An apparatus which may be used in heating and mixing flowable substances, such as a flowable food product, comprises a body through which a duct which extends between an inlet and an outlet. Means 14 is provided for admitting a working fluid, which may be steam, into the duct which further comprises a Coanda surface. A downstream section of the duct comprises an expansion chamber. A plenum chamber 12 may be disposed adjacent the duct, an orifice opening from the plenum chamber into the duct. By virtue of the Coanda surface located in the duct, the working fluid is induced to flow towards the outlet and entrain the flowable substance with it. A downstream end portion of the duct is preferably outwardly flared or frusto-conical in shape and constitutes an expansion chamber. When the working fluid is steam, the expansion chamber may be so dimensioned that, in use, substantially all of the steam entering the expansion chamber condenses into water before reaching the outlet.
Apparatus and method for processing food

This invention relates to the industrial processing of a flowable food product, such as soup or stew.

It is known to inject steam into an industrial cooking vessel containing a flowable food product in order to cook or partially cook the contents. The systems known hitherto for this purpose, such as that disclosed in patent specification No GB 2 106 800A (Giusti), are not altogether satisfactory. In particular, the rate at which food may be processed using the system disclosed by Giusti is limited. Moreover, it is necessary to provide a separate arrangement for stirring the contents of the vessel.

The present invention seeks to overcome the problems inherent in the systems according to the prior art, and in particular to provide an apparatus and method which will process food products, such as soup or stew, more rapidly and effectively than hitherto. Herein, “processing” a food product include the heating, mixing, and cooking, thereof, or any of these processes.

Broadly stated, apparatus in accordance with one aspect of the invention incorporates or consists of at least one device (referred to herein as a “steam injector”) for injecting or introducing steam into a food product to heat the product and using the propulsive effect of the steam to promote the circulation of that product within a vessel such as a cooking kettle. Such apparatus may be mounted on the end of a lance or conduit conventional in the food processing field and connected directly or indirectly to a source of steam. Apparatus in accordance with the
invention may therefore be equated to a nozzle for use with such a lance or conduit.

The construction and operation of apparatus in the form of an individual steam injector will be described in the first instance. However, as will be subsequently explained, the apparatus may incorporate two or more steam injectors. All or both of a plurality of steam injectors incorporated into one and the same apparatus may be of essentially identical or similar construction, although other means for multiple steam injection may be contemplated, and are also described in the following.

A steam injector such as that referred to above and incorporated into, or constituting, apparatus for heating and mixing a food product may have a body through which an elongate unobstructed rectilinear duct extends between an inlet and outlet, the body being preferably of circular cross-section. The inlet is located on one side of the apparatus and the outlet on the other and, in use, the apparatus is positioned such that both the inlet and the outlet open to the interior of the vessel below the level of the food product.

A plenum chamber may be located adjacent to the duct to receive steam supplied to the apparatus by way of the lance or conduit, and may conveniently surround the duct. A constricted orifice may open from the plenum chamber into the duct in the region of its upstream end, so that the steam is injected into the duct at high velocity and, flowing towards the outlet, is used to draw food product through the inlet into the duct, and then propel the food product to the outlet where the food product enters the vessel and circulates within it. The steam may be superheated steam or steam in unsuperheated condition, and is preferably
atomised steam, and be atomised either prior to delivery to the apparatus or within the apparatus itself, conveniently as the steam passes through the orifice, which may be so shaped and dimensioned for this purpose.

5 A Coanda surface may be disposed within the duct in or in the vicinity of the orifice, and be so shaped that steam entering the duct through the orifice is caused by the Coanda effect to flow through the duct towards the outlet.

By “Coanda effect” is meant the phenomenon in which a jet flow attaches itself to an adjacent surface and remains attached even when the surface curves away from the initial direction of the jet. It is found that a jet of fluid subject to the Coanda effect entrains and mixes with a surrounding fluid as it flows away from a nozzle or other outlet. When a surface is brought close to the jet, a pressure difference across the jet results and the jet is deflected closer to the surface, and eventually attaches to it. The jet remains attached to the surface, even if the surface is curved away from the initial direction of the jet. This effect can therefore be used to change the direction of the jet. The Coanda effect is therefore to be contrasted with a system in which a jet of fluid is made to flow into and entrain a fluid along a given linear path, without becoming attached to an adjacent surface.

By “Coanda surface” is meant a surface which is so shaped and positioned that a jet of fluid (in the present case, a jet of steam) directed relative to the surface will become attached to that surface and follow it, as described above.

