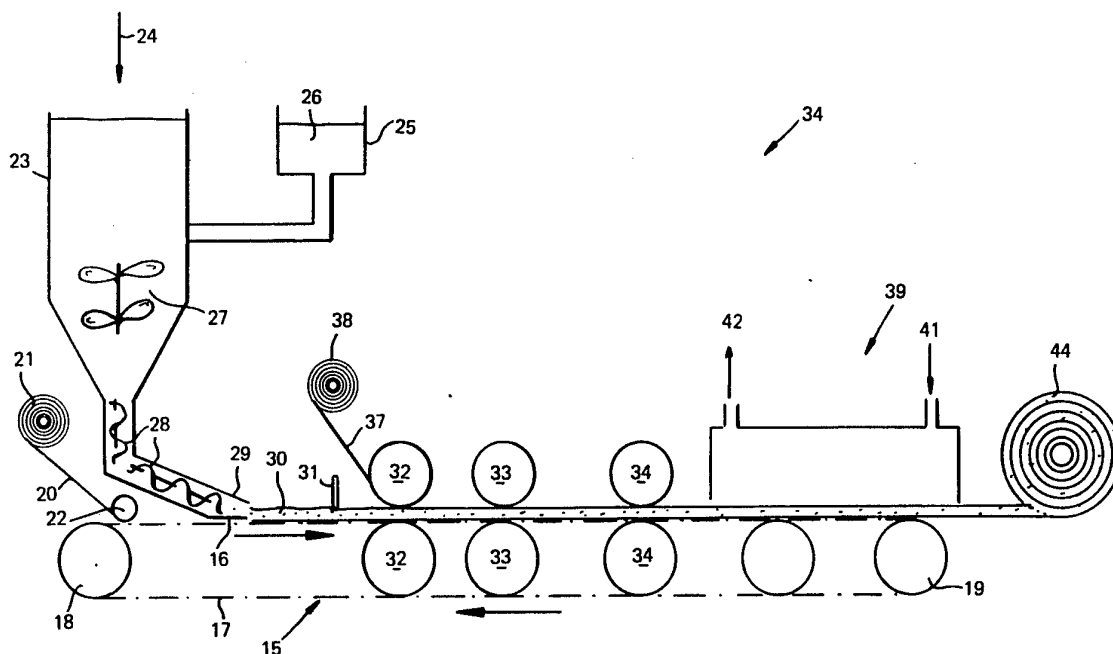




## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

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**(54) Title:** WATER PROOFING LINER**(57) Abstract**

There is described a water-proofing material (10) basically made from a plastic mass containing a liquid and particulate smectite clay, usually montmorillonite such as bentonite, which can be united with a carrier sheet (20). The plastic mass can contain aqueous and/or non-aqueous liquid which can be expelled after forming. The smectite clay can be a smectite liner intercalation complex and the mass is desirably formed by extrusion, in the latter case preferably during reaction of the clay and can have a density of at least 1000 kg/m<sup>3</sup> and can be 1 m or more wide.

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## WATER PROOFING LINER

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This invention relates to a waterproofing material suitable for waterproofing ponds, lakes, lagoons or comparable sites whereby water is retained, or wherein waste is deposited and the ground beneath has to be protected against leakage of aqueous or other liquid. The material can also be used in relation to water proofing structures, covering contaminated land to prevent flow of water into such contaminated land and lining trenches which separate contaminated areas from clear areas. The material can also be used as roofing material on flat or sloping roofs. Several materials have been proposed in the past which include a layer of swellable smectite such as montmorillonite and/or sponite incorporated within the material to act as the sealing agent. The montmorillonite has been carried by a support layer or base which has been provided in various ways. A support layer acts as protection but also gives additional strength within the material.

European patent number 59625 (CLEM) describes a waterproofing material which is a laminate comprising a fabric base, particles of montmorillonite adhered to the base and a scrim adhered over

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the montmorillonite particles to retain them on the base. The CLEM specification requires as an essential feature thereof that the base be capable of venting gas. Although venting of gas from beneath a contained body of water or other matter can be an advantage, it is a great disadvantage to incorporate such ventibility into the actual base. Although there are few sites where venting is necessary it is, when venting is needed, desirable to provide a separate venting layer quite separate from the waterproofing material overlapping the first sheet (10). The sheet (10) has a venting base (13), a layer of montmorillonite (14) adhered to the base (13) and a scrim (15) on top of the montmorillonite. In similar manner sheet (12) has base (16), montmorillonite (17) and scrim (18). As will be seen from the drawing and the arrows (19) the layer of base (16) overlying the montmorillonite (14) provides a path, between the two layers of montmorillonite (14) and (17) which, because it is designed to vent air can also allow liquid such as water to wick out along the path indicated. Thus, the incorporation of a venting base in the sheets (10) and (12) can have undesirable results.

Figure 2 shows how the construction described in European patent application 246 311 (McGROARTY) overcomes these problems. In the MCGROARTY construction a lower sheet (19) has a base (20) and montmorillonite (21). An overlaid sheet (22) has base (23) and montmorillonite (24). In McGROARTY the base (20) and (23) are of solid plastics non-venting and impermeable material. Thus in the construction shown in figure 2 the base (23) forms a non-

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water transmissive layer between the two layers of montmorillonite (21) and (24) thus giving a very good seal. This is a significant advantage over the prior art of figure 1.

Unfortunately, however, the McGROARTY construction does have several practical, other difficulties. Firstly, the bases (20) and (23) are made from a thick, impervious and essentially solid plastics material, described in the specification as HDPE.

Further, the specification describes the fact that granules of montmorillonite are adhered not only to the base but also to each other.

Waterproofing materials of this kind are usually supplied in rolls and have to be unrolled and placed to lie in the pond, lagoon or storage space. With the base (20) (23) made from high density polyethylene the McGROARTY material is less flexible than when using a fabric (non-woven or woven) for the base. This means that the product is much more difficult to handle and the montmorillonite is likely to crack during folding and unfolding. Further, because of the nature of an HDPE plastic sheet the adhering of the montmorillonite to its surface is not easy. Quite large quantities of very strong glue have to be used. As mentioned, in the McGROARTY construction the montmorillonite particles or granules are applied in layers which are adhered not only to the base but also to each other. This makes the product even less flexible and more difficult to handle. Because of the

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high stiffness of the product McGROARTY has to dispense with any scrim such as the scrim (15) (18) and this means that if any montmorillonite is loosened due to folding and unfolding it can easily become displaced leaving voids in the montmorillonite layer. The McGROARTY material is also very stiff and difficult to handle.

A further waterproofing barrier material is disclosed in British patent number 2 202 185 (NAUE). In the NAUE specification a layer of montmorillonite is sandwiched between a pair of layers of non-woven textile material, in which two layers are united by needling, the needles passing through the layer of montmorillonite and uniting all three layers. This product again has disadvantages. Firstly, both the non-woven layers of textile material are essentially gas venting. Therefore, when they are laid they have the same disadvantages as the CLEM construction. Further, because the montmorillonite is not adhered to the layers, as the material is unfolded, folded and manhandled during installation, the montmorillonite can move relative to the two layers leaving voids and/or more permeable thinner areas in the montmorillonite layer.

There is a further disadvantage in that all these earlier materials tend to use particulate montmorillonite which may be from 2 - 5, usually about 3mm in size. Although finer material can be poured to fill gaps between the larger granules, such

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granules tend to make up the bulk of the montmorillonite layer in the waterproofing material. As the water proofing material is only relatively thin, for example containing only perhaps one or two layers of montmorillonite granules, problems can arise in connection with foreign bodies in the montmorillonite used. In its natural state montmorillonite is found alongside shale and other impurities. Whilst the montmorillonite can be quite highly purified, it is not unusual for a low percentage of shale particles to remain in the final sized and graded montmorillonite. An unfortunate result of the use of relatively large granules of montmorillonite in the layer is that granules of impurities can also become incorporated in the material. The chemical nature of shale and some other impurities have the effect that not only are they not montmorillonite (and therefore do not swell upon contact with water), but, when wetted, act as to inhibit swelling in adjacent montmorillonite granules. Thus, a single granule of shale in a layer of waterproofing material can form a small area (perhaps 10mm in diameter) which does not swell upon being contacted with water. Small such areas are generally water impermeable, but medium and larger such areas allow water to pass through the sheet. When water pressure is high this flow can cause significant wash out of adjacent montmorillonite leading to failure of the sealing system. Although the percentage of impurities is small, and although the failure rate is small, when a large area is sealed using sheet material incorporating such impurities it needs only a single

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leak for the whole system to have failed. A pond or lagoon which has a single leak is no pond or lagoon at all!

Particulate montmorillonite has also been mixed with various organic components to form a thick putty (see US Patent Number 4 534 925). Typical components are polypropene and polybutene. This material has been extruded in the form of rods and sheets, usually being stored between layers of release paper. Such material has been used for sealing ground foundations and similar structures. It has not, however, being extruded so as to become united with a carrier sheet and be capable of use in large rolls for covering large areas. Indeed, the polypropene and polybutene used is intended deliberately to give the extruded material a rubbery or formable consistency enabling it to be moulded by hand around small areas such as chimneys, at joints in concrete panels or where drains penetrate foundations. These materials are also quite expensive and prohibitively so for use in relation to large area sheets.

It is an object of the present invention to provide a waterproofing material whereby the above described disadvantages are reduced or minimised.

Smectite includes montmorillonite (dioctahedral) and saponite (trioctahedral) clay minerals and their chemical varieties. They have commercially valuable swelling and ion-exchange properties.



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The smectites have a layer of lattice structure, but differ from micas in that the bonds between layers are weakened because of internal chemical substitutions. Montmorillonite consists of layers of negatively charged oxygen (O) atoms within which several types of positively-charged cations are fixed in specific positions. In a two dimensional schematic diagram of the structure (figure 1), four layers of oxygen atoms can be seen to define upper and lower tetrahedral sheets containing tetravalent silicon (Si) and sometimes trivalent cations (3+) of aluminium (Al) and iron (Fe). The apices of the tetrahedra point toward each other and oxygen atoms at the apices form part of the octahedral sheet that may contain trivalent cations (Al, Fe), divalent cations (Fe, Mg), both divalent (+2) and trivalent cations, or divalent and monovalent (+1) lithium (Li) cations. The presence of two tetrahedral sheets and one octahedral sheet is the basis for classifying the montmorillonite structure as 2.1 (2x tetrahedral 1 x octahedral sheet structure). The 2.1 structural units are separated by interlayers of loosely held hydrated cations. These cations are present to balance the negatively charged structure.

If a particle of Montmorillonite is to expand it needs to take in water into its interlayers. This mechanism is valency dependent. Ionic compounds are formed because a metal atom donates one or two electrons to a non-metal atom (or acid radical group). For example, in table salt (sodium chloride), the

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electron from the highest energy level in the sodium atom is donated to the chlorine atom and they both form ions a sodium one plus cation and chloride one minus anion. The higher the valency the shorter the bond length the more stable is the montmorillonite, ie calcium two plus cations will replace sodium one plus cations. In order for this replacement to take place the cation must get close enough to the montmorillonite substrate, to do this other mechanisms must be considered.

If a particle of montmorillonite is dropped into a beaker of water its interlayers take in water, and gradually the clay spreads until eventually it is uniformly distributed. What causes montmorillonite molecules to behave this way? The answer depends on the fact that the molecules within the interlayers are in a state of random motion. Although they can move in any direction, the fact that initially (wetting of the particle) there are far more molecules in the immediate vicinity of the interlayers increases the probability of their moving away from each other resulting in expansion. This process is diffusion, and is defined in this instance as a movement of molecules from a region where they are at a comparatively high concentration (dry) to a region where they are at a lower concentration (hydration) giving a volume increase. Diffusion will always proceed whenever such a concentration gradient exists, and it will continue until eventually the molecules are uniformly distributed and lattice stabilisation is achieved, at which time

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equilibrium is said to be reached.

Osmosis for the present purpose can be regarded as a special case of diffusion; the diffusion of water from a weaker to a stronger concentration. A weak solution of table salt, for example, will contain relatively less salt and more water than a strong solution of salt. Thus the concentration gradient is from the weak to the strong solution. If two such solutions were in contact, the water molecules would move one way and the salt molecules the other until both were uniformly distributed (equilibrium). If, however, the two solutions are separated by a membrane which allows water but not salt to pass through, only water can diffuse. Such a membrane is said to be selectively permeable or "semi permeable" and the water movement is called osmosis, and is defined in this instance as the movement of a solvent (water) across a selectively permeable interface (membrane) from a weak to a strong concentration of ions in solution. Montmorillonite interlayers are water selective due to the attraction of dipolar water molecules to the highly charged clay particles.

