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UTILIZATION OF NATURAL GAS FOR SYNTHETIC FIBRE PRODUCTION*,

SI/BGD/74/322,

BANGLADESH,

Terminal report.

Prepared for the Government of Bangladesh by the
United Nations Industrial Development Organization
executing agency for the United Nations Development Programme

Based on the work of Robert D. Evans, synthetic fibre and polymer expert

United Nations Industrial Development Organi ation
Vienna

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Explanatory notes

The monetary unit of Bangladesh is the taka. During the preparation of this report the dollar value declined very sharply and the following conversion factors were used $US 1 = taka 13.8.

A period (.) is used to indicate decimals and a comma (,) is used to distinguish thousands and millions. Other abbreviations are m=meter, m^2=square meter, m^3=cubic meter, t=metric tons, d=denier, lb=pounds, M=thousands, MM= millions.

The following symbols are used to denote chemical compounds:

AN = Acrylonitrile
PAN = Polyacrylonitrile
PVC = Polyvinyl Chloride
PVA = Polyvinyl Alcohol
PVAc= Polyvinyl Acetate
DMA = Dimethyl Acetamide
DMF = Dimethyl Formamide

The following abbreviations are used to denote certain companies:

BCIC = Bangladesh Chemical Industries Corporation
BTMC = Bangladesh Textile Mills Corporation.

Mention of company names and commercial products does not imply the endorsement of the United Nations Industrial Development Organization.

Contents

Page

INTRODUCTION 1

SUMMARY 2

FINDINGS ....

General comments 5

PVA fibers 16

PVC fibers 23

Acrylic fibers ....

Marketing factors 29

Economic factors ....

ACRYLIC FIBERS FROM NATURAL GAS 82

CONCLUSIONS AND RECOMMENDATIONS 87

Annexes

I. Job Description 90

II. Market statistics 95

References 99

Tables | Page

1. Fiber Intermediates and Sources for Major Fibers. 7

2. Projected Consumption of Synthetic Fibers in Pakistan. 12

3. Recommended Planned Production Capacity for East Pakistan. 13

4. Fiber Intermediates for Acetylene Based Fibers. 15

5. Production of "Other" Fibers in Japan 1971-77. 20

6. Production of PVA Fibers in Japan 1974-77. 21

7. World Production of "Other" Fibers in 1977. 25

8. Japanese Production of PVC Fibers. 26

9. World Production of Man-Made Fibers. 37

10. World Production of Man-Made Fibers by Fiber Type. 38

11. Consumption of Acrylic Fibers in the United States by End Use. 43

12. Market Share Held by Acrylic and Other Fibers in Selected Textile Applications. 45

13. Market Distribution of Acrylic Fibers in the U.S. Textile Industry. 47

14. Consumption of Fibers in Japan 1976. 50

15. Consumption of Acrylic-Cotton Blends in Japan. 52

16. Cost Plus Return for Major Products from Gas Oil Crackers 69

17. Acrylonitrile Production Costs. 70

18. Acrylic Fiber Production Costs. 79

19. Plant Investments. 83

20. Plant Investments-Monomer. 84

Introduction

Bangladesh has a large and rapidly expanding population with the population growing at a rate of 2.8% per year. The per caput consumption of textiles is only 5 yards and is among the lowest in the world. Its comparatively large textile industry supplies only about 85% of its textile requirements and is based on imported cotton and viscose staple with the remainder imported yarn and finished textile product. The value of these imports was estimated at $95 million in 1977-78, and is a serious drain on foreign exchange. The Government is planning on expanding per caput consumption to 10 yards by 1985 and with the anticipated growth in population this increased textile consumption amounts to an annual growth of 18%.

Since the textile industry is based on cotton and cotton-viscose blends any synthetic fiber produced domestically should be based on blends with cotton. Existing man made fiber production is entirely continuous filament and consists of about 6,000 tons of viscose filament capacity and a very small nylon 6 fiber plant. The Government is very desirous of reducing this drain on foreign exchange by manufacturing synthetic fibers based on its available supplies of natural gas. This report covers an analysis of the production of synthetic fibers based on Bangladesh natural gas. The study executed under UNIDO/UNDP Project SI/BGD/74/822/11-01 (32.1H) started on July 16, 1978 and ended on September 15, 1978.

Summary

Bangladesh has an established textile industry comprising two distinct sectors, Bangladesh Textile Mills Corporation, BTMC, and the very large cottage weaving industry represented by the Hand Loom Board. Bangladesh Textile Mills Corporation produces spun yarns from imported cotton and viscose rayon staple in some 52 mills and weaves about 15-20% of its yarn production in 26 integrated mills. There are 14 mills with dyeing and finishing equipment. The huge cottage industry, roughly estimated at 125,000 hand looms, dyes yarn and weaves yarn into fabric for largely local distribution. The production of spun yarns by BTMC is insufficient to meet demands and additional spun yarns and textile products are imported.

The per caput consumption of textile products per year is only 5 yards and the Government is hopeful of increasing this to 10 yards in the 1980's. With the increasing population and the increase in per caput consumption the projected growth rate per year for textile products is a very substantial 18%. Currently the imports of cotton, viscose rayon, spun yarns and textile products represents a $ 95 million drain on hard won foreign exchange and the hoped for increase in textile products consumption represents an even greater drain on foreign exchange.

Bangladesh has two very small man-made fiber plants producing viscose rayon and nylon 6 continuous filament yarns. Local mills are not well equipped to use these yarns and part of the production is exported. Since the entire textile industry is based on spun yarns and largely on cotton, staple fiber which could be used as such or blended with cotton would be the preferred type of man-made fiber.

In order to reduce the drain on foreign exchange it has been the hope for many years that Bangladesh's methane rich natural gas could provide a basis for producing synthetic fibers. To this end at least three major studies have recommended the conversion of methane to acetylene and the subsequent preparation of fiber intermediate therefrom. The several synthetic fibers which have been proposed include Polyvinyl Chloride or PVC, Polyvinyl Alcohol or PVA and Polyacrylonitrile or PAN. These reports have been reviewed and the suitability of the proposed fibers for use in Bangladesh evaluated. Of the three proposed fibers only one, acrylic fiber or PAN, can be considered a major fiber.

PVC is a specialized fiber with very marginal fiber characteristics. In the United States its use is limited to the manufacture of tea bags while the limited production in France is used chiefly in underwear. It has been used in heavy yarns or monofilaments for outdoor furniture. No broad scale use in Bangladesh can be anticipated.

PVA fiber is produced almost solely in Japan where its production and use are declining and are now at about 50% of their peak. It has been used primarily in industrial or related type applications. Its uses in apparel are handicapped by its poor properties at high humidities. The process of producing this fiber are slow, complicated and costly. The fiber is not recommended for production in Bangladesh.

Acrylic or PAN is one of the major synthetic fibers. As such it has many excellent fiber characteristics particularly in those applications where wool was formerly used. It is an outstanding and preferred fiber for sweaters, pile fabrics and blankets. Its use in broad woven fabrics for apparel is very limited and its use in blends with cotton are insignificant. These latter two areas are major markets for Bangladesh. Although it is a major fiber it is not a major fiber in those countries with a hot and humid climate.

The production of acrylonitrile, the major fiber intermediate for acrylic fibers, from acetylene is an obsolete and costly process and has been replaced world wide by the much cheaper ammoxidation of propylene process. The cost plus return of producing acrylonitrile by this process and the low investment cost of 17 ¢ per annual pound in a medium size efficient plant make this process much more attractive than the obsolete acetylene route.

The cost of producing acrylic fibers in Bangladesh using imported monomers has been estimated and with modest capital charges can be competitive with imported staple. This route would be the preferred route for manufacturing acrylic fibers in Bangladesh. Since acrylic fibers would have only limited market acceptance in Bangladesh the production of acrylic fibers in Bangladesh is not recommended.

A study of the possible production of other man-made fibers particularly polyester fibers using imported terephthalic acid and ethylene glycol, is a viable alternative to the production of fibers based on natural gas. As a second choice a study of the possible production of polynosic fibers using imported and/or domestic raw materials has been suggested.

GENERAL COMMENTS

Although the per caput consumption of textile and fiber products in Bangladesh is probably the lowest of any country in the world the large and growing population coupled with a hopeful increase in per caput consumption would indicate that the demands for fibers products will continue to increase in the immediate future. With the exception of a very small production of filament rayon by Karnaphuli Rayon and Chemicals at Chittagong using pulp derived from bamboo and an even smaller production of nylon 6 filament by Pylon Industries Ltd. at Chittagong using imported nylon 6 chips, essentially all of the textile products available in Bangladesh are based on imported fibers, yarns or textile products. Apparently Bangladesh does produce a small amount, reportedly 3000 bales, of very short staple cotton and a small amount of silk. The primary import is cotton which is spun into yarns and a relatively small amount, estimated at 15-20% of total yardage produced is woven by power looms. There are 52 cotton mills in operation currently. Half of these mills produce yarns and weave while the remainder are yarn spinning mills. Presumably there are no non-integrated weaving mills. Of the 26 spinning and weaving mills 14 have finishing facilities. There are ten yarn spinning mills under construction and there are supposedly some 4 or 5 special mills devoted either to producing synthetic fiber fabrics or some special types of fabrics. There is one woolen mill but it reportedly operates only about 3 months per year.

Prior to independence Pakistan was the major source of cotton used in Bangladesh but all cotton for apparel and yarn must now be imported. This report will consider only the types of synthetic fibers which can be produced from Bangladesh's natural gas. It will review the reports which have been prepared in the past on this subject and as background information will review the location, production and use of these fibers in the world. It will examine the utilization of these staple fibers as possible blending fibres with cotton for use in Bangladesh's hot and humid climate. It will include information on costs of producing at least one of these fibers.

In order to determine the feasibility of producing synthetic fibers from natural gas it will be necessary to review the fiber intermediates which are required to produce the several synthetic fibers. In addition, the basic petrochemicals from which these fiber intermediates can be prepared and ultimately the source of the feedstocks to prepare the basic petrochemicals become important. This information is summarized in Tables 1 and 4 and discussed in general terms on the following pages.

There are very many possible synthetic fibers and literally thousands have been synthesized in the laboratory but only four types have survived to become large scale commercial successes. These fibers together with the fiber intermediate from which they are currently produced are listed in Table 1. There are a number of "other" fibers which are produced either to fill special requirements or for special reasons. These fibers have been considered but the ones which can be produced from methane-rich natural gas are summarized in Table 4.

Table 1

Fiber Intermediates and Sources for Major Fibers

Fibertype	Fiber Intermediates	Basic Petrochemical	Source
Polyamides			
1. Nylon 66	Adipic Acid	Cyclohexane	Oil
	and Hexamethylene Diamine	(a) Cyclohexane (b) Butadiene (c) Acrylonitrile	Oil Oil Oil
2. Nylon 6	Caprolactam	(a) Cyclohexane (b) Phenol (c) Toluene	Oil Oil Oil
Polyesters	Ethylene Glycol	Ethylene	(a) Natural Gas Liq. (b) Oil
	Dimethyl Terephthalate or Terephthalic Acid	(a) p-Xylene (b) Toluene	Oil Oil
Acrylic	Acrylonitrile	Propylene	Oil
Polypropylene	Propylene	Crude Propylene	Oil

Nylon 66, the very first synthetic fiber, which was developed by E.I. Du Pont, Wilmington, Delaware, USA, requires two intermediates as shown. One of these is hexamethylene diamine which was originally and still is made in large quantities from cyclohexane. A long obsolete process used furfural but this process was never a major source. A newer process, again based on du Pont technology, uses butadiene. Originally butadiene was made by dehydrogenation of C_4 streams recovered from refineries. Currently, these old plants in the United States are being phased out as the newer ethylene plants in the United States are based on gas oil feed stocks and large quantities of butadiene are recovered from these units as a by-product. The Monsanto Co. has developed an unique process based on the dimerization of acrylonitrile. The original Monsanto acrylonitrile plant, built about 1951-52, was based on acetylene but this plant was replaced by the Sohio process based on the ammoxidation of propylene coming either from catalytic cracking units in refineries or as a co-product from ethylene plants based either on naphtha or gas oil.

Thus, it would theoretically be possible for Bangladesh to manufacture one of the required fiber intermediates for nylon 66 using acrylonitrile derived from acetylene but such processes could not compete with the current processes based on refinery propylene.

Nylon 6, the type of nylon produced at Chittagong, is based on the polymerization of caprolactam. This intermediate is prepared in large quantities from cyclohexane produced by the hydrogenation of refinery benzene, from refinery toluene or from phenol. The latter can be produced largely from refinery benzene by several processes.

The widely used polyesters require two intermediates, ethylene glycol and either dimethyl terephthalate or terephthalic acid. Ethylene glycol is based on ethylene. In the United States natural gas liquids are the cheapest feedstock and ethylene plants using such feed-stocks have by far the lowest capital costs. However, the economic recovery of such feedstocks from natural gas is supply limited and, although supplies are available for many years for existing plants, the newer U.S. ethylene plants are based on refinery gas oil. Ethylene plants traditionally have been based on naphtha in Europe but the giant ethylene plants planned for Scotland will be based on North Sea natural gas liquids. Similarly, the huge ethylene plants on the Persian Gulf and in Saudi Arabia will be based largely on ethane.

Unfortunately, the Bangladesh natural gas is methane-rich and the recovery of C_2-C_4 streams for a steam cracker may be very costly and limited in quantity. It has recently been pointed out to the expert that ethylene is produced in one plant in India based on ethanol produced by the fermentation of sugar by-products. If ethylene could be produced economically and in sufficient quantities by this process it could be used to prepare ethylene glycol.

The other intermediate required for polyesters is either dimethyl or terephthalate or terephthalic acid and these are usually prepared from p-xylene but one minor process uses toluene.

Acrylonitrile is universally based on propylene using the improved or modified Sohio process. Propylene is produced in huge quantities in U.S. refineries and it has been estimated that U.S. refineries have approximately 20 billion pounds of recoverable propylene. This huge reserve has been used in part for alkylation to produce an anti-knock component for gasoline but in the absence of tetra ethyl lead the alkylate only has fuel value. For this reason the price of propylene in the US will always be substantially lower than ethylene. In Europe, as discussed, propylene is a co-product along with ethylene and other products from naphtha cracking.

Prior to 1950 acrylonitrile was based on ethylene chlorohydrin. This very expensive process was replaced by the acetylene process using the catalytic addition of HCN to acetylene. This process was used by both Monsanto and American Cyanamid but was supplanted as noted by the Sohio process.

Polypropylene requires a purified grade of propylene which is obtained by fractionation of crude propylene from either refineries or from liquid hydrocarbon ethylene steam crackers.

In order to put the amount of production of these four major synthetic fibers in proper perspective it should be noted that the total production of synthetic fibers in the United States in 1977 was 3,320,000 tons and that the four major fibers accounted for 99.7% of the total. In the world the total production of synthetic fibers amounted to 9,996,000 tons and the four major synthetic fibers constituted 98.9% of the total production.

Since this report is concerned solely with the production of synthetic fibers based on natural gas as produced today in Bangladesh a brief review of this resources is important. In addition, a review of past studies on possible production of synthetic fibers from Bangladesh natural gas may be helpful.

Dr. A. Huq[1] has presented data on the reserves and composition of the natural gas resources of Bangladesh. The gas fields with the three largest proven reserves were rich in methane with the ethane and propane content ranging from 1.4 to 2.3%. The large gas field at Bakhrabad was reported to have C_2-C_3 content of 2.2%. Dimitrijevic[2] has reported a C_2-C_4 content of 4.8% for the same field.

Dimitrijevic[2] has suggested that, if the several plans for exploiting the Bakhrabad field are implemented it might be possible to economically extract sufficient natural gas liquids to operate a small ethylene plant. Until a reliable domestic source of C_2-C_5 feedstock is secured he has suggested the importation of natural gas liquids from Persian Gulf or North African States be considered. It was suggested that, although the present consumption of PVC and PE plastics in Bangladesh is low, projections indicate that in ten years the market volume would justify the construction of a small ethylene plant based on natural gas liquids.

As noted in Table 1 even if this ethylene plant is built it would produce the basic petrochemical, ethylene, required for only one of the two fiber intermediates required for the production of polyesters. It is doubtful if the propylene by-product would be produced in sufficient quantities for conversion to acrylonitrile.

Earlier studies by W.L. Badger[3] Associates in 1965 had considered acetylene as the basic building block for synthetic fibers and had suggested PVA, polyvinyl alcohol, as the preferred fibers which could be made. Chemical Consultants (Pakistan)[4] Ltd. in 1969 have considered the manufacture of synthetic fibers as part of the general development of petrochemicals. Their market study carried out for them by Chechi and Co. showed that the markets for nylon, polyesters, acrylic and PVA fibers in 1974-75 in Bangladesh (then called East Pakistan) would be about 8,000-15,000 tons even at prices very competitive with cotton. They further reached the conclusion that only synthetic fiber, which should be considered for Bangladesh, was PVA fiber and this supported the position of Badger Associates.

In a related study Austrian Petrochemical Consultants[5] Ltd. in 1969 reported that the production of synthetic fibers in Pakistan should be as follows :

Table 2

Projected Consumption of Synthetic Fibers in Pakistan (Tons)

Fiber Type	1970	1980
Acrylic	10,000	20,000
Nylon 6	-	10,000
Polypropylene	3,000	5,000
Polyester	5,000	20,000
PVA	-	4,000
TOTAL:	18,000	59,000

This report is based on recommendations in Chemical Industry International March 1967 which was not available for study. In addition, they have referred to a Report for the Industrialization of Pakistan in the field of Chemicals and Fertilizers, again not available, in which the recommended planned capacity for man-made fibers is presented in Table 3.

Table 3

Recommended Planned Production Capacity for Bangladesh

Fiber Type	1970	1980
Acrylic	5,000	10,000
Polypropylene	3,000	5,000
Polyvinylalcohol	-	4,000
Polyester	-	10,000
Total:	8,000	29,000

Based on a UNIDO report, General Survey of Existing Situation in regard to the Manufacture of Man Made Fibers in Pakistan 1968 and their own studies they reached the conclusion that only the synthetic fibers which can be produced from natural gas namely acrylic, polyvinyl chloride or polyvinylalcohol should be produced in Bangladesh. In consideration of fibers which can be produced from natural gas they concluded that first priority should be given to the fiber with the widest field of application and with lowest cost which should be below or equal to the production costs in other countries. On this basis they recommended acrylic fibers.

It should be noted that Chemical Consultants[4] and Austrian Petrochemical Consultants[5] in the same year 1969 arrived at two different recommendations for the type of fiber to be produced.

In a recent review Dr. A. Huq[6] has summarized the advantages and disadvantages of producing the three fibers, acrylic, polyvinyl chloride and polyvinylalcohol from Bangladesh natural gas and has reached the conclusion that of the three possible synthetic fibers acrylic fibers represent the most attractive fiber to be made in Bangladesh. It was further suggested that acrylic fibers plants varying in size from 16,000 - 36,000 m t y be considered depending upon availability of foreign exchange capital. As an alternative it was suggested that 16,000 t/y of acrylic fiber along with about 7-10,000 t/y of polyvinylchloride fiber be considered.