The constricted orifice may be located at the outlet end of a constricted annular passageway leading from the plenum chamber to the duct, and
the passageway and orifice may be referred to herein as constituting the "gap". The gap may be defined between substantially annular surfaces located relatively upstream and downstream of each other, with respect to the direction of flow through the duct, and the passageway and orifice may be inclined in the general downstream direction relative to the duct axis.

The duct may have a widened region, in particular a frusto-conical or flared region, in a downstream section thereof. This region may have a volume greater than that of an upstream section of the duct of substantially equivalent length, and may serve as an expansion chamber in which steam fed into it under the action of the Coanda effect expands and collapses into water, or condensed. The expansion chamber may be such that within it substantially all of the energy (or enthalpy) contained in the steam fed into it is imparted to food product. In consequence, no (or hardly any) bubbles of steam escape from the apparatus and rise to the surface of the food product in the vessel, representing wasted heat. The optimum shape and dimensions of the passageway and associated orifice, as well as those of the expansion chamber, may be determined by experiment.

The body through which the duct passes may be assembled from two principal body components (leaving aside other secondary attachments to the body), the principal components consisting of inner and outer body components, each provided with specific constructional features of the body of the main body of the apparatus, and capable of being assembled to form the body by being sleeved one over the other. A screw connection may be provided between the two body components to allow their relative positions to be finely adjusted in the axial sense. The
upstream and downstream surfaces which define the above-mentioned passageway and the associated orifice may be formed at the upstream ends of the respective principal body components, whereby the gap may be adjusted by varying the relative positions of the two body components in the axial sense, conveniently by means of a screw connection between them.

The inclination of the orifice relative to the axis of the duct, as well as the size of the gap, and the provision of surfaces disposed so as to bring about the Coanda effect, all determined in shape and location by experiment, may be found to lead to optimum performance in most situations, in which the ideal atomised steam releases all or substantially all of its energy into the product being propelled, and suppresses the noise of the steam, referred to as "steam hammer", which occurs when steam collapses into water. Adjusting the gap leads to different mixing characteristics which may be beneficial in other circumstances. Thus, for example, widening the gap to bring about steam hammer may benefit the processing of certain products.

It is possible to predetermine the throughput of an individual steam injector as described above by selecting its dimensions at the design stage, in particular with regard to the internal cross-sectional area of the duct at various positions along its length, as well as that of the preferred flared or frusto-conical section or expansion chamber. However, it has been found that there is a limit to the rate at which food product may be processed using apparatus incorporating a single steam injector embodying the invention. In this respect there comes a point at which doubling the cross-sectional area of the duct, for example, does not result in a doubling of throughput.
This problem may be overcome, according to a second aspect of the invention, by the incorporation into the apparatus of two or more of the aforesaid steam injectors, each having the features referred to above, including a duct provided with Coanda surfaces. Each such steam injector may include a respective body through which the associated duct extends, and the apparatus may be provided with means for detachably coupling the bodies together. In the alternative, a plurality of ducts may extend through a body common to both or all ducts.

The invention also relates to a method of processing food by using apparatus such as that referred to above.

Other and further features of the invention will appear from the description of three embodiments of apparatus in accordance with the invention which follow.

In the drawings:

Figure 1 is a diagrammatic illustration of apparatus for heating and mixing a flowable food product shown mounted on a lance or conduit, the apparatus being immersed in a flowable food product within a cooking vessel,

Figure 2 is an axial section through a first embodiment of apparatus in accordance with the invention, the apparatus being constituted by a steam injector, taken on the line II-II in Figure 3,
Figure 2A is a view similar to Figure 2 but of a steam injector with a modified expansion chamber,

Figure 3 is an end view of the steam injector viewed in the direction of arrow III in Figure 2,

Figure 4A is an axial section similar to Figure 2 but showing an outer body component of the steam injector shown in that Figure,

Figure 4B is an axial section corresponding to Figure 4A but showing an inner body component of the steam injector,

Figure 5 depicts a fragment of the structure shown in Figure 2, showing to a greatly enlarged scale the components of the steam injector at its upstream end, including an orifice for injecting or introducing steam into a duct extending through the apparatus,

Figure 5A is a view similar to Figure 5 illustrating two possible flow patterns within the steam injector,

Figure 6 is an isometric view of a second embodiment of apparatus incorporating two steam injectors,

Figure 7 is a longitudinal section through the apparatus shown in Figure 6,

Figure 8 shows the detail at “B” in Figure 7 to an enlarged scale,
Figure 9 shows to a greatly enlarged scale a fragment of the structure shown in Figure 7, including the components of the apparatus at its upstream end, including a passageway leading to an orifice for injecting or introducing steam into ducts extending through the apparatus,

Figure 10 is a schematic illustration of a third embodiment of apparatus in which two steam injectors are accommodated in a body common to both injectors.

