The document contains a patent application titled "METAL FIBER MAT FOR USE IN FILTERS." The abstract describes a method of manufacturing a filter attached to a tubular pipe having a predetermined diameter, for filtering solid particulates from a fluid stream entering into the pipe, comprising the steps of winding a multi-perforate pipe having a length L and a predetermined diameter by providing a metal fiber wool mat having a width approximately equal to L, L/2, L/3, L/4, or L/5, affixing a leading edge of the metal fiber wool mat to the outer surface of the pipe, actuating the rollers to rotate the pipe and thereby winding the metal fiber wool mat onto the pipe along the width of the mat, while maintaining the metal fiber wool mat under tension during winding: attaching the trailing edge of the mat to the pipe; repeating the above procedure until a fiber wool mat has been wound onto the complete length of the pipe and mounting a second multi-perforate pipe, having a second predetermined inner diameter, on the exterior of the metal wool fiber mat after it has been wound onto the pipe. The metal fiber wool mat for use in such a filter is made by the steps of weaving a cross-ply of the metal fiber wool belts in the perpendicular directions; joining the belts of metal fiber wool to each other to provide an integral fiber wool mat; and by repeating the weaving process thereby producing a desired length L, L/2, L/3, L/4 or L/5 of a mat of fiber-wool material; cutting the mat in a direction transverse to the longitudinal direction in which the first plural belts extend to produce a mat of fiber wool material having a predetermined length and width. A filter for use in a subterranean well or other filtering application, used for filtering a fluid stream entering the pipe through perforations, includes a first perforated pipe, a metal fiber wool mat made in accordance with the above method wound over the outside diameter of the first pipe and a second perforated pipe having a predetermined inner diameter greater than that of the first pipe, disposed over the mat and over the first pipe.
For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.
METAL FIBER MAT FOR USE IN FILTERS

Reference to Related Application

This invention relates to the subject of related provisional application, U.S. Ser. No. 60/278,136, filed on March 23, 2001.

BACKGROUND OF THE INVENTION

Field of The Invention

This invention relates generally to filters for fluid media, and more particularly to filters for filtering entrained solid contaminants from a fluid stream under pressure, and to the related methods of manufacture of such filters.

Background Art

Filters for fluid streams are necessary in a great number of applications, such as oil production, filters for water pumps, industrial filters for use in recirculating cooling fluid systems, and filters for use in the chemical process industry. These filters must be capable of continuously filtering out discrete solids and particulates of a minimum size for long periods while avoiding clogging up the filter mechanism that would inhibit or prevent the fluid from flowing through the filters.

The success and sustainability of such filters have been demonstrated in the field, for example, in the production of oil from oil fields in which sand particles are entrained in the oil. Such sand particles are harmful to the pumping equipment and require filtering. The prior efforts to solve the sand filtering problems in the oil field has led to elaborate, complicated filter systems that for the most part do not meet the requirements of long term continuous use without the need to replace the filters that have become clogged up.

Steel wool filters, having randomly aligned fibers in sufficient depth, have been found to meet the requirements for long term continuous use. Such filters and their methods of
manufacture have been disclosed in commonly owned U.S. Patent Nos. 5,711,879 and 5,833,853. The metal fibers to produce the filters are formed in a continuous web from long fibers, which are then wound on a perforated tube to produce the filter. Some fibers, particularly stainless steel fibers such as Monel and 316 and other high chrome-nickel alloys are very difficult to form into a uniform web so as to enable them to be radially wound over perforated oil intake pipes, as demonstrated in the referenced patents.

It is also important for the manufacturing method to enable the filters to be made from non-corrosive metal fibers, for example, 316L stainless steel, especially in environments where normal stainless steel wool can be corroded by chemicals dissolved in the production fluid, for example oil containing CO₂ or HS₂. A corrosive environment is also encountered in certain oil wells, in which hydrochloric acid (HCL) is often used to treat the wells in order to improve oil production.

Although able to produce filtered pipes having a great many applications, the methods used to produce the filters taught and described in these patents cannot easily be extended for pipes beyond a maximum diameter. The methods used cannot be applied to produce a steel wool filter on pipes exceeding a maximum diameter, for example over 15 inches (38 cm), because of the problems incurred in feeding the fiber strands and applying the necessary pressure to compact the fiber strands.

Thus, what has been found necessary is a fluid filter for use in filtering pressurized fluids and a manufacturing method to make such a filter that gives rise to filters having an increased range of applications, for example, filters made from harder corrosion resistant stainless steels, or filters for pipes having large diameters, such as for intakes used in municipal water wells.
SUMMARY OF THE INVENTION

