Foseco
INTERNATIONAL LIMITED

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BIRMINGHAM 7 ENGLAND
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YOUR REF

OUR REF JMM/NFJ

R and D Report No. 264

Fibre Study - Data Collection

This study was undertaken by the Steelworks Division F.I.L. between June and October 1968. The object was to compile a basic work of reference for any section within the Group that might have an interest in the properties of fibres, including applications other than high temperature insulators.

The report draws no conclusions - it merely lays out a large number of facts about this important area of technology.

It has been impossible to examine all available fibres and therefore representative fibres from each of several key groups have been selected for individual study (see Appendix 2).

Parallel to the work reported here, a comprehensive survey of the patent literature relating to fibres has also been made both here and in the U.S.A. This survey is now being correlated by the Patents Department and a further report will be issued shortly.

Yours faithfully,
(for Foseco International Limited)

J.M. MACNAIR
Technical Director - Reading Systems

PLAINTIFF'S EXHIBIT
FOS-64

0577

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J.M. MACNAIR
<u>Technical Director - Reading Systems</u>

RECEIVED
TECHNICAL DEPT.

FCS-00-000020:659

0578

RAW MATERIAL [illegible]		[illegible]	[illegible]	[illegible]	[illegible]
CATEGORY	[illegible]				
MANUFACTURING AND SLURRY PROPERTIES	DISPERSION	A	[illegible]	[illegible]	[illegible]
	SUSPENSION	A	[illegible]	[illegible]	
	FORMABILITY	A	[illegible]	A	
	DEWATERING	A	[illegible]	A	
	GREEN STRENGTH	A	A	A	A
FINISHED PRODUCT CHARACTER	DRY STRENGTH	A	A	C	[illegible]
	LOW MOISTURE		C	C	[illegible]
	HANDLEABILITY	A	A	[illegible]	[illegible]
APPLICATION	DENSITY REDUCER	A	A	A	A
	INSULATION	A	A	A	A
	PERMEABILITY	A	C	A	A
	REFRACTORINESS	A	C	C	A
	HOT STRENGTH	A	C	C	A
	STRIP	A	C	C	A
	COMPESSIBILITY	A	A	A	A
	FLEXIBILITY	A	A	A	A
PRICE UNITED STATES OF AMERICA		13.5	4c/lb.	(10c/lb).	45c/lb

A = IMPORTANT B= SEMI-IMPORTANT C= NOT IMPORTANT.

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Dear Customer,

Because of the condition of the original, this is the best copy that could be made.

FCS-00-000000166[illegible]

LIST OF APPENDICES

FGS-00-000000:662

Fibre	Cost (£ Sterling per pound)	Suppliers (U.K.)
Kaowool ('Triton')	0.262	Morganite Ceramic Fibres Ltd., Neston, Wirral, Cheshire.
Fiberfrax	ca0.25	Carborundum Co., Trafford Park, Manchester 17.
Zirconium Aluminium Silicate	Not available	
Stillite (R.M.452)	0.011	Stillite Products Ltd., 15, Whitehall, London, S.W.1.
Rocksil	0.036	Cape Insulation Ltd., 114, Park Street, London, W.1.
Courtelle	0.291	Courtalds Ltd., Coventry.
Wool	0.500	International Wool Secretariat, Church Street, Bradford.
Cotton	0.119	Textile Council, Royal Exchange, Manchester, 2.
High Modulus Carbon (Type 1)	115.0	Morganite R and D Ltd., Battersea Church Road, London, S.W.11.
Graphite Wool	22.0	Morganite R and D Ltd., Battersea Church Road, London, S.W.11.
Amosite Asbestos (R.M.265A)	0.038	Cape Insulation Ltd., 114, Park Street, London, W.1.
E-Glass M.S.S.10	0.146	Fibreglass Ltd., Valley Road, Birkenhead.
Refrasil F.25	3.00	Chemical & Insulating Co. Ltd., Darlington.
Zirconium Dioxide Fibres	125.0	Union Carbide Corp., 8, Grafton Street, London, W.1.
Steel Wool	0.287	Brillo Manufacturing Co. Ltd., Maidenhead, Berks.
Aluminium Wool	0.875	Brillo Manufactureing Co. Ltd., Maidenhead, Berks.
Boron Nitride	117.25	Carborundum Co. Ltd., Trafford Park, Manchester 17.
Carbonised Newsprint	0.037-0.2 (estimated)	Royal Aircraft Establishment, Farnborough, Hants.

APPENDIX 1

Final Recommendations of a Fibre Study Group convened at Foseco International Limited on 7th and 11th June, 1968.

[illegible]

Final Recommendations of a Fibre Study Group Convened at Foseco International Limited on 7th and [illegible] June, [illegible]

In the chair : Mr. [illegible] Sharp

Present : Messrs. Wallace, Chappell and [illegible]

OBJECT Discussions to decide how a programme for the detailed study of the fundamental properties of fibres should be [illegible].

At the outset, the committee agreed that a full and comprehensive knowledge of Fibre Technology was of great importance to the Foseco group of companies.

It is possible that a knowledge of Fibre Technology [illegible] Foseco broaden its overall activities, which are to provide chemical products and a service to industry.

Alternative methods of approach were discussed as under:

1. A main-line study of all the physical and chemical properties of the complete range of fibres, irrespective, in the first instance, of [illegible]

   Upon completion of [illegible] their various properties.

or

2. A full study of all the measurable and relevant properties of fibres, as mentioned above, but with particular (but not necessarily specific) reference to:

   (a) Heading materials

   (b) Refractory running materials.

   These two applications for fibrous materials are traditional Foseco interests, and are likely to be important applications in the near future. Other and future applications, however, should be constantly borne in mind, and the information passed to the appropriate sections or Patent Department.

Discussion upon these alternative approaches lead the committee to agree that the latter approach should be adopted.

-Continued-

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A study, [illegible] planned along the following lines

1. Comprehensive literature survey.

2. Investigation into the sources and availability of fibres on a world-wide scale.

3. Tests on discrete fibres.

4. Tests on pre-formed fibre shapes, including fibres in spun and woven form.

5. Tests on refractory filled fibrous masses.

METHOD

Throughout the study, fibres will be grouped as follows:

ALUMINO-SILICATES

(a) Natural - fused Kaolins.

(b) Synthetic - fused mixtures of pure materials.

CALCIUM SILICATES

(a) Blast Furnace slag wools, including resin coated types.

(b) Rock wools - synthetic and natural volcanic.

(c) Synthetic [illegible] slag wools [illegible] silicates.

ORGANIC FIBRES

(a) Synthetic - man-made polymers.

(b) Natural 1. Animal origin. 2. Vegetable origin.

CARBON FIBRES

(a) Coking carbons in fibre form.

(b) Charring carbons in fibre form.

ASBESTOS

(a) Natural - all types.

(b) Synthetic - hydro and fluoro-amphiboles.

-Continued-

GLASS

(a) Devitrified glass fibres e.g. Slagceram, Pulverised Fuel Ash, Pyroceramics etc.

(b) Vitreous fibres.

(c) Silica glasses.

REFRACTORY OXIDE FIBRES

METAL FIBRES

(a) Ferrous

(b) Non-ferrous

SPECIAL FIBRES

e.g. Potassium titanate fibres

Boron nitride fibres

Other fibres arising from literature survey.

