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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 3: E04B 1/19; E04G 11/04; E04B 1/345, 1/344	A1	**(11) International Publication Number:** WO 81/00125 **(43) International Publication Date:** 22 January 1981 (22.01.81)

(21) International Application Number: PCT/GB80/00110

(22) International Filing Date: 1 July 1980 (01.07.80)

(31) Priority Application Number: 7922828

(32) Priority Date: 2 July 1979 (02.07.79)

(33) Priority Country: GB

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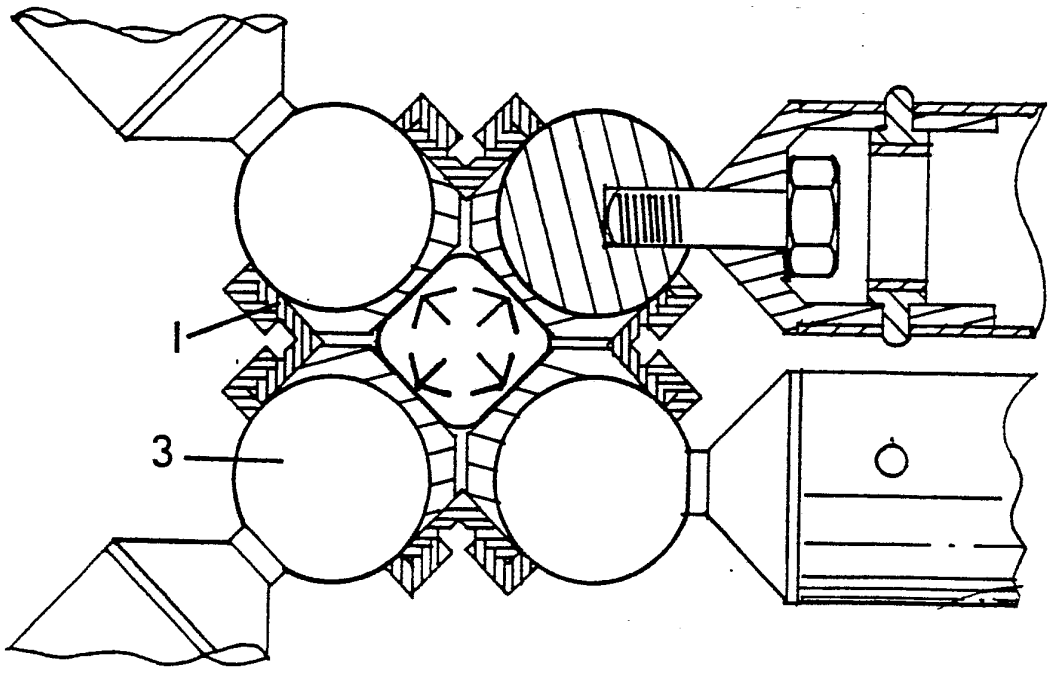
(81) Designated States: AU, GB, JP, US.

Published
With international search report

(54) Title: COLLAPSIBLE STRUCTURE AND METHOD OF ERECTING THE SAME



(57) Abstract

A collapsible structure comprising a series of elongate struts and joints connecting their ends. The struts may be rigid tubes or inflatable hoses. The joints comprise ball joints (3) which connect at least three struts and which are lockable to maintain the struts in any desired relative angular positions. To erect the structure, the struts and joints are joined to form a network, the network is suspended to form a catenary shape, the joints (3) are locked to form a rigid structure and the structure is then inverted. The structure can then be used as a support for forming a mould for a building unit.

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"COLLAPSIBLE STRUCTURE AND METHOD OF ERECTING THE SAME"

This invention relates to frameworks or structures which may be erected from an interconnected plurality of struts and in particular relates to how the nodes or junction of these struts or similar tubes or elements may be constructed, activated and locked.

A mode in this context means the junction of a number of interconnected separate struts or tubes and defines the angular relationship of these struts with respect to one another.

The structure after erection may be used as the load bearing framework for a building when suitably covered or when covered as a mould for producing castings of architectural forms as will be referred to in greater detail later.

Accordingly the invention provides in one aspect a plurality of elongate members or elements, attachment means for joining elongate members together, means for rendering stable the attachment means and elongate members in operation to form a weight supporting structure in a number of pre-selected angular relationships without adding or removing such members or attachment means.

According to a further aspect of the invention, a collapsible structure comprises a plurality of elongate members connected at their ends by joints to form a network, the joints being adjustable to allow the relative angular positions of the elongate members to be varied and further being lockable to maintain the elongate members in their desired relative angular positions.

The elongate members are conveniently rigid struts preferably of variable length and/or may take the form of "self erecting" struts in the sense that they may be operable to be erected by remote means pneumatically hydraulically or by electrical means. Such "self erecting" struts may be formed from high pressure hose material for high pressure inflation.

The attachment means are preferably ball joints which are lockable in the required position having regard to the required angular relationship of the struts or the required shape of the structure. As an alternative to ball joints a universal pivot joint may be used.

The locking of the connections or the ball joints may be provided by friction locking pins, devices which incorporate substances which can readily change their state from liquid to solid for example. The locking may again be remote controlled by hydraulic, pneumatic or electrical systems.

Further stability is provided by pre-attached wires or stays extending between attachment means or ball joints or nodes arranged so that they can slide over one another during erection of the structure. These wires or stays may also be adjustable in length or pre-set in length.

According to another embodiment the invention provides a mould structure or framework adapted to be covered, the structure or framework comprising a network of tubes or similar elements pivotally connected together at their nodal points, the pivotal connections

and the tubular elements having means for pre-setting a pre-selected angular relationship of tubes whereby the structure can be erected to a pre-selected shape foldable down and re-erectable for further use in the pre-set shape or other alternative pre-set shapes.

