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(54) **Lining of tubular structures.**

(57) A tubular structure, such as a sewer, is lined by the use of long length elements having edge formations which facilitate a number of the elements being arranged in a side-by-side interlocked configuration within the tunnel structure. At least some of the elements are formed with a cavity into which a settable compound may be injected thereby to strengthen the lining when set. Preferably the elements are relatively flexible prior to injection with the settable compound so as to facilitate storage of long lengths on a drum.

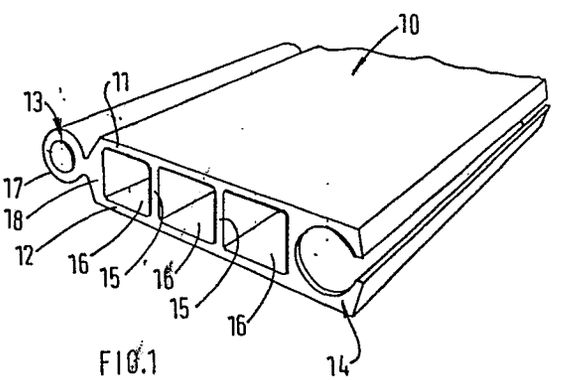

FIG.1

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LINING OF TUBULAR STRUCTURES

This invention relates to a method of and means for forming a lining in a preformed tubular structure, and in particular, though not exclusively, to the lining of tunnel-type structures such as sewers.

Many underground tunnels in the U.K. and overseas, and especially those used as sewers, were constructed some 80 to 150 years ago and it is now found that although the bricks used in construction of the tunnels are still in sound condition in many instances the mortar between the bricks is severely eroded.

In consequence of this erosion a tunnel's ability to withstand external ground pressure is substantially reduced and frequently a localised length of tunnel will collapse thus resulting in much inconvenience and the need for extensive and urgent repair work.

To guard against inadvertent collapse the brickwork can be repointed but this is a very time consuming and expensive operation, particularly for the smaller of the man entry type tunnels in which working space is very restricted.

The alternative approach of forming a new lining within the tunnel has the potential advantage of facilitating provision of a smooth surface having low fluid flow resistance, and also of reducing the requirement for extensive manual work within the restricted space of a tunnel. However, in the currently known lining techniques, the lining structure is relatively expensive, or time consuming to install, or there is a requirement for extensive ground excavation at intervals along the length of the tunnel in order to facilitate maneouvering of the lining structure into the tunnel.

The present invention seeks to provide a method of lining a tubular structure, and lining elements therefor, in which the aforedescribed difficulties are mitigated or overcome.

In accordance with one aspect of the present

invention a method of lining a tubular structure comprises:-

feeding into the structure a plurality of elongate elements, at least some of which are of a kind having at least one cavity; arranging the elements to extend substantially parallel with the direction of the length of the structure, and with said elements disposed in a side-by-side and interlocking configuration to form a lining which conforms substantially to the internal surface of the tubular structure; and then injecting into said cavities a settable compound.

In addition to injecting settable compound into said cavities preferably a settable compound is injected between the internal surface of the tubular structure and the external surface of the lining of elongate elements.

The settable compound may be allowed to set before further compound is injected between the tubular structure and elongate elements, or settable compound may be caused to flow substantially simultaneously into the cavities and between the lining and tunnel structure.

Preferably the elongate elements are brought into side-by-side relationship by feeding successive lengths into the tubular structure in such a manner that they slide along and are guided by the edge of an elongate element which is already installed in the tubular structure. Preferably an elongate element is guided during insertion by means which also effects interlocking of successive elements.

Preferably the elongate element has a length substantially greater than the maximum cross-sectional dimension of the tubular structure being lined thereby to facilitate relatively speedy installation of a lining and minimise the need to effect numerous joints between the ends of successive lengths of the elongate elements.

Typically the length of each elongate element employed should be at least ten times, and preferably 50 or more times the maximum cross-sectional dimension of the element. Lengths of 100 metres or more are envisaged. Where, however, the requirements of the lining dictate otherwise, e.g. gaps in the lining for side entrant tunnels, use may be made of some elongate elements of shorter length.

Particularly where the elongate element is of a very long length, lubricant means, either a low friction material or lubricating fluid, may be employed to facilitate sliding movement of one element into position alongside another element.

Relative movement of an assembled pair of interlocked elements may be restrained by the use of an adhesive. Accordingly those elements which form a roof lining may be supported by adjacent elements with a need for only minimal, if any, temporary support. Preferably the adhesive is of a slow acting kind and incorporated in or serving as the aforementioned lubricant.

The elongate elements may be fed singly into the tubular structure or two or more elements may be preassembled together in side-by-side relationship before being fed into the tubular structure.

Suitable settable compound for filling the cavities of the elongate elements to effect reinforcement thereof include:-

grouts including cement based mixtures, and polymer and/or resin based materials.

Suitable settable compounds for injection between the lining of elongate elements and the internal surface of the tubular structure include those mentioned in the preceding paragraph.

In accordance with another aspect of the present invention an elongate element for use in lining a tubular structure comprises a pair of face members maintained spaced apart to define therebetween at least one cavity into which a settable compound may be injected, and a

pair of substantially longitudinally extending formations at opposite edges of the face members thereby to facilitate interlocking of said elongate element in parallel side-by-side relationship with another elongate element.

Preferably said formations are complementary shaped such that a pair of said elements may be interlocked directly together. Alternatively however a pair of elements with similar formations may be interconnected by a third element having formations complementary to those at the edges of said pair of elements to be joined. The third element may be of a kind as defined in the preceding paragraph or it may be of a different construction.