-Continued-

The five main sections of the study are now explained in more detail.

1. Comprehensive Literature Survey.

An initial report correlating all the information to hand at present to be completed in four man-weeks.

A fully comprehensive survey (agreed a continuing task) to include all patent literature, the committee feel, would take much longer. No time estimate can be given at this stage.

2. Sources and Availability of Fibres.

The correlation of information already to hand is estimated to require one man-week.

3. Tests on Discrete Fibres.

Discrete fibres from each group will be tested according to the pattern given below. The chosen fibre may not of course be truly representative of its generic type, but will provide a valuable datum line by which others may be compared later.

CHEMICAL PROPERTIES

Resistance to acids, alkalis and water (at selected temps).
Chemical composition.
Change in chemical composition upon fusion.
[illegible]

[illegible]

Specific gravity (true)
Bulk density.
Softening point.
Melting point.
Length and diameter of fibres.
Change in crystalline form after heating.
Elongation, at selected temperatures under load.
Electrical and thermal conductivity.
Tensile strength.
Specific Heat.
Coefficients of expansion.
Surface characteristics - absorbency, and "wettability" by aqueous solutions and molten metals.
Heat capacity.
Low temperature stability.
Where existing thermal tests are considered to give insufficient information, full advantage is to be taken of technical liaison with external commercial or academic institutions whose experience and/or equipment may be of value to this study.

-Continued-

Clearly some of the above tests and measurements are straightforward, but the study group feel that many of the tests are complex in nature, and require special apparatus to be set-up.

The committee estimate that between 1 and 2 man-years will be required for the complete setting-up and testing of all the fibres listed above.

4. Fibrous Pre-formed Shapes

This will include the testing of unbonded fibrous shapes, and fibrous shapes bonded with selected binder systems. Also, where applicable, fibres in the spun and/or woven form will be tested.

Tests on these pre-formed shapes will include all the physical tests given under Section 3 above, except specific gravity (true) and length and diameter of fibres, as these properties of the discrete fibres will already be known.

The other physical properties need to be re-measured as they may well differ in the massive compacted form.

This series of measurements is estimated to require 1-2 man-years.

5. Tests on Refractory Filled Fibrous Masses

The physical tests as given under Section 4 above will be necessary, for the selected range of refractory fillers chosen (e.g. [illegible] [illegible] tentative fibre type.

In addition, [illegible]

1. Adhesion to metallic and ceramic surfaces.

2. Physico-chemical behaviour against molten metals.

This particular section is a large and important part of the complete study. Therefore the study group feel that the requirement will be 2-4 man-years to completion.

SUMMARY OF ESTIMATED MAN-YEAR REQUIREMENTS

		Man-Weeks	Man-Years
1.	Literature survey (initial)	4	-
	(comprehensive)	[illegible]	-
2.	Sources and Availability of fibres	1	-
3.	Tests on discrete fibres	-	1-2
4.	Tests on pre-formed fibre shapes	-	1-2
5.	Tests on refractory filled fibre shapes	-	2-4
	Total	5	4-8

-Continued-

[illegible]

It is proposed to neglect engineering requirements at this stage, but it is tacitly accepted that some engineering involvement will be incurred at a later point in time.

The study group realises that the viability of a given fibrous system may well appear to break down if the fibres are not easily manipulated.

It was agreed that the minutes of the meeting should be written up and distributed to all members of the committee by mid-day of Wednesday, 12th June.

The meeting ajourned at 5pm, 11th June, with thanks to the Chairman.

P.S. Clark

APPENDIX 2

Selection of Particular Fibers as Representative of Generic Groups

GROUP	TYPE	FIBRE CHOSEN	REASON
1. Alumina Silicates	Natural	Kaowool	Most readily available.
	Synthetic	Fiberfrax	Most readily available.
	Substituted	Zirconium Aluminium Silicate	To our knowledge the only one made.
2. Calcium Silicates	Blast Furnace Wool	Stillite Wool	Most readily available.
	Rock Wool	Wollastonite Wool	Most common form produced.
3. Organic Fibres	Synthetic	Courtelle	Random choice, also precursor for charred fibres.
	Animal	Wool	Most readily obtained.
	Vegetable	Cotton	Most readily obtained.
4. Carbon Fibres	Charring Carbons	High Modulus Carbon Fibres	Of considerable interest at present time.
	Graphite	Graphite Fibres	Only type which can represent group.
5. Asbestos	Natural	Amosite	More typical than chrysotile which has high water content.
6. Glass	[illegible] Fibres	E-Glass	Most common form available.
	Silica Glass	[illegible]	Only type made.
7. Refractory Oxide Fibres	Polycrystalline	Zirconium Dioxide Fibres	Most commonly used because of its refractoriness.
8. Metal Fibres	Ferrous	Steel Wool	Most commonly used.
	Non-Ferrous	Aluminium Wool	Most readily obtained as fine fibres.
9. Special Fibres		Boron Nitride Fibres	Supposed to have excellent refractory properties.

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[redacted]

APPENDIX [illegible]

[redacted]

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All the data collected to date is given in the following tables, firstly for discrete fibres and secondly for the fibre in bulk form.

Where given the manufacturer's conditions of measurement are stated. In the case of the textile fibres measurements were carried out, where appropriate, at 20°C and 65% relative humidity.

The details given under resistance to chemical reagents have been obtained from technical literature. Details of tests carried out at Fosco International Limited are given in Appendix 6.

-Continued-

[redacted]

[illegible]

[redacted]

-Continued-

[redacted]

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FDS-00-0000001676

[redacted]

BULK FIBROUS FORM

[redacted]

-Continued-

[redacted]

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[redacted]

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FIBERS, FELTS, WOOD AND PAPER

The following tables are reproduced from the Materials Selector (mid-October 1968) supplement to Materials Engineering.

Natural Fibers

Type →	Cotton	Bast				Hard			Animal		
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
NATURE OF FIBER											
Length, in.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	24	30	[illegible]	[illegible]	[illegible]
Width, μ	17	16	17	20	47	19	19	20	[illegible]	[illegible]	[illegible]
Cross Section	Flat tube	Tube	[illegible]	—	Flat tube	[illegible]	[illegible]	[illegible]	Round	Round	Round
PHYSICAL AND MECHANICAL PROPERTIES											
Specific Gravity	1.55	1.50	1.48	1.48	1.50	—	—	—	1.30	1.30	1.25-1.35
Breaking Tenacity, gm/den											
70 F, 65% RH	3.0-4.9	6.5	3.0-5.0	5.0-6.8	6.5	4.0-7.5	4.5	3.0-3.5	2.8-5.2	—	2.5-3.2
Wet	3.3-6.4	—	—	—	—	3.3-6.3	—	2.5-3.8	2.5-4.2	—	[illegible]
Ten Str (70 F, 65% RH), 1000 psi	90-160	115	57-112	112-123	130	125	100-130	—	35-83	—	17-28
Breaking Elong, %											
70 F, 65% RH	3-7	3	—	1-6	3-6	2-3	2-2.5	—	15-25	—	25-35
Wet	—	—	—	—	—	—	—	—	25-30	—	—
[illegible]	[illegible]	[illegible]	[illegible]	—	[illegible]	—	—	—	[illegible]	—	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—	—	—	[illegible]	—	[illegible]
RESISTANCE TO ENVIRONMENTS											
Acids											
Strong	Poor	Poor	Poor	Poor	Poor	Poor	Poor	Poor	Good	—	Poor
Weak	Poor (hot)	Poor	—	Fair	—	—	—	—	Good	—	Fair
Alkalis											
Strong	Exc	Good	Good	Good	Good	Good	Good	Good	Poor	Poor	Poor
Weak	Exc	Good	Good	Good	Good	Good	Good	Good	Moderate	Poor	Poor (hot)
Org Solvents	Have generally good resistance to organic solvents. [illegible]								Attacked by [illegible]	[illegible]	[illegible]
Heat	Good to 275 F	Good to 275 F	—	Good to 275 F	Good to 275 F	—	—	—	Good to [illegible]	—	Decomposes at 260 F
Sunlight (prolonged exposure)	Weakens	None	None	None	None	None	None	None	Weakens	Weakens	Weakens
Microorganisms	Poor	Very good	Good	Good	Exc	Good	Poor	Poor	Fair	Fair	Good
Flame	Burns	Burns	Burns	Burns	Burns	Burns	Burns	Burns	Slow burn	Slow burn	Burns