As has been discussed above, the montmorillonite clay is made up of a plurality of structural plates each of which has four layers of oxygen atoms. The outer layer of each plate has a generally tetrahedral format and presents a surface to the interlayer to which cations are loosely bonded. In sodium montmorillonite which

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is a popular and useful material the cations are sodium ions and are connected to the tetrahedral layers by relatively weak Van Der Waal bonds. The interlayers contain a certain amount of hydrating water molecules. When the montmorillonite is contacted with water more water enters the interlayer, being attracted to the charged cations in the interlayer and moving by diffusion and capillary reaction so as to increase the thickness of the interlayer. If a body of montmorillonite is confined between a pair of relatively immobile surfaces the pressure within it upon contact with water can become so high such as to prevent any further movement of water into the structure. This build up of a high pressure layer which cannot absorb any water makes montmorillonite an excellent water-proofing agent. It is widely used in civil engineering structures.

Often used as a substitute for sodium montmorillonite is calcium montmorillonite wherein the loosely held cations in the interlayer are mainly  $\text{Ca}^{2+}$  rather than  $\text{Na}^{+}$ . Because of their divalency the calcium ions bind more strongly to the outer tetrahedral layers than does sodium. In use calcium bentonite has a property that when initially wetted it will swell and expand in the same way as sodium montmorillonite. However, if the material should dry out, for example due to low rain fall or a falling water table calcium montmorillonite cannot shrink back to its original size upon loss of water without cracking. After cracking and upon re-wetting the interlayer becomes incapable of

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absorbing more water and therefore the clay can not re-wet so as to reform the water proof barrier. Thus, a calcium bentonite water proofing material should only be used in cases where permanent wetness is to be encountered. It is possible to treat calcium bentonite with a strong sodium containing solution so as to displace a certain percentage of the calcium ions from the interlayer and replace them with sodium so as to give the calcium montmorillonite properties closer to sodium montmorillonite. However, this material is not as good as pure sodium montmorillonite, and tends to suffer from the same problems as calcium montmorillonite.

All sodium containing montmorillonites do have a problem when the water which comes into contact with them is contaminated by salts, particularly sea water or other salts which render the ground water ionised and highly active. In ground water calcium is invariable present in quantity from soil and minerals. When such ionic calcium comes into contact with montmorillonite it invariably tends to migrate into the interlayers. Once in the interlayer the double valency of the  $\text{Ca}^{+2}$  cations makes the calcium selectively adhere to the four sides of the tetrahedral layers displacing sodium. Such contamination can quite quickly result in complete stripping of sodium from the interlayer, so converting the montmorillonite from the sodium to the calcium form with the disadvantage which has been outlined above.

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This particular process makes it generally unwise to use even sodium montmorillonite in a situation where the ground water can become rapidly ionised or contaminated by leachates or the like. In particular, fertilisers are a particularly notorious cause of ground water ionisation and can cause sodium montmorillonite break down. It is an object of the present invention to provide an improved smectite clay.

In a paper entitled "Preparation of Montmorillonite - Polyacrylate Intercalation Compounds and the Water Absorbing Property" by Ogawa et al published in Clay Science Number 7, 243 251 (1989), the authors have described the introduction of a acrylamide into montmorillonite and the polymerisation of the acrylamide to form a polyacrylamide intercalation compound. The enhanced water-absorbing properties of the compound are noted.

It is to be appreciated, of course, that the processes carried out in the Ogawa paper were essentially laboratory processes involving small amounts of material. No techniques were described for making any useful product and there was not discussion of the advantages of high density such compounds as waterproofing agents.

The present invention is additionally concerned with smectite liner intercalation complex (herein after referred to as a

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"SLIC") materials having improved properties.

Desirably the smectite containing layer is sandwiched between said support sheet and a cover sheet.

Reinforcement can be provided in the middle of the smectite containing layer.

The reinforcement can be secured to the cover sheet and/or the support sheet.

The invention also provides a method of making a waterproofing material including mixing particular smectite with at least one other substance to form a plastic mass, forming that mass into a layer and uniting it with a support sheet.

The laminate of the smectite layer and the support sheet can be treated after union to cause the layer to loose a degree of plasticity to enable it to be handled and stored without undergoing further deformation.

Desirably the smectite is mixed primarily with water to form a paste or a putty like plastic mass which can be extruded rolled or otherwise formed into a continuous layer.

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After forming the layer can be subjected to a drying step to remove excess water to convert the smectite layer into a more dimensionally stable configuration unlikely to deform further during transportation and storage and further to increase the swellability of the smectite upon contact with water in use.

Additives which modify the behaviour the smectite under certain specified conditions such as salt water, or presence of strong leachates, radiation hydrocarbons or organic chemicals can be added at the mixing stage to be operative when the smectite is in use.

Union of the layer of smectite containing layer with the support sheet can be by adhesive, but desirably no adhesive is used, the mixture of smectite (and other substance(s)) being such as to allow pressure force the plastic mass into the interstices of the cover sheet (which is desirably of a textile nature) physically to unite the two. Similar connection can be effected between the layer and the cover sheet.

Instead of water, or in addition to water, organic materials such as methanol, ethanol and other alcohols, glycerine, diesel and other oils and fats can be used. These materials do have the advantage that it is not necessary to drive off water so as to increase the swellability of the smectite layer, but they also have the disadvantages that they do need a drying step so that



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the material is not subject to further deformation under its own weight during storage and transportation and many organic materials are usually far more expensive than water.

Alcohols, particularly methyl alcohol do, however, have particular advantages. Whilst alcohols are generally expensive, they are also usually far more volatile than water. Thus, a plastic mass made using methyl alcohol can, after having been formed into a cohesive continuous layer be dried using far less heat than would be necessary to drive out the water from a similar mass. In addition to this however, the alcohol driven off can be condensed and reused thus offsetting the cost thereof.

The montmorillonite mesh size can be anything from 50 mesh or smaller, desirably, however the size is a maximum of 100. In practice a mesh size of 200 has been found useful although variations downwards from about 100 mesh do work although with less desirable qualities. Finer meshes are perfectly acceptable, but tend to be unnecessary. The smectite used is desirably sodium montmorillonite although calcium montmorillonite (modified by treatment sodium hydroxide) can be used. As the montmorillonite is usually broken down significantly during mixing to micro sizes, initial grain size is not critical.

The fabrics used as support and/or cover layer can be conventional woven or non-woven textiles such as nylon or

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polypropylene or polyester. They should be non-venting (that is to say they do not allow gas or liquid to pass along the structure in use to any significant degree). The fabrics are desirably woven and this degree of non-venting can be achieved by ensuring that the fabric is of relatively open mesh and fairly thin, a significant portion thereof being embedded in and physically uniting with the outer layer of the montmorillonite layer.

The invention includes of course, a waterproofing sheet made by the methods aforesaid.

The invention also provides apparatus for making a waterproofing material including a conveyor, means for feeding a support to the conveyor, means for applying a plastic smectite-containing mass onto the support, and means for forming said plastic mass into a uniform continuous layer.

Means can be provided for sizing the laminate in thickness and/or in width.

Desirably the apparatus includes means for conditioning the laminate after formation to render it stable in use and storage. Said means can include an oven for evaporating substances, from the laminate.

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Means for supplying the plastic mass to the conveyor can include one or more nozzles, and/or an extrusion head.

Means can also be provided for supplying a cover sheet to a surface of the layer remote from the support sheet.

Means can also be provided for feeding a reinforcement to be embedded within the smectite containing layer.

Means can be provided for uniting said reinforcement with one or both of the cover and support sheets; for example by heat sealing.

The invention method also provides a method of waterproofing a structure to prevent ingress and/or egress of aqueous fluids including the steps of providing a plurality of sheets each in the form of a laminate of a support sheet and a layer of cohesive smectite, formed from a plastic mass, laying the sheets to cover the surface of said article in overlapping relationship and protecting said sheets against accidental damage in use.

The invention further provides a method of sealing a site including providing at that site apparatus as aforesaid, transporting smectite and other substance(s) to the site, making the material of the invention at the site and laying the material of the invention directly at the site after manufacture.

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The invention also provides roofing material in the form of a support sheet in combination with a layer of swellable smectite formed from a plastic mass.

The invention still further provides a roof incorporating as part of its water proofing layer, a layer of swellable smectite clay formed from a plastic mass.

The layer can be part of the material as aforesaid or can be of other convenient construction.

The invention still further provides a seal for a pipe or other plumbing fittings incorporating or consisting of a body formed from a plastic mass of smectite.

The smectite can be in the form of a sealing ring or annulus or can be provided as a continuous length for wrapping around joints. The sealing material can be made by the aforesaid methods of forming a plastic mass and extruding, cutting or moulding therefrom. The smectite can be formed in other ways, for example by dry powder moulding to form a cohesive mass. The sealing material can be provided with a surface layer, for example by having a surrounding sheath of net or like support material. Internal reinforcement can be incorporated if necessary and such internal reinforcement can, if desired, be connected to outer support layer(s) on the body of montmorillonite. The

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sealing body of montmorillonite can be wholly or partial surrounded by an impermeable or partly permeable sheet. Such sheet can be arranged to allow water to enter therein but not to leave so as to swell the montmorillonite within the sheath and to urge part of the sheath into sealing engagement with its surroundings. Such an arrangement can prevent extrusion of the

The invention provides as a second feature thereof a waterproofing material in the form of a body of material formed from a plastic mass, wherein said plastic mass contains a smectite/liner intercalation complex.

The liner can closely bind sodium cations to the outer layers of plates of the smectite structure therefore reducing the possibility of their replacement by calcium cations.

Alternatively the lining can replace the sodium cations leaving a generally neutral face which can absorb water by capillary action, but which is generally neutral and therefore does not attract calcium cations.

The liner used will normally be an organic compound compatible with the outer layers of the smectite plates. Suitable compound can be sugars such as fructose, glucose, dextrose and the like which have comparable molecular shapes and will complex with the tetrahedral layers on the outside of the plate.

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A further and desired liner is an acrylate. The material can be added as the polyacrylate or an acrylation process can be carried out in contact with the clay.

Another possible liner is alkylammonium trimethyl alkyl ammonium.

The acrylate can have the formula shown in figure 2.

Although the sodium salt of polyacrylate is shown other cation forms can be used.

In the sodium cation form the acrylate can replace the sodium cations which normally coat the outer layers of the smectite plates.

The acrylate polymer can be doped with various desirable material to alter various properties of the clay.

One particular doping agent is glycerol. The introduction of glycerol can increase the flexibility of the clay so that a length of the clay can be bent easily without breaking.

Methanol can also be introduced as a useful material for increasing the flexibility and reducing the stiffness of the mixture thus assisting in its processing.

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The invention further provides a method of treating a smectite clay to form a leach-resistant clay including the step of reacting it with a liner capable of complexing with faces of the clay structural plates adjacent the interlayers to form a coating which resists replacement of sodium cations.

The liner can be polyacrylate.

The liner can be alkylammonium trimethyl alkylammonium.

The liner can be mixed with the clay as a monomer or in the polymer form and in the first case can polymerise within the clay.

The invention includes a smectite clay made by the method aforesaid.

The invention also provides a smectite clay having interlayers provided with an organic liner preventing replacement of sodium cations and capable of absorbing water and swelling.

A further problem of smectite clay when used as a waterproofing material, is that its function is very dependent on the amount of montmorillonite used. For example when a body of a montmorillonite is constrained between two surfaces, such as the concrete of a structure and the ground, when contacted by water

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it swells and forms the aforesaid high pressure layer which prevents ingress of water to the structure and therefore effectively waterproofs it. To increase the waterproofing efficiency of the clay body, larger quantities of montmorillonite can be used. However, higher quantities of montmorillonite mean thicker sheets of material which are more difficult to handle and which are heavier have more transportation costs and are bulky. In sheets which consists principally of particulate montmorillonite there can be significant difficulty in getting a large quantity into a small area. Sheet material used for waterproofing in ground situation or for roofs, walls and the like tend to have relatively low densities. This is because they are generally made from particulate montmorillonite adhered to a supporting sheet as of plastics material or textile material and secured thereto by a variety of means ranging from adhesive to needling to sewing or by embedment in a mesh of fibres.

It is a further object of the present invention to provide an improved smectite waterproofing material.

The invention provides a smectite clay waterproofing material having a density greater than 1000 kg. m<sup>3</sup>.

The waterproofing material can be a sheet at least a metre wide and desirably up to four metres wide or more.



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The invention further provides a waterproofing material including smectite clay in combination with an organic material forming a liner on its interlayers and having a density greater than 1000 kg m<sup>-3</sup>.

The material can be formed by rolling, extrusion or the like.

Desirably the material is extruded.

The invention additionally provides a method of forming a SLIC wherein alcohol is used to facilitate introduction of the liner into the smectite interlayer and to remove excess liner.

N.B Introduction and removal seem contradictory? If excess acrylate is removed, where does it go to?

