

“Process and apparatus for producing shaped profile sections”

The present invention relates to a continuous line process and apparatus for producing shaped profile sections, and more particularly but not exclusively, profiled insulating sections.

PCT publication no. WO2004/053380-A1 discloses a phenolic foam pipe insulating section and a process for producing such sections. The pipe insulating section comprises a generally cylindrical hollow phenolic foam body of substantially uniform cross section with an inner facing web and an outer facing web. The phenolic foam body is slit longitudinally to provide section halves which can be opened to facilitate wrapping around a pipe to insulate the pipe. The section halves are linked by the outer web at one side and facing ends of the section halves at the other end are faced with the inner facing web. The process uses an inner mandrel and a number of outer mould sections which are heated to ensure adequate curing of the phenolic foam insulation.

The present invention provides an improved continuous line process and apparatus for producing such shaped profile sections.

Accordingly, there is provided a method for producing a shaped profile section in a continuous line process, the method comprising steps of:

providing an outer facing web;

providing an inner facing web;

laying down liquid foam reactants on the outer facing web;

wherein, the method comprises the further steps of: pre-forming the outer facing web into a desired outer profile shape prior to laying down the reactants, and shaping the inner facing web with foam formed by the liquid foam reactants within the pre-formed outer facing web to provide a desired inner profile shape for the shaped profile section. The liquid foam reactants are suitable for forming thermal insulation foam.

The present invention provides an improved method and apparatus for producing a shaped profile section in a continuous line process in which the outer facing web is pre-formed into the desired outer shape for the shaped profile section before liquid foam reactants are laid down. The inner facing web is engaged with the outer facing web
5 after the reactants are laid down and as the foam formed by the liquid foam reactants rises within the pre-formed outer facing web a desired inner profile shape for the shaped profile section is formed. The preformed outer facing web may have a curvilinear, rectilinear or any other nonlinear shape.

10 The step of pre-forming the outer facing web may comprise deforming the outer facing web to provide a pair of connected sections, each section having a substantially C-shaped cross-section.

The step of deforming the outer facing web further may comprise forming a wing at a
15 free end of each C-shaped section.

The step of pre-forming the outer facing web may comprise passing the outer facing web between engaging surfaces of a complementary roller couple in which the rollers in each roller couple have inter-fitting convex and concave engaging surfaces.

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Desirably, the step of pre-forming the outer facing web comprises passing the outer facing web between surfaces of a series of spaced apart complementary roller couples positioned so that serially consecutive portions of the outer facing web are sequentially engaged by the roller couples.

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Suitably, in the direction of movement of the outer facing web through the roller couples, configuring the engaging surfaces of the series of spaced apart complementary roller couples with rollers of gradually increasing size, such that a last roller couple in the series thereof is provided with engaging surfaces corresponding to the shape of the
30 pair of connected substantially C-shaped sections.

The step of pre-forming the outer facing web may be such that the pre-formed outer facing web maintains its shape after the pre-forming step is complete. That is, after the

outer facing web passes through the roller couples, it may maintain the desired outer shape of the shaped profile section indefinitely (or until an external force is applied thereto). The pre-formed outer facing web may be self-supporting; that is, it may maintain the desired outer profile shape in the absence of support from an external structure.

As an alternative to, or in addition to, the step of shaping the inner facing web with foam formed by the liquid foam reactants within the pre-formed outer facing web to provide a desired inner profile shape for the shaped profile section, the method may comprise the step of pre-forming the inner facing web into the desired inner profile shape prior to engagement with the outer facing web. The preformed inner facing web may have a curvilinear, rectilinear or any other nonlinear shape.

The step of pre-forming the inner facing web may comprise deforming the inner facing web to provide a pair of connected spaced-apart sections, each section having a substantially C-shaped cross-section.

The step of deforming the inner facing web further may comprise forming a wing at a free end of each C-shaped section, and a connecting portion between adjacent ends of each C-shaped section.

The step of pre-forming the inner facing web may comprise passing the inner facing web between engaging surfaces of a complementary roller couple in which the rollers in each roller couple have inter-fitting convex and concave engaging surfaces.

In an embodiment, the step of pre-forming the inner facing web comprises passing the inner facing web between surfaces of a series of spaced apart complementary roller couples positioned so that serially consecutive portions of the inner facing web are sequentially engaged by the roller couples.

Suitably, in the direction of movement of the inner facing web through the roller couples, configuring the engaging surfaces of the series of spaced apart complementary roller couples with rollers of gradually increasing size, such that a last roller couple in

the series thereof is provided with engaging surfaces corresponding to the shape of the pair of connected spaced-apart substantially C-shaped sections.

5 The step of pre-forming the inner facing web may further comprise a micro-ribbing step and/or one or more heating steps.

10 A micro-ribbing step may be performed prior to passing the inner facing web between the complementary roller couple(s). The micro-ribbing step may comprise passing the inner facing web between two spaced-apart pairs of micro-ribbing rollers to provide a pair of elongate ribs or indentations along the length of the inner facing web, each rib corresponding to one of the C-shaped sections of the pre-formed inner facing web. The micro-ribbing step prepares the inner facing web for deformation by the complementary roller couple(s) and allows optimum pre-forming of the inner facing web.

15 One or more heating steps may be performed prior to passing the inner facing web between the complementary roller couple(s). Where a micro-ribbing step is performed, the one or more heating steps may be performed after the micro-ribbing step.

20 The one or more heating steps may comprise an initial heating step comprising passing the inner facing web between a series of heaters to heat the inner facing web to a pre-determined temperature. The temperature may be determined based on the composition of the inner facing web. Preferably, the pre-determined temperature is at least 130 degrees Celsius. In one embodiment, the pre-determined temperature is 260 degrees Celsius. The inner facing web may be formed from a material which is relatively rigid at room temperature. The pre-determined temperature may correspond to a temperature at which the rigidity of the inner facing web is reduced, thereby making deforming of the inner facing web easier.

30 After the inner facing web passes through the series of heaters, the temperature of the inner facing web will begin to fall below the pre-determined temperature. The one or more heating steps may further comprise a final heating step comprising passing the inner facing web along a heater to heat the inner facing web back to the pre-determined temperature. The step of deforming the inner facing web may be performed while the

inner facing web is at or near the pre-determined temperature so that its rigidity is reduced.

