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(54) **FIRE PROTECTION SYSTEM FOR STRUCTURAL MEMBERS**

(57) This invention relates to coverings for structural members to provide passive fire protection. An assembly comprises an elongate structural member; a pre-cast casting disposed around the structural member comprising an elongate heat insulating tube and a support tube. The elongate heat insulating tube being made of a heat insulating material providing passive fire protection, and the heat insulating tube having a continuous inner circumferential surface and a continuous outer circumferential surface. The support tube being encapsulated within the heat insulating tube between the inner circumferential surface and the outer circumferential surface. A stabilising element is arranged to maintain a gap between the inner circumferential surface of the heat insulating tube and an outer surface of the structural member.

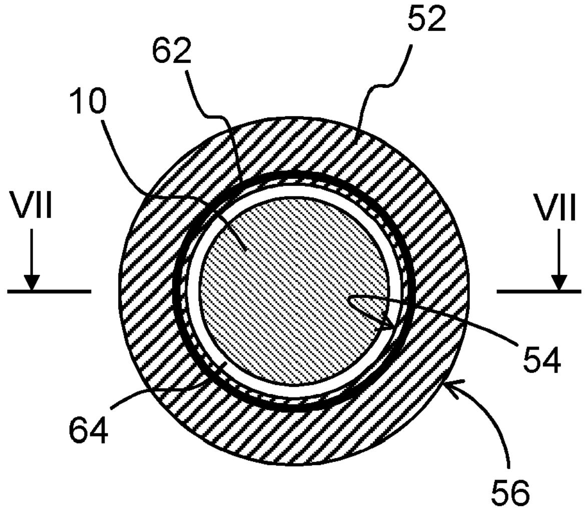

Fig. 6

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Description

FIELD OF THE INVENTION

[0001] This invention relates to coverings for structural members to provide passive fire protection. In particular this invention relates to the provision of intumescent castings for covering structural members. This invention further relates to methods of manufacturing intumescent castings for structural members and to methods of installation of such castings.

BACKGROUND TO THE INVENTION

[0002] A number of different structural members are used in the design and construction of buildings and other structures such as bridges. Such structural members include columns, beams, tension rods and compression struts, among others. These structural members are all under load, which may be compressive, tensile or a combination of both. In many situations the structural member will be made of a suitable metal such as steel that is able to carry such loads.

[0003] For example, tension rods are used in many structures and buildings to support the weight of a part of the structure and/or to provide bracing. Tension rods may, for example, be used in the construction of bridges, to support roofs and canopies, and in large buildings such as shopping centres, offices, apartment blocks and university buildings. Structural tension rods may be used to support elevated walkways, to provide bracing for large glazed facades, and to provide wind bracing for roofs.

[0004] Tension rods are generally made of carbon steel or stainless steel. The use of stainless steel provides corrosion resistance, but is generally more expensive than traditional carbon steel. Carbon steel tension rods may be galvanised or painted to provide the necessary corrosion resistance.

[0005] However, in addition to corrosion resistance, it is also necessary in many structures to provide fire protection to the tension rods or other structural member. In a fire temperatures in a building may reach 1000 °C. At these temperatures the mechanical properties of steel deteriorate and the steel structural member may buckle, twist or otherwise deform, especially as it is also under load. It is therefore necessary to provide fire protection to load supporting steel structures, such as tension rods and other structural members.

[0006] It is known to provide a passive fire protection coating made from an epoxy intumescent. These coatings provide passive fire protection by forming an insulating barrier around the steel structure. Under normal conditions the coating is inert, but under elevated temperatures, such as those experienced in a fire, the coating develops a thick char that provides increased insulation. The aim is to keep the temperature of the coated steel below that at which deformation or failure may occur so that the structure retains its integrity.

[0007] It some applications the epoxy intumescent material is sprayed onto the steel structure. However, this can only provide a relatively thin coating which offers limited passive fire protection. Furthermore, the coating may be easily damaged, and generally it is necessary to repair or reapply the coating every few years. In addition, the finish is non-decorative, so this method is often unsuitable for building projects where the structural steel forms a key part of the appearance of the building.

[0008] Another known method is to form an epoxy intumescent casting that is then adhered to the surface of the steel structure. The use of castings allows a thicker coating or covering to be produced, which provides greater fire protection.

[0009] To form a suitable covering for elongate structural members such as steel tension rods, it is known to pour or inject an epoxy intumescent material into an annular space between two concentric cardboard tubes. Once the epoxy has cured, the cardboard tubes and epoxy casting are cut longitudinally to form two semi-cylindrical or semi-tubular sections. The semi-tubular castings are then adhered around the tension rod or structural member in-situ. The longitudinal joints between the sections must then be filled and decorated to form the required decorative finish.

[0010] It will be appreciated that this method is time consuming, and the quality of the finish is dictated both by the accuracy of the casting of the epoxy material and the additional on-site work that is necessary. Furthermore, the cardboard tubes are destroyed each time a casting is made, such that this method produces considerable waste.

[0011] Against this background it is desirable to provide an improved method of applying passive fire protection to structural members such as steel tension rods. An object of the present invention is to provide an improved system and method of installation that provides the necessary passive fire protection to meet current building regulations, that is quick and easy to install, and which requires the minimum on-site finishing to achieve a desired appearance.

SUMMARY OF THE INVENTION

[0012] A first aspect of the invention provides an assembly comprising:

- an elongate structural member;
- a pre-cast casting disposed around the structural member, the casting comrpising:
  - an elongate heat insulating tube, the heat insulating tube made of a heat insulating material providing passive fire protection, and the heat insulating tube having a continuous inner circumferential surface and a continuous outer circumferential surface; and
  - a support tube encapsulated within the heat in-

sulating tube between the inner circumferential surface and the outer circumferential surface; and

- a stabilising element arranged to maintain a gap between the inner circumferential surface of the heat insulating tube and an outer surface of the structural member.

[0013] The heat insulating tube preferably comprises an intumescent material. The support tube is preferably made of a non-intumescent material. The support tube may be made of metal, such as stainless steel.

[0014] In preferred embodiments the intumescent material is an epoxy intumescent.

[0015] The heat insulating tube preferably has a length of at least 1 m. A thickness of the heat insulating tube, between the inner circumferential surface and the outer circumferential surface, is preferably at least 7 mm, and more preferably between 7 mm and 26 mm. An inner diameter of the heat insulating tube is preferably between 10 mm and 130 mm, and more preferably between 25 mm and 125 mm.

[0016] The support tube preferably comprises a plurality of holes. The support tube may be a perforated tube. The support tube may comprise a wire mesh. The support tube is preferably made of a suitable metal material, such as stainless steel.

[0017] In preferred embodiments a radial dimension of the gap between the inner circumferential surface of the heat insulating tube and an outer surface of the structural member is between 1 mm and 5 mm.

[0018] The structural member may be a tension rod. The structural member may further comprise a fork end and, as such, the assembly preferably further comprises a casting made of an intumescent material surrounding the fork end. The structural member may further comprise a lock nut and, as such, the assembly preferably further comprises a casting made of an intumescent material surrounding the lock nut.

[0019] A second aspect of the invention provides a method of manufacturing a casting to provide a passive fire protection covering for a structural member, the method comprising:

- filling a tubular mould with a heat insulating material for providing passive fire protection, the tubular mould comprising a reusable outer casing and a reusable core rod;
- curing the heat insulating material to form a passive fire protection casting;
- removing the core rod longitudinally from the casting; and
- removing the casting from the outer casing as a complete tube.

[0020] The heat insulating material is preferably an intumescent material.

[0021] The method preferably further comprises, before filling the tubular mould with the heat insulating material, supporting a support tube within the tubular mould.

[0022] Filling of the tubular mould preferably comprises supporting the mould such that an axis of the mould is vertical, and injecting heat insulating material into the tubular mould from a lower end of the tubular mould.

[0023] The step of injecting heat insulating material into the tubular mould may comprise injecting the heat insulating material through a plurality of holes spaced apart around an annular injection region of a feed plate disposed at the lower end of the mould.

[0024] In preferred embodiments the step of removing the core rod longitudinally from the casting comprises mounting the mould in an extruder and advancing an ejection member in a direction parallel to an axis of the mould to push the core rod longitudinally out of the casting. The step of removing the casting from the outer casing as a complete tube preferably comprises advancing an ejection member in a direction parallel to an axis of the mould to push the casting longitudinally out of the outer casing. In some embodiments a first ejection member having a first diameter is advanced to push the core rod longitudinally out of the casting, and subsequently, a second ejection member having a second diameter is advanced to push the casting longitudinally out of the outer casing, the second diameter being larger than the first diameter.

[0025] A third aspect of the invention provides a method of installing a pre-cast casting on a structural member to provide a passive fire protection covering, the method comprising:

- inserting an elongate structural member longitudinally through a bore of an elongate tubular heat insulating casting, the heat insulating casting having a continuous inner circumferential surface and a continuous outer circumferential surface; and
- supporting the heat insulating casting in a position relative to the elongate structural member such that there is a gap between the inner circumferential surface of the heat insulating casting and an outer surface of the structural member.