[illegible]

-Continued-

Synthetic Fibers

Type →	Regenerated Cellulose (Rayons): Viscose: Regular to Medium Tenacity	Regenerated Cellulose (Rayons): Viscose: High Tenacity	Regenerated Cellulose (Rayons): Saponified Acetate: Fortisan	Regenerated Cellulose (Rayons): Saponified Acetate: Fortisan 36	Cellulose Esters: Cellulose Acetate	Cellulose Esters: Cellulose Triacetate (Arnel)	Fluorocarbon: TFE (Teflon)
NATURE OF FIBER							
Length, in.	Staple, filament	Filament	Filament		Staple, filament	Staple, filament	Filament
Width	[illegible]	[illegible]	[illegible]		[illegible]	—	—
Cross section	Irregular	Irregular	Irregular		[illegible]	[illegible]	Circular
PHYSICAL AND MECHANICAL PROPERTIES							
Specific Gravity	[illegible]	—	1.5	1.5	[illegible]	[illegible]	[illegible]
Breaking Tenacity, g/den, Std	[illegible]	[illegible]	[illegible]	8	[illegible]	[illegible]	[illegible]
Wet	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Tensile Strength, 1000 psi	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Breaking Elongation, %	[illegible]	[illegible]	6	[illegible]	[illegible]	[illegible]	[illegible]
Wet	[illegible]	[illegible]	6	[illegible]	[illegible]	[illegible]	[illegible]
Stiffness	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Elastic Recovery	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—
Toughness	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Moisture Regain	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	None
[illegible]							
[illegible]	[illegible]				[illegible]		
[illegible]	[illegible]				[illegible]	[illegible]	[illegible]
[illegible]	[illegible]		[illegible]		[illegible]	[illegible]	[illegible]

[illegible]

-Continued-

[illegible] Fibers

Type →	Acrylic						
	[illegible]	[illegible]	[illegible]	Modified Acrylic [illegible]	[illegible]	[illegible]	[illegible]
NATURE OF FIBER							
Length	Staple	Staple	Staple	Staple	—	—	—
Width	[illegible]	[illegible]	—	—	—	—	—
Cross section	[illegible]	—	—	—	—	—	—
PHYSICAL & MECHANICAL PROPERTIES							
Specific gravity	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Breaking tenacity, [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Wet	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Elongation [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Wet	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Strain recovery [illegible]	—	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Toughness [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Moisture regain [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]							
Strong	[illegible]	[illegible]	Good	Exc	[illegible]	[illegible]	[illegible]
Weak	Exc	Exc	Exc	Exc	Exc	Exc	Exc
Alkalis							
Strong	Poor	Poor	Good	[illegible]	Poor	Poor	Fair
Weak	Fair-good	Fair-good	Exc	[illegible]	Fair-good	Fair-good	Good
Organic Chemicals	[illegible]	[illegible]	[illegible]	[illegible]	Good	Good	Good
Heat	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	—	—	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	—	—	[illegible]	[illegible]
Flame	[illegible]	[illegible]	Self-extinguishing	Self-extinguishing	Burns	Burns	Burns

[illegible]

-Continued-

[illegible]

[illegible]	[illegible]	[illegible]			[illegible]	[illegible]			[illegible]
		[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	
[illegible]									
[illegible]	[illegible]	—	—	—	[illegible]	[illegible]			[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	—	—	[illegible]			—
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			[illegible]
[illegible]									
[illegible]	[illegible]	1.7	1.7	1.7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]									
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—	[illegible]	[illegible]	[illegible]	—
[illegible]									
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—	[illegible]	[illegible]	[illegible]	—
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—
[illegible]	—	[illegible]	[illegible]	[illegible]	—	[illegible]	[illegible]	[illegible]	—
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—
[illegible]	[illegible]	[illegible]			—	[illegible]			[illegible]
[illegible]	[illegible]	[illegible]			—				
[illegible]									
[illegible]	[illegible]	[illegible]			—	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]			—	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]			—	[illegible]			[illegible]
[illegible]	[illegible]	[illegible]			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]			—	[illegible]			[illegible]
[illegible]	[illegible]	[illegible]			[illegible]	[illegible]			[illegible]
[illegible]	[illegible]	[illegible]			[illegible]	[illegible]			[illegible]

-Continued-

FOS-00-0000001682

[illegible]

Type	[illegible] 6.6 Regular	High Tenacity	Staple	[illegible]	[illegible] 6 Regular	High Tenacity	Staple	[illegible] Regular	High Tenacity	Staple
Length	Filament		Staple	[illegible]	Filament		Staple	Filament		Staple
Denier	11-43	16-43	16-43	—	—		—	1-75		1.5-[illegible]
Cross Section	Round	Round	Round	Round	Round		Round	Circular		—
Specific Gravity	1.14	1.14	1.14	1.30	1.14	1.14	1.14	1.38	1.38	1.38
Breaking Tenacity, grams/den										
70 F 65% RH	4.6-5.9	5.9-8.8	4.0-4.7	5.2	4.5-5.8	6.0-8.8	3.5-5.5	4.4-5.0	6.1	[illegible]
Wet	4.0-5.2	5.1-7.6	3.5-4.7	4.1	4.0-5.3	5.4-7.5	—	4.4-5.0	6.1	[illegible]
Ten. Str. 70 F 65% RH 1000 psi	67-85	86-123	56-68	95.5	73-84	108-125	72-80	77-88	105-123	[illegible]
Breaking Elongation %										
70 F 65% RH	26-32	19-28	38-42	12.2	26-30	16-17.5	[illegible]	19-25	[illegible]	[illegible]
Wet	30-37	21-32	42-46	16	26-38	19-24	[illegible]	[illegible]	[illegible]	[illegible]
Strain Recovery at 2% %	100 (2%)	100 (2%)	—	—	100 (2%)	100 (2%)	100	[illegible] (2%)	[illegible] (2%)	—
Toughness	0.76	0.65	0.82	—	0.82	0.75	0.64-0.75	[illegible]	[illegible]	[illegible]
Moisture Regain 70 F 65% RH %	4.5	4.5	4.5	5.0	4.0	4.0	4.0	0.4	0.4	0.4
Effect of Acids	Disintegrated in conc. HCl, H_2SO_4 and HNO_3			[illegible]	Degraded by conc. mineral acids			Dissolves in [illegible]		
[illegible] Acids	[illegible] in 5% [illegible] HCl			[illegible]	[illegible]			[illegible]		
Strong Alkalis	Substantially inert			[illegible]	Substantially inert			[illegible]		
[illegible] Alkalis	Substantially inert			[illegible]	Substantially inert			[illegible]		
Heat	Yellows slightly; after 5 hr at 300 F, melts at 482 F			[illegible]	Yellows slightly after 5 hr at 300 F, melts at 420 F			Melts at 480 F		
[illegible]	[illegible]			[illegible]	[illegible]			[illegible]		
Flame	Self extinguishing			Self ext.	Self extinguishing			[illegible]		

