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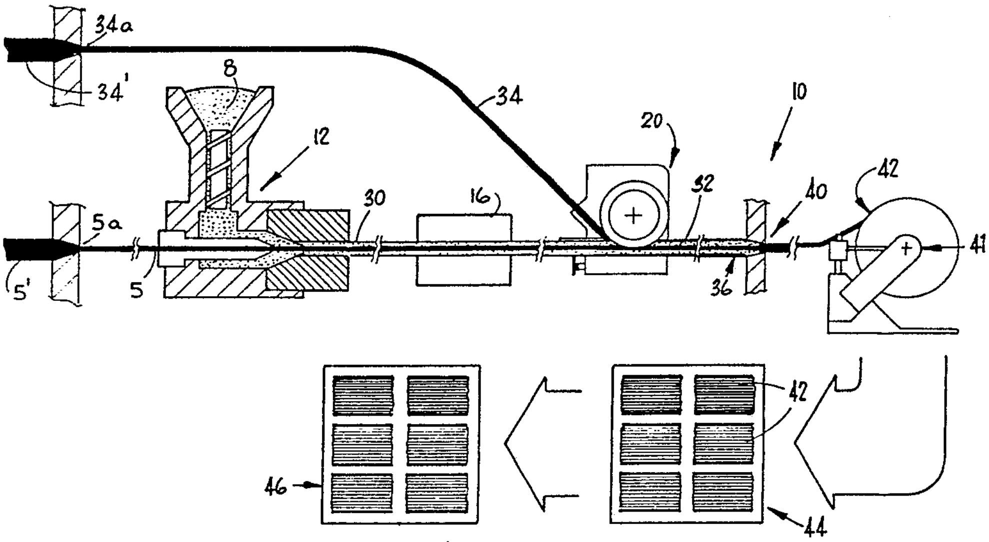
(54) Title: MANUFACTURE OF MINERAL INSULATED METAL SHEATHED CABLES



(57) Abstract

Mineral insulated metal sheathed cables are produced by extruding a mixture of ceramic powder, liquid, and binder onto a moving conductor (5) by means of a co-extruder (12). Liquid and binder are removed from the extruded insulating material while moving through a furnace (16), and a metal sheath (15) then applied, preferably by a conform extruder (20). The process results in the continuous production of the cable.

* See back of page

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"Manufacture of Mineral Insulated Metal Sheathed Cables"

This invention relates generally to the manufacture of mineral insulated metal sheathed cables.

Mineral insulated metal sheathed cables typically comprise one or more metallic conductors embedded in a body of compacted mineral insulating material which is in turn housed within an outer metallic sheath. The conductors and sheath are usually copper and the insulating material may be a ceramic powder such as magnesium oxide.

One method of manufacturing such cables is by packing the mineral insulating material into a vertically extending metallic tube already fitted with conductor cores, and then subjecting the filled length of tube to a succession of drawing and annealing operations. This method suffers from several disadvantages. It is a batch process and cannot be adapted to continuous cable production. The initial tube is a relatively expensive source of the sheath metal, although it has been suggested (U.S. Patent 4,614,024) that the tube could be prepared within the process by forming flat metal strip. The multiple drawing and annealing steps require substantial time. Each annealing step is slow because the conductors, which must be subjected to the annealing along with the sheath, are protected from the heat by the mineral insulating material.

A modification of the method just described is disclosed in U.S. Patent 4,420,881. According to this modification, the mineral insulating material is mixed with an organic binder and either palletized under high pressure or simply extruded, in either case producing a cylindrical preform structure with one or more longitudinal ducts. The preform structure is cut into lengths which are, in the extruded case, heated to burn off the binder and then, in either case, inserted into a metal sheathing tube. A conductor is then passed through each duct and the resultant structure drawn and annealed in the known manner. The extrusion technique of U.S. Patent 4,420,881 is still a batch process and still requires a metal tube for the sheath.