The step of pre-forming the inner facing web may be such that the pre-formed inner facing web maintains its shape after the pre-forming step is complete. That is, after the inner facing web passes through the roller couples, it may maintain the desired inner shape of the shaped profile section. The pre-formed inner facing web may be self-supporting; that is, it may maintain the desired inner profile shape in the absence of support from an external structure. As the inner facing web undergoes the roll-forming portion of the preforming step, its temperature falls below the pre-determined temperature and its rigidity therefore increases, allowing it to hold the desired inner shape of the shaped profile section.

The step of laying down liquid foam reactants may comprise operating a delivery head to dispense the liquid foam reactants into the pre-formed outer facing web.

The delivery head may be a spray head or a pouring head.

The method may comprise steps of providing an outer facing web mould having a supporting surface shaped to support the pre-formed outer facing web thereon, providing an inner facing web mould configured with a moulding surface, arranging the moulding surface of the inner facing web mould to face and engage at least a portion of the supporting surface of the outer facing web mould, and conveying the preformed outer facing web with liquid foam reactants and the inner facing web in between the mould surfaces to provide, from the outer facing web mould to the inner facing web mould, sequential layers comprising the outer web facing web, the liquid foam reactants and the inner facing web.

An advantage of pre-forming the inner facing web is that the shaped profile section may be formed with the exact shape desired. When the inner facing web is shaped only by the foam formed by the liquid foam reactants, the pressure exerted by the foam on the inner facing web may be insufficient to form the facing to the inner facing web mould, results in a misshapen profile section. For example, the internal bore of the profile

section may be tear-drop or oval in cross-section, instead of circular. By pre-forming the inner facing web such that it maintains the desired shape after the pre-forming step is complete, the requirement for the foam to exert sufficient pressure on the inner facing web to form it to the inner facing web mould is removed and instead, the pre-formed inner facing web and the inner facing web mould constrain expansion of the foam to ensure the integrity of the profile is maintained.

The method may comprise providing a mould conveyor arrangement comprising a first rotary conveyor and a second rotary conveyor, in which a plurality of distinct inner facing web moulds are arranged along a perimeter of the first rotary conveyor and a plurality of distinct outer facing web moulds are arranged along a perimeter of the second rotary conveyor, whereby first rotary conveyor and second rotary conveyor are arranged such that the moulds move along a conveyor path and each inner facing web mould engages with an outer facing web mould for at least a portion of the conveyor path.

The moulding surface of each inner facing web mould may comprise a pair of spaced apart substantially C-shaped mould plates. Where the inner facing web undergoes a pre-forming step, the inner facing web mould may correspond in shape to the pre-formed inner facing web.

The substantially C-shaped mould plates may be placed in substantial radial alignment within the C-shaped sections of the outer facing web when the moulds are engaged along the conveyor path.

Desirably, the foam body formed from the liquid foam reactants is shaped and cured between the inner and outer facing webs while an inner facing web mould is engaged with an outer facing web mould.

The method may desirably comprise a step of applying pressure to one or both of the inner facing web mould and the outer facing web mould for a predetermined period of time to maintain the moulds in engagement.

Separating the moulds along the conveyor path may release the shaped profile section from between the moulds.

5 The method may comprise a step of cutting the shaped profile section to a desired length.

The outer facing web may be provided as one of metal foil such as aluminium foil, paper, glass, thermoplastic film or combinations of two or more thereof.

10 The inner facing web may be made of a thin porous material. Where the inner facing web undergoes a pre-forming step, the inner facing web may comprise fibres bound by a PVA binder. The fibres typically comprise a blend of glass fibres and polyester fibres. Preferably, the at least 50% of the fibres are 50% polyester fibres. In an embodiment, 70% of the fibres are polyester fibres. The polyester content of the inner facing web
15 allows the facing to be thermally formed, that is, by heating and roll-forming the facing.

As outlined above, the liquid foam reactants are suitable for forming thermal insulation foam.

20 Desirably, the liquid foam reactants are suitable for forming phenolic foam, poly-ester foam, poly-ether foam and/or poly-isocyanurate foam.

Advantageously, the method of the invention may be used to form insulation foam having excellent thermal insulation properties. For example, the method of the
25 invention may be used to form thermoset foam, such a phenolic foam or polyisocyanurate foam, and advantageously, said thermoset foam may have excellent thermal insulation properties.

Suitably, the foams made by the method of the invention have a density in the range of
30 from about 10 kg/m³ to about 150 kg/m³, for example the density may be in the range of from about 20kg/m³ to about 100 kg//m³, or from 20 kg/m³ to about 60 kg/m³. Foam density may be measured according to BS EN 1602:2013 – Thermal insulating products for building applications – Determination of the apparent density.

The foams made by the method of the invention are preferably closed cell foams, i.e. foams having a closed cell content of at least 85% as determined in accordance with ASTM D6226. Suitably, the foams made by the method of the invention have a closed cell content of at least 90%, such as at least 95%, or at least 97%. Closed cell content
5 may for example be determined using gas pycnometry. Suitably, closed cell content may be determined in accordance with ASTM D6226.

The foams made by the method of the invention preferably are formed using blowing agents having low environmental impact and low thermal conductivity. For example,
10 the foams made by the method of the invention may be formed using blowing agents such as hydrocarbons, chlorinated hydrocarbons, hydrofluoroolefins or combinations/blends thereof.

The blowing agent may for example comprise a C₃-C₁₀ hydrocarbon, selected from
15 propane, butane, pentane, hexane, heptane, octane, nonane, decane and isomers thereof. Suitably, the blowing agent may comprise a butane, such as n-butane or iso-butane, or a pentane, such as n-pentane, isopentane or cyclopentane.

The blowing agent may comprise a blend of a C₃-C₁₀ hydrocarbons, such as a blend of
20 C₃-C₆ hydrocarbons. For example, the blowing agent may comprise a blend of pentane isomers, e.g. a blend of cyclopentane and isopentane.

