartons made with adhesives, which themselves must be sealed with adhesives. To these can be added laminates, cigarettes, paper-backed tapes (both pressure-sensitive and re-wettable), postage stamps, fibre drums and so on.

96. As industry grows in the developing countries and as channels of distribution become more complex, there will be increased need for containers and the adhesives with which to make or seal them.

97. The main adhesives for packaging, in the developing countries as in the United States will certainly be starch and dextrin. Animal glue, if available, can be most useful, especially as an adjunct to dextrin in the manufacture of re-wettable gummed products. Where moisture resistance or high strength is required, polyvinyl acetate will be the preferred adhesive.

Building products

98. Many types of adhesives are used in the building industry of the United States. Here, as in a developing country, cost is a key criterion for the selection of adhesives.

99. One of the cheapest building materials in the United States, gypsum board, is made by bonding hydrated calcium sulphate, which is widely available, with the aid of dextrin and other inexpensive adhesives. Additional adhesive is required for the application of the paper facings, sometimes for replacing nails in fastening the board to the studs, and also for finishing the wall to present a smooth appearance. For the latter purpose, both casein-based joint cement (dry) and polyvinyl acetate joint cement (wet, ready-mixed) are employed.

100. Glass wool insulation is still another adhesive-bonded product. Phenol formaldehyde resin has been found to be the cheapest adhesive that meets the needs, resistance to heat and humidity, of this product.

101. Resilient flooring, typified by vinyl asbestos tile, has been growing in the United States as a means of covering concrete, particleboard or wooden subflooring. A variety of adhesive compositions are employed, many of them based on petroleum-derived asphalt. Natural bitumens would also undoubtedly be serviceable in this application.

Shoes

102. In the developing countries, particularly those with cooler climates, the shoe industry will be turning more and more to adhesives for making products similar to those used in the United States. Adhesives are used for attaching thin soles to uppers, for bonding fabric to leather and leather to leather in the uppers, and for manufacturing built-up heels and boxtoes. Neoprene rubber and natural rubber are two of the most important adhesive materials. The rubbers are utilized both as solvent cements and as latexes. Natural rubber is likely to be available in at least some of the developing countries. It is an outstanding adhesive when properly formulated, and should be adequate for most applications in shoes.

Examples of development

103. Borden Chemical Company has had considerable experience with the manufacture of adhesives in South America. In Brazil they started with casein glues, then proceeded to vinyl acetate-based adhesives, phenol formaldehyde and epoxies. Rhodesia has a pilot plant for the production of vinyl acetate monomer, but it has been necessary to import this essential intermediate from the United States. Epoxy resins are imported from Europe. The Bungeborn Company makes phenol from benzene supplied by Petrobras of Brazil.

104. Borden obtains formaldehyde from methanol, which it makes from bunker C oil by oxidation. They are now progressing to naphtha reforming for making the methanol. In Argentina, on the other hand, formaldehyde is made from natural gas.

105. The use of casein in adhesives is decreasing even in Argentina, formerly the leading exporter of this product. Casein is still being exported to the United States as a binder for the clay coating of paper, but there, as well,

it is being replaced by soya protein and/or synthetics. The chief reason for the decline of casein as an industrial raw material is the increased consumption of milk as food.

106. Professor Ben S. Bryant of the University of Washington has provided interesting information on the feasibility of even very small adhesives operations for the manufacture of plywood and other bonded wood products in China (Taiwan).

107. There are about nineteen plywood plants currently active in Taiwan. These plants peel Philippine mahogany-like woods brought in from the Philippines and Malaysia, which are largely exported in the form of plywood and associated millwork lumber to the United States. Currently, Taiwan enjoys about one fifth of the American market for imported Philippine mahogany plywood manufactured in the Far East. The Republic of Korea and Japan are equally large producers. Because of the type of plywood manufactured, interior, type II and type III (non-water resistant bonds), nearly all of the adhesive used is extended urea resin.

108. Since wheat is not produced locally and is expensive to import, the urea resin is not extended with wheat flour as it is in the United States, but rather with cassava flour. This is a starchy, tuberose root that is cultivated in the Republic of China and elsewhere in countries of Southeast Asia. It is a relative of tapioca and furnishes the primary local source of starch.

109. The only technical man in some plywood plants is likely to be the glue mixer, who has his own formulation for plywood, probably not shared with the other plants.

110. Taiwan is a principal source of urea in the Far East as a result of its low-cost hydroelectric power. Urea fertilizer is exported. Phenol, on the other hand, is imported from Japan. With the growing petrochemical industry in Taiwan, however, there are local sources of formaldehyde available. While most plywood plants and some board plants manufacture their own adhesives, there are two plants not connected with plywood manufacture which produce the following resins: urea formaldehyde, melamine formaldehyde, epoxy, vinyl acetate polymer and phenol formaldehyde.

111. In the Philippines, two American companies have plants for making liquid phenolic resin. In addition, powdered phenolic resin is imported from the Federal Republic of Germany.

112. In Brazil, one of the largest forest products companies makes its own phenolic resin and phenolic paper glue line for gluing aluminium foil to the surface of corrugated plywood. This company also makes a phenolic impregnated paper overlay for plywood to be used for concrete forms.

Conclusions

113. One can see that in both coatings and adhesives it is possible to take advantage of the materials and resources of the region to make products which can be utilized within the region. The coatings and adhesives technologies of developing countries can be greatly simplified compared to those employed in the United States. The economics of production on a small scale are favourable for polyvinyl acetate, alkyd resins, phenolic resins, starches and dextrins and animal glues. With the aid of unsaturated oils and natural rubber, if these are available, one can adjust the technology to make almost all the desired end products.