[illegible]

Type	Asbestos Chrysotile	Crocidolite	Alumina Silica	Carbon	Glass Type E	Type S	Graphite
Length in	Staple to 2	to 3	Staple to 10	Continuous filament	Continuous staple	Continuous	Continuous filament
Diam. microns	0.02	0.02	3.70 microns	0.10	—	—	6.0
Cross Section	Tubular	Cylindrical	—	Irregular	[illegible]	Cylindrical	Irregular
Min. Diameter mil	—	—	—	[illegible]	[illegible]	2.00	[illegible]
Max Diameter mil	—	—	—	[illegible]	0.03	0.03	0.015 [illegible]
Specific Gravity	2.4-2.6	3.2-3.3	2.73	[illegible]	2.54	2.49	[illegible]
Breaking Tenacity, grams/den							
70 F 65% RH	2.5-3.1	—	1.4-4.3	7.5	3.9-4.7	—	3.76
Wet	—	—	—	—	4.0-4.6	—	—
Ten. Str. 70 F 65% RH 1000 psi	300-750	100-300	30-250	25-100	300-530	500-650	100-325
Breaking Elongation, %							
70 F 65% RH	—	None	1.4-2.7	2.5	3-4	—	[illegible]
Wet	—	None	—	—	2.5-3.5	—	—
Strain Recovery at 2% %	—	100	—	100	100	—	100
Toughness	—	—	—	—	0.07	—	—
Moisture Regain 70 F 65% RH %	—	0	—	7-14	0	—	0
Ther. Cond. [illegible]	—	—	—	11	7.2	—	[illegible]
Strong Acids	Poor	Good except for HF	[illegible]	Excellent	Attacked only by [illegible] and hot phosphoric		Excellent
Weak Acids	Poor-good	Excellent	—	Excellent	Stable		Excellent
Strong Alkalis	Excellent	Excellent	—	Excellent	[illegible]		Excellent
Weak Alkalis	Excellent	[illegible]	—	Excellent	[illegible]		[illegible]
Heat	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]

[illegible]

APPENDIX 4(a)

Photomicroscopic Examination of Fibres
(Foseco International Limited)

The fibres have been examined at low and high magnification using a Vickers projection microscope. The appropriate photographs are included in this appendix. In the case of wool the photograph has been reproduced from Fibre Data Summaries ex-Shirley Institute.

It is felt that the photomicrographs are largely self explanatory, however the following points are worth noting.

The residual shot of the melt from which certain fibres were blown can be clearly seen in the low magnification photographs.

The absence of shot in the glass fibres indicates that they have been spun in filaments and not blown.

The cotton photographs show the ribbon-like form with frequent twists and fibre to fibre variation.

The scale-like surface of wool can be clearly seen which gives high inter fibre coherence and high wear resistance.

The good surface quality of the graphite wool can be clearly seen. The surface imperfections on the High Modulus carbon fibre are probably associated with the precursor.

The manner in which the bundles of fine fibres of natural asbestos occur is clearly visible in the low magnification photograph.

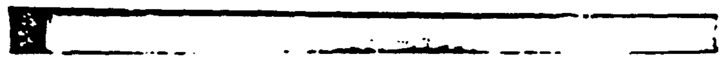
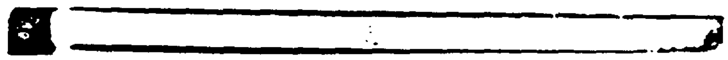
The photographs of E-glass fibre clearly illustrate the [illegible] effect of the organic size.

The zirconium carbide fibres were received in [illegible] form, as can be seen in the X10 magnification photograph.

In the case of the metal fibres the high magnification photographs clearly show a scored surface indicating that they have been made by a shaving or scraping technique.

The very short length and irregular cross-section of carbonised newsprint are clearly visible.

[illegible]

Heat Treatment	X-ray Photograph	Remarks
		
No heat treatment		Trace [illegible]
		
2 hours at [illegible]		Trace [illegible]
		
2 hours at 600°C		No pattern
		
2 hours at [illegible]		No pattern
		
2 hours at 1000°C		No pattern

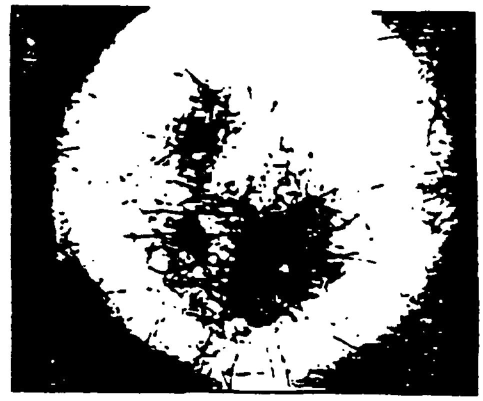
ZIRCONIUM DIOXIDE FIBRE

Heat Treatment	X-ray photographs	Remarks
[illegible]		[illegible]
2 hours at 1000°C		[illegible]

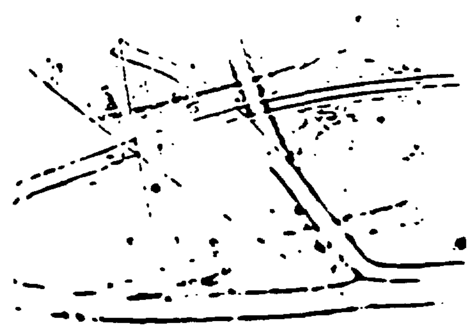
CARBONISED NEWSPRINT

Heat Treatment	X-ray photograph	Remarks
		
No heat treatment		No pattern
		
2 hours at 200°C		No pattern

FOS-00-0000001688

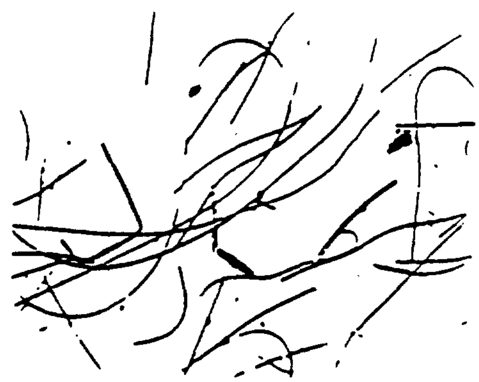


Magnification X10



Magnification X500

Magnification X10



Magnification X500

FOS-00-0000001690

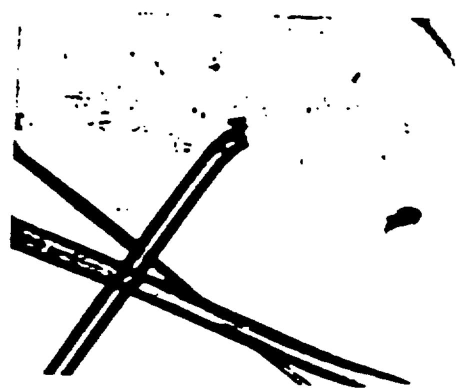
[illegible]