The chlorinated hydrocarbon may be a chlorinated propane, such as 1-chloropropane or 2-chloropropane (isopropyl chloride).
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The blowing agent may comprise a blend of a C₃-C₁₀ hydrocarbon and a chlorinated hydrocarbon. For example, the blowing agent may comprise a blend of a C₃-C₆ hydrocarbon and 2-chloropropane, such as a blend of a pentane and 2-chloropropane.

30 The hydrofluoroolefin may be 1-chloro-3,3,3-trifluoropropene, 1,3,3,3-tetrafluoropropene, 2,3,3,3-tetrafluoropropene or 1,1,1,4,4,4-hexafluoro-2-butene.

The blowing agent may comprise a blend of a C₃-C₁₀ hydrocarbon and a hydrofluoroolefin. For example, the blowing agent may comprise a blend of a C₃-C₆ hydrocarbon and hydrofluoroolefin, such as a blend of a pentane and a hydrofluoroolefin.

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Advantageously, the method of the invention may be used to form a thermal insulating foam having an aged thermal conductivity of below 0.0265 W/m·K when measured at a mean temperature of 10°C after heat ageing for 175 ± 5 days at 70 ± 2°C when measured in accordance with the procedure specified in European standard BS
10 EN13166:2012. Preferably, the thermal conductivity is 0.022 W/m·K or less, such as 0.020 W/m·K or less, or 0.018 W/m·K or less.

The present invention also provide a continuous line apparatus for producing a shaped profile section, the apparatus comprising:

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means for providing an outer facing web;

means for providing an inner facing web;

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means for laying down liquid foam reactants in the outer facing web;

wherein, the apparatus further comprises means for pre-forming the outer facing web into a desired outer profile shape prior to laying down the reactants, and

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means for shaping the inner facing web with foam formed by the liquid foam reactants within the pre-formed outer facing web to provide a desired inner profile shape for the shaped profile section.

The outer facing web may be provided as an elongate web, and the apparatus further comprises means for deforming the outer facing web to provide a pair of connected
30 sections, each section having a substantially C-shaped cross-section.

Desirably, a wing is formed at a free end of each C-shaped section.

Means for pre-forming the outer facing web may comprise a complementary roller couple in which rollers in each roller couple have inter-fitting convex and concave engaging surfaces, whereby the outer facing web is passed between the engaging surfaces.

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The means for pre-forming the outer facing web may also comprise a series of spaced apart complementary roller couples positioned so that serially consecutive portions of the outer facing web are sequentially engaged between the engaging surfaces of the roller couples.

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In the direction of movement of the outer facing web through the roller couples, engaging surfaces of the series of spaced apart complementary roller couples may be configured with rollers of gradually increasing size, such that a last roller couple in the series thereof is provided with engaging surfaces corresponding to the shape of the pair of connected substantially C-shaped sections.

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As an alternative to, or in addition to, the means for shaping the inner facing web with foam formed by the liquid foam reactants within the pre-formed outer facing web to provide a desired inner profile shape for the shaped profile section, the apparatus may comprise means for pre-forming the inner facing web into the desired inner profile shape prior to engagement with the outer facing web. The preformed inner facing web may have a curvilinear, rectilinear or any other nonlinear shape. In these embodiments, foam formed by the liquid foam reactants is shaped and cured between the inner and outer facing webs while the inner facing web is engaged with an outer facing web.

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The means for pre-forming the inner facing web may comprise means for deforming the inner facing web to provide a pair of connected spaced-apart sections, each section having a substantially C-shaped cross-section.

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Desirably, a wing is formed at a free end of each C-shaped section, and a connecting portion is formed between adjacent ends of each C-shaped section.

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The means for pre-forming the inner facing web may comprise a complementary roller couple in which the rollers in each roller couple have inter-fitting convex and concave engaging surfaces, wherein the inner facing web is passed between the engaging surfaces.

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The means for pre-forming the inner facing web may also comprise a series of spaced apart complementary roller couples positioned so that serially consecutive portions of the inner facing web are sequentially engaged between the engaging surfaces of the roller couples.

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In the direction of movement of the inner facing web through the roller couples, engaging surfaces of the series of spaced apart complementary roller couples may be configured with rollers of gradually increasing size, such that a last roller couple in the series thereof is provided with engaging surfaces corresponding to the shape of the pair of spaced-apart substantially C-shaped sections.

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The means for pre-forming the inner facing web may further comprise micro-ribbing means and/or one or more heating means.

20 The micro-ribbing means may comprise two spaced-apart pairs of micro-ribbing rollers between which the inner facing web is passed, to provide a pair of elongate ribs or indentations along the length of the inner facing web, each rib corresponding to one of the C-shaped sections of the pre-formed inner facing web. The spacing between the micro-ribbing rollers in each pair may correspond to twice the desired thickness of the shaped profile section. The centre of each micro-ribbing roller may be positioned at the point at which the centre of the corresponding C-shaped section is to be formed. Each pair of micro-ribbing rollers may be mounted on a telescopic shaft, which allows the spacing between the micro-ribbing rollers in each pair and the positioning of the micro-ribbing rollers relative to the inner facing web (and the inner facing web moulds) to be varied. The width of each micro-ribbing roller may correspond to the circumference of the desired corresponding C-shaped section. Each micro-ribbing roller may be made up of one or more planar discs. The width of each micro-ribbing roller may be altered by adding or removing discs. Each micro-ribbing roller may be formed with a serrated

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edge to provide a discontinuous rib or indentation along the length of the inner facing web. A spacing may be provided between the pairs of micro-ribbing rollers, wherein the spacing is substantially equal to the thickness of the inner facing web.

- 5 The one or more heating means may comprise an initial heating means comprising a series of heaters between which the inner facing web is passed to heat the inner facing web to a pre-determined temperature. The temperature may be determined based on the composition of the inner facing web. In one embodiment, the pre-determined temperature is 260 degrees Celsius.

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The one or more heating means may further comprise a final heating means comprising a heater along which the inner facing web is passed to heat the inner facing web back to the pre-determined temperature.

- 15 The apparatus may comprise a delivery head to dispense the liquid foam reactants into the pre-formed outer facing web. The delivery head is a spray head or a pouring head.