Nodes and tubes may conveniently have flexible ties passing through them flexibly linking the nodes, particularly for safety reasons when erection involves compressed air. This safety wire member is particularly appropriate where the tubes or elongate members are rendered rigid by inflation such as high pressure hose.

According to a further aspect of the invention there is provided a method of erecting a collapsible structure which comprises connecting together a plurality of elongate members, by their ends, by means of joints, to form a network, suspending the network to form a catenary shape, locking the joints to form a rigid structure maintaining the catenary configuration, and inverting the structure.

The invention will now be described by way of example only with reference to Figures 1-19 of the accompanying drawings.

Nodes

The hydraulically operated node, Figures 1 to 3, consists of a casing 1 and friction shoes 2, which are forced against a spherical ball 3, by the action of hydraulic pressure 200 - 10,000 P.S.I. (see Figure 3) supplied via a pipe 4 (see Figure 1). Into the sphere are screwed conic shaped ends which in turn receive the pneumatic or rigid aluminium tubes. As will be

seen from Figure 7 the nodes can be locked by a suitable expanding system indicated by the arrows and one convenient expanding system is a flexible bag which can for example be inflated.

Figure 7A-7D shows a particularly practical form of node. The basic concept is a spherical casting with as many spherical seatings cast into it as required. In this embodiment there are four.

The node Figures 7A and 7B can be locked remotely by hydraulic pressure in the following way. Pressurised fluid from a remote pump travels along a flexible hydraulic line Figure 7D(6) into the joint bottom Figure 7A(6). As the fluid moves along the tube and progressively forces the membrane Figure 7A(5) away from the bottom, it applies pressure over a circular area via the flexible pressure pad 7A(7) onto 4 floating high friction composite shoes (Figure 7A(8). These in turn transmit the pressure to the four spheres 7B (21, 22, 23, 24) which are located in spherical seatings in the spherical joint case. As the pressure increases the balls progressively lock due to increasing frictional and distortional forces. Eight socket head screws Figure 7D(3) and Figure 7A(3) attach the joint bottom to the spherical case 7A(2). In addition they force an adequate seal between the joint bottom, 'O' ring 7A(4) and circular rubber membrane 7A(5). To unlock the spheres the hydraulic pressure is simply removed at the main control pump.

If however the angular relationship at the joints is supposed to be stored without fear of loss of

hydraulic pressure or made more secure, the central wedge shaped pressure cone Figure 7A(9) can be brought into action by screwing down nut Figure 7A(11) onto bolt Figure 7A(10). This forces the shoes apart and up. This action can lock the balls independently of the hydraulic system enabling extra nodes to be attached to the system. Two nodes can be clamped together to form an 8-way node. These can be assembled into three dimensional networks.

Pin 7A(12) forms part of a cable clamping device. It can travel up and down a hole in bolt 7A(10). One or more cables can pass through the holes at 7A(13 & 14), see also Figure 7D(2). The effect of screwing down the dome top 7A(15) is to jam the cables going through holes 7A(13 & 14) by the action of pin 7A(12) moving down the bolt. Unscrewing the down nut releases the pin 7A(12).

The dome nut 7A(15) completes the top of the spherical joint case to present a symmetric surface when a membrane is stretched directly onto the network. Alternatively bolt 7A(12) can be extended by a tapped tube which terminates either in a disc tube of regular or non regular shape onto which or from which a membrane could be supported. Alternatively elastic shock cord could be used, terminated in a shape, which in turn could support a membrane (not shown).

The pneymatic strut consists of two castings as in Figure 7C connected together by high pressure flexible tubes which can be either clamped or bound around set downs or serrations Figure 7C(2). As a safety precaution the two conic end castings are linked together by

a flexible wire or rope which can be attached to a lug as in Figure 7C(3). The wiere could be positioned centrally of the tube and be tensioned which reduces the forces on the tube attachment means.

The castings are conic in shape to enable the joint to pivot through a greater degree of freedom than a square end would permit when the tube diameter is greater than the distance between adjacent sphere centres, i.e. Figure 7B (spheres 21 & 22). The inflation points for the spheres (Figure 7C(4)) are recessed to prevent damage in use to delicate pressure fittings. The flexible pipe Figure 7D(5) connects the pneumatic struts together. They can incorporate non return valves as well as programmable switches as a safety measure. The interconnection of tubes is dependent on the required inflation pattern and the pattern of tube movement that is required.

The connecting pin 7A(18) ferrule 19 enables the joint to be attached to the pneumatic strut 7A(20) or other strut be it variable in length. It also enables the strut and joint to be linked to a special scaffolding connector Figure 7B(20) Figure 7D(20). The principle on which the locking mechanism takes place is in Figure 7A, the ferrule 19 forces the bolt 18 down into the attached strut 20. If the bolt 19 is not screwed right down rotational freedom about the long axis of the bolt is possible, but the member is still fixed vis-a-vis the joint in all other degress of freedom.

In Figure 7B(25) there are 4 holes tapped into the

side of the joint through which the cables in Figure 7D(2) can pass. The tapped holes enable the insertion into the system of variable length (remote control or not) triangulating members which can either stiffen or provide remote control over the system. If the remotely controllable variable length struts were programmed the structure could be made to move about relative to the ground.

It is possible for a structure with rigid aluminium tubes to be folded up for transportation and opened out for use.

To produce catenary compression forms, the structure is suspended from chain hoists or pulleys. Thereby all the forces within the net are resolved in pure tension under the action of gravity and a doubly curving catenary form is produced. The structure is then rigidified by locking the nodes and inverted by rolling or using the form memory capability. The inverted form produces a moulding that would be in pure compression enabling thin economical catenary shells to be produced, without the need for hours of complex dimensioning and calculations. This assumes the loading apart from the self weight is the same as on the hanging net.