Principles of operation

Referring to Figure 1, a vessel A in the form of an industrial cooking kettle contains a quantity of a flowable food product B such as soup or stew. A tubular lance or conduit 4 is connected directly or indirectly to a source of steam which is used to cook, or at least to heat, the food product, and promote its circulation within the vessel. To this end, apparatus 2 incorporating or being constituted by one or more steam injectors or is mounted on the end of the lance or conduit 4. The lance or conduit may be a fixture within the vessel or movable from a rest position externally of the vessel into an operational position within the vessel.

In the case of a first embodiment of the invention to be described below, the apparatus 2 consists of or incorporates a single steam injector for injecting or introducing steam into a food product within the apparatus and promoting circulation of the food product, the apparatus having a duct which extends from an inlet at the right-hand side of the apparatus as viewed in Figure 1 to an outlet at the left-hand side of the apparatus 2. The steam injector is also to be regarded as a nozzle for attachment to a lance.
Steam caused to flow through the duct by virtue of the Coanda effect serves to draw food product into the inlet as indicated by arrows C and eject it from the outlet as indicated by arrows D, so that re-circulation of the food product takes place within the vessel. The steam is mixed with the food product as they are brought into contact within the apparatus, the food product being entrained by the steam, heated and mixed.

In the case of a second embodiment the apparatus incorporates two steam injectors arranged side by side in parallel. Within the scope of the invention more than two such steam injectors may be utilised in an apparatus for processing a food product. While some steam may be discharged from the apparatus along with the food product when carrying out the invention, this is not generally intended, as it is preferred that the steam should collapse completely into water within the apparatus, with the result that minimal amounts of steam, if any, find their way through the outlet.

Generally the apparatus is arranged in such a way that the food product is mixed homogenously with the steam, unless there is a specific requirement to the contrary. Non-homogenous processing may result in bubbles of steam emerging from the apparatus and rising to the surface, representing a loss of energy, without benefitting the mixing and heating process.

Unless steps are taken to prevent it, the external surfaces of the steam injector or injectors incorporated into the apparatus become heated and may lead to food product becoming scalded. Prevention of such scalding may be achieved in accordance with a preferred feature of the invention
by strategic positioning of thermal insulation chambers within the body or bodies within the apparatus.

The construction and operation of embodiments of apparatus incorporating or consisting of steam injectors will now be described in greater detail, but by way of example.

**First embodiment**

A first embodiment of apparatus in accordance with the invention is shown in Figures 2 and 3 and comprises a single steam injector (or nozzle) 2 for injecting or introducing steam into a flowable food product such as soup or stew. The injection or introduction of steam into the food product takes place wholly within the apparatus. The steam injector has a body of circular cross-section machined from stainless steel, the external surfaces of the body being polished. An elongate, rectilinear duct, likewise of circular cross-section, extends through the body and has an upstream section indicated at 6, and a downstream section indicated at 10. The duct is unobstructed throughout its entire length. An inlet at the upstream end of the duct is surrounded by a rim 8 and an outlet at the downstream end of the duct is surrounded by a rim 9.

The upstream section of the duct is delimited by the radially inner surface of a cylindrical peripheral wall 24, which separates the upstream section 6 of the duct from an annular plenum chamber 12 which surrounds the duct. The downstream section 10 of the duct is delimited by the radially inner surface of a peripheral wall 7 of circular cross-section and flared or frusto-conical shape.
A steam inlet passage 14 extends radially through the body to open into the plenum chamber, and a constricted annular orifice 35 opens from the plenum chamber into the duct between the rim 8 and the upstream end of the wall 24 which is flared radially outwardly, as will be described in greater detail below.

The wall 24 and hence an upstream section 6 of the duct is shown as having a length L1, measured from the orifice 35 to an annular wall or surface 58 which defines the downstream end of the plenum chamber, while the radially inner surface of the wall 7, and hence the downstream section 10 of the duct, has a length L2, measured from wall 58 to the rim 9. Throughout its length L2, the inner surface of wall 7 has a diameter which, at least on average, is greater than the internal diameter of the wall 24. As a result, the cross-sectional area of the section 10 of the duct taken at any point along that section is, on average, greater than the cross-sectional area of the upstream section 6 of the duct.

In the case of the modification shown in Figure 2A, the radially inner face of the wall 7 is cylindrical in shape and constant diameter throughout its length L2, and the radially inner surface of wall 7 has a diameter which is greater than the internal diameter of the wall 24 throughout its length L1. In other words, the internal cross-sectional area of the section 10 of the duct is greater than that of the upstream section 6 of the duct.