The substantially longitudinally extending formations may serve also as guide means to facilitate one elongate member being slid into interlocking side-by-side relationship with another elongate element.

At least one of a pair of formations may be formed of a low friction material, or provided with means for facilitating lubrication of movement between two complementary shaped formations.

One of the formations may be hollow, or otherwise shaped such that a lubricant may be supplied therethrough to facilitate relative sliding movement between the complementary shaped formation.

Preferably said cavity within the element extends substantially continuously along the length thereof. The face members of the elements may be maintained spaced apart by dividers extending continuously along the length of the element, and said dividers may serve to define in part two or more cavities.

The elements may be of different shapes; elements of one shape may have a longitudinally extending rib-like formation and act as spacers which contact the wall of the tubular structure and maintain other successive elements spaced therefrom.

Not all of the elements used to form the lining

of a tunnel need be elements of a kind in accordance with the present invention. Thus, some of the elongate elements, such as those used as wall spacers, need not be of a kind having cavities.

Suitable materials for forming the elongate elements include polyethylene, polypropylene, polycarbonates, and unplasticised p.v.c. Of these it is preferred for many applications to employ materials such as unplasticised p.v.c. which are relatively light weight whilst also being of a relatively low coefficient of friction such that complementary shaped formations constructed integral with the elongate element readily facilitate relatively sliding movement of the two elements into side-by-side interlocking relationship.

Although the elongate element should be substantially rigid so as to be adequately self-supporting to form the lining of a tubular structure, at least when cavities thereof are filled with a settable compound which has been allowed to set, the element may be sufficiently flexible along its length so as to be coiled on a large diameter storage drum from which it may conveniently be unwound for feeding into the tubular structure. For this purpose the formation of an elongate element from a pair of face members which are maintained spaced apart by the aforementioned dividers, which preferably are relatively thin as compared with the face members, is particularly advantageous insofar as the resulting construction of the element is sufficiently rigid to be self-supporting when assembled to form the lining of a tubular structure, has a good strength to weight ratio, and is also capable of being wound on a large drum for storage prior to use.

If the materials or other features of the element result in it being insufficiently flexible for storage on a drum, the element(s) may be supplied in pre-selected discrete lengths.

In the case of those elongate elements of a kind having a cavity, openings may be provided in a wall

of the cavity such that in use settable compound injected into said cavity can flow therefrom into any space between the lining and the inner surface of a tubular structure, e.g. a tunnel wall. Thus back grouting is effected substantially simultaneously with filling of the cavities.

Effecting back grouting substantially simultaneous with filling of the cavities results in the lining assembly being required to withstand external, or back, pressure before the lining elements have been strengthened by setting of the compound therein. The consequential need to temporarily support the lining elements may be reduced or avoided in some applications by providing openings of a suitable size and at a sufficient frequency to obviate the need to create localised grouting pressures as great as those required when the back grouting of a long length is effected from a single grout entry location.

To facilitate the flow of grout between the lining elements and internal surface of the tubular structure in the case of elements, spacer elements, of a kind having rib-like spacer formations to space the lining from the tubular structure, the spacer formations should be substantially discontinuous in the longitudinal direction.

The use of a substantially discontinuous spacer formation results in interconnection of the settable compound, either side of the spacer formation, at a substantial number of longitudinally spaced locations. When the grout has set there results a mechanical interlock between the grout and elongate elements by virtue of the spacer formations, thus providing a strong composite lining structure.

Embodiments of the invention will now be described, by way of example, with reference to the accompanying diagrammatic drawings in which:-

Figure 1 shows in perspective an end portion of an elongate lining element;

Figure 2 shows in perspective an end portion of an elongate spacer element;

Figure 3 is a cross-section of part of a tunnel structure lined with the elements of Figures 1 and 2;

Figure 4 is a perspective view of part of a tunnel lining assembly formed from the elements of Figures 1 and 2;

Figure 5 is a perspective view of a connector for longitudinally connecting lining elements;

Figure 6 is a perspective view of an end portion of a space element for use alongside the connector of Figure 5;

Figure 7 shows in perspective part of a lining element for conforming to a side entry junction;

Figure 8 shows in perspective an end portion of another elongate lining element in accordance with the present invention;

Figure 9 shows in perspective an end portion of another elongate spacer element in accordance with the present invention, and

Figure 10 is a view similar to that of Figure 9 of yet another elongate spacer element in accordance with the invention.

An elongate lining element 10 (see Figure 1) for lining a tunnel comprises a pair of face members 11,12 maintained spaced apart by a pair of edge formations 13,14 and a pair of wall dividers 15. The edge formations and wall dividers extend continuously along the length of the lining element and define therebetween, between the face members 11,12, three longitudinally continuous cavities 16 each of substantially rectangular shape in cross-section.

One of the edge formations, 13, comprises a tubular formation 17 having a smooth external surface of

a diameter slightly less than the spacing of the outer surfaces of the face members 11,12. The edge formation 13 additionally comprises an edge strip 18 which is integral with the tubular formation 17 and extends between the neighbouring longitudinal edges of the face members.

The other edge formation 14 is in the form of a longitudinally extending groove the internal surface of which has a shape complementary to that of the tubular formation 17 such that the formation 13 of another element may slide in and be guided by edge formation 14.

The lining element above described is manufactured from unplasticised polyvinyl chloride by extrusion, this material affording the edge formations 13,14 a low coefficient of friction. The described element has a width of 150 mm and thickness of 20 mm.

An elongate spacer element 20 for interconnecting a pair of lining elements and maintaining them slightly spaced from a tunnel wall is shown in Figure 2.