The nodes can be connected in series with hydraulic lines. These are in turn connected to a set of master cylinders. Thus the whole structure could be controlled by one man especially with the use of remotely controlled variable length stays or wires.

Mould surface

This mould surface would be produced in a number of ways using the rigid skeleton net.

1. A material such as fibreglass, cloth, hessian, chicken wire, heat shrunk plastic could be stretched over the net when it is locked in position. The material could then act as a permanent shuttering and reinforcement for a variety of sprayed material.

2. An elastic/fine mesh cloth could be impregnated with a mould release solution (e.g. micromesh weave impregnated with silicone rubber). Five by five metre increments of this material could then be clipped to the grid along the tubes and at the nodes. The material would have to take up the distortion of the rigid net without creasing.

3. A net could be sealed in a double membrane of similar material to that used in 2. It would consist of air tight pockets attached to the tubes. The double membrane could either be evacuated to produce a ribbed mould surface or inflated to produce a coffered mould surface.

As regards the covering or membrane whether permanent or for forming the surface of a mould, a number of diamonds of various angles can be preformed and attached together by sipping or lacing together. About fourteen standard sized panels may be sufficient especially if the material is stretchable to provide for all requirements. If the membrane is double sided this could be inflated to take a quilted appearance.

Mould Memory

Figures 4, 5 and 6 show a way to produce repeat mouldings. Pneumatic tubes instead of aluminium ones are used. They can be rendered flexible by deflation and therefore permit the structure to collapse without the need to unlock the joints. Hence by reinflating the tubes again the structure will self erect to the form that it was last locked in. The locked joints act as the form memory to enable re-erection to the same shape if required.

Figures 18 show examples of structures which are particularly suitable for easily erected and locked networks of the kind described in this Application.

It will be appreciated that the geometric shape of the net or structure may be modified by any suitable mechanism, for example variable length struts or stays or any kind which may be connected across, say the diagonal of a square shape for example whereby the shape can be modified to other diamond shape by pulling a pair of opposite corners in towards one another or pushing opposite corners further apart. One can have two or three dimensional networks or tessalations.

The following is a summary of generating the form of the structure:-

(1) hang from hoists to generate catenary making suitable adjustments for imposed loading and wind loading;

(2) computer programme to design analyse structure having servo controlled jigs either to drill out fixed ball or set lockable node or

preset standard diagonal wires or stays. If one ball is used instead of four as in Figure 1 this is not now a variable structure but preset form for trusses, beams or any form of self erection but not variable;

(3) copy from scale model via computer through to structure.

The following is a summary of the method of covering the network using (a) materials that can expand or (b) materials that can be shrunk:-

(1) mesh material follows network mesh or structure; or

(2) elastic material follows network mesh; or

(3) combination of (1) and (2);

(4) material which can be shrunk to shape on structure.

The following is a summary of method of producing a mould or moulding:-

(1) use heat shrink plastic covering as in 4 above on which can be sprayed the required material and the shape removed from the plastic;

(2) use a material to generate the surface on the structure which will remain part of the moulding;

(3) use a material for generating the mould surface only over the structure, e.g. a coated knitted two-way stretch fabric.

The structure when not used for producing a mould may have a permanent covering by using any of the above

means. In addition when the structure is used as a supporting framework flexible pre-sized "fill in" panels may be attached, assembled only or incorporated into the framework.

The following is a summary of the method for producing a stable structure:-

(1) preset wire lengths + pneumatic tubes + flexible joint nonlocking;

(2) variable length strut + pneumatic tubes + flexible non-locking joint;

(3) remote control diagonal + rigid tubes + non-locking joints;

(4) remote control diagonal variable length strut + pneumatic struts + non-locking joints;

(5) all as above + locking joints.

Self erecting struts may take the following forms pneumatically operated, hydraulically operated or electrically operated.

Preset wire lengths need not be preset if they are anchored automatically by the stabilisation of the joint and the wires become trapped or otherwise fixed in the joint when activated.

Adjustable stays or struts may be electrically operated or operated hydraulically or pneumatically. A meridian scale on the ball may assist erection to the required form in addition to any "gates".

CLAIMS

1. A collapsible structure comprising a plurality of elongate members connected at their ends by joints to form a network, the joints being adjustable to allow the relative angular positions of the elongate members to be varied and further being lockable to maintain the elongate members in their desired relative angular positions.

2. A structure as claimed in Claim 1 in which the joints are adapted to connect at least three elongate members.

3. A structure as claimed in Claim 1 or Claim 2 in which the elongate members are in the form of rigid hollow tubes.

4. A structure as claimed in Claim 1 or Claim 2 in which the elongate members are in the form of collapsible hoses.

5. A structure as claimed in Claim 1 or Claim 2 in which the joints are ball joints which are lockable by means of a fluid under pressure.

6. A structure as claimed in Claim 1 or Claim 2 further including flexible stays connected between the joints.

7. A structure as claimed in Claim 1 or Claim 2 further including a numerical control system for controlling the erection of the structure.

8. A method of erecting a collapsible structure which comprises connecting together a plurality of elongate members, by their ends, by means of joints, to form a network, suspending the network to form a catenary shape, locking the joints to form a rigid structure maintaining the catenary configuration, and inverting the structure.