Disposed within the body, radially outwardly of the plenum chamber, is a closed, annular chamber 16 bounded on its radially outer side by a cylindrical cladding ring 18 manufactured from thin sheet stainless steel. The edges of the cladding ring are received in rebates 17 in the edges of the chamber, and held in place by welding or other suitable means. The
outer surface of the cladding ring is polished so as to appear indistinguishable from the apparatus body.

The chamber 16 is substantially co-extensive with the plenum chamber, except where the steam inlet passage 14 passes through the apparatus body and opens into the plenum chamber. The steam inlet passage 14 is encircled by a cylindrical cladding tube 20 also of thin sheet stainless steel and forming the radially outer wall of an annular chamber 22. The chambers 16, 22 serve to provide thermal insulation as explained below.

The plenum chamber is bounded on its radially inner side by the radially inner surface of a cylindrical portion of wall 24, and at its upstream end by a radially outwardly flared end portion of that wall, as well as by a substantially radially extending annular surface or wall 25 machined into the rim 8 surrounding the inlet to the duct 6. On its radially outer side the plenum chamber is bounded by the substantially cylindrical outer wall of the steam injector body (save where this is penetrated by the inlet 14 where it opens to the plenum chamber). At its downstream end the plenum chamber is bounded by the before-mentioned annular surface or wall 58.

Figures 5 and 5A each depict a radial section through those surfaces of the steam injector associated with the orifice 35, such that the plane of the paper includes the axis CL of duct 6. The surfaces referred to below may therefore be considered to be represented by lines drawn on a radial plane through the steam injector. It will be seen that the wall or surface 25 is undercut in the sense that in the region of its root it has a frusto-conical proximal surface portion 26 inclined in the downstream direction and therefore represented in Figure 5 by a straight line extending at an angle
to the axis CL. Surface 26 merges into a concavely curved distal surface portion 30 which is represented by a curved line likewise inclined in the downstream direction. The surface portion 30 terminates where it meets a relatively sharp circular edge 8A on the rim 8 enclosing the inlet to the duct 6; the edge 8A being represented in Figure 5 by a point, in accordance with the protocol explained above. It will be appreciated that the surface 25 is recessed into the rim 8, so that the orifice 35 is positioned as close as practicable to the inlet end of the steam injector.

The plenum chamber 12 is separated from the duct 6 by the substantially cylindrical wall 24 which is of constant diameter throughout the major part of its length, save at its upstream end where it is flared outwardly to form a lip, the convex surface 32 of which terminates adjacent the outlet in a cylindrical outwardly facing annular surface 27. At its other end the surface 32 of the lip is continued in the downstream direction (where it is indicated at 33) to merge into the radially inner surface of wall 24. In Figure 5 the rim 27 is represented by a line parallel to the axis CL and the lip 32, 33 by a convex line facing in the upstream direction.

An annular passageway of substantially constant width throughout its extent is defined between the concavely curved surface portion 30 and lip 32, the passageway terminating in the orifice 35 defined between the edge 8A and that portion of the lip 32 which faces the sharp edge 8A represented in Figure 5A by a point. The passageway leads from the rearward end of the plenum chamber to the orifice 35 which opens into the duct 6 immediately to the rear of the rim 8. The orifice 35 extends in an arc around the upstream end of the wall 24, part-way along the lip 32, 33. It will be understood that the orifice 35 need not completely encircle the axis CL of the duct 6 but may be interrupted at intervals.
The inlet passage 14 is provided at its free end with a screw-threaded connector 42 or other means to enable the apparatus to be mounted on the lance or conduit through which steam is to be supplied to the apparatus. A peg 44 fixed to the inner side of the connector 42 is received in an opening in the end of the lance or conduit to prevent the connection becoming unscrewed as a result of vibration taking place when the apparatus is in use.

The body of the steam injector constituting the apparatus is assembled from cylindrical outer and inner body components 50 and 52 shown in Figures 4A and 4B, respectively.

The inner body component has a relatively large diameter base portion 53 from which projects the cylindrical wall 24 in the form of a tubular extension having a diameter less than that of the base portion. The base portion of the inner body component is formed on its inner side with the outwardly flared or frusto-conical widened surface 7 which serves to define an expansion chamber 10.

The rim 8, and the undercut wall 25 which delimits the plenum chamber at its upstream end are provided or formed on the outer body component 50, whereas the downstream end wall of the plenum chamber is formed in part by the wall or surface 58 which takes the form of an annular step between the larger diameter base portion 53 and the extension 24 of the inner body component.