Magnification X 10

Magnification X500

[illegible]

Magnification X1[illegible]



Magnification X500

FOS-00-0000001692

Magnification X10

Magnification X500

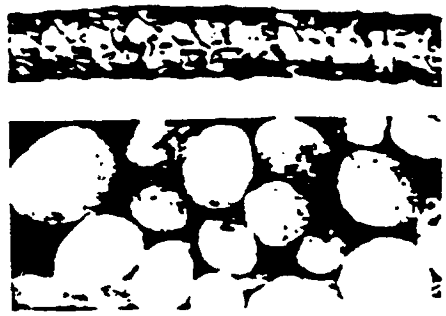
[illegible] 31[illegible]

Magnification X[illegible]

Magnification X500

FOS-00-0000001694

WOOL, 64's GRADE

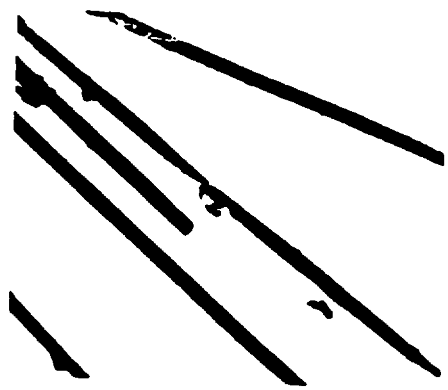


Magnification X750

(From Shirley Institute pamphlet 91, p19)

[illegible]

Magnification X10

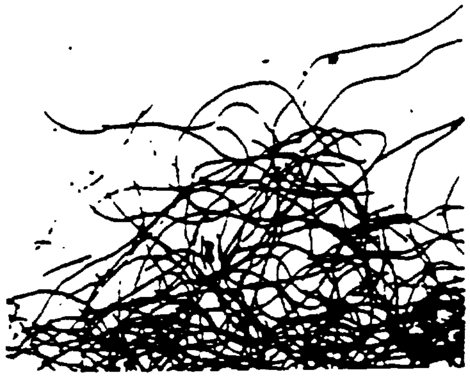


Magnification X500

FOS-00-0000001696

[illegible]

(GRAPHITE [illegible])



Magnification [illegible]

Magnification X500

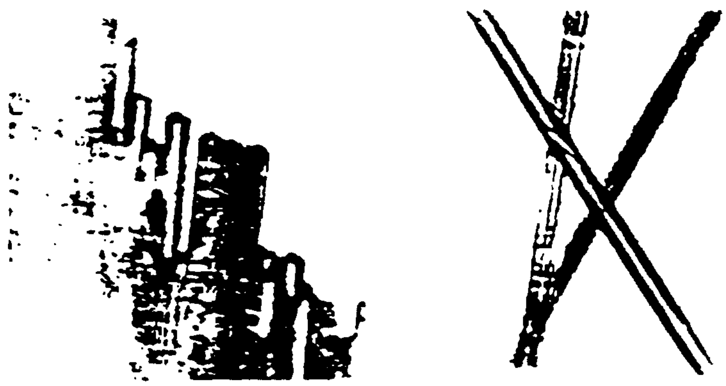
[illegible]

Magnification X10

Magnification X500

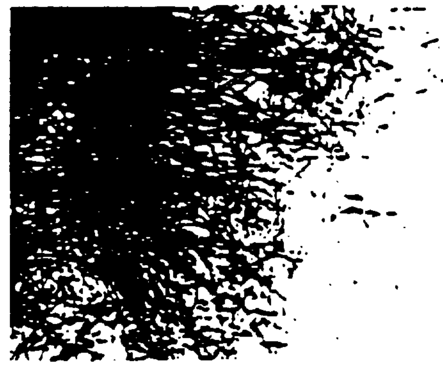
[illegible]

Unwashed Magnification X10 Washed with Acetone

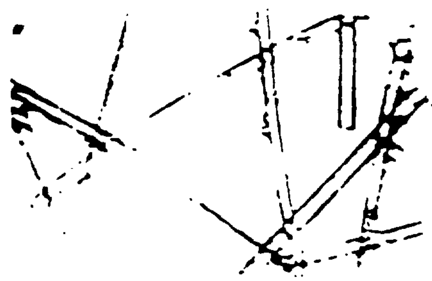


Unwashed Magnification X500 Washed with Acetone

'REFRASIL' SILICA FIBRE CHOPPED STRAND TYPE [illegible]



Magnification X10



Magnification X 500

FOS-00-0000001700

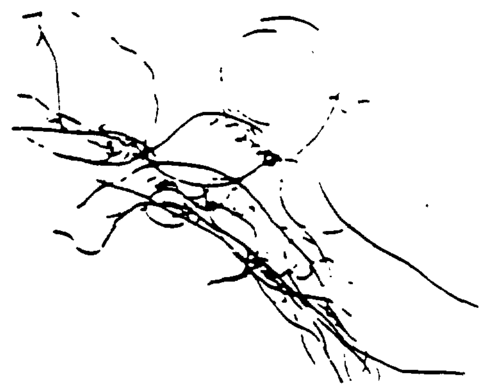
[illegible]

Magnification X10

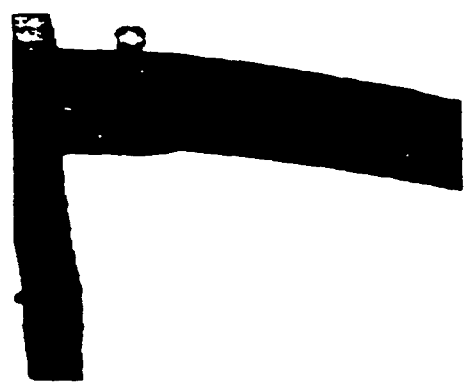
Magnification X500

FOS-00-0000001701

[illegible]



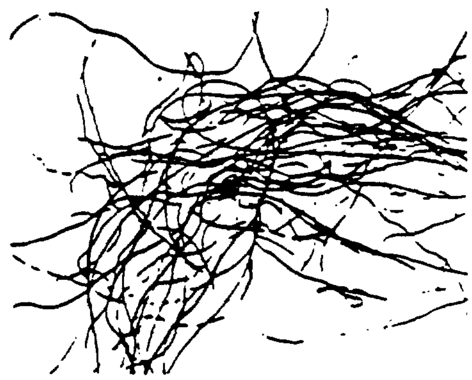
Magnification X 10



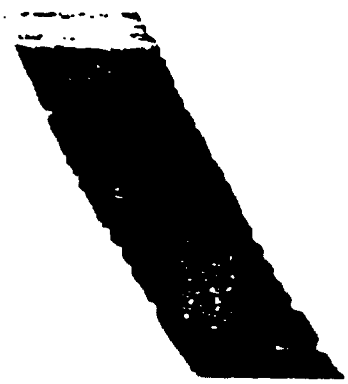
Magnification X500

FOS-00-0000001702

[illegible]