Since Bangladesh's natural gas contains such low amounts of C_2-C_4 hydrocarbons it is clear that any intermediate process based on Bangladesh natural gas must use acetylene as the fundamental building block. As indicated from earlier studies this limits synthetic fibers to PAN, PVC and PVA fibers. Examination of the sources of fiber intermediates for the fibers is shown in Table 4. In this table the economical preferred process is listed first under (a).

As discussed, acetylene processes for acrylonitrile have been replaced by the Sohio process based on propylene. In the United States the newer plants for vinyl chloride monomer have been based on

Table 4

Fiber Intermediates for Acetylene Based Fibers

Fiber Type	Fiber Intermediate	Basic Petrochemical	Source
Acrylic	Acrylonitrile	a) Propylene b) Acetylene	Oil Methane
PVC	Vinylchloride	a) Ethylene b) Acetylene	a) Nat.Gas.Liq. b) Oil Methane
PVA	Vinyl Acetate	a) Ethylene b) Acetylene	a). Nat.Gas.Liq. b) Oil Methane

ethylene so that again acetylene is being replaced by ethylene. The same situation situation has developed in the case of vinyl acetate. The large new plants based on ethylene continue to dominate the market and new plants will use this route rather than the older acetylene process.

In view of the considerable studies which have been undertaken on the utilization of Bangladesh's methane rich natural gas to produce synthetic fiber and which have been under study and consideration for a long period of time one of the main objectives of this report will be to critically examine these many and conflicting proposals. Hopefully, the information developed and presented will lend to a clear understanding of Bangladesh's present textile position and that the required course of action will be self evident.

The general procedure to be followed in the next three sections will be to examine each fiber separately from the general market viewpoint listing all of the fiber plants in the world, the production of the fiber where known, comments about the general applicability of the fiber and finally in the cases where warranted an analysi of production costs.

PVA Fiber or Vinal Fiber

The generic fiber names used in this report are those used by the US. Federal Trade Commission but they are names which have won wide acceptance in the world. Vinal fiber are fibers which contain at least 50% by weight of vinyl alcohol units and, in addition, the vinyl alcohol plus acetal units constitute at least 85% of the weight.

It should be noted that monomeric vinyl alcohol $CH_2=CHOH$ does not exist. Attempts to prepare it produce its tautomer, acetaldehyde. PVA is accordingly prepared by the hydrolysis of a derivative, polyvinyl acetate.

Vinal fibers were developed in Japan. The existing plants are as follows with the trade name of the fiber in paranthesis :

1. Wacker Chemie, Munchen-Burghausen (Federal Republic of Germanv (Wacker M.A. Faser)

2. Kuraray Co. Ltd., Okayama, Japan (Cremona, Kuralon).

3. Nitivy Co. Ltd., Fujieda, Japan (Niti-Vilon).

4. Unitika Ltd. Sakoski (Akhd City), Japan (Newlon)

In addition one plant has been reported but not confirmed in China at Peking. There are no reported plants in the USSR.

The first step in the production of PVA fiber is the polymerization of vinyl/acetate using methanol as a solvent. The molecular weight can be controlled by the methods commonly used in free radical polymerization. The hydrolysis of polyvinyl acetate with caustic produces polyvinyl alcohol and by product, sodium acetate. It should be noted that theoretically at 100% yield one pound of polyvinyl acetate, PVAc, would produce only 0.51 lb of polyvinyl alcohol, PVA. In order to recover the acetic acid used in the original preparation of vinyl acetate the recovered sodium acetate is treated with an acid such as sulfuric acid. Thus, the final products of the hydrolysis of PVAc are the desired PVA, acetic acid and sodium sulfate.

In order to produce satisfactory fiber the hydrolysis has to be nearly complete and free from any residual caustic or sodium acetate. PVA is soluble in hot water and fibers are produced by wet spinning processes similar to viscose using solutions of 15-20% concentration. Spinnable concentrations are dependent upon the molecular weight of the dissolved PVA. Usually the spinning solution, dope, is maintained at 90°C. Most dopes will start to coagulate at temperatures approaching 60°C but in order to maintain fiber uniformity close temperature control of the dope is essential at spinning temperatures.

The spin bath consists of sodium sulfate and zinc sulfate and is usually maintained at a specified temperature usually about 40°C. Spinning speeds are relatively slow averaging around 50 meters per minute. As produced the fibers are relatively weak and must be dried and stretched to give improved strength. Even after stretching the fibers would have little resistance to hot water and in order to improve their water resistance the fibers must be cross-linked using formaldehyde. Cross linking prevents any polymer from dissolving in a solvent but even a highly cross linked polymer will tend to swell in a good solvent. The fiber are crimped, dried and cut.

In reviewing the process for making PVA fiber it should be recalled that carrying out chemical reactions on polymers are usually difficult and costly. In the case of PVA fibers PVAc must be hydrolyzed to PVA and the PVA converted into fiber. The fiber as spun and drawn must undergo another chemical reaction, namely cross-linking, before it can be used. The process is wet spinning which is inherently slow and the many steps involved make the capital cost high. It is evident from the many steps involved that conversion costs, vinyl acetate to finished fiber will be very costly.

In addition, for a country such as Bangladesh there is no easy introductory method using imported vinyl acetate. PVA polymer yields will be less than 50% based on the weight of PVAc hydrolyzed. The current price of vinyl acetate in the United States based on ethylene, a recognized cheaper processes than acetylene, is 23 ¢/pound but large contract prices, in view of the world wide overcapacity, are around 20 ¢/pound. This would mean that imported raw material costs for the fiber probably would be in excess of twice these prices. There will be a small possible credit for recovered acetic acid and sodium sulfate. We have made no attempt to establish these credits but in view of transportation costs their value can not be high. The development of PVA fibers in Bangladesh using imported monomers can not be justified.

No detailed attempt has been made in this study to estimate the cost of producing PVA fiber in Bangladesh. However, Chemical Consultants (Pakistan)[4] in 1969 concluded that the cost of manufacture of PVA fibers with no pay out in a 7,800 ton plant would be 2.5 times the cost of cotton. Furthermore, in order to achieve a sales volume of 7,800 tons it was assumed that the durability of cotton-PVA blends would justify this higher price. There have been no known break throughs in the technology of preparing PVA fibers which would greatly reduce the manufacturing costs.

In the early burst of enthusiasm for PVA fibers it was hoped that the high moisture regain values of vinal fibers, around 10-12% at high humidities, would make vinal a valuable apparel fiber. These high hopes have not been realized. The production of vinal fibers in Japan from 1957 to 1968 is reported by Chemical Consultants (Pakistan)[4] and reached nearly 70,000 tons in 1968. About 23% was consumed in apparel applications in 1965 while about 60% were used in industrial and related areas. Of the fibers used in apparel about 40% were used in general clothing while the remainder was used in work clothing, uniforms and the like.

In the period of 1971-77 the production of "other" fibers in Japan is indicated below in tons per year :

Table 5

Production of "Other" Fibers in Japan 1971-77

(Thousands of Tons)

Year	Filament	Staple	Total
1971	22	75	97
1972	20	69	89
1973	23	70	93
1974	22	66	88
1975	15	38	53
1976	15	43	58
1977	16	45	61

"Other" fibers are defined as largely spandex, saran, vinal and vinyon. Thus, it is apparent that the production of "other" fibers in Japan has been falling whereas the polyester have grown 90% in the same time period.

Through the courtesy of the Mitsubishi Rayon Co. and using recent data from the Japanese Fiber Association the production of PVA fibers in Japan is shown in Table 6. Although part of 1974 and all of 1975 were depression years for fibers current production is only about 60% of the estimated 1968 production.

Although high hopes were expressed for the future of PVA fibers the failure of PVA fibers to achieve a larger market share may be inherent in the fiber and its properties.

Table 6

Production of PVA Fibers in Japan 1974-1977

Tons

Year	Filament	Staple	Total
1977	6,833	36,306	43,139
1976	6,117	33,473	39,590
1975	7,343	32,539	39,882
1974	9,437	47,975	57,412

Although cross linking of the fiber improves the resistance of the fiber to water cross linking is not sufficient to prevent interaction with water. Thus, fabrics from vinal blends lose thus crispness at high humidities and rather quickly have a messy appearance and are not attractive for many apparel uses.

In the mid to late 1950s Air Reduction Corporation, a large acetylene and vinyl acetate producer in the U.S., undertook an extensive program on the possibilities of producing and marketing PVA fibers in the United States. Imported fiber from Japan was used for market evaluation. After considerable effort including a major team of textile experts they reached the conclusion that this fiber would not be a viable product for the U.S. textile industry. As indicated earlier there are no PVA fiber producers in the United States and only one small producer, Wacker Chemie, in Western Europe. Wacker Chemie had been the developer of PVA fiber prior to the Japanese developments and the total production of "other" fibers including PVA fibers in all of Western Europe is only 13,000 tons out of a total of 2,125,000 tons and PVA fiber can represent only a small portion of 13,000 tons of "Other" fibers.

On the basis of high capital investment as a result of the many manufacturing processes involved in the preparation of the monomer and the conversion of monomers into fibers, the high manufacturing cost using either imported or domestically produced monomers and the poor adaptability of the fiber for apparel use the manufacture of PVA fibers in Bangladesh can not be recommended. We believe that this is a supportable conclusion based on the decline in the production of PVA fiber in Japan. Until major breakthroughs in the technology of manufacturing improved PVA fibers are made and until the use and acceptability of these fibers in apparel fabrics has been amply demonstrated we believe that further consideration of the possible manufacture of PVA fibers in Bangladesh is not warranted. Based on current interests in PVA fibers we would rate the possibilities of achieving these breakthroughs as poor. We believe that there are other viable fiber alternatives to PVA and we recommend that these alternatives be thoroughly explored.

PVC Fiber or Vinyon Fiber

Vinyon fibers, as defined by the U.S. Federal Trade Commission are fibers which contain at least 85% vinyl chloride by weight. The International Organization for Standardization, IOS, uses the term chlorofiber which includes both saran and vinyon fibers. Although polyvinyl chloride fibers have been reported for many years the tremendous use for PVC resins have largely been in other fields such as records, flooring, film, sheeting, pipes, building products and the like. Its use as a fiber are not well known nor are they extensive.

The reported plants for production of PVC (vinyon) fibers are listed below based on information contained in the June 1978 Textile Organon. Although the report strives to be as accurate as possible there is some possibility that in certain countries the reported plants for vinyon fibers may actually be producing products which would fall under the IOS definition, chlorofiber.

1. Rhone-Poulenc-Textile, Tronville-en-Barrois(Meuse), France (Clevyl, Rhovyl, Thermovyl)

2. VEB Filmfabrik Fotochemische Kombinat, Wolfen, German Democratic Republic (Piviacid)

3. Kureha Chemical Industry Co., Kaibara and Mibu, Japan (Viclon)(Monofilament only)

4. Nishikawa Chemical Industry Co., Iruma, Japan (Nishikalon)

5. Teijin Ltd., Iwakuni, Japan
(Teviron, Vairen)

6. Toyo Chemical Co., Ofuna, Japan
(Envilon), (Monofilament only)

7. Avtex Fibers Inc., Meadville Pa, USA,

8. Voplex Corpn., Canandaigua
Plastics Division, Canandaigua
N.Y., USA (Volplex, Monofilament only)

In addition these are reported but unconfirmed vinyon plant in the following countries.

China

1. Canton
2. Chungking
3. Fochou
4. Shanghai
5. Shengli
6. Tientsin
7. Sian
8. Sining

Union of Soviet Socialist Republics.

1. Kustanay

Information on plants in these two countries is not available to the writer.

Some of the plants are producers of monofilaments only as indicated. It is believed that these monofilaments are either very coarse products or may be slit tapes or ribbons. In any event such monofilaments would not be useful in blends with cotton nor as a replacement for cotton in apparel applications. Thus, there are only five plants which produce yarn as staple which possibly could be considered in a form which might be suitable for blend purposes or for use in apparel.

The Avetex fibers plant at Meadville Pa. USA produces staple fiber by dry spinning a vinylchloride copolymer from acetone solution on an old cellulose acetate tow machine. The product is sold almost entirely to one paper company who uses this fiber as the bonding fiber in making the common non-woven fabric used in tea bags. The capacity of this plant as reported is about 2 million pounds per year.

Textile Organon does not report the production or consumption of PVC fiber, but reports the production under "other" fiber. The total production of "Other" fibers in the various areas is detailed below for 1977 :

Table 7
World Production "Other" Fibers in 1977
Thousand of Tons

Area	Production	Capacity
Western Europe	13	24
Eastern Europe	12	17
U.S.A.	7	10
Other America	1	1
Japan	61	134
All Other	16	28

As described under discussions of PVA fibers "Other" fibers include spandex, saran,fluorocarbon, vinal, vinyon, azlon and alginate fibers. The production of "other" fibers in all areas except Japan is very small. It is known that there are 6 spandex plants in Western Europe, 1 in Eastern Europe, 3 in the USA, 4 in other Americas, 6 in Japan and one in All Others. With the exception of Japan where some 61,000 tons of "other" fibers were produced the production of "other" fibers is very small. Through cooperation of the Mitsubishi Rayon Co. data from the Japanese Fibers Association on the production of PVC fibers are given in Table 8.

Table 8

Japanese Production of PVC Fibers

Tons.

Year	Filament	Staple	Total
1977	4,914	2,298	7,212
1976	5,179	2,649	7,828
1975	3,840	1,381	5,221
1974	6,544	3,288	9,832

Since the production of spandex fibers must be subtracted from the total the production of PVC fibers is insignificant in the United States and Western Europe. The reported number of PVC fiber plants in China is surprisingly high. The existance of these plants has not been verified and their production is unknown.

From the structure of vinyl chloride monomer and the methods used for polymerization the fiber characteristics of polyvinylchloride can be anticipated to be quite poor. A more likely fiber candidate is polyvinylidene chloride, Saran. In the 1960's attempts were made to produce saran fibers by a joint venture of Dow Chemical and National Plastic Products Co. in Odenton, Maryland, U.S.A. This program was in existance for a number of years and several small carpet programs were actually developed but the production probably never reached a million pounds per year. Today, ribbon monofilaments are produced from saran in relatively small quantities, approximately 2-3 million pounds. These ribbons are used generally in certain types of drapes especially for public buildings where fire protection is demanded and required. No use of these saran monofilaments in apparel is known and all other known uses for monofilaments are either in industrial or related end products.

There are a number of instances where certain yarns such as fibers glass yarns are coated with PVC. Advantage is taken of the fact that the core yarns are used for their strength or other properties while the PVC coating provides protection to the individual filaments from surface abrasion or some means of altering surface characteristics. Such coated products, for example, are used for mosquito screens and the like. One such company in the United States is Engineered Yarns Co. and a corresponding company in Canada is part of Bay Mills, Toronto, Ontario, Canada. At one time Rhone-Poulenc in France tried to promote PVC fiber for use in undergarments for people suffering from arthritis. Supposedly the wearing of PVC undergarments reduced arthritic pains but these claims have not been widely accepted. The production of PVC fibers is thought to be small.

Since PVC polymer has been produced in tremendously large quantities in Western Europe and the United States the fact that production of vinyon is so small is a good indication of its fiber properties. In the mid 60s at the time of the issuance of the Badger[3] study it was well recognized that the fiber properties of PVC were minimal. There have been no developments in the Western World to alter this conclusion. On the other hand the Western World has developed viable alternatives to natural fibers including cotton and the consumption of man made fibers in the USA far exceeds the consumption of cotton. In apparel uses in the United States the consumption of man-made fiber in 1976 was 78% larger than cotton and 67% larger than the total consumption of all natural fibers, cotton, wool and silk. The total shipments of one synthetic fiber, polyester fiber, in continuous filament and staple forms, exceeded the consumption of cotton by 13%. The above production has been achieved even though the US is a major producer and exporter of cotton. With the exception of the production of vinyon by Avtex, discussed previously, there is no production of vinyon fiber in the United States. In our opinion the manufacture of vinyon fiber would not produce a suitable fiber for use in Bangladesh.

Until a suitable fiber has been demonstrated we can not recommend the installation of a major plant for the production of a speciality fiber. In our opinion as in the case of PVA fiber other alternatives exist and we recommend no additional studies on this fiber.

Acrylic Fibers

Marketing Factors

Introduction

Although polyacrylonitrile had been known for many years difficulties were encountered in attempts to convert the polymer into a useful fiber and real progress in this field was dependent upon the discovery of suitable solvents. Solvents based on dimethyl formamide, DMF, were patented by the DuPont Co. in the 1940's and commercial development by a number of other companies were carried out in the early 1950's. Acrylic fibers are unique among the major synthetic fibers since all the other major synthetic fibers polyamides, polyesters and polypropylenes are crystalline products with sharp well defined melting points.

Polyacrylonitrile has no true melting point and at elevated temperatures decomposition starts before the polymer is sufficiently fluid for melt spinning. Since the polymer is soluble in a number of different types of solvents the several approaches which have been used for converting polymer into fiber are dependent, at least in part, on the type of solvent which is selected. Since the original solvent used by Du Pont was dimethyl formamide, DMF, and since this solvent is volatile at high temperatures duPont elected to base their process on dry spinning. In dry spinning, the process used for cellulose acetate, the solvent is removed by extruding the fiber solution into a heated chamber where the solvent is distilled off and recovered. The Monsanto, originally the Chemstrand Corporation process since licensed in Japan to the Mitsubishi Rayon Co., uses dimethyl acetamide, DMA, and since this has a higher boiling point that DMF and is difficult to vaporize Monsanto elected to use a wet spinning process. In this process the fiber solution is extruded into a spinning bath in which the polymer is insoluble and the polymer is recovered in fiber form. American Cyanamid's solvent is a highly concentrated aqueous solution of sodium thiocyanate and the use of this solvent of necessity requires a wet spinning process. Although dry and wet spun continuous filament process have been used for cellulose acetate and viscose rayon and spinning speeds of both dry and wet processes are much slower than melt spun processes and, therefore, the costs of producing continuous filament fibers from these processes are relatively high. One method of compensating for slow spinning speeds is to extrude many more filaments and wet spinning processes are particularly suited for this approach. It is for this reason that there are only two small plants producing continuous filament acrylic while the other acrylic plants produce staple fibers.