British patent application 2,205,263 proposes continuously forming the metallic sheath in an annular die by means of conform extrusion, a technique described generally in British patent 1,370,894. The sheath is disposed vertically, at least at its mouth, so that the mineral insulating material can be fed into the extruded sheath from a hopper. Conductors are fed into the sheath from respective guide tubes. Drawing and annealing follow as before. This proposal suffers from the disadvantage that there is not adequate control in the compaction of the insulating material during filling of the sheath which results in inadequate control of the insulating and dielectric properties of the cable. In addition, displacement of the conductors can occur during subsequent processing stages.

It is an object of the invention to provide a method of manufacturing mineral insulated metal sheathed cables which at least in part alleviates one or more of the disadvantages of the prior methods.

According to the invention, there is provided a method of manufacturing a mineral insulated metal sheathed cable, said method comprising treating mineral insulating material to form an extrudable substance, said treatment including mixing the material at least with a binder, co-extruding a generally cylindrical body of said substance about at least one moving elongate electrical conductor to provide an insulating body, treating the extruded body of insulating material to remove and/or decompose the binder, and applying a metal sheath around the treated body.

The sheath is preferably a metallic sheath and is advantageously formed about said co-extruded cylindrical body by conform extrusion through an annular die. In an alternative arrangement, the sheath might be physically formed from flat strip.

Where the cable is to be an electrical power cable, the conductor(s) and sheath are preferably copper or aluminium and the insulating material is advantageously a ceramic powder such as magnesium oxide, aluminium oxide, or other oxides, carbides, or nitrides.

The invention will now be further described, by way of example only, with reference to the accompanying drawings, in which

Figure 1 is a partially sectioned schematic diagram of apparatus for manufacturing mineral insulated metal sheathed cables in accordance with the invention; and

Figure 2 is a flow chart depicting the steps of an embodiment of the process of the invention utilising the apparatus shown in Figure 1.

The apparatus 10 depicted in Figure 1 includes a co-extruder 12 and a conform extruder 20. Mineral insulating material, pre-mixed with water or water and alcohol, and a suitable binder to form an extrudable feedstock 8, is continuously fed to co-extruder 12 and co-extruded about one or more travelling elongate metallic conductors 5 to form a generally cylindrical body 30 of the material in which the or each conductor is thereby embedded. At conform extruder 20, a metallic sheath 32 is formed about body 30 by conform extrusion from an annular die. The conform extrusion technique is generally as described in British patent 1,370,894, utilising feedstock such as rod 34. The feedstock for the conform extruder may alternatively comprise metallic powder or granules.

The sheathed and insulated cable 36 discharged from conform extruder 20 is drawn in at least one drawing stage 40 for example comprising a series of rolls or extrusion dies, to compact the mineral insulation and reduce the cable to the required size. Thereafter the cable is wound onto formers 41 as successive coils 42 of continuous cable. Alternatively, the coiling may be completed on a bull block or similar device where size reduction is simultaneously achieved.

Coils 42 are annealed in a bell furnace 44, or continuously annealed by other suitable means, according to conventional practice with mineral insulated metal sheathed cables, and passed for storage or transport 46. More than one drawing and/or annealing step may be required or found desirable, depending on the end-product sought, but typically only one drawing and annealing are required.

Conductor 5 and rod 34 are respectively reduced in section from metallic wire 5' and metallic rod 34 by any suitable deformation process such as rolling, drawing, or conform. The reduction steps for the conductor 5 and rod 34 are shown schematically at 5a and 34a. As mentioned, the mineral insulating powder is mixed with both water (or water and alcohol) and a suitable binder to form plastic feedstock 8 for co-extruder 12. Before reaching conform extruder 20, the cylindrical body 30 is treated by heating in a zoned furnace 16 to at least partially drive off the water and to decompose the binder and other additives. The two treatments of the mineral insulating material - the pre-treatment to form the co-extruder feedstock and the treatment of the extruded body in furnace 16 - are such as to optimise the subsequent insulating properties of the cylindrical body while sufficiently preserving the latter's integrity before it is encased by the sheath. If there is to be a subsequent reduction step, there is a further requirement that the extruded and debindered body remains sufficiently plastic to extrude with the conductor(s) and sheath. The characteristics required for the mineral insulating material used in the process of the invention will be discussed in greater detail hereinafter.