The outer body component is formed at its upstream end with the rim 8 which encloses the inlet, together with the wall or surface 25, and at its
downstream end with an end piece 68. The periphery of the outer body component is cut away at 60 so as to form a cylindrical recess, which is rebated along its edges, and serves as the radially inner region of the chamber 16.

The outer body component 50 is provided with a female screw-thread 54A on the endpiece 68 and the inner body component with a complementary male screw-thread 54B. The apparatus is assembled by introducing the inner body component 52 into the outer body component 50 and then screwing it into place by an appropriate distance to set the optimum or other desired width of the passageway or gap defined between surface 30 and lip 32, the width of the gap being determined by experiment.

A locking ring 62 shown in Figure 2 is then screwed onto the base portion 53 to maintain the gap at the desired width, the locking ring being provided with flats to facilitate tightening. It is not essential for the screw-thread 54A to have the length indicated and a shorter screw-thread may be employed instead.

To resist unintended rotation of the locking ring 62 relative to the screw-thread 54B, use may be made of an auxiliary ring (not shown) which is annular in shape and has a tab projecting from its inner edge. A shallow axially extending groove (also not shown) is milled into the screw thread 54B and the auxiliary ring fitted between the endpiece 68 and locking ring 62. The tab is introduced into the groove. Outer edge portions of the auxiliary ring may then be turned over a flat on the outer body component, and ring 62 tightened, whereby the auxiliary ring locks the ring 62 to the endpiece 68.
The cladding ring 18 is introduced into the rebates 17 and welded or otherwise secured in place, and the cladding tube 20 fitted in place so as to embrace the passage 14. The apparatus may then be screwed onto a lance or conduit, the pin 44 entering an opening in a fitting associated with the lance or conduit serving to prevent the screw connection loosening.

It will be seen from Figure 2 that the indicated lengths L1 and L2 are substantially equal. Because the section 10 of the duct is enlarged to form the flared or frusto-conical expansion chamber (or, in the case of the modification shown in Figure 2A, an enlarged cylindrical chamber), the volume of section 10 of the duct of length L2 is greater than the volume of section 6 of the duct of length L1. In both instances, diametrically enlarged section 10 of the duct extends as far as the outlet 9.

In the case of section 6 of the duct, the ratio of the length L1 of that section to its internal diameter D1, i.e. L1/D1, is advantageously in the range of 1.00 to 1.40, and preferably substantially 1.20. In the case of section 10 of the duct, the ratio of the length L2 of that section to the internal diameter D2 of that section, measured at the rim 9, i.e. L2/D2, is advantageously in the range of 0.70 to 1.10, and preferably substantially 0.90.

In operation, steam supplied through a lance or conduit to steam inlet 14 flows into the plenum chamber and escapes into the passageway leading to orifice 35, and is thence injected at high velocity into the duct 6. By virtue of the Coanda effect, the steam attaches to the radially inner surfaces of the lip 32, 33 and radially inner surface of wall 24 and flows
in the downstream direction towards the outlet. A reduction in pressure takes place in the duct and food product is drawn towards the inlet to the duct and passes through the inlet and along the duct, being heated and mixed with the steam, and ultimately discharged from outlet. On being discharged from the apparatus the food product circulates within the kettle.

Herein the term “Coanda surface” will be used to refer to a surface such as the radially inner surfaces of the lip 32, 33 and wall 24 which are so shaped and positioned relative to the orifice to enable the Coanda effect to take place as the steam discharged through orifice 35. The steam, flowing in the downstream direction, is substantially attached to the surface of the lip 32, 33 and the radially inner surface of wall 24.

The steam expands and collapses into water, or is condensed, within the expansion chamber 10, the frusto-conical or flared shape of which (in the embodiment of Figures 2 and 3) ensures that the size of any remaining globules of steam is controlled, and that substantially all of the energy contained in the steam is imparted to the food product. In the ideal case, such steam entering the expansion chamber collapses into water, with the result that only water and food product are discharged from the outlet. However, an apparatus or steam injector in which steam, or some of the steam, does not entirely collapse or condense into water within the steam injector but is discharged still in the form of steam, is to be regarded as falling within the scope of the invention. In the modification of Figure 2A the expansion chamber is of cylindrical shape, but nevertheless of greater internal diameter than the length of the section of duct 6 defined by the wall 24.
The optimum shape of an expansion chamber in the case both of the embodiment of Figures 2 and 3 and the modification of Figure 2A is such as to lead to expansion and collapse of the steam into water, and to be capable of imparting substantially all of the energy remaining in the steam to the food product, the shape and dimensions of the expansion chamber being determined by experiment. In carrying out such an experiment, it is noted whether, for any given shape, bubbles of steam are emitted from the apparatus and rise to the surface of a test vessel. An optimum expansion chamber shape is one in which no bubbles of steam escape in this way, consistent with achieving maximum throughput of product. Such experiments need to take account of the lengths L1, L2 (the length L2 being that of the expansion chamber), as well as its diameter and the cone angle of the surface 7.