The spacer element 20 comprises a side-by-side pair of longitudinally extending formations 21,22 corresponding respectively to the tubular formation 17 and edge formation 14 of the aforedescribed lining element 10. The spacer element additionally comprises a formation 23 which is T-shaped in cross-section and the head portion 24 of which is maintained spaced from but parallel with a plane containing the formations 21,22 by a tail portion 25.

The spacer element is also manufactured from p.v.c. by extrusion.

To line a tunnel long lengths of the elongate lining and spacer elements may be stored on a pair of drums, and said drums positioned at the head of a trench cut in the ground to have a gradual slope extending down to an access point in the tunnel.

A length of the lining element is then drawn into the tunnel from the drum, the length being cut either to that of the length of the tunnel under renovation

or the maximum length for which elements can satisfactorily be slid into engagement, whichever is the greater. The spacer element is then drawn from its supply drum and fed into the tunnel with an edge formation of the spacer element co-operating with an edge formation of the lining element so as to effect guiding of the spacer element relative to the lining element and interlocking therewith.

Alternatively where the elements are provided in preselected discrete lengths they may be fed into the tunnel in a similar manner to result in the required interlocking.

Particularly where elements of long length are being interconnected, liquid lubricant may be supplied through the tubular formation 17 of the lining element (or corresponding formation of the spacer element) in such manner as to apply lubricant to the surface of the complementary groove formation just prior to sliding thereof over the outer surface of the tubular formation.

Successive lengths of the two types of elements are then supplied so as to result, for most installations, in an alternating series of spacer and lining elements. Where, however, there is no requirement for a significant thickness of grout between the tunnel and lining, such as for example at the floor regions, lining elements may be directly interconnected.

Figure 3 shows the upper part of a tunnel 28 lined with an alternating series of lining elements 10 and spacer elements 20 with the spaces between the lining elements 10 and tunnel wall and also the lining elements per se being filled with grout 29.

To facilitate lining of the roof portion of the tunnel use may be made of temporary supports for the elements, these supports being removed after the required number of linings have all been inserted.

Alternatively or additionally successive elements may be restrained from hinging one relative to the other by means of adhesive acting between the complementary formations of a pair of the elements.

The adhesive may be applied instead of the lubricant, may act as the lubricant, or be an additive to the lubricant fed through the tubular formations in the above-described manner when necessary to facilitate relative sliding movement.

Figure 4 shows an assembly of lining and spacer elements for lining the roof and side parts of a tunnel.

Where it is required to line a length of tunnel longer than the length of elements which can readily be slid one relative to the other, use may be made of end connectors 30 (see Figure 6) for joining the ends of successive lining elements. Each connector has edge formations 31,32 corresponding to the formations 13,14 of a lining element, and tapered tubular location portions 33 for engagement in the cavities 16 of a lining element. The connector 30 is of a hollow construction, typically formed by joining two injection moulded sections (having a joint line shown as 34), and thus permits grout to be fed directly from the cavity 16 or tubular formation of one element into another element.

Where spacer elements 20 interconnect a pair of the connector elements it is preferable that the T-shaped formation 23 is cut-away (see Figure 5) for a length corresponding to the longitudinal length of the connector. Thus when grout is fed to the space between the lining and tunnel wall there results a continuous reinforcing hoop of the grout around the joint region.

Having assembled the required lining and spacer elements, one end of each cavity bore of each tubular formation is blanked off (except for a small air vent orifice) and grout is pressure injected into the bores and cavities. When this has set it results in a substantial increase in strength of the lining, and further grout material can then be injected between the lining and tunnel wall to fill the gap therebetween and crevices in the tunnel brickwork without any risk of collapse of the lining. If it is required to provide a lining at a tunnel junction preferably the elements are

either pre-cut (see Figure 7) or cut in situ in the tunnel before grout is injected either into the elements or between the elements and tunnel wall.

An elongate lining element in accordance with a further aspect of the invention is shown in the accompanying Figure 8, in which like reference numerals correspond to those used for similar details as shown in Figure 1.

One of the face members 11 is provided with three series of openings 40. Each series of openings 40 is aligned with a respective one of the three cavities 16, and the positions of the openings in adjacent series are staggered with respect to the longitudinal direction of the element.

In use the openings 40 provided in the wall of the cavities 16 enable settable compound injected into said cavity to flow therefrom into the space between the lining and the inner surface of a tubular structure, e.g. a tunnel wall. Thus back grouting is effected substantially simultaneously with filling of the cavities.

Two embodiments of elongate elements having spacer formations which are substantially discontinuous are shown in part and in perspective in the accompanying Figures 9 and 10.

In Figure 9 there is shown an element 50 having a series of spacer formations 51 each comprising a head portion 52 for bearing against a tunnel wall and a tail portion 53 which interconnects between a head portion and main body portion 54 of the element.

In the embodiment of Figure 10 the tail portions 53 correspond to those of Figure 9 but the head portion 55 is longitudinally continuous. This type of construction is particularly useful when lining tubular structures having irregular lining surfaces because the continuous head portion acts as a smooth skid in the event of sliding contact between the element and inner surface of the tubular structure.

In a further embodiment, not illustrated, the

spacer formations 51 may be provided on an elongate element of a kind having cavities, and preferably of a kind as shown in Figure 8 in which openings are provided for the flow of grout from a cavity.

The head portion(s) 52,55 of the spacer formations of the preceding two above-described embodiments are particularly effective to provide a good mechanical interlock between the elements and grouting, whilst the discontinuous nature of the spacer formations permits a substantial degree of continuity of grouting material in a peripheral direction perpendicular to the length of the lining.