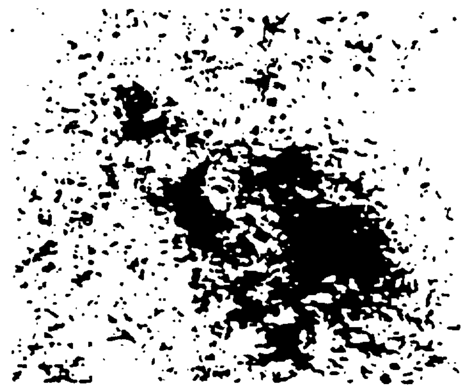


Magnification X10



Magnification X500

CARBONISED [illegible]



Magnification X5

Magnification X500

FOS-00-0000001704

APPENDIX 4(b)

The photomicrographs reproduced in this section are taken from Sandvikens Report No.99502 SK h.r. 1129.

Bilaga 1

Blue asbestos
Diameter 005–02μ

Electron scanning
microscope

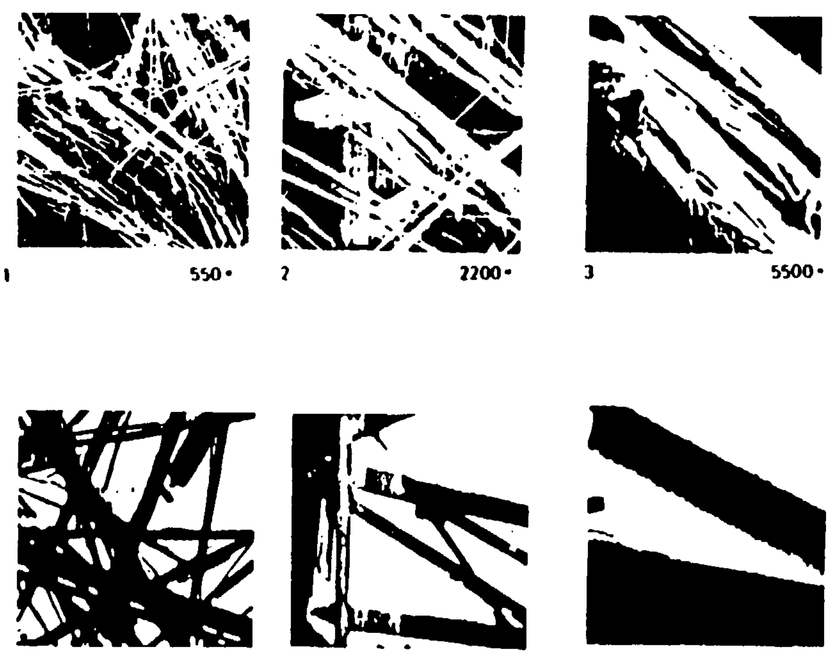
1 500 × 2 2000 × 3 5000 ×

Electron microscope

4 10 000 × 5 60000 × 6 120000 ×

FDS-00-0000001706

Bilaga 2



1 550× 2 2200× 3 5500×

4 10000× 5 40000× 6 120000×

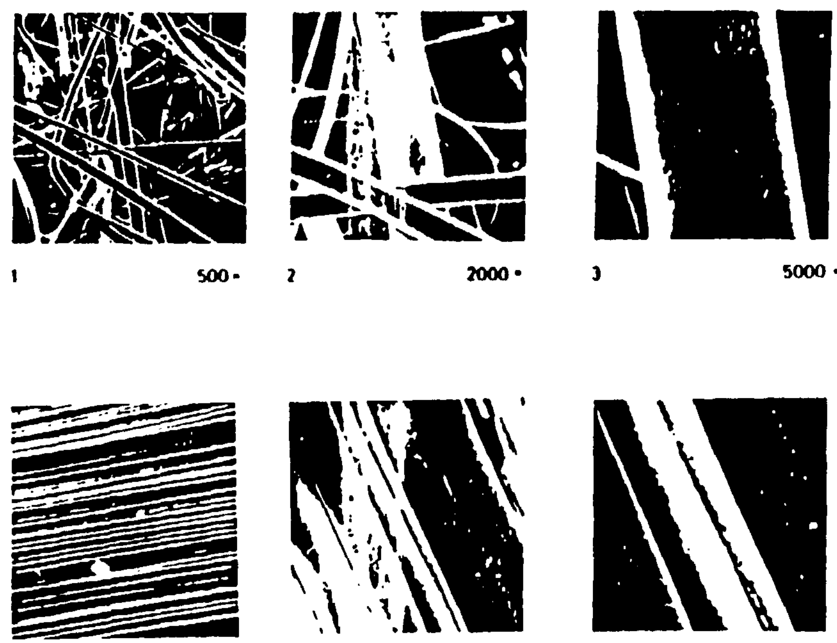
White asbestos
Diameter 0.15–0.3µ

Electron scanning
microscope

Electron microscop

FOS-00-0000001707

Bilaga 1



1 500 ×   2 2000 ×   3 5000 ×

Mineral wool
Diameter 1-12 µ

4 500 ×   5 2000 ×   6 5000 ×

Fiber glass
Diameter 1-6 µ

X-Ray Diffraction

FOS-00-0000001709

Fibres, other than those susceptible to oxidation at relatively low temperatures, were heated at 200°C intervals up to 1,000°C in a muffle furnace. Some fibres were only treated at 1,000°C due to the small size of sample received.

FOS-00-0000001710

TRITON 'B' FIBRE

Heat Treatment	X-ray photograph	Remarks

No heat treatment		No pattern

2 hours at 400°C		No pattern

2 hours at 600°C		No pattern

2 hours at 800°C		No pattern

2 hours at 1000°C		Unidentified pattern (resembles to Al_2O_3).

ZIRCONIUM ALUMINIUM SILICATE FIBRE

Heat Treatment	X-ray photograms	Remarks
		
No heat treatment		No pattern
		
2 hours at 1000°C		Mullite

FOS-00-0000001712

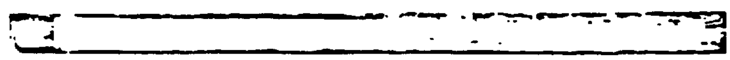
SLAG WOOL (UNCOATED)

Heat Treatment	X-ray photographs	Remarks

Untreated — No pattern

2 hours at 400°C — No pattern

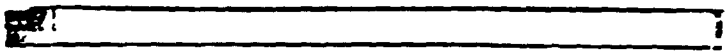
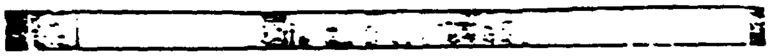
2 hours at 600°C — No pattern



2 hours at 800°C — Trace gehlenite ($Ca_2 Al_2 SiO_7$)

2 hours at 1000°C — Gehlenite + trace unidentified.