Production Volume and Plant Locations

With this brief background we should examine the production of acrylic fibers outlining plant locations, production capacity and production by areas. Such information will be useful in eventually assessing the utilization of acrylic fiber throughout the world as well as fiber preferences. Included in this category will be modacrylic fibers as well. With very few exceptions acrylic fibers are copolymers of acrylonitrile. By definition an acrylic fiber must contain at least 85% acrylonitrile units by weight. A modacrylic fiber will contain from 34 to 84% by weight of acrylonitrile units. The acrylic and modacrylic fibers plants are given below by areas with area production in thousands of tons :

Western Europe

Year	Production	Capacity	
1971	477	1978	1979
1972	524	1106	1124
1973	651		
1974	588		
1975	540		
1976	719		
1977	651		

1. AUSTRIA
   a) Chemiefaser AG Lenzing (Lenzing Acryl)
2. BELGIUM
   a) Courtaulds SA Pont du Leu, Coquelles (Courtelle)
   b) Rhone Poulenc-Textile Colmar(Crylor)
3. FEDERAL REPUBLIC OF GERMANY
   a) Bayer AG Dormagen (Dralon)
   b) Hoechst A.G. Kelheim/Donau (Dolan)

4. GREECE

a) Vomvicryl SA. Stylis, near Lamia

5. IRELAND

a) Asahi Synthetics (Ireland) Ballina, Mayo (Cashmilon)

6. ITALY

a) Anic Societa per Azioni, Pisticci (Euroacril)

b) Fibra del Tirso Ottana

c) Montefibers P.A. Porto Marghera (Leacril)

d) Snia Viscosa, Cesano Maderno & Villacidro, (Velicren)

e) Societa Italiana Resine (SIR) Porto Torres (Siacril)

7. NETHERLANDS

a) DuPont de Nemours, Dordrecht (Orlon)

8. PORTUGAL

a) Fibras Sinteticas de Portugal Lisbon (Vonnel)

9. SPAIN

a) Cyanenka S.A. Prat de Llobregat (Crilenka

b) Montefiber Hispania S.A. Miranda de Ebro (Leacril)

10. UNITED KINGDOM

a) Courtaulds Grimsby (Courtelle) Modacrylic Coventry Teklan

b) Du Pont (U.K.) Maydown, N. Ireland (Orlon)

c) Monsanto Londonderry, N. Ireland (Acrilan)

11. TURKEY

a) **Akrilik Kimya Sanayii, Yaloua (Aksa)**

b) Yaloua Elyaf ve Iplik Sanayii ve Ticaret
Yalova (Yalova)

EASTERN EUROPE

Year	Production	Capacity	
1971	88	1978	1979
1972	103	219	246
1973	133		
1974	151		
1975	163		
1976	172		
1977	184		

1. BULGARIA

a) Kombinat "Dimitar Domous" Burgas (Bulana)

2. GERMAN DEMOCRATIC REPUBLIC

a) Chemiefaserwerk "Friedrich Engels", Premnitz (Wolpryla)

b) Veb Filmfabrik Fotochemisches Kombinat, Wolfen (Wolpryla)

3. HUNGARY

a) Magyar Viscosagyar Nyergesujfalu (Crumeron)

4. POLAND

a) Chemitex-Anilana Lodz (Anilana)

5. ROMANIA

a) Uzina de Fiber Sintetico Savinesti, Savinesti, (Melana)

6. YUGOSLAVIA

a) Organsko Hemijska Inaustrija Skopje, Skopje, (Makrolan)

U. S. A.

Year	Production	Capacity	
1971	247	1978	1979
1972	284	394	394
1973	337		
1974	286		
1975	238		
1976	282		
1977	321		

a) American Cyanamid Co. Pensacola FLA (Creslan)

b) Dow Badische Co. Williamsburg Va, (Zefran)

c) E.I. Du Pont do Nemours & Co., Camden S.C., Waynesboro va., (Orlon)

d) Tennessee Eastman Co., (modacrylic)

e) Monsanto Textile Co., Decatur, Ala,(Acrilan)

OTHER AMERICAS

Year	Production	Capacity	
1971	26	1978	1979
1972	33	128	142
1973	45		
1974	59		
1975	66		
1976	82		
1977	82		

1. ARGENTINA

a) Hisisa Argentina Baradero (Cashmilon)

2. BRAZIL

a) Fisiba - Fibras Sinteticas da Bahia Camacari (Triana)

b) Rhodia S.A., Sao Jose dos Campos Sao Paulo,(Crylor), Tercryl

3. CANADA

a) Du Pont of Canada Maitland Ont. (Orlon)

4. MEXICO

a) Celanese Mexicana S.A. Zacapu

b) Celulosa y Derivados S.A. Atequiza (Crysel)

c) Fibras Sinteticas S.A. Cotaxtla (Fisisa)

5. PERU

a) Bayer Industrial S.A. Lima (Dralon)

JAPAN

Year	Production	Capacity	
		1978	1979
1971	296		
1972	277	456	456
1973	335		
1974	278		
1975	244		
1976	310		
1977	338		

a) Asahi Chemical Industry Co. Ltd. Fuji , and Nobeoka, (Cashmilon and Pewlon

b) Japan Exlan Co. Saidaiji (Exlan)

c) Kanebo Acrylic Fibers Co. Hofu (Kanebo Acryl)

d) Kanegafuchi Chemical Industry Co., Takasago, (Kanecaron)

e) Mitsubishi Rayon Co., Otake (Vonnel)

f) Nitto Spinning Co. Ltd., Fukuyama (Pilot plant only)

g) Teijin Acryl Co. Ltd., Iwakuni, (pilot plant only)

h) Toho Beslon Co., Mishima,(Beslon)

i) Toray Industries, Ehime,(Toraylon)

ALL OTHERS

Year	Production	Capacity	
1971	36	1978	1979
1972	48	214	262
1973	76		
1974	86		
1975	140		
1976	162		
1977	189		

1. CHINA

a) Formosa Plastic Corp. Kaohsiung & Lanchu (Tairylan)

b) Tong Hwa Synthetic Fiber Co. Chu Pei (Town Flower)

2. INDIA

a) Indian Petrochemicals Corp., Jawaharnagar, Baroda, (Cashmilon)

b) J.Y. Synthetics Ltd., Kota, Rajasthan; (Jekrilon)

3. IRAN

a) Polyacryl Iran Corp. Isfahn

4. ISRAEL

a) Israel Chemical Fibers, Ashdod (Acrilan)

5. Republic of Korea

a) Hanil Synthetic Fiber Industrial Co., Masan (Cashmilon)

b) Tae Kwane Industrial Co. Ulsan (Acelan)

Summarizing, the data on the world production of man-made fibers are presented in Table 9 :

Table 9
World Production of Man-Made Fibers
(Thousands of Tons)

	1971	1972	1973	1974	1975	1976	1977
Rayon and Acetate							
a) Yarn and Monofilaments	1,401	1,342	1,363	1,302	1,136	1,185	1,157
b) Staple	2,054	2,217	2,298	2,230	1,823	2,026	2,098
c) Total	3,455	3,559	3,661	3,532	2,959	3,211	3,256
Non-Cellulosic Except Olefin							
a) Yarn and Monofilament	2,867	3,213	3,833	3,785	3,763	4,126	4,315
b) Staple and Tow	2,742	3,164	3,807	3,702	3,583	4,449	4,732
c) Total	5,609	6,377	7,640	7,487	7,346	8,575	9,047
Olefin Fiber (Data Are Incomplete)	479	563	682	720	716	803	970
Total Man-Made	9,543	10,499	11,983	11,739	11,021	12,589	13,273
Raw Cotton	13,008	13,669	13,714	14,019	11,809	12,632	14,138
Raw Wool	1,566	1,457	1,432	1,512	1,504	1,462	1,390
Raw Silk	41	42	43	45	47	48	49
Total Natural	14,615	15,168	15,189	15,576	13,360	14,142	15,577

Table 10

World Production of Man-Made Fibers by Fiber Types

(Thousands of Tons)

	Production							Capacity	
	1971	1972	1973	1974	1975	1976	1977	1978	1979
Cellulosics	3,455	3,559	3,661	3,532	2,959	3,211	3,256	-	-
Acrylics and Modacrylics	1,170	1,269	1,577	1,448	1,391	1,727	1,765	2,517	2,624
Nylon Total	2,166	2,437	2,730	2,623	2,489	2,847	2,939	3,862	4,220
Yarn	1,866	2,042	2,273	2,193	2,084	2,339	2,383	3,103	3,376
Staple	300	395	457	430	405	508	556	759	844
Polyester Total	2,127	2,523	3,177	3,272	3,360	3,835	4,233	5,708	6,097
Yarn	958	1,127	1,510	1,545	1,641	1,745	1,890	2,594	2,785
Staple	1,169	1,396	1,667	1,727	1,719	2,140	2,343	3,114	3,312
Polyolefin	479	563	682	720	716	803	970	NA	NA
Total Synthetics	5,942	6,792	8,166	8,063	7,956	9,262	9,907		
Total Man-Made	9,397	10,351	11,826	11,595	10,915	12,473	13,163		

In reviewing the growth of man-made fibers over the period 1971-1977 cellulosics, rayon and acetate, have actually experienced a total loss of 199,000 tons amounting to 5.8% or an average loss of about 1% per year. It should be noted that filament losses amounted to 244,000 tons or 17.4% with an average loss per year of about 3%. On the other hand rayon staple stayed essentially constant with an actual growth of 44,000 tons or 2%. The price of rayon continuous filaments have increased rather rapidly with the increase in energy prices and there has been increasing competition from other synthetic yarns. As a result in the U.S. the number of textile denier continuous filament plants has decreased in recent years from 9 plants to one and tire cord plants have decreased from 7 to 2 and the latter two are expected to close shortly.

The world production of synthetic fibers, acrylic, nylons, and polyesters have experienced a growth of 3,438,000 tons or 61% over this period corresponding to an annual growth of 10% per year. The production of continuous filament yarns has increased 1,448,000 tons or 51% for an average growth rate of about 8.5% per year. Staple has grown somewhat faster, 1,990,000 tons, or 72.5% for an average growth of 12% per year.

Although the data for olefin fibers, largely polypropylene, are incomplete the estimated growth has been 491,000 tons or 103% for an average growth rate of 17%.

In this short period man-made fiber production has increased at a much more rapid rate than the corresponding growth of natural fibers, 39% versus less than 7%, and the production of man-made fibers should exceed the production of natural fibers within a few years.

On a world basis the production of synthetic fibers by type is as follows :

Acrylics	20%
Polyamides	33%
Polyesters	47%

Polyamides, the oldest synthetic fiber have been the slowest growing with an annual growth of 6%. Acrylic fibers have been growing somewhat faster at 8.5% whereas polyesters have been growing at an annual rate of 16.5%.

In the United States over the period 1971-77 acrylic fiber production peaked in 1973 and along with all other fibers was badly hurt in the 1975 depression. The growth over the period has amounted to 74,000 tons for an average growth rate of 5%. In contrast over the same period polyester production has increased 826,000 tons for an annual growth rate of 16.5%. Nylon production has grown 331,000 tons at an annual rate of 7.5% and polyolefin, largely polypropylene production has grown 138,000 tons or annually 16%. Thus, acrylic fibers are the slowest growing of the synthetic fibers in the United States. The production rate is at 81.7% of capacity with no new plants planned.

In Western Europe the situation is somewhat different. Considering only acrylics, polyamides, and polyesters, the market shares are respectively 31%, 32% and 37% while the growth rates are respectively 6%, 0.5% and 5%. These disappointing growth results reflect the very slow growth rate of the textile industry in W. Europe. The operating rates for the same fibers are 59%, 63% and 63%. These rates account for the very many millions of dollars losses suffered by the fiber makers in Western Europe. These continuing losses and the poor prospects for an early recovery have caused duPont to announce that they are permanently closing their Orlon acrylic fiber plant at Dordrecht, Netherlands and transferring all acrylic fiber operations to their U.K. plant. Similarly, there have been rumors but no announcements that Monsanto would close their acrylic plant in Lingen, Federal Republic of Germany and move their production to their Coleraine, Northern Ireland plant.

The much larger share of the synthetic fiber market held by acrylic fibers may be closely related to the differences in living habits between Americans and Europeans. In general climatic variations in temperatures are much higher in the U.S. than in Europe which accounts for the much more common use of seasonal clothing in the United States. In addition, American homes, offices and factories are operated at much higher temperatures with central heating almost universally used. As a result American clothing is much lighter than European. As a result the use of woolen fabrics and heavy sweaters, which consume large amounts of acrylic fibers, is more common in Europe than in the United States.

In Japan the market shares of the synthetic fiber markets held by acrylics, polyamides and polyesters are respectively 28%, 25% and 47%, and the growth rates are 2.4%, 0% and 7.2%. The acrylic operating capacity of Japan is 74% while for nylon it is 78% and for polyester it is 77%. The production of acrylic fiber in Japan has shown no growth since 1973. Recently some of the major acrylic fiber producers in Japan have agreed on a form of rationalization in which the sales efforts of several producers have been combined into one unit and the required production divided between the several companies. What effect these changes may have had on the increased production of acrylic fiber in 1977 is not clear.

The higher consumption of polyesters in Japan is believed to be related to the much higher average temperatures in Japan compared to Europe and the greater use of lighter weight fabrics.

In examining the number of acrylic plants in other countries it is rather evident that the use of acrylic fibers in these countries, where expected temperature may be high, is rather low. Thus, although Brazil has two acrylic fiber plants the plant capacity of one is quite small and the production rate is known to be quite low. For comparison purposes Brazil has 14 nylon plants and 9 polyester plants.

In India there are two acrylic plants, 12 nylon plants and 14 polyester plants. Taiwan also has two acrylic fiber plants but it has 13 nylon plants and 13 polyester plants. It is known that China is a very large exporter of acrylic sweaters to the United States. Examining Central and South America acrylic plants are located in those countries which are mountainous and therefore relatively cool. Thus, Mexico and Peru have acrylic plants but there are none in Columbia or Venezuela.

Examining the domestic consumption of acrylic fiber in the United States the uses were as follows in millions of pounds:

Table 11

Consumption of Acrylic Fibers in the United States by End Use

(Millions of Pounds)

	1973	1974	1975	1976	1977
Hosiery, Sweater and Craft Yarns	184	166	193	210	262
Pile Fabrics	64	60	71	72	87
Other Circular and Flat Knit	162	117	68	85	111
Blankets	39	31	34	34	51
Other Broadwoven	38	18	14	22	27
Carpet Face Yarn	169	114	83	89	73
All Others	7	9	5	6	9
Total	663	515	468	518	620

Hosiery referred to in this table include mens hosiery in wool like constructions and athletic socks. Craft yarns are those yarns sold to the home craft industries which are used primarily in the acrylic field as hand knitted sweaters, shawls and the like. Sweaters are made from high bulk acrylic yarns, In this process acrylic tow is stretched in a heated oven on a Turbo converter. The tow is broken into a random length staple by running the tow under high tension over a rotating roll fitted with a controlled point for localizing stress. The random length staple is then divided into two parts. One part is shrunk in a steam box and after drying is blended with unshrunk yarn and spun into a yarn comprising a blended array of shrinkable and unshrinkable fibers in a rather coarse yarn. The yarn is knitted into sweaters. In the dyeing process the shrinkable fibers will shrink in length pulling the unshrinkable fibers into a series of loops or some type of curved arrangement in space. The net result is bulky or lofty yarn which is soft to the touch but yet resilient. This so called high bulk process is ideal for knitting purposes and is used extensively in sweaters.

Pile fabrics are fabrics in which individual fibers stand out in a position normal to the fabric surface. In this respect they can resemble a synthetic fur. Depending upon the length and density of the pile such fabrics can be used for many purposes. For example, ladies winter coats are frequently made with a dense pile acrylic fabric. Other pile fabrics may be used to simulate decorative furs while other pile fabrics are used for insulating linings for outer coats and jackets.

There are several processes for knitting, one of which produces a tubular fabric while the other produces flat fabrics. These knitted fabrics can be used for a wide variety of end products where relatively heavy fabrics are desired. Apparently the amount of knitted fabric produced in Bangladesh is relatively low.

"Other broadwoven fabrics" are the woven fabrics commonly used in all types and constructions and for a wide variety of end applications. This category would include the types of woven fabrics commonly produced in Bangladesh from cotton-viscose blends. This category also would include blends with wool.

"All Other" includes fiberfill i.e. fibers used for filling pillows, upholstery padding, quilts, jackets and the like. Non-wovens includes needled batts etc. The market shares in the U.S. held by acrylic fibers in the above areas as well as other staple fibers and tows are given below :

Table 12

Per Cent Market Share Held by Acrylic and Other Fibers in Selected Textile Applications
(R) Rayon (N) Nylon (A) Acrylic (P) Polyester (O) Olefin

Hosiery, Sweaters and Craft Yarns	1973	1974	1975	1976	1977
A	90	94	94	95	91
NPR	10	6	6	5	9
Pile Fabrics					
A	86	85	76	78	78
P	14	15	24	22	22
Other Circular +Flat Knit					
R	4.5	5	4	3	4
A	45.5	42	28	28	33
P	50	53	68	69	63
Blankets					
A	80	84	85	82	78
P	20	16	15	18	22
Other Broadwoven					
R	27	25	16	17	16
N	2	2	2.5	3	3.5
A	2.5	1.5	1.0	1.5	2
P	68	71	80	78	78
O	0.5	0.5	0.5	0.5	0.5

	1973	1974	1975	1976	1977
<u>Carpet Face Yarn</u>					
R	2	-	-	-	-
N	56.5	62	68	66	69
A	18	16	11	9.5	7
P	19.5	18	18.5	21.5	20
O	4	4	2.5	3	4
<u>All Other Uses</u>					
R	54	27	21	22	19
N	10	11.5	8	9	8.5
A	4	7	3.5	5	6.5
P	18.5	38	57	59	62
O	13.5	16	10	5	3.5

The above data give the market share held by the several synthetic fibers in those applications where acrylic are used to any appreciable extent. In other applications such as fiberfill, flock and non-wovens where the amounts of acrylics used are very small the poundages are included in "All others". Note that in only three areas are acrylic fibers the preferred fibers. These areas are (a) sweaters, hosiery and craft yarns (b) pile fabrics and (c) blankets. None of these areas represent significant markets in Bangladesh. In one other area, circular and flat knits, acrylic fibers hold about a third of the market but again this is not a major textile area for Bangladesh.

In the broadwoven area acrylic fibers hold an insignificant <u>share of the market about 2% but this is a major market for Bangladesh. The preferred fiber is polyester,</u> by a very wide margin.

There are very many major apparel markets for continuous filaments but since acrylic are not produced in continuous filament form they do not participate. These areas include circular knit, flat knit and broadwoven. In these areas polyester fibers are the dominent fibers. It should be pointed out that knitting is the cheapest and fastest way to produce fabrics.

Turning now to the uses for acrylic fibers in the United States the distribution of acrylic fibers between the various segments of the spun yarn textile industries is given in the following table.

Table 13

Market Distribution of Acrylic Fibers in the U.S. Textile Industry by Percent.

	1973	1974	1975	1976	1977
Hosiery, Sweaters and craft yarns	27.8	32.2	41.3	40.6	42.3
Pile Fabrics	9.7	11.7	15.2	13.9	14.0
Circular & Flat Knit	24.5	22.7	14.6	16.4	17.3
Blankets	5.9	6.0	7.3	6.6	8.2
Broadwoven	5.7	3.5	3.0	4.3	4.0
Carpet Face Yarns	25.5	22.1	17.8	17.2	11.8
All Other	0.6	1.7	1.0	1.1	1.5

In the above market areas the only ones which might have significant markets in Bangladesh would be the broadwoven category. Over a five year period the average production of acrylic fibers was 556 million pounds and an average of 23.8 million pounds were used in broadwoven products of all kinds. This represents only 4.3% of the total acrylic fiber produced. This is an insignificant share of this huge and important market.