The conform extruder 20 preferably applies sufficient energy to also anneal the sheath; the furnace 16 may in similar fashion anneal the conductor(s) prior the sheathing step.

The sequence of steps set out above is depicted as a process flow chart in Figure 2.

This flow chart further shows pre-treatment 50 of the mineral insulating powder to grade the powder according to particle size and to detect and remove magnetics, indicates at 51 the treatment of this powder by mixing in water (or water and alcohol) and binder, and shows that the co-extrusion step may entail vacuum degassing of the extruder feedstock to remove trapped air. Preparation of the conductor may include welding and straightening steps 52, 53.

Where the cable is to be electrical power cable, the conductor and sheath are typically copper or aluminium, although other metals may of course be employed. The mineral insulating material may be a ceramic powder, e.g. magnesium oxide, aluminium oxide, zirconium oxide or other oxides, or carbides or nitrides which have a high melting point and good insulation resistance.

Suitable binders for mixing with the mineral insulating material include those developed for the extrusion of ceramic materials and are typically water soluble resins, such as gums, polyvinyl alcohols, cellulosic materials and high molecular weight homopolymers or polyethylene oxide. Other additives may be used to improve the formulation, such as wetting agents to assist with dispersion of the binder, extrusion aids to reduce the extrusion forces and lower wear, lubricant to lower wear, and biocides to facilitate preservation. High shear mixing is preferably used to achieve a uniform mix. Heating may be applied at the co-extruder as some binders undergo a gel transition at higher temperatures.

Extrusion of ceramic materials is well known for use in the production of sintered components. The technique is to mix ceramic powder with water and binders to provide a fluid mix which is easily extrudable. Typically the amount of water will be in excess of 15% by weight and the binders will be in the range of 1 to 4% by weight. The extruded product is cut into lengths which are put in batches into a furnace in which the product are heated to remove the binder and then to sinter the particles. A sintered product normally requires a particle size of 25 microns or less in order to provide rapid sintering and sufficient final strength. The small particle size and high liquid content does, however, mean that long heating times (usually several hours) are required to remove the liquid and binder prior to sintering, the long heating times being necessary due to the relatively small amount of free space available within the product for escape of any volatiles and any decomposition products of the binder on heating. Between removal of the binder and sintering, the product is in a fragile condition but remains in the furnace during this phase and does not therefore need to be handled.

The parameters for the ceramic extrusion process are, however, different when used in the process of the invention. The extrusion process again requires the addition of water or other liquid to the ceramic powder to provide an extrudable mixture and also the addition of binder which assists the retention in the shape of the extruded product, with extrusion becoming easier as the added liquid content is increased. However, as the amount of liquid is increased, the product density is reduced which leads to reduced product strength after heating to remove the binder. In a conventional ceramic extrusion process for producing a sintered product in which the product is heated in a furnace to remove the binder and then to sinter the product with no product handling being required between these stages, low product strength after binder removal and prior to sintering does not have a serious affect. In the process of the invention the product is not sintered after binder removal (although a degree of sintering may occur during heating to remove the binder) and the product must have sufficient strength after binder removal to enable the product to be transported to the conform extruder and to thereafter withstand the forces applied during conform extrusion at which the sheath is applied. For this reason, the amount of liquid added to plasticise the mix for extrusion must be a balance between that necessary to achieve adequate extrusion characteristics while preserving adequate product strength after removal of the binder to permit the handling of the product to and through the conform extruder. It is also to be noted that these difficulties cannot be overcome by fully sintering the product after binder removal as this would render the product incapable of being reduced down to the required size after conform extrusion.