[0026] The heat insulating casting preferably comprises an intumescent material.

BRIEF DESCRIPTION OF THE DRAWINGS

[0027] The invention will now be further described by way of example only and with reference to the accompanying drawings, in which like reference signs are used for like features, and in which:

Figure 1 shows a prior art tension rod including fork ends and a turnbuckle;

Figure 2 illustrates a part of a structure including two tension rods used as bracing;

Figure 3 illustrates a prior art system of epoxy intumescent castings that may be used to provide passive fire protection to a tension rod as shown in Figure 1;

Figure 4 is a cross-sectional view along the line IV-IV of the epoxy intumescent castings of Figure 3;

Figure 5 is a plan view of an assembly including a tension rod and an intumescent casting according to a preferred embodiment of the present invention;

Figure 6 is a cross-sectional view along the line VI-VI of the assembly of Figure 5;

Figure 7 is a cross-sectional view of the assembly of Figure 5 along the line VII-VII of Figure 6;

Figure 8 is a perspective view of a mould assembly for use in forming an intumescent casting according to the present invention;

Figure 9 is an exploded view of a bottom pool plate and feed plate of the mould assembly of Figure 8;

Figure 10 is a plan view from the front of the bottom pool plate and feed plate of Figure 9;

Figure 11 is a perspective view of an extruder used in the manufacture of an intumescent casting according to a preferred embodiment of the present invention;

Figure 12 is a cross-sectional view of an intumescent casting for surrounding a coupler or turnbuckle, and mould components used to manufacture such a casting;

Figure 13 is a perspective view of a male component of the mould of Figure 12;

Figure 14 is a perspective view of a female component of the mould of Figure 12;

Figure 15 is a plan view of a pair of fork castings covering a fork end of a tension rod;

Figure 16 is a perspective view of a mould used to manufacture one of the fork castings of Figure 15; and

Figure 17 is a cross sectional view along the line XVII-XVII of Figure 16.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0028] A structural member 10 in the form of a tension rod 12 is illustrated in Figure 1. The tension rod 12 comprises a pair of elongate bars 14, each bar 14 extending between a first end and a second end. A connector, which in this example is in the form of a turnbuckle 16, joins the first ends of the elongate bars 14 together in a central portion of the tension rod 12. A fork end 18 is connected to each of the second ends of the elongate bars 14.

[0029] The bars 14 are generally cylindrical and have a constant diameter along their length. The connector or turnbuckle 16 comprises a central cylindrical portion 20 and two tapered lockcovers 22, each lockcover 22 extending from an end of the central cylindrical portion 20. A diameter of the central cylindrical portion 20 is generally constant and is greater than the diameter of the bars 14.

[0030] Each of the fork ends 18 includes a pair of fork plates 24 extending from a stem portion. The stem portion is connected to the second end of the respective bar 14 and the fork plates 24 extend longitudinally away from the bar 14. The fork plates 24 extend generally parallel to each other and are spaced apart, thereby defining a gap 26 between them. Each of the fork ends 18 may also include a tapered lockcover 22. In other embodiments each of the fork ends 18 includes a locking nut in place of the lockcover 22.

[0031] The fork ends 18, forming the first and second ends of the tension rod 12, are arranged to be connected to a suitable structure as illustrated in Figure 2. In this example, two tension rods 12 provide bracing between a pair of columns 2. Each of the fork ends 18 is secured to a respective gusset plate 4 extending from one of the columns 2. In particular, the gusset plate 4 is inserted into the gap 26 between the fork plates 24, and a retaining pin is inserted through holes in each of the fork plates 24 and through an aligned hole in the gusset plate 4.

[0032] In order to support the required loads, structural members such as tension rods and compression struts are made of a suitable metal such as carbon steel or stainless steel. It is a requirement in many constructions to apply suitable fire protection to load bearing structures to provide insulation which will keep the temperature of the steel below that at which deformation or failure may occur so that the structure retains its integrity. This passive fire protection should provide the necessary heat insulation for between thirty minutes and two hours, and in some circumstances up to four hours.

[0033] Additionally, in many structures, such as buildings and bridges, structural members 10 such as tension rods 12 remain visible and form an important part of the aesthetics of the structure. As such, the final appearance and finish of the structural members 10 may be of significant importance and value. This includes any passive fire protection system or insulation applied externally to the structural members 10, and these are also required to have a suitable decorative finish.

[0034] Figures 3 and 4 illustrate a known passive fire protection system 30 comprising epoxy intumescent castings 32. The castings 32 are positioned around a structural member 10, such as a tension rod 12, to provide heat insulation to the structural member 10. Each casting 32 is semi-cylindrical and the semi-cylindrical castings 32 are adhered to an external surface of the structural member 10 by a layer of adhesive 34 to provide the necessary support to the castings 32. Circumferential and longitudinal joints 36 between neighbouring castings 32 are then filled and the external surface 38 of the assembled castings 32 is decorated to provide the require seamless finish.

[0035] It will be appreciated that the adhering of the castings 32 to the structural member 10, the filling of the joints 36 and the application of the final decorative finish are all time consuming and expensive jobs that must be completed on-site, and which may require good weather conditions to do so. The present invention provides a passive fire protection system that may be applied to a structural member 10 before delivery to the site, thereby avoiding these on-site jobs and the associated time delays and expense.

[0036] An assembly 50 according to the present invention comprising a structural member 10 and a pre-cast heat insulating casting 52 is illustrated in Figures 5 to 7. In this example the structural member 10 is in the form of a tension rod 12.

[0037] In this example the heat insulating casting 52 comprises an intumescent material, in particular, the intumescent material is an epoxy intumescent material. The casting 52 is in the form of a complete tube and, as such, has a continuous inner circumferential surface 54 and a continuous outer circumferential surface 56. In this example the tube has a circular annular cross-section, as shown in Figure 6.

[0038] The casting 52 is elongate and extends between a first end 58 and a second end 60. A length of the casting 52, between the first and second ends 58, 60, is preferably substantially equal to a length of the structural member 10 to be protected. In this way, a length of the casting may vary to provide full coverage, less an adjustment allowance, of a structural member 10 such as a tension rod. In this example, the length of the casting 52 is substantially equal to a length of the bar 14 of the tension rod 12 between the fork ends 18. In some embodiments a casting 52 may have a standard length of one metre. Additional sections of casting may then be added end to end to provide the necessary coverage of the structural member 10.

[0039] The heat insulating casting 52 further comprises a support tube 62 made of a non-intumescent material. The support tube 62 is also in the form of an elongate tube, and a diameter of the support tube 62 is larger than an inner diameter of the tubular casting 52 and smaller than an outer diameter of the tubular casting 52. The support tube 62 is, therefore, encapsulated within the intumescent material. Preferably the diameter of the support tube 62 is such that the support tube 62 is disposed closer to the inner circumferential surface 54 than to the outer circumferential surface 56 of the casting 52.

[0040] The support tube 62 includes a plurality of holes or apertures. The support tube 62 may comprise a wire mesh, for example a 0.5 mm gauge wire mesh. However, in preferred embodiments the support tube 62 comprises a perforated tube. The perforated support tube 62 may include holes having diameters of between 3 mm and 5 mm. The support tube 62 is preferably made of stainless steel. A thickness of the support tube 62 in a radial direction is preferably about 1.2 mm, more preferably about 1 mm, and most preferably 0.9 mm. The support tube 62 may be a spiral wound tube.

[0041] An overall thickness of the casting 52 in a radial direction, i.e. a distance between the inner circumferential surface 54 and the outer circumferential surface 56, is preferably between 7 mm and 12 mm, and more preferably 10 mm. In some embodiments the thickness of the casting 52 may be up to 26 mm. In further embodiments the thickness of the casting may be greater than 26 mm.

[0042] The inner diameter of the casting 52 is preferably between 10 mm and 130 mm, and more preferably between 25 mm and 125 mm. However, it will be appreciated that the inner circumferential diameter of the casting 52 and the length of the casting 52 may be of any suitable size dependent on the type of structural member 10 being protected by the passive fire protection system.

[0043] During pre-construction assembly of the tension rod 12, the pre-cast tubular casting 52 is slid over and along the length of the bar 14 of the tension rod 12 before a fork end 18 is secured in place. A gap 64 of about 1 mm to 5 mm is preferably present between the inner circumferential surface 54 of the casting 52 and an outer surface of the bar 14. In embodiments in which the thickness of the casting 52 is greater than 26 mm the gap 64 may be greater than 5 mm. To centralise the bar 14 within the tubular casting 52, the assembly 50 comprises stabilising elements 66 that maintain this gap 64 evenly around the bar 14. In this example the stabilising elements 66 are in the form of stabilising pads 66 disposed in the gap 64. Each stabilising pad 66 includes a first surface in contact with the outer surface of the bar 14 and a second surface in contact with the inner circumferential surface of the casting 52. The assembly 50 preferably includes a plurality of stabilising pads 66 spaced apart in a circumferential direction around the bar 14 of the tension rod 12.