No detailed analysts of the utilization of the several synthetic fibers in specific apparel markets in the U.S. is available. In order to present information as concisely as possible the tables in Apparel and Home Furnishing from the November 1977, Textile Organon are reproduced in annex II. Formerly much more detailed information on clothing for men and women were detailed. As noted these are not reported as top type fabrics weighing 4 ounces or less per yards or bottom type fabrics which weigh more than 4 ounces per square yards. By reviewing the tables together with the information supplied previously an excellent overall view of the markets for acrylics and other synthetics can be obtained. For example synthetic fibers have almost completely captured the sweater market with 85% of the market. Similarly with craft and handwork yarns synthetic fibers have just under 85% of the market. In the top and bottom type fabrics man-made fibers now have 60% of the market. Again, in retail price goods, these fabrics are sold to housewives primarily to be converted into dresses, blouses and and the like man-made fibers have captured over 70% of the market. Thus, it is clear that man-made fibers play a very important role in apparel and home furnishing markets in the United States. Since the United States produces large quantities of both cotton and man-made fibers of nearly all types and since the markets are very competitive and open the trends in fiber production as previously outlined are the real indications of the differences in fiber properties which can be developed and used in fabrics.

It can be argued with some force that similar analysis of the markets in Europe and Asia should be made. Certainly such information would be helpful and desirable. Unfortunately we are not aware of reliable data from the EEC countries. Surveys undoubtedly have been made by individual companies in selected countries but the writer has had personal experience in attempts to obtain detailed marketing information on specific textile areas using the resources of major firms which have large and sophisticated market research staffs and was unable to obtain reliable information over a wide spectrum of countries.

The consumption of fibers in tons in Japan in 1976 is given in Table 14. Note that in the woven apparel category acrylic fibers had only 1.9% of the total market but in knitted apparel acrylics had 27% of the total market. In the knitted products area outerwear had 66% of the total amount of acrylics used. This is similar to the consumption pattern in the U.S. where sweaters constitute the largest volume use in the knitted area.

Since we are primarily interested in uses for acrylic-cotton blends the Mitsubishi Rayon Co. has kindly supplied us with data on the recent consumption of acrylic-cotton blends in Japan. The data are shown in Table 15 and are taken from the Japanese Fiber Association.

Table 14

Consumption of Fiber in Japan 1976 in Tons

	PET	Nylon	Acrylic	Cellulosic	Wool	Cotton	Total
Woven apparel	128,500	14,400	6,800	28,200	81,200	108,100	367,200
Knitted Apparel	82,100	37,200	90,300	13,800	34,500	73,000	330,900
Blankets & Bed Linen	45,400	7,800	35,700	25,200	4,900	149,900	268,900
Hand Knitting Yarns etc.	9,400	4,800	9,900	1,600	11,600	58,600	95,900
Export (Fabrics)	178,500	26,400	15,500	14,500	3,400	44,100	282,400
Total	443,900	90,600	158,200	83,300	135,600	433,700	1,345,300
Knitted Products							
Innerwear	6,300	5,500	13,100	1,300	1,100	47,100	74,400
Outerwear	72,700	4,500	59,500	5,600	31,700	18,600	192,600
Hosiery	2,200	18,100	6,300	-	400	2,400	29,400
Industrial	1,100	10 000	11 500	11,300	1,000	4,100	39,000
Total	82,300	38,100	90,400	18,200	34,200	72,200	335,400
Home & Ind. Use							
Curtains	5,900	-	10,000	16,400	-	300	32,600
Carpets	2,700	8,600	30,800	6,100	11,100	1,900	61,200
Tire Cord	8,500	79,400	-	6,400	-	3,500	97,800
Fishing Nets -Ropes	2,900	16,400	-	-	-	-	19,300
Heavy Cloth	3,600	6,900	-	32,800	-	7,900	51,200
Total	23,600	111,300	40,800	61,700	11,100	13,600	262,100

The data show conclusively that acrylic-cotton blend yarns only consume about 0.4% of the total acrylic fiber produced.

Table 15

Consumption of Acrylic Cotton Blends *
in Japan

(Tons)

Product	1974	1975	1976
Shirts and Dresses	21	8	49
Skirts	7	4	5
Home Dresses	6	62	24
Blause	22	6	134
Infant Wear	606	30	735
Pajamas	193	137	143
Negloges	164	729	-
Night clothes	-	135	-
Total:	1,019	1,111	1,090

* Acrylic cotton blend yarns by definition contain 50% or more acrylic fiber.

In the United States and elsewhere in the world many millions of dollars have been spent on research and development by many major firms who have a vested interest in promoting the production and use of acrylic fibers. Many different fiber types have been developed and the net results can be judged by the data presented in this report. This research and development activity is continuing although at a slower pace and the outcome of this effort as well as the continuing research and developments efforts on other fibers can not be discounted. Although it is theoretically possible to blend acrylics with cotton all of the evidence shows conclusively that acrylics are not the man-made fibers of choice for blending with cotton. It is our opinion that the results of a free and competitive market have shown very conclusively that acrylic fibers are the best man made fibers available for sweaters, pile fabrics and blankets. Indeed, in some of these areas and from certain aspects fabric properties can be developed using acrylic fibers which are superior to wool and other natural products. Bangladesh possibly has small market demands for such fiber products and at some point in time could consider developing an acrylic fiber industry to serve these needs. For the broad general apparel market in Bangladesh we believe that there are other fibers more suitable. From a marketing view point all of the evidence indicates that the production of acrylic fibers is not the preferred solution to meet Bangladesh's major fiber and textile problems.

Major efforts will be required in the marketing and fiber and textile product development areas if a decision is made to produce acrylic fibers in Bangladesh. From a marketing and textile product development areas, assuming that an improved staple fiber can be developed and produced for blending with cotton, the market development must assess the price performance of acrylic and acrylic cotton blends versus the results achievable with other well known blends. From the market performances to date, as judged from the data, there is very little doubt that other fibers have out performed acrylics in the areas of most interest to Bangladesh. In order to recommend the use of acrylics in acrylic cotton blends it must be assumed that these efforts by Bangladesh will be successful where other countries have failed and that efforts spent pursuing this approach will be more fruitful than efforts based on other fibers. There is little doubt that serious compromises will have to be made but what is unknown is the magnitude of these compromises. Bangladesh must be prepared either to accept the use of acrylic fibers in many textile applications where other countries have found other fibers to be more attractive or it must believe that it can mount efforts which will be successful in overcoming these disadvantages.

Thus, from a marketing and applicability viewpoint it is our recommendation that Bangladesh adopt more conventional and proven approaches to the solution of these textile problems and concentrate its efforts on developing other more suitable fibers.

Economic Factors

Acrylic Fibers - General Features

With the exception of essentially pilot plant quantities of continuous filament, acrylic fibers are produced and marketed only in staple or tow form. There are very many different products varying in denier, brightness, polymer composition, type of crimp and the like. As originally produced by Du Pont acrylic fibers were made only from homopolymers. These homopolymer fibers were almost impossible to dye. The dyeing problems were resolved by the use of copolymers and in some cases by the addition of polymers containing basic groups or the use of a basic monomer to form tripolymers. One of the favorite basic monomers was methyl vinyl pyridine, MVP. These fibers were designed for use with acid type dyestuffs and may still be prepared in small quantities for use primarily in blends with wool. The greatest advance came, however, with the discovery that the usual copolymers contained sufficient acid groups that they could be dyed with basic dyes. Very surprisingly basic dyes when used on cotton have very poor fastness properties but when used to dye acrylic fibers the fastness properties are greatly improved and are satisfactory for many critical uses. Since this early discovery the range of basic dyestuffs, which are available for dyeing acrylics, has been greatly increased and the fastness of basic dyeing on acrylics can no longer be considered a problem. However, polymers containing from 5 to about 10% of comonomers such as vinyl acetate or methyl acrylate are still used.

Since acrylic polymers decompose at melt extrusion temperatures they are spun from solution using either wet or dry spinning systems. The solvents, which have been used, cover a very wide range and to some extent the choice of solvent determines the spinning process which can be used. It will be recalled that in dry spinning the solvent is evaporated by extruding the spinning solution or dope into a heated chamber and evaporating the solvent. This requires the use of a solvent which is relatively volatile and the process can not be used for many solvent systems. In wet spinning the dope is extruded into a spinning both in which the polymer is precipitated in fiber form. Thereafter the precipitated fiber is washed free of solvent and the solvent recovered. As noted the Du-Pont solvent is dimethyl formamide, DMF, while the Monsanto solvent is dimethyl acetamide, DMA. The American Cyanamid solvent is a concentrated about 45% aqueous solution of sodium thiocyanate. The Dow Badische solvent is an aqueous mixture of sodium and zinc thiocyanate.

In the Du Pont system evaporation of DMF is not complete particularly at higher deniers and high spinning speeds and the residual solvent is removed by extraction with water. In the Monsanto system the DMA solution is wet spun into a more dilute aqueous solution of DMA in which the polymer is insoluble and the fiber is washed free of DMA with water. In a similar manner American Cynamid's spinning bath is about a 15% aqueous solution of sodium thiocyanate maintained at about 4°C. Thereafter, the fiber is washed free of solvent with water.

Copolymerization of acrylonitrile can be carried out either in suspension or in the spinning solvent. For many purposes the suspension system is satisfactory and will be the one described. Acrylonitrile has a limited degree of solubility in water but the polymer polyacrylonitrile is insoluble so that as polymerization proceeds the polymer forms a suspension. The polymerization of acrylonitrile is a free radical system and generally a redox catalyst (reduction - oxidation) system is used. The preferred redox system is persulfate-bisulfite in an acidified medium. Polymerization can be either in batch or in continuous reactors. The heat of polymerization is removed either through the walls of the jacketed reactor or by circulation through an external heat exchanger.

Although continuous polymerization is the preferred system and, since polymer color is essential, the original reactors were stainless steel. Unfortunately, in the initial polymerization stages the stainless steel surfaces quickly become coated with an impervious layer of polymer which greatly reduces heat transfer through the jacket wall and it is very difficult to control reaction temperature. One successful solution to this problem is the use of an aluminum reactor on which the precipitated polymer does not form a thick cohesive layer.

The molecular weight of the polymer is controlled primarily by the ratio of the catalyst system to the monomers present and the conversion is related to the temperature and the residence time. The concentration of the suspension, which can be used, is determined by the thickness of the slurry which can be stirred and this in turn is related in part to the type of polymer which is produced. In the case of vinyl acetate copolymers acrylonitrile polymerizes at a faster rate than vinyl acetate so that the general procedure is to feed a higher concentration of vinyl acetate in the monomer stream than is required in the final polymer. In the continuous reactor all of the reactants are fed at some constant rate including the water which will give the desired residence time and the products are constantly withdrawn.

High concentration of acrylonitrile in the air have been recognized for years as a potent health hazard. It has only been recently after the Du Pont Company carefully examined the health records of their employees who had been exposed to acrylonitrile that the real problem was uncovered. The Occupational Safety and Health Administration (OSHA) and the Environmental Protection Agency have now established strict standards even for low concentrations of acrylonitrile in the air. Currently these standards depending upon length of exposure are in the range of 0.2 to 2.0 PPM. These standards would apply to the manufacture of acrylonitrile, transfer or handling of acrylonitrile and to the polymerization and monomer recovery areas. Normally unreacted monomer is recovered by steam stripping. For subsequent processing steps the polymer presents no particular problems from a pollution standpoint.

Polymer is recovered from the suspension by centrifuging. If aquoous solutions are used as a solvent notably the use of aqueous sodium throcyanate it is not necessary to dry the polymer. The amount of water in the wet cake is used to dilute the very concentrated solution coming from the recovery unit to the proper concentration desired in the spinning dope.

The preparation of air free spinning dopes has presented a number of problems whose solution depends upon the solvent employed. Generally these solutions have been to remove as much of the air as possible from the polymer-solvent slurry under conditions such that solution of the polymer is minimized and thereafter subjecting the slurry to dissolving conditions. The remaining air bubbles are removed in a series of falling thin film evaporators. The removal of bubbles is required to prevent fiber breakage in the spinning operation.

The paragraphs to follow will describe a typical wet spinning process. The stored spinning dope is metered to the individual spin packs by a gear pump. In order to control denier the speed of all gear pumps must be accurately controlled. Since the viscosity of the spinning dope is much lower than for melt spinning the spinneretes can be much thinner and the individual holes in wet spinning can be much closer together. The face of the spinnerette is in contact with the spin bath.

As the dope enters the spin bath polymer starts to precipitate out and the fiber resembles a gel. As the concentration of the solvent in the partially precipitated fiber decreases more precipitated polymer forms. The individual fibers are drawn from the spinnerette face by rollers and fibers from a number of spinnerettes are joined to form a tow. The number of fibers in such tows is large and may be as high

300,000 or more. Emerging from the spin bath the fibers contain considerable solvent and this must be removed prior to stretching. One common method is to wash the fibers in a series of troughs in which pure water is introduced into the last trough and flows counter-currently to the fiber flow into the first trough and finally into the spin bath. The rate of flow of the water is controlled so that the composition of the spin bath at the desired concentration is maintained. The overflow from the spin bath is sent to solvent recovery.

The problems encountered in washing involve the removal of the solvent from the individual fibers and also from the many fibers which constitute the fiber bundle or tow. There are a number of ways of accomplishing the breaking up of the solvent rich film which accompanies the tow as it is pulled through the wash bath. One a simple but effective methods is the use of streams of air bubbles.

Solvent free fibers at the end of the washing cycle are very weak and are essentially greatly expanded hydrogels. Although the methods used in washing may be slightly different for each process the procedures followed thereafter appear to vary widely. In one method the washed tow is stretched in very hot water by two sets of rollers operating at different speeds. This stretching, usually 4-6 times, greatly increases the strength of the fibers and reduces not only the diameter of the individual fibers but also the size of the tow. The stretched tow is then fed to the crimper. The crimper consists of a stuffing box into which the fibers are forced at a rate faster than they are released. As a result the fibers are forced back on themselves and form planar wave or zig-zag shape. The tow from the crimper is fed to the wet centrifugal cutter where the tow is cut to the desired staple length. At the same time finish is applied and the amount controlled by the concentration of the finish and the amount of pressure applied on the rollers which squeeze excess finish from the staple blanket as it emerges from the cutter.

At this point the staple fiber has a tight hydrogel structure. Drying of the fiber is a critical operation and in the initial part of the oven drying is carried out under high humidity. Under these conditions the hydrogel structure collapses to form the final dimensionally stable fiber.

In the other general process the washed fibers which may or may not have been given some minimal stretching are dried on heated rotating cans much like the cans in a slashing operation in a textile mill. The dried fibers in tow form are then stretched in a steam tube by two sets of rollers operating at different speeds. The stretched tow is fed to a finish applicator and then to the crimper where it is crimped in the presence of steam. Finally, the crimped tow is cut using a dry cutter. After cutting the fibers are given a final drying to removing any excess moisture introduced at the finish application and crimping stages.

In both cases the applied finish is usually a proprietary product and probably differs for each company. In general it consists of a lubricant and an antistatic agent which is usually a quaternary ammonium compound. The type and amount of finish are critical as is the crimp level. These properties are related to good textile processing into yarn and if these factors are not controlled properly the staple fiber may tend to load the card or fail to make a coherent uniform web between the card doffer and the trumpet. The latter will result in an uneven sliver and eventually lead to a very uneven or irregular yarn.

In order to make fibers of various types of brightness slurries of titanium dioxide in spinning dope can be prepared and added to the spinning dope prior to extrusion. In addition, some companies have prepared dope dyed fibers by using various pigments dispersed in the spinning dopes prior to extrusion. Such colored staples have the ultimate fastness properties. Again, other companies have prepared colored staples which have fastness properties slightly poorer than the pigmented staples but very satisfactory fastness properties for most textile applications by actually carrying out a dyeing operation when the fiber is still in the hydrogel stage and can be easily dyed.

Other companies have prepared conjugate spun fibers by actually extruding two different dopes in such a manner that each individual fiber is composed of two different parts which have different properties including shrinkage. As discussed earlier if blends of two different fibers are made and spun into yarn each with different shrinkage characteristics the fiber which shrinks will force the non-shrinking fiber to adapt itself to a kinked shape thus making a very lofty yarn. If the individual fiber consists of two parts, the so-called conjugate spun fibers, and if the two parts have different shrinkage characteristics, under shrinkage conditions the fiber will assume a helical crimp and such fibers will have much different characteristics than the fibers produced by the previously described stuffing box crimping process.

In order to prepare tows the major features of the process are the same. However, prior to cutting the tows are folded very uniformly into large boxes and sold in this form rather than cut and baled as staples. In this tow process very uniform even tows must be prepared and the packing in the box require very special tow packing or laying equipment. As discussed tows are used to prepare high bulk yarns for sweaters.

Wet spinning is necessarily a slow process since the maximum speed which can be obtained is determined by the force required to pull the gelled fibers through the spin and wash baths and the strength of the gelled fiber at each point. If the strength of the weak gelled fibers is exceeded the fibers will break. Since wet spinning is necessarily slow the processes must use the ability to process a great number of fibers from each spinnerette to reduce the cost. Wet spinning is ideal for this purpose since spin holes can be close together and each fiber is readily surrounded with spin bath. It is for this reason that wet spinning processes, rayons, for example, are at a competitive disadvantage to melt spun process for producing continuous filaments when the number of filaments in each bundle is low.

Inherently dry spinning process is a faster process than wet spinning. Unfortunately since the fibers are sticky when they first emerge from the spinnerattes dry spinning spinnerettes must have much larger distances between holes than wet spinning spinnorettes and the number of individual fibers which can be produced from a given spinnerette is thereby reduced.

The Du Pont dry spinning process for acrylic fibers is much the same as tho wet spinning process through the preparation of the dope. Although we have never seen the process and since no detailed information on this process has been published it is reliable reported in the trade that their spinning speed is so high that the as spun fibers emerging from the spinning chambers contain so much solvent that solvent extraction steps prior to stretching are required. Thereafter, the tow would be processed must as we have discussed in wet spinning with stretching in steam followed by crimping, cutting and baling.

It should be pointed out that one of the reasons for the high investment cost/is the requirement for solvent recovery. In wet spinning process using DMA or DMF the dilute aqueous solutions from the spin bath or wash water must be concentrated and the solvent eventually distilled. The same situation is true for dry spinning using DMF. In the case of solvents such as sodium thiocyanate the aqueous solutions must be concentrated at least to the dope concentration level and decolorized to remove any color bodies either present originally or formed in the process. These steps require considerable energy since removal of water is required.