Accordingly, what is disclosed and claimed herein is a filter for a fluid stream made according to a method of manufacturing a filter attached to a tubular pipe having a first diameter, for filtering solid particulates from a fluid stream entering into said pipe, comprising the steps of providing a preselected length of a multi-perforate pipe having a length L and a second diameter; mounting the length of multi-perforate pipe on at least one horizontally disposed roller; providing at least a second roller; aligning at least the second roller at the apex of said multi-perforate pipe so as to retain the pipe between the rollers; providing a metal fiber wool mat having a width approximately equal to the length selected from one of the multiples of the length of the pipe L, consisting of L, L/2, L/3, L/4, or L/5; affixing a leading edge of the metal fiber wool mat to a line defined by the intersection of the edge of the metal fiber wool mat and the outer surface of the pipe; actuating the rollers to rotate the pipe in a rotational direction away from the metal fiber wool mat; simultaneously with previous step, moving the metal fiber wool mat toward the pipe surface along a path generally tangent to the pipe surface, so that the metal fiber wool mat is wound onto the pipe along the width of the mat as defined, while maintaining the metal fiber wool mat under tension during winding; continuing winding until the trailing edge of the mat engages the mat that has been wound onto the pipe and then attaching the trailing edge of the mat to the pipe; repeating the winding process with successive widths of the metal fiber wool mat L/2, L/3, L/4, or L/5 until a metal fiber wool mat has been wound onto the complete length of the pipe, L; and mounting a second multi-perforate pipe, having a second predetermined inner diameter, on the exterior of the metal wool fiber mat after it has been wound onto the pipe. The invention also comprises a filter for use in a subterranean well made in accordance with the foregoing method. The step of affixing the mat to the pipe may comprise a hot melt adhesive, an epoxy adhesive, a mechanical means, such as bolts, screws, or rivets, but preferably comprises a spot welding of the mat to the pipe surface.
In a second embodiment, a method of making a metal fiber wool mat for use in a filter comprising the steps of providing a plurality of rolls, defining a source of first plural belts of metal fiber wool; transposing the metal fiber wool belts in a first direction, the lateral edges of the belts defining a mat width; indexing the transposition of the first plural fiber wool belts in a longitudinal direction in discrete predetermined index increments; at specified index increments of said first plural fiber wool belt transposition, deploying second plural belts of metal fiber wool in a direction perpendicular to said first metal wool fiber belts, in predetermined widths approximately equal to said mat width; joining said first and second belts of metal fiber wool to each other to provide an integral fiber wool mat; repeating the foregoing steps to produce a desired length of a mat of fiber-wool material; and cutting said mat in a direction transverse to the longitudinal direction of transposing said first plural belts to produce a mat of fiber wool material having a predetermined length and width.

BRIEF DESCRIPTION OF THE DRAWING FIGURES

Fig. 1 is a perspective view showing the manufacture of a filter mat made according to one embodiment of the present invention.

Fig. 2 is a perspective view of a second embodiment of a filter mat made according to the present invention.

Fig. 3 is an elevational view of yet another embodiment of the filter made according to the present invention.

Fig. 4 is a detailed schematic view of the manufacturing method according to one of the embodiments illustrated in Figs. 1-3.
Fig. 5 is an elevational view of the method of attaching the mat made according to the invention as shown in one of Figs. 1-3 to a pipe in accordance with another embodiment of the present invention.

**DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT**

The manufacturing process for filters made according to the present invention essentially comprises two distinct operations that may be performed either sequentially at a single continuous station or at separate stations as time permits. The first operation comprises the fabrication of a metal fiber wool mat, sometimes referred to herein as a "felt pad," having predetermined size, weight, thickness, density and other characteristics. After the mat is fabricated, a second operation is performed to attach to and otherwise cover a length of a tubular pipe completely around its circumference so as to produce a filter medium to cover inlet perforations in the walls of the pipe.

The first operation is performed by mat fabrication or production apparatus, as shown in Fig. 1. Referring now to Fig. 1, a continuous feed apparatus 100 for providing a mat utilizable in filters according to the present invention is shown in a perspective view. Two sets of continuous rolls 112, 114 of metal fiber are disposed above one another. Each set of rolls is mounted on an axis, and the axes 113, 115, respectively of the rolls 112, 114 extend in a direction parallel to each other and, preferably, for each set, are coincident along a common centerline CL, as shown. Preferably, the rolls are disposed above and below a plane defined by the mat 110 being formed in the equipment.

Each of the rolls 112, 114 pays out a continuous strand or belt 116 of fine metal fiber wool which has been previously manufactured in accordance with known methods to have desirable characteristics, such as an average fiber diameter, density, or tension. Use of such metal fiber wool is taught as being randomly aligned in the aforementioned, commonly owned U.S. Patent Nos. 5,711,379 and 5,833,853, the teaching which are incorporated herein
by reference. Such metal fiber wool normally is provided in rolls and such rolls are also commercially available from the assignee of the present invention, American Metal Fibers Inc. of Lake Bluff, Illinois.

Although this invention describes metal fiber wool, such as stainless steel wool, as the preferred material for use with the filters made in accordance with the present invention, it is contemplated that other types of fibers, made from materials other than metal, may also be utilized. For example, mineral capable of being spun into fibers and having the requisite characteristics, such as durability, hardness, etc. may be utilized as the filter medium. Fiber wool made for example, from basalt fibers has been found to work well in filters and may be utilized in filters made in accordance with the present invention.

Referring again to Fig. 1, each of the strands or belts 116 is pulled from the rolls 112, 114, by a series of vertically disposed rollers, such as pinch rollers 120, the vertical positions of which may be adjustable in the direction of the arrows A by adjustment controls 122. The pinch rollers 120 act as weave guides and provide a predetermined spacing between the two rollers for shuttling a cross-weave strand or series of belts, as will be explained below.