[0044] The gap 64 between the bar 14 of the tension rod 12 and the casting 52 is primarily to allow clearance for assembly of the casting 52 around the tension rod 12; however, it will be appreciated that the gap 64 also provides additional heat insulation between the casting 52 and the tension rod 14, as well as permitting some flexing of the tension rod 14 within the casting 52.

[0045] It will be understood that the casting 52 is not adhered or otherwise bonded to the structural member 10 as was the case with the known intumescent casting

32 described above. The support tube 62 therefore acts to support the intumescent material both before and after expansion. Before expansion, during assembly and transportation of the structural member 10, the support tube 62 permits some degree of flexing or bending of the casting 52, which would otherwise crack if bonded directly to the structural member 10. During and after expansion of the intumescent material, for example during a fire, the support tube 62 supports the expanding material to retain its integrity around the structural member 10.

[0046] Figures 8 to 10 illustrate components of a mould assembly 70 suitable for manufacturing an intumescent casting 52 according to the invention.

[0047] The mould assembly 70 comprises an outer casing 74. In this example the outer casing 74 is made of two halves 74a, 74b secured together with suitable mechanical fasteners. The mechanical fasteners may comprise M8 bolts or similar flanged bolts and nuts. Each half of the outer casing 74 includes a semi-cylindrical inner surface, such that when the two halves are secured together the two semi-cylindrical inner surfaces surround and define a cylindrical bore 76 of the outer casing 74. To ensure the two halves of the outer casing 74 are aligned correctly a plurality of dowel pins (not shown) may be provided spaced apart along the length of the casing 74.

[0048] The mould assembly 70 further includes a core rod 78. The core rod 78 is elongate and cylindrical. An outer diameter of the core rod 78 is smaller than a diameter of the bore 76 of the outer casing 74, such that the core rod 78 may be inserted into and extend through the outer casing bore 76. With the core rod 78 disposed in the bore 76, the core rod 78 is co-axial with the bore 76.

[0049] The diameters of the core rod 78 and the bore 76 of the outer casing 74 are such that when the core rod 78 is disposed within the bore 76 of the outer casing 74 an annular cavity is defined around the core rod 78; it is in this cavity that the casting 52 is formed. Accordingly, the diameter of the core rod 78 is preferably at least 14 mm smaller than the diameter of the bore 76 of the outer casing 74, and more preferably between 15 mm and 52 mm smaller.

[0050] The mould assembly 70 also includes a feed plate 82 positionable at a first end of the outer casing 74 and a top plate 72 at an opposite second end of the outer casing 74. The feed plate 82 and top plate 72 support the core rod 78 centrally within the bore 76 of the outer casing 74 to maintain the annular cavity while the casting 52 is formed.

[0051] To form the casting 52 the support tube 62 is positioned within the annular cavity defined between the core rod 78 and the outer casing 74. An inner diameter of the support tube 62 is preferably about 2 mm to 4 mm larger than the outer diameter of the core rod 78. The mould assembly 70 therefore preferably includes suitable supports to maintain the position of the support tube 62 relative to the core rod 78. The support tube 62 may be supported by the feed plate 82 and top plate 72.

[0052] The mould assembly 70 further includes a pool plate 80 which is disposed adjacent the feed plate 82 at the first end of the casing 74. The pool plate 80 includes an injection hole 84 which permits intumescent material, or other heat insulating material, to be injected into the annular cavity in the casing 74 around the core rod 78.

[0053] To form the casting 52, intumescent material is injected into the annular cavity. Preferably the intumescent material is an epoxy intumescent. It has been found that there is an advantage to orienting the mould assembly 70 so that the longitudinal axis of the bore 76 and core rod 78 are vertical, and the feed plate 82 and pool plate 80 are disposed at a lower end of the assembly. This generally produces a denser and more consistent quality of casting 52.

[0054] Figures 9 and 10 shown in more detail the pool plate 80 and feed plate 82 of the mould assembly 70. A central region 86 of the feed plate 82 is arranged to help to support the core rod 78 within the outer casing 74. Surrounding this central region 86 the feed plate 82 includes an annular injection region 88. When the pool plate 80 and feed plate 82 are mounted to the outer casing 74 to form the complete mould assembly 70, the injection region 88 is aligned with the annular cavity between the core rod 78 and the outer casing 74. The injection region 88 includes a plurality of holes 89 spaced in a circumferential direction around the annular region 88. In this example the injection region 88 includes seven equidistantly spaced holes 89. During casting the intumescent material is injected through the injection hole 84 in the pool plate 80 and then through the holes 89 in the feed plate 82 into the annular space. The distribution of the holes 89 means that the injection pressure is distributed evenly around the annular cavity. This helps to prevent air getting trapped and allows the formation of a consistent and dense casting 52.

[0055] It will be appreciated that on filling of the annular space the support tube 62 is fully encapsulated by the intumescent material.

[0056] Once the annular space has been filled, the casting 52 is left to cure. This may take about fourteen hours for epoxy intumescent materials. Once the casting 52 is cured it is removed from the mould assembly 70. Preferably the casting 52 is removed from the mould assembly 70 using an extruder 90 such as the one illustrated in Figure 11.

[0057] The extruder 90 includes a main support frame 92 and an ejection member 94. The ejection member 94, in this example, is in the form of an elongate rod or pin 94. The support frame 92 is arranged to receive a part of the mould assembly 70 between a pair of support end plates 96. Before being positioned in the support frame 92, the pool plate 80, feed plate 82 and top plate 72 are detached from the outer casing 74. An assembly comprising the outer casing 74, casting 52 and core rod 78 is then seated in the support frame 92 such that a first one of the support end plates 96 is disposed at the first end of the outer casing 74 and a second one of the support plates 96 is disposed at the second end of the outer casing 74.

[0058] With the casing 74 mounted in the support frame 92, the ejection rod 94 is arranged such that a longitudinal axis of the ejection rod 94 extends parallel to, and preferably co-axially with, the axis of the core rod 78.

[0059] In a preferred method a first retaining plate 98 is disposed at the second end of the casing 74. The first retaining plate 98 includes an aperture having dimensions greater than an outer diameter of the core rod 78 but at least one dimension smaller than an outer diameter of the casting 52. A first ejection rod 94 is then extended to push the core rod 78 out from the casting 52. It will be appreciated that an outer diameter of the first ejection rod 94 is smaller than the outer diameter of the core rod 78. The first ejection rod 94 is preferably driven by a suitable hydraulic mechanism (not shown). The first retaining plate 98 prevents the casting 52 being pushed out with the core rod 78. The core rod 78 is preferably made of a suitable polymeric material that allows it to slide out of the casting 52. In a preferred embodiment the core rod 78 is made of polypropylene. The core rod 78 may be made of high density polyethylene (HDPE). This also means that the core rod 78 can be reused multiple times.

[0060] Subsequently, the casting 52 is also ejected from the outer casing 74 using a second ejection rod 94 having a larger diameter. The second ejection rod 94 may be an separate ejection rod entirely independent of the first ejection rod or, alternatively, the second ejection rod may be formed by the attachment of a larger diameter adaptor to the first ejection rod. The adaptor may be in the form of an end cap or end plate secured to an end of the first ejection rod 94. A diameter of the second ejection rod 94 is greater than the inner diameter of the casting 52 and smaller than the outer diameter of the casting 52.

[0061] The first retaining plate 98 is removed from the support frame 92, and a second retaining plate 99 is disposed at the second end of the casing 74. The second retaining plate 99 includes an aperture having dimensions greater than an outer diameter of the casting 52 but at least one dimension smaller than an outer dimension of the outer casing 74.

[0062] The second ejection rod 94 is then driven, preferably by a suitable hydraulic mechanism (not shown), to push the casting longitudinally out of the outer casing 74. The second retaining plate 99 holds the casing 74 in position as the casting 52 is removed.

[0063] At least the inner semi-cylindrical surface of the halves of the outer casing 74 are made from a suitable polymeric material to allow the casting 52 to be easily removed from the outer casing 74. In a preferred embodiment at least the inner semi-cylindrical surfaces of the outer casing 74 are made of polypropylene or high density polyethylene (HDPE). In some embodiments all of the outer casing 74 is made of a suitable polymeric material, for example polypropylene or HDPE. This also means that the outer casing 74 can be reused multiple times without disassembly.

[0064] In other examples, the casting 52 may be removed from the outer casing 74 by releasing the fasteners securing the two halves of the outer casing 74 together and separating the two halves of the outer casing 74.

[0065] This method of forming the castings 52 results in discrete lengths of casting 52. Due to the length of time it takes for the intumescent material, for example epoxy intumescent, to cure, it is difficult to form the casting 52 using a continuous extrusion process. The use of the extruder as described above, however, allows a complete tubular casting to be formed without the need to cut the casting longitudinally as was the case with prior art systems.