ACRYLIC FIBERS CON'T

Economic Factors

Acrylonitrile

As indicated in the introduction acrylic fibers contain at least 85% acrylonitrile units. In practice most types of acrylic fibers contain 90-95% of acrylonitrile units and, therefore, fiber raw materials costs will be determined largely by the price of acrylonitrile. The very earliest acrylonitrile plant in the United States, operated by American Cynamid, was based on ethylene chlorohydrin. This process was very costly and with mounting interest in acrylonitrile arising from the development of acrylic fibers by Du Pont, Chemstrand and American Cyanamid, Monsanto and American Cyanamid built acrylonitrile plants in 1951-52 based on the catalytic addition of hydrogen cyanide to acetylene. Some time thereafter Standard Oil of Ohio (Sohio) developed their famous process for acrylonitrile based on ammoxidation of propylene. This process or slight modifications of this process quickly suplanted the acetylene based process and is now the standard process for producing acrylonitrile used world wide.

Acrylonitrile is produced in the United States using the Sohio process in the following plants.

Production of Acrylonitrile
(Millions of Pounds)

Company	Location	Capacity
American Cyanamid	Fortier, La.	200
Du Pont	Beaumont, Texas	300
Monsanto	Alvin, Texas	460
Vistron (Sohio)	Lima, OHIO	390

A new plant was announced by Monsanto at Alvin, Texas with a capacity of 500 million pounds. Monsanto had relied very heavily on the use of acrylonitrile containing polymers to produce family-sized soft drink bottles such as Pepsi and Coca Cola but with the ban imposed by the Food and Drug Administration, U.S. Government on the use of polymers containing acrylonitrile it is not known if the plant will be delayed.

Since no new acetylene based plants for acrylonitrile have been constructed since the early 1950s and since the process is considered obsolete it is very doubtful that accurate estimates of the current costs of producing acrylonitrile from acetylene can be made without access to detailed information upgraded from old information. At best such studies would require detailed engineering investigations since construction costs have escalated so dramatically in recent years. Since the Sohio process has replaced the acetylene process the unknown is the differential cost between the two processes.

Dr. A. Huq[6] has estimated the investment cost of producing acrylic fibers in plants varying in size from 5000 to 36,000 tons per year. In each case the project consisted of the fiber plant and accompanying plants to produce the necessary amounts of acetylene, hydrogen cyanide, acrylonitrile and by product ammonium sulfate. In this analysis the total project costs have been estimated at 613.4 million dollars for the production of 36,000 tons of acrylic fiber. Unfortunately, the costs of producing acrylonitrile were not detailed in this study. However, cost estimates have been made for plants at the above indicated plant capacities.

Rather than attempting to rework this approach we have elected to determine the cost of producing acrylonitrile using the Sohio process. Such an approach will supply information on basic differences in investment and production costs for the two processes when combined with investment and production cost data for acrylic fiber to be estimated in a later section of this report. In addition the report should give a clearer picture of the cost of imported acrylonitrile for future possible use. Since the use of imported acrylonitrile to produce acrylic fibers is much less complicated and presumably much less demanding from a capital point of view this alternative should be investigated.

Obviously, the price of acrylonitrile will establish the major raw material costs for the plant. Currently in the U.S. the list price of acrylonitrile is 27 - 27.50 ¢/pound and is probably selling under contract for 25 ¢/ pound. Since there is only one US non-integrated acrylic fiber producer, Dow Badische, his costs are difficult to estimate but probably are somewhat lower than this 25 ¢. The price to the other producers will be determined by transfer prices. The philosophy used in estimating the future course of chemical prices in the U.S. is rather simple. Over the long time period it is believed that prices in a growing product area will reflect the cost plus return of producing the product in a new efficient grass roots plant. If the price is too low no new plants will be built until a satisfactory return is achieved. Again, if the price is too high new competition will emerge. In addition combined efforts of purchasing agents tend to drive prices down to the cost plus return level. Thus, an estimate of cost plus an acceptable rate of return for acrylonitrile will be valuable in analysing an acrylic fiber project.

Using the Sohio process the key raw material is the price of propylene. Propylene comes largely from naphtha or gas oil crackers and from catalytic cracking of hydrocarbons. In refineries with catalytic cracking to increase yields of gasoline, propylene is produced in large quantities. In the U.S. refinery propylene was the source of the propylene used in the manufacture of polypropylene resin and for other chemical uses. Normally refinery propylene has been alkylated with isobutane and the resultant product added to the gasoline pool to improve the anti-knock rating in the presence of tetraethyl lead. With the gradual elimination of lead propylene alkylate has essentially been reduced to fuel value only.

Propylene is also a coproduct in the cracking of naphtha or gas oil. Thus, about 0.55 pound of propylene is produced per pound of ethylene. The value of any one product from naphtha or gas oil cracking will be related to the value assigned to the other coproducts. In this study we have elected to produce gas oil in a grass roots 160,000 barrel per day refinery and we have estimated the costs of producing the various products produced in a modern 1 billion pound per year ethylene plant based on gas oil from the above refinery. Both of these plants are estimated on a U.S. Gulf Coast location with construction in 1976-76. The data are taken from a private study by Evans[7].

In this study the price of natural gas was related to the delivered price of crude oil as shown below.

Crude oil delivered	$/B	9	10	11	12	13
Natural gas	$/MM BTU	1.35	1.50	1.65	1.80	1.95

The processes used for establishing the estimated prices for the products of a gas oil cracker are very complicated and are too long for this study. However the processes used and the final prices have been reviewed by a number of competent authorities and several oil companies and are believed to meet with their general approval. Both the refinery and the gas oil cracker are based on a 15% DCF. The prices for the various products from the cracker are presented in Table 16.

Table 16

Ethylene Manufactures Cost + Return for Major Products from Gas 0.1 Cracking All Products at 15% DCF

Delivered Crude Price $/B	9	10	11	12	13	
Gas Oil $/B	15.30	16.30	17.20	18.20	19.30	Products Produced
Cost + Return ¢/pound						WT % Gas Oil Charge
Ehtylene	12.9	13.3	13.8	14.2	14.6	25.74
Propylene - Poly. Grade	10.8	11.3	11.7	12.2	12.7	7.25
Propylene-Chem. Grade	9.4	9.9	10.3	10.7	11.1	7.25
Butadiene	17.6	18.1	18.5	19.0	19.5	6.3
Butenes Mixed	6.9	7.3	7.6	8.0	8.4	4.9
Cost + Return ¢ /Gallon U.S.						
Benzene	87	91	96	100	104	3.4
Toluene	63	68	72	76	80	3.5
Xylene	69	74	78	82	86	3.4 Others 37.9

The annual capacity of the acrylonitrile plant was established at 200 million pounds. This size is probably smaller than a current world sized plant which may be approximately 400-600 million pounds. The process selected was Sohio's and uses their improved iron-bismuth catalyst. The costs are given in Table 17. The specific costs shown are for delivered crude at $ 9.40/B. Although delivered crude costs vary with the refinery this cost was the estimated crude cost up to mid 1977. It should be emphasized that tables 16 and 17 permit estimates of costs + returns for higher crude costs.

Table 17

Acrylonitrile Production Cost

Estimated Investment $ MM			
Battery Limits		16.3	
Offsites (Incl. Waste Disposal		8.2	
Total Depreciable		24.5	
Initial Catalyst Fill		4.9	
Working Capital		4.1	
Paid Up Royalty		Not included.	
	Total Investment.	33.5	
Raw Materials	¢/lb	lb/lb AN	¢/lb AN
Propylene Chemical grade	9.6	1.07	10.27
Ammonia	9.0	0.43	3.87
Oxalic Acid	40.0	0.0005	0.02
Sulfuric Acid	3.0	0.152	0.16
Catalyst	500	0.0016	0.80
	TOTAL RAW MATERIALS		15.42

Conversion Costs

	Units	$/Unit	Units/CD*	$/CD*
Operating Payroll	Men/Shift	200	6	1200
Supplies and Misc.				120
Maintenance @ 5%/Yr.				3556
UTILITIES				
Cooling Water	M.Gal.	0.05	25,770	1288
Steam	M. Lbs.	2.20	887	1952
Power	CKWH	2.00	373	746
Process Water	M.Gal.	1.00	87	87
Inert Gas	M.SCF	0.25	60	15
Plant Overhead				2278
Local Taxes & Ins.				926
Depreciation	10 YR.SL.			6712
Running Royalty If Applicable			Not Included	
		Total Conversion/CD		18,660

Pounds/Day 548,000

Conversion Cost ¢/lb 3.4

* CD = Calendar Day.

Summary of Costs

Total Investment	$ 33.5	MM
Raw Materials	15.4	¢/LB
Coversion	3.4	¢/LB
Total Plant Cost	18.8	¢/LB
Additional charges for 15% DCF	3.2	¢/LB
Total Cost + Return	22.0	

The costs plus returns are in reasonably good agreement with the current estimated selling price. No provision has been made for any royalty payment. Current oil prices may differ from those used in this report. It is believed that these costs give a fairly good approximation of the costs of producing acrylonitrile. Of interest is the relatively low investment costs. Investment costs in other areas of the world may differ substantially from these estimates. The major share of construction in these calculations was in mid 1976-1977. It is known that Arabian Gulf investment costs may be 35-40% higher than U.S. Gulf coast. Nevertheless we believe that the investment costs for this process will be much lower than an acetylene based plant. The difficulties of going all the way back to feedstocks for Bangladesh are apparent. This plant probably would be small by world standards but it would be capable of supporting about an 95,000 ton acrylic fiber plant. Thus, it becomes very evident that the marketing factors discussed in the previous section of the report become very important. For example, if the Bangladesh market could support an 95,000 ton acrylic fiber plant propylene could be imported at probably less than 20% of the cost of cotton. It is for these reasons that investments in three stages (a) fiber plants based on imported fiber intermediates, (b) followed later by investments in fiber intermediate plants when warranted by the markets and (c) finally when warranted by the development of synthetic fibers and related products investment in a basic petrochemical plant become so attractivo.

ACRYLIC FIBER PRODUCTION COSTS

The estimated costs of production of acrylic fibers are based on information supplied by the Mitsubishi Rayon Co. who operate acrylic fiber plants in Japan and elsewhere. This process for Vonnel acrylic fiber was based on an original license from the Monsanto Corp. with whom they had a technical exchange agreement for many years. It is known that the Monsanto Corp. is not interested in supplying know-how for an acrylic fiber plant in Bangladesh. In addition to their wet spinning plant Mitsubishi Rayon operate their own version of a dry spinning process. More detailed information on their process can be obtained from Mitsubishi Rayon at a later date under a secrecy agreement. However, it is believed that the current information on which these estimates are based are sufficiently accurate for a preliminary estimation of costs.

Other possible acrylic fiber processes can be licenced, if desired. The American Cyanamid process using aqueous sodium thiocyanate as a solvent can be licensed but their Textile Division does not have a large engineering staff and they have elected to use Zimmer-U.S., a part of Davy Power Gas Co., as their licensing agent and engineering arm. The American Cyanamid acrylic fiber process was licensed to the Toyobo Co. of Japan who formed Japan Exlan Co. to manufacture the acrylic fiber.

As noted earlier the Du Pont Company has announced that they will close their Dordrecht, Holland acrylic fiber plant as a result of the losses which they have incurred in recent years. The disposition of this plant is not known but possibly some portion of the plant could be purchased at considerable savings. Possibly a license from Du Pont could be obtained.

In addition, the Asahi Chemical Industry Co., Japan has apparently either formed joint ventures or has licensed plants in several countries and their process possibly could be licensed. It would appear that obtaining a license or know-how for making acrylic fibers would not be a major problem. From Bangladesh's viewpoint the supplier of technology, either an acrylic fiber producer. . or an engineering firm, must have the ability to give in-plant training to selected Bangladesh personnel.

As indicated earlier the recovery of solvent places certain restrictions on the minimum size plant which can be built economically for acrylic fibers. Our estimate of the minimum size plant is about 16,000 tons or 35 million pounds. The number of producers of acrylic fibers in the United States has remained constant for the last 20 years and no new grass roots plants have been built for at least fifteen years. There have been changes in capacity by improvements within plants and by selective increases in certain key equipment but these types of changes do not permit translations into new plant costs. For this reason we have elected to use information from Mitsubishi Rayon Co who have participated in the construction of several new plants in the recent past. The estimate is based on a Bangladesh location using utility costs typical of those costs associated with the production of viscose rayon and nylon 6 continuous filaments. No provision has been made for a plant site but in Japan where industrial land is at a premium the required land space would be 100,000 m^2.

In the attempts to apply conversion factors for translating current Japanese plant construction costs to Bangladesh plant construction costs discussions were held with a well known engineering firm but no good relationship could be determined. In fact, it was admitted that it would be very difficult to determine actual construction costs for any given segment of the plant. Such attempts were now under way and eventually will be completed and compared with the original estimates. We could not devote the time nor did we have the information required for such an analysis. Under the circumstances we elected to use a factor of 120% of Japanese costs for the equipment, installation of equipment and offsites ex-building. The estimate is certainly not accurate but it is thought that it should cover differences in installation costs since much of the equipment will not require field erection.

In regard to the building we have used a cost of 350 takas per square foot, equivalent to $ 25.36. This cost may be considered high but since very high ventillation will be required in many areas related to polymerization and recovery of acrylonitrile it is hoped that this will be adequate.

The following assumptions were made in estimating the housing colony. Housing will be provided for all direct plant personnel at the supervisory level and above. Provision will be made to house 30% of the skilled and unskilled workers. Usually, the manning in many Japanese plants is substantially higher than in most European and especially American plants. For Bangladesh manning was increased by 25% over the Japanese estimates. The square footage allowance for housing was General Manager 15,00, Area or Departmental Heads 1000, Supervisors 800 and Skilled and Unskilled 500. Regardless of size a uniform cost of 150 Takas ($10.85) per square foot was used. The estimated cost are as follows and are based on suggestions made by Bangladesh Chemical Industry Company :

Position	Number		$ Cost
Skilled	71		385,900
Unskilled	19		103,300
Supervisor	15		130,400
Department Heads	4		43,500
General Manager	1		16,300
		Total:	679,400

The data as supplied give installed equipment and off-site costs combined with no provision for land or building. After examining several estimates we have found that the battery limits for polymer preparation and fiber spinning plants represents about 75% of depreciable investment and offsite about 25%. Using a conversion factor $1 U.S. = 200 yen these estimates are as follows :

Battery Limits		$ 45,000,000
Offsites		15,000,000
Housing Colony		680,000
	Total:	60,680,000 or $ 1.60/LB.

This investment cost is substantially higher than similar costs for other synthetic staple plants such as polyester or nylon staple. Installed equipment costs were estimated at $39,000,000 or $ 1.02/LB.

The installed plant has a rated capacity over the denier range of 3 to 6 of about 16,000 tons based on an 8,000 hour year. For production purposes we have estimated that the plant will be closed seven days per year for maintenance purposes and the plant would have a rated capacity of 17,200 tons or 37,909,000 pounds.

From a raw material standpoint a ton of fiber requires 0.96 tons of acrylonitrile and 0.09 ton of comonomer. Although Mitsubishi Rayon has not disclosed the exact comonomer which they use it is assumed that it is vinyl acetate. Trade rumors in the United States report that Monsanto uses vinyl acetate and since Mitsubishi Rayon has a Monsanto license there is a good chance that their comonomer is vinyl acetate.

Currently, in the U.S. acrylonitrile has a list price of 27-27.5 ¢/pound and reportedly is selling under contract at less than 25 ¢/pound. For these estimates we have used a delivered price of 28 ¢/pound or $617 per ton. Vinyl acetate has been selling in the U.S. at a list price of 23 ¢/pound but under contract at less than 20 ¢/pound. For these estimates we have used 24 ¢/pound or $529 per ton.

The other chemicals used by Mitsubishi Rayon include solvents (probably DMA), polymerization catalysts, titanium dioxide and fiber finish. The amounts of these products required are generally quite small and the exact composition has not been disclosed because of their proprietary nature. The estimated cost has been provided and has been used with no provision for freight.

As indicated utilities are based on costs closely related to the costs incurred in the viscose rayon and nylon filament plants in the Chittagong area. Data are from Bangladesh Chemical Industry Company. All utility costs are in line except for power costs which are much higher than are usually encountered in most industrial uses.

Labor costs have been supplied by BCIC and supposedly are closely related to their experiences in both viscose and nylon production. All costs include a 60% charge for fringe benefits.

Working capital has been based on assuming a four months supply of all imported materials and a four weeks inventory of finished products. Since any fiber used by Bangladesh Textile Mills Company, BTMC, would be used as a replacement for imported cotton or viscose storage facilities should be adequate. No allowance has been made for accounts receivable since sales are really transfers. Since raw material inventory is so high attempts should be made to reduce these costs based on experiences of estimating anticipated delivery dates but the present estimate should be more than adequate.

The projected costs for producing acrylic staple are given in Table 18. The estimated sales price of acrylic staple in the U.S. is about 62-63 ¢/pound for the usual denier ranges. Acrylic staple for blankets reportedly is selling for 52 ¢/pound. Even with the projected very heavy investment of $ 1.60 per annual pound fiber costs ex-capital charges are competitive with cotton and with imported acrylic staple. However, if one applies even modest capital charges the fiber costs are no longer competitive. It is apparent that attempts must be made to reduce capital investment.

Table 18

Acrylic Fiber Production Costs

Plant		Capital Charges	
Construction	1978-79	Battery Limits	45,000,00
Operational	1980	Off-sites	15,000,000
Capacity	17,200 tons	Housing Colony	680,000
		Fixed Capital	60,680,000
		Working Capital	5,171,000

Materials

Product	Quant.	Unit.	$/ Unit Price	$/Annual Cost	¢/LB. Fiber
Acrylonitrile	16,512	ton	617	10,187,000	26.87
Comonomer	1,548	ton	529	819,000	2.16
Other Chemicals Solvents T_1O_2 Finish etc.				3,095,000	8.16
		Sub-Total:		14,101,000	37.19
Packaging Materials				387,000	1.02
TOTAL MATERIALS				14,488,000	38.21

Utilities

Power	30.96×10^6	KWH	0.0543	1,681,000	4.43
Cooling Water	12.9×10^6	M^3	0.00724	93,400	0.25
Process Water	0.69×10^6	M^3	0.254	175,000	0.46
Steam	0.43×10^6	Ton	1.09	469,000	1.24
	Total Utilities			2,418,000	6.38

Operating Cost

Operating Personnel

Type	Number	$/Mo.	$ Annual Cost	¢/
Skilled	193	116	269,000	0.71
Unskilled	63	58	44,000	0.12
Supervision	10	174	21,000	0.06
Sub-Total:			334,000	0.88

Maintenance

Labor				
Skillod	45	116	63,000	0.17
Supervision	5	174	10,000	0.03
Supplies (1.5% Equipment Cost)			585,000	1.54
Sub-Total:			658,000	1.74
Total Operating Cost			992,000	2.62

Overhead Expenses

Direct Overhead (Labor+Superv. @ 30%)		100,000	0.26
Gen. Plant Overhead (60% Operating Cost)		595,000	1.57
Insurance (0.75% fixed capital)		455,000	1.20
Depreciation			
Battery Limits	10%	4,500,000	11.87
Offsites	5%	784,000	2.07
Interest (10% Working Capital)		517,000	1.36
Total Overhead		6,951,000	18.34
Total Costs Ex-Capital Charges		24,849,000	65.5

This possibly could be accomplished by a more accurate assessment of construction and installation costs through a more detailed engineering study. Such studies could possibly reduce investment costs by about 15%. However, in order to reduce these high investment costs to the level where the manufacturing costs of acrylic staples would be more attractive would require drastic reductions in investment costs. As discussed it might be possible to reduce costs considerably by utilizing equipment from an inactive plant such as the plants at Dordrecht, Netherlands.