Desirably, the apparatus may comprise an outer facing web mould having a supporting surface shaped to support the pre-formed outer facing web thereon, an inner facing web
20 mould configured with a moulding surface, in which the moulding surface of the inner facing web mould is operable to face and engage at least a portion of the supporting surface of the outer facing web mould, and means are provided for conveying the preformed outer facing web with liquid foam reactants and the inner facing web in between the mould surfaces to provide, from the outer facing web mould to the inner
25 facing web mould, sequential layers comprising the outer web facing web, the liquid foam reactants and the inner facing web.

Optionally, a conveyor arrangement comprising a first rotary conveyor and a second rotary conveyor is provided, in which a plurality of inner facing web moulds are
30 arranged along a perimeter of the first rotary conveyor and a plurality of outer facing web moulds are arranged along a perimeter of the second rotary conveyor, whereby the first rotary conveyor and second rotary conveyor are arranged such that the moulds

move along a conveyor path and each inner facing web mould are operable to engage with an outer facing web mould for at least a portion of the conveyor path.

5 Desirably, the moulding surface of each inner facing web mould comprise a pair of spaced apart substantially C-shaped mould plates. Where the inner facing web is pre-formed, the inner facing web mould may correspond in shape to the pre-formed inner facing web.

10 The substantially C-shaped mould plates may be placed in substantial radial alignment within the C-shaped sections of the outer facing web when the moulds are engaged along the conveyor path.

15 As the foam formed by the liquid foam reactants rises it may be shaped and cured between the inner and outer facing webs while an inner facing web mould is engaged with an outer facing web mould.

Desirably, the apparatus further comprises means for applying pressure to one or both of the inner facing web mould and the outer facing web mould for a predetermined period of time to maintain the moulds in engagement.

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Desirably, the apparatus further comprises means for separating the moulds along the conveyor path to release the shaped profile section from between the moulds.

Means for cutting the shaped profile section to a desired length may be provided.

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The present invention further provides a shaped profile section produced by the above method and/or apparatus.

The shaped profile section may be joined around an outer surface of a pipe.

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The present invention further provides a mould conveyor arrangement for use in producing a shaped profile section, the conveyor comprising a first rotary conveyor and a second rotary conveyor, in which a plurality of inner facing web moulds are arranged along a perimeter of the first rotary conveyor and a plurality of outer facing web moulds

are arranged along a perimeter of the second rotary conveyor, whereby the first rotary conveyor and second rotary conveyor are arranged such that the moulds move along a conveyor path and each inner facing web mould is operable to engage with an outer facing web mould for a portion of the conveyor path.

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Desirably, each inner facing web mould has a moulding surface comprising a pair of spaced apart substantially C-shaped mould plates, and each outer facing web mould comprises a pair of spaced apart substantially C-shaped supporting surfaces.

10 A preformed outer facing web containing liquid foam reactants and an inner facing web may be conveyed in between the mould surfaces to provide, from the outer facing web mould to the inner facing web mould, sequential layers comprising the outer web facing web, the liquid foam reactants and the inner facing web for the portion of the conveyor path in which each inner facing web mould engages with an outer facing web mould.

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The invention will be more clearly understood from the following description thereof given by way of example only with reference to the accompanying drawings in which -

20 Fig. 1 is a diagrammatic representation of a continuous line apparatus for producing a shaped profile section according to the invention;

Figs. 2(a) and 2(b) are end and plan views of a roller couple for pre-forming an outer facing web according to the invention;

25 Fig. 3 is a side view of an outer facing web being pre-formed by the roller couple shown in Fig. 2;

Fig. 4 is an end view of a pre-formed outer facing web according to the invention;

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Fig. 5 is a perspective end view of a conveyor arrangement receiving the pre-formed outer facing web according to the invention (liquid foam reactants and inner facing web are not shown to aid clarity);

Fig. 6 is a side view of the conveyor arrangement and pre-formed outer facing web shown in Fig 5 (liquid foam reactants and inner facing web are not shown to aid clarity);

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Fig. 7 is an end view of a shaped profile section in the conveyor arrangement shown in Fig 5;

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Fig. 8 is an end view of a shaped profile section in a conveyor arrangement according to the invention;

Fig. 9 is an exploded cross-sectional end view of a shaped profile section formed and separate moulds of a conveyor arrangement according to the invention;

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Figure 10 is a side view of a pre-forming arrangement for an inner facing web, according to an embodiment of the invention (to aid clarity, outer web facing and outer web facing pre-forming means are not shown); and

Figure 11 is an end view of the micro-ribbing arrangement of Figure 10.

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With reference initially to Figs. 1 to 4, there is shown a line apparatus, indicated generally by the reference numeral 1, for continuous production of a shaped profile section (shown in Fig. 9) comprising an inner facing web 3, an outer facing web 4 and foam body 16 formed by liquid foam reactants between the webs 3, 4.

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As shown, the outer facing web 4 is initially provided as an elongate web of material made from metal foil such as aluminium foil, paper, glass, thermoplastic film or combinations of two or more thereof. Means, such as an arrangement of one or more rollers and/or guides 5, are provided for introducing the outer facing web 4, which may be stored as a roll of material, into the apparatus 1 for pre-forming. The inner facing web 3 is made of a thin porous material and means, also provided as an arrangement of one or more rollers and/or guides, are operable to introduce the inner facing web 4, which may be stored as a roll of material, to the apparatus 1.

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The apparatus 1 comprises means for pre-forming the outer facing web 4 into a shape of a pair of connected elongate sections 7, in which each section has a substantially C-shaped end view cross-section. A wing 8 is formed and extends from a free end 9 of each C-shaped section in the pair of connected sections 7.

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Also provided are means for pre-forming the outer facing web 4 comprising one or more complementary roller couples 10 in which rollers 11, 12 in each roller couple 10 have a roller 11 with convex engaging surfaces 13 and a roller 12 with concave engaging surfaces 14, whereby the surfaces 13, 14 are configured to inter-fit. The outer facing web 4 is thus introduced in between the engaging surfaces 13, 14 of the roller couple 10 in the direction of the arrow 'A', and as the web 4 passes through the roller couple 10 it is deformed and shaped. In the instance shown in Fig. 1, a series of spaced apart complementary roller couples 10a to 10f are provided and positioned so that serially consecutive portions of the outer facing web 4 are sequentially engaged between the engaging surfaces 13, 14 of the roller couples 10. Rollers 10 of gradually increasing diameter are provided, and the last roller couple 10f in the series thereof is provided with engaging surfaces 13, 14 adapted to the shape of the pair of connected substantially C-shaped sections 7 of the finally pre-formed outer facing web 4.