[0066] Furthermore, it will be appreciated that the outer casing 74 and core rod 78 may have any suitable length. A single casting 52 may therefore be formed to extend along a complete length of a structural member 10. Some castings 52 may have a length of one metre, although castings 52 may be made that have lengths shorter or longer than this.

[0067] As described above, the finished casting 52 is then subsequently slid onto a structural member 10 such as a tension rod 12. Several castings 52 may need to be joined end to end to cover and protect the full length of the structural member 10. This joining step may be carried out during manufacture or assembly of the structural member 10 before the structural member 10 is transported to site complete with the passive fire protection system. This reduces or eliminates the need to install and decoratively finish the castings 52 on site.

[0068] In the above embodiment the castings 52 were formed to surround the elongate bars 14 of a tension rod 12. It will be understood that similar tubular castings 52 may also be formed to surround the cylindrical portion of a connector or turnbuckle 16 of the tension rod 12. However, any non-cylindrical parts of the structural member 10, such as the fork ends 18 and any locking nuts or lockcovers 22 of a tension rod 12, will remain exposed.

[0069] In preferred embodiments, therefore, additional castings are made to surround each of the fork ends 18 and the lock nuts or lockcovers 22.

[0070] Figures 12 to 14 illustrate an example of a mould 100 that may be used to produce a casting 102 for surrounding a lock nut or lockcover 22. The mould 100 comprises a female mould component 104 and a male mould component 106. The female mould component 104 comprises an end plate 108 and a side wall 110 extending from the end plate 108. The side wall 110 surrounds and defines a cavity 112 of the female mould component 104. The cavity 112 includes a tapered section 114 adjacent the end plate 108 and a cylindrical section 116 extending from the tapered section 114 furthest from the end plate 108. In the tapered section 114 a diameter of the cavity 112 adjacent the end plate 108 is smaller than a diameter of the cavity 112 further from the end plate 108. A diameter of the cylindrical section 116 is preferably generally constant along its length.

[0071] An outer profile of the male mould component 106 is complimentary to the internal profile of the female mould component 104. The male mould component 106 includes an end plate 118 and a post 120 extending from the end plate 118. The post 120 includes a cylindrical portion 122 adjacent the end plate 118 and a tapered portion 124 extending from the cylindrical portion 122. A diameter of the cylindrical portion 122 is generally constant along its length. A diameter of the tapered portion 124 decreases in a direction away from the cylindrical portion 122.

[0072] In use the male mould component 106 is inserted into the cavity 112 of the female mould component 104 such that the tapered portion 124 of the post 120 is disposed in the tapered section 114 of the cavity 112 and the cylindrical portion 122 of the post 120 is disposed in the cylindrical section 116 of the cavity 112. The diameter of the cylindrical portion 122 of the post 120 is less than the diameter of the cylindrical section 116 of the cavity 112, and the diameter of the tapered portion 124 of the post 120 at a certain point along its length is smaller than the diameter of the tapered section 114 of the cavity 112 at an equivalent point along its length. In this way a space is defined between the outer surface of the post 120 and the inner surface of the side wall 110 of the female mould component 104.

[0073] Both the male mould component 106 and the female mould component 104 are preferably made of a suitable polymeric material. The male mould component 106 and the female mould component 104 may be made of polypropylene, high density polyethylene (HDPE), or other similar polymeric material.

[0074] One of the end plates 108, 118 includes at least one hole to allow intumescent material to be poured or injected into the space between the male mould component 106 and the female mould component 104.

[0075] Once the intumescent material has cured, the resultant casting 102 is removed from the mould 100. The dimensions of the casting 102 are preferably such that the casting 102 can be slid over and surround the lock nut or lockcover 22 of a tension rod 12. A thickness of the casting 102 is preferably between 7 mm and 15 mm, and more preferably about 10 mm. The thickness of the casting 102 is preferably uniform throughout the casting 102. The casting 102 is preferably installed over and around the appropriate part of the tension rod 12, or other structural member 10, before the structural member 10 is transported to site. The casting 102 may, however, be installed over and around the appropriate part of the tension rod 12, or other structural member 10, after the structural member 10 is transported to site.

[0076] Figures 15 to 17 illustrate an example of a mould 130 that may be used to produce a casting 132 for surrounding a fork end 18. In particular the mould 130 is configured to form a casting 132 that surrounds half a fork end 18, and two such castings 132 may then be joined together to form a complete casting fully surrounding the fork end 18, as illustrated in Figure 15.

[0077] As shown in Figures 16 and 17, the mould 130 comprises a female mould component 134 and a male mould component 136. The male mould component 136 includes a projection 138 having an external surface and the female mould component 134 has an internal surface defining a cavity 140. A profile of the projection 138 of the male mould component 136 is complimentary to the profile of the cavity 140 of the female mould component 134. Furthermore, the dimensions of the projection 138 of the male mould component 136 are smaller than the dimensions of the cavity 140 of the female mould component 134 such that, when the male mould component 136 is disposed in the female mould component 134, there is a space between the outer surface of the male mould component 136 and the inner surface of the female mould component 134. An intumescent material, such as epoxy intumescent, is poured or injected into this space to cast the fork end 18 cover.

[0078] Both the male mould component 136 and the female mould component 134 are preferably made of a suitable polymeric material. The male mould component 136 and the female mould component 134 may be made of polypropylene or HDPE.

[0079] The shape of the mould 130 is such that the resultant casting 132 covers one of the fork plates 24. A pair of castings 132 is therefore required to fully surround the fork end 18 as shown in Figure 15, and a join between the two castings 132 is aligned with the gap 26 between the two fork plates 24.

[0080] It will be understood that the fork end castings 132 cannot be installed around the fork end 18 until after the fork end 18 has been connected to the gusset plate 4 or other suitable structure. Accordingly, while the tubular castings 52 and tapered castings 102 may be installed on a structural member 10 before transportation to the site of a structure, it is necessary for the fork end castings 132 to be applied after the installation of the structural member 10.

[0081] The tapered casting 102 and the fork end casting 132, together with the elongate tubular castings 52 described earlier, may however form a kit of castings providing a complete passive fire protection system for a tension rod 12, or other similar structural member, for example a compression strut.

[0082] The tubular castings 52 of the present invention, and their method of manufacture, therefore provide a passive fire protection system that may be applied to a structural member 10 during its manufacture or assembly, before the structural member 10 is transported to site. Additionally, the formation of the casting 52 as a complete tube decreases the number of joints in the intumescent covering meaning that less post-application finishing is required.

[0083] Although in the above description the intumescent castings were applied to a structural member in the form of a tension rod, in other embodiments the castings may be sized to surround any form of structural member. The structural member will typically be elongate. The structural member is preferably made of metal, such as carbon steel or stainless steel. The structural member may be a strut, cable or column.

[0084] It will be appreciated that the structural member is not limited to having any particular cross-sectional shape. While in the above description the tension rod bars had a circular cross-sectional shape, in other examples the structural member may have a square, rectangular or other polygonal cross-sectional shape. Similarly, the cross-sectional shape of the tubular castings may not be circular. The tubular casting may have a square, rectangular or other polygonal cross-sectional shape. Accordingly, references above to a circumferential surface should be interpreted accordingly. It will also be understood that the tubular casting need not have the same cross-sectional shape as the structural member it surrounds.

[0085] In the above description of the method of using the extruder 90, the assembly comprising the outer casing 74, casting 52 and core rod 78 was seated in the support frame 92 such that a first one of the support end plates 96 was disposed at the first end of the outer casing 74 and a second one of the support plates 96 was disposed at the second end of the outer casing 74. It will be understood that the assembly comprising the outer casing 74, casting 52 and core rod 78 may be seated the other way around such that the first one of the support end plates 96 is disposed at the second end of the outer casing 74 and the second one of the support plates 96 is disposed at the first end of the outer casing 74.

[0086] Passive fire protection may be provided by a heat insulating material other than an intumescent material. Accordingly, this invention is also applicable to systems and methods in which the intumescent material described above is replaced with a material that may not swell in the same manner as an intumescent material in the raised temperature of a fire but which, nevertheless, provides the necessary passive fire protection. The material may be a suitable ceramic material, for example.

[0087] Other modifications and variations not explicitly disclosed above may also be contemplated without departing from the scope of the invention as defined in the appended claims.

Claims

1. An assembly comprising:

- an elongate structural member;
- a pre-cast casting disposed around the structural member, the casting comrpising:

    - an elongate heat insulating tube, the heat insulating tube made of a heat insulating material providing passive fire protection, and the heat insulating tube having a continuous inner circumferential surface and a continuous outer circumferential surface; and
    - a support tube encapsulated within the heat insulating tube between the inner circumferential surface and the outer circumferential surface; and

- a stabilising element arranged to maintain a gap between the inner circumferential surface of the heat insulating tube and an outer surface of the structural member.