From an investment standpoint it is clear that the use of imported monomers to reduce acrylic fibers is preferred to that based on manufacturing acrylonitrile from acetylene. The much more detailed analysis of A. Huq[6] show that a 16,000 t p y acrylic fiber plant would require an investment of $395 MM. From the information presented in this section the required investment ex land for a 16,000 t p y staple plant would be approximately $61 MM. At usual returns on capital fiber costs would not be competitive with fiber produced in depreciated plants in other countries. These factors coupled with the poor marketing prospects previously discussed in an earlier section of this report make it very clear that a project for manufacturing acrylic fibers based on Bangladesh natural gas can not be recommended. Although the manufacture of acrylic fibers based on imported monomers is more attractive from a cost standpoint this approach can not be recommended because of the poor marketing prospects and the low return on investment.

Acrylic Fibers From Natural Gas

No attempt has been made in this study to re-estimate the cost of producing acrylonitrile from natural gas via acetylene. As indicated in an earlier section of this study plants for the production of acrylonitrile from acetylene were built in the U.S. in the early 1950's by both Monsanto and American Cyanamid. These plants were reasonably successful but were rather quickly replaced by the Sohio process using propylene. It is technically feasible but not economical to produce acrylonitrile from acetylene and this process has been made obsolete by the more economical Sohio process.

Since the U.S. plants for acrylonitrile using acetylene were built in the 1950's it would be very difficult to accurately estimate current costs based on these costs. Since the process is obsolete it is doubtful if any major improvements have been established. It is suggested that if more accurate costs are desired a new detailed engineering study would be required and there would be little current information on which such a study could be based.

As indicated Dr. A. Huq[6] has estimated recently the cost of manufacturing acrylic fibers from natural gas via acetylene. The estimated costs include the cost of preparing the monomer, its conversion into polymer and eventual spinning into fiber. The plants varied in size from 5,000 to 36,000 tons and presumably the same conversion factor was applied to both the monomer and the fiber segments. Since his analysis was project based only certain cost portions were selected from his data and these are detailed in the first portion of Table 19. The estimates are taken director from his study and are approximately 25% to 33% lower than his total estimated project costs.

Table 19

Plant Investments
(Millions of Dollars)

	Monomer and Fiber from Natural Gas		
Plant Capacity (Tons)	36,000	24,000	16,000
Battery Limits	387.23	302.18	236.22
Plant & Machinery	332.10	259.03	202.59
Engineering	11.48	9.11	7.00
Erection Installation	43.65	34.04	26.63
Offsites	50.1	39.13	30.65
Roadway	0.26	0.26	0.26
Civil Engineering Works	49.84	38.87	30.39
Investment	437.33	341.31	266.87
Investment $/Annual Pound	5.51	6.45	7.57
	Monomer & Fiber from Propylene		
Battery Limits Monomer	16.13	16.3	16.3
Battery Limits Fiber	101.3	67.5	45.0
Offsites Monomer	8.2	8.2	8.2
Offsites Fiber	33.75	22.5	15.0
Total Investment :	159.55	114.5	84.5
Investment $/annual Pound	2.01	2.16	2.40
	Fiber From Imported Monomer		
Battery Limits	101.3	67.5	45.0
Offsites	33.75	22.5	15.0
Total Investment	135.0	90.0	60.0
Investment $/Annual Pound	1.70	1.70	1.70

The second portion of Table 19 is an estimate of the investment costs for producing monomer from propylene and the conversion of this into polymer and fiber. Note that the investment costs for the monomer are the same regardless of the fiber plant size. These investment costs are for a plant located in the US Gulf Coast and are for a minimum size plant, 200 million pounds. The original catalyst fill has not been included which could add about $5 million to each of these costs. This plant would have the capacity to supply monomer at rated capacity for a 95,000 ton fiber plant at a depreciable investment cost of 12 to 14 ¢ per annual pound of fiber. The plant capacity is roughly 40-50% of present World Scale plants.

The investment cost for acrylic fiber plants is given in the third portion of Table 19. These investment costs have been projected on a straight line basis from a 16,000 tpy base and are probably somewhat high. If we assume these costs as realistic for the natural gas fiber plant portion the monomer from natural gas plant investment cost would be given below :

Table 20

Plant Investment Monomer
(Million Dollars)

Plant Size Tons	36,000	24,000	16,000
Monomer From N. Gas	302	251	207
Monomer From Propylene	24.5	24.5	24.5

The above differences are so great that even if investment costs in Bangladesh for a propylene based plant were two or three times U.S. costs the conclusion would still be the same. As shown at rated capacity the monomer from propylene plant would have to operate only about 9 weeks per year. Unfortunately, there is a world overcapacity of acrylonitrile so that the export market would be most difficult.

Currently chemical grade propylene in the U.S. is selling at or under 10 ¢/pound. At a delivered price of 14 ¢/pound ($308/ton) the drain on foreign exchange to supply a 16,000 tpy fiber plant would require about $ 5 million. Even if an acrylonitrile from natural gas plant is built a 16,000 tpy fiber plant would require about $4 million of imported comonomers and other chemicals. The import requirements for the three possible 16,000 tpy fiber plants would be natural gas $ 4 MM, propylene $9 MM and imported monomer $14 MM. Thus. an investment of more than $200 mm in a natural gas monomer plant would be required to reduce foreign exchange drain by $ 10 MM.

Although building an acrylic fiber plant in Bangladesh is not recommended for other reasons, if a decision is made to build an acrylic fiber plant, the combined data from Dr. A. Huq[6] and this study would indicate that an acrylic fiber plant should be built first to be followed at some future time with a plant to produce acrylonitrile by the best process available at that time and in all probability in the near term this would be based on propylene. The data clearly show that a monomer plant based on natural gas is not economical and is not recommended.

Although the other reasons for not building an acrylic fiber plant in Bangladesh are based largely on marketing factors the position can be taken that, if no other fibers were available in Bangladesh, fabrics would be produced from acrylic fibers. This position is undoubtedly true. However, the marketing data clearly show that acrylic fibers would not be used for the fabrics marketed in Bangladesh under conditions involving choice of fiber. Bangladesh does have a choice in the type of fibers it manufactures. It can produce polyester fibers from imported raw materials at costs probably lower than acrylic fibers. These fibers are the preferred synthetic fibers for blending with cotton as demonstrated by world wide acceptance. The options to Bangladesh are open. It can move along the routes which have proven successful for other countries or it can pioneer in the development of new acrylic staples and the development of suitable fabrics for the Bangladesh environment using acrylic fibers.

Conclusions and Recommendations

The established textile industry using imported cotton and viscose staple fibers can not meet current demands and must be supplemented by imports of yarns and textile products. The planned increase in consumption and the rapidly growing population places increased pressure on the methods for reducing this drain on foreign exchange. Repeated studies have suggested and recommended the use of Bangladesh natural gas to produce fiber intermediates via the formation of acetylene. The proposed fibers include PVC, PVA and PAN.

Of the fibers only PAN can be considered a major well established fiber. PVC and PVA fibers either have very marginal fiber properties or have poor fiber characteristics at high humidities combined with high production and investment costs. These two fibers, PVC and PVA can not be recommended for production in Bangladesh.

PAN has been shown to be a very desirable fiber for certain end uses such as sweaters, pile fabrics, blankets and certain knitted products but to have very limited uses in broadwoven apparel fabrics and in blends with cotton. Unfortunately acrylic fibers are not used in the major markets of interest to Bangladesh.

The investment cost of a medium size plant for the production of acrylonitrile via the ammoxidation of propylene route has been shown to be 17 ¢ per annual pound. Production costs plus return are approximately equal to current selling prices. These costs are substantially lower than those based on acetylene.

The production costs for an acrylic fiber plant in Bangladesh using imported acrylonitrile have been shown to be competitive with prices of imported fiber produced in older depreciated plants in other countries. However, the high investment costs in an acrylic fiber plant place strict limitations on capital returns.

In view of the limited potential market for acrylic fibers in Bangladesh combined with the high investment and production costs based on monomers from acetylene the production of acrylic fibers in Bangladesh can not be recommended. Similarly, although investment and production costs can be greatly reduced by the use of imported monomers, the production of acrylic fibers through the use of imported monomers can not be recommended.

In contrast to all previous studies on the utilization of Bangladesh natural gas for the production of synthetic fibers this study can not recommend, for the reasons outlined, the production of PVC, PVA and PAN fibers in Bangladesh. It is concluded that additional studies on the use of Bangladesh natural gas as a feedstock for the preparation of synthetic fibers for use in Bangladesh can not be justified and, therefore, it is recommended very strongly that no additional studies be undertaken at this time or in the near term future.

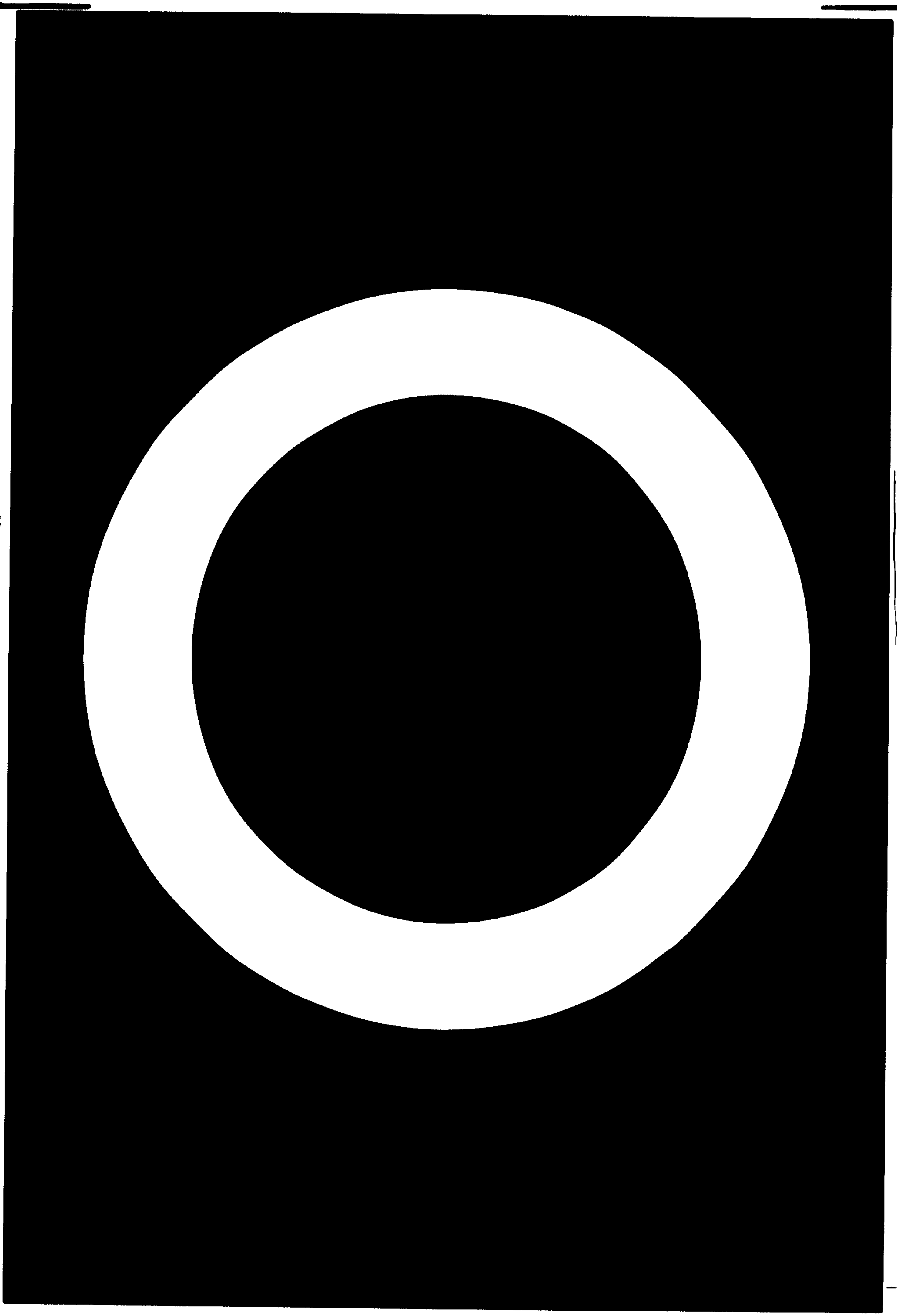
Additional studies might be justified on the production of acrylic fibers via imported acrylonitrile if, as a result of development efforts in other countries, acrylic staples have been developed which are the preferred fibers for blending with cotton as substantiated by the market place and if these developed staples have been shown to produce textile products with broad acceptable properties for hot and humid climates as encountered in Bangladesh. As a judgement factor based on personal experience it is highly unlikely that success in these developments will be achieved.

If, as a result of success in the above developments and if the markets for acrylic fibers have grown to the point where these markets can support a minimum sized plant for acrylonitrile it is recommended that a study be initiated on the best process for the production of acrylonitrile. At any time in the near term this process will utilize either imported or domestic propylene.

In order to reduce the present and ever increasing drain on foreign exchange it is recommended very strongly that Bangladesh study the possible production and use of other man-made fibers more suitable for blending with cotton using imported fibers intermediates or raw materials. It is recommended that the first priority in this study be placed on the production and use of polyester fibers based on imported fiber intermediates such as ethylene glycol and terephthalic acid. Concurrently and as a second choice it is suggested that a study be initiated on the production and use of polynosic fibers based on imported and/or domestic wood pulps.

As a further means of reducing both plant and investment costs it is recommended that Bangladesh study the recovery and use of polyester polymer reclaimed from the explosive growth of the polyester soft-drink bottle industry in the United States.

It is further recommended that these studies must investigate both the use of and the production of these man-made fibers and that these studies will require the full cooperation and participation of BCIC, BTMC and the Hand Loom Board.



Annex I

JOB DESCRIPTION

SI/BGD/74/822/11-01 (32.1.H)

POST TITLE	Expert in Polyacrylonitrile
DURATION	Two months
DATE REQUIRED	1 December 1977
DUTY STATION	Dacca
PURPOSE OF PROJECT	To assist the Government in carrying out a study on natural gas based man-made fiber including polymerization of possibility of eventual integration to natural gas feedstock.
DUTIES	The expert will be assigned to work in close co-operation with Government authorities and is expected to :

Primary duties

1. advise on a comperative basis technical and economic advantages on the production of different types of synthetic fiber from natural gas feed-stock including investment requirements, operating costs and technology;

2. investigate the possible manufacture of poly-acrylonitrile based on imported monomers including investment requirements, operating costs and technology;

3. identify the source(s) from which the monomers can be obtained at a reasonable price;

4. advise on a comparative basis technical and economic advantages on alternative methods of co-polymerization by an appropriate choice of types and quantities of co-monomers to produce modacrylic fibers for textile and industrial applications;

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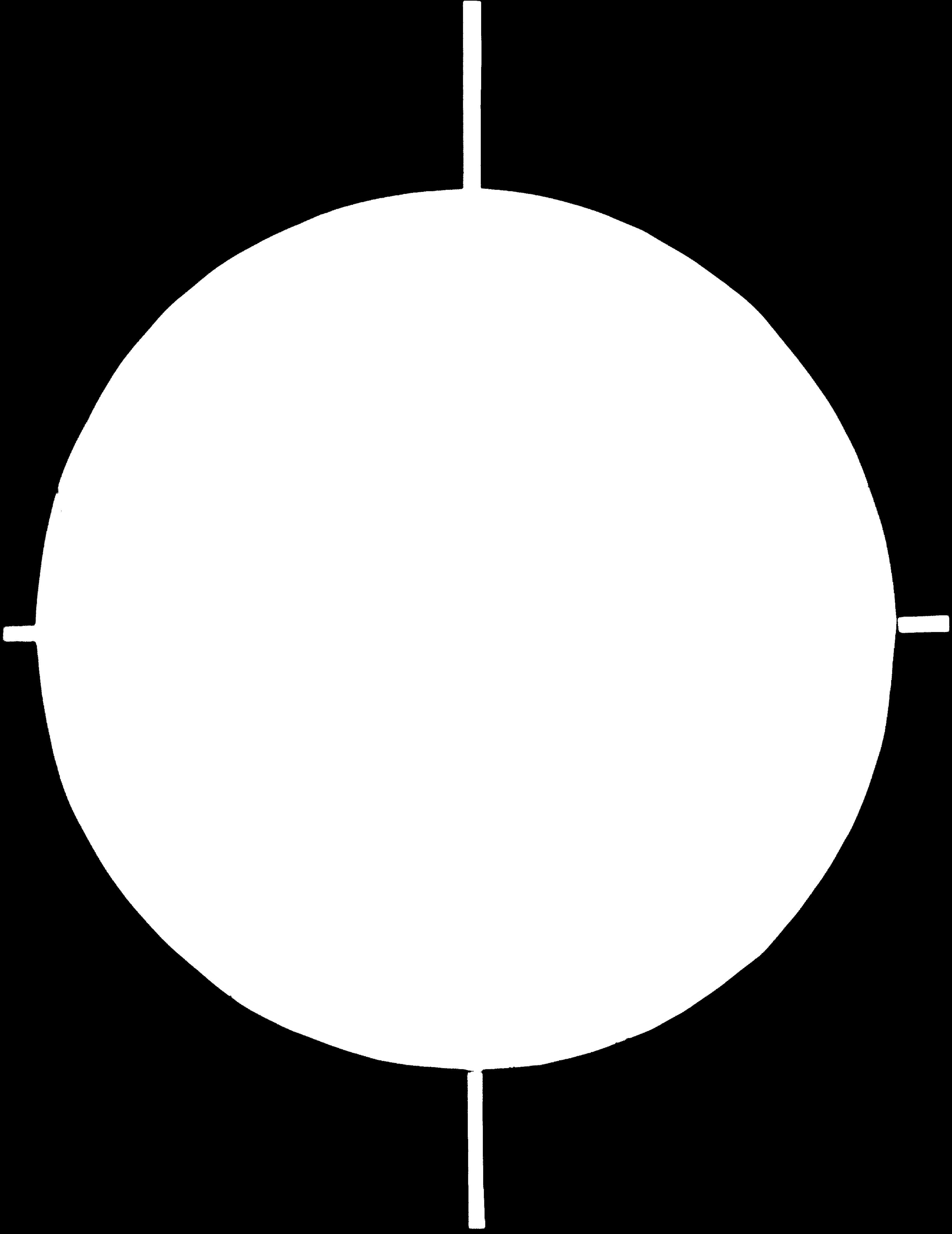

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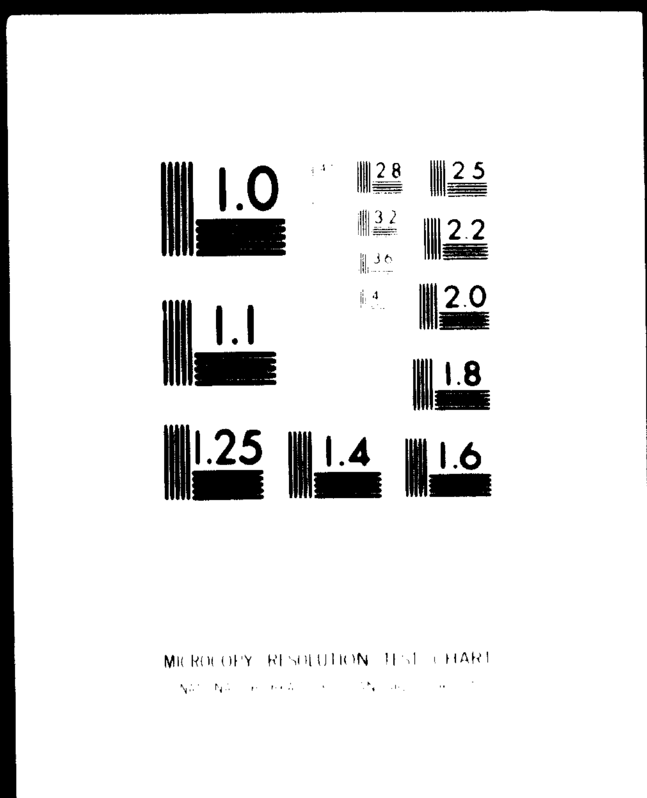

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5. advise on the selection of equipment and investment required to process polyacrylonitriles into fibers.