If the downstream end of the duct were to have the same internal cross-sectional diameter as wall 24, turbulence could occur, and globules of steam escape from the apparatus and rise to the surface of the food product in the kettle, without the energy in the steam being substantially fully imparted to the food product. It will be noted that the radially inner surface of the upstream end of the expansion chamber adjoins, substantially, the downstream end of the radially inner surface of wall 24, which is of constant diameter throughout its length. Within the scope of the invention the inner surface of the expansion chamber 10 may constitute part of the Coanda surface.

The advantage of undercutting or inclining the wall 25, and giving the section 30 of the wall a concave curvature will be appreciated from Figure 5A, where it is shown that by virtue of such undercutting the steam has a greater tendency to follow the path indicated by arrow X,
being attached more securely to the lip 32, 33 and the radially inner surface of the wall 24, thereby providing a more effective operation. If, on the other hand, wall 25 is arranged to lie in a plane more precisely normal to the axis of the duct 6, the steam tends to follow the path indicated by arrow Y and results in less effective operation.

Advantages of the invention generally are that the food product is heated very rapidly with substantially 100% efficiency. Apparatus or steam injectors as described above and illustrated in Figures 2 to 5, and in accordance with the invention, may be used for reducing starches and as an entrainment system for starches and similar substances. The expansion and collapse of steam which takes place in the expansion chamber gives a much improved activation. Far less starch is needed in consequence to obtain the same thickening results. Although the invention may be used to cook a flowable food product, it is described herein as being primarily concerned with heating (and mixing) food product. Cooking as such is in essence a heating and mixing) operation, and to fall within the scope of the expression “heating and mixing”.

Because the presence of steam within the apparatus or steam injector could result in scalding of the food product contacting the outer surfaces of the body, especially those in line with the plenum chamber, the chambers 16 and 22 serve to thermally insulate the food product relative to hottest zones within apparatus, and may contain air, a vacuum or partial vacuum, or an insulating material such as a ceramic fibre or Rockwool (Trade Mark).

The optimum width of the orifice 35, may be determined by experiment, in which connection the inner and outer body components may be
screwed closer together or further apart so as to have different relative positions, the steam injector being tested at intervals. Adjusting the gap between the surfaces 30 and 32 and the width of the orifice can result in different mixing characteristics, so that increasing the gap size results in steam collapsing in larger quantities, and a more vigorous agitation, which could benefit the mixing process in some circumstances. Setting the optimum gap results in the ideal optimised flow of steam through the apparatus, which transfers substantially all of its energy into the food product. This suppresses the noise of the steam (steam hammer as it is termed), which results from steam collapsing into water. Hot gases or vapours, other than steam, may be used in certain alternative circumstances.

The preferred angle at which the expansion chamber is flared may also be determined by experiment. Although it is preferred for the outlet to open directly from the expansion chamber, apparatus in which there is a duct portion of constant diameter between the frusto-conical expansion chamber and the outlet is also intended to fall within the scope of the invention. For convenience of manufacture, the expansion chamber is circular in cross-section, although it is to be understood that expansion chambers of other cross-sectional shapes (for example, square or elliptical cross-sections) are intended to fall within the scope of the invention. Within the scope of the invention the expansion chamber may be cylindrical in shape, as depicted in Figure 2A, although performance will be less controlled than with a flared or frusto-conical expansion chamber. The foregoing also applies in general terms to the second embodiment, which will now be described.
It is possible to vary the throughput of the apparatus hereinbefore described by varying its dimensions at the design stage, in particular the internal diameter of the duct 6 and the expansion chamber 10. However, doubling the internal diameters of the duct, for example, will not necessarily give rise to a doubling of throughput because the intensity of the Coanda effect, or other characteristics of flow through the duct 6, may not be increased in proportion. This problem is overcome by apparatus in accordance with the second embodiment of the invention.

Second embodiment

The apparatus according to the second embodiment of the invention shown in Figures 6 to 9 is in the form of an elongate assembly incorporating two spaced apart, parallel steam injectors 2L, 2R, each substantially in the form of the first embodiment, the pair of injectors being detachably coupled together. The steam injector 2L is positioned to the left of Figure 7, and steam injector 2R is positioned to the right of Figure 7.