A delivery means 15 in the form of a spray head or a pouring head is provided to lay down or discharge liquid foam reactants 16 in the outer facing web 4, and more particularly, continuously into the C-shaped sections 7 of the pre-formed elongate outer facing web 4 as the outer facing web 4 moves under the delivery means 15. The liquid foam reactants 16 are suitable for forming phenolic foam, poly-ester foam, poly-ether foam and/or poly-isocyanurate foam. For example, the liquid foam reactants may be suitable for forming phenolic foam or polyisocyanurate foam.

The pre-formed outer facing web 4 containing liquid foam reactants 16 and the inner facing web 3 are then conveyed to a mould conveyor arrangement 17. As shown in Figs. 5 to 9, the rotary conveyor arrangement 17 comprises a first rotary conveyor 18 and a second rotary conveyor 19, in which a plurality of adjacently arranged inner facing web moulds 20 are disposed along a perimeter of the first rotary conveyor 18, and a plurality of adjacently arranged outer facing web moulds 21 are disposed along a

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perimeter of the second rotary conveyor 19. For illustrative purposes only, the liquid foam reactants 16 within the outer facing web 4 and the inner facing web 3 are not shown in Figs. 5 and 6. The rotary conveyors 18, 19 may be provided as a chain link type conveyor comprising pivotably connected chain links mounting plates 27 operable to mount and convey a respective mould 20, 21 along a substantially rotary conveyor path 'P'.

As shown in Figures 5 and 7 in particular, the conveyors comprise two separate sets of inner facing web moulds and two separate sets of outer facing web moulds 21. This allows two shaped profiles of different sizes to be produced simultaneously. The facing web moulds are interchangeable, so that a set of inner facing web moulds 20 and a set of outer facing web moulds 21 may be removed from the conveyor and replaced with different sets of inner and outer facing web moulds respectively to produce a profile of a different size. In this way, the line apparatus may be adjusted to produce profiles of varying sizes without significant alteration of the apparatus.

The first rotary conveyor 18 and second rotary conveyor 19 are arranged such that the moulds 20, 21 move along the rotary conveyor path 'P', and each inner facing web mould 20 is operable to engage with an outer facing web mould 21 along a substantially portion 'Q' of the conveyor path. Each outer facing web mould 21, has a supporting surface 22 that is shaped to support thereon a portion of the pre-formed outer facing web 4 and the moulding surface 23 of each inner facing web mould 20 comprises a pair of spaced apart substantially C-shaped mould plates 24. The outer facing web mould may thus provide a female mould and the inner facing web mould a male mould. It will be appreciated that Figs. 5 to 8 show an arrangement for conveying a pair of pre-formed outer facing webs 4 and a pair of inner facing webs 3, to thereby produce two runs of separate continuous shaped profile sections 2.

As the moulds 20, 21 exit the portion 'Q' of the conveyor path 'P' they are disengaged. It will be understood that along the portion 'Q' of the conveyor path 'P' the moulds 20, 21 are positioned in a side by side arrangement to provide a substantially straight through passage for the outer facing web 4 with liquid foam reactants 16 and the inner facing web 3.

In operation, the preformed outer facing web 4 with liquid foam reactants 16 and the inner facing web 3 are conveyed in between the mould surfaces 22, 23 to provide, from the outer facing web mould 21 to the inner facing web mould 20, sequential layers comprising the outer web facing web 4, the liquid foam reactants 16 and the inner
5 facing web 3.

In one embodiment, the liquid foam reactants 16 comprise a phenolic resin containing 17% to 22% water and 4% by weight of diethylene glycol as a plasticizer. The resin contains 8% free phenol, and less than 1.5% free formaldehyde, with a viscosity of
10 2000cP to 3500cP at 25°C. The resin is mixed with an acid catalyst and a blowing agent such that the resultant foam has a thermal conductivity of between about 0.0261 and 0.0263 W/mK.

The action of the outer facing web mould 21 engaging with an inner facing web mould
15 20 at the entry to the portion 'Q' of the conveyor path 'P' brings the mould surfaces 22, 23 into moulding engagement. The webs 3, 4 are pinched between surfaces 25 of the inner facing web mould 20 and surfaces 26 of the outer facing web mould 21 to thereby grip and continuously draw the outer facing web 4 and inner facing web 3 through the conveyor arrangement 17. The pinching action between surfaces 25, 26 on the webs 3,
20 4 further acts to fuse these webs together and to provide a link 27 between the C-shaped sections of the webs 3, 4 and to provide a leak proof seal to stop the liquid foam reactants 16 escaping.

The foam formed by the liquid foam reactants 16 is shaped and cured to form a foam
25 body between the inner and outer facing webs 3, 4 while the moulds 20, 21 are engaged along the portion 'Q' of the conveyor path 'P'. In one embodiment, the inner facing web 3 is shaped as the foam rises within the pre-formed outer facing web 4 to provide a desired profile shape for the shaped profile section 1. The action of the liquid foam reactants 16 curing and expanding effectively pushes the inner facing web 3 against the
30 substantially C-shaped mould plates 24 of the inner facing web mould 20 to provide the desired profile for the inner facing web 3 of the shaped profile section 1. In other embodiments, described below, the inner facing web 3 may be pre-formed to the desired profile shape to ensure that the desired shape is achieved. A further function of the

inner facing web is to prevent the liquid foam reactants 16 from adhering to the inner facing web mould 20 during the curing process and formation of the foam body between the webs 3, 4.

5 Means 28 in the form of clamps are provided for applying pressure to one or both of the inner facing web mould 20 and the outer facing web mould 21 for a predetermined period of time to maintain the moulds 20, 21 in engagement. Such a pressure means 27 ensures that the pressure arising in between the moulds 20, 21 as the liquid foam reactants 16 cures and expands against the inner facing web 3 is not sufficient to cause
10 the moulds 20, 21 to separate. As the moulds 20, 21 exit the portion 'Q' of the conveyor path 'P' the moulds 20, 21 continue on their respective rotary path 'P' and separate causing the shaped profile section 1 to be released from between the moulds 20, 21. Means may be provided for cutting the shaped profile section 1, comprising the webs 3, 4 adhered to the foam body, to a desired length.