CLAIMS:

1. Method of lining a tubular structure characterised in that it comprises:-

feeding into the structure a plurality of elongate elements (10) at least some of which are of a kind having at least one cavity (16); arranging the elements to extend substantially parallel with the direction of the length of the structure, and with said elements disposed in a side-by-side and interlocking configuration to form a lining which conforms substantially to the internal surface of the tubular structure; and then injecting into said cavities a settable compound.

2. Method according to claim 1 characterised in that settable compound is injected between the internal surface of the tubular structure and the external surface of the lining formed by said elongate elements (10).

3. Method according to claim 2 characterised in that settable compound injected into the elements is allowed to set before settable compound is injected between the tubular structure and elongate elements.

4. Method according to any one of the preceding claims characterised in that the elongate elements (10) are brought into side-by-side relationship by feeding successive lengths into the tubular structure in such manner that they slide along and are guided by the edge of an element already installed in the tubular structure.

5. Method according to claim 4 characterised in that lubricant means is employed to facilitate sliding movement of one element into position alongside another element.

6. Method according to any one of the preceding claims characterised in that relative movement of an assembled pair of interlocking elements is restrained by the use of an adhesive.

7. Method according to claim 6 characterised in that said adhesive is of a slow acting kind.

8. Method according to claim 6 or claim 7

characterised in that said adhesive is incorporated in or serves as the lubricant.

9. Elongate element for use in lining a tubular structure characterised in that it comprises a pair of face members (11,12) maintained spaced-apart to define therebetween at least one cavity (16) into which a settable compound may be injected, and a pair of substantially longitudinally extending formations (13,14) at opposite edges of the face members thereby to facilitate interlocking said elongate element (10) in parallel side-by-side relationship with another elongate element (20).

10. Elongate element according to claim 20 characterised in that said formations (13,14) are complementary shaped.

11. Elongate element according to claim 9 or claim 10 characterised in that said longitudinally extending formations (13,14) serve also as guide means for facilitating sliding of one elongate member (10) into interlocking side-by-side relationship with another elongate element (20).

12. Elongate element according to any one of claims 9 to 11 characterised in that at least the surface of at least one of a pair of formations (13,14) is formed of low friction material.

13. Elongate element according to any one of claims 9 to 12 characterised in that means is provided for facilitating lubrication of movement between two complementary shaped formations.

14. Elongate element according to claim 13 characterised in that it comprises a longitudinally extending formation (17) which is hollow for supply of lubricant therethrough.

15. Elongate element according to any one of claims 9 to 14 characterised in that said cavity (16) extends substantially continuously along the length of the element.

16. Elongate elements according to any one of claims

9 to 15 characterised in that the face members (11,12) of the elements (10) are maintained spaced-apart by dividers (15) which extend along the length of the element.

17. Elongate element according to claim 16 characterised in that said dividers (15) serve to define in part two or more cavities (16).

18. Elongate element according to any one of claims 9 to 17 characterised in that an opening (40) is provided in one of the face members (11) in communication with said cavity (16) for the flow of settable compound.

19. Elongate element according to any one of claims 9 to 18 characterised in that it comprises a longitudinally extending rib-like formation (51).

20. Elongate element according to claim 19 characterised in that said rib-like formation (51) comprises a longitudinally continuous head portion (52) and a longitudinally discontinuous tail portion (53) between said head portion and the remainder (54) of the element.

21. Tunnel lining characterised in that it comprises a plurality of elongate elements (10) according to any one of claims 9 to 20.

22. Tunnel lining according to claim 21 characterised in that it comprises an elongate element (20) provided with a longitudinally extending rib-like formation.

23. Tunnel lining according to claim 22 characterised in that said rib-like formation (51) is longitudinally discontinuous.

24. Tunnel lining according to claim 22 or claim 23 characterised in that said elongate element is an elongate element in accordance with any one of claims 9 to 22.

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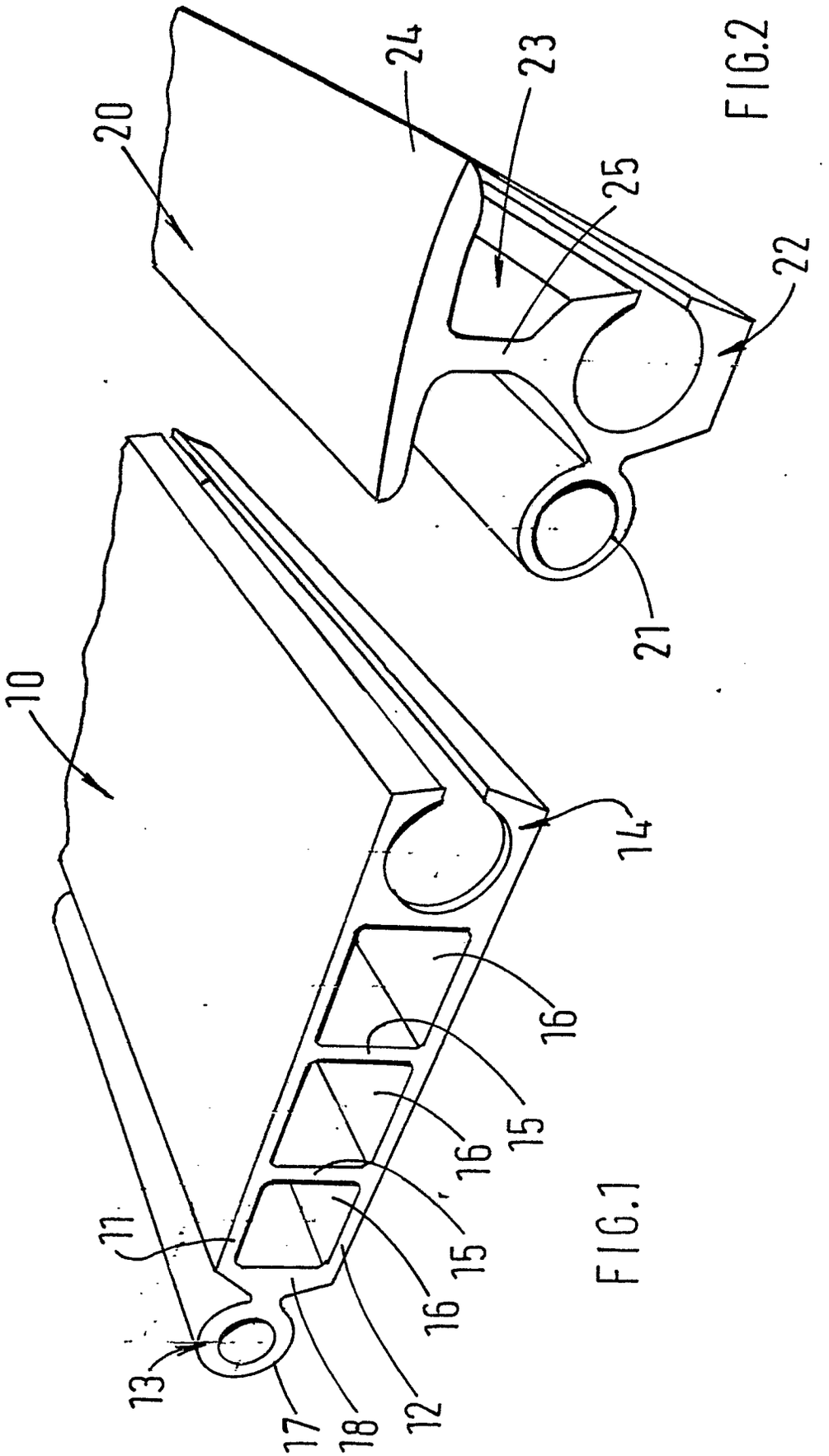