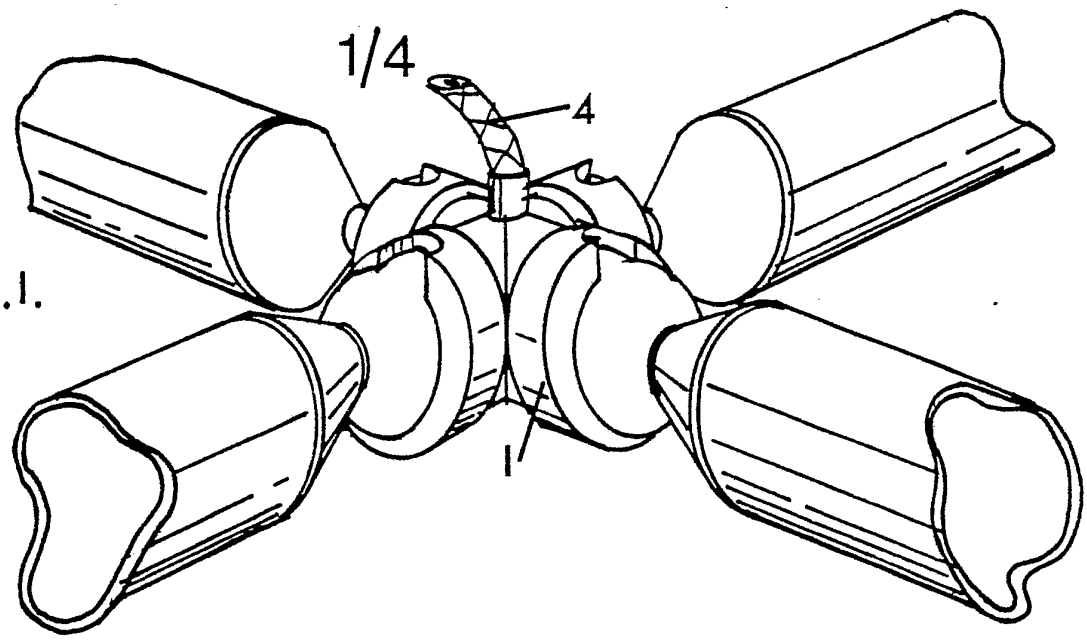

FIG.1.

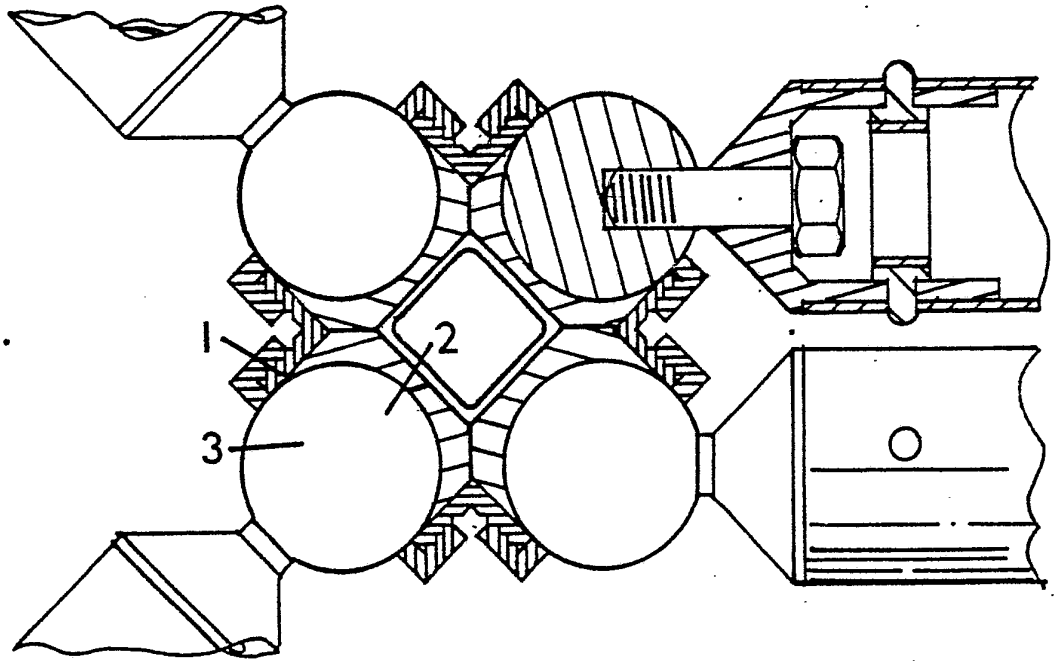

FIG.2.