Secondary duties

6. make recommendations concerning future technical assistance requirements from UNIDO.

The expert will also be expected to prepare a final report, setting out the findings of his mission and his recommendations to the Government on further actions which might be taken.

QUALIFICATIONS

Essential:

Petrochemical engineer or polymer chemist on the production of synthetic fibers with extensive experience in the manufacture of synthetic fiber including polycrylonitrile as well as in carrying out feasibility and market studies.

Desirable:

Experience in processing of acrylic fibers including dyeing and blending with natural fibers.

LANGUAGE

English

BACKGROUND INFORMATION

Bangladesh has sizeable reserves of natural gas of 10 million cubic feet. The Government is at present using this for fertilizer production, power generation and as fuel. Plans were earlier drawn up for a Petrochemical Complex which would include facilities for producing urea, fertilizer polyacrylonitrile fiber and polyvinychloride resin. In view of huge resource requirements, the Government has decided to segregate the project streams. But, before embarking on the PACS project, the Government wants to find out whether technologically it would be possible to economically produce PACK or any other fiber from natural gas. Also whether production of any other fiber from natural gas would be economically desirable. Hence this study which will also include polymerization from imported monomers with possibilities of backward integration to natural gas.

NO CANDIDATES REQUIRED AT THIS TIME

Comments on Job Description SI/BGD/74/822/11.01 (37.1.H)

The job description above issued October 30, 1977 has been amended as a result of certain agreements between UNIDO and the Asian Development Bank in which it was agreed that an unspecified portion of this project time would be spent in assisting the Asian Development Bank in their study of the possible production of synthetic fibers in Bangladesh. In discussions with Dr. Aminul Huq, Chief, Chemical Industries Section of the Bangladesh Planning Commission, Mr. M.C. Verghese, Consultant, and Dr. S. B. Sri Skanda Rajah of the Asian Development Bank, Consultant, it was mutually agreed that the available time would be equally split between the Bangladesh Planning requirements and in assistance to the Asian Development Bank. Dr. A. Huq further modified the Bangladesh Planning Commission request to include the following areas:

1. Advise on the technological feasibility of processing the various types of synthetic fibers from the natural gas produced in Bangladesh.

2. Identify manufacturers and plant locations of the several possible fibers.

3. Identify sources and availability of technology for preparing the several fibers.

4. Estimate cost of manufacturing the required monomers, polymers and fibers.

The Asian Development Bank desired studies include the following areas:

i) Examine and catalogue all past studies on related subjects carried out in Bangladesh.

ii) Examine available data and reports on the synthetic fiber market for apparel and non-apparel usage.

iii) Examine the current level of activity in the domestic synthetic fiber industry in Bangladesh.

iv) Examine available information on indigenous raw materials suitable for the manufacture of synthetic fibers.

v) Examine available information on the suitability or otherwise of existing and planned textile mills for processing synthetic fibers.

vi) Prepare an activity flow chart for the preparation of the proposed Master Plan.

vii) Prepare detailed Terms of Reference for the Team of Experts to be engaged for the provision of technical assistance for the preparation of the proposed Master Plan.

viii) Present findings in the form of a report covering the following aspects :

(a) Need for Technical Assistance.

(b) Approach, Scope and Purpose.

(c) Cost Estimates for Technical Assistance.

(d) Implementation Schedule.

Annex II

MARKET STATISTICS

APPAREL *

END USE & YEAR		TOTAL FIBER	MAN-MADE FIBERS[b] TOTAL	RAYON+ACETATE YARN	RAYON+ACETATE STAPLE	OTHER YARN	OTHER STAPLE	COTTON	WOOL
TOTAL APPAREL	1971	4687.5	2608.2	323.8	285.0	951.4	1047.8	1977.6	101.7
	1972	5172.7	3110.9	376.6	231.4	1311.2	1191.7	1902.9	158.9
	1973	5325.7	3429.7	369.3	230.3	1470.1	1360.0	1761.8	134.2
	1974	4930.9	3151.7	276.1	153.8	1482.8	1239.0	1683.9	95.3
	1975	4781.4	3114.8	250.8	97.3	1568.7	1198.2	1571.4	95.2
	1976	4940.0	3087.3	203.9	101.1	1372.0	1410.3	1737.3	115.4
40 SHEER HOSIERY (W)*	1971	52.2	52.2	0.3	--	51.9	--	€	--
	1972	54.6	54.6	0.1	--	54.5	--	€	--
	1973	56.9	56.9	0.2	--	56.7	--	€	--
	1974	45.8	45.8	0.2	--	45.6	--	€	--
	1975	51.7	51.7	0.1	--	51.6	--	€	--
	1976	56.4	56.4	--	--	56.4	--	€	--
19 41 ANKLETS & SOCKS (MW)*	1971	123.8	68.2	--	€	42.7	25.5	52.2	3.4
	1972	123.0	68.0	--	--	41.3	26.7	51.7	3.3
	1973	122.3	86.8	--	--	50.0	36.8	32.5	3.0
	1974	119.0	84.1	--	0.1	43.0	41.0	32.2	2.7
	1975	120.7	85.8	--	0.1	43.2	42.5	31.9	3.0
	1976	139.4	96.1	--	0.2	46.5	49.4	39.3	2.0
8 29 SWEATERS & RELATED ACCESSORIES (MW)*	1971	97.4	67.8	2.5	€	10.9	54.4	5.9	23.7
	1972	115.0	80.9	€	€	13.4	67.5	7.8	26.3
	1973	126.4	97.9	-	€	13.1	84.6	8.5	20.0
	1974	105.6	82.8	--	€	9.9	72.9	7.8	15.0
	1975	90.9	78.0	--	--	5.6	72.4	6.9	14.0
	1976	114.2	97.1	--	--	6.2	90.9	7.1	10.0
57 CRAFT & HANDWORK YARNS*	1971	78.8	45.3	•	5.3	€	40.0	10.6	22.7
	1972	100.7	69.0	•	8.0	€	61.0	12.0	19.7
	1973	111.6	89.7	•	7.7	€	82.0	10.9	11.0
	1974	82.3	69.4	•	3.7	€	65.7	9.6	3.3
	1975	107.3	95.3	•	5.8	€	89.5	10.1	1.9
	1976	98.0	84.9	•	2.9	€	82.0	10.8	2.3
16-18 UNDERWEAR & NIGHTWEAR (M)*	1971	274.3	39.6	2.7	0.7	1.7	34.5	234.0	0.7
	1972	274.0	41.2	2.2	0.5	1.0	37.5	232.0	0.8
	1973	278.1	47.9	2.0	0.1	1.5	44.3	229.5	0.7
SILK	1974	255.0	44.0	1.0	--	1.7	41.3	210.4	0.8
	1975	251.2	60.3	--	--	3.0	57.3	190.2	0.7
	1976	254.7	57.7	--	--	1.5	56.2	196.1	0.9
35-39 UNDERWEAR, NIGHTWEAR, BRAS AND FOUNDATIONS (W)*	1971	327.7	202.7	53.5	2.5	136.0	10.7	124.0	1.0
	1972	344.1	230.5	65.6	3.0	143.0	18.9	112.6	1.0
	1973	314.0	243.3	62.2	2.5	151.5	27.1	70.0	0.7
	1974	244.6	189.9	54.1	1.6	111.5	22.7	54.1	0.6
SILK	1975	203.4	151.7	79.7	0.5	111.3	10.2	50.9	0.8
	1976	190.5	140.6	22.3	0.4	106.1	11.8	48.9	1.0
10 31 ROBES & LOUNGEWEAR (MW)*	1971	75.4	47.4	29.8	1.0	14.0	2.6	27.0	1.0
	1972	80.0	53.0	33.7	0.5	16.0	2.8	25.5	1.5
	1973	93.6	68.7	36.7	--	25.0	7.0	23.9	1.0
	1974	92.5	69.8	36.8	--	30.0	3.0	21.7	1.0
SILK	1975	80.5	58.8	31.4	--	24.1	3.3	20.2	1.5
	1976	83.4	60.7	28.8	--	28.6	3.3	20.7	2.0
54a PILE FABRICS*	1971	75.6	75.6	--	0.1	0.5	75.0	IN ITEM 54b BELOW	IN ITEM 54b BELOW
	1972	78.9	78.9	--	--	0.9	78.0		
	1973	94.3	94.3	--	--	1.3	93.0		
	1974	86.7	86.7	--	0.7	2.0	84.0		
	1975	104.7	104.7	--	0.1	1.6	103.0		
	1976	110.6	110.6	--	0.1	1.5	109.0		
54b LINING-TYPE FABRICS*	1971	282.8	179.5	125.5	23.0	18.0	13.0	100.0	3.3
	1972	251.7	150.0	82.5	24.0	22.5	21.0	98.7	3.0
	1973	240.6	145.0	76.0	29.0	24.0	16.0	93.0	2.8
	1974	201.6	118.5	54.5	20.5	23.0	20.5	80.6	2.5
	1975	189.9	114.0	60.0	12.5	17.5	24.0	73.1	2.8
	1976	221.8	141.5	78.0	12.5	26.0	25.0	77.1	3.2
43 APPAREL LACE (W)*	1971	13.0	10.8	1.9	--	8.6	0.3	2.2	--
	1972	13.9	11.7	2.9	--	8.6	0.2	2.2	--
	1973	7.6	5.6	2.0	--	3.5	0.1	2.0	--
	1974	6.2	4.7	2.5	--	2.2	€	1.5	--
	1975	5.8	4.0	2.0	--	2.0	--	1.8	--
	1976	5.5	4.0	1.1	--	2.9	--	1.5	--
55 RETAIL PIECE GOODS*	1971	449.0	292.0	10.0	19.0	195.0	68.0	149.0	8.0
	1972	474.5	324.0	11.0	18.0	230.0	65.0	144.0	6.5
	1973	484.0	342.0	10.0	16.0	250.0	66.0	137.0	5.0
	1974	510.5	369.0	10.0	14.0	275.0	70.0	137.5	4.0
	1975	543.0	398.0	8.0	10.0	280.0	100.0	140.5	4.5
	1976	537.0	385.0	4.0	11.0	250.0	120.0	146.0	6.0
56a NARROW WOVEN APPAREL*	1971	68.1	30.5	21.3	3.8	4.7	0.7	37.6	--
	1972	71.9	33.2	22.4	3.7	5.4	1.7	38.7	--
	1973	71.1	34.2	19.5	6.0	7.4	1.3	36.9	--
	1974	63.8	32.3	16.0	6.5	8.0	1.8	31.5	--
	1975	56.0	26.9	9.4	4.3	9.8	3.4	29.1	--
	1976	50.8	25.5	7.7	2.0	14.0	1.8	25.3	--
OTHER APPAREL & ACCESSORIES (MWB)*	1971	95.8	28.9	•	7.5	8.5	12.9	66.9	€
	1972	99.9	31.6	•	3.0	16.2	12.4	68.3	€
	1973	97.8	27.8	•	4.0	12.0	11.8	70.0	€
SILK, LINEN	1974	94.6	18.1	•	1.0	8.0	9.1	76.5	€
	1975	73.3	14.6	•	1.0	7.0	6.6	58.7	€
	1976	72.7	14.2	•	1.0	9.3	3.9	58.5	€
TOP- OR BOTTOM-TYPE FABRICS (NON-ADD)									
TOP-TYPE FABRICS	1975	967.5	698.0	97.0	50.0	252.0	299.0	268.0	1.5
	1976	966.0	661.0	52.0	52.0	164.0	393.0	303.0	2.0
BOTTOM-TYPE FABRICS*	1975	1927.5	1173.0	13.0	13.0	760.0	387.0	690.0	64.5
	1976	2039.0	1150.0	10.0	19.0	657.0	464.0	803.0	86.0
SUBTOTAL TOP- & BOTTOM-TYPE FABRICS*	1971	2673.8	1527.7	175.9	182.9	458.9	710.0	1048.2	97.9
	1972	3090.5	1884.3	156.2	170.7	758.4	799.0	1109.4	96.8
	1973	3227.4	2089.6	160.7	165.0	873.9	890.0	1047.6	90.2
	1974	3030.7	1936.6	101.0	105.7	922.9	807.0	1028.5	65.6
	1975	2895.0	1871.0	110.0	63.0	1012.0	686.0	958.0	66.0
	1976	3005.0	1811.0	62.0	71.0	821.0	857.0	1106.0	88.0

NOTES FOR APPAREL ITEMS ABOVE

a. For all lettered and general footnotes to this table, see below.

40. SHEER HOSIERY (W) includes full-fashioned & seamless full-length, pantyhose, knee-highs and surgical hosiery. Bodywear is in Items 35-39.

19 41. ANKLETS & SOCKS (M W) includes men's and women's foot socks, anklets and nonsheer knee-high hose. Also includes men's mid-calf and surgical hose.

8 29. SWEATERS (M W) includes knitted sweater shirts, coats, jackets and related accessories. Also note Item 57.

57. CRAFT & HANDWORK YARNS includes yarn and thread for crocheting, darning, embroidery, mending, hand knitting, etc. The item does not include sewing thread (Item 72 on page 100).

16-18. UNDERWEAR & NIGHTWEAR (M) includes undershirts, shorts & briefs, sleep coats, pajamas, nightshirts, thermal underwear, etc.

35-39. UNDERWEAR, NIGHTWEAR, BRAS AND FOUNDATIONS. The underwear and nightwear component includes slips, petticoats and half-slips, panties, pettipants, camisoles, vests, bloomers, briefs and thermal underwear as well as nightgowns, sleep & lounging pajamas, sleep coats, peignoir & robe sets with nightgowns or pajamas, negligees and bedjackets. Includes bodywear and all children's and infants' underwear & nightwear. <u>Excludes</u> the trim, elastic webbing, apparel lace, braid or narrow fabric used in these products.

The bras and foundations component includes bandeaux, corsets & girdles, combination and one-piece garments, garter belts and hose supporters, two-way stretch and surgical & maternity foundation garments.

19 31. ROBES & LOUNGEWEAR (M W) includes men's & boys' beach- & bathrobes, dressing gowns and smoking jackets; and women's beach- & bathrobes and house-, breakfast & brunch coats.

54a. PILE FABRICS includes all applications (apparel+home furnishings+industrial). Apparel shell fabrics and "surface lining" garment items are included.

54b. LINING-TYPE FABRICS includes all types except pile fabrics (see Item 54a), lining-type fabrics sold as retail piece goods (see Item 55) and the lining components of shoes and slippers (Item 58) and luggage and handbags (Item 59). The apparel lining component of this series includes main linings, interlinings, tip-in linings (except pile), pocketings and bandings as well as the acetate and nylon tricot used for laminating. Not included here are interlinings of haircloth, urethane and nonwoven fabrics.

43. APPAREL LACE includes the lace on blouses and intimate-wear items, as well as nets and veilings.

55. RETAIL PIECE GOODS are mainly women's apparel-type fabrics but all other types of apparel fabrics are included in addition to fabrics destined for apparel linings and home furnishings application.

56a. NARROW WOVEN APPAREL includes elastic fabrics (mainly webs & braids) and nonelastic fabrics. The "narrow woven goods" made by slicing thermoplastic fiber broad woven fabrics with a hot knife to produce fused-edge narrow fabrics are not included here. Such products are included in broad woven applications.

OTHER APPAREL (M W) includes the following items: men's & women's work gloves; men's & boys' other furnishings, such as ties, handkerchiefs, etc.; women's dress & semidress gloves; mittens (including liners) for all ages and sexes; and women's accessories, such as handkerchiefs, millinery, neckwear, scarves, dickies, etc. <u>Excluded</u> are the knitted accessories (see Items 8 & 29).

TOP-TYPE FABRICS includes all shirts, blouses, lightweight dress and other lightweight fabrics. The fabrics generally weigh 4.0 ounces or less per square yard. Retail piece goods are in Item 55.

BOTTOM-TYPE FABRICS includes pants, sportswear, tailored clothing, career apparel and other heavier weight fabrics. The fabrics generally weigh more than 4.0 ounces per square yard. Retail piece goods are in Item 55.

For 1971-1974 detail on Top- and Bottom-Type Fabrics, see the November 1976 ORGANON, page 163.

GENERAL NOTES FOR THE END USE TABLES

Units are million pounds.

c. Means less than 50,000 pounds, i.e., nominal.

-- Means that little, or none, of the fiber is used.

* When an asterisk appears, there is a footnote at the end of the table.

a Means a significant revision in the 1971-1975 data series compared with the corresponding data shown in the November 1976 ORGANON issue. Earlier years' data on the new basis are not available.

a. This letter in the title of each table refers the reader to these notes.

b. Man-made fiber end use in these tables is divided between Rayon+Acetate (the cellulosic fibers) and Other (the non-cellulosic fibers plus textile glass fiber). Yarn includes monofilaments and olefin "yarn" also includes film fiber and spunbonded polypropylene. Staple includes tow & fiberfill; see Item 59, etc., and its footnote on page 181. All textile glass fiber is tabulated as yarn. Certain waste poundages, which are tabulated with staple, are included; see text on page 171.