FIG.1

FIG.2

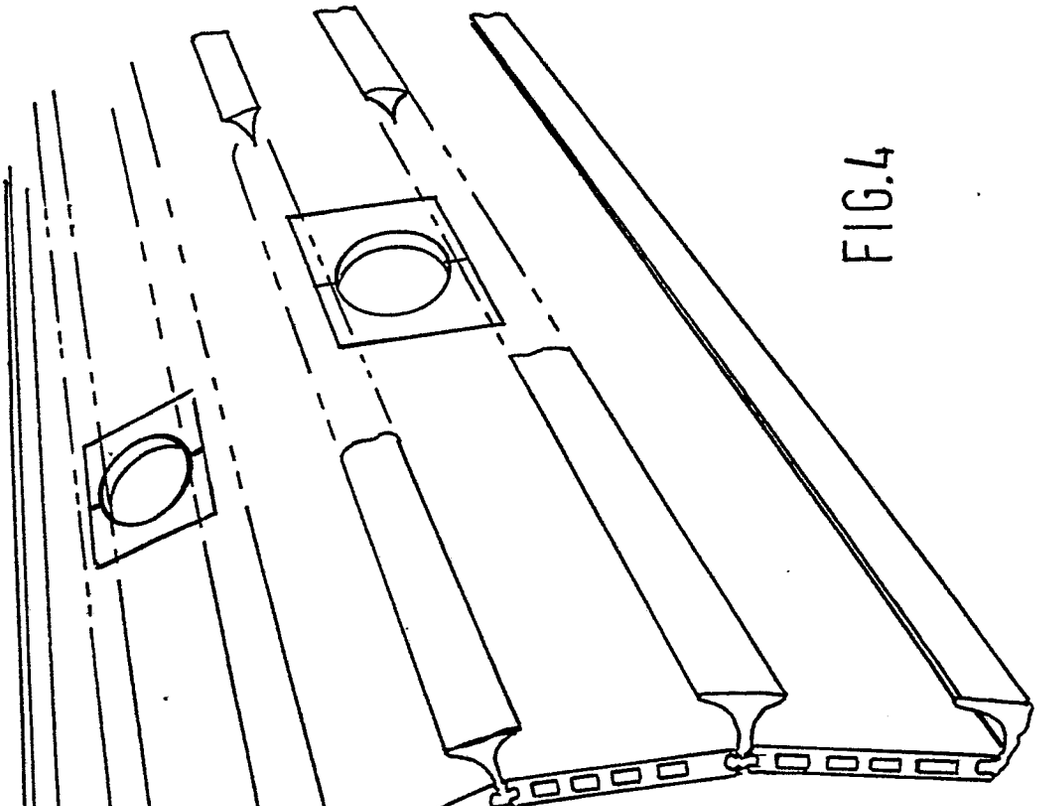

FIG.4

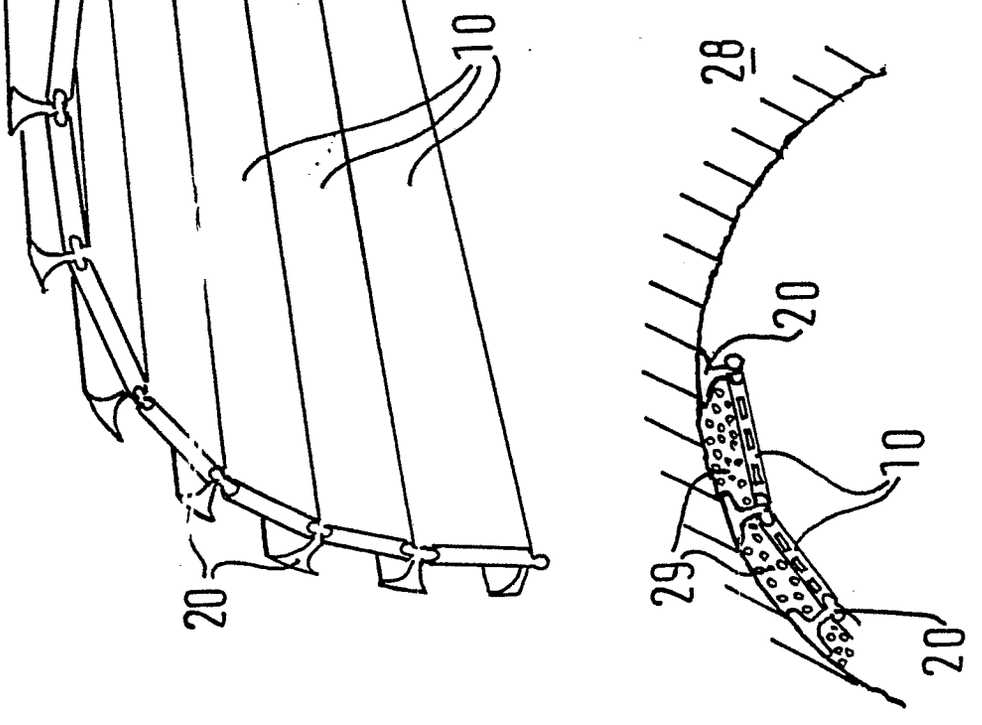

FIG.3

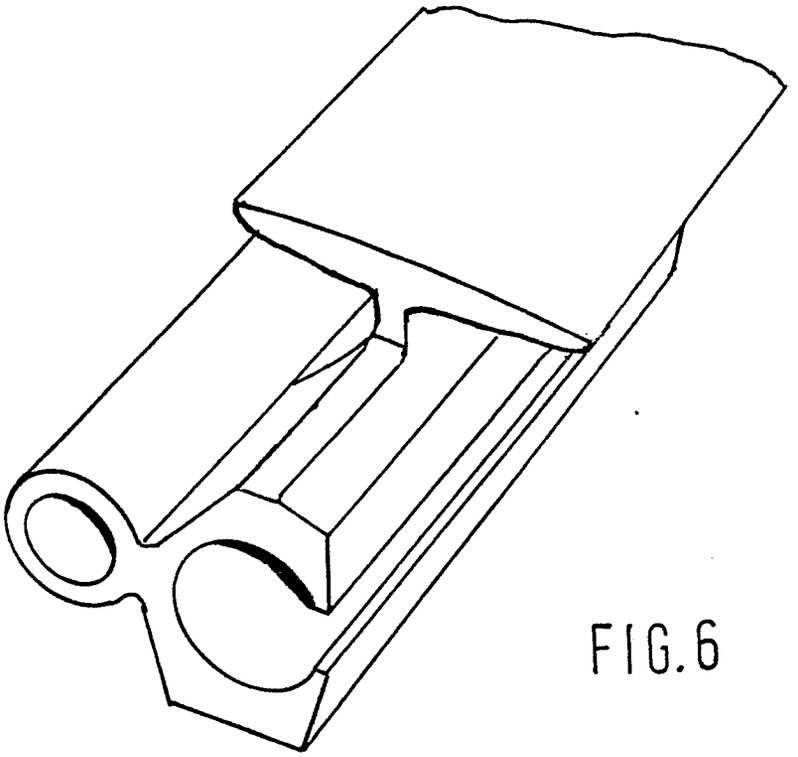

FIG.6

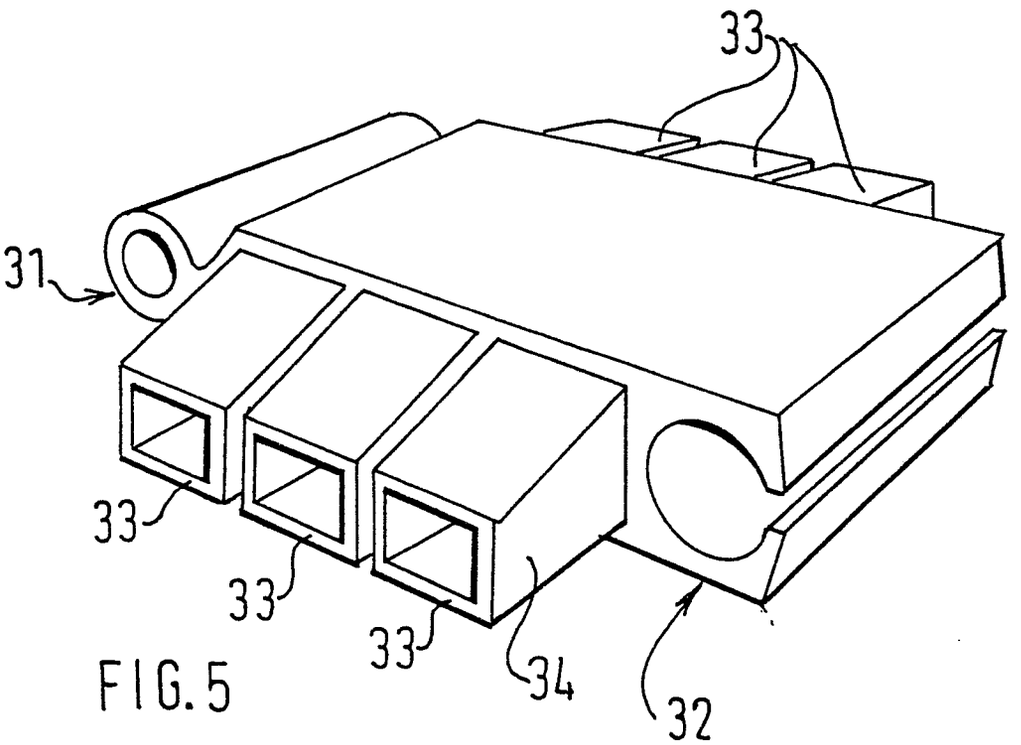

FIG.5

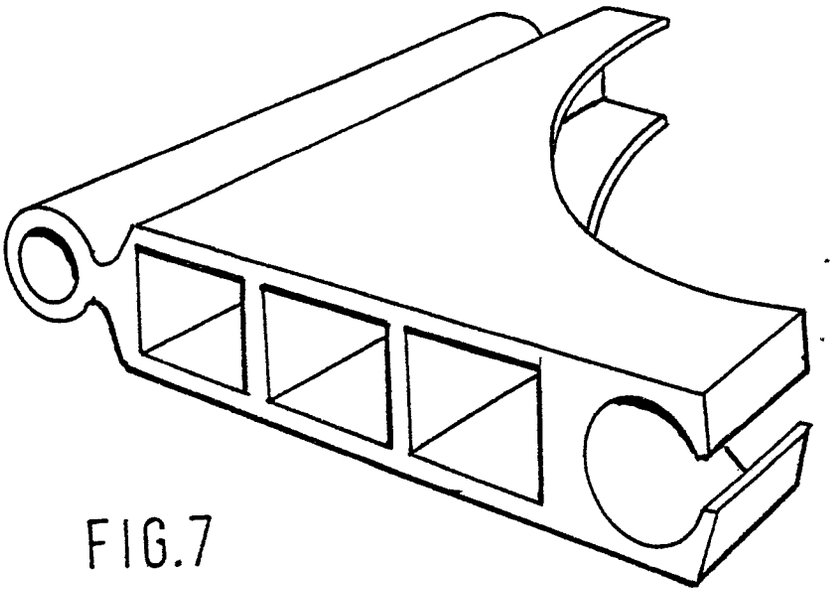

FIG.7

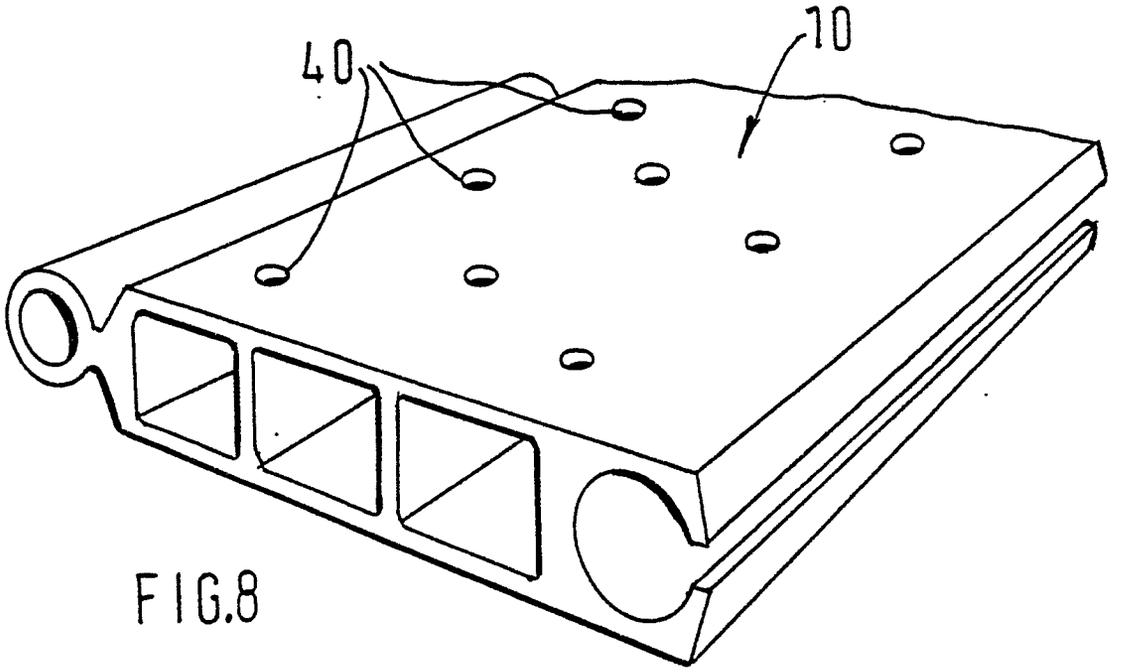

FIG.8

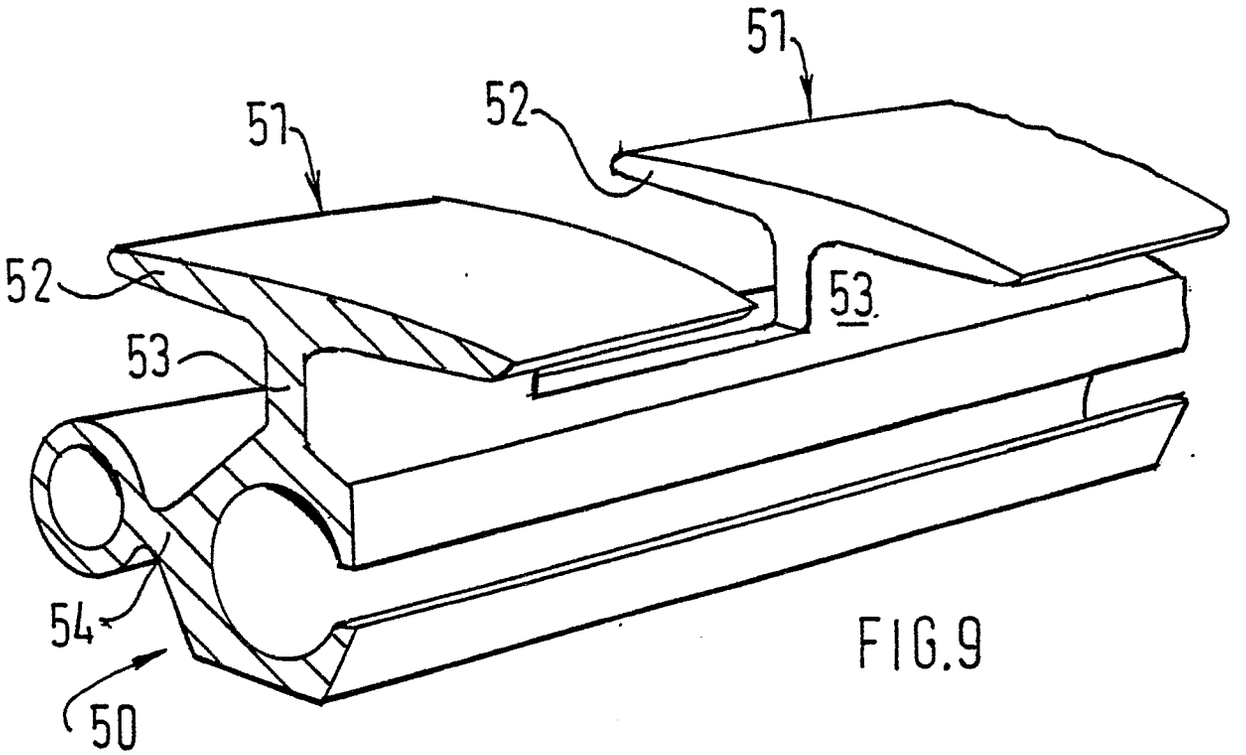

FIG.9

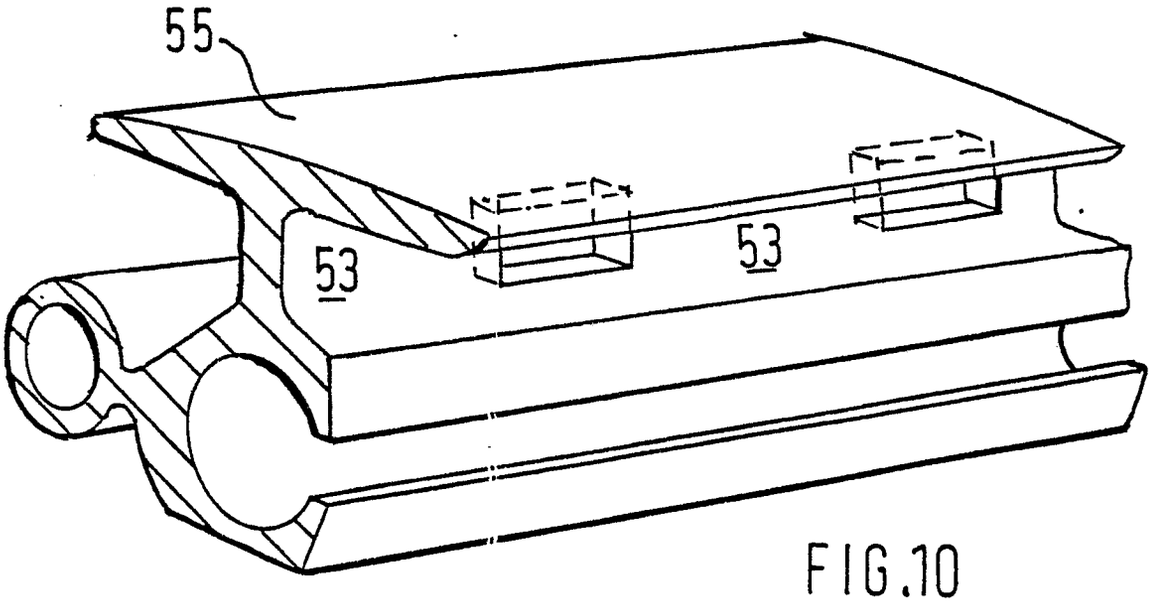

FIG.10

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European Patent Office