2. An assembly as claimed in Claim 1, wherein the heat insulating tube comprises an intumescent material, and the support tube is made of a non-intumescent material.

3. An assembly as claimed in Claim 1 or Claim 2 wherein the support tube is a perforated tube or the support tube comprises a wire mesh .

4. An assembly as claimed in any preceding claim, wherein a thickness of the heat insulating tube, between the inner circumferential surface and the outer circumferential surface, is at least 7 mm.

5. An assembly as claimed in any preceding claim, wherein a thickness of the heat insulating tube, between the inner circumferential surface and the outer circumferential surface, is between 7 mm and 26 mm.

6. An assembly as claimed in any preceding claim, wherein an inner diameter of the heat insulating tube is between 10 mm and 130 mm.

7. An assembly as claimed in any preceding claim, wherein a radial dimension of the gap is between 1 mm and 5 mm.

8. A method of manufacturing a casting to provide a passive fire protection covering for a structural member, the method comprising:

- filling a tubular mould with a heat insulating material for providing passive fire protection, the tubular mould comprising a reusable outer casing and a reusable core rod;
- curing the heat insulating material to form a passive fire protection casting;
- removing the core rod longitudinally from the casting; and
- removing the casting from the outer casing as a complete tube.

9. A method as claimed in Claim 8, wherein the heat insulating material is an intumescent material.

10. A method as claimed in Claim 8 or Claim 9, further comprising, before filling the tubular mould with the heat insulating material, supporting a support tube within the tubular mould.

11. A method as claimed in any one of Claims 8 to 10, wherein filling of the tubular mould comprises:

- supporting the mould such that an axis of the mould is vertical; and
- injecting heat insulating material into the tubular mould from a lower end of the tubular mould.

12. A method as claimed in Claim 11, wherein the step of injecting heat insulating material into the tubular mould comprises injecting the heat insulating material through a plurality of holes spaced apart around an annular injection region of a feed plate disposed at the lower end of the mould.

13. A method as claimed in any one of Claims 8 to 12, wherein the step of removing the core rod longitudinally from the casting comprises mounting the mould in an extruder and advancing an ejection member in a direction parallel to an axis of the mould to push the core rod longitudinally out of the casting, and the step of removing the casting from the outer casing as a complete tube comprises advancing an ejection member in a direction parallel to an axis of the mould to push the casting longitudinally out of the outer casing.

14. A method of installing a pre-cast casting on a structural member to provide a passive fire protection covering, the method comprising:

- inserting an elongate structural member longitudinally through a bore of an elongate tubular heat insulating casting, the heat insulating casting having a continuous inner circumferential surface and a continuous outer circumferential surface; and
- supporting the heat insulating casting in a position relative to the elongate structural member such that there is a gap between the inner circumferential surface of the heat insulating casting and an outer surface of the structural member.