Features of steam injector 2L are suffixed L, and those of the steam injector 2R are suffixed R. The steam injectors 2L, 2R are assembled from outer body components 50L, 50R and inner body components 52R, 52L. The inner body components define respective inlets surrounded by rims 8L, 8R, ducts 6R, 6L and outlets surrounded by rims 9L, 9R. Downstream sections of the ducts constitute expansion chambers 10L, 10R. Locking rings 62L, 62R are screwed onto the inner body components, and may be reinforced by means of annular auxiliary rings as explained in connection with the first embodiment.
The inner body components are also configured to provide walls 24L, 24R which bound the radially inner sides of respective plenum chambers 12L, 12R. The upstream end walls of the outer body components are undercut as at 25L, 25R with planar proximal surfaces 26L, 26R and concavely curved distal surfaces 30L, 24R, ending in a sharp edge 8A(L/R). The upstream ends of the walls 24L, 24R are flared radially outwards and terminate in cylindrical edges 27L, 27R, adjacent to lips 32L, 32R facing in the upstream direction. The surfaces 32L, 32R and 30L, 30R define substantially annular passageways terminating in orifices 35L, 35R where the passageways open into the ducts 6L, 6R. The surfaces 32L, 32R and 33L, 33R serve as Coanda surfaces, so that the Coanda effect comes into play as steam discharges through the passageways and orifices 35L, 35R.

The way in which the steam injectors 2L, 2R operate, including reliance on the Coanda effect to cause steam flow into and through the ducts 6L, 6R, will be understood from the description and illustration of the first embodiment, to which reference should be made for a greater understanding of the second embodiment.

The second embodiment differs from the first with respect to the supply of steam to, and its distribution within the apparatus, upstream of orifices 35L, 35R. A single steam inlet passage 14 is provided at the left hand end of the apparatus (as viewed in Figure 7) and has associated with it a threaded connector 42 and a peg 44 to enable the apparatus to be secured to a lance without risk of disconnection caused by vibration. The passage 14 communicates with plenum chamber 12L as well as with a tubular passageway 70 which extends to, and communicates with, the plenum
chamber 12R. The tubular passageway 70 also serves as a means for coupling steam injector 2L, 2R together.

Referring to Figure 7, it will be seen that, between the steam injector 2L, 2R, the tubular passageway 70 is segmented, being assembled from a section 72 associated with the outer body component 50L and a section 74 associated with the outer body component 50R. The two passageway sections may be brought into juxtaposition where their ends abut along line 75 to form the passageway 70. From this position the passageway sections may be drawn apart for cleaning purposes.

Figure 8 shows, to an enlarged scale the detail at “B” in Figure 7, comprising a mechanism for bringing the passageway sections into juxtaposition during assembly and separating them for disassembly for cleaning after use. The right hand side edge of passageway section 72 has an external rim 79 and the left hand edge of the passageway section 74 has an external rim 78. The rims may be fast or integral with the passageway sections.

An internally threaded ring 76 is provided with an internal screw thread which is screwably engaged with an external screw thread on rim 78. The ring 76 is profiled externally (see Figure 6) to facilitate manual rotation and has an annular, radially inwardly projecting shoulder 80 which engages a complementary, radially outwards projecting shoulder 82 on the rim 79 of section 72.

Rotation of the ring 76 in a first direction draws passageway section 72 towards the right so as to bring the passageway sections into the abutting positions in which they are shown. A PTFE seal 83 received in a groove
in rim 78 of section 74 engages the rim 79 of passageway section 72 to prevent leakage of steam from between the passageway sections during use. Rotation of the ring in the opposite direction allows shoulder 80 to release the shoulder 82 so that the passageway section 72 may move to the left, ultimately into a position in which the two steam injectors may be separated for cleaning.

Each of the passageway sections may be assembled from a pair of cylindrical components, namely components 72, 74 which engage each other, and sections 92, 94 which are fixedly engaged with outer body components 50L, 50R, respectively.

A cladding ring 16R bounds a chamber 18R provided for thermal insulation purposes where otherwise the radially outer wall of the plenum chamber 12R would be exposed. Other regions of the apparatus are thermally insulated by cladding tubes where shown for example at 96.

The arrangement depicted in Figures 6 to 9 provides a convenient approach to incorporating two separate steam injectors into apparatus for injecting or introducing steam into a food product in order to increase throughput of steam and food product, and in such a way that the steam injectors may be readily separated for cleaning. However, other possibilities exist and within the scope of the invention three or more such steam injectors may be grouped together, such as in a row or triangular array, and supplied with steam from a common source through an arrangement of passageways.