The rollers 120 are rotatable around axes that extend transversely to the direction of travel of the fiber strands 116 as they are engaged by the rollers 120. Ideally, the rotation of the rollers 120, as well as the other rollers in the equipment, are indexed to rotate a predetermined number of revolutions so as to index the lateral displacement of the strands 116. The strands are thus pulled by the rollers 120 through the cross directional wool pulling station 124, that is defined by one set of rollers 120 and a second set of vertically disposed rollers 126, as shown. Indexing of the fiber wool strands 116 displaces discrete segments of the fiber wool strands from the first set of rollers 120 to the second set of rollers 126. Between periods of indexing, the strands 116 are woven while they remain stationary in the cross directional wool pulling station 124.
After each indexed displacement of the fiber wool strands 116, a cross directional strand, or as shown, dual strands 130, are pulled out from two rolls 132 that are transversely oriented relative to the direction of travel of the strands 116. As shown, the rolls 132 rotate about axes 133, preferably coincident to each other, which axes extend transversely to the axes 113, 115 of rolls 112 and 114, respectively.

The width of the strands 130 deployed from the rolls 132 may be several times the width of the strand 116, as shown in Fig. 1, but it may be considered advantageous to have the width of strands 116, 130 have an identical width, for example, a width of 4 inches (10 cm). The width of any of the strands 116, 130 may be varied within a range of from about 2 inches (5 cm) to about 10 inches (25.4 cm), as is appropriate for the type of mat desired. The thickness of each strand may also be the same for strands 116 and 130, but alternatively may vary depending on the use of the mat 110.

At the cross directional wool pulling station 124, one set of guides 136 is disposed at a lateral edge of the mat, as it is being formed, and a second set of guides 138 is at the opposite lateral edge of the mat 110. Guides 136 and 138 provide a discrete length between them, for example 10 or 15 feet approximately (3 to 5 meters) which defines the lateral width of mat 110. As strands 130 are pulled by the cross pulling device, similar to a shuttle on a loom used for weaving, the guides 136 provide an end point to stop the further lateral displacement of the cross-directional weave strands 130. This process of pulling the strands 130 across the weave of strands 116 occurs between indexing operations of the strands 116, as described above, and the strands 130 together with the cross strands 116 provide the metal fiber wool material making up the mat 110.

As the distal ends of strands 130 reach the guides 136, a cutting mechanism 140, traveling along cutting guides 142, uses a rotary cutting blade 144 to cut the laterally opposed ends of strands 130 at a point adjacent the guides 138. After the strands 130 are cut into
discrete lengths, as shown, the mat 110 is displaced by the subsequent indexing operation to the next station, which is a joining station 150.

The joining station 150 provides a densifying or compressing function to the metal wool fibers in the strands 116 and 130 so that the strands become joined to each other and compressed to a desirable density. As is shown in Fig. 1, and indeed, for all of the embodiments illustrated and disclosed herein, strands 116 are perpendicularly oriented relative to the cross strands 130. The strands generally comprise metal fiber wool in which the fibers have a fairly long average length and an average diameter or thickness between 15 microns and 200 microns. It should be appreciated that each fiber can be made in one of several fashions, which would produce a longitudinal surface of the fiber that is coarse and jagged in detail. As these fibers are brought together in the compression step at joining station 150, the rough jagged edges, which can act on a microscopics rate as does a barbed fishhook, engage each other and retain the integrity of the mat 110 as it passes through the joining station 150.

Joining station 150 comprises another set of vertically disposed rollers 152. Preferably, the separation between rollers 152 is adjustable so as to provide a means for producing a mat having a fiber wool density that is desirable for an application. Another additional consideration in achieving a desirable density is the initial thickness of the belts 116 or 130 of fiber wool. If it is desired to have a particularly dense mat 110, thicker belts 116, 130 may be utilized and the gap between the surfaces of rollers 152 may be decreased to compress the metal fibers closer together. A greater amount of compression force bring the fibers closer together, and thus produce a thinner, but more dense, mat 110 since a greater number of the fibers engage and adhere to each other. Conversely, thinner belts 116, 130 and a larger gap would produce a thicker, but less dense mat 110.
As will be explained below, the density of mat 110 is important in providing a filter that produces a compromise between a web formed of fibers that can filter out discrete particles, such as sand, but the fibers are not so dense and closely packed that the filter would impede the flow of the fluid through one or more layers of mat 110. It has been determined that for oil well applications, a filter should have a density of between 0.4 and 3.0 gm/cm³, which density range can be consistently obtained by utilizing this or other embodiments of the invention as described herein. More precise and narrower ranges and tolerances in density variation may be required for certain applications, such as oil field filter applications, as is described in the aforementioned U.S. Patent Nos. 5,711,879 and 5,833,853. Fiber densities outside these ranges may be utilized for other applications, as is considered appropriate.

Referring again to Fig. 1, after passing through the joining station 150 the wool fiber mat 110 is cut or sheared into discrete predetermined lengths by a transversely directed cutting rotary knife 160, similar to knife 140, which is guided along the transverse direction by a guide 142. The lengths of the mat 110 which are cut by the cutting mechanism 140 depend on a number of different parameters, such as the diameter of pipe around which the mat will be wound and the number of mat layers that will be disposed over the perforated pipe 120, shown in the tube winding station 180.