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In general, the duration of time for which the shaped profile remains between the mould 20, 21 is dependent on the line speed of the apparatus. The slower the line speed, the longer the moulds remain in contact with the inner and outer facing webs as they pass through portion 'Q' of the conveyor path. The line speed may be selected to ensure that
20 the profile remains between the moulds for sufficient time to allow the foam reactants to cure fully. The line speed may also be limited by other factors such as pouring time for the liquid foam reactants or cutting speed. The duration of time for which the moulds remain in contact may range between about 96 seconds and about 320 seconds.

25 It will be understood that the connected substantially C-shaped sections of the shaped profile section 1 formed according to the invention may be joined around a pipe such that the inner facing web 3 engages the outer surfaces of the pipe.

An embodiment of the invention including means for pre-forming the inner facing web
30 3 into the desired inner profile shape prior to engagement with the outer facing web is shown in Figures 10 and 11. For purposes of clarity, the outer facing web and the means for pre-forming the outer facing web and the means for laying down the liquid foam reactants are not shown in Figures 10 and 11. However, the embodiment of

Figures 10 and 11 may advantageously be combined with the embodiments of the invention shown in Figures 1 to 9.

Figure 10 shows a portion of a line apparatus, indicated generally by the reference numeral 29, for continuous production of a shaped profile section comprising an inner facing web 3, an outer facing web (not shown) and foam body (not shown) formed by liquid foam reactants between the webs.

As shown, the inner facing web 3 is initially provided as an elongate web of material made from 30% glass fibres and 70% polyester fibres bound by a PVA binder. Means, such as an arrangement of one or more rollers and/or guides 6, are provided for introducing the inner facing web 3, which may be stored as a roll of material, into the apparatus 29 for pre-forming.

The apparatus 29 comprises means for pre-forming the inner facing web 3 into a shape of a pair of connected spaced-apart elongate sections, in which each section has a substantially C-shaped end view cross-section (as shown in Figure 9). A wing is formed and extends from a free end of each C-shaped section and a connecting portion is formed between adjacent ends of each C-shaped section.

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The means for pre-forming the inner facing web 3 comprises micro-ribbing means 33, comprising two spaced-apart pairs 35, 36 of micro-ribbing rollers between which the inner facing web 3 is passed to provide a pair of elongate ribs or indentations along the length of the inner facing web 3, each rib corresponding to one of the C-shaped sections.

25 The micro-ribbing means 33 is shown in more detail in Figure 11.

Each pair of micro-ribbing rollers 35, 36 is mounted on a telescopic shaft 40, which allows the spacing X between the micro-ribbing rollers in each pair and the positioning of the micro-ribbing rollers relative to the inner facing web (and the inner facing web moulds) to be varied. The spacing X between the micro-ribbing rollers in each pair corresponds to twice the desired thickness of the shaped profile section. The centre of each micro-ribbing roller 35a, 35b, 36a, 36b is positioned at the point at which the centre of the corresponding C-shaped section is to be formed.

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The width Y of each micro-ribbing roller may correspond to the circumference of the desired corresponding C-shaped section. Each micro-ribbing roller 35a, 35b, 36a, 36b may be made up of one or more planar discs (not shown). The width of each micro-ribbing roller may be altered by adding or removing discs.

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Each micro-ribbing roller 35a, 35b, 36a, 36b may be formed with a serrated edge (not shown) to provide a discontinuous rib or indentation along the length of the inner facing web. A spacing Z may be provided between the pairs of micro-ribbing rollers, wherein the spacing is substantially equal to the thickness of the inner facing web 3.

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The means for pre-forming may also include heating means 34. The heating means 34 comprises an initial heating means comprising a series of heaters 37, 38 between which the micro-ribbed inner facing web 3 is passed to heat the inner facing web to a pre-determined temperature, determined based on the composition of the inner facing web.

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In the present embodiment, the pre-determined temperature is 260 degrees Celsius.

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After the inner facing web passes through the series of heaters 37, 38, the temperature of the inner facing web 3 begins to fall below the pre-determined temperature. The heating means 34 further comprises a final heating means comprising a heater 39 along which the inner facing web is passed to heat the inner facing web back to the pre-determined temperature. After passing through the heaters 37, 38, 39, the rigidity of the inner facing web 3 is reduced, thereby allowing it to be deformed more easily.

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Also provided are one or more complementary roller couples 30 in which rollers 31, 32 in each roller couple 30 have a roller 31 with convex engaging surfaces and a roller 32 with concave engaging surfaces (similar to those shown in Figures 2 and 3), whereby the engaging surfaces are configured to inter-fit. The heated and micro-ribbed inner facing web 3 is thus introduced in between the engaging surfaces of the roller couple 30, and as the web 3 passes through the roller 30 it is deformed and shaped. In the instance shown in Fig. 10, a series of spaced apart complementary roller couples 30a to 30c are provided and positioned so that serially consecutive portions of the inner facing web 3 are sequentially engaged between the engaging surfaces of the roller couples 30. Rollers 30 of gradually increasing diameter are provided, and the last roller couple 30c in the

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series thereof is provided with engaging surfaces adapted to the shape of the pair of connected spaced-apart substantially C-shaped sections of the finally pre-formed inner facing web 3.

- 5 As shown in Figure 10, the pre-formed outer facing web 3 is then conveyed to a mould conveyor arrangement 17, similar to that shown in Figures 5 to 9. The shape of the inner facing web moulds 20 corresponds to the shape of the pre-formed inner facing web. After exiting the complementary roller couples 30, the temperature of the inner facing web 3 is reduced so that it becomes relatively rigid and therefore maintains its
- 10 pre-formed shape while the foam is shaped and cured, thereby ensuring that the shaped profile has the desired profile shape.