One such alternative arrangement takes the form of the third embodiment to which reference will now be made.
Third embodiment

In the case of the second embodiment described above, the apparatus includes two separate, detachably interconnected bodies, each housing the components of a respective one of two steam injectors 2L and 2R.

In contradistinction, in the case of the third embodiment shown in Figure 10, viewed from the inlet end, two such steam injectors are incorporated into a single body or structure, without any provision for the two steam injectors to be separated one from the other. As shown, the body may be manufactured in two pieces, namely a base block 2B and a cover block 2C, with mating faces formed with channels of semi-circular cross-section which are mirror images of each other so that when the blocks 2B and 2C are brought together they define ducts and expansion chambers of circular cross-section. The blocks may be secured together by bolts or other fastening means passed through pairs of aligned holes 104. An inlet passage 14 is provided at one end of the base block, and communicates with the left hand duct 6 (as viewed) and with a passage 102 extending through the base block into the right hand duct. Inserts 100 are provided separately, each being fitted into the upstream end of a respective duct. The inserts are configured so as to contain or cooperate with the body to form the two plenum chambers, the orifices, and appropriately located Coanda surfaces.

Although the invention has been described in connection with food processing, it will be understood that the steam injectors described above and illustrated in the drawings may have other uses, such as in connection with brewing, water treatment and petrochemicals, and the
Applicant reserves the right to divide out claims to such uses. Similarly, the invention may be carried out using working fluids in the form of gases or vapours other than steam to propel fluent materials, and the right to divide out claims to such uses is also reserved.
CLAIMS:-

1. Apparatus comprising a body through which a duct extends between an inlet into and an outlet from the duct, a plenum chamber disposed adjacent the duct, means for admitting a working fluid into the plenum chamber, an orifice opening from the plenum chamber into the duct, a Coanda surface within the duct, and a downstream section of the duct comprising an expansion chamber, the duct being so dimensioned that, in use, working fluid entering the duct through the orifice is caused by the Coanda effect to flow towards the outlet, and in so doing entrain the fluent material and cause it to be discharged through the outlet, whereby substantially all of the energy in the working fluid flowing through the expansion chamber is imparted to the fluent material.

2. Apparatus as claimed in claim 1, wherein the working fluid is steam and the expansion chamber is so dimensioned that, in use, substantially all of the steam entering the expansion chamber condenses into water before reaching the outlet.

3. Apparatus as claimed in claim 1 or claim 2, wherein the downstream section of the duct constituting the expansion chamber is of flared or frusto-conical shape.

4. Apparatus as claimed in any preceding claim wherein the apparatus is adapted for use in heating and/or mixing a food product.

5. Apparatus comprising a body through which a duct extends between an inlet into and an outlet from the duct, means for admitting a working fluid into the duct, a Coanda surface within the duct, and a downstream section of the duct comprising an expansion chamber, the duct being so dimensioned that, in use, working fluid entering the duct is caused by the Coanda effect to flow towards the outlet, and in so doing entrain the fluent material and cause it to be discharged through the outlet, whereby substantially all of the energy in the working fluid flowing through the expansion chamber is imparted to the fluent material.

6. Apparatus substantially as hereinbefore described with reference to and as illustrated in the drawings.
**Patents Act 1977: Search Report under Section 17**

**Documents considered to be relevant:**

<table>
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<tr>
<th>Category</th>
<th>Relevant to claims</th>
<th>Identity of document and passage or figure of particular relevance</th>
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<tr>
<td>X,Y</td>
<td>X: 1, 3 &amp; 5 Y:4</td>
<td>US3795367 A (MOCARSKI) See col 2 lines 36-60 and figure 1</td>
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<td>US3047208 A (COANDA) See col 2 line 42-col 3 line 11 and figures 1, 2 &amp; 5</td>
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<td>US2004/141410 A1 (FENTON) See paragraphs 4 &amp; 89 and figure 1</td>
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<td>A</td>
<td>-</td>
<td>GB2452707 A (D C NORRIS) See abstract and figures 1-3</td>
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**Categories:**

| X | Document indicating lack of novelty or inventive step. |
|  | Document indicating lack of inventive step if combined with one or more other documents of same category. |
|  | Member of the same patent family                      |
| Y | Document indicating technological background and/or state of the art. |
|   | Document published on or after the declared priority date but before the filing date of this invention. |
|   | Patent document published on or after, but with priority date earlier than, the filing date of this application. |

**Field of Search:**

Search of GB, EP, WO & US patent documents classified in the following areas of the UKCN:

Worldwide search of patent documents classified in the following areas of the IPC:

A47J; F04F

The following online and other databases have been used in the preparation of this search report:

EPODOC, WPI

**International Classification:**

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