The tube winding station 180 provides the second general operation of filter production and comprises several rolling retainer members, for example, two lower pinch rollers 182 and 184, which together support a perforated pipe 190 to be used as the base for the filter made according to this embodiment of the invention. The rollers are horizontally disposed, relative to each other, the apex of each tubular roller 182, 184 being substantially in the same horizontal plane along which mat 110 is being transposed.
The two rollers 182, 184 are separated by a gap, as shown. The pipe 190 preferably is tubular and rests upon the two rollers 182, 184 immediately adjacent the gap and supports the pipe for further processing. Depending on the diameter of pipe 190, the lateral separation of rollers 182, 184 may be adjustable, to accommodate different diameter pipes, a larger separation being used for larger diameter pipes in order to retain the pipe within the station 180 while winding the mat 110 thereon. To provide a greater degree of tension, it may be desirable to coat one or more of rollers 182, 184 or 186 with an elastomeric or rubber material to further delay or retain the mat pad before release to the tube winding station 180.

The tube winding station 180 further comprises a compression roller 186 which is disposed over the apex of the tubular pipe 190 thereby, also providing a downward compression force directly on the surface of the tubular pipe 190 at the apex point. Preferably, the compression roller 186 is disposed in its engagement with pipe 190 directly opposite the gap between the rollers 182, 184. The compression roller 186 further may include a mechanism to vary the amount of compression force provided by the downward pressure of the compression roller, depending on how many layers have been wound onto the pipe 190, and the desired fiber density.

The tube winding station further comprises a temporary or, preferably, permanent securing means for securing a first laterally extending edge of the mat 110 to the perforated pipe 190. Ideally, the securing means attaches the edge of mat 110 in a non-obtrusive way, so that the metal fiber wool may continue to permit fluid to flow therethrough. Alternative methods of attachment may be by using glue, a hot melt adhesive, resistance welding, epoxy adhesive or by a mechanical means, such as rivets or screws. Preferably, the lateral edge of the mat 110 is spot welded by a series of spot welders, as will be described below with reference to other embodiments.
After the edge of mat 110 has been attached to the surface of the perforated pipe 190, the rollers 182, 184, 186 all are rotated in the same direction, as shown by arrows B, so as to rotate the pipe 190 in the opposite direction. Tension is provided to keep the mat 110 taut, by variation in the rate of rotation of the rollers 182, 184, 186, which is slightly faster than that of the rollers 152, etc., thereby keeping the mat 110 taut to maintain the metal fiber wool closely adjacent the surface of the perforated pipe 190, and thereby produce a filter medium. Several full revolutions of the pipe 190 will cause the necessary layer(s) of the mat 110 to be wound onto the pipe 190. When the length of mat 110 that is sufficient to provide the desired number of layers over the pipe 190 has been determined, for example, by multiplying the average circumference of the pipe 190 by the number of layers desired, the cutting mechanism can be utilized to cut the desired length in a lateral direction, either before or, as shown, during the winding process, and thereby to provide a second trailing edge of the mat.

To further provide the predetermined and desirable density of fibers necessary for the particular application, the compression roller 186 includes means (not shown) for adjusting the height thereof, and the downwardly directed force that is applied by the roller 186 onto the mat 110 being wound onto the pipe 190. Together with the degree of tension which is produced by the rollers 182, 184, a desirable density range of the fiber mat layers may be achieved.

Following the winding operation, a second perforated, tubular pipe (not shown), having a diameter slightly larger than the pipe 190 is provided and the pipe 190, together with the several layers of metal fiber wool “felt pad” wound thereon, is placed inside the outer pipe, in accordance with known methods or in accordance with the procedures described in aforementioned U.S. Patent Nos. 5,711,879 and 5,833,853. The clearance between the inner diameter of the second outer pipe and the outer diameter of pipe 190 is preferably just enough to accommodate the predetermined thickness of the several compressed layers of the mat 110. The predetermined thickness, and density, of the metal fiber wool can be maintained by the
restriction to expansion of the fibers encountered in the inner diameter of the second outer pipe (not shown). Alternatively, or in conjunction therewith, the second trailing edge of the mat may be spot welded, mechanically or adhesively attached to the outer layer of the mat as it is being wound over the pipe 190.

Preferably, the number of layers covering the perforated surface of pipe 190 are between two and ten, and more preferably, between two and five. Ideally, three layers have been observed to work best in providing a desirable mean or average between production of excellent filters, for example, for oil production or transmission, while simultaneously minimizing the thickness of the filter medium and the pressure drop across the filter material.

The mat 110 can be any width but is, preferably, from 20 cm to 3 meters wide.

Referring now to Fig. 2, another embodiment for the process of fabricating the inventive filter is described and illustrated. The machinery for fabricating the metal fiber wool filter according to this embodiment is similar in some parts and dissimilar in others to the embodiment of Fig. 1. Accordingly, the description of this embodiment will describe in detail those aspects that are different and will describe similar parts only generally. Similar elements will be designated by similar identification references, and by changing the first digit from 1xx to 2xx.