To avoid substantial sintering effects during heating and also to permit removal of liquid and binder during the heating phase over a relatively short period of time (measured in minutes rather than hours), the particle size of the mix will be larger than that used in conventional ceramic extrusion. The major portion of the mix will have a particle size of at least about 30 microns although inevitably the mix will contain a proportion of smaller size particles. Particle size will also affect strength of the product after binder removal, with increased particle size leading us to reduced strength. Accordingly, a compromise is necessary in the particle size to meet these different requirements. Ceramic powders are capable of wide variation in particle size depending on such factors as the source of the product and method of size reduction, and it is possible to mix different grades of powder to obtain a mix with a particle size distribution within the limits necessary to achieve the required characteristics.

Further preferred aspects of the extrudable mix for use in the process of the invention will now be given.

The particle size of the ceramic powder is mainly in the range of 10 microns to 200 microns with the major portion being in the range 30 microns to 125 microns. The actual size distribution is highly variable and this controls the final formulation.

The liquid additive to plasticise the mix is applied in the range of 4-14% by weight, with the most suitable range being 5-8% by weight. The actual value is dependant on the nature of the particles including particle size and surface area. The liquid may be water or a mixture of water and alcohol which will evaporate more readily on heating.

The amount of binder added is typically in the order of 1-8% by weight. The actual amount used is most likely to be in the range of 2-6%. Too high a level will make it more difficult to debinder rapidly enough, while too little and the material will not have sufficient plasticity to be extruded. Again, the actual amount is dependant on the specific grade of ceramic powder used.

Plasticisers may be used to improve the plasticity of the mix. These must be readily decomposed and provide little ash to contaminate the ceramic material. This contamination would lower the resistivity and dielectric characteristics particularly at elevated temperatures. Typical plasticisers are polyethylene or polypropylene glycols with specific molecular weights. A typical material is polyethylene glycol 400 used at the 2-10% of the total binder content. Surfactants may be used to improve the wetting of the ingredients by lowering the surface tension of the aqueous system. These are usually used in the range of 0.1-0.5% by weight.

Lubricant may also be added to improve the lubrication between particles and between the extruder die and walls and the material being extruded. Typical lubricants are stearates (compatible with the ceramic), stearic acid or diglycol stearate. The level of lubricant used is preferably in the range 0.1-2% by weight with 0.5% being especially preferred.

The extruded product is dried rapidly and heated to remove the binder and other additives so that the original resistive and dielectric properties are returned. This usually requires heating to about 900-1000°C using a heating time of several minutes. The total heating time is recorded in minutes rather than hours which is more typical of that used for debindering in conventional ceramic extrusion. Heating is at a temperature below that at which substantial sintering occurs.

All additives used in the mix must be either readily decomposed on heating to provide little or no ash, or alternatively, the product of decomposition must be compatible with the ceramic material being extruded. For example, magnesium stearate can be used as a lubricant for the extrusion of MgO as the product of decomposition is MgO.

Details of suitable mixes will now be given by way of example only

Example I		wt%
Ceramic powder (MgO)	50-125 micron	89.0
Binder (Cellulosic)		2.8
Water		8.2

Example II		
Ceramic powder (MgO)	50-125 micron	88.3
Polyethylene glycol		0.4
Binder (Cellulosic)		2.8
Water		7.5
Magnesium stearate		1.0

Example III		
Ceramic powder (MgO)	30-100 micron	86.2
Binder (Cellulosic)		5.4
Alcohol		2.3
Water		5.6
Magnesium stearate		0.5

In the above examples, the ceramic powder particle size range is given for the majority of the particles, and it is to be understood that the powder may also include some particles outside of this range. The above examples are given in order to provide an understanding of the nature of a typical ceramic mix which can be used in the process of the invention. It is, however, to be understood that the present invention is not restricted just to the use of these formulations