[illegible]

Heat Treatment	X-ray photograph	Remarks
No heat treatment		[illegible]
2 hours at 1000°C		Gave a pattern which was not identified

COURTELLE

Heat treatment	X-ray photograph	Remarks
[redacted]		
No heat treatment		No pattern

COTTON

Heat treatment	X-ray photogram	Remarks
No heat treatment		A few broad unidentified lines

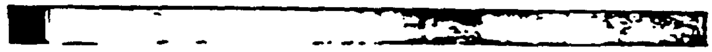
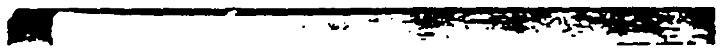
HIGH MODULUS CARBON FIBRE TYPE I

Heat Treatment	X-ray photogram	Remarks
No heat treatment		Graphite
2 hours at 200°C		Graphite

GRAPHITE WOOL

Heat treatment	X-ray photograph	Remarks
		
No heat treatment		No pattern
		
[illegible] hours at [illegible]°C		No pattern

I. GLASS FIBRE

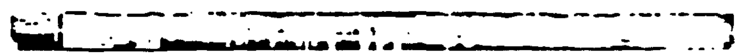
Heat treatment	X-ray photographs	Remarks
No heat treatment		No pattern
2 hours at 400°C		No pattern
		
2 hours at 800°C		No pattern
2 hours at 1000°C		No pattern

AMOSITE ASBESTOS FIBRE

Heat Treatment | **X-ray photographs** | **Remarks**

No heat treatment — Amosite

[illegible] — Amosite



2 hours at 6[illegible]°C — Amosite - unidentified compound

2 hours at 800°C — Amosite - Fe_2O_3 SiO_2 - unidentif[illegible] compound.

2 hours at 1000°C — α and γ Fe_2O_3 - Fe_3O_4 - SiO_2.

APPENDIX 6

Resistance to Chemical Reagents

The tests were carried out on 1g. of fibre at room temperature and under reflux in reagents of [illegible] strength. The times of immersion were [illegible] and 7 hours respectively. After these times the fibre was filtered off, washed, dried and reweighed.

The E-glass fibre as received is coated with an organic size and before the chemical resistance tests were carried out this was removed by washing the fibre in acetone. The removal of the size meant that individual fibres were separated from the small matts into which they had been formed.

-Continued-

FDS-00-0000001722

RESISTANCE TO CHEMICAL REAGENTS
WEIGHT LOST (%) AT ROOM TEMPERATURE
IN 2N REAGENTS AFTER 7 DAYS

FIBRE	HCl	HNO_3	H_2SO_4	KOH	NaOH
Amosite Asbestos	Nil	5	5	10	Nil
	High Liquid Absorption				
Refrasil	5	Slight	5	10	10
Graphite Wool	Nil	Slight	5	5	5
	High Liquid Absorption				
Triton A	10	20	10	15	15
Slag Wool	100	100	100	10	5
	H_2S Evolved With Acids				
[illegible] Neoprene	1	2	3	Nil	Nil
E-Glass	30	30	10	Slight	Slight
Courtelle	Nil	Slight	Nil	Nil	Nil

-Continued-

RESISTANCE TO CHEMICAL REAGENTS
WEIGHT LOST (%) UNDER REFLUX IN 2N
REAGENTS AFTER 7 HOURS

FIBRE	HCl	HNO_3	H_2SO_4	KOH	NaOH
Amosite Asbestos	Slight	5	5	15	50
Refrasil	5	Slight	5	80	100
Graphite Wool	Nil	Slight	5	20	25
Triton A	30	20	25	30	30
Slag Wool	100	100	100	25	25
Carbonised Newsprint	4	6	12	1	1
	H_2S Evolved With Acids				
E-Glass	35	35	35	Slight	10
Courtelle	Nil	Slight	Nil	100	100

APPENDIX 7

[illegible] After [illegible] the Shirley Institute a detailed estimate of costs and times for determining the fibre properties which the Fibre Study Group listed was received. A copy of their letter is given in this Appendix.

[illegible]

...tten response to the
...t until now but, as
...y on holiday at
...d meetings and estimates.

...st immediate line of
...operty values from
...e interested in. The
...will then, possibly,

...nts for the making
...re critically than
...ier heavy work load
...te can be made fairly

...	Charge
	£
	100
	20
	60
	30
	70
	[illegible]

...is approximate and
...rity of the staff
[illegible]
...be discussed before

...'straight forward'
...ments would need to be
...staff who are expert
...ully committed on
...ount of work would
...e present time, and
...ired to complete the
...to be as follows:

...	Charge
	£
	250
	250
	800
	800
	1900

...ning range, melting
... which strength is
...re the undertaking of
...considerable amount of

-Continued-

special equipment. It would probably be more economic for you to have this work done elsewhere.

The following organisations may be able to help you in the provision of data and/or in the making of measurements.

1. British Ceramic Research Association, Queens Road, Penkhull, Stoke-on-Trent, Staffs.
2. British Glass Industry Research Association, Northumberland Road, Sheffield 10, Yorks.
3. British Iron and Steel Research Association, 24, Buckingham Gate, London, S.W.1.
4. Atomic Energy Research Establishment, (Ceramics Laboratory), Harwell, Didcot, Berks.
5. National Physical Laboratory, Teddington, Middlesex.
6. National Engineering Laboratory, East Kilbride, Glasgow.
7. Royal Aircraft Establishment, Farnborough, Hants.

I trust the information given in this letter is of assistance to you in the design of your survey project.

APPENDIX 8

Fibre Prices and Suppliers

RESEARCH AND DEVELOPMENT REPORT NO.264

Fibre Study Data Collection

by: D.J.Dimmock, P.S.Clark, P.J.Hancox and P.V.Jones

[illegible]

CONTENTS

INTRODUCTION

Following the recommendations of the Fibre Study Group (Appendix 1), a data collection exercise has been carried out. The Study Group considered that a full and comprehensive knowledge of fibre technology was of great importance to the Foseco group of companies. It is possible that this knowledge will help Foseco broaden its overall activities.

The exercise has been carried out on fibres selected as being typical of generic groups, but not covering the whole range of fibres that are available. The following points were taken into account for the selection of the fibres.

(i) Does the fibre chosen typify, as far as possible, the group to which it is assigned?

(ii) Is it available, or likely to be available in the near future, in commercial quantities?

The cost of the fibre was not considered.

The particular fibres chosen to represent each group, with reasons for the choice, are tabulated in Appendix 2.

The study has entailed a literature survey, including manufacturer's data sheets, and direct contact for information not generally issued. Where possible certain values have been obtained experimentally at Foseco International Limited and this is shown by an asterisk in the data tables in Appendix 3. To avoid [illegible] the conditions under which the properties were measured have been stated.

The gaps in the tables are due to those particular properties not being measured by the manufacturers and the lack of suitable equipment at Foseco International Limited. If at a later date it is found necessary for these properties to be measured then this may be carried out by an outside body, e.g. Shirley Institute. For costing and timing of this work a letter from Shirley Institute is included in Appendix 7.

-Continued-

FIBRES SELECTED

KAOWOOL AND FIBERFRAX

These alumina silicate fibres are manufactured respectively from Georgian clay and synthetically in the U.S.A. The most interesting property is its non wettability by molten metals.

References: Carborundum Co. [illegible]
Babcock and Wilcox Co.
Technical Data Sheets.