The apparatus 200 for providing the metal fiber wool mats is somewhat different from the first described embodiment in that it is a discontinuous operation apparatus, rather than a continuous operation apparatus, as is apparatus 100 of Fig. 1. The initial portion of the apparatus 200 is essentially identical to apparatus 100. For example, the rotating rolls 212, 214 of metal wool fiber deploy strands or belts 216 to rollers 220 that pull the metal wool fiber belts 216 into a wool pulling station 224.

It should be noted the rolls 212, 214 are separated, between their axes 213, 215 of rotation, by a distance that is considerably smaller than the distance between rolls 112, 114,
resulting in an oblique angle between strands 216 and resulting in the wool fiber mat 210 in the wool pulling station 224 to be considerably larger than the same angle in the embodiment of Fig. 1. There is a range of angles that may be utilized in either of the two embodiments without detracting from the operational efficiency of the apparatus 100 or 200. It is important, however, that the angle permits easy deployment of the belts 216 toward rollers 220, and also belts 116 to rollers 120, so as to maintain the integrity of the belts 116, 216, since excessive tension on the belts 116, 216 can break the fiber strands, thereby resulting in down time. It has been found that the oblique angle may be in a range of from about 120° to 175°, a preferable range of from about 135° to 150° with an angle of approximately 155° being optimal. Other arrangements, for example, utilizing pulleys or rods, to change the direction of travel of the belts 116, 216 are contemplated for minimizing the space used by the apparatus, and one of these is described below with respect to yet another embodiment.

Referring again to Fig. 2, the wool pulling station 224 provides a location for cross-weaving the cross-directional belts 230 deployed from rolls 232, appropriate widths which belts are sheared off by the rotary cutting mechanism 240 before the mat 230 passed on to the joining station 250.

The joining station 250 introduces major differences between the embodiments shown in Figs. 1 and 2. Whereas the embodiment of Fig. 1 relies on the compression against each of the fibers by rollers 126, 152, the embodiment of Fig. 2 utilizes a needle punch press 152 to provide a joining mechanism for joining the perpendicularly oriented belts 216, 230 to each other. The needle punch press is disposed in the production line immediately before the mat length cutter 260, which is similar to the cutter 160 of the first embodiment.

Needle punch press 260 includes a reciprocating element, such as the cam 262 and rotating wheels 264 shown. However, any other reciprocating mechanism may be utilized, such as a linear actuator, a solenoid, hydraulic, pneumatic or other appropriate reciprocator
means. The reciprocating means is attached to a reciprocating carding board 266 by a bolt 268, or other appropriate attachment mechanism. The carding board 266 is oppositely disposed in a facing relation with a stationary carding board 270 that is disposed on the other side of the mat 210 from reciprocating board 266.

Carding boards 266, 270 are planar boards, preferably made of metal or other sturdy material, each having a width at least as wide as the mat 210. It may comprise a rectangular shape, as shown, or may take other appropriate shapes. Each carding board 266, 270 includes a multitude of needles 272, each perpendicularly mounted to point away from the surface of the board 266, 270 and towards the mat 210 extending between the two carding boards 266, 270. Needles 272 are firmly mounted on the boards 266, 270 so as to be able to render its intended function as will be hereinafter described. Needles 272 have a mounting end for mounting onto the boards 266, 270 and a sharp or oblique end for penetrating into the mat 210 as the reciprocating carding board 262 is brought down toward engagement with the stationary carding board 270.

In operation, the mat 210 is indexed, as is done in the embodiment of Fig. 1, so that the cross-ply metal fiber wool belts 230 can be shuttled or pulled across. Simultaneously, or preferably sequentially, the carding mechanism 262 is activated and the reciprocating means 264 is engaged to bring the two carding board assembly 266, 270 toward each other. During the indexing process, the mat 210 has sufficient internal tension to provide a taut web that essentially travels in a plane above stationary carding board 270 with a clearance sufficient to clear the needles 272 of boards 266, 270. However, the reciprocating board 266 applies pressure from above onto mat 210 so that the needles 272 penetrate the material compromising the mat 210 to thereby compress the mat 210 onto the stationary board 270.

The meeting of the needles 272 through the mat 210 provides a means to intermingle the fibers from one series of belts comprising mat 210 with the fibers of the other cross-
directional belts. The needles of carding board 266 are arranged in such a fashion that they will accurately engage the perforations of stationary board 270, and the reciprocal movement of board 266 does not cause the needles of one board to engage the surface of the other board.

The needles 272 may not necessarily have pointed ends, so that the end of a needle may engage a single fiber and to cause it to penetrate, together with the needle 272, into the next layer of the mat 210. When the needle 272 retracts together with the board 266, the fiber will remain engaged with the fibers of the next layer because of the surface roughness of the fibers. Additional intermingling may be provided by the needles during the return of board 266 to its initial position if the needles have a rough surface texture that can engage and hook individual fibers during the upstroke. Although possible to include on the needles, barbs (not shown) may be utilized to pull on individual fibers out of the plane of the belt of which it is a constituent and into a separate layer of belt or belts. Use of barbs on the ends of needles 272 may also require other mechanisms to separate the individual fibers from the barbs of needles 272 to avoid the engagement from impeding the subsequent indexing of the mat 210 out of the joining station 250.