The alcohol can be methyl alcohol, ethyl alcohol or any higher fluid alcohol.

The invention also provides a method of forming a SLIC including exposing the forming complex to suction remove gas whilst reaction is proceeding.

The gas will usually be air but may be air together with by-product gas from the reaction.

Desirably the degassed material is subsequently subjected to

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pressure.

The invention also provides a method of forming a SLIC including exposing the forming complex to pressure during reaction to increase the density of the product.

Desirably the pressure is used after a suction treatment which has removed excess air and possible other gases. The pressure step can, therefore, reduce the number of voids in the product as well as urging the molecules of the product closer together to enhance the reaction to produce a denser product.

Desirably the density of the product is greater than 1000 kilogrammes per cubic metre.

The pressure can be applied by extrusion or by passing the forming material through rollers, or by any other convenient means.

We have also found that the temperature at which the reaction between the smectite and the liner takes place is important. The invention therefore, further provides a method of forming a SLIC wherein the reaction is constrained to proceed at such a rate as to ensure that the temperature of the forming product varies between 15 and 30°C. Desirably the temperature is maintained in a range from 20 to 25°C.

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Where the product is subjected to pressure as aforesaid it is desirable that the pressure is applied when the temperature is within the ranges aforesaid.

A further disadvantage of existing smectite-based waterproofing materials is that upon exposure to water they tend to swell (this is the very factor which gives them their waterproofing properties in that they produce an area of such high pressure of additional water can not penetrate). However, the pressure rise can tend to be very high and, therefore a very significant overlay of either a heavy earth layer (for example one to two metres) or up to 3" or more of concrete are necessary in order that the expansion pressure of the smectite cannot cause movement or displacement of any structure.

Accordingly the invention provides, as a further feature a SLIC having a significantly reduced expansion pressure compared with known smectite based waterproofing material.

The expansion pressure can be as low as 10mm of concrete as carried out in the test later defined herein.

As a further feature the invention provides a barrier against aggressive ionic fluid, the barrier being in the form of a constrained layer of a SLIC, wherein interlayers of the smectite have been treated with said liner to form the complex, the

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interlayer being capable of absorbing water to swell the complex to a barrier pressure and said liner preventing ion exchange between said fluid and the smectite.

The fluid will normally be aqueous and can be highly ionised fluid such as leachate or fluid containing fertilizer and the like. However, the barrier can be equally effective against organic fluids or fluids containing organic material, as the smectite interlayers remain proof against ion exchange with such fluid. Further, it is desirable that the liner be inert in order that its possibility of reaction with materials in the fluid is reduced.

The layer needs to be constrained in order that the barrier pressure can be achieved. The constraint can be a back-fill or overlay of earth or other material or in solid structure an adjacent or surrounding area of concrete or the like can be used.

A further problem with known smectite based waterproofing materials is that it has been very difficult to secure them to surfaces to be waterproofed. Whilst a flat or gradually sloping surface can be easily waterproofed simply by laying a sheet of the smectite material thereon. When vertical surfaces (such as adjacent edges of concrete panels) are to be waterproofed it has been necessary somehow to attach a smectite based strip thereto. Existing methods used have included the provision of rebates into

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which strips of seal material can be pushed and the use of clips or nails. Although nails can be used they tend to be frowned upon as they pierce a waterproof layer and they can introduce metal ions into the surrounding water which may have a detrimental effect. Because of the generally incohesive nature of clays and their friability, adhesives have not been very effective. Some heavy soaking adhesives have been used, particularly the type of adhesive used in the adherence of smectite particles to sheets. However these adhesives have a great tendency to inhibit the swelling properties of the clay and to react adversely.

Accordingly the invention provides a method of securing a seal material to a surface wherein the seal material is a SLIC, comprising use of an adhesive compatible to the liner to cause adhesion.

Where the liner is a polyacrylate the adhesive can be a cyanoacrylate adhesive.

Because molecules of the liner extend outwardly from the particles of smectite they form a very convenient anchor which can become attached to glue molecules. Because they themselves are securely anchored within the interlayer they form adhesion between the entire complex and the structure to which the complex is to be adhered.

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Desirably the adhesive used is an ephemeral adhesive which will hold the seal material for a sufficient period of time to allow it to be installed and for further structure to be formed adjacent, but will soon degrade to allow water entry so as to avoid the provision of any adhesive film or layer which might allow water seepage past the seal.

The invention further provides a method of making a fluid barrier including forming blocks of a high density SLIC and arranging said blocks in a layer.

The layer can be a wall, a floor or a roof. The blocks can be bonded as bricks.

A bentonite containing paste can be used as a lute. The paste can contain a SLIC.

The invention will be described further, by way of example, with reference to the accompanying drawings wherein;

Figures 1 and 2 are cross sectional view illustrating overlap joints in the prior art and their disadvantages;

Figure 3 is a cross sectional view illustrating a preferred waterproofing material of the invention;

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Figure 4 is an enlarged cross sectional view illustrating a surface of a preferred material of the invention;

Figure 5 is a schematic view illustrating the apparatus of the invention suitable for carrying out a preferred method of the invention;

Figure 6 is a plan view of part of the apparatus of figure 5 and illustrating two possible variations;

Figure 7 is a view similar to figure 3 but illustrating a modified material of the invention;

Figure 8 is a view similar to figure 7 but illustrating a still further modified material;

Figure 9 is a view comparable to figure 1, but illustrating an overlap join made using the material of the present invention;

Figure 10 is an enlarged view of the portion ringed at numeral 10 in figure 9.

Figure 11 is a basic two dimensional sketch illustrating structure of montmorillonite;

Figure 12 is a chemical formula illustrating the structure of an

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acrylate useable in the invention;

Figure 13 is an enlarged view illustrating the structure of montmorillonite;

Figure 14 is attempted three dimensional representation of montmorillonite after acylation;

Figure 15 is a view similar to figure 4 but illustrating the addition of doping elements; and

Figure 16 is a view similar to figure 5 but illustrating the microscopic effects of the acrylation.

The preferred waterproofing material (10) of the invention is a laminate consisting of a core layer (11) containing montmorillonite. The core layer (11) is united with a support sheet (12) and is desirably but not essentially overlaid by a cover sheet (13).

The essentials of the material (10) of the invention will probably be best apparent from a detailed description of the way it is made and the apparatus (of the invention) which is used to make it.

Referring, therefore, to figure 5 it will be seen that a



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preferred apparatus (14) of the invention comprises a conveyor (15) having an upper run (16) and a lower run (17) entrained about end rollers (18) and (19). The upper run (16) travels from left to right in figure 5.

At the upstream end of run (16) a support sheet (20) is fed from a supply roll (21) by a guide roll (22) so as to run on and in synchronism with the conveyor (16).

The support sheet (20) is a sheet of woven or non-woven textile material (preferably woven) which is relatively loose weave, being quite porous in a direction transverse to its plane.

The web forming the support sheet can be made of any geotextile material which is suitable for disposal within the ground for long periods. Typical materials for weaving or forming the fabric of the sheet (20) can be polypropylene, polyesters including nylon, and many other plastics materials alone or in blends. The material should be sufficiently strong to support the composite laminate to be formed and can be similar to many of the facing sheets used in relation to the prior known materials discussed in the introduction hereto. Polypropylene and cotton mixers can also be used. A typical support and/or cover sheet can be of a print weave and of a weight 700g per sq.metre.

Downstream of the supply roll is a hopper mixer (23) in which

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particulate montmorillonite can be supplied as indicated by the arrow (24). The particulate montmorillonite can be supplied from a mill or like supply and in the preferred embodiment is of 200 mesh. Finer mesh can be used although great advantages are not obtained. Meshes up to 50 mesh can be used, but at sizes greater than 100 mesh, union between the montmorillonite particles is less effective.

The process which takes place in the hopper mixer (23) can be either a continuous or a batch process. Within the hopper mixer (23) a measured quantity of montmorillonite is mixed with a measured quantity of one or more other substances to produce a fluent mass. The other substance(s) can be supplied from a tank or comparable supply (25). The substance(s) (26) will normally be fluid and when mixed with the montmorillonite will form a shapable mass. A liquid used can be an organic liquid such as glycerine, diesel oil or comparable oils or mixes thereof, gels and other plastic or deformable mass-forming substances. However, for economy and for ease of handling and simplicity the desired substance is water. In the preferred embodiment of method of the invention water is mixed with the montmorillonite there being approximately from 10 to 30% water, desirably about 15 to 20%.

Alternatively or liquid such as alcohol can be used. Methyl, ethyl or propyl alcohol can be used. Methyl is preferred. It

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therefore needs less drying power than water. It can be reclaimed and reused.

It is envisaged that although a fluid will normally be mixed with the montmorillonite to convert it into a fluent body it is possible that some powdered or other non-fluid material could be used. For example, a sticky powder such as a soap or adhesive could be mixed with the montmorillonite to create a pasty plastic deformable mass which could be extruded or spread to form a sheet. However, in view of the likely expense of such materials and the difficulty of mixing it is not felt that these will be practical.

The mixture is, in the preferred embodiment as mentioned pure water. However, where the final product is to have special qualities the chemicals of those special qualities can be included in the mixture of water.

In making a typical product in accordance with the invention 5 killogrammes of montmorillonite were mixed with 0.446 killogrammes of sodium carboxymethyl cellulose (CMC), 2.5 litres of methanol and 1.8 litres of water. Both the CMC and the methanol make the mixed and kneaded product more flexible and extrudable. Water can effect this process, but the more water that is used the more heat is required to drive it out. This

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means added expense.

Although the above particular mixtures have proved suitable many variations can be made.

Methanol alone or water alone can be used, but neither of these is satisfactory.

The material desirably contains a bulking agent, an anti fungicidal preserving agent, to prevent growth of mould in or on the material and desirably a lubricant to assist in the extrusion process and convey also a degree of flexibility to the plastic mass. CMC is a very desirable substance in that it provides all these properties. It has anti fungicidal properties, it is a lubricant and it makes the product more flexible. It also has the great advantage that upon contact by water, in use, it dissolves. Those areas of the outer surface of the material when first contacted by water have the CMC dissolved out of them leaving micro pores into which more water can penetrate, wash out more CMC and cause rapid expansion of the adjacent montmorillonite. This greatly increases the rate of

water transfer into the material. A bulking agent which dissolves in water and aids water ingress to the montmorillonite is very desirable.

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Instead of being provided by a single material these properties can be provided by other materials. Although many synthetic materials do have these properties, they tend to be expensive and simple plant extracts which are much cheaper are desired. As a bulking agent/lubricant guar gum can be used or starch. In connection with these two materials a separate preservative such as any conventional anti fungicidal or micro agent would have to be used.

Any convenient liquid alcohol can be used having from 1 to 12 carbon atoms. Above the 12 alcohols tend to be too viscose for use but below that number any convenient alcohol can be used. It is expected, however, that methyl alcohol will be used because of its cheapness and easy availability. The CC can be in the form of sodium carboxy methyl cellulose or any other convenient compound thereof. Protection against bacterial attack is important because the bacterial reactions can produce hydro carbons which react with the sodium ions in the clay. This can reduce the swellability of the clay.

As a possible variation a soluble coating can be provided to surround a body of material of the invention. This can be arranged to degrade over a relatively short period of time (such as a week). This would enable block seals and the like to be installed without becoming greasy and unhandlable due to adverse weather conditions, but would not affect the function of material

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to swell in use after a brief period of time.

The montmorillonite used is desirably sodium montmorillonite but *(and other smectites)* calcium montmorillonite or treated calcium montmorillonite can also be used. As shown the materials are first mixed by means of a mixer (27) and then extruded by screws (28) to an extrusion nozzle (29). Where the fluid mass is spread out as a thin layer covering the entire width of the conveyor run (16).

If the reinforcement is required within the montmorillonite layer in order that it can be laid on steep slopes without loss of function it can be desirable to incorporate within the plastic mass a reinforcing layer. This can be done by embedding the reinforcing layer into the mass as it is being extruded or it is being spread out into a layer. The reinforcing layer can be made in the form of a core having bristles or comparable formations extending outwards which, with the core disposed centrally in the body of montmorillonite extend to the surface thereof and contact and possibly project through the surface layers. The material of the reinforcement and the surface layers can be made such that the exposed bristles can be heat sealed to contact and be secured to the outer layers. It is envisaged that it would be possible for the montmorillonite mass to be extruded or formed into a pair of sheets and the reinforcement feed between them and to have its bristles projecting through each of the two part layers of the montmorillonite core and project to the other surfaces thereof

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and be united with the support/cover sheets.

Although the extrusion of a thin layer of the plastic mass containing montmorillonite is desirable, as it can be 3 or more metres wide, it could well be that a three metre wide extrusion nozzle is either expensive, slow, or requires inordinate amounts of power to be successful. Such a extrusion nozzle (29) is shown in figure 5 which also shows an alternative which will be described later.