15. A method as claimed in Claim 14, wherein the heat insulating casting comprises an intumescent material.

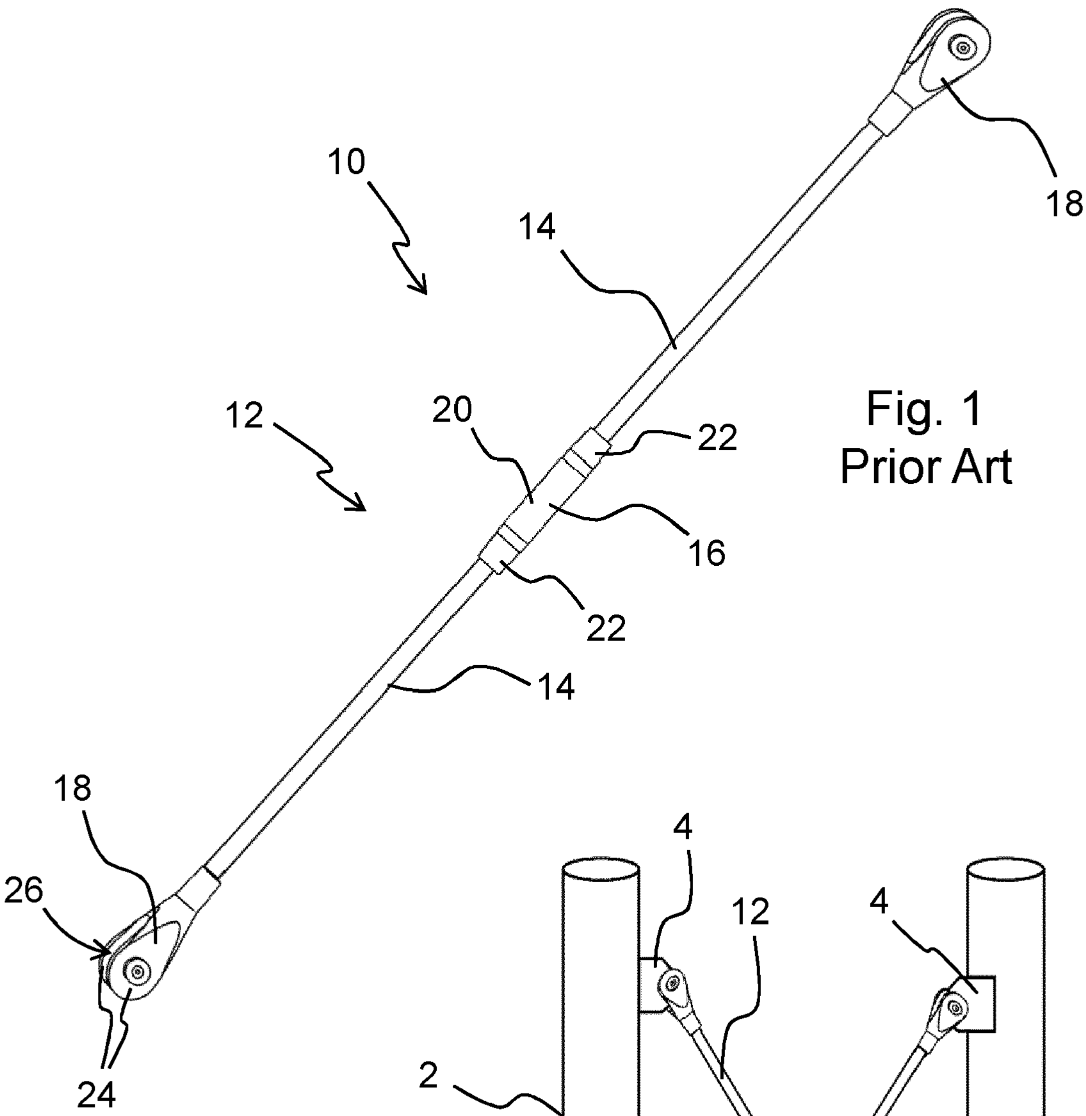

Fig. 1
Prior Art

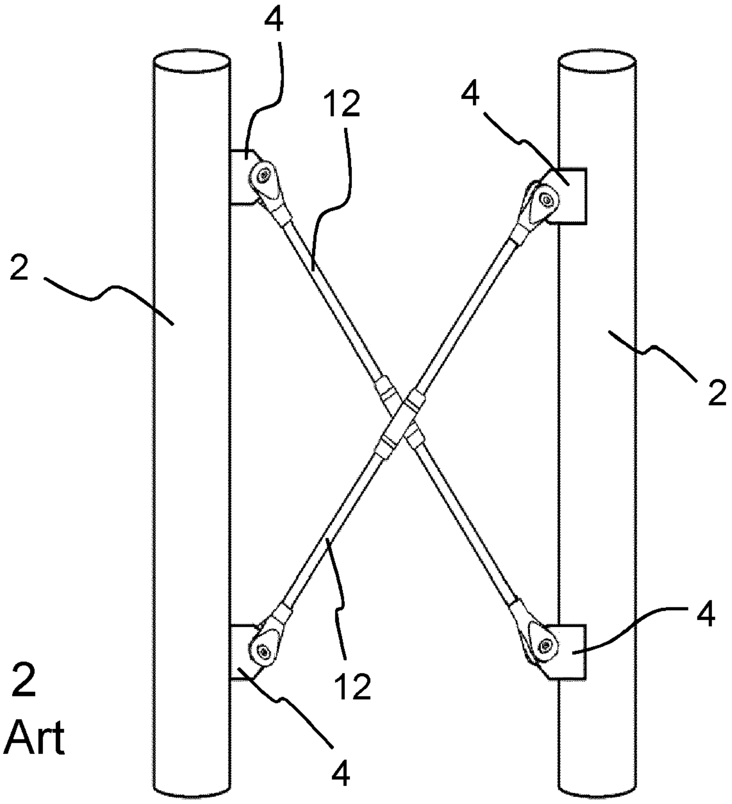

Fig. 2
Prior Art

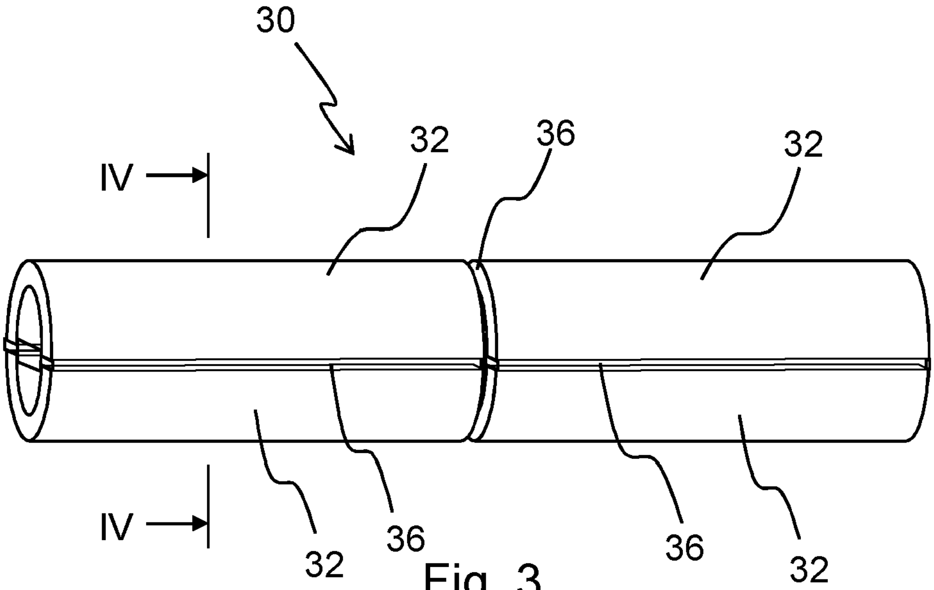

Fig. 3
Prior Art

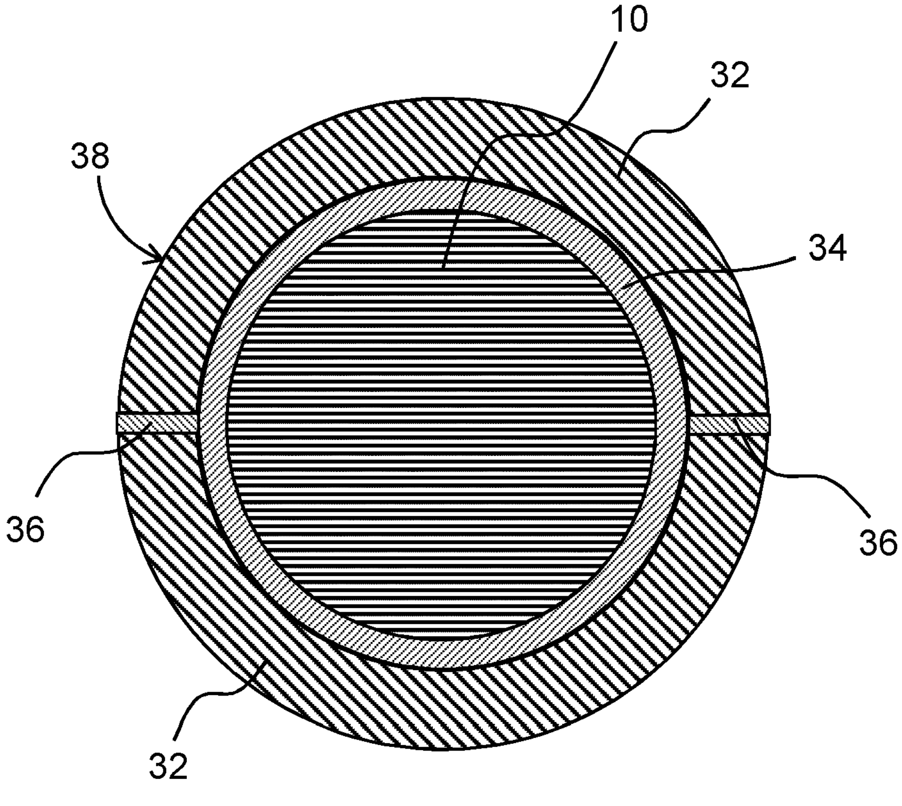

Fig. 4