Application number

EP 82 30 1192

EUROPEAN SEARCH REPORT

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. ³)
Y	FR-A-2 071 769 (DEUTSCHE STEINZEUG UND KUNSTSTOFFWARENFABRIK) *Page 1, lines 26-34; claim 6; figures 1,3*	1,4-8, 10-13, 15,17, 24	E 03 F 3/06 E 21 D 11/08
Y	US-A-1 347 247 (CAINE) *Page 1, column 1, lines 60-108; figures 1-4*	1,4,9-11,15, 17,21, 24	
Y	DE-B-1 191 640 (STEINZEUGWERKE) *Column 3, lines 30-52; figures 1-3*	1	
A	US-A-1 572 197 (FERGUSON) *Page 1, lines 11-23; figures 1-5*	1,4,21 ,24	TECHNICAL FIELDS SEARCHED (Int. Cl. ³) E 03 F E 21 D F 16 L
A	US-A-1 683 025 (DALLAM) *Figure 7*	2	
A	GB-A-1 188 280 (LLEWELLYN) *Figures 1,4,9*	16	
A	US-A-1 642 417 (KOVANDA)		

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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	18-06-1982	ANGIUS P.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
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T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

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European Patent Office

EUROPEAN SEARCH REPORT

0060134
Application number

EP 82 30 1192

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. ³)
A	FR-A-1 194 978 (EUFINGER) -----		

TECHNICAL FIELDS SEARCHED (Int. Cl. ³)

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