It is expected that the mass will be extruded as a rod and rolled flat.

Downstream of nozzle (29) the layer (30) of montmorillonite containing plastic mass is levelled and formed into a uniform uninterrupted layer. This can be achieved by means of an initial doctor blade (31) or more likely, a roller, and subsequent sizing rollers (32) to (34). The pairs of sizing rolls (32) (33) (34) can effect kneading and levelling of the fluid material and subsequent size thickness reductions.

Figure 6 shows one of the rollers and shows the plastics material extruded outwards beyond the edge of the conveyor and being removed by trimming knives (36).

At one of the sets of rollers (32) (33) (34) there is fed a web of cover sheet (37), from a supply roll (38). Of course, if roll

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(31) or (32) and (33) are needed to effect creation of a uniform flat layer of the montmorillonite containing mass, application of the cover sheet can be left until roll (34). However, this is not desirable as rollers (32) and (33) are best protected from the plastic montmorillonite layer by the cover sheet (38).

The substance which convert the powdered montmorillonite into a plastic fluent mass will need some degree of treatment, for example by evaporation, drying or partial chemical change so as to ensure that the final material can not deform further in use or in storage. This can be effected by means of a treatment facility indicated by the reference numeral (39).

When the mixture substance is essentially water or an evaporable liquid the treatment facility (39) will be in the form of an oven and will reduce the solvent water content of the montmorillonite containing layer from 20% down to 5% or less. The treatment facility can be in the form of an oven casing (40) to which hot air is supplied at an inlet (41) and leaves via outlet (42).

After leaving the treatment facility (39) the laminate (40) can be allowed to cool and then be fed to a store roll (44). A knife or the like can be provided for cutting the laminate as it leaves the oven when roll (44) is full.

As discussed previously in relation to the extrusion of the



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product, the consistency of the plastic/fluent mass containing montmorillonite can vary widely from almost a liquid condition to a stiff paste. When water is used, the stiffer the paste the better as water has to be expelled by passage through the oven. Again, in the case of organic or organic-containing mixture substances the stiffer the material the less later treatment is necessary to render the final laminate stable and non-deformable during transportation and storage and use. This process will usually involve evaporation comparable to oven drying or a chemical treatment.

As has previously been mentioned the use of a very wide extrusion nozzle (29) may not be practical in view of the power required for such a device. Instead, as illustrated in figure 6 a smaller extrusion or fluid delivery nozzle (45) can be used which can be mounted so as to perform a generally sinuous path transversely of the direction of travel of the run (17) of the belt (15). Thus, the nozzle (45) can follow a path indicated by the line (46). By altering the speed of travel of the nozzle and/or the rate of delivery of the fluent material can be assured that sufficient material is applied to the belt to allow a layer of desired thickness to be formed throughout the area of the belt without voids, cracks or the like which would be most undesirable. To this end it is advantageous if the material can be applied to some significant access and after having been formed into a uniform coherent layer excess material extruded

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sideways is removed by means of the trimming knives or the like (36). Of course, such material can be reclaimed and re-used.

It has been mentioned that the support sheet and/or the cover sheet can be of woven or non-woven material. Woven material is preferred but it gives significant strength with lesser weight of materials. A non-woven material might have advantage, however in that it can form a physical union with the montmorillonite containing core (11). The term core (11) is used even though the cover sheet (13) may not be provided.

As best seen in figures 4 and 10 the action of the rollers (32) (33) and (34) is to cause the support/cover sheets (12) (13) to be partially embedded in surface zones of the plastic mass of material forming the core (11) whilst the core is in a plastic state. There is no need for any adhesive, which is an expensive and unreliable component.

As the core is treated in the facility (39) either by evaporation or chemically so as to cause the core to harden there is a physical locking of the surface portions of the core (11) with portions of the fabrics (12) (13) physically uniting them to the surface without the need for adhesive.

This has two important consequences.

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Firstly, because a good portion of the sheets (12) and (13) are embedded within the material of the core, only a small portion of the body of the fabric is exposed above the surface. Thus, in use that fabric surface will be in contact either with anchoring overburden (at least 150mm of overlying material is recommended to protect such layers) the underlying earth. The overburden or the earth penetrates the fabric quite easily ( it is a very open fabric and after there is intimate contact between the overburden and the underlying earth). This again has two important consequences. Firstly, once the support layer (12) (which will normally be in contact with underlying earth) is intimately connected by the earth ground water enters contacts the montmorillonite and causes swelling which creates a seal.

It is a further advantage that because of the intimate contact of the underlying soil or the overburden with the montmorillonite through the support and over sheets (12), (13) there is no possibility that either the cover sheet (12) or the support sheet can allow any venting of gas laterally through the fabric.

The second advantage of this is illustrated in figures 9 and 10 which are comparable to figures 1 and 2, but relate to the present invention. In figure 9 a first piece (47) on the material of the invention is shown overlapping a lower piece (48), both lying on the ground (49). The overlap cover sheet (50) of the second sheet (48) is in contact with the support sheet (51) on the piece (47). As illustrated in figure 10 the

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sheets (50) and (51) are in intimate contact and they are significantly penetrated by montmorillonite from the respective cores of the two panels. Upon entry of water in the direction of arrow (52) or (53) the montmorillonite in one or each of the cores can swell and expand into the unfilled portions of the fabrics (50) (51) and forming effectively a continuous layer of expanded montmorillonite uniting the two cores and providing a completely water tight seal.

As mentioned earlier, the invention includes the waterproofing material itself, the method of an apparatus for producing it and a method of waterproofing a structure including the steps of placing sheets material of the invention in overlapping relationship and placing overburden to protect the sheets against damage in use.

The invention is not limited to the precise details of the foregoing and variations can be made thereto.

A further disadvantage of existing methods of waterproofing large sites such as pond filled sites, ponds, lagoons and the like is that the material has to be made in bulk in a factory and then transported to the site. The material is manufactured in as wide a width as possible consistent with manufacturing problems and transpiration. In a similar manner the length of the load which can be transported is strictly limited. The material may be

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from a minimum of 4 up to 10 or 20mm or more in thickness , the length of roll which can be transported is not very high. On large sites the elimination of large amounts of joints and the elimination of road transportation can mean significant cost savings.

The apparatus of the invention can be divided into a number of mobile units, for example the main conveyor, the mixing hopper and the drying could form three separate unit loads.

It is mentioned earlier, the invention envisages the use of a material comprising expandable montmorillonite clay into a flat or slightly slopping roof as the whole or a significant part of the water proofing component thereof. The material of the invention is particularly suitable for this purpose as it can be laid on relatively higher slopes than previously known montmorillonite sheets without them being very expensive. Thus, in the case of a roof which has stands the montmorillonite sheet of the present invention can be laid to extend not only the flat surface but also upstands to form a water proof layer. The montmorillonite core will normally be laid by several cm of gravel or like material providing a bearing layer protecting the montmorillonite beneath. The montmorillonite used with, desirably, be of the sort which can be allowed to dry out and be rewetted repeatedly as this will often happen to a roof structure.

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As mentioned earlier the invention envisages the use of montmorillonite expandable clay as sealant in pipes and other plumbing. The montmorillonite material can be in the form of rings, annular strips or sheets and incorporated in underground drainage or supply pipes, domestic plastics or metal pipes and comparable plumbing installations. The cheapness of the montmorillonite means that they are ready and cheap substitute for rubber or plastic sealing rings and are cheap enough to be replaced when ever the joint needs to be opened or replaced.

In this case the use of an alcohol or a comparable liquid is advantageous because the oven stages do not have to be as long and as powerful as is necessary in the case of driving water from the plastic mass.

When carrying the invention into effect using a SLIC, there can be used a polyacrylate as the liner a quantity of untreated sodium montmorillonite and approximately 10% by weight of a polyacrylate of the formula shown in figure 2, from 2% to 7% of a sodium carboxymethyl cellulose (CMC), 14% of methanol and 5% of glycerol were intimately mixed together. Kneading and mixing were continued until the mixture reached a suitable consistency for extrusion. This can take longer than would normally be necessary for simple mixing as the chemical reaction between the acrylate and the structural plates of the clay takes some time to occur. The heat emitted by such reaction is an

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important factor in bringing the forming smectite acrylic complex to a suitable consistency and structure.

Once this has occurred (Its occurrence can be tested by initial trial extrusions. The products of such extrusions, if unacceptable can be returned for recycling) the mixture is passed to an extruder where it is driven towards an extrusion screw, and subjected to a suction stage to remove significantly all entrained gas from it before being extruded in the form of a rope, profile or sheet as desired.

The montmorillonite used in the process is finely ground and has the structural formula and shape shown in figures 1 and 3, the cations in the interlayer being essentially sodium cations.

During the reaction the clay becomes acrylated and the long organic chains of polyacrylate penetrate into the interlayers and displace water. At the particle surfaces, polyacrylate bonds with strong hydrogen bonds to the free unsatisfied OH groups. This effectively shields the sodium cations, thus greatly resisting their replacement by calcium cations in contaminated ground water.

On the microscopic scale (which is illustrated very schematically in figure 6) a particle of clay consists of a plurality of small structural plates between which the helical acrylate molecules

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are disposed. The surfaces of the helical acrylate molecules are bonded to the tetrahedra within the faces of the structure plates opposite the interlayers and project beyond the edges of the particle. This projection of the acrylate molecules beyond the surface of the particle has a significant effect in the abortion of water by the clay. Thus although the acrylate does, to some extent mask the electro-chemical water absorbing properties of the clay by effectively neutralising the sodium cations in the interlayer the extending helical polyacrylate molecules extending outwardly from the particles have a surface tension effect which draws water towards the particles and causes it to enter into the interlayers by capillary action thus causing a swelling of the particle which is comparable to the electro-chemical swelling which previously occurred but which is not dependent on the presence of cations within the interlayers.

This has the important effect that any cations which enter within the interlayer can not replace sodium cations and thus do not reduce the capacity of the clay to expand, shrink and re-expand after drying out.

Instead of carrying out the method of the invention using acrylate other materials can be used. For example sugars such as fructose, glucose, dextrose can be used. All act in very similar way to the acrylic molecule and have comparable and similar effects. The use of sugar may, however, be undesirable



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in some circumstances in view of its encouragement of microbial growth. Of course, there may well be advantages in this particular property in certain situations.

A further alternative liner material is alkylammonium trimethyl alkyl ammonium which can be used in the manner very similar to the polyacrylic compound to give a similar complex with similar properties.

Turning now to the second aspect of the invention reference is again made to our prior application 9218178.3 and to the foregoing description. In making a smectite clay water proofing material in accordance with the second aspect of the invention the method aforesaid is carried out with or without the acrylic material. In the preferred method of this invention sodium montmorillonite powder was mixed with of polyacrylate glycerol and methanol. The mass was mixed together for some fifteen minutes and then extruded through a 25mm square orifice at a rate of about 0.5 metres per second to produce a rope like concrete sealing strip having a density of about  $1350 \text{ kg m}^{-3}$ .

The actual density can be varied by varying the proportion of materials in the complex.

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Of course, the waterproofing material can be made without using the liner such as polyacrylate. In addition it is possible to use CNC either in addition to the acrylate or as a substitute therefore. The CNC can be useful in varying the reaction rate of the clay but it also has a property of forming, on the surface of the extruded material a layer which improves the life of the sealing material by resisting degradation and swelling by rain over a first few hours or days.

In testing the smectite organic complex of the present invention a layer of conventional particulate smectite clay waterproofing sheet was laid on the ground and contacted with typical water high in ionic leaching chemicals. After six hours the bentonite layer had absorbed the liquid and had swelled to form a uniform water retaining layer.

A complex according to the invention was similarly treated and had, within six hours reached precisely the same condition.

The two sheets were then allowed to dry. In the complex clay sheet according to the invention the sheet reduced in thickness to its original thickness with no significant cracking. In the untreated prior art clay particulate layer sheet there was significant cracking and large gaps appeared in the material. Both sheets were then rewetted (whether pure water or contaminated leachate water was used made no difference). The

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prior art material, wherein clearly sodium montmorillonite had been converted to calcium montmorillonite there was no significant re-swelling. The cracks remained and water was able to penetrate through those cracks even after prolonged soaking with water as would happen in an underground situation. The prior art material was no longer waterproof and did not itself form a waterproof layer by expansion.

On the contrary, however, the complex montmorillonite clay of the present invention formed a uniform waterproofing layer.

In the past it has been possible to adhere particles of bentonite to sheets to form cohesive layers, but rather large quantities of adhesive have

been necessary and the bonds which may form with the bentonite have not been particularly strong.

With a liner material incorporated within the actual structure of the clay itself very strong adhesive bonds can, it has been found now been made between bodies of the smectite complex and structures such as concrete walls, roofs and the like. To obtain such a bond it is only necessary to formulate an adhesive which is suitable for attachment to the liner molecules which protrude from the surface of the clay particles or the clay body if it has been extruded or otherwise formed into a sheet rod or the like.