The furnace in which the extruded product is heated may be a tunnel furnace through which the product continuously moves, the length of the furnace being such that movement through the furnace at a rate determined by the ceramic extrusion and conform operations provides the required heating time. The furnace may be heated by conventional means or alternatively the furnace may be an induction furnace or a microwave furnace. The product is substantially continuously supported on a conveyor during passage through the furnace and during passage from the furnace to the conform extruder. The conveyor may be a moving belt conveyor, a roller conveyor or a combination of both rollers and belts. Due to the fragility of the product during heating and prior to sheathing the product moves along a substantially horizontal rectilinear path from the furnace to the conform extruder.

The described process has a number of advantages over prior disclosed techniques. Continuous rather than batch production of cable may be conveniently achieved. There is less annealing, drawing and handling, because the cable is initially produced close to finished size. The sheath feedstock used in conform extrusion is an inexpensive source of the metal rather than relatively expensive tube. Copper rod for example, is much less than the cost of copper tube for a given weight of metal. Treatment of insulation is achieved prior to covering it with the sheath, and a more uniform density is evident in the extruded body of insulating material than with the prior packing methods. Much of the desirable compaction of the insulating material occurs during the co-extrusion step whereas prior methods need the extensive amount of drawing to, inter alia, compact the insulating material.

Although conform extrusion is preferably used to apply the sheath as the feedstock for this process is relatively inexpensive, the sheath can be formed by other techniques such as forming flat strip into U-shape into which the extruded body is laid and the tube formed and the gap welded. This technique may provide some advantages in handling the fragile extruded ceramic body during sheathing.

The described arrangement has been advanced merely by way of explanation and many modifications may be made thereto without departing from the spirit and scope of the invention which includes every novel feature and combination of novel features herein disclosed.

CLAIMS:

1. A method of manufacturing a mineral insulated metal sheathed cable, said method comprising treating mineral insulating material to form an extrudable substance, said treatment including mixing the material at least with a binder, co-extruding a generally cylindrical body of said substance about at least one moving elongate electrical conductor to provide an insulating body, treating the extruded body of insulating material to remove and/or decompose the binder, and applying a metal sheath around the treated body.

2. A method according to claim 1, wherein the treatment of the insulating material to form the extrudable substance further comprises mixing the material with liquid which is removed prior to application of the sheath around the extruded insulating body, the amount of liquid mixed with the material being such that after the treatment of the extruded insulating body to remove the liquid the body has sufficient strength to permit transportation of the body to a station at which the metal sheath is applied to the body.

3. A method according to claim 2, wherein the said treatment of the body comprises heating the body while moving with the conductor embedded with the body.

4. A method according to claim 3, wherein the mineral insulating material comprises ceramic particles, and the heating of the extruded insulating body prior to application of the sheath takes place at a temperature range below that at which substantial sintering of the particles occurs.

5. A method according to claim 4, wherein the size of the particles, the amount of liquid and the amount of binder is such that removal of liquid, and removal and/or decomposition of the binder in the heating stage occurs within several minutes.

6. A method according to claim 5, wherein a majority of the particles are in a size range of from about 30 to 125 microns.

7. A method according to any one of claims 2 to 6, wherein the amount of added liquid is between about 4 and 14% by weight.

8. A method according to any one of claims 2 to 7, wherein the amount of binder is between about 1 and 8% by weight.

9. A method according to any one of claims 2 to 8, wherein the body is substantially continuously supported during movement from the treatment stage to the station at which the sheath is applied.

10. A method according to any one of claims 1 to 9, wherein the sheath is applied by conform extrusion through an annular die.

11. A method according to claim 10, wherein treatment of the body and sheathing by conform extrusion takes place on a substantially horizontal rectilinear path of movement of the body.