Prior Art

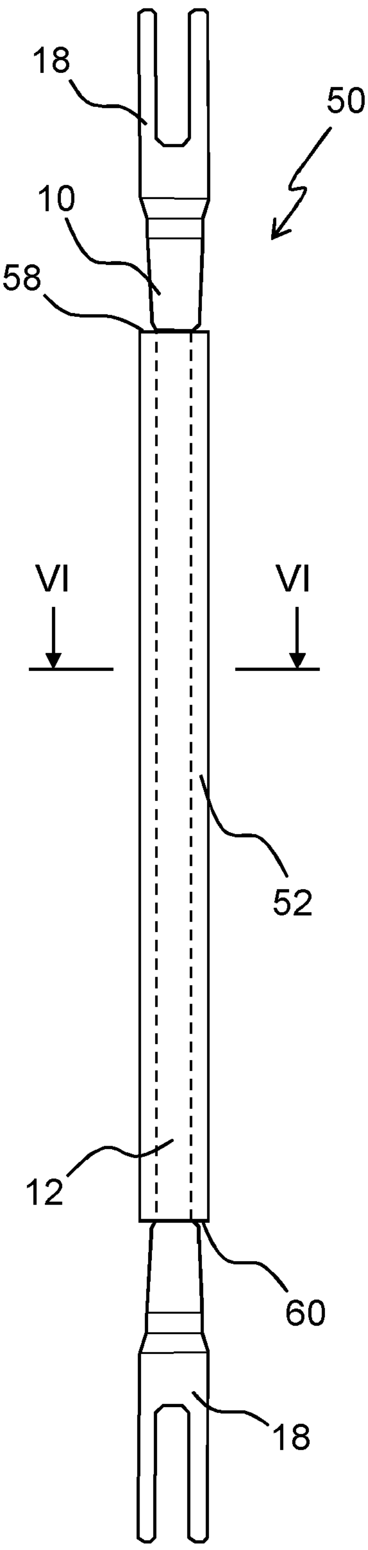

Fig. 5

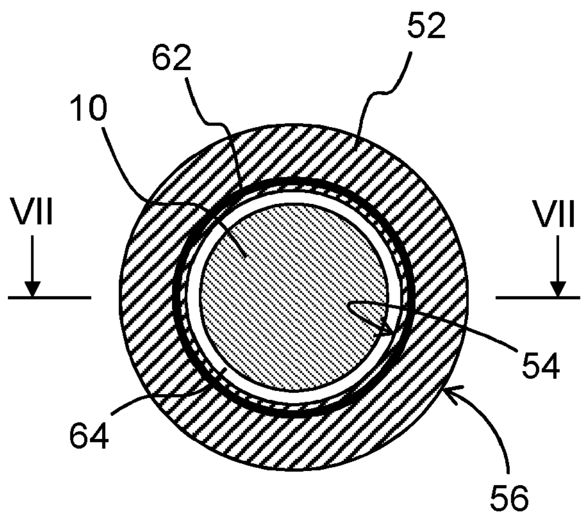

Fig. 6

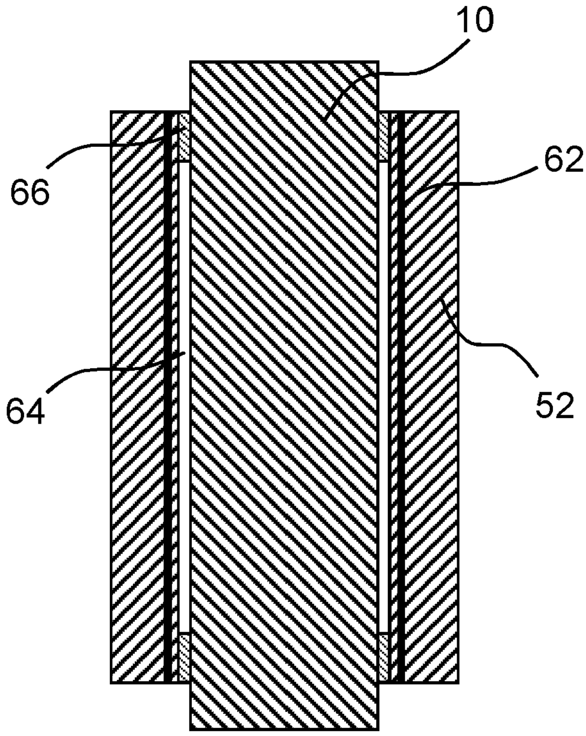

Fig. 7

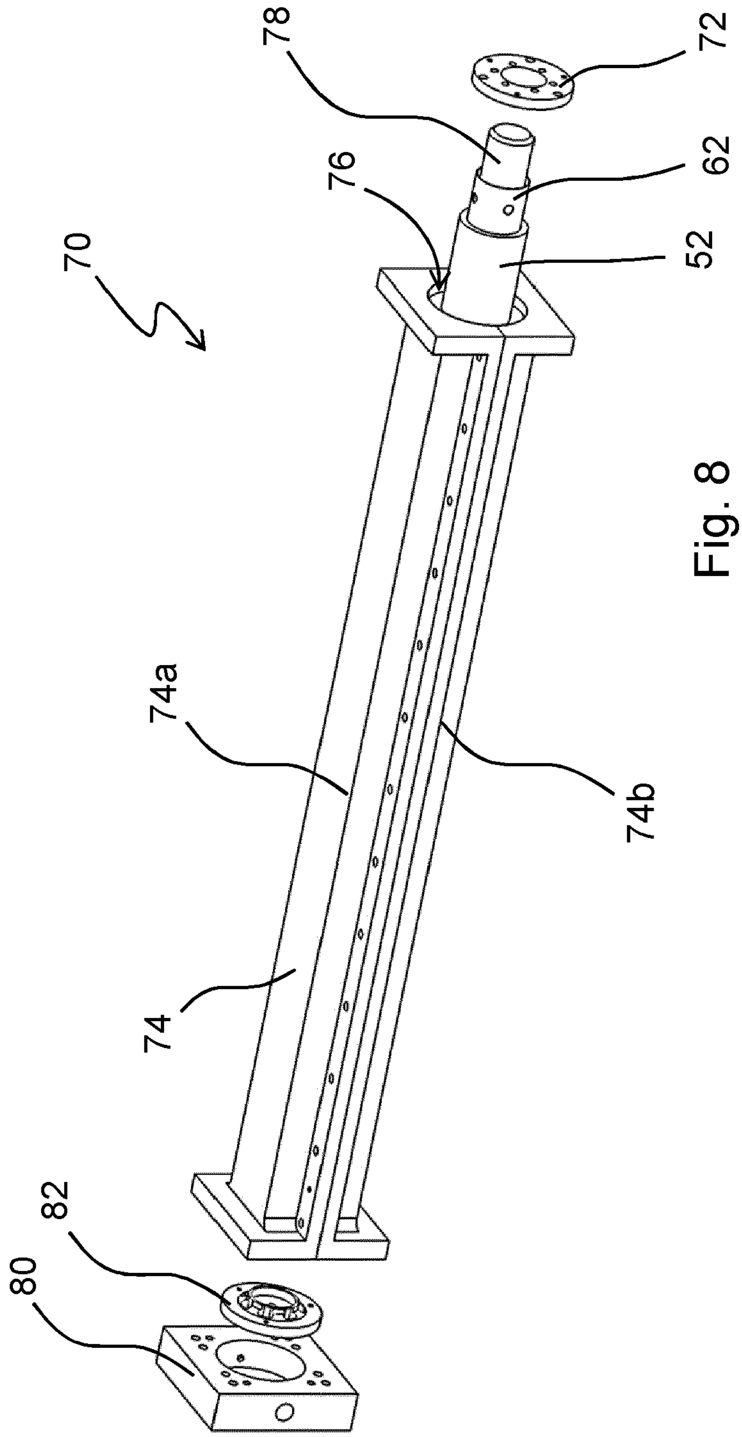

Fig. 8

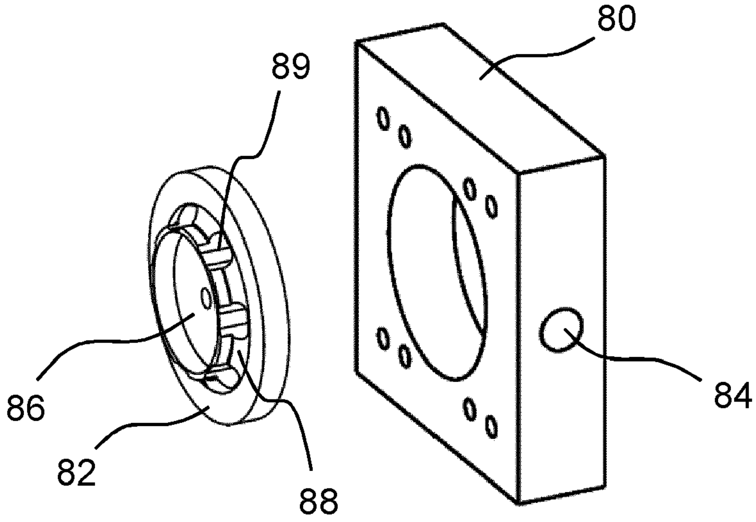

Fig. 9

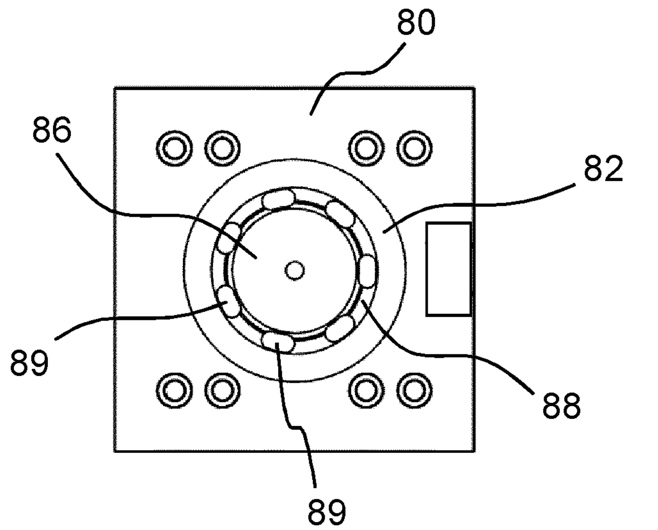

Fig. 10