It is contemplated that a single reciprocal movement of the needles 272 through the mat will be sufficient to provide the joining capacity required to maintain the integrity of mat 210 for further operation, but if considered necessary, additional or repeated reciprocal movements may be performed by reciprocating board 266 to further engage and join the fibers of the mat. The repeated reciprocal motion of board 266 may occur in between incremental indexing of the mat 230 so that the needles 272 penetrate at a different location. In order to facilitate the joining operation, the apparatus may be arranged to index the longitudinal movement of the mat 210 only partially, or by short increments, between each reciprocal movement so that the teeth 272 engage different portions of the mat.
After completion of the joining operation and at the conclusion of the final indexing step, in which the desired length of the mat 210 has been processed and withdrawn downstream from the joining station 250, a second knife mechanism 260 again shears the mat 210 to provide the length necessary for the desired number of layers on the pipe (not shown in Fig. 2) for the end product filter.

The tube winding of the length of mat 210 may then proceed, as in the embodiment of Fig. 1, which will not be further described here as it is an essentially identical process, or the tube winding operation may proceed in accordance with other embodiments described herein, for example that illustrated in Fig. 5, described below. Alternatively, each of the mats, which are at this point separated from the equipment and may be considered as metal fiber wool “felt pads”, may be stacked at a point beyond the cutting mechanism and transported to a remote location for tube winding the “felt pads” onto a pipe, as is considered desirable.

In the tube winding operation, it may not be necessary to have specified lengths of the “felt pads” for winding onto pipes of a specific diameter, but the felt pads may be made to standard lengths and desired lengths of the pads may be cut at the remote the tube winding station (not shown) by a separate cutting mechanism, which can cut the exact lengths necessary for a pipe of a known diameter and for the number of lengths desired. If this embodiment of the tube winding operation is used, an inventory of felt pads may be manufactured irrespective of the time of the winding operation, so that the two processes, that is, metal fiber wool “felt pad” production and tube winding operation, may be separately conducted as needed, or to specification for any particular application later determined to be desirable.

Referring now to Figs. 3 and 4, yet another embodiment of an apparatus 300 is illustrated, having similar elements to the embodiment of Fig. 2, and again the discussion in detail will be confined to only the discrete difference therebetween. As is illustrated in Fig. 3, and in greater detail in Fig. 4, the rolls 312, 314 of metal fiber wool are mounted on a stand
317 having two separate rotation axes 313, 315, respectively, around which the rolls 312, 314 rotate. Each roll 312, 314 deploys a longitudinal web or belt 318 for the base layer and another layer 316 for the top layer. As shown, the layer 318 is deployed essentially in a plane coincident with the surface of a worktable on which the cross-directional wool belts or layer as is described below. The layer 318 does not need to be at an angle to the worktable surface because the upper layer 316 is applied after the cross-directional wool belts are arrayed over the base metal fiber wool layer 318. Belts 316 are deployed from one or more rolls 312 in a direction essentially parallel to the layer 318, the result being strands supported by rollers 319 before turning at an angle toward the rollers 326, where the layer 316 meets the base layer 318, so as to complete the provision of the material of mat 310.

The cross-directional weft strands or belts 330 are deployed from several, preferably contiguous, rolls 332 of metal fiber wool. Each of the belts 330 are pulled or pushed across the top of the longitudinal warp belts 318, as in the embodiment of Fig. 1, or by using a shuttlecock or other appropriate means. When the free ends of the belts 330 extend completely across belt layer 318 to provide the desired width, the rotary cutting mechanism 340 shears or cuts the belts 330 in a transverse direction so that the second end of the cut belts 330 coincides with the outer edge of the layer 318, thus completely overlapping the layer 318 from one lateral edge to the other. As shown, the belts 330 present a contiguous layer, which is not clearly shown in the previous two embodiments, thus avoiding any openings in the joined layers.

Following the shearing of the cross-directional wool belts 330, the belts 316, 318 are indexed by the apparatus 300 so that the trailing edge of the belt 330 is transposed to the end of the last downstream roll 332. It may be desirable at this point to overlap the end of the last of the belts 330, defining one indexed layer, with the leading end of the first belt 330 of the
next indexed cross-directional layer, in order to avoid any surfaces of the mat 310 that are open and not covered by at least one layer of metal fiber wool.

The indexing procedure in the apparatus 300 of Fig. 3 is performed by rollers, one of a pair of rollers 326 being shown. Although other pairs of rollers (not shown) may be utilized to deploy the belts 316, 318, only rollers 326 are shown in Fig. 3 in order that all strands or layers 318, 330 and 316 are pulled together and joined by rollers 326 simultaneously, as needed. Thus, no slack or loose sections of belts 316, 318 can arise. Of course, the rollers 326 should be fairly close to each other, having little gap between their respective surfaces, and so provide a compressive force on the mat 310 to begin the process of joining the layers 318, 330 and 316 together.