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In the case of the acrylate smectite complexed clay a cyano-acrylic adhesive can be formulated which can adhere the smectite complex clay body to concrete and the like and which can allow the body to expand and contract as it is wetted, dried and re-wetted over many cycles.

Further possibilities include the adhesion of a sheet of the clay, either as a cohesive body formed by extrusion or otherwise or in a particular manner to a supporting sheet, for example of high density polyethylene, a geotextile or the like by means of adhesive, needle punching or the like.

Adhesive and/or stitching or penetration by polymer spikes weldable to a sheet on the other side of the clay can be used to form a stable slope engaging material.

As well as montmorillonite, saponite and other smectites can be used.

In carrying out a further preferred process a batch of about 60 kilogrammes was prepared, the figures given in the following being percentage figures for the various components.

Firstly, 25% water was added to a mixer, followed by 16% sodium polyacrylate. To these was added 5% methyl alcohol. When these

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three had been mixed half of the total bentonite load of 63% was added. Once the mixture had become smooth 1% carboxy methyl cellulose (CMC) and a small (about 0.1%) of sodium hexametaphosphate was added. Both these materials were added slowly and after they had been added the mixture was stirred for some while. Thereafter the other half of the bentonite was added, the mixture kneaded for a short time and then passed to an extrusion machine wherein it was first driven towards a perforated plate whence it emerged in vermicelli-like form into a vacuum chamber. In the vacuum chamber air and any other gases such as reaction products and probably some evaporated alcohol are extracted.

The material then falls to the base of the vacuum chamber and is engaged by the rollers of the extrusion machine and driven towards a 25mm square extrusion head having 3mm radius corners. The forming complex (intercalation commences in the mixer and is still continuing as extrusion takes place) has a smooth outer surface and is a coherent flexible and useful seal material for use at the junction between the structural components such as concrete slabs, panels and where service conduits pass through foundations and the like.

The percentages of the various materials used can be varied as follows:-

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ITEM	PERCENTAGE RANGE
Water	15 ~ 25
Sodium Polyacrylate	8 - 16
(Methyl) Alcohol	0 - 5
Wyoming Bentonite	50 - 75
Carboxy Methyl Cellulose	0 - 3
Sodium Hexameta Phosphate	0 - 0.5

The alcohol used can be methyl alcohol, ethyl alcohol or any other liquid alcohol and serves to facilitate introduction of the liner into the smectite interlayers. Further, some of the alcohol is, during the heating stage, (the heating is due to the heat of the reaction which begins to effect the material towards the end of the reaction period) is expelled and carries with it

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excess polyacrylate which can be deposited on the outside of the extruded strip as a shiny layer. This layer may serve as lubricant as the strip passes through the die and helps to produce a smooth continuous surface. In addition this deposited acrylate also forms a coating for the material which delays the onset of severe water briefly and helps in allowing the material to be installed and perhaps wetted or exposed to the atmosphere before additional material is applied to the surround.

The function of the pressure during extrusion is to increase the density of the product by eliminating voids which might otherwise form within a less than coherent mass. This, together with the vacuum step which has removed air has the effect of compressing the material to a high density. This moves the molecules slightly closer together during extrusion thus increasing the rate of reaction and encouraging the formation of the complex from the intercalated polyacrylate liner.

Desirably the density is greater than 1,000 kilogrammes per metre cube and a preferred density is over 1,3000 kilogrammes per metre cubic.

The process described above produces a sealing strip very suitable for use in concrete foundations and the like and also in plumbing applications in the sealing of pipes and comparable

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fittings. The material can be extruded in many shapes for example square, strip, triangular or in any other convenient form. By rolling or extrusion the material can be formed into sheets which can be used to form an ideal barrier against aggressive ionised fluids. Such ionised fluid will usually be leachates from plants or sites or may be atmospheric water or ground water contacting the capping of a landfill site. It has been found that fertiliser and other materials which may be applied to foliage above a landfill site forms a highly ionised material as aggressive as any leachate and which can seriously damage conventional bentonite liners and capping.

The material made in accordance with the invention above, however, has the acrylate or other liner so securely attached to the bentonite interlayers that the cation exchange capacity (CEC) of the material is nil or very low. This means that there is no possibility of the smectite turning to a calcium form which will not reswell after drying out. Further, as the liner is preferably a plastic material the inherently stable nature of a polymeric plastics material makes the possibility of it being attacked by leachate or strong solutions quite remote.

Instead of being extruded as a strip the material of the invention can be formed into bricks, either on a block making machine into which portions of the forming complex can be introduced and compressed to shape, or a generally rectangular



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strip can be extruded and cut as by travelling knives to form blocks. The blocks can be used then to form a barrier by building in the nature of a wall, or by laying them on a floor, or lying them on some support to form a roof for a containment area. The blocks can be bonded as conventional bricks and a bentonite containing or other paste can be used as a lute in the joints. Desirably a SLIC paste is used as the lute. In a wall a cavity layer can be provided and individually drained in order to allow testing of the integrity of a "front line" layer of the wall and provide an air gap to prevent transfer of water from one wall to the other by direct contact.

A further advantage of the material of the invention resides in the fact that by appropriate selection of the liner the susceptibility of the material to adherence can be greatly increased. It is often useful to be able to attach a sealing strip to a, for example, vertical surface. This can be at the junction of various concrete components, between concrete panels or the like. In the past this has involved the provision of a recess into which the strip must be pushed (and the recess accordingly rather carefully dimensioned to receive the strip as a push fit) or the strip must be clipped or nailed in position. Whilst the clipping and nailing are effective methods of securing the strip they can be expensive and the provision of nails in the sealing strip is generally felt to be undesirable as might form a path from leakage, or they might introduce metal atoms into a

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water surrounding them with the possibility of reducing the waterproofing qualities of the smectite.

Therefore, by selecting the liner to be compatible with a convenient adhesive it is possible for a layer of adhesive to be made which will secure a strip of the material invention to, for example, a vertical surface. In the case of a polyacrylate interliner, the ends of the acrylate molecules protruding from the various particles of smectite form ideal sites for forming an adhesive bond with glue such as cyano acrylate adhesive to give a bond to concrete and comparable surfaces.

The bonding can be by means of spaced portions of the adhesive spotted at intervals along the line to which the strip is to be attached. Desirably, the adhesive used is designed to be an adhesive which will hold the strip securely over a maximum period of perhaps three or six days in order to allow the user to carry out all processes in relation to the installation of the seal and the creation of other structures nearby. However, it is important that the adhesive thereafter degrades in order to prevent the possibility of a waterproof adhesive film remaining which might provide a water path which could by-pass the seal strip.

As mentioned the material can be extruded as a strip profile or as a wide sheet. When producing a wide sheet it is desirable to

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extrude the material in the form of a hollow formation and then split that hollow formation to form a sheet. Desirably the material is extruded in the form of a hollow cylinder and then slit and laid flat.

Many other variations are possible within the scope of the invention.

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Claims

1. A water proofing material including a carrier sheet and united therewith a layer containing particulate smectite clay material formed from a plastic mass.
2. A method as claimed in claim 1, wherein the smectite containing layer is sandwiched between said support sheet and a cover sheet.
3. A method as claimed in claim 1 or 2 , wherein reinforcement is provided in the smectite containing layer.
4. A method as claimed in claim 3 wherein the reinforcement is secured to the cover sheet and/or the support sheet.
5. A method of making a waterproofing material including mixing particulate smectite clay with at least one other substance to form a plastic mass, forming that mass into a layer and uniting it with a support sheet.
6. A method as claimed in claim 5 wherein the smectite layer and the support sheet are treated after union to cause the layer to lose a degree of plasticity to enable it to be handled and stored without undergoing significant deformation.

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7. A method as claimed in claim 5 or 6 wherein the smectite is mixed to form an aqueous plastic mass which can be extruded rolled or otherwise formed into a continuous layer.
8. A method as claimed in claim 5 or 6 wherein the smectite is mixed with a non-aqueous or a mixture of aqueous and non-aqueous liquids to form the mass.
9. A method as claimed in claim 7 or 8 wherein after forming the layer is subjected to a drying step to remove liquid from the layer.
10. A method as claimed in any of claims 5 to 9 wherein the smectite containing layer is united with the support sheet by adhesive.
11. A method as claimed in any of claims 5 to 9 wherein the smectite containing layer and the support sheet are physically united.
12. A method as claimed in claim 8 or 9 wherein appendent to claim 8 wherein an alcohol is used as all or part of the liquid.
13. A method as claimed in claim 12 wherein some of the alcohol is removed and recycled after conditioning of the laminate.

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14. A waterproofing material made by the method of any of claims 5 to 13.
15. Apparatus for making a laminate waterproofing material including a conveyor, means for feeding a support to the conveyor, means for creating a plastic smectite containing mass, means for applying the plastic mass onto the support, and means for forming said plastic mass into a uniform continuous layer.
16. Apparatus as claimed in claim 15, wherein means are provided for sizing the laminate in thickness and/or in width.
17. Apparatus as claimed in claim 15 or 16 and including means for conditioning the laminate after formation to render it stable in use and storage.
18. Apparatus as claimed in claim 17 wherein said means includes an oven for evaporating substances from the laminate.
19. Apparatus as claimed in claim 18, wherein means are provided for recovering volatile solvent from said substances and recycling it.

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20. Apparatus as claimed in any of claims 15 to 19 wherein the means for supplying the plastic mass to the conveyor includes one or more nozzles, and/or an extrusion head.
21. Apparatus as claimed in any of claims 15 to 19 wherein means is provided for supplying a cover sheet to a surface of the layer remote from the support sheet.
22. Waterproofing material made by the method of any of claims 15 to 21.
23. A method of waterproofing a structure to prevent ingress and/or egress of aqueous fluids including the steps of providing a plurality of sheets each of material as claimed in any of claims 1 to 5, 14 or 22, laying the sheets to cover the surface of said structure in overlapping relationship and protecting said sheets against damage in use.
24. A method of sealing a site including providing at that site apparatus claimed in any of claims 15 to 21, transporting smectite clay and other substance(s) to the site, making the material of the invention by the method of any of claims 5 to 13 at the site and laying the material of any of claims 1 to 5, 14 or 22 directly at the site after manufacture.

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25. Waterproofing material as claimed in any of claims 1 to 4, 15 to 22 and having a density greater than 1000kg per cubic metre.
26. Waterproofing material as claimed in any of claims 1 to 4, 15, 22 and 25 and being at least one metre wide, preferably greater than two metres wide.
27. Waterproofing material made by forming from a plastic mass containing particulate smectite clay and liquid.
28. Waterproofing material made by forming from a plastic mass containing particulate smectite clay and liquid, a proportion of said liquid having been expelled from the material after forming.
29. Material as claimed in claim 27 or 28 wherein the liquid is aqueous.
30. Material as claimed in claims 27 or 28 wherein the liquid is organic.
31. Material as claimed in claim 27 wherein the liquid is a mixture of aqueous and organic liquids.



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32. Material as claimed in any of claims 27 to 31 and formed by extrusion.
33. Material as claimed in any of claims 27 to 31 and formed by rolling.
34. A method of making a waterproofing material including mixing particulate smectite clay with at least one other substance to form a plastic mass and forming that mass.
35. A method as claimed in claim 34 wherein the mass is treated after union to cause it to lose a degree of plasticity.
36. A method as claimed in claim 34 or 35 wherein the smectite is mixed to form an aqueous plastic mass.
37. A method as claimed in claim 34 or 35 wherein the smectite is mixed with a non-aqueous or a mixture of aqueous and non-aqueous liquids to form the mass.
38. A method as claimed in any of claims 34 to 37 wherein after forming the layer is united with a carrier sheet.
39. A method as claimed in any claim 38 wherein the smectite containing layer is united with the support sheet by adhesive.

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40. A method as claimed in claim 38 wherein the smectite containing layer and the support sheet are physically united.
41. A method as claimed in claim 37 wherein an alcohol is used as all or part of the liquid.
42. A method as claimed in claim 41 wherein some of the alcohol is removed and recycled after conditioning of the laminate.
43. A waterproofing material made by the method of any of claims 34 to 42.
44. Apparatus for making a waterproofing material including a conveyor, means for creating a plastic smectite containing mass, means for applying the plastic mass onto the support, and means for forming said plastic mass into a desired shape.
45. Apparatus as claimed in claim 44 including means for supplying a carrier sheet to the conveyor for union with the mass.
46. Apparatus as claimed in claim 44 or 45, wherein means are provided for sizing the laminate in thickness and/or in width.