The non-cellulosic fibers included in this survey, for one or more years, are the acrylic, modacrylic, nylon, olefin (polyethylene & polypropylene), polyester, saran, spandex and vinyon fibers.

d. The rayon staple data are tabulated in the rayon yarn column and/or the non-cellulosic staple data are tabulated in the non-cellulosic yarn column.

e. The rayon yarn data are tabulated in the rayon staple column and/or the non-cellulosic yarn data are tabulated in the non-cellulosic staple column.

r. This datum shows a significant revision compared with the November 1976 ORGANON data.

When textile glass fiber is included in an end use, the word "Glass" appears in the lower left corner of the end use box, together with the annual consumption data for 1971-1976. These glass fiber poundages are included with non-cellulosic yarn in that end use and in the section totals.

When silk, linen, jute, sisal, etc., are consumed in an end use, in addition to cotton, wool and the man-made fibers, the fiber is named in the middle left of the end use box. But no poundage data for such fibers are included either in such end use or in the section totals.

As described in the footnotes to Items 54a and 54b above, apparel linings, pocketings and such are tabulated in Items 54a and 54b and not with the applicable garments.

In the Apparel section of page 174, the sex and age classifications used are those of the U.S. Census Bureau. Thus M means Men's (all garment sizes) plus Boys' (Students', Cadets' & Junior Boys' of sizes 4-20); and W means all other persons except the foregoing, i.e., Women's, Misses', Girls' Children's & Infants'.

HOME FURNISHINGS[a]

END USE & YEAR		TOTAL FIBER	MAN-MADE FIBERS[b] TOTAL	RAYON-ACETATE YARN	RAYON-ACETATE STAPLE	OTHER YARN	OTHER STAPLE	COTTON	WOOL
TOTAL HOME FURNISHINGS	1971	3330.6	2005.0	102.3	201.0	600.0	976.7	1230.3	84.6
	1972	3719.2	2309.5	85.0	296.9	899.7	1207.1	1304.3	88.5
	1973	3900.2	2756.0	81.6	254.7	967.7	1451.0	1001.5	53.0
	1974	3025.0	2030.1	67.5	202.0	815.7	1204.9	962.3	33.0
GLASS: 1971-1976 48.5, 47.6, 45.4 40.2, 35.1, 30.2	1975	3260.3	2304.2	51.1	136.0	902.0	1203.0	903.1	32.0
	1976	3646.3	2570.0	45.2	172.7	815.0	1037.2	941.0	33.0
45 BEDSPREADS & QUILTS[c]	1971	143.5	34.0	6.6	17.6	9.5	1.3	100.5	--
	1972	147.6	35.5	11.2	17.1	5.0	2.2	112.1	--
	1973	134.4	37.6	13.2	17.0	5.0	1.0	96.0	--
	1974	112.5	33.9	12.4	10.5	4.5	6.5	78.6	--
	1975	121.2	37.5	16.7	6.7	4.0	6.1	83.7	--
	1976	122.9	32.9	12.9	6.4	3.0	9.9	90.0	--
46 BLANKETS & BLANKETING[c]	1971	137.0	113.5	1.1	23.0	5.2	83.6	16.7	4.6
	1972	131.6	113.4	0.9	5.0	5.1	101.6	12.6	5.6
	1973	144.0	130.0	1.0	1.0	5.0	122.4	10.0	3.4
	1974	120.6	106.5	0.8	0.6	4.4	100.7	9.9	4.4
	1975	117.0	103.1	0.5	0.3	4.2	98.1	9.0	4.9
	1976	115.3	100.9	0.3	0.5	4.4	95.7	9.9	5.6
47 SHEETS & OTHER BEDDING[c]	1971	500.2	133.2	4.0	15.2	0.2	113.6	367.0	--
	1972	530.0	175.7	2.1	18.1	0.6	154.9	364.1	--
	1973	521.2	220.4	2.3	19.5	1.0	197.0	300.6	--
	1974	497.4	215.5	1.3	22.1	1.6	190.5	281.9	--
LINEN	1975	475.0	201.1	0.7	7.5	9.5	184.4	273.9	--
	1976	529.9	248.0	0.3	7.0	10.4	230.3	281.9	--
48 TOWELS & TOWELINGS[c]	1971	322.6	0.6	--	0.0	--	6	322.0	--
	1972	343.4	0.9	--	0.8	--	0.1	342.5	--
	1973	301.1	3.3	--	1.5	--	1.9	297.6	--
LINEN, NONE	1974	301.6	4.0	--	2.1	--	1.9	297.9	--
	1975	271.7	13.5	--	1.5	--	12.0	258.2	--
	1976	285.3	13.3	--	0.4	--	12.9	272.0	--

END USE & YEAR		TOTAL FIBER	MAN-MADE FIBERS[b] TOTAL	RAYON-ACETATE YARN	RAYON-ACETATE STAPLE	OTHER YARN	OTHER STAPLE	COTTON	WOOL
50 TOTAL CARPETS & RUGS[c]	1971	1477.7	1320.2	1.9	61.0	536.9	720.4	70.9	77.7
	1972	1700.9	1610.5	1.1	47.2	746.2	865.0	83.2	70.2
	1973	1957.6	1850.7	1.3	25.6	807.3	1024.3	56.0	43.1
SMALL	1974	1672.0	1831.2	1.1	5.7	766.1	850.3	22.0	19.4
SEE DETAIL IN ITEMS 50a & b FOLLOWING	1975	1621.1	1580.6	0.6	2.0	732.0	855.0	14.9	16.6
	1976	1781.4	1752.5	--	1.4	752.5	998.6	13.4	15.5
50a FACE YARN[c]	1971	1310.9	1219.4	0.4	60.6	444.3	712.9	14.9	77.7
	1972	1500.3	1407.9	--	40.5	502.0	850.4	13.2	70.2
	1973	1751.7	1606.6	--	25.0	657.9	1012.9	12.0	43.1
	1974	1407.5	1474.1	--	5.7	622.2	846.2	4.0	19.4
NON-BCF SEE DETAIL IN FOOTNOTE	1975	1454.7	1434.9	--	3.0	583.7	840.1	3.3	16.0
	1976	1582.6	1574.0	--	1.4	577.7	984.9	3.3	15.5
50b BACKING[c]	1971	166.6	101.9	1.5	0.2	92.0	7.5	65.0	--
	1972	200.6	130.0	1.1	0.7	123.2	5.0	70.0	--
	1973	206.1	162.1	1.3	--	149.4	11.4	44.0	--
	1974	175.1	157.1	1.1	--	143.9	12.1	16.0	--
GLASS, JUTE, PAPER NON-BCF, SEE ITEM 50	1975	166.4	154.9	0.6	--	148.3	5.9	11.6	--
	1976	180.6	178.5	--	--	174.6	3.7	10.1	--
51 CURTAINS[c]	1971	40.6	31.2	5.0	6.0	17.4	a	10.4	--
	1972	50.6	33.3	6.4	7.9	19.0	4	17.5	--
	1973	62.1	46.6	7.5	9.6	23.5	6.0	15.5	--
ALSO SEE ITEM 52	1974	40.2	34.9	9.6	3.3	19.5	6.5	14.3	--
GLASS: 1971-1976 1.0, 0.0, 1.2, 1.0, 0.6, 0.4	1975	50.0	44.0	4.0	3.0	26.5	10.5	14.0	--
	1976	50.6	37.4	3.7	2.5	19.7	11.5	13.4	--
52 DRAPERY & UPHOLSTERY[c]	1971	656.7	370.0	80.6	153.4	93.7	42.9	284.1	2.0
	1972	674.0	380.2	63.3	140.9	102.5	74.6	281.3	3.5
	1973	710.0	430.1	55.2	179.4	117.2	78.3	281.0	6.0
SILK, LINEN, BURLAP	1974	613.0	375.3	42.0	156.7	115.0	61.6	228.5	0.2
GLASS: 1971-1976 45.1, 40.5, 38.6 35.0, 32.0, 23.4	1975	554.0	323.7	26.5	113.7	123.7	50.0	220.4	10.5
	1976	610.0	362.6	26.4	150.5	116.2	60.5	236.5	11.9
49 53 MISCELLANEOUS[c]	1971	52.5	21.7	1.1	1.2	4.7	14.7	30.9	--
	1972	51.0	10.0	0.8	1.2	7.3	0.7	33.0	--
	1973	61.7	20.7	1.1	0.3	7.5	10.0	33.0	--
LINEN	1974	50.3	20.6	3.3	1.0	7.6	16.9	29.5	--
GLASS: 1971-1976 3.4, 3.2, 5.6, 4.2, 3.1, 6.4	1975	50.7	21.7	2.1	0.2	3.9	15.5	29.0	--
	1976	40.9	23.3	1.6	2.0	9.6	10.1	26.5	--

ITEM 50A. ANALYSIS OF FACE YARNS BY CARPET TYPE & BY FIBER - MILLION POUNDS

	1971	1972	1973	1974	1975	1976
FILAMENT YARN BCF (BULKED CONTINUOUS FILAMENT)						
A. TUFTED						
Rayon-Acetate	0.4	*	0	9	6	0
Non-Cellulosic						
Nylon	395.6	527.2	596.9	550.1	530.5	510.4
Ester	2.4	3.6	1.2	6.6	0.1	6
Olefin incl. Film Fiber	41.9	45.0	54.5	59.2	60.1	65.1
Total Non-Cellulosic	439.9	575.2	650.7	617.9	590.7	575.5
TOTAL TUFTED	440.3	576.3	651.7	617.0	590.7	575.6
B. WOVEN (includes small bulk poundages)						
Nylon & Total	4.4	6.0	6.3	4.3	3.6	2.2
C. TOTAL FILAMENT YARN BCF						
Rayon-Acetate	0.4	*	*	0	0	0
Non-Cellulosic	444.3	582.0	657.9	622.2	583.7	577.7
TOTAL BCF	444.7	582.0	657.0	622.2	583.7	577.7

NOTES FOR ITEMS 45 TO 53

a. For all lettered and general footnotes in this table, see page 175.

HOME FURNISHINGS. These data cover the use of each item not only in homes, but also in offices, hotels, institutions, etc. For certain transportation uses, note items 50a, 63 & 64.

None of the poundages tabulated include any cotton stuffing or filling materials in items such as furniture, pillows, mattresses, comforters & quilts, sleeping bags, seat padding, etc. For the man-made fibers, however, stuffing & fiberfill is tabulated in item 62. Note text page 171 regarding the inclusion of certain man-made fiber waste poundages here. Certain felt poundages are in item 70.

45. BEDSPREADS includes tufted & throw spreads, both tufted & woven, as well as the backing of these tufted goods. QUILTS includes comforters and their outer shell; quilted pads are in item 47.

46. BLANKETS & BLANKETING includes woven, knitted, needle-punched and flocked full-size & crib blankets and electric blanket shells, as well as the woven acetate-or-nylon filament yarn bindings thereof. Sizable poundages of rayon, acrylic, nylon & wool waste are included here.

47. SHEETS includes pillowcases. OTHER BEDDING includes the outside cover of quilted pads, mattress pads, mattresses & innersprings, civilian cots and sleeping bags. Mattress felts are in item 70. The man-made staple poundages here are mainly polyester for sheets and rayon for bed ticking.

48. TOWELS & TOWELING includes woven hand, bath, dish towels, etc. Nonwoven towels, such as "Handi-wipes" and industrial wiping cloths, are in item 61. The large cotton waste poundage used in these products is not included.

50. CARPETS & RUGS (TOTAL) is the sum of items 50a & 50b.

50a. FACE YARNS. Tufted includes broadloom & roll goods, transportation carpet-

(Continued on page 177 below)

ing, scatter rugs, both mats & "grass." Woven includes carpets such as Axminster, Velvet, Wilton, etc. Knit goods are mainly scatter rugs. Needle-punched are the indoor-outdoor carpets. Item 50a does not include braided, hooked or woven twisted paper carpets.

By-fiber detail on the poundage of fibers used in carpet face yarns is given in the tables to the right. The tables on page 178 show the type of carpet produced and the calculated total carpet yardage by type.

The method used to develop these carpet face yarn data varies somewhat from other products in this end-use survey. For all fibers, it is intended that the data show fiber consumption at the carpet mill production level each year.

Man-Made Fiber Yarn. Producers' shipments of textured nylon, olefin & polyester filament yarn, plus olefin monofil and film fiber, to carpet manufacturers were added to the imports of textured nylon carpet yarn to obtain the available supply of face yarns. When a sizable increase in this available figure was shown, an adjustment was made so as to reflect that part of the estimated increment poundage going into inventory plus goods-in-process (deducted from available and not tabulated here), the residual poundage being that actually used in carpet production, which figure is presented here. This yarn increment (decrement) was taken on a 6-week supply, thus involving a deduction or addition of 12% each year.

Man-Made Fiber Staple. Producers' shipments of staple, tow and waste to the carpet industry were added to staple imports to obtain the available supply of face yarns. Then the inventory plus goods-in-process increment principle was applied, as described above, on the basis of an 8-week supply, i.e., 15% of the increment was deducted to obtain the data presented.

For example, producers' shipments plus imports of non-cellulosic staple, tow and waste to carpet manufacturers totaled 855.5 in 1975 and the corresponding 1976 figure was 1,019.5 or an increase of 164.0. Then 15% of this increment, i.e., 24.6, was subtracted from the 1,019.5 to yield the 1976 "usage" figure of 994.9 shown in Item 50a.

Wool. The wool consumed in face yarns in carpet-class including reprocessed. The division of this poundage as between tufted, woven and knit was calculated based on Census data. Note the December 1976 [illegible], page 190.

Cotton. The cotton face yarn data presented are those of Census report M-22D, increased by an estimated 10% each year.

50b. CARPET BACKING FIBERS. Here the approach is similar. The man-made fiber producers' shipments of fiber for carpet backing were used, with a goods-in-process increment adjustment.

The R+A Yarn of Table 50b is industrial rayon used for woven carpet chain warps; the Staple is rayon. The Other Yarn is olefin (monofil+film fiber+spunbonded) and some nylon & polyester filament yarn; includes some olefin monofil for woven carpet chain warps. The Other Staple is olefin only.

The substantial poundages of jute used on woven primary & secondary backing, as well as the jute yarn used in the warp of woven carpets, are not tabulated in Item 50b. Nor does Item 50b include the sizable poundages of wool, hair and jute used in carpet and rug pads and cushions.

CARPET YARDAGE. The right-hand table on page 178 shows the calculated carpet yardage production by type of carpet compared with Census carpet sales for recent years. The left-hand table presents the same tufted and needle-punched yardages together with a breakdown of kind of fiber used in the primary backing thereof.

The correlation between the calculated primary+secondary jute yardages consumed, and the yardage of imported jute cloth over 100" wide, will be noted. The usage was 96% of said imports over the recent 6-year period. Also see the footnotes to that table.

51. CURTAINS means the lace, ruffled, cottage, cafe & tiered types; shower curtains are in Item 53.

52. DRAPERY & UPHOLSTERY includes furniture slipcovers, vinyl-coated cotton fabrics for upholstery and the olefin & saran webbing for outdoor furniture. Also includes the backing & headers of drapery fabrics.

Also note Retail Piece Goods, Item 55 on page 174, and Transportation Fabrics, Items 63 & 64 on page 180.

49 53. MISCELLANEOUS includes woven & lace napery, such as tablecloths & napkins, doilies, etc.; oilcloth (for tables, shelves, etc.); shower curtains; window shades and stamped art goods for embroidery. Also includes the man-made fibers used in radio & TV grill cloth and insect screening & netting. Wall-covering fabrics is in Item 79.

ITEM 50A. ANALYSIS OF FACE YARNS (Continued)

	1971	1972	1973	1974	1975	1976
STAPLE+WASTE (SPUN YARN)						
A. TUFTED						
Rayon+Acetate	30.7	46.0	26.9	5.7	2.0	1.4
Non-Cellulosic						
Acrylic+Modacrylic	130.0	119.0	135.9	97.2	71.7	72.9
Nylon	303.6	460.4	569.3	511.9	558.5	658.0
Ester	189.7	185.0	192.3	145.6	148.6	202.9
Olefin+Vinyon	6.3	5.0	4.2	4.0	4.7	5.5
Total Non-Cellulosic	629.6	771.0	901.7	730.5	783.5	940.1
Cotton	14.0	12.4	11.6	3.7	2.9	2.9
Wool	35.5	33.0	17.2	8.6	7.2	7.2
TOTAL TUFTED	720.0	862.0	966.9	777.6	796.0	961.0
B. WOVEN						
Rayon	0.2	0.6	0.3	0	0	0
Non-Cellulosic						
Acrylic	21.0	23.0	27.5	28.0	18.0	15.5
Nylon	0.7	0.0	14.8	14.9	10.5	3.9
Ester	0.4	0.7	0.5	*	0	0
Total Non-Cellulosic	30.1	32.5	42.0	42.9	29.3	19.4
Wool	41.3	45.2	25.5	10.7	9.3	0.2
TOTAL WOVEN	71.6	78.3	68.0	53.6	38.6	17.6
C. KNIT						
Non-Cellulosic						
Acrylic+Modacrylic	6.7	6.2	7.5	1.1	0.7	0
Olefin+Ester	1.2	*	0	0	0	0
Total Non-Cellulosic	7.9	6.2	7.5	1.1	0.7	0
Cotton	0.0	0.0	0.4	0.3	0.4	0.4
Wool	0.9	1.0	0.4	0.1	0.1	0.1
TOTAL KNIT	8.8	7.2	8.3	1.5	1.2	0.5
D. NEEDLE-PUNCHED (Includes Filler Fibers)						
Rayon	0.9	1.1	0.6	0	0	0
Non-Cellulosic						
Acrylic+Modacrylic	0.7	0.2	0.5	2.5	1.7	4.7
Nylon	10.2	9.3	15.3	6.0	3.4	2.0
Ester	0.3	0.1	*	0	0	0
Olefin	34.1	39.3	45.1	34.2	30.5	28.7
Total Non-Cellulosic	45.3	48.9	60.9	42.7	35.6	35.4
TOTAL NEEDLE-PUNCHED	46.2	50.0	61.0	42.7	35.6	35.4
E. TOTAL STAPLE+WASTE						
Rayon+Acetate	60.0	46.5	25.0	5.7	2.0	1.4
Non-Cellulosic						
Acrylic+Modacrylic	158.4	149.2	171.4	128.0	92.9	93.1
Nylon	322.5	478.5	599.4	532.0	572.4	664.7
Ester	190.4	186.6	192.0	145.6	140.6	202.9
Olefin+Vinyon	41.6	45.1	49.3	39.0	35.2	31.2
Total Non-Cellulosic	712.9	859.4	1012.9	846.2	849.1	994.9
Cotton	14.0	13.2	12.0	4.0	3.3	3.3
Wool	77.7	79.2	43.1	19.4	16.6	15.5
TOTAL	866.2	998.3	1083.0	875.3	871.0	1015.1

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C-107

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