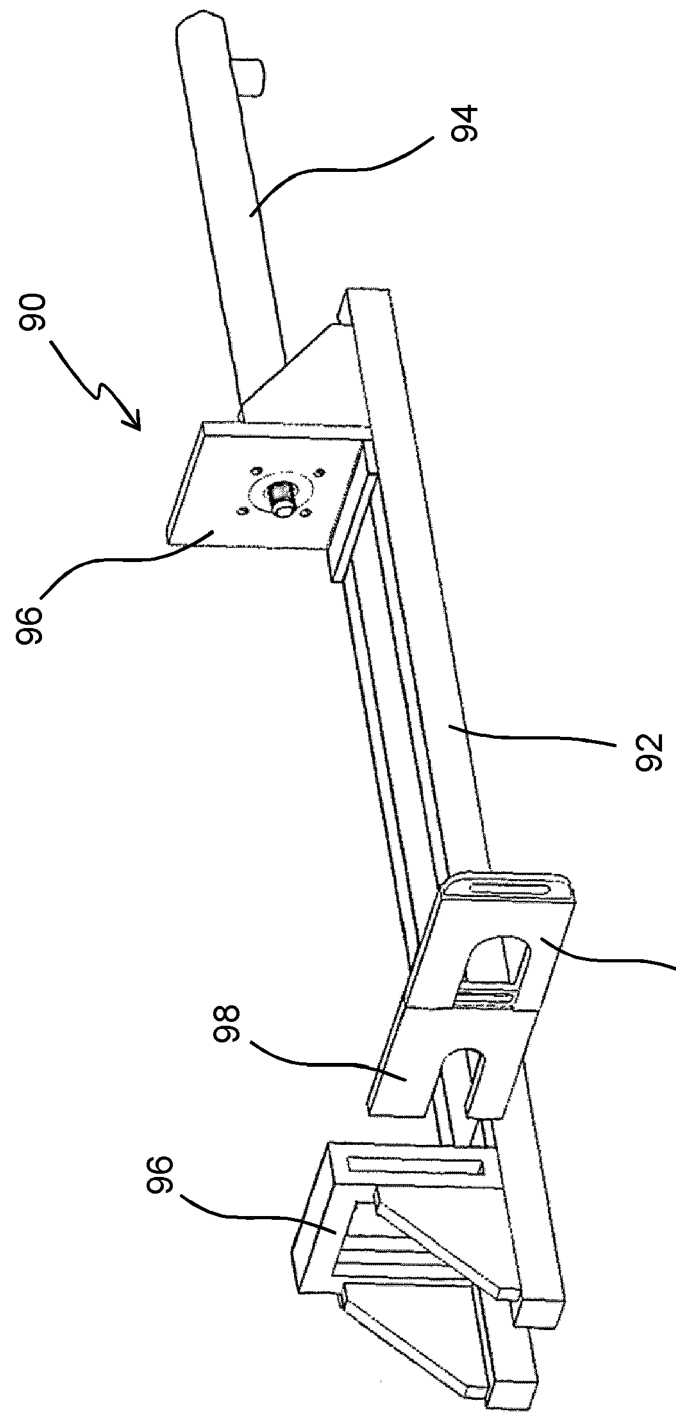

Fig. 11

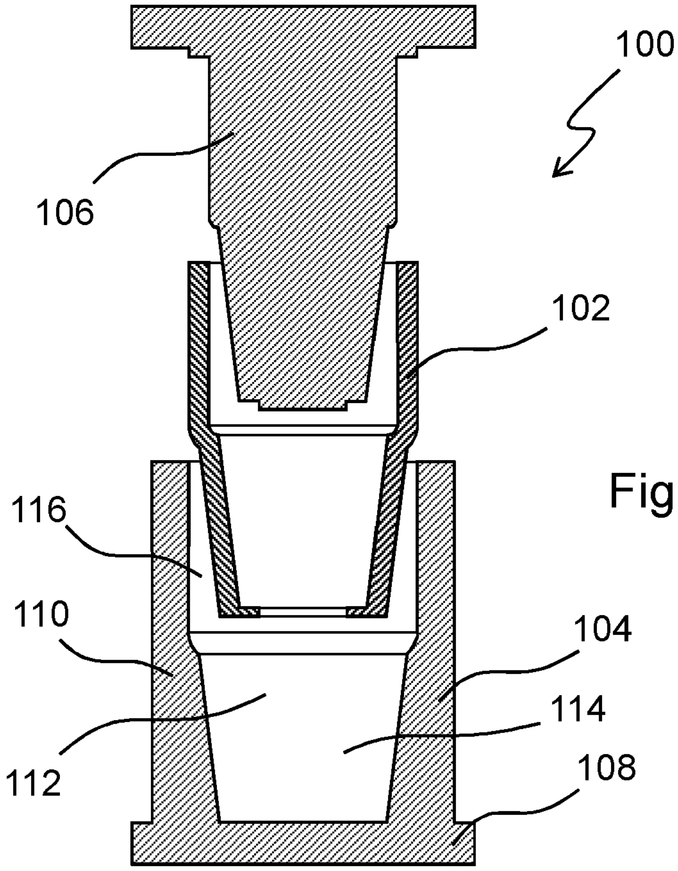

Fig. 12

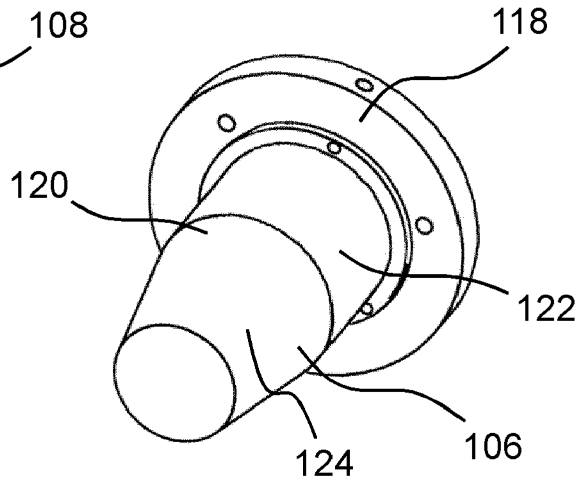

Fig. 13

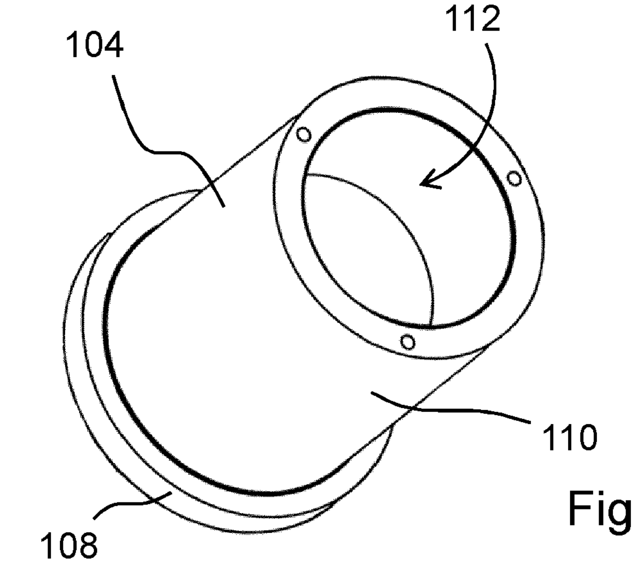

Fig. 14

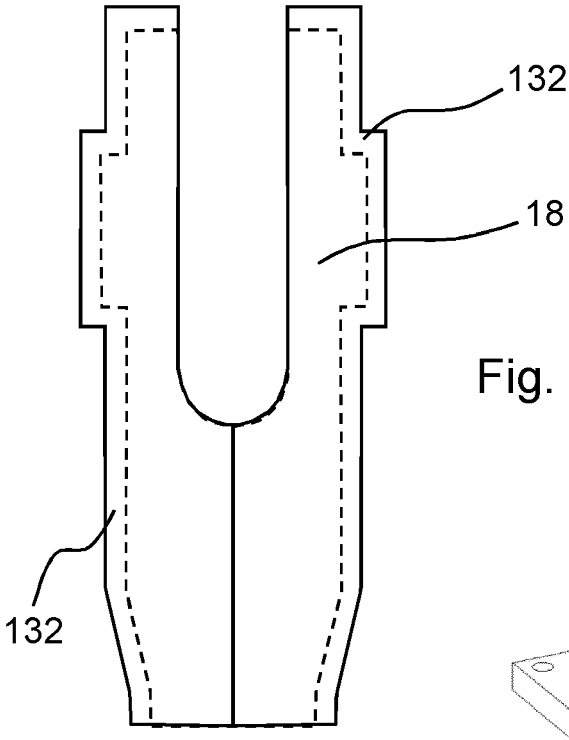

Fig. 15

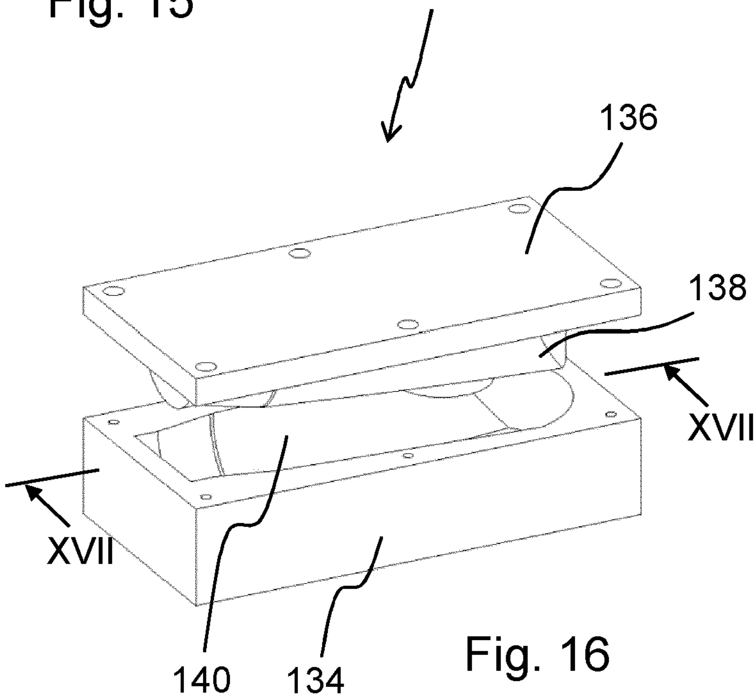

Fig. 16

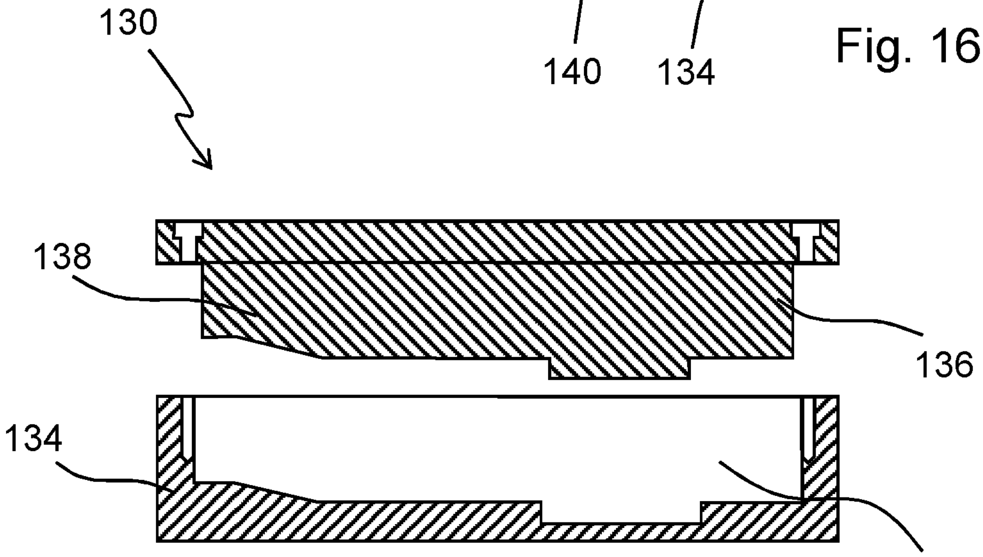

Fig. 17