As the mat 310 is pulled through by rollers 326, it is essentially in completed form, except for further finishing steps, such as the subsequent joining and cutting operations. The mat 310 is directed into a channel or guide 328, which channel captures any loose fibers and retains them in the plane of the mat 310 during the joining process. As described above with reference to Fig. 2, the indexing process for the joining operation may coincide with the cross-directional wool pulling step, or may be done incrementally so that the joining is performed sequentially across small sections of the mat 310, smaller than the width of each cross-layer of belts 330, in order to perform the needle punch joining step on incremental sections of the mat 310 several times per indexing cycle.

Other significant differences exist between the two joining stations 260, 360 which are now described. The mat 310 is directed by the guide 328 to the fiber joining station 360, similar to joining station 260 of the apparatus 200 of Fig. 2. As shown in Fig. 4, the guide 328 may further comprise a pair of rollers 326' to further compress the mat 310 before pushing the mat 310 into and through the guide 328. A first significant difference is that only a single reciprocating board 366, having needles 372, is utilized. Thus, the mat 310 is
transposed over a fiber joining table 368, having an upper working surface 370. In order to accommodate the complete penetration of needles from one surface of the mat 310 to the other across the full width thereof, corresponding apertures, one for each needle 272, may be provided in the surface 370 of joining table 368. As shown in Fig. 3, the reciprocating vertical movement of carding board 366 is provided by one or more wheels 364, each attached to cam 362. Posts 363 are attached to the back surface of carding board 366 to provide a directional orientation to the reciprocating movement of the carding board 366. As shown, posts 363 extend through guides 365 that inhibit any but vertical reciprocating motion in the direction of arrow D to the carding board 366. Again, other reciprocating means may be available and used, as described above.

Following the joining process, and when a full indexing process has been completed, the mat 310 is drawn out of the fiber joining station 360 by rollers 352, until a desired length of the mat 310 is extended beyond the rollers 352, to a predetermined or desired length, as described above. A rotary shearing knife mechanism 376 is utilized to shear the mat 310 transverse to its longitudinal direction for further processing, either to stack the metal fiber wool "felt pads" on a stack or finishing table 378, or as is shown in the embodiment of Fig. 1, to utilize the completed "felt pad" directly in a winding station (not shown in Fig. 3) to wind the "felt pad" in a number of layers over the pipe.

Alternatively, the tube winding station 380 is utilizable at a location close to the table 378, as is illustrated in the alternative winding station of Fig. 5. The particular inventive embodiment of the tube winding station 380 shown in Fig. 5 adjacent the opposite longitudinal end of the table 378 from the cutting mechanism may be utilized with any of the above described embodiments, i.e., with any of the apparatus 100, 200 or 300 of Figs. 1-4, as is considered appropriate for the applications or production line with which it may be utilized. As shown, the tube winding station 380 is especially suited for pipes 390 having
much larger diameters than has heretofore been utilizable, for example, pipes having
diameters approaching or exceeding 24 inches (61 cm).

Wool "felt pad" winding station 380 comprises mat receiving rollers 382 vertically
disposed above and below the mat 310, and an internal tube winding pinch roller 384 and an
external tube winding roller 386. Rollers 384, 386 act as arbors of the pipe 390.

As can be seen from Fig. 5, the internal roller 384 is larger than the external roller
386, so that if the two rollers or arbors 384, 386 are rotated in the direction of arrows E at the
same rate, the surface of the internal roller 384 will move faster relative to the surface of the
external roller 386, so that the rotation of the two rollers 384, 386 causes tension in the mat
310 being wound onto the pipe 390 so as to increase and produce the desirable density in the
filter mat of the filter.

Again, as in the embodiment of Fig. 1, the leading edge of the "felt pad" sheet must
be secured across the length of pipe 390 by an appropriate means. Although hot melt
adhesive, glue or a mechanical attachment is available, it is preferred to spot weld the leading
edge at discrete points along the tubular pipe 390 so that further rotation of the pipe 390 by
the arbor rollers 384, 386 draws the mat 310 tightly over the surface of pipe 390 to further
provide the desired tension. Arbors 384, 386, may comprise a rubber or neoprene material,
and the rotation of the arbors may be powered by an electric motor (not shown) in a
conventional manner. The external roller 384 also provides a downward force so that the
pressure of the roller 384 forces the individual wraps of the mat 310 to nest together and the
fibers to attach themselves to each other.

As is shown in Fig. 5, the mat 310 intersects the longitudinal surface of pipe 390
across a tangential line, and a spot welder 396 attaches the leading edge of the mat to the
surface by spot welding the mat to the surface of perforated pipe 390 at discrete points along
the intersecting longitudinally extending line. Once the edge has been spot-welded, the spot
welder 396 is removed, and the rollers 384, 386 are engaged to roll the pipe in a direction so to pull the mat 310 from the table 378 and cause it to be wound onto the pipe 390, under tension, as described above.

After the complete length of the mat 310 has been completely wound onto the pipe 390, the trailing edge of the mat 390 is also attached to the pipe or to the top layer of the metal fiber wool mat 390, by an appropriate attachment, such as hot melt adhesive, or a second spot welding step. Again, once the metal fiber wool fiber mat has been completely wound onto the pipe 390, the structure is inserted into a second larger pipe (not shown), as described above.