The U.K. equivalent Triton [illegible] manufactured by:

Morganite Ceramic Fibres Ltd.,
Neston, Wirral,
Cheshire.

ZIRCONIUM ALUMINIUM SILICATE

This is an experimental fibre and information on nearly all its properties is not available. A small sample has been obtained which has enabled an analysis, photo-micrographs and X-Ray diffraction patterns to be obtained. A point of interest is the high proportion of shot that is present, whereas Kaowool and Fiberfrax are free from shot.

References: Electro-Refractaire, [illegible]
99, Rue [illegible]
Paris, 1. [illegible]

Agents: Le Pontet,
Vaucluse.

English Associates: Electrocast Ltd.,
Rockware Avenue, Greenford,
Middlesex.

STILLITE

This is manufactured from blast furnace slag and consequently does not possess a high degree of refractoriness.

References: Stillite Products Ltd.,
15, Whitehall,
London, S.W.1.

Technical Data Sheets
Private Communication.

ROCKSIL

Manufactured from rock containing a high proportion of calcium silicate and is thus similar to Stillite.

References: Cape Insulation Ltd., 114, Park Street, London W.1.

Technical Data Sheets
Private Communication.

COURTELLE

An acrylic polymeric textile fibre developed in the U.K. and possessing properties beneficial to the textile industry.

References: Courtaulds Ltd.,
Coventry [illegible]
[illegible]
Fibre Data Summaries,
ex- Shirley Institute,
Manchester, 20

COTTON AND WOOL

The two principal natural textile fibres of, respectively, vegetable and animal origin.

References: Fibre Data Summaries,
ex- Shirley Institute,
Manchester, 20.

Man-Made Fibres,
R.W.Moncrieff,
Heywood and Co. 1963.
[illegible]
[illegible]
S.G.Barker, H.M.S.O. 1931

Fibres, Plastics and Rubber,
W.J.Roff,
Butterworths 1956.

Physical Properties of Textile Fibres,
Morton and Hearle,
The Textile Institute,
Butterworths 1962.

HIGH MODULUS CARBON FIBRE (TYPE 1)

The material is supplied in the form of a tow, each tow containing some 10,000 filaments.

Unless otherwise stated, all physical properties in the table refer to single filaments.

This type of carbon fibre was designed for incorporation in a resin matrix, to give a composite material for applications where a very high stiffness or modulus is required.

The fibrilar structure of the filaments, with a high degree of orientation, accounts for the high modulus values obtained.

-Continued-

GRAPHITE INSULATING FIBRE GRADE 6121C

This material is very similar to the carbon fibre, but heat treated at a high temperature. Since it was designed as an insulating material, to be used in preference to carbon at high temperature under vacuum, the manufacturers have conducted virtually no physical tests on the [illegible] of the [illegible]

References: [illegible] Research and Development Ltd., [illegible] Battersea Church Road, London S.W.11.

Product Data Sheets and Private Communications.

NATURAL AMOSITE B.S.[illegible]

Amosite is comprised of particularly fine filaments, which have extremely high tensile strength and flexibility.

Its relative instability (chemically) with increasing temperature, should be noted, [illegible] melting point. The thermal conductivity figure is quoted for a slab of pure amosite (of unspecified density) by Cape Insulation.

References: Cape Insulation Ltd., [illegible] 114, Park Street, London [illegible]

[illegible] Private Communications.

E-GLASS FIBRE B.S.3.10

This glass fibre, supplied in short chopped lengths, is the most refractory vitreous glass fibre produced. Even this is fully molten at 1200°C.

It is generally supplied coated with an organic size; without this sizing, it would be difficult to chop mechanically.

The fibres have a high tensile strength at room temperature, but this starts to deteriorate at 750°C.

References: Fibreglass Limited, Valley Road, Birkenhead.

Technical Data Sheets and Private Communications.

SILICA FIBRES - "REFRASIL" [illegible]

This fibre is the most refractory of the "glasses", but it commences to embrittle at about 1000°C, when its crystalline form changes. Its extremely low coefficient of expansion allows it to be quenched in cold water from 1000°C without fracture.

The material is produced by acid leaching of low alkali silicate glass fibre, followed by heat treatment.

References: The Chemical and Insulating Co., Ltd., Darlington.

Technical Data Sheets and Private Communications.

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CARBONISED [illegible]

This form of carbon is of very low bulk density, in fibrous form. It was originally developed by R.A.E. Farnborough for the manufacture of steel moulds, by the Bickerdike process.

No physical tests have been carried out on this material by R.A.E.

The fibres are relatively short, having a length to diameter ratio of about 25:1. The small filaments are surprisingly resilient, an aqueous slurry withstanding several minutes in a Silverson high shear emulsifier without much noticeable fibre breakdown.

References: R.A.E. Farnborough, Hants
Private Communications.

REFRACTORY OXIDE FIBRES

Polycrystalline zirconium dioxide fibre was chosen as being typical of this group. Its outstanding properties are its refractoriness, flexibility, and good oxidation and erosion resistance.

A number of suppliers mentioned in the literature no longer deal with this material. Union Carbide are at an early stage in their work, and are actively engaged in assessing the potential market.

References: Union Carbide Corp.,
Tarrytown, New York.

Technical Data Sheets

'Advanced Materials' G.S. Carroll Porczynski

METAL WOOLS

Steel and aluminium wools have been examined as typical examples of this generic group. These are well-known products in industry and in the home, and costs would not be expected to change much in the future.

The suppliers were unable to give us certain data, hence the few gaps in the table (Appendix 3).

References: Brillo Manufacturing Co., Ltd.,
Maidenhead, Berks.

Private Communications.

'Advanced Materials' G.S. Carroll Porczynski.

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BORON NITRIDE FIBRE

This is an advanced material, not yet available in the U.K. At the present time cost is very high (See Appendix 8), and though expected to drop with increasing demand, the difficulty of manufacture will almost certainly mean that it will remain a fairly expensive material.

Its properties are included in the table (Appendix 3). Points of interest are its flexibility, chemical inertness and strength at high temperatures.

References: Carborundum Co., Ltd.,
Trafford Park, Manchester 17.

Technical Data Sheets.

Private Communications.

Union Carbide [illegible]
[illegible]

Technical Data Sheets.

COMMENTS

The [illegible] of the fibres examined falls in the range [illegible]$^{\circ}$C (for aluminium [illegible]) [illegible] (for zirconia). The exceptions are the carbon fibres, which are oxidised unless in an inert atmosphere when they will not melt under atmospheric pressure; Boron Nitride behaves similarly and will withstand [illegible]$^{\circ}$C in the absence of oxygen.

All fibres have high tensile strengths, [illegible] and [illegible] fibres, but the textile fibres have [illegible] moduli of elasticity. Without exception the fibres are very flexible.

The values obtained for thermal conductivity and specific heat are of the same order, the variation in the main being caused by different packing densities. This is to be expected as a very large proportion of a fibrous mass is entrapped air.

The results of the examination to discover any changes in crystalline form on heating are recorded in Appendix 5 together with the X-Ray diffraction photographs.

Resistance to chemical reagents has been examined and the details of the tests are given in Appendix 6.

DJB/PSC/PJM/PVJ/[illegible]/[illegible]

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