12. A method according to any one of claims 1 to 10, further comprising reducing the sheathed body to a required size.

13. A sheathed cable produced by a method according to any one of claims 1 to 12.

14. Apparatus for carrying out a method according to any one of claims 1 to 12, comprising means defining a path of movement for the or each said conductor, an extruder on said path for extruding a cylindrical body of ceramic insulating material around the or each conductor, treatment means on said path downstream of the extruder for removing liquid within the body and for removing and/or decomposing binder within the body, and sheathing means on the path downstream of the treatment means for applying a metal sheath

around the body.

15. Apparatus according to claim 14, wherein said treatment means comprises a furnace through which the body moves, the furnace being so arranged that it heats the body to a temperature range at which the binder is removed and/or decomposed without causing substantial sintering the body.

16. Apparatus according to claim 14 or claim 15, wherein the sheathing means comprises a conform extruder.

17. Apparatus according to claim 16, wherein the said path extends substantially horizontally and rectilinearly between the treatment means and the conform extruder.

18. Apparatus according to any one of claims 14 to 17, comprising conveyor means for substantially continuously supporting the body during movement between the treatment means and the sheathing means.

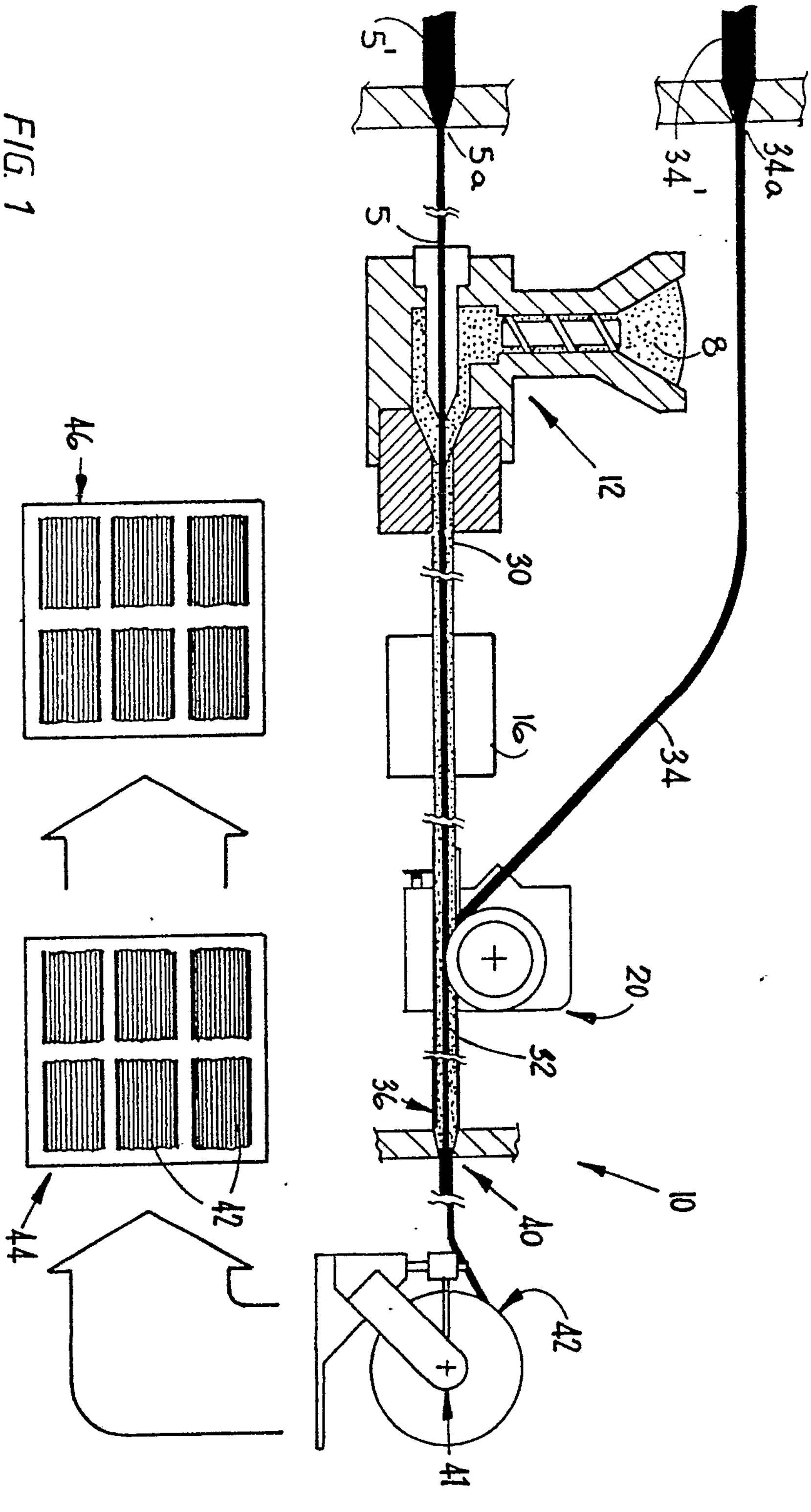

FIG. 1

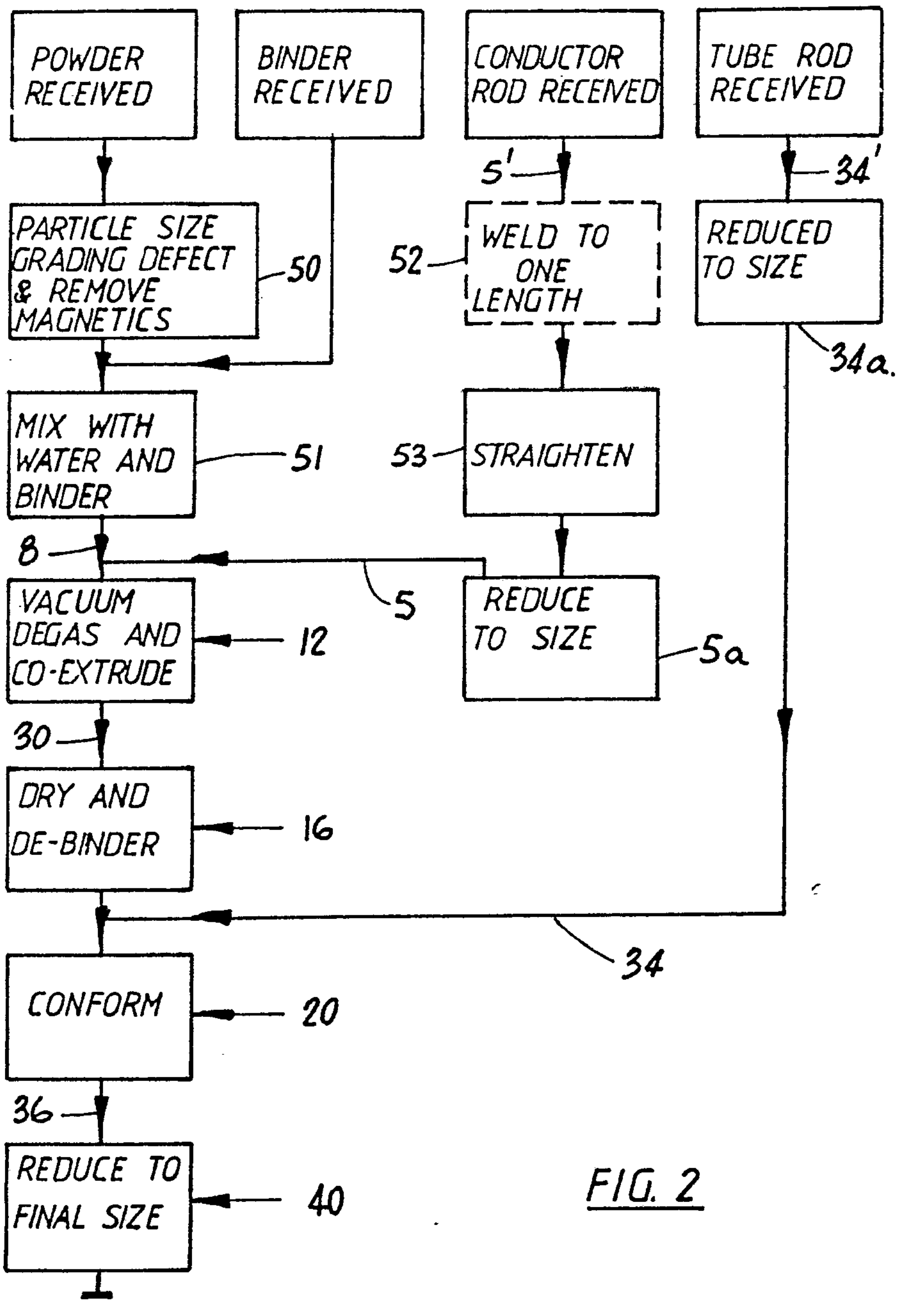
POWDER RECEIVED
BINDER RECEIVED
CONDUCTOR ROD RECEIVED
TUBE ROD RECEIVED
PARTICLE SIZE GRADING DEFECT & REMOVE MAGNETICS
50
5'
52
WELD TO ONE LENGTH
34'
REDUCED TO SIZE
34a.
MIX WITH WATER AND BINDER
51
53
STRAIGHTEN
8
5
VACUUM DEGAS AND CO-EXTRUDE
12
REDUCE TO SIZE
5a
30
DRY AND DE-BINDER
16
34
CONFORM
20
36
REDUCE TO FINAL SIZE
40