The words “comprises/comprising” and the words “having/including” when used herein with reference to the present invention are used to specify the presence of stated

15 features, integers, steps or components but does not preclude the presence or addition of one or more other features, integers, steps, components or groups thereof.

It is appreciated that certain features of the invention, which are, for clarity, described in the context of separate embodiments, may also be provided in combination in a single

20 embodiment. Conversely, various features of the invention which are, for brevity, described in the context of a single embodiment, may also be provided separately or in any suitable sub-combination.

Claims

1. A method for producing a shaped profile section in a continuous line process,
the method comprising steps of:
 - 5 providing an outer facing web;
 - laying down liquid foam reactants in the outer facing web;
 - 10 engaging an inner facing web with the outer facing web;
 - wherein the method comprises the further steps of: pre-forming the outer facing web into a desired outer profile shape prior to laying down the reactants, and pre-forming the inner facing web into a desired inner profile shape for the
 - 15 shaped profile section prior to engagement with the outer facing web, such that the pre-formed inner facing web maintains its shape in the absence of support from an external structure, after the step of pre-forming the inner facing web is complete.
- 20 2. A method as claimed in claim 1, wherein the inner facing web is formed from a material which is relatively rigid at room temperature, the method further comprising:
 - heating the inner facing web to a pre-determined temperature at which the rigidity of the inner facing web is reduced, prior to pre-forming the inner
 - 25 facing web into the desired inner profile shape; and
 - allowing the temperature of the inner facing web to fall below the pre-determined temperature during pre-forming the inner facing web into the desired inner profile shape, such that the pre-formed inner facing web maintains its shape in the absence of support from an external structure, after the step of pre-
 - 30 forming the inner facing web is complete.
3. A method for producing a shaped profile section as claimed in claim 1 or claim 2, in which the outer facing web is provided as an elongate web, and the step of

pre-forming comprises deforming the outer facing web to provide a pair of connected elongate sections, each section having a substantially C-shaped cross-section.

- 5 4. A method for producing a shaped profile section as claimed in any of claims 1 to 3, in which the step of deforming the outer facing web further comprises forming a wing at a free end of each C-shaped section.
- 10 5. A method for producing a shaped profile section as claimed in any preceding claim, in which the step of pre-forming the outer facing web comprises passing the outer facing web between engaging surfaces of a complementary roller couple in which the rollers in each roller couple have inter-fitting convex and concave engaging surfaces.
- 15 6. A method for producing a shaped profile section as claimed in any preceding claim, in which the step of pre-forming the outer facing web comprises passing the outer facing web between surfaces of a series of spaced apart complementary roller couples positioned so that serially consecutive portions of the outer facing web are sequentially engaged by the roller couples.
- 20 7. A method for producing a shaped profile section as claimed in claim 5 or claim 6, comprising a step of, in the direction of movement of the outer facing web through the roller couples, configuring the engaging surfaces of the series of spaced apart complementary roller couples with rollers of gradually increasing size, such that a last roller couple in the series thereof is provided with engaging surfaces corresponding to the shape of the pair of connected substantially C-shaped sections.
- 25 8. A method for producing a shaped profile section as claimed in any of claims 2 to 7, wherein the step of pre-forming the inner facing web comprises deforming the inner facing web to provide a pair of spaced-apart sections, each section having a substantially C-shaped cross-section.
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9. A method for producing a shaped profile section as claimed in claim 8, wherein the step of deforming the inner facing web further comprises forming a wing at a free end of each C-shaped section, and a connecting portion between adjacent ends of each C-shaped section.
- 5 10. A method for producing a shaped profile section as claimed in any of claims 2, 8 or 9, wherein the step of pre-forming the inner facing web comprises passing the inner facing web between engaging surfaces of a complementary roller couple in which the rollers in each roller couple have inter-fitting convex and concave
10 engaging surfaces.
11. A method for producing a shaped profile section as claimed in any of claims 2, 8, 9 or 10, wherein the step of pre-forming the inner facing web comprises passing the inner facing web between surfaces of a series of spaced apart
15 complementary roller couples positioned so that serially consecutive portions of the inner facing web are sequentially engaged by the roller couples.
12. A method for producing a shaped profile section as claimed in claim 10 or claim 11, comprising a step of, in the direction of movement of the inner facing web
20 through the roller couples, configuring the engaging surfaces of the series of spaced apart complementary roller couples with rollers of gradually increasing size, such that a last roller couple in the series thereof is provided with engaging surfaces corresponding to the shape of the pair of connected substantially C-shaped sections.
- 25 13. A method for producing a shaped profile section as claimed in any of claims 10 to 12, wherein the step of pre-forming the inner facing web further comprises a step of micro-ribbing the inner facing web.
- 30 14. A method for producing a shaped profile section as claimed in claim 13, wherein the step of micro-ribbing the inner facing web is performed prior to passing the inner facing web between engaging surfaces of a complementary roller couple.
15. A method for producing a shaped profile section as claimed in claim 13 or claim
35 14, wherein the step of micro-ribbing comprises passing the inner facing web

between two spaced-apart pairs of micro-ribbing rollers to provide a pair of elongate ribs or indentations along the length of the inner facing web, each rib corresponding to one of the C-shaped sections of the pre-formed inner facing web.

- 5 16. A method for producing a shaped profile section as claimed in any of claims 10 to 15, wherein the step of pre-forming the inner facing web further comprises one or more heating steps.
- 10 17. A method for producing a shaped profile section as claimed in claim 16, wherein the one or more heating steps are performed prior to passing the inner facing web between the complementary roller couple.
- 15 18. A method for producing a shaped profile section as claimed in claim 17, wherein the one or more heating steps comprise an initial heating step comprising passing the inner facing web between a series of heaters to heat the inner facing web to a pre-determined temperature.
- 20 19. A method for producing a shaped profile section as claimed in claim 18, wherein the one or more heating steps further comprise a final heating step comprising passing the inner facing web along a heater to return the inner facing web to the pre-determined temperature.
- 25 20. A method for producing a shaped profile section as claimed in claim 18 or claim 19, wherein the step of deforming the inner facing web is performed while the inner facing web is at or near the pre-determined temperature.
- 30 21. A method for producing a shaped profile section as claimed in any one of the preceding claims, in which the step of laying down liquid foam reactants comprises operating a delivery head to dispense the liquid foam reactants into the pre-formed outer facing web.
- 35 22. A method for producing a shaped profile section as claimed in claim 21, in which the delivery head is a spray head or a pouring head.