114. Initially, the petrochemicals (and/or coal chemicals) can be imported. As a petrochemical industry is built up in the region, phthalic anhydride, vinyl acetate, phenol and formaldehyde can be among the first intermediates to be produced.

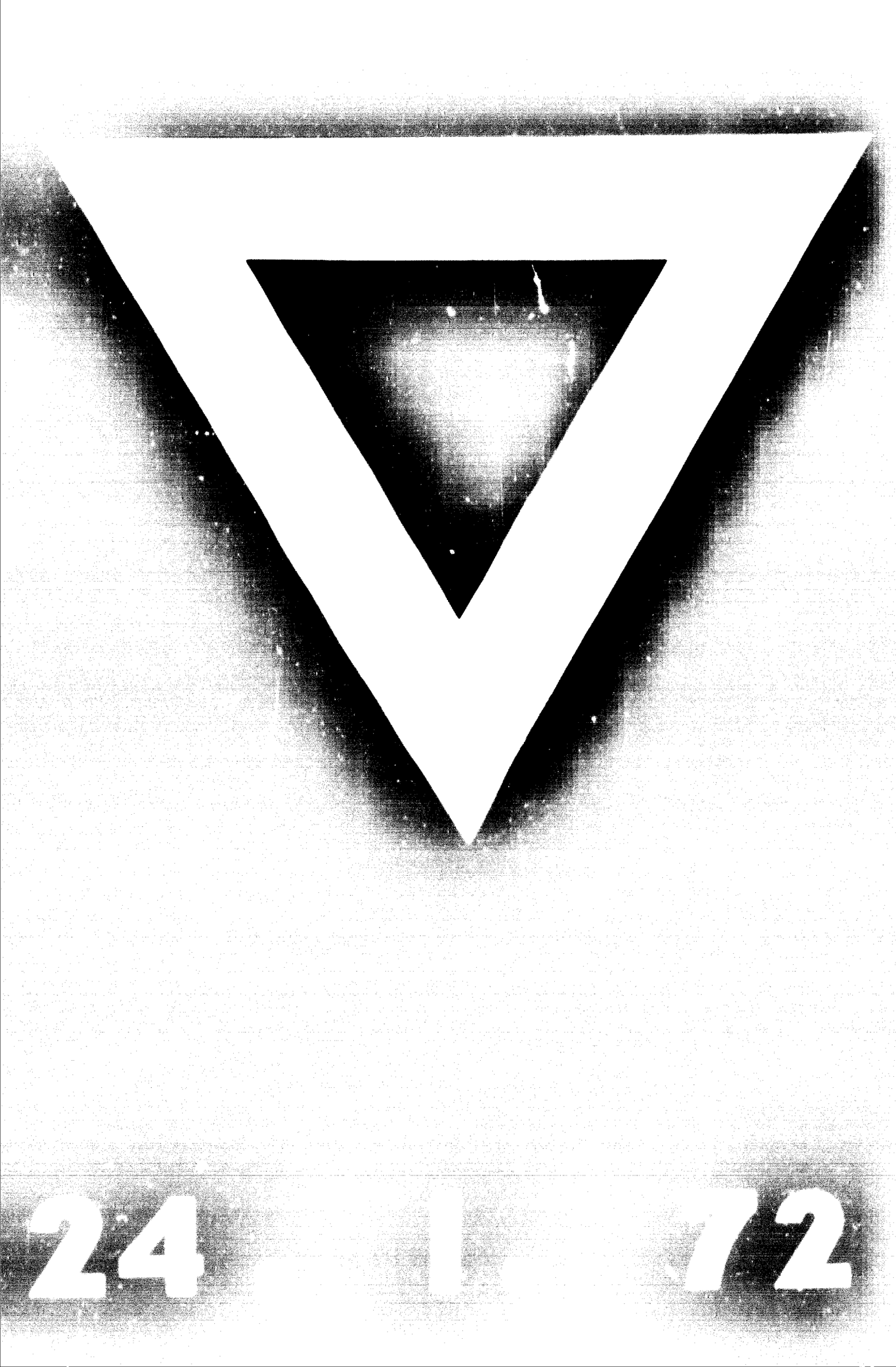
115. Coatings and adhesives are only two phases of the polymer industries, along with plastics, fibres, and elastomers. The equipment and technology for making these few resins is applicable for many other polymers and end products.

116. Where does an entrepreneur or a government in a developing country go for technical assistance in building a coatings or adhesives industry? There are two main sources of information.

117. First, many chemical construction firms have package plants, so-called "turn key operations", in which everything is prepared so that the user, in theory at least, need only turn the key to start the operation. Obviously, the ease with which such a plant can be put into operation and can be made functional will depend upon the experience and skill of the people who must operate it.

118. The other source of assistance, overlapping and complementary to the first, is the consulting firm with relevant experience. A list of chemical consultants qualified to handle a particular topic may be obtained from the Association of Consulting Chemists and Chemical Engineers, Inc., 52 East 41st Street, New York, New York 10017.

119. The chemical construction companies are usually more able to provide plants for the manufacture of phthalic anhydride, vinyl acetate, phenol, and other basic chemicals. On the other hand, the consultants are better adapted to provide know-how on manufacturing formulated products, such as coatings and adhesives, and especially on taking advantage of local raw materials.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