It is contemplated that filters made according to the present invention may be utilized in viscous process fluid applications in which filtering of entrained solid particulates is required. These filters may be utilized in filtering applications in which the process fluid is maintained at high pressures, e.g., over 50 psig, or under varying pressure conditions. Although particularly suited for petroleum production from underground sources, it is contemplated that other processing applications may utilize filters made according the methods and embodiments taught in this invention. For example, filtering applications for industrial oil production, or in machining operations having equipment configurations requiring filtering of recirculating coolant oil.

Other alterations and modifications may also become obvious to a person having ordinary skill in the art after a full understanding of the present invention is attained. For these reasons the above embodiments should be considered as examples only, and not as limiting the scope of this invention. The scope of the invention should only be considered limited by the following claims.
What is claimed is:

1. A method of manufacturing a filter attached to a tubular pipe having a predetermined diameter, for filtering solid particulates from a fluid stream entering into said pipe, comprising the following steps:

   A. providing a preselected length of a multi-perforate pipe having a length L and a predetermined diameter;

   B. mounting the length of multi-perforate pipe on at least one horizontally disposed roller;

   C. providing at least a second roller;

   D. aligning at least the second roller at the apex of said multi-perforate pipe so as to retain the pipe between the rollers;

   E. providing a metal fiber wool mat having a width approximately equal to the length selected from one of the multiples of the length of the pipe L, consisting of L, L/2, L/3, L/4, or L/5;

   F. affixing a leading edge of the metal fiber wool mat to a line defined by the intersection of the edge of the metal fiber wool mat and the outer surface of the pipe;

   G. actuating the rollers to rotate the pipe in a rotational direction away from the metal fiber wool mat;

   H. simultaneously with step E, moving the metal fiber wool mat toward the pipe surface along a path generally tangent to the pipe surface, as taken from the attachment line of the pipe, so that the metal fiber wool mat is wound onto the pipe along the width of the mat as defined in step E, while maintaining the metal fiber wool mat under tension during winding;
I. continuing the winding operation until the trailing edge of the mat engages a portion of the mat that has been wound onto the pipe and then attaching the trailing edge of the mat to the pipe;

J. repeating the winding process with successive widths of the metal fiber wool mat L/2, L/3, L/4, or L/5 until a metal fiber wool mat has been wound onto the complete length of the pipe, L; and

K. mounting a second multi-perforate pipe, having a second predetermined inner diameter, on the exterior of the metal fiber wool mat after it has been wound onto the pipe.

2. The method according to Claim 1 wherein said step of providing the metal fiber wool mat further comprises providing a length of the metal fiber wool mat, defined as the dimension between the leading and trailing edges, that is essentially equal to the product of a whole number integer and the average circumference of the first and second multi-perforate pipes, so that the step of continuing winding results in a filter having the whole number integer layers of said mat wound over said pipe.

3. The method according to Claim 1 wherein said step of providing the metal fiber wool mat further comprises providing a length of the metal fiber wool mat, defined as the dimension between the leading and trailing edges, that is essentially equal to the product of a whole number integer greater than one, II and the average of the predetermined first and second diameters of said first and second pipes.

4. The method according to Claim 3 wherein the whole number integer is between 2 and 10.

5. The method according to Claim 4 wherein the whole number integer is three.

6. The method according to Claim 1 wherein the width of the mat is approximately one-half of the pipe.
7. The method according to Claim 1 wherein the step for affixing the leading edge of the mat to the surface of the multi-perforate pipe further comprises a hot melt adhesive.

8. The method according to Claim 1 wherein the step for affixing the leading edge of the mat to the surface of the multi-perforate pipe further comprises spot welding the leading edge of the mat to the surface of the multi-perforate pipe at discrete points.

9. A filter for use in a subterranean well made in accordance with the method of Claim 1.

10. A method of making a metal fiber wool mat for use in a filter comprising the steps of

   a) providing a plurality of rolls, defining a source of first plural belts of metal fiber wool;

   b) transposing the metal fiber wool belts in a first direction, the lateral edges of the belts defining a mat width;

   c) indexing the transposition of the first plural fiber wool belts in a longitudinal direction in discrete predetermined index increments;

   d) at specified index increments of said first plural fiber wool belt transposition, deploying second plural belts of metal fiber wool in a direction perpendicular to said first metal wool fiber belts, in predetermined widths approximately equal to said mat width;

   e) joining said first and second belts of metal fiber wool to each other to provide an integral fiber wool mat;

   f) repeating steps b) to e) to produce a desired length of a mat of fiber wool material; and
g) cutting said mat in a direction transverse to the longitudinal direction of transposing said first plural belts to produce a mat of fiber wool material having a predetermined length and width.

11. The method according to Claim 10 wherein said joining operation step e) is performed in a compression of said first and second plural belts by a roller mechanism.

12. The method according to Claim 10 wherein said joining operation step e) is performed by a needle punch.

13. The method according to Claim 12 wherein said needle punch operation further comprises penetration of said mat by a plurality of needles affixed on a carding board which reciprocally engages said mat.

14. A filter for use in filtering a fluid stream comprising a first perforated pipe having a predetermined outer diameter, a metal fiber wool mat made in accordance with the method of Claim 10 wound over said outside diameter of said first pipe and a second perforated pipe having a predetermined inner diameter greater than that of said first pipe disposed over said mat.