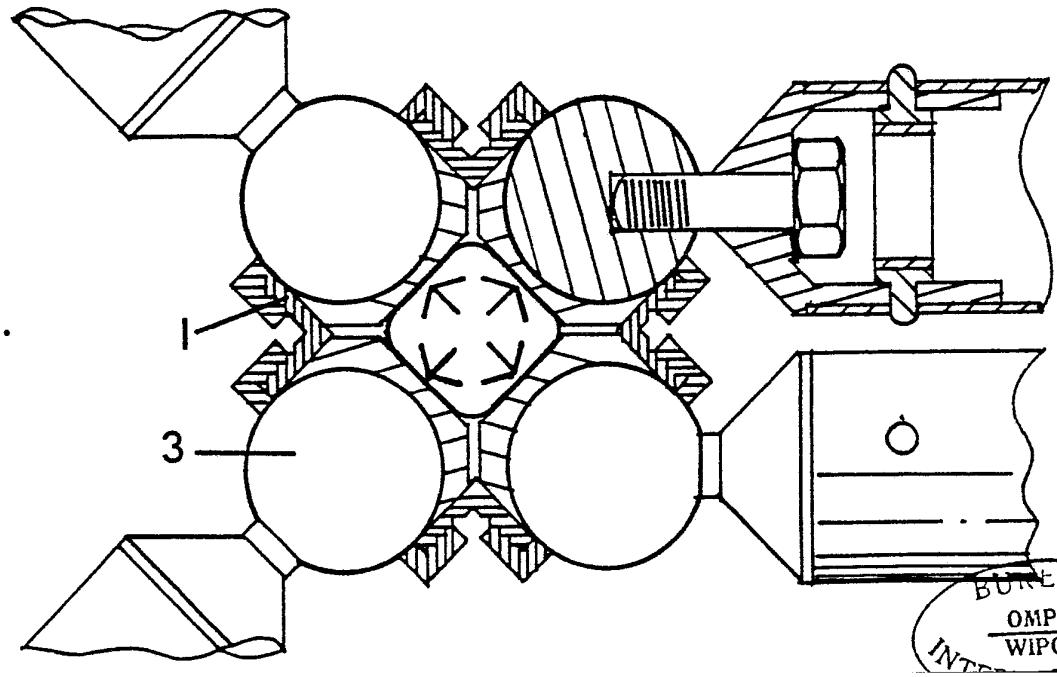

FIG.3.

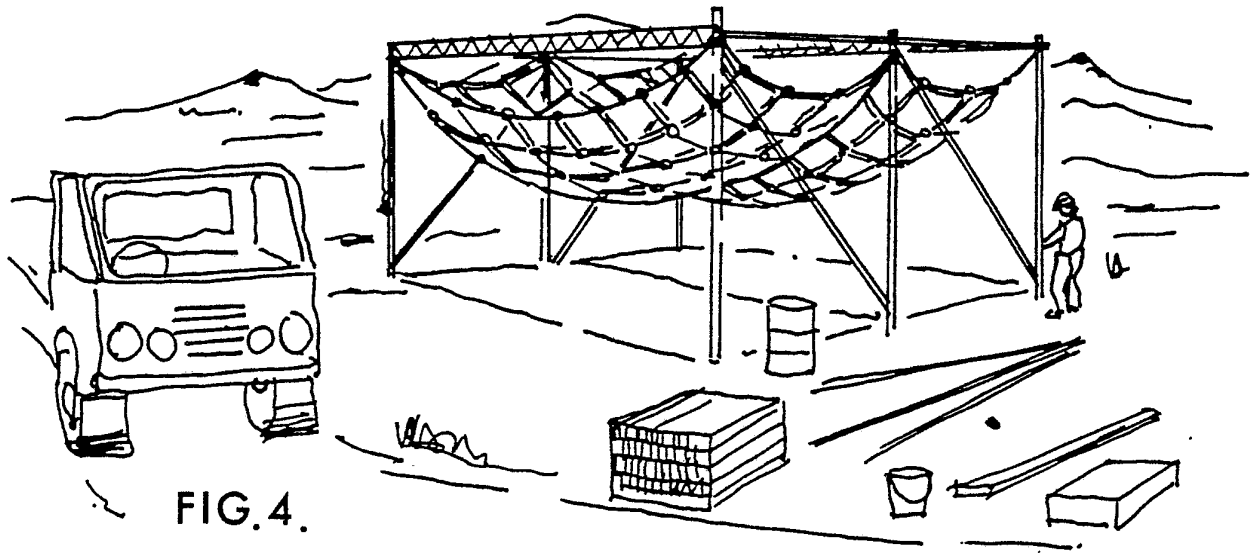

FIG.4.

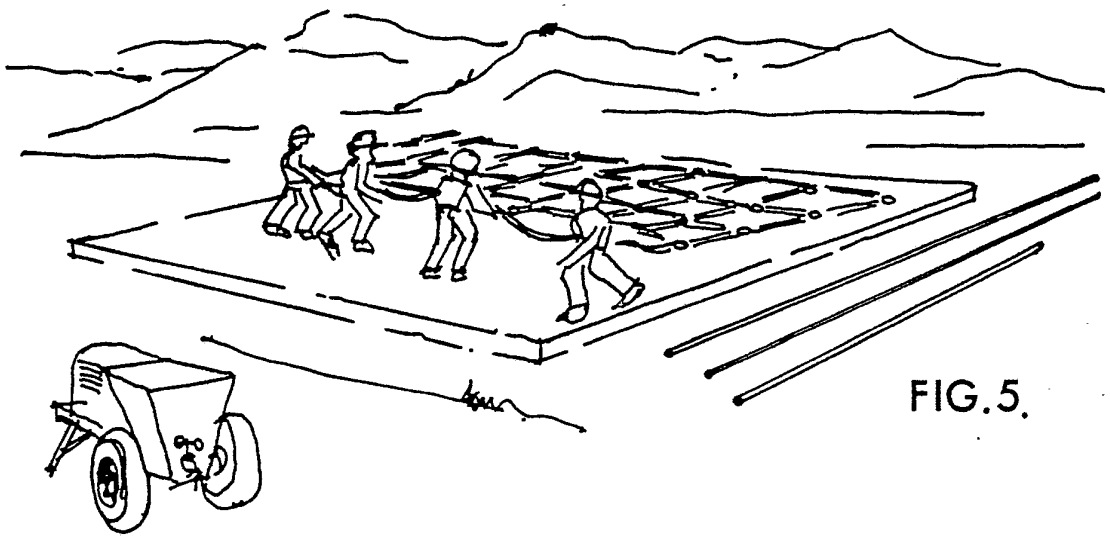

FIG.5.