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47. Apparatus as claimed in any of claims 44 to 46 and including means for conditioning the material after formation to render it stable in use and storage.
48. Apparatus as claimed in claim 47 wherein said means includes an oven for evaporating substances from the laminate.
49. Apparatus as claimed in claim 47, wherein means are provided for recovering volatile solvent from said substances and recycling it.
50. Apparatus as claimed in any of claims 44 to 49 wherein the means for supplying the plastic mass to the conveyor includes one or more nozzles, and/or an extrusion head.
51. Apparatus as claimed in claim 50, wherein the extrusion head is adapted to extrude a tube and means is provided to cut the tube and unfold it to form a flat web.
52. Apparatus as claimed in any of claims 44 to 51 wherein means is provided for supplying a cover sheet to a surface of the layer remote from the support sheet.
53. Waterproofing material made by the apparatus of any of claims 44 to 52.

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54. Material as claimed in any of claims 27 to 33, 45 or 53 and having a density greater than 1000kg m<sub>3</sub>.
55. Material as claimed in any of claims 27 to 33, 45, 53 or 55 and being greater than 1 metre in width, preferably greater than 2 metres.
56. A waterproofing material comprising a plastic mass containing a particulate smectite clay having, at molecular level, structural plates sandwiching interlayers between them, the plates having outer tetredral layers facing the interlayers and an organic liner complexed with said tetrahedral layers.
57. A waterproofing material including a smectite clay having its interlayers provided with organic liner to discourage replacement of sodium ions and being capable of absorbing water and swelling.
58. Material as claimed in claim 56 or 57 wherein the liner closely binds sodium cations to the outer layers of the plates therefore reducing the possiblity of their replacement by calcium cations.
59. Material as claimed in claim 56 or 57, wherein the liner replaces sodium cations leaving a generally neutral face

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which can absorb water by capillary action, but which being generally neutral, does not attract calcium cations.

60. Material as claimed in any of claims 56 to 59 and being selected from organic compounds compatible with the outer layers of the smectite plates and exemplified by sugars; as fructose; glucose; dextrose; acrylate; polyacrylate; and alkylammonium trimethyl alkyl ammonium.
61. Material as claimed in claim 60 wherein acrylate used and polymerises within the clay.
62. Material as claimed in any of claims 56 to 61 and containing glycerol.
63. Material as claimed in any of claims 56 to 62 wherein an alcohol is used in the preparation of the complex.
64. A method of treating a smectite clay including the step of reacting it with a liner capable of complexing with faces of the clay structural plates adjacent the interlayers to form a coating which resists replacement of sodium cations.
65. A method as claimed in claim 64 wherein the liner is selected from fructose; glucose; dextrose; acrylate; polyacrylate and alkylammonium trimethyl alkyl ammonium.

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66. A method as claimed in claim 64 wherein the liner is mixed with the clay as a monomer and polymerises within the clay.
67. A method as claimed in claim 64, 65 or 66 wherein alcohol is used to facilitate introduction of the liner into the smectite interlayer.
68. A method as claimed in any of claims 64 to 67 including exposing the forming complex to suction remove gas whilst reaction is proceeding.
69. A method as claimed in any of claims 64 to 65 wherein the degassed material is subsequently subjected to pressure.
70. A method as claimed in any of claims 64 to 68 wherein the forming complex is subjected pressure during reaction to increase the density of the product.
71. A method as claimed in any of calims 64 to 68 wherein the reaction between clay and liner is constrained to proceed at such a rate as to ensure that the temperature of the forming product varies between 15 and 30°C.
72. A method as claimed in any of claims 71 wherein the temperature range is from 20 to 26°C.

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73. A method as claimed in claims 71 or 72 wherein pressure is applied when the temperature is within the range specified.
74. A material made by the method of any of claims 64 to 73.
75. A material as claimed in any of claims 56 to 74 and having a density greater than 1000 kg. m<sup>3</sup>.
76. A material as claimed in any of claims 56 to 63, 74 and 75 and being a sheet at least a metre wide and desirably at least two metres wide.
77. A material as claimed in any of claims 56 to 63, 74 to 76, and having a significantly reduced expansion pressure compared with known smectite based waterproofing materials.
78. A material as claimed in claim 77 wherein the expansion pressure is below 15mm of concrete as carried out in the test defined herein.
79. A material as claimed in claim 78 wherein the expansion pressure is below 10mm of concrete as carried out in the test defined herein.

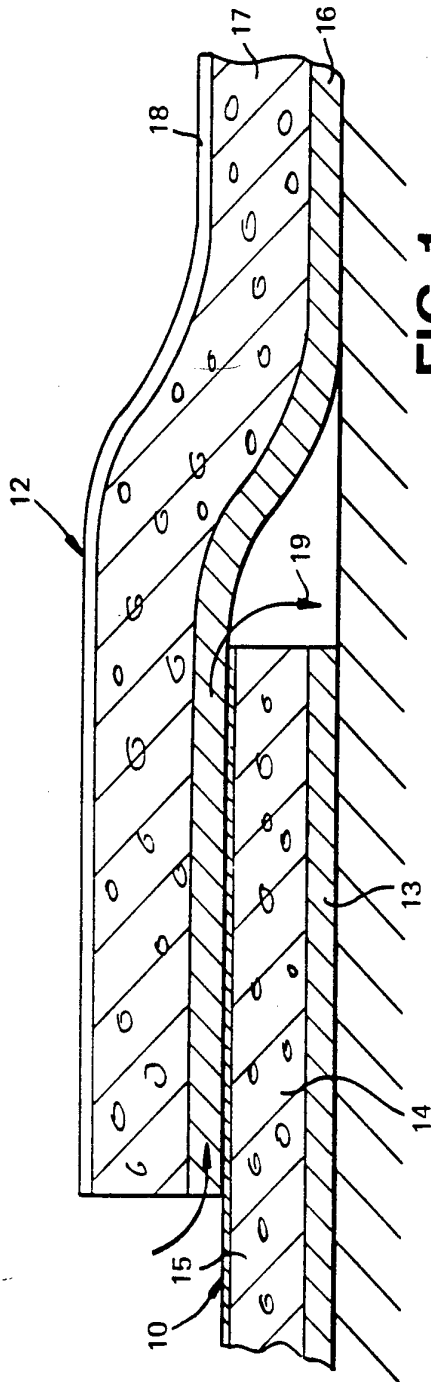
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80. A barrier against aggressive ionic fluid, in the form of a constrained layer of a material as claimed in any of claims 56 to 53 and 74 to 79.
81. A barrier as claimed in claim 80 wherein the constraint is back-fill or overlay of material or solid structure.
82. Material as claimed in any of claims 56 to 63, 74 to 79 secured to a surface by use of an adhesive compatible to the liner.
83. Material as claimed in claim 83 wherein the liner is a polyacrylate the adhesive is a cyano acrylate adhesive.
84. A method of making a fluid barrier including forming blocks of material as claimed in any of claims 56 to 63 and 74 to 79 and arranging said blocks in a layer.
85. A method as claimed in claim 84 wherein the layer is selected from a wall, a floor and a roof.
86. A method as claimed in claim 85 wherein the blocks are bonded.
87. A method as claimed in claim 84, 85 or 86 wherein a smectite-containing paste is used as a lute.

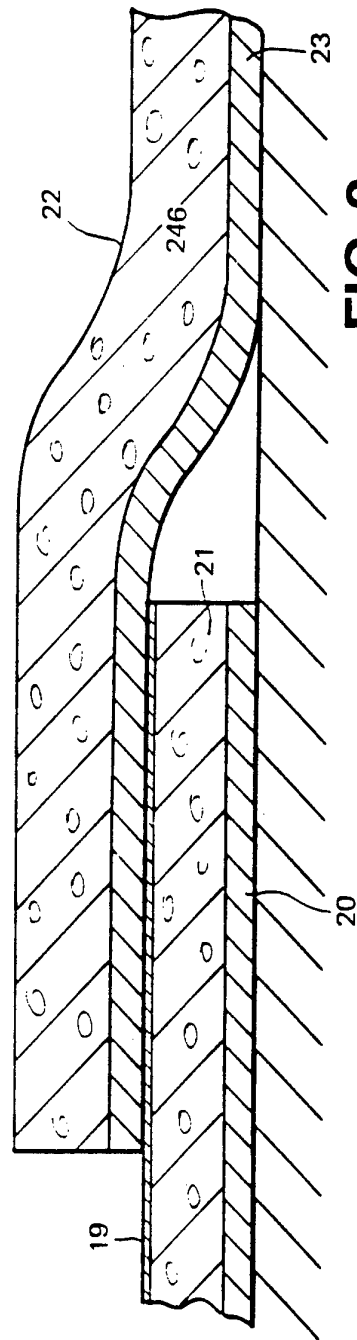


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88. A method as claimed in any of claims 84 to 87, wherein the paste is a SLIC.
89. Sealing material in the form of material as claimed in any of claims 56 to 63, 74 to 79.
90. Sealing material as claimed in claim 88 and being in annular form.
91. Waterproofing material substantially as described with reference to the accompanying drawings.
92. A method of making a waterproofing material substantially as described with reference to the accompanying drawings.

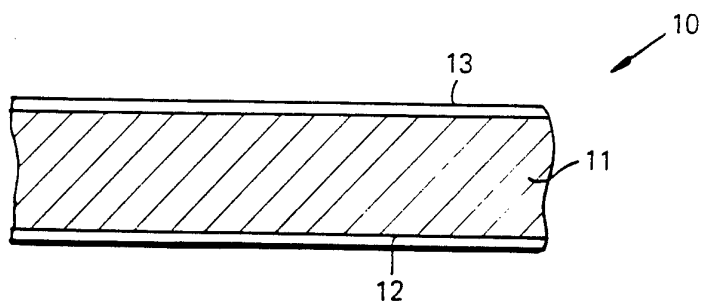
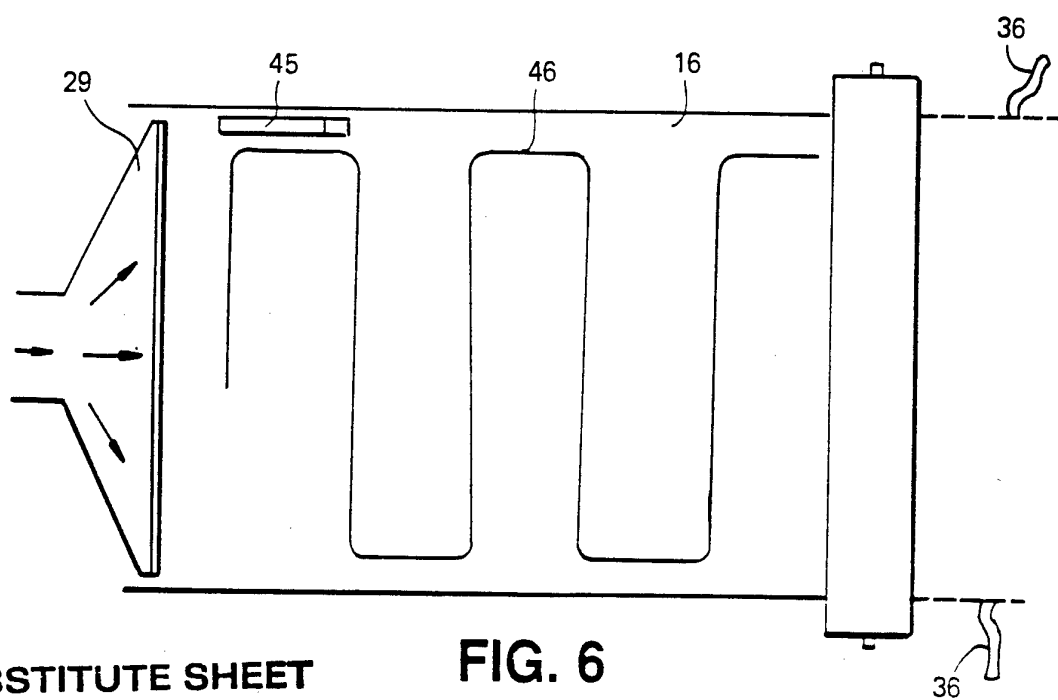


**FIG. 1**  
PRIOR ART



**FIG. 2**  
PRIOR ART

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**FIG. 3****FIG. 4****FIG. 6**