FIG. 2

INTERNATIONAL SEARCH REPORT

International Application No. PCT/AU 90/00198

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) 6

According to International Patent Classification (IPC) or to both National Classification and IPC

Int. Cl.^{5} H01B 13/14, 7/16

II. FIELDS SEARCHED

Minimum Documentation Searched 7

Classification System	Classification Symbols
IPC	H01B 13/14, 7/16

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched 8

AU : IPC as above

III. DOCUMENTS CONSIDERED TO BE RELEVANT 9

Category*	Citation of Document, 11 with indication, where appropriate, of the relevant passages 12	Relevant to Claim No 13
Y	US,A, 4420881 (BOURGET) 20 December 1983 (20.12.83). Claim 1. Figure 1.	1 - 18
Y	AU,B, 57663/80 (535216) (SOCIETA CAVI PIRELLI SOCIETA' PER AZIONI (SpA)) 20 November 1980 (20.11.80). Claim 1. Figure 1.	1
Y	US,A, 4663095 (BATTAIS) 5 May 1987 (05.05.87). Claim 1, 2, 14.	1 - 5
Y	GB,A, 2205263 (ASSOCIATED ELECTRICAL INDUSTRIES LTD) 7 December 1988 (07.12.88). Claim 1.	10, 16

* Special categories of cited documents: 10

"A" document defining the general state of the art which is not considered to be of particular relevance

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
24 July 1990 (24.07.90)	1 August 1990

International Searching Authority	Signature of Authorized Officer
Australian Patent Office	P.F. GOTHAM

Form PCT/ISA/210 (second sheet) (January 1985)

ANNEX TO THE INTERNATIONAL SEARCH REPORT ON INTERNATIONAL APPLICATION NO. PCT/AU 90/00198

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report	Patent Family Members		
US 4420881	AU 75531/81 FR 2490866	CA 1155279 JP 57087015	EP 48426
AU 57663/80	BR 8003012 DE 3018902 FI 801266 NZ 193716	CA 1147935 DK 1829/80 FR 2456998 SE 8003549	CH 637786 ES 492066 IT 1166829
US 4663095	CA 1242005 JP 60093709	EP 140757	FR 2552922
GB 2205263			

END OF ANNEX