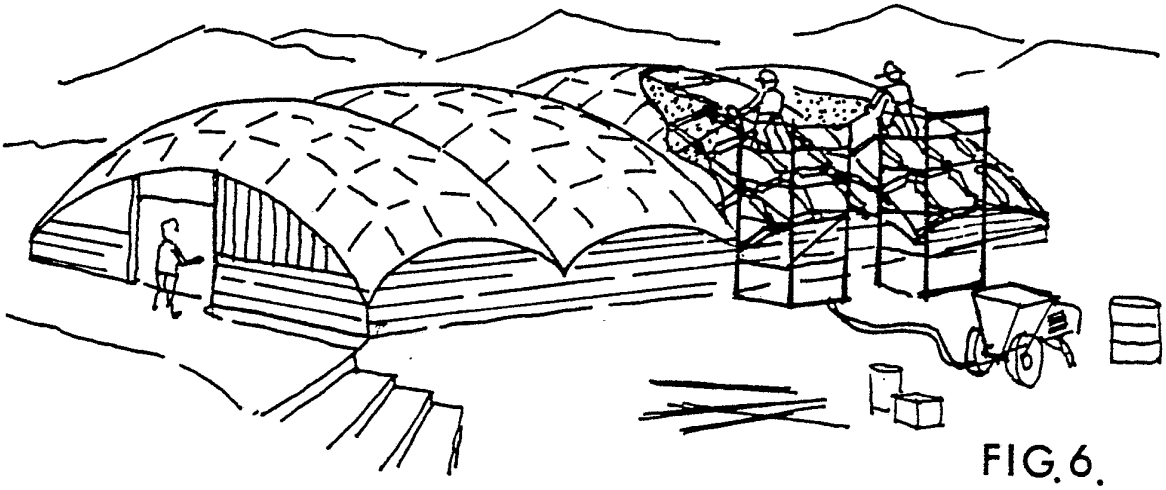

FIG.6.

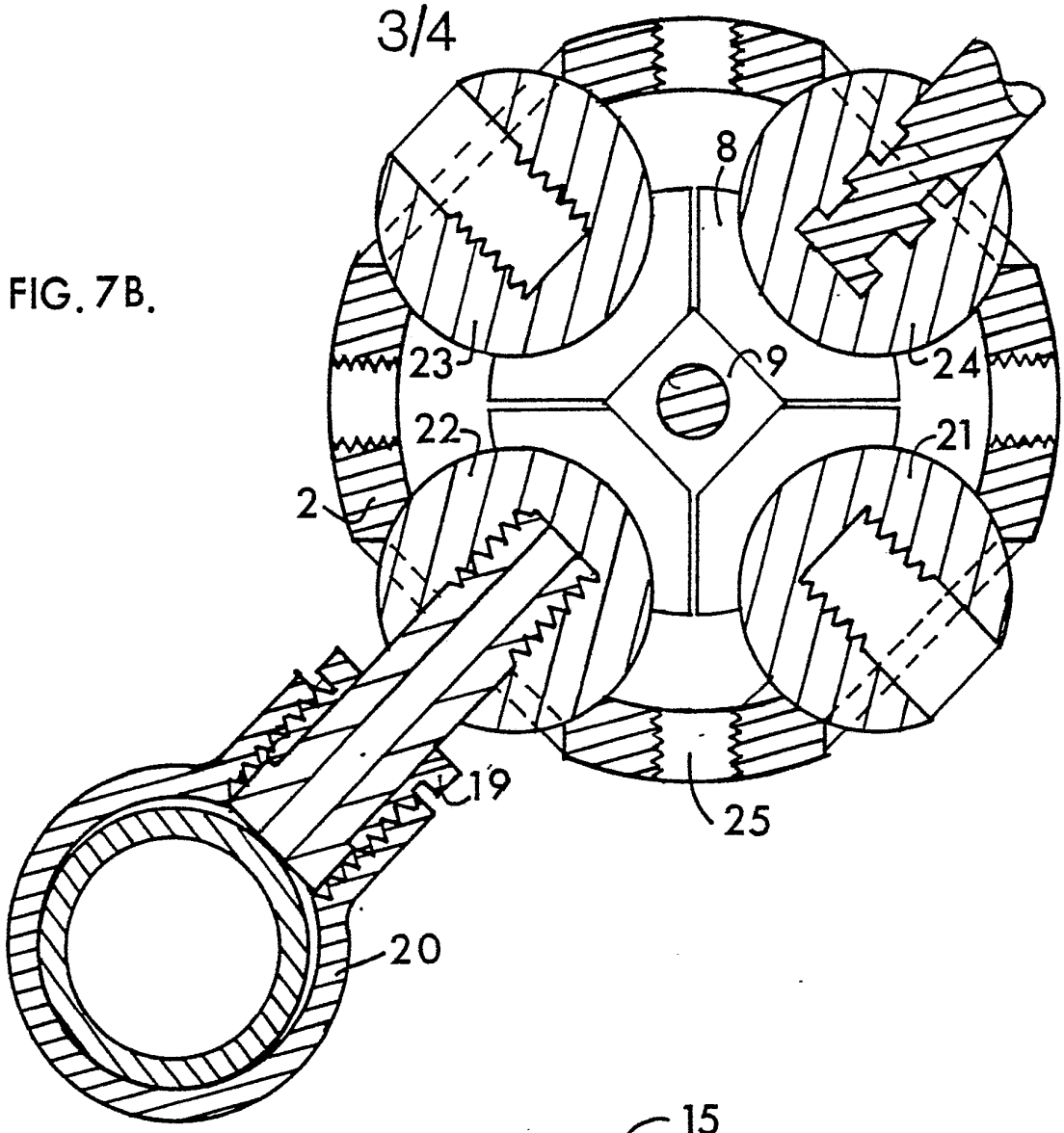

FIG. 7B.