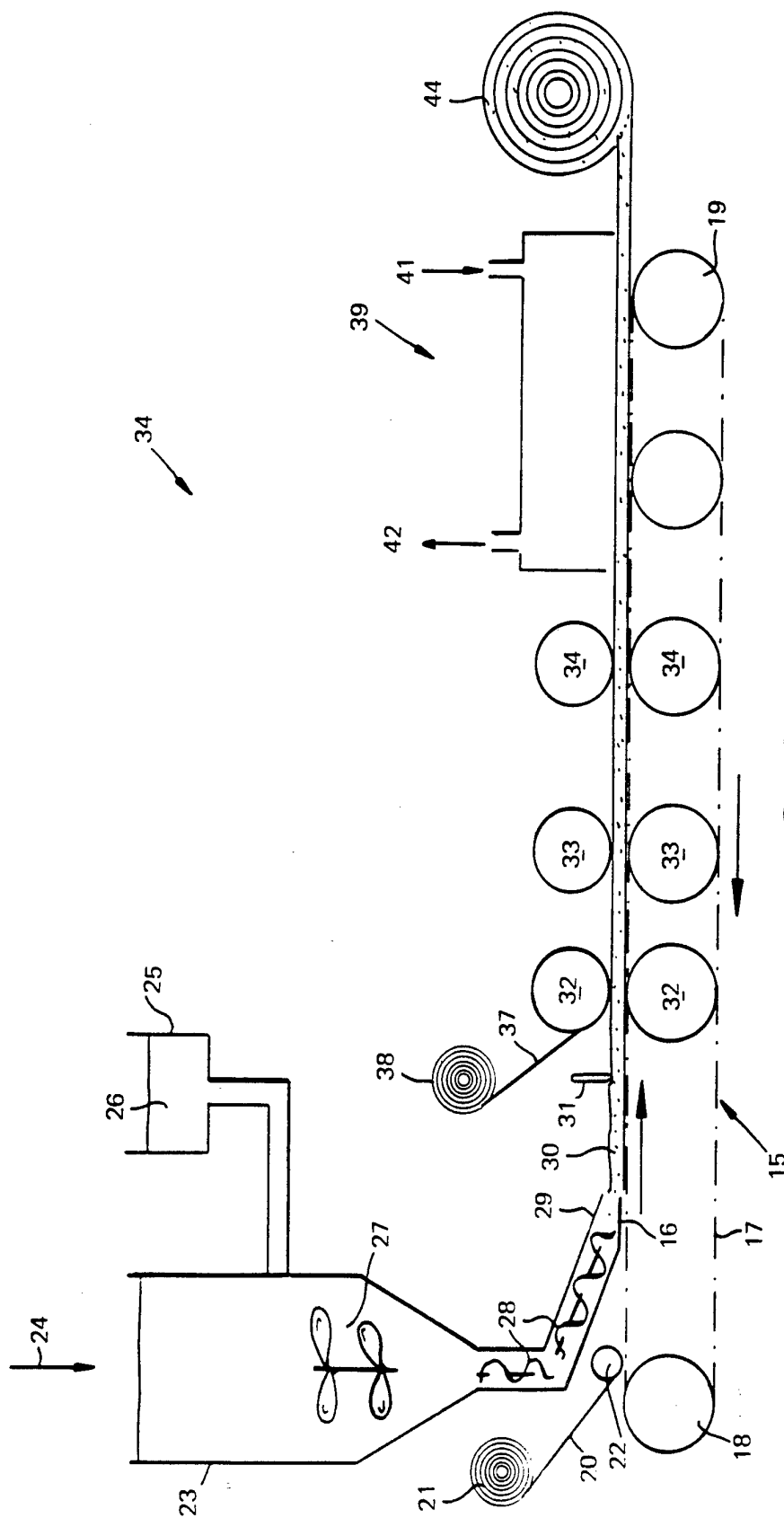
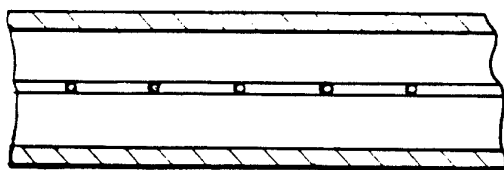
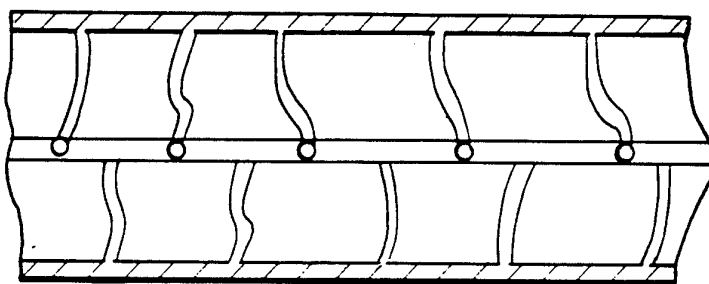


FIG. 5

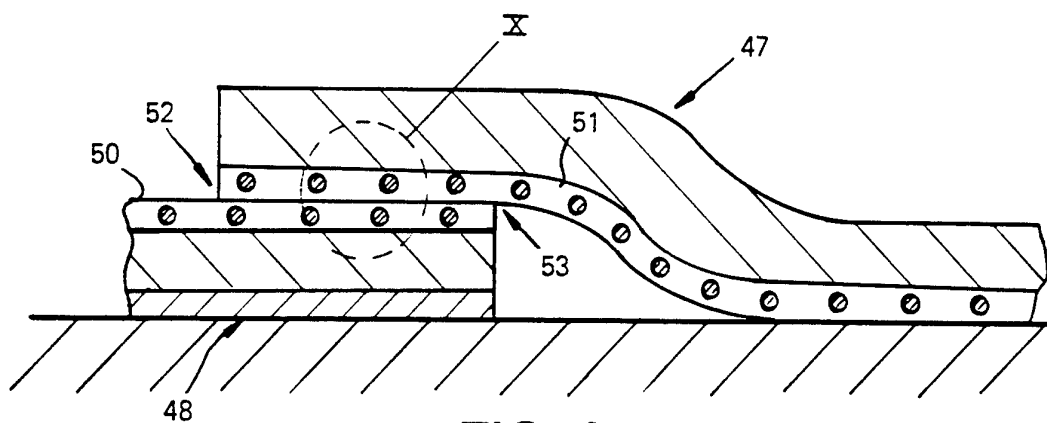
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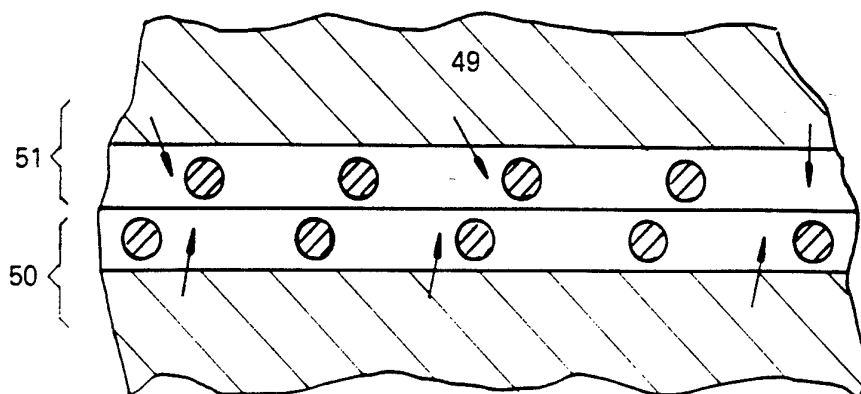
**FIG. 7**



**FIG. 8**



**FIG. 9**



**FIG. 10**

**SUBSTITUTE SHEET**

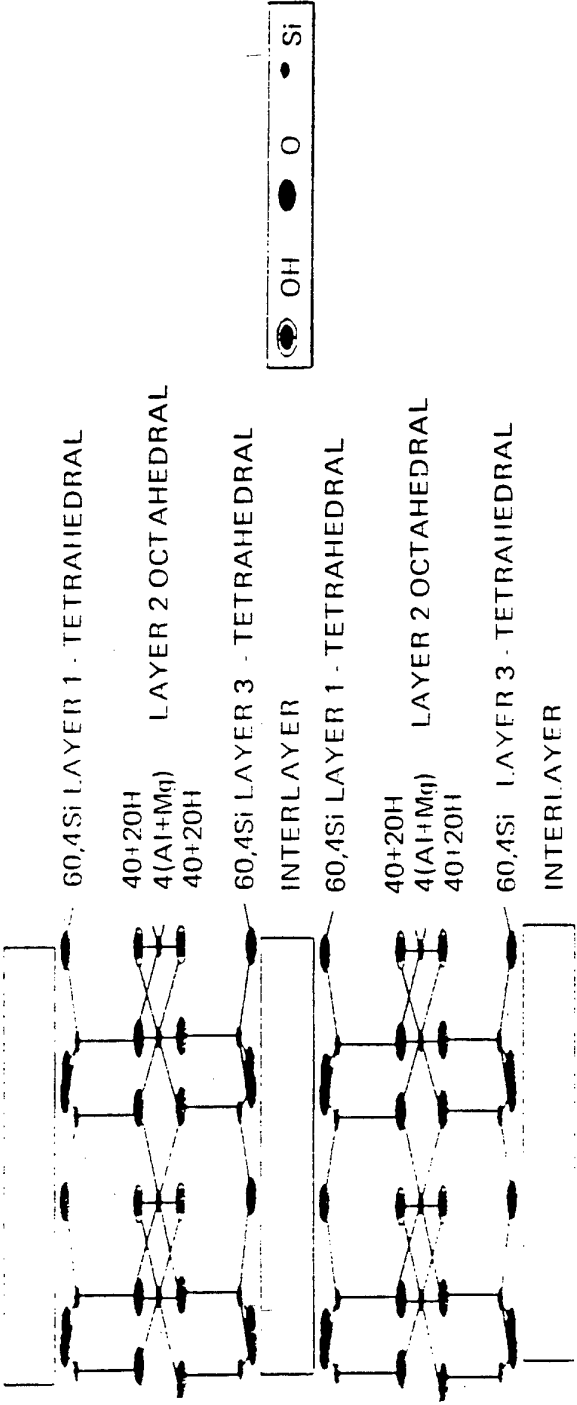


FIG. 11

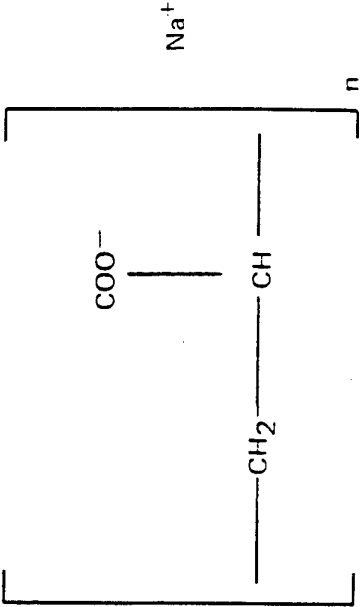


FIG. 12

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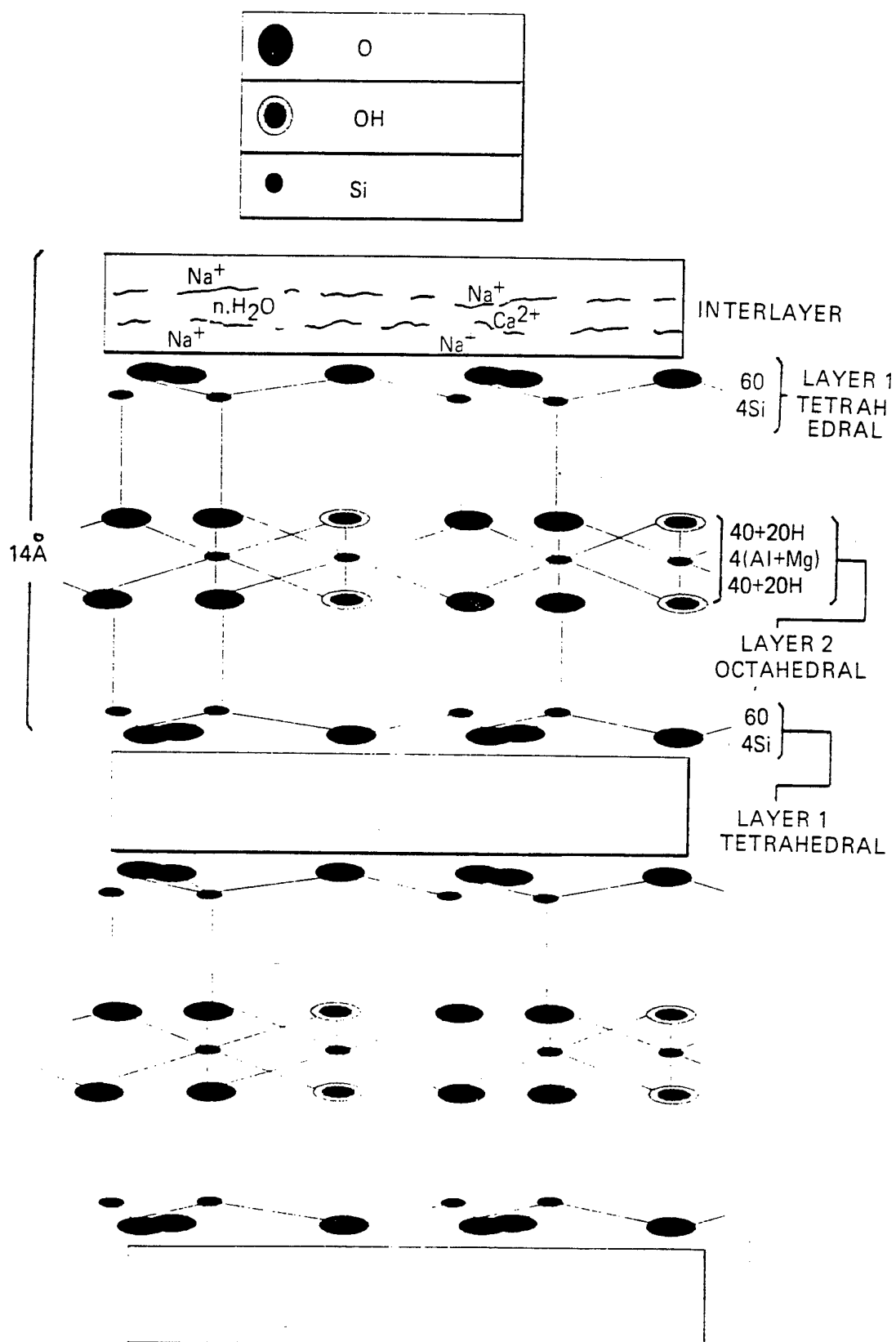