23. A method for producing a shaped profile section as claimed in any one of the preceding claims, comprising a step of cutting the shaped profile section to a desired length.
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24. A method for producing a shaped profile section as claimed in any one of the preceding claims, in which the outer facing web is one of metal foil such as aluminium foil, paper, glass, thermoplastic film or combinations of two or more thereof.
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25. A method for producing a shaped profile section as claimed in any one of the preceding claims, in which inner facing web is made of a thin porous material.
26. A method for producing a shaped profile section as claimed in any preceding claim, in which the inner facing web may comprise fibres bound by a PVA binder.
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27. A method for producing a shaped profile section as claimed in claim 26, wherein the fibres comprise a blend of glass fibres and polyester fibres.
- 20
28. A method for producing a shaped profile section as claimed in claim 27 wherein the at least 50% of the fibres are polyester fibres.
29. A method for producing a shaped profile section as claimed in any one of the preceding claims, in which the liquid foam reactants are suitable for forming phenolic foam, poly-ester foam, poly-ether foam and/or poly-isocyanurate foam.
- 25
30. A continuous line apparatus for producing a shaped profile section, the apparatus comprising:
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- means for providing an outer facing web;
- means for laying down liquid foam reactants in the outer facing web;

means for engaging an inner facing web with the outer facing web;

5 wherein the apparatus further comprises means for pre-forming the outer facing web into a desired outer profile shape prior to laying down the reactants, and means for pre-forming the inner facing web into a desired inner profile shape for the shaped profile section prior to engagement with the outer facing web, such that the pre-formed inner facing web maintains its shape in the absence of support from an external structure, after the step of pre-forming the inner facing
10 web is complete.

31. A continuous line apparatus as claimed in claim 30, in which the outer facing web is provided as an elongate web, and the apparatus further comprises means for deforming the outer facing web to provide a pair of connected sections, each
15 section having a substantially C-shaped cross-section.
32. A continuous line apparatus as claimed in claim 30, in which a wing is formed at a free end of each C-shaped section.
- 20 33. A continuous line apparatus as claimed in any one of claims 31 or 32, in which the means for pre-forming the outer facing web comprises a complementary roller couple in which rollers in each roller couple have inter-fitting convex and concave engaging surfaces, whereby the outer facing web is passed between the engaging surfaces.
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34. A continuous line apparatus as claimed in claim 33, in which the means for pre-forming the outer facing web comprises a series of spaced apart complementary roller couples positioned so that serially consecutive portions of the outer facing web are sequentially engaged between the engaging surfaces of the roller
30 couples.
35. A continuous line apparatus as claimed in claim 34, in which, in the direction of movement of the outer facing web through the roller couples, engaging surfaces

of the series of spaced apart complementary roller couples are configured with rollers of gradually increasing size, such that a last roller couple in the series thereof is provided with engaging surfaces corresponding to the shape of the pair of connected substantially C-shaped sections.

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36. A continuous line apparatus as claimed in any one of claims 30 to 35, in which the apparatus comprises operating a delivery head to dispense the liquid foam reactants into the pre-formed outer facing web.
- 10 37. A continuous line apparatus as claimed in claim 36, in which the delivery head is a spray head or a pouring head.
38. A continuous line apparatus as claimed in any one of claims 30 to 37, further comprising an outer facing web mould having a supporting surface shaped to support the pre-formed outer facing web thereon, an inner facing web mould
15 configured with a moulding surface, in which the moulding surface of the inner facing web mould is operable to face and engage at least a portion of the supporting surface of the outer facing web mould, and means are provided for conveying the preformed outer facing web with liquid foam reactants and the inner facing web in between the mould surfaces to provide, from the outer facing
20 web mould to the inner facing web mould, sequential layers comprising the outer web facing web, the liquid foam reactants and the inner facing web.
39. A continuous line apparatus as claimed in claim 38, further comprising a mould conveyor arrangement comprising a first rotary conveyor and a second rotary
25 conveyor, in which a plurality of distinct inner facing web moulds are arranged along a perimeter of the first rotary conveyor and a plurality of distinct outer facing web moulds are arranged along a perimeter of the second rotary conveyor, whereby the first rotary conveyor and second rotary conveyor are arranged such that the moulds move along a conveyor path and each inner facing
30 web mould are operable to engage with an outer facing web mould for at least a portion of the conveyor path.

40. A continuous line apparatus as claimed in claim 39, in which the moulding surface of each inner facing web mould comprise a pair of spaced apart substantially C-shaped mould plates.
- 5 41. A continuous line apparatus as claimed in claim 40, in which the substantially C-shaped mould plates are placed in substantial radial alignment within the C-shaped sections of the outer facing web when the moulds are engaged along the conveyor path.
- 10 42. A continuous line apparatus as claimed in any one of claims 39 to 41, in which foam formed by the liquid foam reactants is shaped and cured as it rises between the inner and outer facing webs while an inner facing web mould is engaged with an outer facing web mould.
- 15 43. A continuous line apparatus as claimed in any one of claims 39 to 42, further comprising means for applying pressure to one or both of the inner facing web mould and the outer facing web mould for a predetermined period of time to maintain the moulds in engagement.
- 20 44. A continuous line apparatus as claimed in any one of claims 39 to 43, further comprising means for separating the moulds along the conveyor path to release the shaped profile section from between the moulds.
- 25 45. A continuous line apparatus as claimed in any one of claims 30 to 44, further comprising means for cutting the shaped profile section to a desired length.
46. A continuous line apparatus as claimed in any one of claims 30 to 45, in which the outer facing web is one of metal foil such as aluminium foil, paper, glass, thermoplastic film or combinations of two or more thereof.
- 30 47. A continuous line apparatus as claimed in any one of claims 30 to 46, in which the inner facing web is made of a thin porous material.

48. A continuous line apparatus as claimed in any one of claims 30 to 47, in which the liquid foam reactants are suitable for forming phenolic foam, poly-ester foam, poly-ether foam and/or poly-isocyanuarate foam.