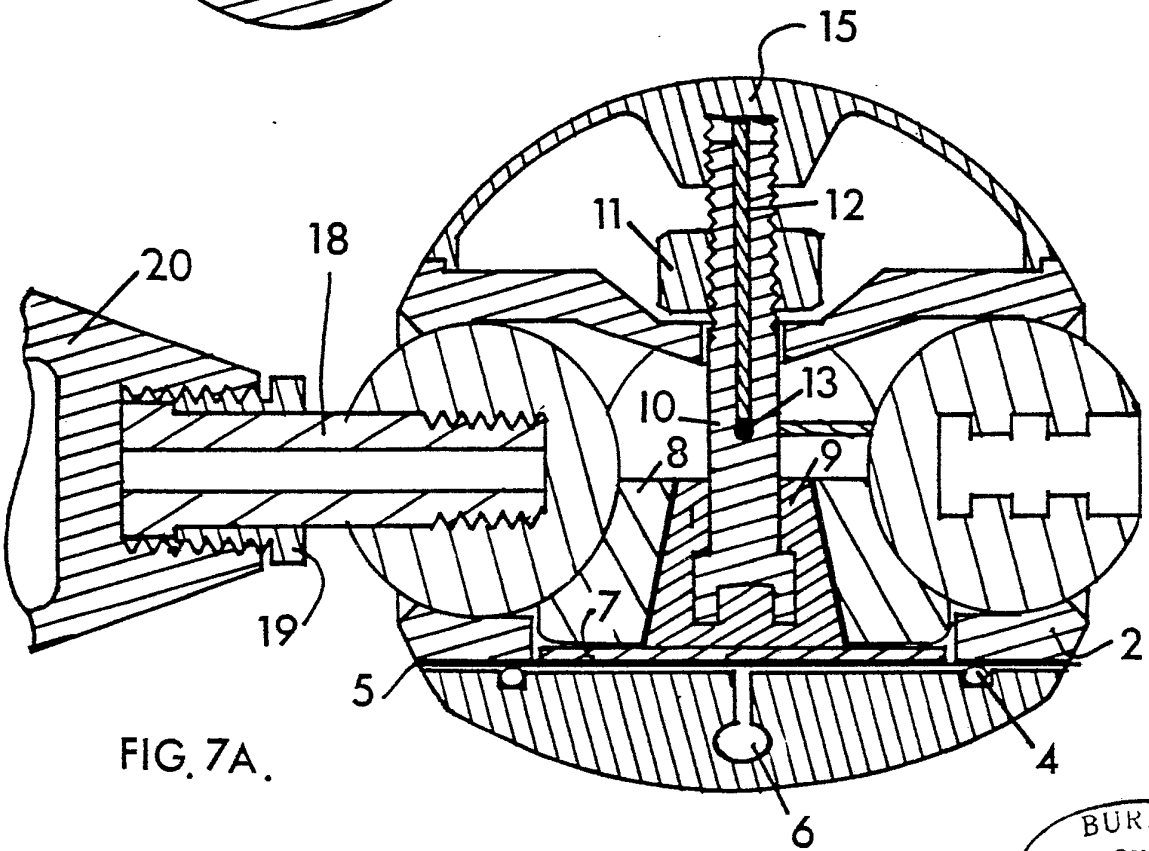

FIG. 7A.