FIG. 13 SUBSTITUTE SHEET

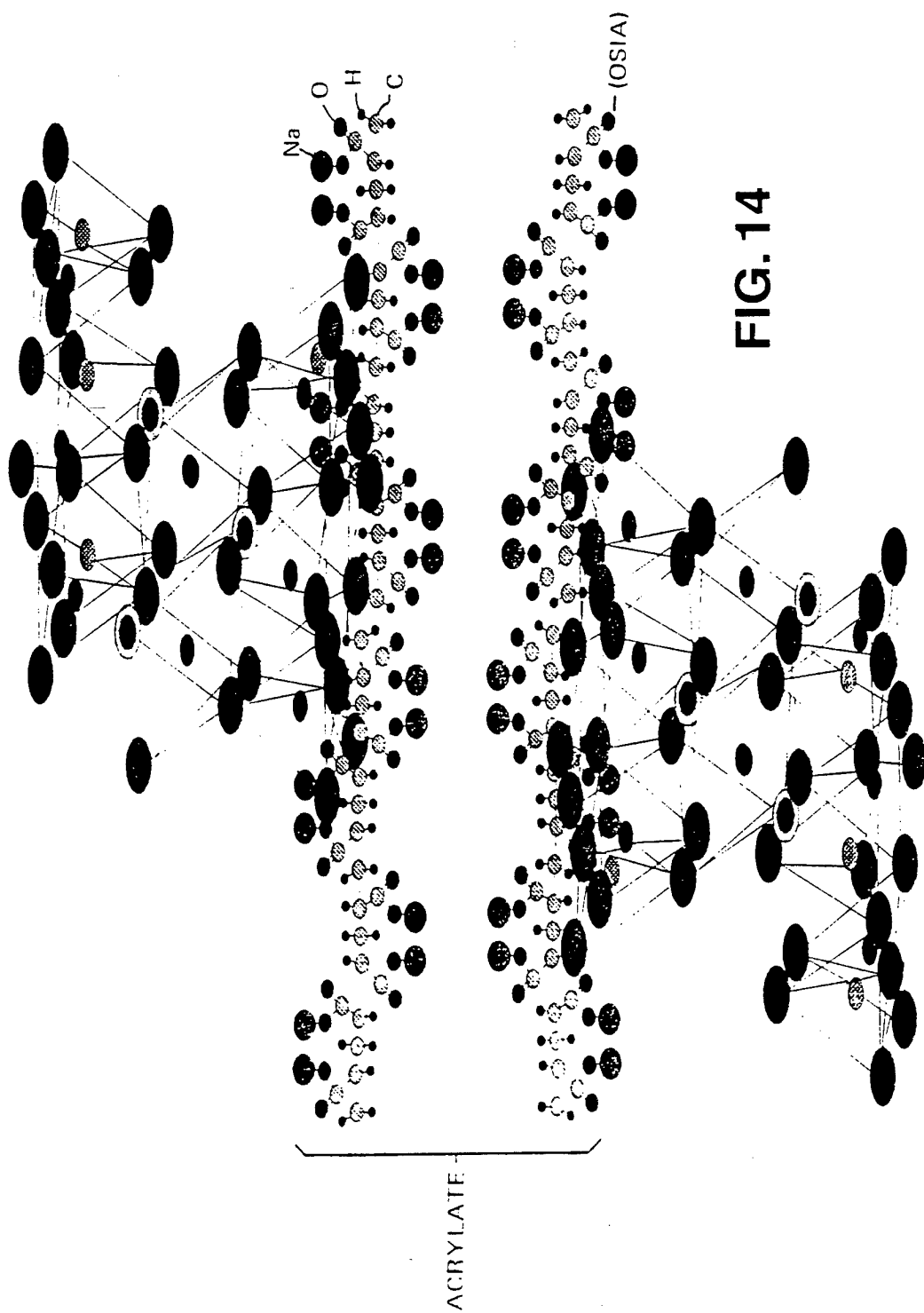


FIG. 14



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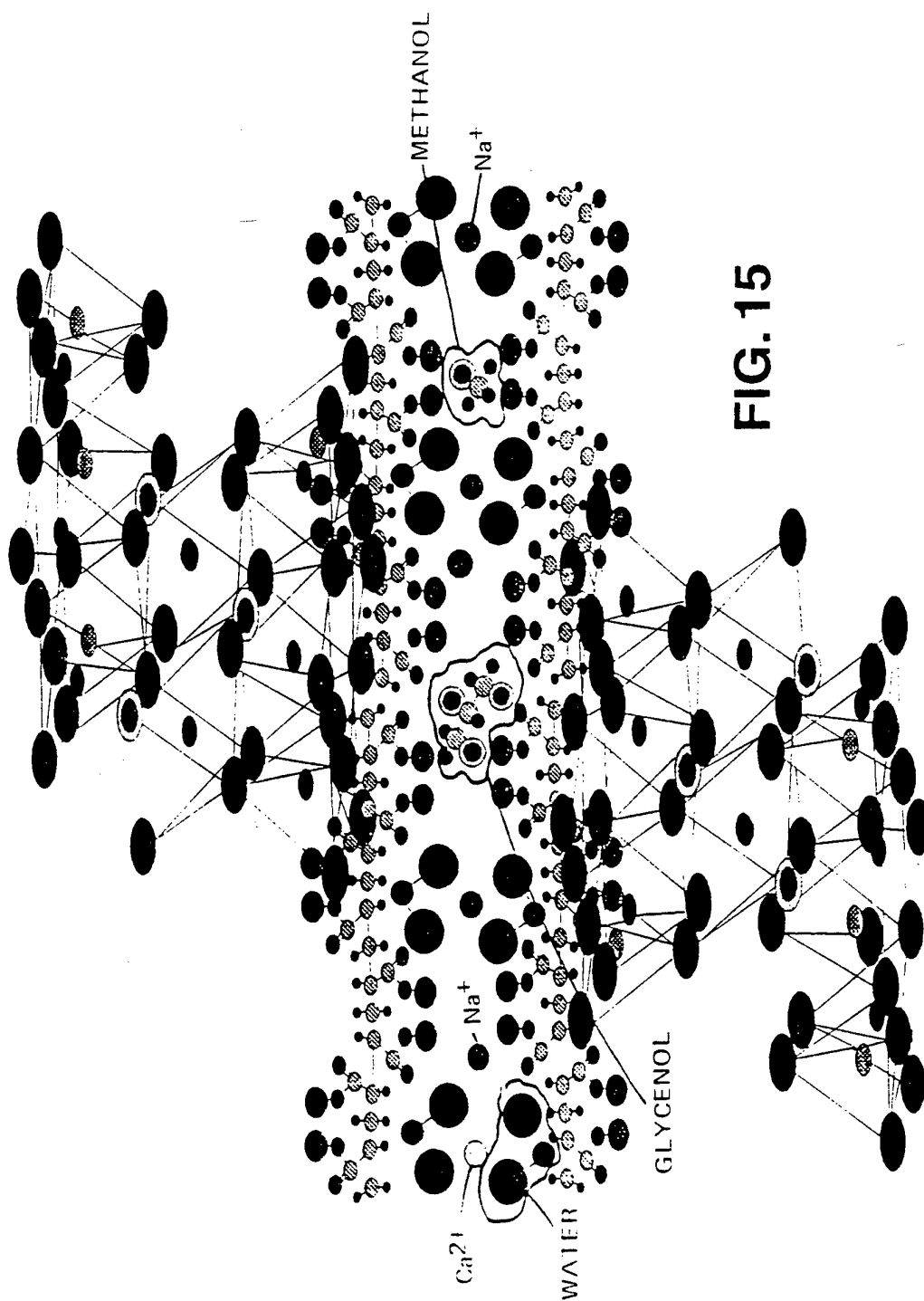


FIG. 15

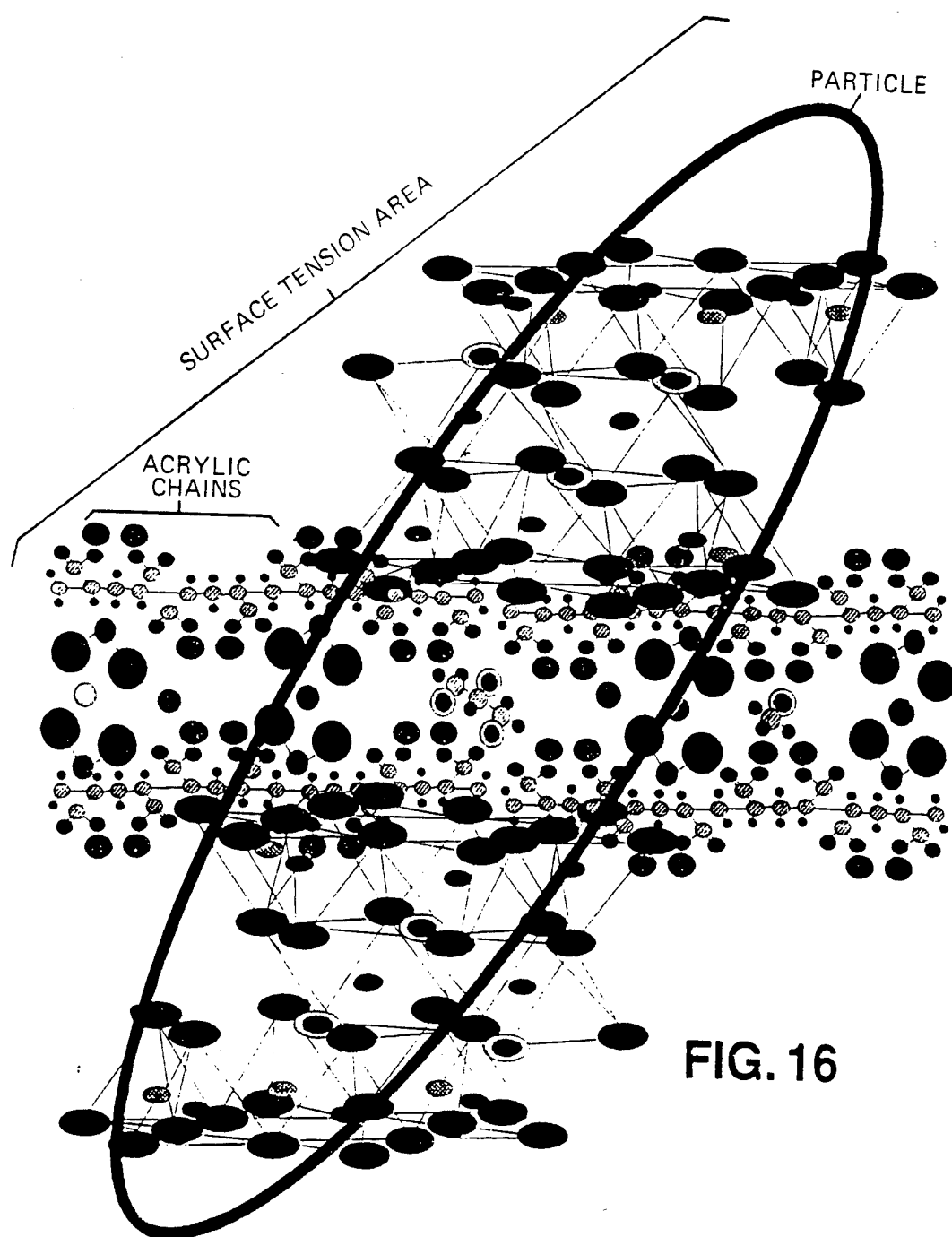


FIG. 16