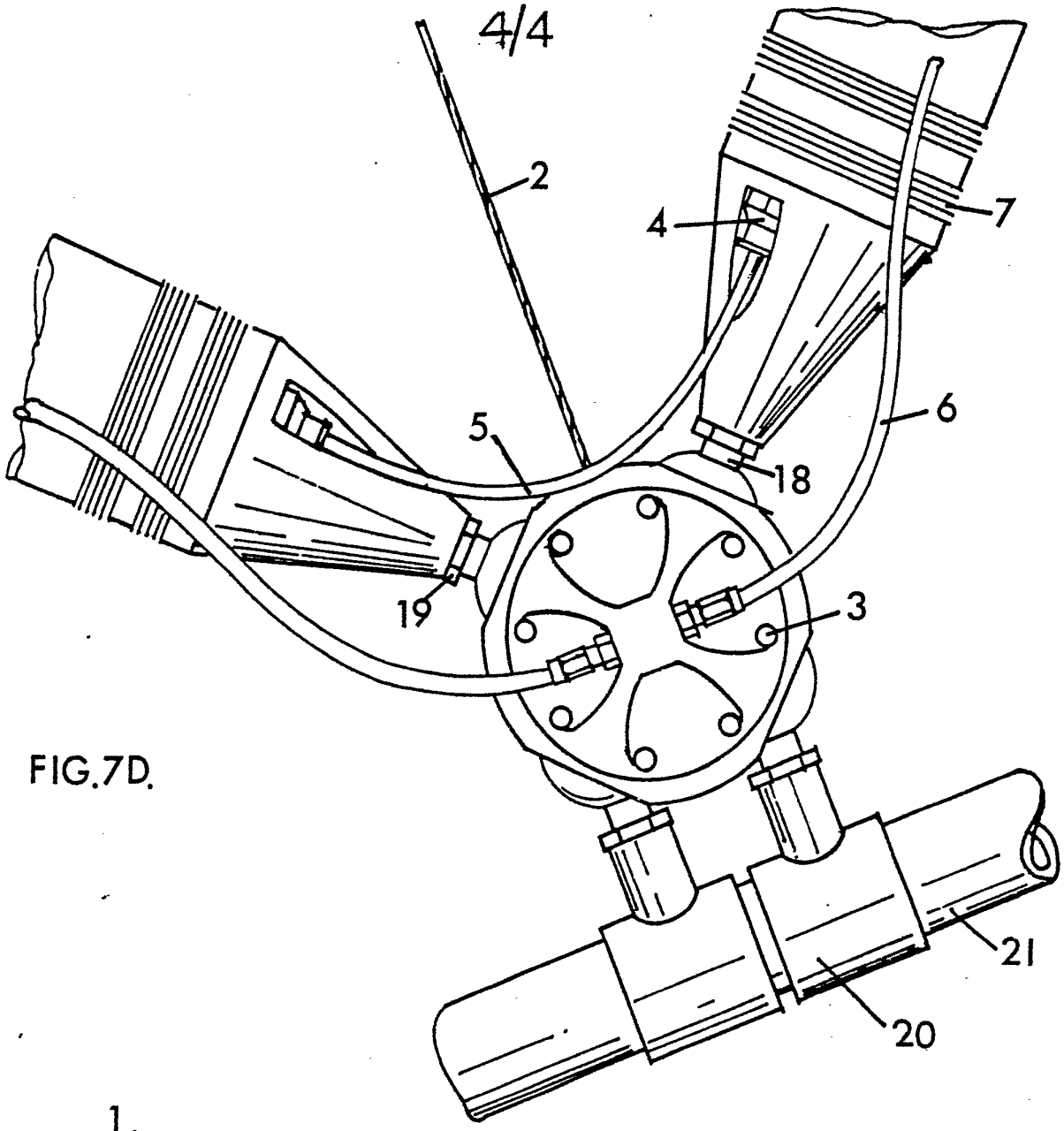

FIG.7D.

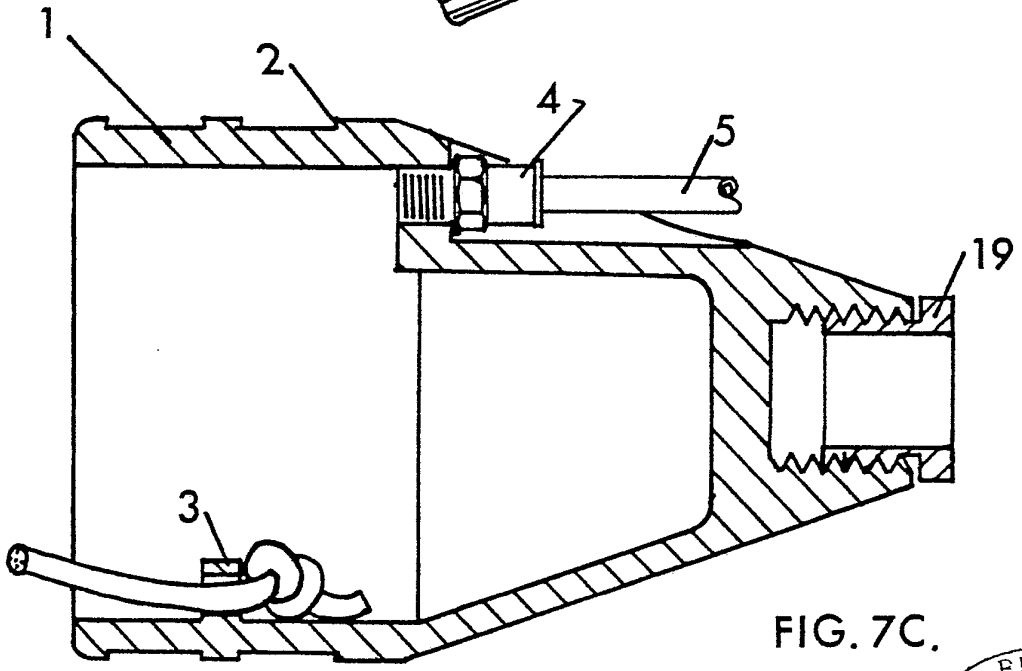

FIG. 7C.

INTERNATIONAL SEARCH REPOR.

International Application No PCT/GB 80/00110

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [3]

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

Int.Cl.[3]: E 04 B 1/19; E 04 G 11/04; E 04 B 1/345; E 04 B 1/344

II. FIELDS SEARCHED

Minimum Documentation Searched [4]

Classification System	Classification Symbols
Int.Cl.[3]	E 04 B; E 04 G

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [5]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [14]

Category *	Citation of Document, [16] with indication, where appropriate, of the relevant passages [17]	Relevant to Claim No. [18]
X	FR, A, 2136936, published 29th December 1972, see page 4, lines 32-40; page 5, lines 1-40; page 6, lines 1-31; figures 1-7, Maymont	1,2,3
X	FR, A, 2081777, published 10th December 1971, see page 13, lines 1-36; page 14, lines 1-36; page 15, lines 1-21; figures 1-8, Peret	1,2,3
X	FR, A, 1406076, published 16th July 1965, see page 1, column 2, lines 32-42; page 2, column 1, line 54; column 2, lines 1-13; figures 1-5, Garcia	1,2,3
	DE, A, 1659121, published 17th December 1970, see page 1, lines 10-33; page 2, lines 1-34; page 3, lines 1-20; figures 1,2,3, Herold	4
	FR, A, 2341017, published 9th September 1977, see page 3, lines 22-36; page 4, lines 1-39; page 5, lines 1-8; figures 1,2,3, Potocki	4

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IV. CERTIFICATION

Date of the Actual Completion of the International Search [1]	Date of Mailing of this International Search Report [2]
24th September 1980	1st October 1980
International Searching Authority [1]	**Signature of Authorized Officer [20]**
European Patent Office	G.L.M. Kruydenberg

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III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)

Category *	Citation of Document, 16 with indication, where appropriate. of the relevant passages 17	Relevant to Claim No 18
X,P	DE, A, 2815243, published 11th October 1979, see page 6, lines 52-56; page 7, lines 1-58; figures 1,2,3,4, Sander	1,2,3